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October 3, 2008

Mr. Ron Bottoms
City Manager
City of La Porte
604 W. Fairmont Parkway
La Porte, Texas 77571

RE: City of La Porte, Texas
City Wide Drainage Study
Draft Study Letter Report #3
Klotz Associates Project No. 0127.008.000

Dear Mr. Bottoms:

Klotz Associates, Inc. was authorized to proceed with the City Wide Drainage Study (CWDS) for the City of La Porte (City) on January 28, 2008. Letter Report No. 1 and Letter Report No. 2 for this study have been previously submitted and accepted by the City. Klotz Associates is submitting this Letter Report No. 3 to present the results of tasks 4.1 to 4.4 of our Scope of Work.

1. Purpose

The purpose of tasks 4.1 to 4.4 of the CWDS is to 1) define standards and criteria for the CWDS, 2) prioritize drainage and flood control problems, 3) identify conceptual solutions to high priority problems, and 4) identify funding sources for drainage projects.

2. Drainage Design Standards and Criteria (Task 4.1 of Scope of Work)

Discussions about criteria and standards as well as recommendations made in this report are for new development and areas of redevelopment.

2.1 Existing Drainage Criteria

The City provides road sided ditches and culverts and storm sewer design criteria for new construction performed within the City's jurisdiction in Chapter 5, Storm Sewer Design Criteria (see Appendix A), of its Code of Ordinance. These storm drainage criteria cover the design of new drainage facilities such as storm water drainage systems and storm water detention ponds, along with a summary of the accepted method of calculating peak flow and detention volume.

The City currently requires that construction of new roadside ditches and storm sewer facilities convey the 3-year storm. For drainage areas greater than 100

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The City currently requires that construction of new roadside ditches and storm sewer facilities convey the 3-year storm. For drainage areas greater than 100 acres, ditches and culverts are sized for the 25-year event. Bridges and major drainage conveyances, (e.g., channels and creeks) are required to provide conveyance for the 100-year event. However, it is noted that significant portions of the City were developed prior to the adoption of the drainage criteria in 1987.

The City's current criteria also specify that all drainage design should be performed using the Rational Method. The time of concentration and rainfall intensity are determined using the City's data and National Weather Service Technical Paper 40 and Hydro-35 data. These design guidelines cover the City's minimum needs for storm water drainage that is to be designed to prevent flooding of structures during smaller storms.

In addition to having storm drainage requirements, La Porte also addresses the need to control the downstream effects of any changes to the drainage pattern in an area through the use of storm water detention ponds. In general, the City's guidelines call for detention ponds on all systems which outfall into Harris County Flood Control District (HCFCD) channels F212, F216, B106, B109, B112 and A104. Storage volumes for these facilities are determined using one of two methods depending upon drainage area size: predetermined storage factors or HCFCD criteria. For smaller drainage areas, the City's drainage criteria specify that 0.20 ac-ft/ac and 0.45 ac-ft/ac of detention storage be provided for drainage areas from 0 to 3 acres and from 3 to 10 acres, respectively. Detention for any area greater than 10 acres but less than 100 acres is to be designed using HCFCD criteria. Larger areas required specific review by the City Engineer. Outfall pipes are designed using an orifice equation with the minimum restrictor size being six inches.

La Porte's design guidelines also list specific limitations on the location of storm water drainage structures in order to assure that the storm water is cleared from the surface efficiently for street systems with curb and gutters. For curb and gutter systems, the guidelines call for a maximum storm water travel distance of 300 feet along major thoroughfares and in commercial districts and 400 feet in single family residential areas. It is to be recognized that inlet spacing and capacity must be designed in conjunction with sufficient storm sewer capacity for the sewer to which the inlet drains; if the sewer capacity is insufficient, then proper drainage will not occur, irrespective of the inlet capacity and spacing.

The City's design manual also requires that a storm sewer be designed to satisfy specific limits for the design storm. The maximum depth of flow cannot exceed the smaller of the top of curb or road crown. For collector streets, maximum storm water depths must be such as to allow one clear lane of traffic (i.e., a 12 foot wide zone), while the clear zone must be at least 24 feet wide on arterial streets. Along with these requirements, the manual indicates that an overland flow path to the storm sewer system's outfall must be provided for the 100-year event.

To provide protection of habitable structures, grading and drainage around a habitable structure must provide a finished floor slab which is at least 1) 12 inches above the top of curb at its highest point along the of the curb fronting the building site; 2) 18 inches above the crown of the road elevation along the road fronting the building site; and 3) 12 inches above the ground elevation along all sides of the building site. Provision is provided for alternative methods of protection with approval of the City Engineer.

2.2 Comparison with Adjacent Communities

A review of the design criteria for the City of La Porte and surrounding areas, including Harris County, Pearland, Galveston County, Chambers County, and Brazoria County, found a mixture of municipal storm water or storm sewer design criteria. Both the City of Houston and the City of La Porte have standardized storm sewer design requirements. The nearby cities of Deer Park and Baytown do not have specific standards that are to be used by the public or engineering consultants for storm water design. Other cities in the region, such as Sugar Land, Pearland, Friendswood, and Missouri City, have storm sewer design requirements. Some cities, such as Mont Belvieu, utilize county standards as surrogates for city-adopted standards. HCFCD has design guidelines available on its website.

2.3 Flood Hazard Requirements

Chapter 94 of the City's Code of Ordinances addresses flood hazard and potential construction in special flood hazard areas. Standards applicable to new construction or substantial improvements in special flood hazard zones require a variety of measures for sound construction of structures and installation of utilities to eliminate or reduce damages from floods. These standards also include the following requirements:

- Lowest floor elevation of new residential structures must be 1-foot above the base flood (100-year) elevation
- Lowest floor elevation of new non-residential structures must be at or above the base flood elevation (or equivalent structure protection must be provided)

Special requirements also apply for manufactured homes to prevent floatation, collapse, or lateral movement.

These above requirements for construction in special flood hazard areas are consistent with many communities in the Houston metropolitan area.

Encroachment into floodways cannot occur unless it can be certified by a professional engineer that such encroachment shall not result in increase in base flood levels.

2.4 Recommendations

The following are criteria and standards considered particular pertinent to the CWDS; potential changes or modifications are recommended to the City for inclusion into its storm drainage design criteria and standards for new development and redevelopment.

- The design frequency for storm sewer design, drainage ditch, and drainage channels
- Sheet flow provision
- Construction in special flood hazard areas
- Bridge clearances
- Capacity of storm sewer systems
- Capacity of open ditch systems
- Allowable depths of ponding in streets and adjacent properties
- Amount of minimal detention
- Regional detention as alternative mitigation
- Types of mitigation
- Encroachment certification

These issues are addressed in the following subsections; specific recommendations are made when appropriate. Recommendations are made for the purpose of application to new development or redevelopment; application to existing developments and facilities is not intended. Criteria or standards which might be considered for existing development requires case-by-case evaluation and cannot typically be imposed, required, or achieved once development has already occurred.

2.4.1 Design Frequency for Storm Sewer Design

The City criteria currently require that storm sewer facilities convey the 3-year storm. Ditches and culvert and other crossing structures for drainage areas more than 100 acres are to be designed for the 25-year event. These levels of storm sewer design capacity are consistent or even slightly more stringent than some other communities, including the City of Houston. However, since the City does experience continuing flooding and drainage problems with small storm events, consideration should be given to the possibility of generally using or using in selected situations a 5-year frequency storm event as the basis for sewer design.

Use of a 5-year frequency for sewer design would lessen the likelihood of street flooding for small storm events; however, sewer system development or redevelopment costs would be increased.

In application of the frequency standards (whether they be a 3-year or a 5-year frequency), caution should be exercised in selection of rainfall intensity-duration-frequency parameters. Different entities have different parameters describing rainfall characteristics, and some data does not currently recognized information developed from the Tropical Storm Allison Recovery Project (TSARP). The parameters for describing rainfall for Harris County, City of Houston, La Porte, Harris County Flood Control District (HFCD), and the Texas Department of Transportation (TxDOT) are compared in Appendix B. The most significant difference in these data are the rainfall intensity duration data for TxDOT as compared to that for Harris County and the City of Houston.

As part of storm sewer design, tailwater levels need to be recognized. The City criteria uses a 25-year frequency level for the outfall channel. For non-tidally influenced outfalls, this level is considered to be adequate unless the 25-year frequency positions the hydraulic grade line (HGL) at the outfall to be less than the top of outfall pipe, in which case the calculated hydraulic grade line should be set at the top of the pipe. Minor losses should be included in the sizing of and HGL calculations for existing and proposed storm sewer systems.

For tidally influence outfalls, recognition should be given to the effects of tides on sewer design for those sewer facilities discharging directly to tidal-influenced waters (i.e., directly to Galveston Bay or major drainage ditches which are significantly affected by tidal levels). For outfalls subject to tidal variation, it is recommended that the outfall tailwater used for sewer design purposes be set at the higher of 1) 25-year frequency level in the receiving water (i.e., the level based upon non-tidal conditions), or 2) the mean high tide (also referred to as the mean high water). Based upon tidal variation at Morgans Point on Barbours Cut (based upon data from National Ocean Service, National Oceanic and Atmospheric Administration), the mean high tide is approximately 0.6 feet above mean sea level.

2.4.2 Provision of Sheet Flow Paths

The City drainage criteria do not specifically address sheet flow paths for drainage relief of accumulated waters which cannot be readily drained by a combination of sewers systems with curbed streets or roadside ditches. Sheet flow paths allow for drainage via overland flow along a directed, controlled pathway which does not adversely affect residential or commercial structures. These pathways are dedicated for this purpose using easements or rights-of-way.

Consideration should be given by the City to requiring that for new development or redevelopment, drainage relief of excess ponding during extreme storm events be provided if significant localized ponding (as determined by engineering evaluation) is to be expected in view of the topography of the drainage area. Such relief would be required to be provided by sheet flow paths or equivalently effective alternate means. If the drainage relief were provided by a sheet flow path, the development or redevelopment would be required to identify and provide drainage pathways and pathway easement(s) which would not adversely affect nearby structures.

2.4.3 Construction in Special Flood Hazard Areas

The limits on construction in floodways should be reconsidered. Infringement on floodways has a cumulative effect that is difficult to identify on an individual project-by-project basis (e.g., the cumulative effect of hydraulic blocking of flows alters the energy losses in a channel and thus eventually impacts floodway capacity). In addition, some construction in floodways, such as construction on piers in wide, shallow floodways, while not increasing flood levels, still poses significant hazard to the constructed structure because of the force of flowing flood waters and the large debris that may be carried in floodway waters. Thus it is generally preferable and is recommended that new construction in floodways not be allowed. However, if the proposed construction can be shown with appropriate study to not have adverse effect and pose no danger to other structures and facilities, the City can make a decision on a case by case basis as to whether such construction could be allowed.

In those cases where the floodway or those portions of a floodway are very wide and shallow, the City Engineer should have the option, based upon appropriate and engineering evaluation, to allow variance to limits on construction in a floodway, provided such variance is consistent with the City's floodplain management ordinances and would not adversely impact the City's compliance to the Federal Flood Insurance Program. A submittal to the Federal Emergency Management Agency (FEMA) may be required as part of the approval for such a variance.

2.4.4 Minimum Low Chord Clearances

The City should consider clarifying the requirement that there should be a minimum 18-inch clearance of the low chord of a bridge above the 100-year flood level when 1) changes in design flood levels are proposed, 2) when new bridges are built, or 3) existing bridges are rehabilitated.

2.4.5 Capacity Improvements in Storm Sewer Systems

A significant limitation to storm sewer capacity, as discussed in regard to sources of drainage problems, is believed to derive from inadequate number or size of storm sewer inlets in sewered areas. The City's drainage criteria specifies that maximum water travel distance in the street to a curb inlet shall not exceed 400 feet in residential areas. The common recurrence of residential street flooding in sewered-areas suggests that the 400-feet criteria may be inadequate.

A reasonable sense of the potential problems arising from inadequate storm sewer inlet capacity because of too few inlets can be obtained by computing the average length between inlets along storm sewered-streets (obtained by dividing the total length of streets in sewered-areas by the number of street inlets in the same area). Representative examples of such calculation are shown in Exhibit 12. The subdivisions were arbitrarily chosen as representative examples and predate the current criteria of 400 ft. Values commonly appear to exceed 400 feet in existing residential areas, suggesting that inlets are typically spaced too far apart along streets.

A detailed analysis for the storm sewer would have to be made to determine if there are any benefits for adding inlets for current storm sewer systems. However, consideration should be given to requiring that maximum inlet spacing be 300-ft for new residential developments, unless it can be shown by engineering calculation that the maximum ponding depth in the gutter upstream of the inlet will not exceed the lesser of the top of street crown or the top of curb along the drainage path leading to the inlet from the farthest point draining to the proposed inlet.

Also to be avoided are the long stretches of no street inlets at the upstream end of a sewer line run. Slight changes in street slope due to construction procedures may reduce the planned gutter flow capacity toward the last upstream inlet in a line of street inlets. It would be recommended that engineering for new developments be required to assess inlet spacing and location in light of the realities of very flat street slopes and inaccuracies in construction, and identify an appropriate maximum distance of gutter runs without sewer inlets which would recognize inaccuracies in slope estimate and construction.

Capacity limits can also be significant at outfalls if outfalls are too small. Small outfalls (i.e., small diameter outfall pipe) produce large energy losses. In addition, small outfalls are quite susceptible to blockage by debris, either from upstream or backup from receiving waters. It would be recommended that the minimum outfall size be 24-inches in diameter (or equivalent diameter).

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2.4.6 Capacity of Open Ditch Systems

In new development situations or where drainage ditches are being improved in existing or infill areas, open ditches should be designed to handle the design storm flow. In addition, design criteria should require the following:

- Minimum bottom width of ditch (recommend 2 feet)
- Maximum side slope of ditch (recommend 4:1 slope)
- Minimum bottom slope of ditch (recommend 0.05% slope)
- Minimum freeboard under design flow conditions (recommend 1 foot)

Engineering evaluations for new development and redevelopment, if roadside ditches are to be used, should account for energy loses at culverts, including driveway culverts.

Discharges to open ditches from adjacent properties should not exceed the capacity of the ditch if 1) the ditch is adequate for generally accepted areas of localized runoff (for the design storm) adjacent to roadways, or 2) specific inclusion of existing large, off-roadway drainage areas are recognized in the design of the original ditch when the natural (i.e., not altered by man) topography drains the area toward the roadway.

Generally accepted areas of localized runoff to roadways and the ditches adjacent to them consists of 150-ft wide strips adjacent to the roadway right-of-way on each side of the road. Drainage from beyond this commonly accepted width zone is to be discouraged and should be directed to areas and/or drainage pathways to which natural drainage occur. If such drainage cannot be safely directed to natural drainage pathways, on-site detention should be required to limit the peak rates of discharge to an acceptable level for discharge either to the roadway or natural drainage paths.

2.4.7 Allowable Depths of Ponding

Allowable street ponding depth of storm waters poses one of the most difficult choices for establishing drainage design criteria, particularly in coastal or near-coastal areas where slopes are quite low and natural drainage is poor. Because of the naturally poor drainage conditions, use of streets as part of the storm water drainage system is common in coastal Texas. However, such use sometimes poses inconveniences to residents. Such use may also prevent access by emergency vehicles or ordinary citizen vehicles dealing with an emergency.

The City currently allows street ponding to depths reaching the top of curb or street crown, with the proviso that one clear lane (of 12-feet width) be maintained in collector streets and two clear lanes (of total 24-feet width) be maintained in arterial streets. Allowing street ponding to depths that keep water within curb lines is not inconsistent with drainage criteria in other communities; that is, allowing limited street ponding is a generally recognized strategy for drainage management in poorly drained areas.

However, we would recommend that consideration be given to implementing the following in future new street and drainage construction:

For the 3-year design storm event,

- Requiring that the HGL be at or below the street gutter line level.

In addition, during extreme flood events (e.g., the 100-year event), in light of the difficulty of drainage in the City because of limited ground slope, we would recommend reduction in the allowable maximum depth of street ponding, as follows:

During a 100-year event storm, the maximum water surface in the street fronting on the structure is recommended to be the following:

- No more than that 3-inches above the top of curb at the highest point of the curb adjacent to the lot; 2) no more than 6-inches above the natural ground at the highest point of the natural ground along the backside of the curb line; 3) and no more than 3-inches above the roadway crown at the highest point within the limits of the lot
- No more than that 6-inches above the top of curb at the lowest point of the curb adjacent to the lot; 2) no more than 9-inches above the natural ground at the lowest point of the natural ground along the backside of the curb line; 3) and no more than 6-inches above the roadway crown at the lowest point within the limits of the lot

Data, including applicable calculations and profile plots, should be provided to the City Engineer demonstrating compliance to these criteria when new development or redevelopment is proposed.

2.4.8 Amount of Minimal Detention

Consideration should be given to assessment of the adequacy of the minimal on-site mitigation detention storage requirement for drainage areas less than 10 acres, as specified by the current unit storage factors of 0.20 ac-ft/ac and 0.45 ac-ft/ac of detention storage for areas from 0 to 3 acres and from 3 to 10 acres, respectively. In view of the drainage problems currently being faced by the City, these factors may be too low to achieve the intended mitigation. Studies previously conducted by Klotz Associates have shown that such unit storage factors in some communities in the Houston metropolitan area tend to be in the range 0.4 to 0.8 ac-ft/ac. New developments should use such storage factors. Engineering review of specific conditions in the City and possible adjustment of these factors need to be considered.

2.4.9 Regional Detention Facilities

For mitigation by detention, the City specifies storage coefficients which depend upon developed area for areas less than 10 acres (as noted in section 2.1 above). For larger areas, HCFCD criteria (10 to 100 acres) or review by the City Engineer (greater than 100 acres) are applied. We would recommend that regional detention alternatives be allowed (but not necessarily required) where conditions would make regional detention feasible and effective, for which the regional detention facility would have to provide for the proposed development area in question the following information:

- The allocated storage in the regional detention facility for the developed area would at a minimum have to meet the storage criteria as currently defined in City criteria for on-site detention basins.
- Conveyance of storm waters from the developed area to the regional detention must be shown to the satisfaction of the City Engineer that such conveyance could be constructed and will be maintained by the development owner (or other identified party acceptable to the City) and that the conveyance would not adversely affect existing flood levels.

2.4.10 Types of Mitigation

Common mitigation techniques are detention ponds, over-sizing of sewers, and, less frequent but of increasing interest, subsurface detention systems. While such detention storage measures are a heavily relied upon mitigation techniques, the City should give consideration to the use of what are termed low impact development (LID) techniques, which are on-site detention devices or systems which limit runoff at or very near the point where runoff begins. Bio-retention, swales, rain barrels, special types of pavement and surfacing, and similar techniques can be used to promote infiltration and lessen direct runoff.

It is recommended that low impact development techniques be allowed to be used to meet mitigation requirements <u>if it can be demonstrated</u> to the satisfaction of the City Engineer that a proposed technique or collection of techniques will, with high likelihood, not only achieve mitigation which equals or exceeds that required for mitigation if a detention pond were to be used but also will, with high likelihood, function as intended in light of required maintenance for such techniques. The demonstration must recognize the potential reduction in effectiveness that limited ground slopes may have on the effectiveness of such LID techniques.

If the City were to consider allowing use of LID techniques, the City should consider defining specific types, criteria, and effectiveness measures that should be required when LID techniques are proposed.

2.4.11 Certification of No Base Flood Increase

The City currently allows encroachment into floodways provided that it can be certified by a professional engineer or architect that such encroachment will not result in increase in base flood levels. It is recommended that such certification can only be provided by a registered professional engineer who is also a certified floodplain manager (CFM).

3. Prioritization of Drainage and Local Flooding Problems (Task 4.2 of Scope of Work)

As part of the CWDS for the City, Klotz Associates was tasked with ranking the recommended projects for implementation to address drainage and flooding problems, both in the short and long term. Short term problems and conceptual ways to address them for some areas have been discussed in Report #2. This report, Report #3, focuses upon the longer term problems requiring more extensive effort, usually reflected in significant capital improvements, to implement.

Because of their greater cost or time to implement, a prioritization of such longer term problems is useful because it helps the more critical problems to be addressed more rapidly and promotes cost effective use of available capital improvement funds. Consequently this section focuses upon procedures used to define priorities for capital improvement projects to address longer term, more extensive drainage and flooding problems in the City.

3.1 Identifying Sources of Drainage and Flooding Problems

Drainage problems can have their root causes in a variety of sources, or combination of sources. Solutions to problems should be keyed to the source of the problem, but for conceptual planning purposes, inferences about the sources of problems must commonly be used as initial surrogates for clarifying problem sources.

When drainage problems arising during periods of extreme rainfall are located in floodplain areas, it is likely that insufficient channel capacity is the primary or a

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significant cause of the flooding problems. Currently known information on floodplain areas in the City comes from two sources: existing FEMA flood models and survey of channels developed specifically for the CWDS. Only primary channels and bayous are including in these studied channels, so inferences from out-of-bank flooding is restricted to the areas along these studied channels. Exhibit 11 shows the location of the studied channels. Section 4 below discusses drainage problems arising primarily from insufficient capacity in major drainage channels. The following section 3.2 examines flooding and drainage problems based not on channel modeling but upon where flooding and drainage problems apparently occur based upon flooding reports, irrespective of the reason for the flooding or drainage problem.

3.2 Prioritization Procedure for Drainage System Problems

The prioritization process presented in this section for resolving flooding and drainage problems recognizes that apparent flooding and drainage problems arise from inadequate storm sewerage capacity, insufficient drainage ditch capacity, capacity limitations at structures, or a combination of these factors. Particular remedies for these inadequate capacities are discussed in Section 5. For the prioritization process discussed here, we developed a quantitative approach which utilizes actual flooding data to distinguish both the severity of the flooding problem and the magnitude of the benefit that remedy of the problem will yield, irrespective of the precise cause of the drainage or flooding problem.

3.2.1 Flood Problem Severity

The City has collected and Klotz Associates has assembled for evaluation the following types of flooding reports:

- Report Type 1: Reports on severely damage residences
- Report Type 2: Repetitive loss reports on structural (residential) flooding
- Report Type 3: Tropical Storm Allison flooding in 2001. (It is noted that in the area of the Texas Medical Center at peak rainfall conditions, 8.5 inches of rain fell within one 2-hour period. This would exceed a 100-year storm event; see Appendix B)
- Report Type 4: Tropical Storm Erin flooding in 2007. (It is noted that this storm event had a frequency of a 100 to 500 year event, depending upon location, for the maximum 3-hour period of rainfall during the storm event.)

In addition, there may be additional information of a miscellaneous character that may become available which provides flooding data. Thus, to deal with such potential, there is also introduced:

- Report Type 5: Miscellaneous but reliable data

Of these types of flood data, Type 1 and Type 2 deal exclusively with structural flooding. The remaining types may deal with structural flooding, street ponding, or other miscellaneous flooding problems.

Exhibits 1, 2 and 3 (adapted and updated from Report #1) shows the locations of these flooding reports (segregated by type of flooding incident) across the City. Clustering of the flooding reports is evident. Available data do not provide information sufficient to determine whether various reports of one type are possibly a duplicate of another type (e.g., a report of flooding of a structure by Tropical Storm Allison might duplicate a repetitive loss report of the same structure). To account for such possibility, less weight is given to Type 3 and Type 4 reports of flooding.

As a first step to quantitatively describing this clustering and assess its implications for prioritization of projects to remedy long term flooding problems, the location of each report can be spatially evaluated using GIS tools to create a "flooding problem intensity" map (much like a elevation contour map). The number of flooding incidents in a small area can be counted using GIS techniques to create a parameter representing the number of flooding incidences (as based upon the above four listed types of flooding reports) per unit area (i.e., a flooding intensity). As the number incidences increase in an area, the flooding intensity increases. As this flooding problem intensity increases, the more serious is the flooding problem in an area. That is, this intensity is a measure of flooding problem severity.

These flooding intensities can be visually depicted as shown in Exhibits 4, 5 and 6. Since it is only the relative magnitude of the intensities that is important to assessing priorities, the intensities are presented only in relative terms. Review of this flooding intensity map shows there to be "hot spots", i.e. areas of high flooding problem intensity. These are prime areas for remedy of long term flooding problems. It is seen from the exhibits that the hot spots can be easily associated with a particular subdivision or major area within a particular subdivision. Thus it is convenient to identify a hot spot by the subdivision in which the hot spot is concentrated.

As presented in Exhibits 4, 5 and 6, the flooding problem intensities assume that each type of flooding report is of similar importance. However, some types of flooding reports imply a potentially more serious flooding condition than others. For example, a report of repetitive structural flooding is expected to represent a more serious flooding problem than a citizen's single report on a flooding incident associated with Tropical Storm Allison (because of the severity of this storm event) for which the flooding may or may not have been a structural flooding report. Consequently, if more weight is given, from a planning standpoint, to

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reports on severe flooding damage than to incidents of repetitive structure which are, in turn, given more weight than flooding reports (whether for residences or streets) arising from tropical storms, a modification of the flooding intensity map can be created by giving different levels of importance to different types of flooding reports, as given in the following table:

Policy Weight Factors for Flood Problem Intensity

Type of Flooding Report	**Policy-based Weighting Factor**
Report Type 1: Reports on severely damage residences	5
Report Type 2: Repetitive loss reports on structural (residential) flooding	4
Report Type 3: Tropical Storm Allison flooding in 2001	1
Report Type 4: Tropical Storm Erin flooding in 2006	1
Report Type 5: Miscellaneous but reliable data	1

The choice of different weights is a policy-based decision. Our primary concern is structural flooding, but street flooding may also be indicative of potential structural flooding. Thus for evaluation of long term flooding problems, the weightings listed in the table above are considered reasonable

When the above weightings (for the first 4 types only; no data are available for Type 5) are applied to each flooding incident report and the flood intensity map is rescaled to have the same average intensity as the un-scaled map (in order to provide comparison between policy-scaled and un-scaled intensities), the intensity maps of Exhibits 7, 8 and 9 results. Table 1 shows problem intensity assuming that each type of flooding occurrence has the same importance and assuming that the policy-weightings given in above table are applied.

3.2.2 Ranking of Problem Areas

The flooding problem intensity maps of Exhibits 4, 5 and 6 or 7, 8 and 9 can be used to identify and rank areas for which remedy of problems should be developed as part of the long terms solution to flood problems in the City. The areas with highest flooding problem intensity are in most urgent need of remedy.

Comparison of the Exhibits 4 and 7, 5 and 8, and 6 and 9 shows considerable similarity between the two intensity results, though the use of the policy weightings provides somewhat more distinction in the description of the hot spots. This comparison between the hot spot identification of Exhibits 4 and 7, 5 and 8, and 6 and 9 suggests, however, that the weighting factors, in the approximate range of values used, is not critical to identify priority areas for remedy of flooding problems. Therefore only the hot spot identification provided by the policy-based weighting factors is used for actual prioritization for remedy of flooding problems.

Based upon the maximum intensity within a hot spot zone, each high priority subdivision is given a rank, with highest ranking given to the area with greatest flood problem intensity. For convenience in analysis, the area with the greatest flood problem intensity is given a ranking of 10. The rankings given in Table 1 indicate the relative need for remedy of flooding problems in various subdivisions. This ranking can be used to identify an order for critical improvements, but as discussed in the following section, does not necessarily identify the most beneficial way to make improvements.

3.2.3 Value of Remedy and Prioritization of Remedies

The relative need for remedy of drainage or flooding problems can also recognize that the importance of remedy of a flooding problem will depend upon the number of people beneficially affected by the remedy. Problem areas discussed above and listed in Table 1 are associated with different subdivisions or different local areas. Different subdivisions or local areas about a hot spot area have different numbers of people, but when the drainage problems in the subdivision area are remedied, all, in broad general terms, of the people in the area benefit to some degree, not just the people with whom drainage problem reports are associated. That is, the value of a remedy of a drainage or flooding problem depends upon not only the severity of the problem but also the number of people who will benefit by remedy of the problem.

Drainage benefits in a subdivision area affect not only the residences which are reported to have flooded but also nearby residences because 1) nearby residences with flooding may not have reported the flooding; 2) street and property flooding would have likely accompanied reported residential structure flooding and reduction of street flooding would benefit everyone living in the approximate area where residential structural flooding occurred; 3) reduction of street flooding would aid emergency access, which would benefit all people in the area if emergency access were required; and 4) less frequent or elimination of residential flooding contributes to improved property values (and consequent ad valorem evaluations).

To capture these two aspects (severity of flooding and the number of people benefiting) for prioritizing CIP projects, we can plot for each subdivision or area identified for potential remedy (i.e., for each subdivision or local area for which a ranking has been established) the flooding problem intensity (as quantified by problem rank) against the number of family units in the general area of where the flooding occurs which are estimated to benefit from remedy of the flooding problem. As a surrogate for the number of family units, we use the number of lots in the area estimated to be beneficially impacted; see Table 1. In identifying the number of lots beneficially impacted, professional judgment is used to identify the boundary of the area where the benefits would be significant in light of where the high concentration of flooding reports occurs. For convenience, the identified areas of benefit are referenced by the subdivision in which they occur.

The most critical and most beneficial problem areas to select for remedy are those which have high problem intensity (corresponding to a high rank number) and high numbers of people benefiting. By examining the pattern of points in the plot of problem rank and people benefiting, we can identify those subdivisions or local areas which have high problem rank and high benefit.

For the ranked subdivisions and local problem areas, Figure 1 plots the number of lots in the subdivisions or local area against the flooding problem rank. Based upon review of these plots, the recommended priority (all other factors, e.g., budget limitations, being equal) for implementing the long term drainage and flooding problem solutions are given in Table 2.

4. Major Drainage Channel Capacity Deficiencies

Runoff from major storm events is conveyed to bay waters via a complex network of primary ditches and channels and smaller ditches (see Exhibit 10 for primary ditches and channels). When the capacity of a major channel ("drainage ditch") is insufficient to carry the flow delivered to it, two basic problems can arise: 1) flood waters can rise above the banks and overflow adjacent properties, and 2) flood waters can back up local runoff attempting to drain to the channel and contribute to local flooding problems These latter problems have been prioritized above.

Hydraulic models can be used to assess channel overflow and flow obstructions (e.g., low bridges, small culverts). In terms of modeling, the major drainage ditches in the City fall into one of the following categories:

- A drainage ditch for which a hydraulic model has been previously developed by FEMA or others; such models referred to as FEMA models.
- A drainage ditch for which field survey has been made to define channel cross section at a limited number of locations.
- A drainage ditch for which no model exists and no type of model is to be developed as part of this CWDS.

Table 3 summarizes the type of studied channels for the first two above categories (see also Exhibit 11).

4.1 Potential Deficiencies in Major Drainage Ditch Capacities

Major drainage ditches or channels evaluated for the CWDS are of two types: 1) those for which FEMA-based hydrologic and hydraulic models are available as a basis for model creation, update and revision, and 2) those for which survey has been done to approximately define the cross sectional shape of the channel.

The FEMA-based models are for extensive lengths of channel and for relatively large drainage areas. The level of detail in the geometric description of these models is good as evidenced by the number of cross sections used in the model (see Exhibits 13, 14 and 15). Existing hydrologic and hydraulic models as given by FEMA models for these major drainage ditches and channels were reviewed and modified to reflect new conditions (e.g., change in channel connectivity, crossing structures, or land use) and information about the waterway and the runoff to the waterway. These models provide a definitive description of flooding conditions along the ditch or channel, and detailed conclusions about flow containment or bank overflow along the length of the channel can be drawn.

On the other hand, those ditches and channels for which no prior hydrologic and hydraulic models are available are generally short tributaries to the FEMA-based models. Only limited data on ditch or channel geometry are available for these ditches and channels; these data were obtained by field survey done for this study (see Exhibits 13, 14, and 15). Typically only 2 or 3 cross sections were surveyed along the ditch or channel. These survey data were collected for this study since no existing data describing channel geometry for the tributaries were available. In addition, information about structures (e.g., bridges) along the length of the channel is generally incomplete. Consequently it is difficult to draw reliable conclusions about the detailed behavior of water levels and consequent flow containment within channel banks. (Along F101-00-00 for which a HEC-RAS model was developed from hard copy data in the appendices of a master drainage plan done by HCFCD for La Porte in 1987, two channel sections between Hwy 146 and Sens Road were field surveyed as a check on the cross section data in the 1987 master drainage plan study. Comparison of the survey cross section data to the cross data provided in the 1987 showed the section data to be reasonable consistent. Bank elevations and bank to bank distances were quite similar, as were channel shape and side slopes except near the channel bottom. Flow line elevations in the surveyed sections were about 4 ft deeper than the sections taken from the 1987 study.)

Thus, two different methods were used to assess the capacity of major ditches and channels, the methods being selected to utilize the available data in a manner consistent with the level of detail about the ditch or channel.

4.1.1 Major Drainage Ditch Assessment for Ditches with FEMA Models

For major drainage ditches for which FEMA hydrologic and hydraulic models were available (with revision to reflect new information), the 10-, 50- and 100-year flood flows were simulated. Figures 2 through 16 show the flow profiles for various flood frequencies for the various modeled channels in the different major watersheds composing the study area. Note that the profiles sometimes combine separate FEMA models into a single model. The location and extent of the drainage ditches for which these flow profiles were determined are shown in Exhibit 11. Table 3 tabulates the models.

When the model computed flood level rises above the bank elevation (compare the computed water surface profiles to the left and right bank elevation in these figures in Figures 2 through 16), channel capacity is at least locally deficient and improvements would likely be warranted to keep flood levels within bank for the frequency of interest. Potential measures to accomplish such lowering are discussed in section 5 below.

Exhibits 16, 17 and 18 compare the locations where the computed flow depths exceed the channel banks for various flood frequencies to the locations of flooding reports (these reports have been discussed in section 3.2.1 above). It is seen that some areas with of out-of-bank conditions occur in the near vicinity of areas where flood reports are frequent, while in other situations out-of-bank locations do not closely correspond to the locations where flooding reports are numerous. Table 2 compares of the out-of-bank conditions to areas where flooding reports are numerous.

Based on where out-of-bank conditions occur relative to flooding reports, an assessment can be made as to whether inadequate channel capacity is likely a significant source of reported flooding problems in a particular area. Table 2 provides such assessment: For a storm frequency of interest, it is concluded that the overflow from the major channel is or is not a likely significant contributor to the reported flooding problems. If the drainage ditch or channel is judged to be a significant source of reported flooding problems, channel improvements should be given high priority in the type of solution proposed to address flooding problems along or near the channel.

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4.1.2 Major Drainage Ditch Assessment for Ditches without FEMA Models

For major drainage ditches without a base FEMA model, a different approach for using the limited information on channel configuration was used to assess the capacity of the channel to contain flows of different frequencies. Since these drainage ditches, conveniently termed tributary channels (though in fact two of these channels drain directly to Galveston Bay) are generally short and drain to a channel (or in the two instances, Galveston Bay) for which a FEMA model has previously been developed, the tailwater level (either at the receiving channel or the bay) will dominate and largely determine the water level in the tributary channel.

The potential out-of-bank conditions can be thus assessed for planning purposes by comparing tailwater levels (i.e., water level in the receiving channel for the storm frequency of interest) to the bank elevation at the available cross sections along the tributary channel. Table 3 summarizes whether or not the tailwater level is or is not above the top-of-bank at the available sections along the tributary. Based upon a review of these levels, an assessment can be made as to whether or not, for the storm event frequency of interest, the tributary size is likely sufficient to keep the flow within banks. These assessments are provided in Table 3. If bank overflow can be expected to be frequent, the tributary should be considered for improvement. If frequent out-of-bank conditions occur in the close vicinity of reported flooding, tributary capacity is likely a significant contributor to the flooding problems, and capacity improvements are of high priority.

4.1.3 Channel Capacity Impacts on Reported Flooding Problems

Flooding problem reports have been described in section 3.2. The evaluation of drainage channel and ditch overflow discussed in sections 4.1.1. and 4.1.2 above can assist in identifying likely significant sources or causes of reported flooding problems. There are different likely significant sources or causes of reported flooding that can be reasonably distinguished by the frequency of channel overflow when there is a drainage channel in the vicinity of an area of numerous flooding reports (i.e., near flooding "hot spot" areas). These sources or causes are categorized as follows:

- *Insufficient Channel Capacity*: The frequency at which channel overflow is so large (in a relatively sense) that it can be expected that an overflowing channel will be a major cause of the reported flooding if the area of flooding is reasonably close to the channel. For evaluation purposes, it is assumed if a channel is estimated to overflow its banks for 10-year and larger storm events that insufficient channel capacity is the primary or certainly a prime cause of the reported flooding. Note that the insufficient channel capacity could be due to insufficient channel size and/or bridges and culverts which produced large hydraulic head changes at isolated locations.

- *Inadequate Sewerage*: In this situation, it is very seldom that channel overflow occurs and that therefore the source of reported flooding is unlikely due to insufficient channel capacity but rather due to the inadequacy of the sewerage (i.e., the pipes, inlets, manholes, etc.) that drains runoff waters from the problem area to the channel. Inadequacy of the sewerage could be attributed to insufficient sewer pipe sizes, numbers of storm water inlets, and/or lack of overland flow pathways. Infrequency of channel overflow is considered to occur if no channel overflow occurs for the 100-year storm event.

- *Mixture of Inadequate Sewerage and Insufficient Channel Capacity:* This is an intermediate overflow condition for which both inadequate sewerage capacity and likely frequent high sewer tailwaters occur, with both contributing to poor drainage. This condition is estimated to occur when overflow does not occur for the 10-year storm event but does occur for the 50- and/or 100-year storm event.

Based upon these categories, the sources of flooding problems are identified in Table 3 in light of the estimated overflow conditions of the studied ditches and channels given in Table 2. This identification provides guidance for selection of likely needed drainage solutions to be identified in the CWDS report.

5. Conceptual Solutions to High Priority Problems (Task 4.3 of Scope)

Some short term flooding issues and conceptual solutions for addressing those issues have been discussed in Report #2. In addition, preliminary concepts for addressing long term problems were identified in Reports #1 and #2. Conceptual solutions to address long term problems are described in the following:

5.1 Problem Remedies

The concepts for remedy of drainage and flooding problems generally applicable to all drainage and flooding problem areas fall into the following categories:

5.1.1 Storm Sewer System Upgrades

Upgrade of storm sewer systems to 1) increase the capacity of a sewer line, 2) convert open ditches to sewers in streets with curb and gutter systems; and/or 3) increase the capacity of street inlets to lessen ponding in streets. To accomplish these types of upgrades, the following improvements may be done:

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- For increasing the capacity of a sewer line:

    - Replacing an existing sewer pipe (or box culvert) with a larger pipe (or box)
    - Adding a new parallel sewer line near an existing pipe or culvert, the new line being of similar or larger size
    - Adding a diversion line which carries a portion of the total flow in an existing line to another location or outfall
    - Altering the slope or invert of existing sewer lines
    - Replacing existing manholes or junction boxes when in poor condition

- For conversion of an open ditch to sewer-drainage system:

    - Placing a new sewer line in an existing ditch with capacity similar to the ditch capacity
    - Placing a new sewer line along an existing ditch line and increasing the capacity of the original ditch with the new sewer line
    - Controlling the points of storm water entry into the sewer line more effectively
    - Altering the outfall configuration for the drainage system

- For increasing the capacity of inflow to a sewer to reduce ponding:

    - Change the configuration of the inlet type or size to be used to one which has greater capture efficiency
    - Increase the size and/or number of inlets
    - Improve location of inlets so that runoff can be more effectively captured
    - Provide an overflow path to a ditch

Note that proper and continuing maintenance of sewers, ditches and channels is an important requirement for maintaining design capacities.

5.1.2 Overland Sheet Flow Paths

To reduce ponding of storm waters, provision of overland sheet flow paths to allow alternative ways to drain areas of ponding and excessive water accumulation can be provided. Provision of overland sheet flow paths have been discussed and proposed in Reports #1 and #2 as more immediate, short term remedies for some drainage problems because provision of sheet flow paths can be implemented rather quickly and often at relatively low cost. Provision of overland flow paths may not always be a comprehensive solution because if the outfall receiving point or water for the overland flow (e.g., a drainage channel) does not have sufficient capacity, then the overland flow path capacity may be reduced or even prevented from functioning. Thus overland flow path solutions should be generally viewed as a complement to long term solutions dealing with channel capacity and sewer system capacity.

5.1.3 Detention

Detention may be onsite or offsite, and usually consists of some type of pond with storage that is dry until a storm event. Wet bottom detention (i.e., the pond never complete drains) is also provided in several areas. Onsite detention is located at or near the source of runoff for which control is sought, while offsite detention is commonly a shared, or "regional detention," facility.

Onsite detention is commonly built and maintained by the property owner of a single parcel of property, while offsite or regional detention is often owned and maintained by a government entity which sells or provides storage in the detention system for areas in need of detention storage. Onsite detention facilities can also be located relatively easily underground, though costs for underground detention will be typically much larger than a surface detention facility.

While onsite detention is primarily used for mitigation of new development, regional detention offers an opportunity to address existing excess runoff and channel flow problems. The regional detention facility can be sized, if adequate space for the regional detention facility can be identified, to reduce downstream impacts of excessive runoff from already developed areas upstream of the detention facility.

Benefits of regional detention include:

- Ability to mitigate excess runoff at far distance points
- Ability to mitigate excess runoff from different points
- Ability to achieve economy of scale in construction costs
- Ability to transfer construction costs of detention facility to others not involved in the construction process
- Possible dual use of the detention pond as an amenity facility
- Reduction in the number of locations to be maintained

Drawbacks to use of regional detention can include:

- Need for the pond owner to construct the pond upfront before full construction cost recovery may be possible
- Owner will typically be responsible for maintenance of the regional facility
- Purchase of storage space by other parties requires proper legal transfers

- If not properly designed, delivery of runoff waters to the regional detention facility from source areas may have adverse effects on upstream or downstream properties.
- The owner is liable for deficiencies in pond operation and maintenance

It should also be recognized that detention ponds offer opportunity for inclusion of best management practices for purposes of storm water quality improvement.

5.1.4 Channel Modifications

Channel modifications are generally made to increase the capacity of the channel. However, in addition to capacity increases, channel modifications can have the following benefits and challenges:

- Lowering water levels for similar flows, with resulting lowering tailwater levels for storm sewer systems discharging to the channel.
- Improvement in aesthetics
- Improvements in habitat along the channel
- Reduction in bank and/or bottom erosion
- It may difficult to enlarge a channel in an already developed areas because of limited right-of-way
- Access for enlarging a channel may be limited or virtually absent
- A channel improvement may require coordination with or permission of an agency, such as HCFCD, U.S. Army Corps of Engineers, or TxDOT
- Channel improvements may also require detention or other mitigation features

Channel modifications for improving capacity can assume a variety of forms, as follows:

- Widening of channel, with or without side slope modification
- Channel flow line adjustment so that channel becomes steeper
- Lateral shifting or realignment of channel to shorten its length and/or reduce loss producing curves or junctions
- Increasing the steepness of side slopes (using concrete or similar material) to both increase the channel area and reduce roughness
- Use smooth materials (e.g., concrete) to line the channel and reduce friction losses

Any channel modification must recognize possible need for increased easement or right-of-way.

When channel improvements are made, consideration should be given to storm water quality controls for the channel; such controls can include channel erosion prevention measures, prevention of excessive siltation, and capture of floatables potentially entering the channel.

5.1.5 Hydraulic Structure Modifications

Drainage channel cross or are crossed by numerous roads, railroads, and pipelines. Bridges and culverts are commonly used to make such crossings. Other miscellaneous hydraulic structures such as flow splitters, drops, and constructed bends can also be present in a channel. Crossings and miscellaneous structures, pipelines, and, in particular, culverts and smaller bridges, can significantly increase energy losses and reduce channel capacity. Improvements in structures can have conveyance improvement benefits and, as well, lower tailwaters.

Structural modification to improve conveyance and capacity of a channel will commonly be one of the following:

- Increasing the size (diameter) of a culvert or the individual barrels of a culvert by adding barrels or replacing existing culvert barrels
- Decreasing the length of culverts as part of culvert replacement
- Upgrade of a bridge by 1) raising the low chord of the bridge, 2) increasing the spacing between bridge piers, 3) reducing the bridge skew, or 4) increasing the size of the opening under the bridge
- Adjustments around pipeline restrictions to reduce constrictions or limit blockage

5.1.6 Property Buyout

Property buyouts can be used for the following purposes:

- To remove a property subject to flood damage from the floodplain by property purchase, followed by removal of structures on the property
- To allow for development of sheet flow pathways for safe discharge of ponded waters
- To use the property for construction of critical flood control facilities, such as a detention pond
- Allow adjustment of floodway boundaries to facilitate development in other areas

5.1.7 Representative Unit Costs

Table 4 presents a summary of representative unit costs for estimating the potential costs of various conceptual projects for addressing particular drainage or flooding problems identified for the City Wide Drainage Study. Estimated costs of specifically recommended solutions will be addressed in the CWDS final report.

6. Sources of Funding (Task 4.4 of Scope)

Cities across Texas have reported a variety of capital project funding methods, including using ad valorem taxes to purchase bonds (the most common method), fee programs, and similar revenue generation measures. While ad valorem taxes are the most common form of revenue generation for construction, such taxes do have limits and municipalities often seek alternative funding sources.

Use of these alternative funding sources can be uncertain because of often high competition for available funds, the often very limited amount of funds for distribution, and the specific purposes and priorities of the funding entities or sources for the use of available funds. Some funding sources, such as royalties from oil and gas drilling, are unique to the community. Many cities seek creative funding tools and, many instances, with success. The following summarizes some alternative funding sources that the City of La Porte could consider as a potential part of their capital improvement planning.

6.1 Special Taxing Districts

A possible source of revenue is the creation of special Storm Water Utility Divisions that allows for the collection of funds dedicated to storm water management and quality issues. When the U.S. Environmental Protection Agency (EPA) required cities to obtain National Pollutant Discharge Elimination System (NPDES) permits for discharge of storm waters, cities have found they often need additional funds to respond to the requirements of these permits. The NPDES storm water permit (as implemented by the Texas Commission on Environmental Quality) requires cities to take responsibility for quality of storm water discharges. Many cities have created Storm Water Utility Divisions as a way to establish a new funding source that could pay for floodplain management, drainage costs, and/or water quality control costs, the latter arising from NPDES permit requirements, rather than using money from the general fund.

The utility establishes a utility fee rate at a level needed to meet the drainage needs of the community. The fees usually appear in the water bill, and are commonly about 1% of the water bill. Dallas was among the first cities in Texas to establish a Storm Water Utility Division, providing an organizational and process model for other cities to follow. San Antonio, Laredo, Tyler and Arlington are among those cities which have successfully implemented their own storm water utilities. Some cities, on the other hand, have after review of storm water utilities issues declined to establish such a utility.

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Another similar method for collecting funds for infrastructure improvements is to create a special taxing zone or tax increment financing zone. Tax increment financing (TIF) allows cities to capture increased property tax value and direct that money into capital projects serving the special taxing zone. For example, the City of Allen allows the developer to front the capital for infrastructure and the city pays back the developer, allowing the developer to keep the incremental increase in tax value. Many cities, including La Porte, establish tax increment reinvestment zones (TIRZ) in existing neighborhoods. The zone or neighborhood keeps the increase in tax value of their particular area by having the City can reinvest that money in capital projects serving the area in question.

6.2 Federal Government Funds

In some cases, cities may seek opportunities to leverage resources with government organizations with which they share interests. Some agencies that cities have worked with in the past include the Houston Galveston Area Council (HGAC), Texas Department of Parks and Wildlife, TxDOT, Texas Water Development Board (TWDB), and the Federal Emergency Management Agency (FEMA).

Of these agencies, TWDB is considered the most likely to provide additional funds for storm water drainage improvements. The agency administers two grant programs to mitigate flooding: the Federal Emergency Management Agency Flood Mitigation Assistance (FMA) Grant program, and the Flood Protection Planning Grant. The first grant covers acquiring property, relocating or demolishing structures, flood-proofing, elevating structures, minor localized structural projects, and beach nourishment (planting grass, etc.). The grant covers only insured property. The second grant, Flood Protection Planning, covers the evaluation of structural and nonstructural flooding solutions in the context of the whole watershed.

The TWDB also has three loan programs to which application can be made for municipal drainage projects. The State Loan Program (Development Fund II) provides loans for storm water projects including the following:

- Construction of storm water retention basins
- Enlargement of stream channels
- Modification or reconstruction of bridges
- Acquisition of floodplain land for use in public open space
- Acquisition and removal of buildings located in a floodplain
- Relocation of residents of buildings removed from a floodplain
- Public beach re-nourishment, control of coastal erosion
- Flood warnings systems
- Development of flood management plans

The second loan administered by the TWDB is the Clean Water State Revolving Fund (CWSRF) Loan Program which provides loans at interest rates lower than the market and can be used for storm water pollution control projects and non-point source pollution control projects.

The third loan program is the Water Infrastructure Fund (WIF) that provides subsidized loans to fund projects already on the State Water Plan or TWDB-approved Regional Water Plan. In order to get a new project on the State or Regional Water Plan, the regional plan would have to be amended.

In addition to the TWDB, FEMA also provides for federal funding to move people out of flood-prone areas. FEMA also has a grant program called the Repetitive Flood Claims Grant Program (RFC), which provides funding to acquire flood damaged structures and convert the property to open space. The money is limited to properties that meet the following requirements:

- One or more claim payments for flood damages
- Property must have flood insurance
- Located within a State or community that cannot meet the requirements of the FMA grant program.

The City of La Porte may consider using this program to fund the creation of recommended overland flow paths in subdivisions with repetitive loss properties located near drainage channels.

Another program, The Governor's Division of Emergency Management at the Texas Division of Emergency Management, serves as the Grantee and administrator the Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation Grant Program (PDM) in Texas. HMGP funds can be used for:

- Acquisition/demolition/elevation of flood-prone structures
- Community and individual storm shelter programs
- Retrofitting facilities (flood proofing, high wind, etc.)
- Small scale structural hazard control/protection projects
- Limited funding of innovative projects such as public awareness, enhanced hazard information systems, enhanced warning capabilities, etc.
- Limited funding of the development of state and local mitigation action plans (MAPs)

Pre-Disaster Mitigation Grant Program (PDM) grants provide money for pre-disaster mitigation planning, and the implementation of mitigation projects addressing natural hazards. Common mitigation projects include buy-outs, individual or community safe-rooms/storm shelters and retention ponds. Both grants require that the city or legal entity have a Mitigation Action Plan in place prior to applying for the grant. Costs for implementation of a PDM program can be quite variable depending upon mitigation projects selected for the program. However, the planning component of a PDM program which identifies mitigation projects can be quite reasonable, comparable to the preparation of a master drainage plan. The benefits of such a program can far outweigh the costs of program preparation.

Finally, the Texas Department of Parks and Wildlife also has a variety of grants available for municipalities, primarily for the construction and enhancement of recreation areas. The Regional Grant was created to assist local governments with the acquisition and development of multi-jurisdictional public recreation areas in the state's metropolitan regions. The program provides 50% matching funds and reimbursement grants to eligible local governments for both recreation and conservation facilities.

6.3 Local Agencies

In some cases, a local agency such as HCFCD, will partner with local cities and community groups on selected flood prevention projects. Frequently, these partnerships arise from the community contacting the District to propose a project. Not all such projects can be accomplished, but all proposals are taken seriously, as evidenced in the District's current partnering with several area entities. Some particular projects include a study of the flooding mechanisms along a local tributary and identifying methods to lessen its flood risks. Cities which have teamed with HCFCD include Tomball, Humble, Pasadena, South Houston, Houston, Galena Park, and Katy.

6.4 Developer Impact Fees

An alternative method of funding that may be used by the City is the collection of developer impact fees. In this situation, fees are collected based on the value of the new development compared to the tax credits. Developer impact fees have been an excellent source of infrastructure funding for some cities. In fiscal year 2004/2005 Sugar Land realized $1,303,000 in revenue from developer fees alone. However, estimating the actual developer fee a city will generate is not always calculated as simply as it is shown in the formula legislated in Local Government Code Chapter 395.015, i.e.,

> Developer Fee = (Cost of capital improvements – Property and utility tax credits) ÷ (Total number of projected service units necessitated by and attributable to new development within the service area based on the approved land use assumptions and calculated in accordance with generally accepted engineering or planning criteria)

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because of the difficulty of determining the total number of projected service units necessitated by and attributable to new development. Impact fees are also subject to certain state regulations that may require advance funding by the City if impact fees are to be utilized.

Overall, securing a grant, loan or partnership for a particular project requires significant effort. While grant money is limited, application deadlines and grant program criteria further limit options, and agencies must select from many partnership proposals to best use their limited resources. A targeted, organized, long-term effort to secure funding can improve a municipality's chances of getting the needed monies to fund critical projects. It is recommended that the City consider beginning applications for several of the funding methods discussed above, particularly for those programs offered by TWDB and FEMA. Partnering with HCFCD should also be pursued. A list of the websites for some of these agencies is also shown in the following section of this report.

6.5 References Related to Funding

6.5.1 Websites References

Websites for Grant and Loan Programs
Harris County Flood Control District Partnerships:
www.hcfcd.org/partnerships.html

Texas Parks and Wildlife:
www.tpwd.state.tx.us/business/grants/

Texas Water Development Board:
www.twdb.state.tx.us/assistance/assistance_main.asp

Governor's Division of Emergency Management:
www.txdps.state.tx.us/dem/pages/index.htm

Federal Emergency Management Agency:
Repetitive Flood Claims Grant Program
www.fema.gov/government/grant/rfc/index.shtm

6.5.2 General References

"Financial Assistance." 2006. Texas Water Development Board. March 14, 2007. <http://www.twdb.state.tx.us/assistance/financial/financial_main.asp>

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Colley, Jack.. Letter to Emergency Management Colleagues. January 29, 2007. Repetitive Flood Claims Grant Program Guidance for FY 2007. Emailed to firm 3.1.07.

Colley, Jack.. Letter to Emergency Management Colleagues. January 29, 2007. Pre-Disaster Mitigation (PDM) Grant Program Guidance for FY 2007. Downloaded from website 3.14.07. <
http://www.txdps.state.tx.us/dem/pages/downloadableforms.htm#hmgpgrants>

"Hazard Mitigation Grant Program (HMGP)." August 30, 2006. Texas Division of Emergency Management. March 14, 2007
<http://www.txdps.state.tx.us/dem/pages/downloadableforms.htm#hmgpgrants>

Texas Statutes Local Government Code Chapter 395.015. Added by Acts 1989, 71st Leg., ch. 1, § 82(a), eff. Aug. 28, 1989. Amended by Acts 2001, 77th Leg., ch. 345, § 3, eff. Sept. 1, 2001. <
http://tlo2.tlc.state.tx.us/statutes/lg.toc.htm>

7. Conclusions

In this report, we have focused on several key issues in regard to long term solution of continuing, critical drainage problems. We have systematically identified areas of significant flooding and provided a prioritization of those areas in a manner which not only recognizes the severity of flooding but also the benefit to be derived by improved drainage to eliminate flooding and ponding in such areas. We have also examined potential overflow conditions in major drainage channels and ditches to generally describe the severity of insufficient capacity in primary channels and ditches and assess whether channel capacity is a likely source of reported flooding for particular areas of reported flooding.

We have also identified and reviewed the various conceptual approaches to address identified drainage and flooding problems. Implementation of such solutions will require funding. To assist the City in obtaining necessary funding, we have provided a general review of likely additional funding sources in addition to traditional tax-based sources.

Critical to long-term prevention of increased flooding and inadequate drainage in the City are the drainage criteria and standards to which new development and re-development must comply. While the City has a basically sound set of drainage criteria, we have identified a series of what we think would be potential improvements in the criteria to be applied to new development and redevelopment.

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We hope that you will give serious consideration to our recommendations for potential changes and additions to the drainage criteria.

Our next and final report will be the City Wide Drainage Study (CWDS). That report will include specific recommended solutions to drainage and flood control problems with emphasis upon higher priority problems, and estimates of costs of implementing identified problem solutions.

We look forward to discussing this report with you at your convenience.

Sincerely,

for GLS

Gary L. Struzick, P.E., CFM
Vice President

mac

CC: Mr. Steve Gillett, City of La Porte
Mr. John Joerns, City of La Porte
Mr. Rodney Slaton, City of La Porte

Attachments: See list on following page

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TABLES

Table 1 - Prioritizing Drainage Problems

Name of Flood-Affected Area (Also Show Name on Map)	Maximum of Intensity in Affected Area Assuming All Flooding Reports of Same Weight	Maximum of Intensity in Affected Area Assuming Flooding Reports have Different Weight	Rank (10 is Highest) Assuming All Flooding Reports of Same Weight	Rank (10 is Highest) Assuming Flooding Reports have Different Weight	Number of Lots in Subdivision Area	Number of Lots Likely to Directly Benefit from Drainage Improvement
Brookglen	11.84	35.37	10	10	835	600
Creekmont Section 1	10.99	15.11	10	10	338	110
Glen Meadows	10.17	13.43	9	9	744	160
La Porte	3.31	8.68	6	9	436	375
Spencer Highway Estates	2.76	8.61	6	8	381	100
Fairmont Park East	4.04	8.15	7	8	1318	500
Pinegrove Valley	4.92	7.64	8	8	275	220
Fairmonth Park West	5.44	6.79	8	7	1232	390
Bay Colony	2.40	6.69	5	7	128	128
Shady River	2.41	6.65	5	7	154	154
Creekmont Section 2	3.60	6.32	7	6	138	30
Fairmont Park	4.00	5.86	7	6	705	330
Lomax Garden	5.47	5.47	9	5	160	160
Meadow Park	4.18	5.32	8	5	91	91
Bayside Terrace	1.30	3.77	3	5	252	252
Old La Porte	1.62	3.36	4	4	1305	150
Battle Grounds Vista	1.10	2.75	3	4	55	10
Bay Shore Park	1.10	2.74	3	3	217	50
Beach Park	1.06	2.67	2	3	73	50
Pine Bluff	0.64	2.20	1	3	189	189
Villa Del Rancho	2.13	2.13	5	2	21	21
Woods On The Bay	0.73	1.84	2	2	76	76
Spencer Landings	0.71	1.78	2	2	216	10
Meadowcrest	1.52	1.52	4	1	351	50
Battleground Estate	0.55	0.55	1	1	197	20
Bay Front To La Porte	0.55	0.55	0	0	436	40
San Jacinto Homes	0.55	0.55	0	0	281	10

Table 2 - Rank of Flood Problems

Name of Flood-Affected Area (See Exhibit 7, 8, & 9 for location)	Rank (10 is Highest) Assuming Flooding Reports have Fifferent Weight	Number of Lots Likely to Directly Benefit from Drainage Improvement	Likely Significant Source/Cause of Flooding
Brookglen	10	600	Mixture of Inadequate Sewerage B112-00-00
Creekmont Section 1	10	110	Inadequate Sewerage
La Porte	9	375	Insufficient Channel Capacity F216-00-00
Glen Meadows	9	160	Mixture of Inadequate Sewerage B106-00-00
Fairmont Park East	8	500	Inadequate Sewerage
Pinegrove Valley	8	220	Mixture of Inadequate Sewerage F101-00-00
Spencer Highway Estates	8	100	Inadequate Sewerage
Fairmont Park West	7	390	Inadequate Sewerage
Shady River	7	154	Mixture of Inadequate Sewerage A104-12-00
Bay Colony	7	128	Inadequate Sewerage
Fairmont Park	6	330	Inadequate Sewerage
Creekmont Section 2	6	30	Inadequate Sewerage
Bayside Terrace	5	252	Inadequate Sewerage
Lomax Garden	5	160	Mixture of Inadequate Sewerage F101-03-00
Meadow Park	5	91	Mixture of Inadequate Sewerage B106-05-00
Old La Porte	4	150	Mixture of Inadequate Sewerage F216-00-00
Battle Grounds Vista	4	10	Inadequate Sewerage
Pine Bluff	3	189	Mixture of Inadequate Sewerage A104-12-00
Bay Shore Park	3	50	Data Insufficient
Beach Park	3	50	Inadequate Sewerage
Woods On The Bay	2	76	Mixture of Inadequate Sewerage A104-12-00
Villa Del Rancho	2	21	Mixture of Inadequate Sewerage B106-05-00
Spencer Landings	2	10	Inadequate Sewerage
Meadowcrest	1	50	Inadequate Sewerage
Battleground Estate	1	20	Inadequate Sewerage
Bay Front To La Porte	0	40	Data Insufficient
San Jacinto Homes	0	10	Data Insufficient

Table 3 - Summary of Studied Channels

	Type	Outfall	Description
Clear Creek Watershed			
A104-00-00 (Taylor Bayou)	Surveyed Sections	Clear Creek	A104-00-00 (Taylor Bayou) with in the city limits stays within its channel banks for the 10 year, 50 year, and 100 year storm event.
A104-07-00 (Tributary 3.93 to Taylor Bayou)	Surveyed Sections	Taylor Bayou	A104-07-00 (Tributary to Taylor Bayou) with in the city limits stays within its channel banks for the 10 year, 50 year, and 100 year storm event.
A104-12-01	Surveyed Sections	Taylor Bayou	A104-12-01 stays within its channel banks for the 10 year storm event. The flow is not contained for the 50 year and 100 year storm event.
Armand Bayou Watershed			
B106-00-00 (Big Island Slough)	Revised FEMA Model	Armand Bayou	B106-00-00 (Big Island Slough) stays within its channel banks for the 10 year and 50 year storm event. The flow is not contained within bank for the 100 year storm event.
B106-02-00	Surveyed Sections	Big Island Slough	B106-02-00 stays within its channel banks for the 10 year, 50 year, and 100 year storm event.
B106-05-00	Surveyed Sections	Big Island Slough	B106-05-00 stays within its channel banks for the 10 year and 50 year storm event. The flow is not contained for the 100 year
B109-00-00 (Spring Gully)	Revised FEMA Model	Armand Bayou	B109-00-00 (Spring Gully) stays within its channel banks for the 10 year, 50 year, and 100 year storm event.
B109-03-00 (B112-02-00 Interconnect)	Revised FEMA Model	Spring Gully	B109-03-00-00 stays with its channel banks for the 10 year storm event. The flow is not contained for the 50 year and 100 year storm event.
B112-02-00 (Connected to B109-03-00)	Revised FEMA Model	Willow Spring Bayou	B109-03-00-00 stays with its channel banks for the 10 year storm event. The flow is not contained for the 50 year and 100 year storm event.
B112-00-00 (Willow Springs Bayou)	Revised FEMA Model	Armand Bayou	B112-00-00 (Willow Spring Bayou) stays within its channel for the 10 year storm event. The flow is not contained for the 50 year and 100 year storm event
B112-02-00 (Tributary 1.78 to Willow Spring Bayou)	Revised FEMA Model	Willow Spring Bayou	B112-02-00 (Tributary 1.78 to Willow Spring Bayou) stays within its channel banks for the 10 year, 50 year, and 100 year storm event
San Jacinto/Galveston Bay Watershed			
F101-00-00	Surveyed Sections	San Jacinto/Galveston Bay	F101-00-00 is not within its channel banks for the 100 year storm event
F101-03-00	Surveyed Sections	F101-00-00	F101-03-00 is not within its channel banks for the 100 year storm event
F212-00-00 (Deer Creek)	Surveyed Sections	San Jacinto/Galveston Bay	Data insufficient
F216-00-00 (Little Cedar Bayou)	Revised FEMA Model	San Jacinto/Galveston Bay	F216-00-00 (Little Cedar Bayou) flow is not contained for the 10 year, 50 year, and 100 year storm event.
F216-01-00	Surveyed Sections	Litter Cedar Bayou	F216-01-00 stays within banks for the 10 year, 50 year, and 100 year storm event.

Table 4 - Summary of Unit Costs

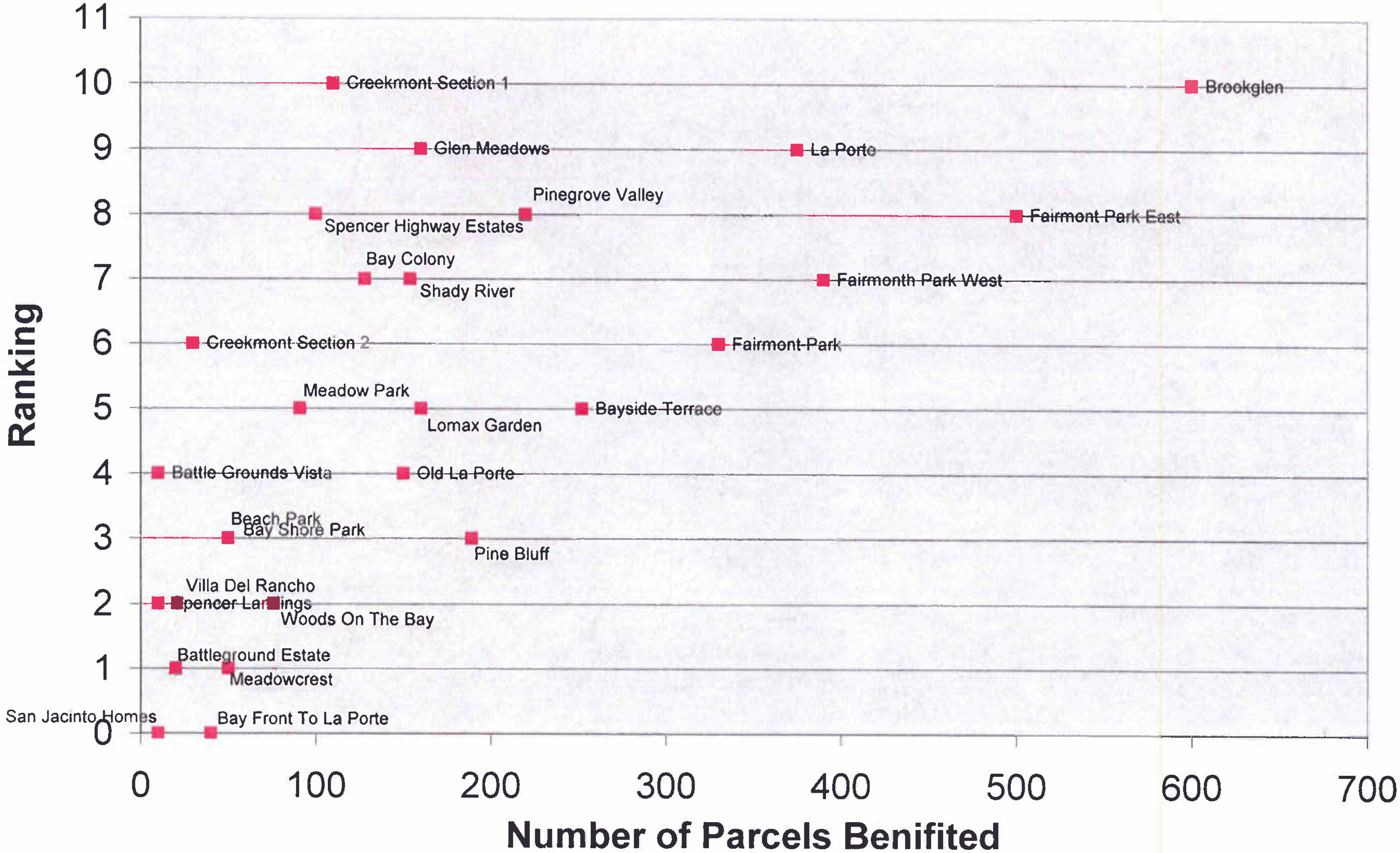
Detention Pond - aboveground (1 ac-ft storage)			
Pond structure	$109,594		
Inlet-outlet-emergency overflow works	$33,158		
SWPPP (storm water pollution prevention plan)	$2,803		
Debris trapping devices	$118,856		
Geotechnical (1 borings per ac-ft of storage)	$4,110		
Total	$268,521		
Estimated Unit Cost		$269,000	per ac-ft of storage
Detention Pond - below ground (1 ac-ft of storage)			
Storage pipes with excavation (from sewer costs-6162 ft total)	$1,101,285		
Inlet-outlet-emergency overflow works	$33,158		
SWPPP (storm water pollution prevention plan)	$2,803		
Debris trapping devices	$118,856		
Geotechnical (1 borings per ac-ft of storage)	$4,110		
Total	$1,260,212		
Estimated Unit Cost		$1,260,000	per ac-ft of storage
In-line Detention (providing 1 ac-ft of additional storage)			
Channel length required (ft):			
Estimated Unit Cost (based upon channel widening)		$ 122,000	per ac-ft of additional storage
Channel Widening (500 ft long, with 4 ft of widening)			
Widening with headwall improvements	$16,136		
SWPPP	$1,600		
Geotechnical (3 borings per 500 ft)	$4,645		
Total Cost	$22,381		
Estimated Unit Cost		$11.00	per ft of channel length per ft of widening
New Channel (for diversion or bypassing-500 ft long, 12 tt bottom width)			
Excavation, headwalls and related	$45,658		
SWPPP	$1,600		
Geotechnical (3 borings per 500 ft)	$4,645		
Total Cost	$51,903		
Estimated Unit Cost		$8.67	per ft of channel length per ft of bottom width

Table 4 Continued

Sewers - replacement or new			
36" pipe installation		$150	per lf of installation
48" pipe installation		$210	per lf of installation
60" pipe installation		$220	per lf of installation
72" pipe installation		$330	per lf of installation
Inlets		$2,000	per inlet
Concrete Pavement		$40	per square yard
Utility Relocation		$30	per lf of relocation
Culverts (20 ft long, 1-5 x 5 box)			
Remove existing, placemenet, material	$80,607		
Roadway repair	$6,400		
SWPPP	$480		
Geotechnical (equivalent to 3 borings per culvert)	$4,645		
Total Cost	$11,525		
Estimated Unit Cost		$24.00	per ft of culvert length per sq-ft of flow area per barrel
Other Unit Costs			
Excavation		$20.00	per cy
Property Buy Outs		$135,000.00	per house
Concrete Flume		$40.00	per square yard
Environmental Improvements and Enhancements			
Floatable trapping devicies for ponds or channels			
Representative cost	$118,856		
Estimated Unit Cost		$119,000	for each pond
Extra sediment trapping for water quality - aboveground pond			
Increase in storage volume - 10%			
Estimated Unit Cost		$26,900	per ac-ft of storage
Extra sediment trapping for water quality - belowround pond			
Increase in storage volume - 10%			
Estimated Unit Cost		$126,000	per ac-ft of storage
Other Costs (as % of construction cost)			
Survey	5%		
Typical Engineering and related costs	20%		
Representative mobilization costs	5%		
Typical contingency	15%		

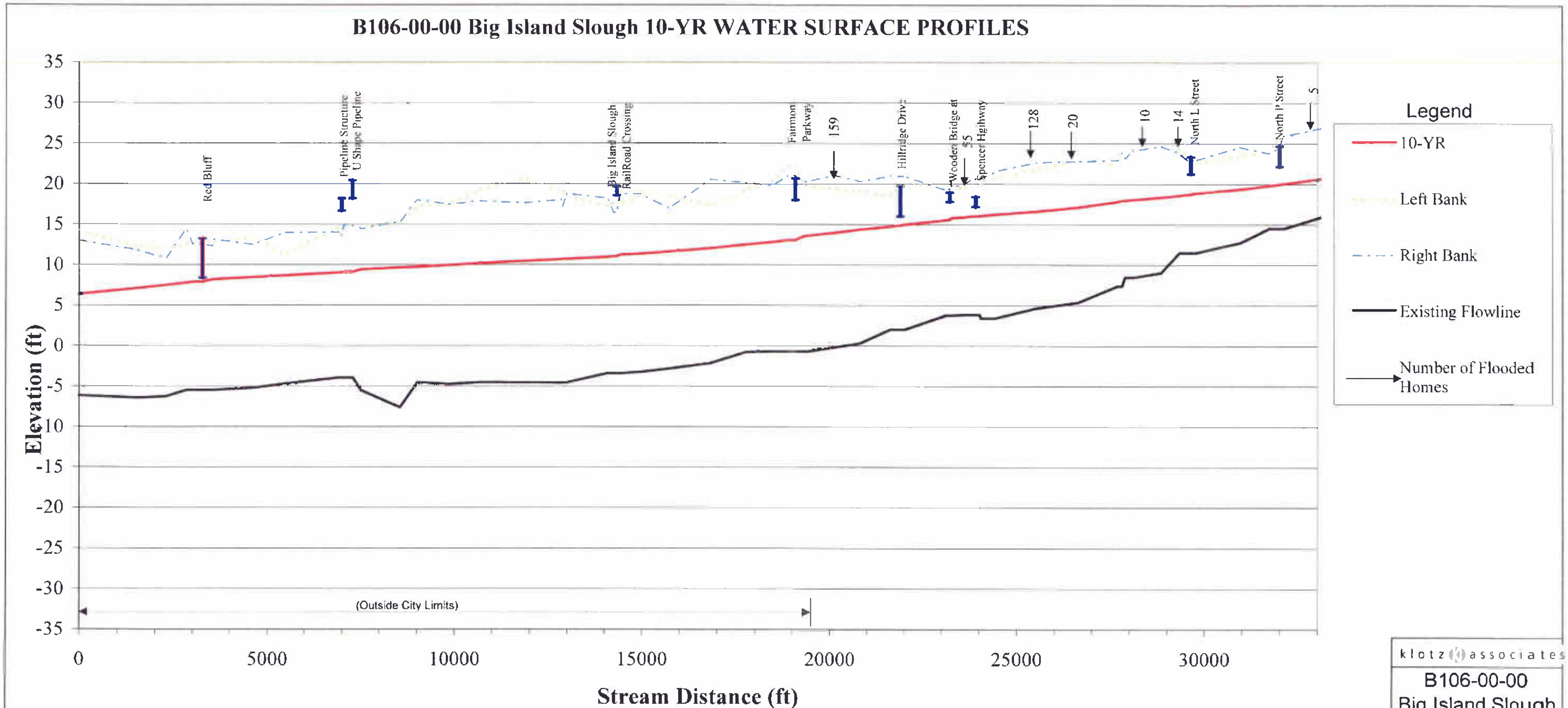
FIGURES

Figure 1 - Prioritizing Drainage Problems



Klotz Associates
Project No.: 0127.008.000

City Wide Drainage Study
City of La Porte



klotz associates

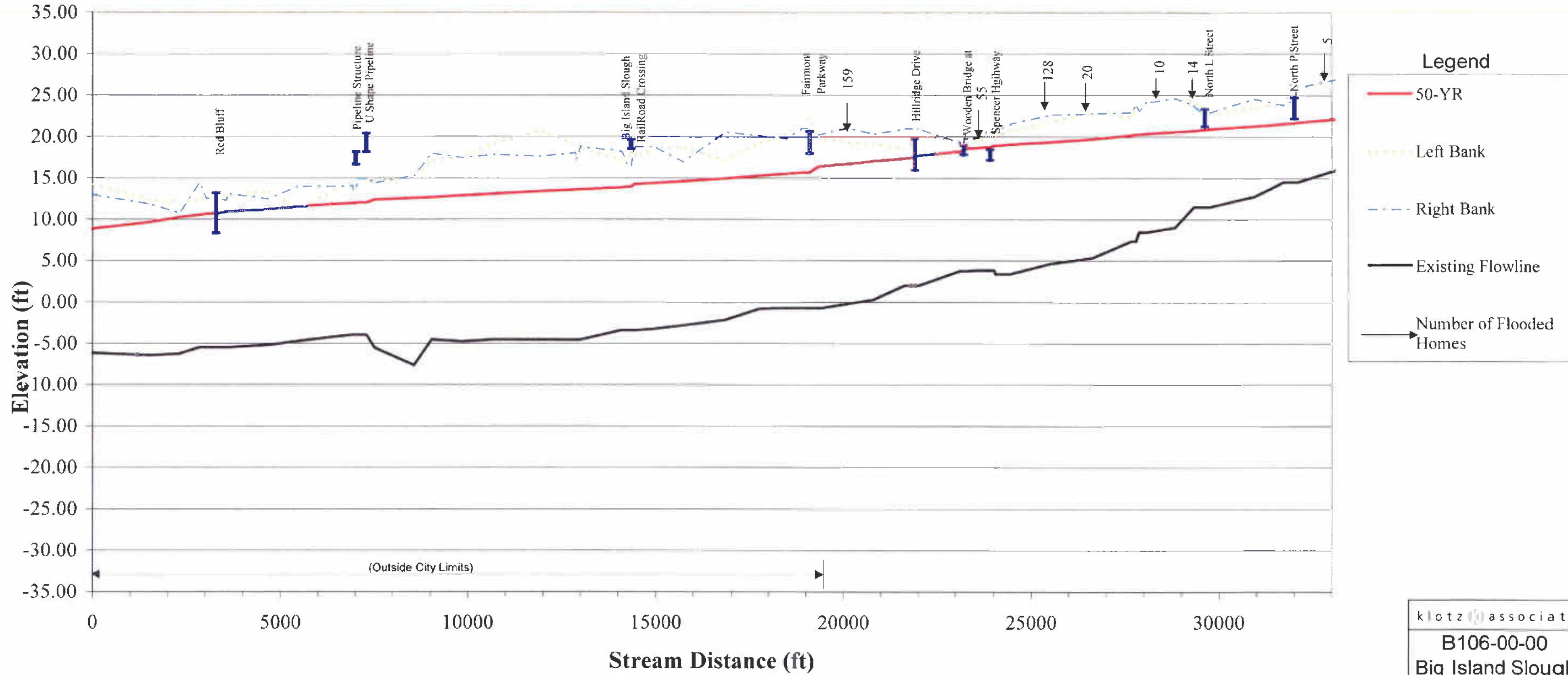
B106-00-00
Big Island Slough

REVISED EXISTING
10 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

2

B106-00-00 Big Island Slough 50-YR WATER SURFACE PROFILES



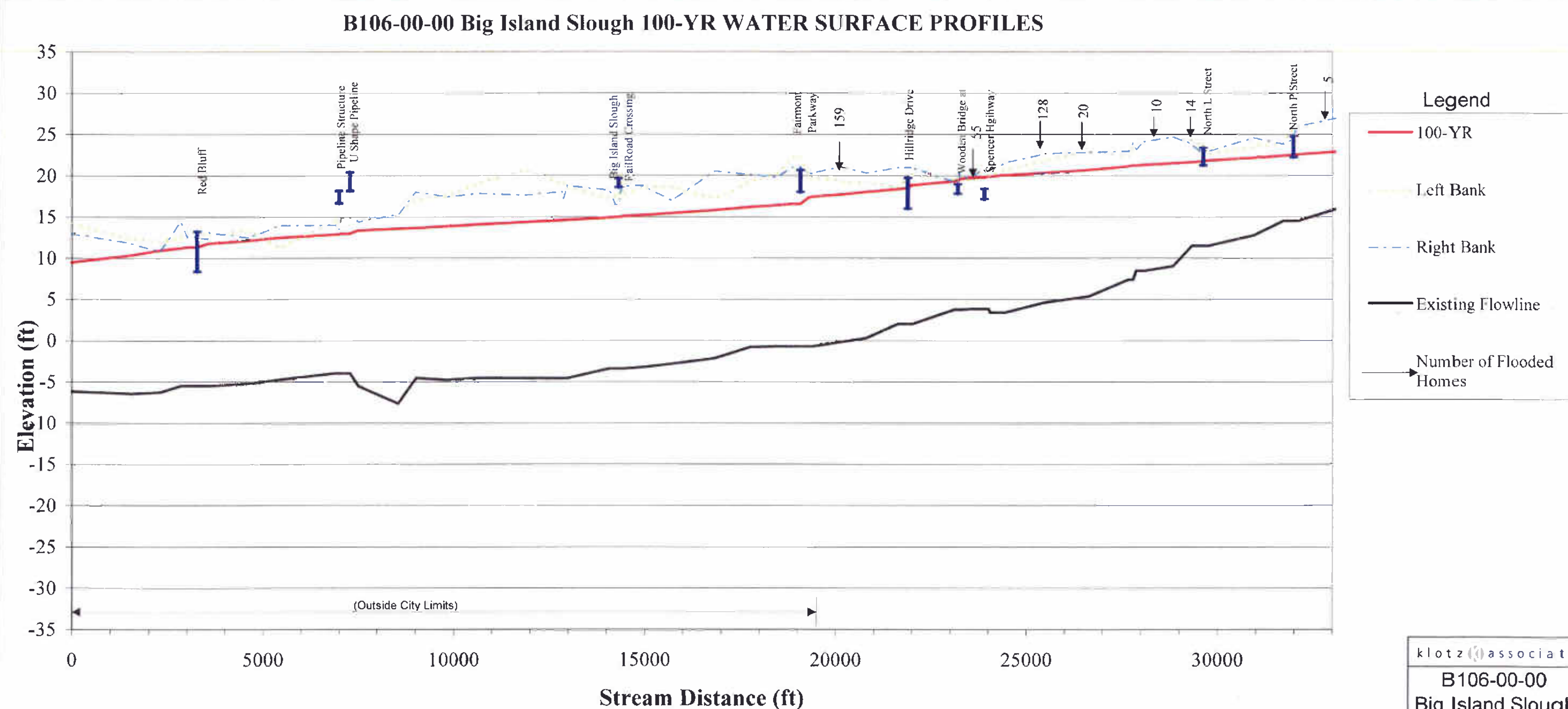
klotz associates

B106-00-00
Big Island Slough

REVISED EXISTING
50 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

3



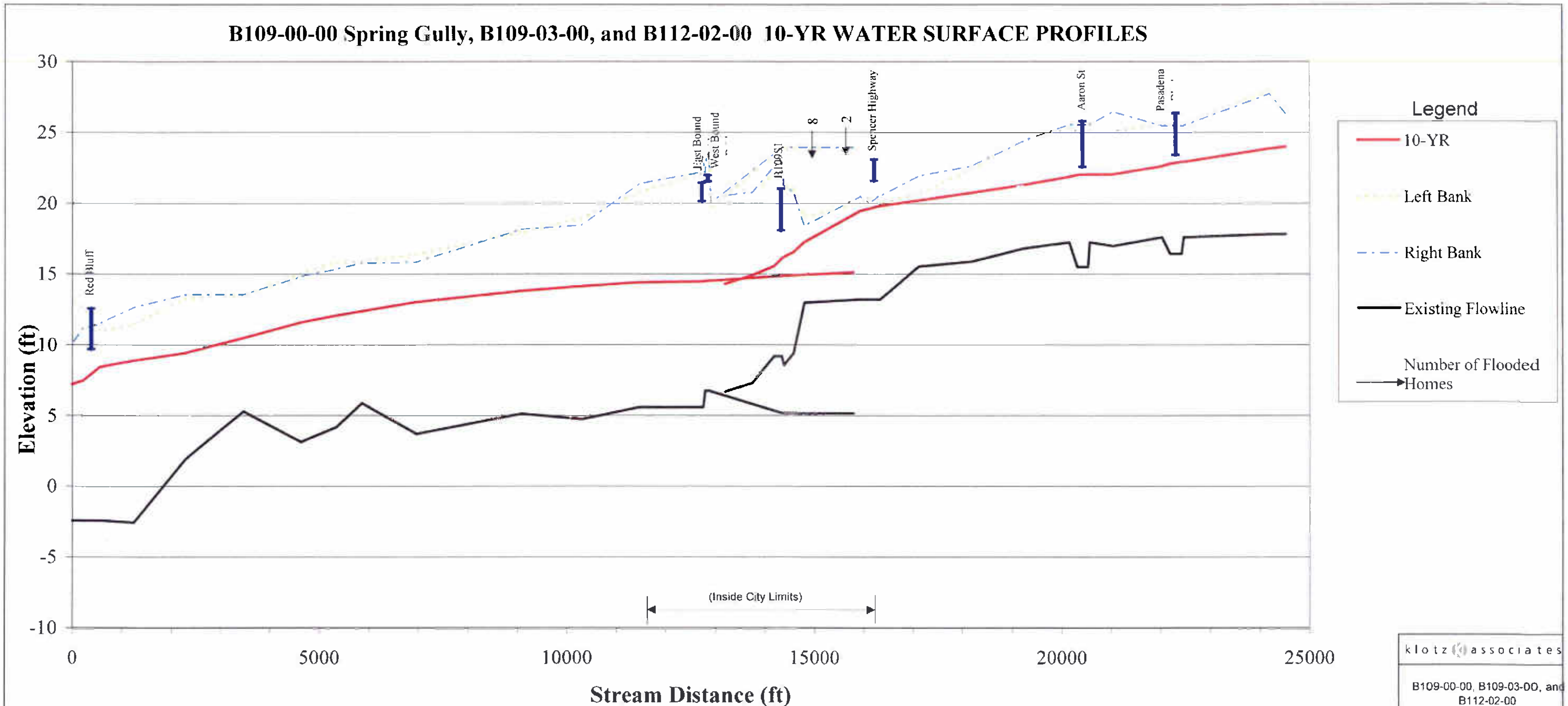
klotz associates

B106-00-00
Big Island Slough

REVISED EXISTING
100 YEAR CONDITION

Project No. 0127.008.000
Scale: NTS
Date: OCT 2008

4



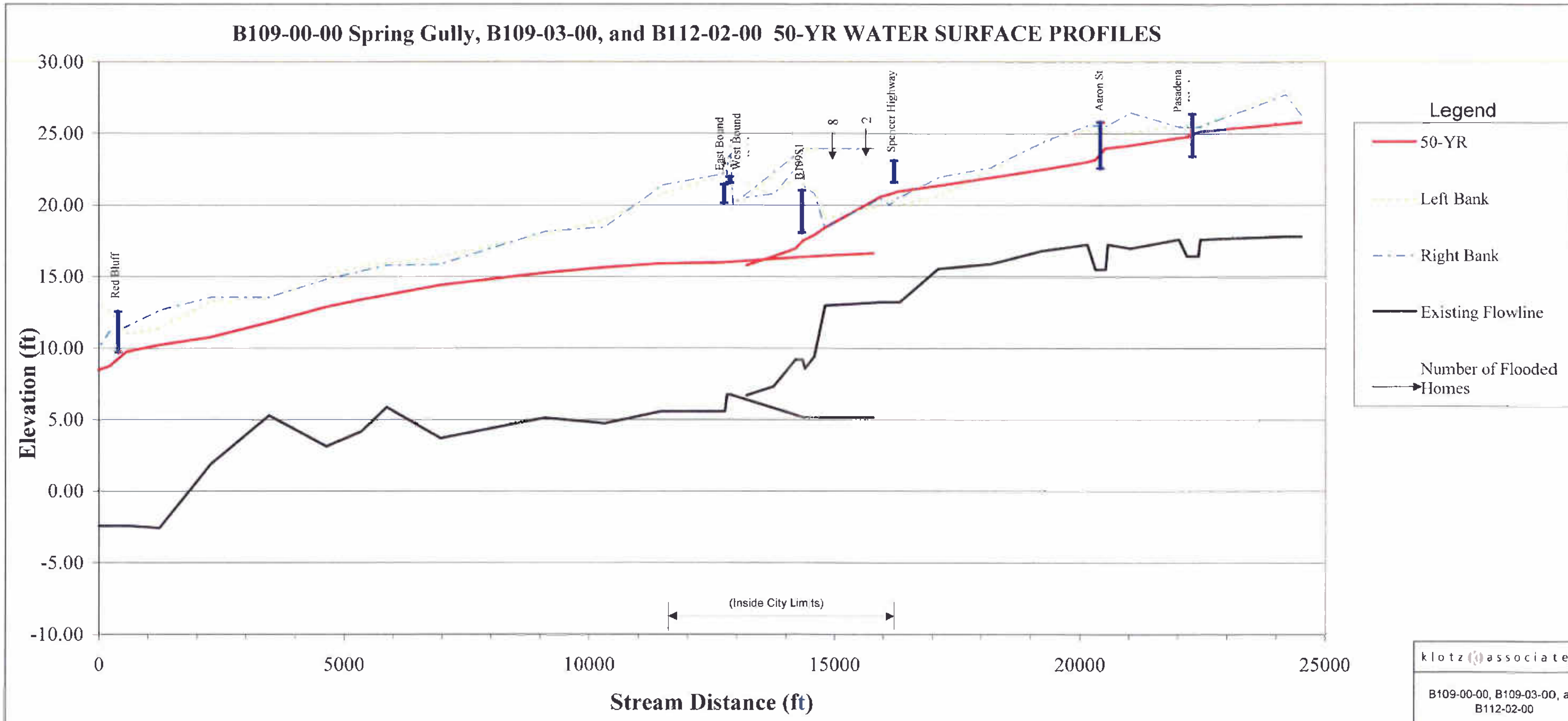
klotz associates

B109-00-00, B109-03-00, and B112-02-00

REVISED EXISTING
10 YEAR CONDITION

Project No.: 0127.008.001
Scale: NTS
Date: OCT 2008

5



klotz associates

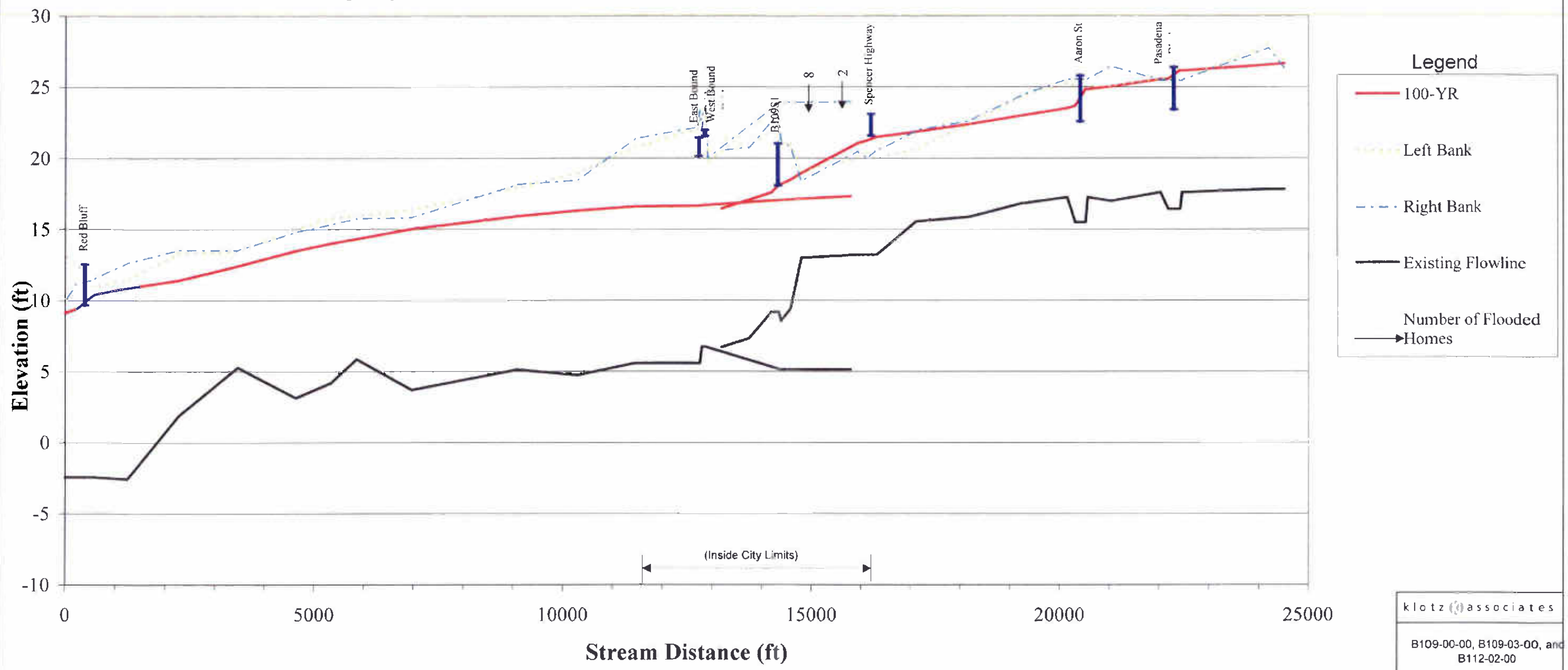
B109-00-00, B109-03-00, and B112-02-00

REVISED EXISTING
50 YEAR CONDITION

Project No.: 0127.008.004
Scale: NTS
Date: OCT 2008

6

B109-00-00 Spring Gully, B109-03-00, and B112-02-00 100-YR WATER SURFACE PROFILES



klotz associates

B109-00-00, B109-03-00, and B112-02-00

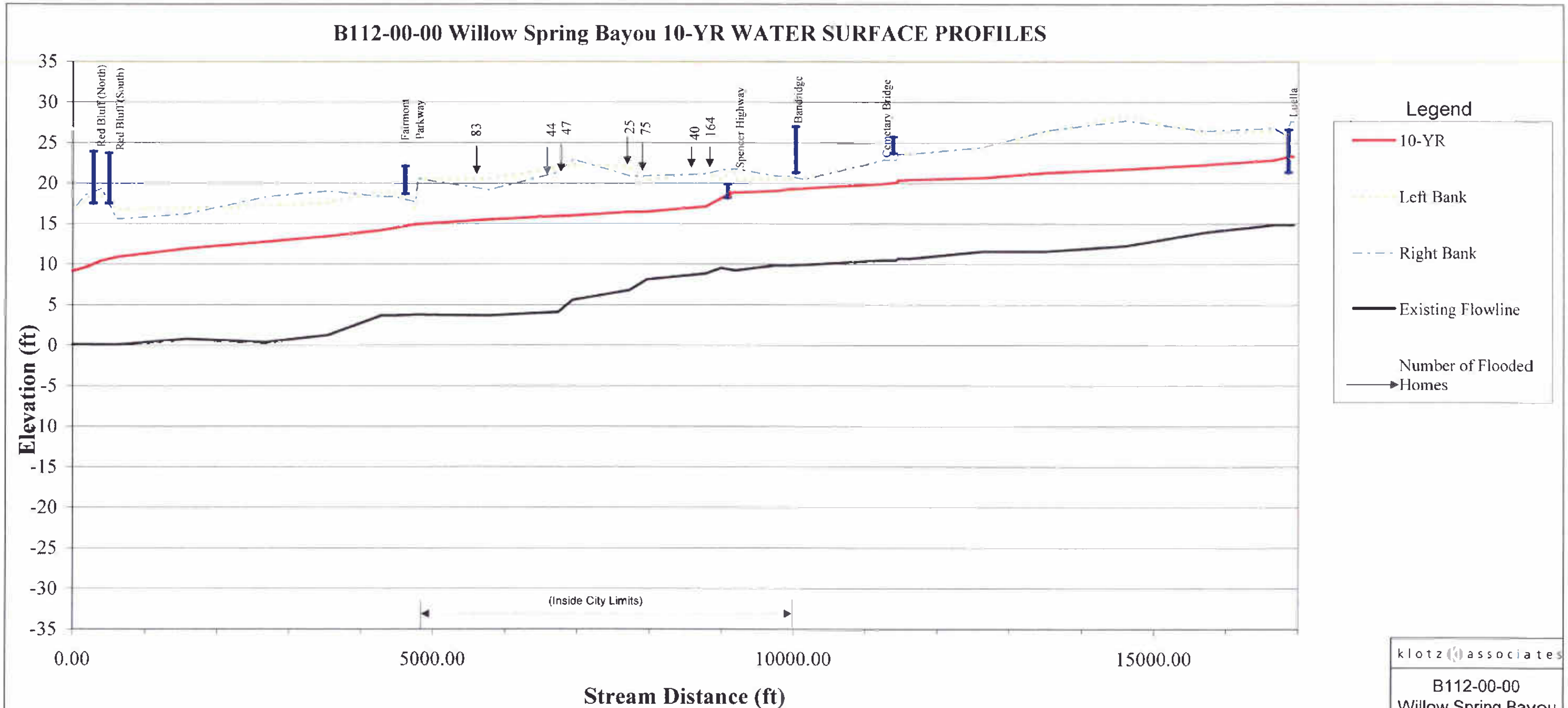
REVISED EXISTING 100 YEAR CONDITION

Project No.: 0127.008.000

Scale: NTS

Date: OCT 2008

7



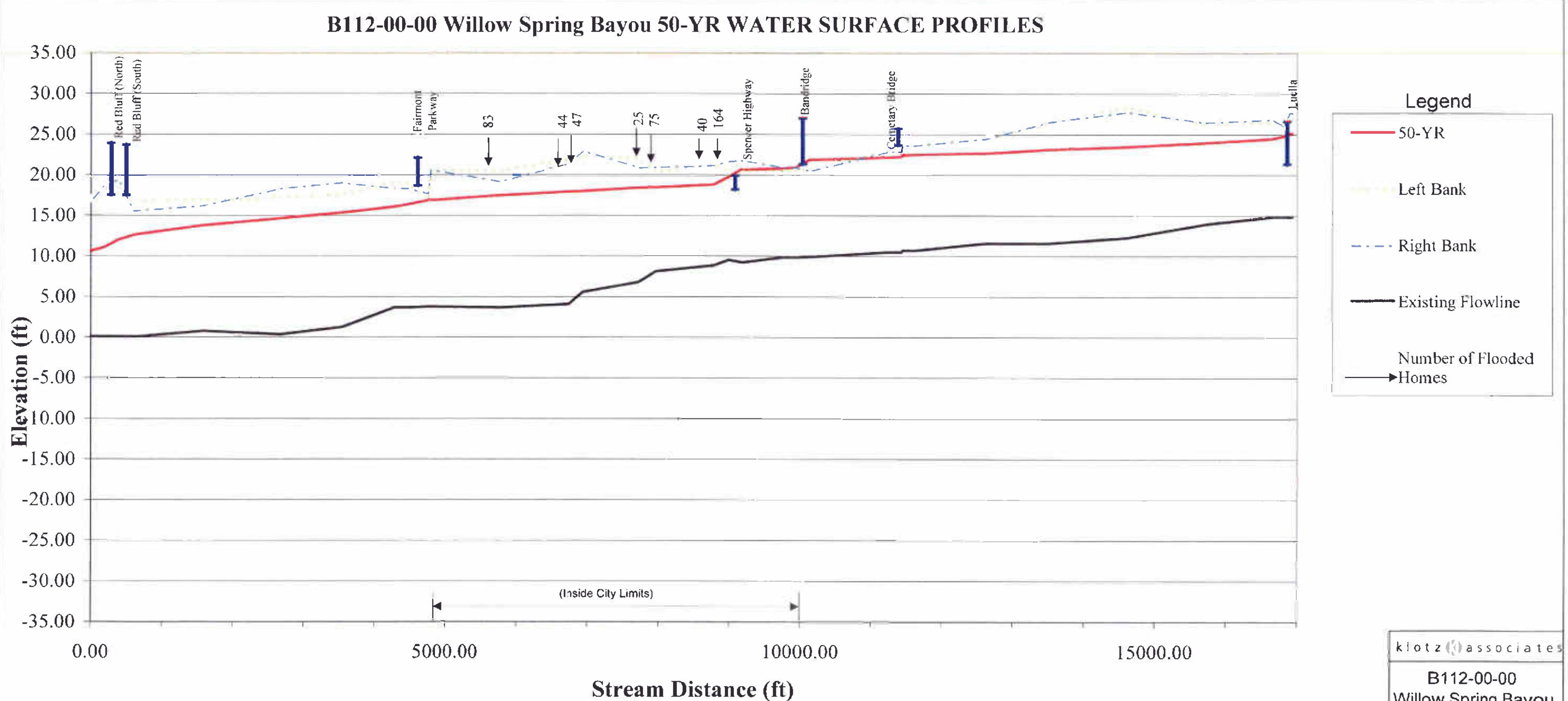
klotz associates

B112-00-00
Willow Spring Bayou

REVISED EXISTING
10 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

8



klotz associates

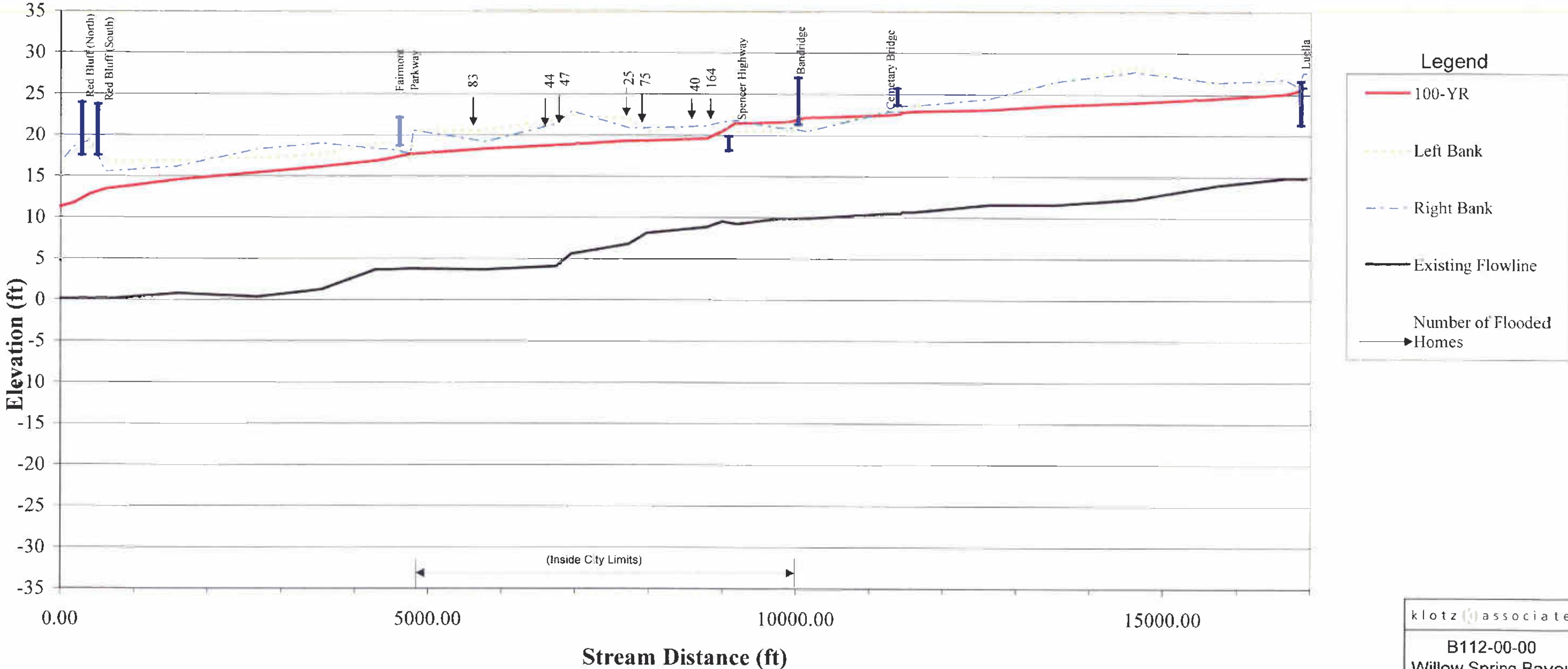
B112-00-00
Willow Spring Bayou

REVISED EXISTING
50 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

9

B112-00-00 Willow Spring Bayou 100-YR WATER SURFACE PROFILES



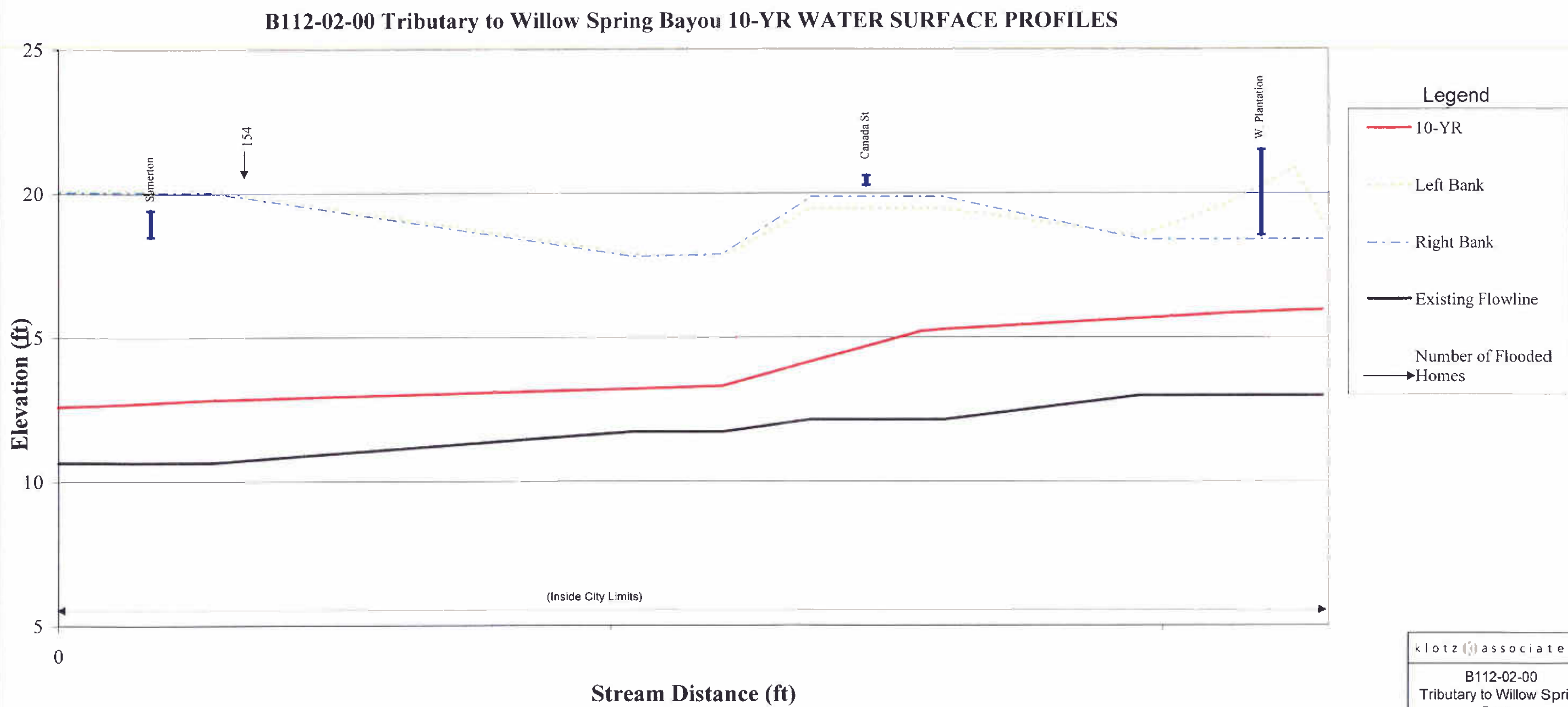
klotz associates

B112-00-00
Willow Spring Bayou

REVISED EXISTING
100 YEAR CONDITION

Project No. 0127.008.000
Scale: NTS
Date: OCT 2008

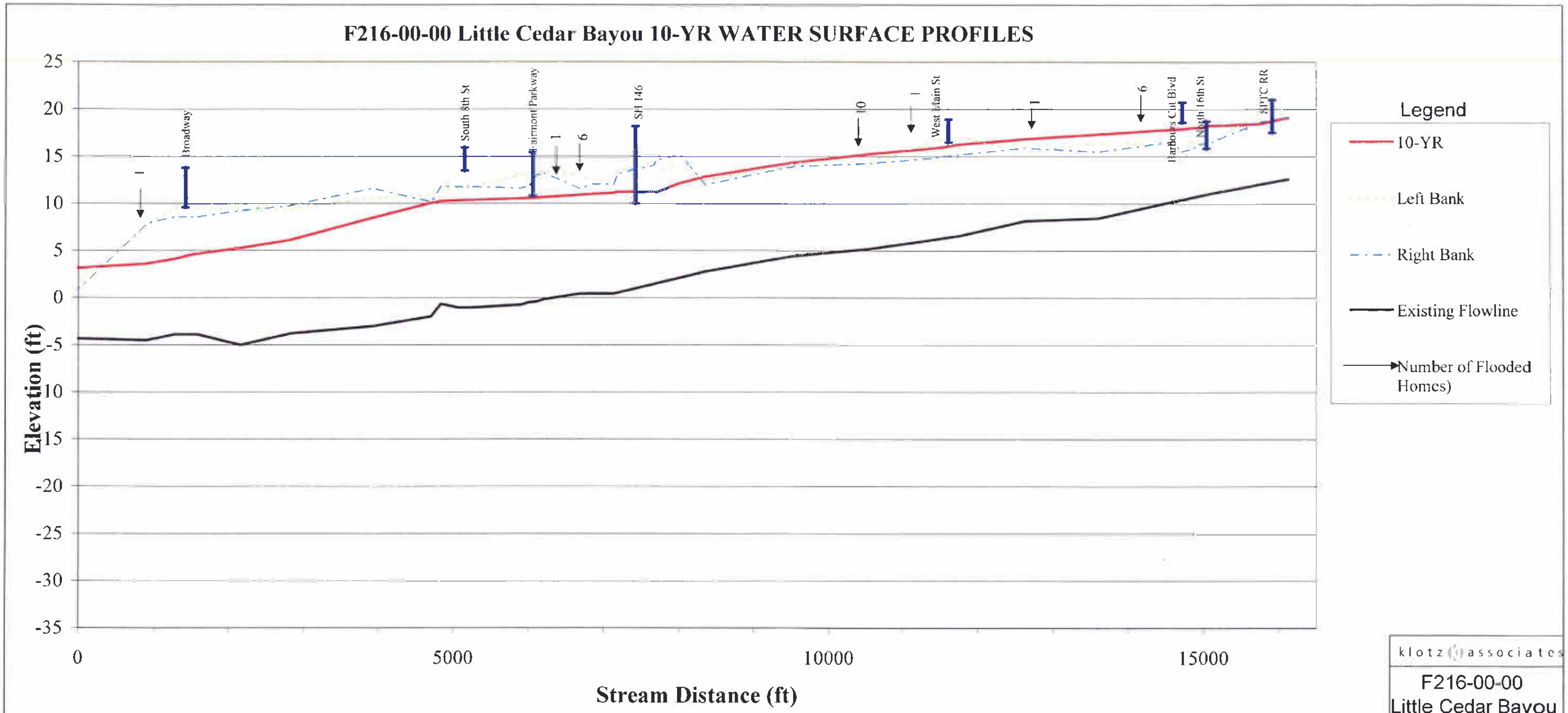
10



klotz associates

B112-02-00
Tributary to Willow Spring Bayou
REVISED EXISTING
10 YEAR CONDITION

Project No.: 0127.008.000 Scale: NTS Date: AUG 2008	11



klotz associates

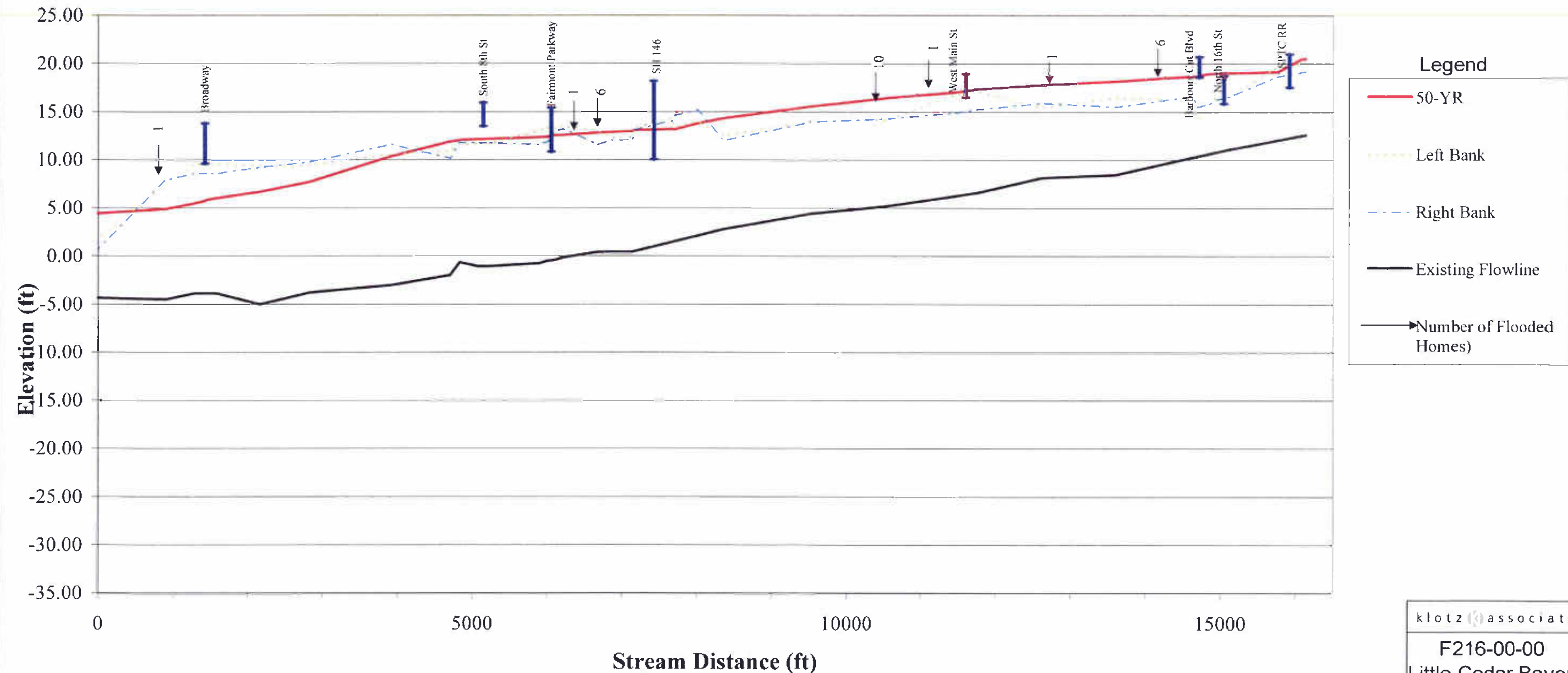
F216-00-00
Little Cedar Bayou

REVISED EXISTING
10 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

14

F216-00-00 Little Cedar Bayou 50-YR WATER SURFACE PROFILES



klotz associates

F216-00-00
Little Cedar Bayou

REVISED EXISTING
50 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

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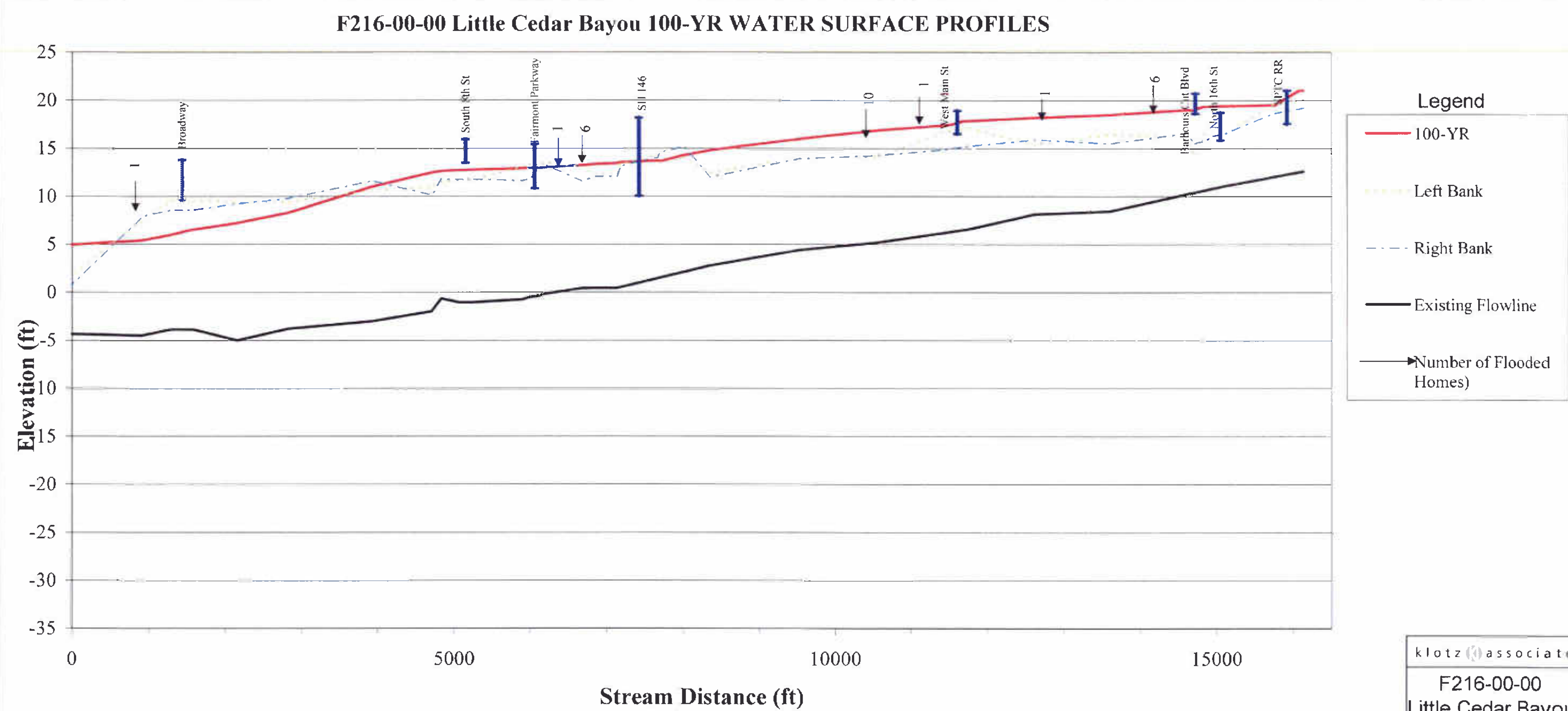


klotz associates

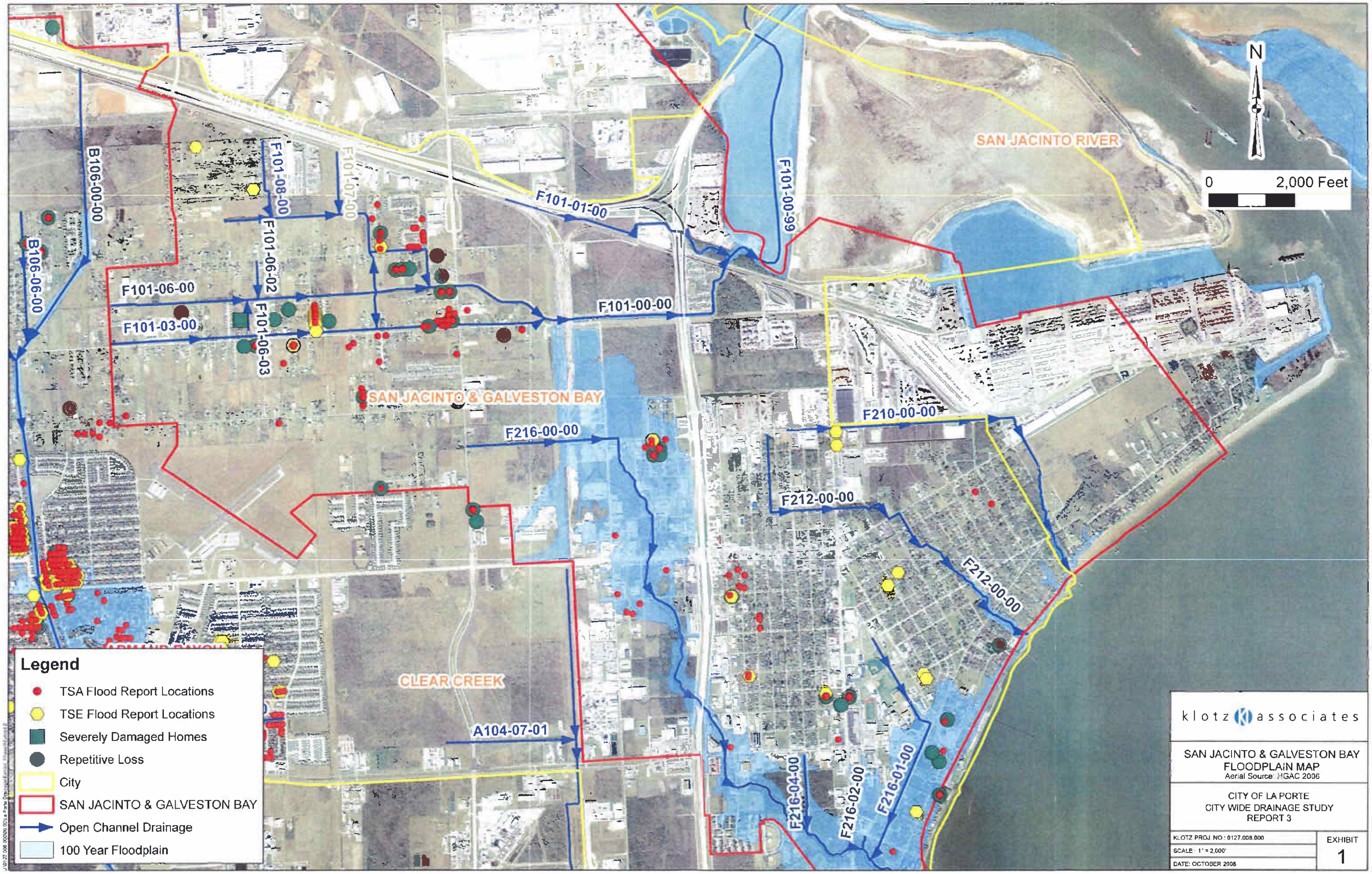
F216-00-00
Little Cedar Bayou

REVISED EXISTING
100 YEAR CONDITION

Project No.: 0127.008.000
Scale: NTS
Date: OCT 2008

16

EXHIIBITS



SAN JACINTO RIVER
SAN JACINTO & GALVESTON BAY
CLEAR CREEK
B106-00-00
B106-06-00
F101-08-00
F101-07-00
F101-06-02
F101-06-00
F101-06-03
F101-03-00
F101-01-00
F101-00-00
F101-00-99
F216-00-00
F210-00-00
F212-00-00
F212-00-00
A104-07-01
F216-04-00
F216-02-00
F216-01-00
N
0
2,000 Feet
Legend
TSA Flood Report Locations
TSE Flood Report Locations
Severely Damaged Homes
Repetitive Loss
City
SAN JACINTO & GALVESTON BAY
Open Channel Drainage
100 Year Floodplain
klotz associates
SAN JACINTO & GALVESTON BAY
FLOODPLAIN MAP
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ NO: 0127.008.000
SCALE: 1" = 2,000'
DATE: OCTOBER 2008
EXHIBIT
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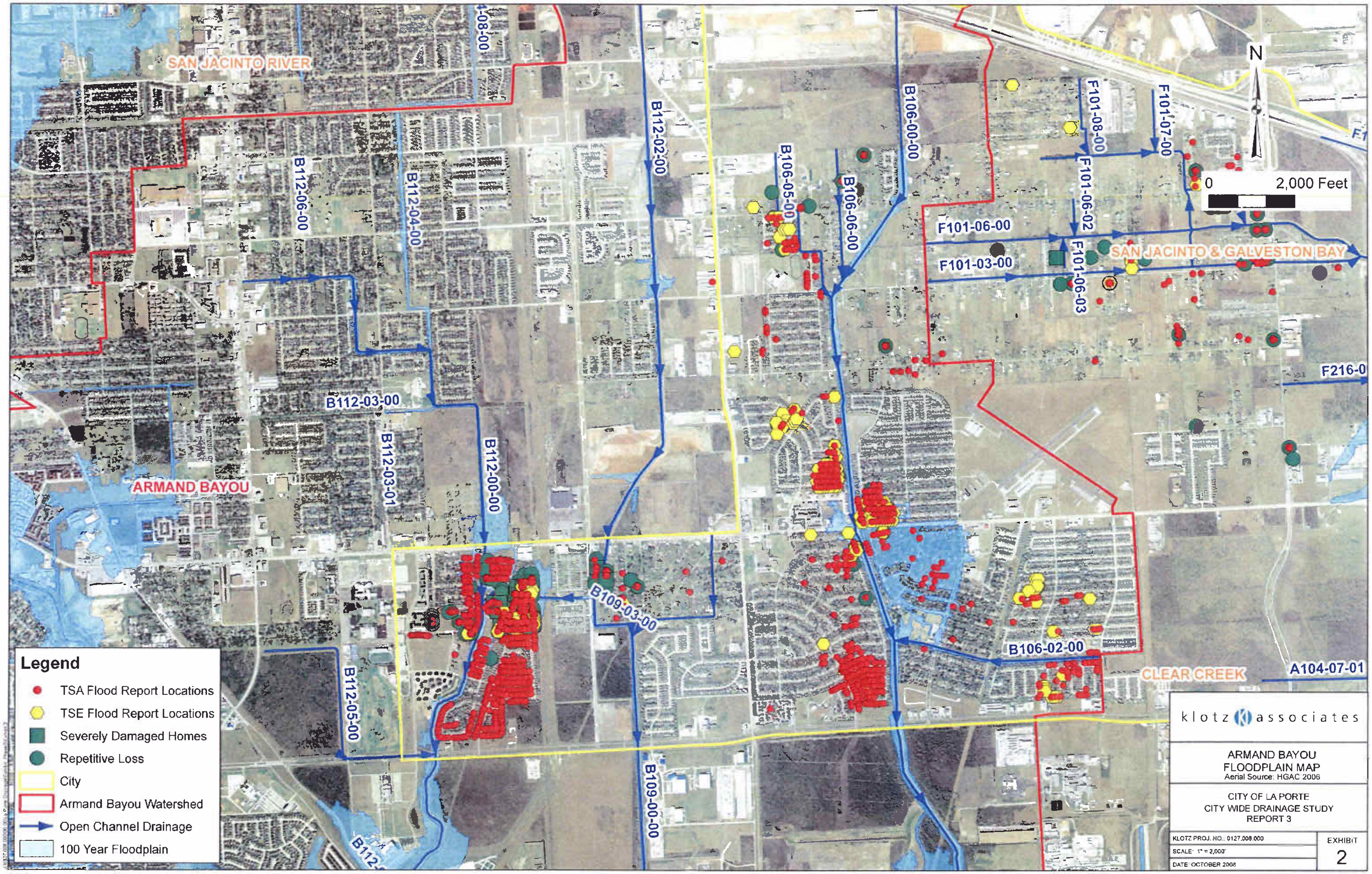
SAN JACINTO RIVER
ARMAND BAYOU
SAN JACINTO & GALVESTON BAY
CLEAR CREEK
N
0
2,000 Feet
B112-06-00
B112-04-00
B112-02-00
B112-03-00
B112-03-01
B112-00-00
B112-05-00
B109-03-00
B109-00-00
B106-05-00
B106-06-00
B106-00-00
B106-02-00
F101-08-00
F101-07-00
F101-06-00
F101-06-02
F101-06-03
F101-03-00
F216-0
A104-07-01
Legend
TSA Flood Report Locations
TSE Flood Report Locations
Severely Damaged Homes
Repetitive Loss
City
Armand Bayou Watershed
Open Channel Drainage
100 Year Floodplain
klotz associates
ARMAND BAYOU
FLOODPLAIN MAP
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO.. 0127.008.000
SCALE: 1" = 2,000'
DATE OCTOBER 2008
EXHIBIT
2

B106-02-00
ARMAND BAYOU
A104-07-01
SAN JACINTO & GALVESTON BAY
F212-00-00
F216-04-00
F216-02-00
F216-01-00
State Hwy 146
A104-13-00
A104-12-01
CLEAR CREEK
A104-12-00
A104-07-00
A104-11-00
A104-10-00
A104-10-03
A104-10-
A104-00-00
A104-14-00
F303-01-00
F300-00-00
13-02
A104-13-01
SAN JACINTO & GALVESTON BAY
N
0 2,000 Feet
Legend
TSA Flood Report Locations
TSE Flood Report Locations
Severely Damaged Homes
Repetitive_Loss
City
Clear Creek Watershed
Open Channel Drainage
100 Year Floodplain
klotz associates
CLEAR CREEK
FLOODPLAIN MAP
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO.: 0127.008.000
SCALE: 1" = 2,000'
DATE: OCTOBER 2008
EXHIBIT
3

Battleground Estate
F101-08-00
F101-07-00
F101-01-00
F101-00-99
SAN JACINTO RIVER
N
0
2,000
Feet
Pinegrove Valley
F101-06-02
F101-06-00
F101-00-00
F101-03-00
Lomax Garden
F101-06-03
SAN JACINTO & GALVESTON BAY
G100-00-00
F210-00-00
F216-00-00
Battle Grounds Vista
Glen Meadows
Spencer Landings
F212-00-00
La Porte
Bay Front To La Porte
F212-00-00
San Jacinto Homes
Old La Porte
Bay Shore Park
Beach Park
A104-07-01
REEK
F216-04-00
F216-02-00
F216-01-00
Legend
Subdivision
Flood Problem Intensity (Unweighted)
Low
Med
High
City
Other Watersheds
San Jacinto & Galveston Watershed
Open Channel Drainage
klotz associates
SAN JACINTO & GALVESTON BAY
INTENSITY PROBLEM AREA MAP
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
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SCALE: 1" = 2000'
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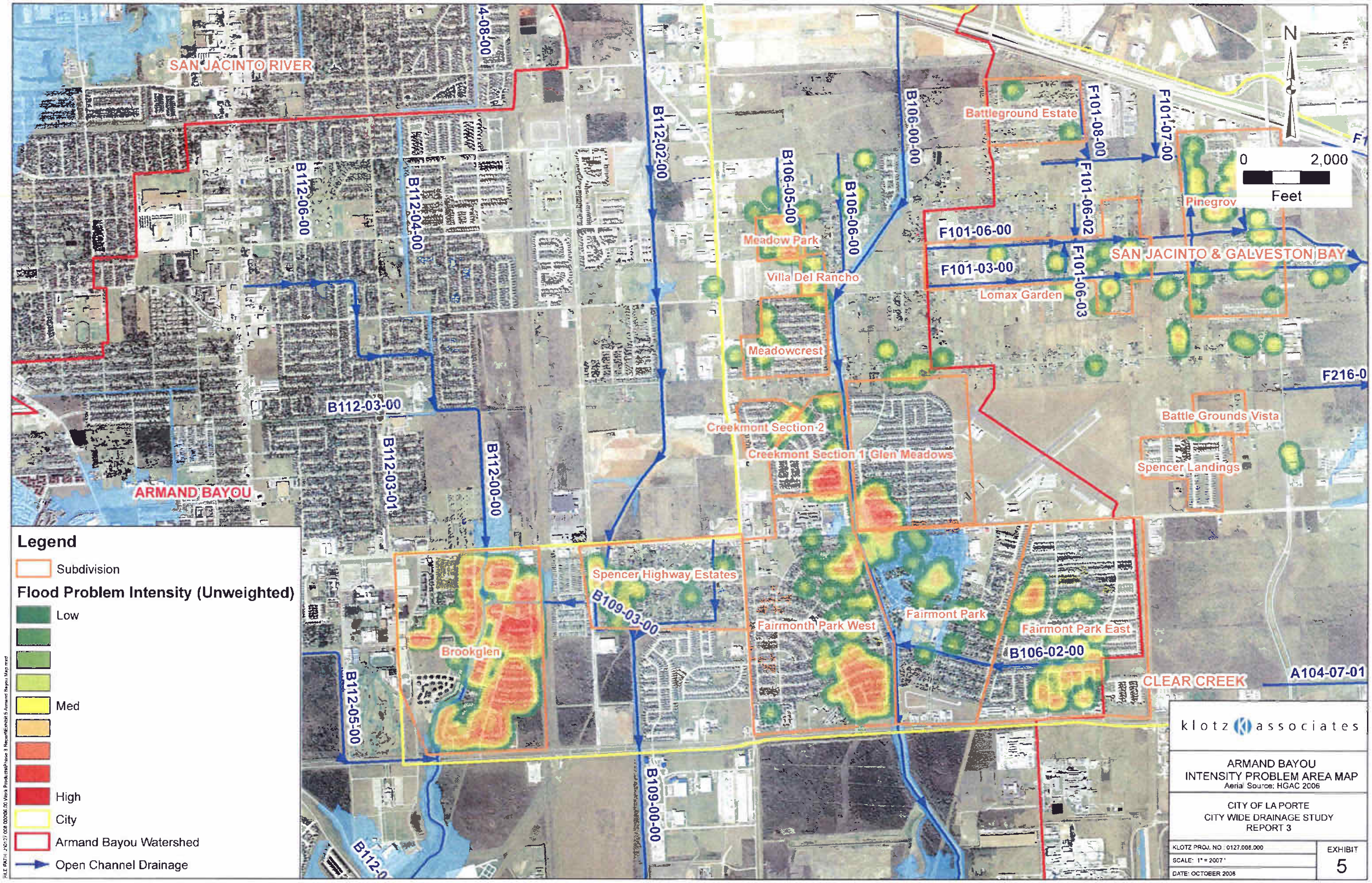
SAN JACINTO RIVER
ARMAND BAYOU
SAN JACINTO & GALVESTON BAY
CLEAR CREEK
B112-06-00
B112-04-00
B112-02-00
B112-03-00
B112-03-01
B112-00-00
B112-05-00
B109-03-00
B109-00-00
B106-05-00
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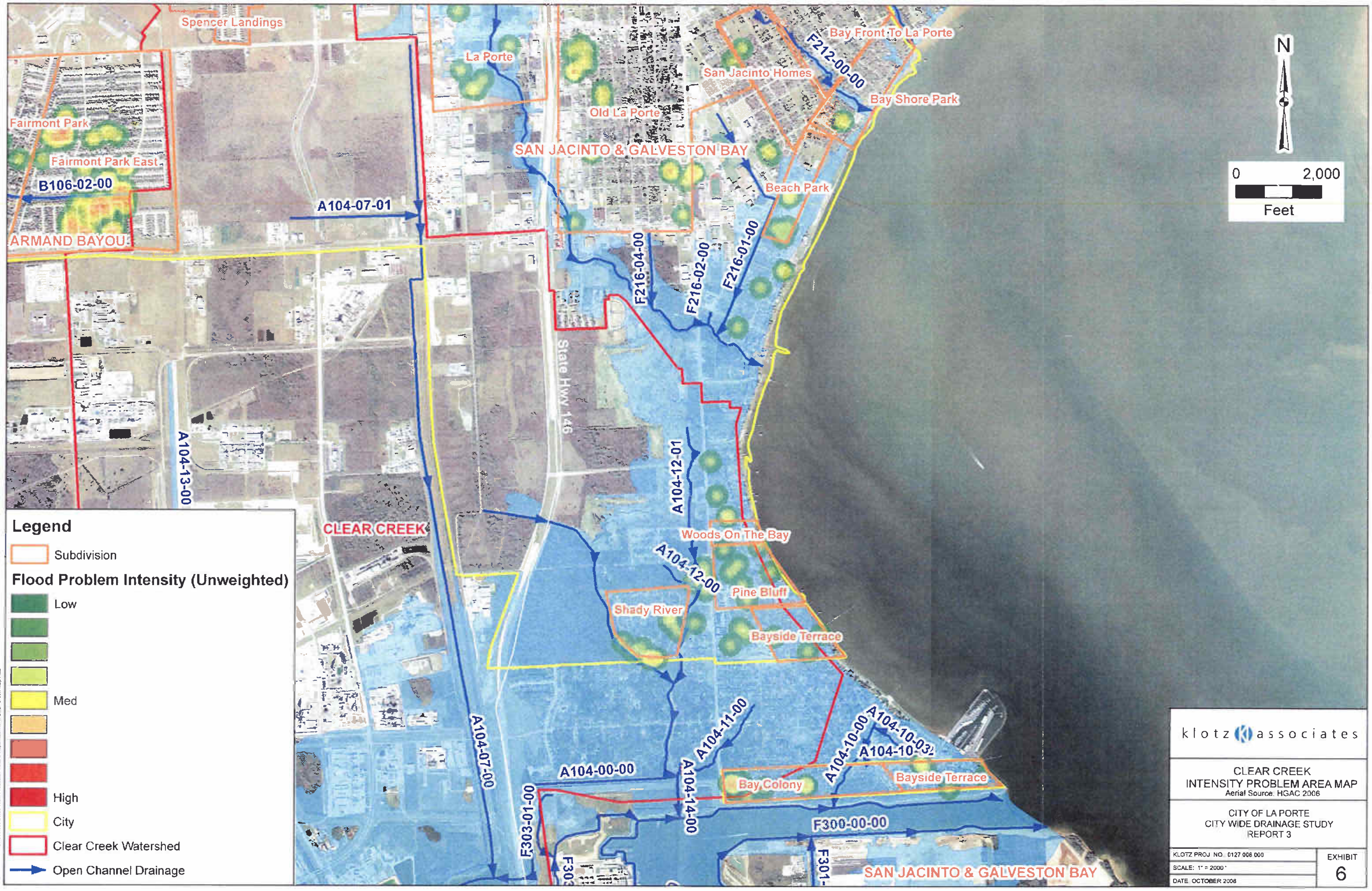
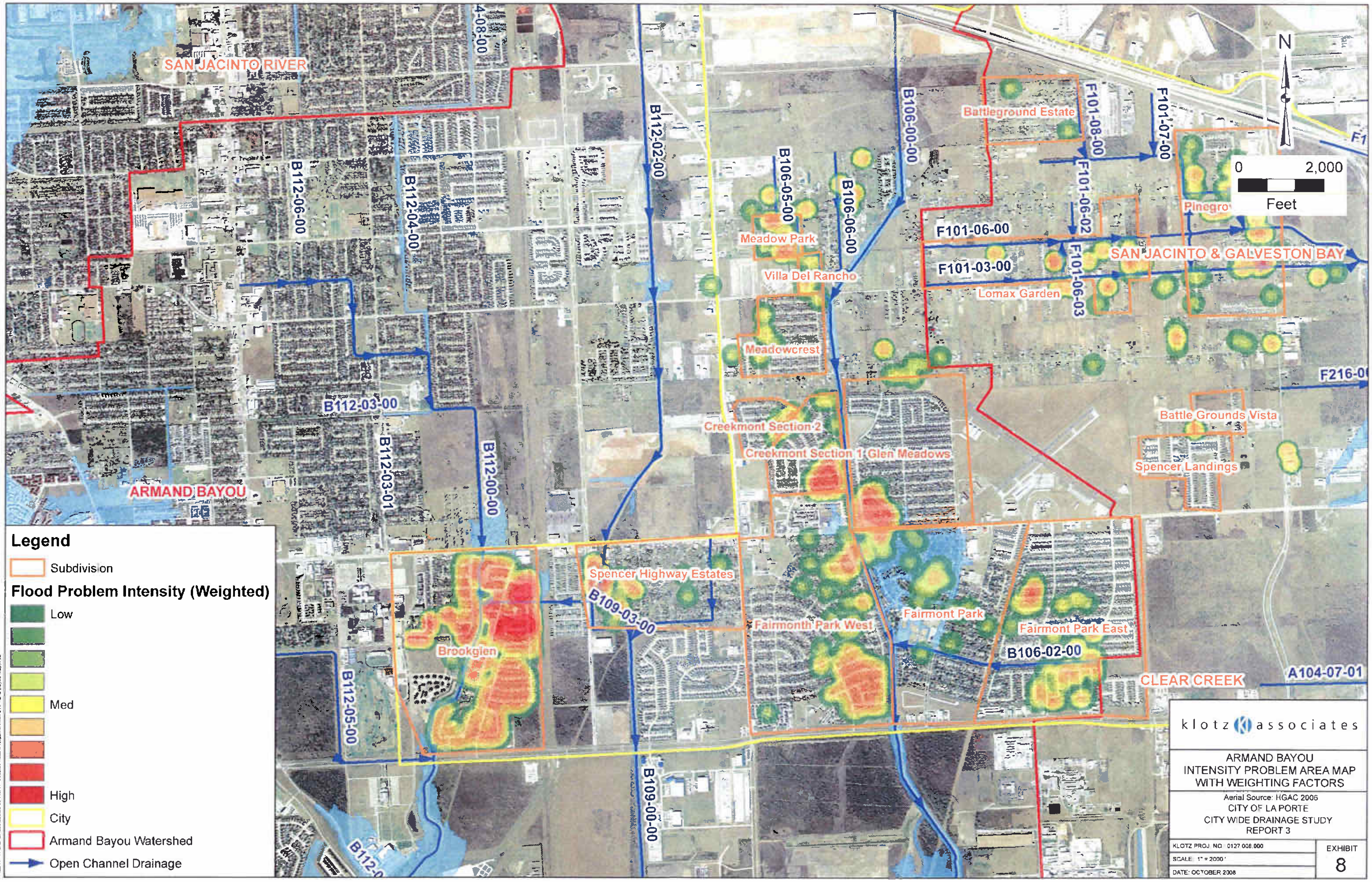
F101-07-00
F101-06-00
F101-06-02
F101-03-00
F101-06-03
F216-0
A104-07-01
Battleground Estate
Meadow Park
Villa Del Rancho
Meadowcrest
Lomax Garden
Pinegrov
Creekmont Section 2
Creekmont Section 1
Glen Meadows
Battle Grounds Vista
Spencer Landings
Spencer Highway Estates
Brookglen
Fairmonth Park West
Fairmont Park
Fairmont Park East
N
0
2,000
Feet
Legend
Subdivision
Flood Problem Intensity (Unweighted)
Low
Med
High
City
Armand Bayou Watershed
Open Channel Drainage
klotz associates
ARMAND BAYOU
INTENSITY PROBLEM AREA MAP
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO.: 0127.008.000
SCALE: 1" = 2007'
DATE: OCTOBER 2008
EXHIBIT
5



Spencer Landings
La Porte
Bay Front To La Porte
F212-00-00
San Jacinto Homes
Bay Shore Park
Old La Porte
Fairmont Park
Fairmont Park East
SAN JACINTO & GALVESTON BAY
B106-02-00
A104-07-01
Beach Park
ARMAND BAYOU
F216-04-00
F216-02-00
F216-01-00
N
0
2,000
Feet
State Hwy 146
A104-13-00
A104-12-01
CLEAR CREEK
Woods On The Bay
A104-12-00
Pine Bluff
Shady River
Bayside Terrace
A104-07-00
A104-11-00
A104-10-00
A104-10-03
A104-10-02
A104-00-00
A104-14-00
Bay Colony
Bayside Terrace
F303-01-00
F300-00-00
F301-
SAN JACINTO & GALVESTON BAY
Legend
Subdivision
Flood Problem Intensity (Unweighted)
Low
Med
High
City
Clear Creek Watershed
Open Channel Drainage
klotz associates
CLEAR CREEK
INTENSITY PROBLEM AREA MAP
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO. 0127 008 000
SCALE: 1" = 2000'
DATE: OCTOBER 2008
EXHIBIT
6

Battleground Estate
F101-08-00
F101-07-00
F101-01-00
F101-00-99
SAN JACINTO RIVER
0
2,000
Feet
N
Pinegrove Valley
F101-06-00
F101-06-02
F101-03-00
F101-06-03
F101-00-00
Lomax Garden
SAN JACINTO & GALVESTON BAY
F210-00-00
G100-00-00
F216-00-00
Battle Grounds Vista
Glen Meadows
Spencer Landings
F212-00-00
La Porte
Bay Front To La Porte
F212-00-00
San Jacinto Homes
Old La Porte
Bay Shore Park
Beach Park
A104-07-01
R CREEK
F216-04-00
F216-02-00
F216-01-00
Legend
Subdivision
Flood Problem Intensity (Weighted)
Low
Med
High
City
Other Watersheds
San Jacinto & Galveston Watershed
Open Channel Drainage
klotz associates
SAN JACINTO & GALVESTON BAY
INTENSITY PROBLEM AREA MAP
WITH WEIGHTING FACTORS
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO. 0127.008.000
SCALE: 1" = 2000'
DATE: OCTOBER 2008
EXHIBIT
7


SAN JACINTO RIVER
ARMAND BAYOU
SAN JACINTO & GALVESTON BAY
CLEAR CREEK
B112-06-00
B112-04-00
B112-02-00
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Battleground Estate
Pinegrov
Meadow Park
Villa Del Rancho
Lomax Garden
Meadowcrest
Creekmont Section 2
Creekmont Section 1 Glen Meadows
Battle Grounds Vista
Spencer Landings
Spencer Highway Estates
Brookglen
Fairmonth Park West
Fairmont Park
Fairmont Park East
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2,000
Feet
Legend
Subdivision
Flood Problem Intensity (Weighted)
Low
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City
Armand Bayou Watershed
Open Channel Drainage
klotz associates
ARMAND BAYOU
INTENSITY PROBLEM AREA MAP
WITH WEIGHTING FACTORS
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
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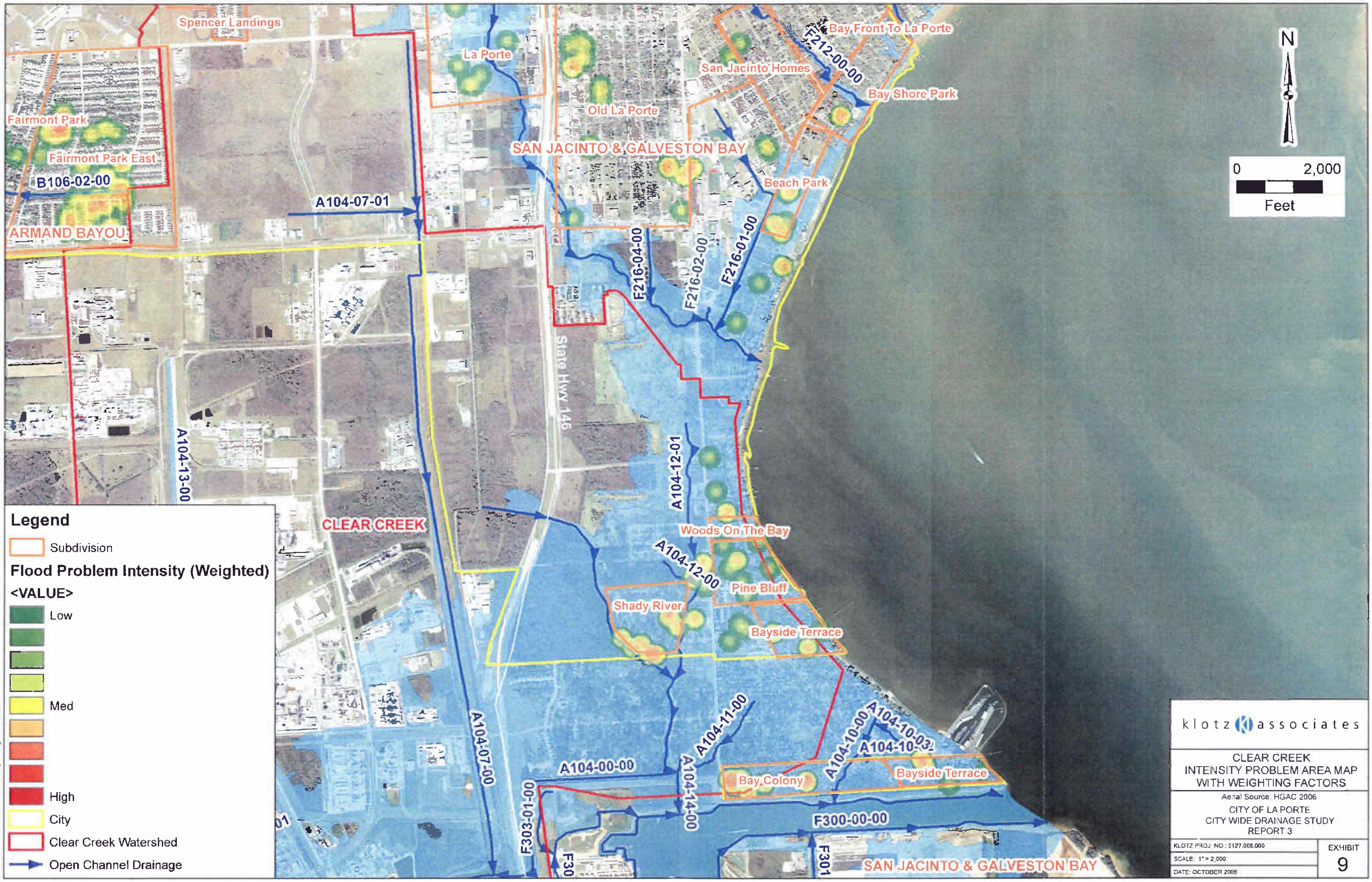

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San Jacinto Homes
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Fairmont Park
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ARMAND BAYOU
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Beach Park
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State Hwy 146
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A104-12-01
CLEAR CREEK
Woods On The Bay
A104-12-00
Pine Bluff
Shady River
Bayside Terrace
A104-07-00
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Bayside Terrace
Bay Colony
A104-00-00
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F303-01-00
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SAN JACINTO & GALVESTON BAY
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Subdivision
Flood Problem Intensity (Weighted)
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City
Clear Creek Watershed
Open Channel Drainage
klotz associates
CLEAR CREEK
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WITH WEIGHTING FACTORS
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
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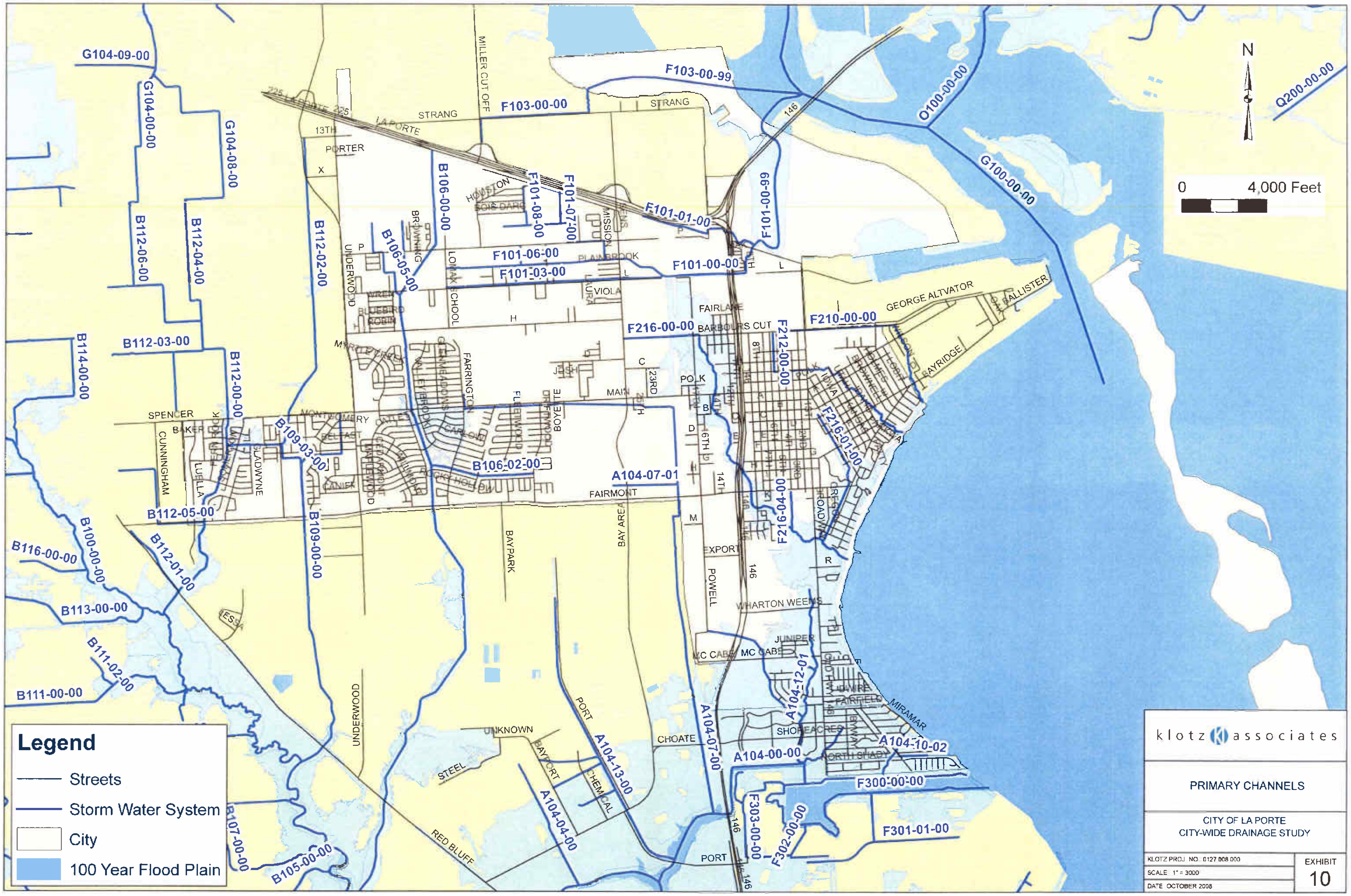

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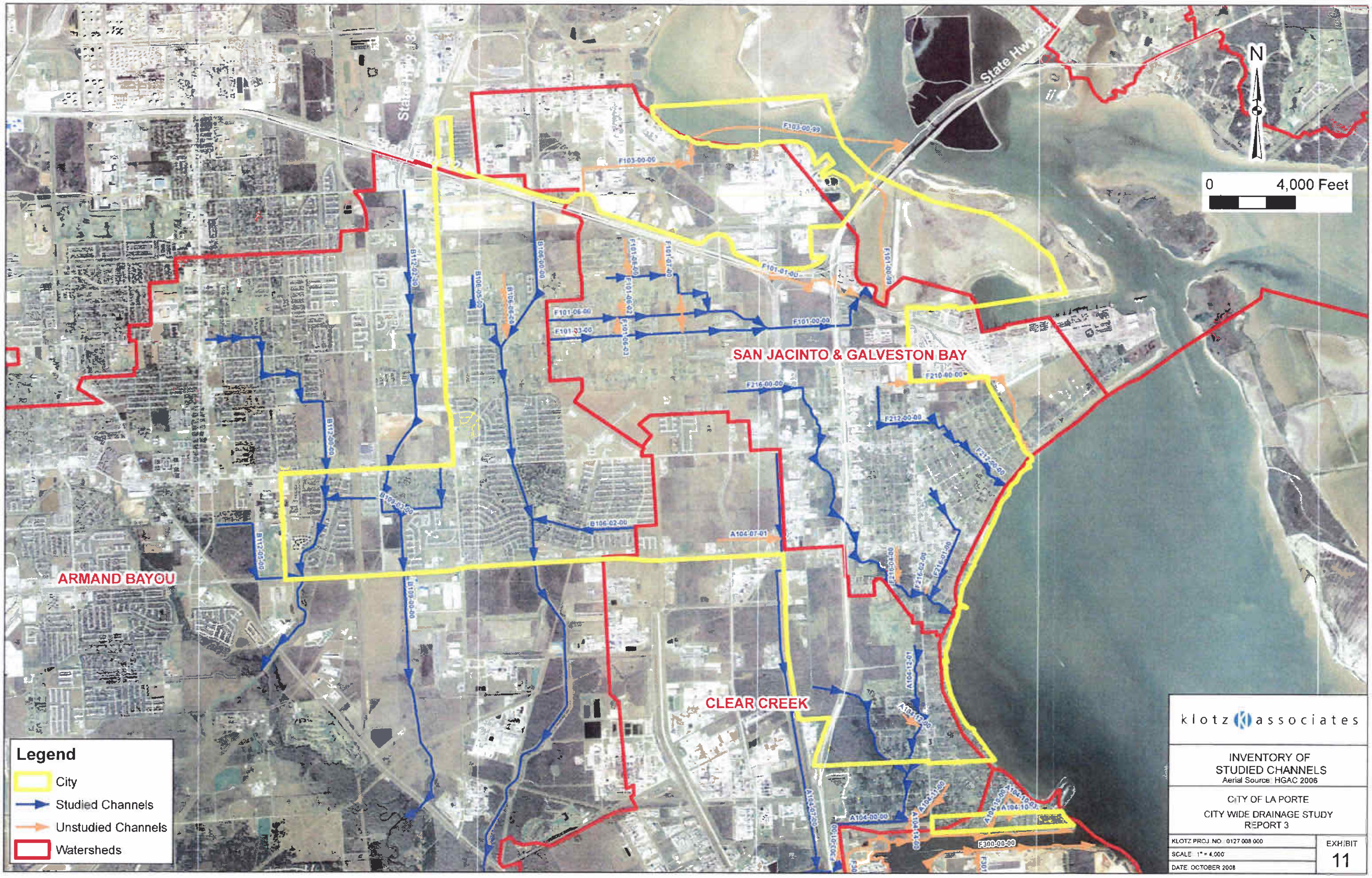
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ARMAND BAYOU
CLEAR CREEK
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B109-00-00
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Legend
City
Studied Channels
Unstudied Channels
Watersheds
klotz associates
INVENTORY OF
STUDIED CHANNELS
Aerial Source: HGAC 2006
CITY OF LA PORTE
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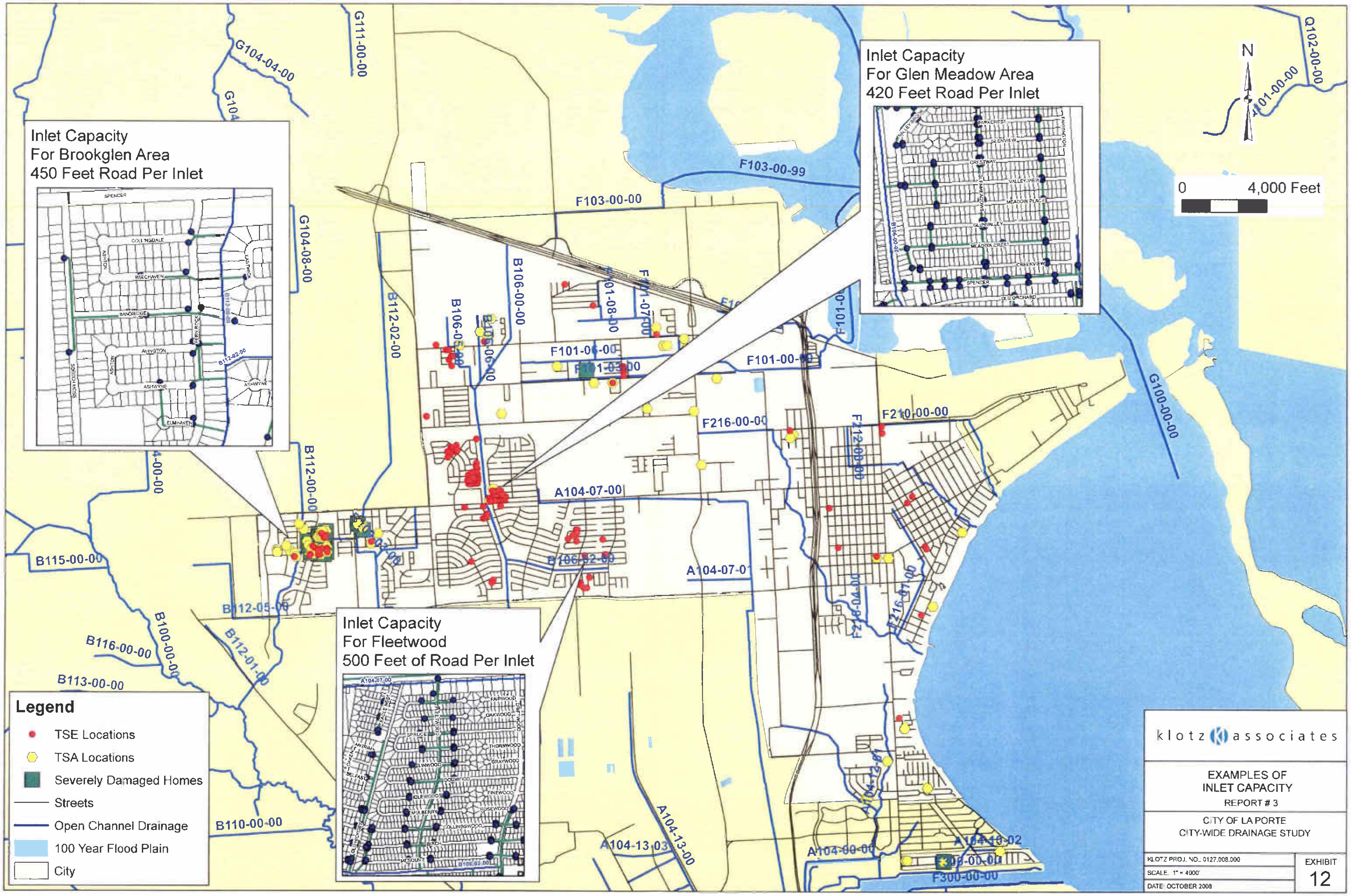

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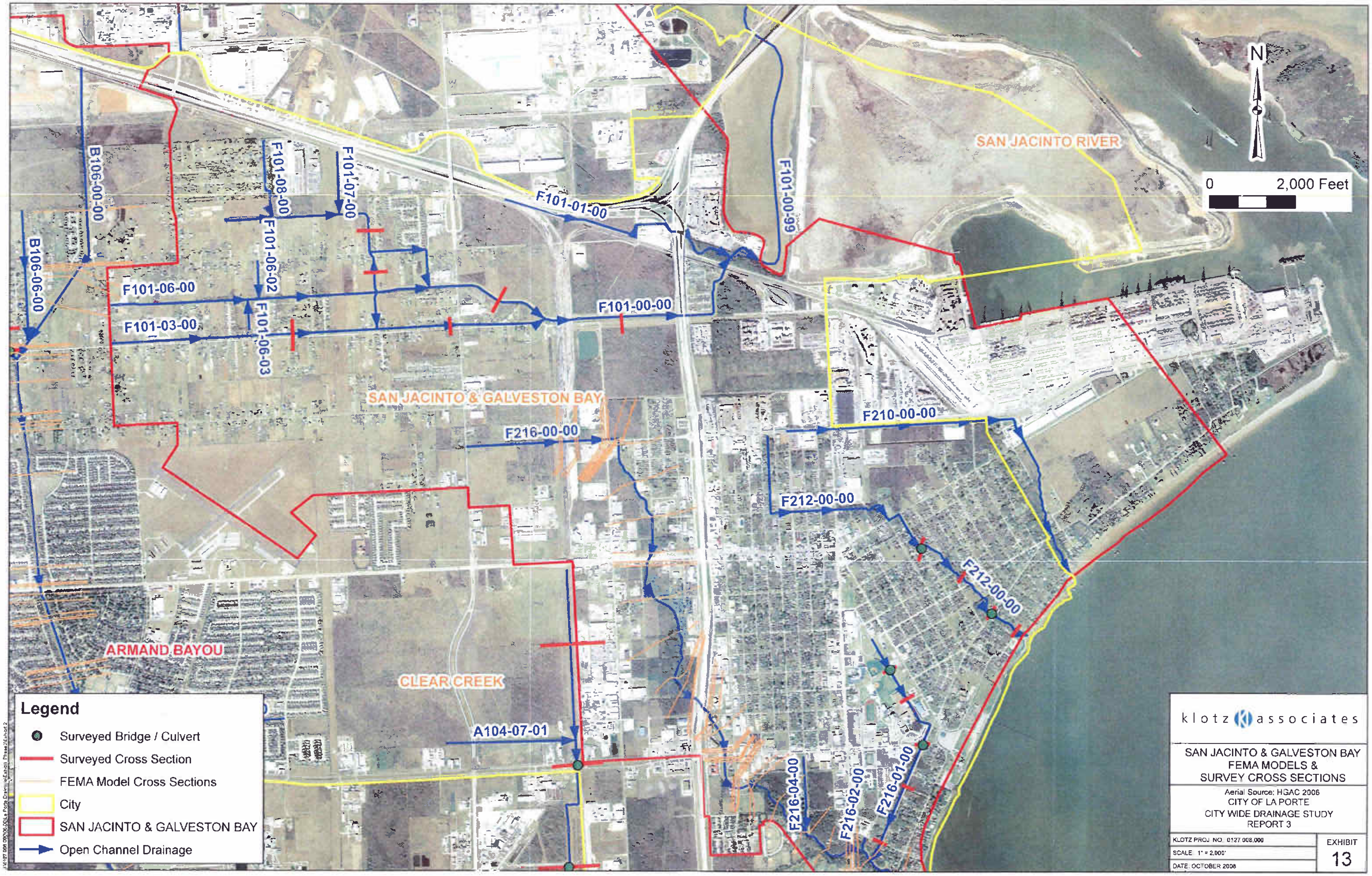

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ARMAND BAYOU
CLEAR CREEK
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F101-08-00
F101-07-00
F101-01-00
F101-00-99
F101-06-00
F101-06-02
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F216-04-00
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Legend
Surveyed Bridge / Culvert
Surveyed Cross Section
FEMA Model Cross Sections
City
SAN JACINTO & GALVESTON BAY
Open Channel Drainage
klotz associates
SAN JACINTO & GALVESTON BAY
FEMA MODELS &
SURVEY CROSS SECTIONS
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
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DATE: OCTOBER 2008
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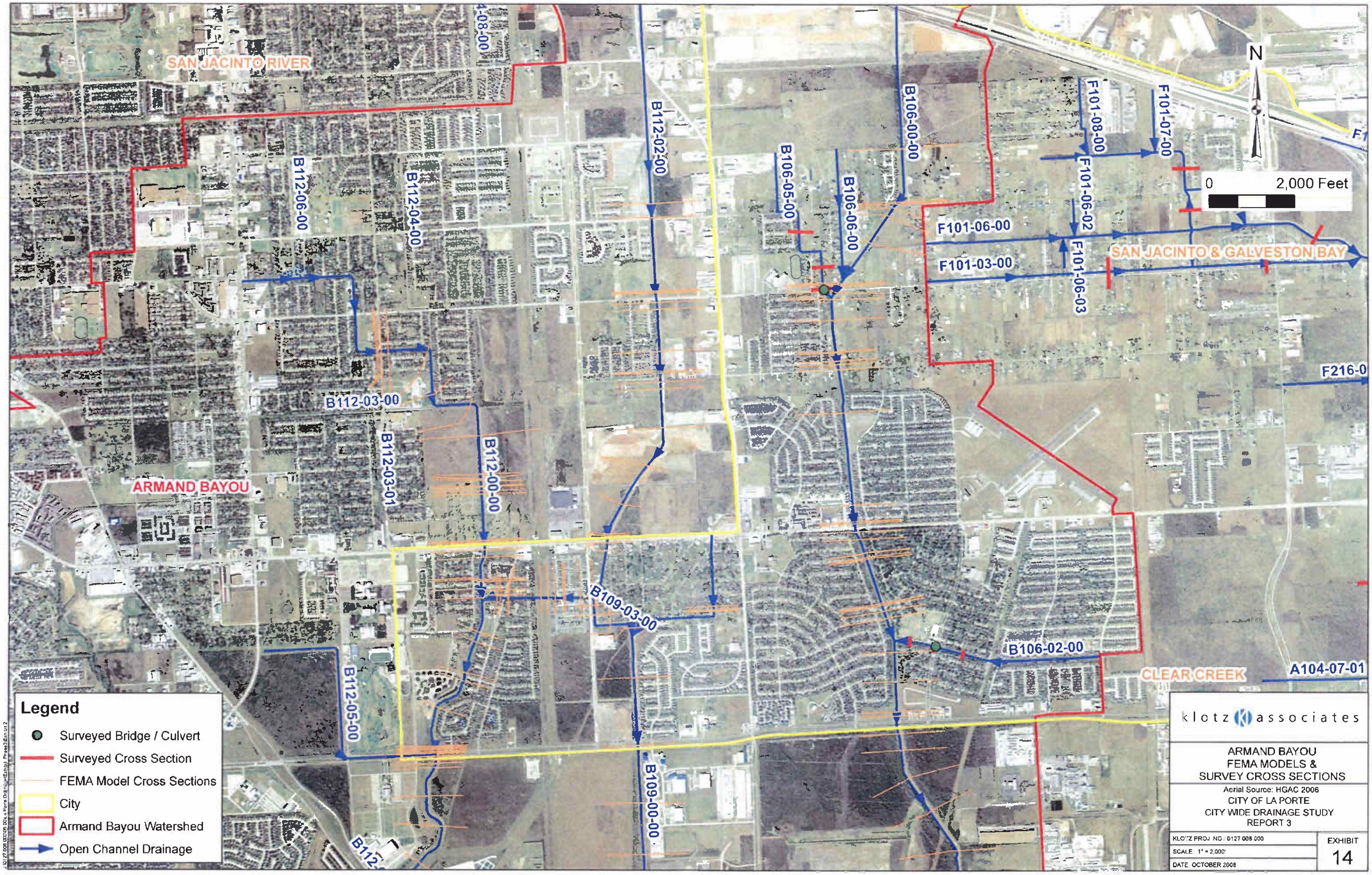
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Surveyed Bridge / Culvert
Surveyed Cross Section
FEMA Model Cross Sections
City
Armand Bayou Watershed
Open Channel Drainage
klotz associates
ARMAND BAYOU
FEMA MODELS &
SURVEY CROSS SECTIONS
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO.: 0127.008.000
SCALE: 1" = 2,000'
DATE: OCTOBER 2008
EXHIBIT
14


N
0 2,000 Feet
B106-02-00
A104-07-01
ARMAND BAYOU
SAN JACINTO & GALVESTON BAY
F212-00-00
F216-04-00
F216-02-00
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State Hwy 146
A104-13-00
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SAN JACINTO & GALVESTON BAY
Legend
Surveyed Bridge / Culvert
Surveyed Cross Section
FEMA Model Cross Sections
City
Clear Creek Watershed
Open Channel Drainage
klotz associates
CLEAR CREEK
FEMA MODELS &
SURVEY CROSS SECTIONS
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
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DATE OCTOBER 2008
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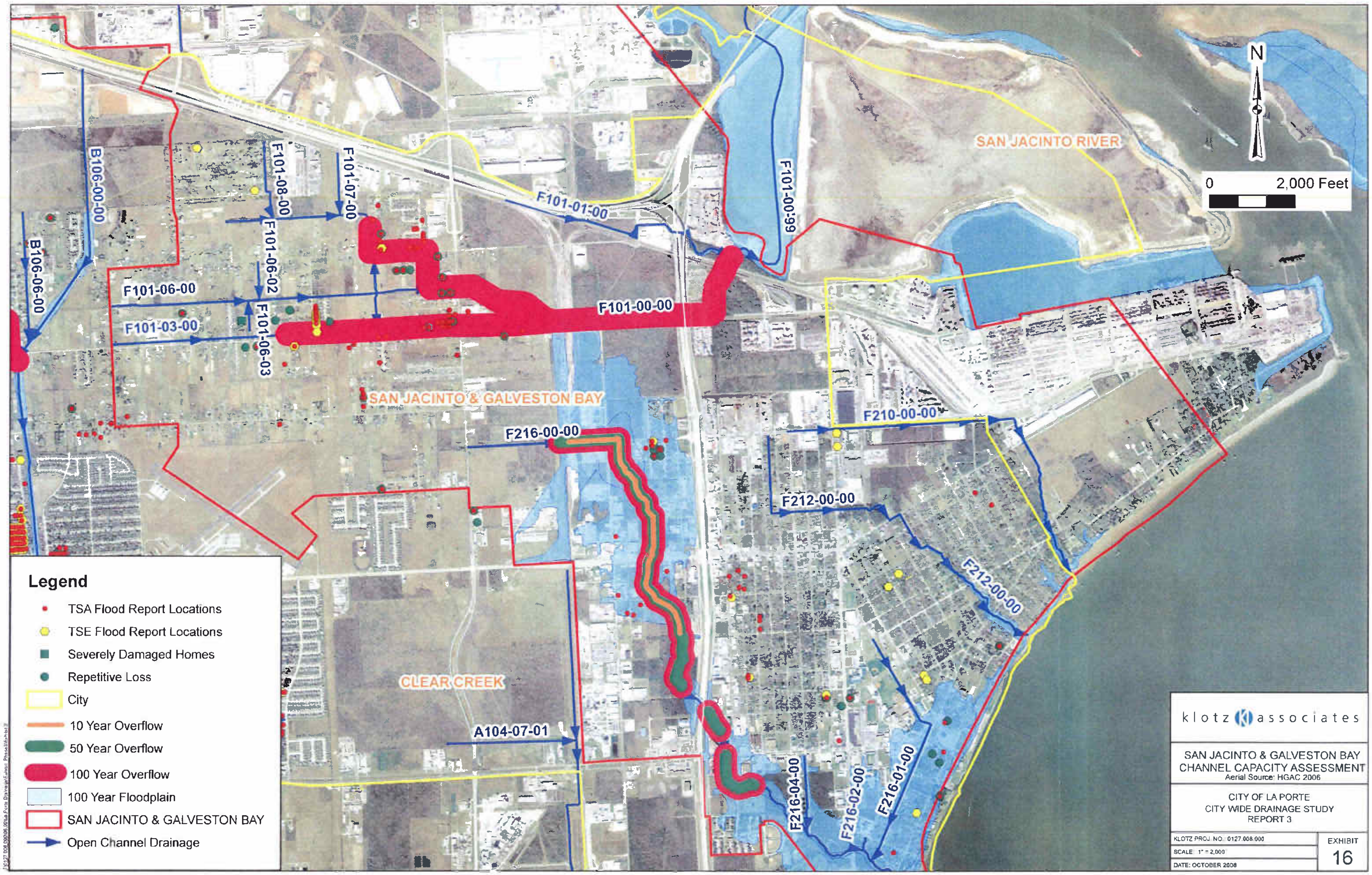
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CLEAR CREEK
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F101-06-02
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F216-04-00
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F216-01-00
Legend
TSA Flood Report Locations
TSE Flood Report Locations
Severely Damaged Homes
Repetitive Loss
City
10 Year Overflow
50 Year Overflow
100 Year Overflow
100 Year Floodplain
SAN JACINTO & GALVESTON BAY
Open Channel Drainage
klotz associates
SAN JACINTO & GALVESTON BAY
CHANNEL CAPACITY ASSESSMENT
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
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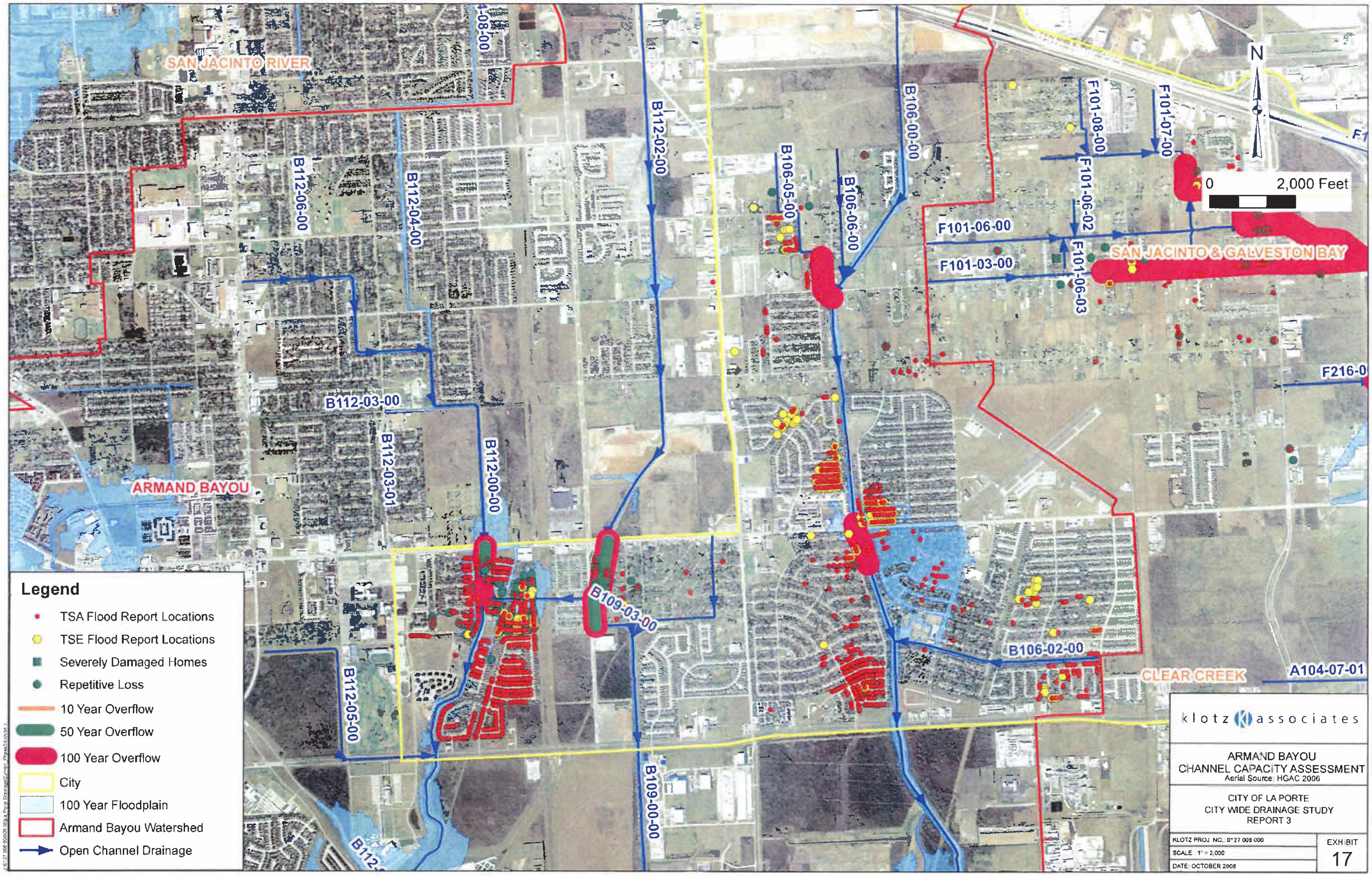

SAN JACINTO RIVER
ARMAND BAYOU
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CLEAR CREEK
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TSA Flood Report Locations
TSE Flood Report Locations
Severely Damaged Homes
Repetitive Loss
10 Year Overflow
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100 Year Overflow
City
100 Year Floodplain
Armand Bayou Watershed
Open Channel Drainage
klotz associates
ARMAND BAYOU
CHANNEL CAPACITY ASSESSMENT
Aerial Source: HGAC 2006
CITY OF LA PORTE
CITY WIDE DRAINAGE STUDY
REPORT 3
EXHIBIT
17

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F212-00-00
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B106-02-00
A104-07-01
ARMAND BAYOU
F216-04-00
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State Hwy 146
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TSARP Flood Report Locations
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Severely Damaged Homes
Repetitive_Loss
City
10 Year Overflow
50 Year Overflow
100 Year Overflow
100 Year Floodplain
Clear Creek Watershed
Open Channel Drainage
klotz associates
CLEAR CREEK
CHANNEL CAPACITY ASSESSMENT
Aerial Source: HGAC 2006
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CITY WIDE DRAINAGE STUDY
REPORT 3
KLOTZ PROJ. NO. 0127.008.000
SCALE: 1" = 2,000'
DATE: OCTOBER 2008
EXHIBIT
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APPENDIX A
CITY OF LA PORTE
DESIGN CRITERIA MANUAL
CHAPTER 5
STORM SEWER DESIGN CRITERIA

CHAPTER 5
STORM SEWER DESIGN CRITERIA

5.1 GENERAL PROVISIONS

Drainage Criteria for development within the City of La Porte, and where applicable within La Porte's Extraterritorial Jurisdiction (E.T.J.) is dependent upon the size and type of development, the conditions within the individual watershed, the conditions or design of the receiving stream, bayou, channel, roadside swale, culvert, or roadway.

The basic objective of this policy is to minimize the threat of flooding to areas within the City and its E.T.J. and to minimize the effect of continued development on individual watersheds.

1. The City believes that the best long-term means of accomplishing its objective is a continued program of improvement and extension of the Harris County Flood Control District's system of open channels. This statement recognizes the technical reality that an essential prerequisite to an effective flood control program is a system of open channels capable of carrying storm runoff of any type in Harris County to Galveston Bay without adversely impacting existing urban areas adjacent to the channels.
2. The City recognizes that both District's and City's existing open channel system is, in many instances, inadequate to accomplish the goal of eliminating existing flooding conditions for existing levels of urban development, or for ultimate development in the watershed.
3. The City therefore recommends that where required, certain additional flood control facilities be utilized to supplement the open channel system. Such flood control facilities shall be designed to preclude flooding in areas that do not presently flood and not increase flood levels where flooding now occurs. Specifically, the City supports the use of storm water detention to supplement the open channel system until long-term channel improvements can be completed, or as permanent facilities where additional open channel improvements are not feasible. The result will be that new development will limit or restrict the impact downstream.

5.1.1 All the drainage plans and construction shall meet or exceed the requirements of the City of La Porte, Harris County Flood Control, Harris County, TxDOT, or any other entities having jurisdiction over a facility (i.e. roadway, channel, etc.).

5.1.2 Unless otherwise provided for in these policies, development shall follow the Harris County Flood Control District Criteria Manual for the design of Flood Control and Drainage Facilities in Harris County, Texas.

5.1.3 If application of the policies and criteria contained in this document conflict with the City's duties under the Flood Hazard Prevention Ordinance, the regulations of the Flood Hazard Prevention Ordinance shall apply.

5.1.4 Drainage structures shall be constructed in such locations and of such size and dimensions to adequately serve the development and the contributing drainage area. In new developments, the developer shall provide all the necessary easements and rights-of-way required for drainage structures, including storm sewer and open or lined channels.

5.2 CONSTRUCTION PLAN REQUIREMENTS

5.2.1 A drainage map shall be included in the construction plans. The drainage area map shall include:

A. Drainage areas, including areas draining from off-site onto or adjoining the project

B. Design storm runoff, based on the type of facility and storm frequency listed in Section 5.4.

C. 100 – year runoff

D. Route of overland flow including the overflow to a drainage channel or detention facility

E. Water surface profiles for the 25-year and/or 100-year storms in the outfall channel. All available information will be considered when making this determination.

F. Flow per inlet

G. Maximum ponding elevation

5.2.2 Detailed drainage calculations shall be submitted with the construction plans.

5.2.3 A lot grading plan should demonstrate that the finished grading plan will drain to approved collection and discharge points and that the overland flow of water from adjacent properties will not be impacted

5.2.4 The hydraulic gradient for the design storm may be shown on the construction drawings. Calculations for the elevation for the hydraulic gradient shall be provided with the design storm drainage calculations. The hydraulic gradient must be below the gutter line for the design storm. The tailwater elevations based on a 25-year frequency in the outfall channel shall be used for calculations of the hydraulic gradient.

5.3 USE OF PREVIOUSLY DESIGNED AND INSTALLED INFRASTRUCTURE

Situations where previously installed infrastructure is in place but not yet utilized to its design capacity will be considered on a case by case basis. The developers engineer shall after consultation with the City, prepare a report that:

a. outline the original design criteria

b. evaluates the impact of the original design on the receiving stream, adjoining properties and/or the 100 year Floodplain.

Based on the report, the City Engineer may allow full or partial use of the previously installed infrastructure and may require it to be supplemented with detention or other facilities.

5.4 STORM FREQUENCY, RUNOFF AND DATUM

A. Storm Frequency

All drainage improvements shall be designed for the following storm frequencies.

Type of Facility	
Road Side Ditches and Culverts	3 year
Storm Sewers	3 year
Ditches & Culverts Drainage 100 acres and more	25 year
Bridges	100 year
Creeks	100 year
Detention Facilities	Refer to Section 5.5

B. Storm Runoff

Design flow of storm water runoff is to be calculated using the Rational Method.

The <u>Rational Method</u> is based on the direct relationship between rainfall and runoff, and the method is expressed by the following equation:

$$Q = CIA, \text{ where}$$

Q is the storm flow at a given point in cubic feet per second (c.f.s).
C is a coefficient of runoff (see Table 1).
I is the average intensity of rainfall in inches per hour for a period equal to the time of flow from the farthermost point of the drainage area to the point under consideration. (See figure 1, I-D-F Curves and Figure 2, Determination of Time of Concentration)
A is the drainage area in acres

The size and shape of the watershed must be determined for each installation. The area of each watershed may be determined through the use of planimetric-topographic maps of the area, supplemented by field surveys in areas where topographic data has changed or where the contour interval is insufficient to adequately determine the direction of flow.

The outline of the drainage area contributing to the system being designed and outline of the sub-drainage area contributing to each inlet point shall be determined.

When calculating the peak flow rate of storm runoff, rainfall intensity will be determined from the rainfall intensity, duration and frequency curves, shown in Figure 1. The storm frequency used for this determination will be according to the facility to be designed as listed in Section A.

1. Runoff Coefficients and Time of Concentration

Runoff coefficients, as shown in Table 1, shall be the minimum used, based on total development under existing land zoning regulations. Where land uses other than those listed in Table 1 are planned, a coefficient shall be developed utilizing values comparable to those shown. Larger coefficients may be used if considered appropriate to the project by the City Engineer.

The time of concentration is defined as the longest time, without unreasonable delay, that will be required for a drop of water to flow from the upper limit of a drainage area to the point of concentration. The time of concentration to any point in a storm drainage system is a combination of the "inlet time" and the time of flow in the drain. The inlet time is the time for water to flow over the surface of the ground to the storm drain inlet. Because the area tributary to most storm sewer inlets is relatively small, it is customary in practice to determine the inlet time on the basis of experience under similar conditions. Inlet time decreases as the slope and the imperviousness of the surface increases, and it increases as the distance over which the water has to travel and retention by the contact surfaces.

Time of concentration shall be computed from Figure 2m and in no case shall the inlet time be more that the time shown in Table1.

where are these?

?

Table 1

Zone	Zoning District Name	Runoff Coefficient "C"	Maximum Inlet Time in Minutes
R-1	Low Density Residential	0.50	15
R-2	Mid Density Residential	0.60	15
R-3	High Density Residential	0.80	10
MH	Manufactured Housing District	0.55	15
NC	Neighborhood Commercial District	0.80	10
GC	General Commercial District	0.85	10
BI	Business Industrial Park District	0.85	10
LI	Light Industrial	0.85	10
HI	Heavy Industrial	0.85	10
PUD	Planned Unit Development District	variable	10 to 15

Miscellaneous Land Uses

Land Use	Runoff Coefficient "C"
Church	0.70 to 0.90
School	0.50 to 0.90
Park	0.30 to 0.70

C. Datum

All drainage plans shall be prepared based on United States Geodetic Survey datum, 1978 adjustment, consistent with National Flood Insurance Program, Flood Insurance Study for the City of La Porte.

update to current FEMA datum

5.5 REQUIRED DETENTION

Detention Basins – Unless otherwise provided for in this Section, Detention Basins will be required for developments within the following watersheds.

Little Deer Creek – F212
- Upstream of Main Street

Little Cedar Bayou – F216
- Upstream of State Highway 146

Big Island Slough – B106
- All segments

Spring Gully – B109
- All segments

Willow Spring Bayou – B112
- All segments

Taylor Bayou – A104
- All segments

The listed watersheds are shown on Figure 3. ?

5.5.1 Design Standards for Detention Basins

Detention requirements for developments less than 50 acres shall be according to the following table. For developed areas of 10 acres or less, the required volume equals the total development area times the appropriate storage coefficient. For areas greater than 10 acres and less than 50 acres the volume is determined by applying Harris County Flood Control District criteria for small watersheds.

Table 2

Developed Area	Storage Coefficient
0 to 3 acres	0.20 acre ft. / acre
3 to 10 acres	0.45 acre ft. / acre
10 to 50 acres	per HCFCD criteria

For developments larger than 50 acres, Harris county Flood Control District and the City Engineer shall approve the detention facility criteria.

5.2.2 Outlet Sizing

1. The outlet structure shall be designed using the orifice equation as follows:

$$Q = CA \times (2gh)^{1/2}$$

Where,
C = 0.8
A = cross sectional area
g = 32.2 feet / sec^2
h = head differential

For head differential use 2' or the 100-year water surface in pond minus the 25-year water surface in receiving channel, if available.

2. Minimum restrictor shall be 6" diameter.

5.5.3 Additional Standards for Detention Basins

The detention facility shall be designed for easy maintenance. For smaller developments the designer is encouraged to use parking lots, underground piping, swales, green spaces, etc. to achieve the volume required.

For larger developments every consideration shall be given to designing of the facility for multipurpose use, such as playgrounds, miniparks, required green spaces, etc. to assure that maintenance will be accomplished. The design shall include the following:

1. an earthen detention basin shall have minimum side slopes of 4:1 and a minimum bottom width of ten feet;
2. the bottom of the detention basin shall have a minimum 0.50% cross slope to facilitate quick drainage.
3. a v-shaped trickle channel a minimum of 5' wide, six-inch thick, reinforced concrete shall be constructed through the detention basin at a longitudinal slope of 0.20% to accommodate low flow and facilitate rapid drainage. For developments less than 3 acres, the trickle channel may be 2 feet wide and 4" thick.
4. a minimum 12-foot wide maintenance berm shall be provided around the perimeter of the detention facility.
5. ingress and egress for maintenance including a dedicated right-of-way if required, shall be provided to the detention basin and clearly shown on the construction drawings or site plan subdivision plat.

6. the detention basins, slopes, bottom, maintenance berm, and other associated right-of-way shall be final graded with a minimum of 6" top soil the hydro-mulch or drill-seeded and watered to facilitate full grass coverage.
7. parties responsible for maintenance of the detention facility must be shown on the plat or plans.
8. Pumped detention systems may be allowed with specific approval from the City Engineer.

5.5.4 Ownership and Maintenance of Facilities

The City will not accept maintenance of on site facilities that serve only one tract or development, unless it is determined to have other public benefits, is recommended by staff and approved by the Planning and Zoning Commission.

Harris County Flood Control District may, at their discretion, accept maintenance of facilities, provided they are designed in accordance with the District's criteria manual. Requests for Harris County Flood Control District to assume maintenance of any facility should be coordinated with the City prior to any development approvals.

5.6 ADDITIONAL DESIGN REQUIREMENTS

5.6.1 Discharge Points

The developer shall terminate all drainage improvements at a discharge point approved by the City. The developer shall design and construct such discharge point, or outlet, to prevent damage to or overflowing into adjacent property. The City may require creek improvement, channel lining, energy dissipaters or other improvements for such outlet to prevent erosion or increase the flow capacity.

Finished elevations of new pavement, parking areas, or other improvements shall be designed so that each succeeding high point is lower when moving in a downstream direction. This ensures the 100-year discharge has an unobstructed path to the discharge point whether discharging to a channel or detention pond.

5.6.2 Public Streets as Drainage Facilities

1. Maximum depth of water to be allowed in local streets during design flow shall be at the top crown, or top of curb, whichever is less.
2. Maximum spread of water in collector streets during design flow shall allow for one clear lane of traffic (12 feet wide).
3. Maximum spread of water in arterial streets during design flow shall allow for two clear lanes of traffic (24 feet wide).

5.6.3 Drainage Channels and Structures

1. The developer shall install an underground storm drain on curb and gutter streets beginning at the point where calculated storm water runoff is of such quantity that it exceeds the height specified above. The developer shall construct the storm drain system from the point to an approved outlet.
2. For non-curb and gutter streets, the developer may use open channel (channel or ditch) methods to dispose of storm water specified above. Such channels may be in dedicated draining easements outside the standard street right-of-way upon City approval of the location and alignment of such easements. Alternatively, the developer may widen the street right-of-way to accommodate an open channel of greater capacity than the standard street/ditch section.
3. If the developer locates the channel in a widened street right-of-way, the City shall approve the right-of-way width and channel configuration. the depth of flow in the channel shall not exceed one (1) foot as measured from the ditch flowline to the point on the roadway established as the high water level in this section.

4. The developer shall design and construct all channels to terminate at an approved outlet.

5.6.4 Habitable Structures

The developer shall provide adequate means for storm water run-off in excess of the "design storm" capacity (i.e., 3, 10-year storm) to flow around habitable structures.

a.) The developer shall provide a grading/drainage plan which shows that all building sites can provide a finished floor elevation:

(1) At least one foot(1') above the top of the curb using the highest point along the portion of such curb fronting the building site, or
(2) At least eighteen inches (18") above the crown of the road elevation, using the highest point along the portion of such road fronting the building site.
(3) At least on foot above the ground elevation along all sides of the building site.

b.) In addition to paragraph (a) above, the developer shall provide a grading/drainage plan which meets or exceeds the provisions of Chapter 94, Code of Ordinances, Flood Hazard Reduction.
c.) The developer shall design and construct all streets to minimize any fill required to bring building pads into compliance with this code.
d.) Alternate methods of building protection may be accepted by the City upon submittal of detailed information, review and approval by the City Engineer.

5.6.5 Drainage System Criteria

If an underground drainage system is required, and a 60-inch or smaller pipe will handle the design slow, pipe shall be used. If a 60-inch pipe is not adequate, the developer has the option to use concrete pipe or natural and/or a lined drainage channel. If pipe is selected, the maximum allowable velocity shall be 8fps in the pipe. Lining materials, if used, shall be approved by the City.

5.6.6 Public storm sewers are defined as sewers and appurtenances that provide drainage for a public right-of-way, or more than one private tract, and are located in public right-of-way or easement, private storm sewers provide internal drainage for a reserve or other tract. Private storm or sewer connections to public storm sewers shall occur at a manhole or at the back of an inlet as approved by the City Engineer. All private storm sewers within the public right-of-way shall be constructed in conformance with the Standards.

5.6.7 All construction shall conform with the City of La Porte Construction Details.

5.6.8 All storm sewers shall meet or exceed the requirements of the "Drainage Criteria Manual for Harris County, Texas" and the requirements of the City of La Porte.

5.7 LOCATION OF STORM SEWER

5.7.1 Public storm sewers shall be located within a public street right-of-way or storm sewer easement, dedicated to the public and adjoining a public street right-of-way. Storm sewers through side lot drainage easements are highly discouraged. Limited use may be approved at the discretion of the City Engineer. If approved, a minimum twenty-foot (20') wide easement is required (10' on each lot).

5.7.2 Recommended alignment within a public street right-of-way.

A. Boulevard pavement section with median – along centerline of the right-of-way.

B. Undivided pavement section five feet (5') inside the right-of-way. For storm sewer located in a public street right-of-way, a minimum of two-foot (2') shall be maintained inside the right-of-way line to the outside edge of the storm sewer unless otherwise accompanied by an adjacent easement.

C. Alternate locations for a storm sewer will be permitted by the City Engineer.

5.7.3 Recommend alignment within an exclusive storm sewer easement.

A. Storm sewers placed in easements shall conform to the requirements of Section 2.4.5

B. Storm sewers within easements shall be placed no closer than five feet (5') measured from the outside edge of the pipe to the edge of an easement, except when adjoining another easement or public right-of-way where the distance may be reduced to two feet (2'). The storm sewer shall be placed in the center of the easement. When the storm sewer easement adjoins a public right-of-way, the easement may be reduced to a minimum of ten feet (10') and the storm sewer may be aligned close to the right-of-way line, as long as required clearances are met, with specific approval of the City Engineer.

5.8 STORM SEWER MATERIALS

5.8.1 Storm sewer and culvert pipe shall be precast reinforced concrete pipe, unless specifically approved by the City Engineer. Concrete pipe shall be manufactured in conformance with the requirements of ASTM C 76, " Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe," current revision. Reinforced concrete pipe shall be Class III or stronger. The design engineer shall provide for increased pipe strength when conditions of the proposed installation exceed the allowable load for Class III pipe. All concrete pipe constructed in water-bearing soil or forty-two inched (42") in diameter or larger, shall have rubber gasket joints meeting the requirements of ANSI/ASTM C 443, "Joints for Circular Concrete Sewer and Culvert pipe, Using Rubber Gaskets", current revision. Concrete pipe with diameter of less than forty-two inches (42") may be installed using pipe with tongue and groove type joint and Ram-nek, or approved equal, as a joint filler. When specifically approved by the City Engineer, reinforced concrete arch and elliptical pipe conforming to ASTM C506 and ASTM C507, respectively, current revision, may be installed in lieu of circular pipe. Reinforced concrete box culverts shall meet the minimum requirements of ASTM C789, "Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers", current revision. pipe joints for arch and elliptical pipe and box culverts shall be sealed using Ram-nek or approved equal.

5.8.2 Storm sewer outfalls into open channels shall be constructed using corrugated steel pipe. Corrugated steel pipe shall be manufactured in conformance with the requirements of AASHTO Designation M-36-82, current revision. Pipe material shall be Aluminized Steel Type 2, meeting the requirements of AASHTO Designation M-27-79I, current revision, or Pre-coated Galvanized Steel, AASHTO M-246, 10 mil coating on both sides. All pipe shall have a full double coating, Type A, in accordance with AASHTO Designation M-190, current revision. Pipe joints and fittings shall meet the minimum requirements of these specifications and shall have an O-ring gasket seal meeting the requirements of AASHTO C-361, current revision. (See City of La Porte Construction Details).

5.8.3 Storm sewer outfalls shall have a slope protection to prevent erosion. Slope protection may be constructed of slope paving or rip rap. Slope paving shall be four-inch (4") five (5) sack concrete with six-inch by six-inch (6" x 6") welded wire mesh (W14 x W14) or three eighths inch (3/8") steel rebar on twenty-four-inch (24") centers, each way. Rip rap shall be a minimum of six-inch (6") broken concrete rubble with no exposed steel or well-rounded stone and shall be a minimum of eighteen inched (18") thick. Slope protection texturing shall be required where public access likely. Refer to the Construction Details for minimum dimensions.

5.9 ADDITIONAL REQUIREMENTS

5.9.1 Minimum depth of storm sewer (measured to the top of pipe) shall be twenty-four (24") below the top of curb or finished grade, whichever is lower. Minimum size storm sewer for main land and inlet lead shall be eighteen inch (18").

5.9.2 Storm sewers shall be bedded using cement stabilized sand (See specification in Section 4.2.3) as shown in the City of La Porte Construction Details.

5.9.3 Pipe requirements.

A. Reinforced concrete pipe installed at a depth greater that thirty feet (30') shall be designed by the engineer for the specific installation and approved by the City Engineer, Reinforced concrete pipe shall be designed in accordance with the American Concrete Pipe Association, "Concrete Pipe Design Manual", Maximum cover on the pipe shall be measured from the top of pipe to the ultimate finished grade or natural ground, whichever is greater.

B. Corrugated steel pipe shall have a minimum thickness as follows:

PIPE SIZE (Inches) Corrugations (Inches	MINIMUM THICKNESS
242-2/3" X 1/2"	0.052
30- 482-2/3" X 1/21	0.064
54- 723't X 1" or 511 X 1"	0.064
78- 102311 X 1" or 5" X 1"	0.079

Bedding for corrugated steel pipe shall be cement-stabilized sand. Corrugated steel pipe less than or equal to fifty-four inches (54") in diameter and less than thirty feet (30') deep shall have the minimum thickness given above.

C. Design storm flow in a street shall not exceed the capacity of the street, for the water surface equal to the top or curb and shall not exceed the inlet capacity. Design storm flow shall meet Harris County criteria.

D. All bridges must be a minimum of eighteen inches (18") above the 100-year water surface elevation or in accordance with the Federal Emergency Management Agency (FEMA) regulations , latest revisions, or HCFCD requirements, whichever is greater.

Low chord

5.9.4 Storm sewers less that forty-two inches (42") in diameter shall be constructed on a straight horizontal and vertical alignment between manholes. Storm sewers greater than or equal to forty-two inches (42") in diameter may be laid along a curve using manufactured bends of less than or equal to 11¼'.

5.10 APPEARANCES

5.10.1 Manholes

A. Manholes shall be placed at all changes in alignment, grade and size of the storm sewers; at the intersection of two or more storm sewers; at all inlet leads; and at the end of all storm sewers.

B. Maximum spacing between manholes shall be six hundred feet (600')

C. Manhole covers shall be cast iron, traffic bearing, type ring and cover with the words "storm sewer" cast into the cover.

5.10.2 Inlets

A. Curb inlets shall be spaced and sized to intercept the calculated runoff for the design storm. The water surface elevation at the inlet shall be less than or equal to the top of curb for the design storm flow.

B. Maximum travel distance of water in the street to a curb inlet shall be three hundred feet (300') on a major thoroughfare and in a commercial area. The maximum travel distance of water in the street permitted in a single-family residential area shall be four hundred feet (400').

C. No Valley Gutter without prior approval.

D. Curb inlets should be on the intersecting side street at intersections with a major thoroughfare. The City Engineer shall specifically approve locations at intersections.

E. Grated inlets will not be permitted in an open ditch.

F. Backslope swale interceptors shall be placed in accordance with the requirements of Harris County.

G. Curb inlets shall have solid inlet lids. Grate or Curb and Grate inlets shall not be allowed for residential subdivisions. Curb inlets shall be recessed, unless otherwise directed by the City Engineer. Revise.

H. Backfill around inlets and to top of first stage inlet with cement stabilized sand.

Revise?

City of La Porte

Intensity vs. Time of Concentration vs. Rainfall Frequency (IDF Curves)

Source: Hydro 35/TP-40

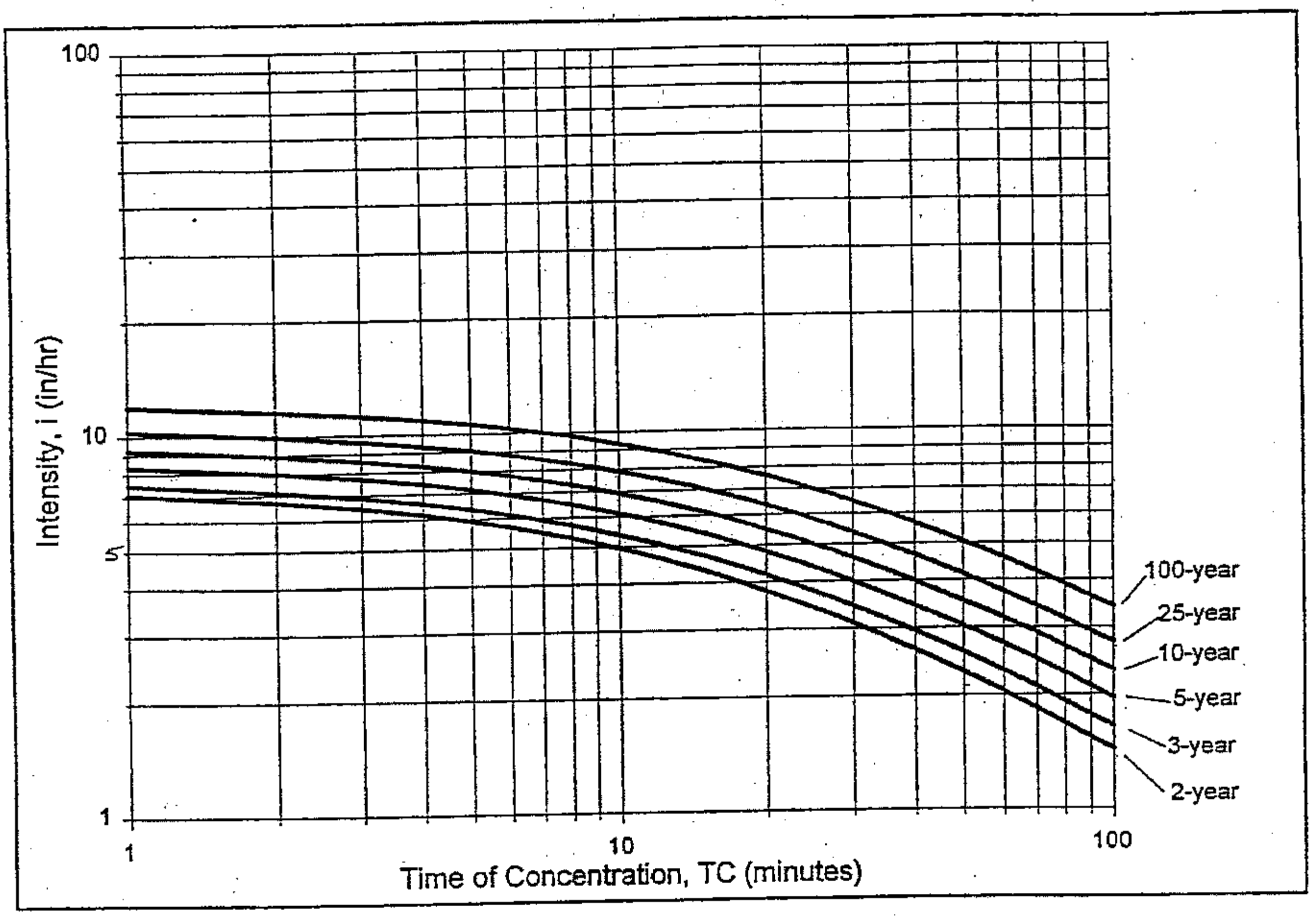


FIGURE 1

$$Intensity, i = \frac{b}{(d+TC)^e}$$

Rainfall Frequency	b	d	e
2-year	75.01	16.2	0.8315
3-year	77.27	17.1	0.8075
5-year	84.14	17.8	0.7881
10-year	93.53	18.9	0.7742
25-year	115.9	21.2	0.7808
100-year	125.4	21.8	0.7500

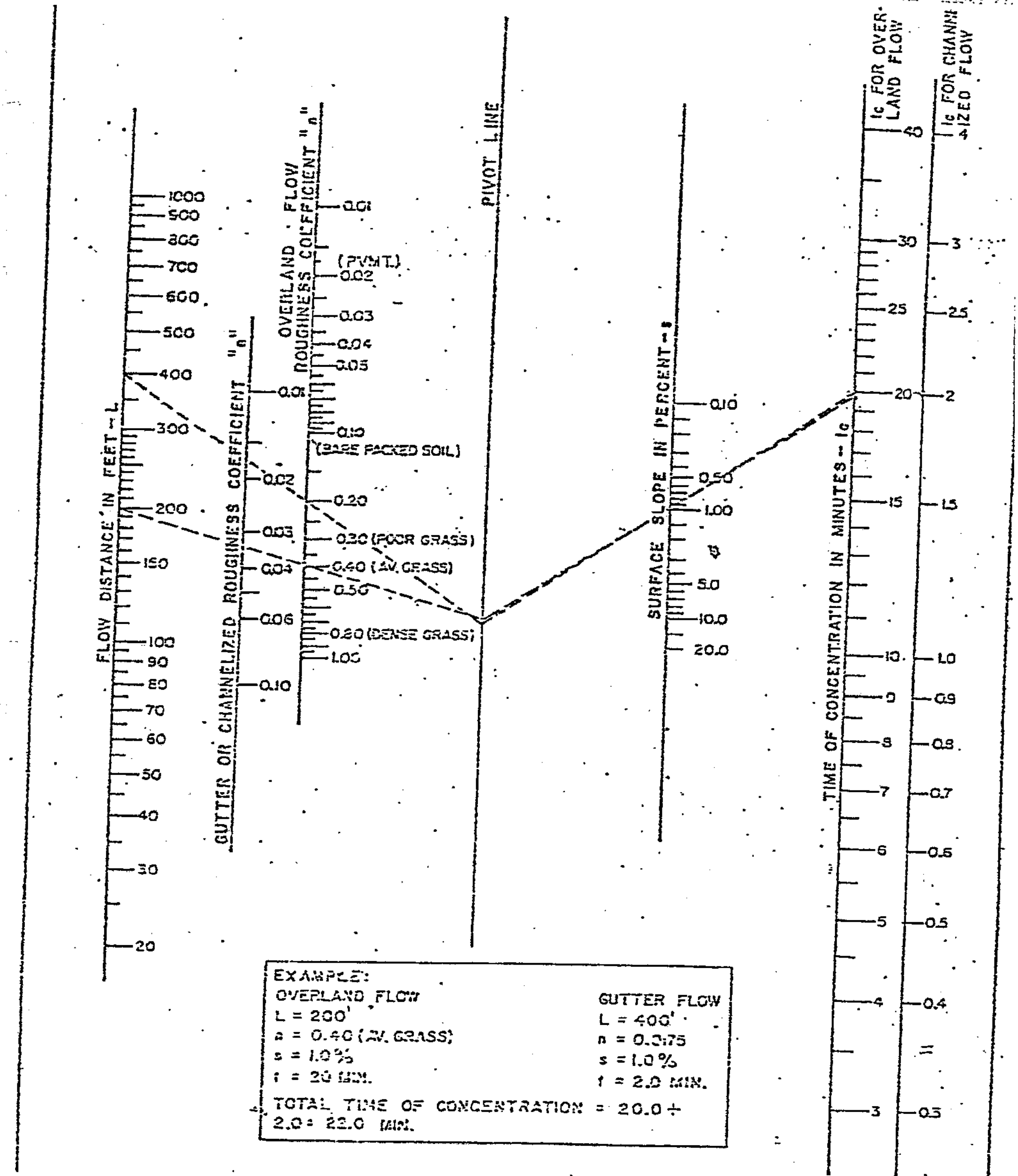


FIGURE 2

TIME OF CONCENTRATION FOR SURFACE FLOW

MAJOR LA PORTE WATERSHEDS

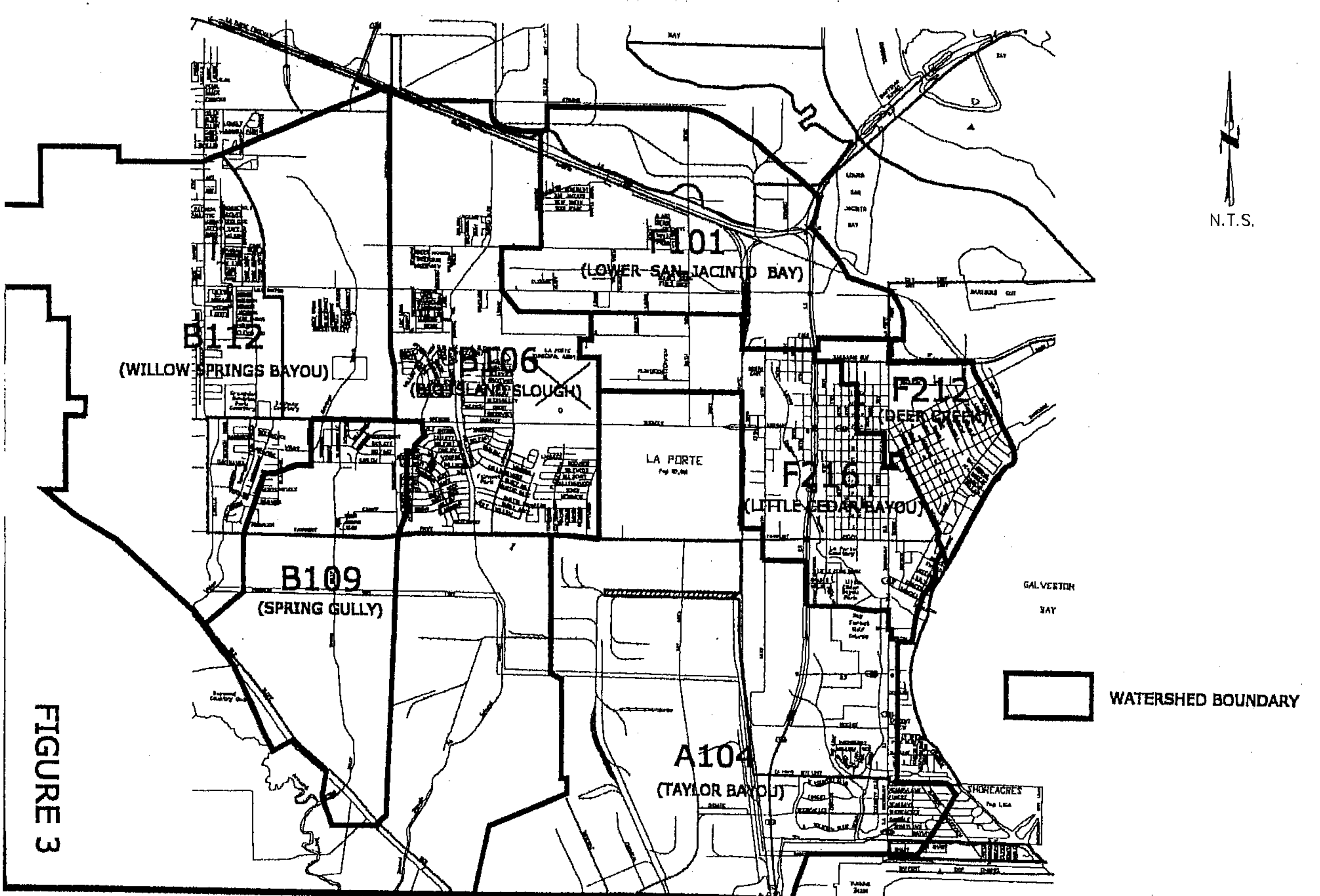
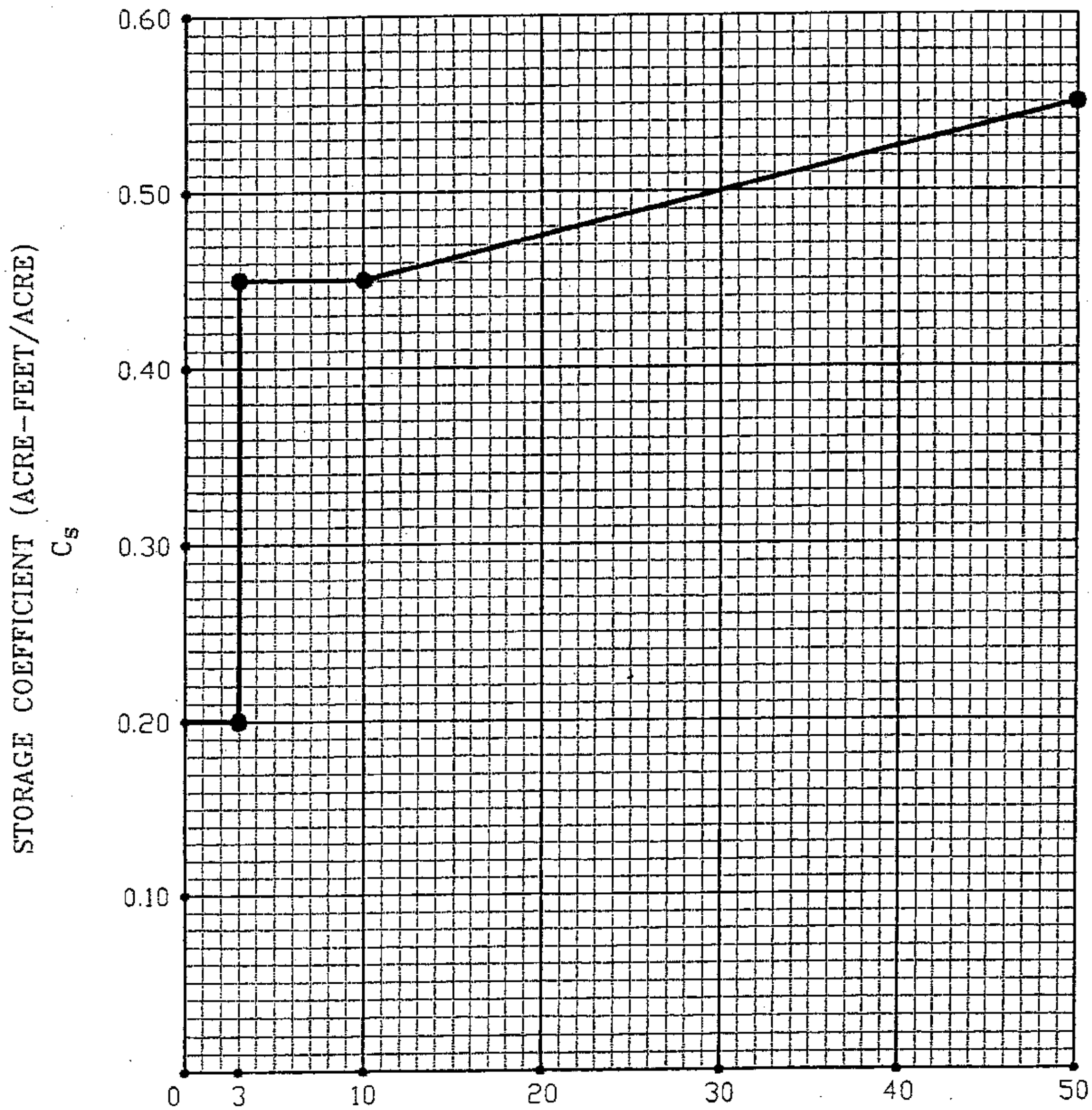


FIGURE 3

CURVE FOR DETERMINING STORAGE COEFFICIENT



DRAINAGE AREA (ACRES)

$S = C_S A$

FIGURE 4

APPENDIX B
RAINFALL PARAMETERS AND AMOUNTS FOR LA PORTE
COMPARISON TABLE

RAINFALL PARAMETERS AND AMOUNTS FOR LA PORTE
COMPARISON TABLE

	City of La Porte (note 1)			TxDOT		
Rainfall Frequency (years)	b	d	e	b	d	e
2-year	75.01	16.2	0.8315	68	7.9	0.800
3-year	77.27	17.1	0.8075	---	---	---
5-year	84.14	17.8	0.7881	70	7.7	0.749
10-year	93.53	18.9	0.7742	81	7.7	0.753
25-year	115.90	21.2	0.7808	81	7.7	0.724
50-year	---	---	---	91	7.7	0.728
100-year	125.40	21.8	0.7500	91	7.9	0.706

City of La Porte	Inches/hour for various times of concentration (minutes)					
Rainfall Frequency (years)	10	20	30	60	120	1440
2-year	5.0	3.8	3.1	2.0	1.3	0.2
3-year	5.4	4.2	3.4	2.3	1.5	0.2
5-year	6.1	4.8	4.0	2.7	1.7	0.3
10-year	6.9	5.5	4.6	3.2	2.1	0.3
25-year	7.9	6.4	5.4	3.7	2.4	0.4
50-year	---	---	---	---	---	---
100-year	9.4	7.6	6.5	4.6	3.1	0.5

TxDOT	Inches/hour for various times of concentration (minutes)					
Rainfall Frequency (years)	10	20	30	60	120	1440
2-year	6.8	4.7	3.7	2.3	1.4	0.2
3-year	---	---	---	---	---	---
5-year	8.1	5.8	4.6	3.0	1.9	0.3
10-year	9.3	6.6	5.3	3.4	2.1	0.3
25-year	10.1	7.3	5.9	3.8	2.4	0.4
50-year	11.2	8.1	6.5	4.2	2.7	0.5
100-year	11.9	8.7	7.0	4.6	3.0	0.5

TSARP Technical Paper Recommendations (Region 3, which includes	Average inches/hour for various times of concentration (minutes)					
Rainfall Frequency (years)	10	20	30	60	120	1440
2-year	---	---	3.0	2.0	1.2	0.2
no recommendation	---	---	---	---	---	---
5-year	---	---	3.8	2.5	1.6	0.3
10-year	---	---	4.2	2.9	1.9	0.3
25-year	---	---	4.8	3.4	2.2	0.4
50-year	---	---	5.4	3.8	1.3	0.5
100-year	---	---	6.0	4.3	2.9	0.6

City of La Porte	Inches of rain for various times of storm durations (minutes)					
Rainfall Frequency (years)	10	20	30	60	120	1440
100-year	1.6	2.5	3.2	4.6	6.1	12.7

TxDOT	Inches of rain for various times of storm durations (minutes)					
Rainfall Frequency (years)	10	20	30	60	120	1440
100-year	2.0	2.9	3.5	4.6	5.9	12.8

Note 1. Same Coefficients as City of Houston, Harris County.
Note 2: HCFCD 24 hour 100-year rainfall for Galveston Bay, as based upon TSARP data, is 13. 5 inches. Compare to the rainfall for the 100-year event for 1440 minutes = 24 hours