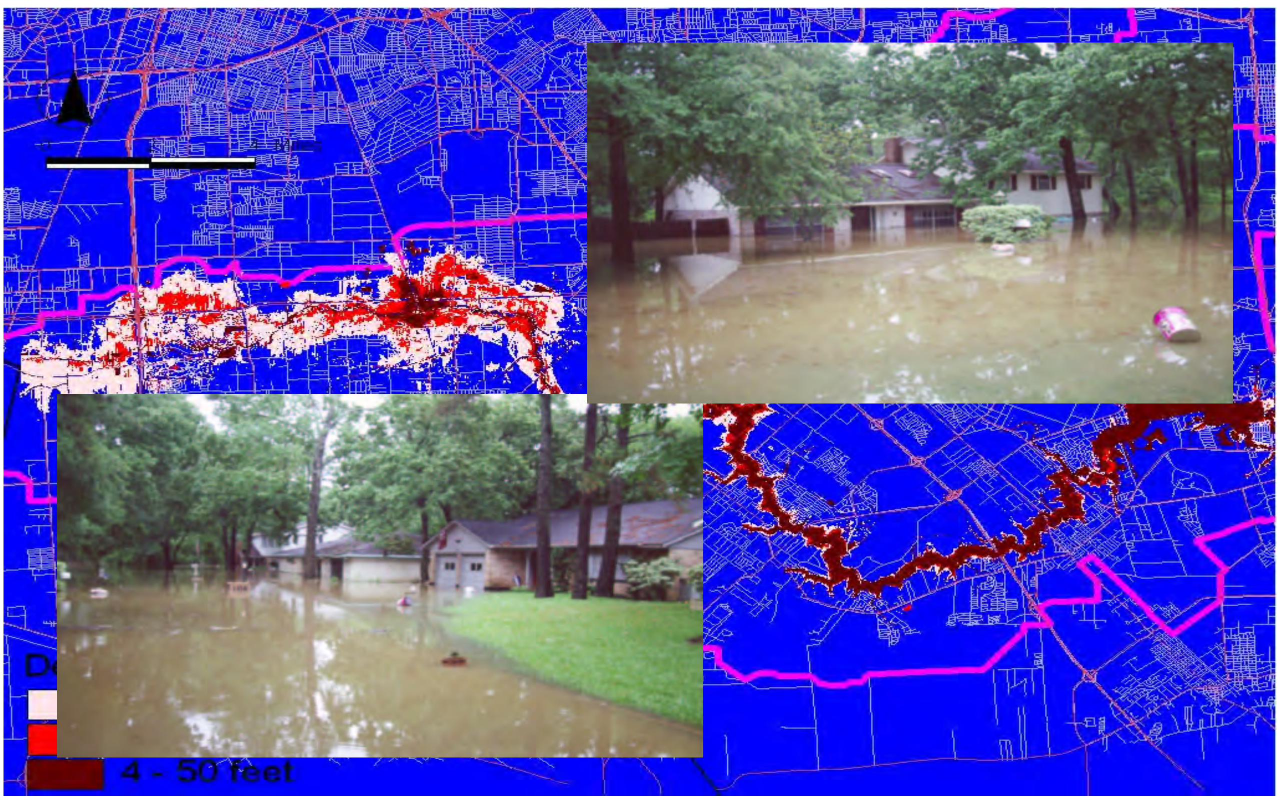
U.S. Army Corps
of Engineers

Galveston District
Southwestern Division

Final
Supplemental Environmental Impact Statement
for the
Clear Creek General Reevaluation Study
Brazoria, Fort Bend, Galveston, and Harris Counties, Texas



MAIN REPORT

October 2012

ABSTRACT
FINAL
SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT FOR THE CLEAR CREEK GENERAL REEVALUATION STUDY BRAZORIA, FORT BEND, GALVESTON, AND HARRIS COUNTIES, TEXAS

The U.S. Army Corps of Engineers, Galveston District (USACE), under the authority of Section 203 of the Flood Control Act approved August 13, 1968 (Public Law 90-483), proposes to develop and evaluate alternatives for flood risk management in the Clear Creek watershed.

This Final Supplemental Environmental Impact Statement (FSEIS) was prepared as required by the National Environmental Policy Act (NEPA) to present an evaluation of potential impacts of the proposed Clear Creek General Reevaluation Study (Clear Creek Project). The proposed project comprises a series of flood risk management measures (conveyance) and mitigation areas.

This FSEIS addresses the potential impacts of the proposed project on the human environment, as identified during the public interest review. All factors that may be relevant to the proposed project were considered, including the following: air quality, economics, general environmental concerns, historic resources, protected species, recreation, water and sediment quality, energy needs, safety, hazardous materials, and, in general, the welfare of the people. This FSEIS provides relevant information to the public on the potential impacts of the proposed project. Public and agency comments received during the DSEIS comment period are addressed in this FSEIS. The public and agency comments on the findings of the FSEIS will be addressed in the Record of Decision (ROD).

Comments should be received by November 12, 2012.

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EXECUTIVE SUMMARY

ES.1 INTRODUCTION

The U.S. Army Corps of Engineers, Galveston District (USACE), along with the Harris County Flood Control District (HCFCD), Galveston County, and Brazoria County Drainage District #4 (acting as the non-Federal sponsors), have undertaken a study to reevaluate the Clear Creek Flood Control Project, as authorized by Congress in the Flood Control Act of 1968. Clear Creek is located south of the City of Houston and is included in parts of Harris, Galveston, Brazoria, and Fort Bend counties.

Under the original 1968 Congressional authorization to improve flood conveyance within Clear Creek, plans were developed in the 1980s to deepen, widen, and realign the creek channel. Project construction was initiated in the late 1980s with the Second Outlet Channel and Gate Structure (May 1989 to March 1991) and modification of two railroad bridges downstream of Interstate Highway 45 (I-45). Construction of the Second Outlet Channel and Gate Structure began in August 1989, was completed in 1991, and in 1997 the structure was rehabilitated. Prior to initiation of construction on the upstream portion of the creek, issues were raised by concerned citizens regarding the amount of environmental impact associated with the project, the project design, and proposed sites for placement of construction material. Based on these concerns, the non-Federal sponsors requested that construction of the authorized channel be delayed. Additionally, HCFCD developed a Sponsor Proposed Alternative (SPA) for consideration to meet project needs. However, the SPA was considered substantially different from the authorized project and, thus, could not be constructed under the current project authorization. Subsequently, HCFCD requested that a reevaluation of the project be initiated. As a result, the USACE went forward with reformulating plans to reduce flood damages within the Clear Creek project area under a reevaluation study, as presented in the Clear Creek General Reevaluation Report (GRR). The current effort is referred to as the Clear Creek Flood Risk Management Project or the Clear Creek Project.

ES.2 PURPOSE AND NEED

Flooding along Clear Creek has historically been a problem associated with severe rainfall events. Damages were typically incurred by a relatively small number of businesses and residences that were established in the existing floodplain. However, continuing commercial and residential growth within the watershed has severely aggravated flooding problems. Rapid urban growth in this region has substantially increased the extent of impervious cover and reduced the watershed’s natural detention capacity, resulting in higher and more-frequent stormwater flows. As a consequence, overbank flows have become more common, even with moderate rainfall events. In addition, continued development within the floodplain has compounded the problem of addressing flood risk management not only by introducing additional flood-prone structures, but also by narrowing flood risk management options. Although local authorities have regulations in place to reduce the effects of new development, these regulations are not in effect for the entire watershed and are not designed to reduce the current flood risk.

The purpose of the proposed project is to develop and evaluate alternatives for flood risk management in the Clear Creek watershed. Authority for the flood risk management portion of the Clear Creek Flood Control Project is contained in Section 203 of the Flood Control Act approved August 13, 1968 (Public Law 90-483). In addition to flood risk management, the study considered developing ecosystem restoration opportunities; however, no additional cost share sponsors were identified and no new authority was given, thus, ecosystem restoration was not considered as the study progressed.

The project is needed to reduce flood damages within the Clear Creek watershed while preserving natural features for aesthetics, recreation, and rehabilitation of fish and wildlife resources. In addition, a comprehensive set of planning objectives was developed to address the following elements over the course of the 2020 to 2070 period of economic analysis:

- Reduce flood risk for economic, social, and environmental purposes along Clear Creek and tributaries;
- Improve fish and wildlife resources of Clear Creek and tributaries for the purpose of attracting more and varied species of fish and wildlife;
- Preserve and protect natural and cultural resources along Clear Creek and tributaries for public and historical appreciation purposes;
- Develop opportunities for recreation along Clear Creek and tributaries;
- Facilitate stabilization of the stream banks of Clear Creek and tributaries; and
- Improve the quantity and quality of habitat on Clear Creek and its tributaries.

ES.3 DESCRIPTION OF PROPOSED ACTION AND ALTERNATIVES

During project planning, a three-phased formulation and screening process was used to identify the General Reevaluation Plan (GRP) Alternative: (1) Phase I: Preliminary Screening – preliminary evaluation and screening of numerous structural and nonstructural component to reduce flood damages, (2) Phase II: First-added Analysis – refinement, hydraulic and economic evaluation and screening of stand-alone alternatives (i.e., first-added measures) to reduce flood damages, and (3) Phase III: Second-added Analysis – further refinement and detailed evaluation and screening of alternatives using high-performing, previously screened first-added measures in combination with additional measures (i.e., second-added measures). During the preliminary screening, the No Action Alternative was developed for comparison with other alternatives. This alternative was carried through the subsequent planning phase for comparison with other alternatives.

In Phase I of the screening process, a list of 72 components or measures were initially identified and included ideas from records of public meetings, web page comments, and letters regarding the project. Criteria for screening these initial components were developed to reduce the number of measures for further evaluation and ensure they meet the four USACE planning criteria of completeness, efficiency, effectiveness, and acceptability. These criteria were Flood Risk Management Effect, Environmentally Sensitive, Acceptability/Aesthetics/Recreational Opportunities, Chance of Success/Cost Effectiveness, and Engineering Implementable. Using these criteria, a list of 24 stand-alone flood risk management measures was identified that would encompass all activities ranked as high priority in the initial screening. These measures were carried forward for further evaluation.

In Phase II of the process, these 24 first-added measures were refined, analyzed, and ranked based on hydraulic and economic performance, as well as environmental effects. The 10 best-ranking first-added measures (i.e., most-cost-effective measures that were most successful in reducing flooding) were identified.

In Phase III of the process, the most successful first-added measures were evaluated in more detail, which began a series of modifications and combinations, called second-added measures, to identify the National Economic Development (NED) Plan.

After the initiation of detailed analysis in Phase III, it became clear that opportunities were missing to reduce flood damages on the tributaries and that measures identified for the tributaries could also create substantial benefits on Clear Creek due to the change of timing associated with flooding events throughout the entire watershed. If timing of floodwaters associated with the tributaries could be modified from existing conditions, benefits could be identified for areas outside of the original study area.

Additional components, including those considered in the first-added measures that were not identified as one of the five with positive net economic benefits, were also considered in the analyses. Analysis began at the upstream, high-damage reaches of Clear Creek, and numerous alternatives were modeled.

Based on considerations for modifications and combinations of the first-added measures, and following additional hydraulic modeling, a Clear Creek upstream conveyance anchor component [Super C(d)] was identified and added to the model. Subsequent tributary and downstream conveyance and detention measures were systematically added and modeled for additional flood risk management.

The highest performing measures that successfully increased benefits (decreased flood damages) greater than estimated costs were added to the system of measures, creating an overall plan that would reduce damages throughout the watershed.

The GRP Alternative has been identified as the Recommended Plan in the GRR and is the preferred alternative in this Final Supplemental Environmental Impact Statement (FSEIS). The GRP Alternative includes a series of flood risk management measures and mitigation areas, referred to as project features. Flood risk management measures include conveyance measures areas on or adjacent to Clear Creek from State Highway (SH) 288 to Bennie Kate Road [Section Super C(d)], Bennie Kate Road to Dixie Farm Road [Section C5(d)], and on three tributaries: Mud Gully, Turkey Creek, and Mary's Creek. Mitigation features include avoidance, minimization, and compensation for project impacts through rehabilitation and reestablishment of floodplain forest. Summary descriptions of the GRP Alternative features are provided below. Excavated material from construction and maintenance activities would need to be placed in upland confined placement areas. Approximately 375.8 acres of placement areas would be identified outside of the 500-year floodplain in areas suitable for placement of excavated material associated with the project. The excavated material would be deposited at a designated upland confined placement area. The locations of the placement areas would be determined during the preconstruction engineering and design phase. Attempts will be made to site the placement areas on agricultural lands, pasture, and other urban land to avoid wetlands and/or other ecological resource areas.

Super C(d) Section Feature: This flood risk management feature provides conveyance improvement on Clear Creek from SH 288 to 4,000 feet downstream of Bennie Kate Road. The conveyance feature includes construction of 10.8 miles of a 200-foot-wide (bottom width) high-flow channel along Clear Creek in Harris and Brazoria counties. The existing Clear Creek channel would be preserved for low-flow conveyance. In addition, a 65-foot corridor of floodplain forest vegetation along the stream bank (riparian zone) of Clear Creek would be preserved and rehabilitated or reestablished.

C5(d) Section Feature: From approximately 4,000 feet downstream of Bennie Kate Road to Dixie Farm Road, this flood risk management feature provides conveyance via construction of 4.4 miles of 90-foot-wide (bottom width) high-flow channel. The existing Clear Creek channel would be preserved for low-flow conveyance. Similar to the Super C(d) Section Feature, a corridor of floodplain forest along the stream bank would be preserved and rehabilitated.

In-Line Detention Features: These features would provide detention for up to 485 acre-feet of water within limited segments of the proposed Clear Creek conveyance measures. Construction of these features would require minor deepening of the high-flow channel in areas where the high-flow channel diverges from the low-flow channel.

Turkey Creek Conveyance Feature: This feature would provide improved conveyance via construction of a 2.4-mile earthen, grass-lined channel on Turkey Creek from Dixie Farm Road to the confluence with Clear Creek. From Dixie Farm Road to 2,000 feet downstream of Well

School, the channel bottom width would be 20 feet, and the remaining channel to the confluence with Clear Creek would have a bottom width of 25 feet.

Mud Gully Conveyance Feature: The conveyance improvement would occur along 0.8 mile of Mud Gully from Sagedowne to Astoria. The proposed channel would be concrete lined with a bottom width of 45 feet. The proposed modifications for the stream are located within the median between the northbound and southbound lanes of Beamer Road.

Mary's Creek Features: Mary's Creek flood risk management measures include construction of a grass-lined trapezoidal channel along 2.1 miles of Mary's Creek. From Harkey Road to 3,940 feet upstream of McClean Road, the channel bottom width would be 15 feet, and from that point to 100 feet downstream of McClean Road, it would be 27.5 feet wide. Downstream of McClean Road to SH 35, the channel bottom width would be 35 feet.

In addition to the GRP Alternative, the No Action Alternative is evaluated in this FSEIS. The No Action Alternative assumes that the GRP Alternative is not implemented, hence retaining the existing Clear Creek at its current configuration. Development upstream of Clear Lake in areas that do not have a detention policy in place will continue to increase the amount of impervious cover in the study area, increasing flows into Clear Creek. These increased flows will continue to cause increases in water elevation sufficient to cause flooding in many areas. The No Action Alternative provides a baseline future without-project scenario with which the GRP Alternative can be compared.

ES.4 POTENTIAL ENVIRONMENTAL IMPACTS

This FSEIS addresses the potential impacts of the proposed project on human and environmental resources identified during the public interest review. All factors that may be relevant to the proposed project were considered, including the following: air quality, hydrology, economics, general environmental concerns, historic resources, protected species, recreation, water quality, sediment quality, safety, hazardous materials, and, in general, the welfare of the people. The following provides a brief description of potential negative impacts that were identified. Resources not potentially negatively affected by the proposed project are not addressed below.

Environmental Setting

The GRP Alternative is the preferred alternative and includes a series of flood risk management measures and mitigation areas, referred to as project features. Flood risk management measures include conveyance measures on or adjacent to Clear Creek from SH 288 to Bennie Kate Road [Section Super C(d)], Bennie Kate Road to Dixie Farm Road [Section C5(d)], and on three tributaries: Mud Gully, Turkey Creek, and Mary's Creek. Mitigation features include avoidance, minimization, and compensation for project impacts through rehabilitation and reestablishment of floodplain forest. Summary descriptions of the GRP Alternative features are provided below.

Excavated material would need to be placed in upland confined placement areas to be identified during the preconstruction engineering and design phase.

Sea Level Rise

The effects of sea level rise and subsidence would be the same for the GRP and No Action alternatives. The only difference would be that the GRP Alternative would have the proposed measures incorporated to reduce stream flooding in the study area.

Water Quality

No Texas Water Quality Standards (TWQS) would be violated from Mud Gully conveyance measures (i.e., material placement and excavation). Since the high-flow channel and side slopes of the Mud Gully conveyance measure would be concrete lined to maintain stability of side slopes, there would be no addition of turbidity during a high-water event from erosion of the side slopes.

The high-flow channels and side slopes of all of the other conveyance measures and in-line detention would be grass lined with trees, which would also reduce turbidity during rainfall and high-flow events. Additionally, reduction of flow velocity during high-flow events would reduce the turbidity flowing downstream and into Clear Lake. Generally, the eventual establishment of a riparian vegetation corridor, combined with slower flows, would contribute to higher water quality. For example, riparian vegetation reduces stream pollutants that enter waterways, reduces erosion dynamics and turbidity, increases dissolved oxygen levels through reduced temperatures from shade, and sequesters potentially harmful nutrient loads such as excess nitrogen and phosphorus. No TWQS would be violated by material excavation and placement during construction of conveyance measures.

Sediment Quality

Excess materials removed from Clear Creek and its tributaries during construction would be placed into upland confined placement areas. Based on previous sediment contaminant analysis, no adverse impacts to or from sediments can be expected with implementation of the proposed project.

Hydrology

The proposed project would reduce flood damage in the Pearland and Friendswood area reaches by improving the capacity of Clear Creek and its tributaries. A high-flow channel, a conveyance improvement measure, would provide additional capacity during flood events. High-flow events would also be mitigated through the eventual establishment of riparian vegetation from tree plantings.

The proposed project would change the floodplain, which could result in changes to the Flood Insurance Rate Maps (FIRMs). Revision to FIRMs, if any, may affect the inclusion of properties within the floodplain.

Construction and operation activities associated with the proposed project are not expected to result in significant impacts to groundwater hydrology, quantity, or quality.

Air Quality

Emissions from the construction-related activities associated with the proposed project would include volatile organic compounds (VOCs), NO_x, CO, sulfur oxides (SO_X), PM_{10}, and $PM_{2.5}$. Emissions from project construction activities would exceed the general conformity threshold (25 tons per year [tpy]) for NO_x for construction years 2014 to 2017. Therefore, a General Conformity Determination is required for each of those years. The VOC emissions are not expected to exceed 25 tpy. As part of the general conformity process, the USACE, in consultation with the Texas Commission on Environmental Quality (TCEQ) and the U.S. Environmental Protection Agency (EPA), has prepared a Draft General Conformity Determination document discussing whether NO_x emissions that would result from the proposed project are in conformity with the Texas State Implementation Plan (SIP) for the Houston-Galveston-Brazoria Nonattainment Area. This document was submitted to the TCEQ, EPA, and other air pollution control agencies, as appropriate, along with the Draft SEIS. Concurrence that the NO_x emissions are consistent with the SIP was provided by the TCEQ via letter dated February 7, 2012 (Appendix H). As the project moves forward, the USACE will update the EPA and TCEQ to ensure that project emissions are consistent with the most currently approved SIP emissions budgets, taking into account any potential changes to the project schedule and future SIP revisions.

Noise

A worst-case scenario noise evaluation was conducted for proposed project construction activities. Within approximately 200 feet of the proposed project footprint, worst-case noise levels would range between 89 and 77 dBA at noise-sensitive receptors. This would likely result in temporary annoyance for approximately 403 receptors. Beyond 400 feet from the proposed project footprint, these noise levels would decrease to more-acceptable levels. Beyond 400 feet, noise related to project activities would not be differentiated from ambient conditions, depending on surrounding land uses and features. Increases to ambient noise levels in the proximity of Loop 8, SH 288, I-45, and other major highways would generally be more tolerable as compared to noise level increases in more-isolated locations.

Soils, Including Prime and Unique Farmlands

Prime farmland soils located within the project area would be impacted by the proposed project. However, due to the rapid urban growth in the project area, these soils are not typically used for farmland. A Form AD-1006 was submitted to Natural Resources Conservation Service (NRCS). The 31 acres of prime farmland potentially impacted received a score of 12, which is below the NRCS threshold of 160 for high-level consideration. The prime farmland soils affected by the proposed project make up a very small percentage of the total prime farmland available in the counties (0.01 percent), and the majority of the project footprint occurs in areas designated by the NRCS as urban. The implementation of the proposed project would make some properties unavailable for future crop production. However, this change is not expected to have an adverse affect on production of agricultural commodities in the area, nor is it expected to impact the local economy or food needs/supplies.

Hazardous, Toxic, and Radioactive Waste (HTRW)

The HTRW assessment revealed potential concerns associated with past industrial activity at three facilities and one spill site: Brio Refinery, Dixie Oil Processors, Gulf Metals Industries, and one spill site at the corner of Scarsdale Boulevard and Beamer Road. The construction of the proposed project may reduce the potential for these sites to be impacted during major flood events.

A total of four permitted oil and gas well sites are located within the project features. These well sites include one active well. The surface completions of the active wells within the project features will require modifications, relocation, or abandonment.

A total of approximately 26 petroleum pipeline systems are located within the project feature areas. The Texas Railroad Commission files indicate that 21 of the pipeline systems are listed as active (in service) and 5 are listed as inactive (abandoned). The USACE has tabulated pipelines within the conveyances requiring relocation. According to this tabulation, a total of approximately 22 pipelines would require relocation.

Vegetation

Floodplain forest in reaches impacted is dominated by native tree species assemblages consisting of sugarberry, water oak, willow oak, black willow, and pecan, as well as invasive species such as Chinese tallow. Common shrub species include the native yaupon holly, as well as invasives such as Japanese and Chinese privet. Approximately 278 acres of floodplain forest within the riparian corridor of Clear Creek would be directly impacted by construction of flood risk management measures associated with the GRP Alternative. No losses of or impacts to coastal prairie or tidal marsh are anticipated. Impacts to existing floodplain forest would be avoided and minimized as much as possible within the design of the conveyance features along Clear Creek.

The environmentally sensitive design features of the GRP encompass preservation, rehabilitation, and reestablishment of 155 acres of floodplain forest within portions of the existing low-flow channels, which includes 7.3 acres of reestablished and restored fringe forested wetlands. In the proposed bench cuts, floodplain forest would be converted to open woodland with ground cover maintained in mowed grasses. A net loss of 106 Average Annualized Habitat Units (AAHUs) would be incurred over the 50-year project life under the GRP.

Potential impacts to wetland resources within the project footprint were assessed using aerial interpretation and limited field verification. Aerial interpretation processes included National Wetlands Inventory data review and comparison with 2004 infrared and 2000 and 2009 true-color aerial imagery in conjunction with limited field verification. Wetland communities were included within the cover type mapping of the floodplain forest, and the acres of wetlands within the study area as well as the conveyance, in-line detention, and mitigation features were captured within the Floodplain Forest Community Habitat Evaluation Procedure Model. In doing so, unavoidable impacts and mitigation were considered and evaluated to ensure no net loss of these resources. Wetlands occurring within these sites include freshwater emergent, forested, scrub-shrub, unconsolidated shore/bottom, and riverine. These wetland communities would be protected, rehabilitated, and reestablished through implementation of the GRP Alternative mitigation efforts.

The locations of the placement areas will be sited to estimate the likely costs of dealing with material excavated from the proposed conveyances and detention features. The actual locations of the placement areas will be determined during the preconstruction engineering and design phase of the project. All reasonable attempts will be made to locate the placement areas in areas that will not result in impacts to ecological resources.

Fish and Wildlife Resources

Along the Clear Creek bench-cut conveyance section, construction activities may have short-term impacts on freshwater fish and benthic macroinvertebrates, if sediment inadvertently bypasses silt fencing and enters the stream during rainfall runoff. However, impacts resulting from the construction of the Clear Creek conveyance bench-cut features are expected to be temporary, reversible, and localized primarily to the reach where construction of this feature is occurring. It is expected that the Clear Creek conveyance feature would result in long-term benefits to the fish community, by allowing the spread of future flood flows over a widened channel, resulting in reduced erosive forces from high-velocity flows, and because of benefits such as shade and structure provided by the rehabilitated floodplain forest corridor.

Turkey Creek, Mud Gully, and Mary's Creek conveyance features would result in short-term impacts to the freshwater fish community caused by construction activities, which would add sediment to the streams during rain events producing increased turbidity. However, to minimize the potential for sediment to reach the streams, silt fencing will be installed as a best management practice. Long-term fish community impacts would be experienced for one of the three conveyance features. Construction of conveyance on Turkey Creek would remove much of the relatively small amount of remaining forested riparian area along the water's edge, resulting in less shading and somewhat lower habitat diversity. However, impacts to the riparian areas were considered in the habitat suitability index (HSI) modeling, and mitigation has been identified to compensate for those impacts. For Mud Gully and Mary's Creek, the long-term impacts from construction activities would be relatively minor, since no natural riparian area and minimal habitat diversity occurs within areas to be modified on each of these channels.

For wildlife resources, temporary construction activities may adversely affect smaller, low-mobility species. Although construction activities may disrupt the normal behavior of many wildlife species, little permanent damage to these populations should result. Clearing of stream-side vegetation within the conveyance channels, while producing temporary negative impacts to wildlife, can improve habitat through revegetation of small shrubs, perennial forbs, and grasses, and help ensure the reestablishment of wildlife assemblages in affected areas.

Threatened and Endangered Species

One federally and state-listed endangered plant species, the Texas prairie dawn-flower, is of potential occurrence within the study area; however, based on review of historic aerial photographs, site reconnaissance, and recent topographical changes, there are no known populations within the project feature footprint. Therefore, the project is expected to have no effect on this species.

The species listed in Table 3.11-1 (Section 3.11) include federally listed threatened or endangered animal species that are included on the U.S. Fish and Wildlife Service (USFWS) Southwest Region Ecological Services County by County lists for Harris, Galveston, Brazoria, and Fort Bend counties, and the Texas list of federally protected species under the jurisdiction of the National Marine Fisheries Service (NMFS). These species include the following: smalltooth sawfish, Attwater's greater prairie-chicken, Eskimo curlew, piping plover, whooping crane, green sea turtle, hawksbill sea turtle, Kemp's ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, blue whale, fin whale, humpback whale, sei whale, and sperm whale. Of these, only the brown pelican is likely to occur. The bald eagle may occur within the project area; however, this species has been delisted. The brown pelican was recently delisted and is currently being monitored for the first 5 years.

None of the federally listed threatened or endangered species presented in Table 3.11-1 have USFWS-designated critical habitat within the study area. Thus, the proposed project would not result in impacts to critical habitat for any federally listed endangered species. Additionally, the implementation of the Clear Creek Project would not result in any direct impact to federally listed species. Thus, the USACE has determined that the project will have no effect on federally listed species.

Cultural Resources

Construction activities related to the current project may impact recorded archeological sites. PBS&J conducted a file review in order to determine the number and types of cultural resources sites that would be potentially impacted by the proposed Clear Creek Project. A total of 100 sites are located within the study area. These sites date to the Prehistoric, Late Prehistoric, and Historic periods including those of the Ceramic, Late Ceramic, and Early Archaic cultures. Twenty-four sites are located specifically within the project area, though only 10 of these sites are in areas that would be impacted by the proposed work. These 10 prehistoric and Late Prehistoric sites were evaluated by Prewitt & Associates, Inc., in 2007. Additional detail regarding recorded historic and prehistoric sites within the study area can be found in the table in Appendix F-2 and Section 3.12. A Memorandum of Agreement (MOA) (Appendix F-1) among the USACE, the State Historic Preservation Officer (SHPO), and the Advisory Council on Historic Preservation (ACHP) is in place to ensure compliance with Section 106 of the National Historic Preservation Act. A new Programmatic Agreement (PA) is currently being coordinated with the SHPO, the ACHP, and the Project Sponsors. This PA was prepared to include the Project Sponsors and to guide implementation of the proposed Clear Creek Project. Work performed under either the existing MOA or the new PA will include, but is not limited to, additional testing of one previously recorded site and additional survey of two previously recorded sites when access is obtained; identification and investigation of unrecorded and, as of yet, unidentified sites; and the investigation of unanticipated cultural resources encountered during the course of work.

Socioeconomic Resources

The proposed project would reduce flood damages along Clear Creek and would potentially result in lower insurance rates for homeowners as well as improving property values. There would be temporary economic effects beneficially accruing from construction activities, resulting from construction employment and purchasing of construction materials. The proposed project is in compliance with Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations."

Land Use/Aesthetics

There is a potential for an increase in structure and population density along Clear Creek, as a result of a decrease in the risk of flood-induced damages stemming from the implementation of the proposed project. Changes to future land uses in response to the improvements could include residential and commercial development and the development of public recreational facilities, such as municipal parks, hike and bike trails, and picnic areas.

The proposed project would have minimal effect on the overall visual quality within the study area. The aesthetic quality in an area along the Clear Creek main channel would potentially be rehabilitated with the proposed improvements by establishing a parklike setting within the floodplain forest. This would be accomplished via the low-flow channel and riparian corridor.

Conveyance and mitigation measures that include preservation/rehabilitation of existing floodplain forest and reestablishment of floodplain forest would serve as potential habitat for birds and wildlife species that could pose a strike hazard to aircraft using nearby public airports. In compliance with the Federal Aviation Administration (FAA) Advisory Circular 150/5200-33B and the MOA with FAA to address aircraft-wildlife strikes, an evaluation of the proximity of these project features to nearby airports was conducted. The USACE provided this information to the FAA on May 12, 2010, and concluded that conveyance and mitigation features of the GRP Alternative would not result in a net change of current land use, as no habitat would be created where it does not or did not once exist. Thus, the GRP Alternative is not expected to introduce new hazardous wildlife attractants to the Ellington Field, Houston-Southwest, La Porte Municipal, William P. Hobby, or Pearland Regional airports.

ES.5 MITIGATION

Approximately 278 acres of floodplain forest within the riparian corridor of Clear Creek would be directly impacted by construction of flood risk management measures associated with the GRP Alternative; no losses or impacts of coastal prairie or tidal marsh are anticipated. Impacts to existing floodplain forest would be avoided and minimized as much as possible within the design of the conveyance features along Clear Creek. The unique flood bench design of the Clear Creek conveyance would preserve the existing morphology of the low-flow channel and allow 122 acres of existing floodplain forest corridor to be preserved and rehabilitated and 33 acres of floodplain forest corridor to be reestablished (total 155 acres). Compensatory mitigation to offset unavoidable impacts to 278 acres of floodplain forest corridor directly impacted by construction of flood risk management measures associated with the GRP Alternative would be accomplished by rehabilitating the low-flow channel to mimic the natural 1955 sinuosity regime of Clear Creek. This would be conducted by reconnecting low flow and meanders through 13 remnant oxbows scattered throughout the system between Country Club Drive and Dixie Farm Road that were cut off as a result of past channelization activities. Portions of the current low-flow channel alignment would be modified to reconnect natural hydrology into the oxbows under low-flow conditions; high-flow conditions would be maintained within the existing conveyance alignment to guarantee flood protection for the area. Excavated material stockpiled along the north bank of the creek would be removed, and the existing cleared overbank areas along the channel would be densely planted to restore the existing floodplain forest to a desired state. These activities would result in the reestablishment of 31 acres (131 AAHUs) of floodplain forest within the riparian corridor of Clear Creek. Mitigation would offset the negative net impacts to floodplain forest from conveyance, avoidance, and minimization features of the GRP (–106 AAHUs) and produce cumulative projects benefits (+25 AAHUs).

ES.6 COORDINATION AND PUBLIC INVOLVEMENT

Public involvement began with a public meeting in Friendswood, Texas, in March 1964. Since initiation of postauthorization studies in early 1972, public meetings and numerous workshop meetings were held regarding the project.

During post-1968 Congressional authorization planning studies, numerous workshop meetings and other informal meetings were held from September through December 1976 with affected groups in the area. In addition, five public meetings were conducted (January 1974, November 1974, May 1977, August 1980, and January 1982) to discuss the flooding problems in the Clear Creek area. Local engineers, civic groups, local governmental bodies, and individuals provided input to the study. A Notice of Intent to prepare a draft EIS was published in the *Federal Register* on July 24, 1980. Strong support for resolving the Clear Creek flooding problems was shown at each of the public meetings; however, a divergence of opinion existed on the flood control method to be used.

Public involvement in the proposed project has occurred through public meetings and other outreach throughout the history of the study. The public, resource agencies, industry, local governments, and other interested parties have been proactively informed about the study, project alternatives, and proposed project through USACE-sponsored public meetings as well as other outreach programs.

Public meetings for the Clear Creek Federal Flood Control Project were hosted by HCFCD in July 1997, September 1997, and November 1997. Over 1,600 people attended the three meetings. In addition to the public meetings hosted by HCFCD, various types of communication were used to keep the public informed of the progress of the project. These included written material that provided a history of the Clear Creek watershed, a description of components of the Federal project that had been implemented, a description of other components of the Federal project, a discussion of the reevaluation process, and recaps of the public meetings. Additional information is presented in Section 12 of the FSEIS.

Three USACE-sponsored public scoping meetings were conducted in 2001 for this project. These meetings occurred on March 15, 2001, in Friendswood, Texas; May 3, 2001, in League City, Texas; and May 9, 2001, in Pearland, Texas. Solicitation of public comments was a primary objective of the scoping meetings to ensure that significant issues were addressed. As such, meeting participants were specifically asked to identify environmental concerns, constraints, opportunities, and recommendations associated with the proposed flood measures.

At each of the three meetings, a presentation of the project was given and the floor was opened to verbal comments from the public. Most comments can be grouped into the following subjects: (1) favor clearing and snagging, (2) favor nonstructural alternatives, (3) support Challenge 21 (also known as the Flood Mitigation and Riverine Restoration Initiative [Section 212, Water Resources Development Act of 1999]), (4) oppose future development in the area, (5) concern with lack of action, and (6) glad project is moving forward.

In addition to National Environmental Policy Act–related public meetings, USACE hosted two open-house workshops in February 2004 to update the public on the status of the project and to report and present examples of the flood risk management and ecosystem restoration measures being considered. Public comments were also accepted at these meetings.

Additional efforts to involve the public include maintenance of the Clear Creek Project website, public field trips, educational sessions, and establishment of the Clear Creek Steering Committee (CCSC) and the Clear Creek Citizens Advisory Committee (CAC). These two committees were formed to incorporate public, agency, and stakeholder interests in the reevaluation process. The CCSC comprises the following:

- Brazoria County Conservation and Reclamation District 3
- Brazoria County Drainage District #4
- City of Friendswood
- City of Houston
- City of League City
- City of Pasadena
- City of Pearland
- Clear Lake Area Council of Cities
- Fort Bend County Drainage District
- Galveston County
- Harris County Flood Control District
- Galveston County Consolidated Drainage District

Members of the CAC include citizens living in the watershed and environmental consultants. Input from these committees as well as local, state, and Federal government agencies, and comments provided at public meetings were considered in the development of flood risk management measures that were evaluated for incorporation into the GRP Alternative.

The DSEIS was made available to all known Federal, State, and local agencies, as well as interested organizations and individuals, on December 16, 2011. The comment period for the DSEIS ended on January 30, 2012. A public hearing was held on January 11, 2012, at the Marie

Spence Flickenger Fine Arts Building located at San Jacinto College South, 13735 Beamer Road, Houston, Texas. A list of SEIS recipients is included in Section 12.3. Comments and corresponding responses from the DSEIS comment period and public hearing are addressed in this FSEIS in Appendix A-8.

ES.7 AREAS OF CONTROVERSY AND UNRESOLVED ISSUES

A General Conformity Determination has been prepared and has been submitted to the TCEQ and EPA with this FSEIS. The USACE will coordinate with TCEQ and EPA as appropriate to ensure compliance with the SIP. The estimate of VOC emissions for the GRP Alternative will not exceed the conformity threshold of 25 tpy for any years of construction. Therefore, a General Conformity Determination for VOC emissions would not be required for this alternative. The estimate of NO_x emissions for the GRP Alternative will exceed the General Conformity threshold (25 tpy) in 2014, 2015, 2016, and 2017. Therefore, a General Conformity Determination for NO_x emissions is required for this alternative. A General Conformity Determination document was submitted to the TCEQ and EPA with the DSEIS. The TCEQ provided concurrence via letter dated February 7, 2012 (Appendix H). As the project moves forward, the USACE will update the EPA and TCEQ to ensure that project emissions are consistent with the most currently approved SIP emissions budgets, taking into account any potential changes to the project schedule and future SIP revisions.

Compliance with the Clean Water Act was achieved through coordination with TCEQ to obtain water quality certification for the project. An evaluation of the project based on Section 401(b)(1) Guidelines and the certification letter from TCEQ is presented in Appendix L of this FSEIS.

A draft Biological Assessment was prepared and submitted to NMFS and USFWS for their review with the DSEIS. In the Coordination Act Report submitted by USFWS (Appendix D-6), the USACE determination of no effect to federally protected species was acknowledged and not disputed. Thus, USACE is in compliance with the Endangered Species Act for species under jurisdiction of USFWS.

An MOA (Appendix F-1) among the USACE, the SHPO, and the Advisory Council on Historic Preservation (ACHP) is in place to ensure compliance with Section 106 of the National Historic Preservation Act. A new Programmatic Agreement (PA) is currently being coordinated with the SHPO, the ACHP, and the Project Sponsors. This PA was prepared to include the Project Sponsors and to guide implementation of the proposed Clear Creek Project. Compliance with the MOA places the project in compliance with Section 106.

A Planning Aid Letter was prepared by USFWS, and suggestions were incorporated into the design and implementation of the project as described in Section 7.8. A Coordination Act Report is included as Appendix D-6 in the SEIS.

Assuming approval of the project, prior to construction, placement areas will be identified for placement of the material removed from high-flow conveyance measures. Potential impacts associated with placement of materials in these areas will be assessed. Additionally, potential impacts associated with the relocation of pipelines would need to be considered when more information is available regarding their relocation.

ES.8 RELATION TO ENVIRONMENTAL REQUIREMENTS

The GRP Alternative is in full compliance with the environmental requirements applicable to this stage of the planning process. A discussion of the applicable laws can be found in Section 7 of the SEIS.

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Acronyms and Abbreviations

AAHU	Average Annual Habitat Unit
ACHP	Advisory Council on Historic Preservation
AEP	annual exceedance probability
AFP	Authorized Federal Project
AOA	air operations area
AOU	American Ornithologists' Union
ASTM	American Society for Testing and Materials
AT&SF RR	Atchison, Topeka & Santa Fe Railroad
BA	Biological Assessment
BCDD4	Brazoria County Drainage District #4, also known as Pearland Drainage District
BEAMS	Bathymetric Engineering and Management System
BEG	Bureau of Economic Geology
BFE	Base Flood Elevation
BGEPA	Bald and Golden Eagle Protection Act
BMP	best management practice
BO	Biological Opinion
BSSC	Brio Site Steering Committee
BSTF	Brio Site Task Force
CAA	Clean Air Act
CAC	Clear Creek Citizens Advisory Committee
CBMB	Coastal Bottomlands Mitigation Bank
CBRA	Coastal Barrier Improvement Act
CCC	Coastal Coordination Council
CCSC	Clear Creek Steering Committee
CE/ICA	cost-effectiveness analysis and incremental cost analysis
CEQ	Council on Environmental Quality
CERCLIS	Comprehensive Environmental Response Compensation and Liability Information System
CFR	*Code of Federal Regulations*
cfs	cubic feet per second
CH_4	methane
CNRA	Coastal Natural Resource Area
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COC	constituents of concern
CT	Census Tract

dB	decibel
dBA	A-weighted decibel level
DDE	dichlorodiphenyldichloroethylene (DDT contaminant)
DDT	dichlorodiphenyltrichloroethane (pesticide)
DEIS	Draft Environmental Impact Statement
DSEIS	Draft Supplemental Environmental Impact Statement
EFH	Essential Fish Habitat
EH&A	Espey, Huston & Associates, Inc.
EIS	Environmental Impact Statement
EO	Executive Order
EOP	Environmental Operating Principles
EPA	U.S. Environmental Protection Agency
ER	Eco-Reach
ERDC	U.S. Army Engineer Research and Development Center
ESA	Endangered Species Act
E-Team	Ecosystem Assessment Team
°F	Fahrenheit
FAA	Federal Aviation Administration
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FM	Farm to Market Road
FPPA	Farmland Protection Policy Act
FSEIS	Final Supplemental Environmental Impact Statement
FWOP	Future Without Project Condition
GBNEP	Galveston Bay National Estuary Program
GBWMB	Greens Bayou Wetlands Mitigation Bank
GHG	greenhouse gas
GLO	Texas General Land Office
GMFMC	Gulf of Mexico Fisheries Management Council
GRP	General Reevaluation Plan
GRR	Clear Creek General Reevaluation Report
GWMP	Global Watershed Management Practices
H&H	Hydrologic and Hydraulic
HCFCD	Harris County Flood Control District
HEP	Habitat Evaluation Procedure
H-GAC	Houston-Galveston Area Council

HGB	Houston-Galveston-Brazoria
HGM	Hydrogeomorphic Model
HHS	U.S. Department of Health and Human Services
HSI	habitat suitability index
HTRW	Hazardous, Toxic, and Radioactive Waste
HU	habitat unit
ICT	Interagency Coordination Team
I-	Interstate Highway
JSC	Johnson Space Center
KCMB	Katy-Cypress Mitigation Bank
L_{dn}	day-night sound level
L_{eq}	equivalent sound level
LOMR	Letter-of-Map-Revision
LPP	Locally Preferred Plan
MBTA	Migratory Bird Treaty Act
MCMB	Mill Creek Mitigation Bank
mg/kg	milligrams per kilogram
mgd	million gallons per day
mhw	mean high water
mlw	mean low water
mm	millimeter(s)
MOA	Memorandum of Agreement
mph	miles per hour
msl	mean sea level
NAAQS	National Ambient Air Quality Standards
NASA	National Aeronautics and Space Administration
NBI	National Bridge Inventory
NED	National Economic Development
NEPA	National Environmental Policy Act
NGVD	North American Geodetic Vertical Datum
NMFS	National Marine Fisheries Service
NO	nitric oxide
NO_2	nitrogen dioxide
N_2O	nitrous oxides
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO_x	nitric oxide and other oxides of nitrogen
NPL	National Priority List

NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWI	National Wetlands Inventory
NWR	National Wildlife Refuge
NWS	National Weather Service
O&M	operations and maintenance
O_3	ozone
OHWM	ordinary high water mark
PA	Programmatic Agreement
PAH	polyaromatic hydrocarbons
PAI	Prewitt & Associates, Inc.
PAL	Planning Aid Letter
Pb	lead
PCB	polychlorinated biphenyls
PE/EA	Preliminary Engineering and Environmental Analysis
PM_{10}	inhalable particulate matter with an aerodynamic diameter less than or equal to a nominal 10 microns
$PM_{2.5}$	fine particulate matter with an aerodynamic diameter less than or equal to a nominal 2.5 microns
ppm	parts per million
ppt	parts per thousand
RCRA	Resource Conservation and Recovery Act
REI	Resource Engineering, Inc.
ROD	Record of Decision
ROW	right-of-way
SAV	submerged aquatic vegetation
SCS	Soil Conservation Service
SEIS	Supplemental Environmental Impact Statement
SH	State Highway
SHPO	State Historic Preservation Officer
SI	Suitability Index
SIP	State Implementation Plan
SO_2	sulfur dioxide
SOC	species of concern
SO_x	sulfur oxide
SPA	Sponsor Proposed Alternative
SSA	sole source aquifer
SSF	State Superfund

SSURGO	Soil Survey Geographic Database
SWPPP	Storm Water Pollution Prevention Plan
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Program
TCOON	Texas Coast Ocean Observation Network
TCWC	USFWS's Texas Colonial Waterbird Census
TDRA	Texas Department of Rural Affairs
TDS	total dissolved solids
TDSHS	Texas Department of State Health Services
TDWR	Texas Department of Water Resources (now TCEQ)
TMDL	total maximum daily load
TNRCC	Texas Natural Resource Conservation Commission (now TCEQ)
TOC	total organic carbons
TPWD	Texas Parks and Wildlife Department
tpy	tons per year
TRC	Texas Railroad Commission
TWC	Texas Workforce Commission
TWDB	Texas Water Development Board
TWQS	Texas Water Quality Standards
TxDOT	Texas Department of Transportation
TXNDD	TPWD's Texas Natural Diversity Database
µg/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTC	Upper Texas Coast Wildlife Trail
VCP	state voluntary cleanup site
VOC	volatile organic compounds
WCC	Woodward-Clyde Consultants
WCID	water control and improvement district
WRDA	Water Resources Development Act

1.0 NEED FOR PROPOSED ACTION

1.1 INTRODUCTION AND PURPOSE

Clear Creek is located south of the City of Houston and is included in parts of Harris, Galveston, Brazoria, and Fort Bend counties, Texas (Figure 1.1-1). Flooding along Clear Creek has been a concern for over 40 years, with floodwaters in 1973, 1976, 1979, 1989, and 1994 causing substantial damage to residences along the creek (Dannenbaum Engineering Corporation, 1997). More recently, heavy rains from Tropical Storm Allison in 2001 resulted in severe flooding along Clear Creek that has prompted the buyout of approximately 300 flood-prone homes. However, flooding is not only a problem associated with severe rain events, but also has become increasingly more frequent along Clear Creek, even with moderate amounts of rainfall.

The problem of flooding along Clear Creek has not been easily addressed. Local authorities have made limited channel improvements to address specific flood concerns, but those efforts have contributed little to resolving the current large-scale flooding problems. In 1968, Congress authorized the Clear Creek Flood Control Project, and plans were formulated in the 1980s that included deepening, widening, and realigning the creek channel. In 1997, concerns regarding the project's design as well as its environmental and hydraulic affects prompted the non-Federal sponsors, Galveston County and Harris County Flood Control District (HCFCD), with input from the public and governmental entities, to ask that construction on the authorized channel be suspended for 6 months. HCFCD developed a modified plan (the Sponsor Proposed Alternative or SPA) for consideration, but the plan was determined to be substantially different from the authorized project and could not be considered for construction under the existing authorization. As a result, in 1999 the U.S. Army Corps of Engineers (USACE) initiated a general reevaluation study to reconsider the project with the HCFCD, Galveston County, and Brazoria County Drainage District #4 (BCDD4) acting as non-Federal sponsors. The purpose of this study is to develop and evaluate alternatives for flood risk management within the Clear Creek watershed. The current study is referred to as the Clear Creek Flood Risk Management Project (sometimes referred to in this report as the Clear Creek Project).

As part of the planning study process conducted in the 1980s, National Environmental Policy Act (NEPA) compliance documents were prepared for the Clear Creek Flood Control Project. The Notice of Intent (NOI) to prepare a Draft Environmental Impact Statement (DEIS) was published in the *Federal Register* on July 24, 1980. The DEIS was released for public and agency review in December 1981, and the Final Environmental Impact Statement (FEIS) was released in May 1982, titled "Clear Creek, Texas Flood Control FEIS." This document has been prepared as a supplement to the 1982 FEIS and is thus referred to as a Supplemental EIS (SEIS). It should be noted that although this document is an SEIS, all resource information has been revised and updated as appropriate due to the length of time (nearly 20 years) between the 1982

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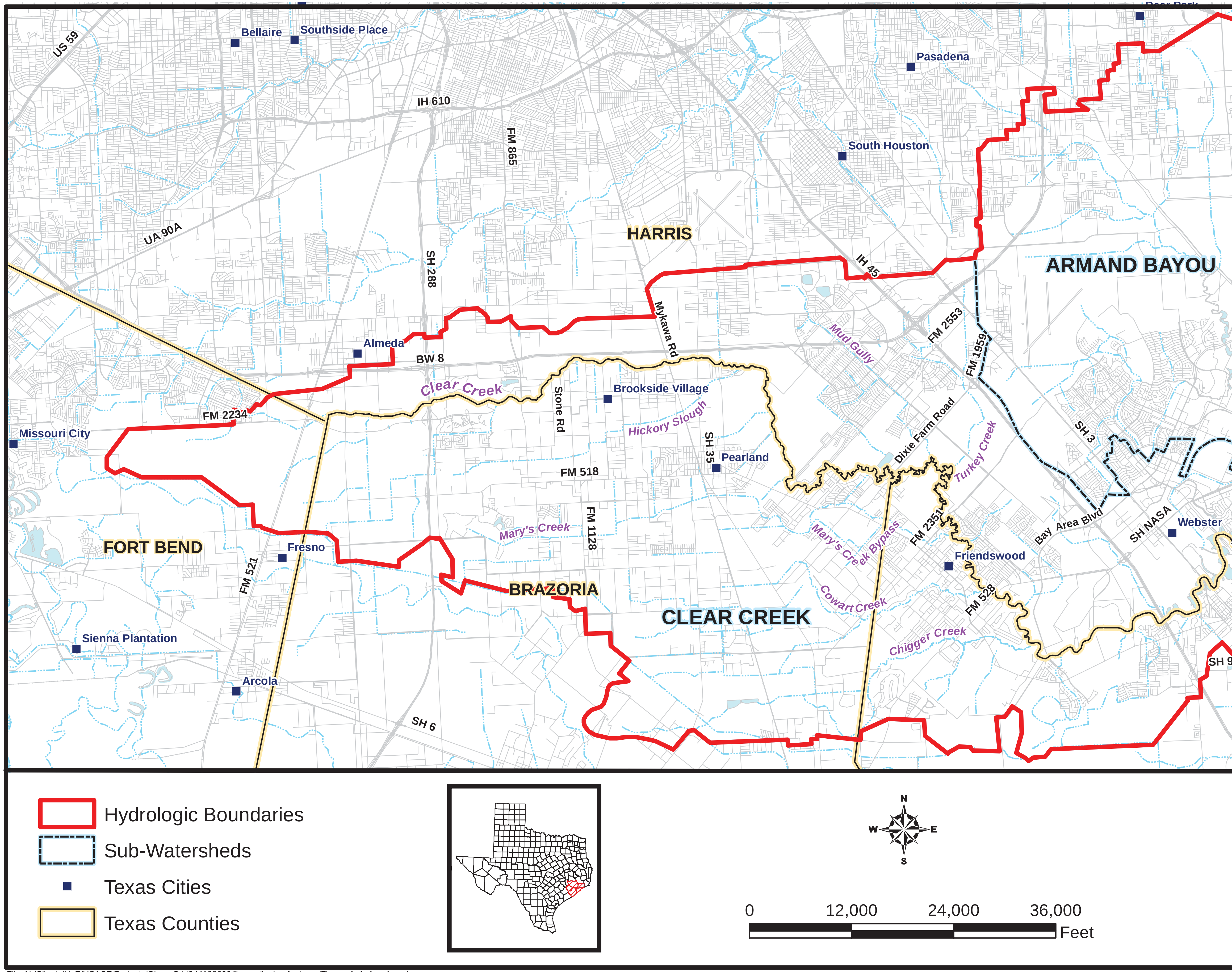

Figure 1.1 - 1

Hydrologic Boundaries

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/10/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/044188600/figures/hydro_features/Figure_1_1_1_vr4.mxd

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FEIS and the initiation of the GRR and SEIS. New baseline resource information was gathered to evaluate the effects associated with the currently proposed action on the current conditions of a more-developed, urbanized stream system, rather than the outdated environmental setting described in the original 1982 FEIS.

1.2 PROJECT HISTORY

In the past, flood risk management planning for the Clear Creek watershed focused primarily on enlargement and rectification of the existing channel. Studies were directed toward developing the most feasible alignment with respect to factors such as hydraulic efficiency, right-of-way (ROW), relocation costs, and other physical factors along and adjacent to Clear Creek.

The initial project, authorized by Congress in 1968, proposed the enlargement of Clear Creek from Clear Lake to just west of the Fort Bend County line, replacing approximately 41 miles of existing winding channel with a 31-mile, grass-lined channel. This congressionally authorized project included directives from the Secretary of the Army that required review of the proposed plan during the preconstruction planning stage to identify modifications that would achieve a reasonable balance among structural modifications of the creek, floodplain regulations, and a broad program of floodplain management. Due to this requirement, subsequent congressional actions, administrative changes, changes within the project area, and changes in the attitude of the public, a restudy was initiated in the early 1970s.

In May 1973, an Environmental Resources Inventory and Evaluation was prepared by Gulf Universities Research Consortium. The purpose of this report was to provide valid data and information for effective and equitable decision-making regarding flooding in the Clear Creek watershed. As a result of that restudy, a Preconstruction Authorization Planning Report was completed in May 1982. The report contains the FEIS, which was noticed in the *Federal Register* in August 1982. The Record of Decision (ROD) for a selected plan was signed by the Southwestern Division Engineer on October 21, 1982 (Appendix M). These documents recommended project modifications from the previous 1 percent annual exceedance probability (AEP) (100-year event) flood event level of protection to a 10 percent AEP flood event level. The plan included 22 miles of Clear Creek channel improvements consisting of channel enlargement and easing of bends within the existing stream to contain floodwater. The project was expected to significantly reduce the 100-year floodplain, leaving only about 50 existing structures unprotected (out of a total of about 2,000 structures in the 100-year floodplain). To ensure upstream channel improvements would not aggravate flooding problems around Clear Lake, an additional channel outlet (Second Outlet Channel and Gate Structure), consisting of a six-gated control structure with associated excavation and dredging, between Clear Lake and Galveston Bay was incorporated into the selected plan. It included conveyance improvement from Mykawa Road to Clear Lake plus the Second Outlet Channel and Gate Structure. In addition, a formal agreement signed in 1986 by the non-Federal sponsors (HCFCD and

Galveston County) and the USACE called for the construction of a 14-mile reach of the project downstream of Dixie Farm Road. This modified authorized plan is referred to as the Authorized Federal Project (AFP). Construction of the AFP was initiated in the mid-1990s with modification to two railroad bridges and construction of the Second Outlet Channel and Gate Structure between Clear Lake and Galveston Bay. Upon completion of the Second Outlet, but before the initiation of construction on the channelized portion of the creek, interested groups and concerned citizens presented credible and qualified objections regarding the project to the non-Federal sponsors. The non-Federal sponsors expressed concerns about the project that included:

- Use of outdated flood control technology
- Function of the Second Outlet
- Effects to recreational uses within the project area from placement of construction material
- Excessive environmental impacts
- Consideration of less-intrusive nonstructural measures

In 1997, the non-Federal sponsors developed an alternative plan to the AFP titled the SPA. A detailed description of this plan is provided in the December 1997 report titled “Clear Creek, Federal Flood Control Project Review” (USACE, 1997a). The main features of the SPA were reduced bottom widths of the channel and a bypass channel that would allow capacity and avoidance of the Friendswood area channel. However, this plan differed too much from the AFP to be considered under the existing authorization. As a result, HCFCD asked that a reevaluation of the project be initiated.

The USACE, supported by the non-Federal sponsors (HCFCD and Galveston County) and joined by BCDD4, initiated a second reevaluation in 1999. To facilitate this process, a project team (Clear Creek project team) led by USACE and composed of staff from Galveston County, HCFCD, BCDD4, and an engineering consultant was created to reevaluate the current Federal project and investigate ways to improve it. A Clear Creek Citizens Advisory Committee (CAC), composed of a group of interested citizens and stakeholders, was also established to provide feedback on flood risk management options to the project team. The resulting alternative is referred to as the General Reevaluation Plan (GRP) Alternative.

This supplemental EIS (SEIS) is essentially equivalent to a new EIS, but is referred to as a supplement for consistency and continuity in the process.

1.3 STUDY AUTHORITY AND LOCATION

The Clear Creek Flood Control Project was authorized by Congress in the Flood Control Act of 1968 (Public Law 90-483, Section 203). The authorized project extended 31 miles from Clear Lake to the Fort Bend County line. In 1982 the Phase I General Design Memorandum, including the FEIS, was signed by the Southwest Division Engineer, thus authorizing the detailed design (USACE, 1982). A formal agreement was signed in 1986 by the non-Federal sponsors (HCFCD and Galveston County) and the USACE to construct the 14-mile reach of the project downstream of Dixie Farm Road. Only the Second Outlet Channel and Gate Structure were ever constructed. In 1997, the non-Federal sponsors requested that the USACE adopt changes to the plans based on concerns regarding the project design and environmental impacts. The changes requested by the non-Federal sponsors were beyond the discretionary authority of the USACE Division Commander to approve. As a result, in February 1999 the USACE decided that a general reevaluation study would be needed. In April 1999, the non-Federal sponsors agreed to accept the USACE recommendation to conduct the general reevaluation study. The general reevaluation study reconsiders the previously authorized project as well as non-Federal sponsor-proposed alternatives and other alternatives that are deemed reasonable. As of June 1999, BCDD4 joined the non-Federal sponsors in this effort. The congressional authorization for this project only allows the consideration of reducing flood damage caused by rainfall runoff along the main channel of Clear Creek and not coastal flooding caused by tropical storm systems (USACE, 1982).

1.4 PROBLEMS, NEEDS, AND PUBLIC CONCERNS

Flooding along Clear Creek has historically been and currently remains a problem associated with severe rainfall events. Table 1.4-1 describes historical flooding events in the watershed associated with some of the storms, named and unnamed, that have had an impact.

Table 1.4-1
Historical Flooding Events in the Project Area

Event/Date	Rainfall Amounts	Damages
Tropical Storm Claudette, July 1979	45 inches	One death from drowning and many residents rescued from flooded low-lying areas
October 1994	15 to 25 inches	3,400 houses and businesses in 90 subdivisions flooded in Harris County
Tropical Storm Allison, June 2001	As much as 25 inches of rain in 10 hours	Severe and record-breaking flooding over 15 major bayous in Harris County; flooding of roads, freeways, basements in downtown Houston; and power outages
October 2006	3 to 10 inches	Flooding of 115 to 125 homes in Harris County and 110 to 120 homes in Brazoria County
April 2009	2 to 12 inches	Flooding of 54 homes along the Clear Creek watershed

As described in the Clear Creek General Reevaluation Report [GRR], flood damages to residential, commercial, and public investment along Clear Creek are caused by frequent low level flood events associated with localized rainfall events and larger less frequent events with significant levels of flooding usually associated with tropical events (see Table 1.4-1). These frequent events up to a 4 percent probability of occurrence impact about 850 structures. Of the frequently flooded structures, the majority are located on Clear Creek, particularly in the upper and middle reaches in the cities of Brookside, Pearland, Friendswood, and Houston. The frequently flooded structures on the main stem of Clear Creek (representing almost 55 percent of the total frequently flooded structures in the study area) consist primarily of slab-on-grade, single-family residential homes. In addition, frequent events also impact structures along Mary's Creek, primarily in the city of Pearland; however, they represent only 35 percent of the most frequently flooded structures. The frequently impacted structures on Mary's Creek are similar in character to those on the main stem, and consist primarily of single-family residential, slab-on-grade construction. Mud Gully and Turkey Creek also experience frequent flooding to structures, but with fewer structures being impacted. Mud Gully's frequently impacted structures represent approximately 6 percent and Turkey Creek represents less than 1 percent of the most frequently impacted structures. Both Chigger Creek and Cowart Creek experience a relatively insignificant number (less than 2 percent combined) of frequently flooded structures when compared with the entire study area. Within the study area, the frequently flooded structures typically would have less than 1 foot of flooding on their first floors. The larger events, represented by events with a 2 percent or greater probability of occurrence, impact upwards of 7,200 structures across a wide area of the basin with slightly more significant flood levels. On average, homes will experience water levels on their first floors of over 1 foot to several feet with the more infrequent events.

The 1982 FEIS identified flooding as a principal problem in the Clear Creek watershed, noting that floodwaters blocked roadways and other transportation corridors, thus disrupting economic and social activities. Structural damages have been typically incurred by a relatively small number of businesses and residences that were established in the existing floodplain. In 1992, all entities in the watershed adopted the regional plan with detention policies in place and a commitment to work together. However, continuing commercial and residential growth within the watershed has severely aggravated flooding problems. Because of the flat topography, rampant growth, and development through the years, the area is prone to flooding, particularly around Friendswood, where the HCFCD estimates there are about 500 houses in the 100-year floodplain along Clear Creek. Although the county has detention policies in place, rapid urban growth in this region has substantially increased the extent of impervious cover and reduced the watershed's natural detention capacity, resulting in higher and more frequent stormwater flows. As a consequence, overbank flows have become more common, even with moderate rainfall events. In addition, continued development within the floodplain has compounded the problem of addressing flood risk management not only by introducing additional flood-prone structures, but also by narrowing flood risk management options.

The expected annual damages (October 2011 price levels) (without-project conditions) for the main stem of Clear Creek and its tributaries as a result of flooding are calculated to be $20,379,000 for 2020 and $32,124,000 for 2070 with the equivalent annual damages (at 4.0% discount rate) calculated to be $24,195,000. These reflect damages accruing to structures and their contents, utilities, vehicles, roads, and costs associated with postdisaster recovery (see the GRR for a detailed description of this analysis).

The proposed project is needed to reduce flood damages within the Clear Creek watershed while preserving natural features for aesthetics, recreation, and rehabilitation of fish and wildlife resources. This will allow a balance between structural modification of the creek, floodplain regulations, and a broad program of floodplain management.

The previously authorized Clear Creek Federal Flood Control Project (presented in the 1982 FEIS) consisted of an earthen channel that would widen and straighten Clear Creek. Also included in the project (and completed) was the construction of a second outlet from Clear Lake to Galveston Bay that would allow for the additional flows from Clear Creek once the channel modifications were made. Interest groups and concerned citizens expressed concerns regarding the project to the non-Federal sponsors. In 1997, a review of the project by the sponsors was submitted to the USACE (Dannenbaum Engineering Corporation, 1997). The concerns from citizens, organizations, and sponsors about the project were:

- Use of outdated flood control technology. Specifically, there were concerns that the design relied only on conveyance measures such as trapezoidal channels without looking for other answers to the problem (i.e., less-intrusive measures such as regional detention ponds, bypass channels, restrictions on development in the floodplain, and buyouts).
- Enlargement of Clear Creek would overpower the second outlet at Clear Lake, especially during episodes of flooding combined with high tides.
- Concerns were raised about converting the last remaining natural area of the creek that supports recreational boating, birding, and eco-tourism into a grass-lined channel as well as the use of environmentally sensitive areas (e.g., riparian forest and wetlands) as placement sites for excavated materials.
- Excessive environmental impacts. The Clear Creek watershed contains some of the last remaining, natural, unchannelized stream beds in the area. The area also contains some high quality riparian habitat that would have been impacted.

Three meetings were held in July, September, and November 1997 by the HCFCD to provide an open forum for public involvement. The first meeting gave interested parties an opportunity to express their concerns, in the second meeting two alternatives were presented and more public input was sought, and in the third meeting recommendations were presented and questions answered from the public. Based on information collected at these meetings, the non-Federal sponsors identified proposed rehabilitations and updates to address some of these concerns. In February 1999 the USACE decided that a general reevaluation study would be needed, and in

April 1999 the non-Federal sponsors agreed to accept the USACE recommendation to conduct the general reevaluation study. To facilitate this process, the non-Federal sponsors brought together a group of interested citizens and stakeholders, the CAC, to provide feedback on flood risk management options.

The Clear Creek watershed supports a wide variety of habitats including areas of coastal prairie, estuarine marsh, and floodplain forest, which include the riparian corridor, bottomland, and wetlands. The lower reaches of the watershed support tidal marsh habitat, and Clear Lake is considered one of the most important fish and shellfish nurseries within the Galveston Bay system (Lohse and Tyson, 1973). Although the majority of land within the middle and upper watershed has been developed, the area still contains some undeveloped coastal prairie. Archeological investigations have revealed numerous prehistoric sites within the watershed that reflect prehistoric human use of the area, especially along the banks of Clear Creek and Clear Lake. The vegetation communities and waters of the Clear Creek watershed also support a wide range of recreational activities and provide opportunity to rehabilitate the aesthetic nature of the increasingly urbanized environment. Because of all these factors, opportunities exist to preserve/ rehabilitate remaining habitats and reestablish previously existing habitat including riparian, prairie, salt marsh, and others. It is this diversity and these opportunities that have prompted the public's concern regarding the impact of flood risk management options within the watershed.

1.5 PLANNING 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. Contributing to National Economic Development (NED) is the primary national objective in water resources planning, with emphasis on assuring a systematic, interdisciplinary approach. This objective should ensure that evaluation of plans addresses natural, cultural, social, and environmental concerns and is responsive to applicable Federal laws and regulations.

Planning objectives take requirements of Section 1 of the Flood Control Act of 1936, the newest guidance, and the public into consideration. A comprehensive set of objectives was developed for the 2020 to 2070 period of economic analysis for the Clear Creek Project that includes:

1. Reduce flood risk for economic, social, and environmental purposes along Clear Creek and its tributaries;
2. Improve fish and wildlife resources of Clear Creek and its tributaries for the purpose of attracting more and varied species of fish and wildlife;
3. Preserve and protect natural and cultural resources for public education and historical appreciation purposes;
4. Develop opportunities for recreation in Clear Creek and its tributaries;
5. Facilitate stabilization of the stream banks of Clear Creek and its tributaries; and

6. Improve the quantity and quality of habitat on Clear Creek and its tributaries.

Four general criteria (technical, economic, environmental, and social) were established and guided the formulation of the Clear Creek General Reevaluation Study. Formulation of plans addressed the problems and needs of the area, taking into consideration how plans compared to the No Action conditions. Additionally, impacts of the proposed action were measured and results accounted for in terms of contributions to the four general criteria. More-detailed information can be found in the GRR, which this Final SEIS (FSEIS) accompanies.

1.6 OTHER PLANNING CONSIDERATIONS

1.6.1 Environmental Operating Principles

As a reemphasis of the USACE's commitment to the environment and to ensure effective participation in sound environmental stewardship, a formalized set of "Environmental Operating Principles (EOP)," containing seven principles, was promulgated and promoted throughout USACE to inform and guide its corporate program execution and project development decision-making process. The purpose of the USACE EOP is to illuminate the ways in which the USACE's missions are to be integrated with natural resources laws, values, and sound environmental practices, in order to focus on achieving greater synergy between environmental sustainability and implementation of the full spectrum of USACE activities, including planning, design and construction, operations and maintenance (O&M), regulatory, research and development, acquisition, real estate, and support for others (USACE, 2003). The seven EOP are summarized as follows:

1. Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse, and sustainable condition is necessary to support life.
2. Recognize the interdependence of life and the physical environment. Proactively consider environmental consequences of USACE programs and act accordingly in all appropriate circumstances.
3. Seek balance and synergy among human development activities and natural systems by designing economic and environmental solutions that support and reinforce one another.
4. Continue to accept corporate responsibility and accountability under the law for activities and decisions under our control that impact human health and welfare and the continued viability of natural systems.
5. Seek ways and means to assess and mitigate cumulative impacts to the environment; bring systems approaches to the full life cycle of our processes and work.
6. Build and share an integrated scientific, economic, and social knowledge base that supports a greater understanding of the environment and impacts of our work.
7. Respect the views of individuals and groups interested in USACE activities, listen to them actively, and learn from their perspective in the search to find innovative win-win solutions to the Nation's problems that also protect and rehabilitate the environment.

These principles have been integrated into the stages of the Clear Creek Project plan formulation and study development process.

1.6.2 USACE Campaign Plan

In August 2006, as a result of lessons learned from hurricanes Katrina and Rita, the USACE Chief of Engineers initiated the "Actions for Change" in an effort to transform USACE planning, design, construction, and operation and maintenance principles and decision-making processes. This program has been further developed into a Campaign Plan. USACE is moving forward with this Campaign Plan to transform the way business is done. The USACE Campaign Plan is available on the internet at http://www.usace.army.mil/about/campaignplan/Pages/Home.aspx.

The successful achievement of the goals and objectives contained in this Campaign Plan are dependent on actions implemented by the entire USACE team. The Campaign Plan includes four goals for USACE. These goals are:

Goal 1: Ready for all Contingencies – Deliver USACE support to combat, stability, and disaster operations through forward-deployed and reachback capabilities.

Goal 2: Engineering Sustainable Water Resources – Deliver enduring and essential water resource solutions through collaboration with partners and stakeholders.

Goal 3: Delivering Effective, Resilient, Sustainable Solutions – Deliver innovative, resilient, sustainable solutions to the Armed Forces and the Nation.

Goal 4: Recruit and Retain Strong Teams – Build and cultivate a competent, disciplined, and resilient team equipped to deliver high-quality solutions.

Goals 1 and 4 do not apply directly to the USACE planning process and are not discussed in detail. Goals 2 and 3 pertain to water resources planning and directly to the Clear Creek General Reevaluation Study. These goals are described in more detail below.

1.6.2.1 Goal 2: Engineering Sustainable Water Resources

With Goal 2, USACE focuses on comprehensive, sustainable, and integrated solutions to the Nation's water resources challenges through collaboration with stakeholders. This goal refers to not only developing and delivering comprehensive and lasting solutions but also ensuring that these solutions are long lasting, integrated, and holistic to respond to today's and future challenges.

The proposed effort has assisted in achieving this goal through coordination with stakeholders, a multifaceted public outreach program, and incorporation of features to address relevant issues.

As a result, the proposed plan effectively addressed the flooding issue, while preserving natural resources, providing recreational areas, and rehabilitating diminishing floodplain forest.

1.6.2.2 Goal 3: Delivering Effective, Resilient, Sustainable Solutions

Goal 3 emphasizes that USACE will provide innovative, resilient, and sustainable infrastructure solutions for the Nation today and in the future. USACE is the Nation's premier public service engineering and construction organization and can provide infrastructure support to serve both the military and national civilian arenas. This effort will improve resilience and life cycle investment in critical infrastructure, deliver reliable infrastructure using a risk-informed asset management strategy, and develop and apply innovative approaches to delivering quality infrastructure.

1.7 INTERAGENCY COORDINATION TEAMS

To provide guidance on matters relating to the evaluation of potential environmental impacts associated with the proposed project, an Interagency Coordination Team (ICT) was established. The ICT is made up of representatives from the non-Federal sponsors, resource agencies, and the USACE. Members include representatives from U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Natural Resources Conservation Service (NRCS), U.S. Environmental Protection Agency (EPA), Texas Parks and Wildlife Department (TPWD), Texas General Land Office (GLO), Texas Commission on Environmental Quality (TCEQ), and the non-Federal sponsors. The objectives of the ICT were to (1) identify environmental issues and concerns; (2) evaluate the significance of fish and wildlife resources and select resources; (3) recommend and review environmental studies; (4) evaluate potential impacts; and (5) recommend and evaluate potential mitigation measures.

One technical workgroup composed of members of the ICT was formed to focus on development of a community-specific model to characterize baseline conditions of the floodplain forest and coastal prairie ecosystems within the study area and to oversee the development and application of a Habitat Evaluation Procedure (HEP) model to evaluate ecological effects of the Clear Creek alternatives. This workgroup is referred to as the Ecosystem Assessment Team (E-Team). Participants included representatives from the USACE, TCEQ, USFWS, NRCS, TPWD, EPA, GLO, Galveston Bay Estuary Program, BCDD4, Galveston County, and the HCFCD. Individuals responsible for project design and management, such as engineers, project managers, NEPA consultants, and cost-share sponsors, were also included in the process.

With assistance and guidance from the U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory, the E-Team conducted a series of workshops over the course of 5 years to complete modeling efforts, which played an integral role in the development of future conditions with and without the proposed project. Comparison of future condition scenarios was used to identify the most effective rehabilitation and mitigation measures.

1.8 PUBLIC SCOPING SUMMARY

The public was actively involved during the preauthorization planning process for the Clear Creek Flood Control Project. This involvement began with a public meeting in Friendswood, Texas, in March 1964. In addition, numerous workshop meetings and other informal meetings were held from September through December 1976 with affected groups in the area. Since initiation of postauthorization studies in early 1972, public meetings and numerous workshop meetings were held on the project. Local engineers, civic groups, local governmental bodies, and individuals provided input to the study. Strong support for resolving the Clear Creek flooding problems was shown at each of the public meetings; however, a divergence of opinion existed on the flood control method to be used. An NOI to prepare a DEIS was published in the *Federal Register* on July 24, 1980.

Public meetings for the Clear Creek Federal Flood Control Project were hosted by HCFCD in July 1997, September 1997, and November 1997. Over 1,600 people attended the three meetings. In addition to the public meetings hosted by HCFCD, various types of communication were used to keep the public informed of the progress of the project. These included written material that provided a history of the Clear Creek watershed, a description of components of the Federal project that had been implemented, a description of other components of the Federal project, a discussion of the reevaluation process, and recaps of the public meetings. Additional information is presented in Section 12 of this document.

Three public scoping meetings were held for the Clear Creek General Reevaluation Study: March 15, 2001, in Friendswood, Texas; May 3, 2001, in League City, Texas; and May 9, 2001, in Pearland, Texas. The three public scoping meetings were advertised in local papers and notices were sent to interested parties (Appendix A). In accordance with Council on Environmental Quality (CEQ) Regulations for Implementing NEPA (1507.3(e)) and USACE NEPA Implementing Regulations (33 *Code of Federal Regulations* [CFR] 230, Appendix C(2)), an NOI to prepare an Environmental Impact Statement (EIS) for this effort was published June 24, 2008 (see Appendix A). Following the decision that the NEPA documentation associated with the Clear Creek General Reevaluation Study should be a supplement to the 1982 FEIS, the decision was made not to publish another NOI in the *Federal Register* announcing the SEIS and not to open a new scoping period for the effort. This decision was made because changing the document to an SEIS does not result in changes to the proposed project and because the information previously provided by the public is still relevant and applicable to the proposed project presented in this SEIS.

Over 250 individuals attended the scoping meetings held in 2001, and more than 100 comments, petitions, and letters were received during the scoping period. Issues raised during the scoping process include the following:

- Request to clear and snag Clear Creek;
- Request to use nonstructural alternatives;
- Support for Challenge 21 (also known as the Flood Mitigation and Riverine Restoration Initiative from Section 212 of the Water Resources Development Act of 1999);
- Opposition to future development in the area;
- Concern with slow action to address the problem; and
- Support for moving forward with the project.

In addition to the three NEPA-related scoping meetings, two open-house workshops were hosted by USACE in February 2004. The purpose of these workshops was to update the public on the progress of the project and present alternatives for flood risk management and ecosystem restoration being considered.

Notices, transcripts, and comments received from the 2001 scoping meetings and the 2004 open houses are presented in Appendix A. Additional information is also presented in subsection 12.1.1 of this FSEIS.

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2.0 ALTERNATIVES

2.1 ALTERNATIVE DEVELOPMENT APPROACH

As previously described, a plan to address flooding within the Clear Creek watershed was authorized in the early 1980s (the AFP), but before the plan could be entirely implemented, concern raised by the public and the non-Federal sponsors resulted in the reevaluation of the plan. The AFP provided a starting point, from which the SPA was derived. Using features of the SPA and other flood risk management features, an alternative was developed for the current study.

Development of an alternative for the Clear Creek General Reevaluation Study (Clear Creek Project) was completed utilizing a three-phased approach. Phase I was preliminary evaluation and screening of numerous structural and nonstructural components to reduce flood damages. Phase II was a refinement, hydraulic and economic evaluation and screening of stand-alone alternatives (i.e., first-added measures) to reduce flood damages. Phase III involved further refinement and detailed evaluation and screening of alternatives using high-performing, previously screened first-added measures in combination with additional measures (i.e., second-added measures). The Clear Creek GRR and its appendices provide a detailed description of these analyses; however, a summary is provided below.

For the purposes of this evaluation, the following definitions are provided. These definitions are consistent with 33 CFR 332.2 (Compensatory Mitigation for Losses of Aquatic Resources: Definitions).

Preservation means the removal of a threat to, preventing the decline of, aquatic resources by an action in or near those aquatic resources. This term includes activities commonly associated with the protection and maintenance of aquatic resources through the implementation of appropriate legal and physical mechanisms. Preservation does not result in a gain of aquatic resource area or functions.

Reestablishment means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former aquatic resource. Reestablishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions.

Rehabilitation means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area.

As described in the following project descriptions and in Section 5.0 (Mitigation), protection and reestablishment/rehabilitation features are incorporated into the GRP Alternative, while the proposed compensatory mitigation for unavoidable impacts includes only reestablishment/ rehabilitation of habitat. General actions that constitute reestablishment/ rehabilitation include removal of development pressure, controlling invasive/exotic vegetation species, and planting of native vegetation.

2.2 PLANNING FRAMEWORK

The USACE planning framework requires the systematic evaluation of economic and environmental impacts of alternatives that address the problems, needs, and opportunities that have been identified for the project. The planning of this project has been driven by the overall objective of developing flood risk management solutions that would meet existing and future needs of the Clear Creek area through both structural and nonstructural measures. USACE planning guidance and NEPA guidance requires evaluation of a Future Without Project Condition (FWOP). The FWOP condition is referred to as the "No Action Alternative" in this FSEIS. The No Action Alternative forms the basis against which all other alternative plans are measured.

Additionally, the planning framework involves coordination through meetings with Federal, State, and local agencies, private groups, stakeholders, environmental organizations, and the affected public to identify alternatives and evaluate them on economic and environmental impacts.

2.3 ALTERNATIVE PLANS CONSIDERED

The following describes the alternative plans that were considered for the Clear Creek Project. This includes the AFP and the SPA, which were considered in the 1980s and 1990s, and which led to the decision to implement the General Reevaluation Study. Additionally, nonstructural alternatives were considered both alone and in combination with a new structural alternative, the GRP. As a result, nine alternatives were considered and are discussed below:

- No Action Alternative
- AFP Alternative
- SPA
- three nonstructural buyout options
- a structural alternative (the GRP)
- the GRP combined with two nonstructural buyout options

The nine alternatives are described in the following subsections. The screening process used to identify the flood risk control measures that have been combined to form the GRP is also described.

It should be noted that the design of the proposed alternatives (including any necessary mitigation) is not final but, rather, is in early stages with detail appropriate for evaluation of potential effects necessary for review and approval processes. Implementation or construction of any of the proposed alternatives is contingent upon approval of the proposed plan by the USACE Southwestern Division and subsequent appropriation of construction funds by Congress. Following approval and appropriation of funds, the project would enter a preconstruction engineering and design phase to develop detailed construction plans for the project, including mitigation.

2.3.1 No Action Alternative

The No Action Alternative would allow Clear Creek and its tributaries to remain in their current configuration. Development upstream of Clear Lake will continue to increase the amount of impervious cover in the study area, increasing flows into Clear Creek. These increased flows will continue to cause increases in water elevation sufficient to cause flooding in many areas.

Many of the upstream municipalities in the watershed have incorporated policies to ensure no future impacts due to development at certain flood levels. These policies require certain levels of detention that prevent flow from newly created impervious areas entering Clear Creek or its tributaries quickly. Some of the downstream communities have not incorporated these policies. These policies will likely ensure that there are no significant increases at certain levels. However, the capacity of the detention areas can be exceeded by certain flood events causing eventual increases in future damages.

Under the No Action Alternative, reduced water quality, habitat loss, and flooding would continue to worsen. There would be no opportunity for flood risk management measures to help reduce turbidity by decreasing erosion during flood events. Future flood damages would not be reduced in the area, and flooding may continue to increase due to continued urban development (despite local regulations on new developments in some areas), and increased impervious cover, which would reduce the watershed’s natural detention capacity. As a result, frequency and velocities of episodic flooding in the area would increase. Flood flows may peak at higher velocities, which would increase erosive forces on stream banks and bottoms, and significant bank erosion may occur, resulting in additional sedimentation. Refer to Table 1.4-1 of this FSEIS and the GRR for a more-detailed description of flood events.

One important aspect of the No Action Alternative is the existence of the Second Outlet Channel and Gate Structure between Clear Lake and Galveston Bay. The Second Outlet Channel and Gate Structure is located on the bayward side of State Highway (SH) 146 and provides additional drainage capacity so the upstream improvements on Clear Creek do not increase flooding in the Clear Lake area. This channel and gate structure is 6,000 feet long, 70 feet wide, and 16 feet deep.

The Second Outlet Channel and Gate Structure are components of the AFP that were actually constructed and became operational prior to the initiation of this reevaluation study. The gates are kept closed under "normal" conditions (i.e., no significant rainfall) to prevent environmental impacts from a second tidal outlet to Galveston Bay. A 3-inch rainfall averaged over the watershed is considered significant, at which time the gates would be opened. Gates open when:

1. Clear Lake's elevation is above +3.0 feet North American Geodetic Vertical Datum (NGVD) and exceeds Galveston Bay's elevation by 0.5 foot or more.
2. The Clear Lake elevation is higher than the Galveston Bay elevation by any amount, and a rise in the Clear Lake elevation is anticipated above +3.0 feet NGVD from rainfall exceeding 3 inches. See attached Operations Worksheets 1 and 2 used by the Flood Watch Leader and Watch Engineer to help determine the bay and lake levels and anticipated lake level.
3. At least twice a year, during a storm ebb tide associated with passage of either a cold front or "norther," spring tide recession, or flood relief and to be used as an aid for flushing deposited sediment from the second outlet channel.
4. Once per month to exercise gates, actuators, and generator. This activity may be cancelled if gates have been operated within the month for reasons listed above.

Gates are closed when:

1. The Clear Lake elevation is equal to or lower than the Galveston Bay elevation.
2. The Clear Lake elevation is below +3.0 feet NGVD.
3. Sustained winds exceed, or are forecasted by the National Weather Service (NWS) to exceed, 55 miles per hour (mph).
4. Clear Lake's elevation is rising and is anticipated to exceed +8.3 feet NGVD.
5. The Galveston Bay elevation is forecasted by the NWS to exceed +6.0 feet NGVD.

Modifications to the gated structure were evaluated as alternatives to further reduce flood risk. As this is an existing structure, the gate in its current configuration was incorporated into the No Action Alternative. Performing the analysis in this manner allows the analysis to document what impacts modifications to the previously constructed feature would have on any additional, recommended flood risk management features while taking into account benefits already generated by the second outlet.

The hydrologic effect of the Second Outlet Channel and Gate Structure is presented in Section 4.4 and in the Hydrology and Hydraulics Appendix to the GRR. Discussion of flood risk management and subsequent economic benefits associated with the Second Outlet Channel and Gate Structure is available in the Economic Appendix to the GRR. It should be noted that the Second Outlet Structure was repaired in 2010 to address storm damage caused by Hurricane Ike (USACE, 2009).

2.3.2 Authorized Federal Project (AFP) Alternative

The AFP Alternative is described in detail in the Preconstruction Authorization Planning Report dated May 1982. The AFP includes 22 miles of modifications to the Clear Creek channel to improve conveyance and includes nonstructural measures and a requirement for the non-Federal sponsors to manage the residual 100-year floodplain. An additional channel opening between Clear Lake and Galveston Bay was incorporated into the AFP to ensure that upstream channel improvements did not contribute to flooding around Clear Lake. This channel opening is referred to as the Second Outlet Channel and Gate Structure (sometimes referred to as the Second Outlet). The proposed AFP alignment can be seen on Figure 2.3-1. The project was designed to contain a 10 percent annual exceedance flood for future watershed development conditions. Conveyance from Mykawa Road to Clear Lake consisted of a trapezoidal earth channel (1v:3h side slopes) with bottom widths ranging from 70 to 130 feet. The Second Outlet was designed to ensure that flows would continue into Galveston Bay without impacting houses around Clear Lake. The channel was gated to ensure that Clear Lake did not experience an increase in salinity due to water flowing in from the bay during high tide circumstances. In 1986 a formal agreement was signed by the non-Federal sponsors (HCFCD and Galveston County) and the USACE to construct the 14-mile reach of the project downstream of Dixie Farm Road. Because of concerns raised by the public, non-Federal sponsors, and agencies regarding potential environmental effects of the AFP, construction of the AFP was halted; the Second Outlet Channel and Gate Structure were the only features constructed.

2.3.3 Sponsor-proposed Alternative

In response to concerns raised about impacts associated with the AFP, the non-Federal sponsors requested that construction of the AFP halt so a revised plan, with reduced environmental impacts, could be developed. Thus, the SPA was developed and introduced in 1997 as an alternative to the AFP. The SPA proposed a trapezoidal channel that generally followed the same alignment as the AFP with reduced bottom widths (30 to 80 feet), and an added bypass channel to avoid impacts to a natural reach of Clear Creek near the Friendswood area (Figure 2.3-2). The bypass channel provided the additional flood capacity without channelizing this portion of the creek.

2.3.4 Nonstructural Alternatives

Nonstructural measures were investigated throughout the plan formulation process. Considering the age of the structures inventoried within the study area and the number of commercial structures involved, raising-in-place and relocation were not considered viable options. Thus, structure removal from floodplain areas was further evaluated.

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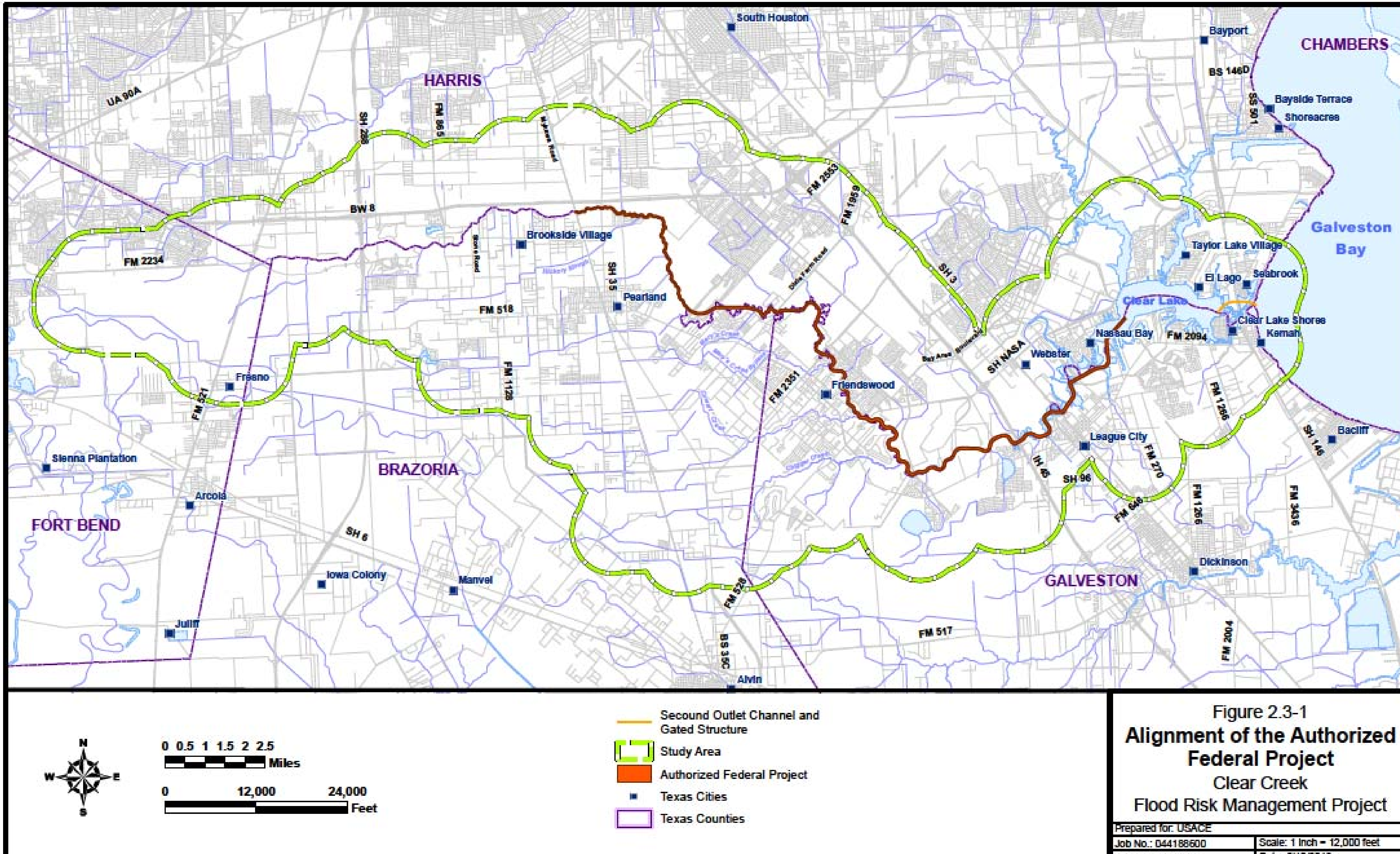

Figure 2.3-1
Alignment of the Authorized Federal Project
Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/10/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/Prev_Auth_Fed_Channels_v3.mxd

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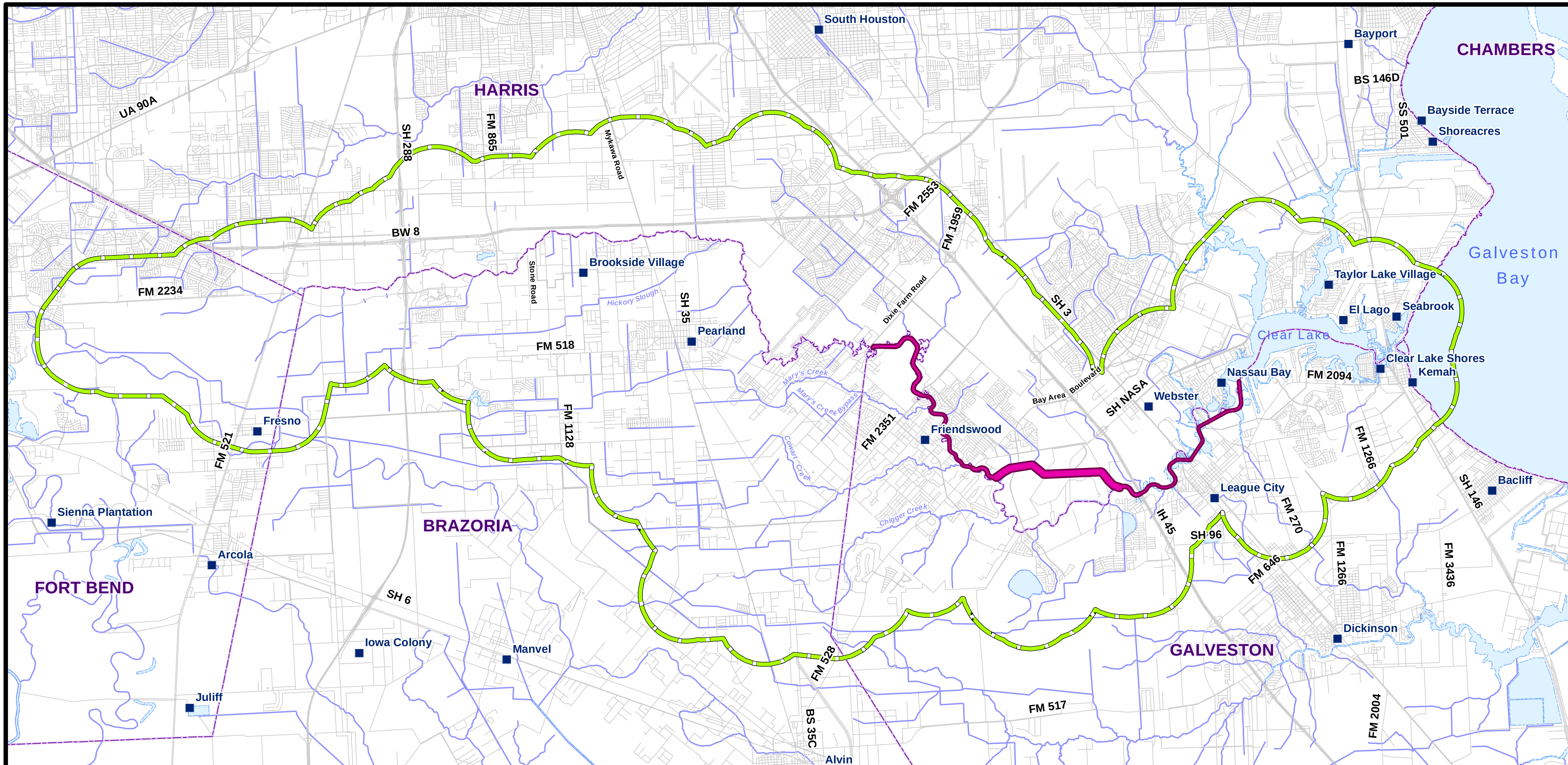

Figure 2.3-2

Alignment of Sponsor Proposed Alternative

Clear Creek

Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/10/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/Buff_Sponsored_Proposed_vr2.mxd

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Structures prone to flooding from the 50 percent, 20 percent, and 10 percent (2-, 5-, and 10-year, respectively) AEP floodplains would be removed. Removal of these structures would include buy-outs at fair market value.

Based on the experience of the Galveston District with structure removal or buyouts, the analysis of this alternative assumed various levels of participation. With several factors taken into consideration, such as time elapsed since the last flood event and level of previous damages, a level of participation was assigned to help determine the number of structures required for the economic analysis. For the nonstructural alternatives described in the following subsections, the levels of participation were assumed to be 75 percent (low), 85 percent (most likely), and 95 percent (high). Ancillary structures, such as barns and sheds, were removed from consideration. Thus, economic analysis was conducted for each buyout scenario described below.

2.3.4.1 Fifty Percent AEP Nonstructural Alternative

Under this alternative, structures prone to flooding from the 50 percent (2-year) AEP would be removed. Per the analysis, as described above, the most likely (assumes 85 percent participation) number of structures to be removed under this alternative is five.

2.3.4.2 Twenty Percent AEP Nonstructural Alternative

Under this alternative, structures prone to flooding from the 20 percent (5-year) AEP would be removed. Per the analysis, as described above, the most likely (assumes 85 percent participation) number of structures to be removed under this alternative is 150.

2.3.4.3 Ten Percent AEP Nonstructural Alternative

Under this alternative, structures prone to flooding from the 10 percent (10-year) AEP would be removed. Per the analysis, as described above, the most likely (assumes 85 percent participation) number of structures to be removed under this alternative is 467.

2.3.5 General Reevaluation Plan (GRP) Alternative

Political and environmental concerns identified for past alternatives that had been considered for the Clear Creek Project led to development of a new structural alternative, referred to as the GRP. The GRP Alternative includes a series of flood risk management measures and mitigation areas, which are referred to in this FSEIS as project features (Figure 2.3-3). Flood risk management measures include conveyance measures and detention on or adjacent to Clear Creek from SH 288 to Dixie Farm Road and on three tributaries: Mud Gully, Turkey Creek, and Mary's Creek. These measures are described in detail in section 2.3.5.2. Mitigation for the GRP Alternative includes the rehabilitation and reestablishment of floodplain forest. Mitigation is discussed in detail in sections 2.5 and 5.0. Placement areas would be required for placement of

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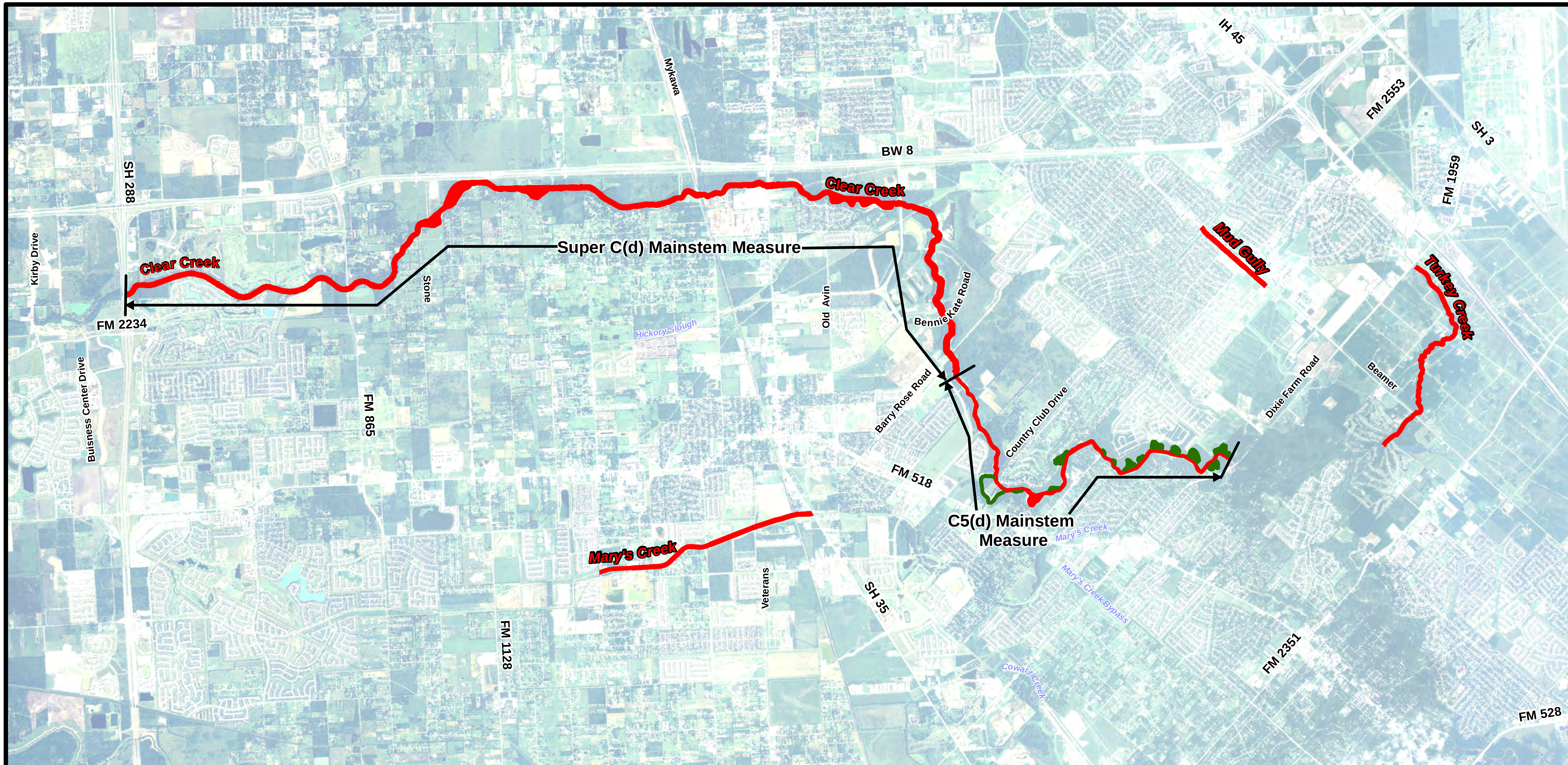

Key

Conveyance and Protected Riparian Habitat Corridor

Mitigation Features:

Floodplain Forest C1

N
W E
S

0 5,000 10,000 Feet

Figure 2.3-3
Project Features of the GRP Alternative
Clear Creek Flood Risk Management Project

Prepared for: USACE	
Job No.: 100002202	Scale: 1 inch = 5,000 feet
Prepared by: 18827	Date: 5/10/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/project_features_vr9.mxd

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excavated material and would occur outside of the 500-year floodplain in areas that are suitable for placement of excavated material associated with the project.

2.3.5.1 Development of the General Reevaluation Plan (GRP) Alternative

A three-phased formulation and screening process was used to identify the GRP Alternative: (1) Phase I: Preliminary Screening – preliminary evaluation and screening of numerous structural and nonstructural components to reduce flood damages, (2) Phase II: First-added Analysis – refinement, hydraulic and economic evaluation and screening of stand-alone alternatives (i.e., first-added measures) to reduce flood damages, and (3) Phase III: Second-added Analysis – further refinement and detailed evaluation and screening of alternatives using high-performing, previously screened first-added measures in combination with additional measures (i.e., second-added measures). A flow chart depicting the process described in the following subsections is presented as Figure 2.3-4. During the preliminary screening, the FWOP (referred to as the No Action Alternative in this FSEIS) was developed for comparison with other alternatives. This alternative was carried through the subsequent planning phase for comparison with other alternatives. A complete description of the No Action Alternative is provided in subsection 2.3.1 and Table 2.4-1.

2.3.5.1.1 Phase I: Preliminary Screening

In 2001, the Clear Creek project team began collecting information on potential measures, structural and nonstructural, that could reduce flood damages on the main stem of Clear Creek. The collection of this information was performed through public scoping meetings and meetings with resource agencies.

Clear Creek was divided into 19 economic reaches (Figure 2.3-5), delineated by easily identifiable landmarks, in an attempt to identify areas most in need of flood risk management. According to the results of the evaluation, the areas with the highest flood damages under the No Action Alternative are reaches 15 through 18 (City of Pearland) and reaches 7 through 10 (City of Friendswood).

Based on information obtained through previous public and agency coordination and scoping, the project team developed a list of structural and nonstructural measures that could potentially reduce flood risk in the Clear Creek watershed and allow for environmentally sensitive construction opportunities. Structural measures considered included:

- Detention
- Levee and floodwall construction
- Conveyance improvements
- Bridge modification
- Removal of sidecast excavated material

Figure 2.3-4
GRP SCREENING PROCESS
FLOW CHART

FS = Formulation Sequence   Yellow text = removed from GRP following further refinement and additional cost/benefit evaluation

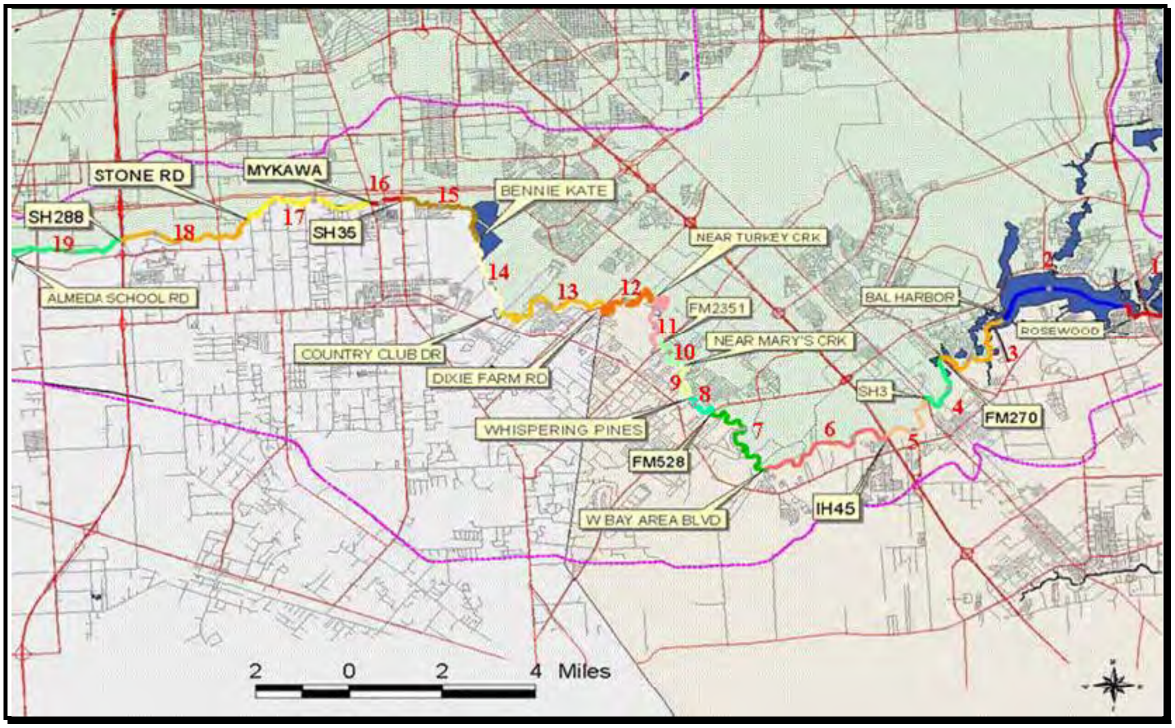

Figure 2.3-5. Nineteen economic reaches identified along Clear Creek

- Reconnecting Clear Creek meanders and low flows into cutoff or isolated oxbows
- Construction of bypasses
- Selective clearing of heavily vegetated reaches
- Use of habitat creation for opportunities to reduce flood risk

Nonstructural measures considered included buyouts, raising of structures, floodplain preservation, and the adoption of new watershed management requirements.

The 72 structural and nonstructural flood risk management measures identified were specific to a single reach or limited number of adjacent reaches. Criteria for screening these initial components were developed to reduce the number of measures for further evaluation and ensure they meet the four USACE planning criteria of completeness, efficiency, effectiveness, and acceptability. These criteria were Flood Risk Management Effect, Environmentally Sensitive, Acceptability/Aesthetics/Recreational Opportunities, Chance of Success/Cost Effectiveness, and Engineering Implementable. Using these criteria, the measures were rated by project team members, with emphasis given to each team member's area of expertise, and then weighted as appropriate. The evaluation resulted in a list of 24 stand-alone flood risk management measures that would encompass all activities ranked as high priority in the initial screening. These measures were carried forward for further evaluation.

2.3.5.1.2 Phase II: First-added Analysis

This analysis evaluated the measures on a "first-added" basis, meaning each measure was tested as a stand-alone element. A detailed description of this analysis can be found in the GRR, which this FSEIS accompanies.

Table 2.3-1 lists the 24 structural and nonstructural measures that met the USACE criteria of completeness, efficiency, effectiveness, and acceptability.

Table 2.3-1
First-added Alternative Measures

	First-added Measures	Abbreviation
1.	Conveyance Improvement from Stone Road to Bennie Kate Road	C1
2.	Offline Detention just West of SH 288	B1
3.	Offline Detention just West of Country Club Drive	B2
4.	Linear Detention from Stone Road to Mykawa Road	LD1
5.	Expand Existing Detention at David L. Smith Site	DLS1
6.	Expand Existing Detention at A521-01	A521
7.	Remove Excavated Material/Deepen for Conveyance	RDM1
8.	Detention on Mud Gully	MG1
9.	Detention on Turkey Creek	TC1
10.	Detention on Mary's Creek	MC1
11.	High-Flow Bypass Downstream of Dixie Farm Road	HFB1
12.	Detention on Chigger Creek	CHG1
13.	Detention on Cowart Creek	CWT1
14.	Enlarge High-Flow Bypasses in Reach 9	EHFB
15.	Interstate Highway 45 (I-45) Bridge Widening	I-45
16.	Buyouts along Clear Creek (Global) (no additional Hydrologic and Hydraulic [H&H] modeling) (Nonstructural)	GBO
17.	Watershed Management Practices (Global) (no additional H&H modeling) (Nonstructural)	GWMP
18.	Conveyance Improvement from SH 288 to Stone Road	C2
19.	Large-scale Linear Detention on Mary's Creek	LD2
20.	Large-scale Linear Detention on Cowart Creek	LD3
21.	Additional Clear Lake Outlet Capacity	ACLO
22.	Selective Clearing and Snag Removal	CS
23.	Conveyance Improvement from Downstream of Country Club to FM 528	C3
24.	Conveyance Improvement from Downstream of FM 2351 to West Bay Area Blvd.	C4
Legacy Plans:		
1.	Authorized Federal Project	AFP
2.	Sponsor-proposed Alternative	SPA

Throughout the process, measures were refined to further identify opportunities to reduce flood risk while preventing environmental damages. Each measure was evaluated on a stand-alone basis for its potential impact to the entire watershed and its capability for reduction of flood damages. The 10 best-ranking first-added measures (i.e., most-cost-effective measures that were most successful in reducing flooding) were identified. Only 5 of the 10 highest-ranking first-added measures had positive net economic benefits:

- Conveyance Improvement from Stone Road to Bennie Kate Road (C1);
- Enlarge High-Flow Bypasses in Reach 9 (EHFB);
- Buyouts along Clear Creek (Global – Nonstructural) (GBO);
- Selective Clearing and Snag Removal (CS); and
- Conveyance Improvement from Downstream of Farm to Market Road (FM) 2351 to West Bay Boulevard (C4)

Detailed descriptions of each measure as well as determination of costs, net excess benefits, and benefit-cost ratios for each of these measures can be found in the First-added Notebook (Appendix to the GRR).

During the analysis of the first-added measures, more-detailed information on environmental impacts was becoming available through the use of the environmental model, and it became clear that the clearing and snagging alternative created greater riparian impacts than previously estimated, significantly increasing the amount of required mitigation. Due to this, costs were modified and clearing and snagging fell out of further consideration.

2.3.5.1.3 Phase III: Second-added Analysis

The project team concentrated on the most successful first-added measures and began a series of modifications and combinations, called second-added measures, to identify the GRP Alternative. The results of the first-added analysis (Phase II) were utilized to identify those measures that were successful on a stand-alone basis and that could then be modified and combined with other measures to reduce flood risk in the high risk reaches of the watershed, while remaining sensitive to environmental impacts. This process identified measures that would come together to work as an overall system. Cost effectiveness was also taken into consideration and identified those measures that increased conveyance in the most cost-effective manner.

During the evaluation of alternatives, additional information was collected in the watershed, including flood damage information on the tributaries, and the potential to reduce these damages became clear. Six tributaries were examined for measures that would generate benefits above those seen in the backwater effects of the Clear Creek modification. The tributaries added to the analysis included Mary’s Creek, Turkey Creek, Mud Gully, Cowart Creek, Chigger Creek, and Hickory Slough. Each tributary was also divided into economic reaches for evaluation. Upon further investigation, it was determined that Hickory Slough did not have sufficient flow to be eligible for consideration and Cowart Creek and Chigger Creek did not have sufficient damages to justify Federal involvement. Therefore, these three tributaries were dropped from further consideration as conveyance features. Mary's Creek, Turkey Creek, and Mud Gully were identified for additional analysis and inclusion in the second-added phase of the study (Phase III). This second evaluation led to the identification of the most efficient alternative for flood risk management. A detailed description of this second analysis can be found in the Second-Added Measures Notebook Appendix to the GRR. Structural alternative measures identified for detailed evaluations are presented in Table 2.3-2.

Table 2.3-2
Second-added Alternative Measures

Measure	Abbreviation	Type
1. Conveyance Improvement on Clear Creek from SH 288 to Bennie Kate Road	Super C	Conveyance
2. Conveyance Improvement on Clear Creek from SH 288 to Atchison, Topeka & Santa Fe Railroad (AT&SF RR)	Super C Short	Conveyance
3. Offline Detention on Clear Creek near Mykawa Road	B3	Detention
4. Offline Detention on Clear Creek at David L. Smith Site	DLS	Detention
5. Linear Detention on Clear Creek from Bennie Kate to Dixie Farm Road	LD4	Detention
6. Conveyance Improvement on Clear Creek from Bennie Kate to Dixie Farm Road	C5	Conveyance
7. Conveyance Improvement on Mary's Creek from AT&SF RR to SH 35	MAC1	Conveyance
8. Conveyance Improvement on Mary's Creek from Harkey Road to SH 35	MAC2	Conveyance
9. Conveyance Improvement of Mary's Creek Bypass Channel	MAC3	Conveyance
10. Detention Basins on Mary's Creek (West Mary's and South West Environment Center Sites)	MAD1	Detention
11. Conveyance Improvement on Mud Gully from Sagedowne to Astoria	MUC1	Conveyance
12. Conveyance Improvement on Turkey Creek from Dixie Farm Road to Mouth	TKC1	Conveyance
13. Conveyance Improvement on Clear Creek from downstream of FM 2351 to West Bay Area Boulevard	C4	Conveyance
14. Clear and Snag	CS	Conveyance
15. Enlarge Existing High-flow Bypasses	EHFB	Conveyance
16. I-45 Bridge Additional Opening	I-45	Conveyance
17. Additional Clear Lake Outlet Capacity	ACLO	Conveyance

The second-added analysis was performed using a series of nine formulation sequences (see Figure 2.3-4). For each sequence, a series or combination of measures was tested for effectiveness, benefits, and costs. Based on the results of each formulation sequence, measures tested were dropped from further consideration or carried forward as part of an overall plan.

The first formulation sequence in the analysis process was the selection and optimization of a Clear Creek upstream anchor component. Based on considerations from the first-added analysis (Phase II), Conveyance Improvement of Main Stem (of Clear Creek) from Stone Road to Bennie Kate Road (Measure C1) was combined with Conveyance Improvement of Main Stem from SH 288 to Stone Road (Measure C2) and identified as an anchor component called Super C. Additional modeling of various sizes of Super C led to the identification of the Super C(d) measure, which generated positive net benefits. Super C(d) is designed to preserve/rehabilitate habitat associated with a low-flow channel.

The second formulation sequence was to test for upper-reach measures to add to Super C(d) for additional flood risk management. This model considered two measures: Measure C5, a bench-cut conveyance on Clear Creek from Bennie Kate to Dixie Farm Road (immediately downstream of Super C); and Measure LD4, a linear detention on Clear Creek from Bennie Kate to Dixie Farm Road. Neither of these measures was found to further reduce damages. Therefore, they were not added to the model.

The third and fourth formulation sequences evaluated conveyance measures on Mud Gully, Turkey Creek, and Mary's Creek. The measures for each of these tributaries are trapezoidal channel construction to facilitate quick movement of water downstream. These measures would not contribute to environmental concerns because the portions of these tributaries identified for inclusion and modification in the project have been previously channelized. These measures were added to the model.

The fifth formulation sequence tested for Clear Creek upper-reach measures again. These model runs led to the modification of the previously modeled measure Remove Dredged Material/ Deepen for Conveyance (RDM1) and the identification of Measure C5, a conveyance measure extending from the downstream end of the Super C measure. These combined measures were successful at one size in increasing net excess benefits. This led to the inclusion of C5(d) as a component of the GRP. This measure is a bench cut on the main stem of Clear Creek that extends from Bennie Kate Road (the downstream extent of Super C(d)) to Dixie Farm Road.

The non-Federal sponsors requested modeling of detention components for potential inclusion in a Locally Preferred Plan (LPP). Modeling of these features (the sixth through ninth formulation sequences) determined that detention, while not successful on a stand-alone basis, was successful in increasing net excess benefits as part of an overall system. With the new modeling results, the GRP was modified to include four detention components: off-line detention on Mud Gully, in-line and off-line detention on Clear Creek, and off-line detention on Mary's Creek. Off-line detention on Chigger Creek was also considered, but did not generate benefits. The off-line detention on Mary's Creek consists of two existing detention facilities that have already been constructed by the project partners. Although the basins were evaluated at their current sizes and at larger and smaller sizes, current sizes were initially found to be most cost effective, relative to additional flood risk management benefits, based on results of preliminary analyses. However, these off-line detention features were ultimately removed from the GRP Alternative based on subsequent plan refinements and more-detailed cost/benefit evaluations.

Each of the measures identified in the formulation sequences were combined to form the GRP. In addition to these flood risk management measures, the project team also looked at potential wetland creation and/or rehabilitation, reestablishment of Clear Creek natural low flows and meanders within oxbows, floodplain preservation, marsh rehabilitation, step pool creation, riparian habitat preservation, wetland functions at detention facilities, and recreation. These features were incorporated into the plan where possible and were also considered during development of the mitigation plan.

2.3.5.2 Description of the GRP

Based on the results of the first-added and second-added analyses (phases II and III), a series of conveyance and detention measures along the main stem of Clear Creek and three of its tributaries were identified to form the GRP. These measures include two conveyance features on the main stem of Clear Creek (Super C(d) and C5(d)) and additional conveyance features on the following tributaries: Turkey Creek (TKC1d), Mud Gully (MUC1b), and Mary's Creek (MAC2a). An in-line detention feature on the mainstem of Clear Creek is also included in the GRP. Each of the measures that make up the GRP is described in detail in the following subsections.

Excavated material from construction and maintenance activities would need to be placed in upland confined placement areas. Approximately 375.8 acres of placement areas would be identified outside of the 500-year floodplain in areas suitable for placement of excavated material associated with the project.

As part of the environmentally sensitive design, the GRP Alternative encompasses avoidance and minimization measures including preserving and rehabilitating 122 acres of floodplain forest, and reestablishing 33 acres of floodplain forest (155 total acres, which includes 7.3 acres of reestablished and restored fringe forested of wetlands). In addition, as part of compensatory mitigation, the GRP Alternative will rehabilitate and/or reestablish an additional 31 acres of floodplain forest.

2.3.5.2.1 Clear Creek Main Stem Measures

Conveyance measures along Clear Creek are divided into two main sections: SH 288 to 4,000 feet downstream of Bennie Kate Road (Super C(d)) and 4,000 feet downstream of Bennie

Kate to Dixie Farm Road (C5(d)) (see Figure 2.3-3). Also included are in-line detention measures.

Super C(d) Section: This flood risk management measure provides conveyance improvement on Clear Creek from SH 288 to 4,000 feet downstream of Bennie Kate Road. The conveyance feature includes construction of 10.8 miles of high-flow channel along Clear Creek in Harris and Brazoria counties. The high-flow channel would be constructed by excavating a shallow, wide flood bench on either side of the existing channel (Figure 2.3-6). The existing channel would be preserved to convey low flows. The flood bench would have a total bottom width of 200 feet. The flood bench areas would consist of grassy, parklike areas with trees planted on the side slopes at a density of approximately 14 trees per acre. These areas would be periodically mowed to maintain the parklike setting. An additional 30-foot ROW would be outside of, and on both sides of, the high-flow bench. This ROW would be utilized to construct backslope drains to prevent erosion during high flows, while acting as a buffer to preserve and rehabilitate existing or reestablish floodplain forest. As shown on Figure 2.3-6, these features combine to require an overall project ROW measuring approximately 300 feet in width.

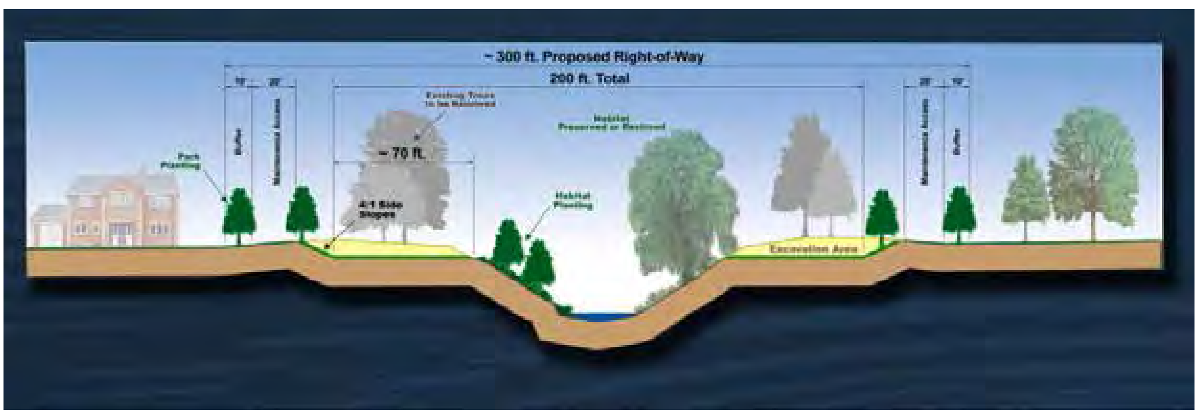

Figure 2.3-6. Super C(d) Conveyance Measure Cross Section

As noted above, the existing Clear Creek channel would be preserved for low-flow conveyance. In addition, a 65-foot corridor of floodplain forest along the low-flow channel would be preserved and rehabilitated or reestablished. Where the channel maintains some sinuosity and floodplain forest, these areas would be preserved and rehabilitated. In areas where the channel has been previously channelized and cleared of trees, floodplain forest would be reestablished through plantings. In some areas the high-flow channel would diverge from the low-flow channel. In these instances, the low-flow channel and resulting isolated lands or “islands” between the low-flow and high-flow channels would be preserved; floodplain forest would be preserved and rehabilitated or reestablished as necessary. The result would be a low-flow channel from SH 288 to Bennie Kate Road with an uninterrupted riparian corridor of floodplain forest, which would provide a continuous shaded watercourse.

C5(d) Section: From approximately 4,000 feet downstream of Bennie Kate Road to Dixie Farm Road, this flood risk management measure provides conveyance via construction of 4.4 miles of high-flow channel. Similar to that described for the Super C(d) Section, the high-flow channel would be created by constructing a shallow, wide flood bench on either side of the existing channel. The existing low-flow channel would be preserved to convey low flows, and floodplain forest along the low-flow channel would be preserved and rehabilitated to provide a 65-foot riparian corridor along the length of the conveyance feature. The flood bench would have a total bottom width of 90 feet (Figure 2.3-7). Bench areas would be maintained as grassy, parklike settings with trees planted on the side slopes at a density of 14 trees per acre. The 30-foot-wide ROW outside of and on either side of the high-flow bench would be used for construction of backslope drains to prevent erosion and to create a buffer preserving and rehabilitating floodplain forest, as described for the Super C(d) Section. These features would combine to create an overall ROW measuring approximately 180 feet in width.

Figure 2.3-7. C5(d) Conveyance Measure Cross Section

In-Line Detention Measures: These measures would provide detention for up to 485 acre-feet of water within limited segments of the proposed Clear Creek conveyance measures, as described above. Construction of these measures would require deepening the high-flow channel in areas where the high-flow channel diverges from the low-flow channel, thus allowing for additional storage with no impact to the low-flow channel (Figure 2.3-8). Gravity flow would be utilized to return temporarily stored waters to the low-flow channel.

Figure 2.3-8. Clear Creek In-Line Detention Measure Cross Section

2.3.5.2.2 Turkey Creek Conveyance

This measure would provide improved conveyance via construction of a 2.4-mile earthen, grass-lined channel on Turkey Creek from Dixie Farm Road to the confluence with Clear Creek (shown as TKC1d on Figure 2.3-4). From Dixie Farm Road to 2,000 feet downstream of Well School, the channel bottom width would be 20 feet, and the remaining channel to the confluence with Clear Creek would have a bottom width of 25 feet (Figure 2.3-9). An additional 60-foot ROW (30 feet on each side of the channel) would be required for maintenance access and construction of backslope drains to prevent erosion caused from sheet flows into the channel.

Figure 2.3-9. Turkey Creek Conveyance Measure Cross Section

2.3.5.2.3 Mud Gully Conveyance

The flood risk management measure proposed for Mud Gully includes conveyance improvements along 0.8 mile of Mud Gully from Sagedowne to Astoria (shown as MUC1b on Figure 2.3-4). The existing channel would be concrete lined to maintain stability of side slopes with a bottom width of 45 feet (Figure 2.3-10). No ROW is needed, as this section of Mud Gully is located immediately between the northbound and southbound lanes of Beamer Road.

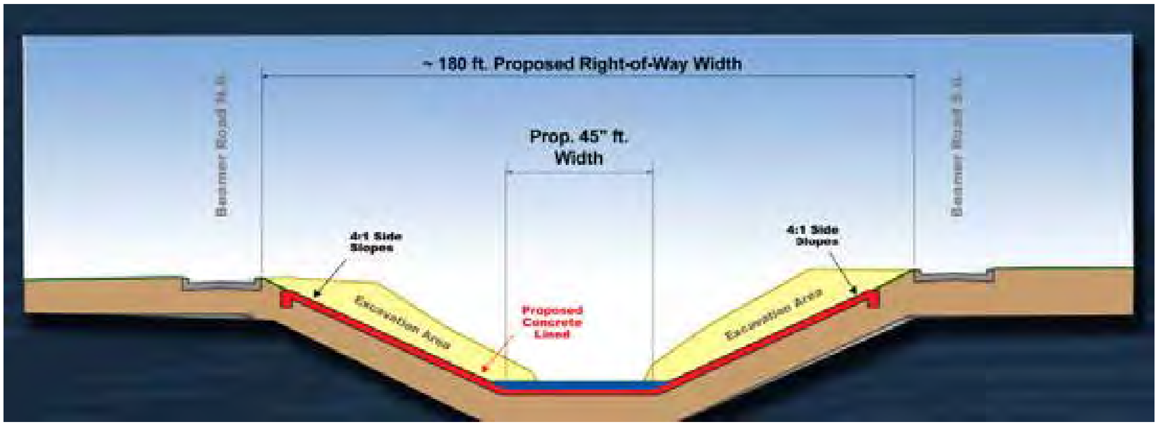

Figure 2.3-10. Mud Gully Conveyance Measure Cross Section

2.3.5.2.4 Mary's Creek Conveyance

Similar to Mud Gully, flood risk management measures for Mary's Creek include conveyance features. The conveyance measure would involve construction of a grass-lined trapezoidal channel (Figure 2.3-11) along 2.1 miles of Mary's Creek (shown as MAC2a on Figure 2.3-4). From Harkey Road to 3,940 feet upstream of McClean Road, the channel bottom width would be 15 feet, and from that point to 100 feet downstream of McClean Road, it would be 27.5 feet wide. Downstream of McClean Road to SH 35, the channel bottom width would be 35 feet. A 30-foot ROW would be needed on both sides of the channel for maintenance access and backslope drains to prevent erosion.

Figure 2.3-11. Mary's Creek Conveyance Measure Cross Section

2.3.6 GRP Alternative with Nonstructural Buyout Components

Two additional alternatives were considered that combined the GRP Alternative (as described in subsection 2.3.5.2) with the 20 percent and 10 percent AEP buyout Nonstructural Alternatives. As described for the Nonstructural Alternatives in subsection 2.3.4, three levels of participation in the buyout program were assumed. Because participation is often reduced with a plan that combines structural components with buyouts, the assumed levels of participation used in the analysis of these two alternatives were 25 percent (low), 50 percent (most likely), and 75 percent (high).

2.3.6.1 GRP Alternative with 20 Percent AEP Buyouts

This alternative includes the GRP with additional buyouts in the 20 percent (5-year) AEP floodplains. The most likely number (50 percent) of homes to be removed or bought out under this scenario is approximately 14.

2.3.6.2 GRP Alternative with 10 Percent AEP Buyouts

This alternative includes the GRP with additional buyouts in the 10 percent (10-year) AEP floodplains. The most likely number (50 percent) of homes to be removed or bought out under this scenario is approximately 68.

2.4 COMPARISON OF ALTERNATIVES AND IDENTIFICATION OF THE RECOMMENDED PLAN

This section provides comparison and discussion of the alternatives considered for further evaluation, along with the No Action Alternative, including discussion of why each was dropped from further consideration or carried forward for additional analysis. This comparison was used to facilitate the identification of alternatives that adequately meet the purpose and need that has been defined for the project and are thus carried through this FSEIS for further evaluation.

Each of the alternatives described in Section 2.3 are included in the alternatives comparison. The nine alternatives considered are:

- No Action Alternative
- AFP Alternative
- SPA
- 50 Percent AEP Nonstructural Alternative
- 20 Percent AEP Nonstructural Alternative
- 10 Percent AEP Nonstructural Alternative
- GRP Alternative
- GRP Alternative with 20 Percent AEP Buyouts
- GRP Alternative with 10 Percent AEP Buyouts

These nine alternatives were compared to one another by considering information presented in the GRR in regards to economics, real estate, and authorization considerations (use of current flood technology, use of nonstructural measures, and allows for broad floodplain management) for each of the nine alternatives. Additionally, the alternatives were compared in regards to biological resources, considerations from the physical environment, and socioeconomic and land use considerations. Although all nine alternatives were not evaluated in detail for these resources, the No Action and GRP alternatives were. Each alternative was compared for these resources relative to the No Action Alternative. The exception is the AFP Alternative, which was evaluated previously, with results presented in the Preconstruction Authorization Planning Report. Where information is available that is comparable to the evaluation performed on the No Action and GRP alternatives, it is included in the comparison. The results of the comparison are presented in Table 2.4-1. Additional detail regarding economics, real estate, and authorization considerations can be found in the GRR.

As described in the GRR and the Economics Appendix to the GRR, economic analyses were conducted on each alternative to assess flood risk management reductions, costs, and net economic benefits. Average annual damages (under 2020 economic base year conditions) for the alternatives range from $19.2 million for the GRP to $40.2 million for the SPA Alternative. The alternative with the smallest average annual damage reductions is the SPA. That alternative, as well as the AFP Alternative, have negative average annual net benefits. The alternative with the highest average annual damage reductions and positive average annual net benefits is the GRP Alternative. The GRP has higher average annual damage reduction ($19.1 million) (see Table 2.4-1).

Review of authorization considerations also identifies the three GRP alternatives (GRP Alternative alone and with 10 and 20 percent AEP buyouts) as the most favorable of the nine alternatives considered. Each of the three alternatives takes into account the use of current flood technology and nonstructural measures and allows for broad floodplain management.

Comparison of the nine alternatives through potential impacts to biological, physical, and socioeconomic resources, relative to what is expected for the No Action Alternative, also indicates that the three GRP alternatives would have the least impact with the most potential for benefits. As can be seen in Table 2.4-1, the AFP and SPA are likely to have the same or increaseed impacts compared to the GRP Alternative, but without potential for benefits such as increased aesthetics and recreational opportunities. Additionally, both the AFP Alternative and the SPA would likely result in impacts to tidal marsh above what would be expected under the No Action Alternative. The three AEP Nonstructural alternatives have fewer impacts than would be expected with the GRP Alternative; however, they also lack potential benefits associated with the GRP Alternative, such as preservation and rehabilitation of floodplain forest and increased aesthetics and recreational opportunities. The GRP with 10 Percent and 20 Percent AEP Buyout alternatives (GRP buyout alternatives) are expected to have essentially the same impacts as the GRP, with slightly higher impacts related to potential construction impacts associated with the removal of structures.

Results of the alternatives comparison highlight the three GRP alternatives as those most likely to meet the need for the proposed Clear Creek Project. All three have similar economic costs and benefits, with the GRP Alternative supporting the best benefit-to-cost ratio and highest average annual net benefits. Thus, the GRP Alternative is the plan that reasonably maximizes net benefits, and is, therefore, identified as the NED plan and the Recommended Plan (preferred alternative) that addresses the need for the Clear Creek Project.

The identification of the GRP Alternative as the Recommended Plan (preferred alternative) was based upon a comparison of economic, engineering, environmental, and socioeconomic factors presented in Table 2.4-1.

In regards to being carried forward for more-detailed evaluation of potential impacts, the GRP alternatives with 10 Percent and 20 Percent AEP buyouts are expected to have essentially the same impact as the GRP Alternative. As can be seen in Table 2.4-1, the only resource that could potentially be substantially different than the GRP Alternative is air emissions. This is because of the potential for emissions associated with removal of structures within the AEP floodplain, in addition to those expected during construction of the GRP Alternative. Because additional evaluation of the GRP with 10 Percent and 20 Percent AEP buyouts would be redundant and unnecessary, only the GRP Alternative is carried forward for comparison with the No Action Alternative.

2.5 MITIGATION

To compensate for unavoidable impacts resulting from construction of project features, a mitigation plan was developed. Selection of mitigation features was conducted by the E-Team through the development of community-based habitat suitability index (HSI) modeling using the HEP, as described in Section 5.2 and Appendix B (USFWS, 1980a). Mitigation costs were included in the analyses for identification of the GRP Alternative. However, they were based on a conservative estimate of mitigation for each measure based on input from the E-Team. A full description of proposed mitigation features for the Clear Creek Project is provided in Section 5 of this FSEIS and in Appendix B.

The E-Team defined the study area for assessment of impact and mitigation alternatives as the 500-year floodplain, and for evaluation purposes, divided the study area into seven reaches (Figure 2.5-1). Three priority ecosystem habitats were identified by the E-Team for assessment: floodplain forest, coastal prairie, and tidal marsh. However, because no impacts to coastal prairie or tidal marsh are expected, these habitats were not included in ecosystem modeling.

A total of 27 different mitigation components were evaluated by the E-Team. Eventually, 10 mitigation components were identified for additional evaluation. Through a series of model runs and E-Team workshop evaluations of results, a mitigation plan was developed. The plan includes reestablishment/rehabilitation of 31 acres of floodplain forest in a single mitigation area (C1). Additional detail regarding mitigation is provided in Section 5.

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Table 2.4-1
Comparison of Alternatives Considered
(price level is 2011)

Resource	No Action Alternative	Authorized Federal Project (AFP) Alternative	Sponsor Proposed Alternative (SPA)	50% Annual Exceedance Probability Nonstructural Alternative	20% Annual Exceedance Probability Nonstructural Alternative	10% Annual Exceedance Probability Nonstructural Alternative	General Reevaluation Plan (GRP) Alternative	GRP Alternative with 20% Annual Exceedance Probability Buyout	GRP Alternative with 10% Annual Exceedance Probability Buyout
Economics & Real Estate									
Average Annual Damage Reduction, 2020 Condition (in $1,000s, at 4.0% Discount Rate)	NA	$8,581.5	–$1,824.2	NA*	NA*	NA*	$19,064.0	NA*	NA*
Net Excess Benefits, 2020 Condition (at 4.0% Discount Rate)	NA	–$9,775.0	–$21,608.3	NA*	NA*	NA*	$9,101.1	NA*	NA*
Number of Structure Buyouts	NA	10	0	5	150	467	28	14	68
Authorization Considerations									
Use of Current Flood Technology	NA	No, included trapezoidal channel on Clear Creek mainstem	No, included trapezoidal channel with flood bypass	NA	NA	NA	Yes, uses concept of restoring natural features such as sinuosity and riparian areas to reduce runoff and flow rates in combination with structural measures for high-flow conveyance and detention	Yes, uses concept of restoring natural features such as sinuosity and riparian areas to reduce runoff and flow rates in combination with structural measures for high-flow conveyance and detention	Yes, uses concept of restoring natural features such as sinuosity and riparian areas to reduce runoff and flow rates in combination with structural measures for high-flow conveyance and detention
Use of Nonstructural Measures	Watershed management policies and practices for minimizing increases in future development-induced runoff	Management of 100-year floodplain by local sponsors	Minimal	Removal of structures within 50% Annual Exceedance Probability	Removal of structures within 20% Annual Exceedance Probability	Removal of structures within 10% Annual Exceedance Probability	Includes preservation and enhancement measures to reduce runoff and flow rates	Includes preservation and enhancement measures to reduce runoff and flow rates and removal of structures within 20% Annual Exceedance Probability	Includes preservation and enhancement measures to reduce runoff and flow rates and removal of structures within 10% Annual Exceedance Probability
Allows for Broad Floodplain Management	Only within areas of flood control district	No	No	No	No	No	Allows the watershed to be managed as a system rather than as flood control components	Allows the watershed to be managed as a system rather than as flood control components	Allows the watershed to be managed as a system rather than as flood control components
Biological Considerations									
Protection, Preservation, and Improvement of Existing Fish and Wildlife Resources	Minimal, if any	Gated structure at second outlet to avoid increased salinity in Clear Lake	Avoided natural Clear Creek reach with bypass channel	Same as the No Action	Same as the No Action	Same as the No Action	Includes preservation/ rehabilitation of approximately 155 acres of floodplain forest as part of green design (includes an anticipated 7.3 acres of forested fringe wetlands to establish along OHWM)	Same as the GRP	Same as the GRP
Floodplain Forest Impacts (acres)	1,652 lost from land use changes	1,652 lost from land use changes; 550 lost from direct impact (Net Loss = 2,202)	1,652 lost from land use changes; 333 lost from direct impact (Net Loss = 1,985)	Same as No Action	Same as No Action	Same as No Action	1,647 lost from land use changes; 278 lost from direct impact; 155 preserved and rehabilitated; 31 restored as mitigation (Net Loss = 1,744)	Same as the GRP	Same as the GRP
Coastal Prairie Impacts (acres)	970 lost from land use changes	970 lost from land use changes 0.4 lost from direct impact (Net Loss = 970)	Same as No Action	Same as No Action	Same as No Action	Same as No Action	Same as No Action	Same as the GRP	Same as the GRP
Tidal Marsh (acres)	148 lost from land use changes	148 lost from land use changes; 46 lost from direct impact (Net Loss = 194)	148 lost from land use changes; 39 lost from direct impact (Net Loss = 184)	Same as No Action	Same as No Action	Same as No Action	Same as No Action	Same as No Action	Same as No Action
Protected Species	No potential impacts	Same as the GRP	Same as the GRP	Same as the GRP	Same as the GRP	Same as the GRP	No potential impacts	Same as the GRP	Same as the GRP

Resource	No Action Alternative	Authorized Federal Project (AFP) Alternative	Sponsor Proposed Alternative (SPA)	50% Annual Exceedance Probability Nonstructural Alternative	20% Annual Exceedance Probability Nonstructural Alternative	10% Annual Exceedance Probability Nonstructural Alternative	General Reevaluation Plan (GRP) Alternative	GRP Alternative with 20% Annual Exceedance Probability Buyout	GRP Alternative with 10% Annual Exceedance Probability Buyout
Physical Environment Considerations									
Water and Sediment Quality	Effects of floods and the generated turbidity and reduced water quality would be as it is presently; no change in the quality of the sediments	Same as the GRP	Same as the GRP	Same as the No Action	Same as the No Action	Same as the No Action	No adverse impacts are expected	Same as the GRP	Same as the GRP
Hydrology	Flooding will not be reduced and may increase due to continued urban development	Not expected to result in significant impacts to groundwater hydrology Smaller reduction in peak flood elevations than the GRP	Not expected to result in significant impacts to groundwater hydrology Smaller reduction in peak flood elevations than the GRP	Not expected to result in significant impacts to groundwater hydrology	Not expected to result in significant impacts to groundwater hydrology	Not expected to result in significant impacts to groundwater hydrology	Not expected to result in significant impacts to groundwater hydrology; reduced peak flood elevations	Same as the GRP	Same as the GRP
Air Quality	No construction or new operating emissions expected. Growth and development expected to continue and would be required to comply with Federal or State requirements.	Same as GRP with similar emissions	Same as GRP with similar emissions	Same as GRP with lower emissions	Same as GRP with lower emissions	Same as GRP with lower emissions	Short-term increase in direct and indirect emissions to the Houston-Galveston-Brazoria (HGB) Nonattainment Area; however, the construction activities associated with this alternative would be considered one-time activities and would not continue past the date of completion.	Same as GRP with slightly higher emissions	Same as GRP with slightly higher emissions
Noise	No potential impacts, except minimal (ambient) levels from continued residential/urban development.	Same as GRP	Same as GRP	Temporary noise increases for shorter duration than for the GRP	Temporary noise increases for shorter duration than for the GRP	Temporary noise increases for shorter duration than for the GRP	Temporary levels increase only during construction	Same as GRP	Same as GRP
Soils	Continued impacts due to flooding, erosion, and residential/urban development	Same as GRP with slightly modified acreage impacts	Same as GRP with slightly modified acreage impacts	Less impact to prime farmland than the GRP	Less impact to prime farmland than the GRP	Less impact to prime farmland than the GRP	Impacts to 31 acres of prime farmland would occur; however, not expected to have significant effect on agricultural production, nor local economy and/or food needs/supplies.	Same as GRP	Same as GRP
Socioeconomic and Land Use Considerations									
Aesthetics	Clear Creek is a natural habitat for riparian forest, prairie grasses, and migratory birds. The creek is considered aesthetically pleasing, with area neighborhoods and subdivisions in addition to parks and walking trails along its banks.	More impact to aesthetics of the area than the GRP because of change to trapezoidal channel. No benefits from green design.	More impact to aesthetics of the area than the GRP because of change to trapezoidal channel. No benefits from green design but change in aesthetics adjacent to bypass channel.	Little to no effect	Little to no effect	Little to no effect	Minimal effect on the overall visual quality within the study area. Green design components potentially add to aesthetic quality.	Same as the GRP	Same as the GRP
Recreation	Recreational opportunities are anticipated to remain constant with potential variation from future development.	Same as No Action	Same as No Action	Same as No Action	Same as No Action	Same as No Action	Net benefits include an increase in recreational opportunities in high-flow conveyance and detention features	Same as GRP	Same as GRP
Cultural Resources	No potential impacts; however, continued impacts to recorded and nonrecorded sites would continue in times of flood.	Same as GRP	Same as GRP	Same as No Action	Same as No Action	Same as No Action	Construction of the proposed project features could impact recorded sites. Stipulations outlined in the Programmatic Agreement would minimize impacts.	Same as GRP	Same as GRP

NA = not available.
*When the GRR and the Economic Appendix were updated in 2011, these alternatives were no longer considered viable based on the analysis performed using the October 2007 price levels and a 4.875% discount rate, and were thus not reevaluated using the new October 2009 price levels and a 4.125% discount rate. In order to maintain consistency across all the economic values, these 2007 values were not included.

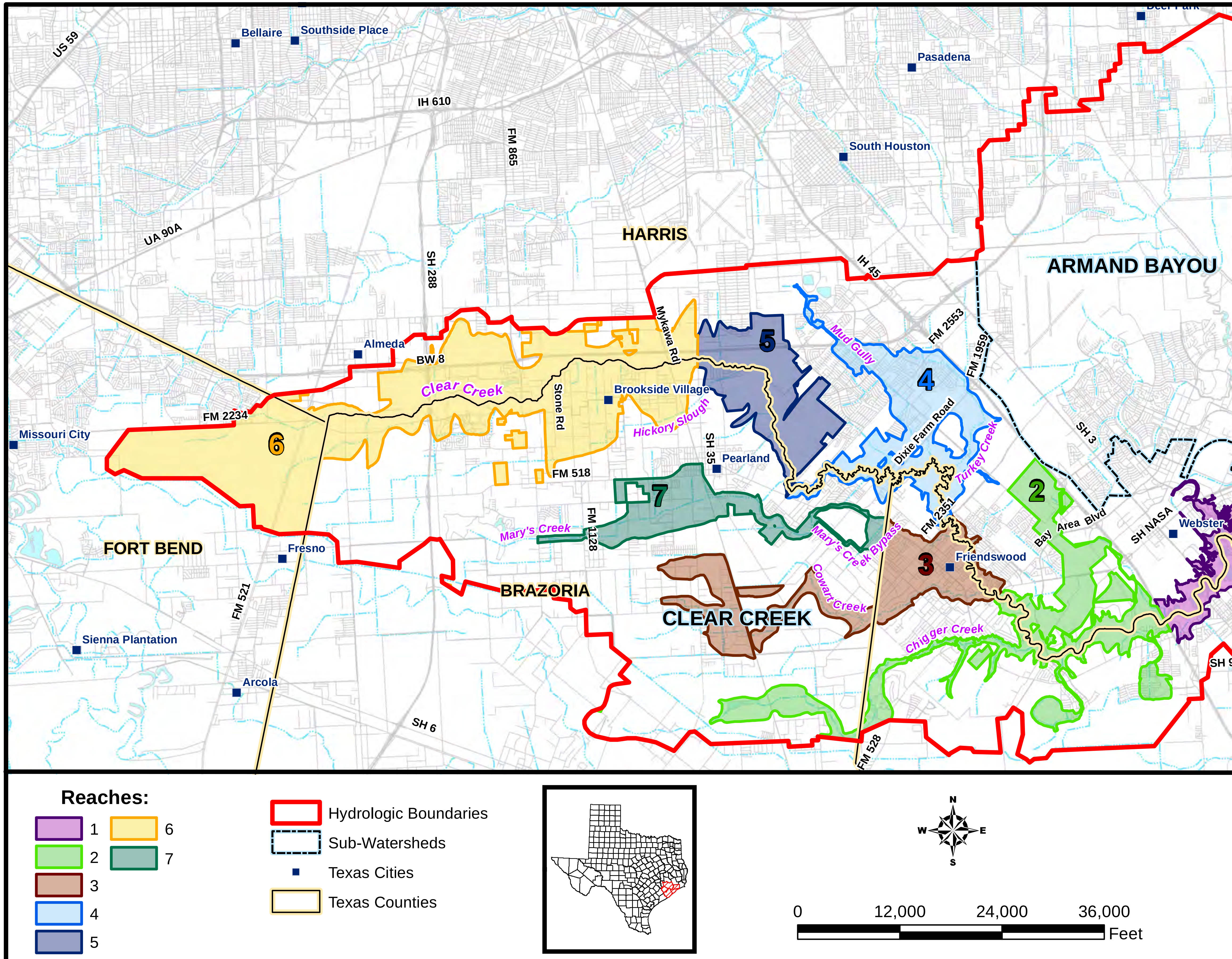

Figure 2.5-1

HSI Modeling Reaches

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 41886.00	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/10/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/044188600/figures/reaches/Reaches_vr3.mxd

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2.6 OPERATIONS AND MAINTENANCE OF PROJECT FEATURES

As previously noted, certain project features would require periodic maintenance to ensure proper function and to maintain aesthetics. The following provides a brief summarization of anticipated O&M activities for different project features.

Conveyances:

- Annual mowing of the high-flow benches and associated side slopes
- Every 3 years, removal of debris that has accumulated within the benches
- Every 10 years, silt removal that has accumulated within the benches (total silt removed over the 50-year maintenance plan will be approximately 121,380 cubic yards)
- Low-Flow Channel at Mykawa Railroad Bridge
  - Every 3 years, removal of debris that has accumulated
  - Every 20 years, replace some riprap

Preserved/Rehabilitated Floodplain Forest:

- Annual removal of invasive plant species would continue through the 35th year to allow the establishment of desired native vegetation and is required due to the prevalence of such species in the study area. Without annual treatment, invasive plant species would displace native vegetation. A "cut stump" or similar method, followed by spot treatment of individual plants through foliar application of herbicide (e.g., Clearcast, Garlon 5, Remedy, or other approved herbicide) would be utilized to achieve this task.
- Watering of planted trees would continue through the third year.
- Replanting of tree species would occur at 5 and 10 years after the end of the establishment year should monitoring determine that such actions are needed to achieve ecological success criteria.

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3.0 AFFECTED ENVIRONMENT

The study area is defined in the 1982 EIS as the Clear Creek watershed. Accordingly, the affected environment is described for the entire watershed. To assist in the description of existing resources and potential impacts associated with the GRP Alternative, a project area and study area have been defined. The project area is meant to provide spatial boundaries for evaluation of resources that may be more directly impacted by the proposed project, and is therefore a smaller area, more immediate to the proposed project features. Specifically, the project area is defined as the footprint of the conveyance, detention, rehabilitation/preservation, and mitigation features, with a ¼-mile buffer around each feature, including slight adjustments so that the project area would be a contiguous polygon (Figure 3.0-1). This project area takes into consideration areas of potential direct impact as well as areas potentially affected by immediate indirect or secondary impacts.

The study area encompasses a much larger area that provides spatial boundaries for resources that could potentially be indirectly impacted by the proposed Clear Creek Project. Although the availability of information for specific resource categories varies from being watershed based to being county based, a study area was delineated in closer proximity to areas considered most likely to be affected by the proposed project. As discussed in Section 5.2, community-based HSI modeling was used to determine potential project impacts and mitigation features. This modeling was based on ecological information collected along seven stream reaches within the Clear Creek watershed (see Figure 2.5-1). These reaches and the footprint of the project features were used to define the study area. Thus, the study area has been defined as a 1-mile buffer surrounding the seven stream reaches and the project features (Figure 3.0-2). Included in the study area are portions of Harris, Galveston, Brazoria, Fort Bend, and Chambers counties. Chambers County is included in the study area to account for the outflow of water into Galveston Bay. However, for resource-specific information that is provided at the county level, Chambers County is not included. This is because the only portion of Chambers County included in the study area is a small portion of Galveston Bay. There are no upland resources and no communities within this portion of Chambers County. Thus, it is eliminated from discussion of the study area. It should be noted that because the study area must sometimes be resource specific, a different study area is used for those resources for which this study area is not appropriate. If this is the case, the study area is defined in the section for that specific resource.

3.1 ENVIRONMENTAL SETTING

3.1.1 Study Area

Clear Creek is located in Harris, Galveston, Fort Bend, and Brazoria counties in southeast Texas. The project study area generally encompasses the Clear Creek watershed, to include Clear Creek,

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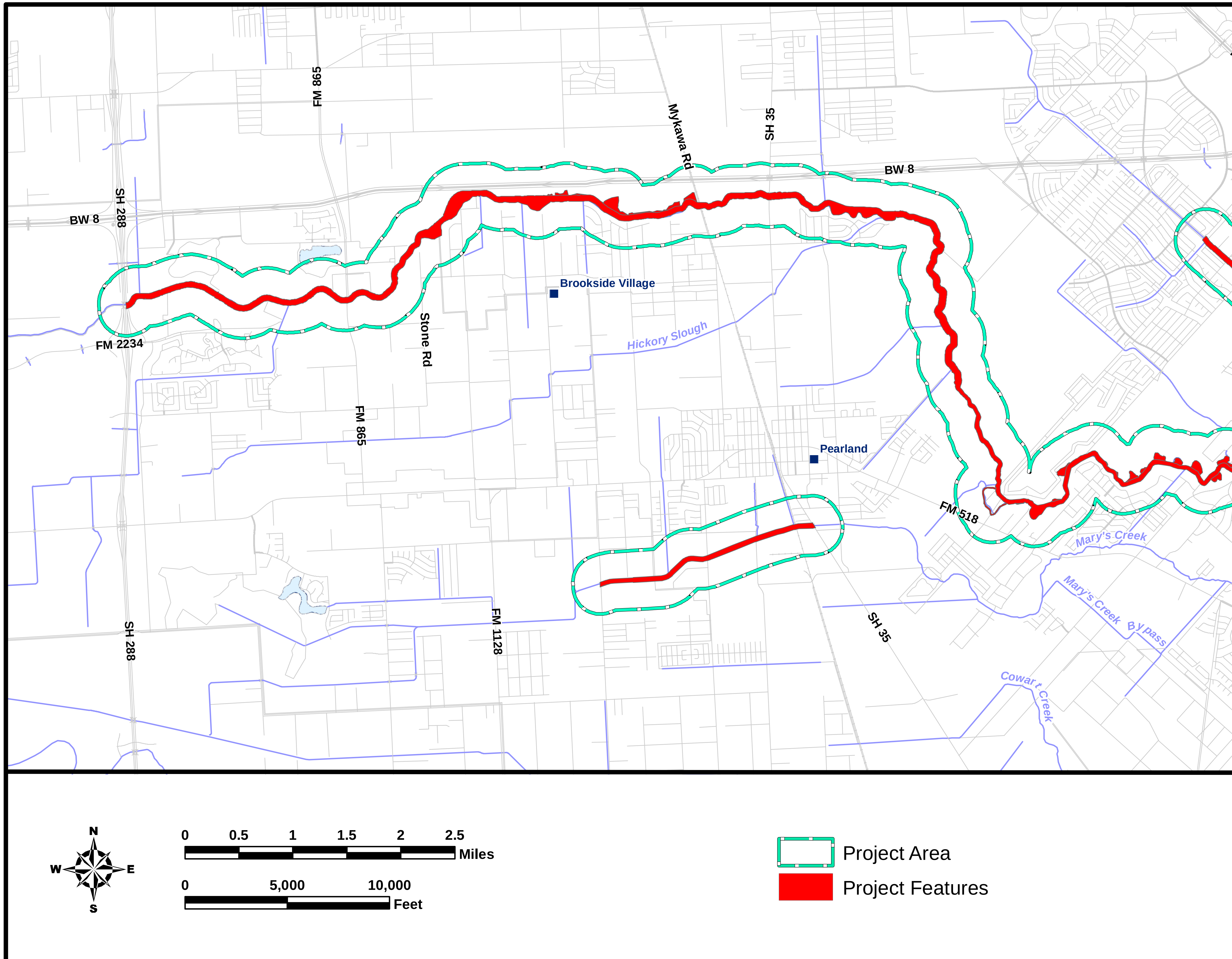

Figure 3.0-1

Project Area

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 5,000 feet
Prepared by: 18827	Date: 5/10/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/Clear_Crk_prj_area_vr4.mxd

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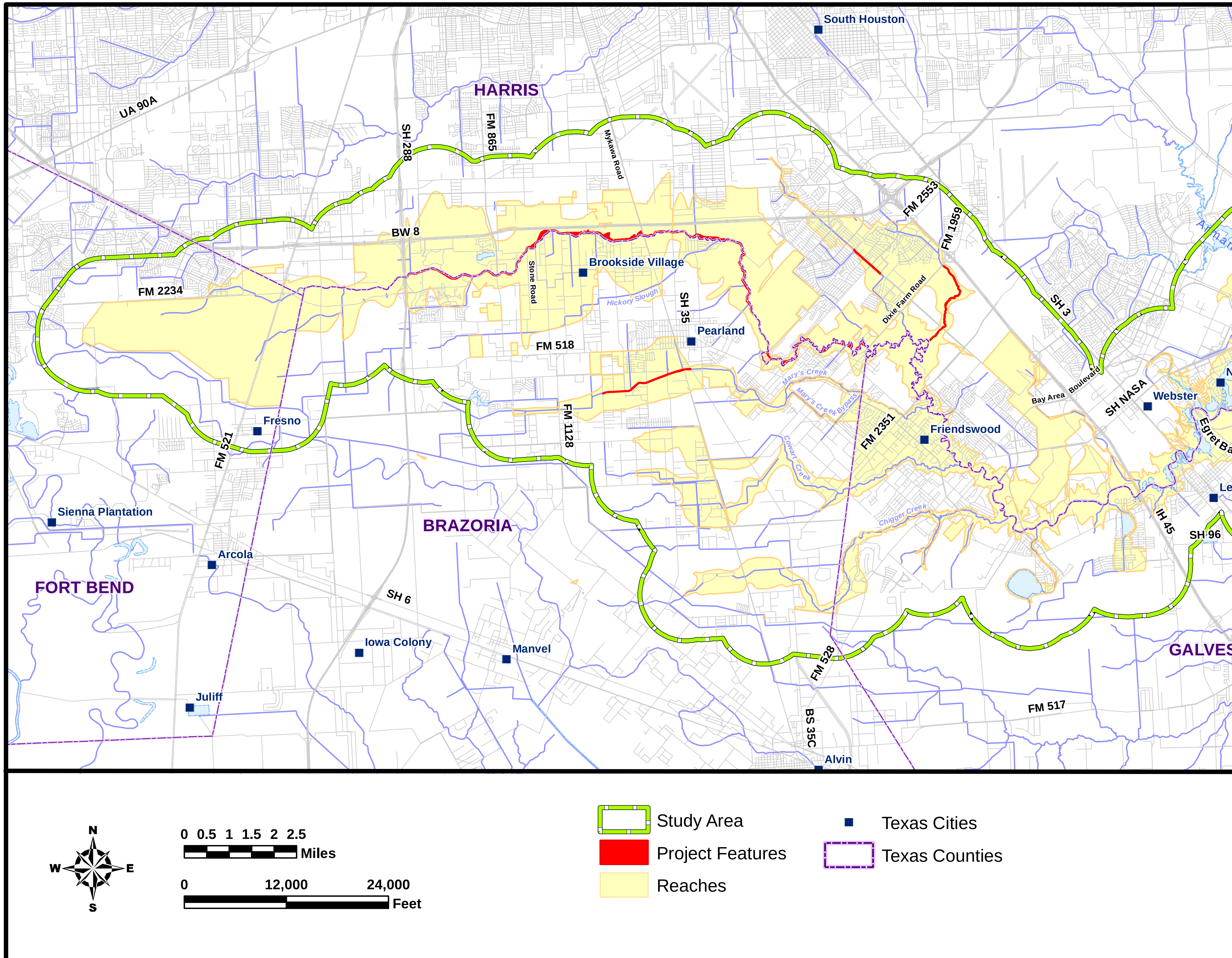

Figure 3.0-2

Study Area

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/10/2012

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its tributaries, Clear Lake, and the surrounding riparian and upland environments. Clear Creek generally flows from west to east and drains into Clear Lake, which eventually drains into Galveston Bay at Seabrook. The Clear Creek watershed covers approximately 260 square miles, which is partly inclusive of the City of Houston and surrounding smaller cities such as Pasadena, Pearland, Friendswood, Webster, and League City. The major tributaries to Clear Creek are Mud Gully, Turkey Creek, Mary's Creek, Cedar Gully, Cowart Creek, Chigger Creek, Magnolia Bayou, Taylor Bayou, Armand Bayou, and Hickory Slough.

Developed portions of the study area consist of commercial buildings and light industrial and manufacturing facilities along major roadways and single-family residences and subdivisions. Other portions of the study area remain vacant, undeveloped land used primarily as pastureland for livestock.

3.1.2 Physiography

The study area is situated within the Gulf-Atlantic Plain Physiographic Division, Gulf Coastal Plain Region of Texas (Rand McNally and Company, 1991). It is characterized by a diversity of features that is a result of the natural transition between freshwater and marine environments. The eastern portion of the study area consists of a series of tidally influenced marginal marine embayments bordered by Galveston Bay. The western portion is defined by a flat, nearly level coastal plain divided by a headward-eroding stream. The Gulf Coastal Plain occurs inland from extensive coastal marshlands and is gently inclined gulfward at about 5 feet or less per mile (Fisher et al., 1972). Surface elevations range from 70 feet in the western portion of the study area to sea level along the eastern boundary.

Physiographic environments of the region include fluvial-deltaic systems, marsh-swamp systems, and bay-estuary lagoon systems (Fisher et al., 1972). Ancient but similar coastal systems, such as wind deflation and deposition, tidal currents, wind-generated waves and currents, delta out-building, and river point-bar and flood deposition, have deposited the underlying sediments within the region (Fisher et al., 1972).

3.1.3 Geology

The regional geology of the Gulf Coast consists of sedimentary beds ranging from late Eocene (about 35 to 55 million years ago) to recent age. These deposits typically occur as parallel bands located along the Gulf Coast. Recent deposits form the coastline, and older beds are at the surface farther inland. The geology of the study area was formed primarily during the Tertiary Period (between 1.5 and 65 million years ago) and the early Quaternary Period (between 0 and 1.5 million years ago) from cyclic marine and continental deposition, fluvial deposits, and sea-level fluctuations associated with recurring glacial events (Van Siclen, 1967).

During the Pleistocene (between 10,000 and 1.5 million years ago), meandering streams changed into relatively straight delta streams extending across broad low deltaic plains. Sand and mud deposits extended the delta lobe into broad embayments. Pleistocene delta lobes west of modern Galveston Bay built coastward and terminated near the current position of West Bay. Small ephemeral streams, such as Chocolate Bayou, Clear Creek, and Cedar Bayou, have cut or eroded into the relict Pleistocene delta plain. Some alluvium (recent deposits) occurs near the streams (Fisher et al., 1972).

The study area is underlain primarily with fluvial-deltaic system deposits of the Beaumont Formation. The Quaternary-aged Beaumont Formation is described as mostly clay, silt, and sand deposited from stream channels, point bars, natural levees, backswamps, and to a lesser extent coastal marshes and mud flats (Bureau of Economic Geology [BEG], 1982). The Beaumont Formation is about 100 feet thick and is overlain by alluvium within portions of the Clear Creek watershed near Clear Lake. Quaternary-aged alluvium is deposited primarily in point bars, natural levees, stream channels, backswamps, coastal marshes, and mud flats, and consists primarily of clay, silt, sand, and organic matter (BEG, 1982).

Within the study area are numerous active and potentially active surface faults that are generally the product of natural geologic processes such as loading by sediment deposition, upward migration of salt masses, coastal land-mass creep, and tectonic subsidence. The amount of surface displacement can range from zero for inactive faults to more than 12 feet for active faults. In addition, man-made activity, such as the heavy withdrawal of groundwater, oil, and gas, has increased the frequency and activity of surface-fault movement. Surface faults cause no real hazard, provided future construction is planned to avoid active or potentially active faults or is engineered to accommodate movement and displacement (Fisher et al., 1972).

Previous studies, field observations, and historical data indicate that Clear Creek has not experienced significant sediment and erosion issues. The soils in the area (discussed in Section 3.7) are dominated by clays and tend not to erode as significantly as other soils.

3.1.4 Climate

The climate of the study area is subtropical. Prevailing winds are usually from the southeast with an average speed of about 10−15 mph. During winter, rapidly moving polar fronts bring in cold air with prevailing northerly winds. Temperatures are moderated by the influence of the winds from the Gulf, resulting in mild winters and warm, humid summer nights. The mean daily temperature ranges from the low 60s (degrees Fahrenheit [°F]) in December and January to the low 90s in the summer months. The temperature rarely drops below 40°F or rises above 96°F. The average annual rainfall is about 51 inches, with monthly precipitation averaging from 3 inches to about 6 inches (World Climate, 2007).

Major storm events affecting the study area include Tropical Storm Claudette (July 1979), Tropical Storm Allison (June 2001), and Hurricane Rita (2005). The study area has experienced major floods, some resulting from tropical storms and others due to major rainfall events. For example, the Clear Creek watershed received 15 to 25 inches of rain in October 1994 that resulted in near-record water levels in the 500-year flood-level range in portions of the project area.

3.1.5 Relative Sea Level Change

There are two primary components to relative sea level change in the study area—subsidence and worldwide or eustatic sea level rise associated with large-scale temperature changes. These are described below, followed by a discussion of expected combined effects on the study area.

3.1.5.1 Local Subsidence

Land subsidence has been occurring in the Clear Creek study area over the last century, primarily from the effects of groundwater pumping. In the first part of the twentieth century, subsidence was greatest along the Houston Ship Channel and the Texas City area. At the end of the twentieth century, control efforts had been successful in the channel area, and the area of greatest subsidence had migrated to the west (Figure 3.1-1).

In response to the subsidence situation, the entire metropolitan area is moving to a surface-water supply and away from groundwater. With that change, it is reasonable to expect that the rate of subsidence will be substantially reduced during the project life (2020–2070). Assuming the more recent period is representative of the distribution of subsidence and probably higher than expected for future conditions, it is representative of the existing or baseline condition.

From the recent contours, as shown on Figure 3.1-1, the upstream end of Clear Creek in Fort Bend County experienced roughly 2 feet of subsidence in the 22 years from 1978 to 2000, or 0.091 foot per year. In the same interval, the downstream end of the study area experienced 0.5-foot subsidence, or 0.023 foot per year. These are taken to be the existing or baseline rates of subsidence for the study area. Note that a higher rate of subsidence in the upstream portion of the study area has and will continue to have the effect of reducing the slope of Clear Creek. This reduced slope reduces the rate at which floodwater drains and thus increases the peak flood elevation that results from a given amount of rain.

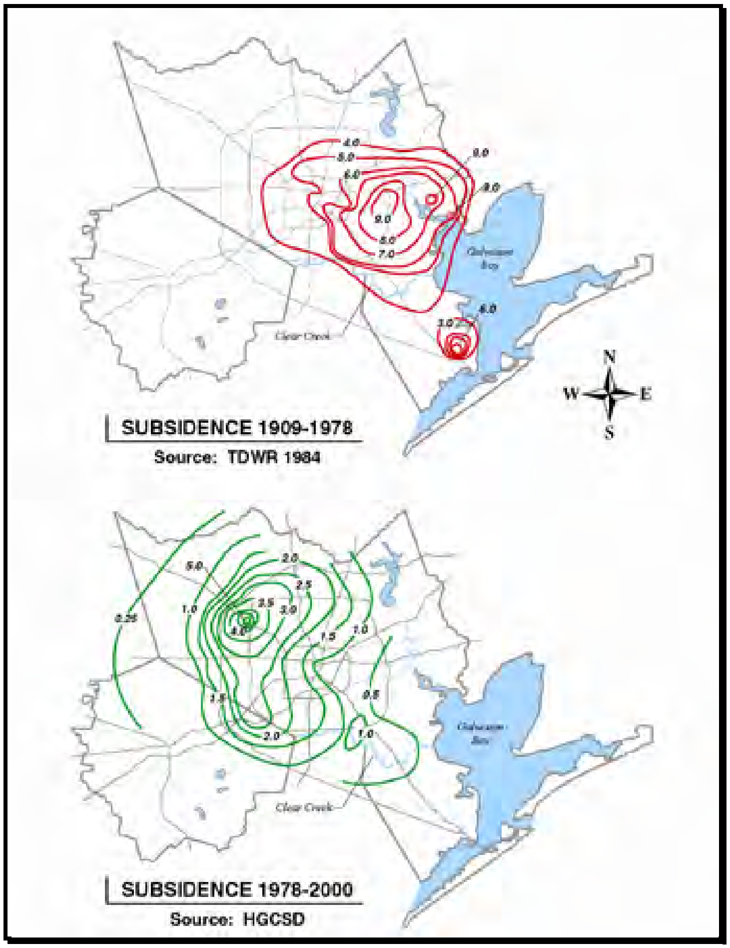

Figure 3.1-1. Historical Subsidence in Study Area

3.1.5.2 Eustatic Sea Level Rise

The eustatic, or global, rate of sea level change is difficult to quantify for a variety of reasons. The National Oceanic and Atmospheric Administration (NOAA, 2001) analyzed the long-term trends in relative sea level for water level recording stations in the U.S. and found a substantial amount of variation in the rates at different locations in the U.S. Figure 3.1-2 shows the long-term mean sea level (msl) trends at stations in the Gulf, Caribbean, and Pacific. The Louisiana and Texas stations have the highest rates, but that may reflect some of the subsidence effect in addition to sea level change. The rates of East Coast stations are on the order of 2 to 3 millimeters (mm)/year and appear reasonably consistent. From this, a baseline rate of eustatic sea level change of 2 mm/year (0.08 inch, or 0.0066 foot per year) is selected. This is much less than the rates of local subsidence in the study area. Over the 50-year project life, this baseline rate would result in 0.33 foot of increase in sea level.

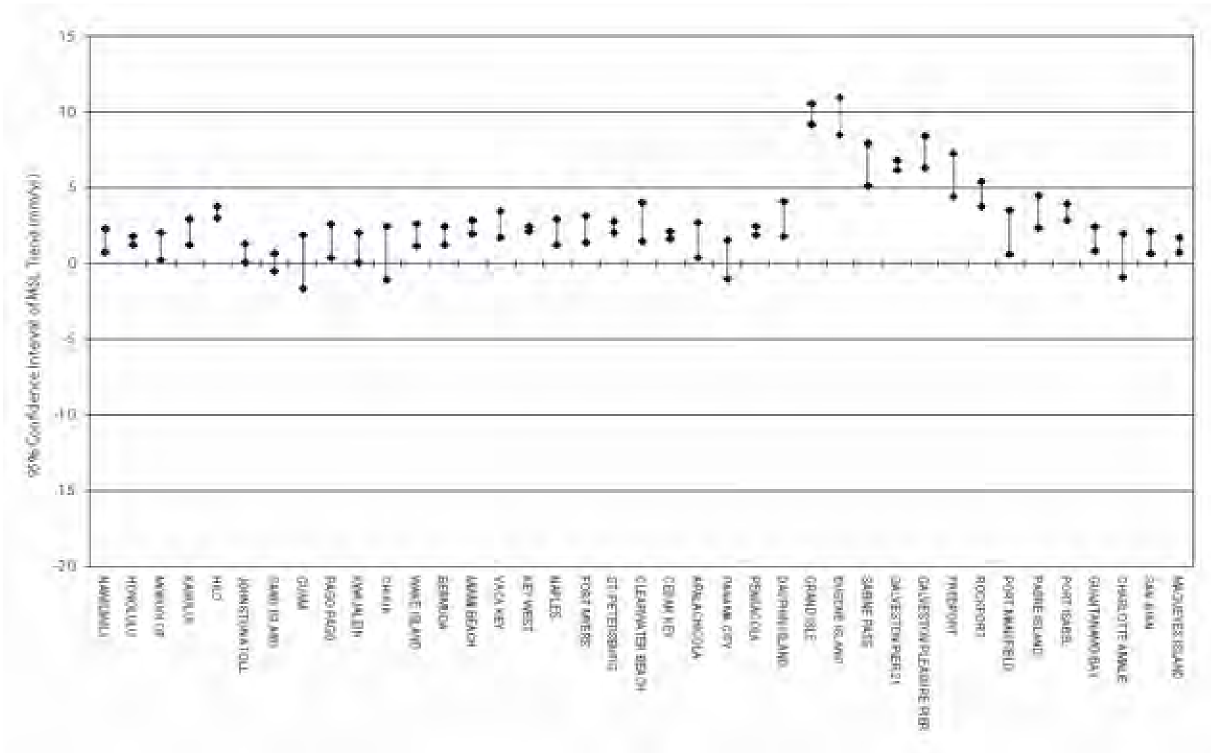

Figure 3.1-2. Trends in Relative Sea Level Rise at Stations along the U.S. Coast

Source: NOAA, 2001, Figure 10.

Because of observed and possibly accelerating climate changes, the rate of sea level change in recent history may not be the best predictor of the rate that will occur in the future. To account for possible accelerated rates of eustatic sea level rise, the USACE has chosen to follow EC 1165-2-211 (2009), which updates the recommendations of the National Research Council (NRC, 1987). Both publications present three possible future scenarios for sea level change: low, intermediate, and high estimates.

The calculated elevations in feet for the three scenarios for the project periods are shown in Table 3.1-1. The change over 50 years with the low scenario (1.05 feet) is based on the rate observed at the Pier 21 water level gauge of 6.39 millimeters per year (mm/yr). This is larger than that predicted from typical U.S. rates (0.33 foot).

3.1.5.3 Combined Effects

From the above, it is clear that a baseline representation of relative sea level change will involve both local subsidence and global sea level increase and is likely to have effects on the study area. One effect will be reducing the slope of the watershed by raising the water elevation at the downstream end and greater subsidence at the upstream end of Clear Creek.

Table 3.1-1
Calculated Future Rates of Sea Level Change
for the Study Area Based on EC 1165-2-211 (2009)

Scenario	Year			Change
	1986	2020	2070	
	Elevations in feet			
Low	0.00	0.71	1.76	1.05
Intermediate	0.00	0.80	2.31	1.50
High	0.00	1.09	4.08	2.99

The change in relative sea level can be expected to increase the tidal exchange in Clear Lake, both from greater surface area and tidal prism in Clear Lake and greater tidal activity in Galveston Bay. This can be expected to increase average salinity in both Galveston Bay and Clear Lake and allow salinity to intrude farther inland during dry or low-flow conditions.

3.2 WATER QUALITY

Relative to water quality, the study area can be logically broken into the TCEQ Water Quality Segments: Clear Creek Tidal, Clear Creek Above Tidal, Clear Lake, and Upper Galveston Bay. As is noted below, the water quality in these segments is generally good, although there have been some areas of concern in the past.

The 1982 EIS reported that the water quality investigation for the project area included Clear Creek, Clear Lake, and 17 tributaries. Concerns described included effluent wastewater treatment, rainfall runoff from agricultural (pesticides) and oil/gas fields (heavy metals and polychlorinated biphenyls [PCBs]), dissolved oxygen levels, fecal coliform counts, and high nutrient levels. Turbidity levels in Clear Lake are adversely affected by increased wind waves, tidal action, weekend and holiday boating activities, dredging activities, and by algal blooms due to high nutrient levels. Additional concerns existed regarding the accidental discharge of styrene tars, sodium sulfide, cresylic acid, cumene, and ethyl benzene into Mud Gully (Texas Department of Water Resources [TDWR], now the TCEQ, 1977). These issues have been monitored and are discussed in more detail in the following subsections.

3.2.1 Clear Creek

The tidal portion of Clear Creek (Clear Creek Tidal, Segment 1101) is approximately 12 miles long, from the confluence with Clear Lake in Galveston/Harris County to a point 110 yards upstream of FM 528 (just west of I-45) in Galveston/Harris County (Houston-Galveston Area Council [H-GAC], 2001). Clear Creek Above Tidal (Segment 1102) starts 110 yards upstream of FM 528 and extends to Rouen Road in Fort Bend County (H-GAC, 2001). The TCEQ-designated uses for both segments 1101 and 1102 are High Aquatic Life and Contact Recreation.

Due to elevated bacteria concentrations from point and nonpoint sources, neither of these segments support Contact Recreation use (TCEQ, 2010a). Between 1969 and 1976, styrene tars, sodium sulfide, cresylic acid, cumene, and ethyl benzene were accidentally discharged into Mud Gully (TDWR, 1977). In November 1993 and 1994, the Texas Department of State Health Services (TDSHS) collected fish and blue crabs from Clear Creek and, based on finding elevated levels of 1,2-dichloroethane, 1,1,2 trichloroethane, carbon disulfide, and pesticides, including chlordane, in fish tissue, issued a fish consumption advisory for Clear Creek (TDSHS, 1994). The TDSHS stated that volatile organic compounds (VOCs) do not ordinarily persist in the environment and that elimination of the source should allow VOCs in tissues to return to normal levels. Chlordane was detected by the U.S. Geological Survey (USGS, 2003) but at concentrations near or below detection levels. The TDSHS resampled and analyzed fish and blue crab tissues in 2000 and prepared a Health Consultation in March 2002 (TDSHS, 2002). They found very low levels of several metals and pesticides and extremely low levels of several VOCs. The conclusion of the Health Consultation was that consumption of fish or blue crabs from Clear Creek "poses no apparent public health hazard to those who consume these species." However, in July 2009, the TDSHS issued a fish consumption advisory for Clear Creek (TDSHS, 2009). The fish consumption advisory was based on the presence of PCBs at elevated levels in fish collected from Clear Creek. The TDSHS stated that concentrations of PCBs exceeded health assessment guidelines and no fish species should be consumed from Clear Creek. According to the TDSHS, the advisory will remain in effect until rescinded or modified. A potential concern exists for nutrient enrichment due to elevated chlorophyll *a* (some subsegments of 1101), ammonia (one subsegment of 1102), nitrite/nitrate, nitrogen, and orthophosphorus levels (some subsegments of both 1101 and 1102). The high nutrient levels appear to affect dissolved oxygen with evidence of frequent depressed dissolved oxygen levels in the above-tidal segment and tidal segment.

The occurrence of high nutrient levels and elevated chlorophyll *a* levels indicates potential water quality problems (algal blooms) and subsequent low dissolved oxygen, especially during extreme summertime conditions. Elevated nutrients in both segments are thought to originate from nonpoint sources, such as domestic and urban runoff. Magnolia Creek (1101A), Cow Bayou (1101C), Unnamed Tributary of Clear Creek Tidal (1101E), and Unnamed Tributary of Mary's Creek (1102G) are all included in the draft 2010 Texas 303(d) list for bacteria (TCEQ, 2010a). According to TCEQ (2010b), the bacteria are introduced from unknown point and nonpoint sources. TCEQ has completed the Total Maximum Daily Load (TMDL), which was adopted on September 10, 2008, for bacteria in the Clear Creek watershed. Clear Creek Above Tidal was designated as Impairment Category 4a for Total Dissolved Solids (TDS) and chloride in 2008. A TMDL, Implementation Plan, and Enforcement Action was adopted by TCEQ and agreed to by the point source, which eliminated the problem.

3.2.2 Clear Lake

Clear Lake (Segment 2425) is a 2.0-square-mile brackish, tidally influenced waterbody on the western shore of Upper Galveston Bay that receives inflows from Clear Creek and Armand Bayou (H-GAC, 2001). The TCEQ-designated uses for Clear Lake are High Aquatic Life and Contact Recreation. In 1998, ammonia, nitrate-nitrite, chlorophyll *a*, orthophosphorus, and total phosphorus exceeded the 85th percentile screening level and were a concern for this segment (Texas Natural Resources Conservation Commission [TNRCC], 1998). By 2006, only chlorophyll *a* and nitrate from municipal point sources, nonpoint-source urban runoff, storm sewers, and other urban nonpoint sources were listed as concerns (TCEQ, 2007a), with the Aquatic Life and Contact Recreation uses fully supported. In addition, dissolved oxygen is listed as a concern from nonpoint-source runoff, storm sewers, and other urban nonpoint sources. In July 2008, the TDSHS issued a fish consumption advisory for Galveston Bay including Clear Lake (TDSHS, 2008). The fish consumption advisory was based on the presence of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs/PCDFs or dioxin) and PCBs at elevated levels in gaftopsail catfish and spotted seatrout collected from Trinity Bay and Upper and Lower Galveston Bay. The TDSHS stated that concentrations of dioxin and PCBs exceeded health assessment guidelines and the consumption of catfish species and spotted seatrout should be limited to no more than one 8-ounce meal per month. In addition, TDSHS stated that women who are nursing, pregnant, or who may become pregnant and children should not consume catfish species or spotted seatrout from Galveston Bay. In 2010, TCEQ (2010b) lists ammonia, nitrate, chlorophyll *a*, and total phosphorus as concerns for this segment from municipal point sources, nonpoint-source urban runoff, storm sewers, and other urban nonpoint sources.

3.2.3 Upper Galveston Bay

Upper Galveston Bay (Segment 2421) covers a 108.2-square-mile portion of Galveston Bay that extends southward from the vicinity of Morgan’s Point to an imaginary east-west line in the area of Redfish Island extending due west from Smith’s Point to the western shore of Galveston Bay near Dickinson, and eastward toward an imaginary north-south line extending southward from the Beach City area to Smith Point (H-GAC, 2001). Salinity gradients from the upper to lower bay are a normal feature, with Gulf inlet values of about 30 parts per thousand (ppt) declining to about 3 ppt near principal points of inflow (Galveston Bay National Estuary Program [GBNEP], 1994a). Ward and Armstrong (1992) summarized major alterations in water quality in the Galveston Bay system over the last several decades. They stated that the dissolved oxygen is generally high throughout the bay, with exceptions in poorly flushed tributaries that receive runoff and waste discharges. They found that, overall, declines in nitrogen and phosphorus concentrations throughout the bay have occurred in the last 2 decades with improved wastewater treatment. In addition, fecal coliform bacteria levels have also generally declined over much of the bay. However, western urbanized tributaries (Clear Creek, Clear Lake, and Armand Bayou) of the bay system continued to retain high levels. The geographical problem areas of Galveston Bay (which include the tributaries discussed earlier) are in regions of intense human activity, including urban areas, points of surface runoff, waste discharges, and shipping. The quality of the bay is generally good, and where it is degraded, there is a general trend toward improvement (GBNEP, 1994b). The TCEQ-designated uses for Upper Galveston Bay are High Aquatic Life/Oyster Waters and Contact Recreation. According to TCEQ (2010b), concerns include total phosphorus, nitrate, and chlorophyll *a* from municipal point sources, nonpoint-source urban runoff, and storm sewers. In addition, TCEQ (2010b) lists iron in sediment as a concern from an unknown source.

A fish-consumption advisory was issued in September 1990 for the Houston Ship Channel and Upper Galveston Bay (TDSHS, 1990). The fish-consumption advisory was based on the presence of dioxin at elevated levels in catfish and blue crabs from the Houston Ship Channel and Upper Galveston Bay. The TDSHS stated that the consumption of catfish species and blue crab should be limited to no more than one 8-ounce meal per month. In addition, TDSHS stated that women who are nursing, pregnant, or who may become pregnant and children should not consume catfish species or blue crab from the Houston Ship Channel or Upper Galveston Bay. In January 2005, the TDSHS issued an additional fish consumption advisory for the Houston Ship Channel and Upper Galveston Bay (TDSHS, 2005). The fish consumption advisory was based on the presence of PCBs at elevated levels in spotted seatrout collected from Upper Galveston Bay, Tabbs Bay, and the tidal portion of the San Jacinto River. The TDSHS stated that elevated concentrations of PCBs may pose a threat to human health if consumed. TDSHS also stated that the consumption of spotted seatrout should be limited to no more than one 8-ounce meal per month. In addition, TDSHS stated that women who are nursing, pregnant, or who may become pregnant and children should not consume spotted seatrout from the Houston Ship Channel or Upper Galveston Bay. As mentioned in subsection 3.2.2, a fish consumption advisory for dioxins and PCBs in catfish species and spotted seatrout was issued in July 2008 (TDSHS, 2008).

3.2.4 Clear Creek Water Chemistry

Reports and data from past studies from Clear Creek were provided to PBS&J by the USACE, HCFCD, Galveston County Department of Health, and Brio Site Task Force (BSTF). Historical data are from studies conducted for the BSTF by Woodward-Clyde Consultants (WCC); for the EPA, Region VI by Roy F. Weston (Weston); for the Brio Site Steering Committee (BSSC) by Resource Engineering, Inc. (REI), and for the USACE by PBS&J (formerly Espey, Huston & Associates, Inc. [EH&A]). Historical data were also collected by the TDWR and by the TNRCC.

Brio Refinery (National Priority List [NPL], Comprehensive Environmental Response Compensation and Liability Information System [CERCLIS], and State Superfund [SSF]), located at 2501 Dixie Farm Road, is a 58.1-acre site that formerly performed copper catalyst regeneration, oil blending, refining, and recycling of styrene tars. From 1957 to 1970, several pits were constructed to support processing operations. The primary pollutants identified at the facility include styrene tars, vinyl chloride, chlorinated solvent residues, metallic catalyst, and fuel oil residues. This refinery is located on the east side of Mud Gully, a tributary to Clear Creek. Operations ceased in December 1982. The EPA announced in January 1988 that the investigation was complete, and a remedy would be selected. The corrective action conducted at the site includes the construction of a containment remedy in 2004. This remedy consists of a surface cap, a subsurface barrier wall, and a groundwater control system that will ensure that contaminated groundwater will not discharge into the surface water of Mud Gully. The surface cap, or multilayer cover system, reduces the risk from direct contact with the residue wastes at the site. Currently, this Superfund site is undergoing regular monitoring and maintenance.

The analytical results of water, elutriate, sediment, and new-work samples taken in Mud Gully and Clear Creek over the 22-year period (1971–1993) are presented in an EH&A (1998) report. Every attempt was made to keep the information as accurate as possible; some of the older reports were copies of copies, and the data were difficult to read. Illegible data were not used. Additional data were sought for the period later than 1998, but none were found other than (1) some TCEQ information (discussed above in subsections 3.2.1 through 3.2.3); (2) information concerning toxic compounds in water (discussed in the following paragraph); (3) information relative to toxic compounds in sediment (Section 3.3); and (4) USGS data relative to chlordane in sediments (Section 3.3).

The TCEQ (2010c) noted no concerns for multiple acute or chronic toxic constituents in water from Clear Creek Tidal, Clear Creek Above Tidal, Clear Lake, and Upper Galveston Bay. No concerns were listed for human health bioaccumulative toxics in water for Clear Creek Tidal, Clear Lake, and Upper Galveston Bay; no information was provided for Clear Creek Above Tidal.

3.2.4.1 Metals

There are no historical metals data for water samples prior to 1998, except at stations CL-91-6, CL-91-5, and CL-91-4 (figures 3.2-1a–c; EH&A, 1991) in Clear Creek downstream of I-45. Arsenic, cadmium, chromium, copper, lead, nickel, and zinc were all below detection limits. Aluminum, antimony, arsenic, beryllium, chromium, copper, iron, lead, nickel, selenium, silver, and zinc were also detected in the 1998 water samples (EH&A, 1998). The chemical analyses of water samples indicated that all detected parameters were below Texas Water Quality Standards (TWQS) promulgated by the TCEQ for the protection of aquatic life, or EPA Water Quality Criteria (EPA, 1986; updated by the EPA since the publication of EH&A [1998]; the latest update can be found at http://www.epa.gov/waterscience/criteria/wqcriteria.html) if there were no TWQS. Additionally, for those compounds that have no TWQS, toxicity data indicate that the compounds were present at concentrations much lower than those expected to cause toxicity (EH&A, 1998).

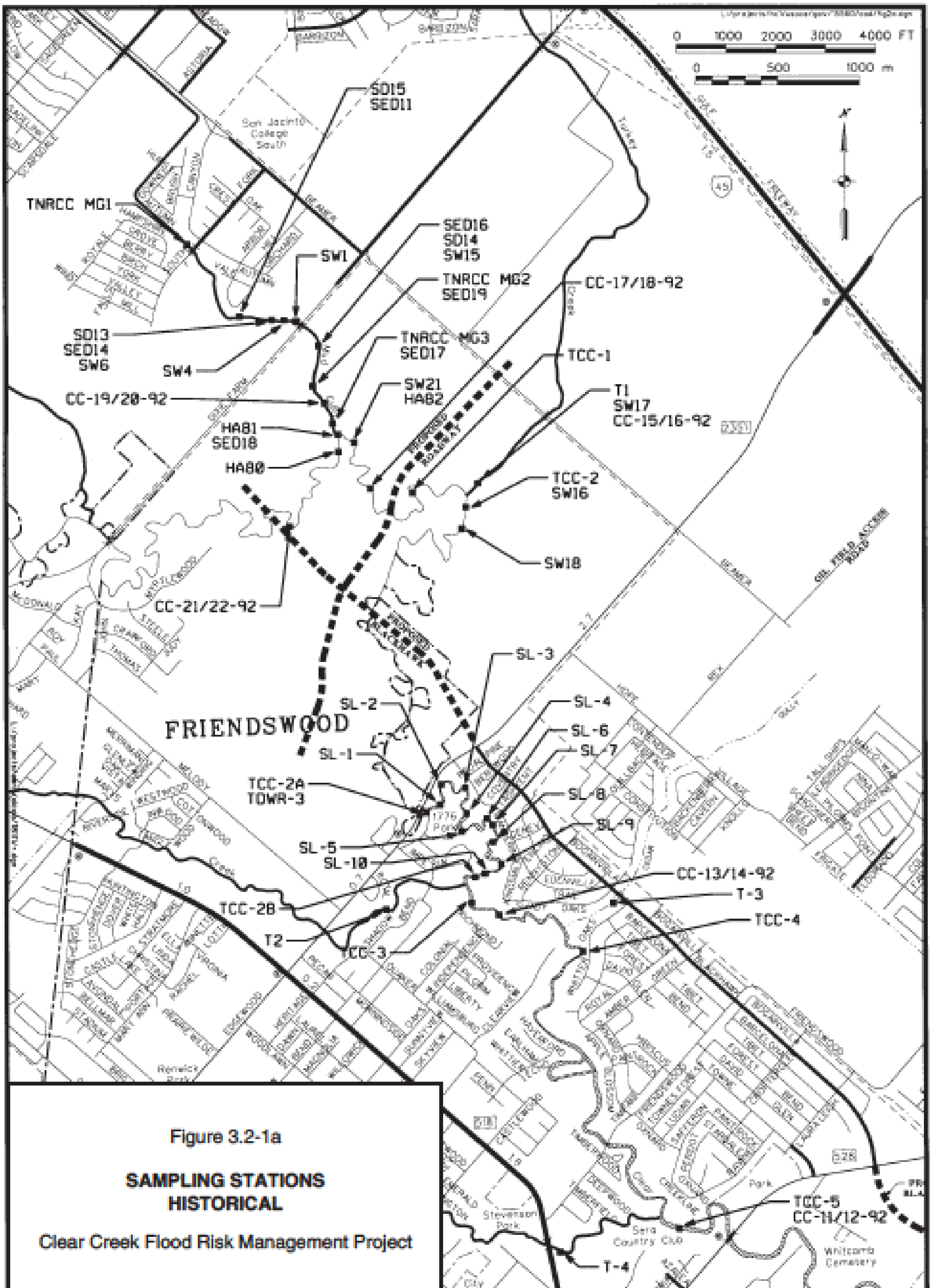

Figure 3.2-1a

SAMPLING STATIONS HISTORICAL

Clear Creek Flood Risk Management Project

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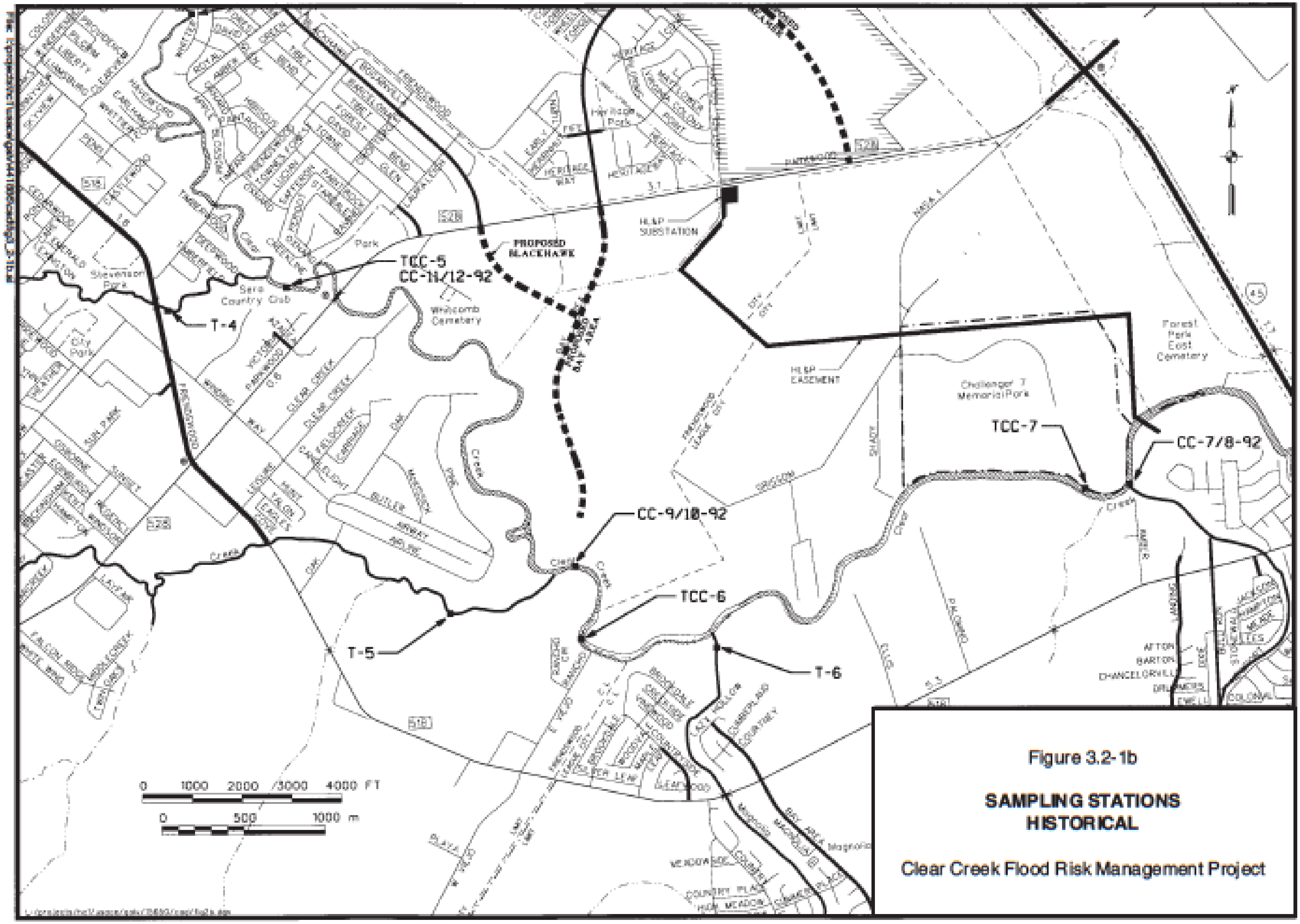

Figure 3.2-1b

SAMPLING STATIONS HISTORICAL

Clear Creek Flood Risk Management Project

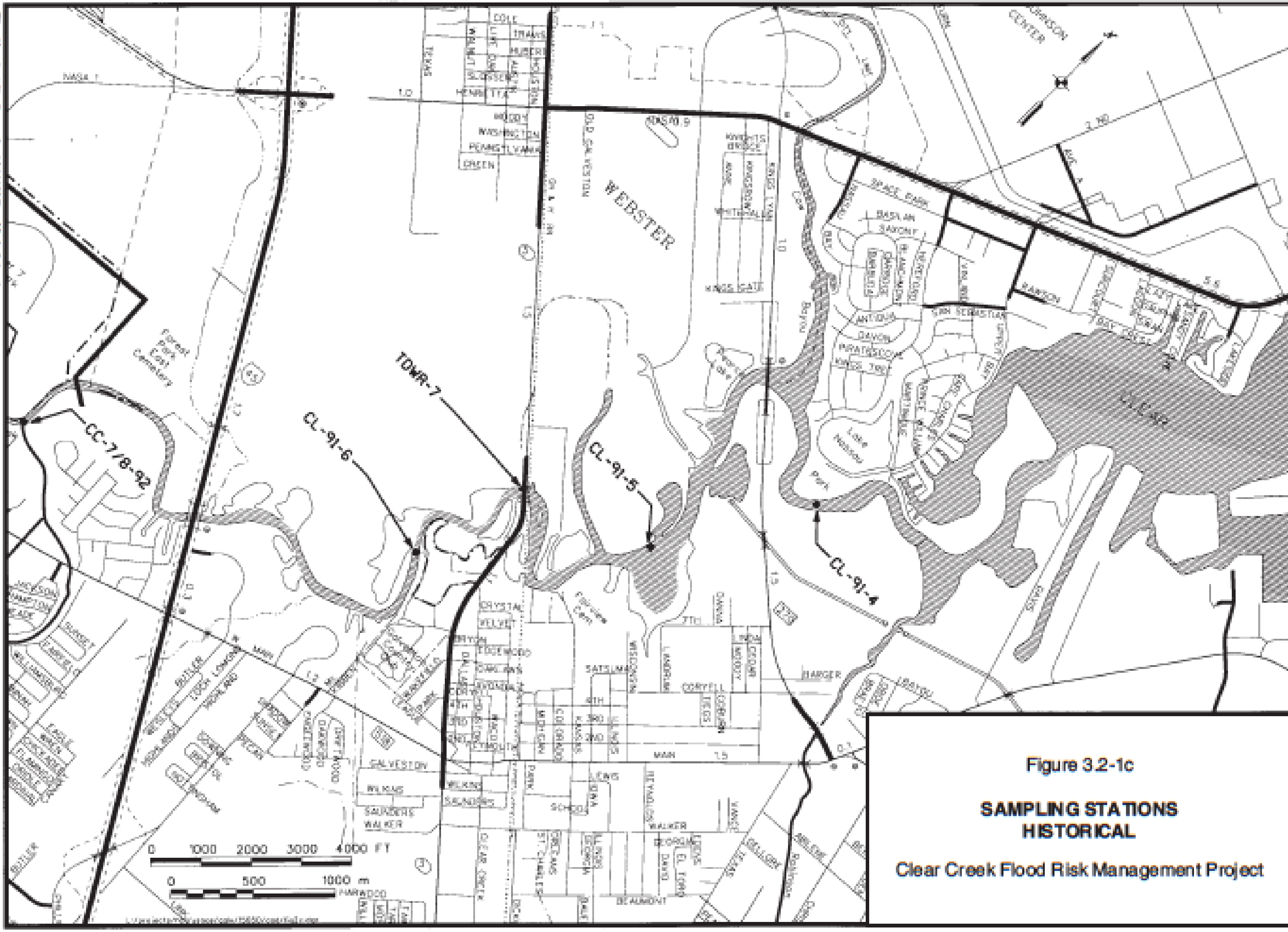

Figure 3.2-1c

SAMPLING STATIONS HISTORICAL

Clear Creek Flood Risk Management Project

3.2.4.2 Volatile Organic Compounds

Nine VOCs were found in the historical data: chloroform, 1,1-dichloroethane, 1,2-dichloroethane, 1,1-dichloroethene, 1,2-dichloroethene, 1,1,2-trichloroethane, 4-methyl-2-pentanone, methylene chloride, and vinyl chloride. Of these, only 1,2-dichloroethane, 1,1,2-trichloroethane, and vinyl chloride were commonly found and in high concentrations. For example, 1,2-dichloroethane was found at concentrations as high as 13,000 micrograms per liter [µg/L] at Station SW-4 (Mud Gully in the Brio Site, December 1993; figures 3.2-1a–c; WCC, 1995–1998). However, concentrations declined so that by fall 1995, some samples on the Brio Site (Station SW-1) had 1,2-dichloroethane concentrations below detection limits. The highest value for this compound in Clear Creek was 190 µg/L at Station SW-21 in winter 1995, followed by 110 µg/L at Station SW-21 in December 1993 and January 1994, and in April–May 1993 at a station in Clear Creek below Mud Gully but upstream of FM 2351 (EPA, 1993). In all of the data collected by WCC for the BSTF (SW stations), there is a definite gradient from SW-4, adjacent to the Brio North Site, to SW-1 at the downstream edge of the Brio North Site, to SW-15 in Mud Gully adjacent to the Brio South Site, to SW-21 in Clear Creek just downstream of its confluence with Mud Gully.

A similar trend can be seen for 1,1,2-trichloroethane, which was found in concentrations as high as 1,2-dichloroethane (13,000 µg/L, Station SW-4, December 1993), and for vinyl chloride, which was found in concentrations as high as 2,300 µg/L at SW-4 in July 1993. By fall 1996, the concentrations of these three compounds were below detection limits some of the time at SW-15, just upstream of EH&A's 1998 Station 3 in Mud Gully, and were consistently below detection limits at Station SW-21, just upstream of Station 4 in Clear Creek. These compounds were not detected in the WCC 1998 study at Station SW-21, nor were they detected at Station 4 in the EH&A 1998 study, although 1,2 dichloroethane and 1,1,2-trichloroethane were detected in low concentrations at Station 3.

All detected parameters were below TWQS or EPA Water Quality Criteria (EPA, 1986; as updated at http://www.epa.gov/waterscience/criteria/wqcriteria.html) if there were no TWQS. Additionally, for those compounds that have no TWQS, toxicity data indicate that the compounds were present at concentrations much lower than those expected to cause toxicity (EH&A, 1998).

3.2.4.3 Semivolatile Organic Compounds

All semivolatile organic compounds were below detection limits, except for simazine (EH&A, 1998). The herbicide simazine was found in one water sample (Station 15 at 0.8 µg/L). However, there are no TWQS for simazine.

3.2.4.4 Pesticides and PCBs

All PCBs were below detection limits in past studies. There are no indications of pesticides in past studies.

3.3 SEDIMENT QUALITY

As noted in the 1982 EIS, pesticides, heavy metals, and PCBs have been found in past sediment samples from Clear Creek. Historically, surficial sediment analyses have indicated presence of various metals concentrations (copper, lead, cadmium, chromium, nickel, iron, zinc, aluminum, and arsenic). Pesticides (including the atrazine and simazine found in water) had not been identified above detection limits in all sediments. However, two types of semivolatile compounds were found in the past: phthalates and polyaromatic hydrocarbons (PAHs). These issues have been monitored since 1982 and are discussed in the following subsections.

As a result of the accidental discharges into Mud Gully that are previously mentioned (Section 3.2), the sediment quality of Clear Creek was negatively impacted. Based on fish samples taken in 1993 and 1994, the TDSHS issued a consumption advisory in 1994. Levels of VOCs have been monitored since then. The fish consumption advisory issued in 1994 was removed based on more-recent fish and blue crab data (TDSHS, 2002). However, in July 2009, the TDSHS issued a fish consumption advisory stating no fish should be consumed from Clear Creek due to elevated PCB levels.

Several sediment studies dating back to 1977 collected and analyzed sediment samples from Clear Creek and tributaries. Two sediment sample types were analyzed in these studies: surficial, or grab samples, and subsurficial, or core samples. These studies tested for metals, VOCs, semivolatile organic compounds, pesticides, PCBs, and total organic carbons (TOCs). Recent monitoring by the USGS (2003) detected chlordane at very low concentrations that were near or below detection levels.

High concentrations of a number of compounds have been found in Mud Gully, with the highest concentrations found near the Brio Superfund Site and Dixie Oil Producers Site. These compounds were found in lesser amounts in Clear Creek. However, data from surficial and subsurficial sediment samples from studies through 1998 show a decrease in concentrations, and the data from the USGS (2003) indicated extremely low concentrations in recent sediments. The TCEQ (2010c) noted no concerns for multiple toxic constituents in sediments from Clear Creek Tidal, Clear Creek Above Tidal, Clear Lake, and Upper Galveston Bay.

EH&A (1998) conducted a study to determine the presence of contaminants in the sediments of Clear Creek (figures 3.3-1a–c). Results of the study are included in the following subsections.

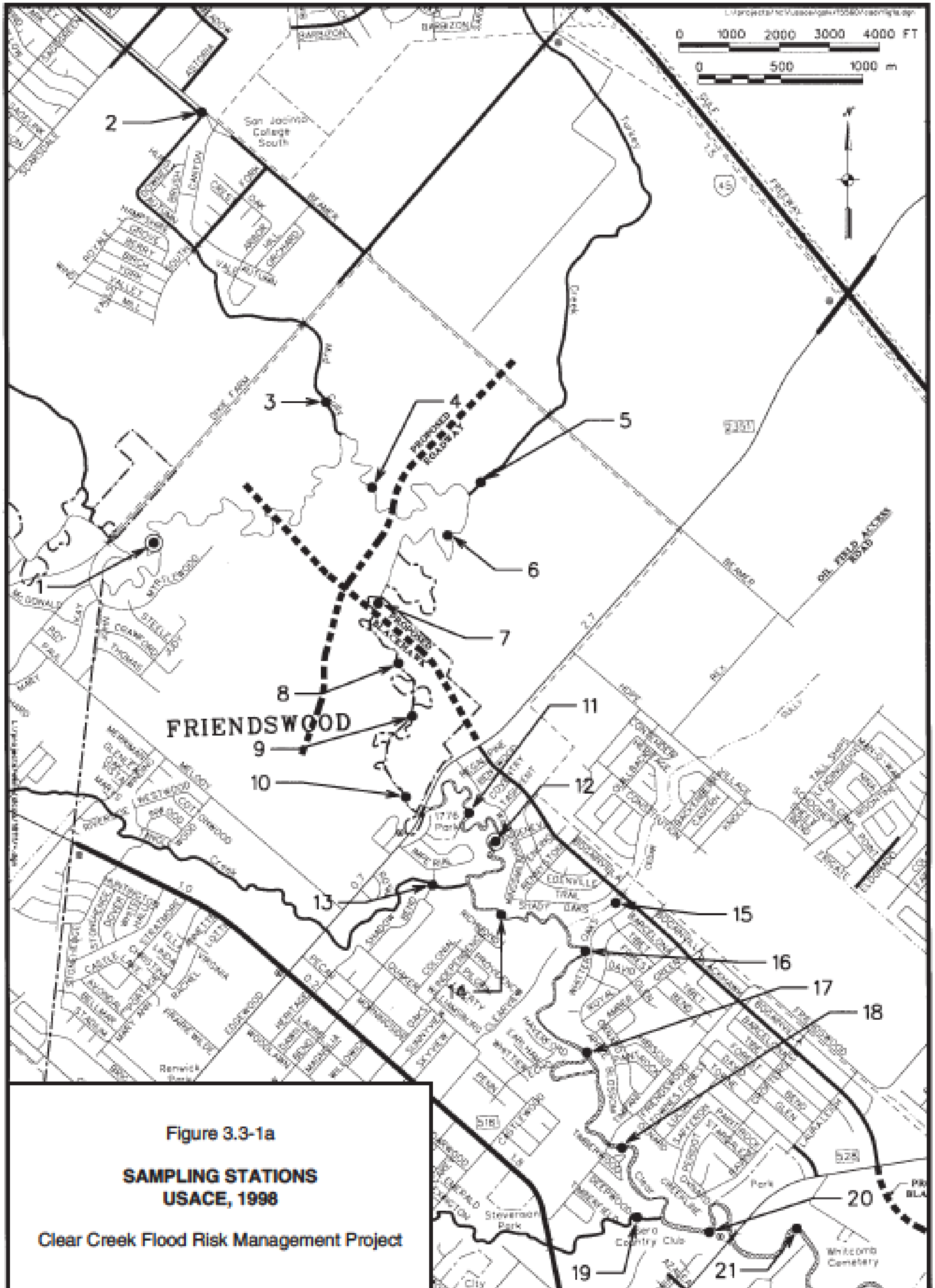

Figure 3.3-1a

SAMPLING STATIONS
USACE, 1998

Clear Creek Flood Risk Management Project

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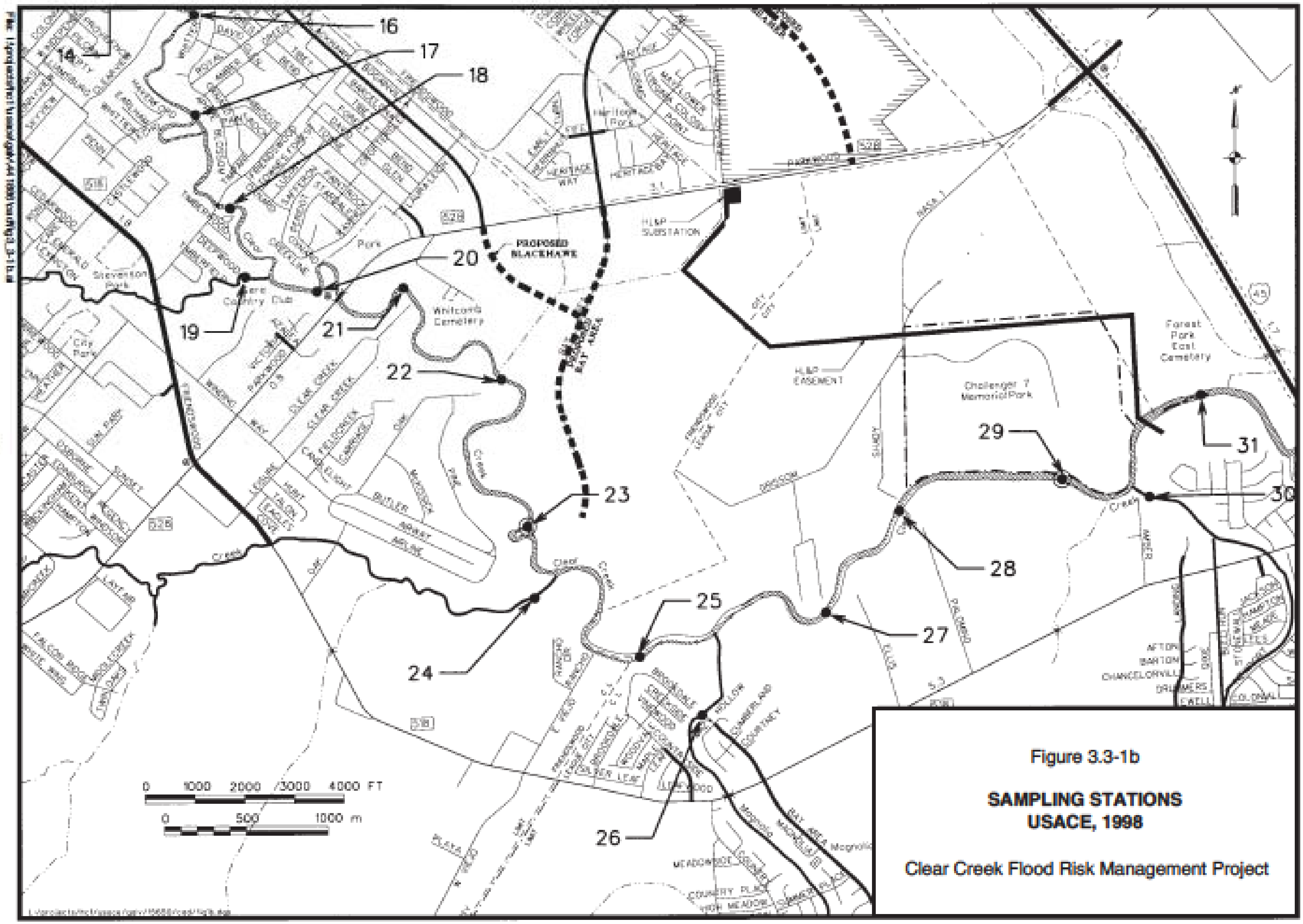


Figure 3.3-1b

SAMPLING STATIONS
USACE, 1998

Clear Creek Flood Risk Management Project

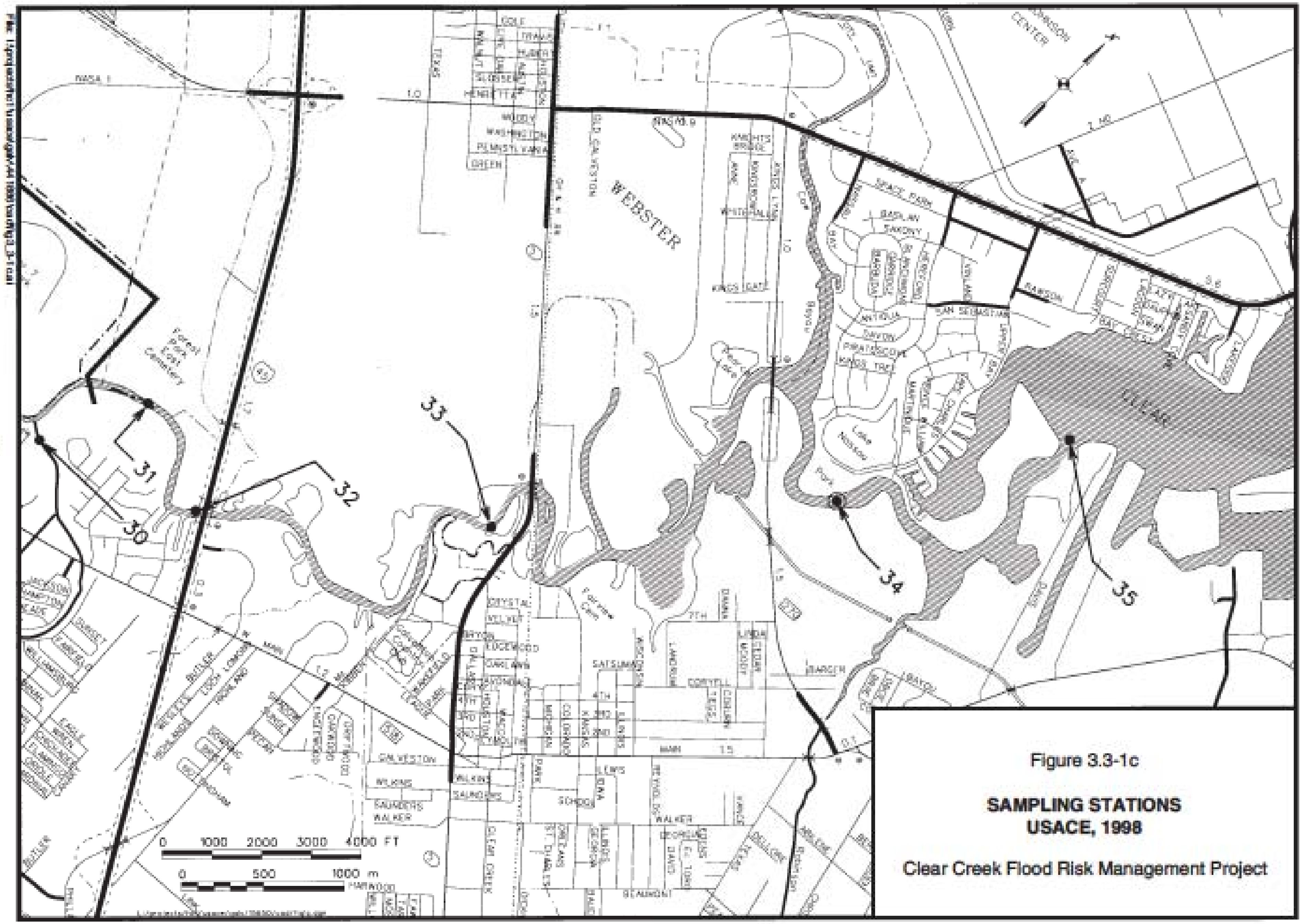


Figure 3.3-1c

SAMPLING STATIONS
USACE, 1998

Clear Creek Flood Risk Management Project

3.3.1 Metals

For surficial sediments, copper concentration data from REI (1986a, 1986b) and TNRCC (1994) indicated an areal trend at and near the Brio Site. These data, as well as the USACE data (EH&A, 1992, 1998) show no areal trend in Clear Creek. There are also no temporal trends evident, although there are some fairly consistent differences between data sets. For instance, when the 1998 data set is compared with the EH&A (1992) and TNRCC (1994) data, lead was consistently lower in 1992 and 1994 than in 1998. Conversely, the lead concentration in sediments from TDWR (1977) are higher than those at comparable sampling stations in the EH&A (1998) study. Cadmium was consistently higher in 1992 than in 1998. There are several metals in the Weston (1996) sediment samples that show similar ranges to the EH&A (1998) study but a higher overall average: chromium, iron, lead, nickel, and zinc. The EH&A (1998) and Weston (1996) data sets showed a wide range of copper values, sometimes between a sample and its duplicate or between nearby stations. The metals concentrations in the sediments show the usual inverse relation to the silt/clay composition of the soil and positive correlation with aluminum concentrations. Copper was an exception, with a low correlation to aluminum, but there were no trends in the copper data that would indicate a source of copper into Clear Creek.

For subsurficial sediments, metals data for core samples were reported for all three studies. The metals concentrations reported for the 1992 study are similar to the values reported in the 1998 study except that, as noted for the surficial sediment samples, cadmium was generally higher in 1992 than in the 1998 study. There was also one high (162 milligrams per kilogram [mg/kg]) copper value in the 1992 new-work data, like those found in 1998 and earlier new-work samples. The arsenic values found in 1994 were much higher than in the 1998 study (37.25 mg/kg versus 1.94 mg/kg, average). The other metals concentrations were similar in 1994 and in the 1998 study.

3.3.2 Volatile Organic Compounds

For surficial sediments, two VOCs (1,1,2-trichloroethane and methylene chloride) were found in 1986 by WCC in Mud Gully, and several others (1,2-dichlorobenzene, cumene, 1,2 dichloro-ethene, and chlorobenzene) were found in the TNRCC (1994) study at the Brio Site and in Mud Gully. However, none were found in Clear Creek or in any of the tributary streams, except Mud Gully. None were found in the 1998 study, even at the Mud Gully station.

For subsurficial sediments, only one VOC was reported in any data set: 42 µg/kg of 1,1,1 trichloroethane at MG-3, in Mud Gully in 1994 (TNRCC, 1994).

3.3.3 Semivolatile Organic Compounds

For surficial sediments, two types of semivolatile compounds were found in the past: phthalates and PAHs. Benzoic acid was also found in 1996 at 1,140 µg/kg.

Bis-(2-ethylhexyl) phthalate was found by Weston in 1996 and EH&A in 1998 at concentrations up to 2,330 µg/kg and 1,156 µg/kg, respectively. Di-n-butyl phthalate was found consistently in 1998 (EH&A); however, detection limits in the 1998 study tend to be lower than in the past, and therefore these compounds could have been present but not detected. As such, direct comparison between the 1998 study and past data is not possible. EH&A (1998) contains a thorough discussion of these phthalate esters.

A total of 18 PAHs were detected in the historical database. PAHs were found in the 1986 and 1987 WCC studies in Mud Gully and in the July 1986 REI study (SED stations, Mud Gully) but not in the October 1986 REI study (SD stations, Mud Gully) or the 1991 USACE study in Clear Lake (EH&A, 1991). EH&A (1998) reported Station 2 (Mud Gully at Beamer Road) sediment samples contained all 18 PAHs that were detected and contained the highest concentrations found for 15 of the 18. The highest value found was for total PAHs at Station HA-77 in the 1986 WCC study, but no map or site description was available for this station and this may be a surficial soil sample, not a stream sediment sample. At any rate, HA-77 is not in Clear Creek (only WCC stations HA-80, HA-81, and HA-82 were in Clear Creek [EH&A, 1998]). In fact, of the stations where PAHs were found in 1986 and 1987, only stations HA-82 and SED-18 were in Clear Creek: SED-18 was at the junction of Mud Gully and Clear Creek, and HA-82 was just downstream of the junction. Fluoranthene, phenanthrene, pyrene, and total PAHs were also found at the April 1996 and May 1996 Weston SL stations that surround EH&A (1998) stations 11 and 12, where PAHs were also found.

For subsurficial sediments, no semivolatile organic compounds were reported in past data sets, although several PAHs, phthalates, and other semivolatiles were found in the 1998 study. As noted for the surficial sediment samples, detection limits may have played a part since the concentrations of the semivolatile organic compounds found in the 1998 study probably would not have been detected in the earlier studies.

3.3.4 Pesticides and PCBs

For surficial sediments, pesticides (including the atrazine and simazine found in water) were below detection limits in all sediments. Aroclor 1260 was the only PCB detected, and it was found in the EH&A (1998) study at Station 28.

For subsurficial sediments, no pesticides or PCBs were found in any sampling efforts, except by the USGS study discussed in the following sentences, although PCBs were not determined in the TNRCC (1994) study. Because of the concerns with chlordane and VOCs in fish tissue, the USGS, in cooperation with the EPA, collected sediment cores from ponds connected to Clear Creek. Only chlordane, DDE (a DDT breakdown product), and PCBs were consistently found at laboratory detection limits. The report found that "concentrations of DDE and PCBs peaked in the mid-1960s and have declined to concentrations near or below reporting levels." Chlordane was found only in more-recent sediment deposits, but concentrations were near or below detection limits that are "not expected to pose a threat to benthic biota" (USGS, 2003).

3.4 HYDROLOGY

3.4.1 Introduction

The Clear Creek watershed is located in the San Jacinto-Brazos Coastal Basin and lies within Harris, Galveston, Brazoria, and Fort Bend counties. The watershed is approximately 250 square miles in size and about 45 miles long in an east-west direction. The width of the watershed varies from 2.5 miles at its upstream end to 13.5 miles at its midpoint. The watershed is a generally flat coastal plain, with a maximum ground surface elevation of approximately 70 feet and a minimum elevation of about 5 feet above msl at the mouth of Clear Creek where it empties into Clear Lake. Clear Lake is a 2.0-square-mile, brackish, tidally influenced waterbody on the western shore of Upper Galveston Bay that receives inflows predominantly from Clear Creek and Armand Bayou.

As shown on Figure 1.1-1, the Clear Creek system includes 15 to 20 tributaries of hydraulic significance. Eight of these tributaries discharge into Clear Creek above mile 3.8 (the approximate dividing line between Clear Creek and Clear Lake) and include Mud Gully, Hickory Slough, Chigger Creek, Cowart Creek, Cow Bayou, Magnolia Creek, Mary's Creek, Robinson Bayou, and Turkey Creek. The remaining 10 tributaries discharge into Clear Lake predominantly through two smaller lakes, Mud Lake and Taylor Lake. Big Island Slough, Horsepen Bayou, Spring Gully, and Willow Springs Bayou drain into Armand Bayou that empties into Mud Lake, which then discharges into the northern portion of Clear Lake. Boggy Bayou and Taylor Bayou empty into Taylor Lake, which also discharges into the northern portion of Clear Lake. Jarbo Bayou drains into the southeast side of Clear Lake, near the lake's outlet into Galveston Bay.

The average annual precipitation over the Clear Creek watershed is approximately 51 inches, most of which occurs as sudden thunderstorms and rainfalls associated with tropical weather systems. The high-intensity rainfall that occurs during very slow-moving or stationary tropical cells normally results in major flooding within the Houston-Galveston area, including the Clear Creek watershed.

3.4.2 Flows

Normal water flow within the lower half of Clear Creek is typically sluggish but persists year round, while the upper reaches of Clear Creek experience intermittent flows. The lower half of Clear Creek consists of perennial, sluggish flow while the upper reaches of Clear Creek consist of intermittent flow. The USGS has maintained a set of gaging stations along Clear Creek, including (period of record shown in parentheses):

- USGS 08077000 Clear Creek near Pearland, Texas (1944–1994)
- USGS 08077100 Clear Creek Tributary at Hall Road, Houston, Texas (1965–1986)
- USGS 08077540 Clear Creek at Friendswood, Texas (1994–1997)
- USGS 08077600 Clear Creek near Friendswood, Texas (1966–current)
- USGS 08077637 Clear Lake Second Outflow Channel at Kemah, Texas (1998–current)

Table 3.4-1 provides information on location, contributing watershed area, and a summary of available flow records of these gages. As can be seen from the table, the gage near Pearland (08077000) contains the greatest amount of flow data, while the other gages contain only limited or no flow data. The Pearland gage has a drainage area of 38.8 square miles and is in the upstream reach of the stream. Table 3.4-2 provides a list of peak flow data recorded at the Pearland gage that shows a 2,170 cubic feet per second (cfs) historical peak flow occurring on March 18, 1957. Figure 3.4-1 shows daily flow values recorded at the Pearland gage, indicating a minimum, average, and maximum daily flow of 0, 37, and 2,030 cfs, respectively.

Table 3.4-1
USGS Gages in Clear Creek Watershed

Gage	08077100			08077600		
Name	Clear Creek Trib at Hall Road, Houston			Clear Creek near Friendswood		
Latitude	29°36¢09²			29°31¢02²		
Longitude	95°16¢41²			95°10¢42²		
Drainage Area	1.31 square miles			122 square miles		
Period	From	To	Count	From	To	Count
Peak flow	12/10/1964	11/29/1977	14	5/13/1972	9/13/2000	24
Daily flow				10/8/1997	9/12/1998	7
Gage	08077000			08077637		
Name	Clear Creek near Pearland			Clear Lake Second Outflow Channel at Kemah		
Latitude	29°35¢50²			29°33¢01²		
Longitude	95°17¢11²			95°01¢26²		
Drainage Area	38.8 square miles			167 square miles		
Period	From	To	Count	From	To	Count
Peak flow	9/28/1946	6/25/1994	46			
Daily flow	8/1/1944	9/4/1994	15958	(Real Time Water Level Data Only)		
Gage	08077540					
Name	Clear Creek at Friendswood					
Latitude	29°32¢31²					
Longitude	95°11¢48²					
Drainage Area	99.6 square miles					
Period	From	To	Count			
Peak flow	10/18/1994	4/26/1997	3			
Daily flow	10/1/1995	8/25/1997	488			

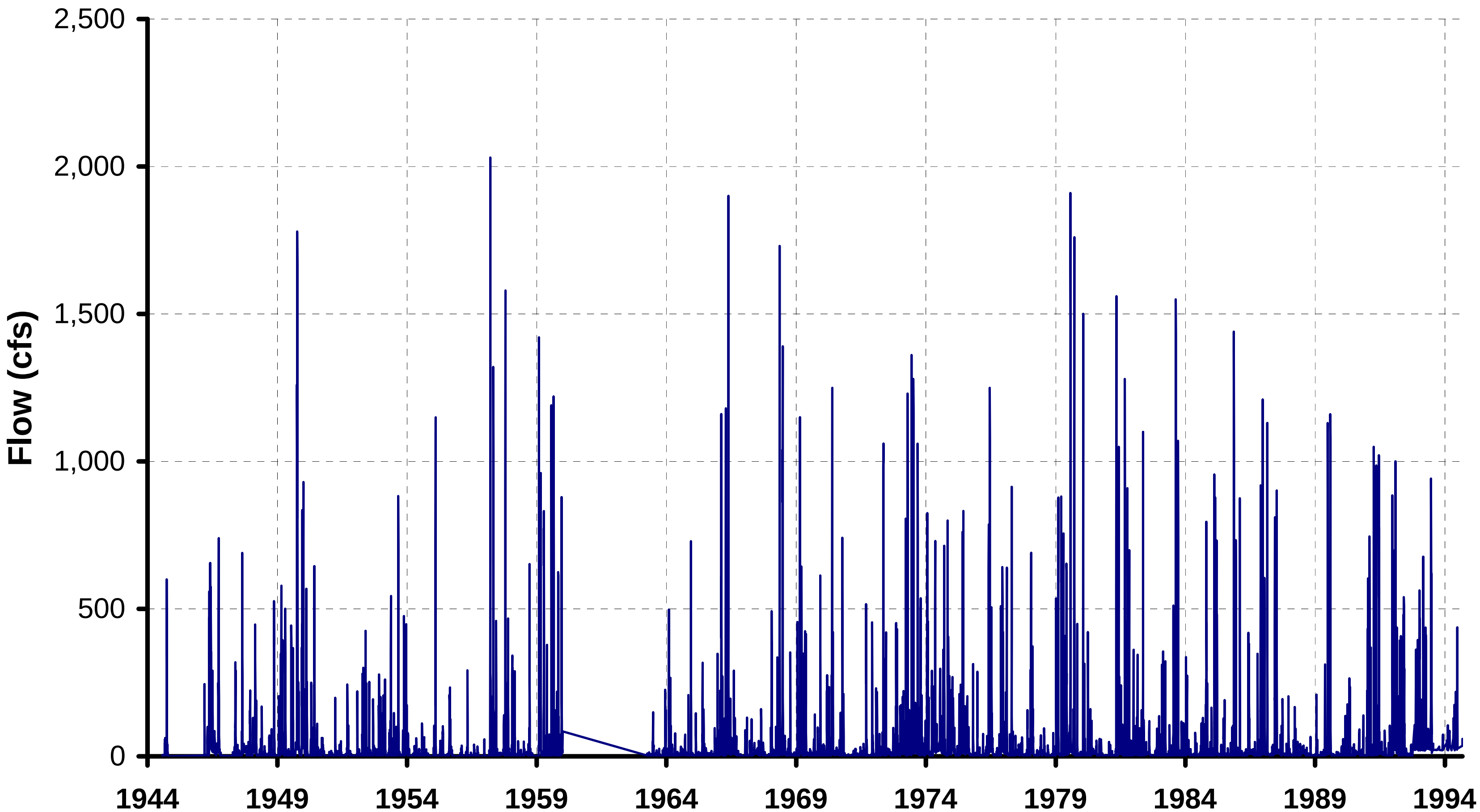
Source: USGS (2007).

Table 3.4-2
Peak Flows at USGS 08077000
Clear Creek near Pearland

Water Year	Date	Gage Height (feet)	Flow (cfs)	Water Year	Date	Gage Height (feet)	Flow (cfs)
1946	09/28/46		880	1972	05/12/72	16.62	1,220
1947	08/25/47		710	1973	06/13/73	17.51	1,370
1948	02/24/48		551	1974	01/19/74	16.07	1,210
1949	11/16/48		759	1975	06/10/75	15.45	1,040
1950	10/08/49		1,840	1976	06/16/76	17.28	1,300
1951	09/14/51		267	1977	04/21/77	14.95	1,150
1952	07/17/52	7.86	673	1978	01/19/78	12.99	801
1953	08/31/53	11.51	1,130	1979	07/26/79	18.57	1,950
1954	11/18/53	9.19	717	1980	01/22/80	17.89	1,800
1955	02/06/55	14.00	1,350	1981	05/04/81	17.11	1,650
1956	05/02/56	8.26	469	1982	05/14/82	15.59	1,230
1957	03/18/57	16.80	2,170	1983	08/19/83	18.17	1,570
1958	10/16/57	17.16	1,640	1984	01/10/84	7.76	390
1959	07/25/59	16.70	1,550	1985	03/14/85	15.18	1,320
1963	06/26/63	7.47	190	1986	11/12/85	17.52	1,450
1964	02/04/64	11.63	820	1987	12/23/86	15.93	1,240
1965	12/10/64	15.22	1,020	1988	12/21/87	6.87	270
1966	05/21/66	17.49	2,050	1989	06/27/89	17.12	1,190
1967	04/13/67	8.60	245	1990	05/04/90	7.95	300
1968	05/11/68	16.93	1,800	1991	04/06/91	16.44	1,110
1969	02/21/69	15.13	1,470	1992	02/04/92	15.73	1,030
1970	05/22/70	15.91	1,430	1993	06/20/93	16.62	1,130
1971	10/12/70	13.25	863	1994	06/25/94	10.26	480
Max Ht.	05/21/66	17.49	2,050	Max Ht.	07/26/79	18.57	1,950
Max Flow	03/18/57	16.80	2,170	Max Flow	07/26/79	18.57	1,950

Source: USGS (2007).

FIGURE 3.4-1
DAILY FLOWS AT USGS 08077000,
CLEAR CREEK NEAR PEARLAND



A more-downstream USGS gage located near Friendswood (USGS 08077600) also has flow data (see Table 3.4-1). This gage has a drainage area of 122 square miles. The gage contains peak gage height and/or peak flow records from 1972 to 2000, and daily flows on October 8, 9, 12, and 13, 1997; December 8, 1997; and September 11–12, 1998. As listed in Table 3.4-3, the maximum peak flow rate recorded was 9,000 cfs occurring on July 27, 1979, which corresponds to a gage height of 19.1 feet. However, the maximum gage height recorded was 20.85 feet on August 1, 1989. The range of the seven daily flows recorded (October 1997–September 1998) (see Table 3.4-1) is between 2,290 and 6,630 cfs, with a mean of 3,849 cfs. Note that flow at this location is influenced by tide, and daily flows are computed only for days in which there is no tidal influence.

Table 3.4-3
Peak Flows at USGS 08077600
Clear Creek near Friendswood

Water Year	Date	Gage Height (feet)	Flow (cfs)	Water Year	Date	Gage Height (feet)	Flow (cfs)
1972	05/13/72	12.06		1985	03/14/85	12.54	
1973	06/13/73	19.27		1987	06/13/87	14.02	
1975	06/10/75	10.89		1988	04/03/88	7.06	
1976	06/17/76	12.75		1989	08/01/89	20.85	
1977	04/21/77	10.40		1990	05/04/90	7.37	
1978	01/19/78	10.00		1991	04/05/91	14.16	
1979	07/27/79	19.10	9,000	1992	06/02/92	11.67	
1980	01/22/80	15.35		1993	03/02/93		
1981	05/04/81	15.89		1994	10/20/93	12.38	
1982	05/14/82	10.23		1998	09/11/98	13.47	7,500
1983	08/18/83	17.29		1999	11/14/98	13.50	7,520
1984	01/09/84	7.73		2000	09/13/00	3.79	1,150
Max Ht.	06/13/73	19.27		Max Ht.	08/01/89	20.85	
Max Flow	07/27/79	19.10	9,000	Max Flow	11/14/98	13.50	7,520

Source: USGS (2007).

As listed in Table 3.4-1, another USGS gage at Friendswood (USGS 08077540) also has flow data. This gage has a drainage area of 99.6 square miles. Figure 3.4-2 shows daily flow values recorded at this Friendswood gage between October 1995 and August 1997, indicating a minimum, average, and maximum daily flow of 19, 224.4, and 4,190 cfs, respectively.

As a summary, typical dry-weather flow in Clear Creek appears to range from 0 (intermittent) in the upstream reaches to about 20 cfs in downstream reaches. Average daily flow increases from about 40 cfs upstream to about 220 cfs downstream. Peak flow ranges from about 2,000 cfs upstream to at least 9,000 cfs downstream.

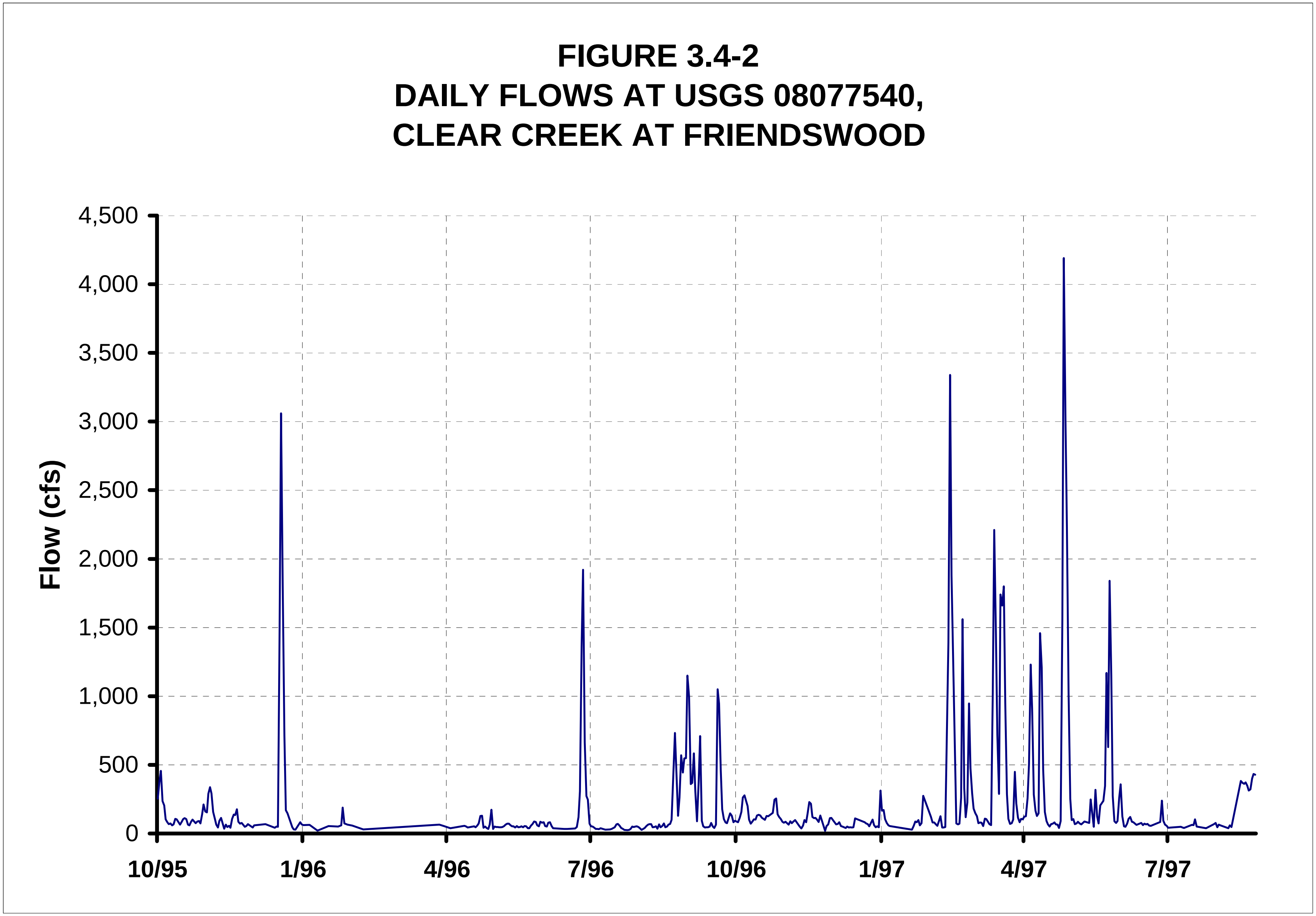


FIGURE 3.4-2
DAILY FLOWS AT USGS 08077540,
CLEAR CREEK AT FRIENDSWOOD
Flow (cfs)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
10/95
1/96
4/96
7/96
10/96
1/97
4/97
7/97

3.4.3 Flow Diversion and Point Source Discharges

The tidal regime of both the Clear Creek Tidal segment and Clear Lake is similar to that of Galveston Bay. Because of Clear Creek's proximity to Clear Lake and Galveston Bay, a saltwater wedge is present within the creek. The leading edge of the salt wedge in Clear Creek is variable with respect to tidal action and season of the year, but typically oscillates between the mouth of Chigger Creek to FM 528 (see Figure 1.1-1). The effect of tidal influence on stream velocity extends another mile above the leading edge of the salt wedge.

The flow regime of lower Clear Creek is also significantly influenced by Reliant Energy's Webster Generating Station that withdraws approximately 690 cfs for cooling water at Mile 7.8 and returns it at Mile 3.0. During low-flow and weak tidal conditions, a circulation pattern may develop. During low-flow conditions, the stream flow in Clear Creek is also influenced by the discharge from permitted wastewater treatment plants or point sources along the creek. In Segment 1102, 19 point sources have a total permitted flow of 22.63 million gallons per day (mgd), or 35.0 cfs. In Segment 1101, nine dischargers have a total permitted flow of 18.23 mgd, or 28.2 cfs (TNRCC, 2002).

3.4.4 Clear Lake and Tides

Clear Lake is a brackish, tidally influenced waterbody of approximately 1,300 acres (2 square miles) on the western shore of Upper Galveston Bay that receives inflows predominantly from Clear Creek, Taylor Bayou, and Armand Bayou. Clear Lake covers an area from Kemah Channel connecting the lake with Galveston Bay to a point about 3.8 miles upstream where Clear Creek flows into the lake. Clear Lake is shallow, averaging about 4 to 6 feet in depth.

Tides in Clear Lake are similar to those in Galveston Bay, but lag by 2 to 3 hours. The water exchange between the lake and the bay during the 24-hour period of diurnal tides varies from 1,500 to 3,000 acre-feet and from one-half to three-fourth as much during the 24-hour period of mixed tides. The Texas Coast Ocean Observation Network (TCOON) maintains a tide gage located at 29°33.8′N and 95°4.0′W within Clear Lake. This tide gage, CBI 502 (NOAA 87709331), has 10 years of water level records. Statistics of tidal records at this Clear Lake TCOON gage (all elevations are above the station datum) are presented in Table 3.4-4.

A tide range of 1.01 feet can be calculated from this table (mean high water–mean low water, mhw–mlw). This is typical of the Galveston Bay area.

Water levels in Clear Lake can be affected by meteorological conditions. Seiches or wind tides can occur during periods with sustained easterly or westerly winds; however, the predominant south-southeast wind does not result in significant wind tide because of the narrow lake width from north to south. Lake levels can also be affected by storm surges produced in the Gulf of Mexico and propagated through Galveston Bay to Clear Lake. For Clear Lake, hurricanes represent the most severe conditions because surges of 10.4 feet can cause severe flooding around Clear Lake and along the Clear Creek Tidal segment.

Table 3.4-4
TCOON, Clear Lake Tidal Records (1992–2000)

	Feet	Meters
Mean Higher High Water	6.20	1.891
Mean High Water (mhw)	6.15	1.874
Mean Tide Level	5.65	1.721
Mean Sea Level (msl)	5.68	1.730
Mean Low Water (mlw)	5.14	1.568
Mean Lower Low Water	5.06	1.542

Source: Texas A&M University at Corpus Christi (2007).

Lake levels are also significantly affected by large volumes of fresh water discharged from the Clear Creek watershed. Because Clear Lake averages from 4 to 6 feet in depth, discharges of large volumes of fresh water can cause significant flooding around Clear Lake that can increase in severity if high tides or storm surges occur simultaneously with large freshwater discharges. It should be noted that the presence of the Second Outlet Channel and Gate Structure allows for the release of flood waters from rainfall events, reducing the potential for flooding around Clear Lake from freshwater discharges (see Hydrology and Hydraulics Appendix to the GRR and Section 4.4).

3.4.5 Flood Insurance Study

A Flood Insurance Study (FIS) approved by the Federal Emergency Management Agency (FEMA) provides Flood Insurance Rate Maps (FIRMs), which are used by the insurance industry to establish flood insurance rates for properties dependent on their location relative to the floodplain. The floodplain is defined by establishing the Base Flood Elevation (BFE) at various locations within a drainage basin using FEMA-accepted hydrologic and hydraulic modeling techniques (Figure 3.4-3). Once an FIS is completed and made "effective," a property's location relative to the floodplain cannot be questioned unless or until either a restudy or a Letter-of-Map-Revision (LOMR) is completed to adjust the BFEs and floodplain delineation. Revisions to an FIS are usually initiated following major flood events or major improvements within a watershed.

The study area is covered under FISs for Harris, Galveston, Brazoria, and Fort Bend counties. The initial countywide FIS for Harris County was effective on September 28, 1990; for Brazoria County on September 22, 1999; for Galveston County on December 6, 2002; and for Fort Bend County on November 7, 2001. A revision was required after Tropical Storm Allison and was effective on June 18, 2007 (FEMA, 2007). Floodplain profiles along Clear Creek from 4.17 to

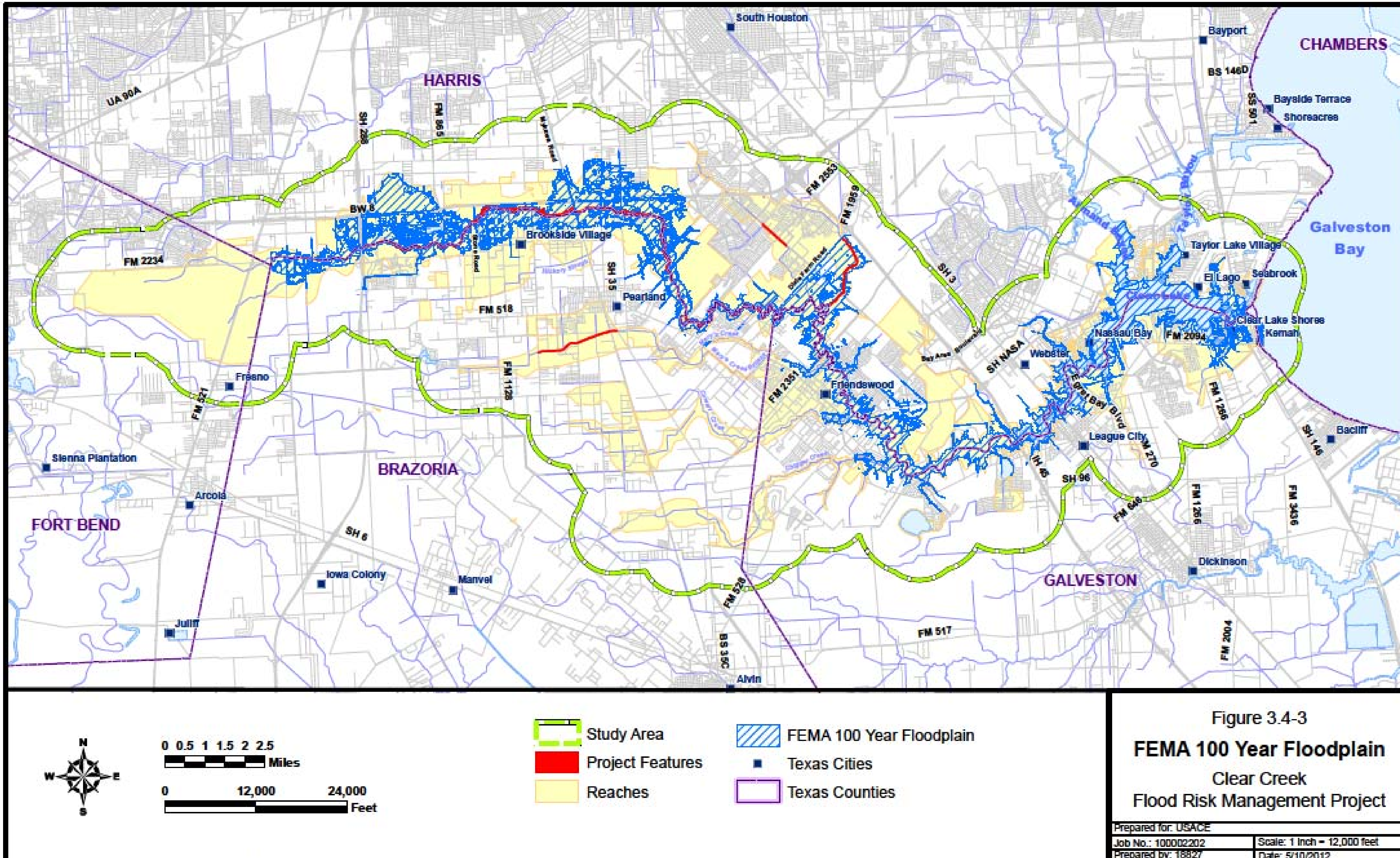


Figure 3.4-3
FEMA 100 Year Floodplain
Clear Creek
Flood Risk Management Project

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11.1 miles upstream of Galveston Bay indicate that the floodplain is affected by the combined flooding effects from both Clear Creek and Galveston Bay.

3.4.6 Groundwater Hydrology

The Gulf Coast regional area includes the Gulf Coast, Yegua-Jackson, and Brazos River Alluvium aquifers. The study area is located within the Gulf Coast aquifer, which is a major supplier of groundwater to Harris, Galveston, and Brazoria counties. The Gulf Coast aquifer is further subdivided into four units, each of which can be correlated to different geologic formations. The uppermost water-bearing unit is the Chicot aquifer, which is composed of the Willis Sand, Bentley, and Montgomery formations, Beaumont Formation, and alluvial deposits at the surface (Texas Water Development Board [TWDB], 2006a). Underlying the Chicot aquifer is the Evangeline aquifer, which contains water within the Goliad Sand. The Chicot-Evangeline boundary runs approximately parallel to the coast and forms an outcrop about 90 miles inland (Baker, 1979). Total thickness of the Gulf Coast aquifer within the study area is estimated to be over 1,000 feet.

Groundwater recharge into aquifers occurs primarily by precipitation onto outcropped areas and downward leakage from overlying saturated layers (perched) and/or aquifers. Regional groundwater flow in the aquifers is generally in a southeastward direction from outcrop areas towards areas of natural discharge (Wesselman, 1971). Superimposed upon this natural discharge regime is artificial discharge from groundwater pumping.

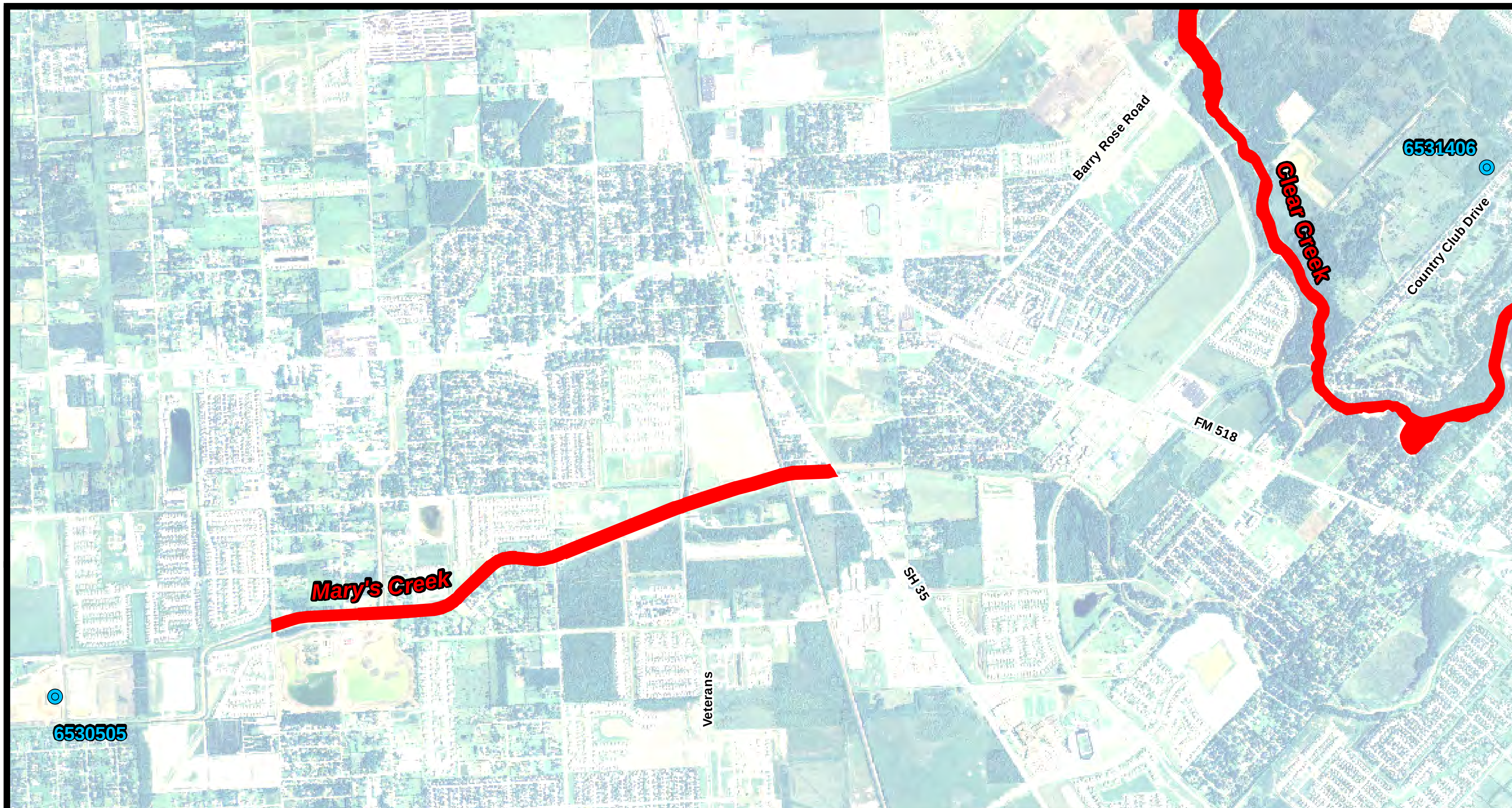
Between 1985 and 2000, over 1 million acre-feet of groundwater per year was pumped from the Gulf Coast aquifer (TWDB, 2006b). Land-surface subsidence, primarily a consequence of the removal of groundwater, affects most of the eastern half of Harris County, parts of adjacent Brazoria County, and most of the mainland part of Galveston County (Fisher et al., 1972).

A sole source aquifer (SSA) is an aquifer that has been designated by the EPA under the Safe Drinking Water Act of 1974 as the sole or principal source of drinking water for an area. As such, a designated SSA receives special protection. The EPA has not designated any SSAs within the study area (EPA, 2007a). Records from the TWDB indicate that there are no water wells located within the project footprint (Figure 3.4-4).

3.5 AIR QUALITY

3.5.1 Regulatory Context

The following sections discuss the applicable regulatory framework and existing ambient air quality within the study area. Due to the regional nature of air quality, the study area for air quality purposes consists of the Houston-Galveston-Brazoria (HGB) Nonattainment Area. For air quality monitoring and planning purposes, the EPA relies on a designation system for air



Key

Water Well Locations

Conveyance and Protected Riparian Habitat Corridor

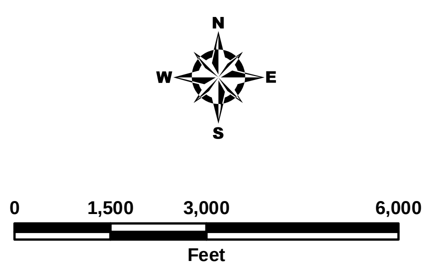


Figure 3.4-4

Water Wells

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1in = 3,000ft
Prepared by: AC/DR	Date: 1/2/2009

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/water_well_locations_vr3.mxd pollutants within the boundaries of the HGB, which includes the counties affected by the study, i.e., portions of Harris County, Galveston County, and Brazoria County.

3.5.1.1 National Ambient Air Quality Standards

The Clean Air Act (CAA), which was last amended in 1990, regulates air emissions from area, stationary, and mobile sources. The CAA requires the EPA to establish primary and secondary National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. Primary standards define the maximum levels of air quality that the EPA judges necessary, with an adequate margin of safety, to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards define the maximum levels of air quality that the EPA judges necessary to protect public welfare, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings. Air quality is generally considered acceptable if pollutant levels are less than or equal to these established standards on a continuing basis.

The EPA has set NAAQS for seven principal pollutants, called "criteria" pollutants. They are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), inhalable particulate matter with an aerodynamic diameter less than or equal to a nominal 10 microns (PM_{10}), fine particulate matter with an aerodynamic diameter less than or equal to a nominal 2.5 microns ($PM_{2.5}$), and sulfur oxides. The NAAQS are further defined in 40 CFR, Part 50 (2007b).

Carbon monoxide is a colorless and practically odorless gas primarily formed when carbon in fuels is not burned completely. Transportation activities, indoor heating, industrial processes, and open burning are among the anthropogenic (man-made) sources of CO.

Nitrogen dioxide, nitric oxide (NO), and other oxides of nitrogen are collectively called nitrogen oxides (NO_x). These species are interrelated, often changing from one form to another in chemical reactions. NO_2 is the species commonly measured in ambient air monitors. NO_x emissions are generally emitted in the form of NO, which is oxidized to NO_2. The principal anthropogenic sources of NO_x are fuel combustion in motor vehicles and stationary sources such as boilers and power plants. Reactions of NO_x with other atmospheric chemicals can lead to the formation of ozone.

Ground-level ozone is a secondary pollutant, formed from daytime reactions of NO_x and VOCs rather than being directly emitted by natural and anthropogenic sources. VOCs, which have no NAAQS, are released in industrial processes and from evaporation of organic liquids such as gasoline and solvents. Ozone contributes to the formation of photochemical smog.

Pb is a heavy metal that may be present as dust or as a fume. Dominant industrial sources of Pb emissions include waste oil and solid waste incineration, iron and steel production, lead smelting, and battery and lead alkyl manufacturing. The lead content of motor vehicle emissions, which was the major source of lead in the past, has significantly declined with the widespread use of unleaded fuel.

The NAAQS for particulate matter are based on two different particle-diameter sizes: PM_{10} and $PM_{2.5}$. PM_{10} are small particles that are likely to reach the lower regions of the respiratory tract by inhalation. $PM_{2.5}$ is particulate matter that is considered to be in the respirable range, meaning these particles can reach the alveolar region of the lungs and penetrate deeper than PM_{10}. There are many sources of particulate matter, both natural and anthropogenic, including dust from natural wind erosion of soil, construction activities, industrial activities, and combustion of fuels.

Sulfur oxide gasses (SO_x) are colorless with a sharp, pungent odor. SO_x are emitted in natural processes, such as volcanic activity, and by anthropogenic sources such as combustion of fuels containing sulfur and the manufacture of sulfuric acid.

The CAA also requires the results of the ambient air quality monitoring data be used by the EPA to assign a designation to each area of the U.S. regarding compliance with the NAAQS. The EPA categorizes the level of compliance or noncompliance with each criteria pollutant as follows:

- Attainment – area currently meets the NAAQS
- Maintenance – area currently meets the NAAQS, but has previously been out of compliance
- Nonattainment – area currently does not meet the NAAQS

Ozone nonattainment areas are further classified as extreme, severe, serious, moderate, or marginal depending on the severity of nonattainment.

Under the CAA, individual states were required to develop a State Implementation Plan (SIP) to define the strategies for assessing and maintaining the NAAQS. The TCEQ has the responsibility for developing the SIP with approval by the EPA. For areas that are in nonattainment with the NAAQS, the SIP describes how the area will reach attainment of the air quality standards. The SIP sets emissions budgets for point sources such as power plants and manufacturers, area-wide sources such as dry cleaners and paint shops, off-road mobile sources such as boats and lawn mowers, and on-road sources such as cars, trucks, and motorcycles.

As previously noted, the project study area for air quality purposes includes Harris, Galveston, and Brazoria counties. These counties are within the HGB ozone nonattainment area. The EPA has classified the HGB as being in attainment or unclassified with the NAAQS for all criteria pollutants except ozone. The HGB is classified as a "severe" nonattainment area under the 1-hour ozone standard and under the 8-hour NAAQS. The attainment date under the 8-hour ozone standard is 2019. Thus, by 2019, the area is expected to achieve and maintain attainment with the NAAQS for ozone. The planning and implementation of the SIP requirements incorporate the effects of population and industrial growth, technology changes, and national or statewide control measures. Counties in the HGB Nonattainment Area affected under this status are Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller.

The topography and meteorology of the study area should not seriously restrict dispersion of airborne pollutants. However, ground-level ozone is typically formed during periods of high solar radiation, low wind speeds, and elevated temperatures. There is a significant amount of variability year to year in regional ozone levels. This year-to-year variability is generally considered to be the result of the important role that weather conditions play in ozone formation.

3.5.1.2 Conformity of Federal Actions

The CAA prohibits Federal agencies from funding, permitting, constructing, or licensing any project that does not conform to an applicable SIP. The purpose of this General Conformity requirement is to ensure that Federal agencies consult with State and local air quality districts to assure these regulatory entities know about the expected impacts of the Federal action and have considered or will include expected emissions in their SIP emissions budget.

Because the project is located in the HGB Nonattainment Area for ozone, if the total emissions from the project are equal to or greater than 25 tons per year (tpy) of VOC or 25 tpy of NO_x, the USACE must prepare a General Conformity Determination demonstrating how the project conforms or will conform with the SIP for that pollutant, prior to providing approval for the project. Even if the emissions of NO_x or VOCs are below these levels, a conformity determination may also be required if the increase in emissions due to the project would equal or exceed 10 percent of the total emissions of those pollutants for the entire nonattainment area (i.e., the project is considered a regionally significant action).

Because project emissions are estimated to exceed 25 tpy for NO_x, a Draft General Conformity Determination has been prepared by the USACE. The determination takes into account estimated project emissions and whether or not those emissions conform to the SIP. The General Conformity Determination was submitted to the EPA and TCEQ for review concurrent with the DSEIS. Concurrence that the NO_x emissions are consistent with the SIP was provided by the TCEQ via letter dated February 7, 2012 (Appendix H). As the project moves forward, the USACE will update the EPA and TCEQ to ensure that project emissions are consistent with the most currently approved SIP emissions budgets, taking into account any potential changes to the project schedule and future SIP revisions.

3.5.1.3 Greenhouse Gas Emissions and Climate Change

Air emissions from the GRP Alternative will result from the operation of construction equipment powered by internal combustion engines that produce exhaust emissions. Emissions from this equipment will result in an increase in Greenhouse Gas (GHG) emissions that could contribute to global climate change. To date, specific thresholds to evaluate adverse impacts pertaining to GHG emissions have not been established by local decision-making agencies, the State, or the Federal government. The Council on Environmental Quality (CEQ) has published “Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions,” February 10, 2010. The Draft Guidance suggests that the impacts of projects directly emitting GHGs in excess of 25,000 metric tons or more of carbon dioxide (CO_2)-equivalent (CO_2e) GHG emissions on an annual basis be considered in a qualitative and quantitative manner. However, the guidance stresses that, given the nature of GHGs and their persistence in the atmosphere, climate change impacts should be considered on a cumulative level.

3.5.2 Air Quality Baseline Condition

Ambient air quality in the project area is directly related to emissions from man-made sources such as stationary sources (stacks, vents, etc.); emissions from mobile sources such as vehicles, ships, trains, etc.; chemical reactions in the atmosphere such as the formation of ozone; and natural sources such as trees, fires, and wind-blown dust. Since all of these sources must be considered in an assessment of air quality, the EPA has identified air emissions inventories and ambient air monitoring as key methods for assessing air quality.

3.5.2.1 Existing Air Emissions Inventory

Baseline emissions were determined using data from the EPA’s emissions inventory database (EPA, 2010). Table 3.5-1 is a summary of emissions for Harris, Galveston, and Brazoria counties for 2002, the most recent data available from the EPA’s database. For comparison, the total emissions inventory for the HGB is also provided. The emissions information for each pollutant is broken out by category: area source, point source, highway, and off-highway emissions. These data provide a base from which to compare the proposed project emissions.

3.5.2.2 Existing Air Monitoring Data

Air pollutants within and near the project area are measured by numerous air-monitoring stations. Most of the stations in the region measure the concentrations of criteria air pollutants, as well as temperature, wind velocity, wind direction, and other meteorological parameters. The monitors operate continuously and are routinely calibrated and maintained to assure quality data. Current monitoring data are available for CO, NO_2, O_3, sulfur dioxide (SO_2), $PM_{2.5}$, PM_{10}, and Pb. Monitoring for other criteria pollutants has either been discontinued or data are not available.

Table 3.5-1
Summary of 2002 Air Emissions Inventory for Harris, Galveston, and Brazoria Counties by Source Category

	Source Category	CO (tpy)	NO_X (tpy)	PM_{10} (tpy)	$PM_{2.5}$ (tpy)	SO_2 (tpy)	VOC (tpy)
Harris County	Area	26,113	45,197	6,301	5,392	30,708	30,270
	Point Source	26,686	10,718	128,789	17,864	17,258	58,219
	Highway Vehicles	428,708	69,984	1,930	1,334	2,290	35,548
	Off-Highway	282,110	74,154	4,548	4,267	7,368	22,529
SUBTOTAL		**763,617**	**200,053**	**141,568**	**28,857**	**57,625**	**146,566**
Galveston County	Area	7,449	16,809	2,081	1,756	8,099	6,899
	Point Source	3,007	1,521	12,396	1,562	759	4,815
	Highway Vehicles	31,428	4,587	119	82	141	2,570
	Off-Highway	19,256	28,536	1,755	1,620	7,315	3,308
SUBTOTAL		**61,140**	**51,453**	**16,351**	**5,020**	**16,314**	**17,591**
Brazoria County	Area	5,974	20,851	898	826	4,705	6,111
	Point Source	7,355	2,114	38,241	4,581	1,441	4,655
	Highway Vehicles	29,211	4,183	115	80	137	2,349
	Off-Highway	17,277	16,980	1,109	1,028	4,911	2,727
SUBTOTAL		**59,817**	**44,128**	**40,363**	**6,515**	**11,194**	**15,842**
TOTAL – HGB		**1,101,693**	**357,353**	**325,353**	**59,155**	**152,017**	**214,128**

Source: EPA (2010).

Review of available monitoring data for the HGB for the years 1997–2007 (EPA, 2007b) shows a decreasing trend over the years for CO, $PM_{2.5}$, and SO_2. Monitored values for ozone also appear to be declining, probably as a result of increased regulations to meet the NAAQS for ozone. Concentrations of PM_{10} appear to have increased over the years. Monitored values for NO_2 and Pb show little variability over the past few years. It is anticipated that there will be a continued reduction in ozone due to controls imposed by the Texas SIP requirements.

Both the 1-hour and 8-hour ozone monitored values have decreased over the past 19 years. A "design value" is used by the EPA to determine the correct designation of an ozone nonattainment area. Air quality data are collected at each monitoring site in the HGB Nonattainment Area and used to calculate the design value. For compliance with the ozone 1-hour ozone standard, NAAQS will be met when the design value is less than or equal to 0.12 parts per million (ppm). For compliance with the ozone 8-hour standard, NAAQS will be met when the design value is less than or equal to 80 parts per billion. The 2009 1-hour design value was 0.127 ppm (TCEQ, 2010d), representing a 42 percent decrease from the value for 1991 of 0.220 ppm, but is still in exceedance of the 0.12 ppm 1-hour ozone standard. For compliance with the ozone 8-hour standard, NAAQS is met when the design value is less than or equal to 0.08 ppm. The 2009 data indicate that the HGB area has reached an 8-hour design value of 0.084 ppm, which because the standard is reported to two decimal places, does not exceed the 8-hour ozone standard (TCEQ, 2010e).

3.6 NOISE

3.6.1 Fundamentals and Terminology

The magnitude of noise is usually described by its sound pressure. Since the range of sound pressure varies greatly, a logarithmic scale is used to relate sound pressures to some common reference level, usually in decibels (dB). Sound pressures described in decibels are called sound pressure levels and are often defined in terms of frequency weighted scales (A, B, C, or D).

The A-weighted scale is used almost exclusively in environmental noise measurements because it places most emphasis on the frequency range detected by the human ear (1,000–6,000 hertz). Sound levels measured using A-weighting are often expressed as dBA. Throughout this section, references are made to dBA, which means an A-weighted decibel level. Common sound/noise levels that an individual may encounter daily are listed in Table 3.6-1. Noise levels associated with equipment that may be used for construction of this project are also included in this table for reference.

In accordance with standard practice, noise levels in this document are discussed in terms of the equivalent sound level (L_{eq}) and the day-night sound level (L_{dn}). Typical noise environments consist of numerous noise sources that vary and fluctuate over time. L_{eq} provides a way to describe the average sound level, in decibels, for any given time period under consideration. L_{dn} is the 24-hour average sound level obtained after the addition of a 10-dB penalty for sound levels that occur during nighttime hours (10 P.M. to 7 A.M.), in order to account for heightened sensitivity to noise during that period. Federal agencies, including the EPA, Department of Defense, and Department of Housing and Urban Development, have adopted this descriptor in assessing environmental impacts. Regulatory agencies generally recognize an L_{dn} of 55 dBA as a goal for the outdoor noise environment in residential areas.

Sound pressure levels of two separate sources are not directly additive. Therefore, as shown in Table 3.6-2, if a sound of 60 dBA is added to another sound of 60 dBA, the resulting noise level is 63 dBA, not 120 dBA. For example, if the noise level of a chain saw is measured at 84 dBA at 50 feet, and the noise level of a bulldozer is measured at 82 dBA at 50 feet, the combined noise level of both would be approximately 86 dBA at 50 feet.

Table 3.6-1
Hearing: Sounds that Bombard Us Daily

Decibels		
140	Shotgun blast, jet 100 feet away at takeoff Motor test chamber	Pain Human ear pain threshold
130		
120	Firecrackers Severe thunder, pneumatic jackhammer Hockey crowd Amplified rock music	Uncomfortably loud
110		
100	Textile loom Subway train, elevated train, farm tractor Power lawn mower, newspaper press Heavy city traffic, noisy factory	Loud
90		
80	**Chain Saw at 50 feet away** **Bulldozer at 50 feet away** Diesel truck 40 mph 50 feet away **Dump Truck at 50 feet away** Crowded restaurant, garbage disposal **Front End Loader at 50 feet away** Average factory, vacuum cleaner Passenger car 50 mph 50 feet away	Moderately loud
70		
60	Quiet typewriter Singing birds, window air conditioner Quiet automobile Normal conversation, average office	Quiet
50	Household refrigerator Quiet office	Very quiet
40		
30	Average home Dripping faucet	
20	Whisper 5 feet away Light rainfall, rustle of leaves Whisper	Average person's threshold of hearing Just audible
10		
0		Threshold for acute hearing

Source: Olishifski and Harford (1975); U.S. Department of Transportation (2006).
Note: Equipment that may be used in this project is indicated in bold.

Table 3.6-2
Decibel Addition

Difference Between Two Sources	For Example	Add To Higher Level	Resultant Sound Level
0 dB	60 and 60 dB	3 dB	63 dB
1 dB	60 and 61 dB		64 dB
2 dB	60 and 62 dB	2 dB	64 dB
3 dB	60 and 63 dB		65 dB
4–9 dB	60 and 65 dB	1 dB	66 dB
10 or more	60 and 70 dB	0 dB	70 dB

Source: Texas Department of Transportation (TxDOT, 1996).

3.6.2 Existing Noise Environment

Noise-sensitive receptors are facilities or areas where excessive noise may disrupt normal activity, cause annoyance, or loss of business. Land uses such as residential, religious, educational, recreational, and medical facilities are more sensitive to increased noise levels than are commercial and industrial land uses. According to 2008 LIDAR data and desktop review of aerial photography, approximately 403 noise-sensitive receptors are located within 200 feet of the proposed project footprint. The majority of noise-sensitive receptors located adjacent to the project corridor are residential subdivisions. The existing noise environment within the study area varies greatly and is generally influenced by the surrounding land uses concentrated in any particular area. For example, industrial and commercial land uses have a higher ambient noise level when compared to areas composed primarily of residential land uses. Transportation facilities within the study area also contribute significantly to ambient noise levels. Noise levels are generally higher in the vicinity of highways, major roadways, railroads, and airports. Noise levels generally decrease as the distance from these facilities increases. Studies have found that outdoor noise environments across the United States range from approximately 40 L_{dn} in rural residential areas, to nearly 60 L_{dn} in older urban residential areas, to as much as 90 L_{dn} in congested urban settings (EPA, 1974).

3.7 SOILS

3.7.1 Soil Types

According to the general soil maps of Harris, Galveston, Brazoria, and Fort Bend counties (Soil Conservation Service [SCS], 1976, 1981, 1983, 1988), the project area is located within the Lake Charles, Lake Charles-Bacliff, and Lake Charles-Bernard soil associations. These soil associations are deep, nonsaline soils that formed on nearly level prairies and coastal terraces. They are described as somewhat poorly drained or poorly drained, very slowly permeable, clayey and loamy soils.

Subsurface soil exploration and lab testing has been done on portions of Clear Creek by USACE Southwestern Division Laboratories, Geotest Engineering, and other laboratories from 1965 through 2002. Test results indicate that foundation soils are predominately clays with intermittent layers of silty clay and occasionally silty sand. The historical test results of the clay samples taken from the ground surface down to 10 feet show the Plasticity Index range from 20 to 75, with more than half over 40. The high Plasticity Index values indicate that clays in the project area will behave more plastically. The high plasticity clays along Clear Creek have high liquid limits, which mean the material has greater potential to expand and shrink with moisture content variation. For instance when the region experiences drought conditions, cracks several inches to 1 foot wide may form in the top 1 to 2 feet of surface soil layers. When moisture returns and the materials become saturated, the cracks will close. Below the top layers, slickenside soils can be found. The deposits of silty sand and silty clay are scattered and wide-ranging in depth with respect to natural ground surface.

3.7.2 Prime and Unique Farmland

Prime farmland soils are defined by the Secretary of Agriculture in 7 CFR, Part 657 (*Federal Register*, Vol. 43, No. 21) as those soils that have the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops. The soil quality, growing season, and moisture supply are available to economically produce sustained high yields of crops when treated and managed, including water management, according to acceptable farming methods. Some soils are considered prime farmland in their native state, and others are considered prime farmland only if they are drained or watered well enough to grow the main crops in the area.

Soil Survey Geographic Database (SSURGO) information acquired from the NRCS indicates that the majority of the soils located within this study area are considered prime farmlands (NRCS, 1999). However, due to the rapid urban growth in the study area, these soils are not typically used for farmland (see Section 3.14). The total estimated acreage of prime farmland (including areas that are considered prime farmland when drained) located within the study area is approximately 111,252 acres out of 140,037 total acres (about 79 percent) (Figure 3.7-1). According to land cover types utilized in the HEP analysis, of the 111,252 acres of agricultural land, only 0.16 acre will be impacted by the project (see Figure 5.3-1a–c). Table 3.7-1 lists the prime farmland soil types.

"Unique farmlands" is a category of farmlands that is recognized by the NRCS. Unique farmlands have very specific and rigid criteria in the states where they occur. There are no soils recognized as "Unique Farmlands" in the state of Texas (Brown, 2002).

3.8 CONTAMINANTS

The presence of man-made contaminants in our environment has increased significantly in recent years. The sources of these contaminants are numerous and occur in rural and urban settings. Common sources include petroleum refining, chemical manufacturing, solid waste disposal, and retail gasoline stations. Government regulation of these sources has attempted to minimize the negative effects that result when contaminants are released in the environment. In order to assess the potential of encountering contaminants during the proposed action, a review of Federal, State, and local data sources was conducted.

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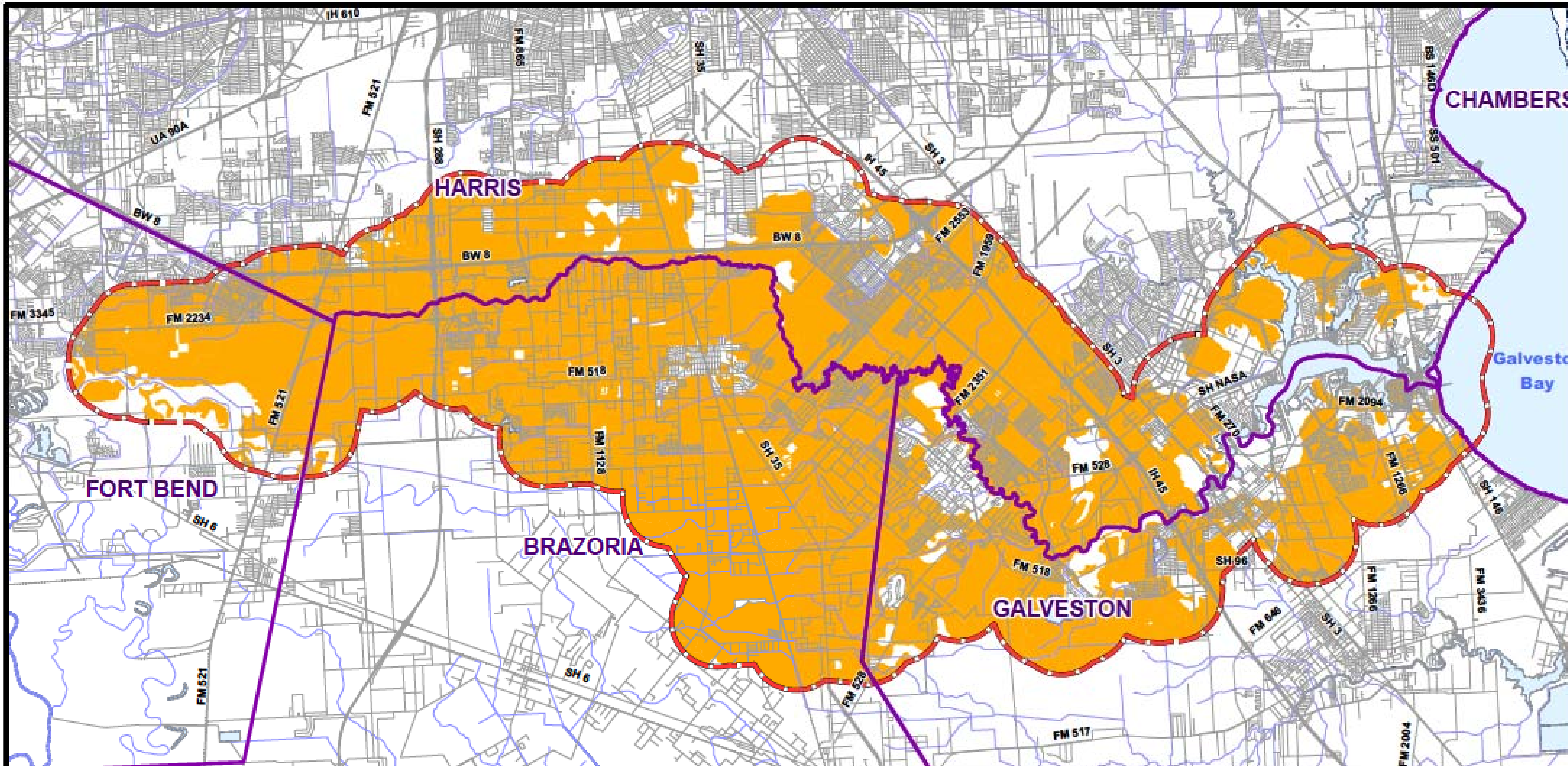

Figure 3.7-1

Prime Farmland

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/10/2012

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Table 3.7-1
Prime Farmland Soil within the Study Area

Prime Farmland Soil Type	Description
Aris Fine Sandy Loam	All Areas Prime Farmland
Bernard-Edna Clay Loams	All Areas Prime Farmland 1 to 4 percent slopes
Bernard-Edna Complex	All Areas Prime Farmland
Bernard-Edna Complex	All Areas Prime Farmland 0 to 1 percent slopes
Bernard Clay Loam	All Areas Prime Farmland
Bernard Clay Loam	All Areas Prime Farmland 0 to 1 percent slopes
Katy-Waller Complex	All Areas Prime Farmland
Katy Fine Sandy Loam	All Areas Prime Farmland 0 to 1 percent slopes
Katy Fine Sandy Loam	All Areas Prime Farmland 1 to 4 percent slopes
Lake Charles Clay	All Areas Prime Farmland 0 to 5 percent slopes
Mocarey-Algoa Complex	Prime farmland where drained
Aris-Gessner complex	Prime farmland where drained
Aris find sandy loam	Prime farmland where drained
Bacliff clay	Prime farmland where drained
Beaumont clay	Prime farmland where drained
Gessner complex	Prime farmland where drained
Gessner loam	Prime farmland where drained
Leton-Aris complex	Prime farmland where drained
Leton loam	Prime farmland where drained
Midland silty clay loam (verland)	Prime farmland where drained
Morey-Leton complex	Prime farmland where drained
Morey silt loam	Prime farmland where drained
Aris-Gessner complex	Prime farmland where drained

3.8.1 Hazardous, Toxic, and Radioactive Waste

The purpose of the Hazardous, Toxic, and Radioactive Waste (HTRW) assessment was to identify indicators of potential hazardous materials or waste issues relating to the proposed project.

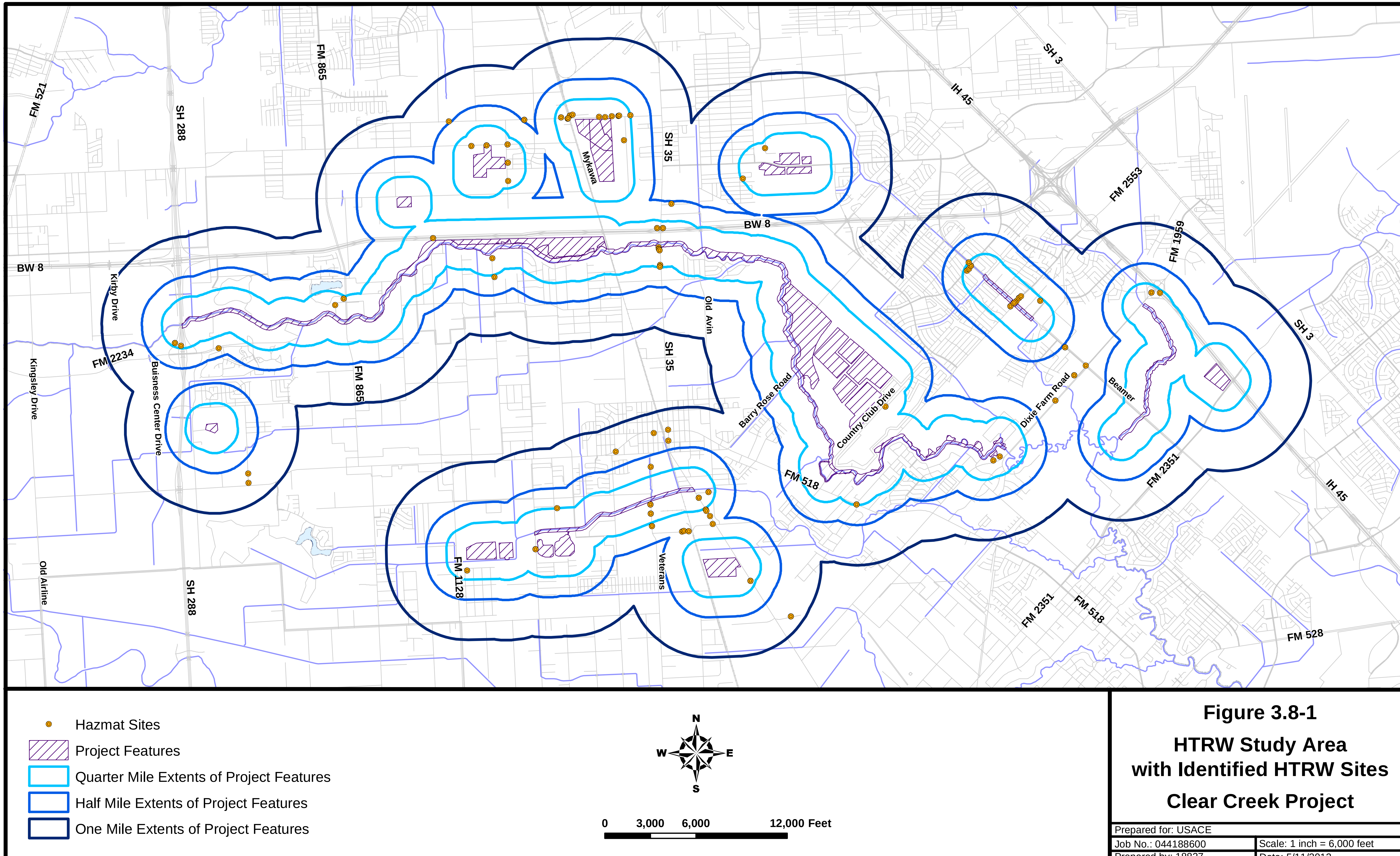
A previous review of databases maintained by Federal, State, and local regulatory agencies, an aerial photographic review, and interviews with officials from the TCEQ were conducted to determine the location and status of sites regulated by the State of Texas and the EPA (PBS&J, 2002). This HTRW study was conducted for the entire watershed area, as shown on Figure 1.1-1.

Examination of aerial photography (Texas Department of Transportation [TxDOT], 1986; U.S. Department of Agriculture, 1944) indicates the study area has had a wide variety of land uses including residential-urban, industrial, recreational, vacant, and undeveloped range-pasture. Currently, the land developed immediately adjacent to Clear Creek is primarily single-family residences within an urban setting. Remaining properties located adjacent to the waterway include recreational, commercial, and light industrial.

An updated review (April 2008) of regulatory agency database records for HTRW is included in the following assessment. The HTRW database review update was conducted according to American Society for Testing and Materials (ASTM) Standards concerning the search radii. Thus, certain sites were identified within a ¼-mile, ½-mile, or 1-mile radius from the project features footprint, as shown on Figure 3.8-1. To account for potential impacts associated with placement areas, the conceptual placement areas used for costing purposes (see GRR Economic Appendix) were included as project footprint features. Tables summarizing results from each database search are included in Appendix C-1. Maps showing approximate locations of HTRW sites within the study area are also included in Appendix C-1.

A total of 92 records were identified within the project area from the updated database searches. Some of these records are associated with the same facility and/or property that contains multiple petroleum storage tanks, reported spills, or emergency response actions. Based on the results of the regulatory agency database searches, the following sites are located within the project area:

- 2 NPL sites;
- 4 CERCLIS sites;
- 4 SSF sites;
- 8 No Further Remedial Action Planned sites;
- 1 Corrective Actions site;



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- 9 Resource Conservation and Recovery Act (RCRA) generators sites;
- 1 RCRA treatment, storage, and disposal site;
- 17 aboveground petroleum storage tanks;
- 23 leaking underground storage tank sites;
- 4 state voluntary cleanup (VCP) sites;
- 4 emergency response notification system sites;
- 7 reported spill sites;
- 3 state/county landfill sites;
- 3 dry cleaner sites; and
- 2 innocent owner/operator sites.

As these records indicate, the project area is moderately industrial. While not all of these sites pose a threat to the environment, several of these facilities have documented impacts to the environment. Due to their proximity to project features, some of these sites have been selected for additional discussion.

Brio Refinery (NPL, CERCLIS, and SSF), located at 2501 Dixie Farm Road, is a 58.1-acre site that formerly performed copper catalyst regeneration, oil blending, refining, and recycling of styrene tars. From 1957 to 1970, several pits were constructed to support processing operations. The primary pollutants identified at the facility include styrene tars, vinyl chloride, chlorinated solvent residues, metallic catalyst, and fuel oil residues. This refinery is located on the east side of Mud Gully, a tributary to Clear Creek. Operations ceased in December 1982, when the Brio Refinery filed for bankruptcy. The corrective action conducted at the site includes the construction of a containment remedy in 2004. This remedy is a subsurface barrier wall and a groundwater control system that will ensure that contaminated groundwater will not discharge into the surface water of Mud Gully. A cap or multilayer cover system reduces the risk from direct contact with the residue wastes at the site.

Dixie Oil Processors (NPL, CERCLIS, and SSF) is a 26-acre site located at 2505 Choate Road (Dixie Farm Road) and borders the west boundary of the Brio Site near Mud Gully. This site was a former copper-recovery and hydrocarbon-washing operation from 1969 to about 1989. The primary pollutants identified at the facility include ethylene, hexachlorobenzene, and copper. The corrective action at the site includes the construction of a containment remedy in 1993. This remedy is a surface cap over the site that reduces the risk from direct contact with the residual wastes at the site.

Gulf Metals Industries landfill (SSF and VCP) is a 16-acre site located northeast of the intersection of Mykawa Road and Almeda-Genoa Road. This site is a former sand and gravel pit that was used as an open dump from the 1950s to the mid-1960s. Hazardous wastes consisting primarily of oily sludges and other miscellaneous wastes were disposed of in the sand pits. The site was used as a commercial landfill from 1965 to 1967 to dispose of metal slag and other foundry debris. The primary pollutants identified at the facility include VOCs, semivolatile organic compounds, metals, solvents, and pesticides. The site is undergoing current groundwater monitoring to determine offsite impacts. The site has reportedly been removed from the SSF program and has entered into the Texas VCP.

The James Barr facility is a 2-acre site located in the 3300 block of Industrial Drive. The facility operated aboveground storage tanks to store hazardous waste. The property was sold at auction for unpaid taxes in 1995. The primary pollutants identified at the site include benzene, 1,2-dichloroethane, metals, and organics. The site is currently undergoing remedial action including an engineering cost analysis of the closure of a surface impoundment.

3.8.2 Oil and Gas Production and Transmission

The search of Texas Railroad Commission (TRC) files indicated a total of 285 permitted well sites located within the study area. According to the TRC database, 274 of the well sites have been drilled, and 84 sites are currently producing oil and/or gas. A map showing the approximate locations of these wells is in Appendix C-2. The database indicates that the well sites include the following status:

- 84 are listed as active producing oil/gas wells
- 86 as plugged
- 56 as dry holes
- 9 as permitted locations
- 1 as injection/disposal well
- 2 as canceled locations

The database also indicates that 46 of the drilled wells include a horizontal or sidetract boring. These wells operate with a unique well identification.

A total of 37 petroleum pipeline systems were identified within the project area. The TRC files indicate that 30 of the pipeline systems are listed as active (in service) and 7 are listed as inactive (abandoned). A map showing the approximate locations of these pipelines is in Appendix C-2. The pipeline systems are reported to transport the following materials:

- 16 transport natural gas
- 4 crude oil
- 3 natural gas liquids
- 4 ethane-propane mix
- 4 propylene
- 4 ethylene
- 1 gasoline distillates
- 1 refined products

3.9 VEGETATION

3.9.1 Introduction

The study area is located in the Gulf Prairies and Marshes Vegetational Region which occupies over 9 million acres along the coast of Texas (Hatch et al., 2001). The region is comprised of a nearly level, slowly drained plain less than 150 feet in elevation, dissected by streams and rivers flowing into the Gulf of Mexico. Ecologically valuable vegetation in the study area is found in the riparian corridors along the river banks of the Clear Creek/Clear Lake drainage system, the surrounding coastal prairies, and tidal marshes at the downstream end of the study area. The waterways and their riparian corridors include tidal and nontidal waters and associated plant communities. Vegetation and/or land cover types are described in the following sections and in greater detail with respect to seven ecological reaches (i.e., eco-reaches).

Clear Lake, like Galveston Bay, developed at the end of the last Ice Age as rising sea level flooded stream valleys. At elevations less than 5 feet above msl, Clear Lake is the downstream portion of what was formerly Clear Creek. Clear Lake and the tidal reach of Clear Creek are estuarine systems that exchange water with upper Galveston Bay. Clear Creek is riverine upstream of the FM 528 bridge. Slight changes in topography and elevation over the watershed and its hydrologic connection to Galveston Bay play roles in determining plant communities in the Clear Creek watershed.

3.9.2 Historical Changes

In pre-European settlement times, the Clear Creek watershed included coastal prairies dominated by little bluestem (*Schizachyrium scoparium*), freshwater marshes including prairie pothole complexes (Jacob and Lopez, 2005; Moulton and Jacobs, 2000), riparian forests (Diamond and Smeins, 1984; Smeins et al., 1991), and estuarine marshes. Over time, urban (i.e., industrial, commercial, and residential) and agricultural development have altered or eliminated many of the natural vegetation communities, including wetlands, in the Clear Creek watershed.

Much of the coastal prairie that once occurred in the region has been converted to urban and agricultural land use and/or is heavily modified by the encroachment of exotic species such as Chinese tallow (*Triadica sebiferum*). Small remnants of coastal prairies, totaling less than 3 percent of the historical statewide distribution, still exist in Texas (Diamond and Smeins, 1984; Smeins et al., 1991).

Riparian forests (i.e. forests that occur along the interface between land and rivers, streams and creeks) within the coastal floodplain of the northwestern Gulf of Mexico are threatened or declining. Factors contributing to loss and degradation of this habitat include development, agriculture, cattle grazing, logging, and invasive species (Barrow et al., 2005). Wear et al. (2004) forecast a decrease of 10 percent of interior forest (not including forest edge, which is more typical in highly fragmented forests) for the Houston area from 1992 to 2020. Channelization of coastal streams in urban areas to reduce flooding has eliminated ecologically valuable riparian vegetation, which has been replaced in cases like Brays Bayou, Sims Bayou, and Whiteoak Bayou in Houston with grass and concrete shores.

Over the last 100 years, rapid urban development along Clear Creek has substantially increased flooding attributed to both the narrowing of the floodplain and the construction of buildings and infrastructure within flood-prone areas (Dannenbaum Engineering Corporation, 1997, 2004; USACE, 2002). At various times in the past, the upper portion of Clear Creek and most of the tributaries have been improved by local drainage districts in an effort to reduce flooding associated with development. In the early 1940s, BCDD4 enlarged and rectified the portion of Clear Creek that forms the boundary between Brazoria and Harris counties (areas upstream of Dixie Farm Road), and in the early 1950s, the upper portion of the creek was further enlarged and rectified by Harris, Brazoria, and Fort Bend counties (USACE, 1982:Appendix I). The Clear Creek Drainage District did some bend easing and bank clearing in the Friendswood area as funds were available during the 1970s (USACE, 1982:Appendix I). Tributaries to Clear Creek including Hickory Slough, Mud Gully, Turkey Creek, and Mary's Creek have also undergone considerable modification over time in an effort to reduce localized flooding as the areas developed.

The combination of development along with the various projects undertaken to reduce associated flooding has caused extensive loss, modification, and degradation of the natural forested and riparian habitat within the Clear Creek floodplain, especially along the upper reaches of Clear Creek. Existing habitat is no longer pristine, and its quality varies depending on location along the creek. A recent study by Jacob and Lopez (2005) over a six-county area revealed a consistent pattern of wetland loss with urban (industrial, commercial, and residential) development. Their map indicated that the Clear Creek area lost between 6 and 25 percent of its wetlands (depending on location) between 1992 and 2000–2002 including the wet prairies of the pimple mound/ prairie pothole complexes.

3.9.3 Vegetation Communities

The following discussion in this section describes ecologically important vegetative communities that are found within the study area. These communities include forests and prairie habitats and their associated wetlands and aquatic areas that occur along Clear Creek and its tributaries, as well as tidal marsh and submerged aquatic vegetation that occurs downstream, in tidally influenced segments of Clear Creek and Clear Lake. Vegetation communities found within the 500-year floodplain are shown on Figure 3.9-1.

Freshwater wetlands occur predominantly upstream of Clear Lake and occur as depressional areas within the 100-year floodplain in both forest and prairie communities, as well as wetland strips at the edges of streams and along stream banks (i.e., riverine wetlands). National Wetland Inventory (NWI) maps (USFWS, 2010) were used, combined with aerial interpretation using recent aerial imagery (years 2000, 2004, and 2009), and field verification, to characterize wetlands and aquatic habitats for baseline conditions and potential future conditions (Figure 3.9-2). (Note: Detailed wetland spatial data for the project area are presented in Appendix O.)

3.9.3.1 Floodplain Forest

Floodplain forest within the Clear Creek study area is a broad vegetative community description that includes the forested habitat of the stream bank, and overbank areas of Clear Creek and its tributaries, known as the riparian zone, as well as the adjacent upland forests and associated forested wetland depressions. Riparian zones are transitional areas between terrestrial and aquatic systems that exhibit functional characteristics of both systems (NRCS, 2007). The floodplain forest within the riparian zone occurs generally as a narrow corridor of forest vegetation along the waterway, but occurs in some areas as a more broad expanse of forested land along Clear Creek due to variations in floodplain topography and development. In some areas of Clear Creek and to a much greater extent along its tributaries, floodplain forest is virtually absent due to urban development and clearing of vegetation.

Hydrology is derived from instream flow, stream bank and overbank flooding, as well as ponding of surface water runoff within the broader, flat areas just outside the creek banks. Wetlands within the floodplain forest may be found in and along Clear Creek and its tributaries as narrow strips along creek shorelines and banks, within cut-off oxbow lakes, and as larger depressions or a complex of numerous, smaller, highly intermingled depressions mixed within the upland forests of the overbank areas.

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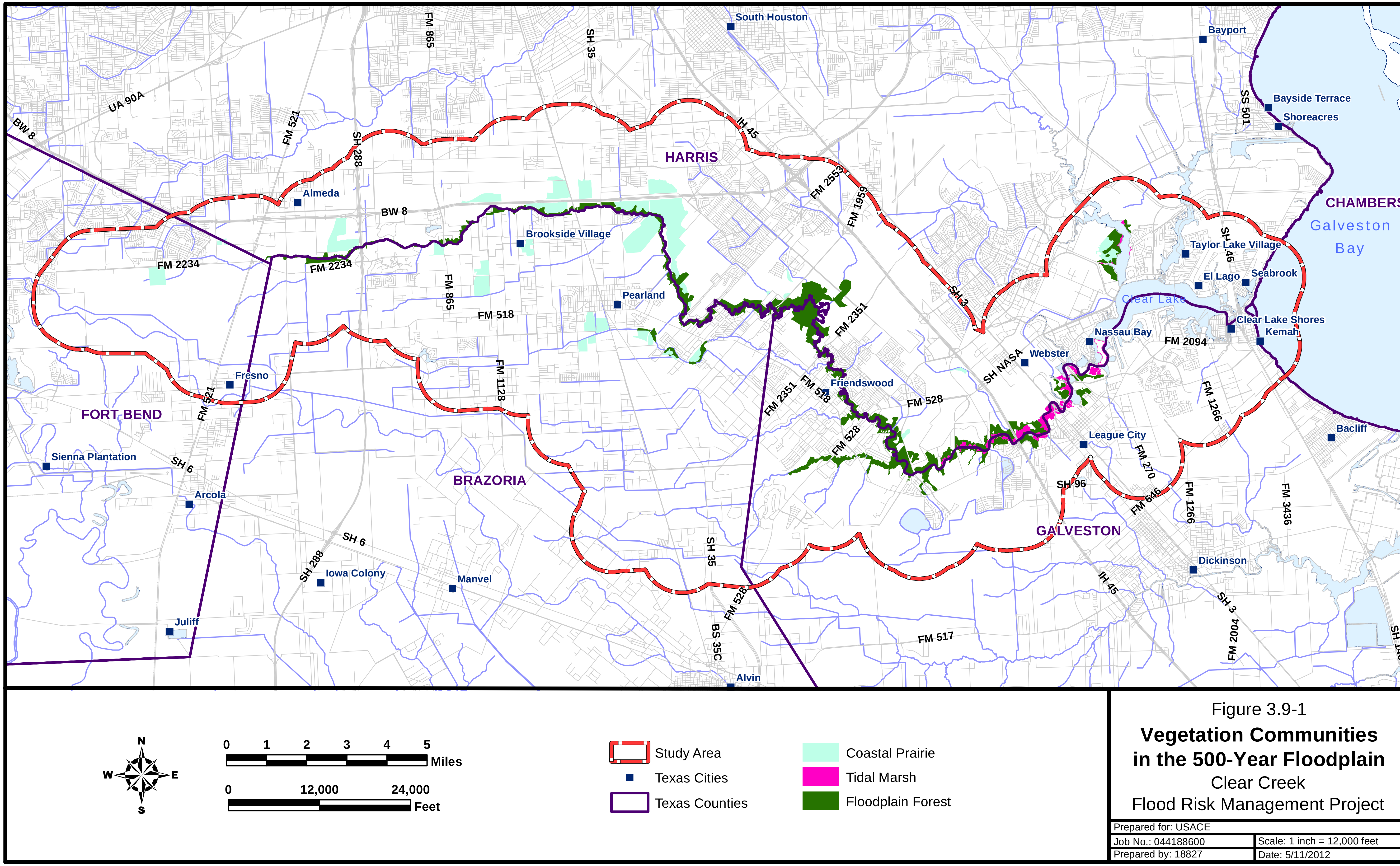

Figure 3.9-1
Vegetation Communities in the 500-Year Floodplain
Clear Creek
Flood Risk Management Project

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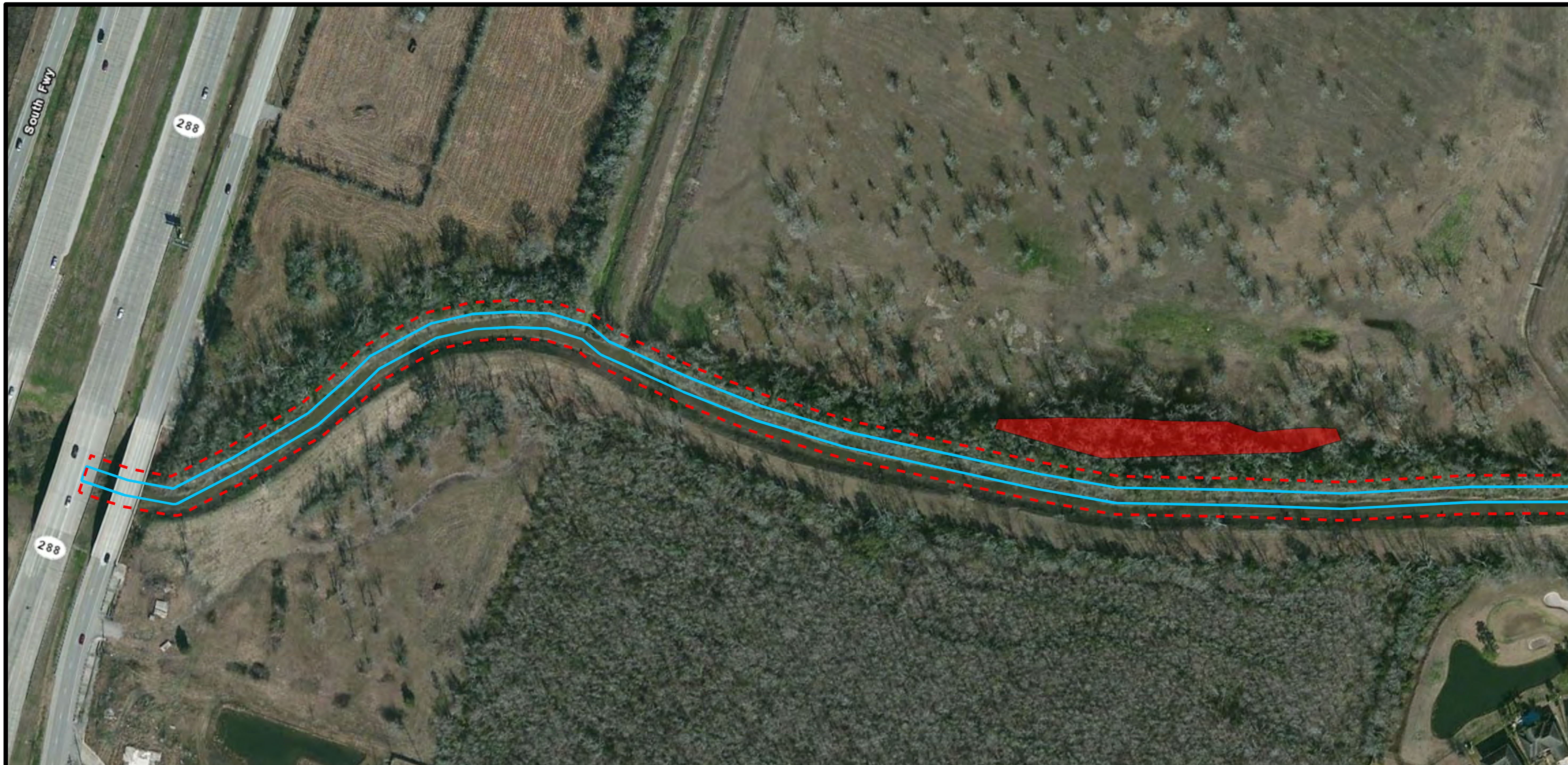

N
W
E
S

0 0.01 0.02 0.03 0.04 0.05
Miles

0 250 500
Feet

Legend

- Low Flow Corridor
- OHWM Fringe Wetlands
- Compensatory Mitigation Area Wetlands
- Impacted Wetlands
- Construction Wetlands

Sources:
Aerials: Microsoft Corporation, Earthstar Geographics LLC, GeoEye, Harris Corporation, NASA, and DigitalGlobe. *Bing Maps Aerial.* 2010. 1:1920; generated by Myron Friedel; using ArcMap. http://www.bing.com/maps (2 May 2012).

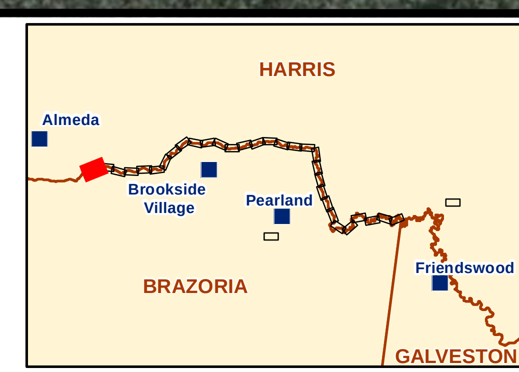

Figure 3.9-2
USFWS NWI Wetlands Mapped Within the Study Area
Clear Creek
Flood Risk Management Project

Prepared for: USACE	Sheet 1 of 33
Job No.: 100013748	Scale: 1inch = 160 feet
Prepared by: 18827	Date: 5/8/2012

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Floodplain forests provide valuable nesting and roosting habitat in close proximity to water for a variety of birds and other wildlife. These habitats provide shelter and resting areas for migratory songbirds. The wooded areas and wetlands slow and store floodwaters and dampen flood crests, helping to control flood damage and erosion; filter sediments, nutrients, and other pollutants from stormwater runoff; and stabilize river flows and groundwater levels (Jacob et al., 2003). Forest trees shade the stream and other floodplain waterbodies like oxbows, which in turn helps moderate summer water temperatures. Fallen branches and trees provide instream habitat for fish and aquatic invertebrates, while fallen leaves provide organic matter for terrestrial and aquatic detritivores. In addition to providing timber and habitats for plants and animals, forested areas along Clear Creek provide other valuable goods and services. The fish and wildlife habitats support fishing, nature tourism, hunting, and other recreational uses. Members of the public and a number of organizations value these forested habitats and associated stream channels, which are being lost in the Galveston Bay watershed as a result of stream channelization and vegetation removal.

Approximately 3,802 acres of floodplain forest were identified within the 500-year floodplain of the Clear Creek study area. Vegetation assemblages of Clear Creek's floodplain forest consist of mixed upland and hardwood trees and associated vegetation. Plants observed within the Clear Creek floodplain forests are listed in Table 3.9-1. Very little floodplain forest occurs in the downstream limits of the Clear Creek study area. Common plant species within the lower reaches of Clear Creek include cedar elm (*Ulmus crassifolia*), willow oak (*Quercus phellos*), sweetgum (*Liquidambar styraciflua*), and dwarf palmetto (*Sabal minor*) in the wetter, brushy areas (Moulton and Jacob, 2000). Farther upstream, water oak (*Quercus nigra*), sugarberry (*Celtis laevigata*), southern red oak (*Quercus falcata*), swamp post oak (*Quercus similis*), pecan (*Carya illinoinensis*), cherrybark oak (*Quercus pagoda*), laurel oak (*Quercus laurifolia*), American elm (*Ulmus americana*), water hickory (*Carya aquatica*), winged elm (*Ulmus alata*), red mulberry (*Morus rubra*), live oak (*Quercus virginiana*), and post oak (*Quercus stellata*) are more common. Loblolly pine (*Pinus taeda*) is also commonly observed in the drier floodplain forest community. Understory species can include yaupon holly (*Ilex vomitoria*) and exotic privet (*Ligustrum* spp.). Green ash (*Fraxinus pennsylvanica*) and water oak are often present on the creek bank slopes (Moulton and Jacob, 2000). In the upper reaches of Clear Creek, the floodplain forest vegetation includes fast-colonizing invasive species like Chinese tallow, black willow (*Salix nigra*), and baccharis (*Baccharis* spp.). Swamp forests dominated by the bald cypress-water tupelo series (*Taxodium distichum-Nyssa aquatica*) or the bald cypress-sycamore series (*Taxodium distichum-Platanus occidentalis*) that occur elsewhere in the Galveston Bay system do not occur within the study area. Exotic plant species that were observed within the Clear Creek floodplain forests include Chinese tallow, Japanese ligustrum (*Ligustrum japonicum*), Chinese privet (*Ligustrum sinense*), Japanese honeysuckle (*Lonicera japonica*), and chinaberry (*Melia azedarach*) (see Table 3.9-1). More-detailed descriptions can be found in the HIS Model report (Appendix B).

Table 3.9-1
Clear Creek Floodplain Forest Plants Observed During Baseline Data Collection for HSI Models

		Native to Texas	Ecoreach					
Scientific Name*	**Common Name***	**(Yes/No)**	**1**	**2**	**3**	**4**	**5**	**6**
Trees								
Carpinus caroliniana Walter	American hornbeam	Yes				X		
Carya aquatica (Michx. f.) Nutt	water hickory	Yes	X	X	X	X	X	X
Carya illinoinensis (Wangenh.) K. Koch	pecan	Yes	X	X		X	X	X
Celtis laevigata Willd.	sugarberry or sugar hackberry	Yes	X	X	X	X	X	X
Fraxinus americana L.	white ash	Yes		X		X		
Fraxinus pennsylvanica Marsh	green ash	Yes	X	X	X	X	X	X
Juglans nigra L.	eastern black walnut	Yes						X
Juniperus virginiana L.	eastern redcedar	Yes	X	X	X	X		
Liquidambar styraciflua L.	sweetgum	Yes				X		
Melia azedarach L.	chinaberry	No					X	
Morus rubra L.	red mulberry	Yes	X	X			X	X
Nyssa sylvatica	blackgum	Yes				X		
Pinus taeda L.	loblolly pine	Yes			X	X		
Quercus spp.	oak	Yes	X	X		X	X	
Quercus falcata Michx	southern red oak	Yes		X		X	X	
Quercus pagoda Raf.	cherrybark oak	Yes				X		
Quercus laurifolia Michx.	laurel oak	Yes				X	X	
Quercus nigra L.	water oak	Yes	X	X	X	X	X	X
Quercus phellos L.	willow oak	Yes	X		X	X	X	X
Quercus similis Ashe	swamp post oak	Yes				X		
Quercus stellata Wangenh.	post oak	Yes	X	X	X	X		
Quercus virginiana Mill.	live oak	Yes	X	X				X
Salix nigra Marshall	black willow	Yes				X	X	X
Ulmus alata Michx.	winged elm	Yes			X	X		
Ulmus americana L.	American elm	Yes	X	X	X	X	X	X
Ulmus crassifolia Nutt.	cedar elm	Yes	X	X	X	X	X	X
Shrubs, Herbs, and Vines								
Acalypha gracilens A. Gray	slender three-seeded mercury	Yes				X		
Acalypha rhomboidea Raf.	common three-seed mercury	Yes				X		
Ambrosia spp.	ragweed	/		X		X		
Ambrosia trifida L.	giant ragweed	Yes		X		X	X	X
Ampelopsis arborea (L.) Koehne	peppervine	Yes		X			X	
Axonopus spp.	carpetgrass	/		X				
Baccharis spp.	baccharis	/				X		
Berchemia scandens (Hill) K. Koch	Alabama supplejack	Yes	X			X	X	
Callicarpa americana L.	American beautyberry	Yes				X	X	
Campsis radicans (L.) Seem. ex Bureau	trumpet creeper	Yes	X	X		X	X	
Carex cherokeensis Schwein.	Cherokee sedge	Yes	X			X	X	X
Carex flaccosperma Dewey	flaccid-fruit caric-sedge	Yes					X	
Carex oxylepis Torr. & Hook.	sharpscale sedge	Yes	X					

Table 3.9-1 (Cont'd)

Scientific Name	Common Name	Native to Texas (Yes/No)	Ecoreach 1	2	3	4	5	6
Carex tribuloides Wahlenb.	blunt broom sedge	Yes				X		
Cephalanthus occidentalis L.	common buttonbush	Yes				X		
Chasmanthium latifolium (Michx.) Yates	Indian woodoats	Yes				X	X	
Chasmanthium laxum (L.) Yates	slender woodoats	Yes	X	X		X		
Cocculus carolinus (L.) DC.	Carolina snailseed	Yes	X			X	X	
Conoclinium coelestinum (L.) DC.	blue mistflower	Yes				X	X	
Crataegus viridis L.	green hawthorn	Yes		X		X	X	
Cynodon dactylon (L.) Pers.	bermudagrass	No			X			
Cyperus ochraceus Vahl	pond flat-sedge	Yes			X	X		
Diodia virginiana L.	Virginia buttonweed	Yes			X			
Diospyros virginiana L.	common persimmon	Yes				X	X	
Elephantopus spp.	elephantsfoot	/				X	X	
Hydrocotyle verticillata Thunb.	whorled marshpennywort	Yes			X			
Hygrophila lacustris (Schltdl. & Cham.) Nees	gulf swampweed	Yes					X	
Ilex decidua Walter	possumhaw	Yes	X			X	X	
Ilex vomitoria Aiton	yaupon holly	Yes	X	X	X	X	X	X
Iva annua L.	annual marsh elder	Yes				X		
Juncus effusus L.	common rush	Yes				X		
Leersia spp.	cutgrass	Yes				X		
Ligustrum japonicum Thunb.	Japanese ligustrum	No	X	X	X	X	X	X
Ligustrum sinense Lour.	Chinese privet	No	X	X	X	X	X	X
Lonicera japonica Thunb.	Japanese honeysuckle	No	X	X				X
Mikania scandens (L.) Willd.	climbing hempvine	Yes			X			
Muhlenbergia spp.	muhly	/				X		
Muhlenbergia filipes M.A. Curtis	gulfhairawn muhly	Yes				X		
Oplismenus hirtellus (L.) P. Beauv.	basketgrass	No	X		X	X		
Ostrya virginiana (Mill.) K. Koch	hophornbeam	Yes				X		
Panicum spp.	panic grass	/				X		
Parthenocissus quinquefolia (L.) Planch.	Virginia creeper	Yes				X		
Paspalum spp.	paspalum grass	/				X		
Paspalum denticulatum Trin.	longtom	Yes			X			
Paspalum dilatatum Poir.	dallisgrass	No			X			
Paspalum langei (Fourn.) Nash	rustyseed paspalum	Yes	X		X	X		
Phyla spp.	frogfruit	/			X			
Polygonum spp.	smartweed	/				X	X	
Poncirus trifoliata (L.) Raf.	hardy orange	No				X	X	X
Rhynchospora corniculata (Lam.) A. Gray	shortbristle horned beaksedge	Yes				X		
Rubus trivialis Michx.	southern dewberry	Yes	X			X	X	

Table 3.9-1 (Cont'd)

Scientific Name	Common Name	Native to Texas (Yes/No)	Ecoreach 1	2	3	4	5	6
Ruellia nudiflora Engelm. & A. Gray	violet wild petunia	Yes			**X**	**X**		
Sabal minor (Jacq.) Pers.	dwarf palmetto	Yes	**X**	**X**	**X**	**X**	**X**	
Sambucus nigra L.	American black elderberry	Yes		**X**	**X**			
Sapindus saponaria L.	western soapberry	Yes			**X**			
Sesbania drummondii (Rydb.) Cory	Drummond's rattlebush	Yes				**X**		
Smilax bona-nox L.	saw greenbrier	Yes	**X**	**X**		**X**	**X**	
Smilax smallii Morong	lanceleaf greenbrier	Yes				**X**		
Solidago sempervirens L.	seaside goldenrod	Yes		**X**		**X**	**X**	
Stenotaphrum secundatum (Walter) Kuntze	St. Augustine Grass	No				**X**		
Toxicodendron radicans (L.) Kuntze	eastern poison ivy	Yes	**X**	**X**		**X**	**X**	**X**
Triadica sebifera (L.) Small	Chinese tallow	No	**X**	**X**	**X**	**X**	**X**	**X**
Vernonia missurica Raf.	Missouri ironweed	Yes				**X**		
Viburnum dentatum L.	southern arrowwood	Yes	**X**			**X**	**X**	
Vitis rotundifolia Michx.	muscadine grape	Yes				**X**		

*Plant names follow the U.S. Department of Agriculture (USDA) Plants Database (http://plants.usda.gov/java/).

/ Indicates unidentified species; no indication of native status.

Changes in forest composition from downstream to upstream vary by location along the creek, but show a decrease in area upstream of Country Club Drive's crossing of Clear Creek. These changes along the stream gradient are illustrated in the HSI Model report (see Appendix B).

Within floodplain forests, scrub-shrub wetlands (dominated by woody vegetation) can occur as temporarily flooded or saturated depressional areas within small clearings. Plant species dominating these depressional scrub-shrub wetlands may include rattlebean, Chinese tallow, baccharis, wax myrtle, buttonbush, cattail, privet, marsh elder (*Iva frutescens*), dwarf palmetto, and common reed. These scrub-shrub areas may also contain young seedlings and saplings of some species found in forested wetlands.

3.9.3.2 Coastal Prairie

The coastal prairie community includes both well preserved coastal tallgrass prairie and prairie habitats compromised in varying degrees by development. Coastal tallgrass prairie is characterized in part by potholes (wetland depressions) and pimple mound topography, though some areas may consist of very broad, flat wetland depressions. Both the vegetation and topography of the prairie habitats have been modified by interruption of the natural cycles (e.g., fire and grazing), and by agriculture and urban development. Despite anthropogenic modification, coastal prairie provides valuable habitat for many amphibians and migratory songbirds, as well as water sources for wildlife (Jacob et al., 2003). The prairie also provides forage for small mammals like rabbits and mice, as well as seeds for passerine birds. These wetlands slow rainfall runoff, facilitating removal of excess nutrients, sediments, and other pollutants, and contributing to groundwater storage and recharge.

The wide range in quality of coastal prairie habitat reflects the type and degree of adjacent land use. In areas where there has been little or no leveling of the land, native species may still be common or dominate the vegetation community. Where the pothole and pimple mound topography has been semi-leveled with only a few pimple mounds remaining, wetland configuration may be intact, although wetlands may have less storage capacity. Pothole and pimple mound areas that have been extensively leveled yet still support significant wetland resources are included in this cover type. In all cases there may be varying degrees of urban disturbance (e.g., roads and drainage improvements) and/or degradation and replacement of this habitat by changes in land use or encroachment by invasives.

Approximately 2,647 acres of coastal prairie were identified within the 500-year floodplain of the Clear Creek study area. Species within this habitat that were observed in predominantly upland prairie areas during the field data collection for the HSI include little bluestem, indiangrass (*Sorgastrum nutans*), eastern gamagrass (*Tripsacum dactyloides*), brownseed paspalum (*Paspalum plicatulum*), switchgrass (*Panicum virgatum*), hairy-awn muhly (*Muhlenbergii filipes*), fimbry (*Fimbristylis* spp.), western ragweed (*Ambrosia psilostachya*), giant ragweed (*Ambrosia trifida*), goldenrod (*Solidago* spp.), wildrye (*Elymus* spp.), dallisgrass (*Paspalum dilatatum*), smutgrass (*Sporobolus indicus*), slender wood oats (*Chasmanthium laxum* var. *laxum*), broadleaf woodoats (*Chasmanthium latifolium*), wooly croton (*Croton capitatus*), sneezeweed (*Helenium amarum*), broadleaf sumpweed (*Iva annua*), gayfeather (*Liatris* spp.), and, rarely, big bluestem (*Andropogon gerardii*). Freshwater coastal prairie wetlands are intermingled throughout this community including streamside (upstream of the estuarine tidal marshes) and in low areas such as abandoned channels, sloughs, and pimple mound/prairie pothole complexes. Woody species (trees and shrubs) associated with this habitat include baccharis, wax myrtle (*Myrica cerifera*), buttonbush (*Cephalanthus occidentalis*), Chinese tallow tree, water oak, loblolly pine, and live oak. Invasive species observed within coastal prairie wetlands and coastal prairie upland communities in the study area included deep-rooted flatsedge (*Cyperus entrarianus),* bahiagrass (*Paspalum notatum*), Brazilian vervain (*Verbena brasiliensis*), Chinese tallow, privet, bermudagrass (*Cynodon dactylon*), chinaberry, spadeleaf (*Centella asiatica*), and alligatorweed (*Alternanthera philoxeroides*).

Within coastal prairies of the Clear Creek floodplain, emergent wetlands occur and are dominated by herbaceous vegetation. Commonly observed emergent wetland plant species within coastal prairie habitat include green flatsedge (*Cyperus virens*), marsh flat-sedge (*Cyperus pseudovegetatus*), sharp edged flat-sedge (*Cyperus haspan*), bushy bluestem (*Andropogon glomeratus*), gaping pancium (*Panicum hians*), rushes (*Juncus* spp.), swamp sunflower (*Helianthus angustifolia*), rattlesnake master (*Eryngium yuccifolium*), California bulrush (*Schoenoplectus californicus*), arrowhead (*Sagittaria* spp.), spikerush (*Eleocharis* spp.), mermaidweed (*Proserpinica* spp.), southern cutgrass (*Leersia hexandra*), blue waterleaf (*Hydrolea ovata*), maidencane (*Panicum hemitomon*), rattlebean (*Sesbania* spp.), beakrush (*Rhynchospora* spp.), pennywort (*Hydrocotyle bonariensis*), water primrose (*Ludwigia* spp.), and smartweed (*Polygonum* spp.).

Similar emergent wetland vegetation such as sedges, spikerush, and smartweed, may occur along with forested wetland species in the numerous, small, highly interspersed wetland depressions within the upland forests in overbank areas. To a lesser extent these herbaceous emergent wetlands occur as vegetated strips along water's edge and stream banks of Clear Creek and its tributaries as a result of clearing and continued maintenance of previously forested areas for urban development and local flood control initiatives. Plant species dominating emergent wetlands include arrowheat, rush, sedge, flatsedge, spikerush, smartweed, rattlebean, cattail, and common reed.

3.9.3.3 Tidal Marsh

Since Clear Creek is a tributary to Galveston Bay, it represents a major ecotone, or mixing zone, with characteristics of both freshwater and marine waters. As a result, the lower reaches of Clear Creek and Clear Lake are dominated by estuarine tidal marsh habitat in waters characterized by

0.05 percent or more salt content, in contrast to the predominantly freshwater tidal marshes occurring upstream to the limits of tidal influence which occurs in the vicinity of FM 528. Some areas of ephemeral submerged aquatic vegetation (SAV) also occur within the shallow downstream estuarine waters Clear Creek and Clear Lake.

Hydrology of the tidal marsh habitat within the study area is highly dependent upon the location and elevation of the marsh, with higher marshes being irregularly flooded by tides and lower marshes being more regularly flooded. Lower subtidal marshes may include ephemeral SAV dominated by widgeongrass (*Ruppia maritima*) may occur within these shallow subtidal areas.

Both tidal marshes and subtidal SAV marsh provide valuable nursery habitat, shelter, and food for juveniles of many recreationally and commercially important species of fish and shellfish like red drum, white shrimp, and blue crabs. Less-saline marshes may provide habitat for reptiles like snakes and alligators, and mammals like river otters. A variety of wading birds like herons and egrets utilize tidal marshes for feeding. Tidal marshes also buffer shorelines from erosion and help filter pollutants from rainfall runoff flowing through the marshes.

Saline-tolerant emergent species such as smooth cordgrass (*Spartina alterniflora*) and marshhay cordgrass (*Spartina patens*) generally dominate the tidal marshes at the mouth and lower reaches of Clear Creek. These estuarine marshes transition upstream into tidally influenced freshwater marshes. These tidal marshes commonly support arrowhead, numerous rush species, sedge species (*Carex* spp.), flatsedges, spikerushes, smartweeds, rattlebeans, cattail (*Typha* spp.), and common reed (*Phragmites australis*) (Moulton and Jacob, 2000). Common invasive plant species within the higher tidal marsh communities include Chinese tallow and salt cedar (*Tamarix ramosissima*), while alligatorweed is a common emergent and submerged nuisance species in the more freshwater areas (Moulton and Jacob, 2000; Texas Invasives.org, 2011). Tidal marsh and SAV are virtually absent upstream of FM 528. Approximately 319 acres of tidal marshes were identified within the 500-year floodplain of the Clear Creek study area.

3.9.4 Modeling Existing Conditions

3.9.4.1 Floodplain Forest HSI Model

The primary environmental concern identified during the scoping process (as well as previous NEPA documentation, and pre-GRR meetings) was the loss of habitat and ecological function that would result if the stream were straightened and channelized. The Clear Creek study team made the decision to assess ecosystem impacts related to this concern and mitigation using HEPs (developed in 1980 by the USFWS) a habitat-based approach to assess ecosystems and provide a mechanism for quantifying changes in habitat quality (i.e., suitability) and quantity over time under proposed alternative scenarios. Within the HEP framework are simple mathematical algorithms known as HSIs used to generate a unitless index of habitat quality derived as a function of one or more environmental variables that characterize or typify a site's conditions (i.e., vegetative cover and composition, hydrologic regime, disturbance, etc.) This index of quality is then applied to an area (e.g., acres) through multiplication to determine units (i.e., habitat units, or HUs = Quality X Quantity).

Over the course of several years, and with facilitation and support from the ERDC and input from the E-Team, the Floodplain Forest Community Index Model was developed for the Clear Creek watershed, Texas (Burks-Copes, 2010). This community HSI model was developed to assist in project plan formulation by identifying and quantifying ecosystem benefits. HSI modeling was performed to broadly capture baseline conditions in terms of HSIs and HUs of the floodplain forest community along Clear Creek against which changes in habitat within the project area associated with proposed flood risk management project alternatives could be measured, and the degree to which formulated mitigation could offset potential impacts. The HSI modeling was not intended to capture the full range of all plant, animal, and physical characteristics of the project area, but to provide a tool for making comparisons between potential plans in order to select plans with the least environmental impact while accomplishing the project mission of reducing flood risk.

The Floodplain Forest HSI model employed three key functional components to model the ecosystem integrity of Clear Creek's floodplain forest community: (1) soils and hydrology, (2) biotic integrity and structure, and (3) spatial context.

The selection of these functional components was justified as follows:

Soils and Hydrology provide water for organisms and physical structure for the floodplain forest community. Pulses of water influence the floodplain forest community by infiltrating its boundaries throughout the year via flooding, precipitation, and overland flow. Geomorphological complexity (e.g., roughness and sinuosity) and adjacent land use practices (e.g., erodability, impervious cover, and altered hydroregime) were thought to influence plant community diversity and ability to support terrestrial and aquatic wildlife inhabitants.

Biotic Integrity and Structure pertains to the ecological integrity of the floodplain forest ecosystem and may be influenced by the species composition and physical structure of living plant biomass and suggests whether the system can support animal populations and guilds. The presence of a particular vegetation species within an ecosystem can dramatically alter the ecosystem's composition, structure, and function. In addition, the presence of specific vegetation types can influence natural complexity of physical features within the floodplain forest providing a greater variety of niches and more-intricate interactions among species. Therefore, emphasis of the model was placed upon the dynamics of the plant community as revealed by the vegetative diversity and community structure of the habitats, as well as the system's ability to provide physical space for its inhabitants to meet key life requisite requirements (e.g., breeding, feeding, and cover).

Spatial Context pertains to whether flora and fauna find the ecosystem serviceable and is thought to be dictated by the pattern and connectivity (i.e., number, size, shape, and distribution) of habitat patches that comprise the floodplain forest community landscape as well as the level of disturbance immediately adjacent to those habitat patches.

3.9.4.2 Preparation of Baseline Data Set to Support the Floodplain Forest Community Index Model

3.9.4.2.1 Habitat Assessment Area

The habitat assessment area encompasses more than 40 miles of Clear Creek and its various tributaries, including Hickory Slough, Mud Gully, and Turkey, Mary's, Cowarts, and Chigger creeks. For this analysis, the study area is contained approximately within the Clear Creek 500-year floodplain. This study area includes about 42,000 acres of the 167,000-acre Clear Creek watershed. Armand and Taylor bayous, which enter Clear Creek much farther downstream in the Clear Lake area, were not included in the habitat assessment area since no flood risk management measures were considered for these water bodies due to the small amount of flood damages projected for them. Furthermore, a large portion of the Armand Bayou sub-watershed is contained within the Armand Bayou Nature Center, a protected natural area that will undergo limited development in the future.

3.9.4.2.2 Eco-Reaches

Clear Creek varies in width, depth, tidal exchange, and flow along its length. Vegetative communities reflect these changing physical and chemical conditions. Forested habitats that are hydrologically connected and/or contiguous with Clear Creek and its tributaries that could be influenced by the proposed project were divided into eco-reaches mapped for the purposes of assessing ecosystem responses to multiple flood risk and mitigation measures at varying scales on a target year basis throughout the project life. The habitat assessment area was divided into seven eco-reaches, identified based on the degree of degradation from human influences. Vegetation changes, land use, and stream morphology (width, bank characteristics, sinuosity, water depth), as well as past channelization activities, were considered in identifying each of these eco-reaches for the habitat analysis.

Baseline conditions were based on field data collected in 2003, and GIS coverages (based on 2000 imagery) were compiled and analyzed on a reach-by-reach basis over the course of the next several years (see Appendix B).

Baseline cover types for the eco-reaches were classified and mapped with the assistance of the ICT. The TPWD and USFWS provided forest, prairie, and tidal marsh habitat mapping; these maps were supplemented and revised as necessary on the basis of expert knowledge and field visits.

Project features will not affect coastal prairies or tidal marshes; therefore, the analysis focuses on floodplain forests. The forest within the 500-year floodplain was mapped and ground-truthed, and thereby provides the most-project-specific data on the vegetation communities within the study area. For these reasons, floodplain forest data were utilized for the baseline analysis.

The existing vegetation and conditions, including detailed descriptions and maps for each eco-reach, are described in the following sections. Table 3.9-2 illustrates each eco-reach as it corresponds to the various economic flood damage reaches.

Table 3.9-2
Eco-Reach with Corresponding Economic Flood Damage Reaches

Eco-Reach (ER)	Corresponding Economic Flood Damage Reaches
1	1-5
2	6 and 7
3	8 through 10
4	11 through 13
5	14 and 15
6	16 through 19

3.9.4.2.3 Eco-Reach 1: Clear Lake from its mouth at Galveston Bay upstream to I-45

Eco-Reach (ER) 1 corresponds to economic flood damage reaches 1 through 5. The lower two-thirds of ER 1 includes the relatively broad, shallow, open-water area known as Clear Lake, which covers about 2 square miles. Farther upstream, the creek narrows to about 180 feet in width with a meandering channel. This reach is moderately developed with more than 60 percent of the adjacent land made up of urban development and pasture, mostly in the lower two-thirds of Clear Lake. Shores are gently sloped throughout much of the reach. The remaining undeveloped areas of riparian corridor along Clear Creek occur mostly in the upstream portion, and these areas are typically forested with small areas of tidal fringe marsh occurring intermittently within small covelike features. The waterway remains relatively unaltered by channelization except for a very short section connecting Clear Lake to Galveston Bay. Important tributaries include Taylor Lake and Armand Bayou. The entire reach is tidally influenced.

This eco-reach includes 490 acres of floodplain forest and 255 acres of tidal marsh. These two types of land cover made up about 9 percent of the study area in ER 1. Areas of tidal marsh are populated by *Spartina, Juncus, Sagittaria,* and in some cases the submerged aquatic *Ruppia.* Some floodplain forest is located along the upper portion of this reach and in the Armand Bayou portion of the reach. Willow oak is common in these forest areas.

3.9.4.2.4 Eco-Reach 2: Clear Creek Tidal from I-45 upstream to FM 528

Eco-Reach 2 (ER 2) corresponds to economic flood damage reaches 6 and 7. Chigger Creek is about 10 miles long and Clear Creek is about 8 miles long in this eco-reach. ER 2 has experienced low to moderate development. Almost 50 percent of land cover in the study area is pasture followed by floodplain forest (27 percent) and urban development (19 percent). Clear Creek is about 180 feet wide just upstream of I-45, narrowing to around 90 feet in width at FM 528. Creek banks are gently sloped throughout, and some small areas of tidal marsh are still present in the lower 0.5 mile of the reach, totaling only 2 percent of the land cover in this reach. Clear Creek has not been channelized in ER 2 and retains its natural meanders and much of its riparian forest. The local drainage district performs some light clearing and snagging of trees along the water's edge.

Tidally influenced marsh at north bank of Clear Creek upstream of I-45

Clear Creek is tidally influenced in this eco-reach, and there is some exposure to estuarine waters in the lower 5 miles of this reach. Eco-reaches upstream of ER 2 are considered perennially fresh and should rarely, if ever, be exposed to salty estuarine waters. TCEQ (2006) identifies Chigger Creek as an intermittent stream with perennial pools for much of its length. Floodplain forest is found along the lower 3 miles of Chigger Creek. This reach of Clear Creek includes the healthiest and most-extensive stands of floodplain forest in the study area, with 1,095 acres of floodplain forest. Willow oak and cedar elm are common.

3.9.4.2.5 Eco-Reach 3: Clear Creek from FM 528 upstream to FM 2351 for a distance of about 4 miles, and Cowarts Creek

Eco-Reach 3 (ER 3) corresponds to economic flood damage reaches 8 through 10. This eco-reach includes the mainstem of Clear Creek and its tributary, Cowarts Creek. This reach has a high degree of development, with more than 90 percent of the adjacent land as pasture and urban development. Clear Creek begins to narrow considerably, ranging from 90 feet wide downstream to less than 30 feet wide at FM 2351. Stream banks steepen considerably in the upstream portion of the reach. Clear Creek has not been channelized and retains its natural meanders in this reach; however, a series of high-flow bypasses have been constructed at various locations in an effort to alleviate impacts of high-velocity flows during flooding. Development has reduced the floodplain forest to a comparatively narrow corridor within this reach. As a result of development, some clearing and snagging of trees along the edge of the creek has been performed by the local drainage district. Cowarts Creek, about 6.4 miles long, is the primary tributary to this reach of Clear Creek and is considered an intermittent stream with perennial pools (TCEQ, 2008a). Floodplain forests in this reach include green ash, American elm, sugar hackberry, water oak, and water hickory. The only floodplain forest on Cowarts Creek consists of a small patch near its confluence with Clear Creek.

Clear Creek at Imperial Estates, downstream view

3.9.4.2.6 Eco-Reach 4: Clear Creek from FM 2351 upstream to Country Club Drive and Mud Gully and Turkey Creek

Eco-Reach 4 (ER 4) corresponds to economic flood damage reaches 11 through 13. It includes about 8 miles of Clear Creek and two tributaries, Mud Gully and Turkey Creek. This reach has experienced a moderate to high degree of development with around 75 percent of the land converted to urban development or pasture. Clear Creek is relatively narrow, about 15 feet wide at the upstream limit, and has considerable meanders in this reach. Stream banks are naturally steep and nearly vertical. Bank slope has increased primarily due to erosion downstream of Dixie Farm Road and human alterations of the channel. The upstream portion of this reach from Dixie Farm Road to Country Club Drive has been shaped into a trapezoidal channel by flood control activities dating back to the 1940s. Past alterations combined with maintenance activities, including routine mowing, vegetation removal, and channel reshaping by the local drainage districts have left this portion of the creek a relatively straight, grass-lined, low-flow channel with steep slopes bordered by remnant fragmented riparian forest.

Channelization of the upstream portion of the reach also cut off many of the natural channel meanders when excavated material was mounded along the north bank. A series of forested oxbow lakes formed in the cutoff portions of the channel. While the oxbows join the creek via culverts, the water elevation at low flow in the rectified channel is too low for water exchange with oxbows except under heavy rainfall conditions. Under high-flow conditions, oxbows may fill to a level where they drain into the creek, or the flooding creek may force water through the culverts into the oxbows. With 1,053 acres of floodplain forest, this reach of Clear Creek has the second-largest area of floodplain forest, about 24 percent of the land cover.

Mud Gully downstream of Sagedowne Boulevard

The tributaries of Mud Gully and Turkey Creek have also been altered extensively as a result of past flood control activities, especially in the upstream areas. Each of these tributary creeks is about 3 miles long, and both are considered perennial streams by the TCEQ (2006). Turkey Creek has been previously channelized and straightened in the upper half, and although some natural sinuosity in the lower half of the channel remains, little natural forested riparian habitat exists. The remaining floodplain forest occurs predominantly in the lower portion of Turkey Creek and provides some shading; however, maintenance practices along the creek include routine mowing of the banks resulting in a predominantly grassy understory with little or no woody vegetation. Mud Gully has been extensively straightened and channelized upstream of Dixie Farm Road, and the creek’s banks in this reach are predominantly grass and concrete lined. As a result of these extensive modifications, floodplain forest habitat along Mud Gully is limited to a few relatively small patches near the tributary’s confluence with Clear Creek.

3.9.4.2.7 Eco-Reach 5: Clear Creek from Country Club Road upstream to SH 35

Eco-Reach 5 (ER 5) corresponds to economic flood damage reaches 14 and 15. This 6-mile reach of Clear Creek has experienced low to moderate development with about 75 percent of the adjacent land covered with tallgrass prairie (including remnant prairie) and, to a lesser extent, pasture. Clear Creek ranges from approximately 15 to 20 feet in width. It has been extensively altered since the 1940s into a trapezoidal-shaped channel by past flood control activities. Continued maintenance activities over the last 10 years, including routine mowing, vegetation removal, and channel reshaping by the local drainage districts, have kept this portion of Clear Creek a relatively straight, steep-sided, grass-lined, low-flow channel with virtually no woody vegetation near the water's edge except in a few isolated locations. The floodplain forest remaining within this reach occurs mostly outside the low-flow channel and is somewhat fragmented.



Clear Creek between Country Club Road and SH 35

3.9.4.2.8 Eco-Reach 6: Clear Creek from SH 35 upstream to just past SH 288

Eco-Reach 6 (ER 6) corresponds to economic flood damage reaches 16 through 19. Like ER 5, this reach of Clear Creek has a low to moderate degree of development with coastal prairie (including remnant prairie) making up about 79 percent of the land cover and, to a lesser extent, pasture. The main channel of Clear Creek is very narrow, seldom exceeding 15 feet in width at low flow. Much of this reach of Clear Creek has been shaped into a trapezoidal channel by past flood control activities back to the 1940s. Channel maintenance activities (e.g., reshaping, mowing, tree removal, etc.) from approximately 1 mile downstream of Cullen Boulevard to SH 35 have kept this section relatively straight with virtually no woody vegetation along the low-flow channel or its side slopes. The upstream portion of the creek in the vicinity of Tom Bass Park has not been maintained for many years allowing forested riparian habitat to return to the edges of the low-flow channel. Hickory Slough is a very small tributary (less than 8 feet wide) to Clear Creek within ER 6.

Clear Creek near Mykawa Road (2004)

Clear Creek floodplain forest (Wayside Drive)

Clear Creek at Tom Bass Park

3.9.4.2.9 Eco-Reach 7: Mary's Creek from its confluence with Clear Creek near Winding Road and Sunset Meadows Road

Eco-Reach 7 (ER 7) includes all of Mary's Creek within the 500-year floodplain. Habitat along Mary's Creek consists of a few small, isolated patches of remnant riparian forest in Brazoria County. ER 7 has less floodplain forest than any other reach in the study area as a result of the extensive urban and agricultural development, totaling 83 percent of the eco-reach area. Floodplain forest covered about 85 acres, or 3 percent of the study area. Urbanized areas and oldfields, haylands, and pasture cover 41 and 42 percent, respectively, of the eco-reach. Much of Mary's Creek has been modified and is currently channelized, with minimal riparian vegetation and habitat diversity. Riparian trees and shrubs have been removed along much of the creek.

Mary's Creek downstream of Harkey Road, Pearland, Texas

Mary's Creek downstream of Veteran's Road

3.9.4.3 Baseline Habitat Suitability Indices for Floodplain Forest Community

Calculation of baseline HSI and HUs using the HEP assessment for the reaches is summarized in Appendix B. Baseline HSI scores for floodplain forests in each of the eco-reaches range from 0.47 (ER 3, Clear Creek) to 0.840 (ER 2, Clear Creek) (Table 3.9-3). ER 3, Clear Creek, and ER 7, Mary's Creek, have the lowest HSI scores primarily because these reaches have been extensively altered. ER 2 has the highest HSI score because it has the largest quantities of floodplain forest. Even though there has been modification of the channel in ER 4, substantial amounts of floodplain forest remain in oxbows cut off from the channel.

Table 3.9-3
Baseline Habitat Units for Clear Creek Floodplain Forest

Eco-Reach	Habitat Suitability Index	Acres	Baseline Habitat Units
1	0.67	490	338
2	0.840	1,095	920
3	0.47	253	119
4	0.74	1,053	781
5	0.62	337	209
6	0.56	489	275
7	0.48	85	41

3.10 FISH AND WILDLIFE RESOURCES

3.10.1 Freshwater

Freshwater fish and macroinvertebrates occur in Clear Creek, Armand Bayou, Taylor Lake Bayou, Clear Lake, and their tributaries. The freshwater zone of Clear Creek is typically upstream of I-45 but varies with the amount of freshwater inflow and tides. The zone of tidal influence fluctuates, and many of the fish species encountered have relatively wide ranges of salinity tolerance. Consequently, fish that are typically considered freshwater species may be found in Clear Lake and fish typically considered saltwater species may at times be found upstream in Clear Creek.

Previous project investigations (Dannenbaum Engineering Corporation and Vazquez Environmental Services, Inc., 1991) describe habitat degradation and fragmentation as a concern. Degradation has been exacerbated by the rapid urbanization of the watershed. As found in the recent TCEQ (2007b, 2007c unpublished data) studies, unstable banks and altered hydrology are some of the factors contributing to habitat degradation. Despite habitat degradation, recent fisheries data from the freshwater and intermediate zones suggest that the communities' structure has changed little over time. Lohse and Tyson (1973) provide one of the earliest comprehensive species accounts of Clear Creek freshwater and intermediate zones. The species they collected were comparable to recent collections by the TCEQ (2007b, 2007c unpublished data).

3.10.1.1 Fisheries

Fish species that occur within the freshwater zones of the study area include those species common to low-gradient, warm-water streams in the southeastern U.S. The TCEQ sampled the fish community and habitat in Clear Creek at SH 35 in 2002 (April and September) and 2005

(June and September) (TCEQ, 2007b, 2007c unpublished data) (Table 3.10-1). The analyses from these assessments suggest the fish communities were relatively healthy at the time the samples were collected. Preliminary aquatic life use determinations were intermediate during three of the sample events and high during one of the sample events. The aquatic life use determinations of intermediate and high are based on the Texas Surface Water Quality Standards for the state of Texas (TCEQ, 2008b). A fish community that receives a high aquatic life use designation has high species diversity, and species that are sensitive to pollution are present and abundant. A fish community receiving an intermediate aquatic life use designation has moderate fish species diversity, and, if species sensitive to pollution are present, they are not abundant.

The only intolerant species collected was the freckled madtom, *Noturus nocturnus,* and only three specimens were collected during only one of the four sample events. The infrequent occurrence in low numbers of this species, which does not tolerate degraded environmental conditions (Thomas et al., 2007), suggests the habitat and/or water quality conditions in Clear Creek have experienced some degree of degradation.

The 2005 TCEQ habitat assessments suggest much of the creek has relatively unstable bottom and banks, with a very narrow riparian zone, averaging 2 meters in width, and with grasses and forbes making up 95 percent of the riparian vegetation. The stream banks were described as moderately unstable with an average stream bank erosion potential of 56 percent and an average bank angle slope of 59°. Instream cover for fish was placed in the rare category with between 10 to 29 percent of the substrate supporting stable habitat and the substrate showing signs of being frequently disturbed or removed.

The TCEQ has also collected fish from Armand Bayou, a major tributary to the tidal reach of Clear Creek, in 2002 (TCEQ, 2007b, 2007c unpublished data) (see Table 3.10-1). The TCEQ additionally collected fish from Dickinson Bayou, which is the watershed to the south of and adjacent to the Clear Creek watershed, in 1992 and 1993. The Clear Creek and Dickinson Bayou watersheds have similar soil, topography, weather, and vegetation, and would be expected to have similar fish faunas. Freshwater species encountered in Dickinson Bayou are therefore included in this description because it is reasonable to expect them to be present in Clear Creek. Although some species listed are considered saltwater species, those species are described in Hubbs et al. (1991) as occasionally being found in the freshwater portions of tidal streams. TPWD does not have species counts for Clear Creek, Armand Bayou, or Taylor Lake Bayou (Webb, 2002).

Table 3.10-1
Fish and Shellfish Expected in Clear Creek (Freshwater and Tidal Reaches) and Clear Lake

Common Name	Scientific Name	Habitat Preference			Clear Creek	Armand Bayou	Dickinson Bayou
		Freshwater	Euryhaline	Marine			
Invertebrates							
Blue crab	*Callinectes sapidus*		X			X	X
Mud crab	*Rhithropanopeus harrisii*		X			X	
Brown shrimp	*Farfantopenaeus aztecus*		X			X	X
White shrimp	*Litopenaeus setiferus*		X			X	X
Pink shrimip	*Farfantepenaeus duorarum*		X				
Arrow shrimp	*Tozeuma carolinense*		X				X
Larval shrimp						X	
Grass shrimp	*Palaemonetes kadiakensis*		X			X	
Grass shrimp	*Palaemonetes paludosus*		X			X	
Grass shrimp	*Palaemonetes pugio*		X			X	X
Grass shrimp	*Palaemonetes intermedius*		X				X
Grass shrimp	*Palaemonetes vulgaris*		X				X
Prawn	*Macrobrachium acanthurus*		X				
Prawn	*Macrobrachium ohione*		X				X
Prawn	*Macrobrachium* sp.		X				
Cambaridae							
Crayfish	*Procambarus* sp.	X					X
Soleidae							
Lined sole	*Achirus lineatus*			X		X	
Hogchoker	*Trinectes maculatus*			X		X	
Engraulidae							
Bay anchovy	*Anchoa mitchelli*			X		X	
Striped anchovy	*Anchoa hepsetus*			X			X
Ariidae							
Sea catfish	*Arius felis*			X			X
Gafftopsail catfish	*Bagre marinus*			X		X	
Clupeidae							
Skipjack herring	*Alosa chrysochloris*		X				X
Gulf menhaden	*Brevoortia patronus*			X		X	
Gizzard shad	*Dorosoma cepedianum*	X				X	
Threadfin shad	*Dorosoma petenense*	X					X
Scaled sardine	*Harengula jaguana*		X				X
Bothidae							
Bay whiff	*Citharichthyes spilopterus*			X		X	
Southern flounder	*Paralichthys lethostigma*			X		X	
Sciaenidae							
Freshwater drum	*Aplodinotus grunniens*	X					X
Sand seatrout	*Cynoscion arenarius*			X		X	
Spotted seatrout	*Cynoscion nebulosus*			X		X	
Spot	*Leiostomus xanthurus*			X		X	
Atlantic croaker	*Micropogonias undulatus*			X		X	

Table 3.10-1 (Cont'd)

		Habitat Preference			Clear Creek	Armand Bayou	Dickinson Bayou
Common Name	Scientific Name	Freshwater	Euryhaline	Marine			
Red drum	*Sciaenops ocellatus*			X		X	
Silver perch	*Bairdiella chrysoura*			X			X
Cyprinodontidae							
Diamond killifish	*Adinia xenica*			X			X
Sheepshead minnow	*Cyprinodon variegatus*			X		X	
Golden topminnow	*Fundulus chrysotus*		X				X
Gulf killifish	*Fundulus grandis*			X		X	
Blackstripe topminnow	*Fundulus notatus*	X			X		
Bayou killifish	*Fundulus pulvereus*			X		X	
Saltmarsh killifish	*Fundulus jenkinsi*		X				X
Longear sunfish	*Fundulus similis*		X				X
Rainwater killifish	*Lucania parva*	X					X
Cyprinidae							
Common carp	*Cyprinus carpio*	X				X	
Golden shiner	*Notemigonus crysoleucas*	X					X
Red shiner	*Cyrpinella lutrensis*	X			X		
Bullhead minnow	*Pimephales vigilax*	X			X		
Elopidae							
Ladyfish	*Elops saurus*			X		X	
Gobiidae							
Violet goby	*Gobioides broussonneti*			X		X	
Naked goby	*Gobiosoma bosci*			X		X	
Clown goby	*Microgobius gulosus*			X		X	
Ictaluridae							
Black bullhead	*Ameiurus melas*	X			X		X
Yellow bullhead	*Ameiurus natalis*	X					X
Blue catfish	*Ictalurus furcatus*		X				X
Channel catfish	*Ictalurus punctatus*	X			X	X	
Freckled madtom	*Noturus nocturnus*	X			X		
Flathead catfish	*Pylodictis olivaris*	X			X		
Catostomidae							
Smallmouth buffalo	*Ictiobus bubalus*	X				X	
Sparidae						X	
Pinfish	*Lagodon rhomboides*			X		X	
Lepisosteidae							
Spotted gar	*Lepisosteus oculatus*	X				X	
Shortnose gar	*Lepisosteus platostomus*	X				X	
Alligator gar	*Lepisosteus spatula*		X				X
Centrarchidae							
Banded pigmy sunfish	*Elassoma zonatum*	X					X
Sunfish	*Lepomis* sp.	X				X	
Green sunfish	*Lepomis cyanellus*	X			X	X	
Warmouth	*Lepomis gulosus*	X				X	
Orangespotted sunfish	*Lepomis humilus*	X				X	
Bluegill	*Lepomis macrochirus*	X			X	X	
Dollar sunfish	*Lepomis marginatus*	X				X	

Table 3.10-1 (Cont'd)

Common Name	Scientific Name	Habitat Preference			Clear Creek	Armand Bayou	Dickinson Bayou
		Freshwater	Euryhaline	Marine			
Longear sunfish	*Lepomis megalotis*	X			X	X	
Redear sunfish	*Lepomis microlophus*	X				X	
Spotted sunfish	*Lepomis punctatus*	X			X		X
Spotted bass	*Micropterus punctulatus*	X			X	X	
Largemouth bass	*Micropterus salmoides*	X			X	X	
Black crappie	*Pomoxis nigromaculatus*	X					X
White crappie	*Pomoxis annularis*	X					X
Atherinidae							
Tidewater silverside	*Menidia peninsulae*			X		X	
Inland silverside	*Menidia beryllina*	X		X	X	X	
Rough silverside	*Membras martinica*			X			X
Mugilidae							
Striped mullet	*Mugil cephalus*			X		X	
Carangidae							
Leatherjacket	*Oligoplites saurus*			X		X	
Jack crevalle	*Caranx hippos*		X				X
Poeciliidae							
Sailfin molly	*Poecilia latipinna*	X			X	X	
Western mosquitofish	*Gambusia affinis*	X			X	X	
Syngnathidae							
Chain pipefish	*Syngnathus louisianae*			X		X	
Gulf pipefish	*Syngnathus scovelli*			X		X	
Cichlidae							
Rio Grande cichlid	*Cichlisoma cyanoguttatum*	X			X		

Source: Hubbs et al. (1991); Parker (1965); TCEQ (2007b, 2007c).

Little is known about the amount of angling that occurs within the freshwater zones of these streams (Webb, 2002). Due to the high recreational use of Clear Lake, Armand Bayou, and Taylor Lake Bayou, fishing in these areas is probably common. However, the popularity of fishing in Clear Creek is questionable since the TDSHS implemented a fish-consumption advisory for Clear Creek in 1993 and 2009 (see subsection 3.2.1 for further detail).

3.10.1.2 Benthic Macroinvertebrates

Benthic macroinvertebrates were sampled at eight sites in Clear Creek, four above the tidal reach and four in the tidal reach, by the TDWR (1977). This survey reported low densities (0 to 21 individuals per square foot) and diversity (0 to 7 taxa per square foot) of benthic macro-invertebrates. Samples from the tidal reach of the creek had the fewest species (0 to 2 taxa). The tubificid worm *Limnodrilus udekemianus* reached the highest densities measured, ranging from 104 to 26,400 individuals/square foot. There are no recent benthic macroinvertebrate data from Clear Creek.

A number of invertebrates that have been collected in Armand Bayou and Dickinson Bayou are also listed in Table 3.10-1 (TCEQ, 2007b, 2007c). These invertebrates typically feed and move along the stream bottoms. These species are an important food source for fish and other organisms.

While no formal mussel collections are known for Clear Creek or other tributaries in the Clear Creek watershed, it is likely that multiple species occur within the study area (Howells et al., 1996). Round pearlshell (*Glebula rotundata*) were recently collected just outside of the study area in Mustang Bayou (Howells, 2002). Other species common to southeast Texas such as the paper pondshell (*Anodonta imbecillis*), yellow sandshell (*Lampsilis teres*), and giant floater (*Anodonta grandis*) are likely to be found within the freshwater zones of Clear Creek, Taylor Lake Bayou, and Armand Bayou. *Rangia cuneata*, a mussel commonly found in estuarine waters, was historically found in Clear Lake, as seen in shell middens (Voellinger, 1987), and probably still occurs in the brackish reaches of the study area.

Other freshwater macroinvertebrates in the study area include those species typically found in low-gradient streams or pools and ephemeral waterbodies such as ditches and wetlands. Examples include dragonflies (Odonata), crayfish (Cambaridae), caddisflies (Trichoptera), snails (Gastropoda), true bugs (Hemiptera), and midge flies (Chironomidae). According to Howells (2002), apple snails (*Pomacea* spp.) have become a serious concern to natural resources and agricultural agencies in Texas. Apple snails are voracious herbivores and have caused extensive damage to rice crops and other vegetation in the Far East. It is likely that apple snails have invaded Clear Creek because individuals were recently collected from American Canal to the south of the study area and Armand Bayou. High flows from Tropical Storm Allison in June 2001 likely facilitated the spread of this species throughout the study area (Howells, 2002).

3.10.2 Estuarine and Marine Resources

3.10.2.1 Finfish and Shellfish

The lower portion of the study area encompasses estuarine and marine habitats that are both naturally dynamic and subject to anthropogenic changes. Due to its estuarine nature and hydraulic tie to Galveston Bay, the biological community present in the lower portion of the study area is diverse and abundant. Clear Lake is considered one of the most important nursery areas of Galveston Bay (Lohse and Tyson, 1973). Many of the species found in Galveston Bay are also found in Clear Lake and the downstream reaches of Clear Creek and Armand and Taylor bayous. TPWD has identified about 13 species of shrimp, 17 species of crab, and over 150 finfish species in Galveston Bay (Loeffler in Green et al., 1992; McEachron et al., 1977; Parker, 1965; Sheridan et al., 1989). However, in one 2-year trawl study for fish, six species were found to account for 91 percent of the total number of fish collected: Atlantic croaker (*Micropogonias undulatus*) (51 percent); bay anchovy (*Anchoa mitchelli*) (22 percent); star drum (*Stellifer lanceolatus*) (8 percent); spot (*Leiostomus xanthurus*) (4 percent); sand seatrout (*Cynoscion arenarius*) (3 percent); and sea catfish (*Arius felis*) (3 percent). These six species, plus striped mullet (*Mugil cephalus*), accounted for 74 percent of the fish biomass collected, whereas Atlantic croaker alone represented 34 percent of the total fish biomass (Sheridan et al., 1989). All of the six species except for the bay anchovy and sea catfish belong to the drum (Sciaenidae) family. Of the seven species making up 74 percent of the fish biomass in Galveston Bay, all have been collected from Clear Lake except the star drum (TCEQ, 2007e, 2007f). Fish and shellfish in Clear Lake represent a range of salinity conditions from freshwater to marine (TCEQ, 2007e, 2007f). With salinity similar to Galveston Bay, the species composition of Clear Lake can be similar to that of Galveston Bay. However, Lohse and Tyson (1973) suggest that the most predominant species by biomass in Clear Lake are those species known to tolerate euryhaline (various ranges of salinity) conditions.

3.10.2.1.1 Recreational and Commercial Species

Commercial and recreational landings are reported for the Galveston Bay area, and little information is available that is specific for Clear Lake. Many of the species that occur in Galveston Bay can also be found in Clear Lake, and their presence is highly dependent upon salinity and temperature. While Clear Lake is not utilized extensively for commercial harvest, recreational anglers often pursue sport fish in this area.

The Galveston Bay system maintains important recreational and commercial fisheries for shrimp, crabs, and fishes. According to the GBNEP (1994b), during the last 100 years, the total landings from the estuary have doubled, mostly due to the shrimp and crabs. The annual finfish catch is a relatively small part (4.9 percent) of the total harvest, averaging about one-half million pounds per year (GBNEP, 1994b). According to 1997 data from Robinson et al. (1998), four species account for nearly 66 percent of the total finfish harvest: southern flounder (*Paralichthys* *lethostigma*) (10 percent), black drum (*Pogonias cromis*) (6 percent), mullet (*Mugil* spp.) (41 percent), and sheepshead (*Archosargus probatocephalus*) (9 percent).

Galveston Bay historically has been the overall leading fisheries resource base in Texas. A comparison of landings among Texas bays for 1993 through 1997 indicates that Galveston Bay landings exceeded landings in all bays for white shrimp (*Litopenaeus setiferus*) (53 percent). Shrimp, blue crabs, and oysters have been the dominant shellfish species in the commercial catch, making up nearly 95 percent of the total annual Galveston Bay catch (GBNEP, 1994b). Over 3 million pounds of white shrimp, along with 1.9 million pounds of brown shrimp, were caught in the bay in an average year (GBNEP, 1994b). There were about 1.8 million pounds of blue crabs in an average year's harvest (Osburn et al., 1987). Finally, by weight, the eastern oyster (*Crassostrea virginica*) was the single most important species harvested in the bay during the period (1920–1990) (3.9 million pounds per year) (GBNEP, 1994b). Lohse and Tyson (1973) indicate that eastern oysters are common in Clear Lake.

Galveston Bay accounted for 32 percent of the coastwide angling pressure and 36 percent of the coastwide fish landings from 1998 through 2008 (TPWD, 2010). These recreational fishing groups caught 27 percent of the spotted seatrout, 66 percent of the Atlantic croaker, 61 percent of the southern flounder, and 27 percent of the black drum taken by recreational anglers on the Texas coast from 1998 through 2008 (TPWD, 2010).

3.10.2.1.2 Estuarine and Marine Communities

Relatively little sampling has been conducted of the estuarine and marine communities of Clear Lake. The food chain within Clear Lake and the lower reaches of Clear Creek is plankton based. Plankton are microscopic plants (phytoplankton) and small animals (zooplankton) that are suspended in the water column. Zooplankton typically consume phytoplankton, and, in turn, the zooplankton (and occasionally phytoplankton) are fed upon by juvenile fish of all species, filter-feeding fish such as menhaden (*Brevoortia gunteri*) and gizzard shad (*Dorosoma cepedianum*), and filter-feeding mollusks. The TDWR (1981) collected over 132 species of phytoplankton in upper Galveston and Trinity bays, with diatoms (54 taxa), green algae (45 taxa), and blue-green algae (14 taxa) being dominant. The copepod *Acartia tonsa* is the dominant zooplankton species in Galveston Bay and other Texas estuaries (Lee et al., 1986).

The benthic and macroinvertebrates of Clear Creek and Clear Lake form a low to moderately diverse group of organisms with a wide variety of functions in the aquatic community. Their diversity is related to salinity, and, as salinity levels increase, marine species are able to colonize the system. Due to the unstable salinity regimes, the benthic diversity is low to moderate (White et al., 1985). In addition to serving as a food source for vertebrate predators such as fish, macroinvertebrates have important roles as herbivores, detritivores, and carnivores. A general survey of lower Galveston Bay by Holland et al. (1973) indicated that four benthic species were ubiquitous at all sites. These included the polychaetes *Nereis succinea*, *Streblospio benedicti*, and *Mediomastus californiensis*, and the barnacle *Balanus eburneus*. Also observed at most of the sites included the polychaete *Diopatra cuprea* and the mollusk *Mulinia lateralis*. The abundance of benthos appeared to peak in the late winter and spring, with the fewest occurring in early summer and fall (Armstrong, 1987).

3.10.2.2 Essential Fish Habitat

The DEIS initiated EFH consultation under the Magnuson-Stevens Fishery Conservation and Management Act. Congress enacted amendments to the Act (PL 94-265) in 1996 that established procedures for identifying Essential Fish Habitat (EFH) and required interagency coordination to further the conservation of federally managed fisheries. Rules published by the NMFS (50 CFR sections 600.805–600.930) specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake an activity that could adversely affect EFH is subject to the consultation provisions of the above-mentioned act and identifies consultation requirements.

EFH is defined as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." EFH is separated into estuarine and marine components. The estuarine component is defined as "all estuarine waters and substrates (mud, sand, shell, rock, and associated biological communities); sub-tidal vegetation (seagrasses and algae); and adjacent inter-tidal vegetation (marshes and mangroves)." The marine component is defined as "all marine waters and substrates (mud, sand, shell, rock, and associated biological communities) from the shoreline to the seaward limit of the Exclusive Economic Zone" (Gulf of Mexico Fisheries Management Council [GMFMC], 2004).

The tidally influenced estuarine areas of the study area occur within Clear Lake and the lower portion of Clear Creek to just upstream of I-45. This area contains substrates and waters that have been identified by the GMFMC as EFH for adult and juvenile white shrimp, brown shrimp, red drum, and Spanish mackerel (*Scomberomorus maculatus*). EFH known to occur in this portion of the study area that may be utilized by these fisheries species includes estuarine emergent wetlands; estuarine mud, sand, and shell substrates; SAV; and estuarine water column. Detailed information on red drum, shrimp, and other federally managed fisheries and their EFH is provided in the 1998 amendment of the Fishery Management Plans for the Gulf of Mexico prepared by the GMFMC.

The following describes the preferred habitat of each species and relative abundance of each species within Clear Lake and Lower Clear Creek, based on information provided by the GMFMC (2004). These species are frequently associated with emergent marsh, and most of the marsh is located in the Taylor Bayou and Armand Bayou arms of Clear Lake and in upper Clear Lake between I-45 and Nassau Bay. Much of the Clear Lake shoreline, particularly in the downstream part of the estuary has been modified with boat basins and bulkheads with very little emergent marsh in the lower portion of Clear Lake.

Brown shrimp eggs are demersal and are deposited offshore. The larvae begin to migrate through passes with flood tides into estuaries as postlarvae. Migrating occurs at night, mainly from February to April, with a minor peak in the fall. Brown shrimp postlarvae and juveniles are associated with shallow vegetated habitats in estuaries, but are also found over silty sand and nonvegetated mud bottoms. Postlarvae and juveniles occur in salinity ranging from zero to 70 ppt. The density of late postlarvae and juvenile brown shrimp is highest in marsh-edge habitat and submerged vegetation, followed by tidal creeks, inner marsh, shallow open water, and oyster reefs. Muddy substrates seem to be preferred in unvegetated areas. Juvenile and subadult brown shrimp can be found from secondary estuarine channels out to the continental shelf, but prefer shallow estuarine habitats, such as soft, muddy areas associated with plant-water interfaces. Juvenile brown shrimp are considered abundant within tidally influenced portions of the study area from February to April, with a minor peak in the fall, while adults are considered common April through October.

Larval brown shrimp feed on phytoplankton and zooplankton. Postlarval brown shrimp feed on phytoplankton, epiphytes, and detritus. Juvenile and adult brown shrimp prey on amphipods, polychaetes, and chironomid larvae, and graze on algae and detritus (Pattillo et al., 1997).

White shrimp inhabit Gulf and estuarine waters and are pelagic or demersal, depending on their life stage. Their eggs are demersal and larval stages are planktonic, and both occur in nearshore Gulf waters. Postlarvae migrate into estuaries through passes from May to November, with most migration occurring in June and September. Migration is in the upper 6.5 feet of the water column at night and at mid-depths during the day. Postlarval white shrimp become benthic once they reach the estuary. Here they seek shallow water with mud or sand bottoms high in organic detritus or rich marsh where they develop into juvenile white shrimp. Postlarvae and juveniles prefer mud or peat bottoms with large quantities of decaying organic matter or SAV. Densities are usually highest along marsh edge and in SAV, followed by marsh ponds and channels, inner marsh, and oyster reefs. White shrimp juveniles prefer salinities of less than 10 ppt and occur in tidal rivers and tributaries. As white shrimp juveniles mature, they migrate to coastal areas where they mature and spawn. Adult white shrimp are demersal and inhabit soft mud or silt bottoms (GMFMC, 2004). Juvenile white shrimp are considered abundant within tidally influenced portions of the study area year-round, with peaks in June and September, while adults are common July through March.

White shrimp larvae feed on phytoplankton and zooplankton. White shrimp postlarvae feed on phytoplankton, epiphytes, and detritus. Juvenile and adult white shrimp prey on amphipods, polychaetes, and chironomid larvae, but also graze on algae and detritus (Pattillo et al., 1997).

Red drum occupy a variety of habitats, ranging from offshore depths of 131 feet to very shallow estuarine waters. Spawning occurs in the Gulf near the mouths of bays and inlets during the fall and early winter. Eggs usually hatch in the Gulf, and larvae are transported with tidal currents into the estuaries where they mature. Adult red drum use estuaries, but tend to migrate offshore where they spend most of their adult life. Red drum occur over a variety of substrates including sand, mud, and oyster reefs and can tolerate a wide range of salinities (GMFMC, 2004).

Estuaries are especially important to larval, juvenile, and subadult red drum. Juvenile red drum are most abundant around marshes, preferring quiet, shallow, protected waters over mud substrate or among SAV. Subadult and adult red drum prefer shallow bay bottoms and oyster reefs (GMFMC, 2004). Estuaries are also important for the prey of larval, juvenile, and subadult red drum. Red drum larvae feed primarily on shrimp, mysids, and amphipods, while juvenile red drum prefer fish and crabs. Adult red drum feed primarily on shrimp, blue crab, striped mullet, and pinfish (GMFMC, 2004). Adult and juvenile red drum are considered common throughout tidally influenced portions of the study area year-round.

Spanish mackerel are pelagic, inhabiting depths to 245 feet throughout the coastal zone of the Gulf. Adult Spanish mackerel are usually found from nearshore to the edge of the continental shelf. However, they may also migrate seasonally into estuaries with high salinity, but this migration is infrequent and rare. Spawning occurs in the Gulf from May through October. Larvae typically occur in the Gulf in depths ranging from 30 to 275 feet. Juveniles inhabit the Gulf surf and sometimes estuarine habitats. However, juvenile Spanish mackerel prefer marine salinities and are not considered estuarine-dependent. Adult and juvenile Spanish mackerel are found in the Gulf year-round and could be present within tidally influenced portions of the study area. Juvenile Spanish mackerel prefer clean sand bottoms, but the substrate preferences of the other life stages are unknown (GMFMC, 2004).

While Spanish mackerel rarely use estuarine environments, estuaries are important for most of their prey. They feed on a variety of fishes, extensively herrings. Squid, shrimp, and other crustaceans are also fed upon by Spanish mackerel. Adult and juvenile Spanish mackerel are considered common in tidally influenced portions of the study area from April through October.

3.10.3 Wildlife Resources

According to Blair (1950), the study area is located along the boundary between the Texan and Austroriparian biotic provinces of Texas. Most of the study area is within the Texan Biotic Province, while only the far eastern portion of the study area is within the Austroriparian Biotic Province. The Texan Biotic Province supports a diverse fauna composed of a mixture of species common to neighboring provinces. Austroriparian species from the east are generally restricted to forests, bogs, and marshes, while grassland species, entering the area from the west, are generally restricted to the prairies (Blair, 1950). Wildlife habitats within the study area correspond to the vegetation types described in Section 3.9 and generally include estuarine and freshwater wetlands, grassland (including coastal prairie), scrub/shrub, woodland/forest, and riparian woodland/forest. Habitat variety within the study area allows for a diversity of species, which are described below in the following section.

According to Dixon (2000), at least 18 anuran species, 5 urodele species, 9 lizard species, 37 snake species, and 13 turtle species occur or have occurred in one or more of the study area counties. Common amphibian and reptile species in the study area may include Blanchard's cricket frog (*Acris crepitans blanchardi*), Gulf Coast toad (*Bufo nebulifer*), eastern six-lined racerunner (*Aspidoscelis sexlineata sexlineata*), Mediterranean house gecko (*Hemidactylus turcicus*), Texas ratsnake (*Elaphe obsoleta*), eastern hog-nosed snake (*Heterodon platirhinos*), several species of watersnake (*Nerodia* spp.), western cottonmouth (*Agkistrodon piscivorous leucostoma*), copperhead (*Agkistrodon contortrix*), coral snake (*Micrurus fulvius tener*), western diamondback rattlesnake (*Crotelus atrox)* snapping turtle (*Chelydra serpentina*), stinkpot (*Sternothorus odoratus*), and red-eared slider (*Trachemys scripta elegans*) (Dixon, 2000).

The study area supports an abundant and diverse avifauna. Upland and riparian woodlands provide excellent habitat for a variety of year-round and seasonal resident songbirds and also provide critical stopover habitat for numerous species of neotropical songbirds during migration. Species common to the study area may include turkey vulture (*Cathartes aura*), eastern screech owl (*Megascops asio*), chuck-will's-widow (*Caprimulgus carolinensis*), red-bellied woodpecker (*Melanerpes carolinus*), American crow (*Corvus brachyrhynchos*), tufted titmouse (*Baeolophus bicolor*), northern mockingbird (*Mimus polyglottos*), cedar waxwing (*Bombycilla cedrorum*), northern cardinal (*Cardinalis cardinalis*), painted bunting (*Passerina ciris*), and American goldfinch (*Carduelis tristis*) (Lockwood and Freeman, 2004; Richardson et al., 1998). Riparian corridors provide habitat for species such as black-bellied whistling-duck (*Dendrocygna autumnalis*), wood duck (*Aix sponsa*), black-crowned night-heron (*Nycticorax nycticorax*), red-shouldered hawk (*Buteo lineatus*), barred owl (*Strix varia*), and belted kingfisher (*Megaceryle alcyon*) (Lockwood and Freeman, 2004; Richardson et al., 1998).

Prairies and marshes provide habitat for numerous migratory avian species, waterfowl, several species of raptors, and a variety of songbirds. Texas is one of the most significant waterfowl wintering regions in North America with 3 to 5 million waterfowl annually wintering in the state (Texas Coastal Management Program [TCMP], 1996). Common species of prairies and marshes include greater Canada goose (*Branta canadensis*), gadwall (*Anas strepera*), northern shoveler (*Anas clypeata*), northern pintail (*Anas acuta*), northern harrier (*Circus cyaneus*), killdeer (*Charadrius vociferus*), mourning dove (*Zenaida macroura*), scissor-tailed flycatcher (*Tyrannus forficatus*), barn swallow (*Hirundo rustica*), white-crowned sparrow (*Zonotrichia leucophrys*), and meadowlarks (*Sturnella* spp.) (Lockwood and Freeman, 2004; Richardson et al., 1998). In the easternmost portion of the study area, estuaries, tidal flats, and bay margins provide excellent habitat for numerous species of herons and egrets, shorebirds, wading birds, gulls, and terns.

According to the USFWS Texas Colonial Waterbird Census (TCWC) (USFWS, 2007a), one documented rookery occurs within the study area. Rookery 600-418 (Raley Colony) along Cow Bayou, which is located east of Egret Bay Boulevard, supports a population of approximately 25 to 27 pairs of green herons (*Butorides virescens*).

According to Schmidly (2004), at least 46 mammalian species occur or have occurred in one or more of the study area counties. Common mammals in the study area may include Virginia opossum (*Didelphis virginiana*), eastern pipistrelle bat (*Pipistrellus subflavus*), nine-banded armadillo (*Dasypus novemcinctus*), eastern cottontail (*Sylvilagus floridanus*), eastern fox squirrel (*Sciurus niger*), hispid pocket mouse (*Chaetodipus hispidus*), white-footed mouse (*Peromyscus leucopus*), hispid cotton rat (*Sigmodon hispidus*), eastern woodrat (*Neotoma floridana*), nutria (*Myocastor coypus*), coyote (*Canis latrans*), common gray fox (*Urocyon cinereoargenteus*), northern raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), and bobcat (*Lynx rufus*) (Schmidly, 2004).

A large portion of the project area consists of infrastructure, urban residential developments, and commercial/industrial areas. The remaining habitat available for wildlife use corresponds to the vegetation types described in Section 3.9 and includes estuarine and freshwater wetlands, grassland (including coastal prairie), scrub/shrub, woodland/forest, and riparian corridors.

3.11 THREATENED AND ENDANGERED SPECIES

Congress enacted the Endangered Species Act (ESA) [16 USC 1531 et seq.] of 1973, as amended, to provide a program for the preservation of threatened and endangered species and to provide protection for the ecosystems upon which these species depend for their survival. All Federal agencies are required to implement protection programs for these designated species and to use their authorities to further the purposes of the act. An endangered species is one that is in danger of extinction throughout all or a significant portion of its range in the U.S. A threatened species is one likely to become endangered within the foreseeable future throughout all or a significant portion of its range. The USFWS and NMFS are the primary agencies responsible for implementing the ESA. The USFWS is responsible for birds and terrestrial and freshwater species, while the NMFS is responsible for nonbird marine species.

The State of Texas also has regulations to protect endangered species (chapters 67, 68, and 88 of the TPWD Code and sections 65.171–65.184 and 69.01–69.14 of Title 31 of the Texas Administrative Code [TAC]). These regulations, administered by TPWD, prohibit commerce of threatened and endangered plants and wildlife and the collection of listed plant species from public land without a permit. This assessment addresses State-listed threatened and endangered species; however, these species are not protected under the ESA.

Table 3.11-1 presents a list of all 58 threatened, endangered, candidate, or species of concern (SOC) plants and animals identified by the USFWS (2012), NMFS (2012), and TPWD (2012a–d) as potentially occurring in one or more of the study area counties. The USFWS (2012) and TPWD (2012a–d) provided county-level lists of threatened and endangered plant and animal species of potential occurrence in the study area (Appendix D-1). In addition, TPWD's Texas Natural Diversity Database (TXNDD, 2007) provided digital map data presenting specific locations of listed plant and animal species within the study area.

The TPWD Annotated County Lists of Rare Species for Harris, Galveston, Brazoria, and Fort Bend counties includes 39 species that are assigned a State and/or Federal status of either threatened or endangered, and 4 species that are candidates for Federal listing. The USFWS Southwest Region Ecological Services County by County lists for Harris, Galveston, Brazoria, and Fort Bend counties include 9 species with a Federal status of either threatened or endangered and 1 delisted species. A list of federally protected species under the jurisdiction of the NOAA Fisheries Service for the State of Texas was provided by NMFS (2012). This list includes 10 species with a Federal status of endangered or threatened, 8 candidate species, and 5 SOC (see Appendix D-1).

The likelihood of occurrence within the study area for each species was determined using the most current available documented information regarding habitat requirements, range, and known occurrences. The likelihood of a species to occur in an area is always subject to change based upon new biological information.

3.11.1 Flora

Only one plant species, the Texas prairie dawn-flower (*Hymenoxys texana*) is listed in Table 3.11-1. Texas prairie dawn-flower (federally listed endangered) is endemic to Texas and is known to occur in Fort Bend and Harris counties, where it occurs on sparsely vegetated areas at the base of pimple (mima) mounds or other nearly barren areas on slightly saline soils in coastal prairie grasslands (USFWS, 1989). Habitat destruction by urban development is the primary threat to this species (USFWS, 1989). According to TXNDD (2007), there is a known occurrence of the species in southeastern Harris County, within the study area. The study area is within the known range of the species, and it is possible that other unrecorded populations are present within the study area where conditions are suitable to support this species. A review of historic and recent aerial photography for the project area has identified areas that could support potential habitat for the Texas prairie dawn-flower; however, none of these occur within the project footprint (Appendix E).

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Table 3.11-1
Threatened and Endangered Species of Potential Occurrence in the Study Area[1]

Common Name[2]	Scientific Name[2]	Status[1, 3]		On TPWD Annotated County List of Rare Species[1]				On USFWS SW Region County by County List[1]				On NMFS List for State of Texas[1]	Likelihood of occurrence in study area[4]
		State	Federal	Brazoria	Fort Bend	Galveston	Harris	Brazoria	Fort Bend	Galveston	Harris		
PLANTS													
Texas prairie dawn-flower	*Hymenoxys texana*	E	E		X		X		X		X		**L**
INVERTEBRATES													
Boulder star coral	*Montastraea annularis*	NL	NMFS-C									X	UL
Boulder star coral	*Montastraea franksi*	NL	NMFS-C									X	UL
Elliptical star coral	*Dichocoenia stokesii*	NL	NMFS-C									X	UL
Lamarck's sheet coral	*Agaricia lamarcki*	NL	NMFS-C									X	UL
Mountainous star coral	*Montastraea faveolata*	NL	NMFS-C									X	UL
Pillar coral	*Dendrogyra cylindrus*	NL	NMFS-C									X	UL
Rough cactus coral	*Mycetophyllia ferox*	NL	NMFS-C									X	UL
MOLLUSKS													
False spike mussel	*Quadrula mitchelli*	T	NL	X	X								UL
Louisiana pigtoe	*Pleurobema riddellii*	T	NL				X						UL
Sandbank pocketbook	*Lampsilis satura*	T	NL				X						UL
Smooth pimpleback	*Quadrula houstonensis*	T	C	X	X								UL
Texas fawnsfoot	*Truncilla macrodon*	T	C	X	X								UL
Texas pigtoe	*Fusconaia askewi*	T	NL				X						UL
FISHES													
Creek chubsucker	*Erimyzon oblongus*	T	NL				X						UL
Dusky shark	*Carcharhinus obscurus*	NL	NMFS-SOC									X	UL
Sand tiger shark	*Carcharias taurus*	NL	NMFS-SOC									X	UL
Scalloped hammerhead shark	*Sphyrna lewini*	NL	NMFS-C									X	UL
Sharpnose shiner	*Notropis oxyrhynchus*	NL	C	X	X								UL
Smalltooth sawfish	*Pristis pectinata*	NL	E	X		X	X						UL
Speckled hind	*Epinephelus drummondhayi*	NL	NMFS-SOC									X	UL
Warsaw grouper	*Epinephelus nigritus*	NL	NMFS-SOC									X	UL
AMPHIBIANS													
Houston toad	*Bufo houstonensis*	E	E		X								UL
BIRDS													
Peregrine falcon	*Falco peregrines*	T	DL	X	X	X	X						L
Attwater's greater prairie-chicken	*Tympanuchus cupido attwateri*	E	E		X	X							UL
Bald eagle	*Haliaeetus leucocephalus*	T	DL	X	X	X	X						**L**
Brown pelican	*Pelecanus occidentalis*	E	DM	X		X	X	X		X			**L**
Eskimo curlew	*Numenius borealis*	E	E	X		X				X			UL
Least tern (Interior population)	*Sternula antillarum*	E	E		X								UL
Piping plover	*Charadrius melodus*	T	T w/CH	X		X		X		X			**L**
Red-cockaded woodpecker	*Picoides borealis*	E	E				X						UL
Reddish egret	*Egretta rufescens*	T	NL	X		X							**L**

Table 3.11-1 (Cont'd)

Common Name[2]	Scientific Name[2]	Status[1, 3]		On TPWD Annotated County List of Rare Species[1]				On USFWS SW Region County by County List[1]				On NMFS List for State of Texas[1]	Likelihood of occurrence in study area[4]
		State	Federal	Brazoria	Fort Bend	Galveston	Harris	Brazoria	Fort Bend	Galveston	Harris		
Sooty tern	*Onychoprion fuscatus*	T	NL	X									UL
Sprague's pipit	*Anthus spragueii*	NL	C	X	X	X	X						L
White-faced ibis	*Plegadis chihi*	T	NL	X	X	X	X						**L**
White-tailed hawk	*Buteo albicaudatus*	T	NL	X	X	X	X						**L**
Whooping crane	*Grus americana*	E	E	X	X	X	X	X	X				UL
Wood stork	*Mycteria americana*	T	NL	X	X	X	X						**L**
AQUATIC REPTILES													
Alligator snapping turtle	*Macrochelys temminckii*	T	NL	X	X	X	X						UL
Green sea turtle	*Chelonia mydas*	T	T	X		X	X	X		X		X	UL
Hawksbill sea turtle	*Eretmochelys imbricata*	E	E	X		X		X		X		X	UL
Kemp's ridley sea turtle	*Lepidochelys kempii*	E	E	X		X	X	X		X		X	UL
Leatherback sea turtle	*Dermochelys coriacea*	E	E	X		X	X	X		X		X	UL
Loggerhead sea turtle	*Caretta caretta*	T	T	X		X	X	X		X		X	UL
TERRESTRIAL REPTILES													
Smooth greensnake	*Opheodrys vernalis*	T	NL				X						UL
Texas horned lizard	*Phrynosoma cornutum*	T	NL	X	X	X	X						UL
Timber rattlesnake	*Crotalus horridus*	T	NL	X	X	X	X						UL
MARINE MAMMALS													
Blue whale	*Balaenoptera musculus*	NL	E									X	UL
Finback whale	*Balaenoptera physalus*	NL	E									X	UL
Humpback whale	*Megaptera novaeangliae*	NL	E									X	UL
Sei whale	*Balaenoptera borealis*	NL	E									X	UL
Sperm whale	*Physeter macrocephalus*	NL	E									X	UL
West Indian manatee	*Trichechus manatus*	E	NL	X		X							UL
TERRESTRIAL MAMMALS													
Jaguarundi	*Herpailurus yaguarondi*	E	E	X									UL
Louisiana black bear	*Ursus americanus luteolus*	T	T	X	X	X	X						UL
Ocelot	*Leopardus pardalis*	E	E	X									UL
Rafinesque's big-eared bat	*Corynorhinus rafinesquii*	T	NL				X						UL
Red wolf	*Canis rufus*	E	E	X	X	X	X						UL

[1] According to USFWS (2012), NMFS (2012), TPWD (2012a–d).
[2] Nomenclature follows American Ornithologists' Union (AOU, 1998, 2000, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011), Baker et al. (2003), Crother et al. (2008), Hubbs et al. (2008), NMFS (2012), TPWD (2012a–d), and USFWS (2012).
[3] E = Endangered; species in danger of extinction throughout all or a significant portion of its range; T = Threatened; T w/CH = Threatened, with Federally designated Critical Habitat; C = Candidate for Federal listing (FWS and NMFS); SOC = Species of Concern (NMFS); DL = Delisted; DM = Delisted Taxon, Recovered, Being Monitored First Five Years; NL = Not listed.
[4] L = Likely to Occur; UL = Unlikely to Occur.

3.11.2 Fauna

Fourteen of the 58 species listed in Table 3.11-1 are federally listed threatened or endangered animal species that are included on the USFWS Southwest Region Ecological Services County by County lists for Harris, Galveston, Brazoria, and Fort Bend counties, and the Texas list of federally protected species under the jurisdiction of the NMFS. Each of these 14 species is discussed below, regardless of likelihood of occurrence in the study area. The brown pelican has recently been delisted, and its recovery is currently being monitored by the USFWS for the first 5 years. In addition, TPWD (2012a–d) includes four species that are candidates for Federal listing, the sharpnose shiner (*Notropis oxyrhynchus*), smooth pimpleback (*Quadrula houstonensis*), and Texas fawnsfoot (*Truncilla macrodon*), on their Brazoria and Fort Bend county lists, and the Sprague's pipit (*Anthus spragueii*) on all four county lists. These species are not currently protected under the ESA. The sharpnose shiner and the two mussels are not likely to occur within the study area; therefore, they are not included in the following discussion.

Seven of the species listed in Table 3.11-1 are listed by TPWD as threatened or endangered but are not included on the USFWS Southwest Region Ecological Services County by County lists for the study area counties and are unlikely to occur within the study area. These species are Houston toad (*Bufo houstonensis*), Attwater's greater prairie-chicken (*Tympanuchus cupido attwateri*), interior least tern (*Antillarum sternula*), red-cockaded woodpecker (*Picoides borealis*), jaguarundi (*Herpailurus yaguarondi*), Louisiana black bear (*Ursus americanus luteolus*), ocelot (*Leopardus pardalis*), and red wolf (*Canis rufus*). These species are not included in the following discussion. Sixteen of the species listed in Table 3.11-1 are listed on the TPWD Annotated County Lists of Rare Species for Harris, Galveston, Brazoria, and Fort Bend counties as having exclusively a State-listed status of either threatened or endangered. These species do not have a Federal status of threatened or endangered and therefore do not receive Federal protection under the ESA. These species, however, may receive protection under other Federal and/or State laws, such as the Migratory Bird Treaty Act (MBTA), Bald and Golden Eagle Protection Act (BGEPA), chapters 67, 68, and 88 of the TPWD Code, and sections 65.171–65.184 and 69.01–69.14 of Title 31 of the TAC. Of these exclusively State-listed threatened or endangered species, only seven are likely to occur in the study area, and are included in the following discussion. These species include the Arctic peregrine falcon (*Falco peregrinus tundrius*), bald eagle (*Haliaeetus leucocephalus*), reddish egret (*Egretta rufescens*), brown pelican (*Pelecanus occidentalis*), white-faced ibis (*Plegadis chihi*), white-tailed hawk (*Buteo albicaudatus*), and wood stork (*Mycteria americana*).

Nine of the species listed in Table 3.11-1 are identified by NMFS as SOC. These species do not receive Federal protection under the ESA. Of these, only the saltmarsh top minnow (*Fundulus jenkinsi*) is likely to occur within the study area and is included in the following discussion.

3.11.2.1 Fishes

Scalloped hammerhead sharks (*Sphyrna lewini*) (NMFS-C) are a very common coastal pelagic species, which occur over shelves and deeper water, often entering bays and estuaries (Compagno, 1984). They are found in inshore and offshore waters to depths of 902 feet, but have been seen at depths of 1,680 feet (Froese and Pauly, 2011). Juvenile scalloped hammerhead sharks occur close to shore in bays but will move to deeper waters as they grow. They prey mainly on a variety of fish and cephalopods (Compagno, 1984). Juvenile scalloped hammerhead sharks are likely to occur in the study area (NMFS, 2006).

3.11.2.2 Reptiles

The five species of sea turtles listed by the USFWS and NMFS as threatened or endangered may occur within Galveston Bay and associated aquatic habitats; however, these occurrences are unlikely. The leatherback is primarily a pelagic species that rarely occurs in Texas's coastal waters. The hawksbill ranges from the Atlantic coast to the Texas coast, but is seldom found along the Texas coast. Kemp's ridley inhabits shallow coastal and estuarine waters and has the most potential among these species to occur in the study area. The loggerhead occasionally nests on the Texas coast, and is common in the Gulf of Mexico. While the green turtle occasionally occurs along the Texas coast and juveniles can be found in inshore waters, the species more frequently occurs along the South Texas coast. It is possible, however unlikely, that these species will occur within the relatively small portion of the study area that encompasses Galveston Bay. Additional information regarding sea turtles may be viewed in Appendix E.

3.11.2.3 Birds

TPWD recently revised the status of the American peregrine falcon (*Falco peregrinus anatum*) from endangered to threatened, and dropped the Arctic peregrine falcon (*Falco peregrinus tundrius*) from the state-threatened and endangered list altogether. The American peregrine falcon is a rare migrant statewide and nests in the mountains of Trans-Pecos Texas, while the Arctic peregrine falcon is an uncommon migrant statewide and an uncommon winter resident on the coastal prairies and the Texas Gulf Coast, where it typically occurs near bays and estuaries (Lockwood and Freeman, 2004). However, because the two subspecies are not easily distinguishable from each other in the field, TPWD will only reference to the species level (TPWD, 2012a–d). Peregrine falcons are likely to occur within the study area during migration or winter, but are not expected to nest in the study area.

The status of the Eskimo curlew (federally listed endangered) is uncertain, and the species is possibly extinct. The Eskimo curlew was formerly a common spring migrant in the eastern half of the state; however, the last fully documented occurrence of this species in Texas was in 1962 (Gill et al., 1998; Lockwood and Freeman, 2004). The Eskimo curlew was extremely abundant in the nineteenth century, but experienced intense hunting pressure, which likely contributed to its decline. Eskimo curlews breed on treeless arctic and subarctic tundra (Gill et al., 1998). Nonbreeding birds use a variety of habitats, such as grasslands, pastures, plowed fields, marshes, and mudflats (American Ornithologists' Union [AOU], 1998; Gill et al., 1998). This species is not likely to occur in the study area.

The piping plover (federally listed threatened) is a small shorebird that inhabits coastal beaches and tidal flats. Approximately 35 percent of the known global population of piping plovers winters along the Texas Gulf Coast, where they spend 60 to 70 percent of the year (Campbell, 1995; Haig and Elliott-Smith, 2004). The piping plover population that winters in Texas breeds on the northern Great Plains and around the Great Lakes. The species is a common migrant and rare to uncommon winter resident on the upper Texas coast (Lockwood and Freeman, 2004; Richardson et al., 1998). USFWS has designated critical habitat for the species in its nesting and wintering range (65 *Federal Register* 41781–41812). Designation of critical habitat became final on July 10, 2001 (66 *Federal Register* 36038–36143). No USFWS-designated critical habitat for the piping plover is present within the study area. Habitat may be present along the margins of Galveston Bay, in the easternmost portion of the study area, and the species is likely to occur within those areas during winter.

The reddish egret (State-listed threatened) is an uncommon to locally common resident along the coast, being most numerous from Matagorda Bay southward (Lockwood and Freeman, 2004). They are typically associated with brackish marshes, tidal flats, and shallow salt lakes, where they nest in brushy yucca and prickly pear thickets on dry coastal islands (Lockwood and Freeman, 2004; Lowther and Paul, 2002; Oberholser, 1974). Reddish egrets are likely present in the study area.

Sprague's pipit is a relatively small passerine endemic to the North American grasslands. It has a plain buff-colored face with a large eye ring. Sprague's pipit is a ground nester that breeds and winters on open grasslands. It is closely tied with native prairie habitat and breeds in the north-central United States in Minnesota, Montana, North Dakota, and South Dakota as well as south-central Canada (FWS, 2012). During migration and winter in Texas, as elsewhere, Sprague's pipit may be found searching for insects and seeds in weedy fields and the vicinity of airports as well as in a wide variety of grasslands (Oberholser, 1974). It is an uncommon migrant, primarily through the center of the state. The species is rare to locally uncommon inland to the Post Oak Savannahs and Blackland Prairies from Williamson and Brazos counties, south through much of the South Texas Brush Country. Wintering Sprague's pipits are rare to locally uncommon in agricultural areas of north-central Texas, the Concho Valley, and the northwestern Edwards Plateau, and are rare migrants and casual winter residents through the remainder of the state (Lockwood and Freeman, 2004). This species may pass through the area during migration.

The white-faced ibis (State-listed threatened) is a medium-sized wading bird that inhabits freshwater marshes, sloughs, and irrigated rice fields, but also frequents brackish and saltwater habitats. White-faced ibis are permanent residents along the Texas Gulf Coast; however, nesting records exist for many scattered inland localities (Lockwood and Freeman, 2004; Ryder and Manry, 1994). The species is a common migrant/summer resident and uncommon winter resident on the upper Texas coast (Richardson et al., 1998). The species is likely present year-round in the study area.

The white-tailed hawk (State-listed threatened) is an uncommon local resident on the Gulf coastal plain, from Harris County south to the Rio Grande (Lockwood and Freeman, 2004). White-tailed hawks inhabit coastal prairies and brushlands, as well as inland mesquite and oak savannahs (Farquhar, 1992; TPWD, 2012a–d). This species likely occurs in the general vicinity of the study area.

The whooping crane (federally listed endangered) is a large wading bird that in the last 50 years has returned from the brink of extinction. Only four wild populations of whooping crane exist, the largest of which is the Aransas/Wood Buffalo population, which breeds in Wood Buffalo National Park in northern Canada and migrates annually to Aransas NWR and adjacent areas of the central Texas coast in Aransas, Calhoun, and Refugio counties where it winters (Lewis, 1995; USFWS, 1995). Other smaller wild populations include the experimental Rocky Mountain population and the nonmigratory Florida and Louisiana populations (Lewis, 1995). Whooping cranes in Texas primarily winter in the Aransas NWR and adjacent areas of the central Texas Gulf Coast. The study area is not within the wintering range of this species (USFWS, 1995). During migration, whooping cranes stop over at wetlands and pastures to roost and feed and are rarely encountered as they migrate along a narrow corridor down the middle of the state (Lockwood and Freeman, 2004). The study area is not within the regular narrow migration corridor as mapped by Lockwood and Freeman (2004). Although the whooping crane could occur in the study area as a rare migrant, such occurrence is unlikely.

The wood stork (State-listed threatened) is an uncommon to locally common postbreeding visitor to coastal Texas and inland waters in east and central Texas (Lockwood and Freeman, 2004). Wood storks historically bred in North America along the Gulf Coast from east Texas to Florida, but their range has significantly declined since the 1960s, and their North American breeding range is now restricted to Florida, Georgia, and South Carolina (Coulter et al., 1999; Oberholser, 1974). In Texas, wood storks typically occur near freshwater or saltwater wetlands, lakes, or along rivers and streams. The USFWS lists the wood stork as federally endangered in Florida, Alabama, Georgia, North Carolina, and South Carolina, but not in Texas. Wood storks are uncommon to common in summer and fall along the upper Texas coast (Richardson et al., 1998). The species likely occurs in the study area during summer and fall.

The USFWS listed the brown pelican (*Pelecanus occidentalis*) as endangered throughout its range outside the U.S. on June 2, 1970 (35 *Federal Register* 8495) and throughout its U.S. range on October 13, 1970 (35 *Federal Register* 16047). On December 17, 2009, it was delisted with a DM (Delisted Taxon, Recovered, Being Monitored First 5 Years) designation; however, the brown pelican will still receive protection at the state level and under provisions of the MBTA. Population declines were largely the result of organochlorine pesticides, particularly endrin and DDT, entering the marine food web. Endrin resulted in direct mortality, while DDT impaired reproduction by causing eggshell thinning; thus, eggs desiccated and became susceptible to breaking during incubation (Shields, 2002). Other factors included human disturbance and habitat loss resulting from commercial and residential development (USFWS, 1995). Pelicans are large, heavy birds and easily flushed from the nest. Flushing exposes the eggs and young to predation, temperature stress, and permanent abandonment by the parents.

3.11.2.4 Mammals

Five whale species are included in the list of federally protected species under the jurisdiction of the NOAA Fisheries Service for the state of Texas provided by NMFS (2012) (see Table 3.11-1), which include the blue whale, fin whale, humpback whale, sei whale, and sperm whale. These species are generally restricted to offshore marine waters of the Gulf of Mexico; therefore, it is unlikely that any of these five species would occur in the study area.

3.12 CULTURAL RESOURCES

3.12.1 Introduction

PBS&J conducted a file review in order to determine the number and types of cultural resources sites that would be potentially impacted by the proposed Clear Creek Project. A total of 100 sites are located within the study area. These sites date to the Prehistoric, Late Prehistoric, and Historic periods including those of the Ceramic, Late Ceramic, and Early Archaic cultures. Twenty-four sites are located specifically within the project area, though only 10 of these sites are in areas that would be impacted by the proposed work. These 10 prehistoric and Late Prehistoric sites were evaluated by Prewitt & Associates, Inc. (PAI) in 2007, as discussed in the following subsections. Additional detail regarding recorded historic and prehistoric sites within the study area can be found in the table in Appendix F-2. It should be noted that the majority of the recorded sites occur in upland areas.

3.12.2 History

The earliest generally accepted culture of the Americas, the Paleoindian (c. 10,000–7000 B.C.), appears to have extended over most, if not all, of North America by the end of the Pleistocene epoch. Paleoindian occupation of the Texas Gulf coast during the Late Pleistocene is evidenced by the recovery of Scottsbluff, Clovis, Plainview, Angostura, and San Patrice projectile points. Research suggests that these groups were small migratory nuclear families or bands (Aten, 1983; Story, 1990). Clovis and Scottsbluff projectile points have been recovered from archeological sites in Galveston Bay, at Bolivar Point, and in Jefferson County (Story, 1990). Two sites, 41HR194 and 41HR195, have been identified near the Clear Creek study area with components dating to multiple periods, including the Paleoindian.

Terminologies developed by Mercado-Allinger et al. (1984) have refined temporal subdivisions within the Archaic period (7000 B.C.–A.D. 100) by grouping the Early and Middle Archaic cultures together into a single, Early Preceramic culture date, with the Late Archaic equating to their Late Preceramic stage. Early Archaic groups are believed to have migrated seasonally, like the Paleoindian cultures, and to have increased the number and diversity of types and styles in lithic production. Middle Archaic sites are frequent along the coast and are often associated with shell middens, an important signifier of subsistence activities during this period. The Middle Archaic is also characterized by the emergence of group territoriality, seen in the use of cemetery burials and more regional variations in artifact assemblages (Aten, 1983; Story, 1985). During the Late Archaic the human population increased significantly, which is indicated by both an increase in the number of sites as well as intrasite artifact frequencies (Aten, 1983). The settlement system during this time may have included a seasonal round with group dispersal in coastal areas during summer months (Aten, 1983). The Late Preceramic, which coincides in part with the Late Archaic in Texas, is characterized by increased sites and intrasite artifact frequencies, developments in trade relations, and by an increase in traumatic death (Aten, 1983; Hall, 1981).

The Late Prehistoric, or Ceramic, period (A.D. 100–1700) lasted from the time ceramics were adopted until the time a well-established interaction between Europeans and aboriginal populations occurred. The first European presence in the current study area was signified by the arrival of Cabeza de Vaca, albeit by shipwreck, on the Texas coast in 1528. Little impact to the indigenous groups is thought to have resulted from the early encounters with European explorers. This period is subdivided into the Early Ceramic and Late Ceramic (Fields et al., 1983; Story, 1990). Several studies have sought to divide the Late Prehistoric/Ceramic period in Galveston Bay into separate components or chronologies based on ceramic seriation (Aten, 1983; Wheat, 1953). The Early Ceramic period is identified by the co-occurrence of sandy or clay paste ceramics and dart points; the addition of Perdiz and Scallorn arrow points marks the beginning of the Late Ceramic period (Aten, 1983).

Despite intermittent European attempts to colonize the Texas coast, successful settlement of the region would not commence until the early nineteenth century. Clear Creek was part of the land awarded to Moses Austin in 1821; however, early settlers preferred the rich bottomland along the banks of the Colorado and Brazos rivers. Clear Creek, therefore, would remain sparsely populated well into the twentieth century (McGuff and Cox, 1973). The first town in the Clear Creek area was formed at the site of League City in the 1870s. The town, originally known as Butler's Ranch or Clear Creek, was renamed League City in 1893 when the land was acquired by John C. League (Kleiner, 2008). The economy of Clear Creek, originally based on agricultural enterprises, would turn to the oil and gas industries after the discovery of these resources in the region. The creation of the Manned Spacecraft Center of the National Aeronautics and Space Administration (NASA) in the 1960s helped diversify the economic base as major aerospace contractors established offices in Clear Lake City.

3.12.3 Previous Investigations

The earliest documented archeological investigation in the Clear Lake region was conducted in the 1950s by avocational archeologist Wayne B. Neyland. Archeological investigation of the area would continue throughout the 1960s until the present. A large-scale boat and pedestrian reconnaissance by the Texas Archeological Survey in 1973 scrutinized an area that would be affected by a flood control project near Clear Lake and along 45 miles of Clear Creek (McGuff and Cox, 1973). Of the 57 sites recorded, only 27 were new. Overall the investigation discovered shell middens, terrace sites, natural mounds, and historic sites. Twenty sites within the current Clear Creek project area were evaluated in the 1973 study: 41BO178, 41HR161, 41HR162, 41HR163, 41HR164, 41HR191, 41HR192, 41HR193, 41HR194, 41HR195, 41HR168, 41HR171, 41GV46, 41GV49, and 41GV58 to 41GV63, inclusive. Most of the sites were variably classified as Late Prehistoric. One site, 41BO178, comprised three historic structures that were featured in a 1938 aerial photo. The structures themselves were not present but were indicated by a foundation and other cultural materials.

Several sites originally recorded by avocational archeologists in the 1960s were revisited by professional archeologists in the early 1990s (Howard et al., 1992). Site 41HR171 was reevaluated, and it was discovered that modern disturbance prevented archeological sampling. The avocational archeologists were interviewed regarding their original findings as part of the investigation. According to the PAI investigation, sites 41HR84, 41HR194, and 41HR195 warranted further investigations to determine National Register of Historic Places (NRHP) eligibility.

In 1990 PAI conducted a pedestrian survey of an 80-acre tract proposed for addition to Randolph Park (Howard and Freeman, 1990). Three historic sites were investigated for the project, including previously recorded prehistoric site 41HR167. Two new prehistoric sites were discovered, one of which was described as the having the best preservation of bone observed along Clear Creek. This significant site, 41HR504, lies within the project area. PAI recommended that proposed hiking trails be directed away from the location of the site and that further measures should be pursued if vandalism were to occur.

Late Prehistoric site 41BO182 was discovered by Charles Hand and was subsequently investigated by Moore Archeological Consulting in 1993 (Moore and Moore, 1994). Flakes and ceramics were associated with the site, which is situated on the remnants of a pimple mound that had been destroyed by land clearing. In 1997, a cultural resources survey was conducted along the upper segment of Clear Creek. This investigation recorded only one prehistoric site, 41HR817, which was described as a small scatter of mussel shell fragments and debitage (Pearl, 1998).

In preparation for the Clear Creek Project, PAI was contracted by the USACE to conduct an archeological reconnaissance and survey of Clear Creek from SH 288 downstream to Dixie Farm Road (Norment and Kibler, 2007). The project area encompassed select properties within the proposed ROW along the upper end of Clear Creek and additional areas expected to be impacted by the project. PAI attempted to relocate nine previously recorded sites (Table 3.12-1) within the project footprint, only two of which were rediscovered. Site 41HR162 was impacted by severe erosion, and the eastern half of the site was covered by excavated material. Three shovel tests conducted at the site were negative. In 1973 site 41HR192 was initially described as a cluster of four pimple mounds with diameters between 30 and 40 feet. The reevaluation of the site in 2007 located a fifth pimple mound, though a single shovel test from each mound did not recover any artifacts. PAI, in their interim report (Norment and Kibler, 2007), recommended both sites be judged ineligible for inclusion in the NRHP. The reconnaissance survey of the project area located three pimple mounds on the upland margin of Clear Creek overlooking the meander loops. The three mounds were 30 to 65 feet in diameter. Shovel testing of the three mounds produced only one positive test, a single chert flake from mound 2. This mound was designated as site 41HR1034 (see Table 3.12-1) and recommended not eligible for NRHP inclusion by PAI. In addition, site 41HR817 was reported by PAI (Norment and Kibler, 2007) as destroyed. The Texas Historical Commission commented on PAI's interim report and agreed that sites 41HR162, 41HR163, 41HR164, 41HR191, 41HR192, and 41HR1034 should not be considered eligible for NRHP listing; further testing was recommended at site 41HR161 (see letter dated April 8, 2008, in Appendix D-2). Buildings, bridges, or other structures over 50 years old that could be affected by the proposed project should be identified.

Table 3.12-1
Cultural Resource Sites Reevaluated/Identified Along Clear Creek, Mary's Creek, and Turkey Creek within the Proposed Project Footprint

Trinomial	Period	Site Type	Site Condition	NRHP Eligibility
41HR161	Late Prehistoric	mound	buried under a few meters of dredged material	Not known; further work needed (see Appendix D-2)
41HR162	Late Prehistoric	mound	severe erosion, partially buried under dredged material	Not eligible
41HR163	Late Prehistoric	mound	buried under a few meters of dredged material	Not eligible
41HR164	Late Prehistoric	mound	likely destroyed	Not eligible
41HR191	Late Prehistoric	mound	buried under a few meters of dredged material	Not eligible
41HR192	Late Prehistoric	mound	disturbed	Not eligible
41HR817	Prehistoric	scatter	destroyed, the site is now a retention pond	Not eligible
41HR1034[1]	Prehistoric	mound	possibly disturbed	Not eligible
41BO78	Prehistoric	mound	unknown	NA
41BO182	Late Prehistoric	mound	likely destroyed	NA

NA indicates that information is not available for these sites because access to these properties was denied.
[1] = Newly identified site (Norment and Kibler, 2007).

3.13 SOCIOECONOMIC RESOURCES

3.13.1 Introduction

This section presents a summary of the demographic and economic characteristics of the study area population. Population, community characteristics, community services, employment, and area economics are key areas of discussion. Information was obtained from the U.S. Census Bureau, TWDB, and Texas Workforce Commission (TWC), as well as various county and municipal data sources. A more-detailed description can be found in Appendix G.

Study area municipalities include Brookside Village, Clear Lake Shores, Deer Park, El Lago, Fresno, Friendswood, Houston (partial), Kemah, La Porte, League City, Missouri City, Nassau Bay, Pasadena (partial), Pearland, Seabrook, Taylor Lake Village, and Webster. The socioeconomic study area comprises census tracts within these municipalities and counties (Figure 3.13-1). Population and demographic information is provided for these municipalities as well the counties within the study area. Demographic information is also provided for the census tracts that occur within the study area.

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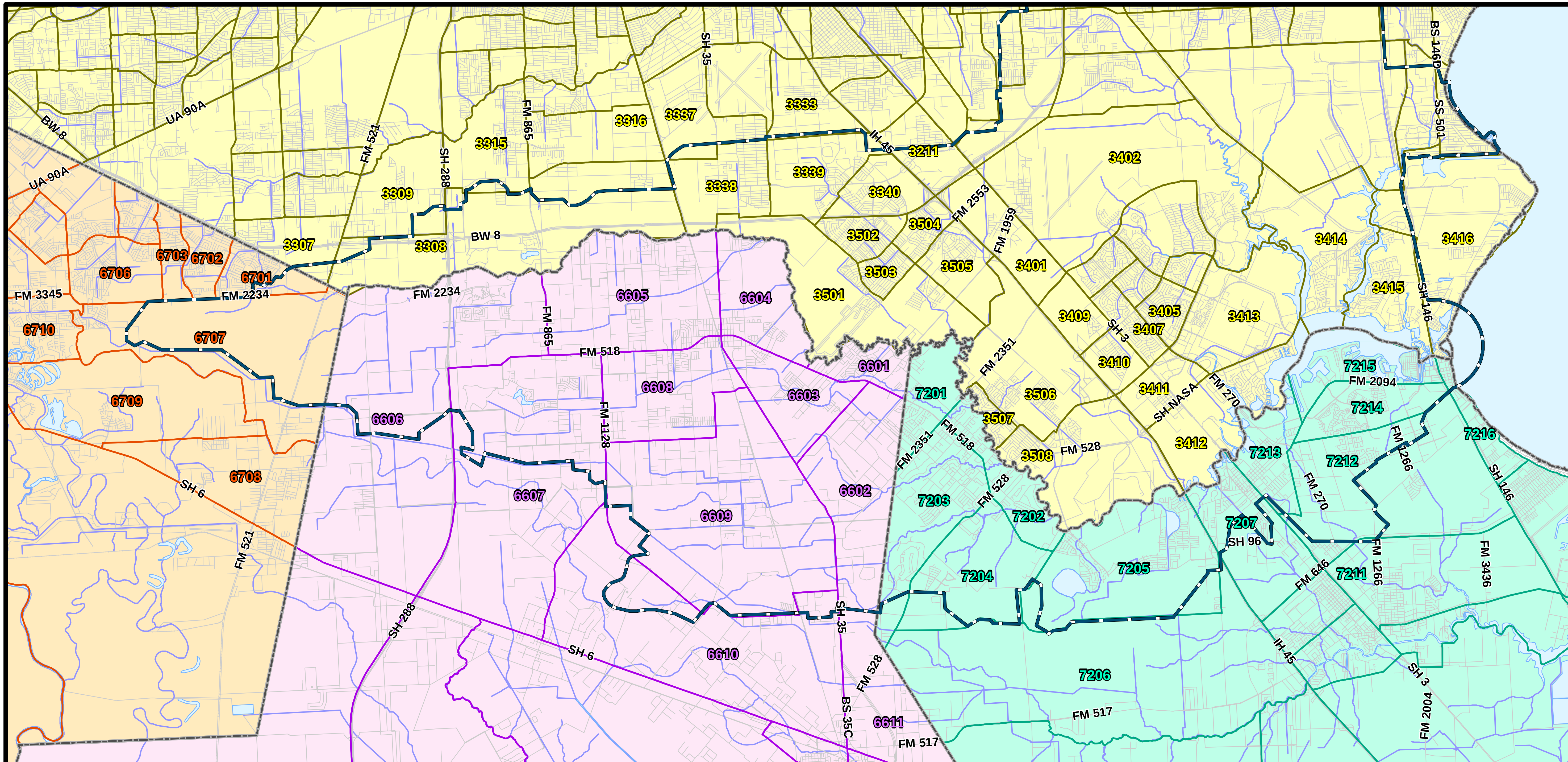

N
W
E
S

0 1 2 4 Miles

0 6,000 12,000 24,000 Feet

2000 Census Tracts

- Fort Bend
- Galveston
- Harris
- Brazoria
- Study Area
- County Boundary

Figure 3.13-1

2000 Census Tracts

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 044188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/11/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/044188600/figures/census/Figure_3_13_1_vr2.mxd

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3.13.2 Population and Demographics

3.13.2.1 Historic and Projected Population

Historic populations in the study area range from 990 in Taylor Lake Village in 1970 to 2,099,451 million in Houston in 2010 (Table 3.13-1). Of the municipalities in the study area, the highest increase in population growth from 1970 to 1980 occurred in Missouri City with a 490.5 percent increase in population. The municipality that experienced the highest population growth from 1980 to 1990 was Friendswood at 112.8 percent increase. Fort Bend County maintained the highest percentage of population growth over a 40-year time period, increasing 150.3 percent from 1970 to 1980 and continuing this increase at 57.2 percent from 1990 to 2000. Compared to the other counties in the study area, Galveston County experienced the lowest overall increase over the same 40-year time period. Overall, the study area has experienced an increase in population between 1970 and 2000 (U.S. Census Bureau, 1990, 2010a).

Table 3.13-1
Study Area Historic Populations

	Year					Percent Change			
Area	1970	1980	1990	2000	2010	1970–1980	1980–1990	1990–2000	2000–2010
Municipalities									
Brookside Village	N/A	N/A	N/A	1,960	1,523	N/A	N/A	N/A	-22.3
Clear Lake Shores	N/A	N/A	N/A	1,205	1,063	N/A	N/A	N/A	-11.8
Deer Park	12,773	22,648	27,652	28,520	32,010	77.3	22.0	3.1	12.2
El Lago	2,308	3,129	3,269	3,075	2,706	35.6	4.5	-5.9	-12.0
Fresno	N/A	N/A	3,182	6,603	19,069	N/A	N/A	107.5	188.8
Friendswood	5,675	10,719	22,814	29,037	35,805	88.9	112.8	27.3	23.3
Houston	1,233,535	1,595,138	1,630,553	1,953,631	2,099,451	29.3	2.2	19.8	7.5
Kemah	N/A	N/A	N/A	2,330	1,773	N/A	N/A	N/A	-23.9
La Porte	7,149	14,062	27,910	31,880	33,800	96.7	98.5	14.2	6.0
League City	10,818	16,578	30,159	45,444	83,560	53.2	81.9	50.7	83.9
Missouri City	4,136	24,423	36,176	52,913	67,358	490.5	48.1	46.3	27.3
Nassau Bay	N/A	4,526	4,320	4,170	4,002	–	-4.6	3.5	-4.0
Pasadena	89,957	112,560	119,363	141,674	149,043	25.1	6.0	18.7	5.2
Pearland	6,444	13,248	18,697	37,640	91,252	105.6	41.1	101.3	142.4
Seabrook	3,811	4,670	6,685	9,443	11,952	22.5	43.1	41.3	26.6
Taylor Lake Village	990	3,669	3,394	3,694	3,544	270.6	-7.5	8.8	-4.1
Webster City	2,231	2,405	4,678	9,083	10,400	7.8	94.5	94.2	14.5
Counties									
Brazoria	108,312	169,587	191,707	241,767	313,166	56.6	13.0	26.1	29.5
Fort Bend	52,314	130,962	225,421	354,452	585,375	150.3	72.1	57.2	65.1
Galveston	169,812	195,738	217,399	250,158	291,309	15.3	11.1	15.1	16.5
Harris	1,741,912	2,409,547	2,818,199	3,400,578	4,092,459	38.3	17.0	20.7	20.3

Source: U.S. Census Bureau (1990, 2010a, 2010b, 2010c).

Populations in the study area are expected to grow each decade from 2000 to 2030 (Table 3.13-2). The City of Pearland is expected to experience the highest population increase from 2000 to 2010; Webster City is expected to have the highest population increase from 2010 to 2030. Deer Park is expected to maintain the lowest population change from 2000 to 2030. Fort Bend County is expected to have the highest population growth, and Galveston County is expected to experience the lowest population growth of the four counties in the study area. Overall, the increases in population seen from 1970 to 2000 are expected to continue through 2030, with growth generally slowing each decade (TWDB 2004a, 2004b, 2006b).

Table 3.13-2
Study Area Population Projections

	Year				Percent Change		
Area	2000	2010	2020	2030	2000–2010	2010–2020	2020–2030
Municipalities							
Brookside Village	1,960	2,282	2,618	2,939	16.4	14.7	12.3
Clear Lake Shores	1,205	1,263	1,313	1,343	11.4	8.8	4.8
Deer Park	28,520	29,513	30,480	31,432	3.5	3.3	3.1
El Lago	3,075	3,075	3,075	3,075	N/A	N/A	N/A
Fresno	6,603	N/A	N/A	N/A	N/A	N/A	N/A
Friendswood	29,037	32,353	35,215	36,910	11.4	8.8	4.8
Houston	1,953,631	2,240,974	2,520,926	2,798,278	14.7	12.5	11.0
Kemah	2,330	2,985	3,550	3,885	28.1	18.9	9.4
La Porte	31,880	35,467	38,960	42,394	11.3	9.8	8.8
League City	45,444	53,546	60,539	64,683	17.8	13.1	6.8
Missouri City	52,913	83,645	104,844	125,194	58.1	25.3	19.4
Nassau Bay	4,170	4,170	4,170	4,170	N/A	N/A	N/A
Pasadena	141,674	161,678	181,156	200,314	14.1	12.0	10.6
Pearland	37,640	66,049	83,462	99,342	75.5	26.4	19.0
Seabrook	9,443	11,943	14,377	16,771	26.5	20.4	16.7
Taylor Lake Village	3,694	4,004	4,004	4,004	8.4	N/A	N/A
Webster City	9,083	13,076	16,964	20,788	44.0	29.7	22.5
Counties							
Brazoria	241,767	285,850	331,731	375,664	18.2	16.1	13.2
Fort Bend	354,452	490,072	630,624	802,486	38.3	28.7	27.3
Galveston	250,158	268,714	284,731	294,218	7.4	6.0	3.3
Harris	3,400,578	3,951,682	4,502,786	5,053,890	16.2	13.9	12.2

Source: TWDB (2004a, 2004b, 2006a).

3.13.2.2 Demographics

The majority of residents within the study area are aged between 35 and 64, followed by the 20 to 34 age group (U.S. Census Bureau, 2010a). The study area population had 21.5 percent of the population being high school graduates, followed by 21.4 percent of the population attaining a bachelor's degree and 10.4 percent of the population attaining a graduate or professional degree (U.S. Census Bureau, 2010b).

3.13.2.3 Housing Characteristics

There were a total of 167,302 housing units within the study area, and the majority (94.5 percent) of these units are occupied, leaving little vacant housing in the study area. Of these occupied units, 66.4 percent are owner-occupied. This is true of the municipalities within the study area as well, with the exceptions of Houston, with the majority (54.2 percent) of housing units being renter-occupied, and within the municipality of Webster, with 86.4 percent of the housing units being renter-occupied.

The majority of residents moved into their houses between 1990 and 2000, resulting in a length of residency of 17 years or less. The median number of persons per unit ranged from 2.04 (Clear Lake Shores and Nassau Bay) to 3.52 (Fresno) for the study area municipalities, and from 2.60 (Galveston County) to 3.14 (Fort Bend County) for the study area counties. Median value for owner-occupied units ranged from $70,300 (Pasadena) to $152,700 (Taylor Lake Village) for the study area municipalities, and from $85,200 (Galveston County) to $115,100 (Fort Bend County) for the study area counties.

An economic evaluation of current flooding impacts was conducted by the USACE (GRR, Economic Appendix). The study considered structures within an identified floodplain in which the probability of first-floor flooding is 0.2 percent each year. According to the economic evaluation, approximately 90 percent of the structures inventoried within the estimated existing median 0.2 percent AEP (500-year) floodplain are residential. Based on 2009 prices, there were 7,500 structures valued at over $860 million within the AEP floodplain on the main stem and tributaries. Approximately 163 residential structures have been purchased and removed from the floodplain under FEMA's Hazard Mitigation Program. Residential structures that lie within the 500-year floodplains of the tributaries (Mary's Creek, Mud Gully, Turkey Creek, Cowart Creek, and Chigger Creek) represent between 50 and 99 percent of their total individual tributary floodplain investment, with structure values ranging from $5 million (Chigger Creek) to $141 million (Mary's Creek).

3.13.2.4 Environmental Justice

Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," signed by the president on February 11, 1994, directs Federal agencies to take the appropriate and necessary steps to identify and address disproportionately high and adverse effects of Federal projects on the health of the environment of minority and low-income populations to the greatest extent practicable and permitted by law. The EO requires that minority and low-income populations not receive disproportionately high adverse human health or environmental impacts, and requires that representatives of any low-income or minority populations that could be affected by the proposed project be involved in the community participation and public involvement process.

The study area population is primarily comprised of white persons (64.9 percent), followed by Hispanic or Latino persons (19.1 percent) and black or African American persons (9.2 percent). Fresno has 78.4 percent racial minority, and the City of Houston has a racial minority population that is 67.8 percent of the total population. Missouri City has 59.7 percent racial minority, while Pasadena has a racial minority population that accounts for 51.8 percent of the total population. While the study area as a whole would not be characterized as predominantly minority, the municipalities identified above would be considered as such (U.S. Census Bureau, 2010a).

U.S. Census Bureau census tract–level data were analyzed for those census tracts in which the project footprint occurs (Figure 3.13-2). Thirteen census tracts are traversed by the project area footprint: Census Tract (CT) 6601, CT 6603, CT 6604, CT 6605, CT 6606, and CT 6608 in Brazoria County, and CT 3308, CT 3338, CT 3501, CT 3503, CT 3504, CT 3505, and CT 3506 in Harris County. Of these census tracts, four were identified as minority census tracts (Table 3.13-3). These are CT 3308 (79.9 percent minority population), CT 3338 (82.5 percent), CT 3504 (56.4 percent), and CT 3505 (67.9 percent).

Low-income persons are defined as “a person whose household income is at or below the Department of Health and Human Services (HHS) poverty guidelines.” The 2008 HHS poverty guideline for a family of four was $21,200. The average household income for the study area was $59,133, which is well above the 2008 HHS poverty guideline. The median household incomes for the study area municipalities ranged from $36,616 (Houston) to $99,535 (Taylor Lake Village). None of the study area counties, municipalities, or census tracts had a median household income below the 2008 HHS poverty guideline (U.S. Census Bureau, 2010b), and there are, therefore, no Environmental Justice populations in the project area.

3.13.2.5 Community Services

The study area has over 60 units of local government, including 4 counties, 12 municipalities, 5 independent school districts, 3 water control and improvement districts (WCIDs), and several special districts and authorities. The four counties provide basic infrastructure and services including roads, community facilities, law enforcement, hospitals, and welfare programs. Fire protection within the study area is handled by a combination of municipal, county, and volunteer fire departments. The municipalities provide a wide range of infrastructure and services. The

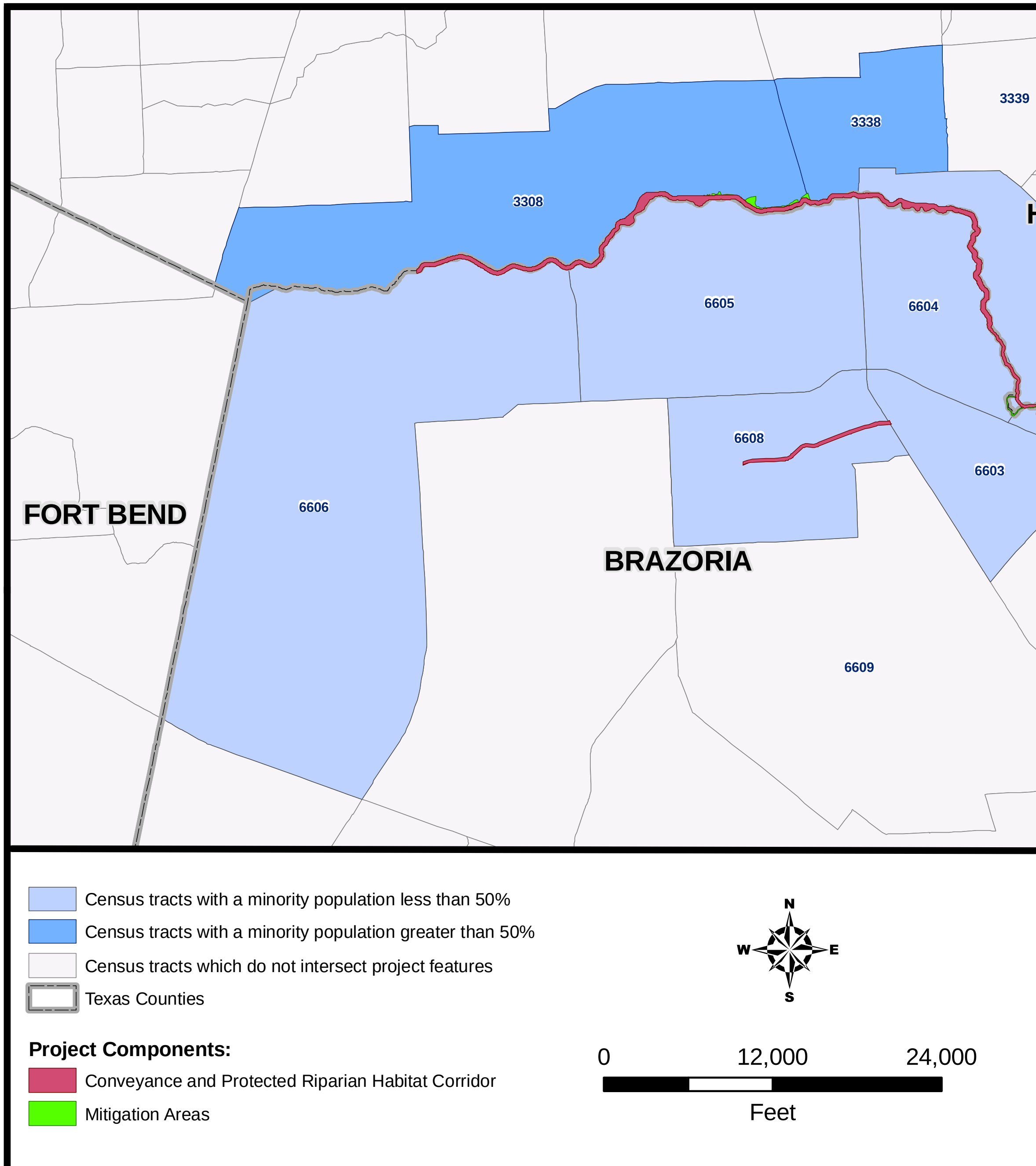


Figure 3.13-2

Potentially Affected Census Tracts

Clear Creek

Flood Risk Management Project

Prepared for: USACE

Job No.: 100002202 | Scale: 1 inch equals 12,000 feet

Prepared by: Christiansen | Date: 09/05/2008

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/census_tracts_20100318.mxd

Table 3.13-3
Study Area Ethnicity/Racial Distribution and Income Characteristics

Area	Total Population	Racial/Ethnic Distribution (Percentage) White	Black	American Indian/ Alaska Native	Asian	Native Hawaiian and Other Pacific Islander	Hispanic or Latino	Minority[1]	Income Percent Below Poverty Level[2]	Median Household Income[3]
Study Area Population	440,479	64.9	9.2	0.5	5.1	< 0.1	19.1	35.1	6.6	$59,133
Census Tracts										
CT 6601	4,869	81.8	3.6	0.1	3.6	<0.1	9.3	16.8	1.0	$76,586
CT 6603	5,701	77.5	4.4	0.2	2.8	0.0	14.2	21.5	5.1	60,380
CT 6604	4,951	78.7	4.2	0.3	3.0	<0.1	12.7	20.2	3.8	58,493
CT 6605	7,684	65.5	2.6	0.5	1.3	<0.1	29.3	33.7	9.5	46,725
CT 6606	8,439	59.9	11.7	0.2	7.1	<0.1	19.8	38.8	5.9	60,192
CT 6608	9,395	68.2	6.3	0.4	2.8	0.1	21.1	30.6	5.4	64,864
CT 3308	2,773	18.6	49.7	0.4	1.6	<0.1	28.2	79.9	10.7	47,407
CT 3338	8,173	16.6	23.2	0.1	2.6	0.1	56.6	82.5	11.8	40,997
CT 3501	3,635	69.8	6.5	0.1	8.5	<0.1	13.3	28.4	2.3	85,953
CT 3503	6,290	56.6	12.4	0.1	10.2	0.1	19.3	42.2	1.7	77,397
CT 3504	5,571	41.3	12.4	0.2	14.1	<0.1	29.7	56.4	4.8	56,875
CT 3505	5,551	30.4	14.1	0.3	14.1	0.0	39.5	67.9	11.5	43,972
CT 3506	10,890	65.9	8.8	0.3	10.2	<0.1	13.0	32.4	2.4	$69,628
Municipalities										
Brookside Village	1,960	51.7	3.1	0.5	0.8	0.0	43.6	48.0	16.0	$44,650
Clear Lake Shores	1,205	92.5	0.3	0.3	0.7	0.0	3.3	4.7	4.2	67,500
Deer Park	28,520	80.8	1.3	0.3	1.1	<0.1	15.2	18.0	5.6	61,334
El Lago	3,075	91.4	0.8	0.2	1.4	0.1	5.0	7.5	2.9	66,223
Fresno	6,603	21.6	26.3	0.1	1.0	0.0	49.9	78.4	15.3	46,290
Friendswood	29,037	84.5	2.7	0.3	2.4	<0.1	8.8	14.2	3.2	69,384
Houston	1,953,631	30.8	25.0	0.2	5.3	<0.1	37.4	67.8	19.1	36,616
Kemah	2,330	67.0	3.8	0.6	3.5	0.0	8.3	33.0	8.2	51,620
La Porte	31,880	70.7	6.1	0.4	1.1	0.1	20.5	28.1	7.5	55,810
League City	45,444	76.6	5.1	0.3	3.1	<0.1	13.5	22.0	4.7	67,838
Missouri City	52,913	38.6	38.1	0.2	10.5	<0.1	10.9	59.7	3.3	72,434
Pasadena	141,674	47.2	1.5	0.3	1.8	<0.1	48.2	51.8	16.0	38,522
Pearland	37,640	73.4	5.2	0.3	3.6	<0.1	16.2	25.4	4.6	64,156
Nassau Bay	4,170	85.2	1.9	0.5	3.9	0.1	6.3	12.7	4.5	57,353
Seabrook	9,443	81.9	2.1	0.5	3.3	<0.1	10.8	16.6	5.5	54,175
Taylor Lake Village	3,694	89.0	2.7	0.4	2.1	0.1	4.6	9.9	0.9	99,535
Webster City	9,083	55.6	8.8	0.3	5.7	0.2	27.2	42.3	13.2	$42,385
Brazoria	241,767	65.4	8.3	0.3	2.0	<0.1	22.8	33.5	10.1	$48,632
Fort Bend	354,452	46.2	19.6	0.2	11.2	<0.1	21.1	52.1	7.1	63,831
Galveston	250,158	63.1	15.3	0.4	2.1	<0.1	18.0	35.7	13.2	42,419
Harris	3,400,578	42.1	18.2	0.2	5.1	<0.1	32.9	56.5	14.9	$42,598

Source: U.S. Census Bureau (2010a, 2010b).

[1] Total number of persons reporting in nonwhite racial categories, including black or African American, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, and Hispanic or Latino.

[2] 1999 poverty-level data as reported in the 2000 Census (most recent available).

[3] 1999 median household income as reported in the 2000 Census (most recent available). The U.S. Department of Health and Human Services 2008 poverty guideline for a family of four is $21,200. For project area totals, it is the average median household income. Median income is shown as average for the study area Census Tracts.

municipalities also have local ordinance-making authority. WCIDs supply water for domestic, commercial, and industrial use. They also operate sanitary wastewater systems and provide irrigation, drainage, and water quality services.

The multitude of political jurisdictions in the study area in addition to the lack of zoning regulations makes development planning, including flood risk management planning, difficult. For example, much of the study area's populations live in unincorporated areas, which fall under the jurisdiction of the county. Counties, however, have only a limited authority to regulate development and provide public services. Infrastructure and services in these unincorporated areas are therefore provided primarily through a combination of special districts and private homeowners' associations.

3.13.3 Economics

3.13.3.1 Historical Perspective

In the early 1900s a shift from agriculture to industry occurred in the study area. The Houston Ship Channel began to flourish at this time. Large energy companies began to locate in the area including Texaco, Arco, Crown Central Refining, Champion Paper Company, and Houston Lighting and Power. The discovery of oil in the Friendswood-Webster oilfields during the 1930s brought some population growth to these two towns, as well as to League City and Pearland. In the 1960s, the land east of Webster became the home of NASA's Manned Spacecraft Center, renamed the Johnson Space Center (JSC) in 1973. The area has since grown to include an array of high-tech companies combined with a mix of traditional industries including the JSC, the Texas Medical Center, and the Houston Ship Channel and its associated world's largest petrochemical complex.

Of growing importance for the regional economy is the boating and recreation industry. Clear Lake has 22 marinas that provide 7,300 boat slips of all sizes and dockage facilities for powerboats and sailboats making it the third-largest boating community in the Nation. The Kemah-Seabrook area also serves as a commercial landing port. The Clear Lake region holds the largest number of boats and slips of any single location along the Texas Gulf coast and provides harborage for the third-largest number of privately owned boats in the Nation (Clear Lake City Information, 2007).

3.13.3.2 Current Regional Economics

The unemployment rate for study area in 2007 municipalities ranged from 5.3 to 4.0 percent. The unemployment rate for the counties ranged from 5.0 to 4.7 percent (TWC, 2007).

First-quarter employment data for 2007 reveal the top three industries for the Gulf Coast Workforce Development Area is trade – wholesale and retail (21.6 percent), government

(20.4 percent), and manufacturing (12.8 percent). Within the study area counties, the top industries were government, trade, educational services, and construction (TWC, 2007).

3.13.3.3 Tax Base

In Texas, property is appraised and property tax is collected by local (county) tax offices or appraisal districts. These monies are used to fund public schools, city streets, county roads, and police and fire protection. The 2006 tax rate for the study area municipalities ranged from $0.21 to $0.72 and from $0.32 to $0.59 for study area counties.

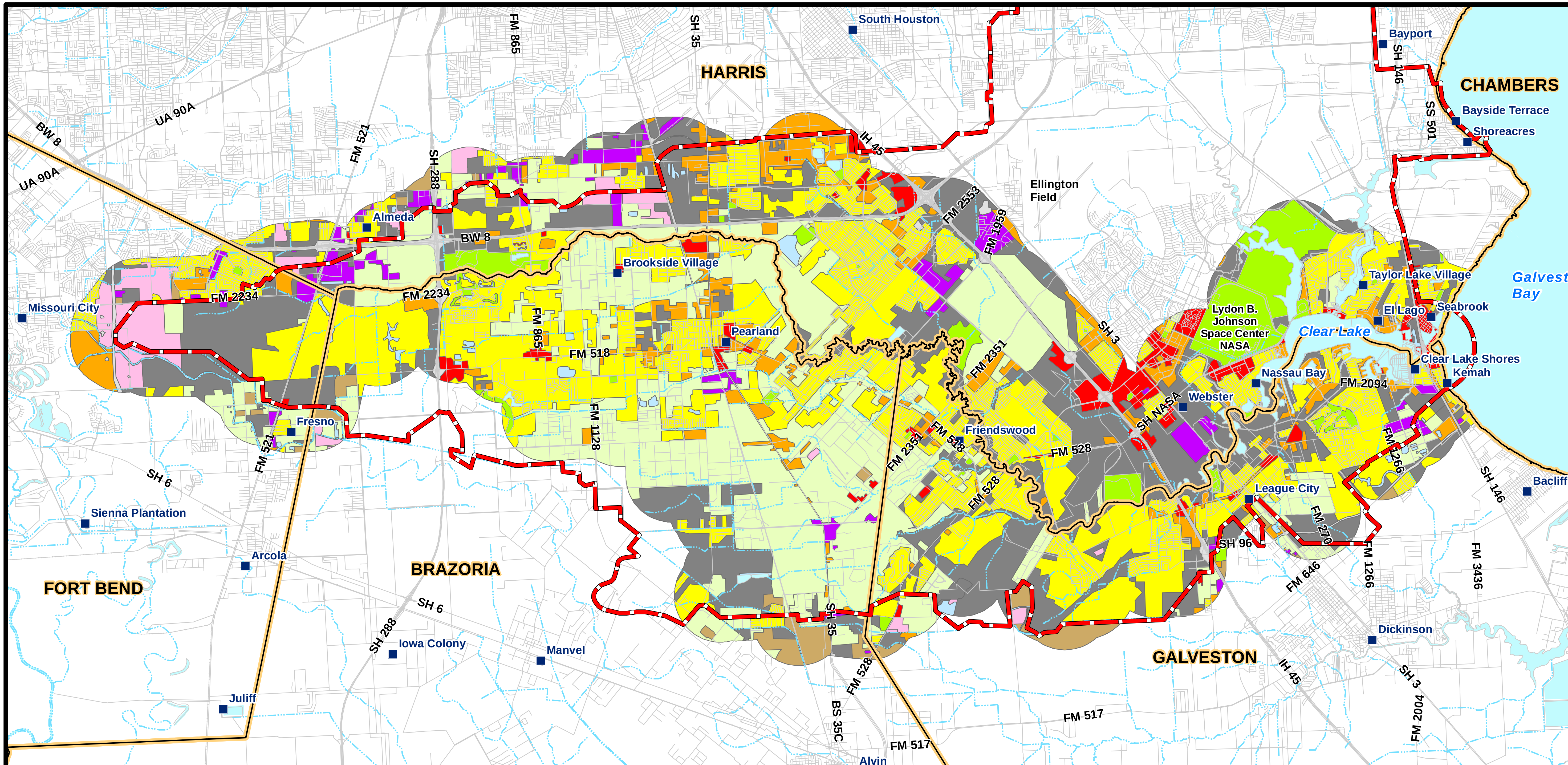
3.14 LAND USE/AESTHETICS

In order to evaluate existing land-use patterns within the study area, data were obtained from a variety of public agencies and private entities, and were integrated into ArcView® GIS. The study area is approximately 219 square miles, and includes portions of Harris, Galveston, Brazoria, and Fort Bend counties. The study area includes 17 communities/municipalities: Brookside Village, Clear Lake Shores, Deer Park, El Lago, Fresno, Friendswood, Houston (partial), Kemah, La Porte, League City, Missouri City, Nassau Bay, Pasadena (partial), Pearland, Seabrook, Taylor Lake Village, and Webster. Land uses for the study area are shown on Figure 3.14-1.

The study area is approximately 140,037 acres in size and includes a variety of land uses, including highly developed residential-urban, industrial, recreational, and agricultural land. Generally, the most intensive development is found in the rapidly growing areas immediately adjacent to the major roadways (SH 288, Sam Houston Tollway/Beltway 8, SH 35, I-45, and SH 146). The remainder of the study area is characterized by agricultural land uses, scattered small residential clusters, and parklands (see Figure 3.14-1).

Based on review of 2005 aerial photography, within the study area, residential, including large lot/ranchettes, composes approximately 52 percent of the total study area, followed by undeveloped land with 22 percent and urban uses with 15 percent, including commercial, industrial, transportation, and other urban land uses. Total parkland within the study area is approximately 4 percent. Between 2000 and 2005, residential land use increased by approximately 86 percent, while undeveloped land decreased approximately 47 percent. Urban uses such as commercial, industrial, and transportation also showed an increase (14 percent), and the amount of land dedicated to parks increased by about 8 percent.

Growth from master-planned communities developed by private entities is rapidly occurring in the study area. The residential pattern of recent developments contrasts sharply with the rural nature of the traditional housing stock of the area where small clusters of homes or individual farm homesteads are scattered along farm to market roads. Many of the residences in more-rural



Land Use/ Land Cover (Source: USGS LU/LC 1990 Digital Data updated by PBSJ using Aerial Photo Interpretation)

- Agricultural Land
- Commercial
- Industrial
- Mining
- Other Urban Land
- Water Features
- Transportation Communication and Utilities
- Park
- Residential
- Rural (Large lot/Ranchette) Residential
- Undeveloped Land

- Study Area
- Texas Cities
- Texas Counties

N W E S

0 12,000 24,000 36,000 Feet

Figure 3.14-1

Land Use

Clear Creek
Flood Risk Management Project

Prepared for: USACE	
Job No.: 04188600	Scale: 1 inch = 12,000 feet
Prepared by: 18827	Date: 5/11/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/044188600/figures/landuse/3_14_1.mxd

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settings include farm-related structures such as garages, barns, storage buildings, and other agricultural outbuildings. Commercial and industrial land uses in the study area tend to be located along Beltway 8, I-45, and SH 146. Many of the study area's municipalities have incorporated no-impact policies in addressing new development. These are established to protect the stormwater flow at a 100-year level of protection; however, these requirements are not in place for the entire watershed.

Transportation land uses in the study area include a network of primary, secondary, and local roads, along with the City of La Porte Municipal Airport. Within the study area there are four railroads that provide rail freight service. These are the Union-Pacific Railroad, the Burlington-Northern Santa Fe Railroad, the Galveston, Houston, and Henderson Railroad, and the Southern Pacific Railroad. These facilities make up about 2 percent of the total land cover in the study area.

3.14.1 Aesthetics

In order to assess the potential impact on a given landscape, two primary elements must be evaluated: (1) the nature of the receiving landscape, and (2) the nature of the land-use change that will be introduced to the viewscape. The study area is largely a flat plain without much variety in terrain. The gullies, creeks, and bayous of the Houston area are collectively considered an aesthetic resource. Clear Creek is a natural habitat for riparian forest, prairie grasses, and migratory birds. Generally speaking, the creek is considered aesthetically pleasing, with area neighborhoods touting parks and residential developments along its banks for their bird-watching, picnicking, walking, and other recreational opportunities. Housing values reflect this, with portions of Friendswood located along the creek having some of the highest housing values in the study area. The winding water flow and tall bordering vegetation provide an attractive contrast to the basically flat and dry terrain.

3.14.2 Recreation

Throughout the study area, 77 parks and other recreational facilities were identified encompassing approximately 5,534 acres (4 percent of total land cover in the study area). Also, many of the parks and recreational activities within the study area are oriented toward water-based activities such as fishing, swimming, wind surfing, boating, birding, and other aquatic-based recreation.

The Clear Lake area is considered to have the Nation's third-largest concentration of pleasure boats, which contributes to the local economy. The fishing industry is important to the area economy as a source of recreation, as a draw for tourism, and for commercial fishing enterprises. There are an estimated nine public boat ramps providing access to Clear Lake and to Galveston Bay (Clear Lake City Information, 2007). Other water-based sports/activities that are popular within the area include water skiing, personal watercraft, wind surfing, rowing, canoeing, and kayaking. Both recreational and commercial boaters are served by hundreds of marine businesses around Clear Lake that provide bait and fuel, ropes and sails, anchors, nets, engine and boat repairs, and skis and lifejackets. Many other businesses in the Clear Lake area contribute to the local fishing and boating economy, including boat sales, brokerage businesses to the boat yards and marinas, marine documenters, and insurance agents (Clear Lake Area Chamber of Commerce, 2002).

Birding is also a popular activity along the Texas Gulf coast that attracts many tourists. TPWD and TxDOT have jointly sponsored the development of the Great Texas Coastal Birding Trail. Within the study area, one birding loop has been identified, the Clear Lake Loop. The Clear Lake Loop is one of several trails within the Upper Texas Coast Birding Trail (a subset of the Great Texas Coastal Birding Trail (TPWD, 1999). Park facilities within the study area that occur along the Clear Lake Loop are McHale Park, Pine Gully Park, Armand Bayou Nature Center, Bay Area Park, Nassau Bay Park, Challenger 7 Memorial Park, and Walter Hall County Park.

3.14.3 Federal Aviation Administration Airport Compatibility Analysis

Due to the increasing concern regarding aircraft-wildlife strikes, the Federal Aviation Administration (FAA) has implemented standards, practices, and recommendations for holders of Airport Operating Certificates issued under Title 14, CFR, Part 139, Certification of Airports, Subpart D (Part 139), to comply with the wildlife hazard management requirements of Part 139. Airports that have received Federal grant-in-aid assistance must use these standards.

In accordance with the FAA Advisory Circular 150/5200-33B and the Memorandum of Agreement with FAA to address aircraft-wildlife strikes, when considering proposed flood risk management measures and mitigation areas, USACE must take into account whether the proposed action could increase wildlife hazards. The FAA recommends minimum separation criteria for land-use practices that attract hazardous wildlife to the vicinity of airports. These criteria include land uses that cause movement of hazardous wildlife onto, into, or across the airport’s approach or departure airspace or air operations area (AOA).

These separation criteria include:

- Perimeter A: For airports serving piston-powered aircraft, hazardous wildlife attractants must be 5,000 feet from the nearest AOA;
- Perimeter B: For airports serving turbine-powered aircraft, hazardous wildlife attractants must be 10,000 feet from the nearest AOA; and
- Perimeter C: Five-mile range to protect approach, departure, and circling airspace.

The airports within the study area that must comply with these standards are the Ellington Field, Houston-Southwest, William P. Hobby, Pearland Regional, and La Porte Municipal airports (Figure 3.14-2). Features in the GRP alternative fall within the 10,000-foot perimeter at the Pearland Regional Airport and the Ellington Field Airport, and within the 5-mile perimeter of the William P. Hobby Airport, Pearland Regional Airport, and Ellington Field Airport. All features of the proposed GRP Alternative occur outside the limits of the 5-mile perimeter of the Houston-Southwest Airport and the La Porte Municipal Airport. The potential for the proposed GRP to affect wildlife movements within these areas is discussed in Section 4.14.2.

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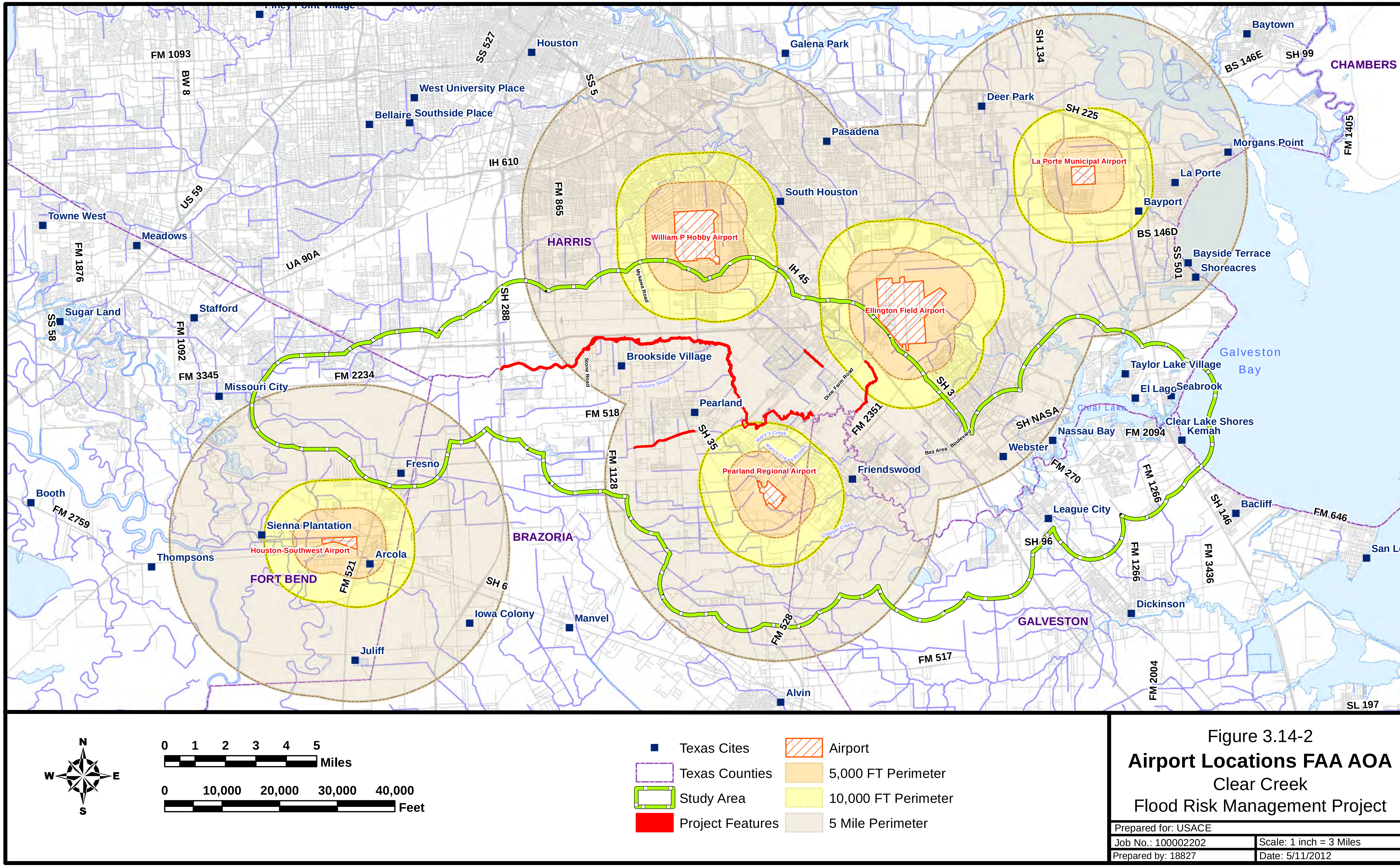

Figure 3.14-2
Airport Locations FAA AOA
Clear Creek
Flood Risk Management Project

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4.0 ENVIRONMENTAL CONSEQUENCES

4.1 ENVIRONMENTAL SETTING

4.1.1 Physiography and Geology

4.1.1.1 No Action Alternative

Under the No Action Alternative, periodic major flooding, i.e., 1 percent AEP (100-year event) and/or 0.2 percent AEP (500-year event), will continue to occur along the Clear Creek watershed resulting in extensive damages to existing and/or future urban infrastructure such as roads, bridges, businesses, and residences. The without-project floodplain for the year 2020 is shown on Figure 4.1-1 (Note: Detailed floodplain spatial data for the project area are presented in Appendix P.) Rapid urban growth has substantially increased the extent of impervious cover and reduced the project watershed's natural detention capacity, resulting in higher and more frequent stormwater flows. As a consequence, overbank flows have become more common, even with moderate rainfall events. In addition, continued development within the floodplain has compounded the problem of addressing flood risk management not only by introducing additional flood-prone structures, but also by narrowing flood risk management options (see GRR for additional information). Frequent flooding could alter physical characteristics of streams in the study area through erosional and depositional processes. Additionally, during flood events, fine-grained alluvium (mud, clay, and silt) is deposited in areas adjacent to stream banks during overbank flows. Thus, natural geologic processes could be accelerated by continued flood events. Other geologic and physiographic processes would continue, as described in Section 3.1, and would not be affected.

One component that has tended to reduce flooding the lower part of the Clear Creek watershed is the addition of the Second Outlet Channel and Gate Structure in 1997. This is part of the No Action Alternative.

4.1.1.2 GRP Alternative

Under this alternative, deepening and widening of the creek channel and its tributaries would have minor effects on the physiography and geology of the study area. The proposed creek channel widening would impact approximately 22 linear miles of the existing channel and its tributaries. Material excavated during construction would be placed in several upland placement areas.

While local changes would occur to topography with construction of this alternative, these alterations would be expected to have minor impacts on the physiography and geology of the subaerial portions of the project area. The GRP Alternative reduces the elevation of flood events,

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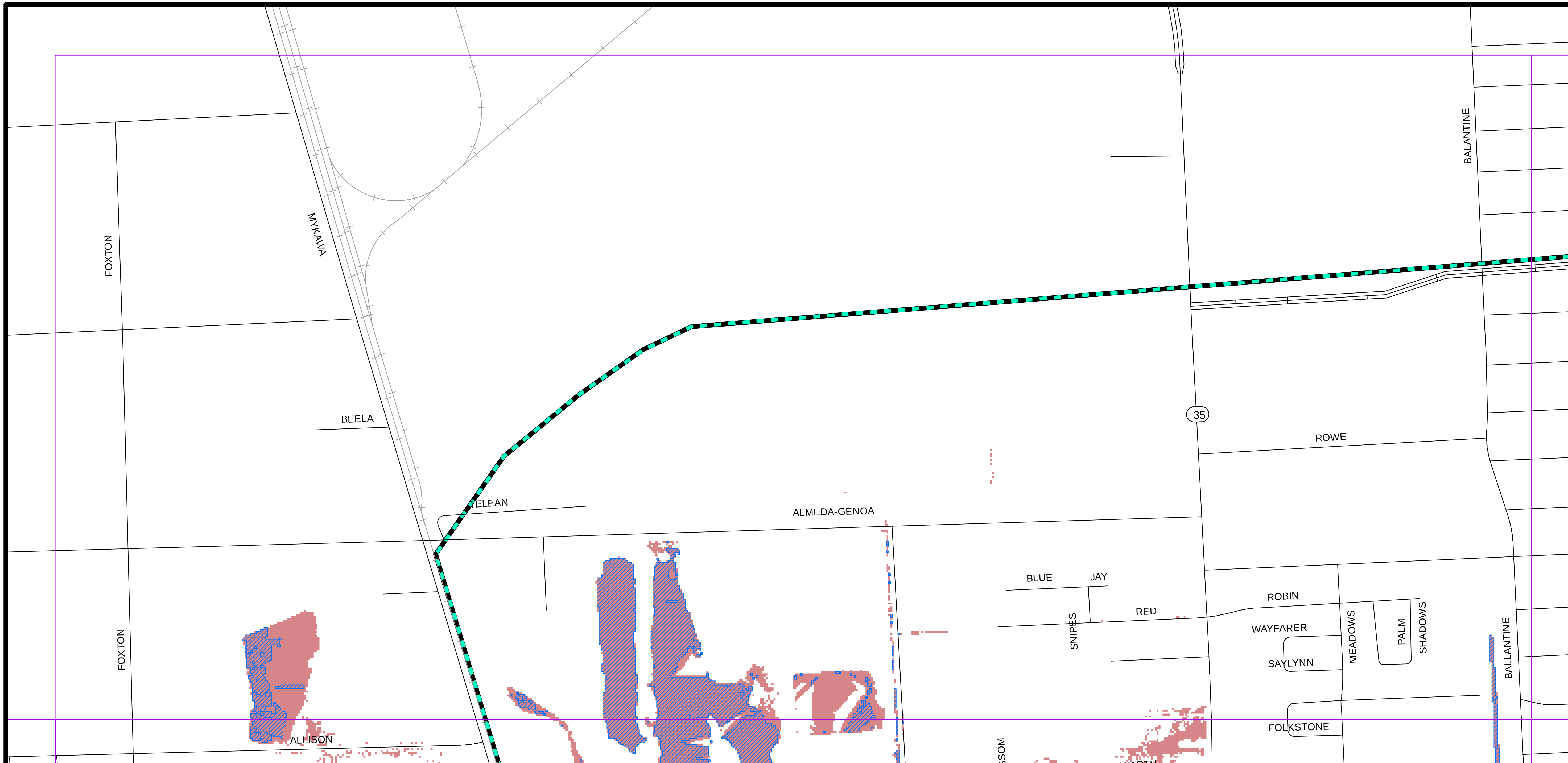


Clear Creek Watershed

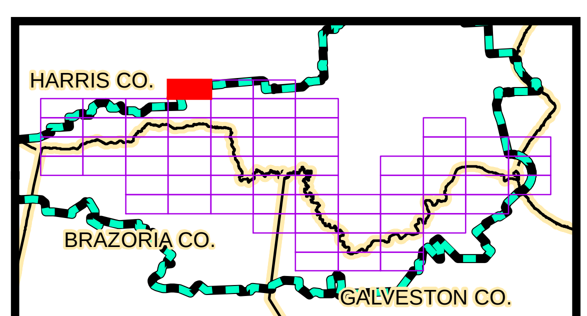
County Boundary

Match Lines

1% Chance (100 year) Floodplain - With Project

1% Chance (100 year) Floodplain - Without Project

5, 4... Economic Damage Reach



N
W E
S

0 800 1,600 2,400 Feet

Figure 4.1 - 1

2020 Floodplain for the No Action and GRP Alternatives

Clear Creek

Flood Risk Management Project

Sheet 1 of 68

Prepared for: USACE	
Job No.: 100013748	Scale: 1 inch = 800 feet
Prepared by: 19895	Date: 5/10/2012

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thus reducing flood damage within the Clear Creek watershed. Figure 4.1-1 shows the floodplain for the year 2020 with the GRP Alternative. The rate of natural geologic processes would be reduced from that described for the No Action Alternative.

The potential for geological hazards such as sinkholes, salt domes, and subsidence associated with Beaumont clay in the Houston area is not anticipated. Additionally, as discussed in the GRR, the clayey soils along Clear Creek are expected to minimize surface sloughing on the slopes of the high-flow channels. If properly maintained with grading and establishment of vegetation, only minor sloughing is expected.

To accommodate conveyance features, 22 pipelines will require relocation; however, directional drilling will likely be utilized to deepen the pipelines in their existing location. Implementation of best management practices (BMPs), which include segregating topsoil for postconstruction redistribution and restoring site topography to preexisting conditions, will assist in the minimization of impacts.

4.1.2 Relative Sea Level Change

As presented in subsection 3.1.5, the baseline condition for relative sea level change is an expected increase in the relative sea level from the combined effects of subsidence and eustatic, or global, sea level rise. Historically, the subsidence effect has been much larger, but in the future it is possible that eustatic increase in sea level may take on greater significance.

These changes could potentially affect flooding and flood protection plans in two ways. One is that higher relative sea level will allow greater coastal storm surge propagation into Clear Lake. The storm surge elevations in the Clear Lake area are now substantially higher than the water elevations, which result from stream flooding, and higher sea level will increase that difference. For example, the 1 percent probability stream flood elevation in Clear Lake is approximately +4 feet msl, much lower than coastal surge elevations, which are typically two to three times higher. This study addresses stream flooding and flood risk management measures proposed for the inland reaches of Clear Creek and its tributaries upstream of Dixie Farm Road. The effect of higher coastal storm surge is limited in that it only has a small increase in the length of the lower stream reaches where proposed measures dealing with the stream flooding effects do not occur. The other major mechanism for relative sea level change to affect flooding is by reducing the slope of Clear Creek by both raising the water level at the downstream end and higher inland subsidence lowering the land level at the upstream end. This aspect is addressed below.

4.1.2.1 No Action Alternative

Under the No Action Alternative, none of the upstream flood protection measures would be constructed. To assess the effects of changes, a future condition model was used in two ways. One was to increase the starting downstream boundary condition elevation in Galveston Bay.

While the most recent analysis (EC 1165-2-211, 2009) indicates that sea level could rise to 2.80 feet by 2070, model runs were performed with an elevation of 2.76 feet based on the NRC (1987) worst-case scenario for 2070. The model results for the 1 percent chance event were reported to show that because of the flow constriction at the natural outlet of Clear Creek (to Galveston Bay), the change in elevation at Clear Lake was only 0.7 foot. The increase reported at I-45 was only 0.3 foot, and it was likely to be even smaller going farther upstream. The difference between 2.76 feet and 2.80 feet in the downstream elevation is not likely to be significant given this result.

The other situation analyzed was to consider the effects of reduced slope. This was done by running the same future condition model with the headwaters of Clear Creek lowered by roughly 5 feet. The upper reach of the stream has an elevation of roughly 55 feet, so the change in slope is about 10 percent. Again, the flow from the 1 percent event was reported to show a 0.5-foot increase in elevation at I-45 and much less impact upstream. The I-45 location is partly affected by the backwater from the flow constriction at SH 146, but the upstream areas where the effect was reported to be smaller are not in this backwater. Note that the Second Outlet for Clear Lake, which exists and is part of the No Action Alternative, has no effect on the slope discussion. The fact that a fairly large change in slope had a small change in peak flood elevation in the upstream area suggests that the model is not sensitive to the slope changes that can be expected with sea level change and subsidence.

The Second Outlet structure is operated and maintained by the HCFCD. The gates do not provide tidal and hurricane protection for lakeside or Clear Creek communities. Any modification in the operation of the Second Outlet to account for conditions under sea level rise are subject to the discretion of the HCFCD.

4.1.2.2 GRP Alternative

The effects of sea level rise and subsidence would be the same for the GRP and No Action alternatives. The only difference would be that the GRP Alternative would have measures incorporated to reduce stream flooding in the upstream reaches of the study area. There has been no separate evaluation of sea level change or slope changes on the No Action Alternative and GRP Alternative, but since sea level and slope have been shown to have modest changes in the future condition model, particularly in the upstream reaches where the flood protection measures are located, the effects of sea level change are likely to be similar.

4.2 WATER QUALITY

4.2.1 No Action Alternative

Under the No Action Alternative, there would be no improvements to the Clear Creek watershed. No increased turbidity from construction would occur, and there would be no possibility for the release of undesired chemicals during construction. The effects of floods and the generated turbidity and reduced water quality would be as it is presently. As noted in subsection 3.2.1, water quality issues have been observed in portions of Clear Creek. These issues include high nutrients and elevated chlorophyll *a* levels from nonpoint sources, high levels of bacteria from point and nonpoint sources, and high TDS and chlorides from an identified point source. TMDLs and Implementation Plans have been proposed and/or adopted to address these issues. Although nonpoint sources are more difficult to address, it is reasonable to expect that, over time, as management tools (such as the TMDLs) are implemented, a reduction in water quality issues should be observed within Clear Creek and its tributaries. This is especially true for the high TDS and chlorides, for which an Enforcement Action has been adopted by TCEQ and agreed to by the point source. This action should eventually eliminate those water quality issues.

4.2.2 GRP Alternative

Under the GRP Alternative, the creation of in-line detention and improved conveyance features would aid in decreasing the turbidity during small storm runoff events and allow for the reduction of water contaminants from runoff from urban areas. Table 4.2-1 presents the various improvements to Clear Creek that might impact water quality and the water-quality sampling station nearest to, or included in, the improvement.

Table 4.2-1
Water and Sediment Quality Sampling Stations in Relation to Project Feature Excavation

Description	Water Quality Stations	Sediment Quality Stations
SH 288 to Mykawa Upper Clear Creek Conveyance	None	None
Mykawa to Bennie Kate Upper Clear Creek Conveyance	None	None
Clear Creek In-Line Detention	None	None
Lower Clear Creek Conveyance	Sta 1	Sta 1
Mary's Creek Conveyance	None	None
Turkey Creek Conveyance	Sta 5, T-1, SW-17	Sta 5, T-1, SW-17, CC 15/16-92
Mud Gully Conveyance	Sta 2, MG-1	Sta 2, MG-1

See EH&A (1998) and Figure 3.3-1 in this report.

The proposed conveyance measure on Mud Gully is located upstream of the Brio Refining Site and the sampling discussed in EH&A (1998) (Section 3.2), and, therefore would not be specifically characterized by any of the water quality stations associated with that sampling. However, the proposed conveyance measure would be located within 600 feet of Station 2 and roughly 4,000 feet from Station MG-1 (EH&A, 1998). There was no exceedance of TWQS by any parameter in the Station 2 and Station MG-1 samples, and no TWQS would be violated from construction of the proposed Mud Gully conveyance measure. Since the high-flow channel and side slopes of the Mud Gully conveyance measure would be concrete lined, there would be no addition of turbidity during a high-water event from erosion of the side slopes.

The grass-lined high-flow channel and side slopes of all other conveyance measures would also reduce turbidity during rainfall and high-flow events. Additionally, reduction of flow speed during high-flow events would reduce the turbidity flowing downstream and into Clear Lake. As noted in Table 4.2-1, there are no water quality stations near the two portions of the Upper Clear Creek conveyance measure or the Mary's Creek conveyance. One station, Station 1, was located just downstream of the Lower Clear Creek conveyance measure, and three stations were located in the Turkey Creek conveyance measure: stations 5, T-1, and SW-17. As with the stations in Mud Gully, there were no exceedances of TWQS by any parameter from these stations, and no TWQS would be violated during the excavation and placement of material from these conveyance measures. The two portions of the Upper Clear Creek conveyance measure run through a residential area with no industry, and no TWQS would be violated during the excavation and placement of material from these conveyance measures.

To accommodate conveyance features, 22 pipelines will require relocation. Directional drilling will be performed to deepen the pipelines in their existing location. Appropriate BMPs such as silt fencing and straw bale barriers will be installed at the entry and exit drill locations; therefore, impacts to water quality as a result of pipeline relocation are not anticipated.

4.3 SEDIMENT QUALITY

4.3.1 No Action Alternative

There will be no change in the quality of the sediments in the project area. As noted in Section 3.3, sediment quality within the project area has been affected by accidental discharges. However, recent testing has indicated an increase in the sediment quality, with constituents being found at or below detection limits. Under the No Action Alternative, it is expected that, unless additional accidental spills continue, this trend will continue. However, it should be noted that, given the high rate of development within the project area, the risk of such a spill increases. Accidental spills of contaminants such as gasoline or oil from facilities or vehicles is a constant possibility in any given area. Such accidental spills can affect sediment quality.

4.3.2 GRP Alternative

Sediment samples were collected for the USACE and others (EH&A, 1998) in portions of Clear Creek and tributaries, including Mud Gully. The conclusion of EH&A (1998) was that "high concentration of a number of compounds have been found in Mud Gully" and "to a lesser extent in Clear Creek." However, a decrease in the concentration of these compounds, with time, was noted. The report concluded that, from the perspective of a flood risk management project in which materials may be removed from Clear Creek and its tributaries and placed into upland confined placement areas, “no adverse impacts can be expected.” Any material excavated during construction would be deposited at a designated upland confined placement area. The locations of the placement areas would be determined during the preconstruction engineering and design phase. There have been no spills or other significant events since 1998 that would change that conclusion. Attempts will be made to site the placement areas, which total approximately 376 acres, on agricultural lands, pasture, and other urban land to avoid wetlands and/or other ecological resource areas. No adverse impacts to or from sediments can be expected with implementation of the GRP Alternative. Accidents, as noted in subsection 4.3.1, can occur just as readily with or without the project and do not, therefore, affect the preceding conclusion.

To accommodate conveyance features, 22 pipelines will require relocation. Directional drilling will likely be utilized to deepen the pipelines in their existing location, and appropriate BMPs such as silt fencing and straw bale barriers will be installed at the entry and exit drill locations; therefore, potential for an inadvertent release of sediment to reach project features is unlikely.

4.4 HYDROLOGY

4.4.1 No Action Alternative

The No Action Alternative means that the existing channels and drainage system will remain in place with no improvements to better convey flood flows. As a result, existing flooding in the Clear Creek Basin will not be reduced in the future. In fact, future flooding may increase due to the continued urban development within the Clear Creek Basin, including its tributaries, despite local regulations for new construction in some areas. The No Action Alternative includes the already constructed Second Outlet Channel and Gate Structure for Clear Lake. This outlet acts to avoid flooding in Clear Lake from major storm flows in Clear Creek.

4.4.1.1 Flows and Discharges

Continued urban development in the Clear Creek Basin will tend to increase the stream flows within Clear Creek and its tributaries unless there is an applicable detention policy. Such detention policies are in place for new construction in portions of the study area, but not the entire study area. Increased discharges would increase flooding in the Clear Creek Basin.

Under the No Action Alternative, the current existing flooding problems in the Clear Creek Basin will continue and are likely to worsen. The projected flood profiles under the No Action Alternative for 2020 are shown on Figure 4.4-1.

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Figure 4.4-1a. Flood Elevation Profiles No Action and GRP Alternatives

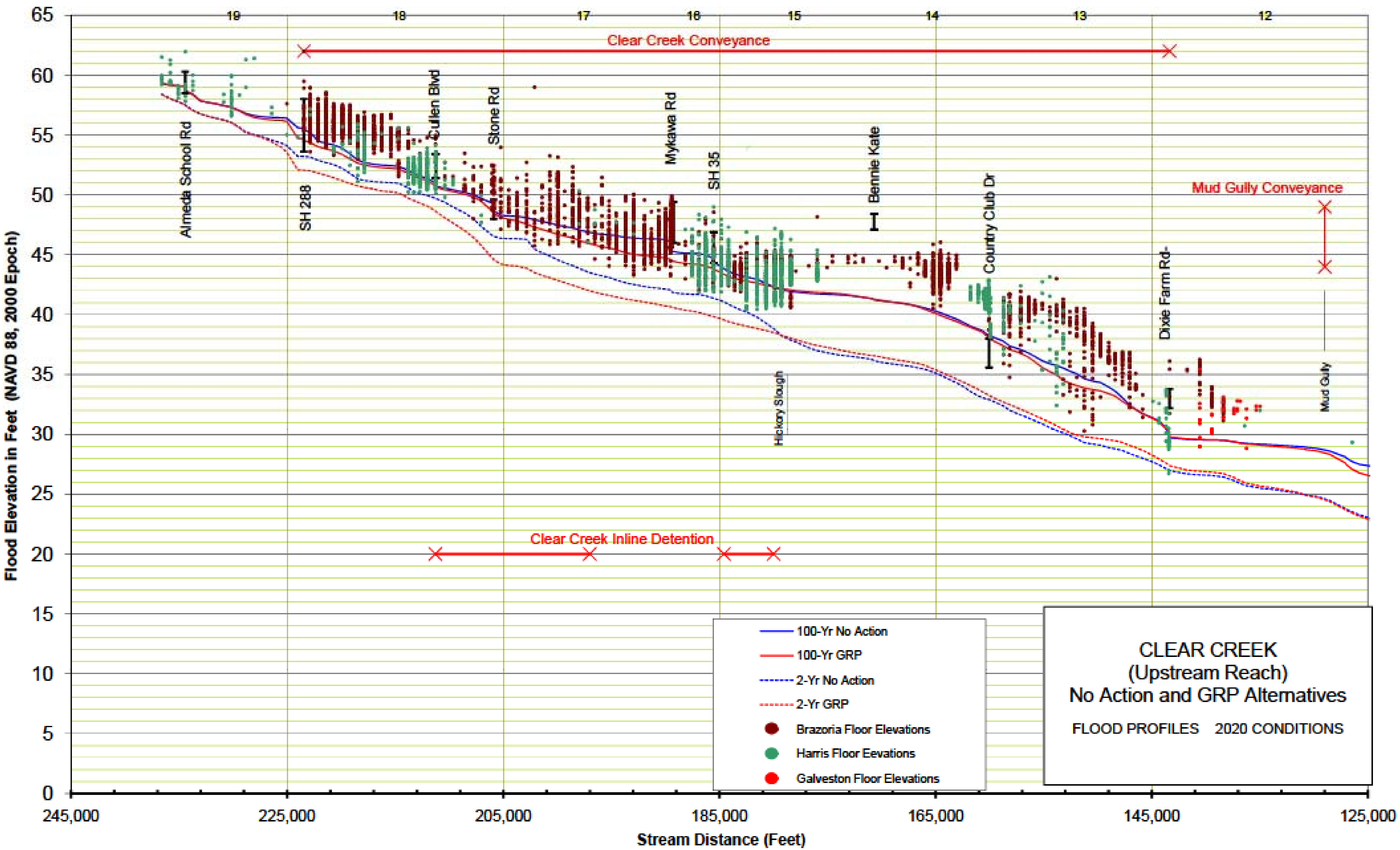

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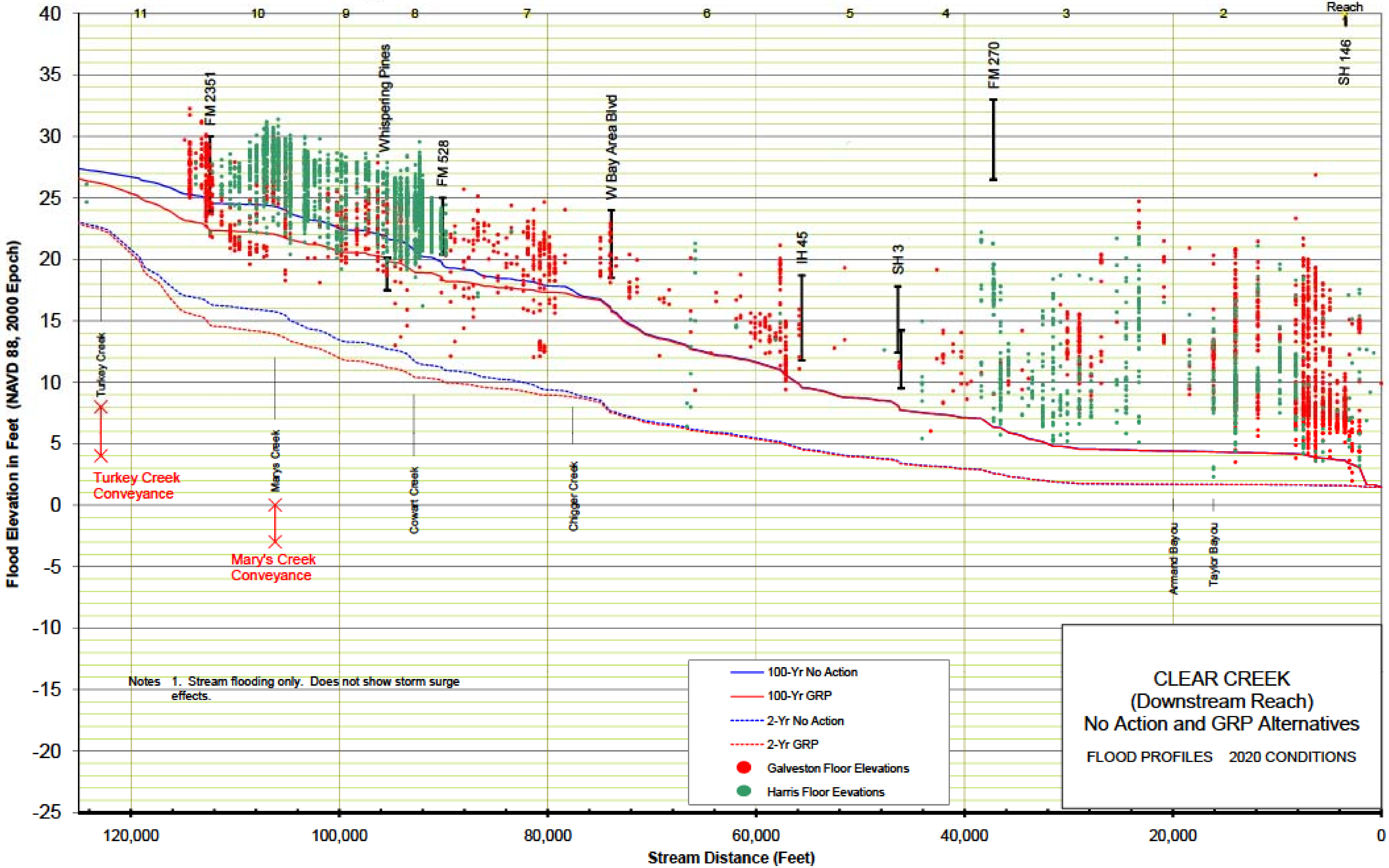
Figure 4.4-1b. Flood Elevation Profiles No Action and GRP Alternatives



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4.4.1.2 Clear Lake and Tides

As stated above, the expected continued development of the urban areas upstream of Clear Lake will increase flows into Clear Lake and Galveston Bay. These increased flows may impact Clear Lake. However, the Second Outlet Channel and Gate Structure were originally constructed in 1997 to mitigate the induced flooding in Clear Lake that would have resulted from the construction of the AFP. As such, under the No Action Alternative, the Second Outlet, when opened, helps to alleviate, but does not eliminate, increased flows to Clear Lake by allowing the flood flows to be more quickly dispersed into Galveston Bay. However, the Second Outlet does not provide protection for Clear Lake or Clear Creek communities from tides or hurricanes.

Under the No Action Alternative, coastal flooding should remain approximate to present conditions. Current trends, due to tides or tidal surge, would continue.

4.4.1.3 Flood Insurance

The effective FIS for Harris County is dated June 18, 2007 (FEMA, 2007). The No Action Alternative means that the resulting FIRMs will not change unless need arises, such as a flood event. However, under the No Action Alternative, flood events are likely to increase as more areas are developed, potentially increasing the risk of a major flood event, which could trigger a revision to the FIS and FIRMs. Thus, the No Action Alternative may increase the number of property owners that require flood insurance in the upper part of the watershed.

4.4.1.4 Groundwater Hydrology

Under the No Action Alternative, flood risk management measures would not be implemented for the Clear Creek watershed, and periodic flooding would continue as it has in the past. Thus, impacts to groundwater hydrology within the study area would not change from current conditions.

4.4.2 GRP Alternative

4.4.2.1 Flows and Discharges

The GRP Alternative would reduce the flood damage in high-damage reaches (Pearland area and Friendswood area) by adding improvements to Clear Creek and some of its tributaries (Mud Gully, Turkey Creek, and Mary’s Creek). The GRP Alternative is composed of numerous conveyance improvements and additional in-line detention components that would reduce flooding and flood damages. The improved channel conveyances would allow Clear Creek and its tributaries to handle the increased peak flows during flood events. The additional in-line detention would contribute to reduced flood risk. Figure 4.4-2a shows the flood elevation profiles for the upstream portion of the study area, and Figure 4.4-2b shows the profiles for the

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Figure 4.4-2a. Flood Elevation Profiles for GRP & No Action Alternatives 2070, Upstream Reach

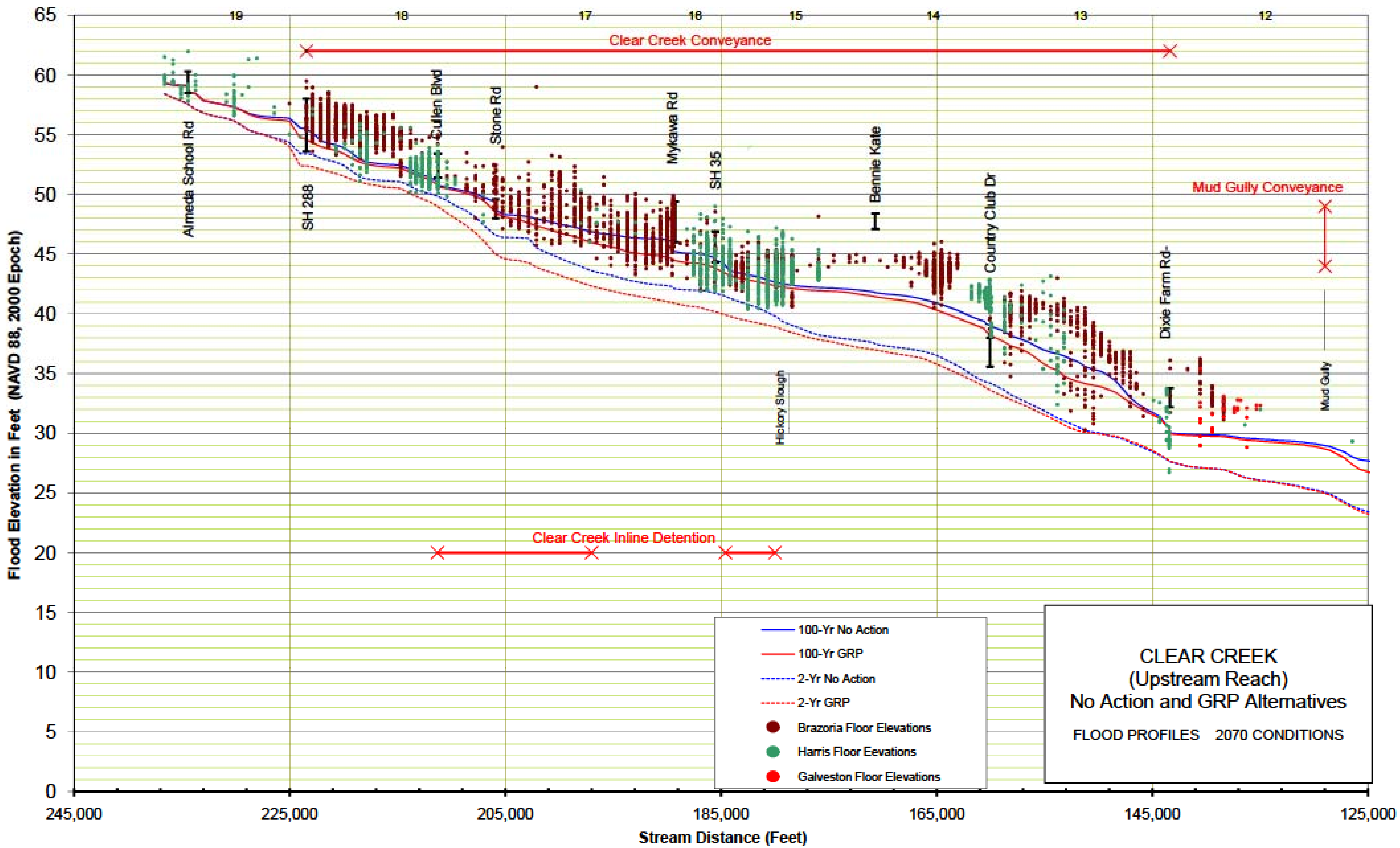

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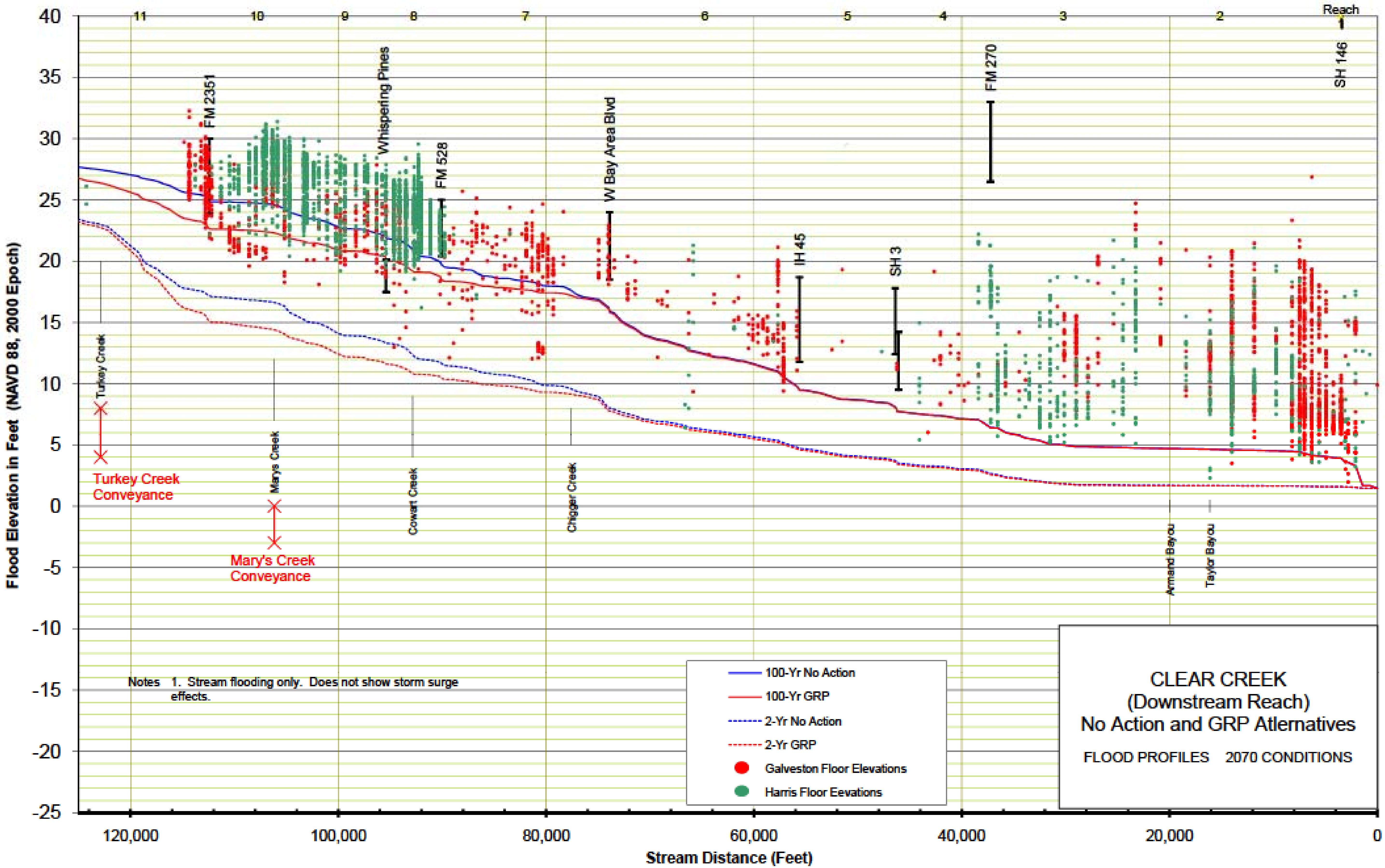
Figure 4.4-2b. Flood Elevation Profiles for GRP & No Action Alternatives 2070, Upstream Reach



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downstream reach. The GRP Alternative would reduce flood damages within the Clear Creek watershed. The proposed project would reduce flood damage in the Pearland and Friendswood area reaches by improving the capacity of Clear Creek and its tributaries. A high-flow channel, a conveyance improvement measure, would provide additional capacity during flood events. High-flow events would also be mitigated through the eventual establishment of riparian vegetation from tree plantings. Because the Second Outlet Channel and Gate Structure have already been constructed, there would be little change to flood damages to the downstream segments of the watershed.

The projected 2020 floodplain under the GRP Alternative is shown on Figure 4.1-1. Although the floodplain itself is not expected to change significantly, the elevation of flood events would be reduced, thus reducing damages caused by flooding.

4.4.2.2 Clear Lake and Tides

The GRP Alternative should reduce the flood risk for the Clear Creek Basin upstream of Clear Lake. The improved channels and added detention facilities planned for the upstream reach of Clear Creek and for some of its tributaries (Mud Gully, Turkey Creek, and Mary's Creek) would help detain runoff and reduce the increased peak flows attributed to increased urbanization. The Second Outlet Channel and Gate Structure that is included in the No Action Alternative substantially contributes to reduced flooding in Clear Lake as it is presently, as can be seen on Figure 4.4-1. Thus, the GRP Alternative would not have a significant effect on flood elevations in Clear Lake itself.

4.4.2.3 Flood Insurance (LOMR, map revision)

The effective FIS for Harris County is dated June 18, 2007 (FEMA, 2007). The GRP Alternative would change the floodplain and BFEs (see Figure 4.4-2). The change in the floodplain could result in a change to the FIRMS. Once construction of the GRP Alternative is completed, an LOMR may be submitted to FEMA so that the FIRM maps could be revised (i.e., include the changes in mapping due to construction of the GRP Alternative). Due to the revised FIRM map, there may be changes with regards to which properties are located within the floodplain.

4.4.2.4 Groundwater Hydrology

Construction and operation activities associated with the GRP Alternative are not expected to result in significant impacts to groundwater hydrology, quantity, or quality. In addition, no groundwater withdrawals are anticipated for the project. However, TWDB records indicate one water well located within the project footprint. The reportedly unused private well (No. 6530505 – C.W. Massey) is located within the western detention pond, north of Mary's Creek (see Figure 3.4-4). Because it occurs within an existing designated detention area, it should be confirmed that it has been plugged and abandoned per TCEQ guidelines for proper well closure prior to construction.

To accommodate conveyance features, 22 pipelines will require relocation. Directional drilling will likely be utilized to deepen the pipelines in their existing location. To reduce the potential impacts to groundwater hydrology, a contingency plan regarding the inadvertent release of drilling fluids into sensitive areas that adheres to state standards should be prepared and implemented prior to construction.

Other possible impacts to shallow groundwater exist from the potential release of petroleum products during construction; however, the use of BMPs such as a sump pump or wet vacuum for potential hazardous material spills that could occur in the project area would greatly minimize the potential for this type of impact. A Spill Response Plan that meets local, State, and Federal requirements would be developed and implemented to address potential spills.

4.5 AIR QUALITY

This section provides a generalized discussion of the air quality impacts associated with the No Action and GRP alternatives relative to the inventory of air emissions for the HGB Non-attainment Area. As discussed in Section 3.5, for air quality monitoring and planning purposes, the EPA relies on the designation of nonattainment areas for air pollutants within the boundaries of geographical planning units.

For consistency with the EPA's designations, the HGB Nonattainment Area was considered the study area for determination of potential air quality impacts of the proposed alternatives. The air contaminants considered are those covered by the NAAQS (except for Pb, which is not relevant to project emissions), including CO, O_3, NO_x, PM_{10}, $PM_{2.5}$, and SO_X.

4.5.1 No Action Alternative

No construction or new operating emission sources are associated with the No Action Alternative. However, growth and development is expected to continue in this area. Air emissions related to any future development would be required to comply with any Federal or State requirements related to air quality. As noted in subsection 3.5.2.2, the ozone monitored values have decreased in the HGB even with an increase in population and corresponding development. Although mobile emission sources are expected to increase in the area, EPA standards for cleaner-burning engines and fuel sources are expected to reduce emissions. It is anticipated that there will be a continued reduction in ozone due to controls imposed by the Texas SIP requirements. The planning and implementation of these SIP requirements incorporate the effects of population and industrial growth, technology changes, and national or statewide control measures. Therefore, it is expected that the HGB will be in attainment with the NAAQS for all criteria pollutants by the year 2019.

4.5.2 GRP Alternative

The evaluation of air quality impacts associated with the GRP Alternative was based on the identification of expected air contaminants and estimated emission rates for this project alternative. The emission sources evaluated include land-based mobile sources that would be used during construction activities, including off-road earth-moving equipment, on-road construction equipment, and support vehicles. Air contaminant emissions associated with this equipment would be primarily combustion products from fuel burned in the engines powering this equipment. In addition, the movement or disturbance of soil and other construction materials would result in emissions of particulate matter to the air. It is expected that the off-road earth-moving equipment would use primarily diesel-powered engines; the on-road equipment would be a mixture of gasoline and diesel-powered engines.

4.5.2.1 Air Quality Analysis Results

Emissions from the construction-related activities associated with the GRP Alternative would include VOC, NO_x, CO, SO_X, PM_{10}, and $PM_{2.5}$. Air emissions would result from construction activities, including excavation, grading, and placement of fill material, as well as from vehicular traffic associated with on-road construction equipment, and support vehicles. It is expected that this alternative would result in an increase in direct and indirect emissions to the HGB Nonattainment Area during the construction period. However, the construction activities associated with this alternative would be considered one-time activities, i.e., the creek improvement activities would not continue past the date of completion, thus they are considered short-term impacts.

A summary of the total estimated emissions in tons resulting from the use of excavation equipment, nonroad equipment, and on-road equipment for the GRP Alternative is presented in Table 4.5-1. A detailed summary of emissions can be found in the reference document (Appendix H).

For a discussion of air quality impacts, the total air contaminant emissions from the GRP Alternative were compared to the 2002 emissions inventory for the HGB Nonattainment Area. The comparison is presented in Table 4.5-2.

As shown in Table 4.5-2, air contaminant emissions from the GRP Alternative would result in a relatively small increase in emissions above those from existing sources in the county and the HGB. As a result, it is expected that air contaminant emissions from the combustion of fuel in equipment used for construction and placement activities would also result in correspondingly minor short-term impacts on air quality in the immediate vicinity of the project area and even less as emissions are dispersed over the HGB. Due to the anticipated short-term duration of the construction activities, there would be no long-term impacts, and therefore emissions from these activities are not expected to adversely impact the long-term air quality in the area.

Table 4.5-1
General Reevaluation Plan Alternative – Total Estimated
Project Emissions of Construction Activity in Tons per Year

	2012	2013	2014	2015	2016	2017	2018
NO_x	6.05	22.41	42.16	52.44	31.59	28.78	15.28
VOC	0.56	2.05	3.36	4.46	2.62	2.49	1.36
PM_{10}	0.55	2.05	3.73	4.67	2.82	2.56	1.34
$PM_{2.5}$	0.53	1.98	3.62	4.52	2.73	2.48	1.30
CO	5.61	16.18	18.86	28.04	15.36	14.85	8.14
SO_2	1.33	4.94	9.40	11.66	6.97	6.30	3.34

Note: Project construction is expected to be completed over a period of approximately 7 years.

Table 4.5-2
General Reevaluation Plan Alternative – Peak Annual Estimated Project Emissions
Compared with HGB Emissions (2002)
(tpy)

	NO_X	VOC	PM_{10}	$PM_{2.5}$	CO	SO_2
GRP Alternative	52.44	4.46	4.67	4.52	28.04	11.66
HGB	357,353	214,128	325,353	59,155	1,101,693	152,017
% HGB	0.01	0.002	0.001	0.01	0.003	0.01

Air contaminant emissions would also result from activities related to periodic maintenance of the Clear Creek conveyance and detention system. The emission sources during maintenance may include off-road earth-moving equipment, on-road construction equipment, and supply vehicles. Air contaminant emissions associated with this equipment would be primarily combustion products from fuel burned in the engines powering this equipment. In addition, the movement or disturbance of soil and other construction materials would result in emissions of particulate matter to the air. These activities associated with maintenance activities would be conducted on a periodic basis, and therefore would result in periodic short-term impacts of relatively short duration at different locations along the drainage system. An estimate of air contaminant emissions for the expected maintenance activities was not conducted at this time due to the lack of detailed information with regard to project equipment and schedule for use.

4.5.2.2 General Conformity

All Federal actions are subject to general conformity unless it meets an exemption specifically provided for in the general conformity rules or if the project emissions are below the general conformity thresholds. In terms of these thresholds, a General Conformity Determination would be required for each year when emissions of either NO_x or VOC exceed 25 tpy.

For comparison with the thresholds defined in the General Conformity Rule, the estimated emissions of NO_x or VOC for the GRP Alternative are summarized in Table 4.5-1 for each year during which the project activities are anticipated to occur. Emissions of CO, SO_2, and particulate matter are not considered in the General Conformity evaluation, as the HGB is in attainment with the NAAQS for those pollutants.

As shown in Table 4.5-1, emissions of VOC for project-related activities are exempt from a General Conformity Determination because they are below the 25 tpy threshold. NO_x emissions for project construction activities show the project would exceed the conformity threshold (i.e., greater than 25 tpy) for the years 2014, 2015, 2016, and 2017. Therefore, a General Conformity Determination for NO_x emissions would be required for these years.

As part of the General Conformity process, the USACE has prepared a Draft General Conformity Determination document discussing whether emissions of NO_x that would result from the GRP Alternative are in conformity with the Texas SIP for the HGB Nonattainment Area. This document (included as Appendix H) was noticed for public comment concurrently with the DEIS, and was submitted to the TCEQ, EPA, and other air pollution control agencies, as appropriate. Concurrence that the emissions are consistent with the SIP was provided by TCEQ via letter dated February 7, 2012 (Appendix H). Coordination with the EPA and TCEQ will continue until consensus is reached that project emissions are consistent with the most currently approved SIP emissions budgets, taking into account any potential changes to the project schedule.

To additionally reduce potential air quality impacts, the USACE will encourage or direct contractors to 1) apply for several grants, including Texas Emission Reduction Plan grants, the EPA's Voluntary Diesel Retrofit Program, or the EPA's Diesel Emission Reduction Plan (offering the opportunity to apply for resources for upgrading or replacing older equipment to reduce NO_x emissions); 2) use cleaner, newer equipment with lower NO_x emissions; and 3) use clean, low-sulfur fuels.

4.5.2.3 Greenhouse Gas Emissions and Climate Change

Greenhouse gas (GHG) emissions from the GRP Alternative will result from construction activities, including excavation, grading, and placement of fill material, as well as from vehicular traffic associated with on-road construction equipment and support vehicles. Emissions from this equipment will result in an increase in GHG emissions that could contribute to global climate change. To date, specific thresholds to evaluate adverse impacts pertaining to GHG emissions have not been established by local decision-making agencies, the State, or the Federal government. The CEQ has published a "Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions," February 10, 2010. The Draft Guidance suggests that the impacts of projects directly emitting GHGs in excess of 22,676 tons or more of carbon dioxide equivalent (CO_2e) emissions on an annual basis be considered in a qualitative and quantitative manner. However, the guidance stresses that, given the nature of GHGs and their persistence in the atmosphere, climate change impacts should be considered on a cumulative level. Appendix N presents a project-level analysis of GHG emissions.

4.5.2.3.1 Quantification of GHG Emissions

An inventory of GHG emissions was prepared for construction activities based on the project schedule and other assumptions as shown in Appendix N. GHG emissions were estimated for emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxides (N_2O), and as CO_2e, which are GHGs that may result from the combustion of fuel. GHG emissions were estimated each year that construction is expected to occur.

4.5.2.3.2 Summary of GHG Emissions

The estimated annual GHG emissions for the GRP Alternative are summarized in Table 4.5-3 for each year of anticipated construction activities.

Table 4.5-3
Summary of GHG Emissions, GRP Alternative
(tons per year)

	2012	2013	2014	2015	2016	2017	2018
CO_2	951	3,536	6,689	8,351	4,994	4,516	2,393
CH_4	0.07	0.26	0.49	0.61	0.36	0.33	0.17
N_2O	0.02	0.09	0.17	0.21	0.13	0.12	0.06
CO_2e	960	3,570	6,752	8,430	5,041	4,559	2,415

4.5.2.3.3 GHG Emissions Contribution to Climate Change

As described above, the GRP Alternative would increase GHG emissions. However, it would be unlikely that GHGs emitted would have an individually discernible impact on global climate change. GHG emissions accumulate in the atmosphere because of their relatively long lifespan. Consequently, their impact on climate change is independent of the point of emission. Because GHGs accumulate in the atmosphere and affect climate change on a global scale, it is not practical to predict the impact on climate change based on a project level evaluation; this analysis is more practically done on a regional or global scale.

4.5.3 Dust Control

Construction sites can generate large areas of soil disturbance and open space for wind to pick up dust particles. Dust from construction activities can result from surface clearance, excavation, grading, storage, placement, and transportation. Proper management practices for dust control reduce or prevent wind erosion by protecting and roughening the soil surface and reducing the surface wind velocity.

Specific BMPs for dust control include the following list provided by the TCEQ and the EPA (TCEQ, 2012; EPA, 2012). To maximize water conservation, the TCEQ recommends that water-intensive dust-control practices, such as sprinkling or irrigation, should be used as a last resort.

Vegetative Cover. In areas that are completed, outside the active construction site, or not expected to handle vehicle traffic, vegetative stabilization of disturbed soil is often desirable. Vegetative cover over surface soils slows wind velocity at the ground surface, reducing the potential for dust to become airborne. Vegetation for this use should be native or adapted and needs no irrigation, fertilizer, or excessive mowing.

Mulch. Mulching can be a quick and effective means of dust control for a recently disturbed area. Mobile mulching may be performed on the site from cleared overburden materials. When rainfall is insufficient to establish vegetative cover, mulching is an effective way of conserving moisture, preventing surface crusting, reducing runoff and erosion, and helping to establish vegetation. It is a critical treatment on sites with erosive slopes.

Wind Breaks. Wind breaks are barriers (either natural or constructed) that reduce wind velocity through a site and, therefore, reduce the possibility of suspended particles. Wind breaks can be trees or shrubs left in place during site clearance or artificial barriers such as wind fences, tarp curtains, hay bales, crate walls, or sediment walls.

Stone. Stone can be an effective dust deterrent for unpaved haul roads and entrances or in areas where vegetation cannot be established.

Tarping. Trucks exiting the site should be tarped to minimize dust.

Speed Limit. Posted speeds of 10–15 mph for unpaved haul roads should be enforced to minimize dust.

Construction Scheduling. Staging or work sequencing techniques could be established so as to minimize the risk of wind erosion from exposure of large areas of bare soil for extended periods of time. Construction sequencing and disturbing only small areas at a time can greatly reduce problematic dust from a site.

Dust Suppression. Commercially available dust suppressors are useful if applied in accordance with the manufacturer's recommendations. The use of a chemical dust suppressant should consider whether it is biodegradable or water-soluble and what effect its application could have on the surrounding environment, including water bodies and wildlife.

Sprinkling (Irrigation). Sprinkling the ground surface with water until it is moist is an effective dust-control method for unpaved haul roads and exposed surface areas.

The application of dust suppressants or sprinkling should be done daily and whenever fugitive dust is observed to control emissions. Follow-up observations should be performed to ensure the effectiveness of these dust control measures.

4.6 NOISE

Project-related noise impacts were evaluated by calculating the worst-case noise levels related to the proposed flood risk management project at noise-sensitive receptors. Worst-case conditions were considered to occur when various pieces of earth-moving or construction equipment would be operating simultaneously in one specific location. Table 4.6-1 presents construction equipment noise levels measured at a distance of 50 feet. Worst-case noise levels were then calculated at increasing distances from the center of construction activity. However, actual noise levels related to the project would likely be less than calculated worst-case conditions, because it is unlikely that each piece of construction equipment listed in Table 4.6-1 would actually be operating simultaneously in one location. It is more likely that this scenario would occur infrequently and that the norm would not produce noise levels of this intensity. Furthermore, project noise levels would fluctuate as equipment is maneuvered within the corridor.

Table 4.6-1
Typical Noise Levels of Construction Equipment

Equipment (at 50 feet)	Noise Level (dBA)
Backhoe	78
Chain Saw	84
Dump Truck	79
Excavator	81
Bulldozer	82
Front End Loader	79

Source: U.S. Department of Transportation (2006).

Noise attenuation between project activities and sensitive receptors was calculated based on the assumption that noise attenuates 6 dBA per doubling distance from its source. For example, if a dump truck is measured at 79 dBA at 50 feet, this noise level would decrease 6 to 73 dBA at 100 feet, decrease an additional 6 to 67 dBA at 200 feet, and decrease to 61 dBA at 400 feet, etc.

4.6.1 No Action Alternative

Under the No Action Alternative, flood conveyance and features associated with the proposed project would not be constructed. Therefore, any potential impacts from noise related to the proposed action would not occur. Land uses adjacent to Clear Creek would likely continue to be utilized for residential, commercial, recreational, and transportation purposes. Any future development would increase ambient noise levels in the area. It is likely that the ambient noise environment would continue to increase slightly as population densities and the volume of traffic continue to increase within the general vicinity.

Additionally, temporary and short-term noise level increases similar to those of the GRP Alternative would occur in the study area as vacant tracts of land are excavated and converted to residential, commercial, or industrial uses. Most developments, particularly those located within the Clear Creek floodplain, require on-site detention. Therefore, any development within the study area would likely require the construction equipment listed in Table 4.6-1 during excavation, grading, and leveling phases of construction. Worst-case noise levels related to development within the study area were calculated by combining the noise levels of equipment presented above in Table 4.6-1. The calculated worst-case noise levels were then adjusted to allow for distance attenuation. The estimated worst-case noise levels related to development construction activities within the study area are listed below in Table 4.6-2.

Table 4.6-2
Estimated Worst-case Construction Activity Noise Levels

Distance From Source	Estimated Noise Level (dBA)
50 feet	89
100 feet	83
200 feet	77
400 feet	71
800 feet	65
1,600 feet	59
2,640 feet (½ mile)	53

4.6.2 GRP Alternative

Construction of the GRP Alternative is not expected to result in long-term noise impacts, as no permanent noise sources would be installed as part of this project. Construction activities related to the GRP Alternative, however, would result in temporary noise level increases at noise-sensitive receptors that would be nearly identical to noise levels associated with construction activities described in the No Action Alternative (Section 4.6-1). Equipment used and duration of construction for the proposed action would vary for different activities occurring at stream channel reaches, detention ponds, and placement areas. Worst-case noise levels under the GRP Alternative were calculated by combining the noise levels of equipment presented in Table 4.6-1. The calculated worst-case noise level was then adjusted to allow for distance attenuation. Table 4.6-3 lists the estimated worst-case noise levels at sensitive receptors as distance increases from project activities. Assuming worst-case conditions, noise levels could range between 89 dBA and 77 dBA at noise-sensitive receptors located within 200 feet of the center of proposed project activities. Noise levels would decrease to more-acceptable decibels beyond 400 feet, where the majority of noise-sensitive receptors are located. Depending on surrounding land uses and features, noise related to project activities beyond 400 feet would not be differentiated from ambient conditions.

The estimated noise levels presented in Table 4.6-3 do not take into account noise-reducing devices such as mufflers, or shielding factors related to obstructions such as barriers, topography, or buildings. Proper muffling devices can reduce sound levels by a range of 1 dBA to 3 dBA. Shielding provided by surrounding topography and buildings can reduce sound levels by approximately 3 dBA to 5 dBA (U.S. Department of Transportation, 2006). Thus, project noise levels would likely be less than the levels presented in tables 4.6-2 and 4.6-3, which assume the worst-case scenario without any shielding. Noise levels would be higher at receptors immediately adjacent to construction activities compared to those shielded by other structures. Regardless, the increase in noise levels would likely result in temporary annoyance at nearby receptors. Increases to ambient noise levels in the proximity of Beltway 8 (BW 8), SH 288, I-45, and other major highways would generally be more tolerable as compared to noise level increases in more-isolated locations. Construction equipment would be operated on an as-needed basis and restricted to daytime hours to assist in reducing noise annoyance. Directional drilling will be utilized to relocate 22 pipelines to a greater depth in their existing location, which will contribute to the noise level; however, to reduce annoyance, construction would be limited to daytime hours.

Table 4.6-3
Estimated Worst-case Project Noise Levels and Gross Estimate of
Noise-Sensitive Receptors within ½ Mile of Project Footprint

Distance From Source	Estimated Noise Level (dBA)	Gross Estimate of Noise-Sensitive Receptors				
		Residential	Religious	Educational	Recreational	Medical
50 feet	89	5	1	0	7	1
100 feet	83	35	0	0	0	1
200 feet	77	350	0	2	0	1
400 feet	71	575	0	0	0	0
800 feet	65	450	0	2	0	0
1,600 feet	59	1,425	0	2	1	0
2,640 feet (½ mile)	53	1,400	2	10	2	0

Noise levels associated with maintenance of the sites would generally be less than those associated with construction of the GRP Alternative, would be more periodic, and would be of shorter duration as described in Section 3.6.

4.7 SOILS, INCLUDING PRIME AND UNIQUE FARMLANDS

4.7.1 No Action Alternative

Loss of prime farmland from the No Action Alternative would occur primarily from commercial and/or residential development, which would continue according to expected trends (Section 4.14). Because no flood risk management measures would be put in place, conditions would continue as in the past. Major flood events would continue to increase erosion rates of soils and prime farmlands within the study area. Thus, areas currently classified as prime farmland soils are likely to erode and be unavailable for agricultural use. Additionally, due to the high rate of development within the study area, it is likely that areas classified as prime farmland soils and currently being used for agriculture will be developed and made unavailable for such uses over the 50-year life of the project.

4.7.2 GRP Alternative

To assess the potential for prime farmland soils located within the project area to be impacted by the GRP Alternative, a Form AD-1006 was submitted to NRCS for completion, review, and response (Appendix D-3).

A review of information available online indicated that the only project feature located in areas considered prime farmland soils is the 31-acre mitigation site C1. This feature would be ecologically reestablished/rehabilitated for floodplain forest community and protected from future development. The remaining project footprint occurs in areas identified by NRCS as Urban (NRCS, 2008), which is exempt from the Farmland Protection Policy Act (FPPA).

According to FPPA Rule 401.24, Section 658.4, if an area being evaluated receives a total rating of more than 160 points, it will receive higher levels of consideration for protection and additional alternatives must be evaluated. Areas considered primeland soils that would be impacted by mitigation site C1 received a rating of 12 by the NRCS. This score is well below this threshold. Even so, the USACE conducted an extensive evaluation of potential flood risk management measures (see Section 2) to identify the GRP Alternative, and because the project features occur in an urbanized area that comprises commercial, industrial, and residential development, the FPPA criteria for a higher level of consideration have been satisfied.

The FPPA regulations also recommend consideration be given to "the total amount of farmable land (the land in the unit of local government's jurisdiction that is capable of producing the commonly grown crop); the percentage of the jurisdiction that is farmland covered by the act; the percentage of farmland in the jurisdiction that the project would convert; and the percentage of farmland in the local government's jurisdiction with the same or higher relative value than the land that the project would convert" (7 CFR 658.4(b)). The prime farmland soils affected by the proposed project (approximately 31 acres) make up a very small percentage (0.01 percent) of the total prime farmland available in the study area (111,252 acres).

The implementation of the GRP Alternative may halt agricultural production in portions of the subject properties that are currently being utilized and make other portions unavailable for future crop production. According to land cover types used in the HEP analysis (see Figure 5.3-1a–c), there are approximately 0.16 acre of land used for agricultural purposes that would be impacted by the project. However, loss of prime farmland soils is also expected to occur under the No Action Alternative due to soil erosion. Additionally, this change is not expected to have an adverse affect on production of agricultural commodities in the area, nor is it expected to impact the local economy or food needs/supplies. Additionally, it is likely that agriculture production may halt, to some extent, under the No Action.

4.8 CONTAMINANTS

4.8.1 Hazardous, Toxic, and Radioactive Waste

4.8.1.1 No Action Alternative

There would be no change in impact from the No Action Alternative on hazardous material sites. However, flood risk management measures would not be implemented within the Clear Creek watershed, and periodic flooding would be expected to continue.

4.8.1.2 GRP Alternative

Historical industrial activity situated along Clear Creek and its tributaries has resulted in quantifiable impacts to the air, soil, groundwater, and surface water. Clear Creek and/or its tributaries receive surface water runoff, wastewater discharge, and some groundwater discharge from these industrial facilities. Contaminants from these sources can accumulate in the sediments of these waterways, and therefore a potential exists for the project to encounter affected or impacted material during construction activities. Sections 3.2 and 3.3 provide additional information regarding surface water and sediment quality. Similarly, construction of the project may reduce the potential for the sites adjacent to Clear Creek and its tributaries to be impacted during major flood events.

The sites reported in the regulatory agency database review were evaluated to determine the potential for the sites to impact the project features and for project features to impact HTRW sites. The evaluation was based on proximity of the site to the project feature, the relative potential for a release at the site, and the nature of the potential release. This evaluation resulted in identifying a total of three separate sites within or immediately adjacent to the project features. A table summarizing the results of the HTRW database review is included in Appendix C-1. Maps showing approximate locations of HTRW sites located within or adjacent to the project feature areas are also included in Appendix C-1. Based on the evaluation, Table 4.8-1 lists sites that have potential impacts to the project features.

Table 4.8-1
Identified HTRW Sites with Potential Impacts to Project Features

Map ID	Databases	Site Name	EPA ID No.	Address
4	CERCLIS, NPL, SSF	Brio Refining, Inc.	TXD980625453	2501 Dixie Farm Rd. Friendswood, TX 77089
1	CERCLIS, NPL, SSF	Dixie Oil Processors, Inc.	TXD089793046	2505 Choate Rd. Friendswood, TX 77546
79	Texas Spills Incident Information System	Texaco	NA	Corner of Scarsdale Blvd. and Beamer Rd., Houston, TX

The HTRW assessment revealed potential concerns associated with past industrial activity at two facilities and one spill site: Brio Refinery, Dixie Oil Processors, and one spill site at the corner of Scarsdale Boulevard and Beamer Road.

Brio Refinery and Dixie Oil Processors are listed in the regulatory agency database as NPL, CERCLIS, and SSF. Additional research reveals that both facilities were deleted from the NPL list in 2006, but for this evaluation both sites are identified as NPL sites. These sites are located immediately east of Mud Gully, a tributary of Clear Creek. Prior activity at these facilities has caused quantifiable impacts to groundwater located adjacent to these waterways. Additionally, the seepage of affected groundwater into Mud Gully has resulted in measurable impacts to surface water and sediments of Mud Gully and Clear Creek (sections 3.2 and 3.3). However, the potential discharge of affected groundwater has in fact been contained through corrective action by the responsible parties and the TCEQ. Subsequently, the concentrations of pollutants in the waters and sediment of Mud Gully and Clear Creek have decreased significantly.

Previous investigations at these sites performed on behalf of the TDSHS, TCEQ, BSTF, and EPA Region 6 have determined that the constituents of concern (COC) include metals, VOCs, semivolatile compounds (specifically PAHs), limited pesticides, and PCBs. An examination of data from these investigations indicates that the presence of select COC was identified in highest concentrations from sediment and water samples collected from Mud Gully adjacent to the Brio and Dixie Oil Processors sites. The compounds were found in lower concentrations in sediment and water samples collected from Clear Creek. Recent studies have determined that concentrations of these COC have decreased significantly in Mud Gully and Clear Creek (PBS&J, 1998). Remedial action at both sites involved the construction of a soil cap over the residual waste, significantly reducing the potential for direct contact. Construction of the project would further reduce the potential impact to the sites during major flood events. There is a limited potential for these facilities to impact project features.

The remaining site is not actually a facility, but rather the location of a reported accidental release that occurred within the upper portion of Mud Gully. In November 1986, a spill of approximately 20,000 gallons of unleaded gasoline reportedly occurred at the corner of Scarsdale Boulevard and Beamer Road. This spill site is identified as Texaco, and its cleanup status is reportedly unknown. The database did not indicate the nature of the release, but the spill apparently occurred on the ground surface and entered into Mud Gully. Due to the extended period of time since the release (21 years) and the biodegradation of gasoline, the lasting impact to the sediment of Mud Gully is limited. However, material to be excavated from this affected segment of Mud Gully may contain detectable levels of COC associated with gasoline. Therefore, sediment characterization will be necessary prior to excavation and placement of excavated material.

4.8.2 Oil and Gas Production Transmission

4.8.2.1 No Action Alternative

Under the No Action Alternative there would be no changes to current oil and gas production facilities.

4.8.2.2 GRP Alternative

A total of four permitted oil and gas well sites are located within the footprint of the proposed project features, and would be potentially impacted. These well sites include one active well. According to the TRC database, one is listed as an active producing oil/gas well, one as plugged, one as a dry hole, and one as a permitted location. A table with well information and a map showing well locations within project feature areas is included in Appendix C-2.

The majority of the well sites are located within the boundaries of proposed placement areas identified for the purposes of project economic/cost estimating. If placement areas are sited in these locations, wells may require modifications, relocation, or abandonment.

Approximately 26 petroleum pipelines are located within the project area and would be potentially impacted. The TRC files indicate that 21 pipeline systems are listed as active and 5 are listed as abandoned. A table with pipeline information and a map showing pipelines within the project area is included in Appendix C-2. There are 13 pipelines that transport natural gas, 4 that transport crude oil, 2 liquid natural gas pipelines, 4 that transport propylene, 2 that transport ethylene, and 1 that transports refined product.

The USACE has identified 22 pipelines within Clear Creek, Mary's Creek, Turkey Creek, and Mud Gully requiring relocation based on data from the Bathymetric Engineering and Management System (BEAMS) database (Appendix C-2). For evaluation purposes, it is assumed that these 22 pipelines would be relocated within their current alignments but at a greater depth.

Although no field verification of these pipelines has been performed, the BEAMS data appear to be consistent with the TRC data on pipelines compiled for this HTRW assessment, and the TRC pipeline database is reported to be the most comprehensive account of pipelines in the State of Texas. Prior to construction activities, an extensive pipeline survey would be performed.

4.9 VEGETATION

4.9.1 Methodology

As described in Section 3.9.5, ecological impacts of the No Action Alternative and the GRP Alternative were determined using an ecological model (Burks-Copes and Webb, 2010b). An ICT (E-Team), in collaboration with ERDC, developed a community-based HSI model, based on the HEP (USFWS, 1980a) (see Appendix B). The assessment of baseline, without-project (No Action), and with-project (GRP Alternative) conditions with the community model required that basic land cover categories (described in Section 3.9), including agricultural fields, floodplain forest, open water, coastal prairie, pastureland, urban areas, and tidal marsh, be defined.

In this analysis, a suitability index referred to as an HSI was mathematically derived to reflect a vegetative community's sensitivity to various measures of ecological structure and function. For example, the floodplain forest community HSI was based on 18 habitat variables including hydroperiod, wetland area, vegetation substrate composition, patch size, and adjacent land use. Suitability index values were scaled from 0 to 1 based on their comparison to the same habitat variables in a reference community. A floodplain forest with all its habitat variables comparable in value to a reference floodplain forest community would have an HSI near 1. Conversely, a floodplain forest with many of its habitat characteristics degraded when compared to those in a reference forest would have an HSI near 0.

Once the HSI was calculated for a vegetative community, the community's habitat value can be quantified for the area covered by that community. The HSI value for a community was multiplied by the area in acres of that community to determine HUs. For example, a 10-acre floodplain forest with an HSI of 0.8 would be equivalent to 8 HUs (0.8 HSI times 10 acres). Calculation of HUs helps compare communities with very different ecological structure and function.

In addition to quantifying habitat by area calculating HUs, changes in the quantity of habitat over time were also calculated. Since habitat quantity and quality are projected to change with or without the project, it is important to be able to quantify these changes over the project life. HUs are annualized by dividing the number of HUs by the number of years since the project was initiated (see Appendix B for more detail). The results of this analysis are expressed as "Average Annual Habitat Units" (AAHUs). Calculation of AAHUs helps agencies analyze ecosystem impacts and restoration needs in ways that can be directly compared to traditional benefit to cost analyses.

The GRP Alternative avoids impacts to coastal prairies or tidal marshes. Consequently, this section focuses on impacts to floodplain forests. Results of the model application to the calculation of HSIs for each eco-reach, for the baseline condition and future without-project condition, are illustrated in Table 4.9-1.

Table 4.9-1
Habitat Suitability Indices for Clear Creek Eco-Reaches,
Baseline and Future Without-Project Condition

	Habitat Suitability Index	
Eco-Reach	Baseline Condition	Future Without-Project
1	0.67	0.49
2	0.84	0.61
3	0.47	0.35
4	0.74	0.61
5	0.62	0.52
6	0.56	0.47
7	0.48	0.37

Burks-Copes and Webb (2010b).

4.9.2 No Action Alternative

4.9.2.1 HSI Model Results

Future projected land use conversion (i.e., urbanization) was based on past and projected trends in population and developed area within the Clear Creek watershed. Estimates of urbanization (or population to developed area ratio) within discrete subbasins of the Clear Creek watershed were made using percent developed area determined from aerial photographs and existing census tract population data from 1980 to 2000. These calculations were then used along with future population projections for 2020 through 2070 to determine future urbanization trends and projected land use conversion. The combined population for Pearland and Friendswood in the Clear Creek watershed is projected to increase from 56,600 in 2010 to 165,000 in 2050, a population increase of almost 300 percent (see Appendix B, Table 12). Population growth will increase urban land use by 9,600 acres from 2000 to 2070 in the Clear Creek 500-year floodplain as natural vegetative communities, including floodplain forest, coastal prairie and other land uses are converted to urban use.

The No Action Alternative assumes the current configuration of Clear Creek and its tributaries would be maintained. As a consequence of increased urbanization, the quantity and quality of the remaining natural vegetation communities would decline. Peak flows resulting from rainfall events and water elevations would increase resulting in increased flooding and reduced base flow. Impervious cover would increase, reducing available land for native habitat and infiltration of runoff. With a reduction of native riparian vegetation accompanied by increased fragmentation and reduced patch size, the abundance and diversity of wildlife species dependent on these habitats would decline. Water quality (dissolved oxygen, turbidity, and salinity) would degrade as a result of reduced pollutant filtration provided by the floodplain forests. In some cases, stream buffer vegetation would be completely removed. Water temperatures would likely increase because of reduced shading of the creek and its tributaries. Noxious and/or exotic species would proliferate rapidly into homogenous stands of undesirable vegetation on disturbed land that would restrict colonization by native vegetation.

Increased flooding and reduced riparian vegetation would increase shoreline erosion and cause additional loss of (or at least changes in the location of) riparian vegetation. Shoreline armoring would probably be done to control erosion, further reducing habitat available to floodplain forest vegetation and aquatic organisms. Wetlands in the 100-year floodplain that are farther from the creeks may experience more-frequent inundation, which could change plant communities within those low areas. Jurisdictional and nonjurisdictional wetlands would also be impacted as a result of continued urban development.

Native scrub-shrub plants may be removed and nonnative grasses and ornamentals planted in their place as residential development expands. Riparian buffers and remaining floodplain forest will be fragmented into smaller patches, with less core area, more edge, and greater distances between patches. In an effort to capture the significant changes in floodplain forest within the 500-year floodplain, the E-Team developed a table to project quality changes in the model's variables on a target year basis for each eco-reach (see Appendix B, tables 10–15).

The community-based HSI model provided baseline data for the year 2000 in order to predict potential impacts of the proposed alternatives including the No Action Alternative. The acreage values for floodplain forests for baseline (year 2000) and future without project (year 2070), as predicted by the community-based HSI model, are shown in Table 4.9-2. Floodplain forests cover an estimated 3,802 acres in the 500-year floodplain, and this area is projected to drop to 2,150 acres by 2070, a loss of 1,652 acres of floodplain forest. Acreage of floodplain forest by Eco-Reach may be found in Section 3.9. The reduction in ecological functionality represented by this loss of floodplain forest is represented by a reduction of 1,515 HUs, or about 57 percent of the target year 2000 HU (Table 4.9-3).

Table 4.9-1 shows that habitat suitability of floodplain forests as determined by the community-based HSI model is forecast to decline in each of the Eco-Reaches with the No Action Alternative with the greatest declines, 0.84 to 0.61, in ER 2. ER 2 currently has more area of floodplain forest, 1,095 acres, than any other eco-reach. Much of the reduction in ecological functionality of floodplain forests in ER 2 is projected to result from increased impervious cover, reduced and degraded wetland area, instream cover, native vegetation, overhanging stream

Table 4.9-2
Baseline and Future Without Project (No Action Alternative)
Acres of Community-based HSI Community Type

Year	Floodplain Forest
2000	3,802
2020	3,326
2030	3,092
2055	2,503
2070	2,150
Total Loss	–1,652

Table 4.9-3
Predicted Vegetation Community Functionality Loss by 2070 Under the No Action Alternative

Community	Baseline Habitat Units	2070 Habitat Units	Net Change in Habitat Units	Percent Loss of Habitat Units	AAHUs
Floodplain Forest	2,673	1,158	–1,515	57	1,646

cover, and reduction in structural integrity variables like total core area, total edge area, and patch size. Declines in these factors indicate floodplain forest in ER 2 will decline from very high ecological functionality down to fair ecological functionality.

The model predicts that ERs 3 and 7 will decline from moderate to fair ecological functionality. ERs 5 and 6 decline from moderately high to moderate ecological functionality, and ER 4 is predicted to remain at high ecological functionality. ER 4, with 1,053 acres of floodplain forest, has the second-greatest area covered with floodplain forest of the eco-reaches. Throughout all the eco-reaches, declines in variables associated with spatial integrity and disturbance of the habitat had the greatest effect on reduced HSI values.

4.9.2.2 Waters and Wetlands

The GRP Alternative footprint includes the mitigation areas, conveyance areas, and protected riparian habitat corridors. To estimate potential impacts to major water features and wetlands within the project footprint, interpretation of wetland coverage was performed using aerial photography. The aerial interpretation process included a review of NWI data within the project footprint, compared to 2004 infrared aerial imagery and 2000 and 2009 true color imagery, supplemented with limited field verification. Most man-made drainage ditches, detention features, and some man-made ponds were not included in potential impacts.

Under the No Action Alternative, wetlands within the floodplain of Clear Creek and its tributaries would continue to be impacted by urban development and erosion from flood events. Thus, continued degradation of these resources is likely. Within the project footprint, approximately 41.5 acres of emergent, forested, and scrub-shrub wetlands occur. Existing wetlands occurring within the project footprint are presented in Table 4.9.4

Table 4.9-4
Wetlands Occurring within the Project Footprint

Waterbody Type	Existing Wetlands (acres)
Emergent Wetland	11.2
Forested Wetland	26.7
Scrub-shrub Wetland	3.6
Total:	41.5

4.9.3 GRP Alternative

4.9.3.1 HSI Model Results

According to the results of the community-based HSI Model analysis (Table 4.9-5), approximately 278 acres of floodplain forest would be directly impacted by construction of project features associated with the GRP Alternative. There would be no impacts to coastal prairies associated with the construction of project features since the detention features that were proposed at one time are no longer part of the GRP Alternative. No losses or impacts of tidal marsh (including SAV) or coastal prairie are anticipated.

Table 4.9-5
Impacts to HSI Habitat Types from the General Reevaluation Plan Alternative
Including Mitigation

	Flood Risk Management Features			Compensatory Mitigation (Vegetation Community Reestablishment and Rehabilitation)		
	Acres					
Vegetation Community*	Unavoidable Impacts	Design Features Providing On-site Preservation/ Creation of Vegetation Community (Avoidance/Minimization)	Net AAHUs	Acres	AAHUs	Net Overall AAHUs
Floodplain Forest	278	155	–106	31	131	25

*Coastal Prairie and Tidal Marsh communities are not expected to be impacted by the GRP Alternative and thus were not assessed in the HSI Modeling.

Design elements of the GRP Alternative aimed to avoid and minimize impacts to habitat include in some cases rehabilitating 155 acres of floodplain forest along the low-flow channel. Proposed compensatory mitigation includes the restoration (rehabilitation and reestablishment) of 31 acres of floodplain forest through reconnecting low flow and meanders within remnant oxbows, soilbank removal, and plantings. Proposed mitigation is described in detail in Section 5.0. Preservation measures incorporated into avoidance and minimization features of the GRP are described in Section 2.5.

The project footprint affects floodplain forest in ERs 4, 5, and 6, with most of the permanent impacts occurring in ERs 4 and 6. The project features combined with expected urban growth are expected to constrict core forest areas and increase overall forest edge. Forest patches would decrease in size, and distance between patches would increase. Increased edge may make remaining forest more susceptible to disease, invasion by exotics, and loss of native species.

As seen in Table 4.9-5, the predicted floodplain forest community change in functionality under the GRP Alternative is expected to be a net loss of 106 AAHUs, despite the avoidance and minimization features built into the project. Mitigation efforts are intended to compensate for unavoidable losses by providing 131 AAHUs (+25 AAHUs in excess of impacts).

The proposed project footprint is an area crossed by 26 pipelines, 22 of which would need to be relocated. The pipelines would be reburied using directional drilling, if necessary, along their current routes and would not need to be rerouted outside the project area. Environmental effects would be primarily restricted to the areas used for the directional drilling or to the current pipeline crossings and would be expected to be minimal in space and time on the existing vegetative communities.

4.9.3.2 Waters and Wetlands

As described in subsection 3.9.4, NWI data were utilized to determine the areas of wetlands within the study area; however, to estimate potential impacts within the project footprint, aerial interpretation of wetlands was also performed. Aerial interpretation process included a review of NWI data within the project footprint, compared to 2004 infrared aerial imagery, and 2000 and 2009 true color imagery, then supplemented with limited field verification. Although the study area includes a variety of wetlands and deep-water habitats (including marine and estuarine areas), only freshwater emergent, scrub-shrub and forested wetland communities would be potentially affected by the project (Table 4.9-4 and Figure 3.9-2). It should also be noted that 60.0 acres of open water occur within the project footprint.

The GRP Alternative footprint includes the conveyance areas and protected riparian habitat corridors; however, potential permanent wetland impacts would only occur within high-flow flood bench areas. Although there are about 41.5 acres of freshwater emergent, scrub-shrub, and forested wetlands within the overall project footprint, there will be permanent impacts to

29.3 acres of these wetlands from bench cutting the high-flow flood bench (Table 4.9-6 and Figure 3.9-2). It should be noted that project objectives target avoidance and preservation of wetlands along the instream and stream bank corridor of the Clear Creek mainstem within the project footprint. Avoidance and minimization of wetland impacts within the project footprint would be accomplished through preservation and rehabilitation of the existing low-flow channel, including a 60-foot-wide corridor of adjacent riparian areas (which includes wetlands). Within the low-flow channel, at least a 2- to 4-foot-wide fringe offorested wetlands are expected to be reestablished along the ordinary high-water mark of Clear Creek, which would result in an additional 7.3–14.7 acres of reestablished wetlands.

Compensatory mitigation wetlands are included as a project component in addition to the avoided, rehabilitated, and reestablished wetlands. Specifically, 21.1 acres of forested wetlands would be hydrologically enhanced and preserved as additional mitigation (Figure 3.9-2). Several oxbows (or former channels cutoff from Clear Creek due to straightening and realignment of the main channel [e.g., near Country Club Drive and FM 518]) would be reconnected to low-flow channels to increase and restore sinuosity that occurred prior to channelization. Wetlands that may be permanently impacted, avoided, and restored by the GRP Alternative are displayed in Table 4.9-6 and in Figure 3.9-2.

Table 4.9-6
Wetlands That May be Impacted, Avoided, and Restored
(Rehabilitation or Reestablishment) by the GRP Alternative

Wetland Type	Existing Wetlands in Construction Footprint (acres)[1]	Potential Permanent Wetland Impacts (acres)	Wetlands Avoided (acres)	Restored acres (Rehabilitated/ Reestablished)	Compensatory Mitigation Wetlands (Acres Rehabilitated)	Sum of Wetlands Avoided, Restored, and Preserved (acres)
Emergent	11.2	2.9	8.3[2]	0.0	0.0	8.3
Forested	26.7	23.7	3.0	7.3[3]	21.1	31.4
Scrub-Shrub	3.6	2.7	0.9	0.0	0.0	0.9
Totals	41.5	29.3	12.2	7.3	21.1	40.6

[1] Does not include compensatory mitigation areas.

[2] A large emergent wetland within an existing HCFCD detention basin is assumed to be deeper than the proposed cut of the high-flow flood bench within the footprint of the linear detention feature. As such, the 4.8 acres of this wetland within the footprint would not likely be impacted and is included within the table as an avoided area.

[3] Within the low-flow corridor, project designs include an anticipated 2- to 4-foot-wide forested wetland fringe to establish along and adjacent to the ordinary high water mark of Clear Creek. The value presented in the tableis based on a conservative estimate of 2-foot width.

For the USACE to achieve "no net loss" of wetlands, the GRP Alternative would use a combination of preservation, avoidance, minimization, and restoration. Combining compensatory mitigation wetlands (21.1 acres), wetlands avoided (12.2 acres), and wetlands rehabilitated within the existing low-flow channels and adjacent riparian vegetation (7.3 acres of wetlands), 40.6 acres of wetland would be preserved, rehabilitated and/or reestablished within the project and compensatory mitigation area footprint. Preservation does not result in apparent wetland acreage gains; however, when compared to "without project" conditions 50 years into the future, acreage gains become more apparent. For example, preservation results in single perpetual land ownership (that will not be sold and converted) and habitat contiguousness results from continuous dedicated landuses (i.e., flood reduction). Additionally, all areas avoided, minimized, and preserved, would also undergo restoration (rehabilitation or reestablishment) of ecological functionality (e.g., removal of invasive vegetation, hydrological enhancement, habitat connectivity). Other project efforts to improve ecological functionality within the project corridor include planting 400 native trees per acre, non-maintenance of vegetation (with the exception invasive plant removal), and potential establishment of herbaceous wetlands within the 39-acre in-line detention feature. Forested wetlands cannot be established within the 39-acre detention to maintain balances of improved conveyance and volumes resulting from the project components (i.e., forested wetlands would slow flows upstream and disrupt project component functionality downstream, potentially resulting in localized flooding).

4.10 FISH AND WILDLIFE RESOURCES

4.10.1 No Action Alternative

4.10.1.1 Freshwater Resources

Fish and benthic macroinvertebrates have generally adapted to natural, episodic floods. Flood flows may benefit species by stimulating spawning, scouring soft sediments that may have accumulated on preferred habitat structures, and transporting habitat structures like large woody debris into the stream. However, flooding that is increased in frequency, magnitude, and velocity by urban development may negatively impact freshwater fish and benthic macroinvertebrates.

As urban areas develop, the proportion of impervious cover in those watersheds tends to increase. When floods are not controlled in these types of watersheds, rainfall runoff tends to enter the stream much more rapidly. Nonpoint-source pollutants on the land may be washed into the stream before there is adequate time for pollutants to be filtered from runoff by natural riparian vegetation. Flood flows may peak at higher velocities, which increase erosive forces on stream banks and bottoms, and significant bank erosion may occur, resulting in sedimentation in the stream. This erosion may eliminate preferred habitat by destroying undercut banks, washing away overhanging brush, and causing sediment beds to accumulate on top of hard-bottom structures. Unmanaged runoff may also result in reduced infiltration into the groundwater and resulting long-term contributions of shallow groundwater to the stream flow during dry periods. These cumulative impacts create more extremes in flow, higher flood flows, and lower base flows, which tend to reduce habitat availability and water quality for fish and benthic macroinvertebrates.

Under the No Action Alternative, the scenario described above may occur because no flood risk management measures would be implemented and episodic flooding would continue and may be expected to worsen if development and population growth continues in the watershed as expected. Thus, impacts to freshwater resources in the study area may be expected to worsen.

As a result, freshwater fish and benthic macroinvertebrate communities would probably experience reductions in species diversity and in the presence and numbers of sensitive species over time. These changes in the freshwater community will result primarily from habitat modifications that will occur if no action is taken to reduce the frequency and magnitude of runoff events. Habitat data collected during the sampling events, as noted in subsection 3.10.1 (TCEQ, 2007b, 2007c unpublished data), reflected the sensitivity of the stream habitat to increasing frequency and magnitude of flooding. The fish species, including four sunfish species, as seen in Table 3.10-1, which contributed to the high aquatic life use assessment, depend on the presence of adequate instream cover for food and protection and stable bottom habitat for reproduction. If increased flooding further reduces the area of stable bottom and instream cover, these species may be lost from the fish community.

Water quality conditions would also be expected to degrade over time if no action is taken. Projected increases in development will result in increased nonpoint-source pollution loading to the stream. The existing riparian buffer currently provides relatively little filtration of nonpoint-source pollution associated with rainfall runoff. It is possible the riparian zone may narrow even more in the future without protective action. This possible narrowing of the riparian zone would further reduce the pollution filtration capacity of the riparian zone.

In conclusion, without future action to reduce flooding impacts, habitat and water quality would be expected to degrade, impacting the fish and benthic macroinvertebrate communities' health in the watershed by reducing species diversity and eliminating the already uncommon occurrence of species sensitive to poor environmental conditions.

4.10.1.2 Marine Resources

Under the No Action Alternative, aquatic communities would remain as described in subsection 3.10.2. Approximately 148 of tidal marsh are expected to be lost over the next 50 years due to development and land use changes. No dredging or construction activities are currently taking place in Clear Lake, and therefore no additional stresses are placed on the system and the system would remain in its present condition (for more information on hydrology refer to the Hydrologic Analysis Appendix to the GRR). During flood events, the velocity of water entering Clear Lake and sediment loading into Clear Lake and Galveston Bay will continue as it is presently. Periodic flushing of freshwater in marine environments can be important for an estuary to function properly. Flushing removes pathogens and pollutants and maintains estuarine productivity because of sediments and nutrients carried by the water that are essential for a healthy estuary.

Sediments help sustain intertidal wetland habitats, and nutrients stimulate plant productivity (Nixon et al., 2004). However, it should be noted that flood events could also introduce higher concentrations of pollutants into Clear Lake and Galveston Bay. Overall, flushing can be a positive impact to estuarine environments.

4.10.1.3 Wildlife Resources

Under the No Action Alternative the existing channels and drainage system within the Clear Creek watershed will remain in place. Existing flooding in the Clear Creek watershed will not be reduced, and in fact, future flooding may increase due to increased urban development and impervious cover.

Flooding that is increased in frequency, magnitude, and velocity may negatively impact terrestrial wildlife species or habitats in or around the study area. Flood flows may result in altered hydrology, habitat fragmentation, and/or loss of preferred habitat. The community-based HSI analysis model projects that future flooding and development will result in a net decrease of 1,652 acres of floodplain forests and a net decrease of 970 acres of coastal prairie habitat. The removal or disturbance of streamside vegetation can result in an increased potential for erosion and sedimentation, and therefore possibly affect local wildlife species dependant on the aquatic environment by destroying riparian corridors, which may result in habitat fragmentation, and understory vegetation communities. A reduction in cover may potentially subject them to increased predation.

4.10.2 GRP Alternative

4.10.2.1 Freshwater Resources

As previously noted, the public and other interested groups expressed concerns regarding potential environmental impacts associated with the Clear Creek Project. Comments were received during public meetings (see Appendix A) expressing concern regarding channelization of portions of Clear Creek that still maintain natural elements such as sinuosity and riparian corridors (i.e., that are aesthetically pleasing and provide wildlife habitat). In response, the Clear Creek study team identified the cities of Pearland and Friendswood as areas with highest damages during flood events. Measures were then identified to reduce flooding in these high-damage reaches, and features to preserve or restore habitat in important corridors were added to the plan. The result of this effort was that the majority of project features are located in the upstream areas of Clear Creek that have been previously modified through channelization. Thus, direct impacts from construction of project features are avoided in downstream reaches of the watershed, which are still relatively natural, and elements of the GRP would protect and rehabilitate existing habitat in the portions of Clear Creek to be modified. This includes increasing sinuosity in some areas and protecting, rehabilitating, or reestablishing riparian habitat in others.

Clear Creek Conveyance

Construction activities would result in temporary increased sedimentation in the stream, especially during rainfall events, causing short-term impacts to freshwater fish and macroinvertebrates. Increased sedimentation may cover spawning habitat for fish like sunfish, which spawn on the bottom. However, in general, fish can tolerate fairly broad ranges of suspended sediment. The concentration of suspended sediment and the duration of high sediment events determines the degree of impact. Fish that feed using sight may be impacted when the water is more turbid than normal, reducing their ability to capture prey. The current fish community may be expected to have already experienced high suspended sediment events resulting from runoff of sediment from home and business construction projects in the watershed. Impacts resulting from the construction of the Clear Creek conveyance are expected to be temporary, reversible, and localized primarily to the reach where construction of this alternative is occurring. Additionally, sedimentation within the stream would be reduced by implementation of BMPs such as silt fencing and straw bale barriers.

It is projected the Clear Creek conveyance would result in long-term benefits to the fish community, compared to the No Action Alternative. The project would spread future flood flows over the widened floodplain and as a result reduce erosive forces from high-velocity flows in the creek channel. Reduced erosion would allow stream banks and the stream bottom to be more stable for a long period of time. The persistent, unmaintained corridor of riparian forest along the low-flow channel would also be a more effective riparian filter of sediments and other pollutants washed into the creek. There may be areas of the creek that would be more shaded in this reach. Reduced penetration of light to the creek may lower temperatures and reduce the chance of noxious growths of algae in the creek. Excessive algal growths can cause wide diurnal variation in dissolved oxygen levels and pH, causing stress to fish communities. Allowing trees to return to reaches of the riparian zone would encourage development of increased cover as branches and root wads occasionally fall into the creek and create habitat for different species of fish.

Turkey Creek, Mud Gully, and Mary’s Creek Conveyances

Turkey Creek, Mud Gully, and Mary’s Creek would each have portions of their channels modified to convey flood flow. Construction activities would result in temporary increased sedimentation in the stream, especially during rainfall events, causing short-term impacts to freshwater fish and macroinvertebrates. These impacts would be associated with some degree of increased turbidity and sedimentation in the stream channels, the same as described for Clear Creek. There would also be long-term impacts to the freshwater fish communities of these streams resulting from these channel modifications, as described in the following discussion.

Impacts resulting from the construction of the Turkey Creek conveyance are expected to be long term. This conveyance would be constructed in a portion of the creek that retains a fairly natural channel that is by a relatively small amount of remaining forested riparian area. The channel would lose most of its shading and a substantial portion of the riparian zone following construction. This modification would reduce habitat diversity in the reach. The fish community can be expected to experience a reduction in species diversity from the current community structure due to the loss of some species that are less tolerant of environmental stresses. The loss of habitat where Turkey Creek flows into Clear Creek would result in a localized negative impact to Clear Creek at that point. However, it should be noted that impacts to riparian areas are considered in the HEP analysis, and mitigation has been identified to compensate for those impacts.

The impact to the fish communities in Mud Gully and Mary's Creek at construction sites would be relatively minor. Mud Gully and Mary's Creek are grass-lined trapezoidal, maintained channels with very little remaining natural stream morphology. The portions of Mud Gully and Mary's Creek proposed for modification are currently straight channels with practically no natural riparian zone and minimal habitat diversity. The proposed modifications would not substantially change the conditions from those that currently exist. Therefore, there is not expected to be a measurable impact to the fish communities in those streams from the project.

4.10.2.2 Marine Resources

Under the GRP Alternative, the amount and velocity of water entering Clear Lake during flood events would not change and marine resources would remain as described in Section 3.10.2. As described for the No Action Alternative, development and land use changes are expected to result in the loss of 148 acres of tidal marsh over 50 years. No additional stresses would be placed on the system and the system would remain in its present condition. (For more information on hydrology, refer to the Hydrologic Analysis Appendix to the GRR.) During flood events, the velocity of water entering Clear Lake and sediment loading into Clear Lake and Galveston Bay would continue as it is presently. Periodic flushing of fresh water in marine environments can be important for an estuary to function properly. Flushing removes pathogens and pollutants, and maintains estuarine productivity because of sediments and nutrients carried by the water that are essential for a healthy estuary. Sediments help sustain intertidal wetland habitats, and nutrients stimulate plant productivity (Nixon et al., 2004). However, it should be noted that flood events could also introduce higher concentrations of pollutants into Clear Lake and Galveston Bay. Overall, flushing can be a positive impact to estuarine environments. No impacts to finfish, shellfish, or EFH are anticipated with the GRP Alternative. However, EFH consultation under the Magnuson-Stevens Fishery Conservation and Management Act is required and was initiated by the DSEIS.

4.10.2.3 Wildlife Resources

The impacts of the proposed project on terrestrial wildlife include short-term and long-term effects. Short-term effects are generally the result of physical disturbance during construction (i.e., clearing of vegetation, noise, pollution, and soil compaction), while long-term effects are generally the result of habitat modification.

The unavoidable clearing of floodplain forest vegetation would cause impacts to wildlife, but these impacts are expected to be offset by the proposed mitigation. Construction-related activities would directly and/or indirectly affect most animals that reside within the areas of impact. Heavy machinery may adversely affect smaller, low-mobility species, particularly amphibians, reptiles, and small mammals. If construction occurs during the breeding season (generally spring to fall), construction activities may adversely affect the young (i.e., nestlings and fledglings) of some birds and potentially destroy some nests. To ensure compliance with the MBTA, suitable nesting areas would be field verified prior to clearing and grubbing activities. Mobile species, such as birds and larger mammals, may avoid initial clearing and construction activities and move into adjacent areas outside the affected areas. Heavy machinery may also cause soil compaction, which may adversely affect fossorial animals (i.e., those that live underground). Construction activities may temporarily deprive some animals of cover, and therefore potentially subject them to increased natural predation. Wildlife in the immediate area may experience a slight loss of browse or forage material during construction; however, the prevalence of similar habitats in adjacent areas and vegetational succession in the affected area following construction could potentially minimize the effects of these losses. The possibility of accidental spills of oil, chemicals, or other hazardous materials during construction activities poses a threat to the aquatic community, and thus the food source of many terrestrial species in the area. The increased noise and activity levels during construction could potentially disturb the daily activities (e.g., breeding, foraging, etc.) of species inhabiting the areas adjacent to the affected areas. Dust and gaseous emissions should minimally affect wildlife. Although construction activities may disrupt the normal behavior of many wildlife species, little permanent damage to these populations should result. Such impacts would be temporary and without long-term implications.

The removal or disturbance of streamside vegetation can result in an increased potential for erosion and sedimentation, and therefore possibly affect local wildlife species dependent on the aquatic environment. Construction activities would be staged by segments to minimize soil exposure time and reduce soil runoff into waterways. Placement of erosion-control devices down gradient of areas disturbed by construction activities would help to minimize runoff into local streams. In close proximity to streams, the positioning of erosion-control measures between the disturbed area and the waterway would prevent or minimize siltation of streams. Clearing of vegetation, while producing temporary negative impacts to wildlife, can improve the habitat for ecotonal or edge species through the increased production of small shrubs, perennial forbs, and grasses.

The construction of conveyance channels and in-line detention facilities would require some excavation. The initial excavation of these sites would likely temporarily preclude its use by wildlife; however, the rehabilitation of habitat would help ensure the reestablishment of wildlife assemblages in affected areas. The excavated material would be deposited at a designated upland confined placement area. The locations of the placement areas would be determined during the preconstruction engineering and design phase. Attempts will be made to site the placement areas on agricultural lands, pasture, and other urban land to avoid wetlands and/or other ecological resource areas. Placement of excavated material at the placement area may temporarily preclude its use by wildlife; however, the duration of the activities would be temporary and the size of the placement area would not be large enough to cause any significant loss of habitat. These effects would be short term and, over time, wildlife habitat would reestablish itself within the placement area. Noise and increased human activities during construction may temporarily affect terrestrial wildlife in areas adjacent to the placement area; however, these impacts would likely be minor and short term.

The GRP Alternative includes, where appropriate, preservation and rehabilitation of existing floodplain forest and reestablishment of floodplain forest in areas where it previously existed and that are now undeveloped pasture or cropland. In these areas, the net gain in floodplain forest would provide additional terrestrial habitat for wildlife in the area, particularly bird species and other organisms dependent on the forested riparian ecosystem.

According to the TCWC (USFWS, 2008a), one documented rookery occurs within the study area. Rookery 600-418 (Raley Colony), located along Cow Bayou in southeastern Harris County, supports a population of approximately 25 to 27 pairs of green herons. This rookery is outside the project area, south of I-45. According to the GRP Alternative, no construction activities would occur immediately adjacent to the rookery, and therefore no impacts would occur.

Because migratory bird species may occur within the project area, construction contracts would include instructions to avoid impacts to migratory birds and their nests from construction-related activities. This should ensure no long-term negative impacts to migratory birds. Potential migratory bird habitat within the study area would be negatively impacted during construction. However, such habitat would benefit in the long term from protection of riparian habitat incorporated in the project design and from mitigation features.

4.11 THREATENED AND ENDANGERED SPECIES

The USFWS, NMFS, and TPWD were consulted to determine the potential for occurrence of federally or State-listed threatened or endangered plant or wildlife species within the study area. Copies of correspondence with these agencies are included in Appendix D-1. According to the USFWS, NMFS, and TPWD, 49 federally and/or State-listed threatened and/or endangered plant and wildlife species, SOC, and Federal candidate species may occur in the study area counties.

A Biological Assessment (BA) for this project has been prepared to fulfill the USACE requirements as outlined under Section 7(c) of the ESA of 1973, as amended, and is included in

Appendix E. USFWS acknowledged and did not dispute the USACE determinations regarding potential effect to protected species in their Coordination Act Report (Appendix D-6). NMFS may review the BA and issue a Biological Opinion (BO) to ensure that all potential project impacts have been discussed and coordinated with the appropriate agencies.

4.11.1 No Action Alternative

4.11.1.1 Flora

Under the No Action Alternative, existing populations of threatened or endangered flora species, if present, would continue to persist in their respective habitats, although some habitats may change independently over time. However, flooding in the Clear Creek watershed will not be reduced, and in fact, future flooding may increase due to increased urban development and impervious cover. Flood-related effects, including degradation of habitat, to threatened or endangered flora would remain.

One federally and State-listed endangered plant species, the Texas prairie dawn-flower, is of potential occurrence in the study area. According to TXNDD (2007), there is a known occurrence of the species in southeastern Harris County, within the study area. The study area is within the known range of the species, and it is possible that other unrecorded populations are present within the study area where potential habitat is present. Thus, the flower could be impacted by future flooding events under the No Action Alternative.

4.11.1.2 Fauna

Under the No Action Alternative, existing populations of threatened or endangered species, if present, would continue to persist in their respective habitats, although some habitats may change independently over time. However, flooding in the Clear Creek watershed will not be reduced, and future flooding may increase due to increased urban development and impervious cover. Flood-related effects, including degradation of habitat, to threatened or endangered fauna would remain.

Fifteen of the 49 species listed in Table 3.11-1 are federally listed threatened or endangered animal species that are included on the USFWS Southwest Region Ecological Services County by County lists for Harris, Galveston, Brazoria, and Fort Bend counties, and the Texas list of federally protected species under the jurisdiction of the NMFS. These species include the following: smalltooth sawfish, Attwater’s greater prairie-chicken, Eskimo curlew, piping plover, whooping crane, green sea turtle, hawksbill sea turtle, Kemp’s ridley sea turtle, leatherback sea turtle, loggerhead sea turtle, blue whale, fin whale, humpback whale, sei whale, and sperm whale. None of these species are likely to occur in the study area.

4.11.2 GRP Alternative

4.11.2.1 Flora

As noted in subsection 3.11.1, review of historic and recent aerial photography and field reconnaissance identified three areas within the general project area that could support habitat for the Texas prairie dawn-flower; however, no suitable habitat occurred within the project footprint. Thus, the proposed Clear Creek Project is expected to have no effect on the Texas prairie dawn-flower.

4.11.2.2 Fauna

None of the 15 species noted in Section 4.11.1.2, are likely to occur in the study area. Thus, the proposed project will have no effect on any of these species.

4.11.2.3 Summary

The implementation of the GRP Alternative would not result in any direct impacts to federally listed species. Thus, the USACE has determined that the proposed project is expected to have no effect on federally listed threatened or endangered species or their critical habitat. A detailed discussion of threatened and endangered species is provided in the Biological Assessment (Appendix E).

4.12 CULTURAL RESOURCES

4.12.1 No Action Alternative

Under the No Action Alternative, the proposed Clear Creek Project would not be implemented, thus there would be no potential to impact cultural resources during construction. However, continued impacts to recorded and unrecorded sites would continue in times of flood. As urban areas develop, the proportion of impervious cover in those watersheds tends to increase, increasing peak flows and resulting in increased erosion and bank cutting. Most of the recorded archeological sites in the study area are located on topographically elevated landforms and not in floodplain settings (see table, Appendix F-2). The impact of severe flooding to these sites could be erosion or collapse as banks are undercut by the flowing water, washing away buried archeological deposits. In some instances, flood flows could conceivably benefit archeological sites by the deposition on the sites of sediments picked up during the time of higher flow velocity. However, flooding that is increased in frequency, magnitude, and velocity by urban development will generally have a negative impact on surficial or shallowly buried archeological sites.

Under the No Action Alternative, the scenarios described above may occur because no flood risk management would be implemented and episodic flooding would continue and may be expected to worsen if development and population growth continues in the watershed as expected. Thus, impacts to archeological sites in the study area may be expected to worsen.

4.12.2 GRP Alternative

Under the GRP Alternative, the conveyance feature improvement for portions of Clear Creek, Turkey Creek, Mary's Creek, and Mud Gully would reduce erosional flooding impacts. However, construction of the proposed project features and directional drilling required to relocate 22 pipelines could impact recorded sites. As noted in subsection 3.12.2, PAI (Norment and Kibler, 2007) conducted a reconnaissance survey of select properties within the proposed Clear Creek Project footprint. Nine previously recorded sites were reevaluated, and one new site was identified. Field investigations determined that most of the project area has been disturbed due to urban development and thus has a low potential to yield intact archeological sites. Seven of the nine previously recorded sites were essentially destroyed, and the status of sites 41BO78 and 41BO82 is unknown. Previously recorded sites 41HR162 and 41HR192 were relocated and determined to have been heavily impacted by looting and erosion. PAI recommended both 41HR162 and 41HR192, in addition to newly discovered site 41HR1034, be judged ineligible for listing in the NRHP and for designation as a State Archeological Landmark. No further archeological investigations are being recommended by PAI for any of the 10 sites that would be impacted by the current proposed work. The THC concurred that sites 41HR162, 41HR163, 41HR164, 41HR191, 41HR192, and 41HR1034 should be considered not eligible for the NRHP. However, the THC recommends more testing at 41HR161. The project areas that include 41BO78 and 41BO82 were not accessible, and further survey will be required there once access is obtained. Additionally, the draft survey report should address buildings, bridges, or other structures over 50 years old that would be affected (see Appendix D-2). In addition, site 41HR817 was reported by PAI (Norment and Kibler, 2007) as destroyed.

A Memorandum of Agreement (Appendix F-1) among the USACE, the SHPO, and the ACHP is in place to ensure compliance with Section 106 of the National Historic Preservation Act. A new Programmatic Agreement (PA) is currently being coordinated with the SHPO, the ACHP, and the Project Sponsors. This PA was prepared to include the Project Sponsors and to guide implementation of the proposed Clear Creek Project. Work performed under either the existing MOA or the new PA will include, but is not limited to, additional testing of one previously recorded site and additional survey of two previously recorded sites when access is obtained; identification and investigation of unrecorded and, as of yet, unidentified sites; and the investigation of unanticipated cultural resources encountered during the course of work. If historic resources are identified, assessment of effects and mitigation for the historic resource would also be conducted pursuant to the Programmatic Agreement.

4.13 SOCIOECONOMIC RESOURCES

4.13.1 No Action Alternative

Under the No Action Alternative, the study area would likely continue on its present course of population growth trends, economic development, and residential and commercial development patterns; however, the location of development could be limited to areas that would not be prone to flooding. Flooding along Clear Creek has historically been a problem associated with severe rainfall events; however, continual residential and commercial growth within the watershed has severely aggravated flooding problems. Rapid urban growth in this region has increased the amount of impervious cover and reduced the watershed's natural detention capacity resulting in higher and more frequent stormwater flows. As a consequence, overbank flows have become more common even with moderate rainfall events. The demand for community facilities, services, and housing would continue to increase within the study area since there is an anticipated population growth. These types of facilities would generally follow development and land-use plans identified by various municipalities and counties.

An economic analysis conducted by USACE (GRR, Economic Appendix) provides an estimate of the impact of "Without Project" flooding to communities and subdivisions along Clear Creek. The analysis provides the expected annual and average annual damages under the No Action Alternative for the years 2020 and 2070. Damages include damages to structures, contents, vehicles, utilities, and roads, and postdisaster recovery costs. The most probable future condition reflects changes in hydrologic conditions from anticipated development within the watershed tempered by runoff restrictions imposed by local authorities over the period of analysis 2020 to 2070. Results of the analysis are shown in Table 4.13-1.

Table 4.13-1
Damages for the No Action Alternative (2020 and 2070)
(values in $1,000s, price levels October 2009)

	Average Annual Damages					
Year	Clear Creek Main Stem	Mud Gully	Turkey Creek	Mary's Creek	Cowart Creek	Chigger Creek
2020	11,115	2,581	525	4,471	290	292
2070	12,370	3,242	813	6,743	316	328

Property taxes are the most significant source of public revenue that could be impacted by flooding. Because property taxes are based according to value of the property, a decline in property value equates to a decline in property tax revenues. Persistent and unmitigated flooding could have a dampening effect on property value. Taxing entities, such as counties, cities, municipal utility districts, WCIDs, drainage districts, independent school districts, and other taxing districts, would be negatively affected if the taxing entities experience a dramatic decrease in their property tax revenue. Similarly, if an entity's tax base were decreased by the removal of taxable property, this could negatively impact the taxing entity (Jack Faucett Associates, Inc., 2001). As indicated, the No Action Alternative could possibly have a negative effect on the local economy from increased costs associated with flood damages.

4.13.2 GRP Alternative

4.13.2.1 Population and Demographics

As noted in Section 3.13, populations in municipalities and counties within the study area are expected to increase. The GRP Alternative is not anticipated to have an effect on population growth trends in the study area; however, it may stimulate growth in portions of the Clear Creek corridor potentially resulting in a shift in density of populations within the study area.

With the added flood risk management protection, there may be changes with regards to which properties are located within the FIRM floodplain map. Thus, the distribution of population densities may increase in close proximity to Clear Creek. As a result, the demand for community facilities, services, and housing would potentially increase.

Improvements to the Clear Creek channel, in addition to the construction of in-line conveyance features, placement areas, and mitigation features, would result in an increased demand for construction workers. These construction workers are likely to come from the labor force that is already living within Harris, Galveston, Brazoria, and Fort Bend counties; therefore, immigration of construction workers to the study area would not be anticipated.

The GRP Alternative effectively reduces flood risks for 2,453 (65 percent) of the structures in the 100-year floodplain of the study area. The proposed project is in compliance with EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations," signed by the president on February 11, 1994, which directs Federal agencies to take the appropriate and necessary steps to identify and address disproportionately high and adverse effects of Federal projects on the health of the environment of minority and low-income populations to the greatest extent practicable and permitted by law. As noted in subsection 3.13.2.4, four census tracts that contain project features were identified as minority census tracts (CT 3308, CT 3338, CT 3504, and CT 3505). No disproportionate impacts to these minority populations are anticipated. The definition of a disproportionately high and adverse effect on minority and low-income populations is whether the impacts from a proposed project are (1) predominantly borne by a minority population and/or low-income population; (2) would be suffered by the minority population and/or low-income population and is appreciably more severe or greater in magnitude than the adverse effect that would be suffered by the nonminority population and/or nonlow-income population. Due to the extent of the GRP Alternative, the effect of potential short-term and long-term impacts would be borne by all census tracts identified on Figure 3.13-2. In addition, the GRP Alternative would reduce the risk of flood damage, which would benefit nonminority as well as minority populations. None of the census tracts containing project features were identified as low-income tracts. Additionally, the GRP Alternative would neither divide nor isolate any particular neighborhood nor separate residents from community facilities. The GRP Alternative would potentially increase the number of community facilities as a result of potential new land being available for development. Therefore, there would be no adverse effect to community cohesion or values as a result of this alternative.

4.13.2.2 Economics

Under the GRP Alternative, reduced flood damages along Clear Creek would potentially result in lower insurance rates for homeowners as well as improving property values. The economic effects accruing from the flood risk management would include a temporary increase in construction employment and local purchases of construction materials. As construction dollars are spent locally, there would be a temporary beneficial effect on local economic output, income, and employment in the area.

The study area has some commercial and business development, but is essentially a set of residential communities. Of growing importance to the regional economy is the boating and recreation industry. Under the GRP Alternative, areas along flood benches (from SH 288 to Dixie Farm Road) would be maintained as a parklike setting (i.e., grasses and trees). These parklike areas, in conjunction with restored, more-natural riparian vegetation, and parks and recreational facilities such as hike/bike trails, scenic parks, and picnic facilities, would provide additional and increased recreation potential for Clear Creek.

4.14 LAND USE/AESTHETICS

4.14.1 No Action Alternative

Under the No Action Alternative, Clear Creek would retain its current configuration. Many of the study area’s municipalities have incorporated no-impact policies to address new development. These are established to protect the flow at a 100-year level of protection; however, these requirements are not in place for the entire watershed. Because of the anticipated population growth in the study area, anticipated development would increase the amount of impervious cover and reduce the watershed’s natural detention capacity, resulting in higher and more frequent stormwater flows. Additionally, development upstream of Clear Lake would continue to increase peak flows into Clear Creek. These increased flows would result in increased water elevation sufficient to cause flooding in many areas. According to economic studies conducted by the USACE (GRR, Economic Appendix), flooding in communities and subdivisions along Clear Creek would be extensive under the No Action Alternative. The equivalent annual damages expected under the No Action Alternative (over the 50-year period of analysis) would be $38,338,000. These damages would be located along the Clear Creek main stem and along Clear Creek's tributaries.

Under tropical storm conditions, the No Action Alternative could result in potential flooding of evacuation routes and could result in accidents and delays in evacuations. These types of impacts as well as increased stormwater runoff from increased impervious cover would continue to have a negative effect on the existing roadways within the watershed.

Currently, Clear Creek has mixed habitats for wildlife including migratory birds. The creek is generally considered aesthetically pleasing, with area neighborhoods and subdivisions in addition to parks and walking trails along its banks. The winding creek and remaining bordering vegetation provide an attractive contrast to the flat terrain found in the area. Under the No Action Alternative, these aesthetic features and recreational opportunities would remain constant although they could be impacted and degraded by future development. In addition, wildlife hazards to aircraft using public use airports would remain as described in Section 3.14.3.

4.14.2 GRP Alternative

Under the GRP Alternative, development would likely continue within the floodplain as under the No Action Alternative; however, with improved conveyance and in-line detention features, the likelihood of flooding and property damage would decrease, thereby potentially increasing the density of development along Clear Creek.

The greatest long-term land-use consequence of this alternative would likely be a change in future land uses that would occur in response to the improvements. With the added flood risk management protection, there may be changes with regards to which properties are located within the FIRM floodplain map. Future land uses could include residential and commercial development, municipal parks (including hike and bike trails and picnicking areas), as well as an increase in available land for residential development. This potential development would be consistent with existing and proposed land uses adjacent to Clear Creek. The demand for community facilities, services, and housing would continue to increase within the study area with anticipated population growth. Although additional development would increase the amount of impervious cover, resulting in increased stormwater runoff, the measures proposed as the GRP Alternative would minimize flooding effects.

Under the GRP Alternative, the existing transportation system within the study area could be temporarily affected by construction activity. The addition of employees accessing or commuting within the study area on a daily basis would not result in a significant increase in volume adversely affecting traffic on area roadways; therefore, no adverse effects are anticipated.

The GRP Alternative would have a minimal effect on the overall visual quality within the study area. Clear Creek is considered aesthetically pleasing, with area neighborhood parks with bird-watching, picnicking, walking, and other recreational opportunities. The study area exhibits a generally moderate to high level of impact from human development and alteration. This would not change with implementation of the GRP Alternative.

The area located along the Clear Creek main channel would potentially be rehabilitated with the proposed improvements. The aesthetic quality would potentially increase from the parklike setting of the floodplain forest from SH 288 to Dixie Farm Road. In addition, proposed riparian habitat rehabilitation and restoration would potentially increase the aesthetic quality of the study area by creating natural environments for residents as well as wildlife.

Among sport-related activities, recreational fishing and wildlife watching continue to be important outdoor recreational activities in the study area. Clear Lake, numerous wetlands, and the Gulf are sources of recreational fishing and wildlife watching. The GRP Alternative would reduce riverine flood damages along Clear Creek and its tributaries and reestablish streamside floodplain forest vegetation to the upstream areas of Clear Creek, thereby inducing recreational opportunities and improving aesthetic qualities of the study area. In addition, net economic benefits include an increase in recreational opportunities along Clear Creek from SH 288 to Dixie Farm Road from the parklike setting created from the flood risk management measures.

The Clear Creek Project was evaluated to determine whether the proposed action could increase wildlife hazards to aircraft using public use airports with a 5-mile approach, departure, and circling radius in the study area: Ellington Field, Houston-Southwest, William P. Hobby, Pearland Regional, and La Porte Municipal airports. Proposed project features fall within the 10,000-foot perimeter at the Pearland Regional Airport and the Ellington Field Airport, and within the 5-mile perimeter of the William P. Hobby Airport. The proposed project features do not occur within 5 miles of the La Porte Municipal Airport or the Houston-Southwest Airport.

Project features of the proposed action that could serve as attractants are conveyance and mitigation measures that include rehabilitation of existing floodplain forest and reestablishment of floodplain forest in areas where it occurred in the past. These areas would provide habitat for birds and wildlife species that pose a potential strike hazard. However, the proposed features would not result in a net change of current land use, as no habitat would be created where it does not or did not once exist. The USACE provided this information to the FAA on May 12, 2010, and concluded that the proposed project would not be expected to introduce new hazardous wildlife attractants to the Ellington Field, Houston-Southwest, La Porte Municipal, William P. Hobby, or Pearland Regional airports since the these features would not result in a net change of current land use, as no habitat would be created where it does not or did not once exist.

4.15 CUMULATIVE IMPACTS ANALYSIS

The President's CEQ defines cumulative impacts as those impacts "on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or persons undertake such actions." Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. Impacts include both direct effects (caused by the action and occurring at the same time and place as the action) and indirect effects (caused by the action but removed in distance and later in time, and reasonably foreseeable).

Cumulative effects can result from a wide range of activities, including the addition of materials to the affected environment, repeated removal of materials or organisms from the affected environment, and repeated environmental changes over large areas and long periods. Complex cumulative effects can occur when different types combine to produce a single effect or suite of effects. Cumulative impacts may also occur when individual disturbances are clustered, creating conditions where effects of one episode have not dissipated before the next occurs (timing) or are so close that their effects overlap (distance).

In assessing cumulative impact, consideration is given to the following:

- the degree to which the proposed action affects public health or safety;
- unique characteristics (physical, biological, and socioeconomic factors) of the geographic area;
- the degree to which the effects on the quality of the human environment are likely to be highly controversial;
- the degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks; and
- whether the action is related to other actions with individually insignificant, but cumulatively significant, impacts on the environment.

The Clear Creek Project FSEIS cumulative impacts assessment method is similar to that used on other Federal projects of this type. It follows a traditional cumulative impact assessment method, addressing impacts for a finite set of criteria and comparing known projects within the study area for which there is publicly available information for the proposed project. Eighteen cumulative impact criteria were identified to evaluate projects relevant to the future condition of the study area (see Table 4.15-1). Over 70 projects were considered in the analysis.

4.15.1 Projects Considered

As previously mentioned, cumulative impacts as those impacts "on the environment which result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or persons undertake such actions." To perform the cumulative analysis, relevant previously-constructed, currently operable, and expected projects must be first identified. Past, present, and reasonably foreseeable projects/activities considered in the cumulative impacts analysis consisted of those in the study area for which publicly available project documents demonstrate effects to select environmental and natural resources. No attempts were made to verify information within published documents of any project. Mitigation outlined in individual project documents may be in place or proposed. This analysis recognizes that some of the projects assessed are undergoing revisions that may alter their environmental effects. Brief project descriptions follow in sections 4.15.1 (Past or Present Actions) and 4.15.2 (Reasonably Foreseeable Future Actions) and detailed project descriptions are located in Appendix I.

4.15.1.1 Past or Present Actions

Primarily rural until the 1970s, the suburban growth of Fort Bend and Brazoria counties has been closely tied to the economic prosperity of Houston (Auch et al., 2004). Most recent development in the study area is in the form of suburban-style master-planned communities. There is less commercial and industrial land use in the study area which tends to be located along Beltway 8, I-45, and SH 146. Population growth and subsequent development has been highest in Missouri City (490.5 percent increase 1970 to 1980), Friendswood (112.8 percent increase 1980 to 1990), and Fresno (107.5 percent increase 1990 to 2000). Compared to the other counties in the study area, Galveston County experienced the lowest overall increase over the same 40-year time period; however, overall, the study area has experienced an increase in population between 1970 and 2000 (see Appendix G).

As previously mentioned, growth in the study area is relatively high (compared with other growth nationally). Houston is one of the fastest growing cities in the U.S., and some areas within the study area are among the fastest growing regions within the greater Houston area (Rice University, 2011). Generally, the most intensive development is found in the rapidly growing areas immediately adjacent to the major roadways (SH 288, Sam Houston Tollway/ Beltway 8, SH 35, I-45, and SH 146). Additionally, other areas within the study area and adjacent to Clear Creek (e.g., between Dixie Farm Road and SH 35, Scarsdale Boulevard, and FM 2351) have undergone extensive residential and commercial development since 2000. The relatively large increase in growth has resulted in loss of vegetation and wildlife habitats, and an increase in impervious urban cover, within the Clear Creek study area watershed. Development and impervious cover associated with this growth may have contributed to the alteration of ecologically important functions such as groundwater recharge, provision of wildlife habitat, or flood abatement (given the presence of wetlands).

The following list of projects was considered during evaluation of past or present actions. Detailed discussion of these projects can be found in Appendix I.

- Brio/Dixie Oil Superfund Site Remediation
- Weiner Development Corporation Shopping Center

- Rail Build-out to the Bayport Loop
- Previous Clear Creek Flood Risk Management Efforts
- Coastal Bottomlands Mitigation Bank (CBMB)
- Cowart’s Creek Diversion and Regional Detention
- East Mary’s Creek Regional Detention Pond Phase I
- Various TxDOT Road Improvement Projects
- Various Pipeline Projects
- Petrakos Fiber Optic Network
- Buffalo Camp Recreational Improvements

4.15.1.2 Reasonably Foreseeable Future Actions

Using population projections from 2000 to 2030 (Texas Comptrollers Office, 2008) for the study area municipalities and counties, Fort Bend County is expected to continue to have the highest population growth compared to the other three counties in the study area, with expected increases of between 27.3 percent and 38.3 percent. Galveston County is expected to experience the lowest population growth of the four study area counties. The City of Pearland will experience the highest population increase, with growth estimates as high as 75.5 percent occurring from 2000 to 2010. The City of Webster is expected to have the highest population increase from 2010 to 2020 at 29.7 percent, and from 2020 to 2030 at 22.5 percent. Deer Park is expected to maintain the lowest population change from 2000 to 2030 with 3.5 percent change from 2000 to 2010, decreasing to a 3.1 percent change from 2020 to 2030. Overall, the increases in population seen from 1970 to 2000 are expected to continue through 2030, with growth generally slowing each decade (Texas Comptrollers Office, 2008); this continued increase in population can be expected to result in continued development within the study area. The following projects were considered for reasonably foreseeable future actions identified in the study area. Detailed descriptions of each project can be found in Appendix I.

- Armand Bayou Watershed Plan
- City of Pearland Capital Improvement Projects
- City of Friendswood Capital Improvement Projects
- Mud Gully Detention Pond
- Galveston Commuter Rail
- Houston Region Freight Rail Improvements
- Various TxDOT Road Improvement Projects

4.15.2 Cumulative Impacts Evaluation Criteria

Criteria include biological, ecological, physical, chemical, socioeconomic, and cultural attributes, listed in Table 4.15-1. These parameters were identified as key resources discussed in NEPA documents and project reports, and they form a basis for comparison with the proposed project.

Table 4.15-1
Cumulative Impacts Criteria

Biological/Ecological Environment	Physical/Chemical Environment	Cultural/Socioeconomic Environment
Vegetation	Air Quality	Environmental Justice
Threatened/Endangered Species	Noise	Cultural Resources
Riparian Habitats	Water Quality	Recreation
Aquatic Community	Sediment Quality	Oil/Gas Production
Terrestrial Wildlife	Circulation and Tides	Public Health and Safety
Essential Fish Habitat	Soils	Commercial and Recreational Fisheries

Biological/ecological, physical/chemical, and cultural/socioeconomic resource impacts were compared between the assessed projects and the proposed project. Table 4.15-2 presents this information for the past, present, and reasonably foreseeable projects, compared to the quantifiable impacts of the Clear Creek Project (sections 4.0 and 5.0). Table 4.15-2 only includes those projects where credible, publicly available documents or sources indicate a possible project effect. However, some project effects were inferred from existing sources due to the nature of the project's objectives. In addition to projects listed in Table 4.15-2, other projects occurring in the study area are described (Appendix I); however, for these particular projects, no environmental effects are documented or available for public disclosure.

Brief descriptions of the projects listed in Table 4.15-2 follow; detailed descriptions are located in Appendix I.

- **Brio/Dixie Oil Superfund Site Remediation**. The site consists of approximately 50+ acres on both sides of Dixie Farm Road, north of Clear Creek, west of Turkey Creek, southwest of Beamer (Hall) Road, and intersected by Mud Gully, near Friendswood. Main cleanup components for the site(s) included the following: remove surface tanks, dispose of residuals, cover the site with 6 inches of topsoil and grade to promote runoff, channelize Mud Gully to remove flow restrictions and improve long-term maintenance and stability, install a sub-grade barrier wall to limit the potential for off-site migration of contaminated groundwater, and add a composite cap (including a gas collection layer, flexible membrane layer, compacted clay, and topsoil to promote vegetation growth) (EPA, 1997, 2002).

Table 4.15-2
Cumulative Assessment Summary Table[1, 2, 4]

	Brio/Dixie Oil Superfund Remediation	Weiner Development	Rail: Bayport Loop	Previous Clear Creek Flood Control	Coastal Bottomlands Mitigation Bank[3]	Armand Bayou Watershed Plan[3]	Cowart Creek Diversion and Regional Detention[3]	East Mary's Creek Regional Detention Pond Phase I[3]	Mud Gully Detention Pond and Channel Improvements[3]	**GRP Alternative**
Biological and Ecological Resources										
Vegetation	Benefit	Benefit	X	NO	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit
Threatened and Endangered Species	NO	NO	NO	NO	Benefit	Benefit	NO	NO	NO	NO
Aquatic Community	Benefit	Benefit	NO	X	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit
Terrestrial Wildlife	Benefit	Benefit	X	X	Benefit	Benefit	X	X	X	NO
Essential Fish Habitat	NA	NO	NO	NA	NA	Benefit	NA	NA	NA	NO
Physical and Chemical Resources										
Air Quality	Benefit	NO	X	NO	Benefit	Benefit	NO	NO	NO	NO
Noise	NO	NA	X	NO	NA	NA	NO	NO	NO	NO
Water Quality	Benefit	NO	NO	X	Benefit	Benefit	NA	NA	NA	Benefit
Sediment Quality	Benefit	NA	NA	X	Benefit	Benefit	NA	NA	NA	NO
Circulation and Tides	NA	NO	NO	X	NA	NA	NO	NO	NO	NO
Soils	Benefit	X	X	X	Benefit	Benefit	X	X	X	NO
Socioeconomic and Cultural Resources										
Environmental Justice	Benefit	NA	unk	NA	NA	unk	NA	NA	NA	NO
Cultural Resources	NO	NA	NO	unk	NO	NO	unk	unk	unk	NO
Recreation	NO	NA	unk	NA	Benefit	Benefit	NA	Benefit	NO	Benefit
Oil/Gas Production	NO	NA	NA	NA	NA	NA	NO	NO	NO	NO
Public Health and Safety	Benefit	NA	X	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit
Commercial and Recreational Fisheries	NO	NA	NA	NA	Benefit	Benefit	Benefit	Benefit	Benefit	Benefit

[1]Numerous past, present, and reasonably foreseeable projects are not included in this table due to unavailable information regarding project impacts; however, these projects are described in Section 6, and general typical project effects are considered in the overall Cumulative Impact Assessment.

[2]Impacts in this table are derived from publicly available project impact documents and are presented as they were in the documents, at the time of this document's writing.

[3]Some project effects were inferred from existing sources due to the nature of the project's objectives.

[4]Project effects include:

Benefit Results that have an overall positive effect when compared to the FWOP condition of the resource; improvement anticipated.

NO No adverse effect from project; limited in duration or extent such that the resource is not adversely affected or impacts are mitigated in some way through regulatory mechanisms; not an improvement over FWOP (e.g., a benefit).

X Impact expected or documented.

NA Information unavailable regarding potential effects, positive or negative, to the resource.

unk unknown at the time of the table composition; will add as environmental documentation is available.

- **Weiner Development Corporation Shopping Center**. The project is located immediately southwest of the intersection of the I-45 south frontage road and El Dorado Boulevard, north of the Baybrook Mall, near Friendswood, Harris County, Texas (General Land Office [GLO], 1999). The Weiner Development Corporation filled 4.03 acres of isolated depressional wetlands on a 76.62-acre site for the construction of a shopping center. Mitigation was proposed for adverse effects from construction.
- **Rail Build-out to the Bayport Loop**. The project involved construction of approximately 12.8 miles of new rail line to serve the petrochemical industries in the Bayport Industrial District (Bayport Loop). The project involved unavoidable new construction in wetlands and included all practicable measures to avoid and minimize harm to wetlands. The mitigation plan compensates for unavoidable impacts to wetlands and includes wetland restoration, creation, and preservation (STB, 2003).
- **Previous Clear Creek Flood Risk Management Efforts**. Galveston County Consolidated Drainage District (GCCDD) and Brazoria County Drainage District #4 (BCDD4) (also known as Pearland Drainage District) have implemented flood risk management and vegetation management steps prior to the Clear Creek General Reevaluation Projects include clearing dead and dying trees, shoreline stabilization using riprap, placement of fill in Clear Creek, and construction of a pier/boardwalk.
- **Coastal Bottomlands Mitigation Bank**. TxDOT has constructed a wetland mitigation bank for roadway improvements. The wetland mitigation bank is not within the Clear Creek study area; however, it can be used for mitigation of TxDOT Houston District projects in the study area. The Coastal Bottomlands Mitigation Bank is active (Environmental Law Institute, 2002; TxDOT, 1999), credits are available, and wetland mitigation credit purchases are expected to continue.
- **Armand Bayou Watershed Plan**. Located in southeast Harris County, the habitat in the watershed was once dominated by tallgrass prairie, punctuated by forest corridors along stream channels and flatwood forest across much of the lower part of the watershed. Trust for Public Lands is coordinating efforts focused on the use of land conservation to meet the community's needs for parks and bayou access, water quality protection, habitat preservation, and stormwater management.
- **Cowart Creek Diversion and Regional Detention for the Bailey Road corridor between FM 1128 and Wells Road**. Completed in April 2012, the project entailed construction of an interceptor box culvert, diversion ditches, a regional detention facility and associated bridge, culvert, and road ditch improvements.
- **East Mary's Creek Phase I, confluence of Mary's Creek and Mary's Creek Bypass**. Completed in September 2010, the project consists of a detention facility at confluence of Mary's Creek and Mary's Creek Bypass. The project is intended to provide floodplain relief for Mary's Creek up to and including a 10-year storm event. The project also provides mitigation for various projects within the study area.

- **Mud Gully Detention Pond and Channel Improvements**. Originally included for study in the Clear Creek Federal Project, the Mud Gully Detention Pond was identified as being effective for flood management. Harris and Galveston Counties have decided to fund the project. The project consists of a detention pond and improvements to an existing conveyance channel.

4.15.3 Cumulative Impacts Analysis Results

Despite the lack of information regarding potential effects of some projects, typical environmental effects (where applicable,) as well as general environmental trends of the study area, are still considered in the cumulative analyses (although conservatively, since these potential effects and trends are not based on actual project effect documentation). Most projects included in this comparative analysis involve earth-moving activities. As a result, impacts may occur to vegetation, soils, adjacent water resources, species dependent on affected habitats, and cultural resources. Additionally, heavy machinery use and materials transport associated with some of these projects can have adverse effects on noise levels, air quality, and public health and safety. Where environmental assessments or environmental impact statements were published for the above-mentioned projects, most of these documents outlined avoidance and minimization measures for regulated resources (e.g., wetlands, threatened and endangered species, sensitive habitats, cultural resources, water quality, and air quality). Where avoidance was not practicable or possible, mitigation measures were proposed and are included in this analysis.

4.15.3.1 Ecological and Biological Resources

Clear Creek is located in an area of rapid urban growth that has realized heavy impacts to natural and cultural resources. Ecologically important habitats within the Clear Creek watershed have been degraded and lost to agricultural range improvement and urbanization in the Houston area and surrounding municipalities. As a result, the remaining habitat is highly fragmented and continues to be severely threatened by exotic invasive species and development. Numerous opportunities exist to preserve remaining habitat as well as rehabilitate additional habitat to supplement or connect existing high importance areas.

The general environmental criteria for flood risk management projects are identified in Federal environmental statutes, EOs, and planning guidelines as well as the EOP of the USACE. The basic guidance during planning studies is to assure that care is taken to preserve and protect significant ecological, aesthetic, and cultural values, and to conserve natural resources. These efforts also should provide the means to maintain and restore, as applicable, the desirable qualities of the human and natural environment.

Adverse cumulative impacts to ecological and biological resources typically relate to compounded direct impacts from loss or take, fragmentation, or modification that can adversely affect ecological functions, connectivity, integrity, size, and viability. Positive cumulative impacts may be obtained where mitigation measures compensate for proposed and past project effects, thereby rehabilitating the potential for recovery or sustainability of the resource. Reasonably foreseeable future projects would be subject to local, State, and Federal regulations, by which resource impacts would be regulated, and any project impacts potentially mitigated.

Vegetation

Terrestrial vegetation impacts occur on most projects considered in this cumulative impacts assessment. Clearing for construction, ROW maintenance (trimming and mowing), prescribed burning, conversion to open water, and utilization of placement areas may affect terrestrial vegetation. Most projects considered in this analysis have compensatory measures and/or minimization or mitigation plans to address vegetation loss and/or impacts. The ecological impacts of the Clear Creek Project and alternatives were determined by the use of a community-based ecological model as described in subsection 3.9.3 (see Appendix B). The model defined basic habitat categories, which include agricultural fields, 500-year floodplain forest, open water, cultivated pastureland, coastal prairie, and tidally influenced marsh.

According to the model, approximately 278 acres of floodplain forest would be directly impacted by construction of project features associated with the GRP Alternative; however, long-term benefits that include protection, rehabilitation, or reestablishment of approximately 186 acres of floodplain forest through measures such as restoration of low-flow channels, reconnecting low flows and meanders within oxbows, and plantings incorporated into the design of the GRP and mitigation plan would offset these temporary impacts. The loss of biological function would be temporary, and a net increase of habitat function would likely increase over time. In addition, the FWOP analysis suggests that current trends within the project area would lead to a net loss of 1,652 acres of floodplain forest and 970 acres of coastal prairie. Cumulatively, the GRP Alternative does not contribute to terrestrial vegetation loss or impacts.

Threatened and Endangered Species

Most of the projects included in this assessment are not expected to significantly impact federally listed threatened or endangered species and two projects, Coastal Bottomlands Mitigation Bank and Armand Bayou Watershed Plan should benefit threatened or endangered species. None of the federally listed threatened or endangered species presented in Table 3.11-1 have USFWS-designated critical habitat within the Clear Creek Project area. Thus, the proposed project would not result in impacts to critical habitat for any federally listed endangered species. A BA was submitted to the USFWS with the DSEIS to fulfill the USACE requirements as outlined under Section 7(c) of the ESA of 1973, as amended, and is included as Appendix E. Projects projected for the future would be subject to local, State, and Federal regulations, which should ensure that construction would not adversely impact threatened and endangered species, thereby mitigating potential cumulative impacts. The implementation of the Clear Creek Project would not result in any direct impact to federally listed species. A cumulative negative effect on threatened and endangered species is not expected from the GRP Alternative.

Aquatic Community

The ecological impacts of the Clear Creek Project and alternatives were determined by the use of a community-based ecological model as described in subsection 3.9.5 (see Appendix B). Under the FWOP condition, reduced water quality, habitat loss, and flooding would continue. There would be no opportunity to maintain or construct grassy vegetated channel flood benches and side slopes or shady riparian low-flow channels to help reduce turbidity by decreasing erosion during flood events. Future flood damages would not be reduced in the area, and flooding may continue to increase due to continued urban development and impervious cover reducing the watershed's natural detention capacity. As a result, frequency and velocities of episodic flooding in the area would increase. Flood flows may peak at higher velocities, which increase erosive forces on stream banks and bottoms, and significant bank erosion may occur resulting in sedimentation in the stream. This erosion may eliminate preferred habitat by destroying undercut banks, washing away overhanging brush, and causing sediment beds to accumulate on top of hard-bottom structures (see GRR). Overall, cumulative negative impacts to aquatic communities are not expected to be significant and ecological benefits may be realized. The GRP Alternative is expected to benefit the aquatic community and will not add to any cumulative negative impacts that may occur.

Terrestrial Wildlife

Cumulative impacts on terrestrial wildlife would include short-term and long-term effects. Short-term effects are generally the result of physical disturbances during construction (i.e., clearing of vegetation, noise, pollution, and soil compaction), while long-term effects are generally the result of habitat modification. The majority of the projects considered in this cumulative impacts analysis adversely affect smaller, low-mobility species, particularly amphibians, reptiles, and small mammals. The increased noise and activity levels during construction may potentially disturb daily activities (e.g., breeding, foraging, etc.) of species inhabiting the areas adjacent to the affected area. Other cumulative impacts on wildlife could include modification to patterns of movement and travel, increased wildlife-vehicle collisions, light and glare impacts, and noise disturbance. Clearing of vegetation, while producing temporary negative impacts to wildlife, can improve habitat connectivity and facilitate the utilization and function of wildlife corridors by removing nonnative vegetation and invasive species. In addition, the improved riparian zones and restoration of existing wildlife habitat may provide positive cumulative impacts to terrestrial wildlife in this area, which is currently a degraded resource. A cumulative negative effect on terrestrial wildlife is not expected from the GRP Alternative.

Essential Fish Habitat

Projects occurring in the area (CBMB and Armand Bayou Watershed Plan) are expected to contribute direct and indirect positive effects on EFH. Other future projects will be regulated under the Magnuson-Stevens Fishery Conservation and Management Act (PL 94-265), which establishes procedures for identifying EFH and requires interagency coordination to further the conservation of federally managed fisheries. Rules published by the NMFS (50 CFR sections 600.805–600.930) specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake an activity that could adversely affect EFH is subject to the consultation provisions of the above-mentioned act and identifies consultation requirements. The GRP Alternative is not expected to contribute to cumulative effects to EFH within the study area. The DSEIS initiated EFH consultation under the Magnuson-Stevens Fishery Conservation and Management Act.

4.15.3.2 Physical and Chemical Resources

Adverse cumulative impacts to physical and chemical resources typically relate to additive impacts (emissions, noise increases, pollutants) or modifications that adversely affect other resources dependent on the physical resources' function (e.g., change in circulation and tides that could affect salinity, flow, sedimentation, etc., in a marsh system). Positive cumulative impacts can be obtained where remediation or mitigation measures compensate for proposed and past degradation, thereby rehabilitating the potential for recovery or sustainability of the resource.

Air Quality

Direct detrimental effects from the GRP Alternative may include air contaminant emissions associated with construction and maintenance equipment, emissions of particulate matter into the air from soil disturbances, or objectionable odors from manipulations of sediments containing high organic matter concentrations; however, these impacts are considered temporary. Air quality analyses indicate project NO_x emissions would exceed the conformity threshold (i.e., greater than 100 tpy) for the years 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, and 2019; a General Conformity Determination for NO_x emissions would be required for these years. The General Conformity process would discuss whether NO_x emissions would conform to the TCEQ SIP for the HGB Nonattainment Area.

Several of the projects in this assessment (see Table 4.15-2) document detrimental effects to air quality (e.g., rail projects), some projects are assumed to decrease air quality (e.g., TxDOT projects may contribute to more vehicle emissions once operational), while others would benefit air quality (e.g., Superfund remediation, wetland mitigation banks, watershed preservation plan). Most project activities that may cause detrimental effects to air quality are considered temporary and localized. All projects within the study area with the potential to affect air quality must conform to the TCEQ SIP. Coordination and compliance with TCEQ and EPA should result in no significant cumulative impacts to air quality within the study area. Generally, air quality has been decreasing in the region (Forswall and Higgins, 2005) and will likely continue to decrease based on projected growth (Texas Comptrollers Office, 2008); however, recent data suggest that air quality has improved in the region despite growth (TCEQ, 2008c). The GRP Alternative may contribute long-term benefits to air quality (e.g., carbon sequestration and oxygen contribution)

Noise

Temporary and localized noise impacts would result from construction and maintenance activities of the GRP Alternative. Most projects in the study area would also contribute to localized and temporary detrimental effects to noise quality. TxDOT projects may result in a permanent contribution to noise levels (see Table 4.15-2); however, the effects on noise from many assessed projects are unknown. Although short-term and localized impacts would occur during construction, the GRP Alternative would not contribute to a long-term cumulative degradation in noise quality in the study area.

Water Quality

The study area's rapid historical growth has resulted in a decrease in water quality (Auch et al., 2004) and is a driver of the GRP Alternative. Flood risk management measures would concomitantly improve water quality through reduced flood elevations, increased detention times, increased detention basins, filtration through vegetation, and sequestration of contaminants through riparian and wet communities rehabilitation and establishment (USDA, 1998). Project efforts are expected to improve water quality. However, study area projects considered in the cumulative impacts analysis would be required to comply with State and Federal water quality standards, including flood regulations, Storm Water Pollution Prevention Plan (SWPPP), and BMPs. With the implementation of a SWPPP and BMPs such as silt fencing and straw bale barriers, the GRP Alternative would not contribute to cumulative water quality impacts in the study area. Some area projects would increase impervious cover, but others, like the Armand Bayou Watershed Plan and CBMB (see Table 4.15-2), may ameliorate any potential detrimental impacts to water quality.

Sediment Quality

Sediment quality impacts of some projects reviewed for this assessment are unknown; however, for projects where contaminant spills or leaks are a potential adverse effect, prevention and response plans would be implemented. BMPs associated with SWPPPs, which may include silt fencing and straw bale barriers, may also prevent a degradation of sediment quality. The GRP Alternative includes flood reduction measures that would maintain sediment quality indirectly through establishment of vegetation, potential to reduce erosion, and rehabilitation of creek sinuosity and morphology. Additionally, none of the sediment analyses conducted for this project identified cause for concern. Lastly, the CBMB and Armand Bayou Watershed Plan would also improve sediment quality through rehabilitation of watersheds (see Table 4.15-2). The GRP Alternative would not contribute to cumulative sediment quality impacts in the study area.

Circulation and Tides

Hydrological modeling suggests that the GRP Alternative would improve circulation and flows within Clear Creek, relative to flood damages. A second outlet from Clear Lake to Galveston Bay was implemented to increase flow through Clear Lake and decrease flood elevations in the lower Clear Creek watershed. The Clear Creek second outlet channel and gated structure were both constructed by the USACE as a part of the Clear Creek AFP. These features of the AFP are located near SH 146 just north of the natural outlet of Clear Lake into Galveston Bay. The purpose of constructing the Second Outlet Channel was to provide an additional outlet for flood flows associated with proposed upstream channel improvements to continue into Galveston Bay without aggravating flooding problems within Clear Lake. The Second Outlet gates were included to reduce sediment inflow into the channel, lessen impacts of currents on navigation adjacent to the second outlet channel, and to prevent changes in tidal inflow and salinity intrusion through the second outlet from causing changes to the existing hydraulic and environmental conditions of Clear Lake. The Second Outlet Channel was designed as a gated structure, which is opened periodically during flooding events to mitigate induced flood flows from the Clear Creek AFP; the gates normally remain closed under normal flow conditions to reduce sediment inflow into the channel, lessen impacts of currents on navigation adjacent to the Second Outlet Channel, and to prevent changes in tidal inflow and salinity intrusion through the Second Outlet from causing changes to the existing hydraulic and environmental conditions of Clear Lake. Construction on the Second Outlet Channel began in August 1996 and was completed in July 1997. Construction of the Second Outlet gated structure began in May 1989 and was completed in March 1991; it was rehabilitated in 1997 and repaired in 2009 following damages from Hurricane Ike. The Second Outlet Channel and gated structure were the only features of the Clear Creek Authorized Federal Project that were constructed at the time the current GRR study was initiated (USACE, 1993, 1997b).

Some of the projects, such as proposed detention areas and mitigation banks, and the GRP Alternative, are not expected to alter tides but would improve freshwater inflow patterns into Clear Lake. The GRP Alternative would not contribute to cumulative circulation and tidal impacts in the study area.

Soils

The GRP Alternative would affect area soils by manipulating substrates and impacting prime farmland; however, BMPs would be implemented during substrate manipulation, and existing prime farmland is not used for farming purposes in the area. Other area projects may impact surface soils from potential releases of petroleum products during construction. However, the use of BMPs for potential hazardous material spills that could occur in the project area would greatly minimize the potential for this type of impact. Given the amount of impervious cover and development, the implementation of BMPs, and notably the lack of prime farmland in current production, the GRP Alternative would not contribute to cumulative soil impacts in the study area.

4.15.3.3 Cultural and Socioeconomic Resources

Cumulative impacts to socioeconomic resources are varied and are based on general trends in economic potential, access to recreation, and the potential threat to public health and safety. Cumulative impacts to cultural resources may result from derivative development and soil disturbance or loss of unique or irreplaceable sites or complexes of sites.

Environmental Justice

The project area population is not considered to be a minority or a low-income population. The GRP Alternative should reduce the risk of flood impacts for those living within the study area. Therefore, the GRP Alternative would not result in disproportionately high or adverse impacts to minority or low-income populations. Additionally, the GRP Alternative would neither divide nor isolate any particular neighborhood nor separate residents from community facilities. The GRP Alternative would potentially increase the number of community facilities as a result of potential new land being available for development. Therefore, there would be no adverse effect to community cohesion or values as a result of this alternative.

Environmental justice effects from other assessed projects are largely unknown; however, the Brio/Dixie Oil Superfund remediation would beneficially contribute to environmental justice (see Table 4.15-2). The GRP Alternative would not contribute negative cumulative effects to environmental justice in the study area.

Cultural Resources

Regarding the GRP Alternative, field investigations determined that most of the project area has been disturbed due to urban development and thus has a low potential to yield intact archeological sites. Discovery of potentially protected features/sites during construction and maintenance activities will require verification and further coordination with the SHPO.

A Programmatic Agreement (Appendix F-1) among the USACE, the SHPO, HCFCD, BCDD4, and Galveston County has been prepared to guide implementation of the proposed Clear Creek Project. The Programmatic Agreement makes stipulations to take into account the effects of the proposed project on historic and cultural resources and to satisfy the USACE Section 106 responsibilities for all individual aspects of the project. Any impacts to NRHP-eligible properties will be mitigated under the conditions set forth in this Programmatic Agreement.

Activities associated with any of the reviewed projects have the potential to adversely affect unknown cultural resources by altering the integrity of the location, design, setting, materials, construction, or association contributing to a resource's significance (related to NRHP eligibility criteria). If other foreseeable projects comply with appropriate Federal and State cultural resource regulations, it would be unlikely that cultural resources would undergo a detrimental cumulative effect in conjunction with the GRP Alternative within the study area.

Recreation

Several assessed projects (including the GRP Alternative via creation of green space, trails, etc.) would contribute to recreational opportunities in the study area. CBMB, Armand Bayou Watershed Plan, Buffalo Bayou Camp Recreational Improvements, and Pearland Park and Trail Improvements would most likely contribute to a cumulative increase in recreational opportunities and areas. The GRP Alternative, in conjunction with other assessed projects, would contribute beneficial cumulative effects regarding recreational opportunities.

Commercial and Recreational Fisheries

The GRP Alternative would potentially affect commercial and recreational fisheries positively. Project flood reduction measures would directly and indirectly (e.g., creation of aquatic sites, rehabilitation of stream hydrogeomorphology, vegetation plantings) benefit fisheries in Clear Creek, its tributaries, and downstream into Clear Lake and Galveston Bay. CBMB and Armand Bayou Watershed Plan would also contribute direct and indirect positive effects on fisheries resources. Other assessed projects are not expected to result in negative effects to the resource. The GRP Alternative, in conjunction with other assessed projects, may contribute beneficial cumulative effects to commercial and recreational fisheries.

Oil and Gas Production

Oil and gas production would not be impacted by the GRP Alternative. Other area projects are not expected to impede or negatively affect oil and gas production. Some projects, such as pipelines, are expected to positively affect oil and gas resources. The GRP Alternative is not expected to contribute to negative cumulative effects on oil and gas production.

Public Health and Safety

The GRP Alternative would contribute to increased public health and safety by reducing flood damages, improving water quality, and providing recreational opportunities. Other projects in the area, such as roadway and drainage improvement projects, mitigation banks, watershed plans, and remediation efforts, would also contribute to public health and safety. The GRP Alternative, in conjunction with other assessed projects, would contribute beneficial cumulative effects on public health and safety.

4.15.4 Conclusions

Historically, the study area has undergone rapid development and growth, which has resulted in decreased quality of some environmental resources such as air and water (Auch et al., 2004). Some past projects, such as the Brio/Dixie Oil Superfund Site, resulted in significant environmental damages in the area. Impervious cover increases altered flood events and intensities. Recently, some environmental resources may have improved (e.g., air quality; TCEQ, 2008c) and projects with objectives similar to the GRP Alternative may promote further improvement trends for environmental resources.

Cumulative impacts from past, existing, and reasonably foreseeable future projects, along with the GRP Alternative, are not expected to have significant adverse effects within the study area. With the exception of direct impacts to air quality during construction (temporarily and locally), the GRP Alternative is expected to contribute beneficially to air quality (long-term), vegetation, wildlife, water quality, recreation, public health and safety, and commercial and recreational fisheries.

Although the effects of many assessed projects are unknown, it is assumed that many projects would adhere to State and Federal regulations, thus reducing potential for significant impacts to resources. Other major projects (e.g., Bayport Loop Rail and previous Clear Creek flood control projects) are expected to negatively affect an environmental resource; however, the GRP Alternative is not expected to contribute negative cumulative impacts to the area.

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5.0 MITIGATION

This chapter discusses the evaluation of mitigation alternatives for the GRP Alternative, and presents the recommended Mitigation Plan that has been developed in consultation with the appropriate resource agencies. Mitigation is necessary because unavoidable impacts to significant resources remained after efforts to avoid and minimize impacts were exhausted. The mitigation plan compensates for unavoidable impacts of the GRP Alternative to floodplain forest.

This chapter is divided into six sections: Section 5.1 summarizes Federal policy and regulatory requirements for mitigation plans, and mitigation objectives that were followed in the plan's development. Section 5.2 provides a brief history of the development and coordination of the recommended Mitigation Plan, including application of the HEP model. Section 5.3 summarizes impacts of the GRP Alternative and describes efforts taken to avoid and minimize those impacts. Section 5.4 discusses the evaluation of alternatives for the mitigation of unavoidable impacts, and Section 5.5 presents the recommended Mitigation Plan.

As described in Section 2.3.5, protection and reestablishment/rehabilitation features are incorporated into the GRP Alternative. The proposed compensatory mitigation for unavoidable impacts includes only reestablishment/rehabilitation of habitat. Definitions for protection, re-establishment, and rehabilitation can be found in Section 2.1 and the glossary. These definitions are consistent with 33 CFR 332.2 (Compensatory Mitigation for Losses of Aquatic Resources: Definitions). General actions that constitute reestablishment/ rehabilitation include removal of development pressure, controlling invasive/exotic vegetation species, and planting of native vegetation.

5.1 MITIGATION PLANNING

In the evaluation of ecological impacts of the GRP Alternative, rehabilitation opportunities have been incorporated into the designs and adverse impacts have been avoided and minimized to the greatest extent practicable, as required by national policy (Section 906(d), Water Resources Development Act [WRDA] 86, as amended), national environmental laws and executive orders, and USACE regulations (Engineer Regulation 1105-2-100 as amended). Unavoidable damages to these resources have been compensated to the extent justified and are described below.

5.1.1 Compliance with Federal Requirements

It is national policy that ecosystem rehabilitation and protection be given equal consideration with other study purposes in the formulation and evaluation of alternative plans. Adverse impacts to ecological resources that are caused by a proposed project must be avoided or minimized to the extent practicable, and remaining unavoidable impacts must be compensated to the extent justified. The GRP Alternative must contain sufficient mitigation to ensure that the Clear Creek Project would not have more than a minor adverse impact on significant ecological resources (Section 906(d), WRDA 86 as amended).

Implementation guidance for Section 2036(a) of WRDA 07 (Mitigation for Fish and Wildlife and Wetland Losses), issued August 31, 2009, requires that water resource projects resulting in wetland impacts within the service area of a mitigation bank shall first consider the use of a bank (assuming appropriate credits are available).

The use of mitigation banks was considered in mitigation planning to compensate for project impacts to forested riparian wetland resources. The GRP Alternative occurs in the service areas of the following existing mitigation banks: Mill Creek Mitigation Bank (MCMB), Greens Bayou Wetlands Mitigation Bank (GBWMB), Katy-Cypress Mitigation Bank (KCMB), and CBMB.

Use of credits from the CBMB for mitigation of impacts associated with the Clear Creek GRP Alternative is prohibited by the banking instrument, as this bank is only available for use as mitigation for TxDOT projects. While the MCMB, GBWMB and KCMB have the appropriate type of credits available for mitigation for impacts resulting from the GRP Alternative, potential project impacts were modeled with a different method (i.e., Floodplain Forest HEP model; see Appendix B) than models required by the banking instruments to determine the appropriate credits to mitigate (e.g., Hydrogeomorphic Model [HGM]).

Central to this requirement is the determination of significance, as mitigation is required only for impacts to significant resources. Significance must be based upon the contribution of the resource to the Nation's economy and technical, institutional, and/or public recognition of the value of the resource. Criteria for determining significance include, but are not limited to, scarcity or uniqueness of the resource from a national, regional, State, or local perspective. The interagency E-Team for the project identified three significant ecological communities present in the study area: floodplain forest, coastal prairie and associated wetlands, and tidal marsh. These habitats are also considered significant and vulnerable by the participants in workshops held to characterize baseline conditions and develop models of the study area in support of the plan formulation and assessment of alternatives. Loss of forested wetlands in coastal Texas has been documented by the TPWD (2007e). It is important to note that models were initially developed under this effort to evaluate tidal marshes and coastal prairies within the Clear Creek watershed. However, further investigation of the problems and opportunities surrounding both the proposed plans and their subsequent mitigation requirements indicated these resources would not be affected by the GRP Alternative.

Mitigation may include avoiding and minimizing project impacts to ecological resources, rectifying impacts by rehabilitating the affected environment and reducing or eliminating impacts with maintenance operations during the life of the project. Replacements of fish and wildlife resources are generally made “in-kind,” but substitutions, or replacements “out-of-kind,” are also acceptable mitigation if they are at least equal in value and significance to the resources lost. The community HEP model, described in subsection 5.2.2, quantifies impacts to ecological communities in the study area and provides a means to establish the appropriate amount of offsetting benefits or compensating mitigation. Recommended mitigation features must be justified by an incremental analysis, which identifies the least-cost mitigation plan by demonstrating that the value of the last increment of losses prevented, reduced, or replaced is at least equal to the costs of the last added increment. An incremental analysis of mitigation alternatives is provided in Appendix B.

5.1.1.1 Resource Significance

As previously mentioned, central to mitigation requirements is the determination of significance. Field data, public views, and professional judgments argue that forested riparian habitat within the Clear Creek floodplain is a significant resource, based on institutional, public, and technical recognition.

Upland and riparian woodlands along Clear Creek provide excellent habitat for a variety of year-round and seasonal resident songbirds and also provide critical stopover habitat for numerous species of neotropical songbirds during migration along the Central Flyway. A number of sites along Great Texas Coastal Birding Trail – Upper Texas Coast Wildlife Trail (UTC) have been designated along Clear Creek to offer shelter to migratory birds passing through the area. The parks along Clear Creek include Nassau Bay Park (UTC 083), Challenger 7 Memorial Park (UTC 084), and Walter Hall County Park (UTC 085). Many of the eastern woodland birds can be found at the Challenger 7 Memorial Park, and white-tailed hawks often nest in the general area. Walter Hall County Park and Nassau Bay Park offers visitors a variety of outdoor activities along Clear Creek, including birding.

Locally, Clear Creek’s public significance is evident by the amount of public interest and controversy generated over the project from national, State, and local perspectives. National evidence of Clear Creek’s public significance is supported by the waterways designation in 2000 as one of America’s 10 most endangered rivers by American Rivers, a national nonprofit organization founded in 1973 to foster river stewardship ethic and promote public awareness about the importance of healthy rivers and the threats they face. Clear Creek received its most endangered river designation based on impacts associated with proposed flood control plans (i.e., the AFP and SPA). These plans would have converted the natural meandering areas of what is considered one of Houston’s last remaining bayous into a uniform channel with stabilized banks. This disruption causes natural flooding, eliminates forested, wetland, and aquatic riparian habitats utilized by fish, birds, and wildlife, and the destruction of the natural beauty of Clear Creek and much of its floodplain, which provides a small amount (10-year level) of flood protection (American Rivers, 2010).

In an article featured in the *Houston Chronicle* in December 1997, Jarrett "Woody" Woodrow, then Regional Coordinator for Resource Protection of TPWD's Seabrook Marine Laboratory, noted that this type of Texas hardwood bottomland forest is under constant threat and the areas along Clear Creek have become particularly valuable for wildlife as coastal Texas has become more developed and the lush forests that once predominated are nearly gone.

Local opposition to channelization practices on Clear Creek like those proposed in the AFP and SPA also reflects the importance of this resource to the public. Local groups like the Bayou Preservation Association, the Galveston Bay Conservation and Preservation Association, the Friends of Clear Creek, the Armand Bayou Nature Center, and the Galveston Bay Foundation are opposed to traditional channelization plans that would destroy habitat and alter the natural conditions of the main bayou channel, and instead favor alternative methods that preserve the natural waterways (e.g., buyouts, regional detention ponds, bypass channels, and restrictions on development in the floodplain). Additional local controversy in the form of tension between the upstream and downstream communities of Clear Creek further reflects the public significance of this resource. Residents living in the downstream reaches of Clear Creek are concerned that a channel project will cause increased flows to their end of the creek, which is prone to flooding, while those living upstream are in favor of the project because of the repeated floodings that have impacted their homes.

In reflection of the importance of Clear Creek to the local public, two advisory committees were created by the non-Federal sponsors: the Clear Creek Steering Committee (CCSC), which comprises representatives of various municipalities in the watershed, and a Citizen Advisory Committee (the CAC), which includes residents and environmental groups and leaders of the area. These committees provide stakeholder input and feedback to the non-Federal sponsors in evaluating flood risk management alternatives on Clear Creek during the reevaluation process.

Field data collected in support of the GRR and recent professional judgments of Federal and State resource protection agencies argue that the riparian forest within the Clear Creek floodplain is a significant resource based on technical merits. While the habitat is a rapidly declining resource, it still contains areas that are representative of the natural riparian habitat of the watershed and surrounding areas of the Houston-Galveston region.

Over the last 100 years, increased flooding along Clear Creek and its tributaries as a result of the cumulative effects of rapid urban development has led to hydrological alterations (e.g., channelization and detention) causing considerable degradation of stream habitat and morphology. While the lower half of Clear Creek has remained a relatively natural meandering channel system with much of its riparian forest habitat intact, the upper portion of Clear Creek and many of its tributaries (e.g., Turkey Creek, Mud Gully, and Mary's Creek) have been extensively channelized resulting in straighter, trapezoidal-shaped, grass-lined channels with almost no trees along the banks to provide instream habitat or overhead cover.

Increased urbanization and concomitant past and present flood risk management practices (e.g., channelization and detention basin construction, etc.) within the Clear Creek floodplain has also led to extensive fragmentation of the riparian forest habitat. The result is a forest community composed of numerous but smaller, more closely spaced patches of forest with smaller interior (core) and edge areas. Another consequence of increased urbanization and associated habitat fragmentation is the colonization of floodplain forest by unwanted, nonnative, invasive species such as privet (*Ligustrum sinense* and *L. japonicum*) and Chinese tallow (*Triadica sebiferum*). Continued development within the Clear Creek floodplain is expected to reduce the quality and quantity of the riparian forest community along the waterway, exacerbate the effects of forest fragmentation, and lead to increased abundance of invasive exotic species.

Despite these declining trends, some remaining areas of riparian forest along Clear Creek like that found near FM 2351 (i.e., Frankie Carter Randolph Park in Harris County) are still considered to be representative of the natural forest plant community desired for rehabilitation or reestablishment along the upper reaches of Clear Creek. This type of forest is temporarily flooded and dominated by green ash (*Fraxinus pennsylvanica*) and water elm (*Planera aquatica*); it is considered representative based on the density and species composition of these dominant and other woody plants (Rosen and Schubert, 2005). The floodplain forest within and along Clear Creek within Frankie Carter Randolph Park occurs within a stretch of Clear Creek that has not been channelized or extensively modified by development. The creek in this location retains its natural sinuousity (meandering characteristics) with trees in and along the low-flow channel that provide the creek with habitat and shade from overstory and instream cover.

5.1.1.2 No Net Loss

USACE regulations (Engineer Regulation 1105-2-100) recognize wetland resources and bottomland hardwoods for special consideration in mitigation planning; these resource types are affected by the GRP Alternative. Impacts to bottomland hardwood forests must be mitigated in-kind. Impacts to wetlands must be fully mitigated, and projects must meet the goal of no net loss of wetland functions and values.

Implementation of the GRP Alternative would support the national objective of no net loss of wetlands in acres and function. Permanent impacts to 29.3 acres of wetlands would be offset in-kind by the preservation and restoration (rehabilitation and reestablishment) of floodplain forest in the avoidance and minimization features of the GRP Alternative, and the compensatory mitigation plan (as detailed in subsection 4.9.3.2 and shown in Table 4.9-6 and Figure 3.9-2). Compensatory mitigation includes the rehabilitation and/or reestablishment of 31 acres of floodplain forest, which constitutes 21.1 acres of wetlands. Combining compensatory mitigation wetlands (21.1 acres), wetlands avoided (12.2 acres), and wetlands rehabilitated within the existing low-flow channels and adjacent riparian vegetation (an anticipated 7.3 acres of reestablished wetlands), 40.6 acres of wetland would be preserved, rehabilitated and/or reestablished within the project and compensatory mitigation area footprint (see Table 4.9-6 and Figure 3.9-2). Based on HEP modeling, functional benefits to floodplain forest would also be achieved through implementation of the GRP Alternative. Terrestrial and wetland reference, impact, and mitigation sites within the floodplain forest cover type were evaluated so that impacts to wetland function could be incorporated into the HEP assessment. Thus the community-based HEP model incorporates the capability to evaluate the combined functional affects to floodplain forest and its associated wetlands (Appendix B).

5.1.2 Mitigation Planning Objectives

The following objectives were established to evaluate rehabilitation and mitigation measures considered for the Clear Creek Project.

- Replace lost habitat quality on a one-to-one basis as measured by AAHUs for a minimum of 106 AAHUs of floodplain forest.
- Replace habitats in-kind to the maximum extent practicable.
- Contribute to the rehabilitation of fish and wildlife resources of Clear Creek and its tributaries.
- Preserve and protect natural, cultural, and historical resources for public education and outreach.
- Meet goal of no net loss of wetlands.

These objectives reflected the most significant expected impacts of the project, widespread interest in potential rehabilitation of habitats, water quality and resource protection, the national policy objective to prevent wetland loss, and USACE requirements to fully compensate for project-caused adverse effects.

5.2 HISTORY OF DEVELOPMENT AND COORDINATION OF THE RECOMMENDED MITIGATION PLAN

5.2.1 Multidisciplinary Ecosystem Assessment Team Involvement

Since the primary environmental concerns are the interrelated issues of wetland losses and destruction of wildlife habitat and fishery areas, an interdisciplinary team (E-Team) was formed in 2003 as a working group to oversee the development and application of the community-based HSI model used to evaluate ecological effects of the Clear Creek Project. This modeling effort played an integral role in the development of future without- and with-project conditions and was used to compare the effectiveness of mitigation measures. E-Team participants included representatives from the USACE, TCEQ, USFWS, NRCS, TPWD, EPA, Texas GLO, GBNEP, BCDD4, Galveston County, and the HCFCD. The technical expertise necessary to support planning efforts included, but was not restricted to, representatives from botany, soils, hydrology, and wildlife ecology disciplines. The E-Team also included individuals who were responsible for project design and management (i.e., engineers, project managers, NEPA consultants, and cost-share sponsors).

5.2.2 Ecological Modeling

The values of the ecological resources arise primarily from the quantity and quality of fish and wildlife habitat in the study area. Therefore, a habitat-based ecological model was used to evaluate the impacts of proposed flood control measures and the benefits of potential mitigation measures. A comprehensive report of this modeling effort is attached as Appendix B to this document. Appendix B maps and characterizes all significant habitats in the study area, describes the ecological model that was selected to evaluate project impacts and benefits, describes the methods and assumptions used in the modeling process, assesses impacts of the GRP Alternative versus the FWOP (No Action Alternative), and evaluates the effectiveness of avoidance and mitigation measures in AAHUs.

The HEP methodology is an environmental accounting process developed to appraise habitat suitability for fish and wildlife species in response to potential change (USFWS 1980a, 1980b, 1980c). HEP is an objective, quantifiable, reliable, and well-documented process used nationwide to generate environmental outputs for all levels of proposed projects and monitoring operations in the natural resources arena. HEP provides an impartial look at environmental effects and delivers measurable products to the decision-maker for comparative analysis.

In HEP, a Suitability Index (SI) is a mathematical relationship that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type. These suitability relationships are depicted using scatter plots and bar charts (i.e., suitability curves). The SI value (Y-axis) ranges from 0.0 to 1.0, where an SI = 0.0 represents a variable that is extremely limiting, and an SI = 1.0 represents a variable in abundance (not limiting) for the species or community. An HSI model is a quantitative estimate of habitat conditions for an evaluation species or community. HSI models combine the SIs of measurable variables into a formula depicting the limiting characteristics of the site for the species/community on a scale of 0.0 (unsuitable) to 1.0 (optimal).

5.3 IMPACTS SUMMARY

The primary impact of the GRP Alternative is the loss of 278 acres of floodplain forest over the period of analysis. Impacts to land cover types used in the HEP analysis from the GRP Alternative footprint can be seen on Figure 5.3-1. These adverse effects are caused by the changes in landforms, hydrologic characteristics, and vegetative cover associated with conveyance improvements and storage features of the project. Design elements were incorporated into the GRP Alternative, providing for the preservation/rehabilitation and

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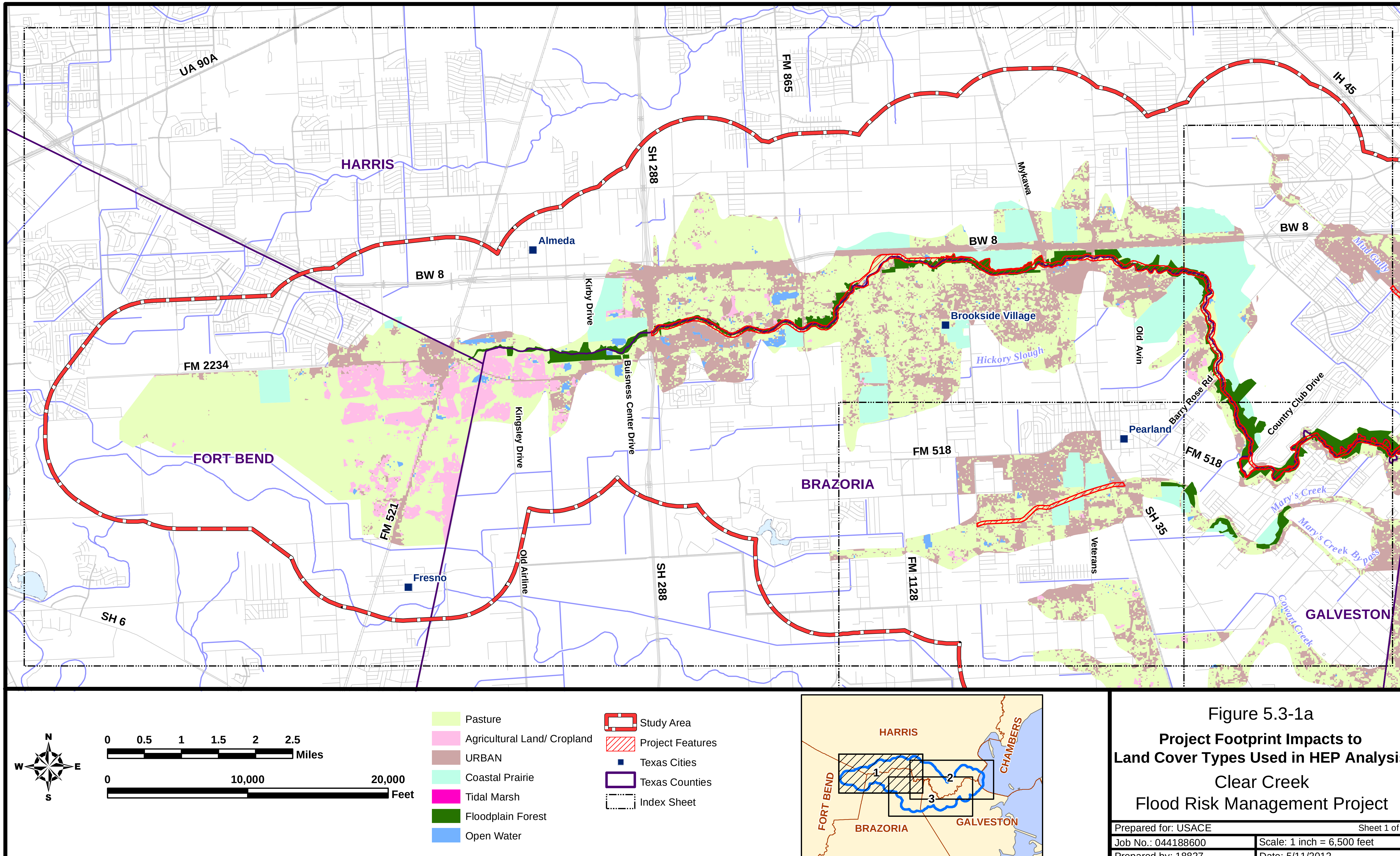

Figure 5.3-1a

Project Footprint Impacts to Land Cover Types Used in HEP Analysis

Clear Creek

Flood Risk Management Project

Prepared for: USACE	Sheet 1 of 3
Job No.: 044188600	Scale: 1 inch = 6,500 feet
Prepared by: 18827	Date: 5/11/2012

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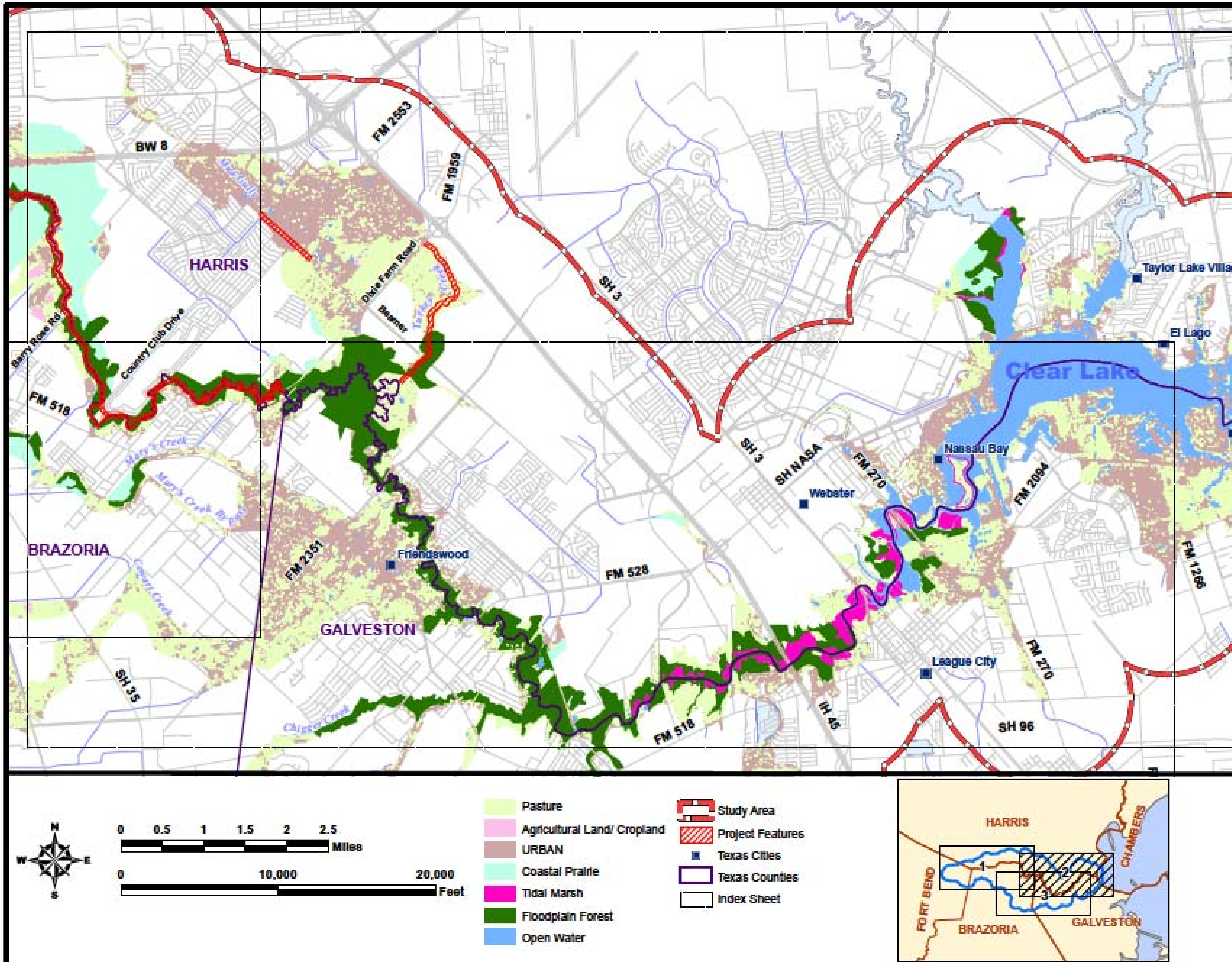

Figure 5.3-1b

Project Footprint Impacts to Land Cover Types Used in HEP Analysis

Clear Creek Flood Risk Management Project

Prepared for: USACE | Sheet 2 of 3
Job No.: 044188600 | Scale: 1 Inch = 6,500 feet
Prepared by: 18827 | Date: 5/11/2012

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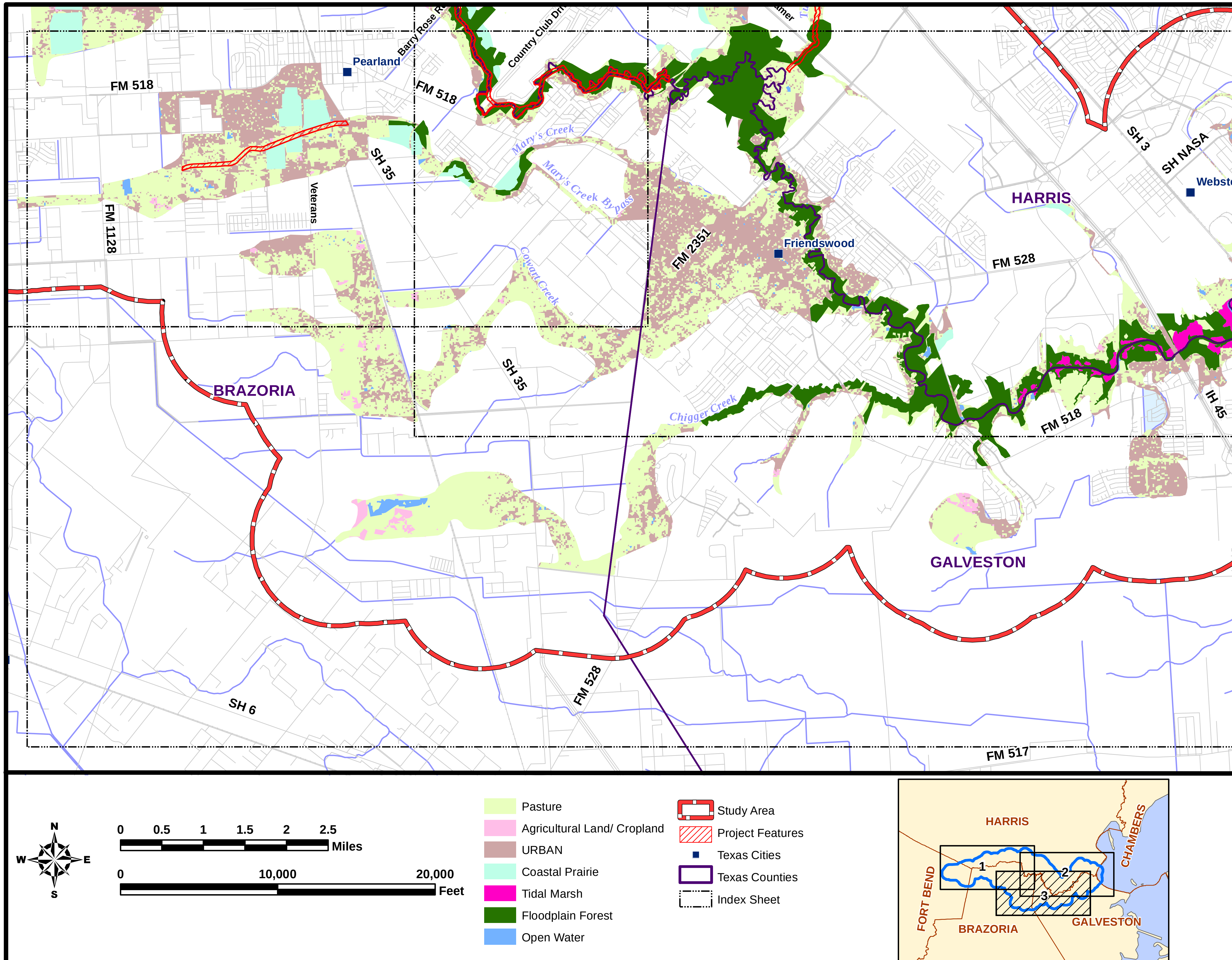

Figure 5.3-1c

Project Footprint Impacts to Land Cover Types Used in HEP Analysis

Clear Creek Flood Risk Management Project

Prepared for: USACE	Sheet 3 of 3
Job No.: 044188600	Scale: 1 inch = 6,500 feet
Prepared by: 18827	Date: 5/11/2012

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reestablishment of 155 acres of floodplain forest in the project area. While this habitat acreage is not part of the compensatory mitigation for the project, it has been incorporated into the project in an effort to avoid/minimize impacts from the project.

The effects of the GRP Alternative on the floodplain forest (and associated forested wetlands) was determined using the community-based HSI models. A detailed discussion of the HSI modeling and impacts analysis is provided in the Ecological Modeling Report (see Appendix B) and is not repeated here. In the discussion below, impacts and mitigation measures are presented in acres and AAHUs for the HSI modeling of the project area.

After incorporating avoidance and minimization features into the GRP Alternative, the unavoidable net loss in ecological value of the floodplain forest is 106 AAHUs. Acres lost due to impacts in the GRP Alternative conditions are summarized for floodplain forest in Table 5.3-1.

Table 5.3-1
General Reevaluation Plan Alternative
Floodplain Forest Impacts and Mitigation from Year 2000 to 2070

Flood Risk Management Features			Compensatory Mitigation (Vegetation Community Reestablishment and Rehabilitation)		
Acres					
Unavoidable Impacts	Design Features Providing On-site Avoidance/ Minimization	Net AAHUs	Acres	AAHUs	Net Overall AAHUs
278	155	–106	31	131	25

5.3.1 Avoidance and Minimization Elements of the General Reevaluation Plan (GRP) Alternative

The GRP Alternative was designed to avoid and minimize impacts to floodplain forest in areas where doing so would be compatible with the flood risk management measures. The GRP includes the preservation and rehabilitation of 122 acres of floodplain forest in the riparian zone and adjacent to the low-flow channel and the reestablishment of 33 acres to avoid and minimize impacts to habitat structure and function. Other features for the GRP Alternative, such as the Mud Gully and Mary’s Creek conveyance, were located in areas that have already been extensively altered by channelization and maintenance activities to avoid impacts to existing habitats while maintaining functionality for flood risk management.

Rehabilitation and reestablishment of floodplain forest serve as effective and essential mitigation instruments to offset impacts in the Clear Creek watershed based on historic and projected local, regional, and national trends for this resource. Forested wetlands, a classification inclusive of wetter floodplain forest areas, are perhaps the most rapidly disappearing wetland type in the United States (Moulton et al., 1997; TPWD, 2007e; Wagner, 2004). Since the mid-1950s, forested wetlands on the Texas coast have decreased in area by approximately 11 percent, which represents a net loss of more than 96,000 acres (Moulton et al., 1997; Jacob et al., 2004; TPWD, 2007; Wagner, 2004). A recent study by Jacob and Lopez (2005) indicated a loss of 6 to 25 percent of wetlands within the Clear Creek area (depending on location) between 1992 and 2000–2002, with a similar trend apparent across the six-county study area.

Multiple interacting factors contribute to the loss and degradation of floodplain forest in the northwestern Gulf Coast, including development, agriculture, cattle grazing, logging activities, and invasive species (Barrow et al., 2005). However, Jacob and Lopez (2005) detected a strong correlation between wetland loss and urban development (i.e., industrial, commercial, and residential development). Increased urbanization within the Clear Creek floodplain has led to extensive fragmentation of floodplain forest habitat, yielding small patches of forest with larger edge effects, and introduction of invasive, nuisance, and exotic plant species. This trend is projected to continue, with Wear et al. (2004) forecasting a decrease of 10 percent of interior forest (not including forest edge typical of more-fragmented forests) for the Houston area from 1992 to 2020. The estimated combined population for Pearland and Friendswood in the Clear Creek watershed is projected to increase from 56,600 in 2010 to 165,000 in 2050—a population increase of almost 300 percent (see Appendix B, Table 12). Therefore, rehabilitation and reestablishment of floodplain forest in the Clear Creek watershed represent essential mitigation measures to prevent the loss of values these communities provide.

5.4 EVALUATION OF ALTERNATIVES FOR THE MITIGATION OF UNAVOIDABLE IMPACTS

5.4.1 Preliminary Screening of Alternatives

Twenty-seven mitigation measures were initially conceived and assessed with HEP at a screening level. Where possible, the E-Team devised strategies to rehabilitate and restore floodplain forest at the same locale, thereby addressing concerns of lost spatial heterogeneity and complexity while taking advantage of the cost savings of performing these activities in the fewest possible locations. The E-Team culled measures that did not meet the in-kind mitigation requirements and/or did not address the spatial connectivity and complexity requirements. Plans were refined to optimize outputs where possible. For example, the original array of mitigation measures included tidal marsh and coastal prairie features. However, because floodplain forest was the only community type impacted by the project, these measures were removed from consideration. In some instances, proposed mitigation measures required compensation to existing property owners to acquire new mitigation areas that potentially provided ancillary flood risk management benefits; however, many of these were dropped from consideration due to the considerable costs involved and implementation considerations. Some measures offered less than full mitigation of habitat losses but generated reasonable amounts of benefits, and as such, offered an opportunity to partially mitigate habitat losses in the region. Because these options might serve as partial fulfillment of the mitigation requirements, and could be combined with additional measures to fully meet the demand for replacement of impacted ecosystem function, these measures were retained and included in the final comparative array. The final array included 12 measures, spanned 5 reaches of the project, and offered a range of AAHU outputs at varying degrees of costs sufficient to offset losses and move forward into cost effective and incremental cost comparisons (Figure 5.4-1). A brief description of each of the 12 measures evaluated follows.

5.4.1.1 Eco-Reach 6-A1a and Eco-Reach 6-A1b

The A1 measure, located in ER 6, proposed the preservation of 20 existing acres of floodplain forest. Intensive O&M (including reconnaissance, removal, and foliar applications to control invasive, noxious, and exotic species) would be performed annually for 35 years. The A1a versus A1b increments of this mitigation measure were formulated to include varying acreages of forested wetlands: (A1a) 20 percent of the site would consist of forested wetlands[1], or (A1b) 30 percent of the site would consist of forested wetlands. The measure would require the purchase of vacant land south of Beltway 8 east of Mykawa Road.

5.4.1.2 Eco-Reach 6-A2a

The A2a measure (also in ER 6) proposed the preservation of 29 existing acres of floodplain forest and the conversion of 9 acres of urban areas and pasturelands to newly planted floodplain forest, with a minimum of 20 percent of the site would consist of forested wetlands. The measure would require the purchase of vacant land south of Beltway 8 west of Mykawa Road.

5.4.1.3 Eco-Reach 4-C1 and Eco-Reach 5-C1

The C1 measure's footprint spanned two reaches (ERs 4 and 5) and offered the reestablishment of the low-flow channel to mimic the 1955 sinuosity regime of the Clear Creek mainstem by reconnecting low flow and meanders within 13 remnant scattered throughout the system between Country Club Drive and Dixie Farm Road that were cut off as a result of past channelization activities. This would be accomplished by modifying portions of the existing conveyance feature, diverting water into the oxbows under low-flow conditions, and maintaining high-flow conditions by converting the current channel into a high-flow bypass to guarantee flood protection for the area. Excavated material stockpiled along the north bank of the creek would be

[1] Forested wetlands would be preserved and rehabilitated or reestablished as necessary to achieve the target percent wetland (i.e., wet core area). This would be accomplished by planting forest tree species along the immediate riparian edge of Clear Creek, or by reestablishing and planting a sufficient number of very shallow (less than 6 inches) depressions throughout the site similar in size and configuration to other depressional wetlands occurring on-site or in the adjacent floodplain forest to achieve the desired wetland area. Construction would be performed using appropriate construction equipment (e.g., bulldozer with blade).

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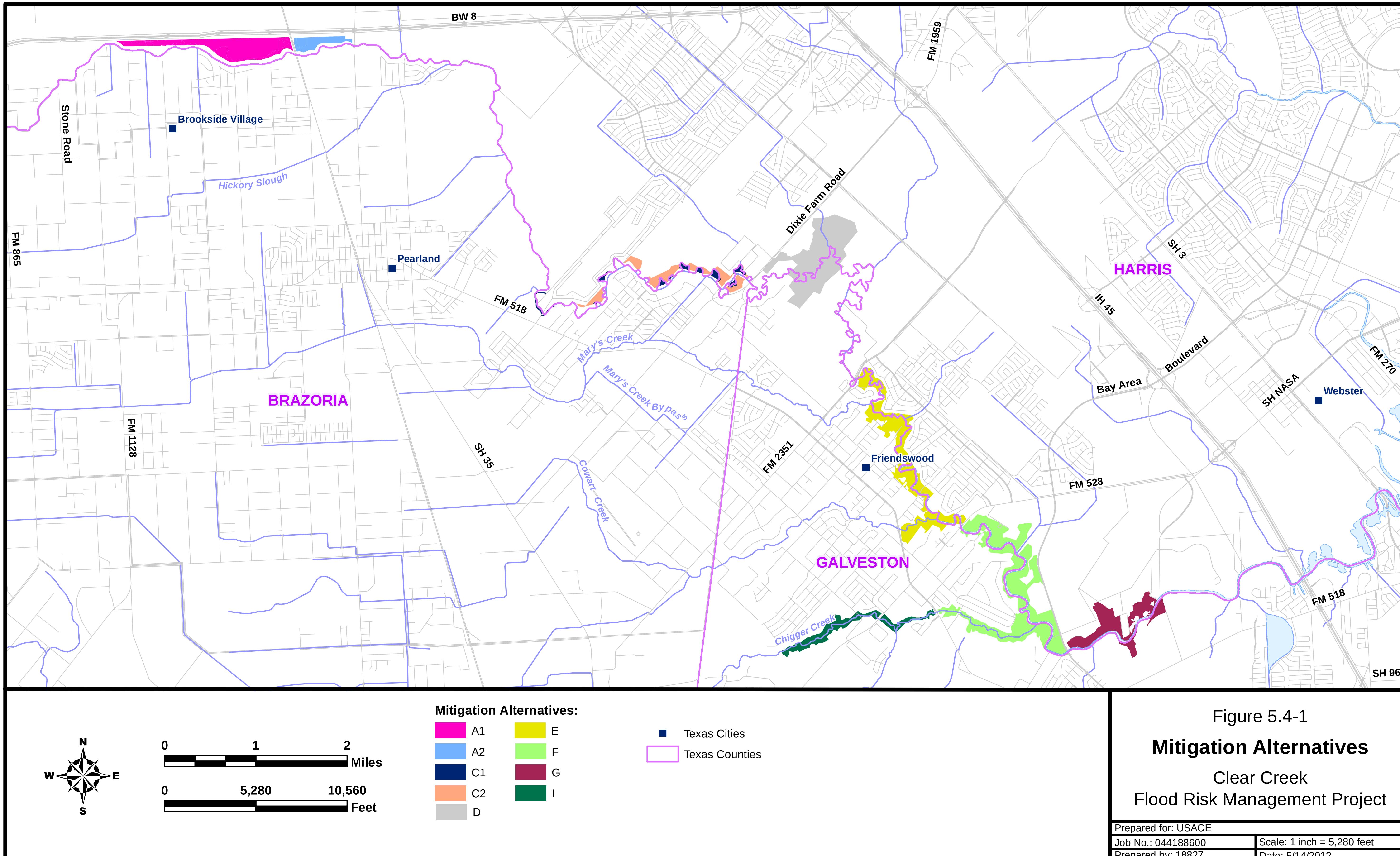

Figure 5.4-1

Mitigation Alternatives

Clear Creek

Flood Risk Management Project

Prepared for: USACE

Job No.: 044188600

Scale: 1 inch = 5,280 feet

Prepared by: 18827

Date: 5/14/2012

File: N:/Clients/U_Z/USACE/Projects/Clear_Crk/100002202/mitigation_areas_vr2.mxd

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removed. The excavated material would be deposited at a designated upland confined placement area. The locations of the placement areas would be determined during the preconstruction engineering and design phase. Attempts will be made to site the placement areas on agricultural lands, pasture, and other urban land to avoid wetlands and/or other ecological resource areas. The existing cleared overbank areas along the channel would be densely planted to restore the existing floodplain forest to a desired state. Approximately 31 acres of floodplain forest would be reestablished and/or rehabilitated.

5.4.1.4 Eco-Reach 4-C2 and Eco-Reach 5-C2

The C2 measure was a modification of the C1 measure involving the addition of 31 acres of floodplain forest rehabilitation via a reconnection of low flows and meanders within cutoff oxbows, and the additional preservation of 67 acres and rehabilitation of 5 acres of floodplain forest. A minimum of 20 percent of the sites would consist of forested wetlands.

5.4.1.5 Eco-Reach 4-D

The D measure proposed the preservation and rehabilitation of 272 acres of existing floodplain forest including the riparian corridor along Clear Creek in ER 4. This measure required the purchase of vacant land around the confluence of Clear Creek and Mud Gully adjacent to and east of Dixie Farm Road and Choate Park. A minimum of 20 percent of the site would consist of forested wetlands.

5.4.1.6 Eco-Reach 3-E

The E measure proposed the preservation and rehabilitation of 241 acres of existing floodplain forest including the riparian corridor along Clear Creek in ER 3. This measure required the purchase of vacant land along Clear Creek between FM 2351 and FM 528 (Parkwood). A minimum of 20 percent of the site would consist of forested wetlands.

5.4.1.7 Eco-Reach 2-F

The F measure proposed the preservation and rehabilitation of 388 acres of existing floodplain forest including the riparian corridor along Clear Creek in ER 2. This measure required the purchase of vacant land along Clear Creek between FM 528 and FM 518. A minimum of 20 percent of the site would consist of forested wetlands.

5.4.1.8 Eco-Reach 2-G

The G measure proposed the preservation and rehabilitation of 144 acres of existing floodplain forest including the riparian corridor along Clear Creek in ER 2 as well. This measure required the purchase of vacant land along Clear Creek between FM 518 and Challenger 7 Park. A minimum of 20 percent of the site would consist of forested wetlands.

5.4.1.9 Eco-Reach 2-I

The I measure proposed the preservation and rehabilitation of 91 acres of existing floodplain forest including the riparian corridor along Chigger Creek near its confluence with Clear Creek in ER 2. This measure requires the purchase of vacant land along Chigger Creek from FM 518 to approximately 9,000 feet upstream. A minimum of 20 percent of the site would consist of forested wetlands.

5.4.2 HEP Results for Mitigation Measures

The HEP analysis results provide the basis for determining the benefits of the individual mitigation measures selected in the screening of mitigation alternatives. The mitigation measures would produce quantifiable benefits for the floodplain forest communities across the watershed (Table 5.4-1).

Table 5.4-1
Final Results for the Floodplain Forest Mitigation Analysis
(in AAHUs)

Mitigation Measure	ER 2	ER 3	ER 4	ER 5	ER 6	SUM of Net AAHUs
ER-6-A1a					8	8
ER-6-A1b					8	8
ER-6-A2a					20	20
ER-4-C1			97			97
ER-5-C1				34		34
ER-4-C2			117			117
ER-5-C2				34		34
ER-4-D			179			179
ER-3-E		48				48
ER-2-F	99					99
ER-2-G	65					65
ER-2-I	46					46

The single most productive measure was the D measure that produces 179 forested AAHUs in ER 4. The C2 scenario was the next most productive measure, generating 117 forested AAHUs in ER 4 and an additional 34 forested AAHUs in ER 5 (Total = 151 AAHUs). Following closely behind was the C1 measure that produces 97 forested AAHUs in ER 4 and an additional 34 forested AAHUs in ER 5 (Total = 131 AAHUs). It is important to note that 106 AAHUs were needed to fully compensate for the proposed GRP —four of these measures could stand alone as replacement measures for the predicted losses (i.e., C1, C2, D, and F).

Ultimately, the identification of suitable mitigation measures hinged upon the cost analyses comparisons of the proposed measures. The cost-effectiveness analysis and incremental cost analysis (CE/ICA) evaluated the productivity of the proposed mitigation measures for the study to identify the most-cost-effective alternative mitigation plan.

5.4.2.1 Final Screening of Ecological Mitigation Measures

The Mitigation Plan was selected by performing CE/ICA using IWR-PLAN software, which weighs the total annualized costs of the mitigation plans against their nonmonetary outputs (AAHUs).

A mitigation plan is defined as a group of mitigation measures. Cost analysis was used to identify the plans that are most efficient at producing the outputs (AAHUs); they provide the greatest increase in the value of the output variable for the least increase in cost.

All possible combinations of these measures were generated in the CE/ICA analysis to form potential mitigation plans with two exceptions:

1. the increments of measure A1 (i.e., a and b) could not be combined together, and
2. measures C1 and C2 could not be combined together.

These increments could not be combined because they represent different management measures (e.g., 20 percent wetland area versus 30 percent wetland area) applied to the same mitigation site. Cost effectiveness analyses identified the least-costly plans for each level of output. The three criteria used for identifying noncost-effective plans or combinations include (1) the same level of output could be produced by another plan at less cost; (2) a larger output level could be produced at the same cost; or (3) a larger output level could be produced at the least cost.

Incremental cost analysis compared the incremental costs for each additional unit of output. The first step was to determine the incremental cost per unit. The plan with the lowest incremental cost per unit over the No Action Alternative was the first incremental Best Buy plan. Plans that had higher incremental costs per unit for a lower level of output were eliminated. The next step was to recalculate the incremental cost per unit for the remaining plans. This process was reiterated until the lowest incremental cost per unit for the next level of output was determined. The intent of the incremental analysis was to identify large increases in cost relative to output.

Total annualized costs for the proposed mitigation measures were identified by combining the annualized first costs (including construction and monitoring costs) and annualized O&M costs for each mitigation measure using a 4.875% interest rate and a 0.053722282 amortization rate for construction (amortized over the 50-year project life) (Table 5.4-2). These costs were then added to the annualized O&M costs for each measure and summed to generate the total annualized costs per measure (Table 5.4-3). The total annualized costs of each plan (i.e., annualized first cost and annualized O&M combined), were compared against the total annualized outputs (AAHUs) generated in the HEP analyses using CE/ICA (Table 5.4-4).

Table 5.4-2
First Cost Annualization Data for the Proposed Mitigation Measures

Measures	Description	Contract Cost	Monitoring	Total	Annualized First Cost
ER-6-A1 (Forest)	20 acre restoration Floodplain Forest	4,738,450	23,692	4,762,142	255,833
ER-6-A2a	29 acre restoration/9 acres creation Floodplain Forest	2,015,770	10,079	2,025,849	108,833
ER-4-C1 + ER-5-C1	31 acres restoration Floodplain Forest	2,739,208	13,696	2,752,904	147,892
ER-4-C2 + ER-5-C2	103 acres restoration Floodplain Forest	5,634,123	28,171	5,662,294	304,191
ER-4-D	272 acres restoration Floodplain Forest	9,446,370	47,232	9,493,602	510,018
ER-3-E	241 acres restoration Floodplain Forest	8,373,210	41,866	8,415,076	452,077
ER-2-F	388 acres restoration Floodplain Forest	13,454,180.00	67,271	13,521,451	726,403
ER-2-G	144 acres restoration Floodplain Forest	5,016,465.00	25,082	5,041,547	270,843

Interest rate = 4.875%.

Amortization factor = 0.053722282.

Project Life =50 years.

Table 5.4-3
Annualized Costs Input into the Cost Analyses for the Clear Creek Mitigation Plans

Measures	Description	Annualized First Cost	Annualized O&M	Total Annualized Costs
ER-6-A1 (Forest)	20 acre restoration Floodplain Forest	255,833	192,341	448,174
ER-6-A2a	29 acre restoration/9 acres creation Floodplain Forest	108,833	116,381	225,214
ER-4-C1 + ER-5-C1	31 acres restoration Floodplain Forest	147,892	94,942	242,834
ER-4-C2 + ER-5-C2	103 acres restoration Floodplain Forest	304,191	315,454	619,645
ER-4-D	272 acres restoration Floodplain Forest	510,018	833,042	1,343,060
ER-3-E	241 acres restoration Floodplain Forest	452,077	738,100	1,190,177
ER-2-F	388 acres restoration Floodplain Forest	726,403	1,188,310	1,914,713
ER-2-G	144 acres restoration Floodplain Forest	270,843	441,022	711,866
ER-2-I	91 acres restoration Floodplain Forest	171,999	278,702	450,701

Table 5.4-4
Annualized Costs and Outputs Submitted to CE/ICA Analysis

Measures	Floodplain Forest (AAHUs)	Contract Costs ($)	Monitoring Costs ($)	Total First Costs ($)	Annualized First Costs ($)	Annualized O&M Costs ($)	Total Annualized Costs ($)	Annualized Cost per Output ($/AAHU)
ER-6-A1	8	4,738,450	23,692	4,762,142	255,833	192,341	448,174	53,801
ER-6-A2a	20	2,015,770	10,079	2,025,849	108,833	116,381	225,214	11,261
ER-4-C1 + ER-5-C1	131	2,739,208	13,696	2,752,904	147,892	94,942	242,835	1,853
ER-4-C2 + ER-5-C2	151	5,634,123	28,171	5,662,294	304,191	315,454	619,645	4,104
ER-4-D	179	9,446,370	47,232	9,493,602	510,018	833,042	1,343,060	7,503
ER-3-E	48	8,373,210	41,866	8,415,076	452,077	738,100	1,190,177	24,795
ER-2-F	99	13,454,180	67,271	13,521,451	726,403	1,188,310	1,914,714	19,341
ER-2-G	65	5,016,465	25,082	5,041,547	270,843	441,022	711,866	10,925
ER-2-I	46	3,185,710	15,929	3,201,639	171,999	278,702	450,701	9,798

Cost Effective Analysis

Cost effective analyses identified the least-costly plans for each level of output. The three criteria used for identifying non-cost effective plans or combinations include (1) the same level of output could be produced by another plan at less cost; (2) a larger output level could be produced at the same cost; or (3) a larger output level could be produced at the least cost. Table 5.4-5 and Figure 5.4-2 detail the results of the cost effective analyses for the floodplain forest mitigation plans. Twenty-nine plans (combinations of measures) were considered cost effective. These ranged from $225,214 to $6,885,782 and produced between 20 and 616 AAHUS of floodplain forest.

Table 5.4-5
Cost Effective Analysis Results for the Floodplain Forest Mitigation Plans

Count	Potential Mitigation Plans for the Floodplain Forest Community	Reaches Affected	Average Annual Habitat Units (AAHUs)	Costs ($1,000)	Average Cost ($1,000)
1	No Action Plan	--	0	0	0
2	A2a	6	20	225,214	11,261
3	C1	4 and 5	131	242,835	1,854
4	C1 + A2a	4, 5 and 6	151	468,049	3,100
5	C1 + I	2, 4 and 5	177	693,536	3,918
6	C1 + I + A2a	2, 4, 5 and 6	197	918,750	4,664
7	C1 + G + A2a	2, 4, 5 and 6	216	1,179,915	5,463
8	C2 + I + A2a	2, 4, 5 and 6	217	1,295,560	5,970
9	C1 + G + I	2, 4 and 5	242	1,405,402	5,807
10	C1 + D	4 and 5	310	1,585,895	5,116
11	C1 + D + A2a	4, 5 and 6	330	1,811,109	5,488
12	C1 + D + I	2, 4 and 5	356	2,036,596	5,721
13	C1 + D + I + A2a	2, 4, 5 and 6	376	2,261,810	6,015
14	C1 + D + G + A2a	2, 4, 5 and 6	395	2,522,975	6,387
15	C2 + D + I + A2a	2, 4, 5 and 6	396	2,638,620	6,663
16	C1 + D + G + I	2, 4 and 5	421	2,748,462	6,528
17	C1 + D + G + I + A2a	2, 4, 5 and 6	441	2,973,676	6,743
18	C2 + D + G + I + A2a	2, 4, 5 and 6	461	3,350,486	7,268
19	C2 + D + G + I + A1a + A2a	2, 4, 5 and 6	469	3,780,891	8,062
20	C1 + D + E + G + I + A2a	2, 3, 4, 5, and 6	489	4,163,853	8,515
21	C1 + D + F + G + A2a	2, 4, 5 and 6	494	4,437,689	8,983
22	C2 + D + E + G + I + A2a	2, 3, 4, 5, and 6	509	4,540,663	8,921
23	C1 + D + F + G + I	2, 4, 5 and 6	520	4,663,176	8,968
24	C1 + D + F + G + I + A2a	2, 4, 5 and 6	540	4,888,390	9,053
25	C2 + D + F + G + I + A2a	2, 4, 5 and 6	560	5,265,200	9,402
26	C2 + D + F + G + I + A1a + A2a	2, 4, 5 and 6	568	5,695,605	10,027
27	C1 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	588	6,078,567	10,338
28	C2 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	608	6,455,377	10,617
29	C2 + D + E + F + G + I + A1a + A2a	2, 3, 4, 5, and 6	616	6,885,782	11,178

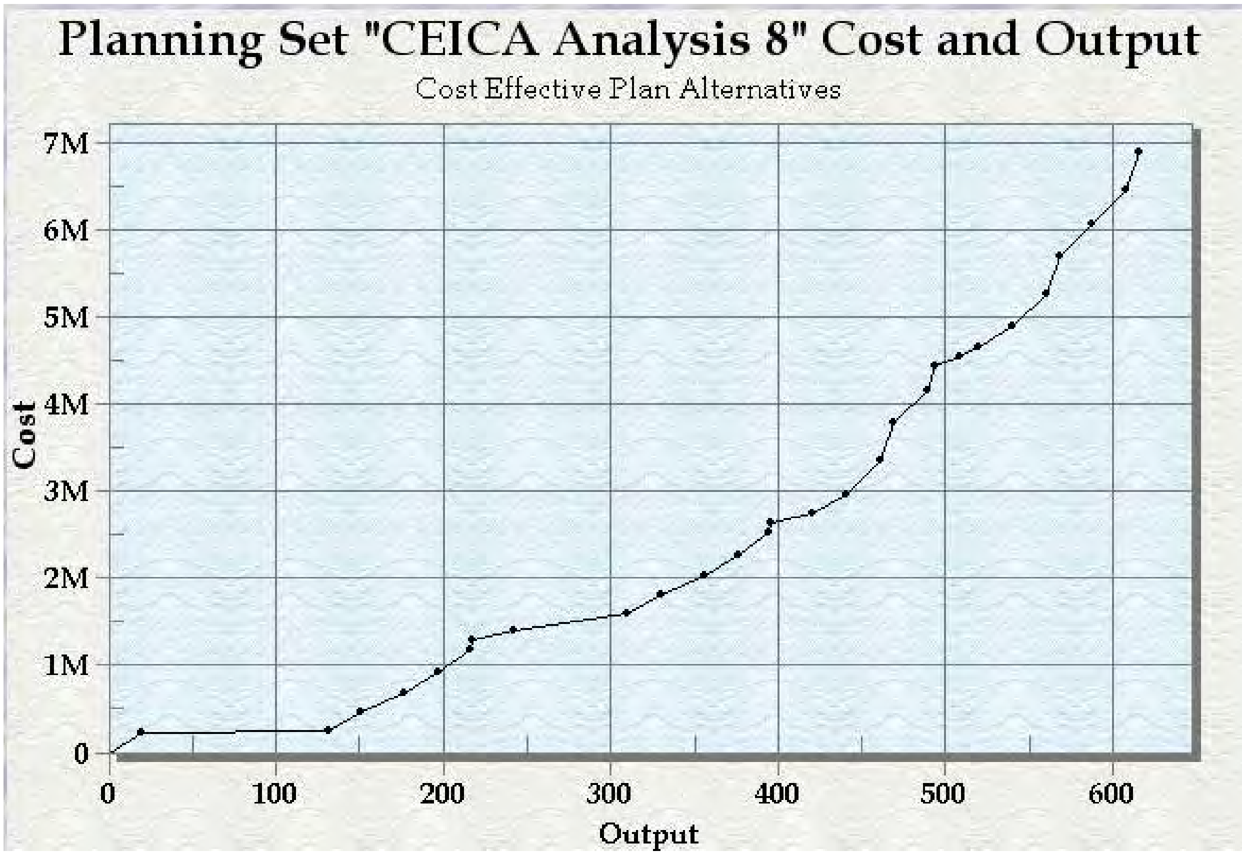

Figure 5.4-2. Cost Effective Analysis Results (graphical depiction) for the Floodplain Forest Mitigation Plans

Incremental Cost Analysis

ICA compared the incremental costs for each additional unit of output. The first step in developing "Best Buy" plans was to determine the incremental cost per unit. The plan with the lowest incremental cost per unit over the No Action Alternative was the first incremental Best Buy plan. Plans that had higher incremental costs per unit for a lower level of output were eliminated. The next step was to recalculate the incremental cost per unit for the remaining plans. This process was reiterated until the lowest incremental cost per unit for the next level of output was determined. The intent of the incremental analysis was to identify large increases in cost relative to output. Table 5.4-6 and Figure 5.4-3 below detail the results of the incremental cost analyses for the floodplain forest mitigation plans. Nine combinations of designs were considered incrementally effective. These ranged from $242,835 to $6,885,782 and produced between 131 and 616 AAHUS of floodplain forest. The first plan, *ER-4-C1/ER-5-C1*, generated enough outputs (131 AAHUs) to satisfy the mitigation requirements (–106 AAHUs), and was the most cost-effective, incrementally effective solution proposed.

Table 5.4-6
Incremental Cost Analysis Results for the Floodplain Forest Mitigation Plans

Potential Mitigation Plans for the Floodplain Forest Community	Reaches Affected	Average Annual Habitat Units (AAHUs)	Costs ($1000)	Average Cost ($1000)	Incremental Cost ($1000)	Incremental Outputs (AAHUs)	Incremental Cost Per Output ($1000)
No Action	--	0	0	0	0	0	0
C1	4 and 5	131	242,835	1,854	242,835	131	1,854
C1 + D	4 and 5	310	1,585,895	5,116	1,343,060	179	7,503
C1 + D + I	2, 4 and 5	356	2,036,596	5,721	450,701	46	9,798
C1 + D + G + I	2, 4 and 5	421	2,748,462	6,528	711,866	65	10,952
C1 + D + G + I + A2a	2, 4, 5, and 6	441	2,973,676	6,743	225,214	20	11,261
C2 + D + G + I + A2a	2, 4, 5, and 6	461	3,350,486	7,268	376,810	20	18,841
C2 + D + F + G + I + A2a	2, 4, 5, and 6	560	5,265,200	9,402	1,914,714	99	19,341
C2 + D + E + F + G + I + A2a	2, 3, 4, 5, and 6	608	6,455,377	10,617	1,190,177	48	24,795
C2 + D + E + F + G + I + A1a + A2a	2, 3, 4, 5, and 6	616	6,885,782	11,178	430,405	8	53,801

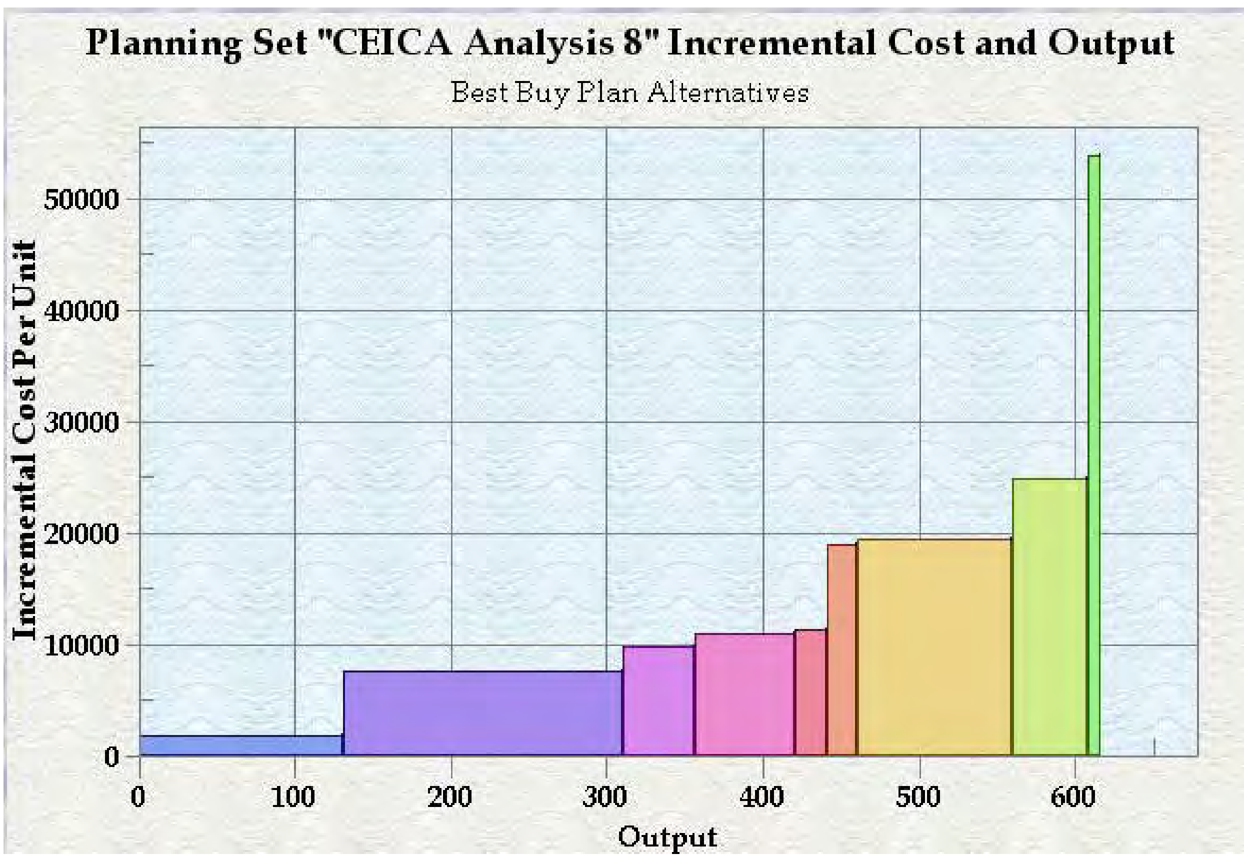

Figure 5.4-3. Incremental Cost Analysis Results
(graphical depiction) for the floodplain forest mitigation plans.

5.5 RECOMMENDED MITIGATION PLAN

Although significant efforts were made to avoid and minimize impacts under the GRP Alternative, impacts to floodplain forest communities were still anticipated (106 AAHUs). These impacts must be fully compensated for (in-kind), and as such, a suite of mitigation plans afforded full compensation in a cost-effective and incrementally effective manner. By focusing on each cost analysis result in turn, the results indicate the ER-4-C1/ER-5-C1 fully compensates for the impacts in a cost-effective, incrementally effective manner. The GRP Alternative, with mitigation, would provide for 131 AAHUs, resulting in benefits of 25 AAHUs in excess of the impacts). Although 278 acres of floodplain forest would be impacted, 186 acres would be preserved, rehabilitated, and/or reestablished with the implementation of on-site avoidance and minimization activities as well as the construction of the indicated off-site mitigation plan (Table 5.5-1).

Table 5.5-1
General Reevaluation Plan Alternative Net Change in AAHUs

	Floodplain Forest (acres)
Impacts	–106
Mitigation	131
Net change	25

Given these results, the goals and objectives for mitigation of the Clear Creek Project can be met—the impacts of the GRP Alternative can be offset, and the community structure and functions would remain intact for the Clear Creek ecosystems. This community-based approach allowed the E-Team to assess impacts and benefits in terms of key components (i.e., hydrology and soils, biotic integrity, and spatial complexity) with the intent of mimicking the dynamic processes seen in comparable natural ecosystems of the region, yielding more-comprehensive and holistic results. The approach served to inject valuable on-the-ground knowledge of experts and stakeholders into the strategic planning of the study's alternative designs and served as a forum for the transparent assessment of impacts to the system's critical ecosystem functions and structure throughout the process.

5.5.1 Goals and Objectives

Mitigation goals and objectives were established by the ICT based on the desired outcome of specific actions that would be taken to avoid, minimize, and compensate for adverse effects of the GRP. The goals and objectives of the mitigation plan are as follows:

- To provide hydrologic function and habitat for the floodplain forest community to rehabilitate the overall ecosystem functioning of Clear Creek watershed.

- To create a sustainable habitat that will withstand environmental conditions and anthropogenic impacts for the life of the project.
- To support the national objective of no net loss of wetlands in acres and function.

5.5.2 Methods

An integrated approach to avoidance, minimization, and compensation methods would be implemented at multiple locations along the project reach of Clear Creek to achieve mitigation goals and objectives under the GRP Alternative. Proposed methods include the following:

- Rehabilitate existing floodplain forest along the mainstem of Clear Creek through avoiding a 65-foot riparian corridor that would expand to include larger forest patches where the high-flow and low-flow channels diverge.
- Offset permanent impacts to 29.3 acres of wetlands in-kind by the preservation, reestablishment, and/or rehabilitation of 35.8 wetland acres, which includes 7.3 acres of wetlands within the low-flow channel of the GRP Alternative and adjacent forested riparian areas and 21.1 acres associated with the compensatory mitigation plan. Combining the 28.4 acres with the avoided 12.2 acres, a total of 40.6 acres of wetlands would be preserved and restored (reestablishment and/or rehabilitation) by the GRP Alternative (Table 4.9-6 and Figure 3.9-2). Assessment of wetland functional impacts for the GRP Alternative was incorporated into the HEP model and supported attainment of net functional benefits through project implementation (see Appendix B).
- Modify portions of the existing conveyance feature of the Clear Creek mainstem to reconnect low flows and meanders within 13 remnant oxbows scattered throughout the system between Country Club Drive and Dixie Farm Road during low flow, while allowing high-flow bypass through the current channel alignment.
- Remove excavated material stockpiled along the north bank during past channelization of Clear Creek mainstem between Country Club Drive and Dixie Farm Road. The excavated material would be deposited at a designated upland confined placement area. The locations of the placement areas would be determined during the preconstruction engineering and design phase. Attempts will be made to site the placement areas on agricultural lands, pasture, and other urban land to avoid wetlands and/or other ecological resource areas.
- Densely plant native tree species (approximately 400 trees per acre) along the existing, cleared overbank areas in Mitigation Area C1 and in areas along the mainstem of Clear Creek that have been previously channelized and cleared of trees. Typical native trees species that would be considered for planting include those known to occur within the Clear Creek reference sites (see Table 3.9-1). The ICT would be consulted to provide input on the future engineering, design and construction of the project features and mitigation, including determining the final native tree planting specifications (i.e., specific native tree species to be planted and the number of each species to be planted to achieve a density of 400 trees per acre).

- Aggressively remove and treat invasive plant species annually for 35 years in avoidance and minimization features of the GRP (i.e., 122 acres preserved and rehabilitated and 33 acres reestablished) and compensatory mitigation areas (31 acres rehabilitated and/or reestablished). Removal of invasive plant species, specifically Chinese tallow, from forested areas will be performed annually in the fall through the 35th year following completion of project construction, using hand pulling or foliar and basal stem application of herbicide (method is dependent on the size and density of trees).[2]

5.5.3 Standards

Mitigation plan implementation and completion require the adherence to standards specified by the ICT so as to ensure the attainment of mitigation goals and objectives. Standards established for the GRP Alternative include the following:

- Sustainable habitat shall be maintained over the life of the project.
- Floodplain forest vegetative cover and structure shall fall within certain parameters as specified in the ecological performance and success criteria.

Specific design considerations for floodplain forest hydrology and soil conditions will be developed during the preconstruction engineering and design phase to support achievement of the ecological success.

5.5.3.1 General Performance and Success Criteria

General performance and success criteria for mitigation plan design and operation are presented below. Reference floodplain forests within a nearby reach of Clear Creek were selected based on representativeness of desired community attributes and then inventoried by USFWS and TPWD members of the ICT to establish appropriate parameters for design (e.g., species composition, planting density, etc.). Specific criteria will be developed by the ICT during the preconstruction, engineering, and design phases.

1. Avoidance and minimization features of the GRP (i.e., preservation and rehabilitation of 122 acres and reestablishment of 33 acres) and compensatory mitigation areas (rehabilitation of 31 acres) will be monitored until the mitigation has been determined successful through attainment of ecological success criteria.
2. Ecological success criteria for the mitigation sites are as follows:
    a. *Percent survival of tree plantings:* Field data would be collected to determine percent survival of planted species within rehabilitated areas. Success criteria for tree seedling survivorship are:

[2] It is important to link optimal herbicide application to a specific stage in the annual cycle of the Chinese tallow tree. Research has shown that maximum movement of herbicide in tallow trees occurs following seed maturation and prior to leaf color change. Generally, this period would be between mid-July and mid-September (Hanselka, 2009; The Nature Conservancy, 2007).

i. At 5 years after planting, a minimum survivorship of 95 percent of original planting density.

ii. At 10 years after planting, a minimum survivorship of 90 percent of the original planting density.

b. *Control of invasive, noxious, and/or exotic plant species annually:* Invasive, noxious, and/or exotic plant species shall compose less than 2 percent areal coverage of mitigation sites measured at 5, 10, and 35 years after construction; and

c. *Vegetation cover requirements:* At 10 and 35 years following construction completion, percent tree canopy cover, instream cover, and stream overhead cover as well as the number of vegetation layers present within mitigation areas for project impacts will be as shown in Table 5.5-2.

Table 5.5-2
Vegetation Cover Ecological Success Criteria

	Avoidance and Minimization Features of the GRP Alternative		Compensation for Unavoidable Impacts
	Clear Creek Mainstem Conveyance, Low-flow Riparian Corridor		Clear Creek Mainstem Low-Flow Channel/Oxbows and Rehabilitation of 31 Acres of Associated Forested Riparian Habitat (i.e., Mitigation Plan C1)
	Preservation/Rehabilitation of 155 Acres of Forested Riparian Habitat	Restoration of 33 Acres of Forested Riparian Habitat	
Vegetative Cover	ER 4, 5, and 6	ERs 5 and 6	ERs 4 and 5
10 Years Postconstruction			
Tree Canopy Cover (%)	65–75	≥5	65–75
Instream Vegetative Cover (%)	5–10	≥5	25–30
Stream Overhead Cover (%)	20–60	≥60	20–60
Vegetation Layers (No.)	6–7	≥2	6–7
35 Years Postconstruction			
Tree Canopy Cover (%)	70–75	≥65	70–80
Instream Vegetative Cover (%)	5–20	≥20	35–65
Stream Overhead Cover (%)	25–60	≥60	30–70
Vegetation Layers (No.)	6–7	≥4	6–7

5.5.3.2 Operation and Maintenance

- Watering of planted trees would continue through the third year.
- Annual removal of invasive, noxious, and/or exotic plant species would continue through year 35 to allow for the establishment of desired native vegetation and is required due to

the prevalence of such species in the study area. A “cut stump” or similar method, followed by spot treatment of individual plants through foliar application of herbicide (e.g., Clearcast, Garlon 5, Remedy, or other approved herbicide) would be utilized to achieve this task.

- Replanting of tree species would occur 5 and 10 years after establishment if monitoring determines that such actions are needed to achieve success criteria.

5.5.3.3 Monitoring and Contingency Plans

Monitoring and contingency plans for the avoidance and minimization features of the GRP Alternative and compensatory mitigation areas are presented in Appendix J. The monitoring and contingency plans for mitigation measures and GRP features have been developed in accordance with recent implementing guidance for section 2036(a) of WRDA 07. Monitoring plans identify specific ecological success criteria to be used in determining whether the mitigation features have been successful. The contingency plan/adaptive management process is intended to allow periodic modifications in order to achieve the necessary functional mitigation for project impacts at the end of the 50-year period of analysis. Details of the monitoring and contingency plan for the avoidance and minimization features of the GRP and compensatory mitigation area are presented in Table 1 in Appendix J. Presented therein are the key monitoring parameters, periodicity, costs, and responsible parties. Brief synopses of the monitoring and contingency/ adaptive management plans and associated costs described in Appendix J follow.

5.5.3.3.1 Monitoring

Annually, the District Engineer will consult with State and Federal agencies regarding the status of mitigation efforts and prepare a report summarizing the results of consultation and the evaluation of the ecological success of the mitigation to date, the likelihood mitigation will achieve success defined in the mitigation plan, the projected timeline for achieving success, and recommendations for increasing the likelihood of success. Copies of these annual reports will be provided to the Division Commander and members of the consulting State and Federal agencies.

The primary monitoring data for evaluating achievement of the ecological success criteria within the mitigation areas would be field data collected at 5, 10, and 35 years postcompletion (i.e., 2025, 2030, and 2055, respectively). General site conditions, damage by herbivory or vandalism, and erosion would be documented during each monitoring effort. Monitoring data on percent survival of planted trees would be collected and assessed at years 2025 and 2030 (i.e., 5 and 10 years following construction completion). Monitoring data on the percent areal coverage of invasive, exotic, and/or nuisance plant species would be documented at years 2025, 2030, and 2055 (i.e., 5, 10, and 35 years following construction completion). Data on percent tree canopy cover, amount of the stream characterized by in-stream vegetative cover, percent of the water surface shaded by overhanging vegetation, and vegetation strata would be collected at years 2030 and 2055 (i.e., 10 and 35 years following project completion). Field collection of monitoring data would follow the protocols discussed herein and provided in Appendix J. Following completion of monitoring events, field data collected to evaluate the success of the mitigation plan would be digitally stored, statistically analyzed and interpreted, and compiled into detailed monitoring reports to be assessed by the ICT.

Monitoring would continue until it has been demonstrated that the mitigation has met the ecological success criteria as documented by the District Engineer and determined by the Division Commander. Upon determination that the desired acres of forest vegetation have met the monitoring ecological success criteria, monitoring activities will cease and the project will be formally closed.

5.5.3.3.2 Contingency Plan and Adaptive Management

A contingency plan has been developed to guide corrective actions where monitoring determines that the vegetation survival, coverage, and composition do not meet the ecological success criteria. Following review of information for annual reporting to the District Engineer and consultation with state and Federal agencies, and after the ICT reviews the 5-, 10- and 35-year monitoring data, an ICT meeting would be convened to address any issues that are raised that will likely affect the ecological success of the mitigation plan. At that time, the ICT will determine whether any necessary corrective actions (e.g., additional plantings, including number, species, spacing, and size of plants, or alternative methods of invasive species control) are warranted to ensure the mitigation is successful and that the requisite acres and quality of floodplain forest are available to produce the total benefits needed to mitigate for project impacts. In the case of catastrophic disturbances such as intense storms and hurricanes, the ICT would assess the nature and extent of the damage and recommend corrective measures to restore mitigation areas to predamage or target conditions.

5.5.3.3.3 Monitoring Cost Estimates

The total 50-year monitoring cost for the proposed mitigation plan is $27,036.00 (constant dollars, 4.375% interest rate). The total cost includes costs for conducting field surveys and measurement of vegetation at 5-, 10-, and 35 years postconstruction is $17,583.00. This cost estimate for vegetation surveying is based on three biologists spending a day in the field conducting pedestrian surveys documenting vegetation survival, coverage, and composition within the mitigation areas for each major monitoring event. The cost included for data analysis and reporting is $9,453.00. This includes the cost of field data collection and management and preparation and distribution of monitoring reports at 5-, 10-, and 35 years postconstruction as well as estimated costs for the preparation of annual reports summarizing data for presentation to the Division Commander and state and Federal resource agencies. Cost estimates may change as details on the number of monitoring locations are developed and monitoring dates identified.

5.5.3.4 Implementation

The GRP Alternative is located within much of the existing low-flow channel and associated ROW along Clear Creek, Mud Gully, Turkey Creek, and Mary's Creek, which are currently owned by or controlled via easements through the project's non-Federal cost-share sponsors, HCFCD and BCDD4. Upon approval of the GRP, any additional real estate purchases or easements necessary for the purposes of performing project and mitigation planning, engineering, and design, as well as construction and postconstruction monitoring of the associated mitigation, will be completed by the project's non-Federal cost-share sponsors. Agencies on the ICT would be consulted to provide input to the future engineering, design, construction, and monitoring of the project. The ICT would also participate in the detailed planning, construction, and postconstruction monitoring of the mitigation areas.

Real estate properties have been identified for the mitigation plan, as described in the Real Estate Plan (Appendix to the GRR). The properties are predominantly located within the flooding of the 100-year floodplain in Harris County. This land has not been purchased, but because local restrictions prohibit development within the floodway, it is expected to be available for future purchase.

5.6 MITIGATION FOR GREEN HOUSE GAS EFFECTS

The GRP Alternative includes a series of flood risk management measures and mitigation areas, referred to as project features. Impacts to existing floodplain forest would be avoided and minimized as much as possible within the design of the conveyance features along Clear Creek. However, it is anticipated that approximately 278 acres of floodplain forest habitat would be directly impacted as a result of the GRP Alternative, and approximately 31 acres of prime farmland that would no longer be available for agricultural use. No losses of or impacts to coastal prairie or tidal marsh are anticipated. Mitigation features include avoidance, minimization, and compensation for project impacts through rehabilitation and reestablishment of floodplain forest.

While the unavoidable impacts of construction may result in loss of the existing natural carbon removal process, clearing of streamside vegetation within the conveyance channels can improve habitat through revegetation of small shrubs, perennial forbs, and grasses. In addition, environmentally sensitive design features of the GRP Alternative encompass preservation, rehabilitation, and reestablishment of floodplain forest comprising 155 acres in portions of the existing low-flow channels, which includes 7.3 acres of reestablished and restored fringe forested of wetlands.

According to the EarthWatch Institute (2012), "Carbon is incorporated into forests and forest soils by trees and other plants. . . . A young forest, composed of growing trees, absorbs CO_2 and acts as a sink. Mature forests, made up of a mix of various aged trees as well as dead and decaying matter, may be carbon neutral above ground, as they will emit and sequester equal amounts of CO_2." Thus, it appears that the reestablishment of floodplain forest would enhance the carbon removal process until the forest is mature.

Measures that may be used to reduce GHG emissions from the GRP Alternative would consider the equipment used for the project over the expected life of the project and the feasibility and practicality of such measures. Alternatives considered for their ability to reduce or mitigate GHG emissions are those that may provide for enhanced energy efficiency, lower GHG-emitting technology, or the use of renewable energy, as appropriate, for the construction equipment to be used. Possible mitigation options include the following:

- design of the construction equipment operation and schedule so as to reduce overall fuel use
- repowering/refitting with cleaner diesel engines
- selection of newer construction equipment with more efficient engines, if possible.

6.0 COMPLIANCE WITH TEXAS COASTAL MANAGEMENT PROGRAM

The Clear Creek project has been reviewed for consistency with the goals and policies of the TCMP. Several of the Coastal Natural Resource Areas (CNRAs) listed in 31 TAC § 501.3 were found reasonably close to the project area and were evaluated for potential impacts from the proposed action. CNRAs found reasonably close to the project area included waters of the open Gulf, waters under tidal influence, coastal wetlands, SAV, tidal sand and mud flats, coastal shore areas, and special hazard areas (i.e., 100-year floodplain). All CNRAs found reasonably close to the project area are not within the project footprint (except for the special hazard area of the 100-year floodplain); thus, no direct or indirect impacts to CNRAs are anticipated as a result of the GRP Alternative. Although the project footprint impacts a special hazard area (i.e., 100-year floodplain), project objectives would decrease the hazard in the flood-prone areas, and a beneficial effect to the hazard area is expected. A Texas Coastal Zone Management Programs Consistency Determination has been included as Appendix K.

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7.0 CONSISTENCY WITH STATE AND FEDERAL REGULATIONS

This FSEIS has been prepared to satisfy the requirements of all applicable environmental laws and regulations and has been prepared using the CEQ NEPA regulations (40 CFR Part 1500–1508) and the USACE's Engineer Regulation 200-2-2 (*Environmental Quality: Policy and Procedures for Implementing NEPA*, 33 CFR 230). The USACE will follow provisions of all applicable laws, regulations, and policies related to the proposed actions, including those for which applicability, review, and enforcement are their responsibility. Additionally, the non-Federal sponsor may be required to secure local municipal permits as a "Land, Easements, Rights-of-Way, Relocation, and Disposal Areas" requirement. The following sections present brief summaries of Federal environmental laws, regulations, and coordination requirements applicable to this FSEIS. Informational request letters and invitation letters to potential cooperating agencies are provided in Appendix D-4. Table 7.0-1 presents a summary of these regulations and the actions taken to satisfy their respective requirements.

Table 7.0-1
Summary of Actions Taken to Achieve Compliance with State and Federal Regulations

Regulation	Coordinating Entity	Actions Taken
Clean Air Act	EPA	Because emissions from project construction activities exceed general conformity thresholds, a General Conformity Determination is required for each year that NO_x or VOC would exceed 25 tpy. The USACE, in consultation with the TCEQ and EPA, prepared a General Conformity Determination document (Appendix H), which was submitted with the DSEIS to the TCEQ, EPA, and any other relevant air pollution control agencies. TCEQ provided concurrence via letter dated February 7, 2012 (Appendix H).
Clean Water Act	TCEQ	Compliance with the act was achieved through coordination with TCEQ to obtain water quality certification for the project. An evaluation of the project based on Section 404(b)(1) Guidelines and the 401 State Water Quality Certification letter from the TCEQ is presented in Appendix L of this FEIS.
Endangered Species Act, Section 7	NMFS and USFWS	A draft BA has been prepared and was submitted to NMFS and USFWS with the DSEIS. USFWS acknowledged and did not dispute the USACE determination of no effect to protected species in their Coordination Act Report (Appendix D-6).
Magnuson-Stevens Fishery Conservation and Management Act	NMFS	No permanent impacts to living marine resources or EFH were identified as a result of this project; the DSEIS initiated EFH consultation under the Magnuson-Stevens Fishery Conservation and Management Act (Appendix D-4). To date, NMFS has not responded.

Table 7.0-1 (Cont'd)

Regulation	Coordinating Entity	Actions Taken
National Historic Preservation Act, Section 106	SHPO and the Advisory Council on Historic Preservation	A Memorandum of Agreement (Appendix F-1) among the USACE, the SHPO, and the ACHP was developed to ensure the project is in compliance with Section 106 of the National Historic Preservation Act. Compliance with the Memorandum of Agreement places the project in compliance with Section 106.
Coastal Zone Management Program	Coastal Coordination Council (CCC)	USACE has determined that the project is consistent with the goals and policies of the TCMP (§ 501.15 Policy for Major Actions and § 501.34 Policies for Levees and Flood Control Projects). The TCMP consistency determination is included as Appendix K. By letter dated December 15, 2010 (Appendix D-4), USACE requested review of the Consistency Determination. Concurrence with the determination was provided by TCEQ via letter dated June 15, 2012 (Appendix K).
National Environmental Policy Act	CEQ	This FSEIS has been prepared in accordance with CEQ regulations in compliance with NEPA provisions.
Fish and Wildlife Coordination Act	USFWS and TPWD	A planning aid letter prepared by USFWS in conjunction with TPWD was received in May 2002 (Appendix D-5). A final Fish and Wildlife Coordination Act Report was received in March 2011 (Appendix D-6). Table 7.8-1 demonstrates how recommendations, opportunities, or problems from the Planning Aid Letter (PAL) or Coordination Act Report (CAR) were incorporated into the project analysis.
Federal Water Project Recreation Act	N/A	The GRP alternative is in compliance with this act.
Farmland Protection Policy Act of 1981 and the CEQ Memorandum for Prime or Unique Farmlands	NRCS	Form AD-1006 was submitted to NRCS for their evaluation, and the NRCS determined that each of the project features evaluated received Farmland Conversion Impact ratings over 160; these features therefore will receive higher levels of consideration for protection, and additional alternatives must be evaluated. Because the USACE conducted an extensive alternatives evaluation, in conjunction with the location of project features in an urbanized area that is composed of commercial, industrial, and residential development, it was determined that FPPA criteria for a higher level of consideration have been satisfied.
EO 11988, Floodplain Management	N/A	As evaluated, the GRP alternative is not expected to induce growth within existing floodplains, but could result in revisions to designated floodplain areas.
EO 11990, Protection of Wetlands	N/A	While the GRP Alternative would directly impact wetlands, compensatory mitigation measures would be taken that would result in no net loss of wetlands as a result of the GRP Alternative.
EO 12898, Environmental Justice	N/A	As evaluated, the GRP Alternative is not expected to disproportionately or adversely affect any low-income or minority populations.

Table 7.0-1 (Cont'd)

EO 13186, Responsibilities of Federal Agencies to Protect Migratory Birds and the Migratory Bird Treaty Act	N/A	The effect of the GRP Alternative on migratory bird species has been assessed in this FSEIS, and impacts are not expected to occur.
FAA Advisory Circular 150/5200-33 and the July 2003 Memorandum of Agreement between FAA, USACE, and other Federal agencies	FAA	Compliance has been achieved through coordination with FAA to determine whether land use changes associated with the project would increase wildlife hazards to aircraft using public use airports in the study area. Via letter dated May 12, 2010 (Appendix D-4), USACE requested written concurrence from FAA. To date, no response has been received.

7.1 CLEAN AIR ACT

As required by the CAA, the EPA has promulgated the General Conformity Rule as codified in 40 CFR Part 51, Subpart W, and Part 93, "Determining Conformity of Federal Actions to State or Federal Implementation Plans." The TCEQ has promulgated its own corresponding regulations in 30 TAC § 101.30, "Conformity of General Federal Actions to State Implementation Plans." Pursuant to these regulations, a Federal agency must make a General Conformity Determination for all Federal actions in nonattainment or maintenance areas where the total of direct and indirect emissions of a nonattainment pollutant or its precursors exceeds de minimis levels established by the regulations. The General Conformity Rule establishes conformity in coordination with and as part of the NEPA process. The rule takes into account air pollution emissions associated with actions that are federally funded, licensed, permitted, or approved, to ensure emissions do not contribute to air quality degradation, thus preventing the achievement of State and Federal air quality goals. The purpose of this General Conformity Rule is to assure Federal agencies consult with State and local air quality districts to assure these regulatory entities know about the expected impacts of the Federal action and would include expected emissions in their SIP emissions budget.

All Federal actions are subject to general conformity unless an exemption specifically provided for in the general conformity rules is met or if the project emissions are below the general conformity thresholds. It is expected that emissions from project construction activities would exceed the general conformity thresholds, and therefore a General Conformity Determination would be required for each year when emissions of either NO_x or VOC would exceed 25 tpy. As part of the general conformity process, the USACE, in consultation with TCEQ and EPA, has prepared a Draft General Conformity Determination document discussing whether emissions that would result from the proposed project are in conformity with the Texas SIP for the HGB Nonattainment Area. This document was submitted to the TCEQ, EPA, and other air pollution control agencies as appropriate with the DSEIS. Concurrence that the emissions are consistent with the SIP was provided by TCEQ via letter dated February 7, 2012 (Appendix H). Coordination with the EPA and TCEQ will continue until consensus is reached that project emissions are consistent with the most currently approved SIP emissions budgets, taking into account any potential changes to the project schedule.

7.2 CLEAN WATER ACT

The CWA, through Section 404 (33 USC 1344), authorizes the Secretary of the Army, acting through the Chief of Engineers, to issue permits for the discharge of dredged or fill material into the waters of the U.S., including wetlands. The USACE provides guidelines for the determination of the areas under Section 404 jurisdiction. Although a Section 404 permit would not be issued for the proposed project, compliance with Section 404 requirements is documented within the FSEIS per Engineer Regulation 1105-2-100.

In Texas, Section 401 of the CWA, the State Water Quality Certification Program, is regulated by the TCEQ. Compliance was achieved through coordination with TCEQ to obtain water quality certification for the project. Coordination includes an evaluation of the project based on the Section 404(b)(1) Guidelines as presented in this FSEIS. The 404(b)(1) evaluation is presented in Appendix L. The TCEQ provided a Section 401 certification letter to the USACE in June 2012 indicating that activities in waters under State jurisdiction comply with the State's water quality requirements (Appendix L).

7.3 SECTION 7 OF THE ENDANGERED SPECIES ACT

Informal consultation procedures under Section 7 of the ESA have been undertaken. A Draft BA was prepared describing the study area and federally listed threatened and endangered species of potential occurrence in the study area per species list provided by NMFS and USFWS (see Appendix E). The implementation of the GRP Alternative would not result in any direct impacts to federally listed species. Thus, the USACE has determined that the proposed project is expected to have no effect on federally listed threatened or endangered species or their critical habitat. The Draft BA was submitted to NMFS and USFWS for review with the DSEIS. USFWS acknowledged and did not dispute the USACE determination of no effect in their Coordination Act Report (see Appendix D-6).

7.4 MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT

Congress enacted amendments to the Magnuson-Stevens Fishery Conservation and Management Act in 1996 that established procedures for identifying EFH and required interagency coordination to further the conservation of federally managed fisheries. Rules published by the NMFS (50 CFR 600.805 through 600.930) specify that any Federal agency that authorizes, funds, or undertakes, or proposes to authorize, fund, or undertake, an activity that could adversely affect EFH be subject to the consultation provisions of the act. No impacts to living marine resources or EFH would occur as a result of the project. The DSEIS initiated EFH consultation under the Magnuson-Stevens Fishery Conservation and Management Act. To date, NMFS has not responsed.

7.5 SECTION 106 OF THE NATIONAL HISTORIC PRESERVATION ACT

Compliance with the National Historic Preservation Act of 1966, as amended, requires identification of all NRHP-listed or NRHP-eligible properties/resources in the project area and development of mitigation measures for those adversely affected in coordination with the SHPO and the Advisory Council on Historic Preservation. As indicated in Section 4.12, a thorough file review and reconnaissance level survey of most of the proposed project ROW did not identify any NRHP-listed or -eligible sites or State Archeological Landmarks within the project footprint. However, per SHPO's concurrence with the USACE, more testing is required at site 41HR161, and project areas that include 41BO78 and 41BO82 will require further survey when access to these sites is obtained. Additionally, buildings, bridges, or other structures over 50 years old that could be affected should be addressed. In addition, site 41HR817 was reported by PAI (Norment and Kibler, 2007) as destroyed.

Section 106 requires that Federal agencies take into account the effect of the undertaking on any historic properties and provide the Advisory Council the opportunity to comment on the undertaking. A Memorandum of Agreement (Appendix F-1) among the USACE, the SHPO, and the ACHP is in place to ensure compliance with Section 106 of the National Historic Preservation Act. A new PA is currently being coordinated with the SHPO, the ACHP, and the Project Sponsors. This PA was prepared to include the Project Sponsors and to guide implementation of the proposed Clear Creek Project. Work performed under either the existing MOA or the new PA will include, but is not limited to, additional testing of one previously recorded site and additional survey of two previously recorded sites when access is obtained; identification and investigation of unrecorded and, as of yet, unidentified sites; and the investigation of unanticipated cultural resources encountered during the course of work. Any impacts to NRHP-eligible properties would be mitigated under the conditions set forth in this Programmatic Agreement. Compliance with the Programmatic Agreement places the project in compliance with Section 106.

7.6 COASTAL ZONE MANAGEMENT PROGRAM

In an effort to encourage states to better manage coastal areas, Congress enacted the Coastal Zone Management Act in 1972, which created the Coastal Zone Management Program. Texas has developed and continues to implement federally approved coastal zone management programs (the TCMP). States with approved plans have the right to review Federal activities to determine whether they are consistent to "the maximum extent practicable" with the policies of the State's coastal zone management program. The Coastal Coordination Council (CCC), composed of several State agencies, local officials, and members of the general public (representing agriculture, local business, and local citizens), administers the TCMP. The CCC reviews all Federal actions that may affect any natural resource in the coastal zone for consistency with the TCMP goals and policies. The responsibility for these reviews belongs to the lead agency—the GLO. Any concerns expressed by the GLO would be addressed before the project is authorized.

The Clear Creek Project has been reviewed for consistency with the goals and policies of the TCMP, which include § 501.15 (Policy for Major Actions) and § 501.34 (Policies for Levees and Flood Control Projects). No CNRAs have been identified in the project area except for a "special hazard" area—the 100-year floodplain. Implementation of the GRP Alternative would result in only beneficial effects to CNRAs, and no adverse effects to CNRAs are anticipated. Additional information regarding the TCMP for the proposed Clear Creek Project is provided in Section 6.0 and Appendix K. By letter dated December 15, 2010 (Appendix D-4), USACE requested a review of the Consistency Determination. TCEQ concurred with the consistency determination via letter dated June 15, 2012 (Appendix K).

7.7 NATIONAL ENVIRONMENTAL POLICY ACT

This FSEIS has been prepared in accordance with CEQ regulations in compliance with NEPA provisions. Impacts to the human environment, including those to terrestrial and aquatic resources and socioeconomic factors, have been identified, evaluated, and disclosed in this document.

7.8 FISH AND WILDLIFE COORDINATION ACT

The Fish and Wildlife Coordination Act provides for consultation with the USFWS and, in Texas, with TPWD whenever the waters or channel of a body of water are modified by a department or agency of the U.S. Under this act, the Federal department or agency shall consult with the USFWS and the State agency with a view to the conservation of wildlife resources. The act's purposes are to recognize the vital contribution of our wildlife resources to the Nation, and their increasing public interest and significance, and to provide that wildlife conservation receive equal consideration and be coordinated with other features of water-resource development programs through planning, development, maintenance, and coordination of wildlife conservation and rehabilitation. A Planning Aid Letter (PAL) prepared by USFWS in conjunction with TPWD was received from USFWS in May 2002 and can be found in Appendix D-5. The letter provided descriptions of habitat in the vicinity of Clear Creek along with recommendations regarding design of the proposed project to avoid, minimize impacts to, and rehabilitate certain features and habitats. Further description regarding how the PAL was integrated into the planning process is provided below. A final Coordination Act Report (CAR) dated March 2011 was prepared by the USFWS and provided to the USACE in a letter dated March 10, 2011 (Appendix D-6). The final CAR expounds on the existing environmental resources within the study area and the potential effects of the project on these resources, in addition to evaluating the proposed mitigation and monitoring plans. Recommendations developed by the USFWS have been based on this evaluation and are detailed in the CAR.

The USFWS and TPWD have been integral coordinating agencies throughout the planning process through participation in the ICT and E-team. Contributions have included, but have not been limited to, participation in the development and screening of proposed alternative and mitigation measures; recognition and design of avoidance and minimization features and rehabilitation possibilities; characterization of baseline resource conditions (e.g., fieldwork and incorporation of other references); development and application of the HEP model to evaluate project impacts and future habitat conditions; and Section 7 ESA consultation. Information and references provided by the USFWS and TPWD in the PAL and CAR were consulted and incorporated into the planning process and throughout this document, as evidenced in the Affected Environment (Section 3.0), Environmental Consequences (Section 4.0), Mitigation (Section 5.0), Cumulative Effects (Section 6.0), HEP model descriptions and analyses, and elsewhere. Table 7.8-1 more-specifically demonstrates how each recommendation, opportunity, or problem from the PAL and the CAR have been incorporated into the GRP Alternative analysis and mitigation alternatives analysis.

7.9 FEDERAL WATER PROJECT RECREATION ACT

This 1995 Act requires consideration of opportunities for outdoor recreation and fish and wildlife rehabilitation in planning water-resource projects. Considerable analysis has been given to such activities in the design of the proposed Clear Creek Project. The GRP Alternative is in compliance with this act.

7.10 FARMLAND PROTECTION POLICY ACT OF 1981 AND THE CEQ MEMORANDUM PRIME OR UNIQUE FARMLANDS

In 1980, the CEQ issued an Environmental Statement Memorandum “Prime and Unique Agricultural Lands” as a supplement to the NEPA procedures. Additionally, the FPPA was passed in 1981, requiring consideration of those soils, which the U.S. Department of Agriculture defines as best suited for food, forage, fiber, and oilseed production, with the highest yield relative to the lowest expenditure of energy and economic resources. A Form AD-1006 was submitted to NRCS for their evaluation (Appendix D-3). NRCS completed the form and determined that the project feature evaluated (mitigation feature C1) received Farmland Conversion Impact Ratings of over 160. According to FPPA Rule 401.24, Section 658.4, if the subject area receives a total rating of more than 160 points, it will receive higher levels of consideration for protection and additional alternatives must be evaluated. Because USACE conducted an extensive alternatives evaluation (see Section 2) to identify the proposed alternative, and because the project features occur in an urbanized area that is composed of commercial, industrial, and residential development, it has been determined that FPPA criteria for a higher level of consideration have been satisfied. Additional information can be found in subsection 4.7.2 and in Appendix D-3.

7.11 EXECUTIVE ORDER 11988, FLOODPLAIN MANAGEMENT

This EO directs Federal agencies to evaluate the potential effects of proposed actions on floodplains. Such actions should not be undertaken that directly or indirectly induce growth in the floodplain unless there is no practical alternative. The GRP Alternative is not expected to induce growth within existing floodplains, but could, as described in subsection 4.4.2.3, result in revisions to designated floodplain areas.

7.12 EXECUTIVE ORDER 11990, PROTECTION OF WETLANDS

This EO directs Federal agencies to avoid undertaking or assisting in new construction located in wetlands, unless no practical alternative is available. Permanent impacts to 29.3 acres of wetlands would be offset in-kind by the preservation/rehabilitation in the avoidance and minimization features of the GRP and the compensatory mitigation plan (as detailed in subsection 4.9.3.2 and shown in Table 4.9-6). Compensatory mitigation includes the preservation and rehabilitation of 31 acres of floodplain forest, which constitutes 21.1 acres of existing wetlands. This 21.1 acres of compensatory mitigation wetlands, combined with 12.2 acres of avoided wetlands, and 7.3 acres of reestablished and rehabilitated wetlands (within the existing low-flow channels and adjacent riparian vegetation), results in a total of 40.6 wetland acres that would be avoided, preserved, or rehabilitated and reestablished within the project and compensatory mitigation area footprint (see Table 4.9-6 and Figure 3.9-2). Thus, no net loss of wetland acreage would be accomplished, and based on HEP modeling, functional benefits to wetlands would be achieved through implementation of the GRP Alternative.

7.13 EXECUTIVE ORDER 12898, ENVIRONMENTAL JUSTICE

This EO directs Federal agencies to determine whether the GRP Alternative would have a disproportionate adverse impact on minority or low-income population groups within the project area. An evaluation of potential Environmental Justice impacts was completed and is presented in Section 3-13 and Appendix G. The GRP Alternative will not disproportionately or adversely affect any low-income or minority populations.

Table 7.8-1

Incorporation of USFWS and TPWD Planning Aid Letter (PAL) and USFWS Coordination Act Report (CAR) into Project Planning

2002 PLANNING AID LETTER	**Recommendations**	
	1. County and State leadership officials explore regulatory measures to limit further development in the floodplain.	Evaluated in Phase I: Preliminary Screening and Phase II: First-Added Alternative Measures as Global Watershed Practices measure. Eliminated due to low benefit-cost ratio.
	2. Restore detention areas to the floodplain by removing the levees and east side spoil banks from SM 30.0 (Scarsdale) to SM 33.0 (Beltway 8 Section of Clear Creek).	Evaluated in Phase I: Preliminary Screening and II: First-Added Alternative Measures as Remove Excavated Material/Deepen for Conveyance measure[1]. Screened based on suitability as a stand-alone measure and ability to be modified and combined with other measures. Incorporated in GRP Alternative avoidance and minimization features.
	3. Remove the spoil banks from SM 26.5 (approximately Dixie Farm Road) to SM 30.0 (Scarsdale) and from SM 21.5 (Friendswood) to SM 26.5 (approximately Dixie Farm Road) to allow the rapid storage of flood waters and the subsequent slow runoff of retained flood waters. These areas can be planted with native tree species.	Evaluated in Phase I: Preliminary Screening and Phase II: First-Added Alternative Measures as Remove Excavated Material/Deepen for Conveyance measure[1]. Screened based on suitability as a stand-alone measure and ability to be modified and combined with other measures. Incorporated in GRP Alternative avoidance and minimization features.
	4. Avoid and minimize impacts to "High Quality" habitat areas identified in the PAL in siting future structural flood risk management features, including detention ponds, and utilize "low" and "medium" quality habitats for restoration and mitigation.	GRP Alternative avoids and minimizes impacts to high quality habitat areas in siting structural flood risk management features and utilizes low and medium quality habitats for restoration and mitigation. In addition, implementation of the mitigation plan will restore the natural flow regime reconnecting 13 remnant oxbows scattered throughout the system between Country Club Drive and Dixie Farm Road that were cut off as a result of past channelization activities.
	Identification of Opportunities and Problems	
	1. USACE should use list of conceptual restoration projects and their potential locations provided to John Baker, from Sept. 25, 2001, meeting of all resource agencies, to determine restoration project possibilities.	Mitigation planning incorporated conceptual restoration projects and interagency collaboration, including the Multidisciplinary Ecosystem Assessment Team, as described in Section 5.0
	2. Two restoration opportunities at stream-side locations along Clear Creek are presented : restoration of native riparian vegetation buffers where dominated by Chinese tallow trees and removal of large stream-side maintenance banks to reconnect Clear Creek with the floodplain.	GRP Alternative and Mitigation Plan include treatment of invasive, noxious, and/or exotic plant species, re-establishment of native riparian vegetation buffers, and removal of large stream-side maintenance banks to reconnect Clear Creek with the floodplain.
2011 FINAL COORDINATION ACT REPORT	**Recommendations**	
	1. Create an interagency work group for post-authorization planning and construction phases to execute important design, inspection, and monitoring functions for habitat creation features outlined in the mitigation section of this document	Interagency work groups, defined as Interagency Coordination Teams (Section 1.7), were established, have been involved, and will continue to be involved in project planning and subsequent activities.
	2. Re-convene the ICT to review, discuss, and make recommendations on the annual mitigation report	ICT will re-convene to review, discuss, and make recommendations on the annual mitigation report, as described in the Mitigation Plan (Section 5.0)
	3. Re-evaluate sea level rise impacts to the project prior to construction using the updated IPCC sea level rise rates	The analysis of sea level rise, as described in sections 3.1.5 and 4.1.2, is based upon the most recent Corps guidance (EC 1165-2-211) that requires the use of updated IPCC sea level rise rates in the evaluation of sea level rise impacts to the project.
	4. Conduct field survey of all areas with suitable bird nesting habitat prior to construction.	Construction contracts would include instructions to identify and avoid impacts to migratory birds and their nests that may result from construction-related activities.
	5. Conduct mussel surveys prior to construction and employ the provided BMPs during construction activities along the main channel and its tributaries to reduce impacts to mussels; include mussel presence/absence surveys in monitoring efforts every 2-5 years; and implement yearly surveys and adaptive management measures should species of interest be found	Construction contracts would include instructions to identify and avoid impacts to mussels that may result from construction-related activities. However, mussel presence/absence surveys as recommended are considered research are not established criteria for evaluating determining success of the project mitigation. While the USFWS may elect to conduct such surveys in collaboration with the project sponsor, such endeavors are not appropriate for inclusion in the recommended project monitoring protocol.
	6. Channel modifications should mimic natural stream features such as riffles and pools to provide habitats for fish species during various life cycle stages	Channel modifications will mimic natural stream features, where appropriate, to provide aquatic habitat.
	7. Implement mitigation measures outlined in document	Mitigation measures will be implemented as described in Section 5.0 and Appendix J.
	8. Beneficial use or disposal of mounded dredge material	Excavated material from the construction of the projection will be placed, as described in Section 2.3.5, in upland confined placement areas outside of the 500-year floodplain defined during the preconstruction engineering and design phase
	9. Require protective easements on privately owned Clear Creek mitigation sites	Easements and/or real estate land purchases will be secured for all features of the Clear Creek project, including the mitigation sites
	10. Implement proposed monitoring plan, and develop and implement a plan to control exotic and invasive species at the mitigation sites based on the success criteria outlined in the monitoring plan.	Monitoring plan will be implemented as described in Section 5.0 and Appendix J.
	11. Monitoring efforts need to be consistent and well-documented, and photo-points should be established throughout each of the mitigation sites to visually record the changes that occur over time	Monitoring efforts will be consistent and well-documented, including the use of photo-points throughout mitigation sites, as described in Section 5.0 and Appendix J.
	12. Conduct surveys in the fall and spring to record the avifauna, mammal, fish, and amphibian and reptile species at each of the mitigation sites	Extensive, seasonal wildlife surveys are considered research are not established criteria for evaluating determining success of the project mitigation. While the USFWS may elect to conduct such surveys in collaboration with the project sponsor, such endeavors are not appropriate for inclusion in the recommended project monitoring protocol.
	13. If buy-outs occur, revert properties to a natural state, remove exotic/invasive tree/shrub species, cap off and/or remove all utilities, and do not allow construction debris to enter any waterways.	No buy-outs are proposed in the GRP Alternative.

1Alternative only included recommended extent from stream mile 26.5 to stream mile 30.0, Acronyms reference specific screening measures.

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7.14 EXECUTIVE ORDER 13186, RESPONSIBILITIES OF FEDERAL AGENCIES TO PROTECT MIGRATORY BIRDS AND THE MIGRATORY BIRD TREATY ACT

The MBTA of 1918 (as amended) extends Federal protection to migratory bird species. Among other activities, nonregulated "take" of migratory birds is prohibited under this act in a manner similar to the ESA prohibition of "take" of threatened and endangered species. Additionally, EO 13186 "Responsibility of Federal Agencies to Protect Migratory Birds" requires Federal activities to assess and consider potential effects of their actions on migratory birds (including, but not limited to, cranes, ducks, geese, shorebirds, hawks, and songbirds). The effect of the GRP Alternative on migratory bird species has been assessed in this FSEIS, and no impacts are expected to migratory birds or their habitat in the study area. Construction contracts will include instructions to avoid impacts to migratory birds and their nests from construction-related activities. The Migratory Bird Conservation Act (16 USC 715–715d, 715e, 715f–715r; 45 Stat. 1222) establishes a Migratory Bird Conservation Commission to approve areas of land or water for acquisition as reservations for migratory birds and is not applicable to the project.

7.15 FEDERAL AVIATION ADMINISTRATION – HAZARDOUS WILDLIFE ATTRACTANTS ON OR NEAR AIRPORTS

In accordance with FAA Advisory Circular 150/5200-33 and the Memorandum of Agreement among the FAA, USACE, and other Federal agencies (July 2003), the GRP Alternative was evaluated to determine whether proposed land uses could increase wildlife hazards to aircraft using public use airports in the study area. Conveyance and mitigation features of the GRP Alternative were found to be located between the 10,000-foot and/or 5-mile perimeters of the William P. Hobby Airport, Ellington Field Airport, and Pearland Regional Airport. The USACE provided this information to the FAA on May 12, 2010 (Appendix D-4), and requested concurrence on their conclusion that these features would not result in a net change of current land use, as no habitat would be created where it does not or did not once exist. To date, no response has been received. The proposed project is not expected to introduce new hazardous wildlife attractants to the Ellington Field, Houston-Southwest, La Porte Municipal, William P. Hobby, or Pearland Regional airports.

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8.0 ANY ADVERSE ENVIRONMENTAL IMPACTS THAT CANNOT BE AVOIDED SHOULD THE GRP ALTERNATIVE BE IMPLEMENTED

It is expected that this alternative would result in a short-term increase in direct and indirect emissions to the HGB Nonattainment Area. However, it is believed that the total estimated emissions of NO_x for this alternative are well within the 2007 Nonroad Mobile Emissions Budget in the most recently approved SIP revision. As part of the General Conformity process, the USACE has prepared a Draft General Conformity Determination document discussing whether emissions of NO_x that would result from the GRP Alternative are in conformity with the Texas SIP for the HGB Nonattainment Area (see Appendix H.)

An increase in noise levels would likely result in temporary annoyance at nearby residences. Increases to ambient noise levels in the proximity of BW 8, SH 288, I-45, and other major highways would generally be more tolerable as compared to noise-level increases in more-isolated locations. Annoyance would also be reduced if construction equipment would be operated on an as-needed basis and restricted to daytime hours.

According to results of the HSI modeling, approximately 278 acres of floodplain forest would be directly impacted by construction of GRP Alternative project features. Although avoidance and minimization measures built into the design of the project compensate for some of these impacts, additional compensation would be required. Loss of habitat from project impacts would result in local wildlife impacts; however, mitigation measures would provide higher quality habitat than is currently present in those areas. Proposed compensatory mitigation includes reestablishment and rehabilitation of approximately 31 acres of floodplain forest where low flows and meanders would be reconnected to cutoff oxbows. These mitigation areas would provide higher-quality habitat than is currently available that is capable of supporting a high diversity of wildlife species. Thus, proposed mitigation compensates for impacts resulting from construction of the project.

Implementation of the GRP Alternative would support the national objective of no net loss of wetlands in acres and function. Permanent impacts to 29.3 acres of wetlands would be offset in-kind by the preservation, reestablishment, and/or rehabilitation of 40.6 wetland acres in the avoidance and minimization features of the GRP Alternative and the compensatory mitigation plan (as detailed in subsection 4.9.3.2). Assessment of wetland functional impacts for the GRP Alternative was incorporated into the HEP model and supported attainment of net functional benefits through project implementation (see Appendix B).

Impacts to the freshwater fish community resulting from the construction of the Turkey Creek conveyance are expected to be long term. The downstream portion of this conveyance feature would be constructed in an area of the creek that has been previously channelized but retains a fairly natural channel alignment as well as some shading from the remaining forested riparian zone. The channel would lose most of its shading and a substantial portion of the remaining riparian zone following construction. This modification would reduce habitat diversity in the reach. The fish community can be expected to experience a reduction in species diversity from the current community structure due to the loss of some species that are less tolerant of environmental stresses. There would be loss of habitat where Turkey Creek flows into Clear Creek, resulting in a localized negative impact to Clear Creek at that point. However, as previously described, proposed mitigation would compensate for project impacts. Additional discussion is provided in Section 5 and in Appendix B.

No other long-term environmental impacts are expected to occur as a result of the GRP Alternative.

9.0 ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES INVOLVED IN THE IMPLEMENTATION OF THE GRP ALTERNATIVE

The labor, capital, and material resources expended in the planning and construction of this project are irreversible and irretrievable commitments of human, economic, and natural resources. Irreversible commitments include approximately 278 acres of floodplain forest habitat that would be lost as a result of the GRP Alternative. Another resource that would be irretrievably committed is the approximate 31 acres of prime farmland that would no longer be available for agricultural use.

Irretrievable commitments include excavation and removal of streamside vegetation as a result of the construction of conveyance channels and detention, which can result in an increased potential for erosion and sedimentation. While producing temporary negative impacts to wildlife, clearing of vegetation can improve habitat through revegetation of small native shrubs, perennial forbs, and grasses.

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10.0 RELATIONSHIP BETWEEN LOCAL SHORT-TERM USES AND MAN'S ENVIRONMENT AND THE MAINTENANCE AND REHABILITATION OF LONG-TERM PRODUCTIVITY

The construction of the GRP Alternative would impact approximately 22 linear miles of the existing channel and its tributaries. In addition, one 485-acre in-line detention basin would be constructed along Clear Creek. Material would be placed in several upland placement areas that have been identified in the project area. Short- and long-term commitments of labor and capital and the use of nonrenewable materials for power and maintenance would be required for construction of the project features.

The impacts of the GRP Alternative on terrestrial wildlife include short-term and long-term effects. Short-term effects are generally the result of physical disturbance during construction (i.e., clearing of vegetation, noise, pollution, and soil compaction), while long-term effects are generally the result of habitat modification. Temporary construction activities include effects from the use of heavy machinery that may adversely affect smaller, low-mobility species, particularly nesting and fledging birds, amphibians, reptiles, and small mammals. Impacts can range from nest destruction to soil compaction. The increased noise and activity levels during construction could potentially disturb the daily activities (e.g., breeding, foraging, etc.) of species inhabiting the areas adjacent to the affected areas. Construction activities may temporarily deprive some animals of cover and, therefore, potentially subject them to increased natural predation. Wildlife in the immediate area may also experience a slight loss of foraging habitat during construction; however, the occurrence of similar habitats in adjacent areas could potentially minimize the effects of these losses.

The construction of conveyance channels and detention features would require excavation and removal of streamside vegetation. The initial excavation of these sites would likely temporarily preclude its use by wildlife; however, the restoration of habitat associated with mitigation and the GRP Alternative itself would help ensure the reestablishment of wildlife assemblages in affected areas.

Overall, the GRP Alternative would reduce the flood damage in high-damage reaches (Pearland area and Friendswood area) by improving the detention capacity of Clear Creek and its tributaries. The high-flow channel would provide additional capacity during flood events, slowing the flow of water and increasing detention time. In addition, the GRP Alternative should reduce the flood risk for the Clear Lake area.

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11.0 ENERGY AND NATURAL OR DEPLETABLE RESOURCE REQUIREMENTS AND CONSERVATION POTENTIAL OF VARIOUS ALTERNATIVES AND MITIGATION MEASURES

NEPA regulations in 40 CFR 1502.16 (e) and (f) require a discussion of project energy requirements and natural or depletable resource requirements, along with conservation potential of alternatives and mitigation measures in an EIS. The following presents discussion to meet that requirement.

Energy (fuel) would be required to perform the channel improvements, but this is a short-term impact. The proposed project would not involve construction or maintenance of any new facilities and is proposed to accommodate conservation of important natural resources as well as to accommodate growth and development.

The proposed project would impact both uplands and wetlands; however, the project has avoided, minimized, and mitigated for these impacts. Compensation for unavoidable impacts from the proposed project includes rehabilitation of approximately 31 acres of floodplain forest. Although the proposed project would impact natural resources (see Section 4), this mitigation measure would provide higher-quality habitat than is currently available in the project area.

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12.0 PUBLIC INVOLVEMENT, REVIEW, AND CONSULTATION

NEPA guidelines require coordination with the public. To meet these requirements, the USACE and non-Federal sponsors, Galveston County, HCFCD, and BCDD4 conducted three public scoping meetings in 2001. The public was made aware of these meetings through mailings, public notices in the local newspaper, and notices in the *Federal Register*. In addition to public scoping meetings, a website for the project, www.clearcreekproject.com, was created to keep the public informed and current on the project's progress, status, and issues. Lastly, the public was able to submit comments to the USACE for greater than the required 30 days and until June 8, 2001.

12.1 PUBLIC VIEWS AND RESPONSES

Public views and concerns expressed during this study have been considered during the preparation of the FSEIS. The views and concerns were used to develop planning objectives, identify significant resources, evaluate impacts of various alternatives, and identify a plan that is socially and environmentally acceptable.

12.1.1 Public Meetings

12.1.1.1 1982 EIS Scoping and Public Meetings

During the preauthorization planning process for the Clear Creek Flood Control Project, the public was actively involved, beginning with a public meeting in Friendswood, Texas, in March 1964. Following initiation of the postauthorization studies in early 1972, numerous workshop meetings and other informal meetings were held from September through December 1976 with affected groups in the area. In addition, five public meetings were conducted on January 12, 1974, November 7, 1974, May 25, 1977, August 13, 1980, and January 26, 1982, to discuss the flooding problems in the Clear Creek area. Local engineers, civic groups, local governmental bodies, and individuals provided input to the study. Strong support for resolving the Clear Creek flooding problems was shown at each of the public meetings; however, a divergence of opinion existed on the flood control method to be used. An NOI to prepare a DEIS was published in the *Federal Register* on July 24, 1980.

The purposes of the public meeting held on January 12, 1974, were to inform the public of the status of planning for the authorized project and to gather public opinion of the improvements being considered for Clear Creek. More than 600 persons attended the meeting. Most attendees indicated the desire for positive flood control measures, but many expressed a preference for improvements with minimal disturbance of environmental and aesthetic resources within their local area. Local governmental officials expressed strong support for the authorized flood control improvements. Using information collected from the January 1974 public meeting, several alternatives to the authorized plan were developed, and representatives of the four non-Federal sponsors, Harris, Galveston, Brazoria, and Fort Bend counties, formed a steering committee to review and discuss potential plans.

The public meeting on November 7, 1974, was held to present three basic plans of improvement for consideration by the public. An additional channel opening between Clear Lake and Galveston Bay and floodplain management along the upper reaches of Clear Creek were common features in all plans. Approximately 450 people attended the meeting, and more than 6 hours of oral testimonies, as well as numerous written statements, were received. Vigorous campaigns conducted by residents of the Clear Creek area resulted in a large volume of written statements being submitted, including petitions containing more than 7,000 signatures. Again, there was a general recognition of the need to mitigate flood effects and maintain aesthetics, but diverse opinions were expressed regarding the appropriate method to accomplish reduced flood damages. Less than 2 percent of the public responses indicated a preference for no action. Some area residents and most environmental and conservation groups advocated a nonstructural plan consisting of Federal acquisition of existing flood-prone developments and local management of future development. One of the proposed plans, the Updated Authorized Plan, which would rectify most of the existing channel, was endorsed by the non-Federal sponsors, nearly all city governments, and many of the residents subject to flooding. Following evaluation of public input, it was concluded that additional attention to design details and individual preferences would be required if an acceptable flood damage prevention plan was to be developed for Clear Creek. An extensive public education and involvement program was developed to present additional, fully developed alternative plans that addressed issues identified at the public meeting.

The public meeting on May 25, 1977, attended by about 700 people, was held to obtain views of the public on the array of plans developed. Individuals were provided an opportunity to indicate their preference regarding a plan for flood risk management within the Clear Creek watershed through an informal poll taken at the meeting. An overwhelming majority of those attending the meeting indicated a high degree of support. More than 87 percent of poll participants indicated a preference for a plan consisting of a channel designed to contain at least a 10-year flood within banks. About 7 percent favored no action. Although a consensus on the nature of the flood control project seemed within reach, public interest appeared to decrease over time.

The record flooding caused by Tropical Storm Claudette in July 1979 renewed interest and support for a speedy resolution of the Clear Creek flooding problems. After Claudette, numerous meetings were arranged by cities, civic associations, and other citizen groups, and USACE technical staff participated in many. These citizen groups expressed strong support for a flood control project. However, many of the groups remained on record as opposing any plan that directly impacts on the existing creek and generally favored some form of land-use regulation to control development throughout the watershed. The citizens around Clear Lake voiced strong concern about the effect that upstream channelization would have on the lake area. Their concern was that channelization of Clear Creek would raise the level of Clear Lake and increase flooding in adjacent areas.

The purpose of the scoping meeting held on August 13, 1980, in League City, Texas, was to solicit additional concerns and comments from the public to aid in the formulation of plans to be analyzed in the EIS. The public meeting on January 26, 1982, was held to present the results of postauthorization planning for the project and to allow discussion concerning the requirements of Section 404 of the Clean Water Act. The plan that would become the AFP was presented and the public was invited to provide comments. The overwhelming majority of the more than 400 people in attendance favored early implementation of the project. Most of the 42 speakers, representing individuals, agencies, and various groups, favored proceeding with construction as expeditiously as possible. Two speakers counseled caution in proceeding with the project, but only one speaker opposed construction. As a result of the public meeting, more than 200 letters providing comments on the project were received. Nearly all of these letters offered strong support for the plan with only about 2 percent opposing the project.

12.1.1.2 1997 Public Meetings

Public meetings for the Clear Creek Federal Flood Control Project were hosted by HCFCD in July 1997, September 1997, and November 1997. On July 22, 1997, the first public meeting was held at the League City Civic Center. Over 600 people attended the public meeting to discuss the AFP. The Executive Director of the HCFCD proposed three options: implement the current project, abandon the project all together, or revise the project to adapt to current needs and priorities. Over 60 speakers expressed their opinions towards the channelization project, with comments and suggestions being received from all sides of the issue. Most of the comments, however, centered on one of four issues:

1. Completion of the current project.
2. Concerns over the environmental impact any flood control project would have on Clear Creek.
3. Concerns that a channelization project would increase flooding impacts on Clear Lake communities.
4. Concerns about the proposal to place excavated material into Swan Lagoon or Clear Lake.

The majority of the speakers were not in favor of the current project, yet most expressed a willingness to work towards a common solution to the watershed's flooding problems.

On September 23, 1997, the second of three public meetings was held at Friendswood High School. Over 900 people attended the public meeting to learn more about the review process currently reexamining the AFP. A presentation by the Executive Director and Chief Engineer of the HCFCD explained the flood control project alternatives being evaluated. Two alternative projects were discussed in detail by the HCFCD and were displayed on maps given out to the public. In addition to submitting oral comments, those attending were asked to comment on the alternatives either through comment cards, letters, or by telephone to the HCFCD.

On November 11, 1997, the third and final public meeting was held at Friendswood High School. Approximately 150 people attended the meeting. The Executive Director of HCFCD stated that the probable recommendation will be a redefined Federal project that lessens environmental impact on the creek, yet offers equivalent flood control on the same schedule. This proposal would incorporate a bypass channel around the most environmentally sensitive portion of Clear Creek, would require additional runoff controls in the Clear Creek Regional Flood Control Plan, and would reduce the amount of channel rectification throughout the entire project's reach.

The Chief Engineer for HCFCD addressed Clear Lake area issues, reviewed alternatives presented at the previous public meetings, and described the recommended alternative. Following HCFCD's presentation, the floor was opened for public comment. Most remarks either reiterated previously voiced concerns from other meetings or were questions concerning the Clear Lake analysis.

In addition to the public meetings hosted by HCFCD, various types of communication were used to keep the public informed of the progress of the project. These included written material that provided a history of the Clear Creek watershed, a description of components of the Federal project that had been implemented, a description of other components of the Federal project, a discussion of the reevaluation process, and recaps of the public meetings. In addition, a telephone hot line was set up by HCFCD that provided information about project status and meetings and provided a means to submit comments. The HCFCD received 3,301 total contacts regarding the project, which included 766 attendance cards from meetings, 317 letters from individuals, 34 letters from organizations/cities, 1,131 people who signed petitions, 713 form letters, and 340 telephone calls. About 400 people who contacted the HCFCD had experienced flooding, and about 1,100 lived outside the watershed.

12.1.1.3 2001 Scoping Meetings

Three public scoping meetings were conducted for the Clear Creek General Reevaluation Study. These meetings occurred on March 15, 2001, in Friendswood, Texas; May 3, 2001, in League City, Texas; and May 9, 2001, in Pearland, Texas. The purpose of these meetings was to inform stakeholders and interested parties about the proposed Clear Creek Project, to outline the planning and feasibility study processes, to present the proposed project schedule, and to solicit public comments/input. Solicitation of public comments was a primary objective of the scoping meetings to ensure that significant issues were addressed. As such, meeting participants were specifically asked to identify environmental concerns, constraints, opportunities, and recommendations associated with the proposed flood risk management measures.

At each of the three meetings, a presentation of the project was given and the floor was opened to verbal comments from the public (see Appendix A). A court reporter recorded these presentations and all verbal comments given by attendees.

More than 250 individuals from the public attended the three scoping meetings. Comments, petitions, and letters received during these meetings totaled more than 100. Most comments can be grouped into the following subjects: (1) favor clearing and snagging, (2) favor nonstructural alternatives, (3) support Challenge 21, (4) oppose future development in the area, (5) concern with lack of action, and (6) glad project is moving forward.

12.1.2 Additional Public Involvement

In addition to NEPA-related public meetings, USACE hosted two open-house workshops in February 2004 to update the public on the status of the project and to report and present examples of the flood risk management and ecosystem restoration measures being considered. Public comments were also accepted at these meetings. Comments from these meetings are attached in Appendix A.

Additional efforts to involve the public include maintenance of the Clear Creek Project website, public field trips, educational sessions, and establishment of the CCSC and the CAC. These two committees were formed to incorporate public, agency, and stakeholder interests in the reevaluation process. The CCSC comprises the following:

- Brazoria County Conservation and Reclamation District 3
- BCDD4
- City of Friendswood
- City of Houston
- City of League City
- City of Pasadena
- City of Pearland
- Clear Lake Area Council of Cities
- Fort Bend County Drainage District
- Galveston County
- HCFCD
- Galveston County Consolidated Drainage District

12.1.3 DSEIS Public Hearing

The notice for the public meeting and availability for the DSEIS was published in local newspapers (the *Facts*, the *Houston Chronicle*, and the *Galveston County Daily News*) and in the *Federal Register* on December 16, 2011 (Appendix A-7). The public meeting was held on January 11, 2012, at the Marie Spence Flickenger Fine Arts Building at San Jacinto College South. A website address for the DSEIS was included in the notice and both physical and email addresses were provided for submission of comments, with a comment submission deadline of January 30, 2012. Comments were received during the comment period via email, letters, comment forms, or verbally (Appendix A-8). Comments were received from local, state and Federal agencies (e.g., Department of the Interior, EPA, NRCS, NMFS, TPWD, GLO, and TCEQ), interest groups (Galveston Baykeeper, The Nature Conservancy), local community organizations (BellaVita HOA), and residents. The various State and Federal agencies provided comments on the DSEIS and others expressed concerns regarding various aspects of the project and/or support for the project. Comments included issues such as alternatives, water quality, mitigation, ecological effects, downstream velocities and flooding, cumulative impacts, greenhouse gas emissions and climate change, and impacts on local wildlife. The residents of BellaVita expressed concern regarding the effect of the proposed project on an area adjacent to their community that is included as a proposed mitigation area. All of the comments received are addressed in Appendix A-8, and text has been inserted or revised in the SEIS as appropriate.

12.2 REQUIRED COORDINATION

As was done for the Draft GRR and DSEIS, the final documents will be circulated to all known applicable Federal, State, and local agencies. Interested organizations and individuals will be sent the Notice of Availability with instructions to access the documents online or request electronic or paper copies. Copies will also be made available for public review at local libraries.

12.3 STATEMENT RECIPIENTS

FEDERAL REPRESENTATIVES

Congressman Ron Paul
U.S. Representative

Congressman Al Green
U.S. Representative

Congressman Gene Green
U.S. Representative

Congressman Pete Olson
U.S. Representative

Senator Kay Bailey-Hutchison
U.S. Senate

Senator John Cornyn
U.S. Senate

FEDERAL AGENCIES

Ms. Aja Bonner
Current Rotation
Center for Disease Control and Prevention

Director
Office of ENV Policy & Compliance
Department of the Interior

Dr. Roy E. Crabtree, Ph.D.
Regional Administrator
National Marine Fisheries Service

Mr. Miles Croom
Assistant Regional Administrator
National Marine Fisheries Service

FEDERAL AGENCIES, cont'd

Mr. Rusty Swafford
National Marine Fisheries Service

Mr. David Bernhart
National Marine Fisheries Service

Mr. David Keyes
NEPA Coordinator
NOAA Fisheries

Mr. Don Gohmert
State Conservationist
Natural Resources Conservation Service

Mr. Scott Alford
Soil Conservationist
U.S. Department of Agriculture
Natural Resources Conservation Service

Ms. Andrea Catanzaro
U.S. Army Corps of Engineers, Galveston District

Ms. Yvonne L. Haberer
SWD-RIT Planner
Headquarters USACE

Ms. JoAnn Duman
PDS-P
USACE Southwestern Division

Mr. Stephen Spencer
Regional Environmental Officer
U.S. Department of the Interior
Office of Environmental Policy and Compliance

Mr. Thomas Diggs
Chief Air Planning Section
U.S. Environmental Protection Agency

Mr. Michael Jansky
Office of Planning and Coordination
U.S. Environmental Protection Agency

Mr. Jeff Riley
Air Conformity
U.S. Environmental Protection Agency

Mr. Herrington Jim
U.S. Environmental Protection Agency

Mr. Robert Lawrence
U.S. Environmental Protection Agency

Ms. Barbara Keeler
U.S. Environmental Protection Agency

Ms. Edith Erfling
Field Supervisor
Clear Lake ES Field Office
U.S. Fish and Wildlife Service

Ms. Donna Anderson
Wildlife Biologist
U.S. Fish and Wildlife Service

FEDERAL AGENCIES, cont'd

Mr. Steve Parris
U.S. Fish and Wildlife Service

Dr. Robert Stickney
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15.0 GLOSSARY

100-year floodplain – These floodplains represent an area of inundation having a 1 percent chance of being equaled or exceeded in any given year.

500-year floodplain – These floodplains represent an area of inundation having a 0.2 percent chance of being equaled or exceeded in any given year.

Aesthetics – The subjective perception of beauty in a landscape.

Amphipods – A type of crustacean.

Anthropogenic – Relating to, or resulting from, the influence of humans on nature.

Anuran – Frogs and toads.

Aquifer – An underground bed or stratum of earth, gravel, or porous stone that contains water.

Assessment Model – A simple mathematical tool that defines the relationship between ecosystem/landscape scale variables and either functional capacity of a wetland or suitability of habitat for species communities. Habitat Suitability Indices are examples of assessment models for which the HEAT software can be used to assess impacts/benefits of alternatives.

Average Annual Habitat Units – A quantitative result of annualizing Habitat Unit (HU) gains or losses across all years in the period of analysis.

Bathymetry – The measurement of depths of water in oceans, seas, and lakes and the information derived from such measurements.

Benthic biota – Aquatic bottom-dwelling organisms that include worms, leeches, snails, flatworms, burrowing mayflies, clams.

Best management practices – An engineered structure, management activity, or a combination of, that eliminates or reduces an adverse environmental effect.

Brackish water – A mixture of fresh and salt water.

Buyouts – The elimination of potential flood damages to houses or other types of structures by acquiring them and removing them.

Compensatory mitigation – The restoration (reestablishment or rehabilitation), establishment (creation), enhancement, and/or, in certain circumstances, preservation of aquatic resources for the purposes of offsetting unavoidable adverse impacts that remain after all appropriate and practicable avoidance and minimization has been achieved.

Confluence – The intersection of two or more streams, or where one flows into another.

Conveyance – The ability of a channel or other drainage element to move stormwater.

Debitage – The waste material produced during lithic reduction and the production of chipped stone tools.

Demersal – At or near the bottom.

Detritivores – Consumers of dead organic materials (detritus). Detritus feeders recycle the carbon in this material by mechanically and chemically breaking it down. During decomposition, carbon is returned to the atmosphere to be reabsorbed by living plants.

Dredged material – Material excavated from waters of the United States or ocean waters. The term dredged material refers to material that has been dredged from a water body, while sediment refers to material in a water body prior to the dredging process.

Ecosystem Assessment Team (E-Team) – An interdisciplinary group of regional and local scientists responsible for determining significant resources, identification of reference sites, construction of assessment models, definition of reference standards, and calibration of assessment models. In some instances the E-Team is also referred to as the Environmental Assessment Team or simply the Assessment Team.

Ecotone – A transition area between two adjacent but different plant communities.

Enhancement – The manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function(s). Enhancement results in the gain of selected aquatic resource function(s), but may also lead to a decline in other aquatic resource function(s). Enhancement does not result in a gain in aquatic resource area.

Environmental Operating Principles (EOP) – These seven principles were promulgated and promoted throughout USACE to inform and guide its corporate program execution and project development decision-making process. The purpose of the USACE EOP is to illuminate the ways in which the USACE's missions are to be integrated with natural resources laws, values, and sound environmental practices, in order to focus on achieving greater synergy between environmental sustainability and implementation of the full spectrum of USACE activities, including planning, design and construction, operations and maintenance (O&M), regulatory, research and development, acquisition, real estate, and support for others (USACE, 2003).

Epiphytes – Any plant that does not normally root in the soil but grows upon another living plant while remaining independent of it except for support.

Essential Fish Habitat (EFH) – Those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.

Establishment (creation) – The manipulation of the physical, chemical, or biological characteristics present to develop an aquatic resource that did not previously exist at an upland site. Establishment results in a gain in aquatic resource area and functions.

Estuary – Bodies of water along coasts.

Euryhaline – Tolerant of a wide range of salinities.

Eustatic sea level rise – Global changes in sea level.

Fair market value – The specific dollar amount a willing buyer will pay and a willing seller will accept.

Flood bench – Typically, a design feature obtained by enlarging a channel's cross-sectional geometry so that it varies in width and steepness, creating flatter slopes and even plateaus, giving completed segments more of a natural appearance.

Flood Insurance Rate Maps (FIRMs) – The official map of a community on which FEMA has delineated both the special hazard areas and the risk premium zones applicable to the community.

Floodplain – The flat, low-lying portion of a stream valley subject to periodic inundation. Residences and businesses within the floodplain are considered to be at risk of being damaged by flooding (HCFCD glossary).

Fluvial deposits – A sedimentary deposit from a river.

Groundwater – The supply of freshwater under the earth's surface in an aquifer or soil that forms the natural reservoir for man's use.

Habitat Assessment – The process by which the suitability of a site to provide habitat for a community or species is measured. This approach measures habitat suitability using an assessment model to determine HSI.

Habitat Suitability Index Model – A quantitative estimate of suitable habitat for a site. The ideal goal of an HSI model is to quantify and produce an index that reflects functional capacity at the site. The results of an HSI analysis can be quantified on the basis of a standard 0–1.0 scale, where 0.00 represents low functional capacity for the wetland, and 1.0 represents high functional capacity for the wetland.

Habitat Unit (HU) – A quantitative environmental assessment value, considered the biological currency in HEP. HUs are calculated by multiplying the area of available habitat (quantity) by the quality of the habitat for each species or community. Quality is determined by measuring limiting factors for the species (or community), and is represented by values derived from Habitat Suitability Indices (HSIs).

Hydrogeomorphology – The study of the physical appearance and operational character of a waterway as it adjusts its boundaries to the magnitude of stream flow and erosional debris produced within the attendant watershed.

Hydroperiod – The period of time during which a wetland is covered by water.

Lacustrine – Of or relating to lakes.

Land subsidence – The sinking of the land surface.

Macroinvertebrates – An invertebrate (lacking a backbone) large enough to be seen without magnification.

No Action Alternative – Also referred to as the future without-project condition (FWOP), the No Action Alternative describes the project area's future if there is no Federal action taken to solve the problem(s) at hand. Every alternative is compared to the same without-project condition.

Ordinary high water mark – The term ordinary high water mark means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas

Oxbow – Generally, a U-shaped bend or meander in a channel. Oxbows are sometimes "cut off" and abandoned when a channel is straightened. This can occur both naturally or by man-made means.

PCBs – Polychlorinated biphenyls, a group of organic compounds used in the manufacture of plastics. In the environment, PCBs exhibit many of the same characteristics as DDT and may therefore be confused with that pesticide. PCBs are highly toxic to aquatic life; they persist in the environment for long periods of time, and are biologically accumulative.

Pelagic – Of, relating to, or living or occurring in the open sea.

Performance standards – Observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine whether a compensatory mitigation project meets its objectives.

Physiography – A landscape whose parts exhibit similar geologic structures and climate, and whose pattern of topographic relief differs significantly from that of adjacent landscapes, indicating a unified geomorphic history.

Polychaetes – Segmented worms, mostly marine, bearing paddlelike appendages on the body segments, which, in turn, carry numerous bristles.

Preservation – The removal of a threat to, preventing the decline of, aquatic resources by an action in or near those aquatic resources. This term includes activities commonly associated with the protection and maintenance of aquatic resources through the implementation of appropriate legal and physical mechanisms. Preservation does not result in a gain of aquatic resource area or functions.

Reestablishment – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former aquatic resource. Reestablishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions.

Rehabilitation – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area.

Restoration – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource. For the purpose of tracking net gains in aquatic resource area, restoration is divided into two categories: reestablishment and rehabilitation.

Riparian – The area of land along and adjacent to a waterway (river, bayou, creek, stream, etc.). Trees, plants, and grasses along these waterways are called riparian vegetation. A riparian zone from an ecological perspective may occur in many forms including grassland, woodland, wetland or even nonvegetative. Riparian zones may be natural or engineered for soil stabilization or restoration. In some regions the terms riparian woodland, riparian forest, riparian buffer, or riparian corridor are used to characterize a riparian zone (HCFCD).

Riprap – Pieces of rock, broken stone, or rubble added to the surface of a fill slope, such as the side of a levee, to prevent erosion.

Risk – The volatility of potential outcomes. In the case of ecosystem values, the important risk factors are those that affect the possibility of service flow disruptions and the reversibility of service flow disruptions.

Riverine – Relating to or resembling a river.

Runoff – The stormwater from rainfall not absorbed by the ground that flows into the local drainage system, and ultimately, streams and bayous.

Saltwater wedge – A wedge-shaped intrusion of salty ocean water into a freshwater estuary or tidal river.

Sediment – The layer of soil, sand, and minerals at the bottom of surface water that absorbs contaminants.

Seiche – A standing wave in an enclosed or partially enclosed body of water.

Shoreline armoring – To protect shoreline, by covering it with erosion-resistant materials such as rock or concrete.

Slough – A creek in a marsh or tide flat.

Soil associations – Group of soil series developed on a similar parent material or on a combination of rocks.

Sole source aquifer (SSA) – An aquifer that has been designated by the EPA under the Safe Drinking Water Act of 1974 as the sole or principal source of drinking water for an area.

Stormwater – Generated when precipitation from rain and snowmelt events flows over land or impervious surfaces and does not percolate into the ground. As the runoff flows over the land or impervious surfaces (paved streets, parking lots, and building rooftops), it accumulates debris, chemicals, sediment, or other pollutants that could adversely affect water quality if the runoff is discharged untreated.

Suitability Index (SI) – A mathematical equation that reflects a species' or community's sensitivity to a change in a limiting factor (i.e., variable) within the habitat type in HEP applications.

Superfund – The common name used for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Texas State Implementation Plan (SIP) – Plan for air quality improvement measures that Texas adopted to meet federal Clean Air Act obligations (http://www.tceq.state.tx.us/nav/eq/sip.html).

Texas Water Quality Standards – Standards set by TCEQ for surface water quality to improve and maintain the quality of water in the State.

Total Maximum Daily Load (TMDL) – A calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. (http://www.epa.gov/owow/tmdl/).

Turbidity – An optical measure of the amount of material suspended in the water. Increasing the turbidity of the water decreases the amount of light that penetrates the water column. High levels of turbidity may be harmful to aquatic life.

Urodele – Any of various amphibians of the order Caudata, including salamanders and newts, in which the larval tail persists in adult life.

Volatile Organic Compounds (VOC) – Volatile organic compounds. Secondary petrochemicals, including light alcohols, acetone, trichloroethylene, perchloroethylene, dichloroethylene, benzene, vinyl chloride, toluene, and methylene chloride, which are used as solvents, degreasers, paint thinners, and fuels. Because of their volatile nature, they readily evaporate into the air, increasing the potential exposure to humans. Due to their low water solubility, environmental persistence, and widespread industrial use, they are commonly found in soil and groundwater.

Waters of the U.S. – 40 CFR 230.3(s). The term waters of the United States means:

1. All waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide;

2. All interstate waters including interstate wetlands;

3. All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation, or destruction of which could affect interstate or foreign commerce including any such waters:

   (i) Which are or could be used by interstate or foreign travelers for recreational or other purposes; or

(ii) From which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or

(iii) Which are used or could be used for industrial purposes by industries in interstate commerce;

4. All impoundments of waters otherwise defined as waters of the United States under this definition;
5. Tributaries of waters identified in paragraphs (s)(1) through (4) above;
6. The territorial sea;
7. Wetlands adjacent to waters (other than waters that are themselves wetlands) identified in paragraphs(s) 1 through 6 above; waste treatment systems, including treatment ponds or lagoons designed to meet the requirements of CWA (other than cooling ponds as defined in 40 CFR 423.11(m), which also meet the criteria of this definition) are not waters of the United States.

Waters of the United States do not include prior converted cropland. Notwithstanding the determination of an area's status as prior converted cropland by any other Federal agency, for the purposes of the Clean Water Act, the final authority regarding Clean Water Act jurisdiction remains with EPA. (http://www.epa.gov/wetlands/guidance/CWAwaters.html).

Watershed – A geographical region of land or "drainage area" that drains to a common channel or outlet. Drainage of the land can occur directly into a bayou or creek, or through a series of systems that may include storm sewers, roadside ditches, and/or tributary channels (HCFCD glossary).

Wetlands – Areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and that, under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated-soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (40 CFR Part 230), especially areas preserved for wildlife, zooplankton (planktonic animals that supply food for fish).

16.0 INDEX