CHAPTER 4
PLAN FORMULATION

This chapter details the steps that were taken to formulate a plan which best meets or exceeds the planning objectives as set forth below. The formulation of a plan to resolve the flood related problems and needs necessitates the exploration of possible alternative measures, including structural and non-structural solutions. Beneficial and adverse contributions of each alternative are evaluated against existing conditions.

PLANNING OBJECTIVES

Planning objectives are an expression of public and professional concerns about the use of water and related land resources resulting from the analysis of existing and future conditions in the study area. These planning objectives were used in guiding the development of alternative plans and their evaluation for the period of analysis.

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

Plans formulated as part of this study were evaluated based on their contribution to the National Economic Development, and are consistent with protection of the Nation's environment. In addition to these National objectives, additional planning objectives evolved from meetings with area residents, from contact with the local sponsor, State and Federal agencies, and from observations made in the area. Specific needs, desires, and goals of the community were identified. The planning objectives for this study were identified during the initial stages, and are as follows:

- Reduce flood damages within the city of Wharton, which are inflicted by flood flows from the Colorado River, Caney Creek, Baughman Slough, and Peach Creek.

- Reduce risk to life, health, and welfare of the residents residing in Wharton by decreasing the risk of flooding to the extent practical.

- Enhance the quality of life available to residents within the city of Wharton by reducing flood risk and providing recreation opportunities.

- Decrease the number of residents who are subject to zoning restrictions pertaining to the 100-year floodplain.

- Reduce emergency costs associated to the occurrence of significant flood events within Wharton.

PLANNING CONSTRAINTS

In order to provide direction for the plan formulation efforts, maximize beneficial impacts, minimize adverse impacts, and to reflect restrictions of the General Investigation Program, the following constraints were taken into account:

- Modification or any adverse impacts to Peach Creek should be avoided, due to its current, high environmental value.

- Structural features of sufficient height and magnitude to cut off the visibility of the Colorado River from the historic business district should be avoided.

- All Federal, State, and local laws must be followed by the proposed solutions.

- To ensure future Federal support, all current administrative policies must be met. This constraint should not impede the development of any viable alternative, but may become important during the selection phase.

FORMULATION AND EVALUATION CRITERIA

Consideration was given to economic, social, and environmental impacts for each alternative during the development of long-term solutions to the flood problems within the Wharton area. Appropriate Corps of Engineers engineering and design manuals, criteria, and regulations relating to flood control channels, outlet works, embankment, streamflow routing, backwater computation, cost estimates, etc., were used in developing alternative plans.

TECHNICAL CRITERIA

Alternative plans must be feasible, practicable, and soundly engineered to provide a service life, with reasonable maintenance, for at least 50 years. Existing facilities should be utilized to the maximum extent possible. The plan should be complete within itself and not require additional future improvements other than normal operation and maintenance.

ECONOMIC CRITERIA

The NED objective is maximization of the economic worth of alternative plans as set forth in the Principles and Guidelines for Planning Water and Related Land Resources Implementation Studies. The NED objective is to increase the nation's output of goods and services and improve national economic efficiency. For flood control projects, this objective relates to a plan's capability to prevent flood damages by comparing the plan's economic benefits with the project cost. The amount that a project's economic benefits exceed the project cost is defined as net benefits. In the plan formulation process, the plan that yields the greatest net benefits best meets the NED objective.

The plan selected as the recommended plan should seek to provide a maximum of net benefits, unless certain provisions can be applied to supercede this criteria. One such provision cited in Corps guidance allows a locally preferred plan to be selected as the recommended plan if the plan yields greater net benefits than any smaller scale alternative. In such instances, larger scale plans need not be investigated in an effort to identify the NED Plan. The other provision allowing recommendation of a plan other than the NED Plan involves the granting of an exception by the Assistant Secretary of the Army (Civil Works). Such an exception may be granted for an economically justified plan when overriding and compelling reasons favor the selection of such a plan. Recommended plans which are less costly than the NED Plan would be cost shared on the same basis as the NED Plan. In the absence of special legislation, Federal participation in a recommended plan that is more costly than the NED Plan would be limited to the Federal share of the NED Plan, unless the increased development is deemed worthy of warranting Federal participation, and is specified as such in the exception. Cost sharing may then be calculated on the same basis as the NED Plan.

To meet the Federal guidelines for planning water resource projects, the following economic criteria were followed:

- The recommended plan must be economically feasible, i.e. the plan's benefits must exceed the cost of the plan.
- Alternative plans should be evaluated using the current Federal interest rate and price levels, and a 50-year period of analysis.
- Annualized costs must include the cost of operation, maintenance, repair, rehabilitation, and replacements.

Economic feasibility of a plan is displayed as a relationship of benefits to costs, expressed in terms of a benefit-cost ratio (BCR). Identified as benefits are the monetary savings or benefits due to damages prevented, reduction in the cost of emergency services, and reduction of economic disruption. These project benefits are subsequently annualized to represent an annual benefit applicable for the period of analysis. The project cost, which includes the construction or first cost, the interest on the first cost during construction, the operation and maintenance costs, and the interest to amortize the project cost over the period of analysis are also annualized to represent an annual project cost applicable for the analysis period of the project. The annual benefits and the annual costs are then related in a ratio of benefits to costs. To be economically feasible, a plan must have greater benefits than costs or, more specifically, a BCR greater than 1.0, based on the current applicable interest rate.

The evaluation of alternatives is presented using October 2004 prices and levels of development. The Fiscal Year 2005 interest rate of 5.375% was used to annualize all costs and compare against annualized benefits. The baseline expected annual damages can be found in Chapter 3, with additional details in Appendix A.

ENVIRONMENTAL AND SOCIAL CRITERIA

Plans formulated under Federal directives should be consistent with protecting and enhancing the existing environment by the management, conservation, preservation, creation, or improvement of the quality of certain natural and cultural resources and ecological systems in the proposed project area. Structural and non-structural measures must be evaluated in accordance with guidelines established by the National Environmental Policy Act of 1969 (Public Law 91 190), as amended, and the Principles and Guidelines for Water and Related Land Resources Implementation Studies, as developed by the U.S. Water Resources Council, dated July 1983. The following environmental and social criteria were considered:

- Promote the protection and enhancement of areas of natural beauty and human enjoyment.
- Protect areas of valuable natural resources.
- Protect quality aspects of water, land, and air resources in the watershed.
- Protect against possible loss of life and hazards to health.
- Promote safety.
- Preserve and enhance social, cultural, educational, and historical values within the project area.

- Minimize and, if possible, avoid the displacement of people and destruction or disruption of community cohesion.

INITIAL SCREENING OF ALTERNATIVES

In selecting alternative plans for flood damage reduction, a full range of structural and nonstructural measures were considered. These were discussed at the Feasibility Scoping Meeting held on August 20, 2003.

Structural measures consist of structures designed to control, divert, or exclude the flow of water from the flood prone areas to the extent necessary to reduce damages to property, hazard to life or public health, and general economic losses. The structural measures considered most appropriate in dealing with the character of the flood problems encountered typically include small detention lakes, channel modifications, flood flow diversions, and levees.

Nonstructural measures, attempt to avoid flood damages by exclusion or removal of damageable properties from the flood prone areas. These measures do not affect the frequency or level of flooding within the floodplain; rather, they affect floodplain activities. The technique of controlled land use is particularly helpful in planning for future development, but is limited in highly developed areas.

The basic alternative to any flood damage reduction plan is the no action plan. Adoption of this alternative implies acceptance of the costs and adverse effects of continued flooding. The no action alternative would recommend no plan and require no allocation of Federal funds.

Certain alternative solutions have been subjected to only preliminary investigations because of their evident economic infeasibility, social unacceptability, or increased adverse impacts on the environment. The more favorable alternative solutions have been subjected to more detailed studies to define their costs and benefits.

NONSTRUCTURAL ALTERNATIVES

No Action

The “no action” alternative would not recommend any type of project, nonstructural or structural, be implemented. While the no-action measure does not require the expenditure of Federal funds, adoption of this alternative implies acceptance of the existing and future flood damages and other adverse impacts caused by continued potential flooding of the 3,252 structures within the 0.2 percent ACE (500 year) floodplain.

The “no action” alternative would not result in impacts to fish and wildlife habitat within the project area. This alternative may result in continued temporary water quality impacts to surface and ground water due to over bank flooding. An out-of-bank flood of the Colorado River impacts the water treatment plant and any septic systems in the city, which could lead to temporary discharges of sewage. Overall, this alternative would not result in any additional environmental impacts compared to the current conditions.

This alternative will continue to subject Wharton citizens to flooding hazards. Although flood insurance would partially compensate for flood damages, they would still be incurred at an estimated average rate of $4.5 million annually. The costs for flood fighting and recovery costs, public damages, the potential loss of life, and the overall threat to health and safety would continue under the no action alternative. The no action alternative does not meet any of the

previously stated planning objectives. For compliance with National Environmental Policy Act regulations (40 CFR 1502.14(d)), the no action alternative will, however, be carried forward to the final array of alternatives.

Floodplain Management

Floodplain management is most effective in controlling future development of the floodplain, thereby assuring that the existing flood problems do not become worse. However, floodplain management cannot, by itself, significantly alleviate existing flooding conditions within an existing floodplain. The technique of controlled land use is particularly helpful in planning for future development but is of limited use in highly developed areas. Effective regulation of the floodplain is dependent on developing enforceable ordinances to insure that floodplain uses are compatible with the flood hazard. Several means of regulation are available, including zoning ordinances, subdivision regulations, and building codes. Zoning regulations permit prudent use and development of the floodplain in order to prevent excessive property damage, expenditure of public funds, inconvenience, and most important of all, loss of life, due to flooding. Subdivision regulations guide the division of large parcels of land into smaller lots, and typically require the developer to show compliance with subdivision regulations, zoning ordinances, the local land use or master plan, and other regulations. A subdivision ordinance would require installation of adequate drainage facilities, prohibit encroachment into floodway areas, require the placement of critical streets and utilities above a selected flood elevation, and building lots or structures above a selected flood elevation, normally one foot above the 100-year floodplain elevation. Building codes specify the building design, materials and construction methods used for both construction of new buildings or repair of flood-damaged structures.

The City of Wharton currently participates in the National Flood Insurance Program (NFIP), and has been enrolled in NFIP's Regular Program since 16 September 1982. After joining this program, the City of Wharton has enacted and enforced numerous floodplain land-use restrictions, regulation, zoning ordinances, subdivision regulations, and building codes. While these measures will not reduce flood damages to the majority of the existing structures in the study area, they are important management tools for limiting the continued increase in population and property susceptible to flooding. However, given that the vast majority of the city is located within the FEMA designated Zone A, or existing 100-year floodplain, this has placed severe restrictions on any further development. From a local economic perspective, this has placed the city in a disadvantage when competing with other local communities to attract new businesses and development. This is directly linked to one of the Planning objectives.

Additional, more intense floodplain management does not warrant further evaluation due to its inability to address existing damages and meet the planning objectives. It should be noted that Wharton will be required to complete and implement a floodplain management plan within one year of the completion of any flood damage reduction plan recommended and implemented by the Corps of Engineers.

Flood Forecast and Warning

Flood forecast and warning involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in evacuation of persons and some personal property. Notification of impending flooding can be by radio, siren, individual notification, or by more elaborate means such as remote sensors to detect water levels and automatically warn residents. These measures normally serve to reduce the hazards to life and damage to portable personal property. Flood warning and emergency evacuation should be considered as part of any flood control plan.

For flooding relating to the Colorado River, sufficient lead time exists, and local officials are already warning residents using various communications methods. Little would be gained, if this was converted to an automated system, and damage to structures would remain the same.

Flood proofing

Flood proofing of residential and commercial structures can include providing water tight coverings for door and window openings, raising structures in place, raising access roads and escape routes, constructing levees and floodwalls around individual buildings or groups of buildings, and waterproofing walls of structures. Flood proofing is more easily applied to new construction and more applicable where flooding is of short duration, low velocity, infrequent, and of shallow depths, and is also appropriate in locations where structural flood protection is not feasible or where collective action is not possible. Flood proofing techniques would require major modifications to existing structures. For water levels that are lower than the first floor of a home, flood proofing would certainly be a possibility. However, if a sustained water level in excess of one foot of the first floor elevation, the structural stability of a watertight home becomes a critical factor. A flood proofed structure generally cannot withstand hydrostatic pressures when water rise three feet above the lowest floor. This is especially true in the older, established neighborhoods that consist of small wood framed houses that flood most frequently. Additional shortcomings include not protecting public facilities such as roads, bridges, and utilities, and the continued threat of road closures and the isolation of residents trapped in their homes and businesses.

The elevating of structures in place has potential in some instances. This is especially true if the flooding involves a small number of structures sparsely distributed within the floodplain, and those structures are of the pier-on-beam foundation type. This criteria, however, does not fit the situation in Wharton, where flooding is to thousands of structures and many of the homes utilize slab-on-grade foundations.

While flood proofing would not likely result in any significant or permanent adverse impacts to ecological or cultural resources, and is appropriate under certain conditions, as a standalone alternative, it does not fully address the planning objectives or criteria previously discussed. In some instances, it may be a viable option in combination with another structural measure. If, however, a levee system is selected, additional flood proofing makes little sense, and would not be considered further under these circumstances.

Floodplain Evacuation

Floodplain evacuation, or buyout as it is commonly known, involves the acquisition, demolition, and removal of structures from the floodplain, and the relocation of residents to flood-free housing. The practicality of evacuation depends on several factors. They include the frequency and severity of flooding, the willingness of residents to move out of the floodplain, the availability of flood-free housing, the value of the property, and the need for areas of a more compatible floodplain use such as parks or nature areas. Permanent evacuation is a very effective means of reducing flood damages, as well as public damages and costs.

Past investigations have demonstrated that permanent evacuation is typically cost effective only up to and including the 4% ACE (25-year) floodplain. Within the study area, there are a total of 1,262 structures that would receive damages from the 4% ACE (25-year) storm. Also, many of these structures are concentrated in the southwestern portion of Wharton, populated by small, wood framed homes which could easily be removed. Based on this assessment alone, permanent evacuation warrants further investigation, and will be developed in more detail.

STRUCTURAL ALTERNATIVES

Detention

This alternative consists of constructing one or more structures to provide flood storage to detain peak flood flows and lessen downstream flood damages. Detention is used to temporarily impound floodwaters for later release when the downstream conditions permit. The feasibility of this measure depends heavily on the volume and timing of the flood flows, and the availability of an impoundment site capable of providing sufficient storage. Flood events within this area of the Lower Colorado River basin have tremendous volumes or extended durations of weeks. Additionally, since the overall topography of the area is relatively flat, no favorable sites exist in the area which could serve as a dam site to impound such high volumes of water. Therefore, this alternative was not considered any further.

Levees and Floodwalls

Levee systems traditionally provide high levels of protection to flood prone areas but often require substantial amounts of real estate between the stream and the structures being protected unless an existing levee is in-place, or the height of the levee is relatively small. Floodwalls (usually made of concrete) are used in lieu of levees in situations where the acquisition of real estate for the levee or other topographic problems may be prohibitive. The feasibility of either of these measures is based on the cost and availability of real estate, the number of structures along the levee alignment, and the additional costs necessary to alleviate interior drainage problems to prevent induced damages in adjacent areas. Construction of individual levees or floodwalls around specific structures or small groups of structures is normally considered cost prohibitive unless the individual structure is very valuable, has cultural significance, or is prone to frequent flooding.

The terrain and type flooding of experienced in the Wharton area lends itself well for resolution through implementation of a complete levee system. While the area flooded by events greater than the 10% ACE event is extensive, flooding at all levels is relatively shallow. In most areas, there is sufficient real estate available without incurring extensive relocation of existing structures or facilities. As a result, this measure will be carried forward for more detailed evaluation.

Channel Modifications

This measure consists of modifying an existing channel by either increasing the cross-sectional area of the stream channel and/or an existing bridge (widening and/or deepening), straightening and realigning the stream channel, and/or reducing the friction losses of an existing channel through concrete lining. The design of the channel modification can vary significantly and is primarily based on the topography of the existing stream channel and the existing development of properties within the floodplain. Other factors to consider in the design of these hydraulic channel improvement alternatives include the existence of known or potential significant ecological and cultural resources as well as contaminated material.

In general, large, mildly sloped rivers such as the Colorado River through Wharton, do not react well to extensive channelization. Only relatively small reductions in water surface profiles are achieved with major excavations. For smaller streams such as Baughman Slough, however, smaller excavations may create significant percent increases in channel area, which may be sufficient to realize significant reductions in flooding potential. For this reason, the channel

modification measure will be further analyzed in more detail for possible plan development on Baughman Slough.

Diversions

Diversions can exist in many types, sizes and shapes. Generally, it is defined as a feature which alters the stream flows in another direction or even into other streams. Diversions may also be used to create short cuts, or "cut-offs", across natural channel meanders.

Four different types of diversion schemes were initially discussed for possible implementation in Wharton:

- As discussed in previous sections, under without project conditions, flood flows overflow the banks of the Colorado River and actually depart the entire Colorado Basin, enter Peach Creek and Baughman Slough, and eventually enter the San Bernard River. Flooding in Wharton could perhaps be reduced in areas adjacent to the Colorado by diverting even more flows to the San Bernard. This, however, was eliminated from further consideration due to the significant flooding problems already existing along the San Bernard River.

- A cut-off diversion on the Colorado was also considered initially. A major meander of the Colorado is located adjacent to the city of Wharton. Preliminary hydraulic analysis revealed, however, that a diversion of this nature would require extensive excavation quantities, with the resulting reduction of water surfaces being relative minor. Thus, this measure was removed from further consideration.

- Significant flooding within Wharton occurs due to the lack of drainage capabilities along Caney Creek. In many areas along the creeks, no defined channel remains. Furthermore, the area along the creek, downstream of Wharton, is sufficiently blocked with low water dams and crossings such that no positive drainage can occur. Given the option of either diverting waters or opening up Caney Creek downstream, it was clear to the formulators that diversion of flows to the river would be by far the most cost effective and least environmentally damaging approach. Thus, diversion of Caney Creek was carried forward into more detailed studies.

- Baughman Slough is a significant source of flooding on the north side of Wharton. It was believed that since Peach Creek, located to the north of Baughman Slough, may have extra capacity during times when the Baughman Slough exceeded capacity, diversion of flows from Baughman to Peach should be investigated in more detail. Thus, it was carried forward to detailed investigations.

VALUE ENGINEERING

The Project Study Plan (PSP) for the Wharton and Onion Interim Feasibility Studies were amended in September 2003 to carry the study through the Feasibility Phase. On February 5, 2005, ER 11-1-321 was published after the final array of alternatives were developed and evaluated, which requires feasibility reports to undergo a Value Engineering (VE) Study before the final array of alternatives are evaluated. Realizing that the study would be grandfathered since the final array of alternatives had already been evaluated, but practicing good business the District Value Engineering Officer (VEO) accompanied the Project Manager to Austin to meet with the local sponsors on Feb 17, 2005 to discuss and perform a mini value engineering analysis and a need to revise the PSP if appropriate to conduct a VE Study. The VEO led the Team in identification of issues of concern associated with Onion Creek, Williamson, and Wharton

Studies. The VEO explained the VE Process and identified how it is used to resolve issues, clarify expectations, and develop alternatives that best meet the functional requirements of the project. The VEO discussed plans for the expanded VE Study, required by law, planned for the Design Phase of the projects. The study team decided that the mini-analysis would suffice for the Feasibility Study since the final array of alternatives were already evaluated and that a detailed study should be completed during the initial stages of the Preconstruction, Engineering and Design Phase.

DETAILED INVESTIGATION OF ALTERNATIVES

As a result of the initial screening of alternatives, four measures were selected to continue with more detailed investigations – the nonstructural permanent evacuation measure, levees and floodwalls, diversions, and the structural channel modification measure. These measures were then used to develop alternative plans in a systematic manner. Not all measures were used for each problem area. In general, Table 4-1 provides a relationship between the major flooding sources in Wharton to flood measures used in detailed plan formulation.

Table 4-1
Flood Measures Used For Various Flooding Sources

Primary Flooding Source	*Measure Used for Detailed Plan Formulation*
Colorado River	Levees and Floodwalls
	Floodplain Evacuation
Baughman Slough	Levees and Floodwalls
	Channel Modification
Caney Creek	Diversion
	Floodplain Evacuation

All structural and nonstructural plans were developed in accordance with the planning objectives, planning constraints, and plan formulation rationale as summarized in the section of this report, "Plan Formulation." Each alternative plan was evaluated for its magnitude in difference between without and with project conditions. This magnitude in difference was expressed in monetary terms (annual project benefits minus annual project costs) and identified as net benefits.

An item-by-item estimate utilizing construction software was not developed for each alternative. Instead, cost estimates for the various plans were developed in sufficient detail for comparison purposes only. In general, this included the construction costs of significant, large components such as excavation, fill, significant structures, real estate, development of plans and specifications, construction management, operation and maintenance, and contingencies.

Due to the many inter-relationships that exist between all major flooding sources within Wharton, solutions for each source cannot be formulated independently. As noted in the Problem Identification section, solutions to river flooding may or may not impact localized problems on Caney Creek or Baughman Slough.

NONSTRUCTURAL FORMULATION

A review of recent historical flooding, as well as the data associated with the existing conditions damages, was performed for the study area. While several areas appear to be good candidates, the development of a floodplain evacuation plan to address the river flooding in southwest Wharton was selected as the best, practical non-structural alternative. This is based on the following additional rationale.

- Flooding in this area typically begins with the 10-year event.

- Significant, continuous areas could be evacuated, if buyouts were undertaken to levels approaching the 4% ACE flood zone. Experience with floodplain evacuation plans of other recent projects reveal that evacuation to the 4% ACE, or 25-year flood level is, indeed, achievable, while maintaining a positive BCR.

- This is a neighborhood in which over 500 homes have flooded twice since 1998. The average depth of flooding was around 2-4 feet, as opposed to a more shallow type of nuisance flooding which occurs in other parts of the city. Implementation of a plan is this area would likely be supported by the residents.

- The area is primarily residential, consisting of older, wood frame, pier-on-beam structures, and not concrete slab-on-grade foundations. They are in less than excellent condition, due in part to recent, recurring flooding.

- The City of Wharton owns, operates, and maintains a city park in southwest Wharton, which could be expanded, if adjacent buyouts occur. An economically justified non-structural alternative is highly dependent on the ability to find suitable alternative used of the evacuated lands, such that additional benefits for the overall project are achieved.

A plan known as the 25-year buyout plan was formulated to buyout and remove structures with first floor elevations lower that the estimated water surface levels resulting from 4% ACE (25-year) storm. Figure 4-1 provides a plan view of the area, and identifies the structures that were included in the buyout plan.

For this level of detail, no specific details were developed regarding alternative uses of the lands. It was assumed that the evacuated lands would be used for recreational development, and possible development of some ecosystem restoration features. The decision was made to forego more detailed development of these features, unless it became apparent that this plan would compete for designation of the NED plan, or the local sponsor expressed an interest in implementation of the buyout as a locally preferred plan.

If the vacated areas were converted to ecosystem restoration areas, then it potentially could yield positive environmental impacts. This may be offset somewhat by areas of new replacement housing and development, which may be necessary. Air quality and noise impacts due to relocation and restoration efforts will be similar to normal background levels within Wharton. The overall environmental impacts would likely be positive.

A total 246 structures were identified for possible buyout in the area. This number consisted of 237 residential, 4 commercial, and 5 other structures. The first cost of this plan, excluding relocation assistance costs and costs for development of features for other purposes, is estimated to be $3.1 million. This results in an annualized cost of $180,000, to achieve annual benefits of approximately $94,000. The associated BCR, while less than untity, is sufficient such that if the alternative uses were fully developed and taken into account, the plan would have a BCR greater than unity, and have net benefits for contribution to NED.

The floodplain evacuation plan as formulated, could potentially be implementable and within current Federal policy. Of major concern, however, is that it fails to provide a complete, effective solution for addressing the flooding problems within the Wharton area. Following implementation, it would still leave nearly 2,900, or 92% of the structures within the 1% ACE (100-yr) flood zone with no flooding relief, which would be unacceptable to the City of Wharton.

Environmental Impacts

From an environmental perspective, this alternative would likely have a positive environmental impact, structures would be bought, removed, and then the area would be restored as riparian habitat. Residences would be offered relocation assistance to assist in finding alternate living arrangements. This plan would reduce county revenue by removing approximately 246 properties off of the Wharton County tax roles. The displacement of the residents would likely cause development in other areas outside of the floodplain and result in indirect environmental impacts to other privately owned properties. However, since there are limited areas out of the 1% ACE floodplain, it is possible that these residences would not be located back in Wharton County, and definitely not in the city of Wharton. Other residents would likely purchase already available housing in the community. The buyout alterative would reduce flooding hazards of the residents located in the most prone areas.

Only short term temporary adverse impacts to air quality, water quality, and aquatic resources would be expected during the Construction phase of the removal of houses. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short term, temporary impacts to water quality and aquatic resources would result in increase in sediment which results in an increase in turbidity from stormwater runoff if rainfall events occurred before vegetation was reestablished. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increases in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal. This alternative is the most environmental friendly alternative that was considered; however, it was not cost effective. A buyout alone with complete restoration of the area would be more environmentally friendly, but the project would not be justified either. There would be no mitigation required to implement this plan. This alternative would have some positive aspects, i.e. a reduction in flood hazards and the creation of additional riparian habitat; however, it does not address the complete flooding issues of the city of Wharton.

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Figure 4-1 Buy out map

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STRUCTURAL FORMULATION

Analysis of the findings from the Problem Identification phase of the study provided the insight to develop a systematic method for formulation of structural solutions to an extremely complex hydraulic regime. The following is a summary of observations provided in more detail in previous discussions:

- Flooding in Wharton can be primarily attributed to three sources: the Colorado River, Caney Creek, and Baughman Slough.

- Colorado River flows greater that the 4% ACE (25-year) storm can impact Caney Creek, Baughman Slough, and Peach Creek. Under existing conditions, any river flows entering these streams have actually exited the Colorado River basin and entered the San Bernard River basin.

- Flooding in areas impacted by Caney Creek, Boughman Slough, and Peach Creek, can be the result of river overflows, local storm events, or even a combination of both.

- The Colorado River is not impacted by localized events.

- The terrain of the area offers little to no relief. Thus, one of the challenges in design of a levee system is to find sufficiently high enough ground elevations to tie in the ends of the levees such that flows will not flank the levee.

- Flood profiles for the more rare events that top the banks are closely spaced. Thus, flood heights for various frequencies can be estimated with a fairly high level of confidence, and the addition of as little as a foot to these heights can result in a high level of confidence that the true elevation for a given frequency is below that height.

- Caney Creek, which has a drainage area of approximately well over the minimum 1.5 square miles as it enters the city from the west, has essentially no remaining conveyance ability through the city, under existing conditions. Remaining low areas along the natural streambed act as storage areas. Following passage of a storm event, these areas are slowly drained primarily by an underground drainage system that is totally inadequate.

- During the inventory and forecast, it was noted that with the exception of the Peach Creek riparian corridor, the area is of relatively low value to the environmental habitat. Any structural measures would likely have similar, insignificant effects, and thus could be assumed as such.

Utilizing the conclusions shown above as guidance, a systematic approach was devised to formulate plans for flood damage reduction. The order of the evaluation of features is listed below:

1. Colorado River -- Since the Colorado River impacts essentially the entire area, it was decided to design and evaluate a levee that would eliminate flooding along the left overbank of the river, and also avoid river flood waters from entering the Caney Creek and Baughman Slough areas, unless the levee is flanked or overtopped. Three levels were evaluated, equating to heights of one foot above the 50-year, 100-year, and 500-year profiles. This was assumed to be the first added increment for evaluation, due to its impact on the entire city.

2. Baughman Slough – Levees, Channels, and combination plans were evaluated as the next added increment.

3. Caney Creek – Various drainage features to evacuate flood waters from major Caney Creek storage areas were evaluated as the final element. It should be noted that Boughman and Caney are essentially independent from one another, and their order of evaluation is irrelevant, as long as the River features are in place first.

COLORADO RIVER

This first increment of any structural flood damage reduction system in Wharton was determined to consist of features which reduce the flooding attributed to the Colorado River. During the initial screening, it was concluded that construction of levees or floodwalls provided the most favorable solution to river flooding.

The original alignment of a proposed levee system was performed by the project delivery team, utilizing available aerial imagery, as well as topographic mapping. These alignments were then discussed with the City staff, and refinements were made primarily in two areas – in Southeast Wharton near the wastewater treatment plant, and on the west side upstream of US 59, as shown in Figure 4-2. Finally, additional on-the-ground field investigations were conducted before a final formulation-level alignment was selected. None of the alignment variations significantly altered the water surface levels. Thus, the key factors for alignment were based on cost, real estate value, and environmental considerations. Availability of material was not a determining factor; all soils in the vicinity are very suitable for levee construction.

An earthen levee template, with a 12 foot top width and 1 foot vertical to 4 feet horizontal side slopes, was assumed for the entire length, with the exception of the reach immediately east of Business 59 and adjacent to East Elm Street. The total length of the earthen levee segments would be approximately 22,000 feet. Due to the extremely limited real estate available between Elm Street and the river bank, a 400 foot flood wall of relatively low height (3-5 foot average) was determined to be a better selection.

The formulation team used several criteria for the placement of the levee: the placement on elevated ground to reduce the footprint of the levee, the avoidance of existing structures, and the avoidance of high quality habitat.

The hydraulic design of the levee entailed use of the existing conditions hydraulic model, and then setting the levee profile to parallel the with-project water surface profiles. Three different levee heights (average levee heights of 4-6 feet) were developed for evaluation of costs and benefits. For the smaller, lower height levee, some consideration was given to acceptable protection levels, but due to the flat nature of the stage versus frequency correlation (less than 2 feet separates the 2% from the 0.2%), it was hypothesized that economic optimization would likely occur near the upper extreme of optimization curve.

Table 4-2 provides the results of the economic evaluation of the various levee heights, using 5.375% interest rate and October 2004 price levels.

Table 4-2
Costs and Benefits of Colorado River Levees
Various Heights by Frequency
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Level	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
2%	$4,052,000	$235,000	$436,000	1.9	$201,000
1%	$5,024,000	$291,000	$781,900	2.7	$490,900
0.20%	$6,316,000	$366,000	$1,032,610	2.8	$666,610

Interior drainage issues were also considered during this preliminary formulation level. It was assumed that only limited areas require any type of feature, primarily due to Caney Creek acting as a natural sump for the majority of the town. Some type of sump feature will be required in the southwest quadrant of town, but ample open areas exist for any possible sump requirements. The magnitude of these features will have no bearing on the level height selection.

During the time that these initial designs were being developed, it was determined that the maximum practical height (and thus protection levels) is actually constrained by the lack of any high ground for tie-in purposes. In reality, the 0.2% protection level is not achievable without extensive lengthening upstream. The 1% level is the maximum protection achievable, and given the results of the net benefits, will be carried forward as the first element.

While the river levees would provide excellent protection for the Wharton area, it must be recognized that for a range of storm frequencies, implementation of this feature will result in a deviation of flow depths and flow rates on the opposite overbank, as well as downstream of Wharton and even on Baughman Slough and the San Bernard Basin. In simple terms, if the levees are providing benefits, they are keeping water from escaping the Colorado River, which otherwise would have entered the San Bernard Basin. The San Bernard Basin has existing flooding issues, which are to be addressed in a separate study, and a possible reduction of this overflow would be beneficial. Larger flow rates, however, may be experienced downstream of Wharton on the Colorado River, affecting primarily agricultural lands such as rice fields. These will result in increased stages of several tenths of a foot for the 2% ACE and 1% ACE storms (assuming implementation of the 1% level levee). All other frequencies would remain unaffected. Utilizing the economic models developed for the main stem Colorado River, the induced damages are estimated at approximately only $1,300 annually, primarily due to the scattered, sparse development in the rural areas downstream of Wharton. This amount is considered to be insignificant, and would not constitute a taking. More details regarding changes in downstream flow rates can be found in the hydraulics section of the engineering appendix.

Environmental Impacts

The habitat along the Colorado River can be classified into three broad general categories: developed, pasture, and forested. The developed area is the area located in downtown Wharton, where, in lieu of a levee, a floodwall would be located along an existing side walk and city park. No environmental impacts will occur in the developed area. Forested habitat occurs sporadically along the levee route. Approximately 15 acres of upland forested habitat will be destroyed by the proposed plan. The loss of the forested habitat will be compensated for in the mitigation plan, and no other relevant resources are being adversely impacted. The remaining areas are categorized as cleared pasture for cattle grazing. The proposed plan would have impact pastures by either turning them into levees or temporarily using them for construction activities during construction

but would be restored to pre-construction use once the project is complete, except for the levees themselves. However, the levees could be used as pastures once vegetation is established. The proposed plan will also cross approximately seven small drainage tributaries, which may involve construction of culvert structures. Overall, the proposed Colorado River levee alternative will only result in the loss of upland forested habitat and minor impacts in the form of sediment discharge and increased turbidity to waters of the U.S. due to levee crossings. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short term, temporary impacts to water quality and aquatic resources would result from stormwater runoff if rainfall events occurred before vegetation was reestablished. The impacts would be increased sediment transport and increased turbidity. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increase in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal.

Differing levee highs have approximately the same direct impacts to the environment; however, differing levee heights provide differing levels of socioeconomic benefits. The 2% level would provide benefit from reduced flood damages, but would not allow for insurance rates to be reduced. The proposed plan would provide substantial socioeconomic benefits to the local community by providing 1% ACE protection for almost the entire city. The 0.2% ACE protection would provide the most economic benefit; however, upon further consideration it would not be economically feasibly nor would it be feasible from an engineering standpoint because there is no high ground to tie into.

Figure 4-2 Colorado River Levees

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BAUGHMAN SLOUGH

General

Two flood damage reduction measures were seriously considered and evaluated in depth for Baughman Slough. These measures were levees and channelization. Both measures serve to reduce flooding resulting from both localized as well as regional (river) flooding, but the levee is related more to the regional flooding, while the channel is related more to the local rain events. Please refer to the Hydraulics Appendix for a more detailed description of the flooding scenarios.

A channel modification was briefly considered, which extended from County Road 135 to the abandoned T&NO railroad. However, it was soon apparent that a levee within this same reach would produce higher benefits at a much lower cost. Preliminary construction costs for the channel were nearly four times the cost of a levee, due to extensive excavation quantities. Further, the initial estimates of benefits were lower. Thus, the full length channel modification alternative was eliminated from further consideration.

A shorter channel modification was also investigated as an add-on component to the levee feature. This alternative is discussed below.

Levee Component

An analysis of the existing conditions damages, as well as the plan view topographic map served as the basis for layout of a levee located adjacent to the right bank of Baughman Slough, extending from County Road 135 (Junior College Blvd.) to the abandoned T&NO railroad embankment, a total distance of about 7,500 feet, as depicted in Figure 4-3. Included within this reach are two road crossings, Fulton Road and State Highway 60 (also known as Business 59).

Two different levels of levees were investigated along Baughman Slough, both with side slopes of 1 foot vertical to 3.5 feet horizontal. As was the case with the Colorado River Levees, the levee heights were severely constrained due to the unavailability of high ground for levee tie-in points. The second height analyzed, which is near the level of the 1% profile, is the maximum levee height that can be effectively be utilized in this area, with the biggest constraint being the height of the downstream terminus at County Road 135. Average height of the levee is approximately 4 feet.

Table 4-3 includes the costs and benefits for the two levee heights evaluated. The second, or maximum height levee produces the highest net benefits, and was thus adopted as the next component of the overall plan.

Table 4-3
Costs and Benefits of Baughman Slough Levee
Various Heights
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Level	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
~2%	$1,098,000	$64,000	$334,400	5.2	$270,400
Max	$1,197,000	$69,000	$388,600	5.6	$319,600

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Figure 4-3 Baughman Slough levee

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Environmental Impacts

Only short term adverse impacts to air quality, water quality, and aquatic resources are expected during the Construction phase of the removal of houses. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short term, temporary impacts to water quality and aquatic resources would be increases in sediment transport and increases in turbidity from stormwater runoff if rainfall events occurred before vegetation was reestablished. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increases in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal. The majority of the area surrounding Baughman Slough is cleared and used as pasture or residential yards. Approximately three acres of forested riparian habitat would be from implementation of the proposed plan. A mitigation plan was developed to compensate for the impacted riparian habitat. No other relevant resources are being impacted. Cost of the mitigation would be similar for all sizes, and would not change the outcome of formulation.

Lower Channel Component

Despite that the maximum practical levee was selected as the Boughman Slough flood damage reduction component, a significant amount of residual damages, $740,000 annually (40% of existing) remained in the leveed reaches. Given that the critical elevation controlling the practical height of the levee was the downstream tie-in point, County Road 135, and that local drainage could be greatly improved by a reduction in tail water at this point, a channel modification component was designed and evaluated which would address these two issues. The grassed channel with 1 foot vertical to 3 foot horizontal side slopes would be approximately 6,500 feet in length, extending from Station 8237, downstream of County Road 150, to Station 14730, located between Fulton Road and County Road 135. Channel bottom widths of 75 foot and 85 foot were evaluated for the portion of the channel downstream of County Road 135.

Table 4-4 lists the costs and benefits associated with each plan. The net benefits of the two channel widths were very close. Both the costs and benefits did not vary significantly, but the larger channel provided just slightly greater net benefits. However, since the smaller channel met the local objective of providing 100-year level of protection, it was selected as the increment to be carried forward as part of the total plan.

Table 4-4
Costs and Benefits of Baughman Slough Lower Channel
Various Bottom Widths
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Size	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
75-foot	$4,188,000	$243,000	$420,200	1.7	$177,200
85-foot	$4,240,000	$246,000	$423,440	1.7	$177,440

Environmental Impacts

Only short term adverse impacts to air quality, water quality, and aquatic resources are expected during the Construction phase of the removal of houses. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short term, temporary impacts to water quality and aquatic resources would be an increase in sediment

transport and turbidity from stormwater runoff if rainfall events occurred before vegetation was reestablished. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increases in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal. Additional impacts to the aquatic resources would result from the excavation portion of the plan. It will impact approximately 2.3 acres of waters of the U.S. due to widening the channel to increase conveyance. The creek is dry on a regular basis, so impacts to aquatic habitat would be minimal. Overall, the Baughman Slough exhibits low habitat value and aquatic features. The Slough routinely goes dry and therefore, limited aquatics exist. The proposed alternative will result in minor impacts to the slough. Cost of the mitigation would be similar for all sizes, and would not change the outcome of formulation.

CANEY CREEK

General

Thousands of years ago, the Colorado River may well have been located where Caney Creek is today. As can be seen in Figure 4-4, its current lower watershed originates near Glen Flora, and extends southeastward through the city of Wharton. Overflows from the Colorado River can occur at several locations, including the area near Glen Flora, as well as just west of Highway 59. Its final outfall is into Matagorda Bay near Sargent, Texas.

The primary trait that makes Caney Creek a unique part of this study, is that it no longer actually flows through Wharton. In fact, it doesn't really flow anywhere. In many areas through Wharton, the channel is essentially gone. Fill has been placed in the area, and many buildings now stand where Caney Creek once had a small channel. West of Highway 59 (above Wharton), Caney Creek still resembles a stream. Downstream of Wharton, Caney Creek also resembles a stream, although it is blocked with many private crossings and low flow dams, causing it to be essentially useless for conveyance of floodwaters.

Through the city, what remains of Caney Creek can be described as a series of storage areas that collect local runoff, and are slowly drained to the river by a few totally inadequate and outdated storm drains. During large local storm events, however, the drainage area upstream of Wharton contributes to flooding by first filling the upstream storage area, the cascading downstream. During rare local events, or during passage of large flood events on the river where overflows have entered the Caney Creek watershed, the storage areas on Caney Creek can actually become so full that the flows cross the watershed boundary between Caney Creek and Baughman Slough.

During the initial formulation phase, an array of different alternatives to reduce flooding within the Caney Creek area were discussed. These included diversions to Baughman Slough, reopening the channel through Wharton and increasing the downstream capacity on Caney Creek, and draining the flows back to the river. The options were discussed in public workshops and at the feasibility scooping meeting held as part of the planning process. In summary, it was determined that the only practical means of reducing flood risk in Wharton from Caney Creek was to drain the flood waters back to the river. The Baughman Slough/ San Bernard system does not have any additional capacity, and in fact has significant downstream flooding issues which are to be addressed in a separate feasibility analysis. Also, the reach of Caney Creek below Wharton is extremely flat, and would require a substantial increase in cross sectional area in order to obtain the necessary drainage capacity. Modifications of this magnitude were deemed to infeasible as well as cause detrimental environmental damages.

Caney Creek – Figure 4-4

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Evaluation of Caney Creek during the development of existing conditions revealed that it could best be modeled for hydraulic purposes with a series of six storage areas. Each of these areas was also modeled as an economic reach for damage evaluation purposes. Existing conditions evaluation determined that the majority of the flood damages occurred in three of the six areas. Alternative solutions were formulated to address the flooding in the areas known as the Outfall, Wharton, and Crestmont storage areas. Locations of these areas are depicted in Figure 4-4.

Outfall Storage Area

The Outfall storage area is generally located immediately west of the abandoned T&NO Railroad. Spanish Camp Road generally follows the southern boundary, and separates it from the area sloping to the river.

After brainstorming with the project delivery team, local engineers, and other local officials, all agreed that the most straightforward, common sense approach was to pursue a storm water conveyance system extending from near the intersection of Spanish Camp and Hughes Street, and provide southward along Hughes Street to Milam Street, which is a distance of approximately 1,000 feet. Validity of this solution was confirmed by conducting an on-the-ground reconnaissance. Also, beyond Milam Street, an old channel (migrated river meander) already exists. The big question from an engineering standpoint was to determine the type and size of conveyance measure that would provide the highest net benefits.

Additional discussions among the team determined that our best possibilities would be to stay within the right-of-way of Hughes Street. Given that as a guide, the following alternatives were considered:

1. Two, 60-inch diameter pipes down Hughes Street.
2. Three, 60-inch diameter pipes down Hughes Street, utilizing the full available right-of-way.
3. Three, 7 foot-by-5 foot box culverts down Hughes Street, utilizing the full available right-of-way.

Costs and benefits for these three alternatives were developed, and the results are shown in Table 4-5 below. The three, 60-inch diameter pipes were found to have the highest net benefits at a significantly less cost that the box culverts. For the 7 foot-by-5 foot box culverts, it was assumed that residual damages were essentially zero. However, the three, 60-inch pipes were still far more cost effective.

Table 4-5
Caney Creek, Outfall Storage Area
Costs and Benefits for Hughes Street Drainage Facilities
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Size	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
2, 60" pipes	$716,000	$42,000	$121,200	2.9	$79,200
3, 60" pipes	$1,039,000	$60,000	$139,700	2.3	$79,700
3, 7'x5' box culverts	$3,097,000	$180,000	$147,600	0.8	-$32,400

Environmental Impacts

Only short term adverse impacts to air quality, water quality, and aquatic resources are expected during the Construction phase of the removal of houses. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short term, temporary impacts to water quality and aquatic resources would be an increase in sediment transport and an increase in turbidity from stormwater runoff if rainfall events occurred before vegetation was reestablished. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increases in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal. Only these minimal impacts to relevant resources would occur in the portion of the plan located along Hughes Street within a residential area. South of Caney Street, the pipes would be located within an old meander of the Colorado River that lies between a residential area and an upland mound. An open cut ditch is located within the meander and runs approximately 2,200 feet to the outfall at the river. This alternative would also utilize an existing drainage ditch and cleared right-of-way to reduce impacts to riparian areas.

Wharton Storage Area

The Wharton storage area is appropriately named because it generally includes the downtown area of the city. The town square, City Hall, and the County Court House are just few of the notable landmarks within the Wharton storage area.

Very similar circumstances and flooding issues can be derived between the Outfall area and the Wharton area. Not surprisingly, the proposed solutions are also similar in nature. Two different plans for draining the Wharton storage area to the river were evaluated for more detailed formulation purposes. These were named the Railroad Culvert, and the Richmond Pipes.

The first, more ingenious idea was to cut off an old filled meander of Caney Creek by placing two 12-foot by 4-foot box culverts through the embankment of the T&NO Railroad, near the intersection of Bolton and Sunset Streets (See Figure in H&H appendix for exact location). These boxes would directly connect the Outfall and Wharton Storage areas. In order to handle the additional flood flows in the Outfall area, the proposed Hughes Street drain would be upgraded from the 3-60 inch reinforced concrete pipes to the 7 foot by 5 foot concrete box culverts that were previously evaluated.

The second, and more straightforward approach was to evaluate the implementation of two, 60-inch reinforced concrete (RCP) pipes, extending from near the intersection of Richmond Road and Caney Street, and then extending approximately 1,350 feet southward under Richmond Road, with its outfall at the Colorado River near the Richmond (Business 59) bridge.

Preliminary findings found the Richmond Pipes alternative to be much more cost effective. As a result, another alternative specifying three 60-inch pipes was also evaluated to see if the additional pipe was incrementally justified. As can be seen in Table 4-6, the three Richmond Pipes alternative is indeed incrementally justified. After consultation with the local sponsor, no additional, larger alternatives were formulated for the purpose of finding a larger plan that would produce even greater net benefits. The three 60-inch Richmond Pipes alternative was identified to be carried forward as part of the overall plan. This plan was sufficient to meet the local objectives, and thus, no larger plan was evaluated.

Environmental Impacts

Only short term adverse impacts to air quality, water quality, and aquatic resources are expected during the Construction phase of the removal of houses. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short

term, temporary impacts to water quality and aquatic resources would be an increase in sediment transport and increased turbidity from stormwater runoff if rainfall events occurred before vegetation was reestablished. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increases in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal. Since the pipes would be located along existing roadways within residential and commercial areas, this alternative would pose no other adverse impacts to relevant environmental resources.

Table 4-6
Caney Creek, Wharton Storage Area
Costs and Benefits for Storm Drainage Facilities
Railroad Culvert and Richmond Road Alternatives
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Feature	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
Railroad Culvert	$2,449,000	$142,000	$419,700	3.0	$277,700
2, 60" Richmond Pipes	$1,288,000	$75,000	$599,200	8.0	$524,200
3, 60" Richmond Pipes	$1,931,000	$112,000	$677,800	6.1	$565,800

Crestmont Storage Area

The last storage area for Caney Creek, as well as the last increment for the overall project to be formulated is named the Crestmont Storage Area, as shown in Figure 4-4.

Under existing conditions, this area floods incurs some amount of flood damages almost annually, and it has been a problematic area for many years. Recently, as reoccurrence of flooding has continued at a particularly frequent pace, the City of Wharton has underscored its commitment to resolve the issues quickly in this area by submitting a request to construct this portion of the project in advance of the overall Federal Implementation. This authority has been provided under Section 104 of the Water Resources Development Act of 1986. The City's request was approved by the Assistant Secretary of the Army for Civil Works on January 25, 2006.

The Corps and the City of Wharton, in concert with its independent Engineering Consultant, began to brainstorm for possible solutions to provide flooding relief to this area even during the earlier phases of the study. While the decision process for this area followed the same rationale as the other storage areas, i.e., the only logical solution is to drain the area to the river, additional constraints exist. For example, for the Wharton area, the transport distance to the river was only about 1,300 feet. For Crestmont, even the shortest distance, ignoring any realism, is about 4,000 feet. Given the much longer distance, an open cut ditch stood out as the most and perhaps the only cost effective solution.

Also, during the formulation, the point was made that the City of Wharton already owned an abandoned Santa Fe Railroad right of way along State Highway 60 and east of Alabama Road. This right-of-way could easily be used, and while it is not a direct route to the river, it

would cut the remaining required distance in half. Also, general channel slope would be acceptable, and only a few bridge crossings would be required. From this point, the remaining portion of the channel would be outside of the city with few right-of-way issues, so the channel could turn, cross State Highway 60, and follow a generally straight path until it outfalls into the river. This alignment is depicted in Figure 4-2.

The Corps' technical staff concurred with this concept as being the most viable and engineeringly feasible option, and the City's consultant began to plan, size, and design the flood damage reduction feature known in this report as the Santa Fe Ditch.

The City of Wharton was advised that the Santa Fe ditch must still be sized and evaluated for NED purposes, and it must ultimately be designed as part of the Federally recommended plan in order for the City to receive credit for its advance expenditures. The urgency of the matter, however, dictated that the City take the risks associated with this uncertainty, and proceed with their advanced design and construction. The City would make available to the Corps any and all design information that can be used for their plan formulation purposes.

Two sizes of the Santa Fe ditch were designed and costs estimated by the City's consultant. These designs could also be considered as an initial and ultimate increment, if the economics of the alternative incrementally support such phasing. The initial design calls for an 8 foot bottom width earthen ditch, with 1 foot vertical to 3 foot horizontal side slopes. Given the open channel concept, this size is considered to be minimum size for ease of construction. Smaller configuration channels would have similar costs, but these would provide less total as well as net annualized benefits and thus, were not evaluated in detail. The ultimate design increases the bottom width to 15 feet. Both plans include a 20 foot maintenance and access area on each side, and 6 culvert-style bridges are also required.

Environmental Impacts

Only short term adverse impacts to air quality, water quality, and aquatic resources are expected during the Construction phase of the removal of houses. Short term impacts to air quality would be an increase in dust particles and exhaust from construction equipment. Short term, temporary impacts to water quality and aquatic resources would be an increase in sediment transport and turbidity from stormwater runoff if rainfall events occurred before vegetation was reestablished. These impacts would be reduced by implementing best management practices such as silt fences. There would also be temporary increases in noise and traffic levels from construction equipment during the construction activities, but these impacts would be minimal. The Santa Fe Ditch plan involves an open cut ditch that runs along the abandoned Santa Fe railroad and then along Mundel Street to the outfall at the Colorado River. This alternative has previously cleared right-of-ways, which would limit impacts to the environment. The outfall would result in the loss of some riparian areas that would be mitigated, but overall, this alternative would have only minor environmental impacts, and would not affect the alternative formulation or optimization.

Table 4-7
Crestmont Storage Area
Cost and Benefits for Santa Fe Ditch
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Size	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
Initial	$2,900,000	$168,000	$723,000	4.3	$555,000
Ultimate	$3,500,000	$203,000	$752,600	3.7	$549,600

Table 4-7 contains the costs and benefits associated with the two sizes. The ultimate increment was not found to be incrementally justified, so the initial, smallest size earthen channel was carried forward as part of the overall plan.

CONSOLIDATION OF COMPONENTS TO FORM A COMPREHENSIVE PLAN

An array of Structural Plans, as well as a non-structural plan and the no action alternative have been evaluated to address specific individual damage areas throughout Wharton. Table 4-8, containing a breakdown of costs by category, as well as associated annualized benefits and benefits-cost ratios, has been compiled for ease of comparison.

The rationale for selection of the first added and incremental elements of the project was presented in a previous section of this chapter. In summary, the proposed Colorado River levees benefit essentially all areas of the city, and was selected as the first element of the evaluation. The remaining features on Baughman Slough and Caney Creek have little, if any effects on other areas, and can be evaluated independently without regard to the other features.

Table 4-8 also identifies the components that are combined to produce the comprehensive plan. The components are identified by shaded columns. A summary of the rationale used for size and component selection is summarized below:

- Colorado River Levees: While the 0.2% ACE levees were shown to have the highest net benefits, there was insufficient high ground to properly terminate the upstream levee segment. Thus, the 1% ACE level was selected.

- Baughman Slough Levees: In similar fashion to the Colorado levees, the Baughman Slough levees were effectively limited in height and protection due to the lack of high ground for tie-in. The maximum practical height produced the highest net benefits, and was selected.

- Baughman Slough Channel: Levels of protection were further increased by channelization at the downstream area. The 85-foot bottom channel produced the highest net benefits, but the smaller 75-foot bottom channel met all the objectives, and was selected as part of the comprehensive plan.

- CC outfall: The three 60-inch pipes were produced the highest net benefits and was selected as part of the comprehensive plan. It should be noted that the net benefits of the two 60-inch pipe was not substantially smaller. However, the additional pipe increased the damages prevented from 85% to over 96%, leaving residual damages of

only $7,900 annually in the CC-Wharton economic reach. The additional increment has a positive BCR, more closely fulfill the study planning objectives, and still has a BCR of 2.3.

- CC Wharton: Three different options were formulated – a railroad culvert, a drain consisting of two 60-inch pipes, and a drain consisting of three 60-inch pipes. The largest plan produced the highest benefits and met the study objectives. Thus, it was selected as part of the comprehensive plan.

- CC Crestmont (Santa Fe Ditch): Two options were evaluated, with the smaller 8 foot wide ditch being selected because it produced the greatest net benefits. For construction purposes, this was deemed the smallest practical alternative; smaller sizes would be constructed with different types of construction equipment that is unable to handle substantial volumes of soil with the same efficiency. Thus, smaller plans may actually cost more with less outputs.

Table 4-9 includes a list of only those components selected to be carried forward as part of the comprehensive flood damage reduction plan, and forms the basis for the plan to be considered as the National Economic Development, or NED Plan. The total first cost of the plan is estimated to be approximately $16,279,000, with an overall benefit-to-cost ratio of 3.3 and net annualized benefits of $2,188,200.

Figure 4-5 provides a plan view of the locations of the various components associated with the Comprehensive Plan.

Table 4-8

Breakdown of Costs and Average Annual Benefits for Final Array of Alternatives, excluding No Action

(Formulation Level Detail, 5.375%, 50 years, October 2004 prices)

Feature	*Floodplain Evacuation 4% ACE SW Wharton*	*Colorado 2% levee*	*Colorado 1% levee*	*Colorado 0.2% levee*	*Baughman Slough 2% levee*	*Baughman Slough Max levee*	*Baughman 75-ft Channel*	*Baughman 85-ft Channel*
Demolition	$923,000	0	0	0	0	$0	0	$0
Lands and Damages	$4,699,000	$75,000	$78,400	$80,000	$127,500	$130,000	$10,000	$12,000
Channels and Canals	$0	$0	$0	$0	$0	$0	$2,007,000	$2,047,000
Levees and Floodways	$0	$2,505,000	$3,164,500	$4,040,000	$603,000	$670,000	$0	$0
Relocations	$0	$0	$0	$0	$0	$0	$832,000	$832,000
F&W Mitigation	$0	$202,100	$206,700	$211,000	$39,100	$40,000	$0	$0
Engineering and Design	$200,000	$300,600	$379,700	$484,800	$72,400	$80,000	$340,700	$340,700
Construction Management	$200,000	$150,300	$189,900	$242,400	$36,200	$40,000	$170,300	$170,300
Contingency	$1,506,000	$819,000	$1,004,800	$1,257,800	$219,800	$237,000	$828,000	$838,000
Total First Cost	**$7,528,000**	**$4,052,000**	**$5,024,000**	**$6,316,000**	**$1,098,000**	**$1,197,000**	**$4,188,000**	**$4,240,000**
LERRD's	$4,699,000	$75,000	$78,400	$80,000	$127,500	$130,000	$842,000	$844,000
Annual Benefits	$130,000	$436,000	$781,900	$1,032,610	$334,400	$388,600	$420,200	$423,440
Annual Costs	$436,000	$235,000	$291,000	$366,000	$64,000	$69,000	$243,000	$246,000
Net Benefits	**-$306,000**	**$201,000**	**$490,900**	**$666,610**	**$270,400**	**$319,600**	**$177,200**	**$177,440**
BCR	0.3	1.9	2.7	2.8	5.2	5.6	1.7	1.7

Table continues on next page.

Table 4-8 (continued)
Breakdown of Costs and Average Annual Benefits
for Final Array of Alternatives, excluding No Action
(Formulation Level Detail, 5.375%, 50 years, October 2004 prices)

Feature	*CC Outfall 2-60 inch pipes*	*CC Outfall 3-60 inch pipes*	*CC Outfall Boxes*	*CC Wharton RR Culvert*	*CC Wharton 2-60 inch Richmond Pipes*	*CC Wharton 3-60 inch Richmond Pipes*	*CC Crestmont SF Initial*	*CC Crestmont SF Ultimate*
Demolition	$0	$0	$0	$0	$0	$0	$0	$0
Lands and Damages	$20,000	$25,000	$25,000	$10,000	$15,000	$18,000	$95,000	$100,000
Channels and Canals	$483,600	$692,900	$2,087,800	$1,652,800	$873,000	$1,309,500	$1,892,000	$2,281,000
Levees and Floodways	$0	$0	$0	$0	$0	$0	$0	$0
Relocations	$11,700	$11,700	$11,700	$7,800	$0	$0	$0	$0
F&W Mitigation	$0	$0	$0	$0	$0	$0	$0	$0
Engineering and Design	$51,600	$79,600	$252,000	$204,300	$104,800	$157,200	$330,000	$390,000
Construction Management	$25,800	$42,300	$126,000	$99,700	$52,400	$78,600	$272,000	$325,000
Contingency	$123,300	$187,500	$594,500	$474,400	$242,800	$367,700	$311,000	$404,000
Total First Cost	**$716,000**	**$1,039,000**	**$3,097,000**	**$2,449,000**	**$1,288,000**	**$1,931,000**	**$2,900,000**	**$3,500,000**
LERRD's	$31,700	$36,700	$36,700	$17,800	$15,000	$18,000	$95,000	$100,000
Annual Benefits	$121,200	$139,700	$147,600	$419,700	$599,200	$677,800	$723,000	$752,600
Annual Costs	$42,000	$60,000	$180,000	$142,000	$75,000	$112,000	$168,000	$203,000
Net Benefits	**$79,200**	**$79,700**	**-$32,400**	**$277,700**	**$524,200**	**$565,800**	**$555,000**	**$549,600**
BCR	2.9	2.3	0.8	3.0	8.0	6.1	4.3	3.7

Figure 4-5 Comprehensive Plan

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Table 4-9
Wharton Comprehensive Flood Damage Reduction Plan
Costs and Benefits by Feature
(Formulation Detail Level, 5.375%, 50 years, October 2004 prices)

Feature	*First Cost*	*Annualized Cost*	*Annualized Benefits*	*B/C Ratio*	*Net Benefits*
River Levees	$5,024,000	$291,000	$781,900	2.7	$490,900
Boughman Slough					
Levee	$1,197,000	$69,000	$388,600	5.6	$319,600
Channel	$4,188,000	$243,000	$420,200	1.7	$177,200
Caney Creek					
Hughes Street Drain	$1,039,000	$60,000	$139,700	2.3	$79,700
Richmond Drain	$1,931,000	$112,000	$677,800	6.1	$565,800
Santa Fe Ditch	$2,900,000	$168,000	$723,000	4.3	$555,000
TOTAL PROJECT	**$16,279,000**	**$943,000**	**$3,131,200**	**3.3**	**$2,188,200**

IDENTIFICATION OF THE NED PLAN

The identification of the NED plan depends upon careful consideration of engineering, economic, social, and environmental factors. The following paragraph outlines the process of identifying the NED plan.

Guidelines for selection of a plan for implementation, as provided by the Water Resources Council's "Principles and Guidelines for Planning Water and Related land Resources Implementation Studies," state that a plan recommending Federal action is to be the alternative plan with the greatest net national economic development (NED) benefits, i.e. the NED plan, unless the Assistant Secretary of Army (Civil Works) grants an exception. Current Policy allows such exceptions for locally preferred plans. Such locally preferred plans must comply with Federal rules and statutes, most important of which, the project benefits must exceed the project costs. Federal participation in a locally preferred plan is limited to the extent which would have been required by the NED plan. Consequently, the local sponsor is responsible for all additional costs of the larger plan above and beyond the costs of the Federal NED plan.

Prior to final selection, another important consideration is the amount of residual damages remaining under with-project conditions. In many instances, the components identified as part of the comprehensive plan reduced damages in more than one economic reach. Thus, in order to get a proper perspective, Table 4-10 was developed to present the residual damages remaining, as each component of cumulatively added to the comprehensive plan. The order of implementation is the same as that used in development of the plan. With all components in place, damages within the affected reaches are reduced by over 76%.

After consideration of all factors, all the features collectively identified as the Comprehensive Plan (shown above) was selected as the NED plan. Agreement and concurrence by Corps' Headquarters and Southwestern Division representatives was received at the Alternative Formulation Briefing held on April 24, 2006.

Table 4-10
Average Annual Residual Damage by Reach
As Components are Cumulatively Added
(Values in thousands, 5.375%, 50 years, October 2004 Prices)

Economic Reach	*No Project*	*Colorado 1% levee*	*Baughman Slough 1% levee*	*Baughman 75-ft Channel*	*CC Outfall 3-60 inch pipes*	*CC Wharton 3-60 inch Richmond Pipes*	*CC Crestmont SF Initial*
Colorado River							
Above Busness 59	$140.3	$17.3	$17.3	$17.3	$17.3	$17.3	$17.3
Below Business 59	$208.2	$45.3	$45.3	$45.3	$45.3	$45.3	$45.3
Baughman Slough							
Below Alabama	$267.5	$267.0	$267.0	$145.4	$145.4	$145.4	$145.4
Alabama to Bus 59	$1,273.3	$918.5	$473.9	$177.2	$177.2	$177.2	$177.2
Business 59 to Hwy 59	$227.6	$177.5	$205.6	$208.5	$208.5	$208.5	$208.5
Above Hwy 59	$95.8	$75.0	$102.8	$98.0	$98.0	$98.0	$98.0
Caney Creek							
South of HEB	$201.0	$201.0	$201.0	$201.0	$201.0	$201.0	$35.0
Wharton	$899.3	$868.6	$868.6	$868.6	$868.6	$193.3	$193.3
Outfall	$183.5	$146.6	$146.6	$146.6	$7.9	$6.0	$6.0
US59 to 102	$2.8	$1.5	$1.5	$1.5	$0.9	$0.9	$0.9
Above US 59	$1.4	$0.6	$0.6	$0.6	$0.2	$0.2	$0.2
Crestmont	$608.9	$608.9	$608.9	$608.9	$608.9	$608.3	$51.3
TOTAL	**$4,109.6**	**$3,327.7**	**$2,939.1**	**$2,518.9**	**$2,379.2**	**$1,701.3**	**$978.4**

SELECTION OF THE RECOMMENDED PLAN

The City of Wharton was involved throughout the formulation process. They indicated during the early stages of the feasibility studies that their planning objectives were similar to the Federal objectives. A project of this magnitude would place a substantial burden on the City's financial abilities, but they fully understand the need to provide their citizens with maximum possible relief from future flooding.

The addition of recreation and ecosystem features was discussed. However, due to fiscal constraints, the City has indicated that their priorities rest solely with flood damage reduction.

Careful consideration was given to all alternatives in the final array, including the no action plan. Based on the findings cited above, the City of Wharton concurs with the Corps of Engineers, and the NED plan was selected as the Recommended plan. This plan will be developed in more detail for implementation purposes.