HARRIS COUNTY FLOOD CONTROL DISTRICT

US Army Corps of Engineers
Galveston District

HARRIS COUNTY FLOOD CONTROL DISTRICT
September 2013 (Revised August 2014)

MAIN REPORT AND ENVIRONMENTAL ASSESSMENT

GENERAL REEVALUATION REPORT

Main Report Document

WHITE OAK BAYOU, TEXAS

FEDERAL FLOOD DAMAGE REDUCTION PROJECT

GENERAL REEVALUATION REPORT ON
WHITE OAK BAYOU
FEDERAL FLOOD DAMAGE REDUCTION PROJECT
HARRIS COUNTY, TEXAS

GENERAL REEVALUATION REPORT
&
ENVIRONMENTAL ASSESSMENT

SUMMARY

This report documents the results of the studies that comprise the General Reevaluation Report (GRR) on the White Oak Bayou Federal Flood Damage Reduction Project. The Harris County Flood Control District (HCFCD) in cooperation with the U.S. Army Corps of Engineers (USACE) directed this report. The White Oak Bayou Flood Damage Reduction Project is being conducted under Section 211 of the Federal Water Resources Development Act of 1996 (WRDA 1996). Section 211 of WRDA 96 provides authority for non-Federal sponsors to undertake the design and construction of federally authorized flood control projects without Federal funding and to be eligible to be reimbursed an amount equal to the estimate of the Federal share, without interest (or inflation), of the design and construction cost of the project or separable element thereof.

Section 211(f) of the Federal Water Resources Development Act of 1996 (WRDA 1996) (Public Law 104-303) specifically authorized the HCFCD to take the lead in developing a flood risk reduction plan on White Oak Bayou. In addition reimbursement for those projects listed in Section 211 (f) will be in accordance with section 211 (e) (2) (A). These special reimbursement rules expand the definition of the work for which the non-Federal sponsor may be reimbursed the Federal share to include studies, planning, design and construction if such work is later recommended by the Chief of Engineers and approved by the Secretary. In addition, for the section 211 (f) projects, a non-Federal sponsor will be credited for the Federal share of any work carried out before completion of a reconnaissance study if such work is determined to be compatible with the project later recommended for construction.

To obtain approval of the project presented in this report it must be planned, designed and constructed in accord with appropriate Federal laws and criteria, standards and policies, including the appropriate National Environmental Policy Act (NEPA) documentation and Section 211 of WRDA 1996. Construction must comply with all applicable Federal and State laws and regulations.

White Oak Bayou, a tributary of Buffalo Bayou, originates in northwest Harris County, Texas and flows southeast for approximately 25 miles through the City of Jersey Village and the City of Houston where it outfalls into Buffalo Bayou in downtown Houston. White Oak Bayou watershed drains approximately 110 square miles and is approximately 90

percent developed. Elevations in the watershed vary from approximately 135 feet to approximately 40 feet and the average streambed slope is about 5 feet per mile.

The existing Federal channel in the lower reach of White Oak Bayou was completed in the mid 1970's under the authorization of the Flood Control Acts of 1954 and 1965 for Buffalo Bayou and Tributaries. The 10.7 miles of channel improvements comprise the existing Federal project that extends from the confluence of White Oak Bayou and Buffalo Bayou to Cole Creek.

The Upper White Oak Bayou project from Cole Creek upstream to the end is authorized by WRDA 1986, Section 401(a) based on a Report of the Chief of Engineers for Buffalo Bayou and Tributaries, Texas dated June 13, 1978 (Reference 4). The accompanying feasibility report prepared by the Galveston District is titled "Buffalo Bayou and Tributaries, Texas (Flood Damage Prevention). Interim Report on Upper White Oak Bayou: and is dated April 1976 (Reference 5).

Two most recent severe floods occurred during Tropical Storm Frances in September 1998 and Tropical Storm Allison in June 2001. The former flooded approximately 1,200 homes and the latter flooded approximately 11,000 residences within the White Oak Bayou watershed. Approximately 1,333 and 6,074 structures respectively are in the 10 percent and 1 percent flood plain.

The purpose of this study was to evaluate whether the authorized project is now appropriate for the current conditions of development, flood risk, and community preferences in the watershed. Also the purpose was to consider possible reformulations and modifications to it that could more effectively and economically manage flood risk along the main stem of the bayou. Evaluation of current recreation needs of the community was also important in evaluating what plan should now be implemented. The GRR has been performed to provide the documentation to show that the project has been performed in conformance with Corps policies, rules and regulations, including Section 211, and applicable Federal and State laws. The study supports a recommendation by the Chief of Engineers that the resulting plan is within the existing project authorization. It also supports an Assistant Secretary of the Army, Civil Works (ASA(CW)) determination for implementation under Section 211 with Federal cost-sharing and also supports requests for Federal funding for construction for the identified project.

This GRR study was conducted following the published procedure, methodology and guidance of the U.S, Army Corps of Engineers (USACE). The USACE HEC-HMS, HEC-RAS, and HEC-FDA computer models were utilized to determine the flood damages for the without project condition and to evaluate the effectiveness of the alternative flood damage reduction plans. The average annual flood damage under without project condition is estimated to be $61.2 million along the main stem of White Oak Bayou. Over 90 different configurations of structural and non-structural components were evaluated, including channel modification, detention, bypass channels, flood protection levees, replacement or modification of existing bridges, elevating structures, and permanent relocation. Over 300 different combinations were considered.

The overall plan recommended for implementation and Federal cost-sharing is identified as the Recommended Plan and as the Environmentally Preferred Alternative. This plan consists of a series of flood risk reduction components and a recreation plan.

The series of flood risk reduction components in the Recommended Plan have been identified that reasonably maximize net economic benefits for the cost associated with the plan. The Recommended Plan consists of the following components:

(1) Earthen channel modifications along 15.4 miles from Cole Creek to FM 1960.
(2) Four detention basins along White Oak Bayou providing approximately 2,938 acre-feet storage.

The Local Sponsor has already constructed segments of the channel modifications and the detention basins. The segments that have been constructed conform with the Recommended Plan and the requirements of Section 211 of WRDA 1996.

Also included in the Recommended Plan is the least-cost mitigation of wetlands by utilizing 4.99 acres of wetlands at the Greens Bayou Wetlands Mitigation Bank. For the Recommended Plan also included is the Local Sponsor Volunteer Mitigation, consisting of construction of seven acres of wetlands funded 100 percent by the Local Sponsor, HCFCD. The cost of the Local Sponsor Volunteer Mitigation is not included in the project costs and economic benefits calculations.

The Recommended Plan also consists of the following recreation components.

(1) Creation of a 12-mile linear park/bikeway from the confluence of White Oak Bayou and Cole Creek upstream to north of West Road.
(2) Recreational opportunities will also be provided within the detention basins consisting of four parks containing multi-purpose trails, observation/teaching facilities, multi-purpose fields, and play areas.

None of the recreation components have been constructed.

The Recommended Plan of flood risk reduction components reduces the average annual flood damages by $35.6 million, or approximately 58 percent. No significant adverse environmental impacts were identified. Tree and shrub plantings will promote the reintroduction of native habitat for wildlife and provide an opportunity for use as multipurpose facilities with recreation elements as well. The support for this plan has been expressed by the White Oak Bayou Advisory Committee and by the public in general based on the public meetings held during the planning process.

The Recommended Plan impacts 13.17 acres of isolated and fragmented wetland areas along the bayou. The Federal cost is the least-cost amount of $103,000, with the remainder, the Local Sponsor Volunteer Mitigation, being paid for by the Local Sponsor

outside of the cost-sharing. In addition, habitat that is disturbed by construction will be restored to its pre-construction condition.

No significant adverse social effects result from the plan. The proposed project plays an important role in social aspects of the community by reducing the impacts caused by flooding, improving the safety, and contributing towards community cohesion.

Regional Economic Development impacts are positive. The damage reduction and construction investment both are positive factors for the economy of the Houston region.

The Recommended Plan reduces average annual damages from $61.2 million to approximately $25.7 million, providing annual flood damage reduction benefits of approximately $35.6 million. Flood insurance savings create an additional $0.2 million of benefits. Based on the FY 2013 interest rate of 3.75 percent, the project has a benefit/cost ratio of approximately 6.9 and net economic benefits are $30.5 million. Based on a 7.00 percent interest rate, the net benefits are $27.3 million and the benefit-cost ratio is 4.2. The estimated first cost based on the MCACES cost estimate is $106.1 million and the fully funded cost is $110.3 million. These costs are based on the actual costs without escalation for the components that have already been constructed, and the estimated future costs based on FY 2013 price levels for components remaining to be constructed, plus future escalation of $4.2 million, at the current 2013 Federal interest rate of 3.75 percent. The Federal and non-federal cost allocations for the fully funded project cost are estimated to be $60.9 million and $49.4 million respectively. The proposed cost sharing for the segments that have already been constructed is in conformance with the requirements for reimbursement specified in Section 211. The proposed project reduces the extent of the 10 percent and 1 percent flood plain areas so that 1,283 and 1,325 structures, respectively, would now be located outside of the two reduced flood plain areas, leaving 50 and 4,749 structures, respectively within the two reduced flood plain areas.

The proposed Recreation Plan has an estimated first cost of $ 10.9 million, a fully funded cost of $11.8 million, provides net benefits of $ 2.1 million and has a benefit-cost ratio of 4.4 based on the FY 2013 interest rate of 3.75 percent. Based on a 7.00 percent interest rate, the net benefits are $1.7 million and the benefit-cost ratio is 2.7. The Federal cost of a project including recreation may not exceed the Federal cost of the project excluding recreation by more than ten percent without prior approval by the Secretary of the Army. The maximum allowable Federal participation would be $5.9 million. The Federal and non-Federal shares based on a 50-50 split would be $5.9 million, which is within the allowable limit. The costs presented here are first costs and do not include escalation.

After careful consideration of the economic, environmental, social and technical aspects for obtaining efficient, environmentally acceptable, and safe flood damage reduction the Harris County Flood Control District recommends that the Recommended Plan be approved for design and construction and that it continue as a Section 211(f) project in accordance with Section 211 of WRDA 1996, as amended.

WHITE OAK BAYOU FEDERAL FLOOD DAMAGE REDUCTION PROJECT
HARRIS COUNTY, TEXAS

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MAIN REPORT

1.0 INTRODUCTION

This General Reevaluation Report (GRR) documents the results of a comprehensive study of White Oak Bayou in Harris County, Texas. This study has focused on evaluating potential solutions and developing a flood risk management plan for White Oak Bayou to reduce flood risk and damages due to flooding along the main stem of the bayou. White Oak Bayou originates in northwest Harris County and flows southeast through the City of Jersey Village and the City of Houston where it outfalls into Buffalo Bayou in downtown Houston. White Oak Bayou is approximately 25 miles long and the watershed drains an area of approximately 110 square miles, as shown on Exhibit 1-1. For the purposes of this study the channel upstream of Cole Creek is referred to as Upper White Oak Bayou and the channel downstream of Cole Creek is referred to as Lower White Oak Bayou.

The Harris County Flood Control District (HCFCD) in coordination with the U.S. Army Corps of Engineers (USACE) directed this report. Section 211 of the Water Resources Development Act (WRDA) of 1996 gave the HCFCD the opportunity to take the lead in planning, design and construction for the project in cooperation with the USACE. (The full text of Section 211, as amended, is provided as Attachment 5 at the end of this report.)

This chapter outlines the existing and authorized projects, prior studies, local lead authority, study authority, authorized project, purpose and scope, study participants, and prior studies performed for this study area.

1.1 Existing and Authorized Projects

The Flood Control Act of 1954 authorized the construction of channel improvements for White Oak Bayou from its confluence with Buffalo Bayou to the Burlington Northern Railroad bridge at stream mile 8.6. The Flood Control Act of 1965 authorized extending the channel improvements an additional 2.1 miles to the confluence with Cole Creek at stream mile 10.7. Construction of these improvements was completed in 1976 and consisted of channel realignment, enlargement, and partial concrete paving to reduce flood levels in Lower White Oak Bayou. As Local Sponsor for this project, the HCFCD currently performs routine maintenance and major rehabilitation as needed.

Construction of Upper White Oak Bayou was authorized by WRDA 1986, Section 401(a) based on a Report of the Chief of Engineers for Buffalo Bayou and Tributaries, Texas, dated June 13, 1978 (Reference 4). The accompanying feasibility report prepared by the Galveston District is titled “Buffalo Bayou and Tributaries, Texas (Flood Damage Prevention), Interim Report on Upper White Oak Bayou” and is dated April 1976 (Reference 5). The proposed project included 9.2 miles of White Oak Bayou channel enlargement, rectification, and partial concrete paving upstream of the existing Federal channel to the

north side of Jersey Village at stream mile 19.9. The proposed project also included channel modifications to Cole Creek and Vogel Creek; nonstructural flood plain management upstream of the channel improvements; and recreation, aesthetic, and beautification features. The authorization language is as follows:

> *"SEC. 401. AUTHORIZATION OF PROJECTS.*
> *(a) Authorization of Construction.--The following works of improvement for the control of destructive floodwaters are adopted and authorized to be prosecuted by the Secretary substantially in accordance with the plans and subject to the conditions recommended in the respective reports designated in this subsection, except as otherwise provided in this subsection:*
>
> *… The project for flood control, Buffalo Bayou and Tributaries (Upper White Oak Bayou), Texas: Report of the Chief of Engineers, dated June 13, 1978, House Document Numbered 96-182, at a total cost of $92,100,000, with an estimated first Federal cost of $69,100,000 and an estimated first non-Federal cost of $23,000,000."*

The Buffalo Bayou and Tributaries authorization in Water Resources Development Act of 1990, Section 101(a)(21) authorized implementation of six separate flood damage reduction projects on tributaries of Buffalo Bayou. While the Buffalo Bayou and Tributaries Feasibility Study dated May 1988 (Reference 7) did evaluate Lower White Oak Bayou, federal participation in a flood damage reduction project was not recommended because the benefit to cost ratio was less than 1.0. WRDA 1990 did not modify or request deauthorization of the 1986 WRDA Upper White Oak Bayou authorization.

The HCFCD developed a regional flood control plan for the entire reach of White Oak Bayou in the early 1980's because the prospect of federal assistance seemed unlikely (previous WRDA was in 1976). In 1984, the HCFCD adopted a Regional Flood Control Plan (Reference 2) that, if fully implemented, would reduce flood levels based on existing conditions, but also included an impact fee from new developments to pay for additional capacity and mitigation they needed. Since then, the HCFCD has been constructing components of this regional plan. The regional plan was updated in 1998 (Reference 3) using updated hydrology and hydraulic models and to reflect changed watershed conditions. As described later, some of these components are included in the Recommended Plan in this report.

Limits of the project authorizations discussed above are shown in Exhibit 1-1a.

1.2 Prior Studies

The federal studies referenced above in association with the project authorizations and the federal study presented below were conducted in response to a Congressional resolution adopted April 20, 1948 by the House of Representatives Committee on Public Works. The resolution reads:

"Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Houston Ship Channel and Buffalo Bayou, Texas, contained in House Document No. 456, 75th Congress, 2nd Session, with a view to determining a comprehensive plan for the betterment of navigation and for the control of floods throughout the Buffalo Bayou watershed including modifications, if any, of the presently approved plan of improvement and of the requirements for local cooperation in order to meet the materially changed conditions resulting from the rapid industrial expansion and growth of the City of Houston, Texas, and contiguous areas."

In 1982, a general reevaluation study was initiated for Upper White Oak Bayou. The findings are presented in the "General Reevaluation Report on Upper White Oak Bayou" dated April 1985 (Reference 6). No federal or local action resulted from this 1985 General Reevaluation Report. The WRDA 1986 authorization was based on the June 1978 Chiefs Report (Reference 4), not the 1985 General Reevaluation Report.

1.3 Local Lead Authority

Section 211 of WRDA 1996 (Public Law 104-303) authorized the HCFCD to develop a flood risk reduction plan on White Oak Bayou. Specific language from WRDA 1996, Section 211(f), as amended by WRDA 1999, Section 223, provides for the following:

"(f) SPECIFIC PROJECTS.-- For the purposes of demonstration the potential advantages and effectiveness of non-Federal implementation of flood control projects, the Secretary shall enter into agreement pursuant to this section with non-Federal interests for development of the following flood control projects by such interest.--

- *(8) White Oak Bayou, Texas.--The project for flood control, White Oak Bayou watershed, Texas".*

Even though the non-Federal interest is in the lead, the planning, design, and construction are still done in accordance with established Corps of Engineers' regulations, guidance, and requirements for Federal participation. The primary advantage of the HCFCD taking the lead is that the project can be constructed and benefits realized sooner based on the potential for reimbursement of the Federal share as stated below in Section 211(e)(2)(A):

"(e) REIMBURSEMENT.—
(2) SPECIAL RULES.—
(A) REIMBURSEMENT OR CREDIT.— For work (including work associated with studies, planning, design, and construction) carried out by a non-Federal interest with respect to a project described in subsection (f), the Secretary shall, subject to the availability of appropriations, reimburse, without interest, the non-Federal interest an amount equal to the estimated Federal share of the cost of such work, or provide credit (depending on the request of the non-

Federal interest) for the non-Federal share of such work, if such work is later recommended by the Chief of Engineers and approved by the Secretary."

This provision allows the inclusion of previously constructed regional components in the Recommended Plan.

1.4 Study Authority

When this study was initiated in 1999, it began as a feasibility study of the entire length of White Oak Bayou based on the 1948 Congressional study resolution presented in Section 1.2, Prior Studies above.

Based on analysis and early component evaluations, the study team concluded in 2002 that further consideration of components in Lower White Oak Bayou, where the existing Federal project exists, was not necessary due to low economic performance. (Lower White Oak Bayou was still considered in this study to evaluate the overall amount of damage reduction achieved, since it does receive benefits from Upper White Oak Bayou plan alternatives.) In consultation with the Galveston District, it was decided to reclassify this effort as a post authorization study, or general reevaluation study, of the project authorized in WRDA 1986 for Upper White Oak Bayou, presented in Section 1.1, Existing and Authorized Projects above. This was to evaluate whether the authorized plan is still appropriate, feasible, or desired considering changed conditions, guidance, policy, and/or assumptions due to the time lapse since the 1978 Chiefs Report.

In addition, Section 211(f)(8) of WRDA 1996 presented in Section 1.3, Local Lead Authority above directs the Secretary to enter into an agreement with Non-Federal interests to develop a flood control project on White Oak. While this is not a traditional study or project authorization, it is a clear directive from Congress.

1.5 Authorized Federal Project

This General Reevaluation Study encompassed the entire length of White Oak Bayou. Since the recommended (NED) plan described later in this report is in Upper White Oak Bayou, only the authorized project in Upper White Bayou is described below. The Federal project in Upper White Oak Bayou authorized by WRDA 1986 consists of the following:

1. Channel enlargement, rectification, and partial paving of 9.2 miles of upper White Oak Bayou channel, 4.9 miles of Cole Creek, and 4.5 miles of Vogel Creek;

2. Nonstructural floodplain management consistent with the National Flood Insurance Program requirements along the remaining headwater reaches of the streams including about 5.6 miles of upper White Oak Bayou, 2.0 miles of Cole Creek, and 2.0 miles of Vogel Creek;

3. Installation and construction of aesthetic and beautification features; and

4. Construction of a recreational development plan on existing flood control rights-of-way along 3.8 miles of the White Oak Bayou to include 8.1 miles of hike and bike trails on either stream bank and one neighborhood park with recreation equipment and picnic facilities.

The current year FY 2013 estimate of the total project first cost of the authorized plan is $176 million ($172 million for the flood damage reduction components and $4 million for the recreation components). As discussed later in this report, Section 902 of WRDA 1986 defines the maximum amount that a project may cost, allowing for inflation and other factors. The Section 902 limit, based on the current estimate of the authorized project, is compared to the Recommended Plan cost in Chapter 5 of this report.

1.6 Study Purpose and Scope

The purpose of this study is to evaluate whether the authorized project is now appropriate for the current conditions of development, flood risk, and community preferences in the watershed. Also the purpose is to consider possible reformulations and modifications to it that could more effectively and economically manage flood risk along the main stem of the bayou. Evaluation of current recreation needs of the community is also important in evaluating what plan should now be implemented. The GRR needs to provide the documentation to show that the project has been performed in conformance with Corps policies, rules and regulations, including Section 211, and applicable Federal and State laws. The study should support a recommendation by the Chief of Engineers that the resulting plan is within the existing project authorization. It should also support an Assistant Secretary of the Army, Civil Works (ASA(CW)) determination for implementation under Section 211 with Federal cost-sharing and also support requests for Federal funding for construction for the identified project.

This study was performed under the guidance for Federal water resources projects using the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, March 10, 1983 (P&G) (Reference 9) and the Planning Guidance Notebook, ER 1105-2-100, April 2000 (Reference 8). To accomplish the project purpose, the engineering, economic, and environmental aspects were reanalyzed and additional components and alternatives were analyzed, all in accordance with current Federal planning policies and guidance, including the WRDA of 1996, and in accordance with HCFCD criteria and policies. Public input and acceptance of the proposed improvements were essential features of the planning study.

This document describes in detail the problems and opportunities identified, alternatives formulated, the engineering and economic feasibility of each alternative, and the social and environmental benefits and impacts for each. The GRR complies with the requirements of the National Environmental Policy Act (NEPA) 40CFR 1500-1508 to ensure environmental protection. A self-standing NEPA compliance document (Environmental Assessment) has been prepared that describes all activities leading to the assessment of environmental impacts related to the alternatives investigated. A draft Recreation Plan has also been

prepared as part of this study and is presented in Appendix F – Recreation Plan. Harris County Precinct No. 4 has agreed to be the Local Sponsor for the Recreation Plan. The costs of the Recreation Plan have been included in the plan presented herein.

1.7 Study Participants and Cooperation

The study was conducted by the HCFCD, with support from the USACE, a consultant team, and public participation. The following describes the role of each of the study participants.

1.7.1 HCFCD Management

Overall management of this Section 211(f) study was the responsibility of the HCFCD. Regularly scheduled meetings with the consultant team were held frequently throughout the study to review study progress, finances, and findings as they were developed and reported by the consultant team. Periodic meetings with representatives from the USACE-Galveston District (USACE-SWG) were held during the study. The HCFCD managed the overall study by: (1) maintaining a working knowledge of the study and verifying all materials presented to the public and transmitted to the USACE for review, (2) assisting in resolving emerging policy issues, (3) ensuring that evolving study results and policies were consistent and coordinated, (4) directing the consultant team, and (5) reviewing and approving decisions made by the consultant team.

1.7.2 USACE

The USACE has provided oversight, policy review, quality assurance, and consultation throughout the study. Quality Assurance review responsibility was assigned to USACE.

1.7.3 Consultant Team

The HCFCD is utilizing a consultant team, led by LJA Engineering, Inc. to perform the planning study for White Oak Bayou. Supporting members of the consultant team include, Cervenka & Associates, Inc., Civil Tech Engineering, Inc., GEC, Inc., The Lentz Group, Moore Archeological, Inc., Atkins (formerly PBS&J, Inc.), and Zarinkelk Engineering Services, Inc.

1.7.4 Others

Coordination of the environmental aspects of the project has been maintained with the appropriate agencies, including United States Fish & Wildlife Service (USFWS), Texas Commission on Environmental Quality (TCEQ), Texas Parks and Wildlife Department (TPWD), Texas State Historic Preservation Officer (SHPO), and the United States Coast Guard.

Public involvement was facilitated through periodic meetings held throughout the study area with the White Oak Bayou Citizens Advisory Committee (WOBCAC), which was created at the onset of the study. The WOBCAC members include people representing the City of Houston, the City of Jersey Village, TxDOT, civic associations, representatives from neighborhood civic associations and precincts, the West Houston Association, the White Oak Bayou Association, industry, developers, environmental groups, and others with an interest in White Oak Bayou. A summary of public involvement for the study is provided in Appendix G - Public Involvement.

1.8 Terminology

Terminology specific to water resources planning and flood improvement projects is used throughout this report. The definitions of some key terms are defined to assist the reader.

Alternative is a set of one or more flood risk management components functioning together to address one or more planning objectives.

Base without project condition (base condition) is the most likely condition expected to exist in the year 2010 in the absence of a proposed project. The date January 1, 1998 is used to establish the engineering conditions for the base year (2010). All White Oak Bayou channel modifications and detention facilities that have been completed by January 1, 1998 are included in the hydraulic analysis for the base without project condition.

Base year is the year 2016 and is defined as the year in which a flood damage reduction project is completed and the benefits of the project are first realized.

Component is an individual structural or nonstructural flood risk management measure that forms the building blocks of alternative plans.

Local Sponsor is the Harris County Flood Control District.

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2.0 STUDY AREA DESCRIPTION

This section describes the study area from a broad perspective. The material discussed includes a summary of the physical environment, biological resources, and socioeconomic resources within the watershed.

2.1 Watershed Description

White Oak Bayou is a major tributary in the Buffalo Bayou watershed that drains much of the urbanized area of Houston and the surrounding area. White Oak Bayou originates in northwest Harris County and flows southeast for approximately 25 miles through the City of Jersey Village and the City of Houston where it outfalls into Buffalo Bayou in downtown Houston. The White Oak Bayou watershed is approximately 110 square miles and approximately 90 percent developed (2002 conditions). The watershed boundary in relation to the local jurisdictions, including local municipalities, and County precincts is shown on Exhibit 1-1.

Elevations in the watershed vary from approximately 135 feet at the upstream end of the watershed to approximately 40 feet at the confluence with Buffalo Bayou, and the average streambed slope is about 5 feet per mile. Elevations in this study are referenced to the North American Vertical Datum (NAVD) 1988, 2001 subsidence adjustment. Before 2001, the entire White Oak Bayou watershed experienced relatively uniform subsidence, in the range of six to seven feet from 1906 to 2000. It is recognized that inland riverine flooding is not altered by land subsidence when it is relatively uniform in magnitude and areal extent. It is known that subsidence has continued to occur through certain portions of the project area after 2000. In the watershed near Jersey Village approximately one foot of subsidence has occurred over the last 10 years from groundwater withdrawals in this area. To a lesser extent subsidence has also occurred downstream from this area**.** Since the subsidence is not uniform along the bayou, the potential for differential changes in the channel slope and adjacent topography exist. However, the differential subsidence and change in channel slope from 2001 to 2011 are minor. A previous study in 1986 entitled “A Study of The Relationship Between Subsidence and Flooding”, directed by the Harris County Flood Control District, the Harris-Galveston Coastal Subsidence District, the City of Houston, and the Fort Bend County Drainage District, concluded that even under the most unusual amount of differential subsidence that was considered to be possible, flood levels would typically only change by approximately one-tenth of the related subsidence. Even if the differential subsidence was one foot, a tenth of a foot of change in flood level would not be significant. Also, as the City of Houston and Harris County continues to convert from groundwater to surface water supplies, based on regulatory mandates, the rate and overall amount of subsidence have declined. Within the watershed area, subsidence is not expected to increase in magnitude over the study evaluation period. In addition subsidence

would not impact the flood damage results obtained based on the use of the 2001 LIDAR topographic data.

White Oak Bayou has four major tributaries: Vogel Creek that enters from the north near station 64000, at W. Little York Road; Cole Creek which enters from the west near station 56000, at West Tidwell Road; Brickhouse Gully which enters from the west near station 46500, one mile upstream of 34th Street; and Little White Oak Bayou which enters from the north near station 7000, at Quitman Street.

Major highways within the watershed are Interstate Highway (IH) -10, IH-45, IH-610, US-290, Beltway 8, and FM 1960. These highways provide good access to and through the watershed and to unincorporated Harris County, the City of Houston, and the City of Jersey Village.

2.2 Study Area

The study area defined for the White Oak Bayou flood risk management project is the area along White Oak Bayou within the 0.2 percent (500-year) probability floodplain as determined from the latest hydrologic and hydraulic models. White Oak Bayou extends from its upstream headwaters on Huffmeister Road, downstream to its confluence with Buffalo Bayou in downtown Houston. Consideration of alternative flood reduction measures below the confluence with Cole Creek, referred to herein as the lower reach, was halted in year 2002 of this study. This decision was based on the low net economic benefits associated with additional flood damage reduction measures in the lower reach in the vicinity of the existing Federal project. This partially lined concrete channel was originally designed and constructed by the USACE. The study area, project area and watershed boundary are shown on Exhibit 1-1. As mentioned above, the study area is the entire reach of White Oak Bayou, from the mouth to Huffmeister Road, within the 0.2 percent probability flood plain. The project area is the White Oak Bayou channel from its confluence with Cole Creek upstream to Huffmeister Road. Portions of the Upper Reach channel have been modified in the past by the HCFCD, the Local Sponsor. Flood damage reduction planning for the major tributaries of White Oak Bayou was not considered for this study. They are being considered by the HCFCD outside of the 211(f) study. The tributaries were included in the hydrologic models used to analyze flooding along White Oak Bayou. Any future projects along the tributaries will be required to mitigate any potential adverse peak flow and timing impacts to the White Oak Bayou main channel through the study reach.

2.3 Environmental Setting

The study area is a part of the rapidly expanding Houston metropolitan area, which, according to the U.S. Census Bureau, is the fourth largest city in the United States with a year 2000 population of 1.9 million. Harris County, of which Houston is a part, has a year 2000 population of 3.4 million and has a diversified residential development, multi-family

development, commercial development, and retail support services along major thoroughfares. (No updated census data have been provided, because the base conditions are based on the development that was in place in 1998, because the watershed was already approximately 90 percent developed, and because current population and development conditions are very similar to year 2000 conditions.) In addition, the project study area is served by major railroads.

White Oak Bayou upstream of Cole Creek to its headwaters is primarily an earthen channel. White Oak Bayou downstream of Cole Creek to the confluence with Buffalo Bayou in downtown Houston is a partially concrete-lined channel. Figure 2-1 shows typical photos of the existing White Oak Bayou channel.

A more detailed description of the environmental setting for the project is provided in the Environmental Assessment. The EA describes in detail the climate; geology and soils; biological resources; aquatic species; threatened and endangered species; water and air quality; surface waters and wetlands; historic properties including archeological and historic resources; hazardous, toxic, and radioactive wastes; socioeconomic conditions including human resources, population and community cohesion, employment, income, the tax base, life, health and safety considerations, community services, social and economic impacts of flooding, and environmental justice.

Figure 2-1 Photos of White Oak Bayou

1. Downstream partially concrete-lined channel, viewing north towards I-610

2. Upstream earthen channel, looking downstream from North Tahoe Drive

3. Upstream earthen channel, looking upstream from Fairbanks-North Houston Road

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3.0 IDENTIFICATION OF PROBLEMS AND OPPORTUNITIES

This chapter identifies and investigates the problems and opportunities of the study area with regard to flood risk management, environmental resources, and recreation.

3.1 Flooding Problems and Opportunities

Problem Statement: On a frequent basis, out-of-bank flooding occurs along White Oak Bayou that causes significant economic damages to homes, businesses, vehicles and public utilities.

3.1.1 Description of Flooding Problem

3.1.1.1 Chronology of Studies and Improvements

Congressional authorization of an improvement plan on lower White Oak Bayou was granted in September 1954. The plan provided for clearing, straightening, enlarging, and concrete lining, where necessary, the lower reach of White Oak Bayou. In this report the reach of the bayou from the mouth to Cole Creek is referred to as the lower reach. Between 1954 and 1955, the Harris County Flood Control District enlarged and rectified White Oak Bayou between the Burlington-Rock Island Railroad (BRIRR) at station 45000 (mile 8.5) and Cole Creek.

From 1958 to 1962, the HCFCD cleared, straightened, and enlarged the channel upstream of Cole Creek to Huffmeister Road, near station 132000. In addition to the channel modifications, HCFCD acquired drainage right-of-way throughout the stream length.

The U.S. Army Corps of Engineers (USACE) prepared numerous technical design memorandums in the early 1960s to address channel rectification for the lower reach of White Oak Bayou. These 10.7 miles of channel modifications comprise the existing Federal project that extends from the confluence of White Oak Bayou with Buffalo Bayou to Cole Creek, as shown on Exhibit 1-1. The modifications consisted of clearing, straightening, enlarging, and partial concrete lining the channel section. The partially concrete-lined channel from James Street (station 5600) to BRIRR (station 45000) was completed in September 1967. The partially concrete-lined channel from BRIRR (station 45000) to Cole Creek was completed in January 1970. A 1.1 mile reach of modifications near the mouth was completed in March 1976.

3.1.1.2 Flooding History & Characteristics

History

Many damaging floods have occurred along White Oak Bayou in the past. Flooding causes extensive property damage, and threatens the life, health, and safety of residents.

In the *Interim Report on Upper White Oak Bayou* (Reference 5), it was reported that flooding of more than 200 homes from a storm in October 1970 had caused estimated property damages of $1.10 million (1976 dollars) and that the March 1972 flood had damaged 292 homes with estimated property damages of $2.65 million (1976 dollars).

Severe flooding has also occurred and was documented by the USACE and/or the HCFCD in May 1983, October 1984, May 1989, June 1989, and March 1992. An estimated 225 homes in the Arbor Oaks, Woodland Trails North, and the Inwood Forest subdivisions were flooded during the May 1989 storm. Approximately 159 homes were flooded in June 1989. A total of 380 homes were flooded in March 1992 in the Arbor Oaks, Woodland Trails North, and Inwood Forest subdivisions in addition to the Studemont, Inwood Pines, Bayou Bend, Candlelight Forest, and Mangum Manor subdivisions. All of the approximately 200 homes in Arbor Oaks flooded in 1992. The HCFCD has estimated that both the 1989 and 1992 storms had a greater return frequency than a 10 percent flood event.

Approximately 1,200 homes were flooded, primarily in the reach from Woodland Trails West Subdivision upstream to Jersey Village, during the September 1998 flooding associated with Tropical Storm Frances.

On June 8-9, 2001, Tropical Storm Allison brought approximately 10 to 18 inches of rain to the watershed in only 12 hours. The storm flooded approximately 73,000 residences (homes, apartment units, and mobile homes) in the Houston area, with approximately 11,000 flooded residences in the White Oak Bayou watershed. Flood levels approximated or exceeded the 1 percent probability flood and record levels were reached along the entire length of White Oak Bayou. The 11,000 flooded residences include those flooded along the tributaries of White Oak Bayou and those flooded due to exceedance of local drainage capacity within the watershed.

Subsequent flooding occurred along the bayou during storm events on October 28-29, 2002 and November 17, 2003. The November 2003 storm event flooded approximately 75 homes in the Arbor Oaks and Inwood Forest subdivisions.

Characteristics

Warning time of impending inundation is generally in the range from 1 to 3 hours from the start of the rainfall producing flooding, depending upon the type of rainfall and the location along the bayou.

The rate of rise of channel flood levels typically range from 8 to 12 feet per hour. Typical flooding durations of 3 to 5 hours are likely. Depths of structural flooding may typically range from 1 to 4 feet for the 1 percent flood, and 3 to 4 feet for the 0.2 percent flood. Street flooding that occurs as the level of flood water in the bayou rises is likely to be one to three feet deeper than the structural flood depths. Floodwater velocities in the bayou channel typically range from 4 to 7 feet per second in the project area. Typically, flood water velocities in the flood plain areas away from the bayou channel range from 0.1 to 0.5 feet per second and are not hazardous.

The photographs presented as Figure 3-1 illustrate the type of flooding experienced during historic flood events in the watershed.

3.1.1.3 Economic Flood Damages

As part of the economic analysis performed for this study, a survey of the economic conditions within the approximate 0.2 percent floodplain was performed. The following summarizes the number of structures, structure value and single-occurrence damages for the 0.2, 1 and 10 percent floods.

Flood Frequency	Number of Structures Impacted	Structure Value ($ million)	Single Occurrence Damages ($ million)
10%	1,333	$116	$79
1%	6,074	$649	$423
0.2%	10,495	$1,139	$857

The average annual equivalent (AAE) damages for the without project conditions were estimated at approximately $60.0 million, at 2011 price levels using the 2012 Federal interest rate of 4.00 percent. (The economic damages were further updated to FY2013 price levels and interest rate later in this report.)

3.2 Flood Risk Reduction Opportunities

The frequency of flooding and the significant amount of damages indicate that significant opportunities for reducing the magnitude and frequency of flooding due to White Oak Bayou and creating net economic benefits exist.

The historical flooding in the watershed, substantial flood damages, and the significant property investment along the bayou support the need for a flood risk management project along White Oak Bayou. Further planning, design, and implementation of additional flood risk management in the White Oak Bayou watershed is warranted.

3.3 Environmental Problem Statement

Problem Statement: Past development activities and channel modifications have reduced the wetland and riparian habitat areas along White Oak Bayou.

3.3.1 Description of Environmental Problem

The White Oak Bayou watershed lies within the Houston Metropolitan Area, which has been highly impacted by human activities. Extensive urbanization, previous channel clearing, and enlargement of the channel to provide flood relief have resulted in significant alterations to and removal of riparian habitat. This has resulted in a substantial decline in populations of birds, mammals, reptiles, and amphibians. Much of the wetland and riparian areas have been lost or severely impacted, and water quality has declined with increased urbanization.

3.4 Environmental Opportunities

Typical flood risk management alternatives include stormwater detention basins and buyout of flood prone areas. With these alternatives typically occur the opportunity to revegetate with native plants and to construct wetland and riparian habitat areas. In addition certain channel modification alternatives offer opportunities to provide additional aquatic habitat and water quality improvement zones.

3.5 Recreational Problem Statement

Problem Statement: Along White Oak Bayou there is a lack of recreational areas that are typically associated with bayous in other highly developed areas around Houston

3.5.1 Recreational Problem Description

Extensive development and rapid population increases are placing pressure on the Houston metropolitan region for quality recreation opportunities. This need creates a demand for new and expanded park facilities and open spaces. The provision for recreational areas has not kept up with the demand for such recreational areas along White Oak Bayou.

Recreational resources in the White Oak Bayou watershed are primarily limited to man-made facilities due to the extensive urban development in the watershed. Much of the area along the bayou has been disturbed through past channel modifications, allowing very little native vegetation to thrive within the area. As would be expected, these areas are less desirable for aesthetic and recreation uses and the least utilized by area canoeists and bird watchers.

3.6 Recreational Opportunities

Some of the areas along the bayou, including detention facilities, have the potential for recreation amenities such as trails, practice fields, and open play areas. There is also the potential for other recreation opportunities such as fishing, picnicking, and natural areas. Aesthetic and functional recreation improvements including access points, trees and shrub plantings, and wildlife habitat improvements are needed to enhance the appearance and create more of a park-like setting to attract recreational users to White Oak Bayou.

Harris County Precinct 4 has expressed interest to be the Local Sponsor to address these recreation opportunities. A draft Recreation Plan was developed as a part of this study to address the concerns expressed by local citizens along White Oak Bayou and to evaluate the opportunities presented by a flood risk management project. The costs of the Recreation Plan have been included in the overall project costs presented in Chapter 5.0.

Figure 3-1 Photos of Historical Flooding

1. March 1992 Flood, Downtown Houston (Copyright - Houston Chronicle)

2. September 1998 Flood, Woodland Trails Subdivision

Figure 3-1 Photos of Historical Flooding, page 2 of 3

3. June 2001 Flood, Woodland Trails West Subdivision

4. June 2001 Flood, Woodland Oaks Subdivision

Figure 3-1 Photos of Historical Flooding, page 3 of 3

5. June 2001 Flood, White Oak Bayou at Alabonson Road

6. June 2001 Flood, White Oak Bayou at Yale & Heights Street

4.0 PLAN FORMULATION

This chapter describes the steps that were taken to formulate a plan which best meets the planning objectives. The formulation of a plan to manage flood risk requires the exploration of non-structural and structural components.

4.1 Planning Objectives and Constraints

Legislation requires that Federal water and related land resources planning be directed at contributing to National Economic Development (NED), consistent with protecting the Nation's environment. Contribution to NED is achieved by increasing the net value of the Nation's output of goods and services, expressed in monetary units. NED contributions must also consider the environmental effects of proposed changes to natural and cultural resources.

Plans formulated as part of this study were evaluated based on their contribution to NED, and their impact on the Nation's environment. The objectives and constraints were also formulated to address the four plan evaluation criteria (i.e., completeness, effectiveness, efficiency, and acceptability) suggested by the U.S. Water Resources Council in *Economic and Environmental Principles and Guidelines (P&G) for Water and Related Land Resources Implementation Studies* (Reference 9). In addition to the National objectives, local objectives were developed to assist in communication with area residents.

The following objectives, and constraints reflecting local and federal considerations have been established for the White Oak Bayou study:

National Objectives

The fundamental national objective of Federal participation in water resources development projects is to assure that an optimum contribution is made to the welfare of all people. The Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies dated March 1983 and the National Environmental Policy Act of 1969 (NEPA) provide the basis for Federal policy for planning Federal water resources projects. Principles and Guidelines (P&G) state that the Federal objective of water and related land resources planning is to contribute to national economic development (NED) consistent with protecting the Nation's environment, in accordance with national environmental statutes, applicable executive orders, and other Federal planning requirements. National objectives are designed to assure systematic interdisciplinary planning, assessment, and evaluation of plans addressing natural, cultural, and environmental concerns, which will be responsive to Federal laws and regulations. Four national objectives were considered in this project. The four objectives considered are discussed as follows.

- *NED*. The alternative plan that reasonably maximizes net economic benefits consistent with protecting the Nation's environment, the NED plan, shall be selected. The Assistant Secretary of the Army for Civil Works (ASA (CW)) may grant an exception when there are overriding reasons for selecting another plan based upon other Federal, State, local and international concerns.
- *Effects on Environmental Quality (EQ)*. The Environmental Quality account identifies the non-monetary effects on significant natural and cultural resources (ER 1105-2-100).
- *Regional Economic Development (RED).* The Regional Economic Development (RED) account identifies changes in the distribution of regional economic activity.
- *Other Social Effects (OSE)*. The Other Social Effects (OSE) account identifies the plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts (ER 1105-2-100).

Overall Local Objectives

- To identify and recommend an effective, affordable, and environmentally-sensitive flood risk management project for White Oak Bayou.
- To conduct the necessary engineering, economic, and environmental analyses in a timely manner in order to obtain Federal appropriation.

Specific Planning Objectives

- Reduce damages to residences and businesses caused by flood flows in White Oak Bayou.
- Enhance or improve the aesthetics, environmental quality, and recreational opportunities where possible, given the limited authority of the HCFCD to fund such activities.
- Minimize adverse impacts on existing neighborhoods and wildlife habitat.
- Minimize the total project cost.
- Maximize the economic benefits to the community.
- Develop a project that satisfies federal criteria for financial participation.

Constraints

- The project should have the general support of the affected citizens and businesses in the watershed.
- The project must conform to the mission of the HCFCD and be implementable by the HCFCD under existing laws, ordinances, and policies.
- The project must be developed following the applicable policies and guidelines of the USACE.
- No adverse flood impacts may be created by the implementation of the project.

4.3 Without Project Conditions Analyses

The base without project condition (base condition) is the watershed land use condition in the year 2010, assuming the configuration of the channel and detention facilities as of January 1, 1998. The 1998 date was selected because the Federal project study began in January 1998 and because the 1998 date occurs after the passage of WRDA 1996 which authorized the Section 211(f) planning process. This date was also selected because the HCFCD intended to construct flood reduction measures along White Oak Bayou in advance of the completion of the Federal planning process and needed a baseline start date for environmental conditions prior to construction of these measures and for potential reimbursement of funds used to construct them. Existing flood reduction facilities considered in place as of January 1998 are discussed later in Section 4.3.1

The base year of 2010 (base conditions) was selected as the beginning of the 50-year project life since it is the year in which the project was anticipated to be completed and benefits were expected to begin to accrue. The year 2060 future conditions based on the 50-year analysis period specified by USACE guidance documents were assumed to be equivalent to the 2010 conditions. This assumption is based on three factors:

(1) The watershed is approximately 90 percent developed, including the internal drainage systems for the watershed subbasins. In addition, if existing public rights-of-way, parks, and undevelopable open space are considered, only 5 percent of the watershed remains available for development.
(2) The Harris County Flood Control District, Harris County, and the City of Houston all require that any new development or significant redevelopment provide stormwater detention so that no increases in peak flood flows or flood elevations result from the development. They also require that first floor structure elevations be 18 inches above the 1-percent flood elevation. Therefore there is no expectation that the flood flows and resulting flood damages would increase during the next 50 years. Also, the first floor elevation requirements would prevent any significant increase in new developed properties being subject to flood damage.
(3) Based on experience in similar primarily single-family residential areas throughout Harris County, it appears unlikely that during the 50-year analysis period significant redevelopment would occur within the major subdivisions and developments within the upper White Oak Bayou watershed.

Based on these factors, the Without Project hydrologic and hydraulic models for present conditions and future conditions at the end if the 50-year analysis period are identical. This assumption is based on the requirements that all future development have no impact on current flood levels and that any new development within the existing flood damage area be built at least 18 inches above the 1% flood level. The base conditions serve as the foundation for the plan formulation process. For the selected plan, as presented later in Chapter 5, the base year was changed to 2016. This change has no effect on the results because the base year and future condition flood levels are unchanged.

4.3.1 Hydrologic and Hydraulic Base Conditions

The hydrologic and hydraulic (H&H) analyses were conducted on the main stem of White Oak Bayou for the base conditions. Updated models of White Oak Bayou created in the aftermath of the June 2001 Tropical Storm Allison flood event were used to create the base without project condition models for this study. The restudy was undertaken by the Federal Emergency Management Agency (FEMA) and HCFCD working under a Cooperative Technical Partner (CTP) agreement. The updated base models were created using the HEC-HMS and HEC-RAS computer models along with current topographic information from a Light Detection and Radar (i.e., LIDAR) survey to map the ground's topography. The datum of the topography and all the elevations presented herein are based on the North American Vertical Datum (NAVD) 1988, 2001 subsidence adjustment.

The base without project condition models served as the basis for evaluating the relative effects of both structural and non-structural flood damage reduction components. A detailed discussion of the analyses is found in Appendix A - Hydrology and Hydraulics.

An in-line detention facility, also known as a flow-through facility, is one in which all the flow passes through the facility, regardless of the size of the event. An off-line detention facility is one in which only the peak of the stormwater event that exceeds a certain design elevation will pass through a regulating structure such as a diversion spillway or side weir.

White Oak Bayou channel modifications and detention facilities that were completed by January 1, 1998 are included in the hydraulic analysis for the base without project conditions. The base condition model incorporates the following elements: a partially concrete-lined channel in the lower reach (i.e. the existing Federal channel completed in 1976) and numerous constructed or partially constructed detention facilities. The base without project conditions facilities shown in Exhibit 4-1 include the following HCFCD elements:

- E500-05-00 is an in-line detention facility with a storage volume of 160 acre-feet located north of the main stem of White Oak Bayou and north of Tidwell between stations 58000 and 59500.

- E500-01-00 is an in-line detention facility with a storage volume of 360 acre-feet located north of the main stem of White Oak Bayou and east of Fairbanks-North Houston Road between stations 85000 and 87500.

- E500-04-00 is an in-line detention facility with a storage volume of 360 acre-feet located north of the main stem of White Oak Bayou and east of North Houston Rosslyn Road between stations 73500 and 75500.

- E200-00-00 is an unconnected channel segment located north of Jersey Village between White Oak Bayou and HCFCD channel E141-00-00.

Flood flows and water surface elevations for the required frequency events along White Oak Bayou were computed using HEC-HMS and HEC-RAS computer models. The procedure used for this study uses HEC-HMS to compute runoff hydrographs, unsteady HEC-RAS for stream and storage routing along the main stem and major tributaries and steady HEC-RAS for computation of flood stages. Figure 4-1 depicts the analysis procedure.

HEC-HMS was used to compute runoff hydrographs for the 41 subbasins within the watershed. The subbasin/tributary hydrographs from HEC-HMS were used as input to the HEC-RAS unsteady routing model.

Peak flows from the HEC-RAS unsteady routing model were input into the steady HEC-RAS model. The steady HEC-RAS model was used to compute flood stages for the design flood events for the White Oak Bayou main stem. The steady HEC-RAS flood flows and water surface elevations for the required exceedance probabilities for base without project conditions and for the with-project conditions were imported to HEC-FDA for economic analysis. This process mimics the one developed in conjunction with FEMA for the Flood Insurance Studies in Harris County.

The base Without Project condition model was developed to simulate flows and water surface elevations for eight annual exceedance probability events (50%, 20%, 10%, 4%, 2%, 1%, 0.4%, 0.2%). Exhibits 4-2.1 and 4-2.2 show the exceedance probability water surface profiles of the without project conditions model. The channel cross-section of White Oak Bayou varies along the length of the Bayou and, as can be seen in the exhibits, the channel capacity varies along the length of White Oak Bayou with the water surface elevations exceeding the channel bank elevations at various locations for the events analyzed.

4.3.2 Economic Base Conditions

Detailed economic investigations and analyses were performed to assess base Without Project conditions flood risk and damages. The economic database presented in this section represents 2011 price levels and property values. The economic database was also updated previously to 2009 price levels and property values during the analysis. (For the plan formulation steps presented later in Chapter 4, the economic database for the Without Project Condition and for the alternatives analysis was based on 2002 price levels and property values.) A detailed discussion of the economic analysis is provided in Appendix B - Economic Analysis. The following summarizes the results of the base conditions analysis.

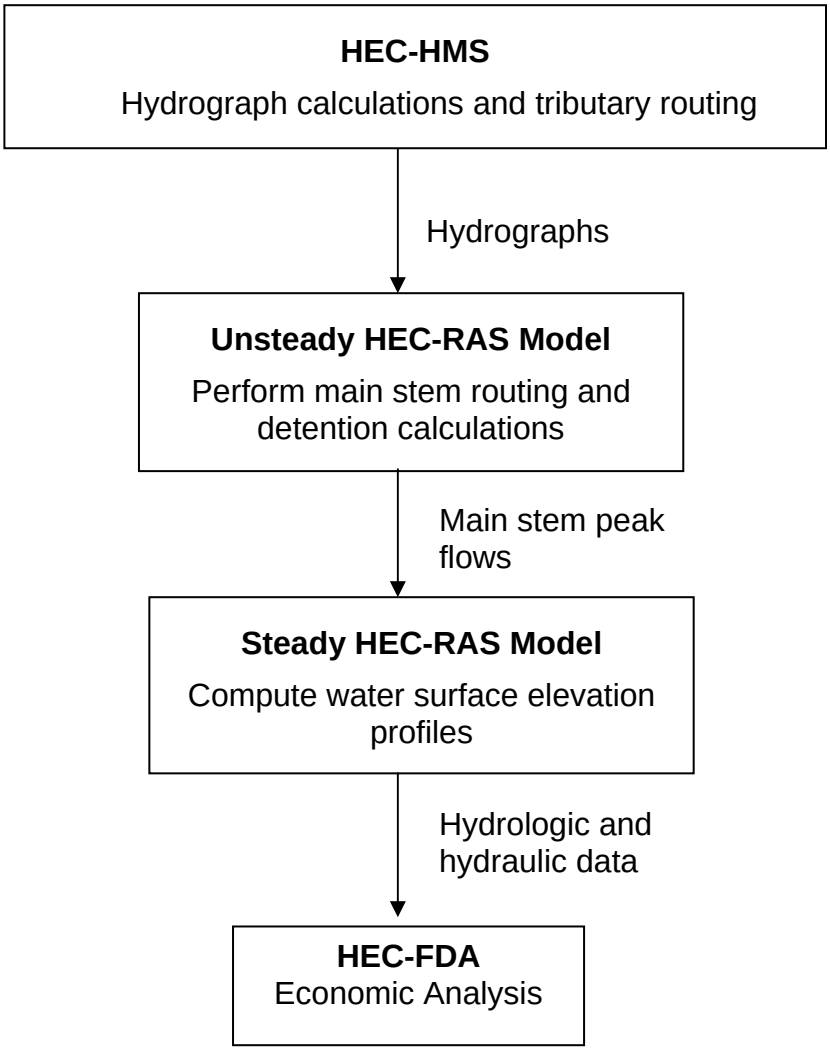


Figure 4-1 Model Interrelationships

Properties surveyed within the estimated 0.2 percent flood event were assigned to the nearest stream cross-section along the centerline length of White Oak Bayou. The stream was divided into 19 economic planning reaches with representative index stations for modeling purposes. Reach divisions were made based on changes in hydrology and stream hydraulics, and risk and uncertainty characteristics. Three economic planning reaches were further subdivided to evaluate the damages to areas to be protected by potential structural levees. Exhibit 4-3 shows the defined economic reaches, and Table 4-1 presents the information in tabular format by showing reach name, reach stationing, index station, and geographical reference.

Structures and Investment Identified

The final structure inventory includes a total of 10,495 structures inventoried within the approximate 0.2 percent floodplain and its vicinity, with a total structure value of approximately $1.44 billion, based on 2011 prices.

Over 91 percent of the structures, representing approximately 61 percent of the value of investment in the 0.2 percent floodplain, are either single- or multi-family residences. Nonresidential properties, including commercial and some public facilities, represent approximately 9 percent of the total number of structures and 39 percent of the total 0.2 percent floodplain investment.

Single-Occurrence Flood Losses

The total damages associated with single occurrence flood losses are computed by considering the depth of flooding and interpolating the damages from the stage-damage curve. As previously presented in Section 3.1.1.3, approximately $79 million in flood damage would occur during a 10 percent flood event. A 1 percent flood event would result in over $422 million in flood damage. The one-time damages expected during a 0.2 percent flood event are over $857 million. All events consider impacts to structures, contents, roads, utilities, and vehicles, and post disaster costs.

Flood Damages

The expected annual (EA) damages for year 2010, the base year, and for year 2060, the end of the planning period are both approximately $60.0 million each. The total base conditions average annual equivalent (AAE) damages in the study area, for the risk-based analysis, are also $60.0 million over the 50-year planning period, at 2011 price levels and the 2012 Federal interest rate of 4.00 percent. Table 4-2 shows the distribution of AAE damages by reach, and Exhibit 4-4 graphically depicts the flood damage distribution. Damages are highest in Reach 10a and 10b because this area is characterized by flat topography, a wide floodplain, and a large concentration of single-family residential structures. This reach contains approximately 70 percent of the single-family residences within the 10 percent exceedance probability flood plain for the study reach, and approximately 50 percent for the 4 percent flood plain. There are no expected changes in damages over the planning period because of the existing controls on development.

Table 4-1 Economic Reach Definitions

HEC-FDA Reach	Start Station	End Station	Index Station	Bank	Description
1	0	5525	4687	Both	Mouth to IH-45
2	5525	18176	9779	Both	Houston Ave. to Yale St.
3	18176	23944	23944	Both	Yale St. to D/S Hidden Lake Town Homes
4a(L)	23944	25536	25536	Left	D/S Hidden Lake Town Homes to U/S Hidden Lake Town Homes
4(R)	23944	35718	30779	Right	D/S Hidden Lake Town Homes to Ella Blvd.
4b(L)	25536	35718	32570	Left	U/S Hidden Lake Town Homes to Ella Blvd.
5	35718	44983	41337	Both	Ella Blvd. to Burlington Northern RR
6	44983	56811	48942	Both	Burlington Northern RR to W. Tidwell Rd.
7	56811	63780	57918	Both	W. Tidwell Rd. to W. Little York Rd.
8a(L)	63780	65878	65878	Left	W. Little York Rd. to Antoine Dr.
8(R)	63780	70347	67624	Right	W. Little York Rd. to Alabonson Rd.
8b(L)	65878	70347	69408	Left	Antoine Dr. to Alabonson Rd.
9	70347	76222	74115	Both	Alabonson Rd. to N. Houston Rosslyn Rd.
10a(R)	76222	79748	77625	Right	N. Houston Rosslyn Rd. to Hollister Rd.
10a(L)	76222	82633	77625	Left	N. Houston Rosslyn Rd. to HCFCD Ditch E124-00-00
10b(R)	79748	84932	82633	Right	Hollister Rd. to Woodland West Dr
10b(L)	82633	84932	83815	Left	HCFCD Ditch Unit E124-00-00 to Woodland West Dr.
11	84932	88972	88972	Both	Woodland West Dr. to W Gulf Bank Rd.
12	88972	92851	90490	Both	W Gulf Bank Rd. to N Gessner Rd.
13	92851	96514	95013	Both	N Gessner Rd. to Sam Houston Pkwy.
14	96514	104527	100723	Both	Sam Houston Pkwy. to Wyndham Village Dr.
15	104527	110346	107598	Both	Wyndham Village Dr. to West Rd.
16	110346	116549	112547	Both	West Rd. to Jones Rd.
17	116549	122498	119390	Both	Jones Rd. to FM 1960 W.
18	122498	130861	127300	Both	FM 1960 W. to Oak Acres Dr.
19	130861	135006	131721	Both	Oak Acres Dr. to US 290

Table 4-2
Distribution of AAE Damages by Reach

HEC-FDA Reach	Average Annual Damages ($1,000)	Average Annual Percent Distribution
1	$1,415.01	2.4
2	260.67	0.4
3	142.42	0.2
4a(L)	425.65	0.7
4(R)	443.42	0.7
4b(L)	1,163.96	1.9
5	3,331.81	5.6
6	2,660.17	4.4
7	1,344.66	2.2
8a(L)	39.56	0.1
8(R)	1,033.82	1.7
8b(L)	1,396.63	2.3
9	3,145.52	5.2
10a(R)	2,145.76	3.6
10a(L)	6,942.29	11.6
10b(R)	4,046.37	6.7
10b(L)	7,062.18	11.8
11	2,281.11	3.8
12	4,002.98	6.7
13	1,613.48	2.7
14	6,640.11	11.1
15	1,073.25	1.8
16	2,985.41	5.0
17	3,828.07	6.4
18	468.83	0.8
19	126.26	0.2
Total	**$60,019.40**	100.0

Notes: (1) Damages shown include risk and uncertainty.
(2) Damages are based on 2011 property values and year 2012 Federal discount rate of 4.00.
(3) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the recommended plan identified later in this report.

4.4 Description of Plan Formulation Process

Plan formulation is the process by which alternatives are developed through a process of identifying and evaluating individual components and then combining components in a consistent fashion to reasonably maximize net economic benefits. Alternative plans are formulated using incremental first-added analysis. Once anchor components are established, remaining components are added individually to determine if they are incrementally justified as next-added components. The component that produces the largest positive incremental benefit becomes part of the formulated plan. The then formulated plan is then used as the base for the next step and other components are added individually. The optimal combination of components (with the highest net EA benefits) is then used as the base plan in the next step. This process continues until the optimal combination of components is found and no more components can be added that increase net annual benefits.

A re-optimization is performed on the remaining components after two components are added to the alternatives. This is done because as components are added to the plan, changes may occur in flows, water surface elevations, and resulting economic damages, and the component configuration that performed the best in a previous iteration may not be the configuration that performs best in a subsequent iteration. After all components are added, a last-added analysis is performed to insure that all components continue to add net benefits. After the alternatives have been developed through the process of combining components, one of the alternatives is identified as the Net Economic Development or NED Plan, that is, the plan that reasonably maximizes net annual economic benefits.

4.4.1 Introduction

The HCFCD began this planning study in 1998 with a reconnaissance phase, a general level of investigation that was submitted to the USACE in a 905(b) expedited reconnaissance report dated January 19, 1999. Subsequent to the reconnaissance phase, a detailed level of planning was undertaken to evaluate flood risk management solutions for White Oak Bayou. This detailed planning phase included identification of components, component analysis, and alternative formulation. An administrative draft GRR dated June 2002 (Reference 20) was developed for internal review based on this technical analysis.

A review of this report by USACE-Galveston District (SWG) and by the Independent Technical Review (ITR) team identified issues with portions of the formulation process. Near the end of the review period, it was recognized that the Local Sponsor would be acquiring new, updated hydrology and hydraulic models for the White Oak Bayou watershed and channels as a result of Tropical Storm Allison. With consideration of the information gained in the review process and the availability of improved models, another cycle of alternative formulation was initiated to leverage significant information newly available and to comprehensively address some of the issues identified in the review. The following paragraphs summarize the Plan Formulation Methodology and identify changes between the process started in 1999 and the process started in 2002.

4.4.2 Summary of Current Plan Formulation Methodology

The steps used in the current plan formulation may be summarized as follows:

- Step 1 – Identification of components.
- Step 2 – Single-component evaluation and optimization
- Step 3 – Identification of anchor components
- Step 4 – Reoptimization of remaining components
- Step 5 – Incremental addition of components
  Steps 4 & 5 were repeated in a cyclical manner until all beneficial components were added to each alternative
- Step 6 – Final optimization

Section 4.4.3 describes each of the steps in more detail. Sections 4.5 through 4.12 document the technical analysis that was performed. Significant portions of the plan formulation documented in the draft June 2002 report followed these steps and were used as guidance in the current plan formulation.

The following items describe the significant changes from the 1999 process to the current process.

- **Components in lower White Oak** - No components were evaluated downstream of Interstate 610 on White Oak Bayou for several reasons:

  (A) This reach of White Oak Bayou is outside of the area with the majority of the economic damages and has been provided protection with the first White Oak Federal project.

  (B) There is the potential for induced damages downstream on Buffalo Bayou outside of the project area. This part of Buffalo Bayou consists of downtown Houston. To bring the Buffalo Bayou area into the study area would be a significant time and funds expenditure.

  (C) This reach of White Oak Bayou is part of the Buffalo Bayou and Lower White Oak Flood Damage Reduction and Eco-System Restoration Federal Project.

- **Channel components** – Several channel components were considered in the 1999 plan formulation effort. Only channel components upstream of Cole Creek along the bayou performed strongly. Channel components were re-segmented into three shorter channel components to improve evaluation in this area.

- **Detention basins** - Some detention basins were aggregated due to their geographic proximity and evaluated as one basin, with varying sizes.

- **Optimization** of all individual component sizes was performed prior to identifying the anchor or first plan component. The process for optimizing component sizes when building alternatives always included “breaking the curve”, that is, ensuring that the maximum net benefits were identified by plotting net benefits versus component size.

- **Re-optimization** - All components were reevaluated and re-optimized for each anchor component to accurately identify the second-best performing component for each alternative. Additionally, during the building of alternatives all unselected components were periodically re-optimized during the process of adding components to each alternative plan, to ensure identification of the best performing components and component sizes.

- **Risk-based analysis** was extended to the component evaluation phase.

- **Components** were added to alternatives based on incremental net benefits, without consideration or priority being given to upstream components over downstream components.

4.4.3 Current Plan Formulation Steps

The six current plan formulation steps, as listed previously in Section 4.4.2, are described in more detail in the following paragraphs.

Step 1 – Identification of Components

The identification of components is the step where potential components for flood risk management are identified. A thorough effort to identify suitable structural and non-structural components for subsequent analysis is considered essential to a productive plan formulation.

The initial identification of components for White Oak Bayou was based on a review of several sources of data that are summarized below:

- Previous studies – The work already done by the HCFCD and the USACE was reviewed. A list of the studies utilized is presented in the references at the end of this document. This effort started with the results of the draft June, 2002 report discussed in Section 4.4.1.

- A review of the Without Project conditions (revised in 2002 and 2003) economic data, hydrology and hydraulic data Some of the indicators used for identifying potential components include consideration of high damage reaches, changes in flow regime, changes in existing channel cross section, and vacant land for detention basins in potentially suitable locations.

- An overview of the study area by field trips, study of aerial photography, and interaction with the public through public meetings, the citizens advisory committee, and communication with resource agencies.

Step 2 – Single-Component Optimization

The next step after the identification of components is evaluation of a series of different sizes or configurations for each individual component. This was done to identify the economically best-performing components, when evaluated without any other components being implemented. The net annual economic damage reduction (net benefits) for each size or configuration was compared to the Without Project economic damages.

To determine the optimum size of each component, at least three different feasible sizes of each component were analyzed, and the resulting annual net benefits were calculated. A curve of net benefits versus component size was plotted to determine if the maximum net benefits had been determined. Additional sizes were evaluated if the initial three sizes did not show that the maximum net benefits had been identified.

Step 3 – Identification of Anchor Components

For each alternative to be built, the anchor (first selected component) must be identified. A review of the economic performance of each individual component and their sizes was performed to decide how many alternatives would be developed. One component would be selected as an alternative's anchor based on having the highest economic performance. A second criterion for selecting additional components to be an alternative anchor is identification of a significant variation of the first selected anchor such as size and cost, that is a strongly performing component. The last criterion initially considered in selecting a component to be an alternative anchor is that the component provides a level of performance similar to other alternative anchor components but is functionally different. In selecting alternative anchors, environmental factors and local public preferences were also considered in addition to economic performance.

Three alternative plans were developed based on the selection of the various anchors or first components.

Step 4 – Reoptimization of Remaining Components

For each alternative, each of the remaining unselected components was re-optimized in combination with the anchor component to identify the best performing size of each of the remaining unselected components. This re-optimization also occurred after two or three components had been identified and added to the alternative during the building process. The optimum configuration was determined based on the maximum increase

in net benefits. This re-optimization was performed because it was anticipated that the anchor component (or the effect of adding two or three components during the building process) might significantly change the water surface and economic damage profile, which might in turn alter the selection of the best performing size for each of the remaining unselected components. Again, as in Step 2, at least three sizes of each component were considered to ensure that the optimum size was again selected. After components were added to the alternative, they were not re-optimized during the building process. Only unselected components were subject to re-optimization.

Step 5 – Incremental Addition of Components

After reoptimization in Step 4, the economically best-performing additional component was selected as the next component to be added in the process of building the alternative. After the addition of the next best performing component, the remaining components were added to each alternative to determine the remaining best performing component. The assumption was made that the optimum size of each component would not change due to adding two or three components in the alternative building process. After the addition of two or three individual components, the Step 4 re-optimization of the remaining unselected components was performed again.

Steps 4 and 5 were repeated in a cyclical manner multiple times until all the components that produced incremental net benefits were added to each alternative. Steps 4 and 5 constitute the majority of the process referred to as “building the alternatives”, the systematic process for adding components to form alternatives which would be reasonably expected to maximize the net annual benefits.

It should be noted that Steps 4 and 5 occurred independently for each alternative being built –i.e. the selection of a component for one alternative had no influence on the selection of a component, or identification of best performing size of a component, during the building of a different alternative. The iterative process involving Steps 4 and 5 was continued until all components that increased net economic benefits were added to the alternative plans.

Step 6 – Final Optimization

After the alternative plans were built, a final optimization was performed for each alternative. The final optimization included the following:

(1) A “last-added” analysis of each component was performed, in which each component was individually removed from the final plan to check that the final plan provided greater net benefits with each component than without each.

(2) A review of each component was made in the order in which it was added to the alternative in the building process, and, where feasible, the component was individually re-optimized with a “tighter” range of sizes, starting with the first-

added component. This component review also included a review of the component costs and associated factors (mitigation and physical site). This was done to provide a final optimization of component sizes.

(3) For selected alternatives an analysis of additional component variations was performed.

In addition a final review of each component included in each alternative was performed to identify any potential implementation issues that may have arisen during the study period.

After this final step, the net economic benefits of each alternative were compared and the NED Plan was identified.

4.5 Step 1 - Identification of Components

The identification of components is the planning step where possible alternative components for flood risk management are identified. This section provides an explanation of the process that was used to identify flood risk management components.

The current GRR study leverages previous efforts by both the USACE and the HCFCD, as mentioned in sections 1.4 and 4.4.1. In the analysis presented herein, some of the components previously analyzed in the Draft GRR, June 2002 (Reference 20) have been modified to facilitate the analysis process and to develop better alternatives, as described in section 4.4.2.

This initial step of the component analysis includes listing components that might fit into a flood risk management plan. Both structural and non-structural components were considered. Each independent flood risk management measure was considered as a component. Flood risk management components were sought that best addressed the planning goals and objectives.

4.5.1 Non-Structural Components

A non-structural component is one that reduces flood risk without significantly altering the nature or extent of the floodplain. This is accomplished by changing the use made of the floodplain or by accommodating existing uses to the flood hazard. The range of non-structural components considered includes floodplain management, flood warning, flood proofing, raising structures, and structure relocation/buyout.

The major characteristics of each are summarized below:

Floodplain Management

- Potential components, practices, and policies which reduce the impacts of future development on flooding
- Enforceable floodplain regulations compatible with the needed level of protection

Flood Warning

- Determination of imminent flooding
- Implementation of a warning plan
- Evacuation of persons and personal property

Flood Proofing

- Property options such as seepage control, check valves and sandbags
- Structure options such as water-tight doors and window seals

Raising Structures

- Installation of piers
- Extension of foundations
- Imported fill

Structure Relocation/Buyout

- Structure purchase and demolition or removal of structures to higher ground
- Relocate families to safer structures

4.5.1.1 Floodplain Management

A floodplain management plan should address potential components, practices, and policies which will reduce the impacts of future flooding, help preserve levels of protection, and preserve and enhance natural flood plain values. Effective floodplain management is dependent on the development of enforceable regulations, which insure that uses of floodplain lands are compatible with the level of flood hazard.

Harris County, the City of Houston and surrounding communities participate in the National Flood Insurance Program. Building regulations are in place that require the lowest floor elevation of new or substantially improved structures located within a 1 percent floodplain be elevated so that the lowest floor is a minimum of 12 or 18 inches above the base flood elevation, depending on the local jurisdiction. Development within designated floodplain areas is regulated to ensure that the cumulative effect of proposed development will result in zero increase in flood levels during the occurrence of the 1 percent flood discharge. In addition, development within the floodway may not impede the flow of floodwaters and may not create an adverse effect on the carrying capacity and flood storage of the 1 percent floodplain.

Because of these ongoing controls and because the programs will not reduce the existing flood damages along the main stem of White Oak Bayou, the consideration of floodplain management techniques as a component in the plan formulation process was not warranted.

4.5.1.2 Flood Warning

Flood forecasting and temporary evacuation involve the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in the evacuation of persons and some personal property. Some typical elements of a flood warning system may include radio, siren, television, individual notification, or elaborate remote sensor devices. HCFCD, the National Weather Service (NWS), the Harris County Office of Emergency Management (HCOEM), and the United States Geological Service (USGS) have established a network of rain and stream flood gauging stations to collect data for flood warning purposes. The NWS issues flood watches and warnings, sometimes in consultation with the HCOEM. If necessary, a warning is issued through the National Oceanic and Atmospheric Administration (NOAA) weather radio system and media via the weather wire.

Either heavy rainfall from frontal-type storms, intense rainfall associated with localized thunderstorms, or heavy rainfall from tropical storms from the Gulf of Mexico typically produces the major floods experienced in the White Oak Bayou study area. The frontal type storms typically develop over time and have consistent rainfall intensities over several days. Flood-producing tropical storms, such as Tropical Storms Frances and Allison, also develop over time and may have consistent higher-intensity rainfall. For these two types of storms, a flood warning system can be effective. Flood warning components often serve to reduce the hazards to life and damage to portable personal property, including contents and vehicles.

Although local warning for certain types of storm events may be successful in avoiding some damage and possible loss of life, it is not considered to be of significant value in providing significant damage reduction for the following reasons:

1. The Local Sponsor already has an extensive flood monitoring system.

2. Primary damage reduction from flood warning would be for automobiles. However, in most floods in the Houston area, traveling to safer areas is difficult and may be dangerous because of the extensive street flooding that occurs quickly due to storm sewer overflows.

3. Advance flood warning would not reduce damages to structures.

4. Warning times typically less than 3 hours are too short to reduce contents damage.

Therefore, this non-structural component was not considered for further evaluation.

4.5.1.3 Flood Proofing

Flood proofing components help protect personal property inside structures by preventing floodwaters from entering the structure. This option is most applicable where flooding is of short duration, shallow depth, low velocity, and infrequent occurrence. Typical techniques include watertight doors, window seals, seepage controls, check valves, and sandbagging. This non-structural option is not considered practical for residential homes in frequently flooded areas that are subjected to flooding depths in excess of the heights of windowsills. In addition, the flood proofing of residences requires personal effort to protect each home from the rising water.

These techniques were not considered viable for all locations of flooding within White Oak Bayou, nor for all flooding situations that do occur. In addition, flood proofing is not a viable option for the White Oak Bayou watershed because of the large number of residences subject to flooding and the rapid rise of water during a storm event. This non-structural component will not be considered for further analysis because of the large number of residences in the study area and the prohibitive amount of notification and coordination required to implement a flood-proofing program.

4.5.1.4 Raising Structures

One method of flood proofing is raising structures at their existing site. Five elevating structure plans were developed as part of the component analysis. The plans considered raising the structures receiving damages resulting from the 2, 4, 10, 20 and 50 percent floods. This non-structural component is considered for further evaluation in Section 4.6.2.

4.5.1.5 Structure Relocation/Buyout

Five structure relocation or buyout plans were developed as part of the component analysis. Structures were identified for buyout if they experienced flooding depths that exceeded their first floor elevations for specified events. The five plans evaluated buyout of the structures receiving damages resulting from the 2, 4, 10, 20 and 50 percent floods, respectively. This non-structural component is considered for further evaluation in Section 4.6.1.

4.5.2 Structural Components

Structural components consist of structures or facilities designed to control, divert, or exclude the flow of water from flood prone areas to reduce damages to property, hazards to life or public health, and general economic losses. A list was developed of structural solutions or components that were likely to be effective at flood damage reduction along White Oak Bayou and produce net positive economic benefits. The list was based on the

component analysis in the June 2002 draft GRR (Reference 20). Certain components were modified, combined, or eliminated from consideration in the analysis presented herein. These changes are discussed, where necessary, in the following sections. The base condition hydrologic and hydraulic (H&H) analyses and economic analyses were used to identify stream reaches in need of flood risk management components. The water surface profile generated for the base conditions (Exhibits 4-2.1 and 4-2.2) identified the stream reaches with limited flow conveyance capacity. Flood damages along the stream length were identified from the base conditions economic damage profile (Exhibit 4-4).

The structural components identified for initial screening are grouped into four categories, as summarized in Table 4-3. The list of components identified is not an exhaustive list since the intent was to develop a range of feasible components to target high damage areas based on engineering assessment, available right-of-way, and available vacant land. A more detailed description of the components and the rationale behind developing the components is provided in the following sections.

Table 4-3
Structural Components

Component	Characteristics
Channel Modification	• Increase flow conveyance capacity of the bayou • Add by-pass channel to increase reach conveyance
Detention	• Off-line or in-line storage facility
Bridge Modification	• Modifications to bridges spanning White Oak Bayou • Bridge removal or replacement
Levees	• Construction of levees around areas that have experienced repeated floods

4.5.2.1 Channel Modification

Channel modification focuses primarily on channel enlargement and/or channel lining to increase conveyance capacity with the objective of lowering the water surface elevations on the main stem. Bypass channelization is also considered around selected segments of White Oak Bayou to help contain flows within these segments. The main channel will continue to be the primary flow route, while the bypass channel would provide a secondary flow route for the additional flows associated with more severe flood events.

4.5.2.2 Detention

Previous studies, including the Regional Plan (Reference 10) and interim reports (References 16,17,18) for the June 2002 Draft GRR, were reviewed to help identify potential detention sites. Large, vacant tracts of land located closest to the bayou were

identified as the favorable detention sites. Vacant areas adjacent to the bayou are limited because of the extensive development within the watershed. Occupied tracts of land adjacent to the bayou would require buyouts and were considered less favorable for detention. Included in the evaluation was the expansion and/or modification of a number of existing detention basin facilities constructed prior to 1998.

4.5.2.3 Bridge Modification

Bridge modification components consist of removal, replacement or modifications of bridges spanning White Oak Bayou. Bridges were reviewed to identify ones with large head loss. The bridge at North Houston-Rosslyn Road is the only bridge within the high damage area with a substantial head loss and was the only bridge analyzed, as presented in Section 4.7.

During early analyses of the bridges in the lower reaches of White Oak Bayou, it was determined that the benefits resulting from modification or removal of a bridge are due to the lowering of the water surface elevation upstream from the bridge. However, removing a restriction at a bridge has the effect of increasing the water surface elevations and peak flows downstream from the bridge. While assessment of the benefits of a bridge modification or removal are possible in this current study, the impacts on the downstream system in Buffalo Bayou affecting downtown Houston cannot be assessed in this study because the economic study area does not include the Buffalo Bayou watershed.

It was decided that for the analysis of White Oak Bayou, bridge removal, replacements, or modifications downstream of IH 610 should be included in the study of Buffalo Bayou downstream, because of their potential to induce damages downstream along Buffalo Bayou that are not being evaluated in this study. That study has commenced.

Bridge modifications were considered in conjunction with channel modifications only when the channel modifications would require a specific bridge modification.

4.5.2.4 Levees

These components consist of constructing levees around areas that have experienced repeated floods. A typical levee that would extend along the bank of a stream is not practical in the highly developed White Oak Bayou area and would not appropriately function as a flood risk management component. It was previously studied and discarded as an option .The only type of levee option that was determined to have a potential application was one that would form a ring that surrounds or partially surrounds a development situated in a low-lying area. Several locations were identified for analysis with such a levee component. Levee heights and interior drainage facilities were optimized.

4.6 Step 2 - Single Component Optimization

The following sections summarize the component optimization process. The hydrologic and hydraulic analysis was performed using the methodology described in Section 4.4. For each component analyzed, flood flows and water surface elevations for the eight exceedance-probability events were transferred to HEC-FDA for economic analysis. The HEC-FDA model was used to perform a risk-based analysis taking into consideration the error due to uncertainty in measuring and predicting such things as stage, discharge, and structure value. Construction costs of the components were developed as part of the process to determine net economic benefits. An environmental mitigation cost was applied for each component. The estimated construction cost was compared to the reduction of damages from the HEC-FDA model to determine the net economic benefit the component provides.

4.6.1 Permanent Relocation/Buyout

Five structural buyout options were evaluated for all structures damaged by floods within the 50, 20, 10, 4, and 2 percent exceedance probability floodplains, respectively. The five options are identified and summarized in Table 4-4. The structures were identified for buyout if they experienced flooding depths that exceeded their first floor elevations for the specified events. The guidance from Section 219 of the Water Resources Development Act of 1999 on non-structural projects was followed. It should be noted that some of the structures in the list with damages are adjacent to portions of the stream for which the model shows the flood flow completely contained within the banks of the stream. However, there are drainage structures through the banks at those locations that allow flow from the stream to enter these low-lying areas where the structures are located.

In accordance with USACE guidance, non-structural benefits were computed as the reduction in externalized costs of floodplain occupancy. Annualized residual value of the vacated land was not considered in this study. It was assumed that the land will remain as open space.

As shown in Table 4-5, the optimization of buyouts indicates that net EA benefits of $125,000 are obtained with the buyout of approximately 13 structures within the 50 percent floodplain at a capital cost of approximately $6 million. All other buyouts produce negative net benefits.

Table 4-4
Non-Structural Component Characteristics

NON-STRUCTURAL			
ID	**Location**	**Classification**	**Description**
Buyouts			
NSB-50%	throughout watershed	13 structures within 50% floodplain	Removal of structures within 50% floodplain
NSB-20%		674 structures within 20% floodplain	Removal of structures within 20% floodplain
NSB-10%		1277 structures within 10% floodplain	Removal of structures within 10% floodplain
NSB-4%		3277 structures within 4% floodplain	Removal of structures within 4% floodplain
NSB-2%		4934 structures within 2% floodplain	Removal of structures within 2% floodplain
Elevating Structures			
ELEV-50%	throughout watershed	13 structures within 50% floodplain	Elevating structures within 50% floodplain
ELEV-20%		674 structures within 20% floodplain	Elevating structures within 20% floodplain
ELEV-10%		1277 structures within 10% floodplain	Elevating structures within 10% floodplain
ELEV-4%		3277 structures within 4% floodplain	Elevating structures within 4% floodplain
ELEV-2%		4934 structures within 2% floodplain	Elevating structures within 2% floodplain

Table 4-5
Non-Structural Component Analysis Results

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
Non-structural buyouts							
NSB-50%	$58,881	$555	$5,898	$7,143	$430	1.29	$125
NSB-20%	$48,394	$11,042	$157,773	$191,080	$11,493	0.96	-$451
NSB-10%	$40,731	$18,705	$321,071	$388,852	$23,389	0.80	-$4,684
NSB-4%	$30,247	$29,189	$833,410	$1,009,351	$60,711	0.48	-$31,522
NSB-2%	$21,844	$37,592	$1,378,881	$1,669,977	$100,446	0.37	-$62,854
Elevating Structures							
ELEV-50%	$58,922	$514	$12,953	$15,687	$944	0.55	-$429
ELEV-20%	$49,237	$10,199	$117,878	$142,763	$8,587	1.19	$1,612
ELEV-10%	$42,206	$17,230	$291,068	$352,515	$21,203	0.81	-$3,973
ELEV-4%	$33,697	$25,739	$687,174	$832,244	$50,058	0.51	-$24,319
ELEV-2%	$25,800	$33,636	$1,077,628	$1,305,126	$78,501	0.43	-$44,865

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual

4.6.2 Elevating Structures

This flood-proofing component considered elevating or raising the structures that sit on pier or slab foundations at their existing location. The majority of the residential structures in the study area are typically slab-on-grade construction. The cost and the potential technical issues of raising slab-on-grade structures generally make this component impractical; nonetheless, for completeness, slab-on-grade structures were also considered as part of the component analysis.

Five options were evaluated for structures damaged by floods within the 50, 20, 10, 4, and 2 percent floodplains, as listed in Table 4-4. Structures to be elevated were assumed to be structurally sound and were identified within each of the exceedance probability floodplains. The flood proofing option consists of raising the structures 18 inches above the elevation of the 1 percent floodplain. The maximum raise height was limited to 8 feet. The benefits were estimated by determining the reduction in damages for each property within the respective flood plain.

As shown in Table 4-5, the optimization of raising structures indicates that maximum benefits of $1.6 million are obtained at a capital cost of approximately $118 million with the raising of approximately 674 structures within the 20 percent floodplain. All other exceedance probabilities produce negative net benefits.

4.6.3 Channel/Bypass Optimization

The channel modification components focus primarily on channel enlargement and/or channel lining to improve conveyance capacity with the objective of lowering the water surface elevations on the main stem of White Oak Bayou. For this formulation effort White Oak Bayou was broken into three separate reaches defined as follows:

- Lower Reach (Station 0 to Station 56231): Buffalo Bayou to Cole Creek (Existing Federal Project)
- Middle Reach (Station 56231 to Station 105000): Cole Creek to the confluence with E135-00-00.
- Upper Reach (Station 105000 to Station 135000: Confluence with E135-00-00 to Huffmeister Road

Exhibit 4-5 shows the three reaches and the channelization components considered for optimization.

Lower Reach

As mentioned previously, the lower reach, the existing bayou in the reach of the existing Federal Project, is a partially concrete-lined channel. Compared to the middle reach, observed flood damages are significantly lower. The without project conditions expected annual damages within the lower reach range from less than $0.5 million to approximately $3 million per mile, as shown on Exhibit 4-4.

Based on previous formulation iterations as described in the June 2002 report, which showed that lower reach channel modifications are not effective at reducing flood damage and have the potential to induce damages downstream along Buffalo Bayou, no channel components were developed within this reach. In addition, as mentioned previously, the portion of the study area from IH-610 to the mouth of Buffalo Bayou is now included as part of the separate Buffalo Bayou Study that HCFCD is currently performing.

Middle Reach

The middle reach, located along Upper White Oak Bayou upstream of the existing Federal Project from Cole Creek to the E200-00-00 detention basin, has expected annual damages in the range of $2 million to approximately $19 million per mile for the without project conditions. The highest damages are located in three segments, between North Houston-Rosslyn Road and Fairbanks-North Houston Road, between West Gulf Bank and Gessner, and between Sam Houston Parkway (Beltway 8) and the confluence of White Oak Bayou and E135-00-00. The area of the watershed between North Houston-Rosslyn Road and Fairbanks-North Houston Road has the highest concentration of damages because it is characterized by flat topography, a wide floodplain with a natural overflow to Cole Creek to the south, and a large concentration of residential structures. The wide flood plain and

overflow to Cole Creek result in relatively small differences in flood stages for the less frequent storm events during which overflow occurs, such as the 1 percent and 0.2 percent.

Two separate channel components were developed within the middle reach. Component TG extends from Cole Creek to Gessner. Between Gessner and the E135-00-00 confluence, a bypass channel component was identified, located as shown on Exhibit 4-5. Component GE200 was identified specifically to analyze this bypass component. The segmentation of the middle reach into more channel components differs from the single-reach component presented in the June 2002 Draft GRR.

Upper Reach

The limits for the upper reach component along Upper White Oak Bayou are from the confluence of White Oak Bayou and E135-00-00 to Huffmeister Road. The annual damages for the upper reach of the stream range from $0.5 to $3 million per mile for the base conditions in the reaches where major damages occur. Only one channel component was developed within this reach (component E200H).

The following sections describe in detail the specific channel components that were analyzed.

4.6.3.1 Channel TG

Component TG is located in the middle reach and includes channel modifications from Tidwell to Gessner, as shown on Exhibit 4-5. Channel cross sections are shown in Exhibits 4-6.1 and 4-6.2. Incremental configurations to provide conveyance for the 20, 10, 4, 1, 0.4 and 0.2 percent exceedance probability flood flows were initially identified using normal depth analysis (i.e., Manning's Equation) and then evaluated.

Both earthen and concrete-lined channels were considered. The flowline would be lowered to match the flowline of the existing channel at the downstream end of this reach near Tidwell. Additional details of the various options are provided in Appendix D – Engineering Design and Analysis.

Eleven channel configurations were evaluated for component TG, as shown on Table 4-6. Each of the configurations evaluated provides water surface reduction and increased flows within the limits of the channel modifications. Increased flows and increased water surface elevations are observed downstream of the channel modifications. Details of the performance of the various options of this component are included in Appendix A – Hydrology and Hydraulics.

The optimum economic configuration was determined through comparison of net EA benefits, as shown in Table 4-7. Option TG.8 provides the largest net economic benefits and is the optimized configuration for this channel component. This is a trapezoidal

concrete-lined channel with a bottom width of 80 to 90 feet with 2 to 1 side slopes. The decrease in water surface elevation ranges from 1.0 to 8.3 feet. This option reduces EA damages by $24.4 million, has a capital cost of approximately $71 million and net EA benefits of $19.2 million.

Table 4-6
Channel Component Characteristics

ID	Location	Length (ft)	Bottom Width (ft)	Classification	Description
Middle Reach: Tidwell to Gessner (TG)					
TG.1	Sta. 56231 - 77129	21,340	50	earthen	Channelization of White Oak Bayou within existing ROW.
	Sta. 77129 - 93534	17,700	45		
TG.2	Sta. 56231 - 77129	21,340	60		Channelization of White Oak Bayou. ROW acquisition required (~15 ft).
	Sta. 77129 - 93534	17,700	50		
TG.3	Sta. 56231 - 77129	21,340	80		Channelization of White Oak Bayou. ROW acquisition required (~35 ft).
	Sta. 77129 - 93534	17,700	60		
TG.4	Sta. 56231 - 77129	21,340	100		Channelization of White Oak Bayou. ROW acquisition required (~55 ft).
	Sta. 77129 - 93534	17,700	80		
TG.5	Sta. 56231 - 77129	21,340	120		Channelization of White Oak Bayou. ROW acquisition required (~75 ft).
	Sta. 77129 - 93534	17,700	100		
TG.6	Sta. 56231 - 93534	39,040	200		Channelization of White Oak Bayou. ROW acquisition required (~145 ft).
TG.7	Sta. 56231 - 77129	21,340	50	concrete	Channelization of White Oak Bayou within ROW. Concrete-lined channel with 3:1 side slopes.
	Sta. 77129 - 93534	17,700	45		
TG.8	Sta. 56231 - 77129	21,340	90		Channelization of White Oak Bayou within ROW. Concrete-lined channel with 2:1 side slopes.
	Sta. 77129 - 93534	17,700	80		
TG.9	Sta. 56231 - 77129	21,340	50	Concrete / earthen	Channelization of White Oak Bayou within ROW. Concrete-lined channel with 2:1 side slopes from flowline to 10 ft height. Earthen channel with benches (10 ft wide) and 3:1 SS to top of banks.
	Sta. 77129 - 93534	17,700	45		
TG.10	Sta. 56231 - 77129	21,340	70	Concrete	Channelization of White Oak Bayou within ROW. Concrete-lined channel with 2.5:1 side slopes.
	Sta. 77129 - 93534	17,700	60		
TG.11	Sta. 56231 - 77129	21,340	120		Channelization of White Oak Bayou. ROW acquisition required (~35 ft). Concrete-lined channel with 2:1 side slopes
	Sta. 77129 - 93534	17,700	100		

Table 4-6 (continued)

ID	Location	Length (ft)	Bottom Width (ft)	Classification	Description
Middle Reach: Gessner to E200-00-00 (GE200)					
GE200.0	E100-00-00: Sta. 97052 - 101269	4,200	30	earthen	Channelization of E100-00-00 within ROW.
GE200.1	E200-00-00: remove berm	500	40		Remove berm area at E200-00-00 and E141-00-00 confluences.
GE200.2	E200-00-00: Sta. 150 - 2000	1,850	50		Channelization of E200-00-00 and E141-00-00 within existing ROW. Lower bypass flowline by ~ 5-10 ft.
	E200-00-00: Sta. 2000 - 7500	5,500	80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
GE200.3	E200-00-00: Sta. 150- 2500	2,350	50		Channelization of E200-00-00 and E141-00-00 within existing ROW. Lower bypass flowline by ~7-15 ft.
	E200-00-00: Sta. 2500 - 7500	5,000	60 - 80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
GE200.4	E200-00-00: remove berm	500	40		Channelization of E100-00-00 within ROW. Remove berm area within E200-00-00; channelization of White Oak Bayou within existing ROW.
	E100-00-00: Sta. 97052 - 101269	4,200	30		
Middle Reach: Gessner to E200-00-00 (GE200)					
GE200.5	E100-00-00: Sta. 97052 - 101269	4,200	30		Channelization of E100-00-00 within ROW. Channelization of E200-00-00 within existing ROW. Limited channelization within E141-00-00. Lower bypass flowline by ~ 5-10 ft.
	E200-00-00: Sta. 150 - 2000	1,850	50		
	E200-00-00: Sta. 2000 - 7500	5,500	80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		
GE200.6	E100-00-00: Sta. 97052 - 101269	4,200	30	earthen	Channelization of E100-00-00 within ROW. Channelization of E200-00-00 and E141-00-00 within existing ROW. Lower flowline by ~7-15 ft.
	E200-00-00: Sta. 150- 2500	2,350	50		
	E200-00-00: Sta. 2500 - 7500	5,000	60 - 80		
	E141-00-00: Sta. 1071 - 3225	2,154	80		
	E141-00-00: Sta. 3225 - 4100	875	50		

Table 4-6 (continued)

ID	Location	Length (ft)	Bottom Width (ft)	Classification	Description
Upper Reach: E200-00-00 to Huffmeister (E200H)					
E200H.1	Sta. 105000 - 115000	10,000	60	earthen	Channelization of White Oak Bayou within ROW.
	Sta. 115000 - 125000	10,000	40		
E200H.2	Sta. 105000 - 115000	10,000	80		Channelization of White Oak Bayou within ROW.
	Sta. 115000 - 125000	10,000	50		
E200H.3	Sta. 105000 - 115000	10,000	100		Channelization of White Oak Bayou within ROW.
	Sta. 115000 - 125000	10,000	60		

Table 4-7
Channel Component Analysis Results

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
TG: Channel Modification from Tidwell to Gessner							
TG.1	$51,459	$7,977	$15,374	$18,620	$1,120	7.12	$6,857
TG.2	$47,529	$11,907	$33,779	$40,910	$2,461	4.84	$9,447
TG.3	$45,619	$13,817	$65,249	$79,023	$4,753	2.91	$9,064
TG.4	$41,556	$17,880	$115,914	$140,384	$8,444	2.12	$9,437
TG.5	$39,235	$20,202	$136,838	$165,726	$9,968	2.03	$10,233
TG.6	$33,707	$25,730	$238,478	$288,823	$17,372	1.48	$8,357
TG.7	$43,503	$15,933	$62,245	$75,385	$4,534	3.51	$11,399
TG.8	$35,037	$24,399	$71,309	$86,363	$5,195	4.70	$19,205
TG.9	$47,486	$11,950	$35,487	$42,979	$2,585	4.62	$9,365
TG.10	$35,637	$23,800	$64,869	$78,563	$4,725	5.04	$19,074
TG.11	$36,265	$23,171	$117,943	$142,842	$8,592	2.70	$14,579
GE200: Channel Modification from Gessner to E200-00-00							
GE200.0	$59,018	$418	$1,470	$1,780	$107	3.90	$311
GE200.1	$62,971	-$3,535	$493	$597	$36	N/A	N/A
GE200.2	$61,857	-$2,421	$7,445	$9,017	$542	N/A	N/A
GE200.3	$59,460	-$23	$22,091	$26,754	$1,609	N/A	N/A
GE200.4	$61,827	-$2,391	$1,922	$2,328	$140	N/A	N/A
GE200.5	$61,170	-$1,734	$8,875	$10,748	$646	N/A	N/A
GE200.6	$59,150	$286	$23,520	$28,485	$1,713	0.17	-$1,427
E200H: Channel Modification from E200-00-00 to Huffmeister							
E200H.1	$64,582	-$5,146	$7,827	$9,480	$570	N/A	N/A
E200H.2	$65,421	-$5,985	$11,107	$13,451	$809	N/A	N/A
E200H.3	$62,516	-$3,080	$16,376	$19,833	$1,193	N/A	N/A

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the plan identified later in this report.

4.6.3.2 Channel GE200

The limits of component GE200 are from Gessner Road to E135-00-00, as shown on Exhibit 4-5. Incremental configurations of this component developed using normal depth analysis were evaluated to provide conveyance for the 10, 4, 1, and 0.4 percent exceedance probability flood flows. Typical cross-sections are shown on Exhibit 4-7.

The proposed modifications provide conveyance through a combination of modifications to one or both the main channel and a bypass channel. Modification of the existing facility E200-00-00, and the existing channel E141-00-00 would allow them to function as the bypass channel. Additional details of the various options are provided in Appendix D – Engineering Design and Analysis.

It was determined through analysis of construction costs that expansion of E200-00-00 would be expected to be less expensive than expansion of the main stem to achieve a similar conveyance capacity increase. This is due to the fact that nearly all options requiring the acquisition of right-of-way along White Oak Bayou through Jersey Village are in highly developed areas, resulting in negative net benefits. Therefore, components in this reach focused on the E200-00-00/E141-00-00 bypass corridor where right-of-way was already available.

Seven channel configurations were evaluated for component GE200. Each configuration provides water surface reduction within the limits of the channel modifications along the main stem as flow is diverted out of the main stem and into the bypass channel. Increased water surface elevations are observed in the main stem downstream of the bypass channel where flows are returned from the bypass channel to the main stem. Details of the performance of the various options of this component are included in Appendix A – Hydrology and Hydraulics.

The optimum configuration was determined through comparison of net EA benefits, as shown in Table 4-7. Option GE200.0 provides the only net economic benefits and is the optimized configuration for this channel component. The other options considered do not produce net positive benefits. Option GE200.0 is an earthen trapezoidal channel modification of White Oak Bayou with a 30-foot bottom width and provides conveyance of flow for the 10 percent event based on a normal depth analysis. Through Jersey Village it requires no acquisition of right-of-way. This option reduces EA damages by $0.42 million, has a capital cost of $1.5 million and net EA benefits of $0.31 million.

4.6.3.3 Channel E200H

This component is located in the upper reach, as shown on Exhibit 4-5, and includes earthen channel modifications from E135-00-00 to N. Eldridge Road. Incremental configurations developed using normal depth analysis were evaluated to provide conveyance capacities for the 10, 4 and 1 percent flood flows. Typical cross-sections are shown on Exhibit 4-8.

The proposed modifications generally consist of an earthen trapezoidal channel as shown in Table 4-6. Additional details of the various options are provided in Appendix D – Engineering Design and Analysis.

Each of the three configurations provides water surface reduction and reduced flows within the limits of the channel modifications. Increased flows and increased water surface elevations are observed downstream of the modifications along White Oak Bayou. Details of the performance of the various options of this component are included in Appendix A – Hydrology and Hydraulics.

None of the configurations provides net positive benefits. Option E200H.3 provides the lowest net economic loss and is the optimized configuration for this channel component. Option E200H.3 is a trapezoidal channel with a bottom width ranging from 60 to 100 feet, which provides conveyance of the 1 percent flood flow based on normal depth analysis. This option does not reduce EA damages, has a capital cost of $16 million, and negative net EA benefits as shown in Table 4-7.

4.6.4 Detention Optimization

High damage areas in the middle reach of the bayou were recognized as target areas for flood risk management. Previous studies, including the Regional Plan (Reference 10) and interim reports (References 16, 17, 18) for the June 2002 Draft GRR, were reviewed to help identify potential detention sites. Large, vacant tracts of land located closest to the bayou were identified as the most favorable detention sites. Occupied tracts of land adjacent to the bayou would require buyouts and were considered less favorable for detention. Additionally, a review was completed which looked at groups of flood-prone structures as candidates for buyout using a benefit-cost (B/C) ratio of 0.8 as a lower limit for consideration. No occupied tracts of land were found that satisfied this criterion.

Included in this section is the expansion and/or modification of a number of existing detention basin facilities constructed prior to 1998. All White Oak Bayou detention facilities that were completed by January 1, 1998 were included in the base conditions (year 2010) models. Detention facilities E500-01-00, E500-04-00, and E500-05-00 were completely or partially excavated as of January 1, 1998. These are all incorporated into components as indicated below. The existing portions of the facilities as of January 1, 1998, are considered part of the without project condition, and the expansions and modifications are introduced as components in the study. All land costs for the modification and expansion areas were based on fair market values. Exhibit 4-9 shows the locations of the detention components considered. Modifications and expansions of existing in-line facilities to off-line facilities were also evaluated.

Five detention components were identified in the middle reach, and two were identified in the upper reach. Some of the individual detention components analyzed previously in the June 2002 Draft GRR that were in close proximity to each other were analyzed as one detention component in the analysis presented herein. The lower reach of the watershed is highly developed, and all tracts of vacant land suitable for detention identified during the previous formulation effort have been developed by others and are no longer available for use.

4.6.4.1 Detention Site TWLY

This facility is in the middle reach and is located near Tidwell and West Little York, as shown on Exhibit 4-9. The facility would be sited on land adjacent to and east of the bayou between stations 58000 and 61000. The options presented include the modification and/or expansion of the 1998 existing 160 acre-foot in-line E500-05-00 to an off-line facility.

Six options were initially considered. However, a proposed facility north of White Oak Bayou and just south of West Little York has become a mitigation area for a project on Vogel Creek, a tributary of White Oak Bayou, and this component was dropped from consideration in this study. Therefore, option TWLY.1 and TWLY.4 that utilized the mitigation area were eliminated from the analysis.

Four remaining configurations were evaluated for component TWLY as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits as shown in Table 4-10. Option TWLY.3 provides the largest net economic benefits and is the optimized configuration. This is a 1,032 acre-feet basin. This option reduces EA damages by $1.9 million, has a capital cost of approximately $23 million (not including the costs of the existing basin) and net EA benefits of $0.2 million. This option would require modification and expansion of the 1998 existing detention facility E500-05-00.

Table 4-9
Detention Component Characteristics

ID	Location	Area (ac)	Volume (ac-ft)	Description
Detention at Tidwell – W. Little York (TWLY)				
TWLY.0	Tidwell/T.C. Jester/W. Little York; Sta. 57990-65400	18	160	Modification of E500-05-00 to off-line facility
TWLY.2		45	516	Expansion of E500-05-00
TWLY.3		69	1032	Expansion of E500-05-00
TWLY.5		123	1658	Expansion of E500-05-00
Detention at North Houston-Rosslyn Rd. (NHR)				
NHR.1	North Houston-Rosslyn Road; Sta. 75800	33	595	Modification and expansion of E500-04-00; to off-line facility
NHR.2		62	811	Expansion of E500-04-00
NHR.3		83	1069	Expansion of E500-04-00
NHR.4		139	1211	Expansion of E500-04-00
Detention at Hollister Road (HOL)				
HOL.1	Hollister Rd.; Sta. 80200	57	444	Off-line facility with excavation north of pipeline
HOL.2		94	522	Expansion south of pipeline
HOL.3		136	730	Expansion of facility to the west
Detention at Fairbanks-North Houston (FNH)				
FNH.1	Fairbanks-North Houston; Sta. 87150 - 87489	86	843	Expansion of E500-01-00
FNH.2		143	1271	Expansion of E500-01-00 & new facility E500-02-00 south of bayou
FNH.3		184	1717	Expansion of E500-01-00, new facility E500-02-00 south of bayou, & new facility west of Fairbanks-North Houston
FNH.4		222	2111	Expansion of E500-01-00, new facility E500-02-00 south of bayou, & new facility west of Fairbanks-North Houston

Table 4-9 (continued)

ID	Location	Area (ac)	Volume (ac-ft)	Description
Detention at Gessner-Beltway 8 (GBW)				
GBW.1	Gessner / Beltway 8; Sta. 94856	21	229	In-line facility north of bayou
GBW.2		45	427	In-line facility of bayou north and off-line facility south of bayou.
GBW.3		56	519	New facility located north and south of bayou, with additional expansion of facility to the south.
ID	**Location**	**Area (ac)**	**Volume (ac-ft)**	**Description**
Detention at Rio Grande (RG)				
RG.1	Rio Grande; E135-00-00 Sta. 3000	26	277	Off-line facility north of E135-00-00
RG.2		45	399	Expansion of facility north of E135-00-00
RG.3		117	882	Expansion of facility south of E135-00-00
RG.4		45	277	RG.1 and channelization of E135-00-00
Detention at Jones Road (JR)				
JR.1	Jones Road; Sta. 114940 - 118000	23	134	Off-line facility; south of pipeline easement and east of Jones Rd.
JR.2		39	220	Expansion of facility north of pipeline easement, east of Jones Rd.
JR.3		53	295	Expansion of facility west of Jones Rd.
JR.4		69	420	Expansion on additional land west of Jones Rd.
JR.5		74	470	Expansion on additional land west of Jones Rd.

Table 4-10
Detention Component Analysis Results

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
TWLY: Detention at Tidwell / West Little York (E500-05-00)							
TWLY.2	$58,933	$503	$9,340	$11,312	$680	0.74	-$177
TWLY.3	$57,557	$1,880	$22,834	$27,655	$1,663	1.13	$216
TWLY.5	$56,749	$2,687	$52,629	$63,740	$3,834	0.70	-$1,147
NHR: Detention at North Houston-Rosslyn Road (E500-04-00)							
NHR.1	$58,697	$740	$7,956	$9,635	$580	1.28	$160
NHR.2	$58,368	$1,069	$14,527	$17,593	$1,058	1.01	$10
NHR.3	$56,083	$3,353	$21,721	$26,306	$1,582	2.12	$1,771
NHR.4	$56,349	$3,088	$46,276	$56,045	$3,371	0.92	-$283
HOL: Detention at Hollister Road							
HOL.1	$56,564	$2,872	$15,102	$18,290	$1,100	2.61	$1,772
HOL.2	$56,032	$3,404	$18,816	$22,788	$1,371	2.48	$2,033
HOL.3	$55,797	$3,640	$28,533	$34,557	$2,079	1.75	$1,561
FNH: Detention at Fairbanks-North Houston (E500-01-00)							
FNH.1	$56,846	$2,590	$15,096	$18,283	$1,100	2.36	$1,490
FNH.2	$54,004	$5,432	$29,438	$35,653	$2,144	2.53	$3,288
FNH.3	$51,698	$7,738	$45,188	$54,727	$3,292	2.35	$4,446
FNH.4	$50,761	$8,676	$58,684	$71,073	$4,275	2.03	$4,401
GBW: Detention at Gessner-Beltway 8							
GBW.1	$58,797	$639	$5,066	$6,135	$369	1.73	$270
GBW.2	$57,335	$2,101	$12,741	$15,431	$928	2.26	$1,173
GBW.3	$57,227	$2,209	$18,271	$22,129	$1,331	1.66	$878
RG: Detention at Rio Grande							
RG.1	$58,371	$1,066	$9,900	$11,990	$721	1.48	$344
RG.2	$57,872	$1,564	$14,529	$17,597	$1,058	1.48	$505
RG.3	$57,368	$2,069	$44,883	$54,358	$3,270	0.63	-$1,201
RG.4	$64,718	-$5,282	$10,607	$12,846	$773	N/A	N/A
JR: Detention at Jones Road							
JR.1	$57,461	$1,975	$5,252	$6,361	$383	5.16	$1,593
JR.2	$56,603	$2,833	$8,829	$10,693	$643	4.41	$2,190
JR.3	$55,525	$3,911	$12,422	$15,044	$905	4.32	$3,006
JR.4	$54,187	$5,249	$17,247	$20,888	$1,256	4.18	$3,993
JR.5	$53,806	$5,630	$29,386	$35,589	$2,141	2.63	$3,489

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual

4.6.4.2 Detention Site NHR

This facility is in the middle reach and is located at North-Houston Rosslyn Road and Gulf Bank Road, between stations 73600 and 75400, as shown on Exhibit 4-9. Four options were considered, all of which modify the 1998 existing 360 acre-foot in-line detention facility E500-04-00 to an off-line facility.

Four configurations of this detention basin were evaluated as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits as shown in Table 4-10. Option NHR.3 maximizes the net economic benefits and is the optimized configuration. This option reduces EA damages by $3.4 million, has a capital cost of approximately $22 million and net EA benefits of $1.8 million. This is a 1,069 acre-feet basin on two tracts of land. This option would require modification and expansion of the 1998 existing E500-04-00 facility.

4.6.4.3 Detention Site HOL

This facility is in the middle reach located at Hollister Road on land south of the bayou between stations 79000 and 81600, as shown on Exhibit 4-9. Two tracts of land were considered for this component. An Exxon/Mobil pipeline traverses the larger tract of land located adjacent to the bayou in an east/west direction, dividing the property into approximately 57 acres between the pipeline and the bayou and approximately 37 acres between the pipeline and West Little York to the south.

Three configurations of component HOL were evaluated as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits as shown in Table 4-10. Option HOL.2 maximizes the net economic benefits and is the optimized configuration. This option reduces EA damages by $3.4 million, has a capital cost of approximately $19 million and net EA benefits of $2.0 million. This is a 522 acre-feet basin constructed north and south of the pipeline easement.

4.6.4.4 Detention Site FNH

This facility is located in the middle reach at Fairbanks-North Houston Road north and south of the bayou between stations 85000 and 89000, as shown on Exhibit 4-9. Four configurations of this component were evaluated, all of which include the modification and/or expansion of the 1998 existing 360 acre-foot in-line detention facility E500-01-00 to an off-line facility.

Four configurations of this detention basin were evaluated as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits, as shown in Table 4-10. Option FNH.3 provides the maximum net economic benefits and is the optimized configuration of the basin. This option reduces EA damages by $7.7 million, has a capital cost of approximately $45 million and net EA benefits of $4.45 million. Land

acquisition costs for the existing basin are not included. This option includes three basins providing a combined storage volume of 1,717 acre-feet. Expansion and enlargement of the 1998 existing E500-01-00 facility is also included.

4.6.4.5 Detention Site GBW

This combination off-line and in-line detention basin is in the middle reach at Gessner Road and Beltway 8 adjacent to and north and south of the bayou between stations 93300 and 95900. Three configurations of this component were evaluated. The detention basin north of the bayou is an in-line basin that is centered on the confluence of E141-00-00 and White Oak Bayou.

Three configurations of this basin were evaluated as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits, as shown in Table 4-10. Option GBW.2 shows the largest net economic benefits and is the optimized configuration for this component. This option reduces EA damages by $2.1 million, has a capital cost of approximately $13 million and net EA benefits of $1.2 million. This option provides a combined storage volume of 345 acre-feet and consists of an in-line basin north of the bayou and an off-line basin south of the bayou.

4.6.4.6 Detention Site RG

This facility is in the upper reach and would be situated on land north and south of E135-00-00, a tributary to White Oak Bayou just downstream of station 105000, as shown on Exhibit 4-9. The proposed facilities would be located between stations 1525 and 3300 on the tributary. Four options of this component were considered. One option considered detention in addition to E135-00-00 channel modifications to flatten the bottom slope and allow backwater from the main stem to fill the detention basin.

Four options of this component were evaluated as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits, as shown in Table 4-10. It should be noted that component RG.4 also includes channel improvements that will increase flow to White Oak Bayou. Option RG.2 provides the maximum net economic benefits and is the optimized configuration. This option reduces EA damages by $1.6 million, has a capital cost of approximately $15 million and net EA benefits of $0.5 million. This is a 398 acre-foot basin.

4.6.4.7 Detention Site JR

This facility is in the upper reach adjacent to the bayou, with options that would situate it north and/or south of the bayou between stations 113000 and 118000, as shown on Exhibit 4-9.

Five configurations of this component were evaluated as summarized in Table 4-9. The optimum configuration was determined through comparison of net EA benefits, as shown in Table 4-10. Option JR.4 has the largest net economic benefits and is the optimized configuration. This option reduces EA damages by $5.6 million, has a capital cost of approximately $17 million and net EA benefits of $4.0 million. This is a basin that provides a combined storage volume of 420 ac-ft.

4.6.5 Levees

Levees may be feasible flood risk management components for relatively isolated areas of repeated high flood damage. Two areas were identified for potential levees, with each area protected by two levees separated by a significant geographical feature, which precludes the analysis of a single levee. Although two levees were used for each identified area, these are considered single components because of their proximity. In the analysis, both walls were treated as one structure and were designed to provide the same level of protection. Exhibit 4-10 shows the locations of the levee components considered.

Because the annualized construction cost of all the internal drainage options other than the minimum facility system exceeded the total damages within the levee area, indicating that no positive net benefits were possible, only the minimum facility internal drainage system associated with each levee height option was considered. Levee heights to provide protection against the 4, 2, 1, 0.4, and 0.2 percent exceedance probability events were analyzed for this component. Overall, five levee heights and one internal drainage option were evaluated in detail for this component, as summarized in Table 4-4. Because of the limited internal detention storage associated with the minimum facility drainage system, there was an increase in damages for all events and negative net benefits resulted for all options considered.

4.6.5.1 Levee Site LIA

Component LIA consists of two flood protection walls: one wall would surround the Inwood Forest subdivision from approximately station 66500 to station 70270, and the second wall would surround the Arbor Oaks subdivision from approximately station 65500 to station 66500. The levee component would require the relocation of an existing 48 inch storm sewer around the outside of the Inwood Forest Subdivision and the acquisition of approximately 394,800 square feet of right-of-way for construction of the walls.

Because the annualized construction cost of all the internal drainage options other than the minimum facility system exceeded the total damages within the levee area, indicating that no positive net benefits were possible, only the minimum facility internal drainage system associated with each levee height option was considered. Levee heights to provide protection against the 4, 2, 1, 0.4, and 0.2 percent exceedance probability events were analyzed for this component. Overall, five levee heights and one internal drainage option were evaluated in detail for this component, as summarized in Table 4-11. Because of the

limited internal detention storage associated with the minimum facility drainage system, there was an increase in damages for all events and negative net benefits resulted for all options considered as shown in Table 4-12.

Table 4-11
Levee Component Characteristics

ID	Location	Maximum Height (ft)	Interior Volume	Description
Levee at Inwood Forest / Arbor Oaks (LIA)				
LIA1.1	Sta. 65500 - 70270	6.8	minimum	Optimize height for 1% flood
LIA2.1		6.5		Optimize height for 2% flood
LIA3.1		5.0		Optimize height for 4% flood
LIA4.1		7.0		Optimize height for 0.4% flood
LIA5.1		7.5		Optimize height for 0.2% flood
Levee at Woodland Trails (LWT)				
LWT1.1	Sta. 77100 - 85000	7.4	minimum	Optimize height for 1% flood
LWT1.2			20% capacity	Optimize interior volume, 20% pumping capacity
LWT1.3			4% capacity	Optimize interior volume, 4% pumping capacity
LWT1.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT1.5			20% capacity	Optimize interior volume, 20% detention capacity
LWT1.6			4% capacity	Optimize interior volume, 4% detention capacity
LWT1.7			1% capacity	Optimize interior volume, 1% detention capacity
LWT2.1		6.8	minimum	Optimize height for 20% flood
LWT2.2			20% capacity	Optimize interior volume, 20% pumping capacity

Table 4-11 (continued)

ID	Location	Maximum Height (ft)	Interior Volume	Description
LWT2.3	Sta. 77100 - 85000		4% capacity	Optimize interior volume, 4% pumping capacity
LWT2.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT2.5			20% capacity	Optimize interior volume, 20% detention capacity
LWT2.6			4% capacity	Optimize interior volume, 4% detention capacity
LWT2.7			1% capacity	Optimize interior volume, 1% detention capacity
LWT3.1		7.0	minimum	Optimize height for 4% flood
LWT3.2			20% capacity	Optimize interior volume, 20% pumping capacity
LWT3.3			4% capacity	Optimize interior volume, 4% pumping capacity
LWT3.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT3.5			20% capacity	Optimize interior volume, 20% detention capacity
LWT3.6			4% capacity	Optimize interior volume, 4% detention capacity
LWT3.7			1% capacity	Optimize interior volume, 1% detention capacity
LWT4.1	Sta. 77100 - 85000	8.0	minimum	Optimize height for 0.4% flood
LWT4.2			20% capacity	Optimize interior volume, 20% detention capacity
LWT4.3			20% capacity	Optimize interior volume, 20% pumping capacity
LWT4.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT5.1		8.2	minimum	Optimize height for 0.2% flood
LWT5.2			20% capacity	Optimize interior volume, 20% detention capacity
LWT5.3			20% capacity	Optimize interior volume, 20% pumping capacity
LWT5.4			1% capacity	Optimize interior volume, 1% pumping capacity
LWT5.5			0.4% capacity	Optimize interior volume, 0.4% pumping capacity
LWT5.6			0.2% capacity	Optimize interior volume, 0.2% pumping capacity

Table 4-12
Levee Component Analysis Results

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
LIA: Levee at Inwood Forest and Arbor Oaks							
LIA3.1	$59,797	-$361	$9,153	$11,086	$667	N/A	N/A
LIA2.1	$59,741	-$305	$10,497	$12,713	$765	N/A	N/A
LIA1.1	$59,489	-$53	$11,186	$13,548	$815	N/A	N/A
LIA4.1	$59,820	-$383	$13,236	$16,030	$964	N/A	N/A
LIA5.1	$59,648	-$212	$14,620	$17,707	$1,065	N/A	N/A
LWT: Levee at Woodland Trails							
LWT2.1	$66,689	-$7,253	$8,117	$9,831	$591	N/A	N/A
LWT2.2	$58,192	$1,244	$57,014	$69,050	$4,153	0.30	-$2,909
LWT2.3	$56,848	$2,588	$65,919	$79,835	$4,802	0.54	-$2,214
LWT2.4	$56,782	$2,654	$74,519	$90,251	$5,428	0.49	-$2,774
LWT2.5	$59,207	$230	$47,827	$57,924	$3,484	0.07	-$3,254
LWT2.6	$57,889	$1,547	$63,423	$76,813	$4,620	0.33	-$3,073
LWT2.7	$56,997	$2,440	$84,785	$102,683	$6,176	0.40	-$3,737
LWT3.1	$69,656	-$10,220	$11,239	$13,612	$819	N/A	N/A
LWT3.2	$58,579	$857	$60,136	$72,831	$4,381	0.20	-$3,524
LWT3.3	$55,631	$3,805	$69,041	$83,616	$5,029	0.76	-$1,224
LWT3.4	$55,201	$4,235	$77,641	$94,032	$5,656	0.75	-$1,421
LWT3.5	$60,499	-$1,063	$50,949	$61,705	$3,711	N/A	N/A
LWT3.6	$58,360	$1,077	$66,545	$80,594	$4,848	0.22	-$3,771
LWT3.7	$55,845	$3,591	$87,907	$106,464	$6,404	0.56	-$2,813
LWT1.1	$69,655	-$10,219	$13,031	$15,782	$949	N/A	N/A
LWT1.2	$57,725	$1,711	$61,928	$75,002	$4,511	0.38	-$2,800
LWT1.3	$54,537	$4,900	$70,833	$85,787	$5,160	0.95	-$260
LWT1.4	$53,745	$5,691	$79,433	$96,203	$5,786	0.98	-$95
LWT1.5	$59,934	-$498	$52,741	$63,875	$3,842	N/A	N/A
LWT1.6	$57,685	$1,751	$68,338	$82,764	$4,978	0.35	-$3,227
LWT1.7	$55,305	$4,131	$89,699	$108,635	$6,534	0.63	-$2,403
LWT4.1	$70,321	-$10,885	$15,677	$18,986	$1,142	N/A	N/A
LWT4.3	$57,478	$1,958	$64,573	$78,206	$4,704	0.42	-$2,745
LWT4.2	$59,944	-$507	$55,386	$67,079	$4,035	N/A	N/A
LWT4.4	$53,278	$6,159	$82,079	$99,407	$5,979	1.03	$179
LWT5.1	$70,109	-$10,673	$16,623	$20,133	$1,211	N/A	N/A
LWT5.3	$56,588	$2,848	$65,520	$79,352	$4,773	0.60	-$1,925
LWT5.2	$59,482	-$46	$56,333	$68,225	$4,104	N/A	N/A
LWT5.4	$52,109	$7,327	$83,025	$100,553	$6,048	1.21	$1,279
LWT5.5	$51,834	$7,602	$87,219	$105,632	$6,354	1.20	$1,249
LWT5.6	$51,598	$7,839	$93,537	$113,283	$6,814	1.15	$1,025

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

4.6.5.2 Levee Site LWT

Because it is situated on both sides of White Oak Bayou, component LWT consists of two flood protection walls. One wall surrounds the Woodland Trails North subdivision from approximately station 77100 to station 83000. The second wall surrounds the Woodland Trails West subdivision from approximately station 80800 to station 85000. Approximately 430,800 square feet of right-of-way would need to be acquired for construction of the walls.

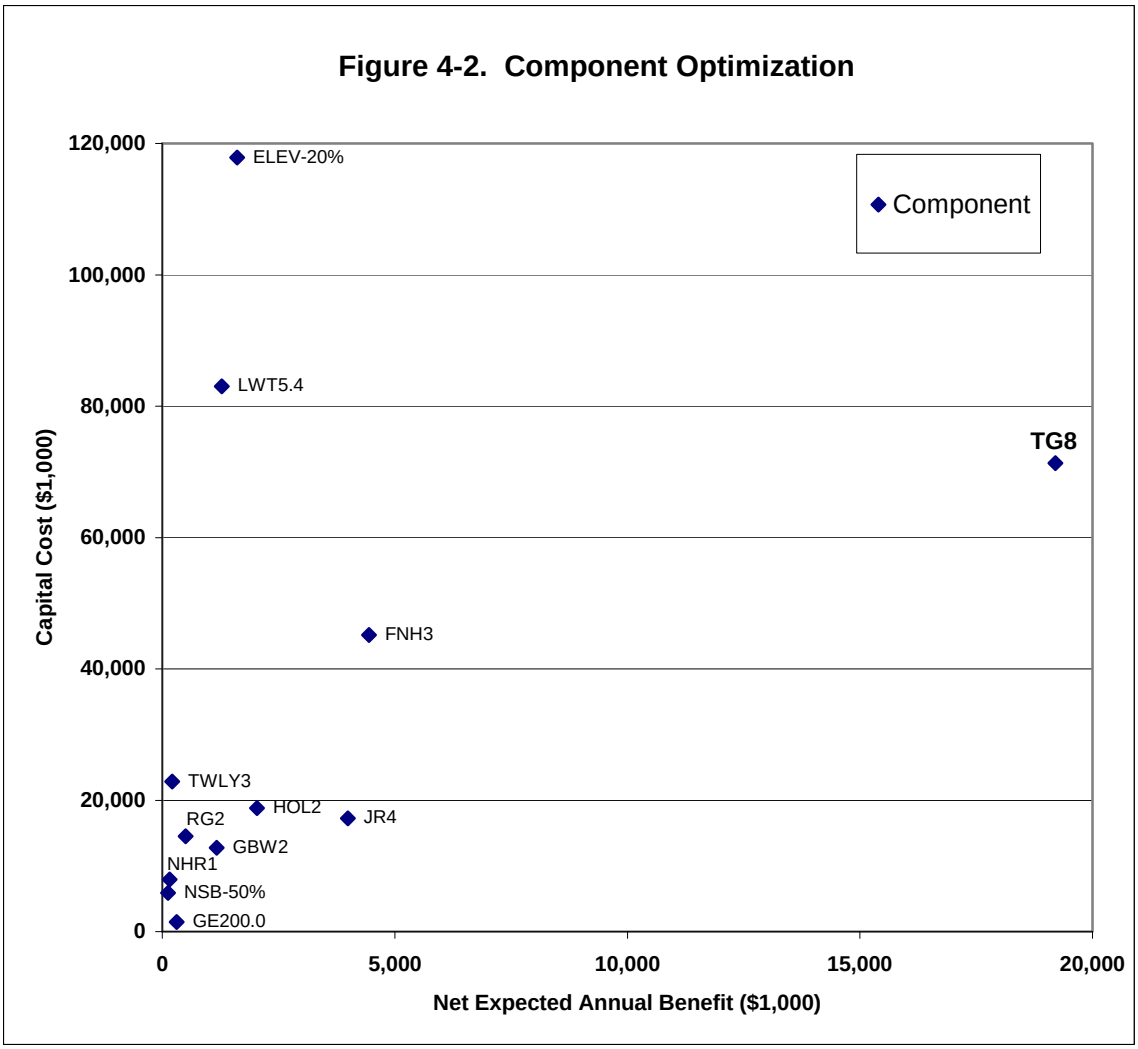
Five levee heights to provide protection against the 4, 2, 1, 0.4, and 0.2 percent events were analyzed for this component. Table 4-11 provides a description of each option evaluated. Table 4-5 summarizes the economic damages and net benefits resulting from these levee heights and internal drainage options. The results show that none of the options for the 20-percent, 4-percent and 1-percent levee heights produce positive Net EA Benefits.

LWT5.4, the 0.2 percent levee height with the 1 percent pumping capacity internal drainage option, maximizes Net EA Benefits at $1.28 million as shown in Table 4-12. It has EA benefits of $7.3 million and a capital cost of approximately $83 million. The next best option is the 0.2 percent levee height with the 0.4 percent pumping capacity, LWT5.5. Net EA Benefits are $1.25 million. It has EA benefits of $7.6 million and a capital cost of approximately $87 million.

4.7 Step 3 - Identification of Anchor Components

The results of the component optimization process are shown in the tables of the previous sections and in Figure 4-2. The tables display the following information for each component: EA damages, EA benefits, capital cost, base year equivalent cost, EA costs, benefit-cost (B/C) ratio, and net EA benefits. A benefit-cost ratio is not computed for those components that have negative net EA benefits. Figure 4-2 plots the capital cost and net EA benefits for the optimized size of each component with positive net EA benefits.

Figure 4-2. Component Optimization



The results of the component optimization process indicate that TG.8 produces the maximum net benefits of all components evaluated, with net EA benefits of approximately $19 million. Component TG.8 is a channel modification component for the main stem reach between Tidwell and Gessner, consisting of a concrete-lined channel with an 80 to 90 foot bottom width. No other components produced net EA benefits that approached the economic effectiveness of this TG option. Other effective components include detention components NHR, GBW, HOL, FNH and JR.

During the latter stages of the process of component evaluation, minor revisions to the models were identified. At the same time, minor refinements were being made to the economic structure list for the HEC-FDA models. The changes to both the models, as well as a comparison between the model results before and after the changes, are documented in a memorandum dated May 19, 2004 (Reference 21).

The hydrologic and hydraulic revisions and the economic structure list revisions were incorporated into the Base Without Project Conditions model and the results were found to be similar to the previous model. Nonetheless, the top ranked components were rerun with the updated HEC-RAS model and the updated HEC-FDA model to ensure that the economically best-performing component had been identified. These verification runs were completed on several configurations of component TG, two top-performing detention components, and one bridge modification component.

The numerical results of the verification process are shown in Table 4-13. Option TG.8 remained the top ranking option for component TG. Top detention components lag far behind TG.8, with the best-performing detention component, FNH.3, producing less than half the net benefits of TG.8. The bridge modification component BR-NHR resulted in negative net economic benefits. Therefore, this bridge was not considered as a single component in the plan formulation process.

TG.8 was the economically best-performing component, or anchor. Based on these results, it was carried forward into plan formulation as the initial anchor component in the process to determine the economically best-performing plan. Two additional plans were evaluated with different anchor components to ensure that this study identifies the best performing plan that reasonably maximizes net benefits and to address the concerns of HCFCD regarding the use of the concrete-lined channel in TG.8.

Formulation with channel option TG.2, a trapezoidal earthen channel with a bottom width from 50 to 60 feet, was selected as an additional anchor for several reasons. First, it is an earthen channel modification. Second, it requires a minimal amount of additional right-of-way acquisition.

Option TG.5 was another earthen channel option considered; however it would require extensive right-of-way acquisition and associated relocation of residents, would have a capital cost approximately $100 million greater and it achieves only $1.8 million more in net EA benefits than TG.2. The selection of TG.2 as the second anchor was not based solely on cost, although that was a primary factor. It was also based on the extensive issues related to the additional right-of-way required associated with TG.5, the likely public opposition to such a wide channel, and the small differences in net benefits between TG.2 and TG.5.

In addition, a detention component anchor was also identified. From the component evaluation process, two detention components rank as the first and second best performing detention components of those evaluated, and are generally independent of each other in

their impact on system hydraulics. These two components are FNH.3 and JR.4. FNH.3 is a 1,357 acre-foot expansion of the existing E500-01-00 facility, and JR.4 is a new detention basin with a 420 acre-foot capacity. Combined they form the detention anchor. A detention-anchor plan was considered because of the public interest in general and the interest of environmental groups in a plan that would not involve larger scale buyouts or additional channel modifications.

Table 4-13 Verification Results

ID	EA Damages ($1,000)	EA Benefit ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	B/C	Net EA Benefit ($1,000)
TG.1	$48,686	$4,337	$15,374	$18,620	$1,120	3.87	$3,217
TG.2	$43,972	$9,052	$33,779	$40,910	$2,461	3.68	$6,591
TG.5	$34,723	$18,300	$136,838	$165,726	$9,968	1.84	$8,332
TG.6	$30,286	$22,737	$238,478	$288,823	$17,372	1.31	$5,365
TG.8	$33,749	$19,275	$71,309	$86,363	$5,195	3.71	$14,080
TG.10	$35,408	$17,615	$64,869	$78,563	$4,725	3.73	$12,890
TG.11	$33,550	$19,474	$117,943	$142,842	$8,592	2.27	$10,882
FNH.2	$45,934	$7,089	$29,438	$35,653	$2,144	3.31	$4,945
FNH.3	$43,331	$9,692	$45,188	$54,727	$3,292	2.94	$6,400
FNH.4	$44,047	$8,977	$58,684	$71,073	$4,275	2.10	$4,702
JR.4	$47,647	$5,376	$17,247	$20,888	$1,256	4.28	$4,120
BR-NHR	$53,937	$43	$2,098	$2,541	$153	0.28	-$109

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the plan identified later in this report.

4.8 Step 4 - Re-optimization of Components with Anchor

After identification of the anchor component(s), the remaining components were re-optimized because the initial anchor component(s) changes the hydraulics of the system, typically resulting in significant changes to the flows and water surface elevations, and resulting economic damages. The anchor component(s) was the only component that was not re-optimized during this step. The anchor component(s) was included in all of the runs as a base condition, and all other components from the component evaluation were each run individually with the anchor component. The best performing size of the component that increased the net benefits to the greatest degree was the next component added to the anchor plan. The re-optimization was performed in conjunction with Step 5, which is discussed later in Section 4.9, in a cyclical manner iterating between Steps 4 and 5 until all viable components were added that increased net economic benefits.

The levee components presented in Section 4.6.5 were not carried forward in this re-optimization step because it was determined through analysis that none of the levee components would have the possibility of producing positive net economic benefits. In the initial levee optimization, most of the levee options resulted in negative benefits and only one levee component showed positive net benefits that were substantially smaller than the net benefits from either of the three identified anchors. The analysis also indicated that the channel anchors and detention anchors provide a significant decrease in the water surface elevations in the reaches with the remaining levee components, thereby further reducing the potential benefits of the levee. Therefore, the levee components were not included in the re-optimization because a comparison of the levee construction costs to the maximum possible benefits indicated that positive net benefits were not possible, even if all the internal damages were eliminated with the levees.

The following subsections present a summary of the re-optimization of components for the three selected anchors.

4.8.1 Anchor TG.8

Table 4-14 and Figure 4-3 show the results of the re-optimization of components with the anchor component TG.8. The table shows EA damages, EA benefits, capital costs, base year equivalent costs, EA costs, B/C ratio and the net EA benefits. In addition, the incremental EA benefits, incremental EA cost, and incremental net EA benefits resulting from the addition of the component to the anchor are shown to provide a comparison to the anchor component. A unique plan identification for each run is provided for reference purposes only (e.g., TG8_1.1). The optimized size of each component is highlighted in Table 4-14 and plotted on Figure 4-3.

Table 4-14 Re-optimization of Components with Anchor TG.8

ID	Component Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,981									
TG8 (concrete channel modifications)		$34,462	$19,519		$71,309	$86,363	$5,195		3.76	$14,324	
TG.8+GE200											
TG8_1.1	GE200.0	$33,586	$20,395	$876	$72,778	$88,142	$5,302	$107	3.85	$15,093	$769
TG8_1.2	GE200.2	$33,182	$20,798	$1,280	$78,754	$95,380	$5,737	$542	3.63	$15,062	$738
TG8_1.3	GE200.3	$32,998	$20,983	$1,464	$93,399	$113,117	$6,804	$1,609	3.08	$14,179	-$145
TG8_1.4	**GE200.5**	**$32,786**	**$21,195**	**$1,676**	**$80,183**	**$97,111**	**$5,841**	**$646**	**3.63**	**$15,353**	**$1,030**
TG8_1.5	GE200.6	$32,678	$21,303	$1,785	$94,829	$114,848	$6,908	$1,713	3.08	$14,395	$71
TG.8+E200H											
TG8_1.6	E200H.1	$32,708	$21,273	$1,754	$79,136	$95,842	$5,765	$570	3.69	$15,508	$1,184
TG8_1.7	E200H.2	$31,877	$22,104	$2,586	$82,415	$99,814	$6,004	$809	3.68	$16,101	$1,777
TG8_1.8	**E200H.3**	**$31,016**	**$22,965**	**$3,446**	**$87,684**	**$106,196**	**$6,387**	**$1,193**	**3.60**	**$16,577**	**$2,253**
TG8_1.9	E200H.4	$30,355	$23,625	$4,107	$133,804	$162,052	$9,747	$4,553	2.42	$13,878	-$446
TG.8+TWLY											
TG8_1.10	TWLY.0 (160 ac-ft)	$33,820	$20,161	$643	$75,293	$91,188	$5,485	$290	3.68	$14,676	$352
TG8_1.11	**TWLY.2 (516 ac-ft)**	**$32,986**	**$20,995**	**$1,476**	**$80,649**	**$97,675**	**$5,875**	**$680**	**3.57**	**$15,120**	**$796**
TG8_1.12	TWLY.3 (1032 ac-ft)	$32,511	$21,470	$1,951	$94,143	$114,017	$6,858	$1,663	3.13	$14,612	$288
TG8_1.13	TWLY.5 (1658 ac-ft)	$30,985	$22,996	$3,477	$123,938	$150,103	$9,028	$3,834	2.55	$13,967	-$356
TG.8+NHR											
TG8_1.14	NHR.0 (360 ac-ft)	$34,113	$19,868	$349	$74,330	$90,022	$5,415	$220	3.67	$14,453	$129
TG8_1.15	**NHR.1 (595 ac-ft)**	**$33,658**	**$20,323**	**$804**	**$79,265**	**$95,998**	**$5,774**	**$580**	**3.52**	**$14,549**	**$225**
TG8_1.16	NHR.3 (1069 ac-ft)	$32,887	$21,094	$1,576	$93,029	$112,669	$6,777	$1,582	3.11	$14,317	-$7
TG8_1.17	NHR.4 (1211 ac-ft)	$32,871	$21,110	$1,592	$117,584	$142,408	$8,566	$3,371	2.46	$12,545	-$1,779
TG.8+HOL											
TG8_1.18	HOL.1 (444 ac-ft)	$34,215	$19,765	$247	$86,410	$104,652	$6,295	$1,100	3.14	$13,471	-$853
TG8_1.19	**HOL.2 (522 ac-ft)**	**$33,680**	**$20,300**	**$782**	**$90,124**	**$109,150**	**$6,565**	**$1,371**	**3.09**	**$13,735**	**-$589**
TG8_1.20	HOL.3 (730 ac-ft)	$33,613	$20,368	$849	$99,842	$120,920	$7,273	$2,079	2.80	$13,095	-$1,229

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(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

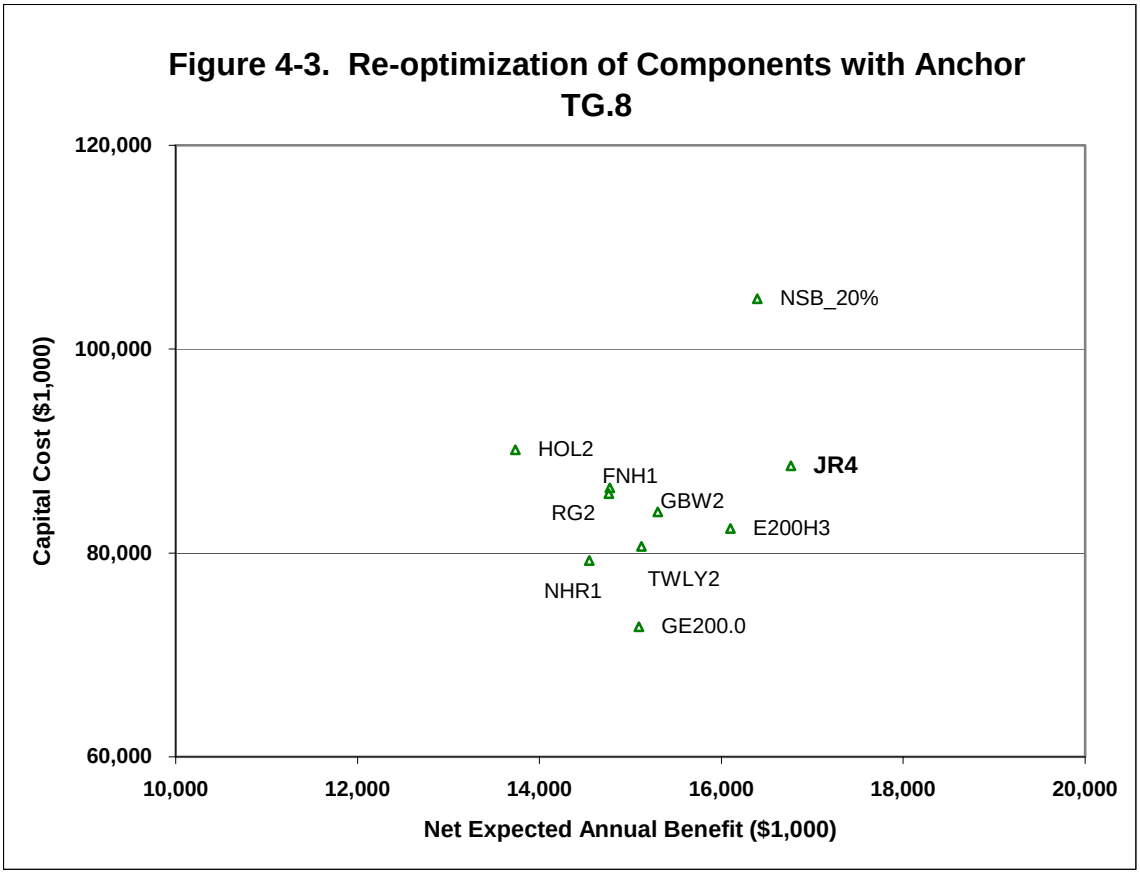
Table 4-14 (continued)

ID	Component Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr.Net EA Benefits ($1,000)
TG.8+FNH											
TG8_1.21	FNH.0 (360 ac-ft)	$34,124	$19,857	$338	$75,528	$91,473	$5,502	$307	3.61	$14,355	$31
TG8_1.22	**FNH.1 (843 ac-ft)**	**$32,912**	**$21,069**	**$1,550**	**$86,404**	**$104,645**	**$6,294**	**$1,100**	**3.35**	**$14,774**	**$450**
TG8_1.23	FNH.2 (1271 ac-ft)	$32,168	$21,813	$2,294	$100,747	$122,015	$7,339	$2,144	2.97	$14,474	$150
TG8_1.24	FNH.3 (1717 ac-ft)	$31,971	$22,009	$2,491	$116,496	$141,090	$8,486	$3,292	2.59	$13,523	-$801
TG.8+GBW											
TG8_1.25	GBW.1 (229 ac-ft)	$34,693	$19,288	-$230	$76,374	$92,498	$5,564	$369	3.47	$13,725	-$599
TG8_1.26	**GBW.2 (427 ac-ft)**	**$32,559**	**$21,422**	**$1,904**	**$84,050**	**$101,794**	**$6,123**	**$928**	**3.50**	**$15,299**	**$976**
TG8_1.27	GBW.3 (519 ac-ft)	$32,225	$21,756	$2,238	$89,580	$108,491	$6,526	$1,331	3.33	$15,230	$907
TG.8+RG											
TG8_1.28	RG.1 (277 ac-ft)	$33,372	$20,609	$1,091	$81,209	$98,353	$5,916	$721	3.48	$14,693	$369
TG8_1.29	**RG.2 (399 ac-ft)**	**$32,966**	**$21,015**	**$1,496**	**$85,838**	**$103,959**	**$6,253**	**$1,058**	**3.36**	**$14,762**	**$438**
TG8_1.30	RG.3 (882 ac-ft)	$32,248	$21,732	$2,214	$116,192	$140,721	$8,464	$3,270	2.57	$13,268	-$1,056
TG.8+JR											
TG8_1.31	JR.2 (220 ac-ft)	$32,546	$21,435	$1,917	$80,138	$97,055	$5,838	$643	3.67	$15,597	$1,273
TG8_1.32	**JR.4 (420 ac-ft)**	**$30,766**	**$23,214**	**$3,696**	**$88,556**	**$107,251**	**$6,451**	**$1,256**	**3.60**	**$16,763**	**$2,439**
TG8_1.33	JR.5 (470 ac-ft)	$30,403	$23,578	$4,060	$100,694	$121,952	$7,335	$2,141	3.21	$16,243	$1,919
TG.8+Non-structural buyouts											
TG8_1.34	NSB-50%	$34,427	$19,554	$35	$71,503	$86,597	$5,209	$14	3.75	$14,345	$21
TG8_1.35	**NSB-20%**	**$31,371**	**$22,609**	**$3,091**	**$104,485**	**$126,543**	**$7,611**	**$2,417**	**2.97**	**$14,998**	**$674**
TG8_1.36	NSB-10%	$27,415	$26,566	$7,048	$229,993	$278,546	$16,754	$11,560	1.59	$9,812	-$4,512
TG8_1.37	NSB-4%	$18,873	$35,107	$15,589	$589,472	$713,916	$42,941	$37,746	0.82	-$7,833	-$22,157
TG8_1.38	NSB-2%	$15,171	$38,810	$19,291	$867,086	$1,050,137	$63,164	$57,969	0.61	-$24,354	-$38,678
TG8_1.39	**TG.8+Elev_TG8_50%**	**$34,432**	**$19,549**	**$31**	**$71,441**	**$86,523**	**$5,204**	**$10**	**3.76**	**$14,345**	**$21**
TG8_1.40	TG.8+Elev_TG8_20%	$31,573	$22,407	$2,889	$119,972	$145,299	$8,739	$3,545	2.56	$13,668	-$656
TG8_1.41	TG.8+Elev_TG8_10%	$27,827	$26,154	$6,635	$266,288	$322,504	$19,398	$14,204	1.35	$6,756	-$7,568
TG8_1.42	TG.8+Elev_TG8_4%	$20,042	$33,939	$14,420	$612,551	$741,867	$44,622	$39,428	0.76	-$10,683	-$25,007
TG8_1.43	TG.8+Elev_TG8_2%	$16,837	$37,144	$17,625	$868,870	$1,052,297	$63,294	$58,099	0.59	-$26,150	-$40,474

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Ten components were run with TG.8 for a total of 38 separate options. The component that maximized net EA benefits was detention basin JR. The option that produced the maximum increase in EA benefits over the anchor component was JR.4, a 420 acre-foot detention basin. The two components combined have EA benefits of $23.2 million and a capital cost of approximately $89 million. The net EA benefits are $16.8 million, an incremental increase in net EA benefits of $2.4 million over the anchor component by itself. The anchor and first-added component for this plan are identified as TG.8+JR.4.

Figure 4-3. Re-optimization of Components with Anchor TG.8



4.8.2 Anchor TG.2

Table 4-15 and Figure 4-4 show the re-optimization of all of the components along with the anchor component TG.2. Ten components were run with TG.2, for a total of 36 separate options. The component that maximized net EA benefits was detention basin JR. The option that produced the maximum increase in EA benefits over the anchor component was JR.4, a 420 acre-foot detention basin. The two components combined have EA benefits of $15.5 million and a capital cost of approximately $51 million. The net EA benefits are $11.8 million, an incremental increase in net EA benefits of $4.0 million over the anchor component by itself. TG.2+JR.4 are the identified anchor and first-added component for this plan.

Table 4-15 Re-optimization of Components with Anchor TG.2

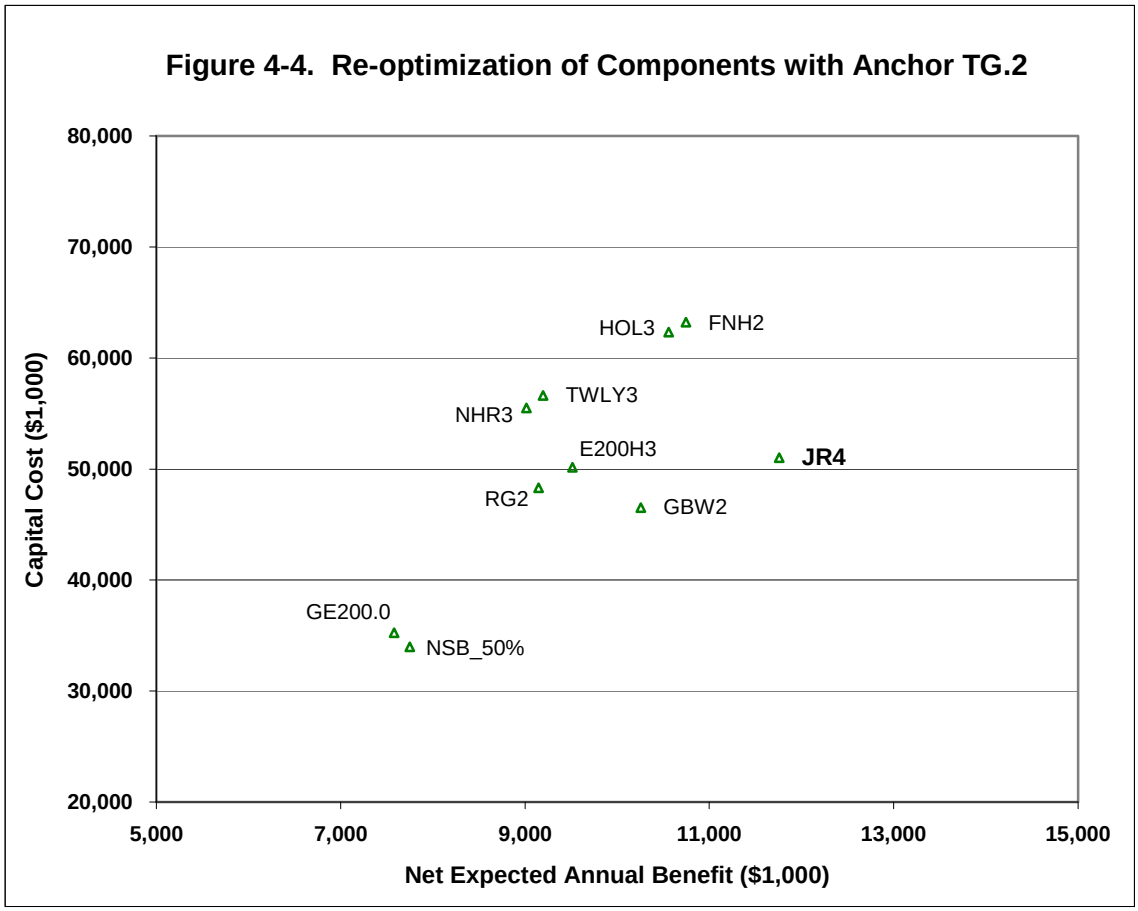
ID	Component Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,981									
TG2 (earthen channel modifications)		$43,789	$10,192		$33,779	$40,910	$2,461		4.14	$7,731	
TG.2+GE200											
TG2_1.1	**GE200.0**	**$43,832**	**$10,149**	**-$43**	**$35,249**	**$42,690**	**$2,568**	**$107**	**3.95**	**$7,581**	**-$150**
TG2_1.2	GE200.2	$43,613	$10,368	$176	$41,224	$49,927	$3,003	$542	3.45	$7,365	-$366
TG2_1.3	GE200.3	$43,461	$10,520	$328	$55,870	$67,664	$4,070	$1,609	2.58	$6,450	-$1,281
TG2_1.4	GE200.6	$45,289	$8,692	-$1,500	$57,299	$69,396	$4,174	$1,713	2.08	$4,518	-$3,213
TG.2+E200H											
TG2_1.5	E200H.1	$42,538	$11,443	$1,251	$41,606	$50,390	$3,031	$570	3.78	$8,412	$681
TG2_1.6	E200H.2	$41,711	$12,270	$2,078	$44,886	$54,362	$3,270	$809	3.75	$9,000	$1,269
TG2_1.7	**E200H.3**	**$40,813**	**$13,168**	**$2,976**	**$50,155**	**$60,743**	**$3,654**	**$1,193**	**3.60**	**$9,514**	**$1,783**
TG2_1.8	E200H.4	$40,151	$13,829	$3,638	$96,275	$116,599	$7,013	$4,553	1.97	$6,816	-$915
TG.2+TWLY											
TG2_1.9	TWLY.2 (516 ac-ft)	$42,292	$11,688	$1,497	$43,120	$52,223	$3,141	$680	3.72	$8,547	$816
TG2_1.10	**TWLY.3 (1032 ac-ft)**	**$40,660**	**$13,321**	**$3,129**	**$56,613**	**$68,565**	**$4,124**	**$1,663**	**3.23**	**$9,197**	**$1,466**
TG2_1.11	TWLY.5 (1658 ac-ft)	$39,927	$14,054	$3,862	$86,409	$104,650	$6,295	$3,834	2.23	$7,760	$29
TG.2+NHR											
TG2_1.12	NHR.1 (595 ac-ft)	$44,258	$9,723	-$469	$41,735	$50,546	$3,040	$580	3.20	$6,683	-$1,048
TG2_1.13	**NHR.3 (1069 ac-ft)**	**$40,924**	**$13,057**	**$2,865**	**$55,500**	**$67,216**	**$4,043**	**$1,582**	**3.23**	**$9,014**	**$1,283**
TG2_1.14	NHR.4 (1211 ac-ft)	$40,540	$13,441	$3,249	$80,055	$96,955	$5,832	$3,371	2.30	$7,609	-$122
TG.2+HOL											
TG2_1.15	HOL.1 (444 ac-ft)	$41,445	$12,536	$2,344	$48,881	$59,200	$3,561	$1,100	3.52	$8,975	$1,244
TG2_1.16	HOL.2 (522 ac-ft)	$39,852	$14,129	$3,938	$52,595	$63,698	$3,831	$1,371	3.69	$10,298	$2,567
TG2_1.17	**HOL.3 (730 ac-ft)**	**$38,885**	**$15,096**	**$4,904**	**$62,313**	**$75,468**	**$4,539**	**$2,079**	**3.33**	**$10,557**	**$2,826**
TG2_1.18	HOL.4 (827 ac-ft)	$38,505	$15,475	$5,284	$71,945	$87,133	$5,241	$2,780	2.95	$10,234	$2,503

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-15 (continued)

ID	Component Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG.2+FNH											
TG2_1.19	FNH.1 (843 ac-ft)	$40,460	$13,521	$3,330	$48,875	$59,193	$3,560	$1,100	3.80	$9,961	$2,230
TG2_1.20	**FNH.2 (1271 ac-ft)**	**$38,629**	**$15,352**	**$5,160**	**$63,217**	**$76,563**	**$4,605**	**$2,144**	**3.33**	**$10,747**	**$3,016**
TG2_1.21	FNH.3 (1717 ac-ft)	$38,396	$15,584	$5,393	$78,967	$95,637	$5,752	$3,292	2.71	$9,832	$2,101
TG2_1.22	FNH.4 (2111 ac-ft)	$38,459	$15,521	$5,330	$92,463	$111,983	$6,736	$4,275	2.30	$8,786	$1,055
TG.2+GBW											
TG2_1.23	GBW.1 (229 ac-ft)	$42,042	$11,938	$1,747	$38,845	$47,045	$2,830	$369	4.22	$9,109	$1,378
TG2_1.24	**GBW.2 (427 ac-ft)**	**$40,336**	**$13,644**	**$3,453**	**$46,520**	**$56,341**	**$3,389**	**$928**	**4.03**	**$10,256**	**$2,525**
TG2_1.25	GBW.3 (519 ac-ft)	$40,272	$13,709	$3,518	$52,051	$63,039	$3,792	$1,331	3.62	$9,918	$2,187
TG.2+RG											
TG2_1.26	RG.1 (277 ac-ft)	$41,961	$12,020	$1,828	$43,679	$52,900	$3,182	$721	3.78	$8,838	$1,107
TG2_1.27	**RG.2 (399 ac-ft)**	**$41,316**	**$12,664**	**$2,473**	**$48,309**	**$58,507**	**$3,519**	**$1,058**	**3.60**	**$9,145**	**$1,414**
TG2_1.28	RG.3 (882 ac-ft)	$40,934	$13,046	$2,855	$78,662	$95,269	$5,730	$3,270	2.28	$7,316	-$415
TG.2+JR											
TG2_1.29	JR.2 (220 ac-ft)	$41,081	$12,899	$2,708	$42,608	$51,603	$3,104	$643	4.16	$9,796	$2,065
TG2_1.30	**JR.4 (420 ac-ft)**	**$38,507**	**$15,473**	**$5,282**	**$51,027**	**$61,799**	**$3,717**	**$1,256**	**4.16**	**$11,756**	**$4,025**
TG2_1.31	JR.5 (470 ac-ft)	$38,096	$15,885	$5,693	$63,165	$76,500	$4,601	$2,141	3.45	$11,283	$3,552
TG.2+Non-structural buyouts											
TG2_1.32	**NSB-50%**	**$43,756**	**$10,225**	**$33**	**$33,973**	**$41,145**	**$2,475**	**$14**	**4.13**	**$7,750**	**$19**
TG2_1.33	NSB-20%	$42,067	$11,914	$1,723	$54,777	$66,341	$3,990	$1,530	2.99	$7,924	$193
TG2_1.34	NSB-10%	$36,530	$17,450	$7,259	$189,895	$229,983	$13,833	$11,372	1.26	$3,617	-$4,114
TG2_1.35	NSB-4%	$25,280	$28,701	$18,509	$613,741	$743,308	$44,709	$42,248	0.64	-$16,008	-$23,739
TG2_1.36	NSB-2%	$20,791	$33,190	$22,998	$1,006,180	$1,218,594	$73,297	$70,836	0.45	-$40,107	-$47,838
TG2_1.37	TG.2+Elev_TG2_50%	$43,760	$10,221	$29	$33,912	$41,071	$2,470	$10	4.14	$7,751	$20
TG2_1.38	**TG.2+Elev_TG2_20%**	**$42,167**	**$11,814**	**$1,622**	**$51,402**	**$62,254**	**$3,744**	**$1,284**	**3.15**	**$8,069**	**$338**
TG2_1.39	TG.2+Elev_TG2_10%	$36,969	$17,012	$6,821	$209,679	$253,944	$15,274	$12,814	1.11	$1,738	-$5,993
TG2_1.40	TG.2+Elev_TG2_4%	$26,732	$27,249	$17,057	$611,568	$740,676	$44,550	$42,090	0.61	-$17,302	-$25,033
TG2_1.41	TG.2+Elev_TG2_2%	$23,117	$30,864	$20,672	$923,469	$1,118,422	$67,271	$64,811	0.46	-$36,408	-$44,139

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.



4.8.3 Anchor FNH.3 + JR.4

Table 4-16 and Figure 4-5 show the re-optimization of all of the components along with the anchor detention components FNH.3+JR.4. Six components were run with FNH.3+JR.4 for a total of 22 separate options. The component that maximized net EA benefits was detention basin GBW. The option that produced the maximum increase in EA benefits over the anchor component was GBW.3, a 519 acre-foot detention basin. The three components combined have EA benefits of $19.0 million and a capital cost of approximately $81 million. The net EA benefits are $13.1 million, an incremental increase in net EA benefits of $2.8 million over the anchor by itself. FNH.3+JR.4+GBW.3 are the identified anchor and first added component that form the basis for further formulation of this plan.

Table 4-16 Re-optimization of Components with Anchor FNH.3+JR.4

ID	Component Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,981									
DA_1	FNH.3+JR.4	$39,090	$14,891		$62,435	$75,616	$4,548		3.27	$10,343	
FNH.3+JR.4+GE200											
DA_1.1	GE200.0	$38,082	$15,899	$1,008	$63,904	$77,395	$4,655	$107	3.42	$11,244	$901
DA_1.2	GE200.1	$39,894	$14,087	-$804	$62,928	$76,213	$4,584	$36	3.07	$9,503	-$840
DA_1.3	**GE200.2**	**$37,631**	**$16,350**	**$1,459**	**$69,880**	**$84,632**	**$5,091**	**$542**	**3.21**	**$11,260**	**$917**
DA_1.4	GE200.3	$37,560	$16,420	$1,529	$84,525	$102,370	$6,157	$1,609	2.67	$10,263	-$80
DA_1.5	GE200.6	$37,078	$16,902	$2,011	$85,955	$104,101	$6,262	$1,713	2.70	$10,641	$298
FNH.3+JR.4+TWLY											
DA_1.6	**TWLY.2 (516 ac-ft)**	**$37,338**	**$16,643**	**$1,752**	**$71,775**	**$86,928**	**$5,229**	**$680**	**3.18**	**$11,414**	**$1,071**
DA_1.7	TWLY.3 (1032 ac-ft)	$36,788	$17,192	$2,301	$85,269	$103,270	$6,212	$1,663	2.77	$10,981	$638
DA_1.8	TWLY.5 (1658 ac-ft)	$36,301	$17,680	$2,788	$115,064	$139,356	$8,382	$3,834	2.11	$9,298	-$1,045
FNH.3+JR.4+NHR											
DA_1.9	NHR.1 (595 ac-ft)	$36,946	$17,034	$2,143	$70,391	$85,251	$5,128	$580	3.32	$11,907	$1,564
DA_1.10	**NHR.3 (1069 ac-ft)**	**$35,378**	**$18,603**	**$3,712**	**$84,155**	**$101,921**	**$6,130**	**$1,582**	**3.03**	**$12,473**	**$2,130**
DA_1.11	NHR.4 (1211 ac-ft)	$35,170	$18,811	$3,920	$108,711	$131,661	$7,919	$3,371	2.38	$10,891	$548
FNH.3+JR.4+HOL											
DA_1.12	HOL.1 (444 ac-ft)	$36,290	$17,691	$2,800	$77,537	$93,905	$5,648	$1,100	3.13	$12,043	$1,700
DA_1.13	HOL.2 (522 ac-ft)	$35,682	$18,298	$3,407	$81,251	$98,403	$5,919	$1,371	3.09	$12,379	$2,036
DA_1.14	**HOL.3 (730 ac-ft)**	**$34,921**	**$19,060**	**$4,169**	**$90,968**	**$110,173**	**$6,627**	**$2,079**	**2.88**	**$12,433**	**$2,090**
DA_1.15	HOL.4 (827 ac-ft)	$34,389	$19,592	$4,701	$100,601	$121,838	$7,328	$2,780	2.67	$12,264	$1,921
FNH.3+JR.4+GBW											
DA_1.16	GBW.1 (229 ac-ft)	$37,208	$16,772	$1,881	$67,500	$81,750	$4,917	$369	3.41	$11,855	$1,512
DA_1.17	GBW.2 (427 ac-ft)	$35,679	$18,302	$3,411	$75,176	$91,047	$5,476	$928	3.34	$12,825	$2,482
DA_1.18	**GBW.3 (519 ac-ft)**	**$35,007**	**$18,974**	**$4,083**	**$80,706**	**$97,744**	**$5,879**	**$1,331**	**3.23**	**$13,095**	**$2,752**
DA_1.19	GBW.4 (618 ac-ft)	$34,901	$19,080	$4,189	$97,686	$118,308	$7,116	$2,568	2.68	$11,964	$1,621
FNH.3+JR.4+RG											
DA_1.20	**RG.1 (277 ac-ft)**	**$37,386**	**$16,595**	**$1,703**	**$72,335**	**$87,606**	**$5,269**	**$721**	**3.15**	**$11,325**	**$982**
DA_1.21	RG.2 (399 ac-ft)	$37,120	$16,861	$1,970	$76,964	$93,212	$5,607	$1,058	3.01	$11,255	$912
DA_1.22	RG.3 (882 ac-ft)	$35,782	$18,199	$3,307	$107,318	$129,974	$7,818	$3,270	2.33	$10,381	$38

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
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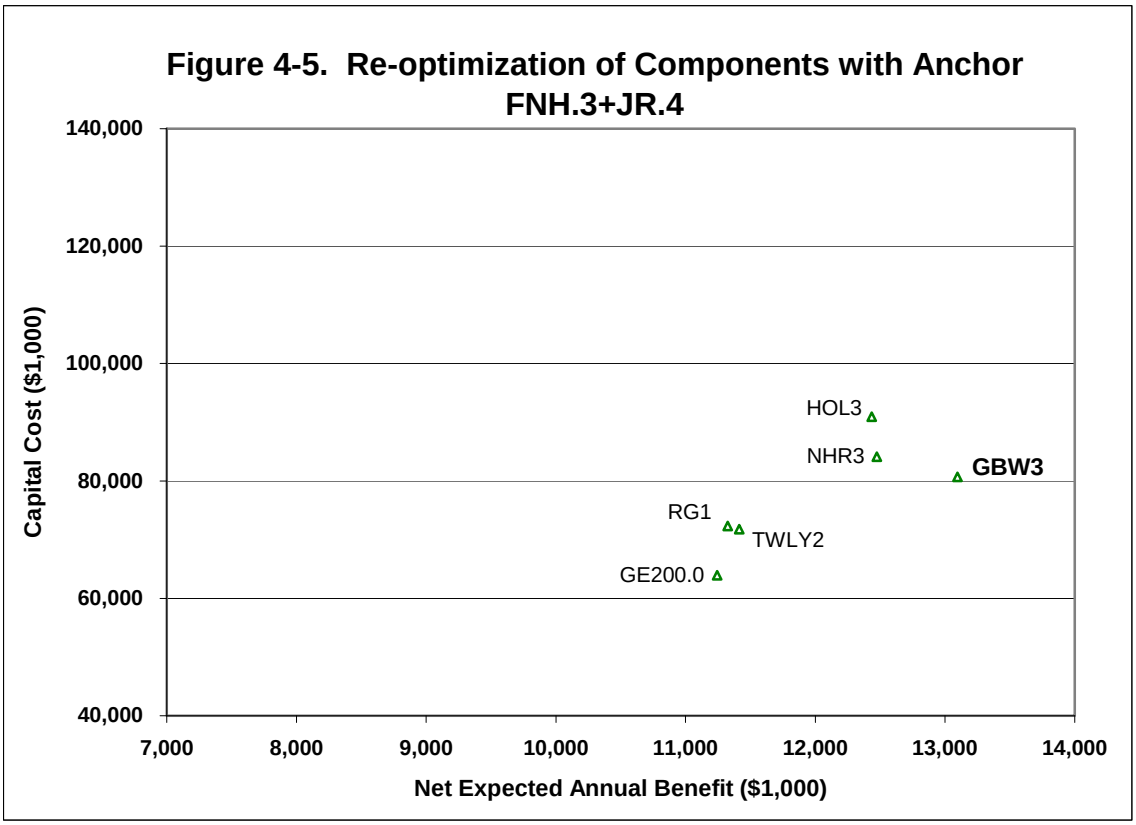
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.



4.9 Step 5 - Incremental Addition of Components

For each anchor and first identified component, the plan was built in a logical and incremental fashion until the net benefits were maximized. At each iteration, the best performing combination of best performing sizes of the components, from the previous iteration was combined and analyzed with each of the best performing sizes of the remaining components, one at a time. The one component that produced the highest incremental annual net benefits was added to the group that was carried forward to the next iteration. The analysis continued in a cyclical fashion until no more components could be added that increase net annual benefits.

As previously mentioned, all components were not re-optimized at each iteration as they were in Section 4.8 after selection of the anchor components. However, re-optimization of remaining components was performed as part of the iterative cycles between Steps 4 and 5 after two components were added to the alternatives. This was done because as components are added to the group, changes occur in flows, water surface elevations and resulting economic damages, and the component configuration that performed the best in a previous iteration may not be the configuration that performs the best in a subsequent iteration. The following sections present a summary of the results for the incremental addition of components.

4.9.1 Anchor TG.8

As presented in Section 4.8, the plan with anchor TG.8 and the first added component was TG.8+JR.4. This consists of approximately seven miles of concrete-lined channel modifications and one upstream detention basin. To this plan components were added incrementally through eight iterations of alternative models developed in a sequential fashion, as described above.

The results of the addition of components with TG.8 as anchor are presented in Table 4-17. The results for the previous runs with TG.8 and TG.8+JR.4 are also presented for ease of comparison. A distinct heading in bold text to distinguish between the iterations separates each iteration step. As shown in the table, two iterations re-optimized the unselected components. The table is arranged similar to those in the previous section and shows EA damages, EA benefits, capital costs, base year equivalent costs, EA costs, B/C ratio, and net EA benefits. In addition, the incremental EA benefits, incremental EA cost, and incremental net EA benefits are shown to provide a comparison to the previous iteration. Figure 4-6 graphically displays the progression steps. The figure shows the performance of the components as they were evaluated at each individual step. The different symbols show the component results at each successive step. In each step a unique symbol was used to show the different components analyzed for addition to the plan in that step. The component that provided the largest net economic benefits as plotted along the horizontal axis of the figure was selected for inclusion in the plan. The selected component name is shown on the graph adjacent to the plotting point for that component. Then in the subsequent step, a different unique symbol was used to show the results for the remaining components analyzed. This graphical presentation of the results is used throughout the various steps of the planning process, as presented in the following sections.

The formulated alternative plan with TG.8 as anchor consists of three channelization components, six detention components, and a non-structural buyout component as listed below and shown on Exhibit 4-11:

- TG.8 + JR.4 + GBW.2 + E200H.3 + TWLY.3 + FNH.1 + GE200.0 + NSB_20% + NHR.1 + RG.0.

The formulated alternative has EA benefits of $35.5 million at a capital cost of approximately $177 million. The plan has net EA benefits of $22.6 million.

Table 4-17 Incremental Addition of Components with Anchor TG.8

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,981									
TG8	TG.8	$34,462	$19,519	$19,519	$71,309	$86,363	$5,195		3.76	$14,324	
TG8_1.32	TG.8+JR.4	$30,766	$23,214	$3,696	$88,556	$107,251	$6,451	$1,256	3.60	$16,763	$2,439
TG.8+JR.4+											
TG8_2.1	GE200.5	$29,821	$24,160	$945	$97,431	$117,999	$7,097	$646	3.40	$17,062	$299
TG8_2.2	E200H.3	$28,566	$25,415	$2,200	$104,932	$127,084	$7,644	$1,193	3.32	$17,771	$1,007
TG8_2.3	TWLY.2	$29,565	$24,415	$1,201	$97,897	$118,563	$7,131	$680	3.42	$17,284	$521
TG8_2.4	NHR.1	$30,081	$23,900	$686	$96,512	$116,887	$7,031	$580	3.40	$16,870	$106
TG8_2.5	HOL.2	$30,126	$23,855	$641	$107,372	$130,039	$7,822	$1,371	3.05	$16,034	-$730
TG8_2.6	FNH.1	$29,135	$24,846	$1,632	$103,652	$125,534	$7,551	$1,100	3.29	$17,295	$532
TG8_2.7	**GBW.2**	**$28,774**	**$25,206**	**$1,992**	**$101,297**	**$122,682**	**$7,379**	**$928**	**3.42**	**$17,827**	**$1,064**
TG8_2.8	RG.2	$29,583	$24,398	$1,183	$103,086	$124,848	$7,509	$1,058	3.25	$16,888	$125
TG8_2.9b	NSB-20%	$29,085	$24,895	$1,681	$103,800	$125,714	$7,561	$1,110	3.29	$17,334	$571
TG.8+JR.4+GBW.2+											
TG8_3.1	GE200.5	$29,092	$24,888	-$318	$110,172	$133,430	$8,026	$646	3.10	$16,863	-$964
TG8_3.2	**E200H.3**	**$25,966**	**$28,015**	**$2,808**	**$117,673**	**$142,515**	**$8,572**	**$1,193**	**3.27**	**$19,443**	**$1,615**
TG8_3.3	TWLY.2	$27,442	$26,538	$1,332	$110,638	$133,994	$8,060	$680	3.29	$18,479	$652
TG8_3.4	NHR.1	$27,962	$26,019	$812	$109,253	$132,318	$7,959	$580	3.27	$18,060	$233
TG8_3.5	HOL.2	$28,074	$25,907	$701	$120,113	$145,470	$8,750	$1,371	2.96	$17,157	-$670
TG8_3.6	FNH.1	$26,976	$27,005	$1,799	$116,393	$140,965	$8,479	$1,100	3.18	$18,526	$699
TG8_3.7	RG.2	$27,580	$26,400	$1,194	$115,827	$140,279	$8,438	$1,058	3.13	$17,963	$136
TG8_3.8	NSB-20%	$27,146	$26,835	$1,629	$116,364	$140,930	$8,477	$1,098	3.17	$18,358	$531
***TG.8+JR.4+GBW.2+E200H.3+ (*re-optimization of remaining components)**											
TG8_4.1	GE200.0	$25,702	$28,278	$264	$119,143	$144,295	$8,679	$107	3.26	$19,599	$157
TG8_4.2	GE200.2	$26,356	$27,624	-$390	$125,118	$151,532	$9,114	$542	3.03	$18,510	-$933
TG8_4.3	GE200.3	$26,508	$27,472	-$542	$139,764	$169,269	$10,181	$1,609	2.70	$17,291	-$2,152
TG8_4.4	GE200.5	$26,860	$27,121	-$894	$126,548	$153,263	$9,219	$646	2.94	$17,902	-$1,540
TG8_4.5	GE200.6	$26,459	$27,522	-$493	$141,193	$171,000	$10,285	$1,713	2.68	$17,236	-$2,206

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
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(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-17 Incremental Addition of Components with Anchor TG.8 (continued)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG8_4.6	TWLY.0 (160 ac-ft)	$25,352	$28,628	$614	$121,657	$147,341	$8,862	$290	3.23	$19,766	$324
TG8_4.7	TWLY.2 (516 ac-ft)	$23,796	$30,185	$2,170	$127,014	$153,827	$9,252	$680	3.26	$20,933	$1,490
TG8_4.8	**TWLY.3 (1032 ac-ft)**	**$22,455**	**$31,526**	**$3,511**	**$140,507**	**$170,170**	**$10,235**	**$1,663**	**3.08**	**$21,291**	**$1,848**
TG8_4.9	TWLY.5 (1658 ac-ft)	$20,984	$32,997	$4,982	$170,302	$206,255	$12,406	$3,834	2.66	$20,591	$1,148
TG8_4.10	NHR.0 (360 ac-ft)	$25,866	$28,115	$100	$120,694	$146,174	$8,792	$220	3.20	$19,323	-$120
TG8_4.11	NHR.1 (595 ac-ft)	$25,070	$28,911	$896	$125,629	$152,150	$9,152	$580	3.16	$19,759	$317
TG8_4.12	NHR.3 (1069 ac-ft)	$24,295	$29,685	$1,671	$139,394	$168,821	$10,154	$1,582	2.92	$19,531	$88
TG8_4.13	NHR.4 (1211 ac-ft)	$24,254	$29,727	$1,712	$163,949	$198,560	$11,943	$3,371	2.49	$17,784	-$1,659
TG8_4.14	HOL.1 (444 ac-ft)	$25,816	$28,165	$150	$132,775	$160,805	$9,672	$1,100	2.91	$18,493	-$950
TG8_4.15	HOL.2 (522 ac-ft)	$25,082	$28,899	$884	$136,489	$165,303	$9,943	$1,371	2.91	$18,956	-$486
TG8_4.16	HOL.3 (730 ac-ft)	$25,017	$28,964	$949	$146,206	$177,072	$10,651	$2,079	2.72	$18,313	-$1,129
TG8_4.17	FNH.0 (360 ac-ft)	$25,596	$28,385	$370	$121,892	$147,625	$8,879	$307	3.20	$19,505	$63
TG8_4.18	FNH.1 (843 ac-ft)	$24,137	$29,843	$1,829	$132,769	$160,798	$9,672	$1,100	3.09	$20,172	$729
TG8_4.19	FNH.2 (1271 ac-ft)	$23,350	$30,631	$2,616	$147,111	$178,168	$10,716	$2,144	2.86	$19,915	$472
TG8_4.20	RG.0 (100 ac-ft)	$25,563	$28,418	$403	$121,384	$147,009	$8,842	$270	3.21	$19,576	$133
TG8_4.21	RG.1 (277 ac-ft)	$24,910	$29,070	$1,056	$127,573	$154,505	$9,293	$721	3.13	$19,777	$335
TG8_4.22	RG.2 (399 ac-ft)	$24,644	$29,337	$1,322	$132,203	$160,112	$9,630	$1,058	3.05	$19,707	$264
TG8_4.23	RG.3 (882 ac-ft)	$23,727	$30,254	$2,239	$162,556	$196,873	$11,842	$3,270	2.55	$18,412	-$1,031
TG8_4.24	NSB-50%	$25,932	$28,049	$34	$117,868	$142,752	$8,586	$14	3.27	$19,463	$20
TG8_4.25	NSB-20%	$24,375	$29,606	$1,591	$132,740	$160,763	$9,670	$1,098	3.06	$19,936	$494
TG8_4.26	NSB-10%	$20,999	$32,982	$4,967	$206,674	$250,305	$15,055	$6,483	2.19	$17,926	-$1,516

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(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-17 Incremental Addition of Components with Anchor TG.8 (continued)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG.8+JR.4+GBW.2+E200H.3+TWLY.3+											
TG8_5.1	**FNH.1**	**$20,942**	**$33,038**	**$1,512**	**$155,603**	**$188,452**	**$11,335**	**$1,100**	**2.91**	**$21,703**	**$413**
TG8_5.2	HOL.2	$21,609	$32,372	$846	$159,323	$192,957	$11,606	$1,371	2.79	$20,766	-$525
TG8_5.3	NHR.1	$21,759	$32,222	$695	$148,463	$179,805	$10,815	$580	2.98	$21,407	$116
TG8_5.4	RG.1	$21,603	$32,378	$852	$150,407	$182,160	$10,957	$721	2.96	$21,421	$130
TG8_5.5	GE200.0	$22,273	$31,708	$182	$141,977	$171,949	$10,342	$107	3.07	$21,365	$75
TG8_5.6	NSB-20%	$21,482	$32,498	$972	$148,791	$180,203	$10,839	$603	3.00	$21,659	$369
TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+											
TG8_6.1	HOL.2	$20,210	$33,771	$733	$174,419	$211,240	$12,706	$1,371	2.66	$21,065	-$638
TG8_6.2	NHR.1	$20,304	$33,677	$638	$163,559	$198,088	$11,915	$580	2.83	$21,762	$59
TG8_6.3	RG.1	$20,063	$33,918	$879	$165,503	$200,442	$12,056	$721	2.81	$21,861	$158
TG8_6.4	**GE200.0**	**$20,465**	**$33,515**	**$477**	**$157,073**	**$190,232**	**$11,442**	**$107**	**2.93**	**$22,073**	**$370**
TG8_6.5	NSB_T8J4G2EH3T3F1 -20%	$19,993	$33,987	$949	$163,887	$198,485	$11,939	$603	2.85	$22,049	$345
***TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+GE200.0+ (*re-optimization of remaining components)**											
TG8_7.1	NHR.0 (360 ac-ft)	$20,212	$33,769	$253	$160,094	$193,891	$11,662	$220	2.90	$22,107	$33
TG8_7.2	NHR.1 (595 ac-ft)	$19,732	$34,248	$733	$165,028	$199,868	$12,022	$580	2.85	$22,227	$153
TG8_7.3	NHR.3 (1069 ac-ft)	$19,068	$34,913	$1,398	$178,793	$216,538	$13,024	$1,582	2.68	$21,889	-$185
TG8_7.4	HOL.1 (444 ac-ft)	$20,180	$33,801	$286	$172,174	$208,522	$12,542	$1,100	2.69	$21,259	-$815
TG8_7.5	HOL.2 (522 ac-ft)	$19,736	$34,245	$729	$175,888	$213,020	$12,813	$1,371	2.67	$21,432	-$641
TG8_7.6	HOL.3 (730 ac-ft)	$19,693	$34,288	$772	$185,606	$224,789	$13,521	$2,079	2.54	$20,767	-$1,306
TG8_7.7	RG.0 (100 ac-ft)	$20,172	$33,809	$293	$160,784	$194,727	$11,712	$270	2.89	$22,096	$23
TG8_7.8	RG.1 (277 ac-ft)	$19,779	$34,201	$686	$166,973	$202,222	$12,163	$721	2.81	$22,038	-$35
TG8_7.9	RG.2 (399 ac-ft)	$19,673	$34,308	$792	$171,602	$207,829	$12,501	$1,058	2.74	$21,807	-$266
TG8_7.10	NSB-50%	$20,431	$33,550	$34	$157,268	$190,469	$11,456	$14	2.93	$22,093	$20
TG8_7.11	**NSB-20%**	**$19,494**	**$34,487**	**$972**	**$165,357**	**$200,265**	**$12,046**	**$603**	**2.86**	**$22,441**	**$368**
TG8_7.12	NSB-10%	$17,996	$35,985	$2,469	$201,493	$244,030	$14,678	$3,236	2.45	$21,306	-$767

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(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-17 Incremental Addition of Components with Anchor TG.8 (continued)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+GE200.0+NSB_20%+											
TG8_8.1	**NHR.1**	**$18,758**	**$35,223**	**$736**	**$173,313**	**$209,900**	**$12,625**	**$580**	**2.79**	**$22,597**	**$156**
TG8_8.2	HOL.2	$18,758	$35,223	$736	$184,172	$223,053	$13,416	$1,371	2.63	$21,806	-$635
TG8_8.3	RG.0	$19,193	$34,787	$300	$169,068	$204,760	$12,316	$270	2.82	$22,471	$30
TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+GE200.0+NSB_20%+NHR.1+											
TG8_9.1	HOL.2	$18,067	$35,914	$692	$192,128	$232,688	$13,996	$1,371	2.57	$21,918	-$679
TG8_9.2	**RG.0**	**$18,465**	**$35,515**	**$293**	**$177,024**	**$214,395**	**$12,896**	**$270**	**2.75**	**$22,620**	**$22**

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
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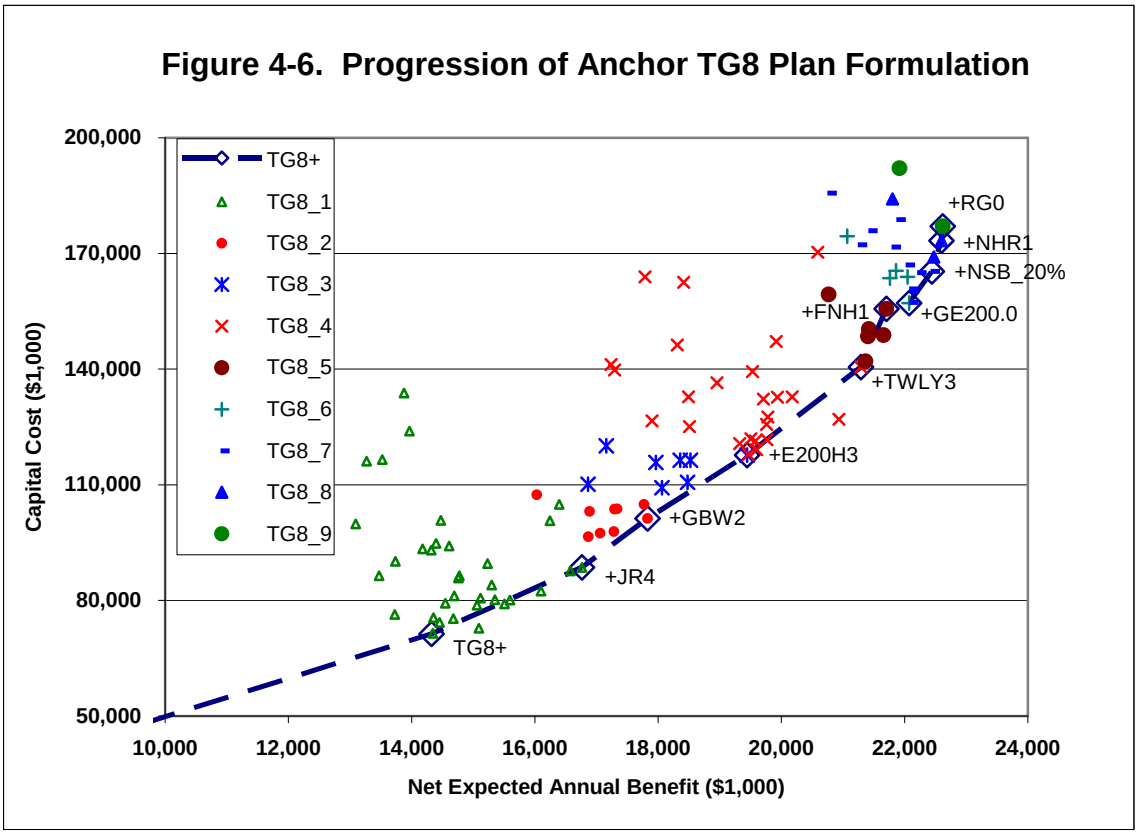
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.



4.9.2 Anchor TG.2

As presented in Section 4.8, the plan with anchor TG.2 and the first added component was defined as TG.2+JR.4. This consists of approximately seven miles of earthen channel modifications and one upstream detention basin. To this plan were added components incrementally through seven iterations of alternative models developed in a sequential fashion. Unselected components were re-optimized at two of the iterations.

The results for the alternative formulated with TG.2 as anchor are presented in Table 4-18. The results for the runs with TG.2 and TG.2+JR.4 are also presented for ease of comparison. Figure 4-7 graphically displays the progression steps. The figure shows the performance of the components as they were evaluated at each individual step.

Table 4-18 Incremental Addition of Components with Anchor TG.2

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,981									
TG2	TG.2	$43,789	$10,192	$10,192	$33,779	$40,910	$2,461		4.14	$7,731	
TG2_1.30	TG.2+JR.4	$38,507	$15,473	$5,282	$51,027	$61,799	$3,717	$1,256	4.16	$11,756	$4,025
TG.2+JR.4+											
TG2_2.1	GE200.0	$37,748	$16,233	$760	$52,496	$63,579	$3,824	$107	4.24	$12,409	$653
TG2_2.2	E200H.3	$36,917	$17,064	$1,591	$67,402	$81,632	$4,910	$1,193	3.48	$12,154	$398
TG2_2.3	TWLY.3	$35,616	$18,365	$2,892	$73,861	$89,453	$5,380	$1,663	3.41	$12,985	$1,228
TG2_2.4	NHR.3	$35,297	$18,684	$3,210	$72,747	$88,105	$5,299	$1,582	3.53	$13,384	$1,628
TG2_2.5	**HOL.3**	**$33,771**	**$20,209**	**$4,736**	**$79,560**	**$96,356**	**$5,796**	**$2,079**	**3.49**	**$14,414**	**$2,657**
TG2_2.6	FNH.2	$34,045	$19,935	$4,462	$80,465	$97,451	$5,862	$2,144	3.40	$14,074	$2,318
TG2_2.7	GBW.2	$35,089	$18,892	$3,418	$63,768	$77,230	$4,645	$928	4.07	$14,246	$2,490
TG2_2.8	RG.2	$36,580	$17,401	$1,928	$65,556	$79,396	$4,776	$1,058	3.64	$12,625	$869
TG.2+JR.4+HOL.3+											
TG2_3.1	GE200.0	$32,763	$21,217	$1,008	$81,030	$98,136	$5,903	$107	3.59	$15,315	$901
TG2_3.2	E200H.3	$32,219	$21,762	$1,553	$95,936	$116,189	$6,989	$1,193	3.11	$14,774	$360
TG2_3.3	TWLY.3	$31,812	$22,169	$1,959	$102,394	$124,011	$7,459	$1,663	2.97	$14,710	$296
TG2_3.4	NHR.3	$31,996	$21,985	$1,775	$101,281	$122,662	$7,378	$1,582	2.98	$14,607	$193
TG2_3.5	FNH.2	$30,357	$23,623	$3,414	$108,998	$132,009	$7,940	$2,144	2.98	$15,683	$1,269
TG2_3.6	**GBW.2**	**$30,996**	**$22,985**	**$2,776**	**$92,301**	**$111,787**	**$6,724**	**$928**	**3.42**	**$16,261**	**$1,847**
TG2_3.7	RG.2	$31,900	$22,081	$1,872	$94,090	$113,953	$6,854	$1,058	3.22	$15,227	$813

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Table 4-18 Incremental Addition of Components with Anchor TG.2 (continued)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
***TG.2+JR.4+HOL.3+GBW.2+(*re-optimization of remaining components)**											
TG2_4.1	GE200.0	$30,644	$23,337	$352	$93,771	$113,567	$6,831	$107	3.42	$16,506	$245
TG2_4.2	GE200.2	$30,172	$23,808	$823	$99,746	$120,804	$7,266	$542	3.28	$16,542	$281
TG2_4.3	GE200.3	$30,003	$23,978	$993	$114,392	$138,541	$8,333	$1,609	2.88	$15,645	-$616
TG2_4.4	GE200.5	$29,995	$23,985	$1,000	$101,176	$122,535	$7,370	$646	3.25	$16,615	$354
TG2_4.5	GE200.6	$29,827	$24,154	$1,169	$115,821	$140,272	$8,437	$1,713	2.86	$15,717	-$544
TG2_4.6	E200H.1	$30,438	$23,542	$557	$100,128	$121,266	$7,294	$570	3.23	$16,248	-$13
TG2_4.7	E200H.2	$29,839	$24,141	$1,156	$103,408	$125,238	$7,533	$809	3.20	$16,608	$347
TG2_4.8	E200H.3	$29,678	$24,303	$1,318	$108,677	$131,620	$7,917	$1,193	3.07	$16,386	$125
TG2_4.9	E200H.4	$29,515	$24,465	$1,480	$154,797	$187,476	$11,276	$4,553	2.17	$13,189	-$3,072
TG2_4.10	TWLY.0 (160 ac-ft)	$30,900	$23,081	$96	$96,286	$116,613	$7,014	$290	3.29	$16,067	-$195
TG2_4.11	TWLY.2 (516 ac-ft)	$29,984	$23,996	$1,011	$101,642	$123,099	$7,404	$680	3.24	$16,592	$331
TG2_4.12	TWLY.3 (1032 ac-ft)	$29,189	$24,792	$1,807	$115,135	$139,442	$8,387	$1,663	2.96	$16,405	$144
TG2_4.13	TWLY.5 (1658 ac-ft)	$28,314	$25,667	$2,682	$144,931	$175,527	$10,558	$3,834	2.43	$15,109	-$1,152
TG2_4.14	NHR.1 (595 ac-ft)	$31,133	$22,848	-$137	$100,257	$121,422	$7,303	$580	3.13	$15,544	-$717
TG2_4.15	NHR.3 (1069 ac-ft)	$29,399	$24,582	$1,597	$114,022	$138,093	$8,306	$1,582	2.96	$16,276	$15
TG2_4.16	NHR.4 (1211 ac-ft)	$29,166	$24,814	$1,829	$138,577	$167,832	$10,095	$3,371	2.46	$14,720	-$1,542
TG2_4.17	FNH.0 (360 ac-ft)	$30,363	$23,618	$633	$96,520	$116,897	$7,031	$307	3.36	$16,587	$326
TG2_4.18	**FNH.1 (843 ac-ft)**	**$28,610**	**$25,371**	**$2,386**	**$107,397**	**$130,070**	**$7,823**	**$1,100**	**3.24**	**$17,547**	**$1,286**
TG2_4.19	FNH.2 (1271 ac-ft)	$27,839	$26,142	$3,157	$121,739	$147,440	$8,868	$2,144	2.95	$17,274	$1,013
TG2_4.20	FNH.3 (1717 ac-ft)	$27,328	$26,653	$3,668	$137,489	$166,514	$10,016	$3,292	2.66	$16,637	$376
TG2_4.21	RG.1 (277 ac-ft)	$29,597	$24,384	$1,399	$102,201	$123,777	$7,445	$721	3.28	$16,939	$678
TG2_4.22	RG.2 (399 ac-ft)	$29,246	$24,735	$1,750	$106,831	$129,384	$7,782	$1,058	3.18	$16,953	$692
TG2_4.23	RG.3 (882 ac-ft)	$27,655	$26,325	$3,340	$137,184	$166,145	$9,993	$3,270	2.63	$16,332	$71

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-18 Incremental Addition of Components with Anchor TG.2 (continued)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG.2+JR.4+HOL.3+GBW.2+FNH.1+											
TG2_5.1	GE200.5	$27,628	$26,353	$982	$116,272	$140,818	$8,470	$646	3.11	$17,883	$336
TG2_5.2	E200H.2	$27,472	$26,508	$1,138	$118,504	$143,521	$8,633	$809	3.07	$17,876	$329
TG2_5.3	TWLY.2	$27,926	$26,054	$684	$116,738	$141,382	$8,504	$680	3.06	$17,551	$3
TG2_5.4	NHR.3	$27,655	$26,326	$955	$129,118	$156,376	$9,406	$1,582	2.80	$16,920	-$627
TG2_5.5	**RG.2**	**$26,880**	**$27,101**	**$1,730**	**$121,927**	**$147,666**	**$8,882**	**$1,058**	**3.05**	**$18,219**	**$672**
TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+											
TG2_6.1	GE200.5	$26,731	$27,249	$148	$130,801	$158,415	$9,528	$646	2.86	$17,721	-$498
TG2_6.2	**E200H.2**	**$25,871**	**$28,109**	**$1,008**	**$133,033**	**$161,118**	**$9,691**	**$809**	**2.90**	**$18,418**	**$199**
TG2_6.3	TWLY.2	$26,219	$27,762	$661	$131,267	$158,979	$9,562	$680	2.90	$18,200	-$20
TG2_6.4	NHR.3	$25,967	$28,013	$912	$143,647	$173,972	$10,464	$1,582	2.68	$17,549	-$670
***TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+E200H.2+ (*re-optimization of remaining components)**											
TG2_7.1	**GE200.0**	**$24,895**	**$29,085**	**$334**	**$134,503**	**$162,897**	**$9,798**	**$107**	**2.97**	**$19,287**	**$227**
TG2_7.2	GE200.2	$25,183	$28,798	$47	$140,478	$170,135	$10,233	$542	2.81	$18,565	-$496
TG2_7.3	GE200.5	$24,801	$29,180	$428	$141,908	$171,866	$10,337	$646	2.82	$18,842	-$218
TG2_7.4	GE200.6	$24,566	$29,414	$663	$156,553	$189,603	$11,404	$1,713	2.58	$18,010	-$1,050
TG2_7.5	TWLY.0 (160 ac-ft)	$25,245	$28,735	-$16	$137,018	$165,943	$9,981	$290	2.88	$18,754	-$306
TG2_7.6	TWLY.2 (516 ac-ft)	$24,448	$29,533	$781	$142,374	$172,430	$10,371	$680	2.85	$19,161	$101
TG2_7.7	TWLY.3 (1032 ac-ft)	$23,647	$30,333	$1,582	$155,867	$188,772	$11,354	$1,663	2.67	$18,979	-$81
TG2_7.8	NHR.1 (595 ac-ft)	$25,232	$28,749	-$2	$140,989	$170,753	$10,271	$580	2.80	$18,478	-$582
TG2_7.9	NHR.3 (1069 ac-ft)	$24,262	$29,718	$967	$154,754	$187,424	$11,273	$1,582	2.64	$18,445	-$615
TG2_7.10	NHR.4 (1211 ac-ft)	$24,171	$29,810	$1,059	$179,309	$217,163	$13,062	$3,371	2.28	$16,748	-$2,312
TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+E200H.2+GE200.0+											
TG2_8.1	**TWLY.2**	**$24,063**	**$29,917**	**$832**	**$143,843**	**$174,210**	**$10,478**	**$680**	**2.86**	**$19,439**	**$151**
TG2_8.2	NHR.3	$23,850	$30,131	$1,045	$156,223	$189,203	$11,380	$1,582	2.65	$18,750	-$537

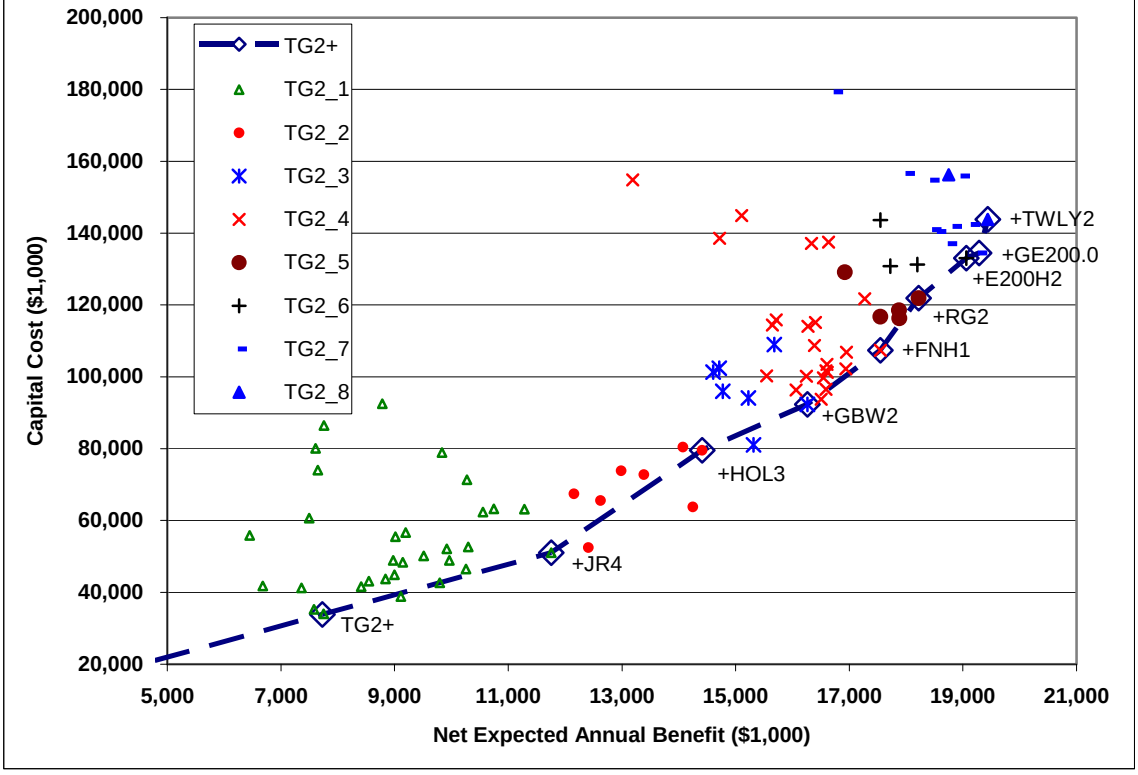
Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

The formulated alternative plan with TG.2 as anchor consists of three channelization components and six detention component as listed below and shown on Exhibit 4-12:

- TG.2 + JR.4 + HOL.3 + GBW.2 + FNH.1 + RG.2 + E200H.2 + GE200.0 + TWLY.2.

The formulated alternative has EA benefits of $29.9 million at a capital cost of approximately $144 million. The plan has net EA benefits of $19.4 million.

Figure 4-7. Progression of TG2 Anchor Plan Formulation



4.9.3 Detention Anchors FNH.3 + JR.4

From Section 4.8, the components that form the basis for further evaluation of this alternative plan are detention components FNH.3 + JR4 + GBW.3. To this plan were added components incrementally through three iterations of alternative models developed in a sequential fashion. One iteration was used to re-optimize the unselected components.

The results of the alternative formulated with FNH.3+JR.4 as anchor are presented in Table 4-19. The results for the runs with FNH.3+JR.4 and FNH.3+JR.4+GBW.3 are also presented for ease of comparison. Figure 4-8 graphically displays the progression steps. The figure shows the performance of the components as they were evaluated at each individual step.

The formulated alternative plan with FNH.3+JR.4 as anchor consists of five detention components and one channelization component as listed below and shown on Exhibit 4-13:

- FNH.3 + JR.4 + GBW.3 + HOL.3 + GE200.2 + RG.1.

The formulated alternative has EA benefits of $24.3 million at a capital cost of approximately $127 million. The plan has net EA benefits of $15.1 million.

Figure 4-8. Progression of Detention Anchor Plan Formulation

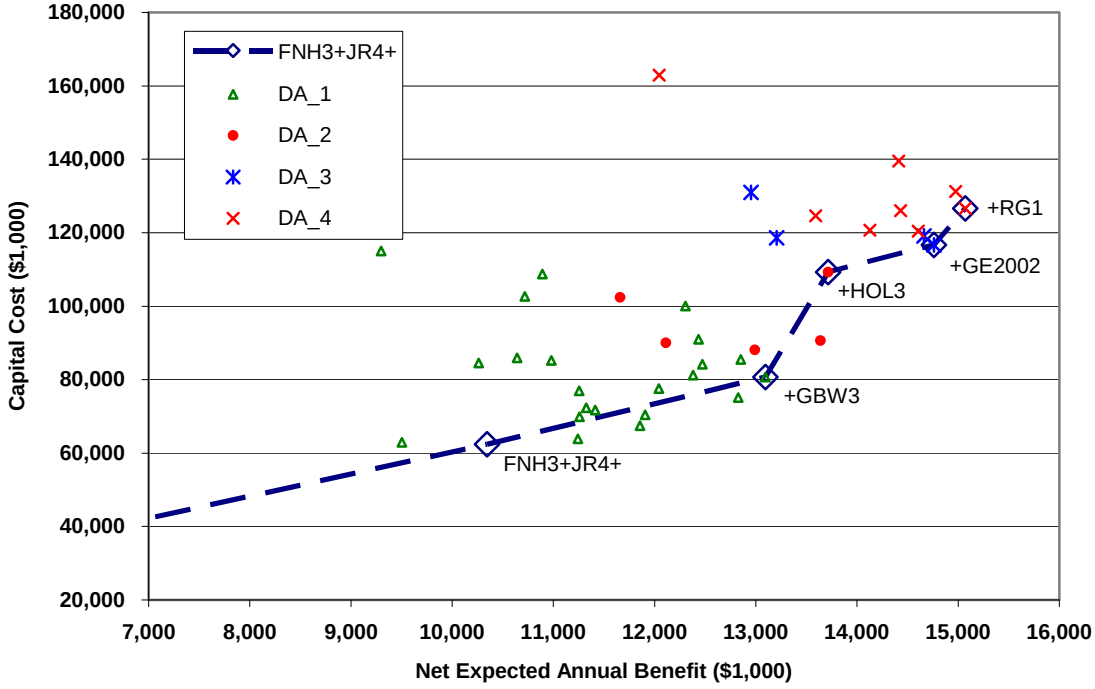


Table 4-19 Incremental Addition of Components with Anchor FNH.3+JR.4

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,981									
DA_1	FNH.3+JR.4	$39,090	$14,891	$14,891	$62,435	$75,616	$4,548		3.27	$10,343	
DA_1.18	FNH.3+JR.4+GBW.3	$35,007	$18,974	$4,083	$80,706	$97,744	$5,879	$1,331	3.23	$13,095	$2,752
FNH.3+JR.4+GBW.3+											
DA_2.1	GE200.2	$34,570	$19,411	$974	$88,152	$106,761	$6,422	$542	3.02	$12,990	$432
DA_2.2	TWLY.2	$35,308	$18,673	$236	$90,047	$109,057	$6,560	$680	2.85	$12,113	-$445
DA_2.3	NHR.3	$34,858	$19,123	$686	$102,427	$124,050	$7,461	$1,582	2.56	$11,661	-$897
DA_2.4	**HOL.3**	**$32,309**	**$21,672**	**$3,235**	**$109,240**	**$132,301**	**$7,958**	**$2,079**	**2.72**	**$13,714**	**$1,156**
DA_2.5	RG.1	$33,741	$20,240	$1,803	$90,606	$109,734	$6,600	$721	3.07	$13,639	$1,081
FNH.3+JR.4+GBW.3+HOL.3+											
DA_3.1	**GE200.2**	**$30,721**	**$23,260**	**$1,588**	**$116,685**	**$141,318**	**$8,500**	**$542**	**2.74**	**$14,760**	**$1,046**
DA_3.2	TWLY.2	$32,138	$21,843	$171	$118,580	$143,614	$8,638	$680	2.53	$13,205	-$509
DA_3.3	NHR.3	$31,489	$22,492	$820	$130,960	$158,607	$9,540	$1,582	2.36	$12,952	-$762
DA_3.4	RG.1	$30,638	$23,343	$1,671	$119,140	$144,291	$8,679	$721	2.69	$14,664	$950
***FNH.3+JR.4+GBW.3+HOL.3+GE200.2 (*re-optimization of remaining components)**											
DA_4.1	TWLY.0 (160 ac-ft)	$31,061	$22,919	-$340	$120,669	$146,144	$8,790	$290	2.61	$14,129	-$631
DA_4.2	TWLY.2 (516 ac-ft)	$30,368	$23,612	$352	$126,025	$152,631	$9,180	$680	2.57	$14,432	-$328
DA_4.3	TWLY.3 (1032 ac-ft)	$29,405	$24,576	$1,316	$139,519	$168,973	$10,163	$1,663	2.42	$14,413	-$347
DA_4.4	NHR.1 (595 ac-ft)	$31,310	$22,671	-$589	$124,641	$150,954	$9,080	$580	2.50	$13,591	-$1,169
DA_4.5	NHR.3 (1069 ac-ft)	$30,172	$23,809	$549	$138,405	$167,624	$10,082	$1,582	2.36	$13,727	-$1,033
DA_4.6	NHR.4 (1211 ac-ft)	$30,064	$23,916	$657	$162,961	$197,363	$11,871	$3,371	2.01	$12,045	-$2,714
DA_4.7	RG.0 (100 ac-ft)	$30,604	$23,377	$117	$120,396	$145,813	$8,770	$270	2.67	$14,606	-$153
DA_4.8	**RG.1 (277 ac-ft)**	**$29,689**	**$24,292**	**$1,032**	**$126,585**	**$153,308**	**$9,221**	**$721**	**2.63**	**$15,071**	**$311**
DA_4.9	RG.2 (399 ac-ft)	$29,447	$24,533	$1,274	$131,214	$158,915	$9,558	$1,058	2.57	$14,975	$215

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

4.10 Step 6 - Final Optimization

The formulated alternative plans presented in Section 4.9 underwent a final optimization to check that each component was still providing positive net benefits to the formulated plan and to check that the optimum size had been selected for each component. The two final optimization steps were:

1. Last-added analysis of each component.
2. Re-optimization and review of each component.

The following subsections present a summary of the final optimization results.

4.10.1 Last-added Analysis

The last-added analysis of each component considered the individual effect of each isolated component in comparison to the net economic benefits of the formulated plan with all the components in place. The last-added analysis was carried out in the order in which the components were added to the plan, beginning with the anchor or best-performing component. For each component to be economically feasible, the net benefits without the last-added component should be less than the net benefits with all the components in the formulated plan.

4.10.1.1 Anchor TG.8

As mentioned in Section 4.9.1, the formulated alternative plan with TG.8 as anchor consists of the following components:

- TG.8, JR.4, GBW.2, E200H.3, TWLY.3, FNH.1, GE200.0, NSB_20%, NHR.1, and RG.0.

With the formulated TG.8 plan as the starting point, nine last-added runs were performed. The results of the last-added analysis are presented in Table 4-20, with the formulated TG.8 plan presented on the first row to provide a comparison to the last-added runs. The table shows EA damages, EA benefits, capital costs, base year equivalent costs, EA costs, and net EA benefits. Columns are also provided that show the contributed incremental EA benefits, EA costs, and net EA benefits of the last-added component as compared to the formulated plan. Each last-added analysis resulted in a decrease in net EA benefits, showing that all the components still warranted inclusion in the plan.

Table 4-20 Anchor TG.8 Last-Added Analysis

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Formulated Plan: TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+GE200.0+NSB_20%+NHR.1+RG.0										
TG8_9.2	Formulated Plan	$18,465	$35,515		$177,024	$214,395	$12,896		$22,620	
TG8_LA1	Remove TG.8	$32,846	$21,135	$14,381	$105,715	$128,032	$7,701	$5,195	$13,434	$9,186
TG8_LA2	Remove JR.4	$20,435	$33,546	$1,969	$159,776	$193,507	$11,639	$1,256	$21,907	$713
TG8_LA3	Remove GBW.2	$19,641	$34,339	$1,176	$164,282	$198,964	$11,967	$928	$22,372	$248
TG8_LA4	Remove E200H.3	$20,642	$33,339	$2,176	$160,648	$194,562	$11,703	$1,193	$21,636	$984
TG8_LA5	Remove TWLY.3	$21,659	$32,322	$3,194	$154,189	$186,740	$11,232	$1,663	$21,090	$1,530
TG8_LA6	Remove FNH.1	$19,907	$34,074	$1,442	$161,928	$196,112	$11,796	$1,100	$22,278	$342
TG8_LA7	Remove GE200.0	$19,220	$34,761	$754	$175,554	$212,615	$12,788	$107	$21,973	$647
TG8_LA8	Remove NSB-20%	$19,434	$34,547	$969	$168,739	$204,362	$12,292	$603	$22,255	$365
TG8_LA9	Remove NHR.1	$19,152	$34,829	$686	$169,068	$204,760	$12,316	$580	$22,513	$107
TG8_LA10	Remove RG.0	$18,758	$35,223	$293	$173,313	$209,900	$12,625	$270	$22,597	$22

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

4.10.1.2 Anchor TG.2

As mentioned in Section 4.9.2, the formulated alternative plan with TG.2 as anchor consists of the following components:

- TG.2, JR.4, HOL.3, GBW.2, FNH.1, RG.2, E200H.2, GE200.0, and TWLY.2.

With the formulated TG.2 plan as the starting point, eight last-added runs were performed. The results of the last-added analysis are presented in Table 4-21, with the formulated TG.2 plan presented on the first row to provide a comparison to the last-added runs. Each last-added analysis resulted in a decrease in net EA benefits, showing that all the components still warranted inclusion in the plan.

4.10.1.3 Detention Anchors FNH.3+JR.4

As mentioned in Section 4.9.3, the formulated alternative plan with anchor FNH.3+JR.4 consists of the following components:

- FNH.3, JR.4, GBW.3, HOL.3, GE200.2, and RG.1.

With the formulated plan as the starting point, five last-added runs were performed. The results of the last-added analysis are presented in Table 4-22, with the formulated plan presented on the first row to provide a comparison to the last-added runs. Each last-added analysis resulted in a decrease in net EA benefits, showing that all the components still warranted inclusion in the plan.

4.10.1.4 Comparison of Plans

The results of the last-added analysis indicate that all components of the three formulated alternative plans are economically justified and contribute positive economic benefits to the formulated plan. Figure 4-9 provides a comparison of the three formulated plans. As presented in the figure, the detention anchor alternative (i.e., FNH.3+JR.4) shows significantly lower benefits than either of the channel anchor alternatives. The detention anchor alternative was formulated based upon public interest in a detention plan as an alternative to a channel alternative. This plan produces substantial flood damage reduction; however, the net economic benefits are more than 20 percent lower than the second best performing channel TG.2 alternative and more than 30 percent lower than the TG.8 alternative. Because further re-optimization of the components for the detention anchor

Table 4-21 Anchor TG.2 Last-Added Analysis

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Formulated Plan: TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+E200H.2+GE200.0+TWLY.2										
TG2_8.1	Formulated Plan	$24,063	$29,917		$143,843	$174,210	$10,478		$19,439	
TG2_LA1	Remove TG.2	$32,604	$21,377	$8,540	$110,064	$133,299	$8,018	$2,461	$13,359	$6,080
TG2_LA2	Remove JR.4	$27,633	$26,348	$3,569	$126,596	$153,321	$9,222	$1,256	$17,126	$2,313
TG2_LA3	Remove HOL.3	$27,168	$26,812	$3,105	$115,310	$139,653	$8,400	$2,079	$18,413	$1,026
TG2_LA4	Remove GBW.2	$26,048	$27,933	$1,985	$131,102	$158,779	$9,550	$928	$18,382	$1,057
TG2_LA5	Remove FNH.1	$26,207	$27,774	$2,144	$128,747	$155,927	$9,379	$1,100	$18,395	$1,044
TG2_LA6	Remove RG.2	$25,740	$28,241	$1,677	$129,314	$156,613	$9,420	$1,058	$18,821	$618
TG2_LA7	Remove E200H.2	$25,818	$28,163	$1,754	$132,737	$160,759	$9,669	$809	$18,494	$945
TG2_LA8	Remove GE200.0	$24,448	$29,533	$385	$142,374	$172,430	$10,371	$107	$19,161	$278
TG2_LA9	Remove TWLY.2	$24,895	$29,085	$832	$134,503	$162,897	$9,798	$680	$19,287	$151

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

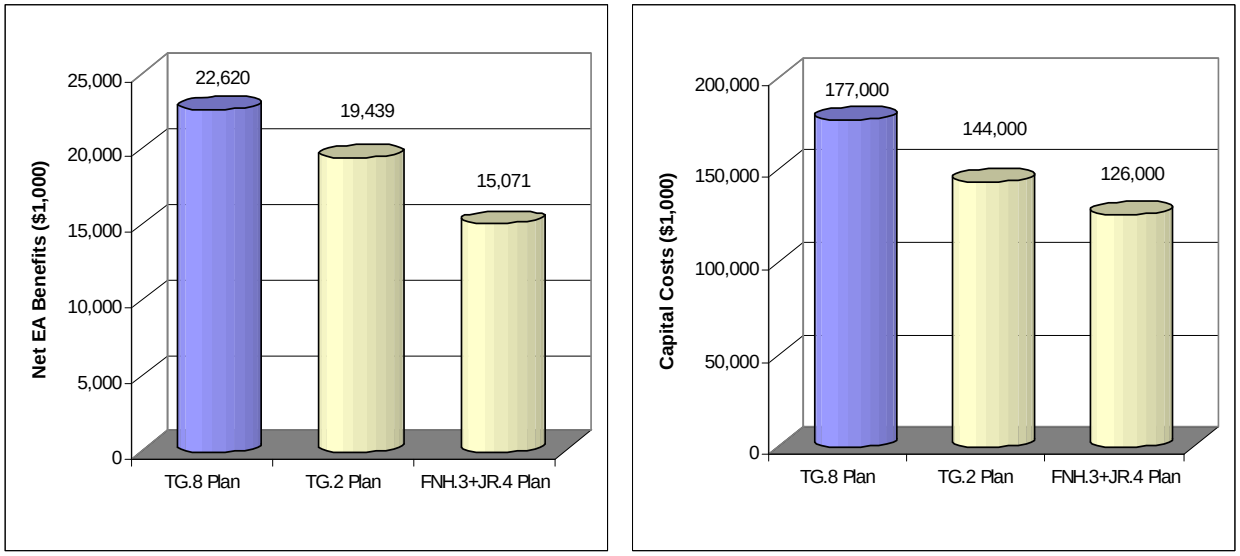
Table 4-22 Anchor FNH.3+JR.4 Last-Added Analysis

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Formulated Plan: FNH.3+JR.4+GBW.3+HOL.3+GE200.2+RG.1										
DA_4.8	Formulated Plan	$29,689	$24,292		$126,585	$153,308	$9,221		$15,071	
DA_LA1	Remove FNH.3	$36,356	$17,625	$6,667	$81,397	$98,581	$5,930	$3,292	$11,696	$3,375
DA_LA2	Remove JR.4	$33,998	$19,983	$4,309	$109,338	$132,420	$7,965	$1,256	$12,018	$3,053
DA_LA3	Remove GBW.3	$33,040	$20,941	$3,351	$108,314	$131,180	$7,890	$1,331	$13,050	$2,020
DA_LA4	Remove HOL.3	$32,977	$21,004	$3,288	$98,052	$118,751	$7,143	$2,079	$13,861	$1,209
DA_LA5	Remove GE200.2	$32,100	$21,881	$2,411	$119,140	$144,291	$8,679	$542	$13,202	$1,869
DA_LA6	Remove RG.1	$30,721	$23,260	$1,032	$116,685	$141,318	$8,500	$721	$14,760	$311

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

plan was unlikely to result in net benefits that exceed either channel anchor alternative, the detention anchor alternative was not considered for further re-optimization. Only the formulated plans with TG.8 and TG.2 as anchors were carried forward for further re-optimization in the next step of the final optimization.

Figure 4-9. Comparison of Formulated Plans



4.10.2 Re-optimization

To determine that the size of each component was still the optimum size, within reasonable limits, each component was individually re-optimized. A "tighter" range of sizes was considered by reviewing the previous range of sizes used to optimize the component in the formulated plan. For channel components, in addition to optimizing the channel width, where appropriate, the upstream and downstream limits of the channel component were also optimized. The re-optimization was carried out in the order in which the components were added to the plan, beginning with the best performing or anchor component. After the best-performing component was re-optimized, it served as the new anchor from which re-optimization of the second added component was based. The same process of looking at a "tighter" range of the component followed. This process was continued for each component until all components were re-optimized.

This second step of the final optimization is best considered a final fine-tuning of the components of the plan. Further fine-tuning of component sizes was done because of the potential for the combination of plan components to change the performance of the individual components. At the start of this step the project costs and economic structure inventory were reviewed and minor adjustments were made using any updated information. Environmental mitigation costs were updated to reflect a more current estimate of the anticipated mitigation costs based on more detailed environmental field investigations of the components. The HOL detention component was adjusted to reflect a new multi-family residential development on a previously undeveloped tract, and the TWLY.1 detention

component was removed from the plan as it has become mitigation for a separate project on Vogel Creek. In addition, a minor adjustment to the economic structure inventory was made to update the first-floor elevation of a multi-family residential structure based upon a closer evaluation of the ground topography. These adjustments to the costs and the economic inventory generally resulted in insignificant differences in EA damages and net benefits.

4.10.2.1 Anchor TG.8

Prior to beginning the re-optimization of each component, adjustments to the project costs and economic inventory were made to the formulated alternative as discussed above. The environmental mitigation costs for this plan were approximately $15 million. The environmental mitigation costs consist of 750 acres of habitat restoration to compensate for the loss of approximately 107 acres along the channel between Cole Creek and Gessner. The area required was based on the length and width of the concrete lining. The estimated cost per acre of restored area used in the Plan Formulation was $20,000 and was based on the cost of mitigation at an approved mitigation bank. With these adjustments, the alternative formulated with TG.8 as anchor has EA benefits of $35.6 million, capital costs of $204 million, and net EA benefits of $20.7 million. As compared to the results presented in Section 4.9.1, the difference in net benefits is decreased by $1.9 million due largely to increased capital costs of environmental mitigation. This update of the formulated alternative was the basis of comparison for the final re-optimization of components. The following paragraphs describe the re-optimization results that are presented in Table 4-23. It should be noted that the final cost used in Chapter 5 for mitigation associated with the selected plan is based on a more detailed mitigation analysis, with mitigation unit costs ranging from approximately $24,000 to $40,000 per acre, depending upon the type and location of wetland mitigation.

The re-optimization of components began by optimizing the upstream and downstream limits of the proposed channel modification project. The original limits of channel modification are Eldridge Road (~station 125000) at the upstream end of component E200H.3 and Tidwell Road (~station 56231) at the downstream end of component TG.8. To optimize the upstream limit, two re-optimization runs were completed with limits at FM 1960 (~station122500) and at Jones Road (~station 116459). These re-optimizations of component E200H.3 are designated E200H.3A and E200H.3B, respectively. A shorter channelization reach as opposed to a longer reach was evaluated based on the economic damages from the FDA model (see Exhibit 5-11) that showed insignificant flood damages upstream of Eldridge Road (~station 125000). A larger channel width was not considered because it would require right-of-way acquisition, and previous analysis indicated a larger size produced smaller net benefits. Similarly, a smaller channel size was not evaluated because the previous analysis indicated smaller net benefits.

As shown in Table 4-23, the plan with component E200H.3A (i.e., upstream channelization limit at FM 1960) provided an increase in net EA benefits of $181,000 over the formulated alternative plan. Smaller net benefits were obtained for component E200H.3B, the option that considers a shortened channelization reach. The re-optimized alternative plan has EA benefits of $35.5 million, capital costs of $201 million, and net EA benefits of $20.9 million. The overall plan capital cost was reduced by approximately $3 million. This plan (TG8-RF1) served as the anchor plan for comparison of further re-optimization of the remaining components.

The limits of the channel anchor TG.8 were next evaluated. The downstream limits of channel modification coincide with the upstream limits of the existing Federal channel project. Based on previous formulation iterations, which showed that lower reach improvements are not effective at reducing flood damage, the downstream limit of the channel modification was established at Tidwell Road and no further runs were considered within the limits of the existing Federal channel. The upstream limits of the concrete-lined channel TG.8 are at Gessner Road (~station 93534). To optimize the upper limits of TG.8, two re-optimization runs were completed with the upper limits of the concrete-lined channel terminating at Fairbanks-North Houston (~station 86621) and at tributary E122-00-00 (~station 77447). An earthen channel section with a 50-to 60-foot bottom width upstream of the concrete-lined section was used to extend the modifications to Gessner Road. These re-optimizations of TG.8 were designated TG.8A and TG.8B, respectively. As shown in Table 4-23, neither of these runs produced an increase in net benefits.

Table 4-23 Final Optimization of TG.8 Anchor Plan

ID	Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,430									
Formulated Plan: TG.8+JR.4+GBW.2+E200H.3+TWLY.3+FNH.1+GE200.0+NSB_20%+NHR.1+RG.0											
TG8_9.2	Formulated Plan	$17,872	$35,558		$203,700	$246,704	$14,839		2.40	$20,719	
Optimize Upstream Limits of E200H.3											
TG8-RF1	**E200H.3A**	**$17,922**	**$35,508**	**-$50**	**$200,537**	**$242,872**	**$14,608**	**-$230**	**2.43**	**$20,900**	**$181**
TG8-RF2	E200H.3B	$18,826	$34,604	-$954	$196,661	$238,178	$14,326	-$513	2.42	$20,278	-$441
Optimize Upstream Limits of TG.8											
TG8-RF3	TG.8A	$19,697	$33,732	-$1,776	$187,949	$227,627	$13,691	-$917	2.46	$20,041	-$859
TG8-RF4	TG.8B	$21,364	$32,066	-$3,443	$166,279	$201,382	$12,113	-$2,496	2.65	$19,953	-$947
Optimize Detention JR.4 (420 ac-ft)											
TG8-RF5	JR.3 (295 ac-ft)	$18,444	$34,986	-$522	$195,726	$237,046	$14,258	-$350	2.45	$20,728	-$172
TG8-RF6	JR.5 (470 ac-ft)	$17,890	$35,540	$32	$212,668	$257,564	$15,492	$884	2.29	$20,048	-$852
Optimize Detention GBW.2 (427 ac-ft)											
TG8-RF7	**GBW.1 (229 ac-ft)**	**$18,460**	**$34,970**	**-$538**	**$192,823**	**$233,530**	**$14,046**	**-$562**	**2.49**	**$20,924**	**$24**
TG8-RF8	GBW.3 (519 ac-ft)	$17,903	$35,526	$18	$206,066	$249,569	$15,011	$403	2.37	$20,515	-$384
TG8-RF9	Remove GBW.2	$19,094	$34,335	-$1,173	$186,029	$225,301	$13,552	-$1,057	2.53	$20,784	-$116
Optimize Detention TWLY.3 (1032 ac-ft)											
TG8-RF10	TWLY.2.5 (774 ac-ft)	$18,885	$34,545	-$425	$187,136	$226,643	$13,632	-$414	2.53	$20,913	-$11
TG8-RF11	TWLY.3.5 (1290 ac-ft)	$18,217	$35,213	$243	$198,510	$240,418	$14,461	$414	2.44	$20,752	-$172
Optimize Detention FNH.1 (843 ac-ft)											
TG8-RF12	FNH.0 (360 ac-ft)	$19,491	$33,939	-$1,031	$181,943	$220,354	$13,254	-$793	2.56	$20,685	-$239
TG8-RF13	FNH.2 (1271 ac-ft)	$17,985	$35,445	$475	$207,128	$250,855	$15,089	$1,042	2.35	$20,356	-$567
Optimize Channel GE200.0											
TG8-RF14	GE200.2	$18,285	$35,145	$175	$198,765	$240,726	$14,479	$433	2.43	$20,666	-$258
TG8-RF15	GE200.5	$18,496	$34,934	-$36	$200,202	$242,467	$14,584	$538	2.40	$20,350	-$574
Optimize Detention NHR.1 (595 ac-ft)											
TG8-RF16	NHR.0 (360 ac-ft)	$19,138	$34,291	-$679	$187,889	$227,554	$13,687	-$359	2.51	$20,604	-$319
TG8-RF17	NHR.2 (811 ac-ft)	$18,191	$35,239	$269	$199,373	$241,462	$14,524	$477	2.43	$20,715	-$208

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-23 Final Optimization of TG.8 Anchor Plan (continued)

ID	Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Optimize Detention RG.0 (100 ac-ft)											
TG8-RF18	RG.1 (277 ac-ft)	$18,016	$35,413	$443	$198,991	$241,000	$14,496	$449	2.44	$20,917	-$6
TG8-RF19	Remove RG.0	$19,059	$34,370	-$600	$189,125	$229,051	$13,777	-$269	2.49	$20,593	-$330
Optimize Detention TW.3 (1032 ac-ft)											
TG8-RF20	- TWLY.3B	$20,618	$32,812	-$2,158	$178,782	$216,524	$13,024	-$1,023	2.52	$19,788	-$1,136
TG8-RF21	- TWLY.3C	$20,582	$32,847	-$2,123	$179,502	$217,396	$13,076	-$970	2.51	$19,771	-$1,152
TG8-RF22	- TWLY.3D	$20,567	$32,863	-$2,107	$180,189	$218,228	$13,126	-$920	2.50	$19,736	-$1,187
Optimize Non-structural Components											
TG8-RF23	**- NSB_20% + 1 Buyout**	**$18,778**	**$34,652**	**-$318**	**$187,747**	**$227,382**	**$13,677**	**-$370**	**2.53**	**$20,975**	**$52**
Remove GE200.0 and replace with GE200.7											
TG8-RF24	**GE200.7**	**$19,464**	**$33,966**	**-$686**	**$189,478**	**$229,478**	**$13,803**	**$126**	**2.46**	**$20,163**	**-$812**
Remove TWLY Detention Basin											
TG8-RF25	**Remove TWLY.3**	**$22,679**	**$30,751**	**-$3,215**	**$166,729**	**$201,928**	**$12,146**	**-$1,657**	**2.53**	**$18,605**	**-$1,558**

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Component GE200 was next optimized to complete the re-optimization of all channel modification components, before re-optimizing the detention components. Two options that included the bypass channel were evaluated. Option GE200.2 considered the bypass channel and no channelization within the main channel, while option GE200.5 evaluated the combination of channel modifications within the main stem and the bypass channel. Neither option provided an increase in net benefits.

The re-optimization of detention components considered a “tighter” range of sizes. Component JR was the first detention component to be evaluated. Larger and smaller sizes than option JR.4 were considered. Neither option provided an increase in net benefits. In considering larger and smaller sizes for detention components, consideration was given to the available land. Detention basin sizes were established so that whole parcels could be utilized where possible and partial takings would not be necessary. Component GBW was next re-optimized by evaluating a larger and a smaller size than option GBW.2 (427 acre-feet). Option GBW.1 (229 acre-feet) produced an increase in net EA benefits of $24,000. A third run was considered by removing component GBW to confirm that option GBW.1 is the optimized size. With option GBW.1 as the optimized size, the re-optimized alternative plan has EA benefits of $35.0 million, capital costs of $193 million, and net EA benefits of $20.9 million. The capital cost was reduced by $8 million. This plan (TG8-RF7) served as the anchor plan for comparison of further optimization of the remaining components.

For the next detention component TWLY, a narrower range of storage volume was evaluated based on approximately 75 percent and 125 percent of the TWLY.3 (1,032 acre-feet) storage volume. Neither of these options produced an increase in net benefits.

Two additional options of detention component FNH were then considered for further re-optimization. Again, neither option provided an increase in net benefits. Similarly, further re-optimization of detention component NHR did not result in increased net benefits. Component RG was the final detention component to be re-optimized. Option RG.1, a larger size than RG.0, did not produce an increase in net benefits. A second run was considered by removing component RG to confirm that option RG.0 is the optimized size. This run also resulted in a decrease in net benefits.

Following the re-optimization of structural components, a final re-optimization of the non-structural components (permanent relocation/buyout and elevating structures) was performed. A parcel-by-parcel evaluation was performed to identify the most efficient non-structural component that would provide increased flood protection and maximum economic benefits. Structures located downstream of IH-610 were not included in the evaluation because this area will be evaluated as part of the Buffalo Bayou study that is currently being pursued by the HCFCD.

One property was identified for permanent relocation and no properties were identified for raising. With this non-structural component, net EA benefits are increased by $52,000. The re-optimized alternative plan (TG8-RF23) has EA benefits of $34.7 million, capital costs of $188 million, and net EA benefits of $21.0 million. The re-optimized plan components are:

- E200H.3A: upstream channel terminating at FM 1960
- GBW.1: detention component providing 229 acre-feet storage volume
- NSB_1: permanent relocation of 1 structure within residual 20 percent floodplain.

Geotechnical investigations identified slope stability concerns with GE200.0. Gabion structures will have to be added to portions of GE200.0. A model run was prepared with the revised channel section (GE200.7). The revised, re-optimized alternative plan (TG8-RF24) has EA benefits of $34.0 million, capital costs of $190 million, and net EA benefits of $20.2 million.

Finally, the decision to drop the TWLY detention basin was made based on the discovery of hazardous material on the site. The revised, re-optimized alternative plan (TG8-RF25) has EA benefits of $30.8 million, capital costs of $167 million, and net EA benefits of $18.6 million.

4.10.2.2 Anchor TG.2

A similar re-optimization procedure was performed for TG.2 as was performed for TG.8. The following paragraphs describe the results.

Similar to the TG.8 plan, minor adjustments to the project costs and economic inventory were made to the formulated TG.2 alternative prior to beginning the re-optimization of each component. With these adjustments, the alternative formulated with TG.2 as anchor has EA benefits of $29.8 million, capital costs of $143 million, and net EA benefits of $19.4 million. The net benefits decreased by $0.1 million, a difference of less than 0.5 percent, as compared to the results presented in Section 4.9.2.

During the course of the study, recent construction of a multi-family residential complex on a previously undeveloped tract designated for use as component HOL.3 has occurred, increasing the capital costs by more than $26 million and decreasing the net EA benefits by $1.9 million. This component is now less favorable because of the displacement of residents and the increased acquisition cost. A smaller size, HOL.2, was evaluated as an alternative to HOL.3. Option HOL.2 resulted in an increase in net benefits of $1.8 million. HOL.2 replaced HOL.3 in the formulated alternative plan. This plan has EA benefits of $29.1 million, capital costs of $135 million, and net EA benefits of $19.2 million. The overall plan capital costs were reduced by approximately $34 million from the formulated plan (TG2_8.1 with the updated HOL.3 costs). The following paragraphs describe the re-optimization results, which are presented in Table 4-24.

Table 4-24 Final Optimization of TG.2 Anchor Plan

ID	Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Base Without Project Conditions		$53,430									
Formulated Plan: TG.2+JR.4+HOL.3+GBW.2+FNH.1+RG.2+E200H.2+GE200.0+TWLY.2											
TG2_8.1	Formulated Plan	$23,604	$29,825		$143,352	$173,615	$10,443			$19,383	
TG2_8.1	**Update HOL.3 cost**	**$23,604**	**$29,825**		**$169,591**	**$205,393**	**$12,354**	**$1,911**	**2.41**	**$17,471**	**-$1,911**
Optimize Detention HOL.3 (730 ac-ft)											
TG2-RF1	**HOL.2 (522 ac-ft)**	**$24,325**	**$29,104**	**-$721**	**$135,405**	**$163,990**	**$9,864**	**-$2,490**	**2.95**	**$19,240**	**$1,769**
Optimize Upstream Limits of E200H.2											
TG2-RF2	**E200H.2A**	**$24,314**	**$29,115**	**$11**	**$133,135**	**$161,241**	**$9,698**	**-$165**	**3.00**	**$19,417**	**$177**
TG2-RF3	E200H.2B	$25,019	$28,411	-$693	$131,562	$159,335	$9,584	-$280	2.96	$18,827	-$413
Optimize Upstream Limits of TG.2											
TG2-RF4	**TG.2A**	**$24,793**	**$28,637**	**-$479**	**$124,634**	**$150,945**	**$9,079**	**-$619**	**3.15**	**$19,557**	**$140**
TG2-RF5	TG.2B	$30,079	$23,351	-$5,765	$119,518	$144,750	$8,706	-$992	2.68	$14,644	-$4,773
TG2-RF6	TG.2C	$33,526	$19,903	-$9,212	$105,606	$127,900	$7,693	-$2,005	2.59	$12,210	-$7,207
Optimize Detention JR.4 (420 ac-ft)											
TG2-RF7	JR.3 (295 ac-ft)	$25,872	$27,557	-$1,079	$119,823	$145,119	$8,729	-$350	3.16	$18,829	-$729
TG2-RF8	JR.5 (470 ac-ft)	$24,324	$29,106	$469	$136,765	$165,637	$9,963	$884	2.92	$19,143	-$414
Optimize Detention HOL.2 (522 ac-ft)											
TG2-RF9	HOL.1 (444 ac-ft)	$25,805	$27,624	-$1,012	$120,836	$146,346	$8,802	-$277	3.14	$18,822	-$736
TG2-RF10	HOL.3 (730 ac-ft)	$24,222	$29,208	$571	$158,820	$192,349	$11,569	$2,490	2.52	$17,638	-$1,919
Optimize Detention GBW.2 (427 ac-ft)											
TG2-RF11	**GBW.3 (519 ac-ft)**	**$24,098**	**$29,332**	**$695**	**$130,163**	**$157,642**	**$9,482**	**$403**	**3.09**	**$19,850**	**$292**
TG2-RF12	GBW.4 (618 ac-ft)	$23,314	$30,116	$1,479	$145,379	$176,070	$10,590	$1,511	2.84	$19,526	-$32
Optimize Detention FNH.1 (843 ac-ft)											
TG2-RF13	FNH.0 (360 ac-ft)	$25,566	$27,864	-$1,468	$119,283	$144,465	$8,689	-$793	3.21	$19,175	-$675
TG2-RF14	FNH.2 (1271 ac-ft)	$22,030	$31,400	$2,068	$144,468	$174,966	$10,524	$1,042	2.98	$20,876	$1,026
TG2-RF15	**FNH.3 (1717 ac-ft)**	**$20,065**	**$33,364**	**$4,033**	**$160,288**	**$193,982**	**$11,676**	**$2,195**	**2.86**	**$21,688**	**$1,838**
TG2-RF16	FNH.4 (2111 ac-ft)	$20,035	$33,394	$4,063	$173,711	$210,383	$12,654	$3,172	2.64	$20,740	$890

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Table 4-24 (continued)

ID	Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
Optimize Detention RG.2 (399 ac-ft)											
TG2-RF17	**RG.1 (277 ac-ft)**	**$20,383**	**$33,047**	**-$317**	**$155,673**	**$188,537**	**$11,340**	**-$336**	**2.91**	**$21,707**	**$19**
TG2-RF18	RG.3 (882 ac-ft)	$19,394	$34,035	$671	$190,582	$230,816	$13,883	$2,207	2.45	$20,152	-$1,536
TG2-RF19	RG.0 (100 ac-ft)	$21,225	$32,205	-$1,159	$149,506	$181,068	$10,891	-$785	2.96	$21,314	-$374
Removing Detention TWLY.2 (516 ac-ft)											
TG2-RF20	Remove TWLY.2	$21,167	$32,263	-$784	$146,367	$177,267	$10,662	-$678	3.03	$21,600	-$107
Updating Channel Component GE200											
TG2-RF21	Remove GE200.0	$22,639	$30,790	-$1,472	$144,890	$175,477	$10,555	-$108	2.92	$20,236	-$1,365
TG2-RF22	**Add GE200.7**	**$21,653**	**$31,777**	**$986**	**$146,507**	**$177,436**	**$10,672**	**$118**	**2.98**	**$21,104**	**$869**
Optimize Non-structural Components											
TG2-RF23	**1 Buyout**	**$21,153**	**$32,277**	**$500**	**$149,715**	**$181,321**	**$10,906**	**$234**	**2.96**	**$21,370**	**$266**
Optimized Plan: TG.2+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+Buyout 1											
Last Added Analysis											
TG2-RF23-LA1	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+GE200.7+NSB_1+ELEV_1	$22,900	$30,529	-$1,747	$140,874	$170,614	$10,262	-$644	2.97	$20,267	-$1,103
TG2-RF23-LA2	TG.2A+JR.4+HOL.2+GBW.3+RG.1+E200H.2A+GE200.7+NSB_1+ELEV_1	$27,180	$26,249	-$6,027	$104,491	$126,550	$7,612	-$3,294	3.45	$18,637	-$2,733
TG2-RF23-LA3	TG.2A+JR.4+HOL.2+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1+ELEV_1	$23,035	$30,394	-$1,882	$129,677	$157,053	$9,447	-$1,460	3.22	$20,948	-$423
TG2-RF23-LA4	TG.2A+JR.4+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1+ELEV_1	$23,128	$30,302	-$1,975	$130,868	$158,495	$9,533	-$1,373	3.18	$20,769	-$602
TG2-RF23-LA5	TG.2A+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1+ELEV_1	$24,439	$23,990	-$3,286	$132,521	$160,498	$9,654	-$1,252	3.00	$19,337	-$2,034

Table 4-24 (continued)

ID	Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG2-RF23-LA6	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+E200H.2A+GE200.7+NSB_1+ELEV_1	$22,217	$31,213	-$1,063	$139,849	$169,372	$10,187	-$719	3.06	$21,026	-$345
TG2-RF23-LA7	JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB_1+ELEV_1	$26,403	$27,027	-$5,250	$124,833	$151,187	$9,094	-$1,813	2.97	$17,933	-$3,437
TG2-RF23-LA8	TG.2A+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+NSB_1+ELEV_1	$22,115	$31,315	-$962	$148,098	$179,363	$10,788	-$118	2.9	$20,526	-$844
Additional Component Analysis											
TG2-RF24	TG.2A1+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,491	$33,938	$1,662	$175,444	$212,482	$12,780	$1,874	2.66	$21,158	-$212
TG2-RF25	**TG.2A3+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1**	**$19,267**	**$34,162**	**$1,886**	**$175,000**	**$211,945**	**$12,748**	**$1,842**	**2.68**	**$21,414**	**$44**
Last Added Analysis											
TG2-RF25-LA1	TG.2A3+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$22,504	$30,926	-$1,351	$168,456	$204,018	$12,271	$1,365	2.52	$18,654	-$260
TG2-RF25-LA2	TG.2A3+JR.4+HOL.2+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$20,068	$33,361	$1,085	$162,049	$196,259	$11,805	$899	2.83	$21,557	$143
TG2-RF25-LA3	TG.2A3+JR.4+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1+LLP03	$23,088	$30,342	-$1,935	$143,202	$173,433	$10,432	-$474	2.91	$19,910	-$1,504

Table 4-24 (continued)

ID	Option	EA Damages ($1,000)	EA Benefit ($1,000)	Incr. EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Incr. EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Incr. Net EA Benefits ($1,000)
TG2-RF25-LA4	TG.2A+JR.4+HOL.5+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$21,139	$32,291	$14	$169,211	$204,933	$12,326	$1,420	2.62	$19,965	-$1,449
Hollister Optimization (compare to TG2-RF25)											
TG2-RF26	TG.2A3+JR.4+HOL.1+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$21,219	$32,210	-$66	$158,251	$191,659	$11,528	$622	2.79	$20,682	-$732
TG2-RF27	TG.2A3+JR.4+HOL.3+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,619	$33,810	$1,534	$171,740	$207,996	$12,511	$1,604	2.70	$21,300	-$114
TG2-RF28	TG.2A3+JR.4+HOL.3B+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1	$19,575	$33,855	$1,579	$166,503	$201,653	$12,129	$1,223	2.79	$21,726	$312
TG2-RF29	**TG.2A1+JR.4+HOL.3B+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7A+NSB_1**	**$19,372**	**$34,058**	**$1,782**	**$166,946**	**$202,190**	**$12,161**	**$1,255**	**2.80**	**$21,897**	**$483**

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) EA – Expected Annual
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

Similar to the re-optimization runs for the plan formulated with TG.8 as anchor, the re-optimization began by optimizing the upstream and downstream limits of the proposed channel modifications. The limits of the channel modifications were also from Eldridge Road at the upstream end and to Tidwell Road at the downstream end. Following a similar approach as described in the previous section, two re-optimization runs were performed to evaluate the upstream limits of component E200H.2. As shown in Table 4-24, the plan with component E200H.2A (i.e., upstream channel modifications limit at FM 1960) provided an increase in net EA benefits of $177,000 over the formulated alternative plan. Smaller net benefits were obtained for component E200H.2B, the option that considered a shortened channel reach stopping at Jones Road. Capital costs were reduced by $2.5 million over the previous plan (TG2_RF1). The re-optimized plan (TG2-RF2) stopping at FM 1960 has EA benefits of $29.1 million, capital costs of $133 million, and net EA benefits of $19.4 million. This plan served as the anchor plan for comparison of further optimization of the remaining components.

The limits of the channel anchor TG.2 were next evaluated. As previously discussed, the downstream limit of the channel modification was established at Tidwell Road. Three re-optimization runs were performed to investigate the upstream limits of TG.2. This was accomplished by considering the upstream limits of the channel terminating at Fairbanks-North Houston (~station 86621), tributary E122-00-00 (~station 77447), and Vogel Creek (~station 65422). These re-optimizations of TG.2 are designated TG.2A, TG.2B, and TG.2C, respectively. As shown in Table 4-24, option TG.2A (i.e., upstream channelization limit at Fairbanks-North Houston) provided an increase in net EA benefits of $140,000 over the anchor plan (i.e., TG2-RF2). The re-optimized alternative plan has EA benefits of $28.6 million, capital costs of $125 million, and net EA benefits of $19.6 million. Capital costs are reduced by $10.3 million. This plan (TG2-RF4) served as the anchor plan for comparison of further optimization of the remaining components.

The remaining channel component, GE200, which extends from Gessner to E200-00-00, provides conveyance through a combination of modifications to one or both the main channel and the bypass channel. Component GE200 was not re-evaluated for several reasons. First, the upstream limit of GE200 was not extended because it coincides with the downstream limit of channel E200H. Second, the downstream limit of GE200 was not lengthened because the re-optimization of TG.2 showed a decrease in net benefits with a longer channel segment terminating at Gessner Road rather than a shorter segment ending at Fairbanks-North Houston. Similarly, modifying the bypass reach limits would eliminate its function as a bypass. Furthermore, alternate sizes of the bypass and the main channel were not evaluated because previous analyses demonstrated a reduction in net benefits for both.

The re-optimization of detention components was next evaluated by considering a “tighter” range of sizes. Component JR was the first detention component to be evaluated. A larger and a smaller size than option JR.4 were considered. Neither option provided an increase in net benefits. A smaller option than component HOL.2 was next evaluated. This analysis did not provide increased net benefits. As previously discussed, a larger option than HOL.2

was not re-evaluated because this would require significant displacements of a newly constructed multi-family residential development, which would obviously reduce net benefits.

The re-optimization of detention component GBW looked at one smaller and two larger sizes than option GBW.2 (427 acre-feet). Option GBW.3 (519 acre-feet) resulted in increased net benefits of $292,000 over the anchor plan (TG2-RF4). The resulting re-optimized plan has EA benefits of $29.3 million, capital costs of $130 million, and net EA benefits of $19.9 million. Capital costs are increased by $5 million. This plan (TG2-RF11) served as the anchor plan for comparison of further optimization of the remaining components.

Component FNH was the next detention component to be re-optimized. One smaller and three larger sizes than option FNH.1 (843 acre-feet) were evaluated. Option FNH.3 (1,717 acre-feet) produced an increase in net benefits of $1.8 million over the anchor plan (TG2-RF11). The re-optimized alternative plan has EA benefits of $33.4 million, capital costs of $160 million, and net EA benefits of $21.7 million. Capital costs increased by $30 million. This plan (TG2-RF15) served as the anchor plan for comparison of further optimization of the remaining components.

Re-optimization of detention component RG considered two smaller and one larger size than option RG.2 (399 acre-feet). Option RG.1 (277 acre-feet) produced increased net benefits of $19,000 over the anchor plan (TG2-RF15). The re-optimized alternative plan has EA benefits of $33.0 million, capital costs of $156 million, and net EA benefits of $21.7 million. Capital costs were reduced by $4 million. This plan (TG2-RF17) served as the anchor plan for comparison of further optimization of the remaining components.

Component TWLY.2 was the last detention component in the formulated plan to be evaluated. (This site is not to be confused with the TWLY.1 component of the TG.8 plan which is located at a separate location altogether.) It was decided at this juncture to remove TWLY.2 from the plan, based on the discovery of hazardous material at the site. Net EA Benefits were reduced by $0.11 million. The re-optimized alternative plan has EA benefits of $32.3 million, capital costs of $146 million, and net EA benefits of $21.6 million. Capital costs were reduced by $10 million. This plan (TG2-RF20) replaced the previous plan. The re-optimized plan components are:

- E200H.2A: upstream limit of channelization terminating at FM 1960
- TG.2A: channelization from Tidwell to Fairbanks-North Houston
- GBW.3: detention component providing 519 acre-feet storage volume
- FNH.3: detention component providing 1,717 acre-feet storage volume
- RG.1: detention component providing 277 acre-feet storage volume

A final evaluation of an additional detention component (NHR) that was not included in the formulated plan was considered; however, this option did not provide an increase in net benefits.

During this analysis, additional geotechnical investigations identified slope stability concerns with TG.2A and GE200.0. Certain portions of TG2.A may require additional excavation on the side slopes and placement of select material between stations 633+00 and 740+00 adding $1.5 million to the capital costs of the component. Gabion structures will have to be added to portions of GE200.0 adding $0.6 million to the capital costs. A model run was prepared with the revised channel section (GE200.7). With this change, net EA benefits decreased by $500,000 (from TG2-RF20). The re-optimized alternative plan (TG2-RF22) has EA benefits of $31.8 million, capital costs of $146 million, and net EA benefits of $21.1 million.

Following the re-optimization of structural components, a final re-optimization of the non-structural components was performed on a parcel-by-parcel basis. One property was identified for permanent relocation. With this non-structural component, net EA benefits are increased by $266,000. The re-optimized alternative plan (TG2-RF23) has EA benefits of $32.3 million, capital costs of $150 million, and net EA benefits of $21.4 million.

Following these steps, it was decided that additional modifications to components TG.2A, GE200.7 and HOL.2 would be evaluated for flood risk management and economic benefits, to identify a potential Locally Preferred Plan (LPP).

Modifications to these components consisted of the following:

(1) TG.2A – the channel cross-section was modified in the reach from Station 77625 near the Hollister (HOL) detention basin to Gessner Road and in an alternative smaller reach length.
(2) GE200.7 – the combined Jersey Village Channel and E141 were added to GE200.7.
(3) HOL.2 – the storage volume was increased within the land area for HOL.2. The increased volume would be added, without additional land acquisition by deepening the basin and providing a permanent pool.

Initially two alternative options were evaluated. These two are described as followed.

(1) TG2-RF24 – the same as TG2-RF23 except:
- TG.2A was changed to TG.2A1, which has a revised cross-section from Station 77625 near the Hollister detention basin up to Station 86621 at Gessner Road.
- GE200.7 was changed to GE200.7A which adds the Jersey Village Channel and the E141 connection to White Oak Bayou.
- HOL.2 was changed to HOL.5, which has a volume of 1,100 acre-feet within the land area of HOL.2.

(2) TG2-RF25 – the same as TG2-RF24 except the revised cross-section for TG2.A extends only from the upstream side of the Fairbanks – North Houston Road Bridge at Station 87025 upstream to Station 86621 at Gessner Road. This component was called TG.2A3.

The results of the analyses are presented in Table 4-24. They show that of these two alternatives, TG2-RF25 has the higher net benefits, $21,414,000. These results were compared to TG2-RF23, and they show that TG2-RF25 generates net benefits approximately $44,000 higher than TG2-RF23.

To check that all the different component changes made to TG2-RF23 as part of TG2-RF25 add net benefits, a last-added analysis of these components was performed. Each of the revised components, TG.2A3, GE200.7A, and HOL.5, were removed as last-added components. In the case of HOL.5, two last-added runs were made, one removing the entire Hollister basin, and the other reducing the volume to the same as HOL.2. The results presented in Table 4-24 show that all the components add net benefits to TG2-RF25. The results for the Hollister basin show that HOL. 2 adds more benefits than HOL.5. These results indicate that the Hollister basin size was not optimized for this set of components. To optimize the size of the basin, additional volumes of the basin were considered, including 444 acre-feet (HOL.1), 730 acre-feet (HOL.3) with additional land acquired, and 730 acre-feet without additional land (HOL.3B). The results in Table 4-24 show that TG2-RF28, which has the HOL.3B basin volume, generated net benefits of $21,726,000, approximately $356,000 more than TG2-RF23, and $312,000 more than TG2-RF25.

An additional plan (TG2-RF29) was then evaluated that was the same as TG2-RF28 except that the TG.2A1 channel modifications were substituted for the TG.2A3 channel modifications. The resulting net benefits of $21,897,000 for TG2-RF29, shown in Table 4-24, are approximately $527,000 more than TG2-RF23, and $171,000 more then TG2-RF28.

Based on the results of the additional evaluation TG2-RF29 is the best performing plan.

4.11 Evaluation and Comparison of Alternative Plans

Along with the No Action Plan (without project), three alternative plans were developed as described in the previous sections of this chapter. As presented in Section 4.10.2, the final re-optimization of the two channel component anchor component plans consists of channel modifications, detention, and permanent relocation, as depicted on Exhibits 4-14 and 4-15, respectively. Table 4-25 is a comparative summary of the plans that includes the plan description, hydraulic/engineering effects, economic results, environmental impacts, and other social effects.

The plans presented in Table 4-25 were compared and evaluated on characteristics that demonstrate the four evaluation criteria described in the P&G (Reference 9): completeness, effectiveness, efficiency, and acceptability. In terms of all four of the evaluation criteria the No Action Plan is the least favorable of the plans because it does not in any way meet the primary objective of reducing flooding along White Oak Bayou. In terms of completeness nothing is accomplished. Regarding effectiveness and efficiency it is not achieving either,

Table 4-25. Summary Comparison of Alternative Plans

	No Action	TG.8 Plan	TG.2 Plan
Plan Components	none	TG.8, JR.4, GBW.1, E200H.3A, TWLY.3, FNH.1, GE200.0, NHR.1, RG.0, NSB1	TG.2A1, JR.4, HOL.3B, GBW.3, FNH.3, RG.1, E200H.2A, GE200.7, NSB1
Plan Description	No Action / Without Project Condition	--7 miles concrete-lined channel modifications --5.5 miles earthen channel modifications --5 detention basins providing 2,187 ac-ft storage --permanent relocation of 1 property	--15.4 miles earthen channel modifications --5 detention basins providing 3,663 ac-ft storage --permanent relocation of 1 property
Hydraulic/Engineering Conditions			
Flood Damage Reduction	None.	58%	64%
Adverse Impacts to Buffalo Bayou for storms smaller than the 1% flood	N/A	Flow increase of 1,974 cfs for 1% flood and 1,198 cfs for 10% flood.	None.
Adverse Impacts within White Oak Bayou for storms smaller than the 1% flood	N/A	Water surface increases of 0.5 to 1.5 ft downstream of channel modifications.	None.
Economic Conditions			
Capital Cost ($1,000)	$0	$166,729	$166,946
Expected Annual Cost ($1,000)	$0	$12,146	$12,161
Expected Annual Damages ($1,000)	$53,430	$22,679	19,372
Net Expected Annual Benefits ($1,000)	$0	$18,605	$21,897
Benefit-Cost Ratio	N/A	2.53	2.80
Environmental / Social / Other Effects			
Induced Flooding	N/A	Over 500 newly flooded structures for 4% event, over 800 newly flooded structures for 1% event.	None.
Life, Health and Safety	No adverse impacts. Continued flood damage.	Increased safety risk downstream of project due to induced flooding.	No adverse impacts. Potential benefit from reduced flood damages.
Aesthetics, environmental quality	No adverse impacts.	Concrete-lined channel will damage aquatic environment, remove the already limited habitat areas, decrease dissolved oxygen and increase water temperature.	Limited adverse impacts during construction. Opportunity exists to enhance or improve existing conditions.

Notes: (1) All values shown are based on February 2002 costs and assessed values, and the year 2004 Federal discount rate of 5.625%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2004 Federal discount rate of 5.625%.
(3) Flood Damage Reduction is based on average annual dollar damages.
(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

and to do nothing is not acceptable to the flood prone residents. Of the two channel plans, TG.2 provides higher performance and effectiveness and is more complete and more acceptable. With regard to flood risk management, the TG.2 Plan is a more complete plan in terms of reducing flooding and not creating adverse flood impacts; the plan is only slightly more costly and is more efficient than TG.8, and TG.8 creates significant adverse hydraulic and economic damage impacts along the lower reach of White Oak Bayou downstream of the proposed channel modifications. The TG.2 plan creates no adverse impacts.

The TG.8 Plan has significant adverse hydrologic and environmental consequences and incurs significant environmental mitigation costs, primarily due to proposed concrete lining of the channel. The TG.8 Plan would add over 500 newly flooded structures to the 4 percent floodplain, over 800 newly flooded structures to the 1% floodplain and increase flooding to over 900 structures within the 4% floodplain with depths increasing on average from 0.12 to 0.79 feet and 2,700 structures within the 1% floodplain with depths more than doubling from 0.74 to 1.93 feet. These impacts result in a less complete, less effective and less acceptable plan.

The TG.2 plan (TG2-RF29), on the other hand, provides a higher level of flood protection, reducing average annual damages by $34.0 million compared to the $30.8 million for the TG.8 Plan, without creating any adverse impacts downstream of the proposed project. Its first cost is only slightly greater than the TG.8 Plan and produces net EA benefits that are approximately $3.3 million greater than Plan TG.8.

As mentioned above, regarding Environmental Quality effects, the TG.8 Plan has significant detrimental consequences associated with the concrete-lining, in comparison to the earthen channel modifications in the TG.2 Plan. The concrete lining in the TG.8 Plan would produce negative aesthetic impacts, damage or reduce aquatic habitat, decrease dissolved oxygen, and increase water temperature. Plan TG.2 would only have limited adverse impacts to aquatic habitat during construction and can be designed to improve existing habitat conditions. It would have no significant long-term negative aesthetic impacts. The TG.2 Plan is the most efficient plan and provides the greatest opportunity for enhancement of aesthetics and environmental resources within the project study area. In addition, there is much greater public support (acceptability) for earthen channel modifications (TG.2 Plan) than for concrete-lined channel modifications (TG.8 Plan).

Regarding the Other Social Effects, as mentioned above, the TG.8 Plan will induce additional downstream flooding for over 500 structures at the 4% event and over 800 structures for the 1% event. The plan would indirectly reduce job productivity and would reduce the quality of life for impacted residents, and would result in increased safety risks. On the other hand the TG.2 Plan does not increase flooding and provides significant benefits by reducing flood damages. It also increases job productivity, improves the quality of life, and reduces safety risks.

Regarding Regional Economic Development impacts in the area, the TG.8 and TG.2 plans would increase the potential for economic development, due to reduced risk of flooding and resulting economic damages in the area. Also, both would increase economic development due to the construction investment in the project area. However, the TG.8 plan would induce additional flooding, causing a negative economic impact.

4.12 Cost Update

Based on the analysis presented above, the TG.2 Plan (TG2-RF29) was identified as the best-performing plan economically and the plan that best meets the planning objectives. Analysis of this plan as well as the other alternatives was based on 2002 prices and damages. To finalize the analysis, the cost and economic damage data were updated to 2009 values for the TG.2 Plan (TG2-RF29). To update the plan to 2009 conditions, the following process was followed.

1. To update the plan costs, a cost estimate was developed for the TG.2 Plan (TG2-RF29) components using the MCACES cost estimating program and 2009 labor, equipment and material cost data. Real estate costs were revised based on an updated Gross Appraisal that was prepared in March 2009. The resulting total capital cost is $239 million, with the flood control components costing a total of $221 million and the Recreation Plan components costing $18 million, based on 2009 price levels. No contingencies are included in these costs.

2. To update economic damage data, the economic data base of properties within the study area was updated to 2009 values. The process used to update the data base is described in Appendix B-Economic Analysis. Also, the methodology to estimate vehicle damages was changed to reflect new guidance regarding this damage category. A description of the change in the vehicle damage methodology is presented in Appendix B also.

3. The FDA economic model was run for Without Project conditions and then for With Project conditions for the TG.2 Plan (TG2-RF29) plan using the updated 2009 economic data base and updated vehicle damage methodology. Net benefits were then calculated for the plan, based on the new MCACES costs and updated real estate values, using the current 2010 Federal discount rate of 4.385 percent. The net benefits based on 2009 conditions are $24.2 million, with a benefit–cost (B/C) ratio of 2.9. The results are summarized in Table 4-26.

4.13 Review of Economic Performance of Plan Components

A review of the current economic performance of the individual components of the TG.2 Plan (TG2-RF29) was performed as part of the update, based on the updated cost and economic data. The review was performed because of the changes in costs and economics data, and also to confirm that the components were still effective after the last changes to TG2.A1, GE200.7A and HOL.3B mentioned above. The following process was followed.

Table 4-26. TG.2 Last Added Analysis (2009 Costs and Economic Data)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Contributed EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Contributed EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Contributed Net EA Benefits ($1,000)
Formulated Plan: TG.2A1+JR.4+HOL.3B+GBW.3+FNH.3+RG.1+E200H.2A+GE200.7+NSB1											
TG2 RF-29	**Formulated Plan**	**$21,347**	**$36,943**		**$220,520**	**$257,115**	**$12,747**		**2.90**	**$24,196**	
TG2_LA1	Remove TG.2A1										
TG2_LA2	Remove JR.4										
TG2_LA3	Remove HOL.3B										
TG2_LA4	Remove GBW.3										
TG2_LA5	Remove FNH.3										
TG2_LA6 (RF-30)	**Remove RG.1**	**$21,713**	**$36,576**	**$367**	**$208,188**	**$242,736**	**$12,034**	**$713**	**3.04**	**$24,542**	**-$346**
TG2_LA7	Remove E200H.2A	$23,399	$34,890	$2,053	$212,114	$247,314	$12,261	$486	2.85	$22,629	$1,567
TG2_LA8	Remove GE200.7A	$23,603	$34,686	$2,257	$208,209	$243,121	$12,053	$694	2.88	$22,633	$1,563
TG2 RF-29 RG.0	Replace RG.1 with RG.0	$21,630	$36,659		$213,475	$248,901	$12,340		2.97	$24,319	-$124
TG2 RF-29 RG.2	Replace RG.1 with RG.2	$20,979	$37,310		$225,600	$263,038	$13,041		2.86	$24,269	-$74
RF-30 (TG2_LA6)	**RF-30 (Remove RG.1 from RF-29)**	**$21,713**	**$36,576**	**$367**	**$208,188**	**$242,736**	**$12,034**	**$713**	**3.04**	**$24,542**	
RF-30 LA FNH.3	last added FNH.3	$29,057	$29,232	$7,344	$144,701	$168,714	$8,364	$3,670	3.49	$20,868	$3,674
RF-30 LA GBW.3	last added GBW.3	$23,835	$34,454	$2,122	$181,811	$211,982	$10,509	$1,525	3.28	$23,945	$597
RF-30 LA HOL.3B	last added HOL3.B	$25,960	$32,329	$4,247	$173,087	$201,810	$10,005	$2,029	3.23	$22,324	$2,218
RF-30 LA JR.4	last added JR.4	$24,602	$33,687	$2,889	$181,797	$211,966	$10,509	$1,526	3.21	$23,178	$1,363
RF-30 LA TG.2A1	last added TG2A.1	$29,694	$28,595	$7,981	$177,187	$206,591	$10,242	$1,792	2.79	$18,353	$6,189
RF-30 LA E200H.2A	last added E200H.2A	$24,084	$34,205	$2,371	$199,474	$232,576	$11,530	$504	2.97	$22,675	$1,867
RF-30 LA GE200.7A	last added GE200.7A	$24,879	$33,410	$3,166	$195,877	$228,382	$11,323	$712	2.95	$22,087	$2,454
RF-30 LA NSB1	**last added NSB1**	**$21,958**	**$36,331**	**$245**	**$203,594**	**$237,380**	**$11,769**	**$266**	**3.09**	**$24,562**	**-$21**

Notes: (1) All values shown in black are based on 2009 costs and assessed values, and the year 2010 Federal discount rate of 4.375%.

(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2010 Federal discount rate of 4.375%.

(3) EA - Expected Annual

(4) Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the selected plan identified later in this report.

1. A last-added analysis was performed starting with the plan components that were generally the least economically beneficial components of the TG.2 Plan (TG2-RF29). The first three components evaluated were E200H.2A, GE200.7A, and RG.1. Each was evaluated individually by removing each separately from the TG.2 Plan (TG2-RF29), then running the hydrologic and hydraulic models for the resulting plan, and then running the updated FDA with the resulting water surface profiles, to determine the resulting damage reduction. Net benefits were then calculated using the 2009 cost information without including each component separately in the TG.2 Plan (TG2-RF29). The results are shown in Table 4-26. It may be seen that the two channel components, E200H.2A and GE200.7A, both remain viable components, each contributing net benefits of over $1.5 million. However, detention basin RG.1 is no longer beneficial, since removing RG.1 from the plan increases net benefits by approximately $350,000.

2. Because RG.1 no longer was found to add net benefits, it was decided to see if other sizes of RG would provide net benefits. RG.0 and RG.2, which provide 100 acre-feet and 399 acre-feet of detention storage respectively, were added to the remaining TG.2 Plan (TG2-RF29) components, and the economic benefits were determined following the same procedure used for the other runs. The results are shown in Table 4-26. The results show that neither of these two sizes added net benefits. Because of these results, it was decided that the RG detention component should be eliminated from the plan. A review of the performance of this component was made to determine why it now was not found to be economically beneficial. The addition of the Jersey Village and E141-00-00 channel system, identified as component GE200.7A, results in flood waters being conveyed around Jersey Village that would have otherwise passed through Jersey Village in the White Oak Bayou channel. This channel system around Jersey Village was added to the TG.2 Plan (TG2-RF29) after the Rio Grande detention basin was added previously. The Jersey Village and E141-00-00 channel system is more effective in reducing flooding by reducing the flow in the White Oak Bayou through Jersey Village. This channel system reduces flood levels through Jersey Village approximately 1 to 2 feet. The Rio Grande basin reduces flood levels in the range of only 0.1 to 0.2 feet through Jersey Village. Moreover, with the damage reduction resulting from the channel system, damage reduction resulting from the detention basin is considerably less, resulting in the negative net benefits.

The resulting plan, which eliminated RG as a component, is identified as RF-30. A last-added analysis was then performed for this plan. All of the remaining components were removed individually from the plan, and net benefits were then calculated. The results are shown in Table 4-26. The results show that all the channel modifications and the remaining four detention basins contribute substantial net benefits to the overall plan. The one non-structural component, NSB.1, buyout and removal of an 80-unit apartment building, was shown to no longer contribute net benefits. Therefore it was removed from the plan. The resulting plan, identified as RF-30 LA NSB1 in Table 4-26, is now considered to be the best performing plan.

4.14 Additional Non-Structural Analysis

In the initial component analysis in Sections 4.6.1 and 4.6.2, both non-structural buyout and structure raising were evaluated. They were evaluated for the individual 50, 20, 10, 4, and 2 percent exceedance probabilities for the entire study reach. The results as shown previously in Table 4-5 indicate that buyout or structure raising for only the 20 percent exceedance probability might warrant additional consideration as a major plan component on an individual reach basis.

As shown in the Table 4-5, the buyout capital cost for the 20 percent event is approximately $157 million and produces a B-C ratio only in the range of 1.0, which would be only marginally beneficial at best. However, for the 20 percent event, 475 of the 568 structures in the 20 percent flood plain are located within Reach 10. In comparison, the NED Plan has a capital cost of approximately $211 million, produces net benefits of over $25 million and has a B-C ratio over 3.1.

Based on these results, these two non-structural measures would only be likely to contribute net benefits as a last-added feature, looking at individual properties. To address this possibility, a structure-by-structure buyout and structure raising last-added analysis was performed for the 297 residential structures that show damages in the combined 2-yr, 5-yr and 10-yr events under the current NED HEC-FDA model. The Expected Annual Damages (EAD) for each of these properties, under the NED With Project conditions, was calculated for each property.

The EA damages (damages reduced) for each individual buyout property were calculated by manual integration of the damages that remain in the With Project condition for each structure as produced by the HEC-FDA model. The damages resulting from vehicles associated with these properties were included in this calculation as were the associated utilities and post disaster costs.

The EAD damages reduced for structure raising were calculated as the EAD for each structure under the NED less the EAD calculated in the HEC-FDA model after the structure raising. Calculation of the EAD after structure raising was performed by raising the finished floor elevation of these structures to 1.5 feet above the With Project 100-year stage elevation. A reduction in damages to vehicles was not considered for structure-raising, as raising a structure does not include raising a garage or driveway.

For the 297 residential properties analyzed, no buyouts were found to provide net benefits, and only two structures were found to warrant possible consideration for structure raising. The resulting EA damage reduction for these two totals only $13,000. Because of the small damage reduction and the uncertainties associated with structure raising, it is not considered appropriate to add these to the proposed plan.

4.15 Cost & Benefits Update

As a final step in the determination of the NED Plan, the costs and economic data base were updated to 2011 levels, following the procedure described in Section 4.12. A last-added analysis of all the components was performed again, as presented in Table 4-27. The results confirmed that RF-30 LA NSB1 is still the best performing plan.

4.16 Identification of NED Plan

Based on cost and economic damage data updated to 2009 levels and then again to 2011, the NED Plan (RF-30 LA NSB1) has been identified, consisting of the following components:

Channel Modification Components:

1. TG2A.1
2. E200H.2A
3. GE200.7A

Detention Basin Components:

1. HOL3.B
2. FNH.3
3. GBW.3
4. JR. 1

Based on 2011 costs and benefits, the NED Plan (RF-30 LA NSB1) has a total capital cost of $263 million, with flood control capital costs of $248 million. It reduces flood damages by $37 million, produces net economic benefits of approximately $23.7 million and a BC ratio of 2.7. By removing the RG detention basin and the non-structural buyout NSB.1 the capital cost of the flood control components of the plan is reduced by $20 million, when compared to the 2011 cost of the TG.2 Plan (TG2-RF29). These costs and economic results do not include contingencies or risk. These costs are based on Corps' procedures and are not based on any costs related to actual construction that has occurred. Actual costs related to construction that has occurred are discussed in Chapter 5.

This plan is the alternative that now best meets the planning objectives and is identified as the NED Plan. It is also the flood risk management plan supported by the Local Sponsor. The plan provides substantial flood damage reduction, maximizes net economic benefits, does not create adverse impacts downstream of the project, and would be favorably received by the public. The project provides opportunities to incorporate recreation elements into the flood risk management project. In comparison to the No Action and TG.8 alternatives, it provides all the same advantages that the previous TG.2 Plan (RF-29) provides, as presented in Table 4-25. The Environmental Quality, Other Social Effects, and Regional Economic Development impacts are equivalent to those discussed in Section 4.11 for the previous TG.2 Plan (RF-29). However, the elimination of the NSB.1 apartment buyout reduces a significant social relocation impact.

Table 4-27
TG2.A Last Added Analysis (2011 Costs and Economic Data)

ID	Plan	EA Damages ($1,000)	EA Benefit ($1,000)	Contributed EA Benefits ($1,000)	Capital Cost ($1,000)	Base Year Equivalent Cost ($1,000)	EA Cost ($1,000)	Contributed EA Cost ($1,000)	B/C	Net EA Benefits ($1,000)	Contributed Net EA Benefits ($1,000)
	Without Project (2011)	**$60,019**									
RF-30 LA NSB	NED Plan July 2010 GRR (2011 Damages and Costs)	**$22,652**	**$37,367**	**N.A.**	**$248,044**	**$286,675**	**$13,632**	**N.A.**	**2.74**	**$23,735**	**N.A.**
	Plan Components TG2A1, E200H2A, GE200.7A, FNH.3,GBW.3, HOL3.B, JR.4										
RF-30 LA FNH.3	**last added FNH.3**	$29,874	$30,146	$7,221	$168,675	$194,945	$9,270	$4,362	3.25	$20,876	-$2,859
RF-30 LA GBW.3	**last added GBW.3**	$24,488	$35,531	$1,836	$216,784	$250,546	$11,914	$1,718	2.98	$23,617	-$118
RF-30 LA HOL.3B	**last added HOL3.B**	$26,694	$33,326	$4,041	$202,940	$234,546	$11,153	$2,479	2.99	$22,173	-$1,562
RF-30 LA JR.4	**last added JR.4**	$25,251	$34,768	$2,599	$218,512	$252,543	$12,009	$1,623	2.90	$22,759	-$976
RF-30 LA TG.2A1	**last added TG2A.1**	$30,514	$29,505	$7,862	$210,997	$243,858	$11,596	$2,036	2.54	$17,910	-$5,826
RF-30 LA E200H.2A	**last added E200H.2A**	$24,705	$35,314	$2,053	$237,860	$274,905	$13,072	$560	2.70	$22,242	-$1,493
RF-30 LA GE200.7A	**last added GE200.7A**	$25,497	$34,522	$2,845	$232,941	$269,220	$12,802	$830	2.70	$21,721	-$2,015
TG2 RF-29	**Add RG.1**	$22,182	$37,837	$470	$263,398	$304,420	$14,475	$844	2.61	$23,362	-$374
TG2 RF-29 RG.0	**Replace RG.1 with RG.0**	$22,473	$37,546	$179	$256,122	$296,011	$14,076	$444	2.67	$23,470	-$265
TG2 RF-29 RG.2	**Replace RG.1 with RG.2**	$21,807	$38,212	$845	$270,318	$312,418	$14,856	$1,224	2.57	$23,356	-$379
RF-30 (TG2_LA6)	**Add NSB**	$22,407	$37,612	$245	$252,576	$291,913	$13,881	$249	2.71	$23,731	-$4

Notes:
(1) All values shown are based on 2011 costs and assessed values, and the year 2011 Federal discount rate of 4.125%.
(2) Base year equivalent cost is based on a 7-year construction period and interest during construction based on the 2011 Federal discount rate of 4.125%.
(3) EA - Expected Annual
(4) No contingencies are included in the capital costs

4.17 Locally Preferred Plan

The NED Plan (RF-30 LA NSB1) was identified as the Tentatively Recommended Plan described in the previous section. This plan was presented in the February 2013 draft of the GRR and the EA. This version of the GRR and EA was distributed to required agencies, interested parties and to the public for review and comment as part of the NEPA process. Significant public comment was received in opposition to the acquisition of the area identified as the FNH.3-W cell for construction of additional detention storage. Acquisition of this area would require relocation of 11 residences. Concerns were raised regarding the historical, social, and environmental significance of the area to be acquired. Based on these concerns the Local Sponsor reviewed the performance of the flood protection plan resulting from the removal of this area from the plan. The resulting plan is referred to in the plan formulation as RF-31. Damages are reduced approximately $35.6 million in comparison to the NED damage reduction of $37.4.The capital cost of the plan is approximately $232 million in comparison to the NED Plan cost of $ 248 million. Net benefits are approximately $22.1 million in comparison to the NED net benefits of $23.7 million. The benefit-cost ratio is 2.73 in comparison to the NED benefit-cost ratio of 2.74. Based on these comparisons, it was decided that the flood protection and economic performance of the Tentatively Recommended Plan would not be significantly impacted by removing this area. It was decided to adopt the resulting plan which contains all the features of the NED Plan (RF-30 LA NSB1) except the FNH.3-W cell as the Locally Preferred Plan (RF-31). This plan meets the planning objectives and provides similar flood protection benefits in comparison to the NED Plan at a lower cost. It also avoids the social, historical, and environmental impacts of relocating 11 residences in a sensitive area.

In selecting this plan the Local Sponsor is utilizing the categorical exemption that is available based on paragraph 3-3b(11) of the Planning Guidance Notebook (Reference 8). This categorical exemption is for the Locally Preferred Plan (RF-31) which has greater net benefits than all other plans with lesser costs. The LPP (RF-31) is only slightly smaller than the NED Plan (RF-30 LA NSB1) and does not contain any uneconomical increments. The Local Sponsor will submit a letter to the ASA(CW) requesting that the LPP be approved.

The costs presented here in this section are based on the Corps' procedures used throughout Chapter 4 and are not based on costs related to actual construction that has occurred. Actual costs related to construction that has occurred are discussed in Chapter 5. Chapter 5 also presents the results with risk included, based on the risk analysis performed using Crystal Ball risk software. Damages and resultant benefits were updated to FY2013 price levels and 3.75 interest rate for the Locally Preferred Plan (RF-31) in Chapter 5. In Chapter 5 this plan is referred to as the Recommended Plan.

4.18 Recreation Plan

As part of the development of the plan recommended for implementation by the and for cost-sharing by the Federal government, a Recreation Plan was developed for the project area. The development of the plan followed the procedure described below:

Phase 1 - Inventory & Analysis

Step 1 - Inventory

The first step involved a complete inventory of existing City of Houston, City of Jersey Village, Harris County and Homeowners Association recreation facilities within a ½ mile corridor of White Oak Bayou. A recreation use inventory was also conducted to evaluate the estimated use of facilities along the corridor. Other information that was gathered during this step included demographics of census tracts in the corridor, information concerning existing and proposed environmental conditions, and design features of the Recommended Plan.

Step 2 - Aesthetic Assessment

This step involved dividing the corridor into geographical regions and rating the individual regions according to an established aesthetic evaluation method. The aesthetic evaluation considered views, quality of plant life, changes in topography, and community use in each region.

Step 3 - Opportunities and Constraints

Opportunities and constraints were identified, taking into account the components of the flood damage reduction NED Plan, environmental conditions along the bayou, and the elements of the Recreation Inventory.

Phase 2 - Physical Plan & Recreation Benefits Analysis

Step 4 - Recreation Master Plan Recommendations

Recommendations for recreation facilities were made based on evaluating the opportunities and constraints identified in Step 3. Budgets for the recreation enhancements were also performed during this step.

Step 5 - Benefits Analysis

Using information gathered relating to number of users, quality of experience and construction budgets, the total budget of the recreation plan was compared to the expected use of facilities proposed in the plan. The result of this step is the benefit cost ratio of the project and determines the net benefits of the proposed recreation facilities.

Recreation Plan Features

As part of the recreation plan (see Appendix F – Recreation Plan), several concepts were considered for use. A linear park system with multipurpose trail and picnic facilities was considered along the channel modifications. For the detention basins, wetland interpretative facilities, open play areas, playgrounds, jogging paths, picnic areas and multi-purpose fields were considered. The following summarizes the plan features that were developed for the plan.

Linear Parks

- Provide a new hike and bike trail in coordination with the City of Houston Master Plan from the confluence of White Oak Bayou and Cole Creek upstream to Hollister. The City of Houston will not participate in the sponsorship of this trail. The trail system downstream of Cole Creek is not part of the Recreation Plan.
- Extend linear park trail from Hollister to West Road, along channel modifications TG.2A1, GE200.7A and E200H.2A.

Detention Basins

- Detention Basin FNH.2 (NORTH)
  - Provide trail head and access to the White Oak Bayou Greenbelt from the neighborhood.
  - Dry area of detention basin to be used as open play and multi-purpose fields.

- Detention Basin HOL.3B
  - Seven acres of wetlands will be constructed as Local Sponsor Volunteer Mitigation. (This cost is not part of the final project costs or the Recreation Plan.)
  - Provide access to the White Oak Bayou trail from surrounding neighborhoods.
  - Provide urban wetlands/wildlife teaching overlook facilities at created wetlands.

- Detention Basin FNH.2 (SOUTH)
  - Provide urban wetland/wildlife observation/teaching overlook facilities.
  - Provide a new hike and bike trail through the site.

- Detention Basin GBW.3
  - Provide a new hike and bike trail around the site.
  - Provide access to White Oak Bayou trail.
  - Provide multi-purpose fields and play areas.

- Detention Basin JR.4
  - Create a trail head.
  - Provide multi-purpose fields.

The plan features are shown on Exhibit 5-1a

Recreation Plan Costs

The first cost of the White Oak Bayou recreation plan is shown below.

Project Element	Cost (FY 2013)
Parks	$5.6 million
Trails	$5.1 million
Total First Cost	$10.6 million

Cost estimates for the individual parks are presented in Appendix F. Amortizing the costs over fifty years at a discount rate of 3.75% yields annual costs of approximately $501,000. Annual OMRR&R costs are estimated at $73,000 for the recreation plan. The total annual cost for the recreation plan is $574,000.

Net Benefits & B/C Ratio

The recreation plan for the White Oak Bayou Flood Control project has an estimated first cost of $10.6 million, a fully funded cost of $11.2 million, with an annual OMRR&R cost of $73,000. The total amortized recreation cost is $574,000. The economics of the recreation plan are:

	Annual Value
Park Benefits	$1,788,000
Multi-Use Path Benefits	$874,000
Total Recreation Benefits	**$2,662,000**
Construction Costs	$501,000
OMRR&R Costs	$73,000
Total Costs	**$574,000**
Net Benefits	**$2,088,000**
B/C Ratio	**4.6**

The plan provides net benefits of approximately $2,088,000 and produces a benefit-cost ratio of 4.6. Benefits were computed using Corps Unit Day Value methodology, as described in Appendix F.

4.19 Environmental Mitigation

Wetlands were identified as the only significant resource warranting compensatory mitigation. A total of 13.17 acres of wetlands would be impacted during construction of the flood risk reduction components. Compensatory wetlands mitigation would be provided for the impact. Eight viable alternatives for compensatory mitigation were identified. A Cost Effectiveness/Incremental Cost Analysis was completed using the USACE's IWR Planning Suite software for each mitigation alternative. The analysis was performed using Average Annual Habitat Units as the measure of the impact and the related compensatory mitigation associated with the project. Although Alternative 4, purchasing acreage at Subdivision B of the Greens Bayou Wetlands Mitigation Bank (GBWMB), is less expensive, HCFCD proposes to use for mitigation the previously purchased acreage they already own at Subdivision A of the GBWMB. Coordination with various resource agencies was initiated to obtain input during the development of the wetland mitigation plan. As part of a local initiative, to comply with resource agency requests, HCFCD would additionally create seven acres of forested wetlands within the Hollister Road detention basin complex, identified herein as Local Sponsor Volunteer Mitigation. This would bring the total acres of wetland mitigation to approximately 12 acres. Federal cost sharing would only apply based on the least cost of Alternative 4. All other costs would be the Local Sponsor's responsibility and are not included in the project costs or economic analysis of benefits. The resulting plan is considered to be the Environmentally Preferred Alternative.

A detailed discussion of the wetlands mitigation analysis is presented in the Environmental Assessment.

5.0 RECOMMENDED PLAN

This chapter provides information regarding the various aspects of the Recommended Plan (RF-31), including a summary of plan features, environmental considerations, economic performance, plan implementation, and public involvement. The Recommended Plan is the plan proposed for implementation and for cost-sharing with the Federal government.

5.1 Summary of Plan Features

The Recommended Plan (RF-31) consists of the following major components that are schematically shown on Exhibits 5-1 and 5-1a. The plan consists of flood risk reduction components, recreation components, and environmental mitigation. The plan components include:

- **Channel TG.2A1:** approximately 7.0 miles of earthen channel modifications from Cole Creek to Gessner Road with minor right-of-way acquisition required. Acquisition of approximately 10.8 acres of right-of-way is required.

- **Channel GE200.7A:** approximately 2.1 miles of earthen channel modifications from Gessner Road to channel E200-00-00 within the existing right-of-way of White Oak Bayou, and approximately 2.9 miles of channel modifications to the Jersey Village channel and ditch E141-00-00 within the existing right-of-way.

- **Channel E200H.2A:** approximately 3.4 miles of earthen channel modifications from detention channel E200-00-00 to FM1960 within the existing right-of-way.

- **Detention JR.4:** detention facility on two properties totaling approximately 65.8 acres located north and south of White Oak Bayou near Jones Road, providing an estimated detention volume of 420 ac-ft. HCFCD has acquired the property for the detention facility.

- **Detention HOL.3B:** detention facility providing 730 ac-ft of detention volume on 93.7 acres located at Hollister Road on land south of the bayou. HCFCD has acquired the property for the detention facility.

- **Detention GBW.3:** detention facility on three properties totaling 51.0 acres located north and south of the bayou near Gessner Road and Beltway 8 and providing an estimated detention volume of 519 ac-ft. HCFCD has acquired two of the properties for the detention facility. Acquisition of the third property consisting of 11 acres is required.

- **Detention FNH.2:** detention facility near Fairbanks-North Houston Road on two properties totaling 142 acres and providing an estimated total detention volume of 1,269 ac-ft. This detention basin includes the expansion of the 1998 existing

detention facility E500-01-00. HCFCD has acquired the two properties for the detention facility.

- **Recreation Plan:** Creation of 12 miles of a linear park/bikeway from the confluence of White Oak Bayou and Cole Creek upstream to north of West Road. Recreational opportunities will also be provided by four day-use park facilities within the four detention basins such as multi-purpose trails, observation/teaching facilities, multi-purpose fields, and play areas.

- **Mitigation:** Mitigation of wetlands by utilizing 4.99 acres of wetlands at the Greens Bayou Wetland Mitigation Bank, Subdivision A. This is the least-cost mitigation developed as part of the Wetlands Mitigation Cost Analysis. Also proposed is construction of seven acres of wetlands in the HOL detention basin, identified herein as Local Sponsor Volunteer Mitigation. This mitigation will be a 100 percent local cost and is not included in the Recommended Plan costs or economic results.

The following sections describe in further detail the engineering and design considerations associated with each of these components. As described in Section 5.1.5, some of the components have already been constructed by HCFCD.

5.1.1 Channel Modifications

The proposed channel modifications consist of approximately 15.4 miles of earthen channel modifications from Tidwell Road to FM 1960. The proposed alignment of the channel modifications would follow the alignment of the existing channel. The channel flowline will be lowered to the elevation of the existing Federal low flow channel at the downstream reach at Tidwell Road. A 200-foot transition length will be assumed at changes in channel bottom width (i.e., the ends of the channel modifications). The proposed channel modifications generally consist of a trapezoidal channel with 3 horizontal to 1 vertical side slopes, Bottom widths are increased to widths ranging from 30 to 80 feet. Specific bottom widths are described later in this section. Various utility crossings will have to be relocated or adjusted as part of the channel modifications.

The channel modifications will include a low flow, geomorphologic channel that will prevent sediment buildup. Therefore, the bayou stream will appear to have a more natural meandering flow within the boundaries of the channel bottom. This low flow channel also provides opportunity for additional plant and animal habitat along the bottom banks of the bayou through the growth of herbaceous vegetation, which is expected to attract birds and other wildlife. New trees and shrubs will be planted along the channel modifications. The trees and shrubs will be planted in small clusters, based on an equivalent of four trees and four shrubs/understory plants per 100 feet of channel length, along each side of the channel. Generally, existing trees along the bayou are adjacent to the fence lines of adjacent property owners and do not appear to be within HCFCD right-of-way. Where existing trees may be in conflict with the proposed channel modifications, consideration will

be given to moving and replacing the trees at unaffected locations. The banks of the bayou will be reseeded after construction is complete in order to reduce erosion and establish ground cover. A detailed description of the tree planting and revegetation plan is provided in Section 5.3. Recreational features along the reaches of the proposed channel modifications are planned, as discussed in Section 5.1.3.

The following sections describe specific aspects of the three channel modification components.

Channel TG.2A1

Channel TG.2A1 consists of approximately 7.0 miles of earthen channel modifications from Tidwell Road to Gessner Road, with some minor right-of-way acquisition required in certain locations. Typical sections are shown on Exhibit 5-2.

Two reaches describe the channel modifications:

1) Tidwell Road (station 56231) to tributary E122-00-00 (station 77129): 60 foot bottom width; and
2) Tributary E122-00-00 (station 77129) to Gessner Road (station 86621): 30 foot bottom width.

Channel GE200.7A

Channel GE200.7 consists of approximately 2.1 miles of earthen channel modifications from Gessner Road to detention channel E200-00-00, within the existing right-of-way. Conveyance improvements to the existing channel will be made by providing a uniform channel flowline with approximate 30-foot bottom width. Portions of the channel are to be gabion-lined due to slope stability concerns. Typical sections are shown on Exhibit 5-2. The component also includes approximately 2.9 miles of earthen channel modifications to the Jersey Village channel E200-00-00 and channel E141-00-00. Typical sections are shown on Exhibit 5-2.

Channel E200H.2A

Channel E200H.2A consists of approximately 3.4 miles of earthen channel modifications from detention channel E200-00-00 to FM 1960, within the existing right-of-way. Typical sections are shown on Exhibit 5-2.

Two reaches describe the channel modifications:

1) Detention channel E200-00-00 (station 105000) to Jones Road (station 116549): 80 foot bottom width; and

2) Jones Road (station 116549) to FM 1960 (station 122498): 50 foot bottom width.

All three channel components will have a low-flow geomorphologic channel to prevent sediment buildup.

5.1.2 Detention Basins

Four detention basins providing an estimated total storage volume of 2,938 acre-feet are proposed. The detention basins will be constructed on a total of 353 acres of land. The detention basins were designed with 3 horizontal to 1 vertical side slopes, a spillway or side weir to divert runoff into the detention basin, and, with the exception of detention basin HOL.3B, all generally have a low-flow pilot channel sloped to drain towards a low-flow outfall pipe. HOL.3B has a wet bottom instead of a dry-bottom and pilot channel. A maintenance berm surrounding the detention basin is designed with backslope drains and perimeter maintenance drainage swales to control erosion of the side slopes. Actual maintenance berm widths and detention basin side slopes will be varied to enhance the appearance of the detention basin and to accommodate environmental and recreational features.

Trees and shrubs will be planted within the detention sites and along the channel to restore the aesthetic resources. A substantial amount of the trees and shrubs will be planted in clusters to provide a more natural appearance. In order to screen the detention basin from the surrounding land uses, an approximate 50 to 150 foot vegetative buffer will be left intact or provided by planting the trees and shrubs. The side slopes and perimeter will be seeded with grass after construction is completed to establish ground cover and reduce erosion. A detailed description of the tree planting and revegetation plan is provided in Section 5.3.1.

Recreational features for the proposed detention basins have been developed as discussed in Section 5.1.3.

The following sections describe the specific aspects of each detention basin.

Detention JR.4

Detention JR.4 is a detention component on two properties located north and south of the bayou near Jones Road. The first property, located south of the bayou and east of Jones Road, provides an estimated storage volume of 220 acre-feet on approximately 36 acres. An oil pipeline easement divides the property. The second property, located north of the bayou and west of Jones Road, provides an estimated storage volume of 200 acre-feet on approximately 30 acres. A schematic site layout of this detention component is shown on Exhibit 5-3.

Detention HOL.3B

Detention HOL.3B consists of a detention basin on a 93.7-acre site currently owned by the HCFCD near Hollister Road. An Exxon/Mobil pipeline divides the property into approximately 57 acres between the pipeline and the bayou, and approximately 37 acres between the pipeline and West Little York Road. This off-line detention facility will provide an estimated volume of 730 acre-feet. As part of the overall plan to mitigate wetlands impacts, construction of seven acres of forested wetlands is planned in this basin. A schematic site layout of the detention basin is shown on Exhibit 5-4.

Two previously identified prehistoric sites are located in the northern portion of the property. The layout of the detention basin has been designed to avoid the sites. Prior to construction, the area near the prehistoric sites will be flagged and protected.

Detention GBW.3

Detention GBW.3 consists of a combination in-line and off-line basin located at Gessner Road and Beltway 8 on three properties adjacent to and north and south of the bayou. The three properties total 51.0 acres and provide an estimated detention volume of 519 acre-feet. The detention component is configured as three storage cells with a diversion weir to convey floodwaters into the basin. Pipes to equalize storage of runoff would interconnect the storage cells. A schematic site layout for this detention site is shown on Exhibit 5-5.

The detention basin north of the bayou and centered on the confluence of E141-00-00 and White Oak Bayou is an in-line basin with a total area of approximately 21 acres. Prior to construction, utility modifications included rerouting a 4-inch force main and a 10-inch sanitary sewer located along the bayou from an existing lift station located west of E141-00-00 to an alternate lift station located south of Brookriver Drive and Gessner Road.

The detention basin south of the bayou consists of one property located between White Oak Bayou and Brookriver Drive, and a second property located south of Brookriver Drive. A 21-inch sanitary sewer line crosses through the middle of the first property located between White Oak Bayou and Brookriver Drive. This utility will not be adjusted; therefore, the detention basin has been designed as two cells. A third storage cell will be constructed on property south of Brookriver Drive.

Detention FNH.2

Detention basin FNH.2 consists of one property located north of the bayou and one property located south of the bayou near Fairbanks-North Houston Road. The detention complex is designed as two separate storage cells with a total estimated detention volume of 1,269 acre-feet. A schematic site layout for this detention site is shown on Exhibit 5-6.

Detention north of the bayou is on a 86-acre site with an estimated storage volume of 843 acre-feet. This detention is an expansion on 46 acres of the 1998 existing 360 acre-foot detention facility E500-01-00.

Detention south of the bayou is on a 56-acre site located east of Fairbanks-North Houston Road, providing an estimated 426 acre-feet of storage.

5.1.3 Recreation Plan Components

A Recreation Plan was developed as part of the Recommended Plan. The overall proposed plan is shown on Exhibit 5-1a. Harris County Precinct No. 4 has expressed interest to be the Local Sponsor for the recreation elements. The plan is discussed in detail in Appendix F – Recreation Plan. As part of the recreation plan (see Appendix F – Recreation Plan), a linear park system with approximately 12 miles of multipurpose trails and picnic facilities is proposed to be constructed along the channel modifications. Federal cost-sharing has been included in the costs presented later in this chapter. Recreational opportunities will also be provided by four day-use park facilities within the four detention basins. The features that comprise the facilities are consistent with the features eligible for cost-sharing as described in the feature list in ER1105-2-100, Exhibit E-2. Detailed exhibits of the plan components are provided in Appendix F- Recreation Plan.

<u>Linear Parks</u>

- Provide a new hike and bike trail of approximately 3.8 miles in coordination with the City of Houston Master Plan from the confluence of White Oak Bayou and Cole Creek upstream to Hollister. The City of Houston will not participate in the sponsorship of this trail. The trail system downstream of Cole Creek is not part of the Recreation Plan. Any cost associated with damage to any existing trails in the reach between Cole Creek and Pinemont is included in the Recreation Plan cost as new trail construction.
- Extend linear park trail approximately_8.1 miles from Hollister to West Road, along channel modification TG.2A1, GE200.7A and E200H.2A.

<u>Detention Basins</u>

- Detention Basin FNH.3 (NORTH)
  - Provide trail head and access to the White Oak Bayou Greenbelt from neighborhood.
  - Dry area of detention basin to be used as open play and multi-purpose fields.
- Detention Basin HOL.3B
  - Seven acres of Local Sponsor Volunteer Mitigation will be constructed. The cost of the wetlands is not part of the Recreation Plan or the Recommended Plan.
  - Provide access to the White Oak Bayou trail from surrounding neighborhoods.
  - Provide urban wetlands/wildlife teaching overlook facilities at created

wetlands.

- Detention Basin FNH.3 (SOUTH)
  - Provide urban wetland/wildlife observation/teaching overlook facilities.
  - Provide a new hike and bike trail through the site.
- Detention Basin GBW.3
  - Provide a new hike and bike trail around the site.
  - Provide access to White Oak Bayou trail.
  - Provide multi-purpose fields and play areas.
- Detention Basin JR.4
  - Create a trail head at the termination of the White Oak Bayou trail system.
  - Provide multi-purpose fields.

5.1.4 Environmental Mitigation Components

Construction of the Recommended Plan impacts a total of 13.17 acres of wetlands (5.31 acres of emergent fringe and depressional wetlands and 7.86 acres of forested scrub-shrub wetlands). The environmental mitigation components of the Recommended Plan, also considered to be the Environmentally Preferred Alternative, consists of buying 4.99 acres of wetlands at the Greens Bayou mitigation bank and constructing seven acres of wetlands at the HOL.3B detention basin. A summary on these two components is provided as follows. More detailed information is located in the Environmental Assessment.

Greens Bayou Wetlands Mitigation Bank (GBWMB)
Impacts to wetlands will be mitigated at the GBWMB Subdivision A through purchase of 4.99 acres. Although Alternative 4 of the various alternatives evaluated in the cost-effectiveness analysis, purchasing acreage at Subdivision B, is less expensive, HCFCD proposes to use the acreage already owned in Subdivision A. Federal cost-sharing is proposed only to the extent of the cost of Alternative 4.

The GBWMB is owned and operated by HCFCD and is approximately 18 miles east of the project area within the Greens Bayou watershed. The project impacts occur within the White Oak Bayou watershed and Harris County. Both the White Oak Bayou and Greens Bayou watersheds are part of the Buffalo Bayou watershed. The GBWMB includes all of Harris County in its service area.

The proposed mitigation includes the purchase of acreage at the GBWMB to mitigate for forested and emergent wetland impacts. The forested wetland component would mitigate for both forested and scrub-shrub wetland impacts. Wetland impacts associated with the proposed project will exceed the requirements established in the 1995 Memorandum of Agreement between the HCFCD and the members of the Mitigation Bank Review Team, consisting of the USACE, the Environmental Protection Agency, the United States Fish and Wildlife Service, the National Marine Fisheries Service, Texas Parks and Wildlife

Department, Texas General Land Office, and the Texas Commission on Environmental Quality. Use of the GBWMB also complies with Implementation Guidance for WRDA 2007 Section 2036(c).

Hollister Road Detention Basin Local Sponsor Volunteer Wetlands Mitigation
Seven acres of forested wetlands, identified as Local Sponsor Volunteer Mitigation, would be created within the Hollister Road detention basin complex. Native species of forested wetland vegetation would be planted at the Hollister Road detention basin. The created forested wetland mitigation on the Hollister Road detention basin complex would be monitored for a minimum period of five years or until success criteria are achieved. In addition, native emergent wetland species would be planted among the trees and shrub species to create a forested wetland that consists of a shrub and tree stratum as well as an herbaceous vegetation stratum. This will create a balanced wetland area and reduce the potential for invasive species. No Federal cost-sharing is proposed, and no costs are included in the Recommended Plan costs or economic results.

5.1.5 Construction Status

The Local Sponsor has already constructed certain components of the Recommended Plan, Status of construction components is as follows:

- **Channel TG.2A1:** channel modifications from E122-00-00 to Gessner have been constructed. Modifications to the channel segment from Cole Creek to E122-00-00 remain to be constructed.
- **Channel GE200.7A:** 2.9 miles of channel modifications to the Jersey Village channel and ditch E141-00-00 within the existing right-of-way has been constructed. Modifications to the approximately 2.1 mile channel segment of the bayou remain to be constructed
- **Channel E200H.2A:** none of the approximately 3.4 miles of earthen channel modifications from detention channel E200-00-00 to FM1960 has been constructed.
- **Detention JR.4:** detention facility providing a detention volume of 420 ac-ft. has been constructed.
- **Detention HOL.3B:** detention facility providing 730 ac-ft of detention volume on 93.7 acres located at Hollister Road on land south of the bayou has been constructed.
- **Detention GBW.3:** detention facility on two properties totaling 40.4 acres located north and south of the bayou near Gessner Road and Beltway 8 and providing an estimated detention volume of 427 ac-ft. has been completed. Acquisition of the third property consisting of 10.6 acres and construction of the 92 ac-ft volume are required.
- **Detention FNH.2:** detention facility near Fairbanks-North Houston Road on two properties totaling 142.2 acres and providing an estimated total detention volume of 1,269 ac-ft. has been constructed.
- **Environmental Mitigation:** The 4.99 acres in Mitigation Bank A have been constructed and purchased. Construction of the Local Sponsor Volunteer Mitigation,

consisting of seven acres of wetlands at the Hollister basin was started in January, 2013. No costs are included in the Recommended Plan costs or economic results.

None of the Recreation Plan components have been constructed. All of the constructed items described above are consistent with the Recommended Plan and have been constructed in conformance with Corps of Engineers' requirements. Reimbursement will be requested for the Federal-share costs expended based on the Section 211 cost-sharing rules.

5.2 Flood Damage Reduction

Table 5-1 presents the economic performance of the flood risk management components of the Recommended Plan (RF-31) by damage reach based on FY 2013 price levels and the FY 2013 Federal interest rate of 3.75 percent. The table shows the average annual equivalent (AAE) damages per reach and the probability that the damage reduced exceeds an indicated value. Tables 5-2 and 5-3 summarize the long-term risk and conditional non-exceedance probability by damage reach for the base without project conditions and the Recommended Plan.

The water surface profile for the Recommended Plan is shown on Exhibits 5-8.1 and 5-8.2. Computed water surface elevations would be lowered from approximately 2 to 3 feet and 0.5 to 1.5 foot in the high damage reaches for the 10 and 1 percent probability flood events respectively. Flood plain maps comparing the without project flood plain to the resulting Recommended Plan flood plain for the 10, 4 and 1 percent events are shown on Exhibits 5-9 through 5-11, respectively. The economic performance of the Recommended Plan is graphically shown on Exhibit 5-12. The economic plot shows the reduction in damages achieved by the plan. The economic performance of the Recommended Plan is presented in terms of AAE values which are equivalent with EAD values, since base and future hydrologic conditions are the same.

The Recommended Plan reduces AAE flood damages by approximately 58 percent, from approximately $61.2 million without the plan to approximately $25.7 million with the plan at the current FY 2013 Federal interest rate of 3.75 percent. After completion of the project, the 1 percent floodplain would be removed from approximately 22 percent of the structures damaged under the 1 percent flood and the 10 percent floodplain would be removed from approximately 96 percent of the structures. Single occurrence damages for the 1 percent flood would be reduced by approximately $105 million, from $431 million to $333 million. Single occurrence damages for the 10 percent flood would be reduced by approximately $68 million, from $80 million to $12 million. Presented below in Table 5-3a is a summary of typical reductions in flood depths at various locations along White Oak Bayou for a range of flood-producing exceedance probabilities. For the 10 % event, within the high damage reaches within the project area, flood depths are reduced typically from two to three feet. For the 1 % event, the range is typically from 0.5 to 1.5 feet within the high damage reaches.

Table 5-1 Distribution of Average Annual Equivalent Damages by Reach for Recommended Plan ($1,000's, FY 2013 Values, 3.75 % Interest Rate)

Plan Name	Plan Description	Total Without Project	Total With Project	Damage Reduced	Probability Damaged reduced Exceeds Indicated Values		
					0.75	0.5	0.25
WOB-1	Mouth to IH-45	$1,443.31	$1,332.71	$110.60	21.13	72.60	165.78
WOB-2	IH-45 to Yale St.	265.88	249.23	$16.66	9.94	17.62	23.26
WOB-3	Yale St. to D/S Hidden Lake	145.27	125.95	$19.32	4.31	13.75	24.15
WOB-4a(L)	D/S Hidden Lake Town Homes to U/S Hidden Lake Town Homes	434.16	388.07	$46.09	32.51	44.70	57.38
WOB-4(R)	D/S Hidden Lake Town Homes to Ella Blvd.	452.29	378.57	$73.72	11.56	41.38	102.26
WOB-4b(L)	U/S Hidden Lake Town Homes to Ella Blvd.	1,187.24	973.44	$213.80	64.42	160.06	303.52
WOB-5	Ella Blvd. to Burlington Northern RR.	3,398.45	2,715.91	$682.53	297.08	568.74	939.72
WOB-6	Burlington Northern RR. to W. Tidwell Rd.	2,713.37	2,096.09	$617.28	226.36	496.63	876.49
WOB-7	W. Tidwell Rd. to W. Little York Rd.	1,371.55	846.27	$525.28	156.07	376.30	714.11
WOB-8a(L)	W. Little York Rd. to Antoine Dr.	40.35	28.92	$11.43	4.20	8.41	15.54
WOB-8(R)	W. Little York Rd. to Alabonson Rd.	1,054.50	458.64	$595.85	214.47	428.56	790.13
WOB-8b(L)	Antoine Dr. to Alabonson Rd.	1,424.56	510.65	$913.90	282.90	652.23	1,251.41
WOB-9	Alabonson Rd. to N Houston Rosslyn Rd.	3,208.43	1,308.17	$1,900.26	780.12	1,484.55	2,575.80
WOB-10a(R)	N Rosslyn Rd to Hollister Rd.	2,188.68	570.98	$1,617.70	551.67	1,177.66	2,153.06
WOB-10a(L)	N Rosslyn Rd to HCFCD Ditch Unit E124-00-00	7,081.14	2,149.43	$4,931.71	2,934.53	4,591.29	6,541.50
WOB-10b(R)	Hollister Rd. to Woodland West Dr.	4,127.30	696.93	$3,430.37	1,391.75	2,857.09	4,891.92
WOB-10b(L)	HCFCD Ditch Unit E124-00-00 to Woodland West Dr.	7,203.42	1,159.02	$6,044.41	1,669.72	4,128.40	8,423.81
WOB-11	Woodland West Dr. to W Gulf Bank Rd.	2,326.73	1,151.94	$1,174.80	548.87	1,020.24	1,621.22
WOB-12	W Gulf Bank Rd. to N Gessner Rd.	4,083.04	2,212.13	$1,870.91	395.48	1,225.73	2,700.43
WOB-13	N Gessner Rd. to Sam Houston Pkwy.	1,645.75	864.75	$781.00	126.38	426.77	1,045.78
WOB-14	Sam Houston Pkwy. to Wyndham Village Dr.	6,772.91	2,509.36	$4,263.55	1,255.24	2,939.26	5,698.64
WOB-15	Wyndham Village Dr. to West Rd.	1,094.72	358.81	$735.91	162.57	198.59	855.71
WOB-16	West Rd. to Jones Rd.	3,045.12	820.86	$2,224.26	493.40	713.45	2,576.40
WOB-17	Jones Rd. to FM 1960 W.	3,904.63	1,218.51	$2,686.11	462.78	891.59	3,288.32
WOB-18	FM 1960 W. to Oak Acres Dr.	478.21	403.82	$74.38	26.73	32.66	75.26
WOB-19	Oak Acres Dr. to US 290	128.79	128.89	-$0.10	-0.19	-0.23	-0.33
	Total (October 2012 Values, 3.75 % Interest Rate)	**$61,219.79**	**$25,658.02**	**$35,561.75**	**$12,124.00**	**$24,568.04**	**$47,711.26**

Table 5-2 Long Term Risk and Conditional Non-Exceedance Probability under Base Conditions

Reach	Target Stage	Target Stage Annual Expected Probability		Long Term Risk (Years)			Conditional Non-Exceedance Probability by Event					
		Median	Expected	10	25	50	10%	4%	2%	1%	.4%	.2%
1	32.96	0.0640	0.0630	0.4789	0.8040	0.9616	0.8234	0.3353	0.1369	0.0503	0.0111	0.0030
2	32.21	0.1070	0.1040	0.6676	0.9363	0.9959	0.5223	0.1152	0.0274	0.0051	0.0004	0.0000
3	44.17	0.0920	0.0890	0.6054	0.9022	0.9904	0.6328	0.2099	0.0694	0.0184	0.0024	0.0004
4a(L)	39.33	0.4030	0.3700	0.9902	1.0000	1.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000
4(R)	50.30	0.0740	0.0740	0.5366	0.8538	0.9786	0.7402	0.2691	0.1004	0.0361	0.0091	0.0027
4b(L)	50.38	0.0910	0.0890	0.6069	0.9031	0.9906	0.6320	0.1991	0.0672	0.0209	0.0040	0.0010
5	54.85	0.1700	0.1580	0.8203	0.9863	0.9998	0.2589	0.0411	0.0071	0.0008	0.0000	0.0000
6	62.25	0.1050	0.0970	0.6406	0.9226	0.9940	0.5615	0.1830	0.0792	0.0365	0.0128	0.0045
7	68.36	0.0820	0.1040	0.6672	0.9361	0.9959	0.5649	0.1690	0.0541	0.0172	0.0038	0.0016
8a(L)	71.48	0.0980	0.1200	0.7210	0.9589	0.9983	0.4887	0.1581	0.0557	0.0182	0.0036	0.0011
8(R)	72.67	0.1660	0.2170	0.9129	0.9978	1.0000	0.2312	0.0389	0.0083	0.0020	0.0006	0.0002
8b(L)	75.23	0.1640	0.2040	0.8982	0.9967	1.0000	0.2440	0.0502	0.0159	0.0064	0.0027	0.0016
9	77.36	0.2840	0.3080	0.9749	0.9999	1.0000	0.0928	0.0207	0.0068	0.0022	0.0007	0.0003
10a(R)	80.58	0.2450	0.2760	0.9606	0.9997	1.0000	0.1330	0.0226	0.0049	0.0011	0.0002	0.0001
10a(L)	79.15	0.4550	0.4230	0.9959	1.0000	1.0000	0.0228	0.0021	0.0003	0.0000	0.0000	0.0000
10b(R)	85.62	0.5230	0.4770	0.9985	1.0000	1.0000	0.0268	0.0134	0.0089	0.0062	0.0042	0.0034
10b(L)	86.95	0.5190	0.4670	0.9981	1.0000	1.0000	0.0356	0.0230	0.0174	0.0138	0.0107	0.0094
11	90.37	0.5390	0.4980	0.9990	1.0000	1.0000	0.0147	0.0046	0.0024	0.0014	0.0008	0.0006
12	92.51	0.3870	0.3690	0.9900	1.0000	1.0000	0.0889	0.0395	0.0240	0.0151	0.0092	0.0070
13	96.64	0.1920	0.2150	0.9117	0.9977	1.0000	0.2630	0.1153	0.0639	0.0381	0.0201	0.0132
14	100.24	0.3020	0.3160	0.9776	0.9999	1.0000	0.0915	0.0293	0.0133	0.0065	0.0027	0.0016
15	105.31	0.2220	0.2390	0.9351	0.9989	1.0000	0.2302	0.1081	0.0693	0.0507	0.0379	0.0328
16	110.61	0.1610	0.2070	0.9014	0.9969	1.0000	0.3207	0.1336	0.0737	0.0461	0.0297	0.0239
17	117.04	0.1430	0.1870	0.8735	0.9943	1.0000	0.3499	0.1678	0.1089	0.0760	0.0516	0.0417
18	121.58	0.0880	0.1410	0.7805	0.9774	0.9995	0.5202	0.2670	0.1472	0.0779	0.0339	0.0199
19	124.23	0.1400	0.2180	0.9148	0.9979	1.0000	0.3987	0.2202	0.1252	0.0652	0.0267	0.0144

Table 5-3 Long Term Risk and Conditional Non-Exceedance Probability under Recommended Plan

Reach	Target Stage	Target Stage Annual Expected Probability		Long-Term Risk (Years)			Conditional Non-Exceedance Probability by Event					
		Median	Expected	10	25	50	10%	4%	2%	1%	.4%	.2%
1	32.94	0.0550	0.0550	0.4322	0.7570	0.9410	0.8792	0.4067	0.1700	0.0637	0.0141	0.0040
2	32.26	0.0900	0.0880	0.6031	0.9007	0.9901	0.6389	0.1751	0.0485	0.0108	0.0010	0.0001
3	44.13	0.0750	0.0760	0.5457	0.8609	0.9807	0.7254	0.2791	0.1014	0.0301	0.0046	0.0008
4a(L)	39.83	0.3460	0.3200	0.9789	0.9999	1.0000	0.0103	0.0001	0.0000	0.0000	0.0000	0.0000
4(R)	50.19	0.0610	0.0620	0.4732	0.7986	0.9594	0.8242	0.3614	0.1455	0.0521	0.0121	0.0036
4b(L)	50.38	0.0730	0.0730	0.5301	0.8486	0.9771	0.7464	0.2931	0.1117	0.0378	0.0078	0.0020
5	55.14	0.1280	0.1200	0.7224	0.9594	0.9984	0.4280	0.1082	0.0288	0.0059	0.0005	0.0000
6	61.04	0.1130	0.1050	0.6702	0.9375	0.9961	0.5128	0.1424	0.0441	0.0116	0.0014	0.0003
7	68.25	0.0500	0.0700	0.5161	0.8371	0.9735	0.7658	0.3611	0.1535	0.0546	0.0117	0.0034
8a(L)	71.43	0.0620	0.0840	0.5845	0.8887	0.9876	0.6799	0.2904	0.1178	0.0412	0.0086	0.0024
8(R)	72.75	0.0730	0.0990	0.6463	0.9256	0.9945	0.6147	0.2175	0.0729	0.0214	0.0036	0.0011
8b(L)	75.32	0.0410	0.0590	0.4543	0.7800	0.9516	0.8413	0.4407	0.1994	0.0785	0.0233	0.0101
9	77.35	0.1010	0.1340	0.7619	0.9723	0.9992	0.4605	0.1410	0.0473	0.0157	0.0035	0.0013
10a(R)	80.97	0.0470	0.0750	0.5407	0.8570	0.9796	0.7607	0.3959	0.1901	0.0800	0.0226	0.0077
10a(L)	79.15	0.1430	0.1860	0.8731	0.9943	1.0000	0.3370	0.0974	0.0305	0.0084	0.0014	0.0004
10b(R)	85.44	0.0870	0.1190	0.7174	0.9575	0.9982	0.5303	0.1915	0.0758	0.0321	0.0133	0.0085
10b(L)	87.01	0.0720	0.0950	0.6310	0.9173	0.9932	0.6216	0.2514	0.1112	0.0520	0.0265	0.0195
11	90.45	0.2600	0.2910	0.9678	0.9998	1.0000	0.1205	0.0266	0.0087	0.0031	0.0014	0.0009
12	92.54	0.1710	0.2030	0.8966	0.9966	1.0000	0.2633	0.0958	0.0467	0.0251	0.0127	0.0087
13	96.64	0.0740	0.1030	0.6637	0.9344	0.9957	0.5905	0.2944	0.1586	0.0810	0.0348	0.0210
14	100.25	0.0940	0.1360	0.7672	0.9739	0.9993	0.4975	0.1920	0.0781	0.0302	0.0082	0.0031
15	105.31	0.0610	0.0970	0.6400	0.9222	0.9940	0.6492	0.3356	0.1782	0.0916	0.0414	0.0275
16	110.53	0.0350	0.0710	0.5225	0.8424	0.9752	0.7752	0.4999	0.3007	0.1603	0.0632	0.0325
17	117.02	0.0370	0.0610	0.4669	0.7925	0.9569	0.8140	0.4957	0.2963	0.1832	0.1146	0.0907
18	121.58	0.0700	0.1200	0.7225	0.9594	0.9984	0.5938	0.3115	0.1718	0.0902	0.0382	0.0220
19	124.23	0.1330	0.2160	0.9125	0.9977	1.0000	0.4031	0.2061	0.1193	0.0650	0.0274	0.0148

TABLE 5-3a
FLOOD REDUCTIONS FOR 10%, 4% & 1% EVENTS

	TYPICAL REDUCTION IN FLOOD DEPTHS (FEET)		
REACH	**10%**	**4%**	**1%**
Mouth	1.3	0.9	0.05
I-610	0.5	0.3	0.05
Cole Creek	0.2	0.1	0.1
North-Houston Rosslyn	3.2	2.3	1.7
Fairbanks-North Houston	3.0	1.4	0.4
Beltway 8	3.4	2.4	1.2
Jones Road	2.5	1.8	0.9
Huffmeister	0.1	0.0	0.0

5.3 Environmental Quality Considerations of Recommended Plan

An environmental assessment was performed to evaluate social, economic, and environmental impacts of the Recommended Plan (RF-31). The findings of the environmental assessment are presented in the Environmental Assessment. The following summarizes the main findings of the Environmental Assessment.

5.3.1 Wildlife and Wildlife Habitat

The White Oak Bayou watershed lies within the Houston metropolitan area, which has been highly impacted by human activities. The degree and extent of the changes in habitat have directly influenced the numbers and species of wildlife found in the area. The project study area has been disturbed through past channel modifications and urban development. Forested areas within the study area can be found within existing detention facilities and scattered areas adjacent to the bayou.

For the earthen channel modifications, impacts to wildlife, including aquatic species, are expected to be minimal and temporary in nature since displaced wildlife is expected to return following completion of the construction activities. The existing HCFCD right-of-way along the top of banks on both sides of the White Oak Bayou channel is generally grass, which is mown on a regular basis. The 10.81 acres of additional right-of-way required for the project is defined as urban. The banks of the bayou including the additional right-of-way will be reseeded after construction is complete in order to reduce erosion and establish ground cover.

Generally, existing trees along the bayou are adjacent to the fence lines of adjacent property owners and do not appear to be within HCFCD right-of-way; therefore, there would be no impacts to trees with at least an eight inch diameter-at-breast height (dbh) within the White Oak Bayou channel component. New trees and shrubs would be planted along the bayou. Tree species planted will be similar to those which currently exist along White Oak Bayou and will be planted in clusters. Approximately 4,810 trees and 4,810 shrubs are estimated to be planted along the bayou.

The Jersey Village channel is a combination of two manmade HCFCD drainage channels. The vegetation within these drainage channels is maintained grassland and herbaceous wetland vegetation. Once deepening and widening of the Jersey Village is complete, the banks will be reseeded and the wetland vegetation is expected to reestablish within the channel. Therefore, no additional plantings are being considered along the Jersey Village channel.

In the areas of the proposed detention basins, impacts to wildlife would be temporary, and wildlife species may change from forest and scrub/shrub to grassland species. Existing trees and shrubs will remain in place to create an approximate 50 to 150 foot vegetative

buffer zone at each basin; however, sight lines into the detention facility will be cut for the safety of the users and surrounding neighbors. These vegetative buffer zones will act as a buffer between the detention basins and the surrounding roadways. In addition, the basins will be revegetated with trees, shrubs, and native grasses.

It is anticipated that the 5,600 trees and shrubs will be planted in clusters. The side slopes and perimeter would be seeded with grass after construction is completed to establish ground cover and reduce erosion.

5.3.2 Threatened and Endangered Species

One federally listed endangered plant species, the Texas Prairie Dawn-Flower (*Hymenoxys texana*), was identified within the FNH.3-south detention basin land area but will not be impacted by basin development. Suitable habitat also exists on the HOL.3B detention basin land area. The known *H. texana* populations that exist on FNH.3-south are flagged and monitored yearly. The suitable habitat site on HOL.3B will not be impacted as a result of the proposed project, as it lies within the proposed 150-foot buffer zone.

5.3.3 Water Quality

Water quality in White Oak Bayou and its tributaries is generally poor. The water quality is representative of an urbanized basin in which streamflow consists primarily of effluent from active wastewater treatment plants and urbanization along the channel. No significant impacts to the area surface water quality are expected to occur as a result of the proposed project. No long-term water quality impacts are expected as a result of the proposed project. Temporary impacts would be associated with localized increases in turbidity levels during construction, which would dissipate shortly after completion of construction activities. Since the project would not involve the need for subsurface water, no effect on groundwater or the water table is anticipated.

Construction activities for the proposed project would comply with the Texas Pollutant Discharge Elimination System (TPDES) permit and the local Stormwater Quality (SWQ) permitting process, mandated by the Texas Commission on Environmental Quality (TCEQ) and the Environmental Protection Agency (EPA) to control discharges of pollutants to surface waters of the United States. Construction for the proposed project will require preparation of a notice of intent (NOI) and the preparation of a stormwater pollution prevention plan (SW3P) per the NPDES permit and a stormwater quality management permit (SWQMP) per the local municipal separate storm sewer system (MS4) permit. HCFCD and its contractor(s) are responsible for filing the NOI.

5.3.4 Wetlands

Wetland determinations were conducted along White Oak Bayou within the project area from Cole Creek to FM 1960. The results indicated stream channel wetlands exist within the proposed project right-of-way located within and along both banks of the bayou. The stream channel wetlands impacted totals 2.3 acres.

Excavated soil from the proposed project will not be disposed of in a wetland area.

Wetland determinations were also conducted on the detention basins. The detention basin impact to wetlands totals 10.87 acres. The total amount of impacts to waters, including wetlands, within the Recommended Plan (LPP) totals approximately 13.17 acres (2.3 acres/channel and 10.87 acres/detention basins). A least cost mitigation plan was developed to off-set the impact to the 13.17 acres. The least cost plan consists of buying 4.99 acres of wetlands at the Greens Bayou mitigation bank. In addition Local Sponsor Volunteer Mitigation, consisting of constructing seven acres of wetlands at the HOL.3B detention basin, is proposed. The cost of this mitigation is a Local Sponsor cost, and is not included in the Recommended Plan costs or economic results. More detailed information on the wetlands mitigation is contained Section 5.1.4 and in the Environmental Assessment.

5.3.5 Cultural Resources

The following summarizes the findings of the archeological and historic investigations that have been conducted along the proposed project. Coordination with the Texas Historical Commission (THC) began in 1999 and is on-going.

<u>Channel Modifications</u>
Although no archeological resources impacts are anticipated to occur along the White Oak Bayou channel, archeological investigations resulted in the determination that a qualified archeologist should monitor all bank excavation deeper than 75-centimeters (30 inches) between Cole Creek and West Road, including the areas encompassing the 10.81 acres of additional ROW. The THC concurred with the recommendations that no further cultural resources investigations are necessary prior to construction from West Road to FM 1960.

No archeological resources impacts are anticipated to occur along the Jersey Village channel. Archeological investigations resulted in THC concurrence that no further archeological work would be required for the proposed Jersey Village channel improvements.

No historical impacts would occur to buildings or structures 50 years or older within the existing ROW of the White Oak Bayou channel from Cole Creek to FM 1960 or the 10.81 acres of additional ROW required from Cole Creek to Gessner Drive.

Detention Basins

No archeological resources impacts would occur within the HOL.3B detention basin complex. The proposed design to deepen and widen this detention basin complex would continue to protect two prehistoric sites that exist within the forested buffer zone from impacts by allowing the sites to remain in the forested buffer zone.

No archeological resources impacts would occur to the northern and southern portions of the FNH.2 detention basin complex.

No archeological resources impacts would occur to the portion of the GBW.3 detention basin complex located north of Brookriver Drive; however, additional work is recommended in the portion south of Brookriver Drive, due to lack of right-of-entry at this time.

No historical impacts would occur to buildings or structures 50 years or older within the five detention basin complexes.

Soil Disposal

Excavation activity was initiated after January 1, 1998 on some properties that were subsequently identified as components of the Recommended Plan.

During the start of the proposed project (January 1, 1998) to December 2005, complete soil disposal records were not maintained; however, communications with contractors confirm the vast majority of the soil generated from local project construction went to private developments, building pads, road projects, landfills, and sandpits. Those uses are expected, considering the high urbanization of Houston and Harris County.

Beginning in December 2005, the HCFCD began analyzing soil disposal sites. Records of Environmental Consideration (REC's) have been used to document approved soil disposal sites after June 2007. During the analysis to complete a REC, if it is discovered that there is a potential to impact environmental resources on the proposed disposal site, the disposal site will be rejected for project use. If the site is clear after the REC investigation, a REC for the disposal site will be kept on file at HCFCD and USACE.

If a contractor cannot dispose of soil at a site approved as a REC, two alternative disposal sites have been identified. The two disposal sites are a landfill and a sand pit. Both operations are fully functioning, licensed vendors who have stated they are available to receive the excavated material. Should the soil not remain with the licensed vendor, the operators would notify HCFCD of the location to which the soil is to be removed prior to removal. The HCFCD would conduct environmental investigations to assure the soil removal locations are free of environmental concerns.

Programmatic Agreement

A Programmatic Agreement (PA) has been prepared for the Recommended Plan. The PA addresses cultural and historical resources to ensure that the most recent guidance, policies and interpretation is utilized. A copy of the PA and correspondence is included in the Environmental Assessment.

5.3.6 Hazardous, Toxic and Radioactive Wastes (HTRW)

Based on the HTRW investigations for the Recommended Plan, three Leaking Underground Storage Tank (LUST) sites and one Texas Voluntary Cleanup Program (TXVCP) site were identified as potential concerns.

Further investigation of the three LUST sites results in the sites not presenting a significant environmental concern based on the regulatory status and lack of contaminants of concern in the monitoring well located closest to the project area.

A file review of the TXVCP site was conducted to determine the extent of soil contamination, depth to groundwater, groundwater gradient, and plume size. The file review concluded that a Limited Phase II investigation would be necessary to determine if any subsurface impacts from the TXVCP site are present. A Limited Phase II investigation was conducted on July 20, 2006 and a subsequent investigation was conducted in August 2006. The investigations concluded that the excavation depths planned at the JR.4 west detention basin are located above the impacted groundwater. A letter was sent to the TCEQ on August 23, 2006, requesting concurrence with the findings of the above-referenced Limited Phase II investigation. The TCEQ responded in a letter dated September 20, 2006 that they concur with the findings of the report. Specifically, in the event that soils encountered at depth in the southeast portion of the site have been impacted by chlorinated solvents from the TXVCP site, they should be tested to determine the possible reuse of the soil as fill material.

5.3.7 Air Quality and Ambient Noise Levels

Air Quality

In Harris County, Texas, the approved Clean Air Act (CAA) implementation plan is the Attainment Demonstration State Implementation Plan for the Houston-Galveston-Brazoria (HGB) Ozone Nonattainment Area. HGB is categorized as a moderate nonattainment area for ozone and its precursors Nitrogen Oxides and Volatile Organic Compounds. Based on an air emissions inventory of proposed project emissions, NOx and VOC emissions do not exceed the current de minimis threshold of 25 tons per year for the duration of the proposed project. As a result, project emissions are deemed to be in General Conformity with the HGB State Implementation Plan and no further analysis is required.

Emissions produced by construction vehicles and equipment as well as dust from construction activities are anticipated; however, these emissions would be temporary. The adverse impact of temporary emissions during construction can be minimized by the use of emission control devices.

Noise

No noise impacts are anticipated as a result of the proposed project due to the fact that the proposed project will not generate lasting increases in traffic or noise as a result of project implementation.

5.3.8 Land Use and Recreational Resources

Land Use

Based on aerial photographs, approximately 90 percent of the study area is developed (2002 conditions). Development in the watershed is continuing at a significant level. The proposed development in the watershed will be primarily located in the upstream (northwest) reaches. The detention sites provide recreation opportunities.

Recreational Resources

Recreational resources in the White Oak Bayou watershed are primarily man-made facilities due to the extensive urban development within the watershed. Very limited natural areas still remain within the project study area. Exhibit 2-5 depicts the existing and proposed recreation facilities within the watershed. A Recreation Plan was prepared as part of this study (see Appendix F - Recreation Plan). Harris County Precinct No. 4 has agreed to be the Local Sponsor for Recreation. Federal cost-sharing of the Recreation Plan has been included in the Recommended Plan.

The proposed project would utilize the existing right-of-way along White Oak Bayou, requiring 10.81 acres of additional right-of-way for the channel modifications, and 395 acres of additional right-of-way for detention facilities. No temporary construction easements and no additional ROW are required from the six parks within the project area. Therefore, no impacts would occur to the six parks.

The City of Houston has a planned City of Houston Bicycle Network to connect the surrounding communities within the Houston metropolitan area. Impacts would occur to 3.5 miles of the 9.81-mile West White Oak Bayou Trail Extension. However, the City has use of the HCFCD ROW for the trail with the understanding that HCFCD projects will take priority over City projects. Coordination has begun to replace any trails impacted by construction.

5.4 Flood Damage Reduction and Other Social Effects

The proposed project plays an important role in social aspects of the community by reducing the impacts caused by flooding and improving the safety of the community. In addition, those residences where potential property acquisition is required to implement the project are directly affected by the plan. The following paragraphs describe the social effects associated with implementation of the Recommended Plan (RF-31).

5.4.1 Flood Damage Reduction

As shown in Exhibit 5-12, the Recommended Plan reduces flood damages along the entire reach of the stream length. The plan results in approximately 58 percent average annual flood damage reduction as compared to the No Action Plan. It is estimated that, with the implementation of the Recommended Plan, the flood damages would be reduced from approximately $80 to $12 million for a single ten percent occurrence flood event and from $431 to $333 million for a single one percent occurrence flood event. After implementation of the Recommended Plan, the existing one percent floodplain would be reduced in size to the extent that approximately 1,325 structures that are currently within the one percent floodplain would no longer be within the reduced one percent floodplain resulting from the Recommended Plan.

5.4.2 Potential Property Acquisition

The Recommended Plan would result in the potential displacement of 32 structures; 18 residences and one out-building located along the channel, and two commercial structures located within the Gessner/Beltway 8 (south of Brookriver Drive) detention basin complex, These displacements and relocations will result in social impacts to those being displaced, unless they find nearby areas to relocate. The proximity to churches, schools, and friends will be changed due to these relocations.

5.4.3 Impacts on Environmental Justice

Executive Order (EO) 12898, Federal Action to Address Environmental Justice in Minority Populations and Low-Income Populations, requires that minority and low-income populations not receive disproportionately high and adverse human health or environmental effects. This EO requires agencies to ensure that achieving environmental justice is part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.

An environmental justice analysis was performed to determine the potential effects of the Recommended Plan on low-income and minority populations. The environmental justice

analysis concluded that the proposed action would not result in disproportionately high adverse impacts to minority populations. A detailed description of the analysis is presented in the Environmental Assessment.

5.4.4 USACE Environmental Operating Principles

Regarding the USACE's seven Environmental Operating Principles, the Recommended Plan supports the USACE's Principles as follows:

(1) Foster sustainability as a way of life throughout the organization – The plan components do not compromise the needs of future generations and do not unreasonably commit the resources of future generations.
(2) Proactively consider environmental consequences of all Corps activities and act accordingly – The environmental consequences were considered throughout the plan development and the plan mitigates wetlands habitat losses.
(3) Create mutually supporting economic and environmentally sustaining solutions – The plan produces significant flood reduction and recreation economic benefits and avoids detrimental environmental actions.
(4) Continue to meet our corporate responsibility and accountability under the law for activities undertaken by the Corps – All applicable laws and regulations are being adhered to in the plan development and implementation.
(5) Consider the environment in employing a risk management and systems approach throughout life cycles of projects and programs – Risk factors were identified for the plan, and the project was evaluated for environmental impacts over the life of the project
(6) Leverage scientific, economic, and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner – Not applicable to this project.
(7) Employ an open transparent process that respects the views of individuals and groups interested in Corps activities – The views of all stakeholders and groups affected by the plan were solicited and considered in the plan development.

The USACE published its Campaign Plan, published on August 24, 2006, resulting from lessons learned during Hurricane Katrina and were updated on October 2012. The Recommended Plan was reviewed for consistency with the actions.

5.5 Regional Economic Development

Implementation of the Recommended Plan (RF-31) is expected to have positive benefits for Regional Economic Development (RED). The reduction of flooding will have positive benefits in terms of reduction in business losses, reduced disruption to residents, reduced disruption to traffic patterns and increased public wellbeing. The reduction in flooding events can also be expected to remove the economic stigma for the areas affected, resulting in increases in property values.

Construction related to the Recommended Plan will also create jobs in a wide variety of industries extending throughout the region. In addition to direct construction jobs, this increased economic activity will have a multiplier effect resulting in increased job activity for support industries such as equipment rental, suppliers and contractors that are located throughout the region.

5.6 Recreation Plan

A Recreation Plan has been prepared as part of this GRR (see Appendix F - Recreation Plan). The Recreation Plan proposes recreational activities that are compatible with the proposed channel modifications and detention facilities, such as hike/bike trails, nature trails, picnic areas, multi-purpose fields, play areas and public open space areas. The proposed project would incorporate many of the same recreation features as proposed in the City of Houston Parks and Recreation Master Plan and the Harris County Parks and Recreation Master Plan. Harris County Precinct No. 4 has agreed to be the Local Sponsor for Recreation. The overall Recreation Plan is shown on Exhibit 5-1a and is discussed in more detail in Section 5.1.3 and in Appendix F – Recreation Plan. Benefits for the Recreation Plan were computed using the Corps Unit Day Value methodology, as described in Appendix F.

5.7 Operation and Maintenance Considerations

Typical operations, maintenance, repair, replacement and rehabilitation (OMRR&R) activities primarily consist of mowing the right-of-way, slope repair, riprap or concrete slope protection, maintenance of inlet and outlet control structures, weed control, debris removal, turf maintenance, desilting, and backslope drain system repair. The OMRR&R program for the components of the proposed action will be similar to the current OMRR&R activities within the watershed. Additional maintenance will be required for newly planted trees and shrubs.

OMRR&R costs are defined as the increase in cost associated with the implementation of the proposed project. The annual OMRR&R costs associated with the flood risk management components of the Recommended Plan (RF-31) are approximately $328,000 based on FY 2013 costs. A detailed discussion of the OMRR&R costs is found in Appendix C - Cost Estimates. Annual OMRR&R costs for the Recreation Plan are estimated to be $73,000, also based on FY 2013 costs. The costs are discussed in Appendix F- Recreation Plan

5.8 Plan Implementation

The Recommended Plan, as described previously in Section 5.1, is the plan proposed for implementation. The plan consists of several flood risk reduction components, several recreation components and two environmental mitigation components, all described in

Section 5.1. The plan complies with all USACE policies including those under Section 211 of WRDA 1996. The plan is economically well justified based on the net benefits that have been calculated for the plan. The components of the plan are technically feasible and environmentally acceptable and the plan is in compliance with all NEPA requirements. All the Recommended Plan components comply with USACE standard policies and are proposed for Federal cost-sharing, with the exception of the wetlands mitigation components. The least cost wetlands mitigation alternative was identified and the Federal cost share is based on this alternative. The Local Sponsor intends to provide Local Sponsor Volunteer Mitigation, consisting of additional wetlands mitigation in excess of the amount required by Federal law which will be paid for entirely by the Local Sponsor. The cost of this mitigation is not included in the Recommended Plan costs or economic results.

Under the authority of Section 211of WRDA 1996, the Local Sponsor has constructed some of the flood risk reduction components of the Recommended Plan and acquired the environmental mitigation component located in Subdivision A of the Greens Bayou Mitigation Bank. The status of the construction is discussed in Section 5.1.5. All of the recreation features remain to be constructed. The components that have already been constructed and those planned to be constructed are compatible with the Recommended Plan, as required by Section 211 (e)(2)(B). The costs associated with the components already constructed as well as the future construction are presented in Section 5.9.1 and Table 5.6. Cost-sharing for the constructed items has been shown in conformance with Corps of Engineers requirements.

Implementation of the remaining project components and project cost-sharing for the entire project will be based on a Project Partnership Agreement (PPA). The PPA outlines the responsibilities of the Federal government and the HCFCD (Local Sponsor) for specifically authorized new construction projects. A PPA for the White Oak Bayou project will be prepared upon approval of the GRR. Presented as Attachment 1 is a letter of intent from the HCFCD (Local Sponsor), expressing its intent to support the Recommended Plan and to cooperate fully with its responsibilities to implement the plan, as described later in this section. Attachment 2 provides a statement from the HCFCD (Local Sponsor) regarding its commitment to provide the required local financing of the Recommended Plan.

The following paragraphs provide a description of the anticipated implementation responsibilities and implementation schedule for the White Oak Bayou project.

5.8.1 Assistant Secretary of the Army for Civil Works Approval

It is recommended that the Assistant Secretary of the Army for Civil Works (ASA(CW)) approve the Recommended Plan (Plan RF-31) in this GRR. Approval of the Recommended Plan (RF-31) by the Assistant Secretary falls within the existing statutory construction authority approved by Congress.

5.8.2 Federal Funding

Prior to executing the PPA and initiating construction as a federal project, a construction new start is needed to move the project from General Investigations account to the Construction General account.

In addition, White Oak Bayou Project is subject to the federal funding limitations designated in the Section 102 of Public Law 106-60, FY 2000 Energy and Water Development Appropriations Act, as amended. Section 102 was enacted to clarify the rules regarding credit or reimbursement for work performed by non-federal interests and to ensure that such credits or reimbursement agreements do not have unanticipated fiscal consequences.

Policy Guidance Letter No. 53, Implementation of Section 211 of WRDA 1996, includes the following information related to federal funding worth noting that is not included in the law itself:

- The non-Federal sponsor is required to remit previously received reimbursements in the event that the non-Federal sponsor fails to complete the entire project.
- For Section 211(f) projects, incremental reimbursement is possible for completion of a discrete segment. A discrete segment is a physical portion of the project described in design documents, that is environmentally acceptable, is complete, will not create a hazard, and functions independently so that the non-Federal sponsor can operate and maintain it in advance of completion of the total project. The HCFCD has tentatively arranged the flood damage reduction components into discrete segments as shown in the implementation schedule in Table 5-5.
- Any reimbursement desired by a non-Federal sponsor for studies or design it accomplished prior to authorization must be specifically identified and requested in the authorizing document. To the extent this requirement might apply to the White Oak Bayou Section 211(f) Project, the estimated Federal share for previously completed work for which reimbursement would be requested is included in Table 5-8.

5.8.3 Implementation Responsibilities

Implementation of the Recommended Plan will be carried out under a PPA. Based on the project authority of Section 401(a) of WRDA 1986 and the sponsor implementation authority of Section 211 of WRDA 1996, the following generally describes the roles of the USACE (Federal Government) and the HCFCD (Local Sponsor).

The Federal Government will have the responsibility to:

1) Review the plans and specifications and approve them if they satisfy the criteria for this project.

2) Monitor and inspect, if desired, the construction of the project.
3) Confirm that the project is constructed in accordance with the plans and permits and according to applicable Federal and Corps standards.
4) Audit requests submitted by the Local Sponsor for credit toward the local sponsor's share of the total project costs and reimbursement for the federal share of the costs.
5) Reimburse the HCFCD for the eligible and reasonable Federal share of the costs, subject to appropriations being available.

The HCFCD will have the following responsibilities for all the flood risk reduction and mitigation components:

1) Provide the lands, easements, rights-of-way, relocations, and disposal areas (LERRD's) for the project
2) Conduct the design for the project and prepare items such as planning and design documents, environmental documentation, real estate requirements, cost estimates, schedule for design and construction, and operation and maintenance requirements.
3) Obtain all applicable permits required for the project. HCFCD will apply for section 404 permits before and after the GRR and EA are approved.
4) Prepare detailed plans and specifications and solicitations for construction contracts.
5) Construct the work in accordance with the plans and specifications and permits.
6) Prepare operations and maintenance manuals, then operate and maintain the project after construction.
7) Submit invoices documenting credit and reimbursement requests.
8) Submit documentation supporting credit toward the local sponsor's share of the total project costs.

The Local Sponsor for the Recreation Plan, Harris County Precinct No.4, in cooperation with the HCFCD will have these same responsibilities for implementation of the Recreation Plan components.

Items of Local Cooperation

Presented as follows is a more detailed list of the items of local responsibility with which the HCFCD will be required to comply. Federal participation in the Recommended Plan would be subject to the HCFCD agreeing to comply with applicable Federal laws and policies, including but not limited to these items to be performed by the Local Sponsor:

a. Section 211 Work (Planning and Design)

1. Provide written notice to the Government that identifies the nature and scope of the Section 211 work to be carried out.
2. Within a mutually agreed upon time thereafter, submit detailed plans for carrying out such work to the Government for approval. Such plans shall include, but are not necessarily limited to, planning and design documents, environmental

documentation, real estate requirements including relocations and P.L. 91-646 assistance benefits, cost estimate, schedule for the further design and construction of the Section 211 work, and operations and maintenance requirements.

3. After the District Engineer provides the written determination and the written approval of the plans, prepare detailed plans and specifications and solicitations for construction contracts for implementation of that Section 211 work and submit such documents to the District Engineer for review and approval.
4. Submit such additional documentation as the District Engineer may require to reflect that all necessary Federal and State permits have been obtained and to reflect compliance with all requirements of NEPA including those contained in Section 401 and Section 404 of the Federal Water Pollution Control Act, as amended (33 U.S.C. Sec. 1341 and Sec. 1344).

b. Section 211 Work (Construction)

1. Construct Section 211 work in accordance with the approved plans, plans and specifications, and permits.
2. The Section 211 work may be accomplished with their own work forces or by contract. If performed by contract, secure competitive bids by advertising, and award all contracts to the lowest responsive, responsible bidder.
3. To the extent possible, afford the Government the opportunity to review and comment on all contract claims prior to resolution thereof.
4. Notify the District Engineer in writing when construction of each discrete segment of the Section 211 work is physically complete.
5. Furnish the Government with an Operation, Maintenance, Repair, Replacement, and Rehabilitation Manual (hereinafter the “OMRR&R Manual”), subject to review and approval by the Government.
6. After Government acceptance of Section 211 work as part of the Project, submit such information as the Government may require to determine the amount of costs of the Section 211 work that shall be included in total project costs and the amount of reimbursement owed to the Local Sponsor for construction of such work.

c. (Item deleted)

d. May elect to construct betterments during the period of construction. If so, will notify the Government in writing and describe the betterments it intends to construct. Solely responsible for all costs due to the requested betterments, including costs associated with obtaining permits and shall pay all such costs directly to its contractor or contractors and without reimbursement by the Government.

e. Provide a minimum of 25 percent, but not to exceed 50 percent of total flood damage reduction costs as further specified below:

1. Provide the required non-Federal share of design costs allocated by the Government to flood damage reduction in accordance with the terms of a design agreement entered into prior to commencement of design work for the flood damage reduction features;

2. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs allocated by the Government to flood damage reduction;

3. Provide, during construction, a contribution of funds equal to 5 percent of total flood damage reduction costs;

4. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the flood damage reduction features;

5. Provide, during construction, any additional funds necessary to make its total contribution for flood damage reduction equal to at least 25 percent of total flood damage reduction costs;

f. Provide 50 percent of total recreation costs as further specified below:

1. Provide the required non-Federal share of design costs allocated by the Government to recreation in accordance with the terms of a design agreement entered into prior to commencement of design work for the recreation features;

2. Provide, during the first year of construction, any additional funds necessary to pay the full non-Federal share of design costs allocated by the Government to recreation;

3. Provide all lands, easements, and rights-of-way, including those required for relocations, the borrowing of material, and the disposal of dredged or excavated material; perform or ensure the performance of all relocations; and construct all improvements required on lands, easements, and rights-of-way to enable the disposal of dredged or excavated material all as determined by the Government to be required or to be necessary for the construction, operation, and maintenance of the recreation features;

4. Provide, during construction, any additional funds necessary to make its total contribution for recreation equal to 50 percent of total recreation costs;

g. Provide, during construction, 100 percent of the total recreation costs that exceed an amount equal to 10 percent of the Federal share of total flood damage reduction costs;

h. Shall not use funds from other Federal programs, including any non-Federal contribution required as a matching share therefore, to meet any of the non-Federal obligations for the project unless the Federal agency providing the Federal portion of such funds verifies in writing that expenditure of such funds for such purpose is authorized;

i. Not less than once each year, inform affected interests of the extent of protection afforded by the flood damage reduction features;

j. Agree to participate in and comply with applicable Federal floodplain management and flood insurance programs;

k. Comply with Section 402 of the Water Resources Development Act of 1986, as amended (33 U.S.C. 701b-12), which requires a non-Federal interest to prepare a floodplain management plan within one year after the date of signing a project cooperation agreement, and to implement such plan not later than one year after completion of construction of the flood damage reduction features;

l. Publicize floodplain information in the area concerned and provide this information to zoning and other regulatory agencies for their use in adopting regulations, or taking other actions, to prevent unwise future development and to ensure compatibility with protection levels provided by the flood damage reduction features;

m. Prevent obstructions or encroachments on the project (including prescribing and enforcing regulations to prevent such obstructions or encroachments) such as any new developments on project lands, easements, and rights-of-way or the addition of facilities which might reduce the level of protection the flood damage reduction features afford, hinder operation and maintenance of the project, or interfere with the project's proper function;

n. Keep the recreation features, and access roads, parking areas, and other associated public use facilities, open and available to all on equal terms;

o. Comply with all applicable provisions of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, Public Law 91-646, as amended (42 U.S.C. 4601-4655), and the Uniform Regulations contained in 49 CFR Part 24, in acquiring lands, easements, and rights-of-way required for construction, operation, and maintenance of the project, including those necessary for relocations, the borrowing of materials, or the disposal of dredged or excavated material; and inform all affected persons of applicable benefits, policies, and procedures in connection with said Act;

p. For so long as the project remains authorized, operate, maintain, repair, rehabilitate, and replace the project, or functional portions of the project, including any mitigation features, at no cost to the Federal Government, in a manner compatible with the project's authorized purposes and in accordance with applicable Federal and State laws and regulations and any specific directions prescribed by the Federal Government;

q. Give the Federal Government a right to enter, at reasonable times and in a reasonable manner, upon property that the non-Federal sponsor owns or controls for access to the project for the purpose of completing, inspecting, operating, maintaining, repairing, rehabilitating, or replacing the project;

r. Hold and save the United States free from all damages arising from the construction, operation, maintenance, repair, rehabilitation, and replacement of the project and any betterments, except for damages due to the fault or negligence of the United States or its contractors;

s. Keep and maintain books, records, documents, or other evidence pertaining to costs and expenses incurred pursuant to the project, for a minimum of 3 years after completion of the accounting for which such books, records, documents, or other evidence are required, to the extent and in such detail as will properly reflect total project costs, and in accordance with the standards for financial management systems set forth in the Uniform Administrative Requirements for Grants and Cooperative Agreements to State and Local Governments at 32 Code of Federal Regulations (CFR) Section 33.20;

t. Comply with all applicable Federal and State laws and regulations, including, but not limited to: Section 601 of the Civil Rights Act of 1964, Public Law 88-352 (42 U.S.C. 2000d) and Department of Defense Directive 5500.11 issued pursuant thereto; Army Regulation 600-7, entitled "Nondiscrimination on the Basis of Handicap in Programs and Activities Assisted or Conducted by the Department of the Army"; and all applicable Federal labor standards requirements including, but not limited to, 40 U.S.C. 3141-3148 and 40 U.S.C. 3701 – 3708 (revising, codifying and enacting without substantial change the provisions of the Davis-Bacon Act (formerly 40 U.S.C. 276a et seq.), the Contract Work Hours and Safety Standards Act (formerly 40 U.S.C. 327 et seq.), and the Copeland Anti-Kickback Act (formerly 40 U.S.C. 276c et seq.);

u. Perform, or ensure performance of, any investigations for hazardous substances that are determined necessary to identify the existence and extent of any hazardous substances regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Public Law 96-510, as amended (42 U.S.C. 9601-9675), that may exist in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project. However, for lands that the Federal Government determines to be subject to the navigation servitude, only the Federal Government shall perform such investigations unless the Federal Government provides the non-Federal sponsor with prior specific written direction, in which case the non-Federal sponsor shall perform such investigations in accordance with such written direction;

v. Assume, as between the Federal Government and the non-Federal sponsor, complete financial responsibility for all necessary cleanup and response costs of any hazardous substances regulated under CERCLA that are located in, on, or under lands, easements, or rights-of-way that the Federal Government determines to be required for construction, operation, and maintenance of the project;

w. Agree, as between the Federal Government and the non-Federal sponsor, that the non-Federal sponsor shall be considered the operator of the project for the purpose of CERCLA liability, and to the maximum extent practicable, operate, maintain, repair, rehabilitate, and replace the project in a manner that will not cause liability to arise under CERCLA; and

x. Comply with Section 221 of Public Law 91-611, Flood Control Act of 1970, as amended (42 U.S.C. 1962d-5b), and Section 103(j) of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2213(j)), which provides that the Secretary of the Army shall not commence the construction of any water resources project or separable element thereof, until each non-Federal interest has entered into a written agreement to furnish its required cooperation for the project or separable element.

Additions and modifications to these items may occur during the process of developing the final PPA.

Value Engineering

A value engineering study of the Recommended Plan will be performed in the future during the Preliminary Engineering Design (PED) phase of the plan implementation, per previous discussions with the USACE Galveston project team. The results of the previous value engineering study for the Brays Bayou project, which is a similar project, and the input received from the USACE Galveston District concerning development of alternatives and engineering methodologies have been considered in the engineering planning that has occurred.

5.8.4 Implementation Schedule

A preliminary implementation schedule for the construction of the remaining unconstructed components of the project is presented in Table 5-5. The following assumptions were used to develop the schedule:

1) The start of construction of the project is 1998. The current goal is to complete the remaining flood control components and all the recreation components by mid-year 2018. All of the flood control components of the Recommended Plan except those listed in Table 5-5 were constructed between 1998 and 2011.
2) Approximately $20 million would be available per year to fund the project.
3) Each detention basin and each remaining channel component are and would be constructed as discrete segments.

A preliminary list of the remaining steps for approval of this report is presented here. The first two steps have already been completed

	Start Date	Completion Date
USACE Galveston distribute GRR & EA	***3/2013***	***4/2013***
EA Public Comment Period	***4/2013***	***4/2013***
Final Policy Review	**9/25/2013**	**10/25/13**
ASA (CW) Approval	**10/25/13**	**11/25/13**
ASA Review & Approval of Project Partnership Agreement	**11/25/13**	**11/25/14**

5.9 Project Financial Analysis

The following paragraphs present the costs associated with the Recommended Plan (RF-31), the economic summary, the cost sharing responsibilities, and a discussion of the Local Sponsor's ability to pay.

5.9.1 Project Costs

The estimated first cost for the Recommended Plan is approximately $117 million, based on the actual costs expended for completed construction, and estimated costs for future construction. A summary of the project first costs, based on the actual costs and future estimates are presented in Table 5-6. The construction costs for future construction were based on year FY 2013 price levels. Estimates of material, equipment, and labor costs for typical work in this area were used to develop the construction costs for the future phases. Real estate costs were developed based on gross appraisals as described in Appendix E - Real Estate Plan. Detailed cost estimates with quantities and descriptions based on the MCACES are provided in Appendix C - Cost Estimates. A risk analysis was performed using estimated risk factors for the major cost items, without percentage contingencies. The analysis used the Crystal Ball risk analysis software. A contingency of 23 % was recommended to provide an 80 % probability that the resulting cost would not be exceeded. This contingency was applied only to the future construction items and is included in the cost summary. The Total Project Cost Summary is provided as Attachment 4. All costs are consistent with the requirements of Section 211 of WRDA 1996. The approval of this report does not guarantee the tracts previously acquired by the Local Sponsor will receive full credit solely based on the amounts stated in Table 5-6 of the GRR Report.

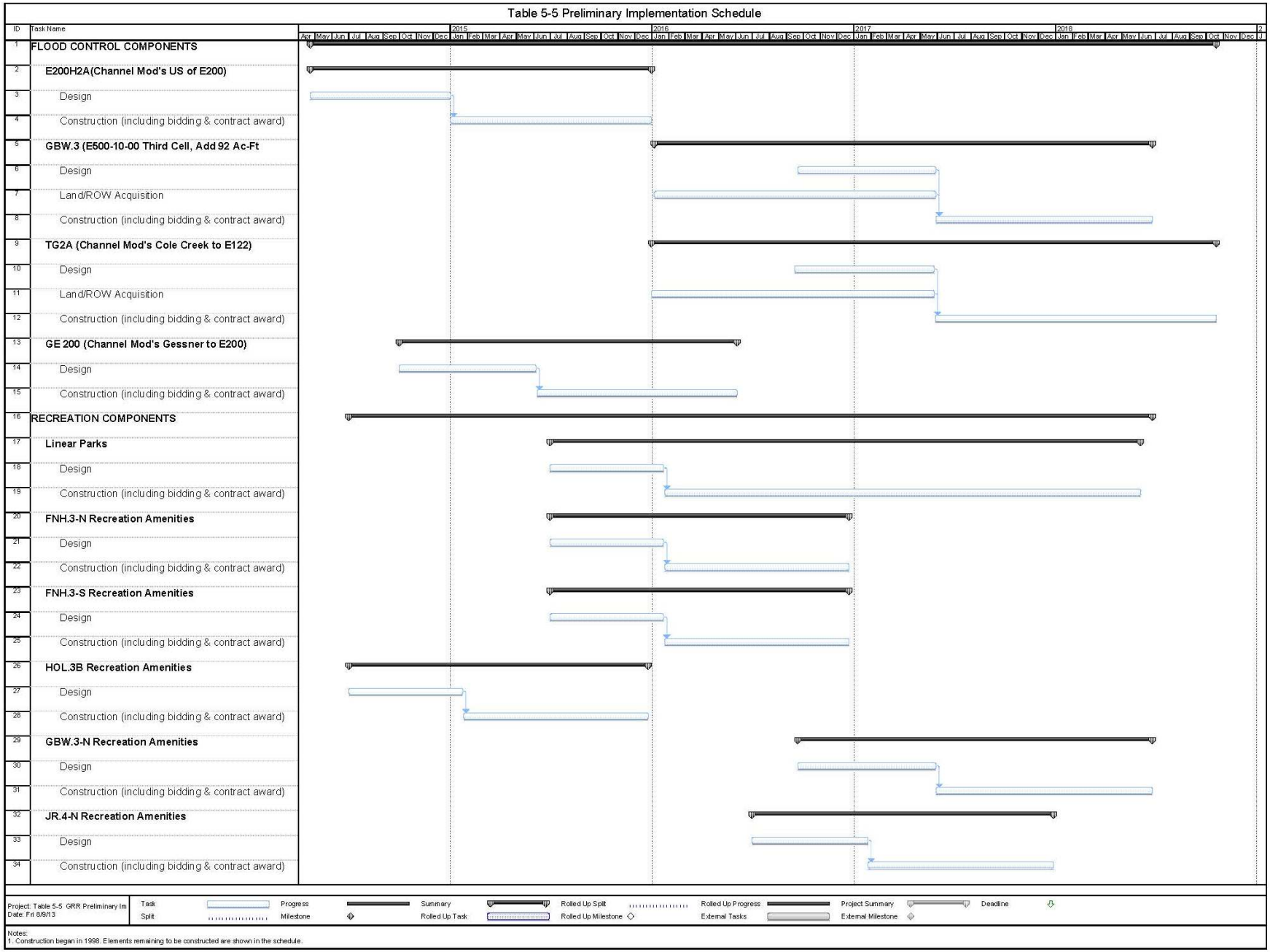


Table 5-5 Preliminary Implementation Schedule
ID
Task Name
1 FLOOD CONTROL COMPONENTS
2 E200H2A(Channel Mod's US of E200)
3 Design
4 Construction (including bidding & contract award)
5 GBW.3 (E500-10-00 Third Cell, Add 92 Ac-Ft
6 Design
7 Land/ROW Acquisition
8 Construction (including bidding & contract award)
9 TG2A (Channel Mod's Cole Creek to E122)
10 Design
11 Land/ROW Acquisition
12 Construction (including bidding & contract award)
13 GE 200 (Channel Mod's Gessner to E200)
14 Design
15 Construction (including bidding & contract award)
16 RECREATION COMPONENTS
17 Linear Parks
18 Design
19 Construction (including bidding & contract award)
20 FNH.3-N Recreation Amenities
21 Design
22 Construction (including bidding & contract award)
23 FNH.3-S Recreation Amenities
24 Design
25 Construction (including bidding & contract award)
26 HOL.3B Recreation Amenities
27 Design
28 Construction (including bidding & contract award)
29 GBW.3-N Recreation Amenities
30 Design
31 Construction (including bidding & contract award)
32 JR.4-N Recreation Amenities
33 Design
34 Construction (including bidding & contract award)
2015
2016
2017
2018
Project: Table 5-5 GRR Preliminary Im
Date: Fri 8/9/13
Task
Split
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Split
Rolled Up Milestone
Rolled Up Progress
External Tasks
Project Summary
External Milestone
Deadline
Notes:
1. Construction began in 1998. Elements remaining to be constructed are shown in the schedule.

Table 5-6
Cost Estimate Summary for the Recommended Plan
Values in $ FY 2013 Price Level

Description	Total Costs w/ 23% Cont.	Actual	Future Costs w/ 23% Cont.
LANDS & DAMAGES			
Channelization E122 to Gessner (37,313 LF)	$456,000	$456,000	$0
Detention at Gessner/Beltway 8 (1,175 AC-FT TOTAL)	$7,555,000	$4,095,000	$3,460,000
Detention at Fairbanks North Houston (3,831 AC-FT)	$5,569,000	$5,569,000	$0
Detention at Hollister (730 AC-FT)	$1,011,000	$1,011,000	$0
Detention at Jones Road (774 AC-FT)	$9,879,000	$9,879,000	$0
Channelization Vogel Creek to E122	$531,000		$531,000
Channelization Vogel Creek to Cole Creek	$239,000		$239,000
RELOCATIONS			
Detention at Gessner/Beltway 8 (1,175 AC-FT TOTAL)	$1,779,000		$1,779,000
Detention at Fairbanks North Houston (3,831 AC-FT)	$0		$0
Detention at Hollister (730 AC-FT)	$103,000	$103,000	$0
Channelization from E200 to FM 1960 (17,971 LF)	$4,610,000		$4,610,000
Channelization Vogel Creek to E122	$5,589,000		$5,589,000
Channelization Vogel Creek to Cole Creek	$2,371,000		$2,371,000
CHANNELS & CANALS			
Channelization E122 to Gessner (37,313 LF)	$7,408,000	$7,408,000	$0
Detention at Gessner/Beltway 8 (1,175 AC-FT TOTAL)	$4,327,000	$2,821,000	$1,506,000
Detention at Fairbanks North Houston (3,831 AC-FT)	$5,578,000	$5,578,000	$0
Detention at Hollister (730 AC-FT)	$7,504,000	$7,504,000	$0
Detention at Jones Road (774 AC-FT)	$8,003,000	$8,003,000	$0
Channelization from E200 to FM 1960 (17,971 LF)	$2,656,000		$2,656,000
Channelization from Gessner to E200 (10,983 LF)	$12,410,000	$8,965,000	$3,445,000
Channelization Vogel Creek to E122	$4,648,000		$4,648,000
Channelization Vogel Creek to Cole Creek	$2,290,000		$2,290,000
MITIGATION			
Wetlands Mitigation - Greens Bayou Mitigation Bank	$127,000	$0	$127,000
Cultural Resources Mitigation – None	$0	$0	$0
PLANNING, ENGINEERING, and DESIGN (Flood Control)	$3,093,000	$1,352,000	$1,741,000
CONSTRUCTION MANAGEMENT (Flood Control)	$8,369,000	$5,467,000	$2,902,000
TOTAL COST FLOOD RISK COMPONENTS	$106,105,000	$68,211,000	$37,894,000

Table 5-6 (cont.)
Cost Estimate Summary for the Recommended Plan
Values in $FY 2013 Price Level

Description	Total Costs w/ 23 % Cont.	Actual	Future Costs w/ 23 % Cont.
RECREATION FACILITIES			
Detention at Gessner/Beltway 8 (1,175 AC-FT TOTAL)	$1,174,000		$1,174,000
Detention at Fairbanks North Houston (3,831 AC-FT)	$1,948,000		$1,948,000
Detention at Hollister (730 AC-FT)	$1,118,000		$1,118,000
Detention at Jones Road (774 AC-FT)	$633,000		$633,000
Linear Parks	$4,492,000		$4,492,000
PLANNING, ENGINEERING, and DESIGN (Recreation)	$562,000		$562,000
CONSTRUCTION MANAGEMENT (Recreation)	$937,000		$937,000
TOTAL COST RECREATION PLAN COMPONENTS	$10,864,000		$10,864,000
GRAND TOTAL	$116,969,000	$68,211,000	$48,758,000

Note 1. Contingencies of 23 % applied only to Future Costs.
Note 2. All costs shown are first costs without escalation.
Note 3. All costs listed as Actual are for construction already completed.
Note 4. Grand Total includes the total first cost of Flood Risk Components and Recreation Plan Components.
Note 5. Only the least-cost Environmental Mitigation Plan cost of $127,000 ($103,000 plus contingency) will be cost-shared with the Federal government. Local Sponsor Volunteer Mitigation is not included in the costs.

Table 5-7 : Economic Summary for the Recommended Plan, FY 2013 Price Level

Value in $ FY 2013 Price Level, 3.75% interest,
50-year period of analysis

Item No.	Description	Recommended Plan with 23% Contingencies for Future Construction Items Only
1	LERRD (Flood Risk Management)	$42,131,000
2	Construction (Flood Damage Reduction)	$63,974,000
3	Project First Cost	$106,105,000
4	Interest During Construction	$3,258,000
5	Total Investment	$109,363,000
Flood Risk Management Plan Annual Cost		
6	Interest and Amortization	$4,875,000
7	OMRR&R	$328,000
8	Total Annual Cost	$5,203,000
Flood Risk Management Plan Equivalent Annual Benefit		
9	Flood Damage Reduction Benefit	$35,562,000
10	Benefits from Saving Insurance Cost	$179,000
11	Total Equivalent Annual Benefit	$35,741,000
Flood Risk Management Plan Comparison of Benefit to Cost		
12	Benefit-Cost Ratio	6.9
13	Net Annual Benefit	$30,538,000
Recreation Plan Costs		
14	Recreation Plan First Cost	$10,864,000
15	Interest During Construction	$940,000
16	Total Investment	$11,804,000
Recreation Plan Annual Cost		
17	Interest and Amortization	$526,000
18	OMRR&R	$73,000
19	Total Annual Cost	$599,000
Recreation Plan Benefit		
20	Recreation Benefit	$2,662,000
Recreation Plan Comparison of Benefit to Cost		
21	Benefit-Cost Ratio	4.4

5.9.2 Economic Summary

Table 5-7 presents the economic summary of the Recommended Plan (flood risk management components) and the Recreation Plan. The flood risk management cost includes the $127,000 cost of environmental impact mitigation. The project first cost plus interest during construction were converted to an annual basis, using a 50-year amortization period and the current 2013 Federal interest rate of 3.75 percent.

Phased construction of the remaining unconstructed components of the proposed project is anticipated. The proposed project implementation schedule is summarized in Table 5-5, which shows the anticipated construction schedule. Table 5-6 also shows the first cost for each component of the project. The total investment cost was computed to account for interest during the construction period, which was estimated based on the implementation schedule presented in Table 5-5. The annualized cost for the plan was used to compute the benefit-cost ratio.

For the Recommended Plan, based on FY 2013 price levels the total project investment for the flood risk management components, including the total project first cost of $106.1 million and interest during construction of $3.3 million, is $109.4 million, as shown in Table 5-7. The plan would have annual costs of $5.2 million, net annual equivalent benefits of $30.5 million, and a benefit-cost ratio of 6.9, based on the FY 2013 interest rate of 3.75 %. Based on a 7.00 % interest rate, the net benefits are $27.3 million and the benefit cost ratio is 4.2.

For the Recreation Plan, based on FY 2013 price levels the total first cost is $10.9 million and the total investment is $11.8 million, as shown in Table 5-7. The annual costs are $0.60 million, with net annual benefits of $2.1 million and a benefit-cost ratio of 4.4. Based on a 7.00 % interest rate, the net benefits are $1.7 million and the benefit cost ratio is 2.9.

5.9.3 Cost Sharing

Section 103 of WRDA 86 (Public Law 99-662) specifies the cost sharing requirements for this project. The requirements are summarized below.

The following is a summary of cost sharing for flood control components:

1) The Local Sponsor will contribute a minimum of 5 percent of the flood control features in cash.
2) The Local Sponsor will provide all lands, easements, rights-of-way, relocations, and material disposal (LERRD) necessary for the project.
3) OMRR&R costs will be the sole responsibility of the Local Sponsor. .
4) If the Local Sponsor ’s contribution from cash and LERRD is less than 25 percent of the total project cost, the Local Sponsor will contribute the additional amount in cash to make the total contribution equal to 25 percent. The 25 % contribution amount is based on the cost-sharing in place when the Upper White Oak Bayou project was authorized under WRDA 1986.

5) The maximum non-Federal contribution will not exceed 50 percent of the total project cost.
6) If the value of LERRD exceeds 45 percent of the total project cost, the Federal government will reimburse the Local Sponsor the value in excess of 45 percent of the total project cost.

The Recommended Flood Risk Management Plan has an estimated total project fully funded cost of $110.3 million, based on FY 2013 price levels. The Federal share of these costs is calculated to be $60.9 million or 55.2 percent, and the Local Sponsor's share of these costs is calculated to be $49.4 million or 44.8 percent. Table 5-8 summarizes the cost sharing details. The Federal LERRD cost is for a railroad bridge modification. The bridge modification of the Burlington Northern Railroad bridge, located at station 72983, would be the only Federal LERRD cost item. Also shown in the table are costs for the proposed Recreation Plan. The total fully funded cost of the Recreation Plan is $11.8 million. The Federal cost of a project including recreation may not exceed the Federal cost of the project excluding recreation by more than ten percent without prior approval by the Secretary of the Army. The maximum allowable Federal participation would be $5.9 million. The Federal and non-Federal shares based on a 50-50 split would be $5.9 million, which is within the allowable limit.

Table 5-8

White Oak Bayou, Texas

Cost Apportionment for the

Recommended Plan

(FY 2013 Price Level - All Costs in $)

Item	Federal Cost	Non-Federal Cost	Total Cost
Flood Risk Management Components			
5% Cash	($5,514,000)	$5,514,000	$0
LERR&D	$266,000	$43,883,000	$44,149,000
Construction-Federal Cost Share	$66,138,000	$0	$66,138,000
50% Adjustment	$0	$0	$0
Subtotal	$60,890,000	$49,397,000	$110,287,000
(Percent) *	55.2	44.8	
HTRW	$0	$0	$0
Recreation Plan	$5,900,000	$5,900,000	$11,801,000
Recommended Plan Total Project			**$122,088,000**

LERR&D = Lands and damages, easements, rights-of-way, relocations, & disposal costs.

* Non-Federal costs will be no less than 25% and not greater than 50% for the NED Plan.
All costs shown are fully funded costs.
Local Sponsor Volunteer Mitigation Cost is not included in this table.

5.9.4 Section 902 Limitations

Section 902 of WRDA of 1986 defines the maximum amount that a project may cost. This is often called the 902 Limit or Project Cost Cap. It is, “The maximum project cost limit imposed by Section 902 is a numerical value specified by law which must be computed in a legal manner according to guidance provided in ER 1105-2-100 Appendix G).” The maximum project cost includes the authorized cost (adjusted for inflation), the current cost of any studies, modifications, and action authorized by WRDA ’86 or any later law, and 20 percent of the authorized cost (without adjustment for inflation). The cost of modifications required by law is to be kept separate and added to other allowable costs. These three components equal the maximum project cost allowed by Section 902.

The project authorized under WRDA 1986 consists of the following components:

1. Channel enlargement, rectification, and partial paving of 9.2 miles of upper White Oak Bayou channel, 4.9 miles of Cole Creek, and 4.5 miles of Vogel Creek;

2. Nonstructural floodplain management consistent with the National Flood Insurance Program requirements along the remaining headwater reaches of the streams including about 5.6 miles of upper White Oak Bayou, 2.0 miles of Cole Creek, and 2.0 miles of Vogel Creek;

3. Installation and construction of aesthetic and beautification features; and

4. Construction of a recreational development plan on existing flood control rights-of-way along 3.8 miles of White Oak Bayou to include 8.1 miles of hike and bike trails on either stream bank and one neighborhood park with recreation equipment and picnic facilities.

The authorized cost is $92.1 million, based on 1986 cost levels. Using the procedure prescribed in ER1105-2-100, the current Section 902 limit was estimated. The limit is $201 million. The flood damage reduction components of the Recommended Plan are estimated in Section 5.9.1 above to cost approximately $110 million including risk and uncertainty, and the total project cost is estimated to be approximately $122 million including risk and uncertainty and recreation costs All these project costs are for FY 2013 and are based on actual cost for components that have already been constructed. Attachment 3 contains the Section 902 calculations summary and related information. Based on these costs, the Recommended Plan is within the Section 902 limit.

5.10 Public Involvement

Public involvement and participation is an integral part of the planning study to ensure that a flood risk management project for the White Oak Bayou watershed is publicly supported. The public involvement was coordinated through a series of public meetings, citizen advisory committee meetings, and literature prepared by HCFCD. Documentation of the public involvement is provided in Appendix G - Public Involvement.

5.10.1 Public Meetings

Two public meetings were held to date during the study. The first public meeting was held at the start of the study to introduce the public to the project. The second meeting was held after the initial formulation of alternatives for the project.

The first meeting was held on September 17, 1998 at which the residents expressed interest for a Federal flood control project for White Oak Bayou. The purpose of the meeting was to introduce the public to the project and project team, provide background information on channel improvements and studies within the watershed, and provide an overall description and schedule of the project planning process. The meeting was attended by approximately 500 persons. A large audience attended the meeting because of the heightened public awareness of flooding experienced during a September 11, 1998 tropical storm event (Tropical Storm Frances) that affected many residents in the watershed. The written comments submitted by the public meeting attendees are included as Attachment G-2 in Appendix G - Public Involvement.

A second series of meetings was held on November 29, 2000 at St. Matthew Catholic Church, 9915 Hollister and on November 30, 2000 at Scarborough High School, 4141 Costa Rica to present the status of the Federal planning study along with some of the alternatives under consideration. A total of 452 persons signed attendance sheets at the two meetings. The public response was generally favorable to the material presented. The written comments submitted by the attendees at the two public meetings are included as Attachments G-4 and G-5 in Appendix G - Public Involvement.

5.10.2 Citizens Advisory Committee

The White Oak Bayou Advisory Committee (WOBAC) was created at the onset of the study through the Harris County Flood Control Task Force. The primary focus of the committee was to review project status periodically, to provide comments and suggestions regarding project direction and public involvement, and to serve as a point of contact for interested individuals or groups in the watershed. The WOBAC members included people representing the City of Houston, the City of Jersey Village, the Texas Department of Transportation (TxDOT), civic associations, industry, developers, and environmental groups. Six meetings with the WOBAC were held during the study. The meetings were held prior to the public meetings and to periodically provide updates on the status of the project.

5.10.3 Other Activities

The following is a list of other activities conducted to insure public involvement and communication for the project.

1. The White Oak Bayou Association (WOBA) is a citizen's organization that has participated in the public involvement process. HCFCD attended numerous meetings of the WOBA.
2. HCFCD has held and continues to hold coordination meetings with the affected municipalities, especially the City of Jersey Village.
3. Newspaper articles have been published regarding the project and the status of construction activities.
4. In areas where individual residents and landowners are impacted by the project, the HCFCD has communicated directly with the affected persons.
5. The HCFCD maintains a website where information on all its projects is available. A specific page is dedicated to the White Oak Bayou Flood Damage Reduction Plan. This page describes the project history and the ongoing project activities and provides a map of the project area. Over the past two and one half years, the page has received an average of 220 unique visitors per month.
6. The draft Environmental Assessment as well as the draft Final Report for the project will be distributed to public libraries within the project area and placed on the HCFCD website for review and receipt of public comment, when these documents have been approved for publication by the USACE-HQ. All comments received will be addressed by the HCFCD.

5.11 Section 575 Analysis

No construction or buyout efforts performed by the local sponsor need analysis as required in Section 575

5.12 Comparison of Recommended Plan & Previously Authorized Project

The following is a comparison of the Recommended Plan to the project previously authorized by Congress in Section 401(a) of WRDA 1986. A brief discussion of the authorized project is presented in Sections 1.1 and 1.5. The evaluations in this section show that the level of protection features and environmental effects of the Recommended Plan remain within the scope of the project authorized by Congress and are within the discretionary authority of the Chief of Engineers to approve changes to the Authorized Project without additional Congressional authorization.

The Authorized Federal Project in Upper White Oak Bayou is based on the Report of the Chief of Engineers dated June 13, 1978 (Reference 4). A full range of alternatives was considered including three nonstructural measures - flood proofing, floodplain evacuation (buyout), and land use restrictions as well as three structural measures – channel enlargement, detention reservoirs, and diversion of floodwaters. The Authorized Project consists of the following features:

1. Channel enlargement, rectification, and partial paving of 9.2 miles of White Oak Bayou, 4.9 miles of Cole Creek, and 4.5 miles of Vogel Creek;

2. Nonstructural floodplain management consistent with the National Flood Insurance requirements along the remaining headwater reaches of the streams including about 5.6 miles of White Oak Bayou, 2.0 miles of Cole Creek, and 2.0 miles of Vogel Creek.
3. Installation and construction of aesthetic and beautification improvements in areas frequently viewed by the public; and
4. Construction of a recreational development plan on existing flood control rights-of-way along 3.8 miles of White Oak Bayou to include 8.1 miles of hike and bike trails on either stream bank and one neighborhood park with recreation equipment and picnic facilities.

The Recommended Plan as described previously in Section 5.1 is different in scope and concept. The Recommended Plan is described in Section 5.1. It includes measures for the White Oak Bayou main channel but not Cole Creek or Vogel Creek because the Local Sponsor decided to develop plans for those tributaries outside of the Federal planning process prior to the initiation of this GRR. The current planning process considered several types of structural and non-structural components in building a solution, including combinations of channel modifications and detention basins. The result is a flood risk management plan that includes stormwater detention basins and less extensive earthen channel modifications than the authorized project. A comparison of the major plan features, costs, and economic results to the Authorized Project is presented in Table 5-9.

The Authorized Project was designed to control flooding for the Standard Project Flood, which in 1976 was considered to be a flood greater than the 1 percent probability flood. The peak flow for the Standard Project Flood at Cole Creek is approximately 26,000 cfs, based on the 1976 hydrological methodology, and inundates approximately 4,500 residences prior to implementation of the Authorized Project. For the Recommended Plan, the without project 1 percent peak flow at Cole Creek is approximately 24,500 cfs based on the current hydrological methodology, and inundates approximately 5,633 residences for existing conditions. The Recommended Plan generally controls flooding up to approximately between the 10 percent and 4 percent flood and reduces flooding for less frequent events. For the 10, 4 and 1 percent floods, the residences inundated are 50,, 1,283, and 4,749, respectively, after implementation of the Recommended Plan. Average annual damages are estimated to be reduced by $10.5 million and $35.7 million respectively, for the Authorized Project and the Recommended Plan, based on FY 2013 values. The FY 2013 values for the damages for the Authorized Project were estimated using the same escalation factors that were used to escalate the costs. Significant differences exist in how damages were calculated for the Authorized Project and the Recommended Plan including differences in hydrological methodologies and economic analysis methodologies including how future development is handled.

Table 5-9 Comparison of Recommended Plan To Authorized Federal Project

Item	1986 Authorized Plan	Recommended Plan
Channel Modifications	White Oak Bayou 9.2 miles, Cole Creek 4.9 miles, Vogel Creek 4.5 miles	White Oak Bayou 12.4 miles
Detention Basins	None, detention basins were considered in the planning process.	Four basins - 403 acres, 3386 acre-feet of storage
Non-Structural	Nonstructural floodplain management consistent with the National Flood Insurance requirements along the remaining headwater reaches of the streams including about 5.6 miles of White Oak Bayou, 2.0 miles of Cole Creek, and 2.0 miles of Vogel Creek.	None, although non-structural components including floodplain management through controls on building locations and first floor elevations and buyout were evaluated in the planning process and have been undertaken separately by other municipalities and the HCFCD.
Environmental Mitigation	None	Wetlands mitigation - least-cost mitigation 4.99 acres Greens Bayou Wetlands Mitigation Bank, Local Sponsor Volunteer Mitigation 7 acres in Hollister detention basin
Recreation Plan	Construction of a recreational development plan on existing flood control rights-of-way along 3.8 miles of White Oak Bayou to include 8.1 miles of hike and bike trails on either stream bank and one neighborhood park with recreation equipment and picnic facilities.	12 miles hike-and-bike trails along White Oak Bayou, 2 wetlands/wildlife areas and 4 neighborhood parks located at the four detention basins
Flood Protection Performance	Protection for Standard Project Flood (greater than 1% probability flood, based on 1976 criteria and methods	Generally provides protection to 4% probability flood and reduces the magnitude of flooding and severity of damages during less frequent
Annual Flood Damage Reduction	$3.14 million (1976), $10.5 million (FY 2013)	$35.7 million (FY 2013)
Flood Plan Total Cost (Fully Funded)	$53.4 million (1976), $173 million (FY 2013)	$110.3 million (FY 2013)
Flood Plan Net Benefits	$2.89 million (1976), $9.7 million (FY 2013)	$30.5 million (FY 2013)
Flood Plan B-C Ratio	1.75	6.9
Recreation Plan Total Cost (Fully Funded)	$0.854 million (1976), $2.6 million (FY 2013)	$11.8 million (FY 2013)
Recreation Plan Net Benefits	$0.109 million (1976), $0.73 million (FY 2013)	$2.1 million (FY 2013)
Recreation Plan B-C Ratio	1.11	4.4
Federal - Non Federal Cost Share Amount (Including Recreation)	Federal $47.6 million (1976), $153 million (FY 2013), Non-federal $7.0 million (1976), $22.9 million (FY 2013)	Federal $66.8 million, (FY 2013) Non-Federal $55.3 million (FY 2013)
Federal - Non Federal Cost Share % (Including Recreation)	Federal 87 %, Non-Federal 13 %	Federal 54.7 %, Non-Federal 45.3 %
Section 902 Limit	$194 million (FY 2013)	$110 million (FY 2013, Fully Funded)
Environmental Compliance	No significant adverse environmental effects were identified for the Authorized Plan in the Environmental Impact Statement	No significant impacts to the environment were identified for the Recommended Plan in an Environmental Assessment prepared in accordance with NEPA requirements
Public Acceptance	Yes	Yes

Notes : Authorized project benefits were escalated to FY 2013 using same escalation factor as used for cost escalation.

Regarding costs and net benefits, the FY 2013 escalated cost of the Authorized Project is $173.2 million. The cost of the flood risk management portion of the Recommended Plan is $110.3 million. All costs are fully funded costs. Net benefits of the two are $9.7 million and $30.5 million, respectively. The benefit-cost ratios of the Authorized Project and the Recommended Plan are 1.7 and 6.9 respectively. Recreation plan current costs are $2.6 million and $11.8 million respectively, with net benefits of $0.73 million and $2.1 million respectively. Benefit-cost ratios are 1.1 and 4.4, respectively.

No significant adverse environmental effects were foreseen for the Authorized Project as documented in the Interim Report on Upper White Oak Bayou in April 1976. The Environmental Assessment, determined that implementation of the Recommended Plan would not result in significant impacts to the environment.

Public involvement was sought in the process of developing both the plans. For the development of the Recommended Plan, the local sponsor used an advisory committee and met numerous times with residents and interests groups. Multiple public meetings were held during the planning processes for both.

Based on a comparison of the physical features, benefits, and costs of both plans, Congressional reauthorization is not needed because:

- Recommended Plan is within the physical limits of the Authorized Project.
- Recommended Plan economic benefits are greater than for the Authorized Project.
- Relative level flood level reductions are comparable.
- Aesthetic and recreation features are comparable.
- Recommended Plan costs are less than the Authorized Project.

5.13 Determinations Required by Section 211

Section 211 and associated Policy Guidance Letter 53 contain several requirements and determinations to obtain approval of the plan from the ASA(CW) as a federal project and for HCFCD to be eligible for reimbursement of the Federal share and for credit toward the non-Federal share of the total project cost. Below are the requirements and a summary of how the plan satisfies the requirements.

- Technically sound – Based on the experience, capability, and integrity of the HCFCD staff, USACE staff, and local consultants who worked together, a technically sound plan was developed that was extensively reviewed in the Peer Review and ATR process.
- Economically justified – Applicable Corps requirements for economic analysis and evaluation were followed. Excess net economic benefits are $30.5 million and the BCR is 6.9 at 3.75 % satisfying the eligibility requirement as a Federal project, as shown in Section 5.9. Based on a 7.00 % interest rate, the net benefits are $27.3 million and the benefit cost ratio is 4.2.
- Environmentally acceptable – the full NEPA process was followed and successfully completed, as described in Section 5.3 and in the Environmental Assessment.

Permits such as Section 404 and the State's water quality Section 401 certification were and will be obtained for construction components.

- Follow appropriate Federal laws and criteria, standards and policies – The HCFCD and consultants staff have followed all applicable laws, criteria, standards and policies, to the best of their knowledge. The plan has also been reviewed by USACE staff for adherence to the applicable laws, criteria, standards and policies.
- Comply with applicable Federal and State laws and regulations – see response above.

Additional requirements of Section 211 related to construction, operation, maintenance and reimbursement are discussed above in Section 5.8.4.

5.14 Executive Order 11988 Compliance

Executive Order No. 11988 Floodplain Management requires to the extent possible that the Recommended Plan avoid or minimize adverse effects associated with use of the floodplain and avoid inducing development in the floodplain unless there is no practicable alternative. Attachment 6 presents a detailed discussion of the requirements of EO 11988 and how the Recommended Plan complies with the requirements of the EO.

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6.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations resulting from the studies that comprise the White Oak Bayou General Reevaluation Report. After careful consideration of the economic, environmental, social and technical aspects for obtaining efficient, environmentally acceptable, and safe flood damage reduction the Harris County Flood Control District recommends that the Recommended Plan as summarized in this chapter as follows and as described in more detail in Chapter 5 be approved for design and construction and that it continue as a Section 211(f) project in accordance with Section 211 of WRDA 1996, as amended. The Recommended Plan includes both a flood risk management plan and a recreation plan.

6.1 Summary and Conclusions

White Oak Bayou watershed drains approximately 110 square miles. It originates in northwest Harris County and flows southeast for approximately 25 miles through the City of Jersey Village and the City of Houston to its confluence with Buffalo Bayou in downtown Houston. The watershed is approximately 90 percent developed. Frequent flooding is primarily caused by a limited channel capacity and development in the watershed prior to floodplain regulations. Over 90 different configurations of structural and non-structural components were evaluated, including channel modification, detention basins, bypass channels, flood protection levees, replacement or modification of existing bridges, flood proofing, elevating structures, permanent relocation, and flood warning systems. Over 300 different combinations of structural/non-structural components were evaluated to maximize the net economic benefits.

These conclusions are based on the results, investigations, and analyses performed as part of this study. The summary of results is described in detail in this main report and the supporting technical appendices.

1. The need for this project is supported by the significant flooding history in the watershed and the inadequate capacity of the existing main channel. Nine significant floods have occurred since the completion of the Federal channel in the mid 1970's. Two most recent, substantial floods occurred in 1998 and 2001. Approximately 1,200 homes were flooded in the White Oak Bayou study area during Tropical Storm Frances in September 1998. Approximately 11,000 residences were flooded in the White Oak Bayou study area during Tropical Storm Allison in June 2001.

2. The Recommended Plan (RF-31) consists of the following improvements:

    - Earthen channel modifications along 15.4 miles from Tidwell Road to FM 1960. The channel modifications will utilize a trapezoidal earthen channel with varying bottom width, 3 horizontal: 1 vertical side slopes, and bottom widths ranging from 30 to 80 feet. A low-flow geomorphologic channel will be provided within the bottom width. This more natural modification will enhance the ambiance of the bayou and provide a suitable habitat for wildlife. The banks of the bayou will be reseeded to reduce erosion and establish ground

cover. New trees and shrubs will be planted along the channel modifications as restoration of aesthetic resources. An added benefit of the shrubs/understory plants is enhancement of the channel appearance.

- Four detention basins along White Oak Bayou providing approximately 2,938 acre-feet of storage. Detention sites will be revegetated with a substantial amount of trees and shrubs planted in clusters in order to mitigate the damages due to construction activities. The trees and vegetation within the detention facilities will promote the reintroduction of native habitat for wildlife. A minimum of a 50 foot vegetative buffer will be left around the sites in order to screen the detention facility from the surrounding land uses. There is opportunity to incorporate recreation elements within the detention basins, including multipurpose trails, picnic facilities, practice fields, and open play areas.

- **Recreation Plan:** Creation of a 12-mile linear park/bikeway from the confluence of White Oak Bayou and Cole Creek upstream to north of West Road. Recreational opportunities will also be provided with four parks within the detention basins which will provide multi-purpose trails, observation/teaching facilities, multi-purpose fields, and play areas.

- **Mitigation:** Mitigation of wetlands by utilizing 4.99 acres of wetland at the Greens Bayou Wetland Mitigation Bank, Subdivision A. This is the least-cost mitigation developed as part of the Wetlands Mitigation Cost Analysis. Also Local Sponsor Volunteer Mitigation consisting of construction of seven acres of wetlands in the HOL detention basin is proposed. This component will be a 100 percent local cost and is not included in the Recommended Plan costs or economics results.

3. The Recommended Plan is the plan supported by the Harris County Flood Control District.

4. No significant adverse Environmental Quality impacts were identified, and the proposed plan is considered to be the Environmentally Preferred Alternative. A total of approximately 13.2 acres of wetlands will be impacted with construction of the proposed project. Mitigation of this impact will be provided by the least-cost mitigation, purchasing 4.99 acres of wetlands at the Greens Bayou mitigation bank, and by Local Sponsor Volunteer Mitigation, consisting of constructing seven acres of wetlands at the HOL.3B detention basin. The Federal cost-share is based on the least-cost mitigation alternative, which costs $103,000. The additional Local Sponsor Volunteer Mitigation costs will be a 100 percent Local Sponsor cost, and are not included in the Recommended Plan costs or economics results. Proposed tree and shrub plantings along the channel improvements and within the detention facilities will be provided as part of the restoration of aesthetic resources and mitigation for woody vegetation impacts. It is anticipated that trees and shrubs will be planted in small clusters to provide a more natural forest setting, based on an equivalent of four trees and four shrubs per 100 foot length. The trees and vegetation within the detention facilities will promote the reintroduction of native habitat for wildlife.

5. No significant adverse Social Effects result from the plan. The proposed project plays an important role in social aspects of the community by reducing the impacts caused by flooding, improving the safety, and contributing towards community cohesion.

6. Regional Economic Development impacts are positive. The damage reduction and construction investment both are positive factors for the economy of the Houston region.

7. A Recreation Plan is included with this study. Harris County Precinct No. 4 has agreed to be the Local Sponsor. Federal cost-sharing for the recreation plan has been included in the Recommended Plan. The plan proposes passive recreational activities that are compatible with the proposed channel modifications and detention basins, such as hike and bike trails, nature trails, and public open spaces. Detention basins provide an opportunity for use as multipurpose facilities with recreation elements, including play areas, and ball fields.

8. The flood risk management components of the Recommended Plan have a first cost of $106.1 million and a fully funded cost of $110.3 million. The Federal and non-federal cost allocations for the fully funded cost are estimated to be $60.9 million (55.2 percent) and $49.4 million (44.8 percent), respectively. The Recreation Plan has a first cost of $10.9 million and a fully funded cost of $11.8 million. The Federal cost of a project including recreation may not exceed the Federal cost of the project excluding recreation by more than ten percent without prior approval by the Secretary of the Army. The maximum allowable Federal participation would be $5.9 million The Federal and non-Federal shares based on a 50-50 split would be $5.9 million, which is within the allowable limit. The costs presented here are based on FY 2013 price levels.

9. The Recommended Plan reduces average annual flood damages by approximately 58 percent, from approximately $61.2 million for the No Action Plan (without project) to approximately $25.7 million. Net annual benefits, including $0.2 million in flood insurance benefits, are approximately $30.5 million. The benefit-cost ratio is approximately 6.9. These values are based on FY 2013 price levels. Based on a 7.00 % interest rate, the net annual benefits are $27.3 million and the benefit cost ratio is 4.2. The following table summarizes the reduction in structural flooding for selective flood frequencies:

	Number of Flooded Structures		
Flood Frequency	**Without Project**	**With Recommended Plan**	**Reduction of Flooded Structures**
1%	6,074	4,749	1,325
4%	2,665	1,283	1,382
10%	1,333	50	1,283

The Recommended Plan reduces the one percent flood plain so that 1,325 are no longer subject to flooding from the one percent flood.

10. The Recreation Plan provides net benefits of $2.1 million and produces a benefit-cost ratio of 4.4, based on FY 2013 price levels. Based on a 7.00 % interest rate, the net annual benefits are $1.7 million and the benefit cost ratio is 2.7.

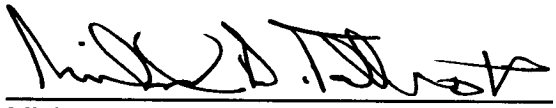
After careful consideration of the economic, environmental, social and technical aspects for obtaining efficient, environmentally acceptable, and safe flood damage reduction, the Harris County Flood Control District recommends that the Recommended Plan be approved for design and construction and that it continue as a Section 211(f) project in accordance with Section 211 of WRDA 1996, as amended.

Based on a comparison of the physical features, benefits, and costs of both plans, Congressional reauthorization is not needed and the Recommended Plan is within the discretionary authority of the Chief of Engineers because:

- Recommended Plan is within the physical limits of the Authorized Project.
- Recommended Plan economic benefits are greater than for the Authorized Project.
- Relative level flood level reductions are comparable.
- Aesthetic and recreation features are comparable.
- Recommended Plan costs are less than the Authorized Project.

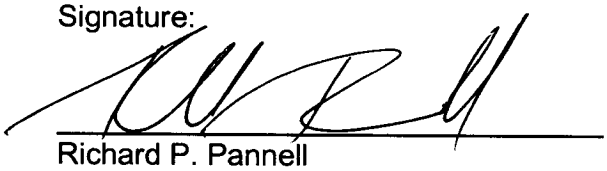
The Recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels within the Executive Branch. Consequently, the recommendations may be modified before they are transmitted to the Congress as proposals for implementation funding. However, prior to transmittal to the Congress, the Local Sponsor, the State, interested Federal agencies, and other parties will be advised of any modifications and will be afforded an opportunity to comment further.

Signature:



Michael Talbott, P.E.
Executive Director
Harris County Flood Control District

Signature:



Richard P. Pannell
Colonel, U.S. Army Corps of Engineers
District Engineer

7.0 REFERENCES

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2. Harris County Flood Control District, September 1984, *Harris County Flood Hazard Study, Final Report*.

3. Klotz Associates, Inc., April 1998, *Final Recommended Plan For White Oak Bayou*.

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6. U.S. Army Corps of Engineers, April 1985, *General Reevaluation Report of Upper White Oak Bayou*.

7. U.S. Army Corps of Engineers, 1988, *Feasibility Report on Buffalo Bayou and Tributaries*.

8. U.S. Army Corps of Engineers, Revised April 22, 2000 (December 28, 1990), *Guidance for Conducting Civil Works Planning Studies, ER 1105-2-100*.

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11. Texas Parks and Wildlife Department, August 1999, *Annotated County Lists of Rare Species.*

12. U.S. Army Corps of Engineers, 1961, *White Oak Bayou Channel Rectification, Design Memorandum No. 1.*

13. U.S. Army Corps of Engineers, 1963, *Buffalo and White Oak Bayou Channel Rectification General Design Memorandum No. 1 and White Oak Bayou Feature Design Memorandum No. 2.*

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17. U.S. Army Corps of Engineers, 1985, *General Reevaluation Report of Upper White Oak Bayou.*

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19. Hedwig Village, Texas; Satsuma, Texas; 1982.

20. CivilTech Engineering, Inc., 2004. *Memorandum Summarizing Verification Results*.

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Supporting Documentation

22. Carter & Burgess, Inc., June 2002, *Draft General Reevaluation Report, White Oak Bayou Federal Flood Control Project*.

23. Carter & Burgess, Inc., June 1999, *Component Screening Analysis, Hydrology & Hydraulics and Cost Estimates.*

ATTACHMENT 1

LOCAL SPONSOR LETTER OF INTENT

Harris County
Flood Control District

9900 Northwest Freeway
Houston, Texas 77092
713-684-4000
www.hcfcd.org

September 15, 2011

Colonel Christopher W. Sallese
District Engineer
U.S. Army Corps of Engineers
Galveston District
P.O. Box 1229
Galveston, TX 77553-1229

RE: Letter of Intent for the White Oak Bayou Flood Damage Reduction Project

Dear Colonel Sallese:

This letter is written to provide assurances to you that the Harris County Flood Control District ("HCFCD"), as the designated Local Sponsor for the White Oak Bayou Flood Damage Reduction Project, supports the project as described in the draft General Reevaluation Report, dated August 2011. Section 211(f) of the Federal Water Resources Development Act of 1996 (WRDA 1996, Public Law 104-303) authorized HCFCD to take the lead in developing a flood damage reduction plan for White Oak Bayou. The plan developed by HCFCD with the assistance of the U.S. Army Corps of Engineers, Galveston District, consists of the following elements:

1. Earthen channel modifications along 15.4 miles of White Oak Bayou from the confluence with Cole Creek to FM 1960.
2. Four detention basins along White Oak Bayou providing approximately 3,386 acre-feet of storage.

HCFCD intends to support implementation of the required design and construction of the project as well as fund the non-federal share of the project. The project will be implemented in accordance with all applicable federal, state, and local laws and regulations, and in accordance with the applicable provisions of the model Project Partnership Agreement (PPA), subject to any mutually agreeable revisions that may be made prior to formal acceptance and signing of the PPA.

We look forward to continuing our partnership with your office as we proceed with the implementation and funding of the project.

Sincerely,

Michael D. Talbott, P.E.
Director

MDT:WWC:cg

11MDT19.DOC

ATTACHMENT 2

LOCAL SPONSOR STATEMENT OF FINANCIAL RESPONSIBILITY

NON-FEDERAL SPONSOR'S
SELF-CERTIFICATION OF FINANCIAL CAPABILITY
FOR DECISION DOCUMENTS

I, Michael D. Talbott, do hereby certify that I am the Director of the Harris County Flood Control District (the "Non-Federal Sponsor"); that I am aware of the financial obligations of the Non-Federal Sponsor for the WHITE OAK BAYOU, TEXAS FEDERAL FLOOD DAMAGE REDUCTION PROJECT; and that the Non-Federal Sponsor will have the financial capability to satisfy the Non-Federal Sponsor's obligations for that project. I understand that the Government's acceptance of this self-certification shall not be construed as obligating either the Government or the Non-Federal Sponsor to implement the project.

IN WITNESS WHEREOF, I have made and executed this certification this 27 day of SEPTEMBER, 2011.

BY: _____
Michael D. Talbott

TITLE: Director

DATE: 9/27/11

ATTACHMENT 3

SECTION 902 COST LIMITATION DOCUMENTS

White Oak Bayou Federal Flood Risk Management Project
Section 902 Limit Determination (September 2013)

1. **White Oak Bayou Flood Risk Management Project**

2. **Section and Law That Authorized or Modified the Project:**

   Section 401(a)(30) WRDA 86 authorized the Upper White Oak Bayou project.

3. **Section 902 Limit on Project Cost: using certified 902 Tool.**

   a. **Authorized project cost (w/price level): $92.1 million (1986 price levels).**
   This amount was obtained from the WRDA 1986 authorization language.

   b. **Price level increases from date of authorized cost (FY 86 through FY 13): $82.7 million**.
   [$182.7 million-$92.1 million = $90.6 million].

   c. **Current cost of modifications required by law: $0**
   There are no known cost modifications required by law.

   d. **20% of authorized cost: $18.4 million.**

   e. **Maximum project cost limited by Section 902: $201.1 million.**

4. **Current Project Estimate, inflated through construction: $ 122.1 million**

5. **Computation of Percentage Increase:**

   a. **Current estimate: $122.1 million**

   b. **Less total of lines 3a, b, and c: $182.7 million**
   (5b=3a+3b+3c).

   c. **Subtotal: - $60.6 million**
   (5c=5a-5b)

   d. **Percent increase: -66 %.**
   (5c/3a*100)

6. **Explain cost indexes used in 3b; whether national or regional for real estate, and single state or two state average for construction.**

EM 1110-02-1304, dated 31 March 2000 with tables revised as of 31 March 2013, was utilized to determine national index costs. No attempt was made to escalate real estate separately because no information was available on real estate costs in the WRDA 1986 authorization language.

The cost indices were applied in accordance with the guidance in ER 1105-2-100, Appendix G, Tables G-1, G-3, and G-4.

7. Explain increases in 3c; Legislation requiring the modification and how accommodated.

There are no known cost modifications required by law.

8. Explain reasons for cost change other than inflation.

The cost has changed primarily because the project has been reformulated based on the ongoing General Reevaluation Study, that was initiated in 1998.The current plan calls for approximately 15 miles of channel modifications and four regional detention basins which provide approximately 2,938 acre-feet of flood storage. The current plan also provides for recreation features consisting of approximately 10 miles of trails along the bayou and recreation features at the four detention basins. The plan also provides wetlands mitigation at two different locations.

The current cost estimate is based on the actual cost of project components that have already been constructed, and the estimated cost of the components remaining to be constructed, based on 2013 price levels.

9. Explain any changes in benefits and provide current BCR.

Benefits have been updated to year 2013 based on the plan formulation process performed as part of the current General Reevaluation Report for the White Oak Bayou Project. The current BCR is 6.9.

10. Provide detailed explanation of the status of the project.

The draft General Reevaluation Report has been submitted to the USACE-HQ. An AFB was completed and the Local Sponsor has updated the GRR in response to the comments received. The Local Sponsor has already constructed most of the flood risk management components of the Recommended Plan contained in the GRR. None of the Recreation Plan components have been constructed. The current project schedule calls for all the project components to be constructed by 2018.

ATTACHMENT 4

TOTAL PROJECT COST SUMMARY

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/20/2013

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
PROJECT NO: 114646
LOCATION: Harris County, TX

DISTRICT: SWG Galveston
POC: COST ENGINEERING, William Stevenson, Atkins

PREPARED: 8/6/2013

This Estimate reflects the scope and schedule in report: 211(f) GRR STUDY
and is based on the Detailed cost estimate file "Aug2013_White_Oak_Bayou_Rev7_211(f)_GRR_Feasibility_Estimate.mip

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
						Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13								
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Spent Thru: 1-Oct-12 ($K)		COST ($K)	CNTG ($K)	FULL ($K)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
02	**RELOCATIONS Cost Remaining**	$11,666	$2,683	23%	$14,349	4.7%	$12,216	$2,810	$15,026			$13,027	$2,996	$16,023
02	*Relocation Cost to Date by Local Sponsor*	*$103*			*$103*		*$103*		*$103*			*$103*		*$103*
09	**CHANNEL & CANAL Cost Remaining**	$11,826	$2,720	23%	$14,545	5.7%	$12,503	$2,876	$15,379			$13,290	$3,057	$16,346
09	*Channel Cost to Date by Local Sponsor*	*$40,279*			*$40,279*		*$40,279*		*$40,279*			*$40,279*		*$40,279*
14	**RECREATION Cost Remaining**	$7,614	$1,751	23%	$9,365	2.4%	$7,796	$1,793	$9,589			$8,261	$1,900	$10,162
14	*Recreation Cost to Date by Local Sponsor*	*$0*			*$0*		*$0*		*$0*			*$0*		*$0*
18	**CULTURAL PRESERVATION Cost Remaining**	$103	$24	23%	$127	2.4%	$106	$24	$130			$110	$25	$135
18	*Cultural Resources Cost to Date by Local Sponsor*	*$0*			*$0*		*$0*		*$0*			*$0*		*$0*
	CONSTRUCTION ESTIMATE TOTALS:	$71,591	$7,178		$78,769	2.2%	$73,003	$7,503	$80,506	$0		$75,070	$7,978	$83,048
01	**LANDS and DAMAGES Cost Remaining**	$3,439	$791	23%	$4,230	3.8%	$3,571	$821	$4,392			$3,654	$840	$4,494
01	*Lands and Damages Cost to Date by Local Sponsor*	*$21,010*			*$21,010*		*$21,010*		*$21,010*			*$21,010*		*$21,010*
30	**PLANNING, ENGRING, DESIGN Cost Remaining**	$1,872	$431	23%	$2,303	2.8%	$1,924	$442	$2,366			$2,006	$461	$2,467
30	*PED Cost to Date by Local Sponsor*	*$1,352*			*$1,352*		*$1,352*		*$1,352*			*$1,352*		*$1,352*
31	**CONSTRUCTION MANAGEMENT Cost Remaining**	$3,121	$718	23%	$3,839	4.0%	$3,247	$747	$3,994			$3,455	$795	$4,249
31	*CM Cost to Date by Local Sponsor*	*$5,467*			*$5,467*		*$5,467*		*$5,467*			*$5,467*		*$5,467*
	PROJECT COST TOTALS:	$107,852	$9,117	8%	$116,969		$109,574	$9,514	$119,088	$0		$112,013	$10,075	$122,088
	Total Estimated Remaining Cost	*$39,641*	*$9,094*		*$48,631*		*$41,258*	*$9,489*	*$50,747*			*$43,692*	*$10,049*	*$53,742*
	Spent Cost to Date by Local Sponsor	*$68,211*	*$0*		*$68,211*		*$68,211*	*$0*	*$68,211*			*$68,211*	*$0*	*$68,211*

COST ENGINEERING, William Stevenson, Atkins

ENGINEERING, Dave Winslow, PE, LJA

PROJECT MANAGER, Wayne Crull, PE, CFM, HCFCD

CONSTRUCTION, Richard Scott, PE, HCFCD

COST ENGINEERING, Chief of Professional Services, Willie J Honza (USACE)

PROGRAMS, Chief of Programs Sections, Valeire Miller (USACE)

REAL ESTATE, Chief of Real Estate Division, Hyla J. Head (USACE)

ESTIMATED FEDERAL COST:	60.3%	$73,619
ESTIMATED NON-FEDERAL COST:	39.7%	$48,469
ESTIMATED TOTAL PROJECT COST:		**$122,088**

Filename: Aug2013_WhiteOak_TPCS_Rev7_Update.xlsx
TPCS

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/8/2013

****** CONTRACT COST SUMMARY ******

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
LOCATION: Harris County, TX
This Estimate reflects the scope and schedule in report; 211(f) GRR STUDY

DISTRICT: SWG Galveston PREPARED: 8/6/2013
POC: COST ENGINEERING, William Stevenson, Atkins

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
CONTRACT A **UNCONSTRUCTED, Phase A (2012 to 2014)**		Estimate Prepared: Effective Price Level:		Updated 8/6/13 1-Oct-2012		Program Year (Budget EC): Effective Price Level Date:		2014 1 OCT 13						
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	TOTAL ($K) *J*	Mid-Point Date *P*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
02	RELOCATIONS	$3,748	$862	23%	$4,610	4.7%	$3,925	$903	$4,827	2016Q2	4.3%	$4,092	$941	$5,033
09	CHANNELS & CANALS	$4,960	$1,141	23%	$6,101	5.7%	$5,244	$1,206	$6,451	2016Q2	4.3%	$5,468	$1,258	$6,726
14	RECREATION FACILITIES	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
18	CULTURAL RESOURCE PRESERVATION	$103	$24	23%	$127	2.4%	$106	$24	$130	2016Q2	4.3%	$110	$25	$135
	#N/A	$0	$0	23%	$0	0.0%	$0 $0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$8,811	$2,027	23%	**$10,838**		$9,275	$2,133	$11,408			$9,670	$2,224	$11,895
01	LANDS AND DAMAGES		$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$44	$10	23%	$54	2.8%	$45	$10	$56	2014Q1	0.0%	$45	$10	$56
0.3%	Planning & Environmental Compliance	$26	$6	23%	$32	2.8%	$27	$6	$33	2014Q1	0.0%	$27	$6	$33
3.0%	Engineering & Design	$269	$62	23%	$331	2.8%	$276	$64	$340	2014Q1	0.0%	$276	$64	$340
0.5%	Reviews, ATRs, IEPRs, VE	$44	$10	23%	$54	2.8%	$45	$10	$56	2014Q1	0.0%	$45	$10	$56
0.2%	Life Cycle Updates (cost, schedule, risks)	$18	$4	23%	$22	2.8%	$18	$4	$23	2014Q1	0.0%	$18	$4	$23
0.2%	Contracting & Reprographics	$18	$4	23%	$22	2.8%	$18	$4	$23	2014Q1	0.0%	$18	$4	$23
0.5%	Engineering During Construction	$44	$10	23%	$54	2.8%	$45	$10	$56	2016Q1	8.0%	$49	$11	$60
0.3%	Planning During Construction	$22	$5	23%	$27	2.8%	$23	$5	$28	2016Q1	8.0%	$24	$6	$30
0.5%	Project Operations	$44	$10	23%	$54	2.8%	$45	$10	$56	2014Q1	0.0%	$45	$10	$56
31	CONSTRUCTION MANAGEMENT													
8.5%	Construction Management	$749	$172	23%	$921	4.0%	$779	$179	$958	2016Q2	4.3%	$813	$187	$1,000
0.5%	Project Operation:	$44	$10	23%	$54	4.0%	$46	$11	$56	2016Q1	4.3%	$48	$11	$59
1.0%	Project Management	$88	$20	23%	$108	4.0%	$92	$21	$113	2016Q1	4.3%	$96	$22	$117
	CONTRACT COST TOTALS:	$10,221	$2,351		**$12,572**		$10,735	$2,469	$13,204			$11,176	$2,570	**$13,746**

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/8/2013

****** CONTRACT COST SUMMARY ******

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
LOCATION: Harris County, TX
This Estimate reflects the scope and schedule in report; 211(f) GRR STUDY

DISTRICT: SWG Galveston PREPARED: 8/6/2013
POC: COST ENGINEERING, William Stevenson, Atkins

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
CONTRACT B **UNCONSTRUCTED, Phase B (2014 to 2016)**		Estimate Prepared: Effective Price Level:			Updated 8/6/13 1-Oct-2012	Program Year (Budget EC): Effective Price Level Date:			2014 1 OCT 13					
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
02	RELOCATIONS	$7,918	$1,821	23%	$9,739	4.7%	$8,292	$1,907	$10,199	2018Q1	7.8%	$8,935	$2,055	$10,989
09	CHANNELS & CANALS	$6,865	$1,579	23%	$8,444	5.7%	$7,259	$1,670	$8,928	2018Q1	7.8%	$7,821	$1,799	$9,620
14	RECREATION FACILITIES	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
18	CULTURAL RESOURCE PRESERVATION	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	#N/A	$0	$0	23%	$0	0.0%	$0 $0	$0	$0	0	0.0%	$0	$0	$0
	CONSTRUCTION ESTIMATE TOTALS:	$14,784	$3,400	23%	**$18,184**		$15,551	$3,577	$19,127			$16,756	$3,854	$20,610
01	LANDS AND DAMAGES	$3,439	$791	23%	$4,230	3.8%	$3,571	$821	$4,392	2015Q2	2.3%	$3,654	$840	$4,494
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$74	$17	23%	$91	2.8%	$76	$17	$94	2015Q1	3.7%	$79	$18	$97
0.3%	Planning & Environmental Compliance	$44	$10	23%	$54	2.8%	$45	$10	$56	2015Q1	3.7%	$47	$11	$58
3.0%	Engineering & Design	$449	$103	23%	$552	2.8%	$461	$106	$568	2015Q1	3.7%	$478	$110	$588
0.5%	Reviews, ATRs, IEPRs, VE	$74	$17	23%	$91	2.8%	$76	$17	$94	2015Q1	3.7%	$79	$18	$97
0.2%	Life Cycle Updates (cost, schedule, risks)	$30	$7	23%	$37	2.8%	$31	$7	$38	2015Q1	3.7%	$32	$7	$39
0.2%	Contracting & Reprographics	$30	$7	23%	$37	2.8%	$31	$7	$38	2015Q1	3.7%	$32	$7	$39
0.5%	Engineering During Construction	$74	$17	23%	$91	2.8%	$76	$17	$94	2018Q1	17.5%	$89	$21	$110
0.3%	Planning During Construction	$37	$9	23%	$46	2.8%	$38	$9	$47	2018Q1	17.5%	$45	$10	$55
0.5%	Project Operations	$74	$17	23%	$91	2.8%	$76	$17	$94	2015Q1	3.7%	$79	$18	$97
31	CONSTRUCTION MANAGEMENT													
8.5%	Construction Management	$1,257	$289	23%	$1,546	4.0%	$1,308	$301	$1,609	2018Q1	7.8%	$1,410	$324	$1,734
0.5%	Project Operation:	$74	$17	23%	$91	4.0%	$77	$18	$95	2018Q1	7.8%	$83	$19	$102
1.0%	Project Management	$148	$34	23%	$182	4.0%	$154	$35	$189	2018Q1	7.8%	$166	$38	$204
	CONTRACT COST TOTALS:	$20,587	$4,735		**$25,323**		$21,571	$4,961	$26,532			$23,028	$5,297	**$28,325**

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/8/2013

****** CONTRACT COST SUMMARY ******

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
LOCATION: Harris County, TX
This Estimate reflects the scope and schedule in report; 211(f) GRR STUDY

DISTRICT: SWG Galveston PREPARED: 8/6/2013
POC: COST ENGINEERING, William Stevenson, Atkins

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
CONTRACT C		Estimate Prepared:			Jpdated 8/6/13	Program Year (Budget EC):			2014					
UNCONSTRUCTED, Recreation A, (2012 to 2013)		Effective Price Level:			1-Oct-2012	Effective Price Level Date:			1 OCT 13	FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
02	RELOCATIONS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
09	CHANNELS & CANALS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
14	RECREATION FACILITIES	$909	$209	23%	$1,118	2.4%	$930	$214	$1,144	2016Q1	3.8%	$965	$222	$1,187
18	CULTURAL RESOURCE PRESERVATION	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	#N/A	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$909	$209	23%	**$1,118**		$930	$214	$1,144			$965	$222	$1,187
01	LANDS AND DAMAGES	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$5	$1	23%	$6	2.8%	$5	$1	$6	2014Q1	0.0%	$5	$1	$6
0.3%	Planning & Environmental Compliance	$3	$1	23%	$4	2.8%	$3	$1	$4	2014Q1	0.0%	$3	$1	$4
3.0%	Engineering & Design	$26	$6	23%	$32	2.8%	$27	$6	$33	2014Q1	0.0%	$27	$6	$33
0.5%	Reviews, ATRs, IEPRs, VE	$5	$1	23%	$6	2.8%	$5	$1	$6	2014Q1	0.0%	$5	$1	$6
0.2%	Life Cycle Updates (cost, schedule, risks)	$2	$0	23%	$2	2.8%	$2	$0	$3	2014Q1	0.0%	$2	$0	$3
0.2%	Contracting & Reprographics	$2	$0	23%	$2	2.8%	$2	$0	$3	2014Q1	0.0%	$2	$0	$3
0.5%	Engineering During Construction	$5	$1	23%	$6	2.8%	$5	$1	$6	2016Q1	8.0%	$6	$1	$7
0.3%	Planning During Construction	$2	$0	23%	$2	2.8%	$2	$0	$3	2016Q1	8.0%	$2	$1	$3
0.5%	Project Operations	$5	$1	23%	$6	2.8%	$5	$1	$6	2014Q1	0.0%	$5	$1	$6
31	CONSTRUCTION MANAGEMENT													
8.5%	Construction Management	$77	$18	23%	$95	4.0%	$80	$18	$99	2016Q1	3.8%	$83	$19	$102
0.5%	Project Operation:	$5	$1	23%	$6	4.0%	$5	$1	$6	2016Q1	3.8%	$5	$1	$7
1.0%	Project Management	$9	$2	23%	$11	4.0%	$9	$2	$12	2016Q1	3.8%	$10	$2	$12
	CONTRACT COST TOTALS:	$1,055	$243		**$1,297**		$1,082	$249	$1,330			$1,121	$258	**$1,379**

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/8/2013

****** CONTRACT COST SUMMARY ******

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
LOCATION: Harris County, TX
This Estimate reflects the scope and schedule in report; 211(f) GRR STUDY

DISTRICT: SWG Galveston PREPARED: 8/6/2013
POC: COST ENGINEERING, William Stevenson, Atkins

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
CONTRACT D **UNCONSTRUCTED, Recreation B, (2013 to 2015)**		Estimate Prepared: Jpdated 8/6/13 Effective Price Level: 1-Oct-2012				Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13				FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER *A*	Civil Works Feature & Sub-Feature Description *B*	COST ($K) *C*	CNTG ($K) *D*	CNTG (%) *E*	TOTAL ($K) *F*	ESC (%) *G*	COST ($K) *H*	CNTG ($K) *I*	TOTAL ($K) *J*	Mid-Point Date *P*	INFLATED (%) *L*	COST ($K) *M*	CNTG ($K) *N*	FULL ($K) *O*
02	RELOCATIONS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
09	CHANNELS & CANALS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
14	RECREATION FACILITIES	$1,584	$364	23%	$1,948	2.4%	$1,622	$373	$1,995	2016Q1	3.8%	$1,683	$387	$2,070
18	CULTURAL RESOURCE PRESERVATION	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	#N/A	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$1,584	$364	23%	**$1,948**		$1,622	$373	$1,995			$1,683	$387	$2,070
01	LANDS AND DAMAGES	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$8	$2	23%	$10	2.8%	$8	$2	$10	2014Q1	0.0%	$8	$2	$10
0.3%	Planning & Environmental Compliance	$5	$1	23%	$6	2.8%	$5	$1	$6	2014Q1	0.0%	$5	$1	$6
3.0%	Engineering & Design	$48	$11	23%	$59	2.8%	$49	$11	$61	2014Q1	0.0%	$49	$11	$61
0.5%	Reviews, ATRs, IEPRs, VE	$8	$2	23%	$10	2.8%	$8	$2	$10	2014Q1	0.0%	$8	$2	$10
0.2%	Life Cycle Updates (cost, schedule, risks)	$3	$1	23%	$4	2.8%	$3	$1	$4	2014Q1	0.0%	$3	$1	$4
0.2%	Contracting & Reprographics	$3	$1	23%	$4	2.8%	$3	$1	$4	2014Q1	0.0%	$3	$1	$4
0.5%	Engineering During Construction	$8	$2	23%	$10	2.8%	$8	$2	$10	2016Q1	8.0%	$9	$2	$11
0.3%	Planning During Construction	$4	$1	23%	$5	2.8%	$4	$1	$5	2016Q1	8.0%	$4	$1	$5
0.5%	Project Operations	$8	$2	23%	$10	2.8%	$8	$2	$10	2014Q1	0.0%	$8	$2	$10
31	CONSTRUCTION MANAGEMENT													
8.5%	Construction Management	$134	$31	23%	$165	4.0%	$139	$32	$171	2016Q1	3.8%	$145	$33	$178
0.5%	Project Operation:	$8	$2	23%	$10	4.0%	$8	$2	$10	2016Q1	3.8%	$9	$2	$11
1.0%	Project Management	$16	$4	23%	$20	4.0%	$17	$4	$20	2016Q1	3.8%	$17	$4	$21
	CONTRACT COST TOTALS:	$1,837	$423		**$2,259**		$1,884	$433	$2,317			$1,952	$449	**$2,401**

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/8/2013

****** CONTRACT COST SUMMARY ******

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
LOCATION: Harris County, TX
This Estimate reflects the scope and schedule in report; 211(f) GRR STUDY

DISTRICT: SWG Galveston PREPARED: 8/6/2013
POC: COST ENGINEERING, William Stevenson, Atkins

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
CONTRACT E **UNCONSTRUCTED, Recreation C, (2014 to 2016)**		Estimate Prepared: Jpdated 8/6/13 Effective Price Level: 1-Oct-2012				Program Year (Budget EC): 2014 Effective Price Level Date: 1 OCT 13				FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
02	RELOCATIONS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
09	CHANNELS & CANALS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
14	RECREATION FACILITIES	$1,469	$338	23%	$1,807	2.4%	$1,504	$346	$1,850	2018Q1	7.8%	$1,621	$373	$1,994
18	CULTURAL RESOURCE PRESERVATION	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	#N/A	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$1,469	$338	23%	**$1,807**		$1,504	$346	$1,850			$1,621	$373	$1,994
01	LANDS AND DAMAGES	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$7	$2	23%	$9	2.8%	$7	$2	$9	2019Q3	25.1%	$9	$2	$11
0.3%	Planning & Environmental Compliance	$4	$1	23%	$5	2.8%	$4	$1	$5	2019Q3	25.1%	$5	$1	$6
3.0%	Engineering & Design	$46	$11	23%	$57	2.8%	$47	$11	$58	2019Q3	25.1%	$59	$14	$73
0.5%	Reviews, ATRs, IEPRs, VE	$7	$2	23%	$9	2.8%	$7	$2	$9	2019Q3	25.1%	$9	$2	$11
0.2%	Life Cycle Updates (cost, schedule, risks)	$3	$1	23%	$4	2.8%	$3	$1	$4	2019Q3	25.1%	$4	$1	$5
0.2%	Contracting & Reprographics	$3	$1	23%	$4	2.8%	$3	$1	$4	2019Q3	25.1%	$4	$1	$5
0.5%	Engineering During Construction	$7	$2	23%	$9	2.8%	$7	$2	$9	2018Q1	17.5%	$8	$2	$10
0.3%	Planning During Construction	$4	$1	23%	$5	2.8%	$4	$1	$5	2018Q1	17.5%	$5	$1	$6
0.5%	Project Operations	$7	$2	23%	$9	2.8%	$7	$2	$9	2019Q3	25.1%	$9	$2	$11
31	CONSTRUCTION MANAGEMENT													
8.5%	Construction Management	$125	$29	23%	$154	4.0%	$130	$30	$160	2018Q1	7.8%	$140	$32	$172
0.5%	Project Operation:	$7	$2	23%	$9	4.0%	$7	$2	$9	2018Q1	7.8%	$8	$2	$10
1.0%	Project Management	$15	$3	23%	$18	4.0%	$16	$4	$19	2018Q1	7.8%	$17	$4	$21
	CONTRACT COST TOTALS:	$1,704	$392		**$2,096**		$1,748	$402	$2,150			$1,898	$437	**$2,335**

****** TOTAL PROJECT COST SUMMARY ******

Printed:8/8/2013

****** CONTRACT COST SUMMARY ******

PROJECT: WHITE OAK BAYOPU FLOOD RISK REDUCTION
LOCATION: Harris County, TX
This Estimate reflects the scope and schedule in report; 211(f) GRR STUDY

DISTRICT: SWG Galveston PREPARED: 8/6/2013
POC: COST ENGINEERING, William Stevenson, Atkins

Civil Works Work Breakdown Structure		ESTIMATED COST				PROJECT FIRST COST (Constant Dollar Basis)				TOTAL PROJECT COST (FULLY FUNDED)				
CONTRACT E **UNCONSTRUCTED, Recreation D, (2013 to 2016)**		Estimate Prepared: Effective Price Level:			Jpdated 8/6/13 1-Oct-2012	Program Year (Budget EC): Effective Price Level Date:			2014 1 OCT 13	FULLY FUNDED PROJECT ESTIMATE				
WBS NUMBER	Civil Works Feature & Sub-Feature Description	COST ($K)	CNTG ($K)	CNTG (%)	TOTAL ($K)	ESC (%)	COST ($K)	CNTG ($K)	TOTAL ($K)	Mid-Point Date	INFLATED (%)	COST ($K)	CNTG ($K)	FULL ($K)
A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*P*	*L*	*M*	*N*	*O*
	PHASE 7													
02	RELOCATIONS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
09	CHANNELS & CANALS	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
14	RECREATION FACILITIES	$3,652	$840	23%	$4,492	2.4%	$3,740	$860	$4,600	2017Q3	6.8%	$3,992	$918	$4,910
	#N/A	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
	#N/A	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
							$0							
	CONSTRUCTION ESTIMATE TOTALS:	$3,652	$840	23%	**$4,492**		$3,740	$860	$4,600			$3,992	$918	$4,910
01	LANDS AND DAMAGES	$0	$0	23%	$0	0.0%	$0	$0	$0	0	0.0%	$0	$0	$0
30	PLANNING, ENGINEERING & DESIGN													
0.5%	Project Management	$18	$4	23%	$22	2.8%	$18	$4	$23	2014Q1	0.0%	$18	$4	$23
0.3%	Planning & Environmental Compliance	$11	$3	23%	$14	2.8%	$11	$3	$14	2014Q1	0.0%	$11	$3	$14
3.0%	Engineering & Design	$113	$26	23%	$139	2.8%	$116	$27	$143	2014Q1	0.0%	$116	$27	$143
0.5%	Reviews, ATRs, IEPRs, VE	$18	$4	23%	$22	2.8%	$18	$4	$23	2014Q1	0.0%	$18	$4	$23
0.2%	Life Cycle Updates (cost, schedule, risks)	$7	$2	23%	$9	2.8%	$7	$2	$9	2014Q1	0.0%	$7	$2	$9
0.2%	Contracting & Reprographics	$7	$2	23%	$9	2.8%	$7	$2	$9	2014Q1	0.0%	$7	$2	$9
0.5%	Engineering During Construction	$18	$4	23%	$22	2.8%	$18	$4	$23	2017Q3	15.0%	$21	$5	$26
0.3%	Planning During Construction	$9	$2	23%	$11	2.8%	$9	$2	$11	2017Q3	15.0%	$11	$2	$13
0.5%	Project Operations	$18	$4	23%	$22	2.8%	$18	$4	$23	2014Q1	0.0%	$18	$4	$23
31	CONSTRUCTION MANAGEMENT													
8.5%	Construction Management	$310	$71	23%	$381	4.0%	$323	$74	$397	2017Q3	6.8%	$345	$79	$424
0.5%	Project Operation:	$18	$4	23%	$22	4.0%	$19	$4	$23	2017Q3	6.8%	$20	$5	$25
1.0%	Project Management	$37	$9	23%	$46	4.0%	$38	$9	$47	2017Q3	6.8%	$41	$9	$51
	CONTRACT COST TOTALS:	$4,236	$974		**$5,211**		$4,344	$999	$5,344			$4,627	$1,064	**$5,691**

ATTACHMENT 5

SECTION 211 WRDA 1996 AMENDED TEXT

CECW-AA 9 Dec 1997

MEMORANDUM FOR MAJOR SUBORDINATE COMMANDS AND DISTRICT COMMANDS

SUBJECT: Policy Guidance Letter No. 53 - Implementation of Section 211 of the Water Resources Development Act of 1996

1. **Purpose.** This memorandum provides policy guidance on Section 211 of the Water Resources Development Act (WRDA 96) of 1996, "Construction of Flood Control Projects by Non-Federal Interests." A copy of the Act language is enclosed for your information. Detailed guidance will be forthcoming in an Engineering Regulation (ER).

2. **Background.** Section 211 of WRDA 96 provides authority for non-Federal sponsors to undertake the design and construction of federally authorized flood control projects without Federal funding and to be eligible to be reimbursed an amount equal to the estimate of the Federal share, without interest (or inflation), of the design and construction cost of the project or separable element thereof. The Energy and Water Development Appropriations Act, 1998, provided additional guidance on the section 211 regarding notification of the Committees on Appropriations of the House and Senate and on scheduling of reimbursements.

3**. Applicability.** This guidance applies to all HQUSACE elements and major subordinate commands of the U.S. Army Corps of Engineers. Only projects or separable elements of projects which have been specifically authorized by Congress will be considered eligible for reimbursement under this provision. Reimbursement of non-Federal sponsor work under section 211 (e) will not be considered for the Continuing Authorities Program projects.

4**. Policy.**

a. General: It is Corps policy that reimbursement for the construction of any authorized flood control project undertaken by a non-Federal sponsor pursuant to section 211 is contingent upon approval by the Secretary of the plans for construction and the Secretary's determination, after a review of studies and design documents, that the project or separable element thereof, is economically justified and environmentally acceptable. This approval must be obtained after project authorization and prior to the initiation of construction of the work for which the reimbursement request will be made. Further, prior to initiating negotiations for a reimbursement agreement for the construction of any authorized project pursuant to Section 211 of WRDA 96, the Secretary of the Army must notify the Committees on Appropriations of the

House and the Senate. This notification must include the estimated total commitment and the reimbursement requirements that the Administration intends to support in future budget submissions. Budgetary and programmatic priorities will be taken into account when reviewing plans submitted by non-Federal sponsors.

All projects pursued under the authority of section 211 must be planned, designed and constructed in accord with appropriate Federal laws and criteria, standards and policies, including the appropriate National Environmental Policy Act (NEPA) documentation, and construction must comply with all applicable Federal and State laws and regulations. The non-Federal sponsor will normally be required to develop the design, engineering plans and specifications for the construction it proposes to undertake. In addition, the non-Federal sponsor must conduct NEPA investigations, prepare appropriate NEPA documents, conduct all public and agency coordination, and obtain all necessary Federal and State permits. The Corps may undertake these efforts if funds are provided by the non-Federal sponsor and if such work does not delay the completion of other Corps assignments. Further, funds for activities undertaken by the Corps district offices which are necessary for the successful completion of a section 211 project or separable element, thereof, and construction of the sponsor proposed work including, but not limited to, design, review of project economics, environmental assessments, determination of lands, easements, rights-of -way and suitable borrow and dredged or excavated material disposal areas (LERRD's) requirements, auditing, permit evaluations, and inspections, must also be provided by the non-Federal sponsor.

The non-Federal sponsor must provide all LERRD's and shall perform or ensure performance of all relocations that the Corps determines are required for the construction, operation and maintenance of the project. The value of LERRD's provided by the non-Federal sponsor that are required for the project will be determined in accordance with standard valuation procedures as contained in the model Project Cooperation Agreement (PCA) for structural flood control projects. In addition, the non-Federal sponsor will be responsible for the operation, maintenance, repair, replacement and rehabilitation of the project in accordance with regulations or directions prescribed by the Corps and shall perform all other items of sponsor cooperation required by the project authorization.

In the development of a section 211 agreement, the normal procedures for processing and reviewing a PCA will be used. The decision document approved by the Secretary must be included as support for the section 211 agreement. Negotiations for proceeding with a project under section 211 are to be accomplished at the district level once approval to initiate the negotiations has been received.

b. Reimbursement pursuant to Section 211 (e) (1): Reimbursements pursuant to section 211 (e) (1) cannot occur until the flood control project, or separable element thereof,

has been constructed. Reimbursements are subject to appropriations Acts. Any eligible reimbursable Federal share of costs associated with studies or design efforts conducted by non-Federal sponsors after authorization and prior to construction will be included in the final auditing of the total project costs upon completion of the construction of a project or separable element thereof. Any reimbursement desired by a non-Federal sponsor for studies or design it accomplished prior to authorization must be specifically identified and requested in the authorizing document.

c. Reimbursement pursuant to Section 211 (e) (2) (A) (Specifically named projects): Reimbursement for those projects listed in section 211 (f) will be in accordance with section 211 (e) (2) (A). These special reimbursement rules expand the definition of the work for which the non-Federal sponsor will be reimbursed to include studies, planning, design and construction if such work is later recommended by the Chief of Engineers and approved by the Secretary. In addition, for the section 211 (f) projects, a non-Federal sponsor will be credited for the Federal share of any work carried out before completion of a reconnaissance study if such work is determined to be compatible with the project later recommended for construction. As required by section 211 (e) (2) (A) the reimbursement must be contained *in* (emphasis added) an Appropriations Act; that is, the reimbursement must be earmarked in law. Any eligible reimbursable Federal share of costs associated with studies, planning or design efforts will be included in the final auditing of the total project costs upon completion of the construction of a project or separable element thereof.

For the specifically named projects, consideration will be given to reimbursement on an incremental basis; that is, reimbursement will be recommended upon completion of the construction of a discrete segment of an economically justified and environmentally acceptable project or separable element, thereof, provided that the non-Federal sponsor has entered into a binding agreement with the Secretary and has committed to the construction of the total project or separable element thereof. A discrete segment is defined as a physical portion of the project, as described in design documents, that is environmentally acceptable, is complete, will not create a hazard, and functions independently so that the non-Federal sponsor can operate and maintain it in advance of completion of the total project or separable element thereof. Reimbursements will not be made unless and until the Secretary has determined that the construction for which reimbursement is requested is complete, is consistent with the authorization of the project and its overall economic justification, and has been performed in accordance with applicable permits and approved plans. Further, the agreement must contain a provision which will require the non-Federal sponsor to remit previously received reimbursements in the event that the non-Federal sponsor fails to complete the entire project or separable element thereof.

d. Reimbursement for Flood Damage Prevention Measures at Morgan City and Berwick, Louisiana (Section 211(g)): Section 211 (g) of WRDA 96 provides that, for the purposes of section 211, flood damage prevention measures at or in the vicinity of Morgan City and Berwick, Louisiana, shall be treated as an authorized separable element of the Lower Atchafalaya Basin feature of the project for Flood Control, Mississippi River and Tributaries.

As such, this separable element may be designed and constructed by the non-Federal sponsor and considered for reimbursement subject to the law and to the policies established under section 211 (e) (1) as discussed in paragraph 4b, above.

5**. Implementation.** This guidance is effective immediately. Detailed guidance will be issued in an ER. In the event non-Federal sponsors wish to pursue construction of an authorized flood control project using section 211 prior to the issuance of the ER, the division program manager must contact HQUSACE, ATTN: CECW-AA.

FOR THE COMMANDER:

/s/

Encl

RUSSELL L. FUHRMAN
Major General, USA
Director of Civil Works

SEC. 211. CONSTRUCTION OF FLOOD CONTROL PROJECTS BY NON-FEDERAL INTERESTS.

(a) Authority.--Non-Federal interests are authorized to undertake flood control projects in the United States, subject to obtaining any permits required pursuant to Federal and State laws in advance of actual construction.

(b) Studies and Design Activities.--

(1) By non-federal interests.--A non-Federal interest may prepare, for review and approval by the Secretary, the necessary studies and design documents for any construction to be undertaken pursuant to subsection (a).

(2) By secretary.--Upon request of an appropriate non-Federal interest, the Secretary may undertake all necessary studies and design activities for any construction to be undertaken pursuant to subsection (a) and provide technical assistance in obtaining all necessary permits for such construction if the non-Federal interest contracts with the Secretary to provide to the United States funds for the studies and design activities during the period in which the studies and design activities will be conducted.

(c) Completion of Studies and Design Activities.--In the case of any study or design documents for a flood control project that were initiated before the date of the enactment of this Act, the Secretary may complete and transmit to the appropriate non-Federal interests the study or design documents or, upon the request of such non-Federal interests, terminate the study or design activities and transmit the partially completed study or design documents to such non-Federal interests for completion. Studies and design documents subject to this subsection shall be completed without regard to the requirements of subsection (b).

(d) Authority To Carry Out Improvement.--

(1) In general.--Any non-Federal interest that has received from the Secretary pursuant to subsection (b) or (c) a favorable recommendation to carry out a flood control project, or separable element of a flood control project, based on the results of completed studies and design documents for the project or element may carry out the project or element if a final environmental impact statement under the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) has been filed for the project or element.

(2) Permits.--Any plan of improvement proposed to be implemented in accordance with this subsection shall be deemed to satisfy the requirements for obtaining the appropriate permits required under the Secretary's authority. Such permits shall be granted subject to the non-Federal interest's acceptance of the terms and conditions of such permits if the Secretary determines that the applicable regulatory criteria and procedures have been satisfied.

(3) Monitoring.--The Secretary shall monitor any project for which a permit is granted under this subsection in order to ensure that such project is constructed, operated, and maintained in accordance with the terms and conditions of such permit.

(e) Reimbursement.--

(1) General rule.--Subject to appropriations Acts, the Secretary may reimburse any

Enclosure

non-Federal interest an amount equal to the estimate of the Federal share, without interest, of the cost of any authorized flood control project, or separable element of a flood control project, constructed pursuant to this section--

(A) if, after authorization and before initiation of construction of the project or separable element, the Secretary approves the plans for construction of such project by the non-Federal interest; and

(B) if the Secretary finds, after a review of studies and design documents prepared pursuant to this section, that construction of the project or separable element is economically justified and environmentally acceptable.

(2) Special rules.--

(A) Reimbursement.--For work (including work associated with studies, planning, design, and construction) carried out by a non-Federal interest with respect to a project described in subsection (f), the Secretary shall, subject to amounts being made available in advance in appropriations Acts, reimburse, without interest, the non-Federal interest an amount equal to the estimated Federal share of the cost of such work if such work is later recommended by the Chief of Engineers and approved by the Secretary.

(B) Credit.--If the non-Federal interest for a project described in subsection (f) carries out work before completion of a reconnaissance study by the Secretary and if such work is determined by the Secretary to be compatible with the project later recommended by the Secretary, the Secretary shall credit the non-Federal interest for its share of the cost of the project for such work.

(3) Matters to be considered in reviewing plans.--In reviewing plans under this subsection, the Secretary shall consider budgetary and programmatic priorities and other factors that the Secretary considers appropriate.

(4) Monitoring.--The Secretary shall regularly monitor and audit any project for flood control approved for construction under this section by a non-Federal interest to ensure that such construction is in compliance with the plans approved by the Secretary and that the costs are reasonable.

(5) Limitation on reimbursements.--The Secretary may not make any reimbursement under this section until the Secretary determines that the work for which reimbursement is requested has been performed in accordance with applicable permits and approved plans.

(f) Specific Projects.--For the purpose of demonstrating the potential advantages and effectiveness of non-Federal implementation of flood control projects, the Secretary shall enter into agreements pursuant to this section with non-Federal interests for development of the following flood control projects by such interests:

(1) Berryessa Creek, California.--The Berryessa Creek element of the project for flood control, Coyote and Berryessa Creeks, California, authorized by section 101(a)(5) of the Water Resources Development Act of 1990 (104 Stat. 4606); except that, subject to the approval of the Secretary as provided by this section, the non-Federal interest may design and construct an alternative to such element.

(2) Los Angeles County Drainage Area, California.--The project for flood control, Los Angeles County Drainage Area, California, authorized by section 101(b) of the Water Resources Development Act of 1990 (104 Stat. 4611).

(3) Stockton Metropolitan Area, California.--The project for flood control, Stockton Metropolitan Area, California.

(4) Upper Guadalupe River, California.--The project for flood control, Upper Guadalupe River, California.

(5) Flamingo and Tropicana Washes, Nevada.--The project for flood control, Las Vegas Wash and Tributaries (Flamingo and Tropicana Washes), Nevada, authorized by section 101(13) of the Water Resources Development Act of 1992 (106 Stat. 4803).

(6) Brays Bayou, Texas.--Flood control components comprising the Brays Bayou element of the project for flood control, Buffalo Bayou and Tributaries, Texas, authorized by section 101(a)(21) of the Water Resources Development Act of 1990 (104 Stat. 4610); except that, subject to the approval of the Secretary as provided by this section, the non-Federal interest may design and construct an alternative to the diversion component of such element.

(7) Hunting Bayou, Texas.--The Hunting Bayou element of the project for flood control, Buffalo Bayou and Tributaries, Texas, authorized by such section; except that, subject to the approval of the Secretary as provided by this section, the non-Federal interest may design and construct an alternative to such element.

(8) White Oak Bayou, Texas.--The project for flood control, White Oak Bayou watershed, Texas.

(g) Treatment of Flood Damage Prevention Measures.--For the purposes of this section, flood damage prevention measures at or in the vicinity of Morgan City and Berwick, Louisiana, shall be treated as an authorized separable element of the Atchafalaya Basin feature of the project for flood control, Mississippi River and Tributaries.

ATTACHMENT 6

COMPLIANCE WITH EXECUTIVE ORDER 11988
FLOOD PLAIN MANAGEMENT

February 2014

GRR Attachment 6

White Oak Bayou Flood Damage Reduction Project

Compliance with Executive Order 11988 – Flood Plain Management

1. Purpose. This document identifies the information that decision documents recommending flood and coastal storm risk management actions should display in order to demonstrate compliance with EO 11988 and to adequately evaluate public safety.

2. References.

a. Executive Order (EO) 11988, Floodplain Management, May 24, 1977.b. Water Resources Council, Floodplain Management Guidelines for Implementing E.O. 11988, February 10, 1978 (43 FR 6030).

b. ER 1165-2-26, Implementation of Executive Order 11988 on Flood Plain Management, March 30, 1984.

3. Compliance

To comply with this EO, the policy of USACE is to formulate projects that, to the extent possible, avoid or minimize adverse effects associated with use of the floodplain and avoid inducing development in the floodplain unless there is no practicable alternative. As a flood damage risk reduction project, modification of the floodplain cannot be avoided while achieving project objectives. A number of non□structural measures were evaluated during the feasibility phase of this study, which would have reduced flood damages; however, these measures either did not satisfactorily meet planning criteria or were not economically justifiable.

The White Oak Bayou study team developed a plan in compliance with the objectives of EO 11988 and in conformance with the principles from ER 1165-2-26 in plan formulation for alternatives to reduce flood risks in the White Oak Bayou floodplain. Executive Order 11988, Floodplain Management, signed 24 May 1977, has an objective to avoid long- and short-term adverse impacts associated with the occupancy and modification of the base floodplain and the avoidance of direct and indirect support of development in the base flood plain wherever there is a practicable alternative. Under the Order, the Corps is required to provide leadership and take action to:

- Avoid development in the base flood plain unless it is the only practicable alternative;
- Reduce the hazard and risk associated with floods;

- Minimize the impact of floods on human safety, health and welfare; and
- Restore and preserve the natural and beneficial values of the base flood plain.

According to ER 1165-2-26, there are general procedures that must be followed to assure the project is in compliance with EO 11988. The Recommended Plan for White Oak Bayou does involve work within the flood plain, but all practical alternatives to avoid impacts to floodplain were evaluated and compared against the Recommended Plan. Sections 4.5.1, 4.6.1, 4.6.2, and 4.14 of the Main Report discuss the management and non-structural measures evaluated to reduce flooding. Measures such as removing structures from the floodplain would improve natural floodplain values and return the floodplain to a more natural condition. However, the management and non-structural measures did not have net positive benefits, as discussed in Sections 4.6.1, 4.6.2, and 4.14 of the Main Report. It is important to note, that the Harris County Flood Control District has programs already in place to remove frequently flooded structures from the floodplain and improve floodplain values.

Additionally, through implementation of the NEPA process, consideration of measures which would avoid adverse impacts to floodplains, minimization of impacts on the human environment resulting from flooding, and restoration of floodplain functions where possible, the Proposed Action is in compliance with EO 11988, Protection of Floodplains.

A. Executive Order 11988

EO 11988 requires Federal agencies to avoid to the extent possible the long- and short□term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative. In accomplishing this objective, "each agency shall provide leadership and shall take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by flood plains in carrying out its responsibilities." The Water Resources Council Floodplain Management Guidelines for implementation of EO 11988, as referenced in USACE ER 1165-2-26, require an eight-step process that agencies should carry out as part of their decision-making for projects that have potential impacts to or within the floodplain. The eight steps reflect the decision-making process required in Section 2(a) of the EO. The eight steps and responses to them are summarized below.

1. Determine if the proposed action is in the base flood plain.

The project, which consists of channel modifications along White Oak Bayou and four detention basins adjacent to the bayou, is located in the base flood plain, with the exception of some of the detention basins which are generally located adjacent to the base flood plain. All impacts from the Recommended Plan are located within the base flood plain.

2. If the action is in the base flood plain, identify and evaluate practicable alternatives to the action or to location of the action in the base flood plain.

Chapter 4 of the Main Report presents an analysis of alternatives. Non-structural buyouts and flood plain management alternatives were evaluated as alternatives to structural actions in the flood plain. These are the only alternatives that would avoid action in the base flood plain. Sections 4.5.1, 4.6.1, 4.6.2, and 4.14 of the Main Report discuss these measures. None were found to be feasible alternatives to the Recommended Plan features.

3. If the action must be in the flood plain, advise the general public in the affected area and obtain their views and comments.

Public involvement activities are described in Section 5.10 Public Involvement, and in Appendix G Public Involvement. The draft and final General Reevaluation Report and Environmental Assessment were published for public comment and for review by local, state and federal agencies during a 30-day comment period. All comments received from the public on the proposed action were addressed to the satisfaction of the commenters.

4. Identify beneficial and adverse impacts due to the action and any expected losses of natural and beneficial flood plain values. Where actions proposed to be located outside the base flood plain will affect the base flood plain, impacts resulting from these actions should also be identified.

Potential impacts associated with the Recommended Plan are summarized in Chapter 5 of this report. The proposed plan has no significant adverse impact to the natural and beneficial flood plain values. The flood plain is highly urbanized with numerous improved earthen and concrete channels. The proposed earthen channel modifications have been designed to provide a low-flow channel that resembles a natural channel condition. Four detention basins in or adjacent to the flood plain reduce flood flows downstream. Recreation features are also planned in the four detention basins and along the bayou, that in some areas involve wetlands creation and wildlife observation areas.

5. If the action is likely to induce development in the base flood plain, determine if a practicable non-flood plain alternative for the development exists.

The Recommended Plan is not likely to induce development in the base flood plain. Section 4.3 describes the future Without Project assumptions. Based on GIS and ground analysis, the watershed is determined to be almost fully developed under existing conditions. For new development and significant redevelopment, the Harris County Flood Control District, the City of Houston, and the City of Jersey Village have stringent floodplain management regulations. Any new construction must prove that they have zero impact on their neighbors or landowners downstream at any flood event. The Harris County Flood Control District is also involved in buying out residences subject to frequent flooding. Although this is not part of the federal project, it is part of the overall plan for the White Oak Bayou watershed.

6. As part of the planning process under the Principles and Guidelines, determine viable methods to minimize any adverse impacts of the action including any likely induced

development for which there is no practicable alternative and methods to restore and preserve the natural and beneficial flood plain values. This should include reevaluation of the "no action" alternative.

Mitigation measures were identified and are being implemented as part of the project to eliminate any potential adverse impacts resulting from the proposed action. Four detention basins are being provided to eliminate any potential for increased downstream flooding. As discussed in item 5. above, stringent controls on future development are in place to prevent any adverse induced development. Full mitigation of minor wetlands impacts resulting from the Recommended Plan is being provided, as described in Section 5.3.4 of the Main Report.

7. If the final determination is made that no practicable alternative exists to locating the action in the flood plain, advise the general public in the affected area of the findings.

The Draft General Reevaluation Report and EA was released for public review between March 1 and April 1, 2013. The Final General Reevaluation Report and EA were released for public, state and federal agency review in August 2013. Eight comments were received from the public and agencies. All were addressed to the satisfaction of the commenters.

8. Recommend the plan most responsive to the planning objectives established by the study and consistent with the requirements of the Executive Order.

The objective of the project is to reduce the probability and consequences of flooding in the study area. The project is responsive to the EO 11988 objective of "avoidance, to the extent possible, of long and short term adverse impacts associated with the occupancy and modification of the base flood plain and the avoidance of direct and indirect support of development in the base flood plain wherever there is a practicable alternative" because the proposed features focus on reducing the threat of flooding to the existing urban area, and altering a very small footprint within the flood plain. These features would reduce the hazard and risk associated with floods, thereby minimizing both the probability and the consequences of flooding within the urban area, and would preserve the natural and beneficial values of the base flood plain.

The White Oak Bayou Flood Damage Reduction Study documents the measures and alternatives evaluated during the study process. Because of the urban nature of the stream corridor environmental restoration was not considered as a planning objective in the study process due to the minimal output potential. Numerous non–structural alternatives were evaluated. However none were found to be economically feasible. Channel modifications and the four detention basins which comprise the Recommended Plan have been planned to enhance the natural environment where possible.

B. Residual Risk

1. Vulnerabilities

The Recommended Plan will result in reduced risk and improved public safety. The 1 percent flood plain will be reduced by approximately 1,650 acres and affected structures will be reduced by 1,325, from 6,074 structures to 4,749 structures. The population at risk of flooding is estimated to be approximately 15,000. The loss of life is estimated to be zero. The reductions in flooding for other exceedance probabilities are presented in Section 6.1 of the Main Report. The numbers of impacted structures are presented in Appendix B, Section 18. No induced growth is anticipated which would reduce public safety, as the area is almost fully developed now, and regulations are in place to control the safety of future development. For new development and significant redevelopment, the Harris County Flood Control District, the City of Houston, and the City of Jersey Village have stringent floodplain management regulations. Any new construction must prove that they have zero impact on their neighbors or landowners downstream at any flood event. The Harris County Flood Control District is also involved in buying out residences subject to frequent flooding. Although this is not part of the federal project, it is part of the overall plan for the White Oak Bayou watershed.

2. Residual Risk

The Recommended Plan reduces the risk of flooding along White Oak Bayou. The Recommended Plan will remove 1,650 acres and 1,325 structures from the one- percent annual chance exceedance floodplain, but this report acknowledges residual risk, which helps to prevent further development in the floodplain, as shown in Tables 5-1, 5-3, and 5-3a. Detention basins and channel modifications in the mid and upper reaches of the White Oak Bayou watershed reduce the flood heights along the bayou for all storm events. Safety issues related to the probability of exceeding the proposed plan's capability are discussed in Section 8.3 of Appendix A. The Recommended Plan consists of channel modifications and excavated detention basins. If the capacity of these features is exceeded, gradual increases in flood levels would occur during the flood event.

There is no potential for catastrophic failure or increased public safety hazards associated with exceedance of the capacity of the plan features. Flood depths are typically in the range of one to three feet and velocities in the flood plain are minimal due to the shallow flood depth. The rate of rise of flood levels is relatively slow, providing warning times of one to three hours typically. Due to the slow rate of rise and the shallow flood depths, evacuation routes are typically available. The Harris County Office of Emergency Management has an extensive flood warning and monitoring system and emergency action plans, which include the White Oak Bayou watershed area. Based on these factors the residual risk to public safety is small.

In summary, the residual risk is for low-velocity, low-depth flooding in residential areas of approximately 5,700 acres adjacent to the bayou containing approximately 4,750 structures . No significant concern for potential loss of life or emergency access routes exists.

3. Managing Residual Risk

The public review process has made the public aware of the flood plain risks and values. The Recommended Plan reduces flood risk along White Oak Bayou , but this report acknowledges residual risk, which helps to prevent further development in the flood plain.

Additionally, for new development and significant redevelopment, the Harris County Flood Control District, the City of Houston, and the City of Jersey Village have stringent floodplain management regulations, as discussed in Section 4.3. Any new construction must prove that they have zero impact on their neighbors or landowners downstream at any flood event. The Harris County Flood Control District has also been involved in buying out residences in the flood plain. Although this is not part of the federal project, it is part of the overall plan for the White Oak Bayou watershed.

C. Conclusion

The project is in compliance with EO 11988. The White Oak Bayou Flood Damage Reduction Plan Report documents the measures and alternatives evaluated during project planning. The proposed plan does have some improvements to the flood plain values by adding detention and widening the channel in the mid and upper reaches of the flood plain. There are no anticipated induced flooding impacts. The proposed action minimizes impacts to the flood plain and where possible has minor flood value improvements. Due to the urban nature of the stream, riparian corridor ecosystem restoration was not considered as a planning objective early in the study. Numerous non–structural alternatives were evaluated. Channel modifications using natural low-flow channels sections are being implemented. Significant active and passive recreational features are being provided in the Recommended Plan.

ADDENDUM 1

COST & ECONOMIC DAMAGE UPDATE

White Oak Bayou Flood Damage Reduction Project
Addendum 1 - Cost & Economic Damage Update
January 9, 2014 (Revised August 13, 2014)

1.0 Purpose

The following addendum documents the results of the update that was performed of the project costs, economic damages and resulting benefits for the White Oak Bayou Flood Damage Reduction Project. This addendum updates the results presented in the final General Reevaluation Report, dated September 2013. The September GRR presents the costs, damages, and benefits based on FY 2013. The results have been updated in this addendum to October 2013 (FY 2014) with the FY 2014 discount rate of 3.50%.

2.0 Cost Update

The cost of the Recommended Plan developed in MCACES was updated using the Region VI Cost Book for applicable equipment and fuel costs, 2013 R.S. Means Labor rates, and a real estate escalation rate of 3.1%.

The resulting first costs are presented in Table 1. The total is $119.436 million, in comparison to the total of $117.0 million presented in the September 2013 GRR. Table 2 presents the cost apportionment between Federal and non-Federal, based on the updated first costs. The Federal and non-Federal costs of the Flood Damage Reduction Plan are $59.563 million and $47.853 million, respectively. Percentage shares are 55.5 and 44.5% respectively. For the Recreation Plan, the calculated Federal 50% share exceeds the maximum allowable 10% of the Federal flood damage cost by $54,000. The excess cost has been included in the non-Federal share, resulting in Federal and non-Federal costs of $5.956 million and $6.064 million, respectively. Percentage shares are 49.6% and 50.4%, respectively.

3.0 Economic Damages Update

The economic damages were updated to October 2013 (FY 2014) as follows:

1. Changes in structure value from 2011 to 2014 were analyzed using a sample comparison of Harris County Appraisal District depreciated replacement costs of structure values between 2011 and current values. The resulting change in value was determined to be 3.1%. This index value was applied to the damage estimates for the residential and commercial properties within the project area.
2. Other costs (unit costs for vehicle, utilities, post disaster costs, and road damage categories) and flood insurance benefits were updated to October 2013 price levels using an adjustment factor based on the Consumer Price Index (CPI). The adjustment was also 3.1%. No adjustment was made to the flood insurance benefits.

Based on the indices developed, the resulting Without Project and Recommended Plan damages were calculated to be $61.9 million and $25.9 million, respectively. Presented in Table 3 is the updated Economic Summary for the Recommended Plan. Based on FY 2014 price levels, the total project investment for the flood risk management components, including the total project first cost of $107.416 million and interest during construction of $3.146 million, is $110.562 million, as shown in Table 3. The plan would have annual costs of $5.048 million, net annual equivalent benefits of $31.076 million, and a benefit-cost ratio of 7.2, based on the FY 2014 interest rate of 3.50%. Based on a 7.00% interest rate, the net benefits are $27.551 million and the benefit cost ratio is 4.2.

For the Recreation Plan, based on FY 2014 price levels the total first cost is $12.020 million and the total investment is $12.990 million, as shown in Table 3. The annual costs are $0.586 million, with net annual benefits of $2.160 million and a benefit-cost ratio of 4.7. Based on a 7.00% interest rate, the net benefits are $1.660 million and the benefit cost ratio is 2.5.

Presented in Table 4 for the combined flood damage reduction plan and recreation plan is an economic summary of the consolidated first costs, total investment, annual costs and benefits, and net benefits and benefit-cost ratio. For the combined plan, based on FY 2014 price levels, the total first cost is $119.436 million and the total investment is $123.552 million, as shown in Table 4. The annual costs are $5.634 million, with net annual benefits of $33.236 million and a benefit-cost ratio of 6.9. Based on a 7.00% interest rate, the net benefits are $29.211 million and the benefit cost ratio is 4.0.

4.0 Status of Construction

The Local Sponsor has already constructed certain components of the Recommended Plan. Status of construction components is as follows:

Channelization E122 to Gessner: channel modifications from E122-00-00 to Gessner have been constructed.
Detention at Gessner/Beltway 8: detention facility totaling 40.4 acres near Gessner Road and Beltway 8 and providing an estimated detention volume of 427 ac-ft. has been completed. Acquisition of 10.6 acres and construction of the 92 ac-ft volume are required.
Detention at Fairbanks-North Houston: detention facility near Fairbanks-North Houston Road totaling 142.2 acres and providing an estimated total detention volume of 1,269 ac-ft. has been constructed.
Detention at Hollister: detention facility providing 730 ac-ft of detention volume on 93.7 acres located at Hollister Road on land south of the bayou has been constructed.
Detention at Jones Road: detention facility providing a detention volume of 420 ac-ft. has been constructed.
Channelization from E200 to FM 1960: none of the approximately 3.4 miles of earthen channel modifications from detention channel E200-00-00 to FM 1960 has been constructed.

Channelization from Gessner to E200: 2.9 miles of channel modifications to the Jersey Village channel and ditch E141-00-00 within the existing right-of-way has been constructed. Modifications to the approximately 2.1 mile channel segment of the bayou remain to be constructed

Channelization from Vogel Creek to E122: Modifications to the channel segment from Vogel Creek to E122-00-00 remain to be constructed

Channelization from Vogel Creek to Cole Creek: Modifications to the channel segment from Vogel Creek to Cole Creek remain to be constructed:

Environmental Mitigation: The 4.99 acres in Mitigation Bank A have been constructed and purchased. Construction of the Local Sponsor Volunteer Mitigation, consisting of seven acres of wetlands at the Hollister basin was started in January, 2013.

Recreation Facilities: None of the recreation facilities have been constructed.

Table 1
Cost Estimate Summary for the Recommended Plan
Values in $ FY 2014 Price Level, All First Costs

Description	Total Costs w/ 23% Cont.	Actual Costs (Sunk Costs)	Future Costs w/ 23% Cont.
LANDS & DAMAGES			
Channelization E122 to Gessner (37,313 LF)	$456,000	$456,000	$0
Detention at Gessner/Beltway 8 (519AC-FT TOTAL, 92 AC-FT Remaining to be constructed)	$7,663,000	$4,095,000	$3,568,000
Detention at Fairbanks North Houston (1,269 AC-FT)	$5,569,000	$5,569,000	$0
Detention at Hollister (730 AC-FT)	$1,011,000	$1,011,000	$0
Detention at Jones Road (420 AC-FT)	$9,879,000	$9,879,000	$0
Channelization Vogel Creek to E122	$547,000		$547,000
Channelization Vogel Creek to Cole Creek	$246,000		$246,000
RELOCATIONS			$0
Detention at Gessner/Beltway 8 (519 AC-FT TOTAL, 92 AC-FT Remaining to be constructed)	$1,830,000		$1,830,000
Detention at Fairbanks North Houston (1,269 AC-FT)	$0		$0
Detention at Hollister (730 AC-FT)	$103,000	$103,000	$0
Channelization from E200 to FM 1960 (17,971 LF)	$4,742,000		$4,742,000
Channelization Vogel Creek to E122	$5,750,000		$5,750,000
Channelization Vogel Creek to Cole Creek	$2,439,000		$2,439,000
CHANNELS & CANALS			$0
Channelization E122 to Gessner (37,313 LF)	$7,408,000	$7,408,000	$0
Detention at Gessner/Beltway 8 (519 AC-FT TOTAL, 92 AC-FT Remaining to be constructed)	$4,408,000	$2,821,000	$1,587,000
Detention at Fairbanks North Houston (1,269 AC-FT)	$5,578,000	$5,578,000	$0
Detention at Hollister (730 AC-FT)	$7,504,000	$7,504,000	$0
Detention at Jones Road (420 AC-FT)	$8,003,000	$8,003,000	$0
Channelization from E200 to FM 1960 (17,971 LF)	$2,770,000		$2,770,000
Channelization from Gessner to E200 (10,983 LF)	$12,578,000	$8,965,000	$3,613,000
Channelization Vogel Creek to E122	$4,893,000		$4,893,000
Channelization Vogel Creek to Cole Creek	$2,400,000		$2,400,000
MITIGATION	$0		$0
Wetlands Mitigation - Greens Bayou Mitigation Bank	$127,000	$0	$127,000
Cultural Resources Mitigation – None	$0		$0
PLANNING, ENGINEERING, and DESIGN (Flood Control)	$3,126,000	$1,352,000	$1,774,000
CONSTRUCTION MANAGEMENT (Flood Control)	$8,388,000	$5,467,000	$2,921,000
TOTAL COST FLOOD RISK COMPONENTS	$107,416,000	$68,211,000	$39,205,000

Table 1 (cont.)
Cost Estimate Summary for the Recommended Plan
Values in $ FY 2014 Price Level, All First Costs

Description	Total Costs w/ 23 % Cont.	Actual Costs (Sunk Costs)	Future Costs w/ 23% Cont.
RECREATION FACILITIES			
Detention at Gessner/Beltway 8 (519 AC-FT TOTAL)	$1,272,000		$1,272,000
Detention at Fairbanks North Houston (1,269 AC-FT)	$2,090,000		$2,090,000
Detention at Hollister (730 AC-FT)	$1,219,000		$1,219,000
Detention at Jones Road (420 AC-FT)	$688,000		$688,000
Linear Parks	$4,986,000		$4,986,000
PLANNING, ENGINEERING, and DESIGN (Recreation)	$647,000		$647,000
CONSTRUCTION MANAGEMENT (Recreation)	$1,119,000		$1,119,000
TOTAL COST RECREATION PLAN COMPONENTS	$12,020,000		$12,020,000
GRAND TOTAL	$119,436,000	$68,211,000	$51,225,000

Note 1. Contingencies of 23 % applied only to Future Costs.
Note 2. All costs shown are first costs without escalation.
Note 3. All costs listed as Actual are for construction already completed.
Note 4. Grand Total includes the total first cost of Flood Risk Components and Recreation Plan Components.
Note 5. Only the least-cost Environmental Mitigation Plan cost of $127,000 ($103,000 plus contingency) will be cost-shared with the Federal government. Local Sponsor Volunteer Mitigation is not included in the costs.

Table 2
White Oak Bayou, Texas
Cost Apportionment for the Recommended Plan
(FY 2014 Price Level – All Costs in $)

Item	Federal Cost	Non-Federal Cost	Total Cost
Flood Risk Management Components			
5% Cash	-$5,371,000	$5,371,000	$0
LERR&D	$258,000	$42,482,000	$42,740,000
Construction-Federal Cost Share	$64,676,000	$0	$64,676,000
50% Adjustment	$0	$0	$0
Subtotal	$59,563,000	$47,853,000	$107,416,000
(Percent) *	55.5	44.5	
HTRW	$0	$0	$0
Recreation Plan	$5,956,000	$6,064,000	$12,020,000
(Percent)	49.6	50.4	
Recommended Plan Total Project			**$119,436,000**

LERR&D = Lands and damages, easements, rights-of-way, relocations, & disposal costs.

* Non-Federal costs will be no less than 25% and not greater than 50% for the NED Plan.

All costs shown are first costs.
Local Sponsor Volunteer Mitigation Cost is not included in this table.

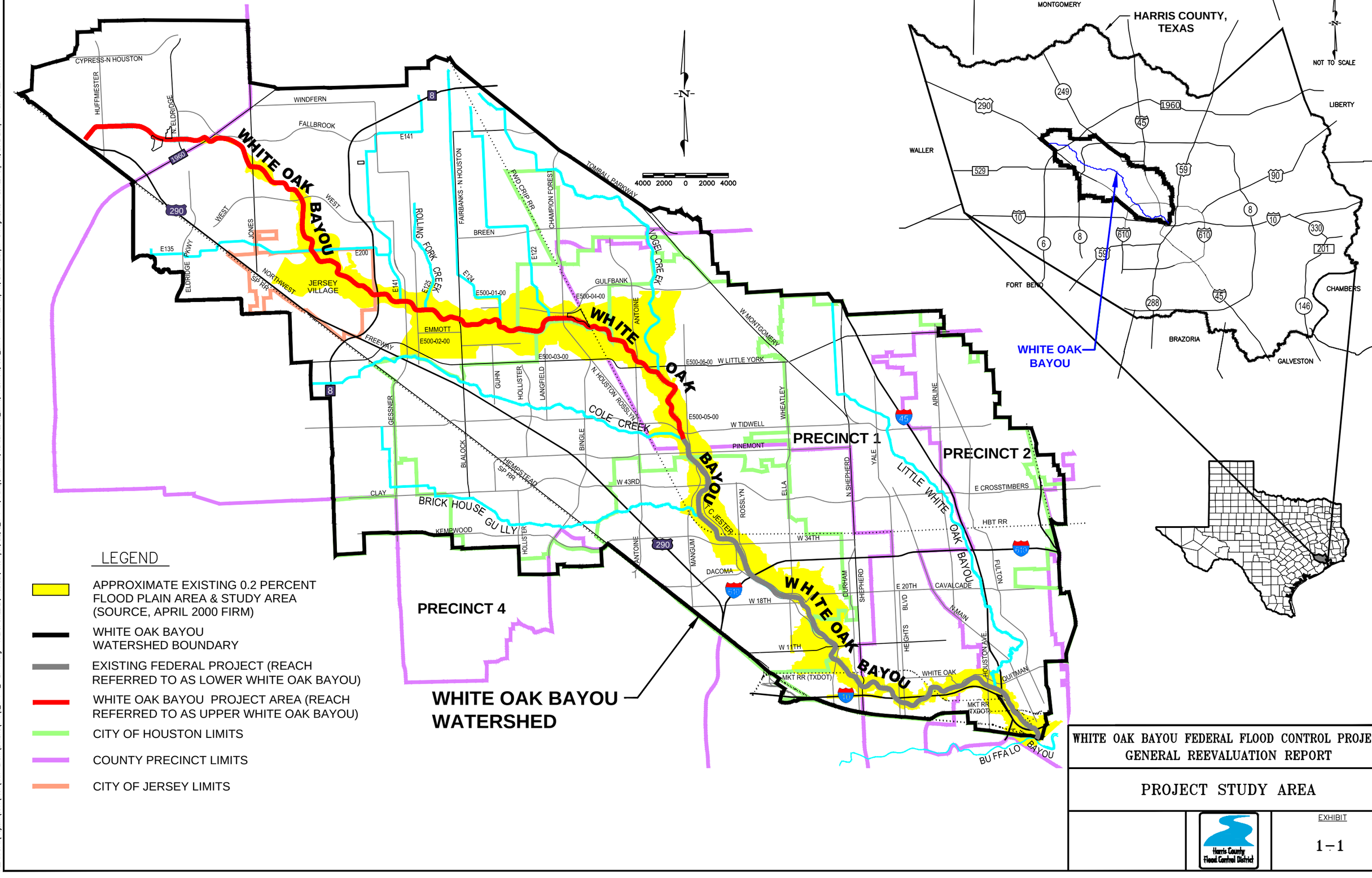
Table 3
Economic Summary for the Recommended Flood Risk Management Plan & Recreation Plan Separately
FY 2014 Price Level
Value in $ FY 2014 Price Level, 3.50% interest,
50-year period of analysis

Item No.	Description	Recommended Plan with 23% Contingencies for Future Construction Items Only
1	LERRD (Flood Risk Management)	$42,740,000
2	Construction (Flood Damage Reduction)	$64,676,000
3	Project First Cost	$107,416,000
4	Interest During Construction	$3,146,000
5	Total Investment	$110,562,000
Flood Risk Management Plan Annual Cost		
6	Interest and Amortization	$4,714,000
7	OMRR&R	$334,000
8	Total Annual Cost	$5,048,000
Flood Risk Management Plan Equivalent Annual Benefit		
9	Flood Damage Reduction Benefit	$35,945,000
10	Benefits from Saving Insurance Cost	$179,000
11	Total Equivalent Annual Benefit	$36,124,000
Flood Risk Management Plan Comparison of Benefit to Cost		
12	Benefit-Cost Ratio	7.2
13	Net Annual Benefit	$31,076,000
Recreation Plan Costs		
14	Recreation Plan First Cost	$12,020,000
15	Interest During Construction	$970,000
16	Total Investment	$12,990,000
Recreation Plan Annual Cost		
17	Interest and Amortization	$512,000
18	OMRR&R	$74,000
19	Total Annual Cost	$586,000
Recreation Plan Benefit		
20	Recreation Benefit	$2,746,000
Recreation Plan Comparison of Benefit to Cost		
21	Benefit-Cost Ratio	4.7

Table 4
Economic Summary for the Combined
Recommended Flood Risk Management Plan & Recreation Plan
FY 2014 Price Level
Value in $ FY 2014 Price Level, 3.50% interest,
50-year period of analysis

Item No.	Description	Total Combined Recommended Plan with 23% Contingencies Future Construction Items
Combined Project Costs		
1	Total Project First Cost	$119,436,000
2	Interest During Construction	$4,116,000
3	Total Investment	$123,552,000
Combined Project Annual Costs		
4	Interest and Amortization	$5,226,000
5	OMRR&R	$408,000
6	Total Annual Cost	$5,634,000
Combined Project Equivalent Annual Benefits		
7	Total Equivalent Annual Benefit	$38,870,000
Combined Project Net Annual Benefits		
8	Net Annual Benefit	$33,236,000
Combined Project Benefit-Cost Ratio		
9	Benefit-Cost Ratio	6.9

EXHIBITS



LEGEND

- APPROXIMATE EXISTING 0.2 PERCENT FLOOD PLAIN AREA & STUDY AREA (SOURCE, APRIL 2000 FIRM)
- WHITE OAK BAYOU WATERSHED BOUNDARY
- EXISTING FEDERAL PROJECT (REACH REFERRED TO AS LOWER WHITE OAK BAYOU)
- WHITE OAK BAYOU PROJECT AREA (REACH REFERRED TO AS UPPER WHITE OAK BAYOU)
- CITY OF HOUSTON LIMITS
- COUNTY PRECINCT LIMITS
- CITY OF JERSEY LIMITS

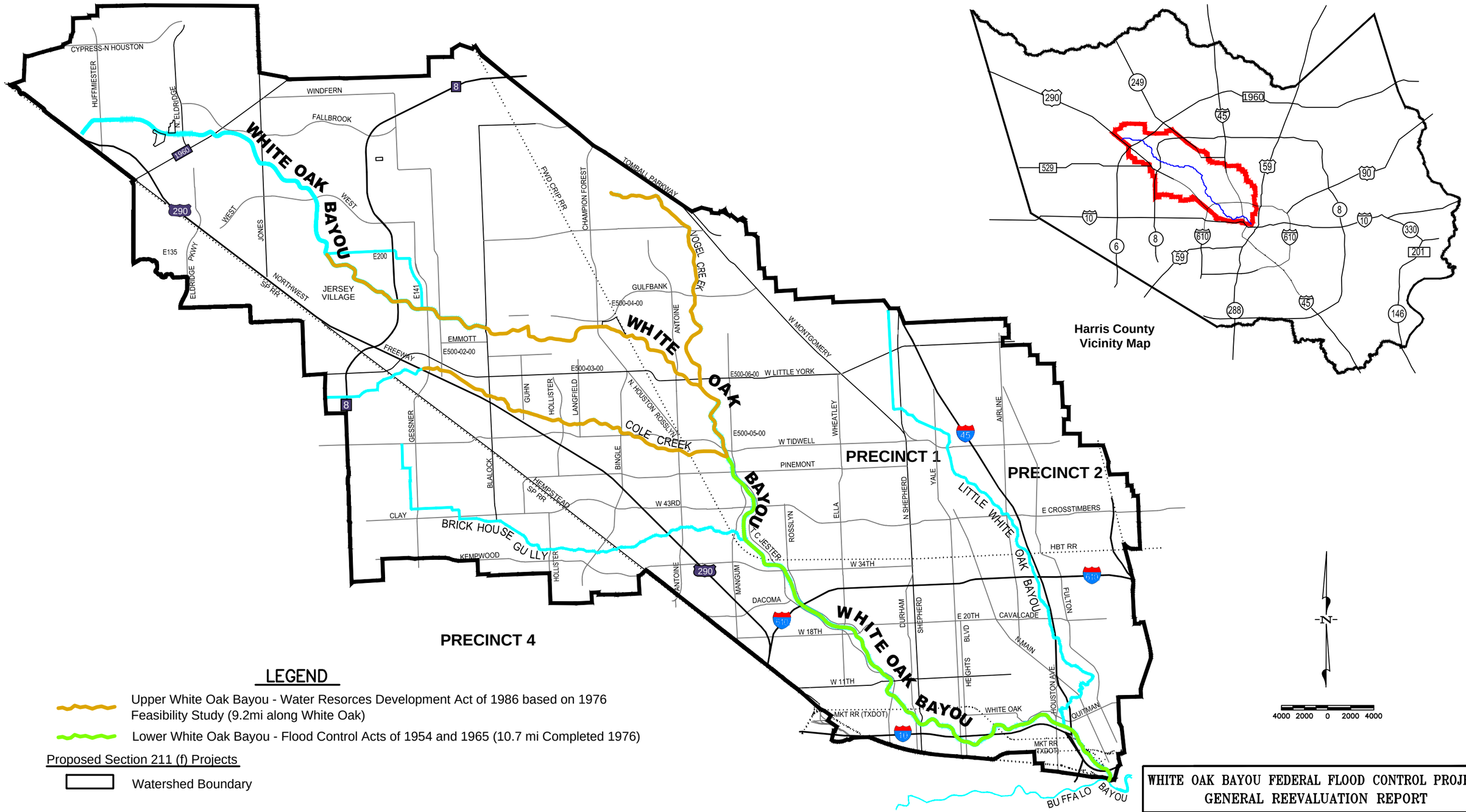
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

PROJECT STUDY AREA

Harris County Flood Control District

EXHIBIT
1-1

FILE INFO: E:\Projdsk1\0344\1607\MAIN REPORT\EXHIBITS\1-1\E_M-1-1_7-27-11.dwg XREFS: STREET2A; WOBTBLK; Wob-fp01; 2.2; E_M-1-1%; Pomap; Wob-row; JERSEYVILLAGE_LIMITS; PRECINCTS; COH_LIMITS MODIFIED: Sep 13, 2012 12:28pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:33pm PLOT SCALE: 1=4000



LEGEND

Upper White Oak Bayou - Water Resorces Development Act of 1986 based on 1976 Feasibility Study (9.2mi along White Oak)

Lower White Oak Bayou - Flood Control Acts of 1954 and 1965 (10.7 mi Completed 1976)

Proposed Section 211 (f) Projects

Watershed Boundary

4000 2000 0 2000 4000

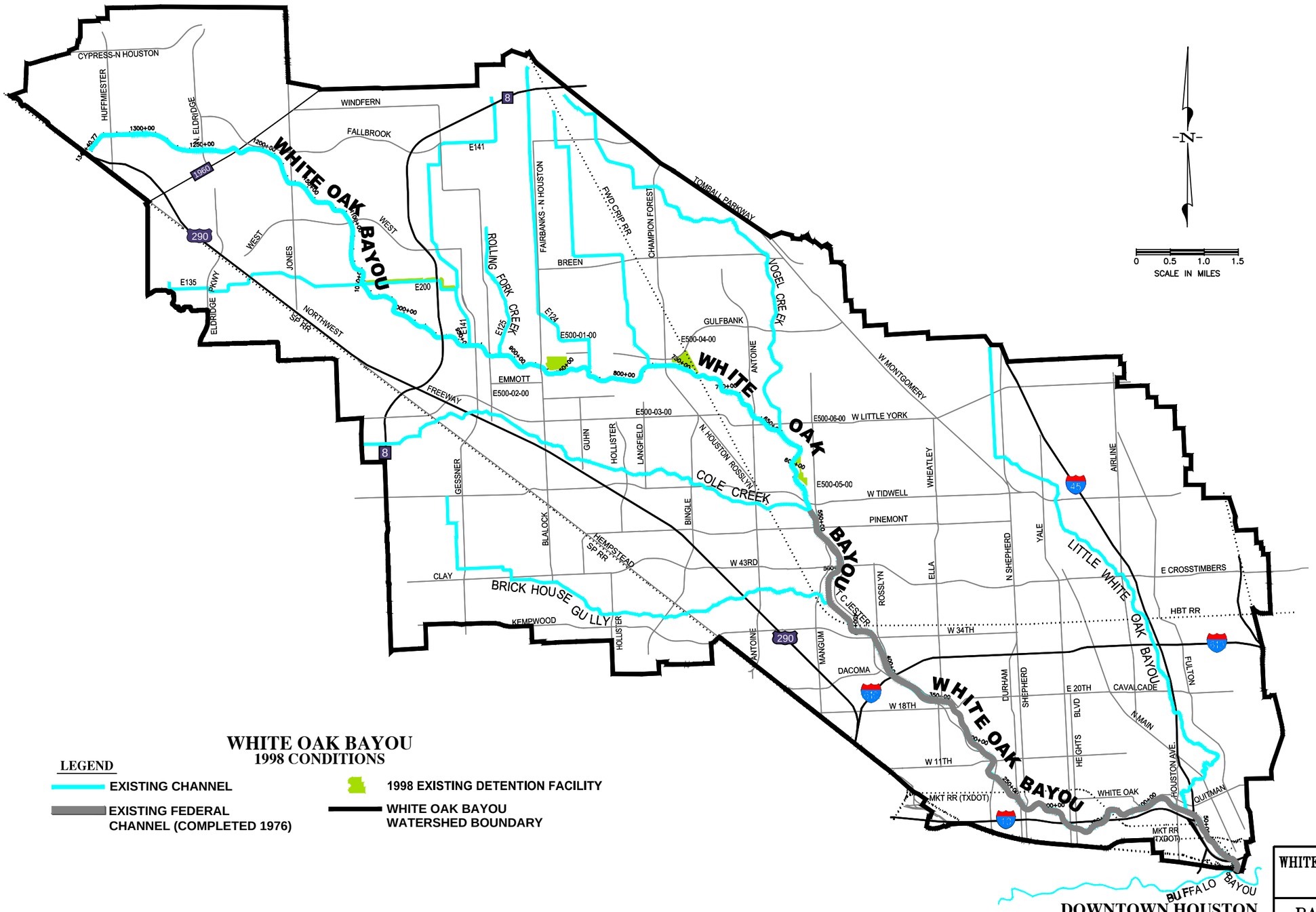
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

PROJECT AUTHORIZATIONS

Harris County Flood Control District

EXHIBIT

1–1a



WHITE OAK BAYOU
1998 CONDITIONS

LEGEND

- EXISTING CHANNEL
- EXISTING FEDERAL CHANNEL (COMPLETED 1976)
- 1998 EXISTING DETENTION FACILITY
- WHITE OAK BAYOU WATERSHED BOUNDARY

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT GENERAL REEVALUATION REPORT
BASE WITHOUT PROJECT CONDITIONS EXISTING 1998 FACILITIES
Harris County Flood Control District
EXHIBIT 4-1

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ELEVATION IN FEET (1973 ADJUSTMENT)
(CONTINUED BELOW)

130
120
110
100
90
80
70
60
50

700+00 800+00 900+00 1000+00 1100+00 1200+00 1300+00 1400+00

FWDCRIP RR
NORTH HOUSTON –ROSSLYN
FAIRBANKS NORTH –HOUSTON
WINDFERN
GESSNER
BELTWAY 8
JERSEY VILLAGE
EQUADOR
LAKEVIEW
TAHOE
WEST
RIO GRANDE
BENT SPUR
JONES
FM 1960
ELRIDGE PARKWAY
WORTHAM
HUFFMEISTER

E500–01–00
E500–04–00
FLOWLINE

80
70
60
50
40
30
20
10
0
–10

0 100+00 200+00 300+00 400+00 500+00 600+00 700+00

TN&O RR
SP RR,
MAIN
IH–10
MKT RR
HOGAN
MKT RR
IH–45
HOUSTON
TAYLOR
STUDEWOOD
MKT RR
IH–10
HEIGHTS
YALE
RAILROAD
BRIDGE
NORTH
SHEPHERD
DURHAM
MKT RR
T.C. JESTER
WEST 11TH
T.C. JESTER
WEST 18TH
ELLA
IH 610
WEST 34TH
T.C. JESTER
W.
HBT RR
BRICKHOUSE
GULLY
WEST 43RD
MANGUM
PINEMONT
CREEKMONT
COLE CREEK
W. TIDWELL
VOGEL
CREEK
LITTLE
WEST
YORK
ANTOINE
VICTORY
ALABONSON

E500–05–00
FLOWLINE
CONCRETE

(CONTINUED ABOVE)

STATION IN FEET

SCALE:
HOR: 1" = 5000'
VER: 1" = 20'

LEGEND WITHOUT PROJECT

- BRIDGES
- LEFT OVERBANK
- RIGHT OVERBANK
- INVERT
- 50 PERCENT EXCEEDANCE PROBABILITY FLOOD
- 20 PERCENT EXCEEDANCE PROBABILITY FLOOD
- 4 PERCENT EXCEEDANCE PROBABILITY FLOOD
- 0.4 PERCENT EXCEEDANCE PROBABILITY FLOOD

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

HEC–RAS FLOOD PROFILE
BASE WITHOUT PROJECT CONDITIONS

Harris County Flood Control District

EXHIBIT
4–2.1

ELEVATION IN FEET (1973 ADJUSTMENT)
(CONTINUED BELOW)

130
120
110
100
90
80
70
60
50

700+00
800+00
900+00
1000+00
1100+00
1200+00
1300+00
1400+00

FWDCRIP RR
NORTH HOUSTON –ROSSLYN
FAIRBANKS NORTH –HOUSTON
WINDFERN
GESSNER
BELTWAY 8
JERSEY VILLAGE
EQUADOR
LAKEVIEW
TAHOE
WEST
RIO GRANDE
BENT SPUR
JONES
FM 1960
ELDRIDGE PARKWAY
WORTHAM
HUFFMEISTER

E500–01–00
E500–04–00
FLOWLINE

80
70
60
50
40
30
20
10
0
–10

0
100+00
200+00
300+00
400+00
500+00
600+00
700+00

SP RR,
TN&O RR
MAIN
IH–10
MKT RR
HOGAN
MKT RR
IH–45
HOUSTON
TAYLOR
STUDEWOOD
MKT RR
IH–10
HEIGHTS
YALE
RAILROAD
BRIDGE
NORTH
SHEPHERD
DURHAM
MKT RR
T.C. JESTER
WEST 11TH
T.C. JESTER
WEST 18TH
ELLA
IH 610
WEST 34TH
W. T.C. JESTER
HBT RR
BRICKHOUSE
GULLY
WEST 43RD
MANGUM
PINEMONT
CREEKMONT
COLE CREEK
W. TIDWELL
VOGEL
CREEK
LITTLE
WEST
YORK
ANTOINE
VICTORY
ALABONSON

E500–05–00
FLOWLINE
CONCRETE

LEGEND WITHOUT PROJECT
BRIDGES
LEFT OVERBANK
RIGHT OVERBANK
INVERT
10 PERCENT EXCEEDANCE PROBABILITY FLOOD
2 PERCENT EXCEEDANCE PROBABILITY FLOOD
1 PERCENT EXCEEDANCE PROBABILITY FLOOD
0.2 PERCENT EXCEEDANCE PROBABILITY FLOOD

SCALE:
HOR: 1" = 5000'
VER: 1" = 20'

STATION IN FEET

(CONTINUED ABOVE)

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

HEC–RAS FLOOD PROFILE
BASE WITHOUT PROJECT CONDITIONS

Harris County Flood Control District

EXHIBIT
4–2.2

WHITE OAK BAYOU WATERSHED

LEGEND:

18 **ECONOMIC REACH AND NUMBER**

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

ECONOMIC REACHES

EXHIBIT 4-3

Harris County Flood Control District

4000 2000 0 2000 4000

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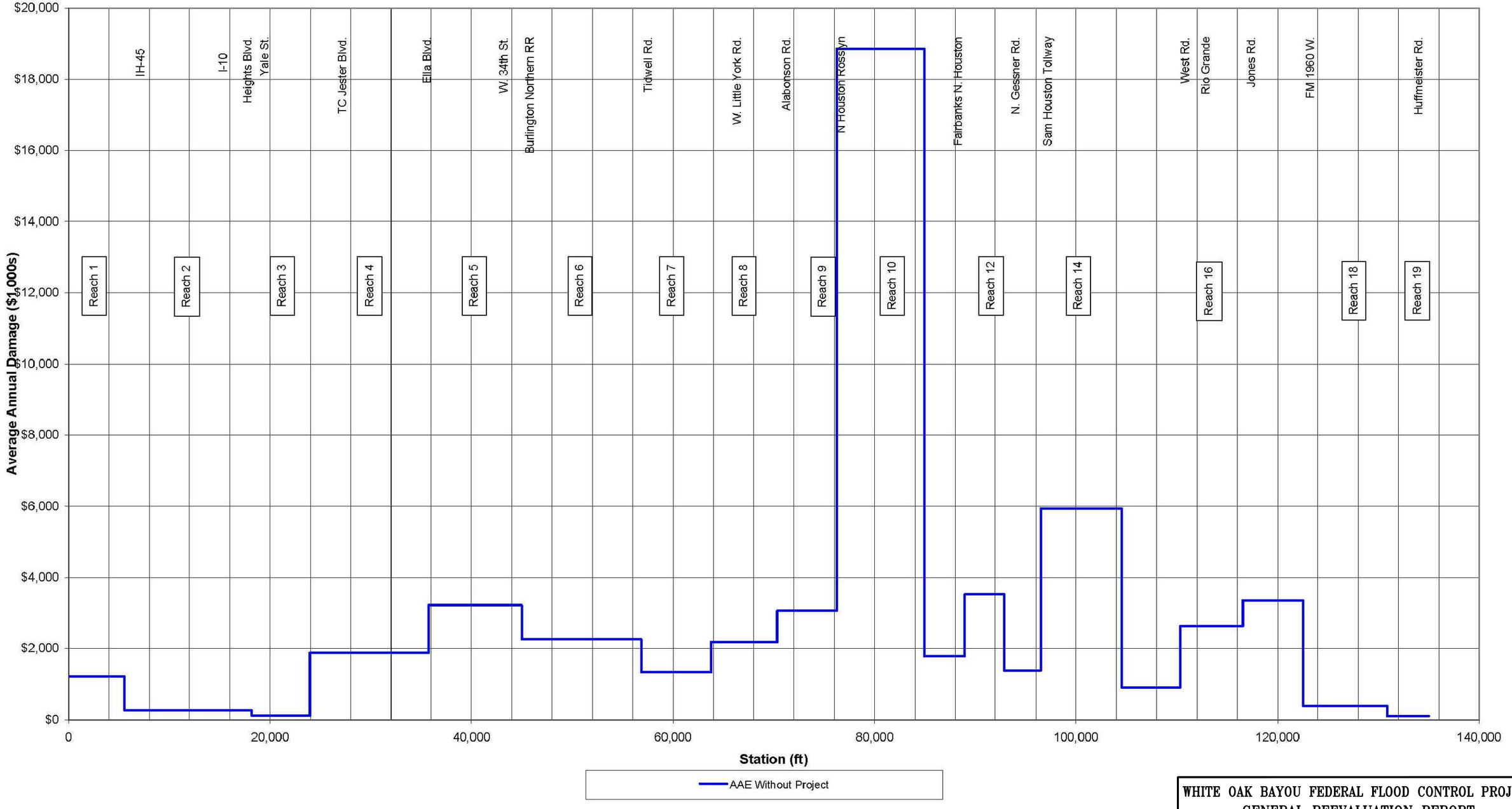
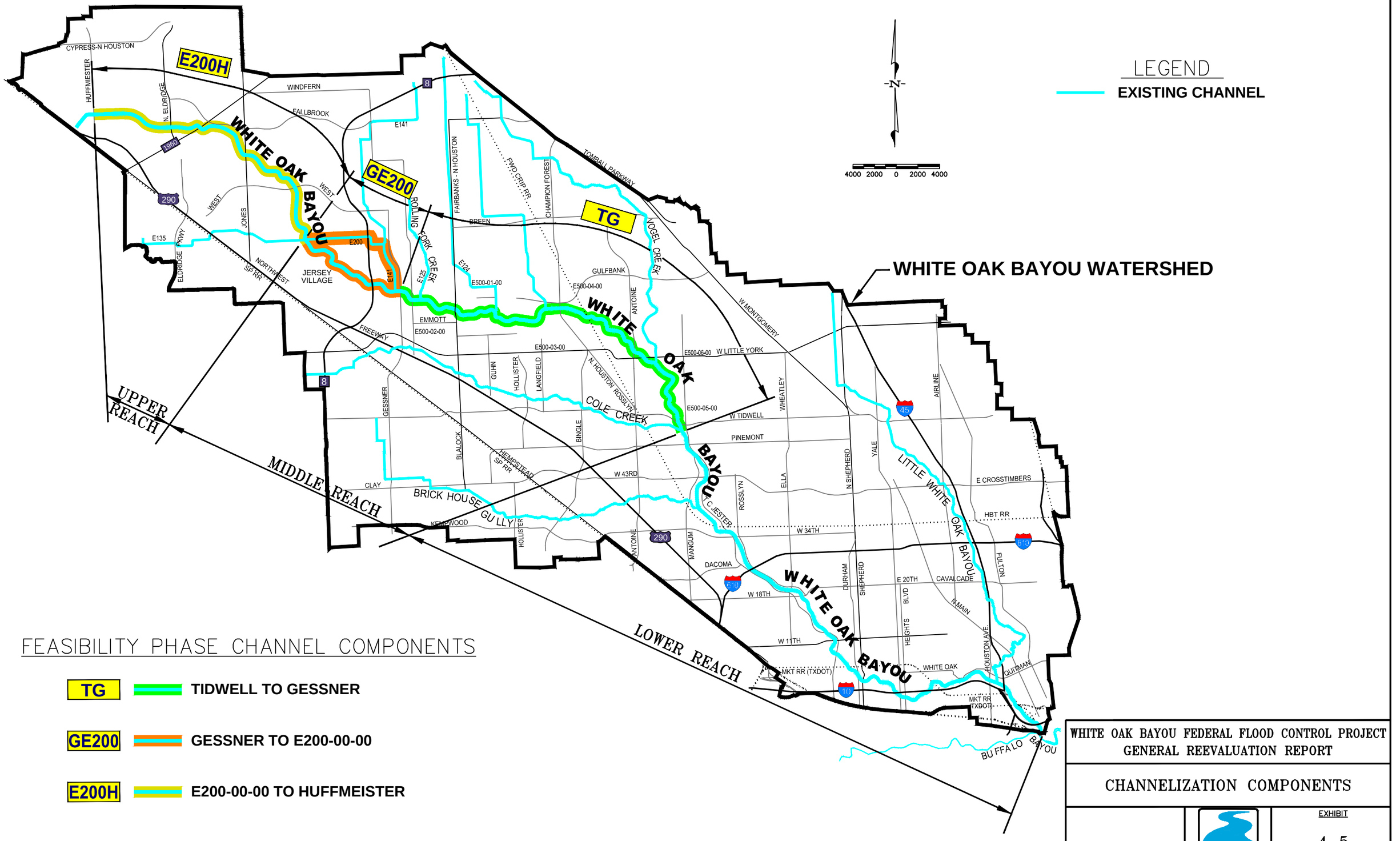
Exhibit 4-4: Existing Flood Damage Profiles for White Oak Bayou



WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT GENERAL REEVALUATION REPORT		
Existing Flood Damage Profile For White Oak Bayou		
	Harris County Flood Control District	EXHIBIT 4-4



FEASIBILITY PHASE CHANNEL COMPONENTS

TG	TIDWELL TO GESSNER
GE200	GESSNER TO E200-00-00
E200H	E200-00-00 TO HUFFMEISTER

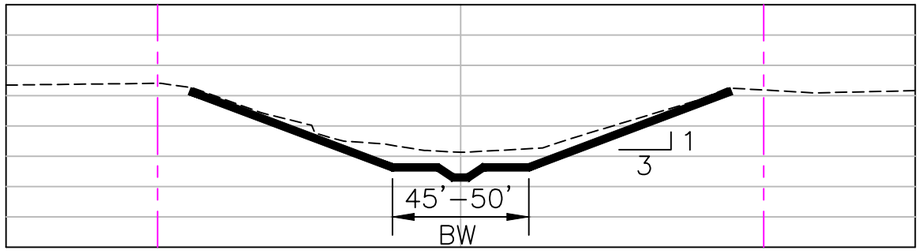
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

CHANNELIZATION COMPONENTS

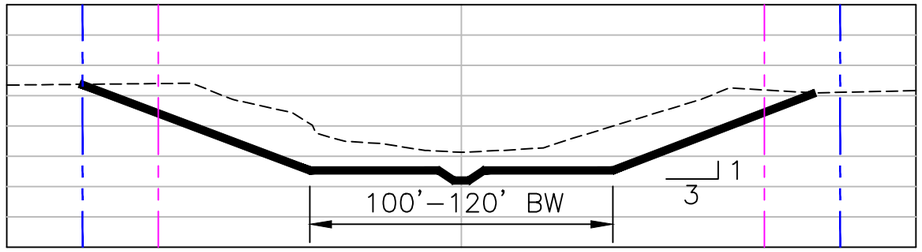
Harris County Flood Control District

EXHIBIT 4-5

FILE INFO: L:\Projdat\0344\1607\MAIN REPORT\EXHIBITS\4-5\E_LM-04-5.dwg XREFS: STREET24; WOBTBLK; WOB-CLB1; 2.2 MODIFIED: Sep 13, 2012 12:32pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:33pm PLOT SCALE: 1=4000



TG.1 DETAIL
(NTS)



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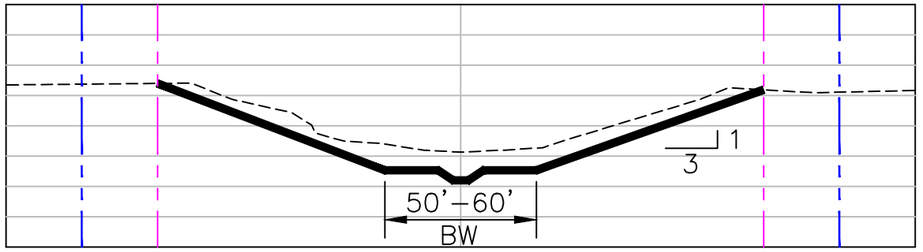

TG.2 DETAIL
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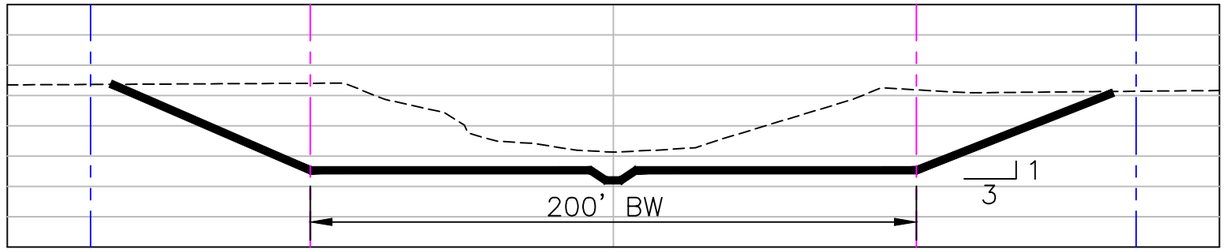
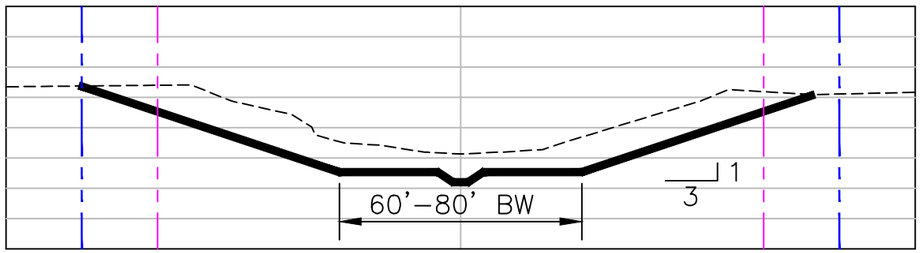


TG.6 DETAIL
(NTS)



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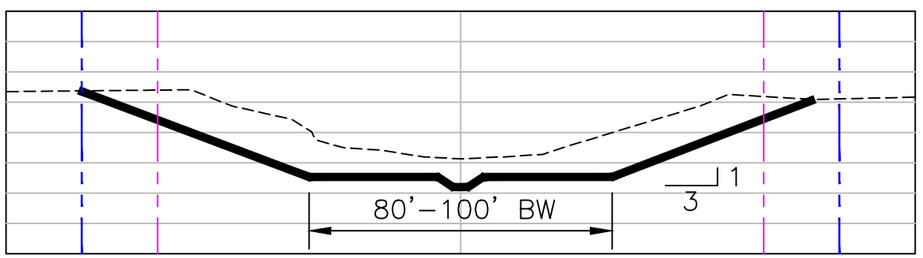
(NTS)



TG.4 DETAIL
(NTS)

LEGEND

- EXISTING CHANNEL
- EXISTING R.O.W.
- R.O.W. REQUIRED
- EARTHEN-GRASS LINED
- CONCRETE LINED

SCALE IN FEET
0 50 100 150

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

CHANNELIZATION COMPONENT
TG – CROSS SECTIONS

Harris County Flood Control District

EXHIBIT
4–6.1

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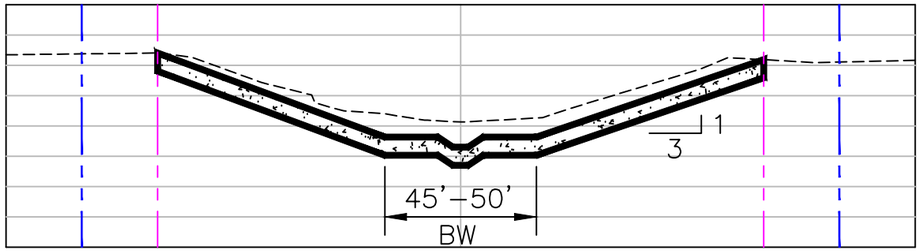
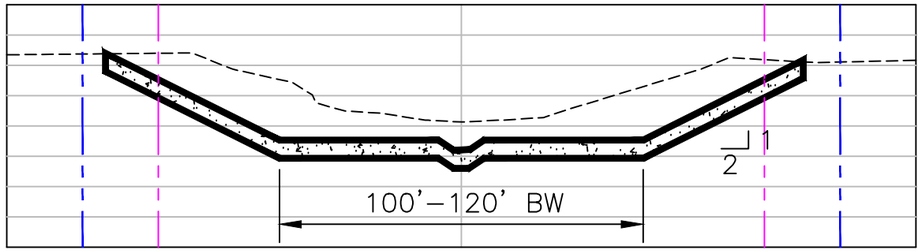
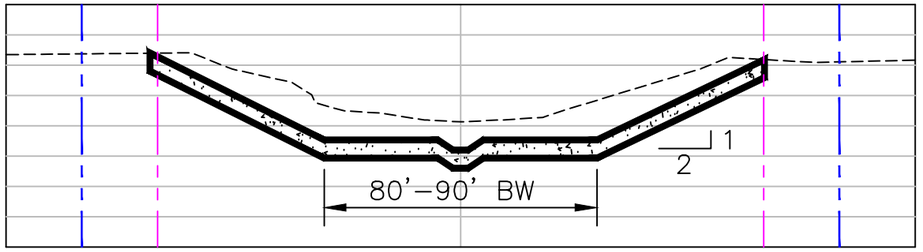


TG.7 DETAIL
(NTS)



TG.11 DETAIL
(NTS)



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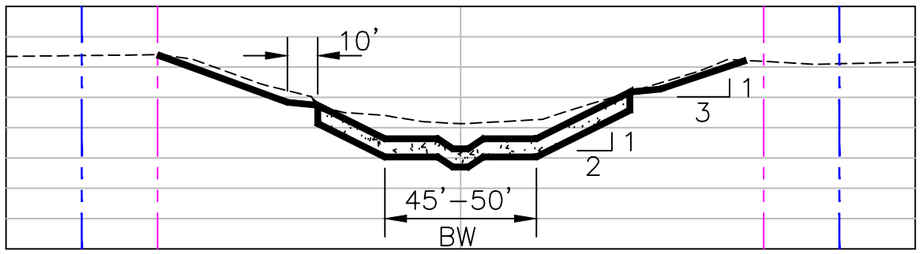
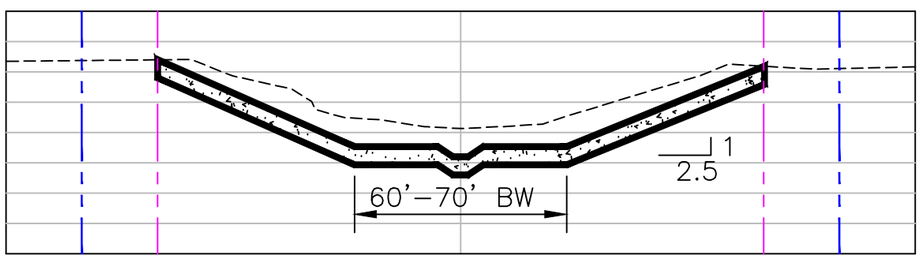
(NTS)



TG.9 DETAIL
(NTS)



TG.10 DETAIL
(NTS)

LEGEND

- **EXISTING CHANNEL**
- **EXISTING R.O.W.**
- **R.O.W. REQUIRED**
- **EARTHEN-GRASS LINED**
- **CONCRETE LINED**

SCALE IN FEET
0 50 100 150

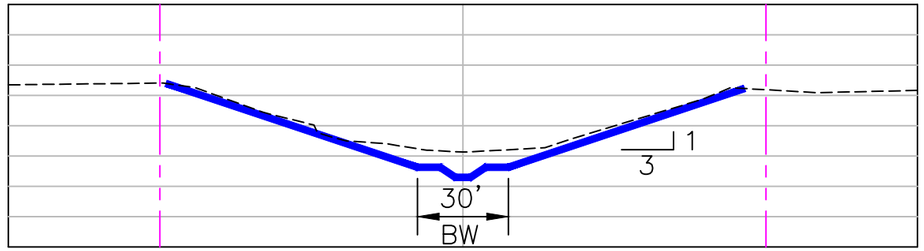
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

CHANNELIZATION COMPONENT
TG – CROSS SECTIONS

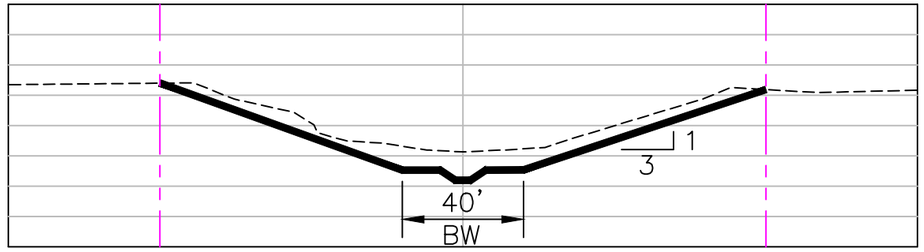
Harris County Flood Control District

EXHIBIT
4–6.2

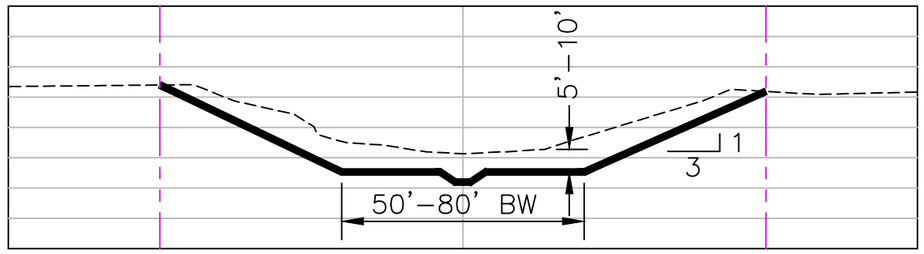
FILE INFO: I:\Projdat1\0344\1607\MAIN REPORT\EXHIBITS\4-6.2\E_M-04-6.2.dwg XREFS: WOBTBLK MODIFIED: Sep 13, 2012 12:34pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:33pm PLOT SCALE: 1=4000



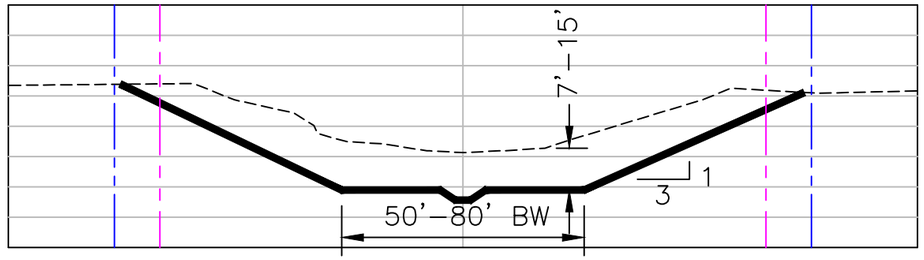
GE200.0 DETAIL (WHITE OAK BAYOU CHANNEL MODIFICATIONS)
(NTS)



GE200.1 DETAIL (BY-PASS CHANNEL MODIFICATIONS)
(NTS)



GE200.2 DETAIL (BY-PASS CHANNEL MODIFICATIONS)
(NTS)



GE200.3 DETAIL (BY-PASS CHANNEL MODIFICATIONS)
(NTS)

GE200.4 = **GE200.0** + **GE200.1**

GE200.5 = **GE200.0** + **GE200.2**

GE200.6 = **GE200.0** + **GE200.3**

LEGEND

GE200.0 - MAIN STEM CHANNEL

- EXISTING CHANNEL

- EXISTING R.O.W.

- PROPOSED R.O.W.

GE200.1 - BYPASS EARTHEN-GRASS CHANNEL

SCALE IN FEET

0 50 100 150

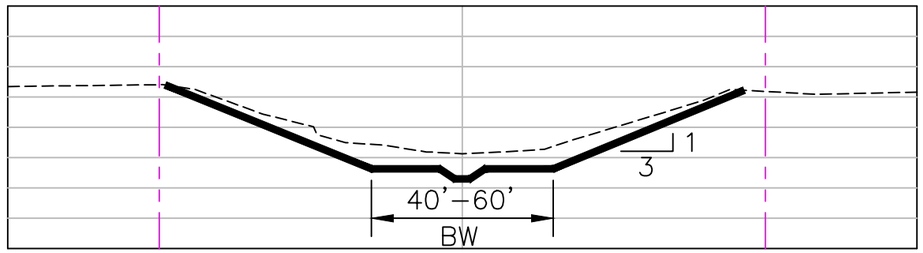
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

CHANNELIZATION COMPONENT
GE200 – CROSS SECTIONS

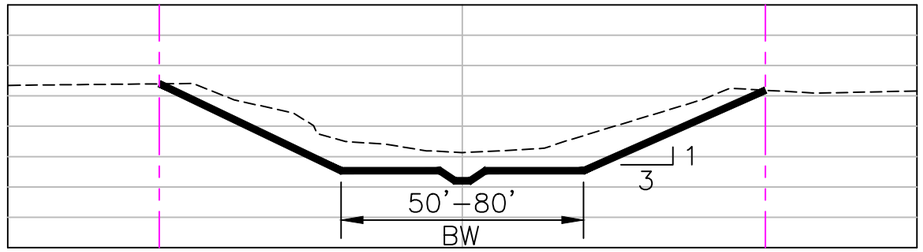
Harris County Flood Control District

EXHIBIT
4-7

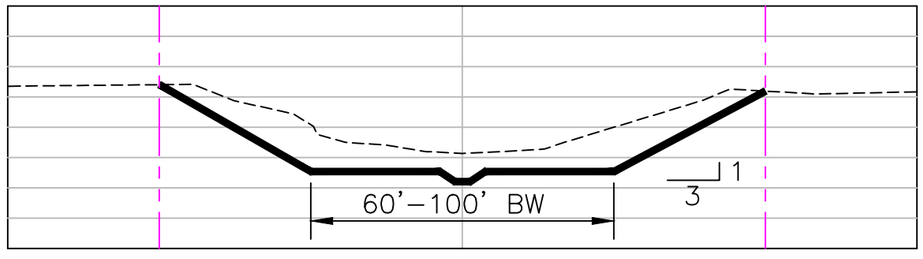
FILE INFO: I:\Projdat\0344\1607\MAIN REPORT\EXHIBITS\4-7\E_M-04-7.dwg XREFS: WOBTBLK MODIFIED: Sep 13, 2012 12:34pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:33pm PLOT SCALE: 1=4000



E200H.1 DETAIL
(NTS)



E200H.2 DETAIL
(NTS)



E200H.3 DETAIL
(NTS)

LEGEND

- **- EXISTING CHANNEL**
- **- EXISTING R.O.W.**
- **- EARTHEN-GRASS LINED**

SCALE IN FEET

0 50 100 150

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

CHANNELIZATION COMPONENT
E200H – CROSS SECTIONS

Harris County Flood Control District

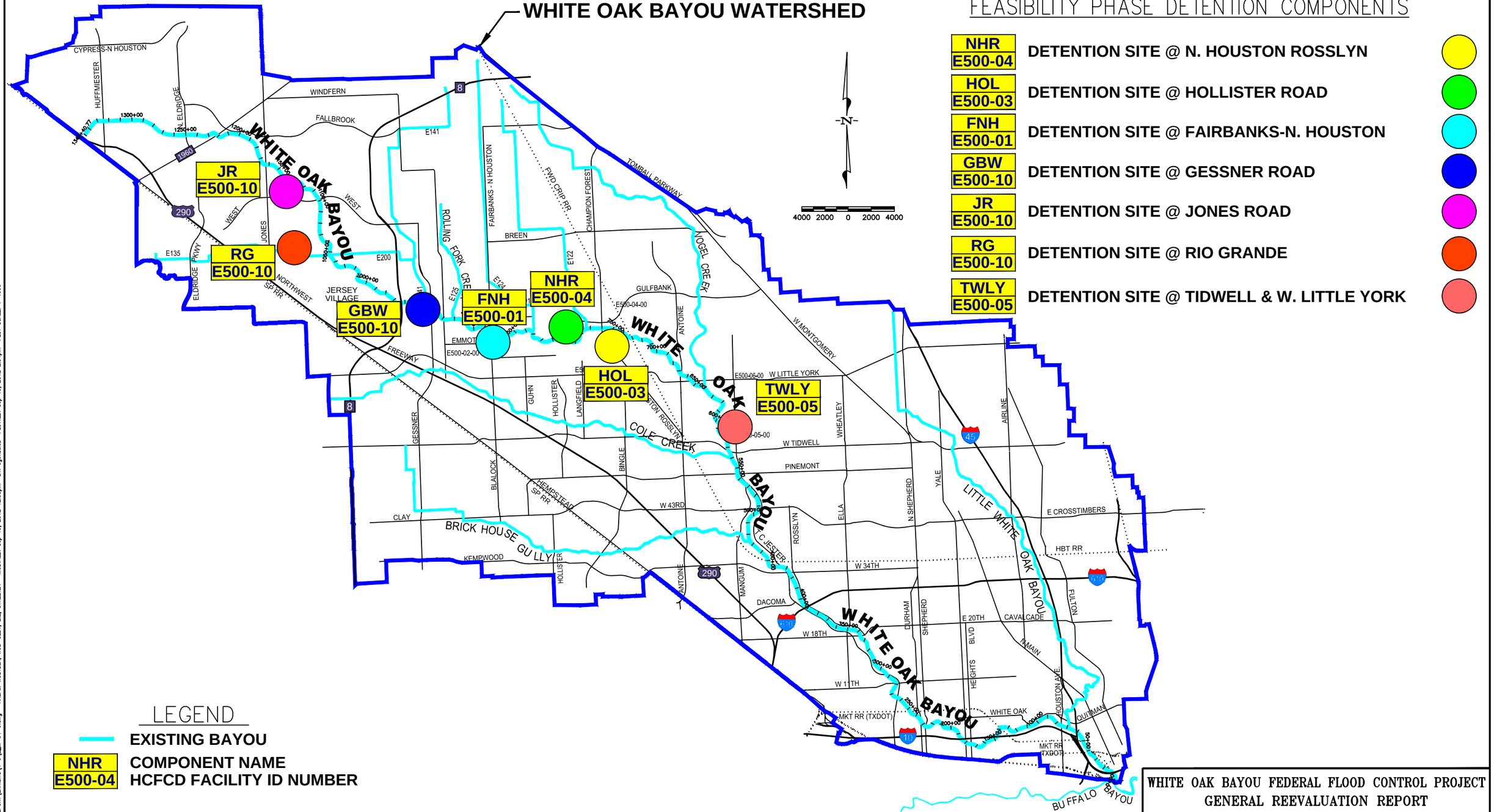
EXHIBIT

4-8

WHITE OAK BAYOU WATERSHED

FEASIBILITY PHASE DETENTION COMPONENTS

NHR E500-04	DETENTION SITE @ N. HOUSTON ROSSLYN
HOL E500-03	DETENTION SITE @ HOLLISTER ROAD
FNH E500-01	DETENTION SITE @ FAIRBANKS-N. HOUSTON
GBW E500-10	DETENTION SITE @ GESSNER ROAD
JR E500-10	DETENTION SITE @ JONES ROAD
RG E500-10	DETENTION SITE @ RIO GRANDE
TWLY E500-05	DETENTION SITE @ TIDWELL & W. LITTLE YORK



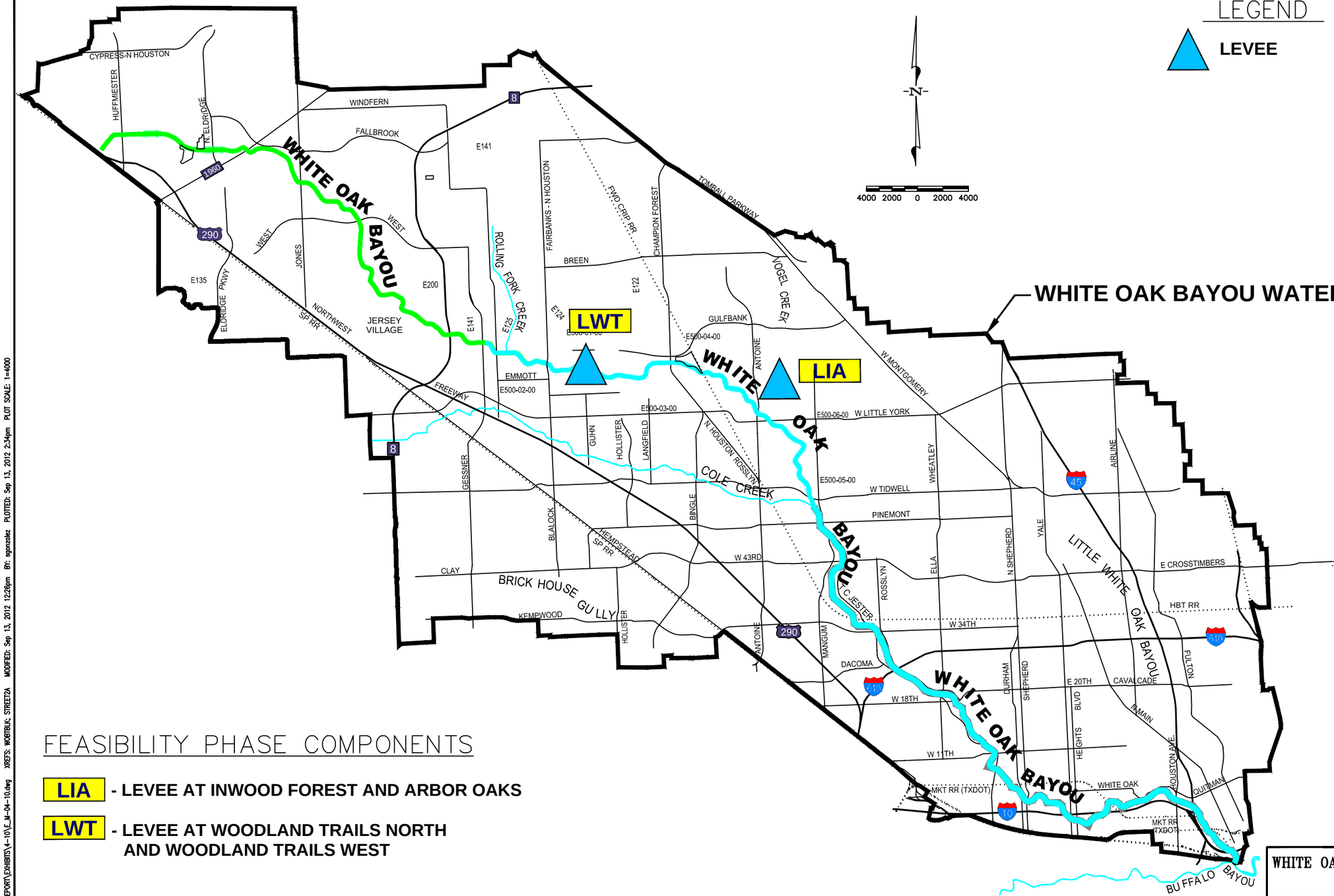
LEGEND

EXISTING BAYOU

NHR / E500-04 — COMPONENT NAME / HCFCD FACILITY ID NUMBER

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT GENERAL REEVALUATION REPORT	
DETENTION BASIN COMPONENTS	
Harris County Flood Control District	EXHIBIT 4-9

FILE INFO: I:\Projdat\0344\1607\MAIN REPORT\EXHIBITS\4-9\E_M-04-9.dwg XREFS: WOBTBLK; WOB-CLR1; 2-2; STREET2A MODIFIED: Sep 13, 2012 12:38pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000



FEASIBILITY PHASE COMPONENTS

LIA - LEVEE AT INWOOD FOREST AND ARBOR OAKS

LWT - LEVEE AT WOODLAND TRAILS NORTH AND WOODLAND TRAILS WEST

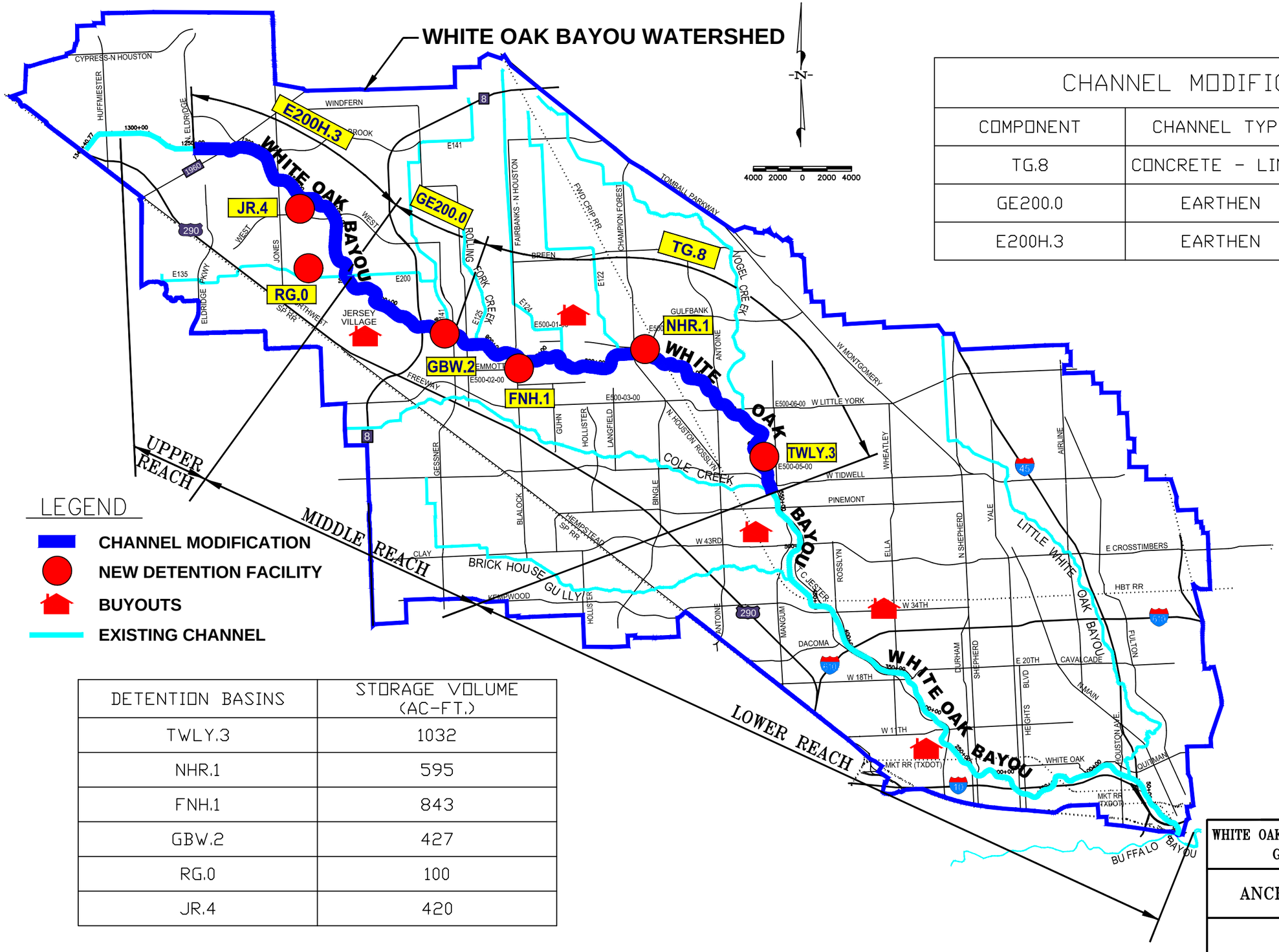
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

LEVEE COMPONENTS

Harris County Flood Control District

EXHIBIT 4-10

FILE INFO: I:\Projekt\1034A\1607\MAIN REPORT\EXHIBITS\4-10\E_H-04-10.dwg XREFS: WOBTBLK; STREET2A MODIFIED: Sep 13, 2012 12:26pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000



CHANNEL MODIFICATIONS		
COMPONENT	CHANNEL TYPE	TYPICAL BOTTOM WIDTH (FT.)
TG.8	CONCRETE - LINED	80′-90′
GE200.0	EARTHEN	30′-0″
E200H.3	EARTHEN	60′-100′

LEGEND

- CHANNEL MODIFICATION
- NEW DETENTION FACILITY
- BUYOUTS
- EXISTING CHANNEL

DETENTION BASINS	STORAGE VOLUME (AC-FT.)
TWLY.3	1032
NHR.1	595
FNH.1	843
GBW.2	427
RG.0	100
JR.4	420

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

ANCHOR TG.8 FORMULATED PLAN

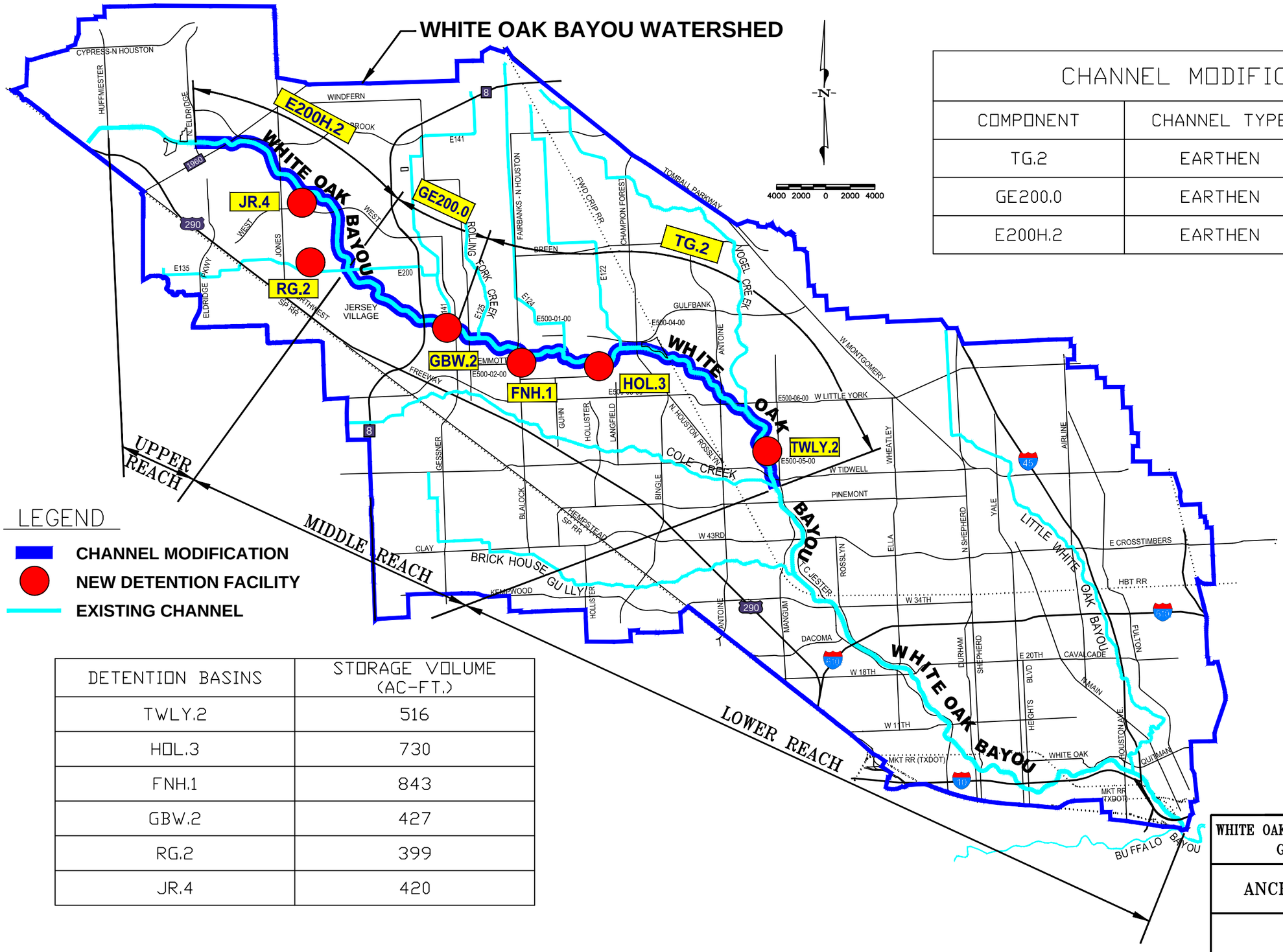
Harris County Flood Control District

EXHIBIT

4-11

FILE INFO: I:\Projdat1\0344\1607\MAIN REPORT\EXHIBITS\4-11\E_LH-04-11.dwg XREFS: WOBTBLK; WOB-CLB1; STREET2A MODIFIED: Sep 13, 2012 12:38pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000

WHITE OAK BAYOU WATERSHED



CHANNEL MODIFICATIONS

COMPONENT	CHANNEL TYPE	TYPICAL BOTTOM WIDTH (FT.)
TG.2	EARTHEN	50′-60′
GE200.0	EARTHEN	30′-0″
E200H.2	EARTHEN	50′-80′

LEGEND

- CHANNEL MODIFICATION
- NEW DETENTION FACILITY
- EXISTING CHANNEL

DETENTION BASINS	STORAGE VOLUME (AC-FT.)
TWLY.2	516
HOL.3	730
FNH.1	843
GBW.2	427
RG.2	399
JR.4	420

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

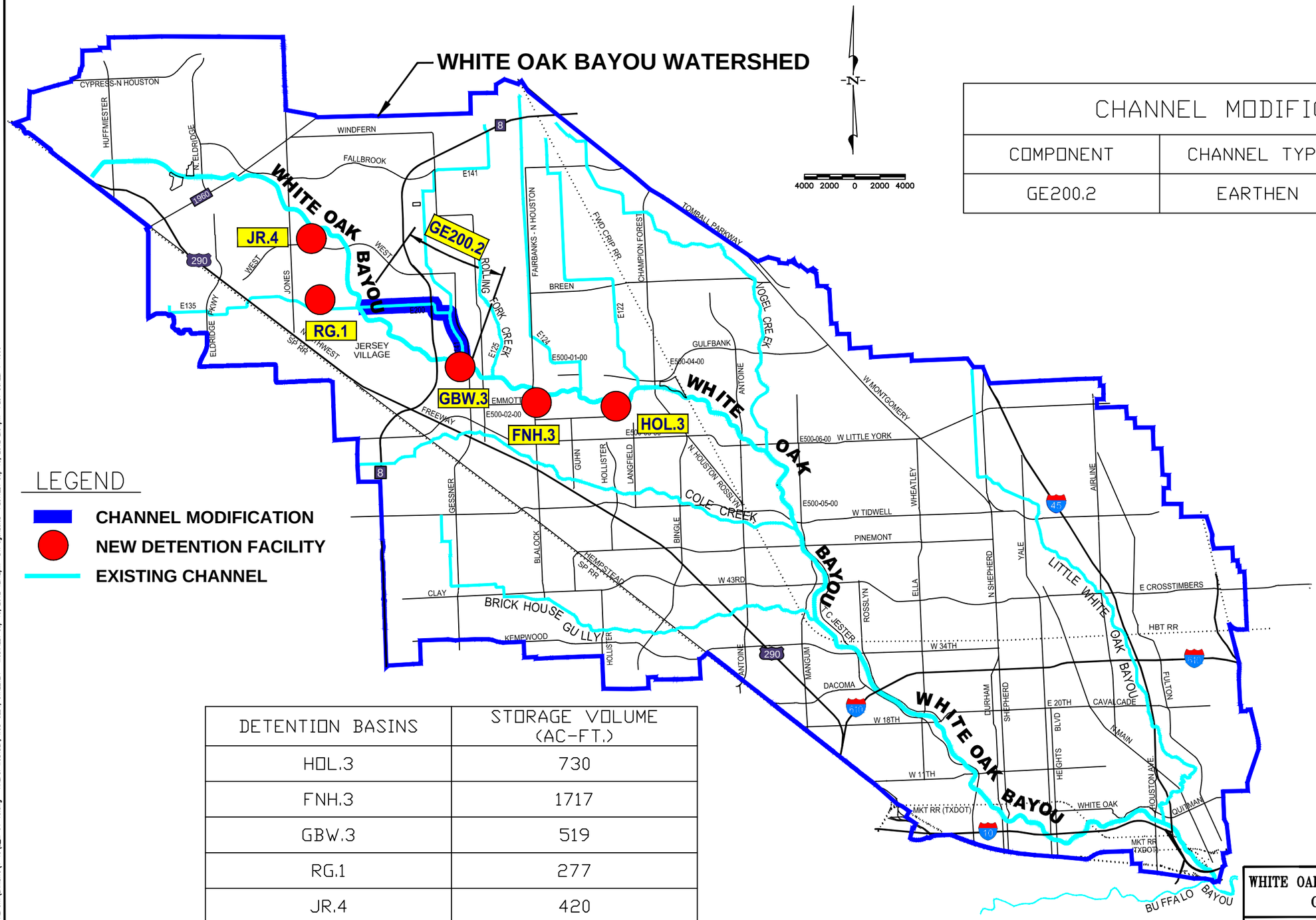
ANCHOR TG.2 FORMULATED PLAN

Harris County Flood Control District

EXHIBIT
4-12

FILE INFO: I:\Projdsk1\0344\1607\WAN REPORT\EXHIBITS\4-12\E_JM-04-12.dwg XREFS: WOBTBLK; WOB-CLBT; STREET2A MODIFIED: Sep 13, 2012 12:40pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000

WHITE OAK BAYOU WATERSHED



LEGEND

- CHANNEL MODIFICATION
- NEW DETENTION FACILITY
- EXISTING CHANNEL

CHANNEL MODIFICATIONS

COMPONENT	CHANNEL TYPE	TYPICAL BOTTOM WIDTH (FT.)
GE200.2	EARTHEN	50'-80'

DETENTION BASINS	STORAGE VOLUME (AC-FT.)
HOL.3	730
FNH.3	1717
GBW.3	519
RG.1	277
JR.4	420

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

ANCHOR FNH.3 & JR.4 FORMULATED PLAN

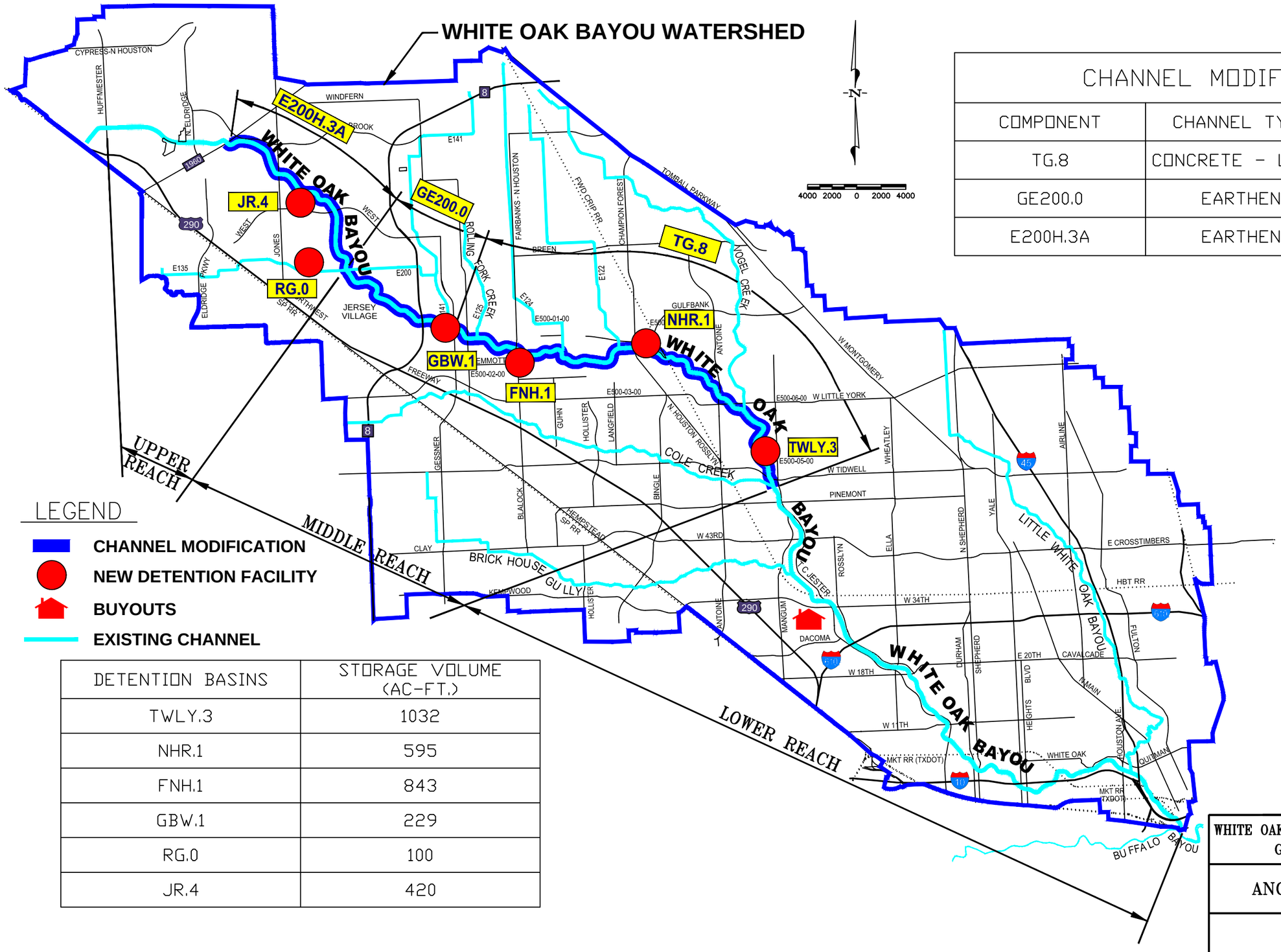
Harris County Flood Control District

EXHIBIT

4-13

FILE INFO: I:\Projdat1\0344\1607\MAIN REPORT\EXHIBITS\4-13\I_JM-04-13.dwg XREFS: WOBTBLK; WOB-GLB1; STREET2A MODIFIED: Sep 13, 2012 12:42pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000

WHITE OAK BAYOU WATERSHED



LEGEND

- CHANNEL MODIFICATION
- NEW DETENTION FACILITY
- BUYOUTS
- EXISTING CHANNEL

DETENTION BASINS	STORAGE VOLUME (AC-FT.)
TWLY.3	1032
NHR.1	595
FNH.1	843
GBW.1	229
RG.0	100
JR.4	420

CHANNEL MODIFICATIONS

COMPONENT	CHANNEL TYPE	TYPICAL BOTTOM WIDTH (FT.)
TG.8	CONCRETE - LINED	80'-90'
GE200.0	EARTHEN	30'-0"
E200H.3A	EARTHEN	30'-90'

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

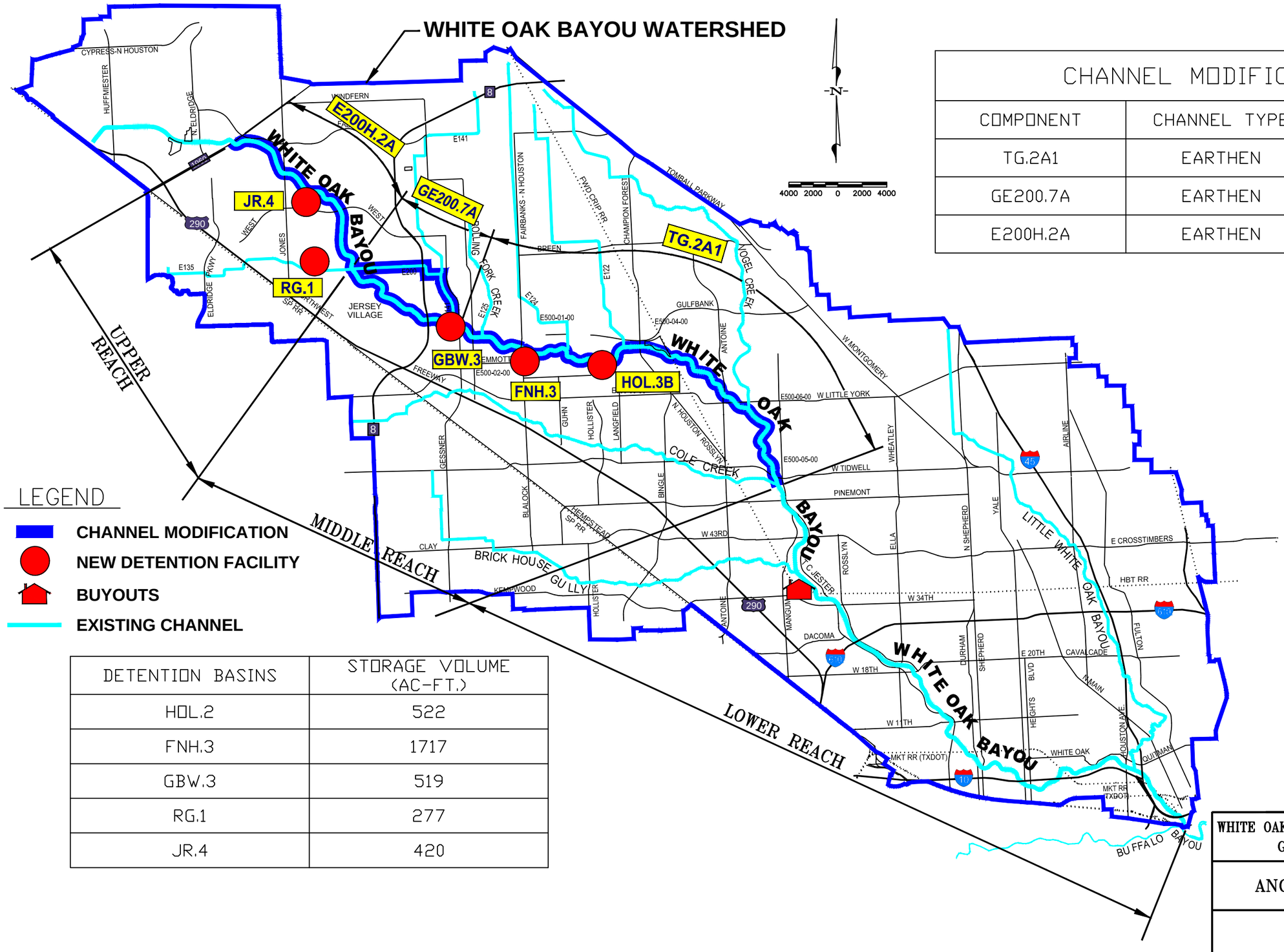
ANCHOR TG.8 OPTIMIZED PLAN

Harris County Flood Control District

EXHIBIT
4-14

FILE INFO: I:\Projdsk1\0344\1607\MAIN REPORT\EXHIBITS\4-14\E_M-04-14.dwg XREFS: WOBTBLK; WOB-CLBT; STREET2A MODIFIED: Sep. 13, 2012 12:41pm BY: sgonzalez PLOTTED: Sep. 13, 2012 2:34pm PLOT SCALE: 1=4000

WHITE OAK BAYOU WATERSHED



LEGEND

- CHANNEL MODIFICATION
- NEW DETENTION FACILITY
- BUYOUTS
- EXISTING CHANNEL

DETENTION BASINS	STORAGE VOLUME (AC-FT.)
HOL.2	522
FNH.3	1717
GBW.3	519
RG.1	277
JR.4	420

CHANNEL MODIFICATIONS

COMPONENT	CHANNEL TYPE	TYPICAL BOTTOM WIDTH (FT.)
TG.2A1	EARTHEN	50′-60′
GE200.7A	EARTHEN	30′-0″
E200H.2A	EARTHEN	50′-80′

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

ANCHOR TG.2 OPTIMIZED PLAN

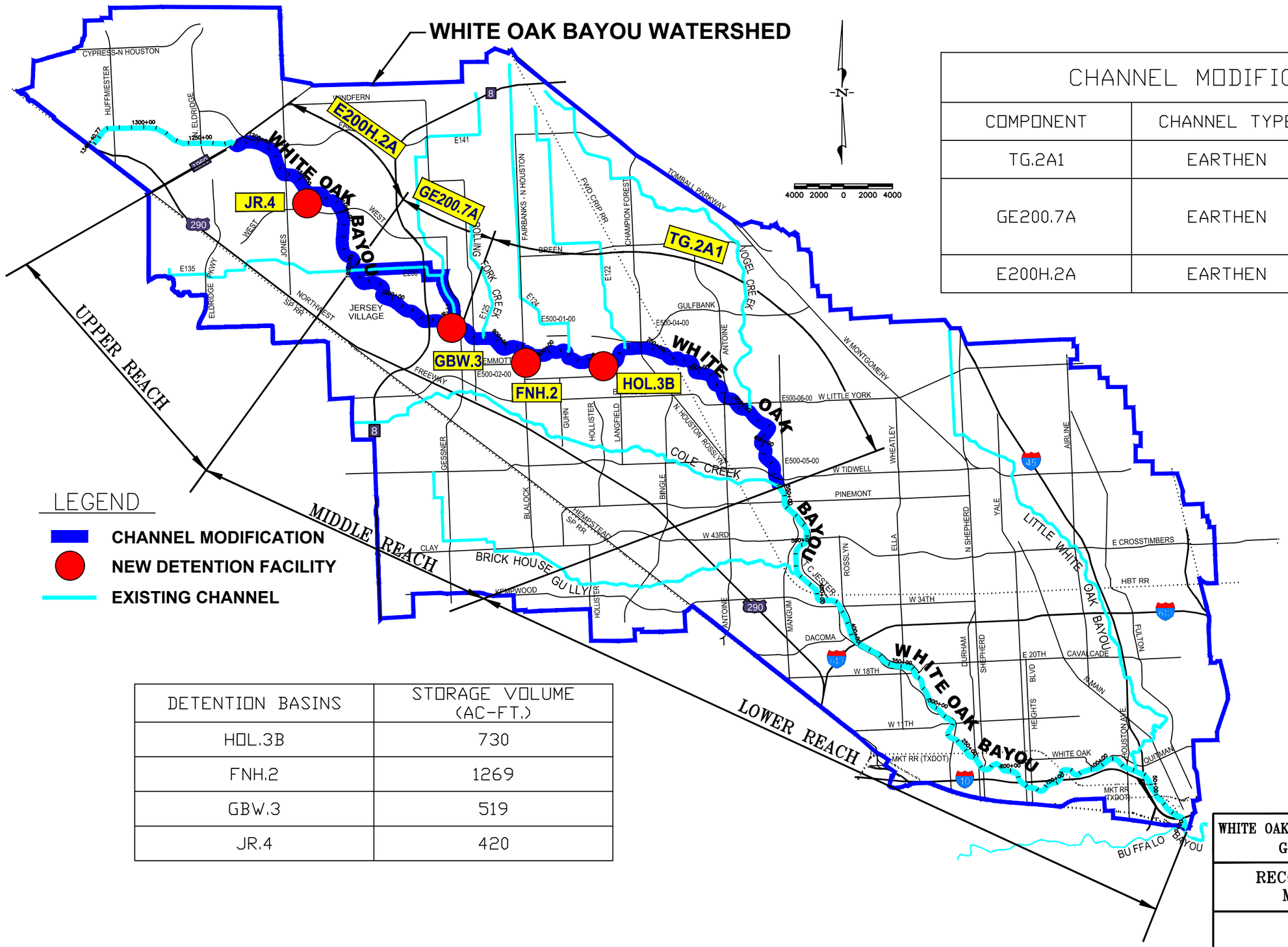
Harris County Flood Control District

EXHIBIT

4-15

FILE INFO: I:\Projekt1\0344\16077\MAIN REPORT\EXHIBITS\4-15\E_LM-04-15.dwg XREFS: WOBTBLK; WOB-CLB1; STREET2A MODIFIED: Sep 13, 2012 12:45pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000

WHITE OAK BAYOU WATERSHED



LEGEND

- CHANNEL MODIFICATION
- NEW DETENTION FACILITY
- EXISTING CHANNEL

CHANNEL MODIFICATIONS		
COMPONENT	CHANNEL TYPE	TYPICAL BOTTOM WIDTH (FT.)
TG.2A1	EARTHEN	50′-60′
GE200.7A	EARTHEN	30′-80′ (WITH GABIONS FOR EROSION PROTECTION)
E200H.2A	EARTHEN	50′-80′

DETENTION BASINS	STORAGE VOLUME (AC-FT.)
HOL.3B	730
FNH.2	1269
GBW.3	519
JR.4	420

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

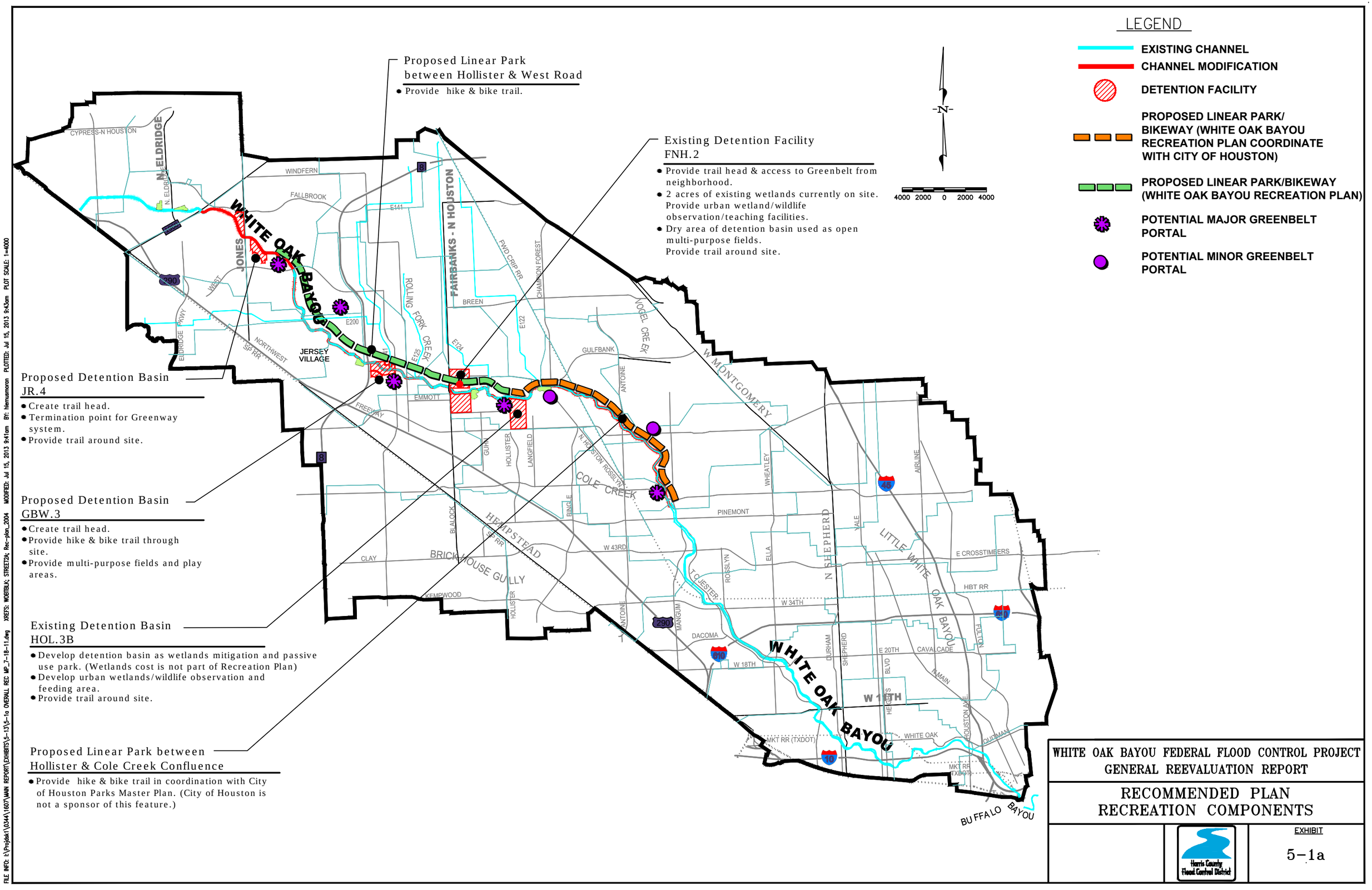
RECOMMENDED PLAN FLOOD RISK MANAGEMENT COMPONENTS

Harris County Flood Control District

EXHIBIT

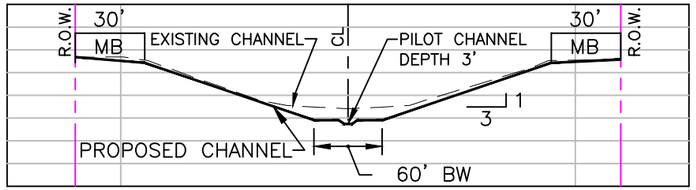
5-1

FILE INFO: I:\Projdat\10344\1607\MAIN REPORT\EXHIBITS\5-1\EM-05-1_5-13-10.dwg XREFS: WOBTBLK; WOB-CLB1; STREETZA MODIFIED: Mar 06, 2013 11:57am BY: Nemusmoron PLOTTED: Jun 05, 2013 1:43pm PLOT SCALE: 1=4000

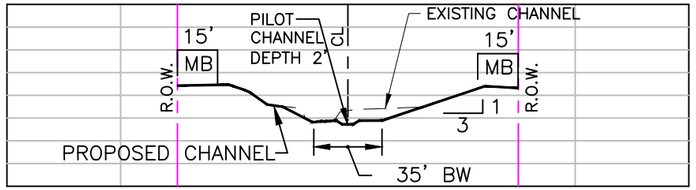


WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT GENERAL REEVALUATION REPORT	
RECOMMENDED PLAN RECREATION COMPONENTS	
	Harris County Flood Control District
	EXHIBIT 5-1a

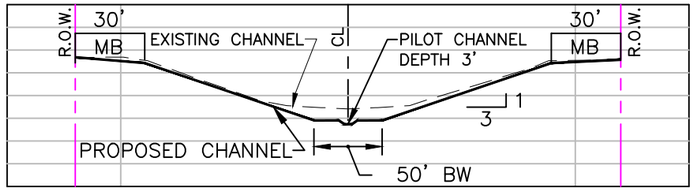
FILE INFO: I:\Projekt\0344\1607\MAIN REPORT\EXHIBITS\5-13\5-1a OVERALL REC MP_7-18-11.dwg XREFS: WOBTBLK; STREET24; Rec-plan_2004 MODIFIED: Jul 15, 2013 9:41am BY: hlemusmoron PLOTTED: Jul 15, 2013 9:43am PLOT SCALE: 1=4000



TYPICAL SECTION TG.2A1
STATION 625+00
(NTS)



TYPICAL SECTION GE200.7A
STATION 1020+00
(NTS)



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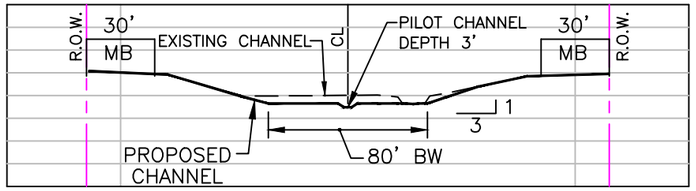
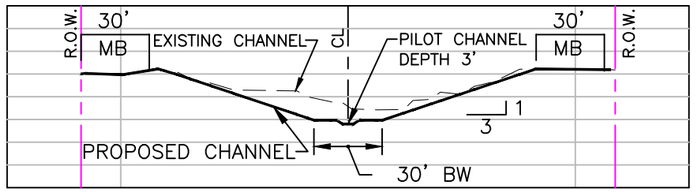
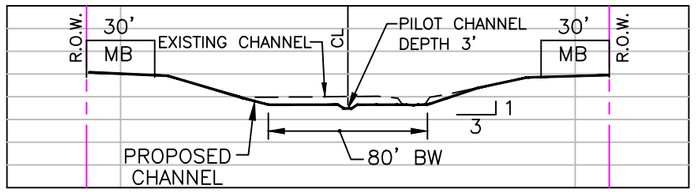
STATION 790+00
(NTS)



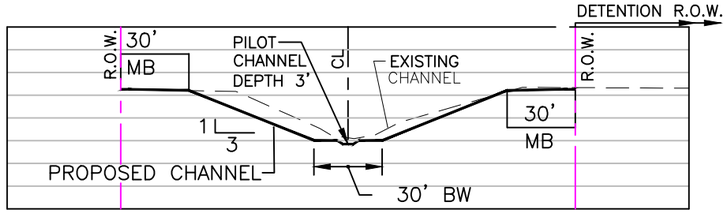
TYPICAL SECTION GE200.7A
STATION 1070+00
(NTS)



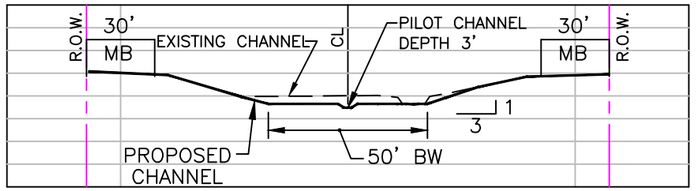
TYPICAL SECTION TG.2A1
STATION 815+00
(NTS)



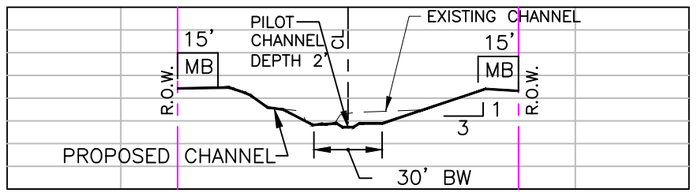
TYPICAL SECTION E200H.2A
STATION 1130+00
(NTS)



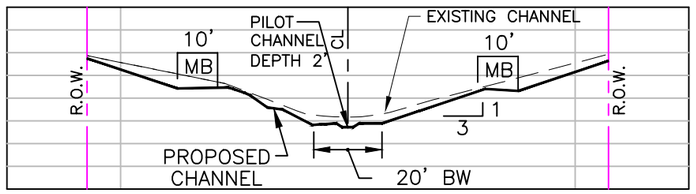
TYPICAL SECTION GE200.7A
STATION 950+00
(NTS)



TYPICAL SECTION E200H.2A
STATION 1175+00
(NTS)



TYPICAL SECTION GE200.7A
STATION 990+00
(NTS)



TYPICAL SECTION E200
STATION 62+00
(NTS)

LEGEND

- **- EXISTING CHANNEL**
- **- EXISTING R.O.W.**
- **- BYPASS EARTHEN-GRASS CHANNEL**

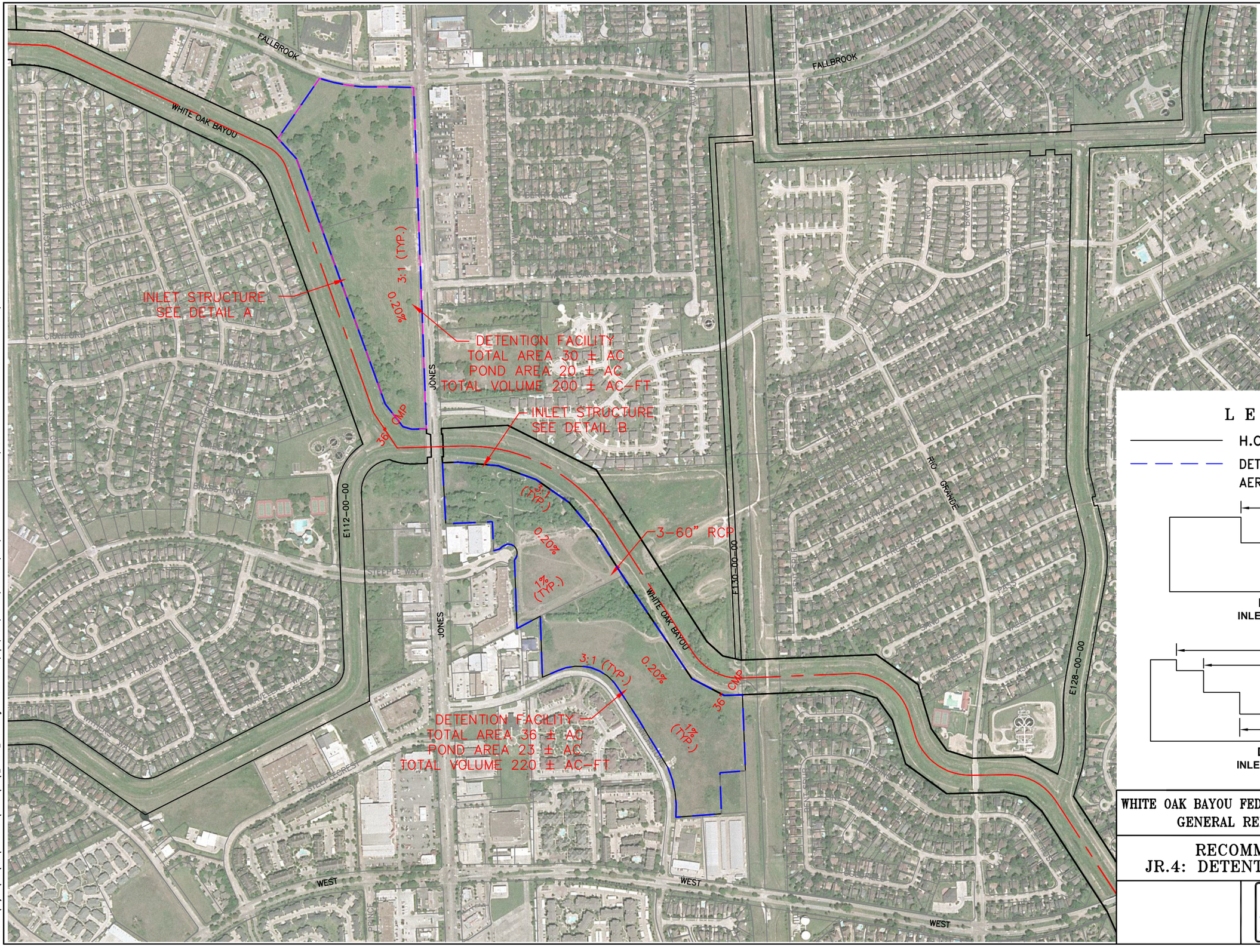
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

CHANNELIZATION COMPONENTS
TYPICAL CROSS SECTIONS

Harris County Flood Control District

EXHIBIT
5-2

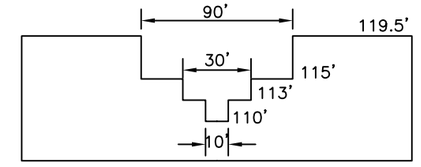
FILE INFO: I:\Projdat\10344\160\MAIN REPORT\EXHIBITS\5-2\E_H-05-2.dwg XREFS: WORTBLK MODIFIED: Sep 13, 2012 12:52pm BY: sgonzalez PLOTTED: Sep 13, 2012 2:34pm PLOT SCALE: 1=4000



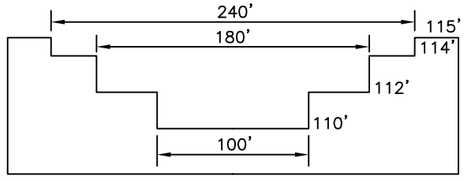
LEGEND

- H.C.F.C.D. R.O.W.
- DETENTION FACILITY SITE LIMITS

AERIAL DATE: 2002



DETAIL A
INLET STRUCTURE
(NTS)



DETAIL B
INLET STRUCTURE
(NTS)

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN
JR.4: DETENTION AT JONES RD.

Harris County Flood Control District

EXHIBIT

5-3

FILE INFO: I:\Projdat\0344\1607\WWA REPORT\EXHIBITS\5-3\E_LM-05-3_9-4-12.dwg XREFS: Wob-row; Bp03; Sn400; WOBTBLK; WOB-CM-3; BP04; WOB-CLB1 MODIFIED: Mar 06, 2013 11:22am BY: hlemusmoran PLOTTED: Mar 06, 2013 11:25am PLOT SCALE: 1=1

INLET STRUCTURE SEE DETAIL

WHITE OAK BAYOU

60" RCP

WOODLAND OAKS

WOODLAND TRAILS

WOODLAND TRAILS NORTH SEC 1

HOLLISTER

NORTH HOUSTON ROSSLYN

OAKWOOD FOREST

WETLANDS

LAKE

3:1 (TYP.)

0.25% (TYP.)

ISLAND

DETENTION FACILITY
TOTAL AREA 94 ± AC
POND AREA 84 ± AC

HOL.3B

W LITTLE YORK

E117-05-00

DENNY

LANSFIELD

STONEBROOK

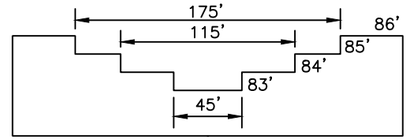
N

SCALE IN FEET
0 250 500 750

L E G E N D

H.C.F.C.D. R.O.W.

DETENTION FACILITY SITE LIMITS
AERIAL DATE: 2002



DETAIL
INLET STRUCTURE
(NTS)

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN
HOL.3B: DETENTION AT HOLLISTER

Harris County Flood Control District

EXHIBIT
5-4

DETENTION FACILITY
TOTAL AREA 16± AC
POND AREA 14 ± AC
TOTAL VOLUME 229± AC-FT

INLET STRUCTURE
SEE DETAIL

DETENTION FACILITY
TOTAL AREA 11 ± AC
POND AREA 8 ± AC
TOTAL VOLUME 92± AC-FT

DETENTION FACILITY
TOTAL AREA 24 ± AC
POND AREA 13 ± AC
TOTAL VOLUME 198± AC-FT

2-36" RCP
1-48" RCP

1-36" RCP

3:1 (TYP.)
1% (TYP.)
0.20%

BELTWAY 8
GESSNER
WINDFERN
PHILLIPINE
WHITE OAK BAYOU
BROOKRIVER
BROOKHOLLOW WEST
GULFBANK
BENT OAK
ROLLING FORK
E141-00-00
E139-00-00
E125-00-00
WOODWIND LAKES
WINDFERN FOREST
JERSEY VILLAGE COUNTRY CLUB ESTATES
TED BURGER ESTATES
OAKHOLLOW R/P SEC. 1

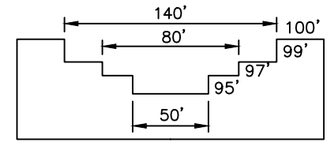
SCALE IN FEET
0 250 500 750

LEGEND

H.C.F.C.D. R.O.W.

DETENTION FACILITY SITE LIMITS

AERIAL DATE: 2002



DETAIL
INLET STRUCTURE
(NTS)

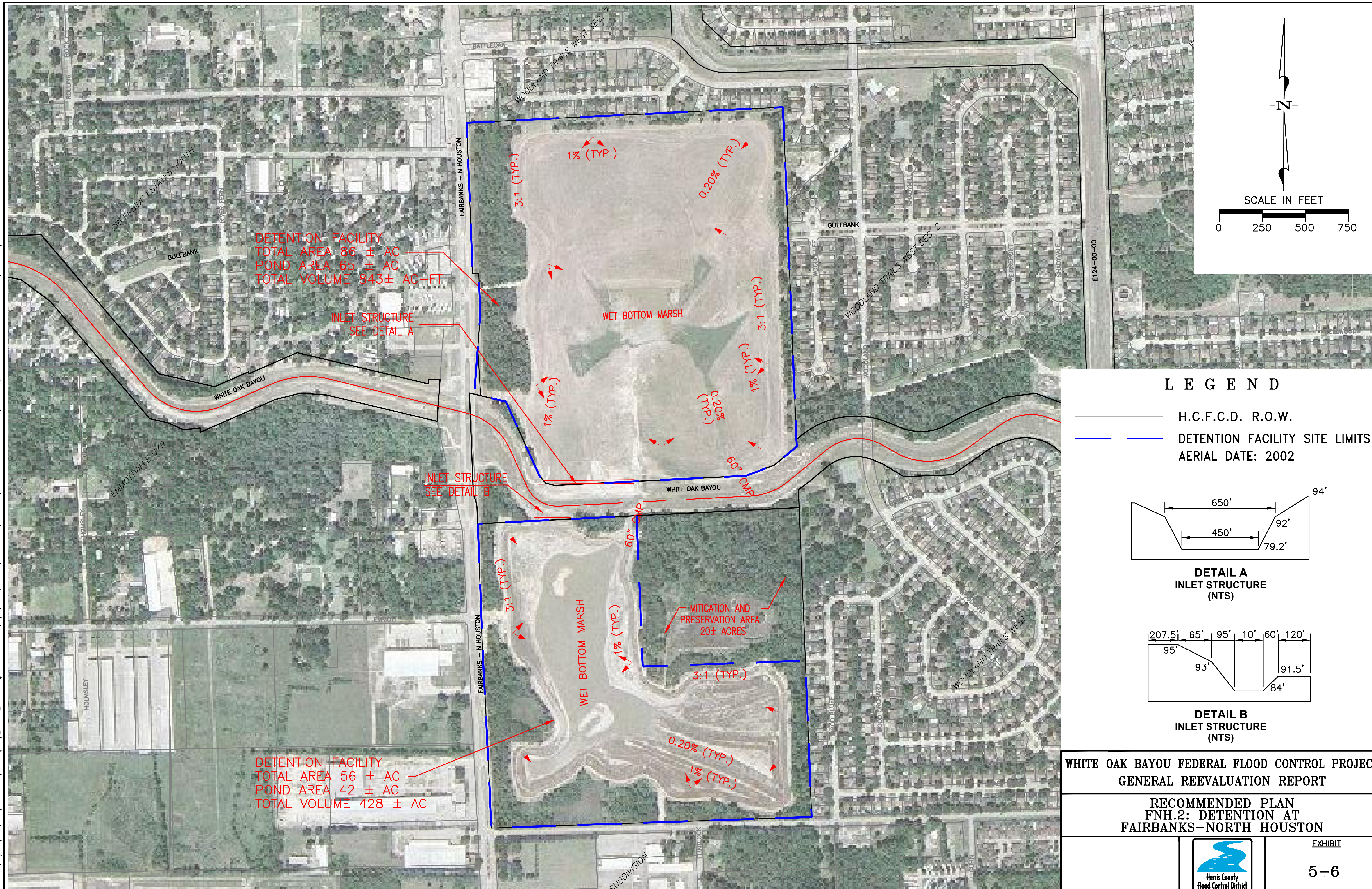
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN
GBW.3: DETENTION AT GESSNER AND BELTWAY 8

Harris County Flood Control District

EXHIBIT
5-5

FILE INFO: I:\Projdsk1\0344\1607\MAIN REPORT\EXHIBITS\5-5\E_M-05-5_9-4-12.dwg XREFS: Wob-row; Bp03; Sn400; ALT-COMP; WOBTBLK; WOB-UTILS01; WOB-CM-3; BP04; WOB-CLB1 MODIFIED: Mar 07, 2013 2:14pm BY: hlemusmoron PLOTTED: Mar 07, 2013 2:16pm PLOT SCALE: 1=1

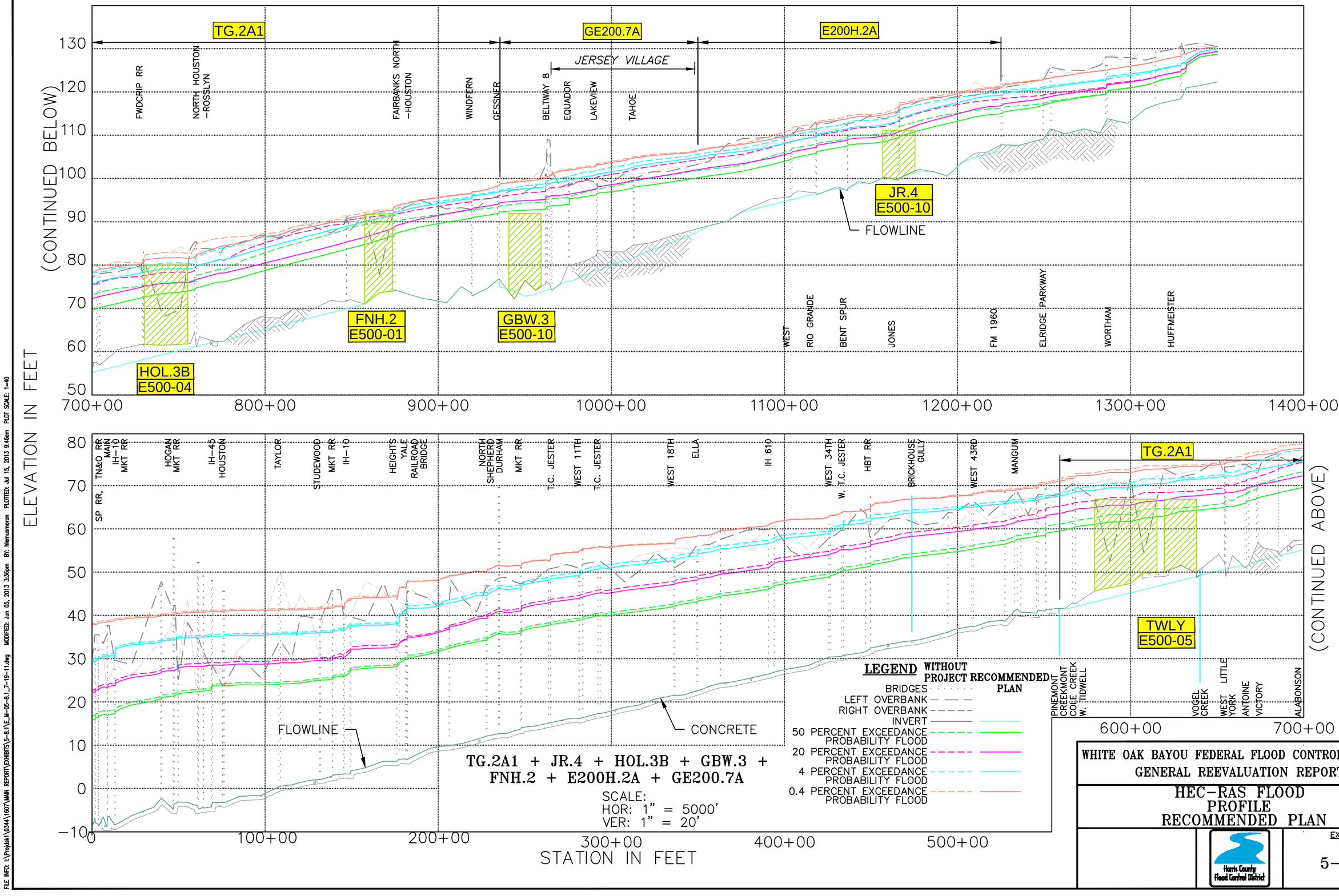


WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN
FNH.2: DETENTION AT
FAIRBANKS–NORTH HOUSTON

Harris County Flood Control District

EXHIBIT
5-6



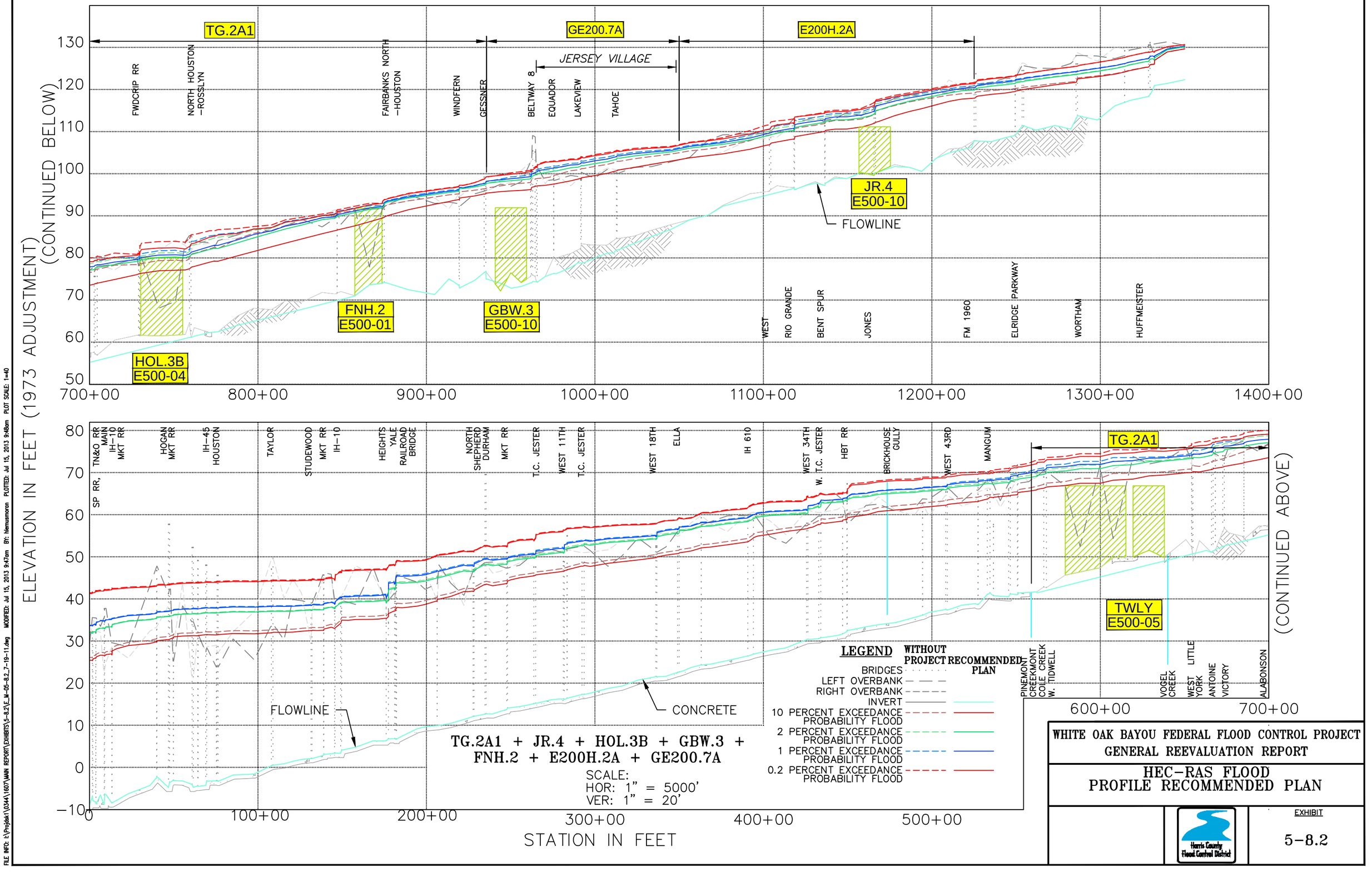
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

HEC-RAS FLOOD PROFILE RECOMMENDED PLAN

Harris County Flood Control District

EXHIBIT 5-8.1

FILE INFO: I:\Projekt\0344\1607\MAIN REPORT\EXHIBITS\5-8.1\E_H-05-8.1_7-19-11.dwg MODIFIED: Jun 05, 2013 3:36pm BY: hlemusmoron PLOTTED: Jul 15, 2013 9:46am PLOT SCALE: 1=40



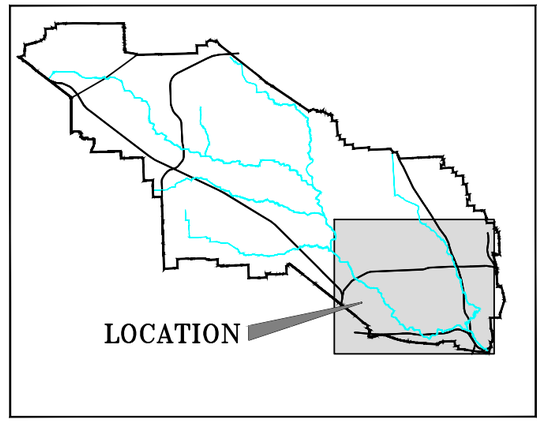
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

HEC-RAS FLOOD PROFILE RECOMMENDED PLAN

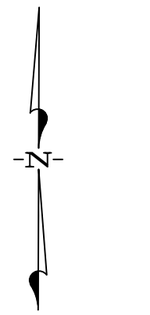
Harris County Flood Control District

EXHIBIT
5-8.2

FILE INFO: L:\Projdat\U344\1607\MAIN REPORT\EXHIBITS\5-8.2\E_M-05-8.2_7-19-11.dwg MODIFIED: Jul 15, 2013 9:47am BY: Nemusamaan PLOTTED: Jul 15, 2013 9:48am PLOT SCALE: 1=40



LOCATION MAP
NOT TO SCALE



SCALE IN FEET
1,0005000 1,000 2,000

NOTE:
1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND
- CHANNEL
- WITHOUT PROJECT – 10% FLOOD PLAIN
- RECOMMENDED PLAN – 10% FLOOD PLAIN

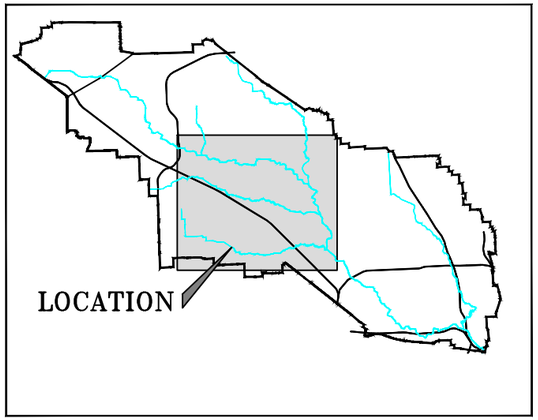
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN & WITHOUT PROJECT
10% FLOOD PLAIN COMPARISON

Harris County Flood Control District

EXHIBIT
5-9a

FILE INFO: I:\Projdat\10344\1607\MAIN REPORT\EXHIBITS\5-9a\5-9a.dwg XREFS: Bp02; WOBTBLK; STREET24; PARCELS; WOP_10YR; NED_10YR MODIFIED: Mar 11, 2013 9:34am BY: hlemusmoron PLOTTED: Mar 11, 2013 9:42am PLOT SCALE: 1=40



LOCATION MAP
NOT TO SCALE

N

SCALE IN FEET
1,000 5000 1,000 2,000

NOTE:

1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND

- CHANNEL
- WITHOUT PROJECT – 10% FLOOD PLAIN
- RECOMMENDED PLAN – 10% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN & WITHOUT PROJECT
10% FLOOD PLAIN COMPARISON

Harris County Flood Control District

EXHIBIT
5-9b

CYPRESS-N HOUSTON

HUFFMEISTER

N. ELDRIDGE

FM 1960

WINDFERN

FALLBROOK

1960

WHITE OAK BAYOU

BELTWAY 8

WEST

290

JACKRABBIT

WEST

JONES

PKWY

ELDRIDGE

US HWY 290

SP RR

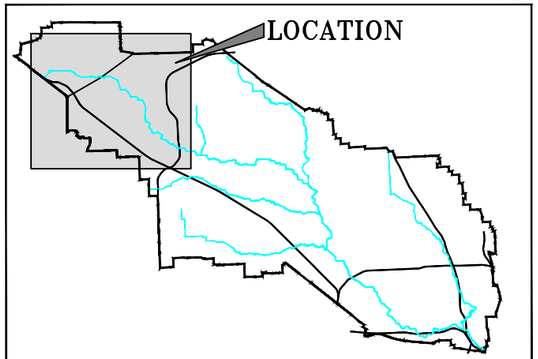
SPENCER

BAYOU

HEIT

00-00

LOCATION



LOCATION MAP
NOT TO SCALE

N

SCALE IN FEET

1,000 5000 1,000 2,000

NOTE:

1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND

- CHANNEL
- WITHOUT PROJECT – 10% FLOOD PLAIN
- RECOMMENDED PLAN – 10% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

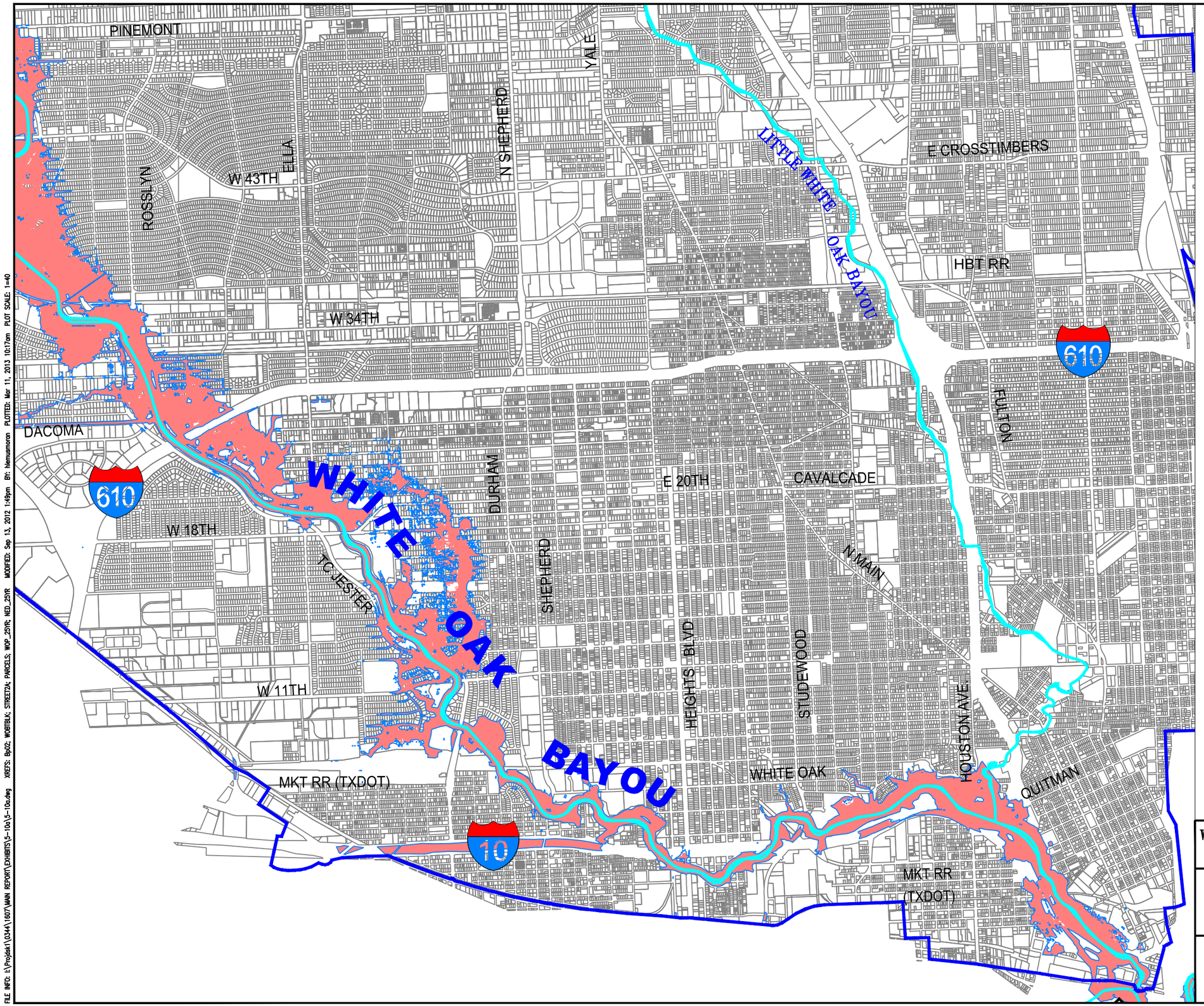
RECOMMENDED PLAN & WITHOUT PROJECT
10% FLOOD PLAIN COMPARISON

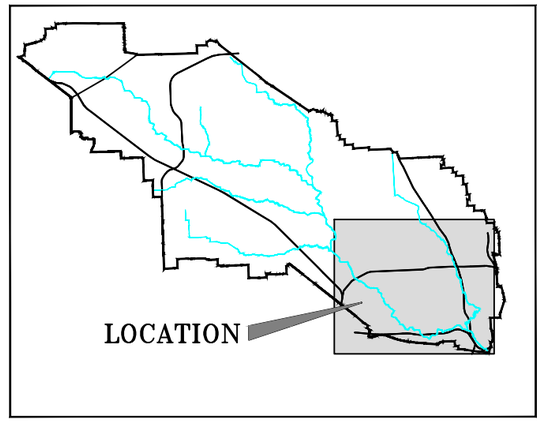
Harris County Flood Control District

EXHIBIT

5-9c

FILE INFO: I:\Projdata\0344\1607\MAIN REPORT\EXHIBITS\5-9c\5-9c.dwg XREFS: WORTBLK; STREET2K; BpO3; WOP_10YR; NED_10YR; BpO4; PARCELS_40C MODIFIED: Mar 11, 2013 10:06am BY: hlemusamoran PLOTTED: Mar 11, 2013 10:10am PLOT SCALE: 1=40





LOCATION MAP
NOT TO SCALE

-N-

SCALE IN FEET
1,0005000 1,000 2,000

NOTE:
1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND
- CHANNEL
- WITHOUT PROJECT – 4% FLOOD PLAIN
- RECOMMENDED PLAN – 4% FLOOD PLAIN

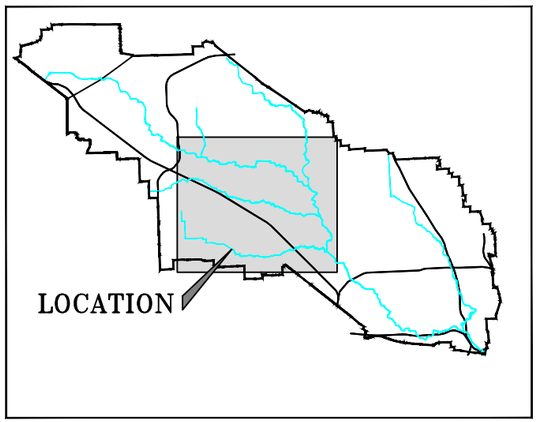
WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN & WITHOUT PROJECT
4% FLOOD PLAIN COMPARISON

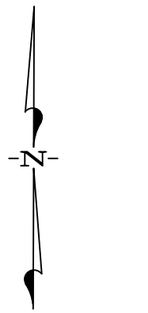
Harris County Flood Control District

EXHIBIT
5-10a

FILE INFO: L:\Projdat\0344\1607\MAIN REPORT\EXHIBITS\5-10a\5-10a.dwg XREFS: BpO2; WOBTBLK; STREET2A; PARCELS; WOF_25YR; NED_25YR MODIFIED: Sep 13, 2012 1:49pm By: hlemusmoran PLOTTED: Mar 11, 2013 10:17am PLOT SCALE: 1=40



LOCATION MAP
NOT TO SCALE



SCALE IN FEET
1,000 5000 1,000 2,000

NOTE:
1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND
- CHANNEL
- WITHOUT PROJECT – 4% FLOOD PLAIN
- RECOMMENDED PLAN – 4% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN & WITHOUT PROJECT
4% FLOOD PLAIN COMPARISON

Harris County Flood Control District

EXHIBIT
5-10b

FILE INFO: I:\Projekt\0344\1607\MAIN REPORT\EXHIBITS\5-10b\5-10b.dwg XREFS: BpO2; WOBTBLK; STREET2A; BpO3; WOP_25YR; NED_25YR; PARCELS_40B MODIFIED: Sep 13, 2012 1:51pm BY: hlemusmoron PLOTTED: Mar 11, 2013 10:22am PLOT SCALE: 1=40

CYPRESS-N HOUSTON

HUFFMEISTER

N. ELDRIDGE

FM 1960

WINDFERN

FALLBROOK

1960

WHITE OAK BAYOU

BELTWAY 8

WEST

290

JACKRABBIT

WEST

JONES

PKWY

ELDRIDGE

US HWY 290

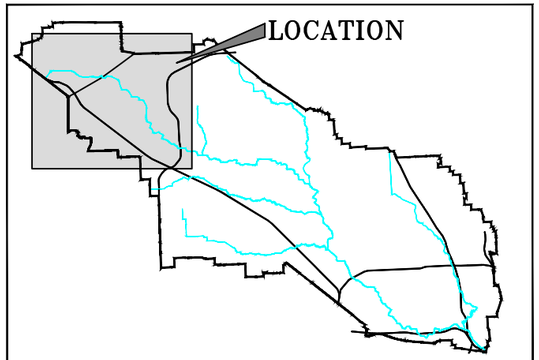
SP RR

SPENCER

BAYOU

00-00

LOCATION



LOCATION MAP
NOT TO SCALE

N

SCALE IN FEET

1,000 0 0 0 5 1,000 2,000

NOTE:

1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND

- CHANNEL
- WITHOUT PROJECT – 4% FLOOD PLAIN
- RECOMMENDED PLAN – 4% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

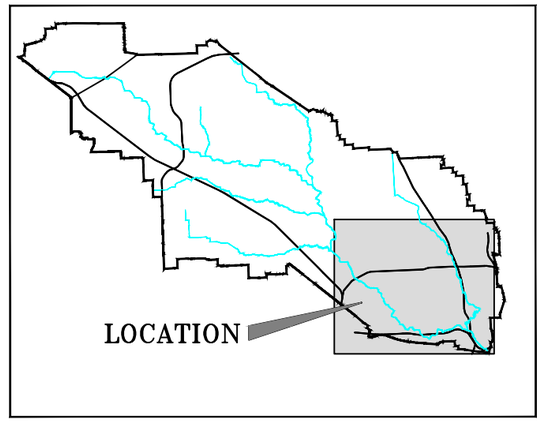
RECOMMENDED PLAN & WITHOUT PROJECT
4% FLOOD PLAIN COMPARISON

Harris County Flood Control District

EXHIBIT

5-10c

FILE INFO: I:\Projdsk1\0344\1607\MAIN REPORT\EXHIBITS\5-10c\5-10c.dwg XREFS: WOBTBLK; STREET24; BpO3; WOP_25YR; NED_25YR; Bp04; PARCELS_40C MODIFIED: Mar 11, 2013 10:25am BY: hlemusamron PLOTTED: Mar 11, 2013 10:26am PLOT SCALE: 1=40



LOCATION MAP
NOT TO SCALE

-N-

SCALE IN FEET
1,0005000 1,000 2,000

NOTE:
1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

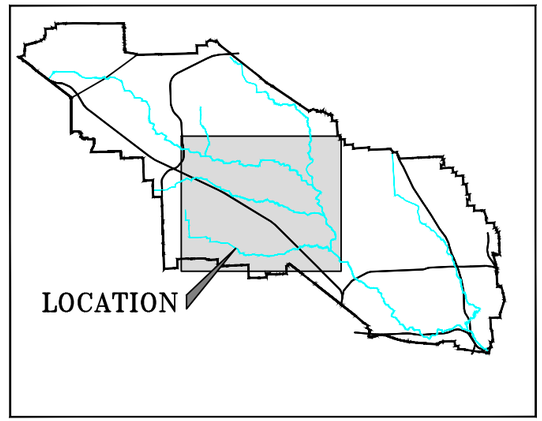
LEGEND
- CHANNEL
- WITHOUT PROJECT – 1% FLOOD PLAIN
- RECOMMENDED PLAN – 1% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

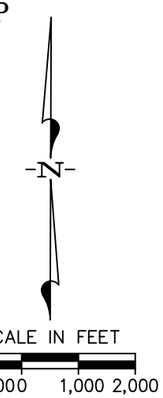
RECOMMENDED PLAN & WITHOUT PROJECT
1% FLOOD PLAIN COMPARISON

Harris County Flood Control District

EXHIBIT
5-11a



LOCATION MAP
NOT TO SCALE



SCALE IN FEET
1,000 5000 1,000 2,000

NOTE:

1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND

- CHANNEL
- WITHOUT PROJECT – 1% FLOOD PLAIN
- RECOMMENDED PLAN – 1% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN & WITHOUT PROJECT
1% FLOOD PLAIN COMPARISON

Harris County Flood Control District

EXHIBIT
5-11b

FILE INFO: I:\Projdsk1\0344\1607\WAN REPORT\EXHIBITS\5-11b\5-11b.dwg XREFS: Bp02; WOBFBLK; STREET24; Bp03; WOP_100YR; NED_100YR; PARCELS_408 MODIFIED: Mar 11, 2013 BY: Nemusmoran PLOTTED: Mar 11, 2013 10:41am PLOT SCALE: 1=40 Mar 11, 2013 10:40am

CYPRESS-N HOUSTON

HUFFMEISTER

N. ELDRIDGE

FM 1960

WINDFERN

FALLBROOK

1960

WHITE OAK BAYOU

BELTWAY 8

WEST

290

JACKRABBIT

WEST

JONES

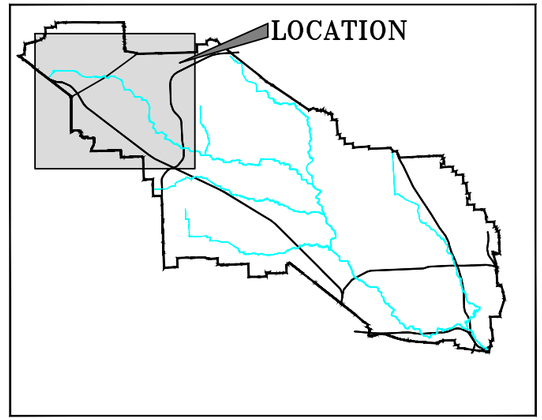
PKWY

ELDRIDGE

US HWY 290

SP RR

SPENCER



LOCATION MAP
NOT TO SCALE

-N-

SCALE IN FEET
1,0005000 1,000 2,000

NOTE:

1. FLOOD PLAIN BOUNDARIES SHOWN ARE PRELIMINARY AND MAY VARY SIGNIFICANTLY BASED ON MORE DETAILED TOPOGRAPHIC INFORMATION AND HYDROLOGIC ANALSIS.
2. PRELIMINARY RESULTS FROM HEC-GEORAS.

LEGEND

- CHANNEL
- WITHOUT PROJECT – 1% FLOOD PLAIN
- RECOMMENDED PLAN – 1% FLOOD PLAIN

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

RECOMMENDED PLAN & WITHOUT PROJECT
1% FLOOD PLAIN COMPARISON

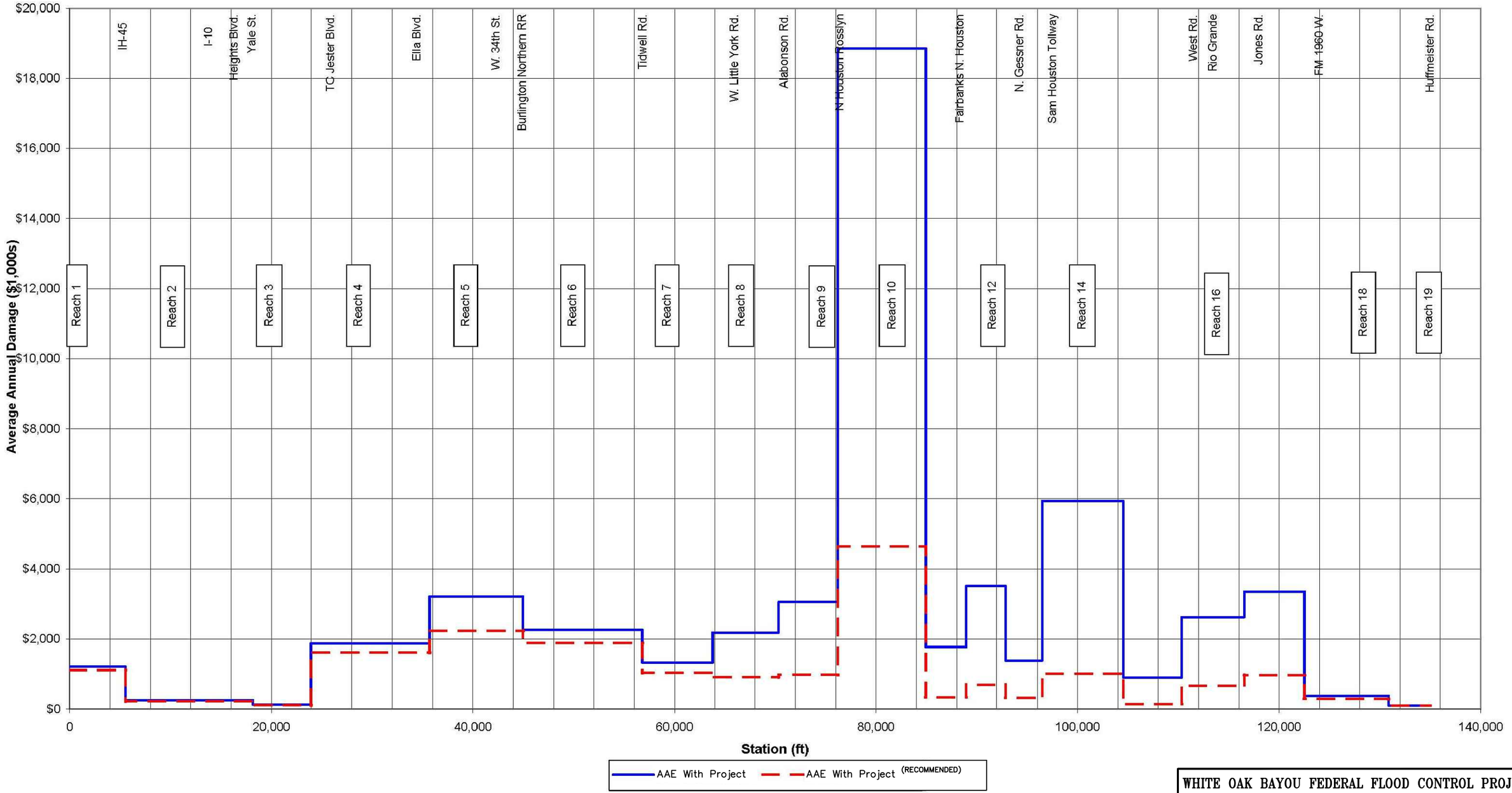
Harris County Flood Control District

EXHIBIT

5-11c

FILE INFO: I:\Projdat\0344\1607\MAIN REPORT\EXHIBITS\5-11c\5-11c.dwg XREFS: WOBTBLK; STREET24; BpO3; WOP_100YR; NED_100YR; BpO4; PARCELS_40C MODIFIED: Mar 11, 2013 10:43am BY: hlemusmoron PLOTTED: Mar 11, 2013 10:43am PLOT SCALE: 1=40

EXHIBIT 5-12: FLOOD DAMAGE PROFILE FOR RECOMMENDED PLAN



FILE INFO: I:\Projdat\10344\1607\MAIN REPORT\EXHIBITS\5-12\5-12.dwg MODIFIED: Mar 15, 2013 9:48am BY: hlemusmoron PLOTTED: Mar 15, 2013 9:50am PLOT SCALE: 1=1

WHITE OAK BAYOU FEDERAL FLOOD CONTROL PROJECT
GENERAL REEVALUATION REPORT

FLOOD DAMAGE PROFILE
FOR RECOMMENDED PLAN

Harris County Flood Control District

EXHIBIT
5-12