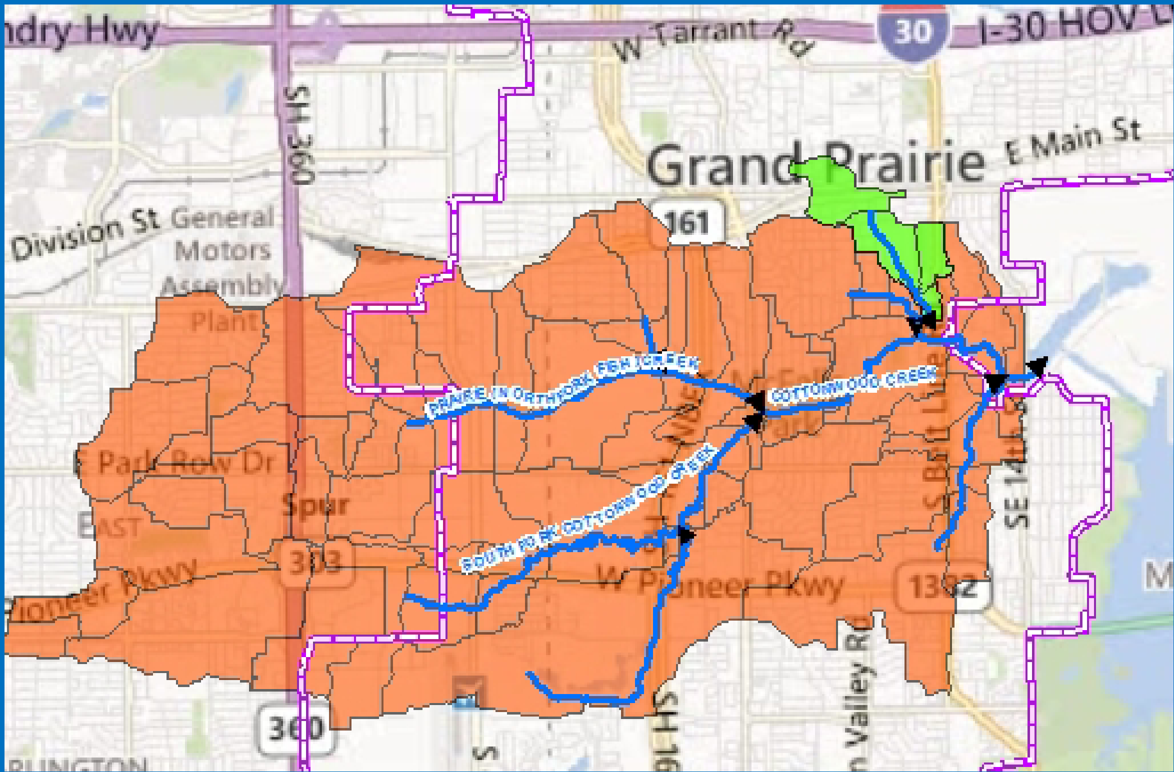
City of Grand Prairie Supplemental City-Wide Drainage Master Plan for Cottonwood Creek (Y#0882)

Henry Branch



March 2013

Prepared by

HALFF

AVO 27930

Grand Prairie TEXAS

RESOLUTION NO. 4614-2013

A RESOLUTION APPROVING THE CITY OF GRAND PRAIRIE'S CITY-WIDE DRAINAGE MASTER PLAN FOR HENRY BRANCH.

WHEREAS, The "City-Wide Drainage Master Plan for Henry Branch" (the Plan) is about providing comprehensive, updated technical data for the management of the Henry Branch watershed;

WHEREAS, the Plan addresses existing flooding, erosion, and sedimentation problems within the watershed and provides planning alternatives and design concepts to help alleviate potential flood damages;

WHEREAS, the Plan provides the City of Grand Prairie with the necessary updated drainage information to coordinate future development according to the City's drainage requirements to help minimize existing and potential flood damages within the Henry Branch watershed;

WHEREAS, any revisions to the floodplain and the floodways identified in these studies shall also include ultimate development conditions and shall be for the whole creek as determined in these studies and not for portions of it to ensure that there are no downstream adverse effects; required submittals to FEMA shall be for the whole creek (as determined in these studies) and not for portions of it; and

WHEREAS, the recommendations of this report shall be incorporated for all future development as well as CIP budget considerations.

NOW THEREFORE, BE IT RESOLVED, BY THE CITY COUNCIL OF THE CITY OF GRAND PRAIRIE, TEXAS:

SECTION 1. THAT the City of Grand Prairie, Texas, having developed the "City-Wide Drainage Master Plan for Henry Branch" to cost-effectively manage flood or storm waters within budgeting constraints, approves and adopts the "City-Wide Drainage Master Plan for Henry Branch" thereby setting the standard for future drainage master plans, addressing existing flooding problems and providing planning recommendation, alternatives and design concepts for future development, to include CIP as well as possible developer participation projects.

PASSED AND APPROVED BY THE CITY COUNCIL OF THE CITY OF GRAND PRAIRIE, TEXAS, ON THIS THE 16TH DAY OF APRIL, 2013.

APPROVED:

Charles England

Charles England, Mayor

ATTEST:

Catherine E. DiMaggio

~~City~~ Secretary

APPROVED AS TO FORM:

City Attorney

HALFF

March 13, 2013
AVO 27930

Mr. Romin Khavari, P.E., CFM
City Engineer
City of Grand Prairie
206 W. Church Street
P.O. Box 534045
Grand Prairie, TX 75053-4045

Re: Supplemental City-wide Drainage Master Plan for Cottonwood Creek (Y#0882) Henry Branch – Final Report

Dear Mr. Khavari:

Transmitted herewith is the Final Report for the Supplemental City-wide Drainage Master Plan for Cottonwood Creek (Y#0882), including technical data and exhibits. This report compiles existing and newly developed technical data for the Henry Branch watershed into a single comprehensive document. The report also includes a DVD containing HEC-HMS hydrologic models, HEC-RAS hydraulic models, PDFs, and GIS data for City review and use.

Please do not hesitate to call me or Stephen Crawford if you have any questions or concerns regarding the Supplemental CWDMP for the Cottonwood Creek watershed.

Sincerely,

HALFF ASSOCIATES, INC.

Benjamin B. Pylant, PE, CFM
Project Manager

STATE OF TEXAS
BENJAMIN B. PYLANT
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LICENSED
PROFESSIONAL ENGINEER
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EXECUTIVE SUMMARY

This report is intended to supplement the City-wide Drainage Master Plan (CWDMP) for Cottonwood Creek with comprehensive, updated technical data for the Henry Branch watershed. This report addresses flood dangers and erosion problems within the Henry Branch watershed and provides planning alternatives and design concepts to help alleviate potential damages to local residents and City infrastructure. The information presented in this report will provide the City of Grand Prairie with the necessary updated drainage information to coordinate future development and help minimize existing and potential flood damages within the Henry Branch watershed. This study is in compliance with the requirements set forth in the "City-wide Drainage Master Plan Roadmap." The City Council of Grand Prairie passed Resolution No. 4614-2013 approving this study on April 16, 2013.

A total of four (4) structures were identified within the existing 100-year floodplain in the Henry Branch watershed. Of these structures, one (1) was considered a significant, enclosed structure that would qualify as an insurable structure. The majority of the watershed is currently developed with commercial, single-family residential, multi-family residential and industrial use. The alternatives included in this report are ranked in two different categories: open channel alternatives and stream stability alternatives. The only open channel alternative is the resizing of the Skyline Road crossing and it is considered a long-term alternative. Three stream stability alternatives to protect public infrastructure are considered short-term Capital Improvement Project (CIP) priorities. See the following pages for a summary of the prioritization rankings and a location map.

The current developable areas for the Henry Branch watershed is approximately 15% of the total drainage area. As development occurs in the watershed, the Floodplain Workmaps and the Erosion Hazard Setbacks should be utilized to assist in identifying a site as being in a high risk area for flooding, bank erosion or channel degradation. If the site is in a high risk area, then the developer should be alerted to the risk, and mitigation should be considered.

This report is intended to be a living document that can be updated as additional information becomes available for the Henry Branch watershed.

Grand Prairie TEXAS

CIP Location Map

Legend

- Roadway Improvement
- Erosion Alternative Locations
- Stream Centerline
- Cottonwood CTP 100yr FP
- Henry Existing 100yr FP

0 150 300 600 Feet

1 inch = 300 feet

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Capital Improvement Project Summary

Preliminary Short-Term Priorities & Long-Term Implementation

Rank	Stream	Capital Improvement Project	Short-Term/Long-Term	Public/Private	Probable Cost
Stream and Open Channel Alternatives					
1	Henry Branch	Replace Skyline Drive	Long-Term	Public	$280,000
Stream Stability Alternatives					
1	Henry Branch	Remove Concrete Dam Structure & Install Rock Chute (Approximate Station 22+70)	Short-Term	Public	$72,000
2	Henry Branch	Place 24" Rock Rip-Rap Downstream of Concrete Channel (Approximate Station 20+00)	Short-Term	Public	$17,000
3	Henry Branch	Install Rock Chutes (Approximate Stations 6+50 & 36+00)	Short-Term	Public	$88,000

I. Introduction

I. INTRODUCTION

A. ACKNOWLEDGMENTS

Halff Associates would like to acknowledge the significant contributions of all City of Grand Prairie staff in preparation of the City-Wide Drainage Master Plan. In particular, the following individuals have provided invaluable input and assistance:

Romin Khavari – City Engineer
Gabriel Johnson – Floodplain Administrator
Chris Agnew – Storm Drainage Engineer

B. PURPOSE OF STUDY

This study is in compliance with the requirements set forth in the "City-wide Drainage Master Plan Road Map." The purpose of this supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek is to provide comprehensive, updated technical data for the management of the Henry Branch watershed. This report addresses existing flooding, erosion, and sedimentation problems within the watershed and provides planning alternatives and design concepts to help alleviate potential damages. The information presented in this report will provide the City of Grand Prairie with the necessary updated drainage information to coordinate future development according to the City's drainage requirements (see Section I.C) and help minimize existing and potential flood damages within the Henry Branch watershed.

Specific objectives of this supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek for the City of Grand Prairie, Texas for the management of the Henry Branch watershed include:

1. Compile pertinent existing engineering data and newly developed information into a comprehensive report to include an up-to-date existing conditions and fully urbanized watershed (hereafter known as ultimate conditions) and the existing 100-yr floodplain for Henry Branch.

2. Prepare detailed descriptions of alternative improvement solutions (structural and non-structural) to help reduce or eliminate flooding problems for streams and open channels within the study watershed.

3. Perform a Channel Stability Assessment/Erosion Hazard Analysis to analyze factors influencing stream stability and formulate alternatives to help stabilize stream banks.

4. Evaluation of existing and future roadway crossings utilizing the City's Master Thoroughfare Plan.

5. Locate and provide detailed descriptions of dams/levees/detention, include table of existing drainage plan reviews, and include associated plans, photos, and descriptions of potential problems associated with these features.

6. Utilize the City's Storm Drain Outfall Assessment to provide detailed descriptions of locations where maintenance needs to occur.

7. Evaluate and Prioritize proposed alternative improvement projects and describe the methodology utilized to phase and implement the proposed alternative improvement projects.

8. Determine Short Term and Long Term Plan to prioritize proposed alternative improvement projects including benefit-cost analysis ratios.

C. CITY ORDINANCES AND DEVELOPMENT REQUIREMENTS

The City of Grand Prairie is especially progressive in their storm water management program. The City's Drainage Design Manual was updated as recently as November 2012 and is intended to "…protect the general health, safety, and welfare of the public by reducing flooding potential, controlling excessive runoff, minimizing erosion and siltation problems, and eliminating damage to public facilities resulting from uncontrolled storm water runoff."

Articles 14 and 15 of the Unified Development Code, included in the City's Drainage Design Manual, contain the City ordinances for Drainage and Floodplain Management, respectively. Requirements include the elevation of new construction a minimum of one foot above the ultimate 100-year floodplain or two feet above the existing conditions floodplain, whichever is higher. Construction of detention basins is required when downstream facilities are not adequately sized to convey a design storm based on current City criteria for hydraulic capacity. Post project peak flows are not allowed to exceed the existing conditions peak flows unless sufficient downstream capacity above existing discharge conditions is available. When required, detention facilities are to be designed such that peak discharges or velocities are not increased when compared to pre-project conditions for the 2-, 10- and 100-year floods.

The City ordinances allow for responsible development of the watershed such that flood risks to future structures can be minimized. The ordinances also allow for protection of existing structures so that future development will not increase the flooding hazard in areas that do not have the capacity to convey increased flood discharges. Upon review of the City's Drainage Design Manual and existing development requirements, it has been determined that the requirements in combination with the technical data provided in this report are adequate to properly manage the watershed going forward.

D. WATERSHED DESCRIPTION

The Cottonwood Creek watershed originates within the City of Arlington and continues downstream through the City of Grand Prairie to a point where it discharges into Mountain Creek Lake. The watershed is approximately 85% urbanized and is characterized by a mix of industrial, commercial, and residential use with the City of Arlington's area approaching build-out while the City of Grand Prairie's area is experiencing continuing fill-in growth. This supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek will focus on the Henry Branch watershed, which is located in the northeastern corner of the Cottonwood Creek basin. A detailed description of the Henry Branch watershed can be found in Section II.B of this report.

1. Major Streams and Tributaries

The Henry Branch watershed contains one major tributary, Henry Branch. Table I-1 lists this stream's downstream limit, upstream limit, Federal Emergency Management Agency (FEMA) designation, and length.

Table I-1 – Study Streams

Stream Name	Downstream Limit	Upstream Limit	Proposed FEMA Designation	Length (ft)*
Henry Branch	Confluence with Indian Hills Branch	Dallas Street	Zone A	4,720
* Note: Length was taken from centerline data in GIS from Dallas Street to the confluence with Indian Hills Branch.				

2. Unique Attributes of Watershed

The most unique attributes of the Henry Branch watershed are the multiple public facilities located in the central portion of the watershed. The Charley Taylor Recreation Center/Park is located just west of Beltline Road and is adjacent to Robert E. Lee Middle School and the Gentry Long Service Center. A portion of the City's central business district is also located in the upper Henry Branch watershed.

E. PRINCIPAL FLOODING PROBLEMS

1. Drainage Complaint Database

Halff Associates, Inc. obtained the latest information from the City of Grand Prairie's Drainage Complaint Database for the Henry Branch watershed from the City-wide Drainage Master Plan for Cottonwood Creek developed by RPS Espey Consultants in July 2012. Twenty two (22) drainage complaints at seventeen (17) different locations have been filed with the City of Grand Prairie within the Henry Branch watershed. Of these complaints, nine (9) were structure flooding problems related to streets or storm drains, nine (9) were street ponding problems, one (1) was a lot-to-lot property flooding problem (primarily water standing in the yard due to grading issues), and three (3) were complaints about debris obstructing flow in the channel. There were no complaints coinciding with riverine flooding locations. Complaints in the watershed primarily involved storm drainage system performance or local flooding due to grading issues.

2. Hot Spot Locations

City records indicate the Main Street drainage system located in the central business district in the upper Henry Branch watershed has been subject to flooding on numerous occasions. Multiple property owners in this location have reported flooding according to the City's drainage complaint data base. The flooding issues in this area are currently being studied by Halff Associates using the InfoWorks SD modeling package as part of a separate contract. Results of the study are anticipated to be available by the end of 2012.

F. PERTINENT STUDY AND TECHNICAL DATA RELATED TO WATERSHED PRIOR TO THE MASTER PLAN PREPARATION

1. Existing Data

i. *Main Street Drainage at Center Street Report (Y #200)*

Halff Associates developed alternative solutions to reduce flooding in the Main Street project study area located within the central business district of the City of Grand Prairie at the headwaters of Henry Branch.

ii. *2003 Henry Branch Watershed Study*

Technical hydrologic and hydraulic data for the 2003 Henry Branch Watershed Study was prepared by Halff Associates as part of the Main Street Drainage Preliminary Design Report. The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) model developed for this study was used to analyze the proposed alternative improvements for the Main Street project study area. The hydrologic and hydraulic models developed for this study provided comparison data for the updated Henry Branch models developed for the 2011 City of Grand Prairie Cooperating Technical Partners (CTP) Flood Study.

iii. *City of Grand Prairie – Y#0882 FEMA FY10 Cooperating Technical Partner (CTP) Project*

Existing conditions hydrology, hydraulics, and floodplain mapping were developed and submitted to the FEMA by Halff Associates, Inc. in 2011 as part of the FEMA CTP studies funded in FY10. The models and mapping resulting from that study were the basis for this City-wide Drainage Master Plan report and alternatives.

iv. *2012 City-wide Drainage Master Plan for Cottonwood Creek*

RPS Espey Consultants was hired by the City of Grand Prairie to develop the City-wide Drainage Master Plan for Cottonwood Creek. The fundamental objective of this study was to comprehensively integrate and update the various hydrologic and hydraulic models that have been developed historically for the Cottonwood Creek watershed as well as to address existing flooding, erosion, and sedimentation within the basin.

2. Ongoing/Future Studies

i. *Cottonwood & Lakeview Watershed Internal Storm Drain Master Plan Detail Study (Y#0927) W.O. #590.31*

Halff Associates was contracted in March 2012 by the City of Grand Prairie to analyze the limitations and deficiencies of the drainage system for portions of the Hot Spot Study Area #4 watershed through the use of detailed hydraulic analysis and to provide improvement recommendations that are effective both functionally and financially. Hot Spot Study Area #4 is located in the upper Henry Branch watershed upstream of Dallas Street. Analysis for this master plan will be performed using the InfoWorks SD modeling package.

ii. *Cottonwood & Lakeview Watershed Internal Storm Drain Master Plan Detail Study (Y#0929) W.O. #590.31*

Halff Associates was contracted in March 2012 by the City of Grand to analyze the limitations and deficiencies of the drainage system for portions of the Cottonwood Creek watershed through the use of detailed hydraulic and hydrologic analysis, and to provide improvement recommendations that are effective both functionally and financially. A total of over 200,000 linear feet of storm drain trunk lines (24" or larger) were analyzed for the 2-year, 10-year, and 100-year events using StormCAD v8i modeling package. Drainage areas were delineated for each modeled inlet and rational method discharges were computed for each modeled storm event. Improvement alternatives were developed for portions of the Henry Branch watershed as part of this study to address flooding problems caused by existing inadequate drainage systems.

II. Hydrologic Studies

II. HYDROLOGIC STUDIES

A. GENERAL

Hydrologic analyses were conducted by Halff Associates for the Henry Branch watershed located within the Cottonwood Creek basin. It is bordered by the Dalworth Creek basin to the northwest, West Fork Trinity River basin to the north and northeast, Fish Creek basin to the south and southeast, and Indian Hills Branch basin to the west. Henry Branch is located within the Lower West Fork Trinity hydrologic region which is characterized by generally flat terrain and impermeable soils.

The USACE Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS, Version 3.5) was utilized to develop the following hydrologic scenarios:

1. Existing (2011) Land Use Conditions
2. Ultimate Land Use Conditions

Significant rainfall events considered for the hydrologic model were the 2-, 5-, 10-, 25-, 50-, 100- and 500-year frequency floods. Detailed watershed delineation, existing and ultimate land use determination, and the hydrologic soil coverage were used to develop the HEC-HMS hydrologic computer model for the Henry Branch watershed. The City's Drainage Design Manual along with Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55) Second Edition were used as guidelines for the new hydrologic analyses in 2011.

B. WATERSHEDS

The following is a brief description of the Henry Branch watershed as part of this supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek. The Overall Watershed Map showing the Henry Branch watershed in relation to the Cottonwood Creek basin can be seen in Appendix A of this report.

The Henry Branch watershed is located just south of Interstate 30 in the northern portion of the City of Grand Prairie. The total contributing watershed area draining to Henry Branch is about 0.37 square miles or approximately 235 acres with an estimated affected population of 1,300 people (U.S. Census Bureau, 2010). Henry Branch is a tributary to Indian Hills Branch and stretches 0.89 miles from its confluence with Indian Hills Branch to just downstream of Dallas Street.

The watershed is currently about 85% urbanized. The upper watershed, upstream of Dallas Street, is heavily developed with commercial and retail properties with a large percentage of impervious area. Multiple storm drainage systems in the upper watershed converge and outfall just downstream of Dallas Street at the headwaters of Henry Branch. The central and lower watershed consists of residential development and public structures including Robert E. Lee Middle School and Charley Taylor Park and Recreation Center. The Overall Watershed Map found in Appendix A of this report shows the Henry Branch watershed and the studied tributary with their locations in regards to the City of Grand Prairie and adjacent communities.

The Henry Branch watershed was sub-divided into four (4) sub-basins. Sub-basin delineations were generated in ESRI's ArcGIS Version 9.3 based on the City of Grand Prairie 2009 Light Detection and Ranging (LiDAR) Terrain Data. Digital storm sewer lines supplied by the City of Grand Prairie, supported by current aerial photography, aided in the basin delineation process.

C. LAND USE

Land use for the Henry Branch watershed has been determined for both existing and ultimate conditions.

1. Existing Land Use

The Henry Branch watershed land use was developed based on the 2005 North Central Texas Council of Governments (NCTCOG) land use data and updated based on current aerial photography (2011). The Henry Branch watershed is 85% developed with commercial, single family residential, multi-family residential, and industrial use. A map of the existing land use within the Henry Branch watershed can be seen in Appendix A of this report.

2. Ultimate Land Use

Ultimate land use conditions were based on the City of Grand Prairie's future land use conditions shapefile. The City's future land use zoning was not revised unless current aerial photography indicated land use with a higher percent impervious than the future land use designation. In these cases, the future land use designation was changed to match existing conditions. A map of the ultimate land use within the Henry Branch watershed can be seen in Appendix A of this report.

D. IMPERVIOUS COVERAGE

Percent impervious is a function of the various land uses within a watershed basin. The percent impervious values for this study were obtained from the City's Drainage Design Manual (December 2010) Table 4.1a and Table 4.1c. A composite percentage of impervious area was computed for each sub-basin for both existing and ultimate conditions. The percent impervious values input into the HEC-HMS model represent the corresponding amount of existing or anticipated development. Table II-1 provides the specific land use classifications and the corresponding percent impervious values for the Henry Branch watershed.

Table II-1 – Land Use and Percent Impervious

Land Use Classification	Impervious (%) Condition	% Land Use in Watershed
Impervious	98%	33.0%
Open Space	0%	15.7%
Single Family Residential	50%	14.9%
Institutional	72%	13.4%
Commercial	85%	10.3%
Multi-Family Residential	65%	9.3%
Industrial	72%	1.2%
Under Construction	15%	1.1%
Utilities	40%	0.6%
Water	100%	0.5%

E. SOIL TYPES

Soil information was obtained from the 2009 United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) 2.2 data model for Dallas County. The watershed is almost entirely Group D soils which are defined as clayey with slow infiltration rates and a high potential for runoff. A small portion of the watershed consists of Group B soils which are defined as soils having some content of gravelly sand with moderate infiltration rates and a low/moderate runoff potential. The hydrologic soils for the Henry Branch watershed are illustrated in the Hydrologic Soils Map found in Appendix A of this report.

The antecedent moisture condition (AMC) defines the soil moisture condition prior to a storm. AMC-II, average soil moisture conditions, was used for the purposes of this study.

F. LOSS RATES

The loss rate of rainfall, caused by evaporation, interception, depression, storage, and infiltration, is typically evaluated and subtracted from the rainfall to determine rainfall excess for each time increment of a storm. For this study, the National Resources Conservation Services (NRCS, previously the Soil Conservation Service, (SCS)) Loss Rate Method was utilized to compute peak flood discharges based on land use, soil classification, and antecedent moisture conditions.

Baseline Curve Numbers (CN) were obtained from TR-55, Table 2.2c, for pasture, grassland, or range for AMC-II, average soil moisture conditions (See Appendix B). Curve Numbers were computed based on a composite percentage of soil types within each sub-basin. Group A soils were defined as having a CN of 39, Group B soils were defined as having a CN of 61, Group C soils were defined as having a CN of 74, and Group D soils were defined as having a CN of 80. Percent impervious values calculated based on land use were used in addition to Curve Numbers for hydrologic computations (Refer to Section II.D).

The initial abstraction (IA) for all watersheds was computed for AMC-II, average soil conditions using the following equation from TR-55:

$$IA = 0.2\left(\frac{1000}{CN} - 10\right)$$

A summary of Curve Numbers, percent impervious values and initial abstractions is included in Appendix B for the Henry Branch watershed.

G. SYNTHETIC UNIT HYDROGRAPH METHOD

The unit hydrograph technique is used to transform rainfall excess to sub-basin runoff. The NRCS Dimensionless Unit Hydrograph method was utilized to compute lag times for each sub-basin to determine runoff hydrographs. Existing time of concentration was computed based on TR-55 methodology. Travel times for channel flow were based on velocities from the hydraulic model.

Halff Associates computed lag times using the following equation:

$$t_P = 0.6 * time\ of\ concentration$$

Time of concentration was computed separately for existing and ultimate conditions. Overland flow length was limited based on existing and ultimate land use conditions. Overland flow was limited to 100 feet for undeveloped and residential land use and 50 feet for industrial/commercial land use. Ultimate conditions shallow concentrated flow was assumed to be all paved.

A summary of lag times is also included in Appendix B for the Henry Branch watershed.

H. RAINFALL

Point rainfall depths were obtained from the City's Drainage Design Manual (December 2010), Table 5.4B, for five minute to twenty-four hour duration rainfall events. The rainfall data is summarized in Table II-2 below.

Table II-2 - Rainfall Depth / Duration for the Henry Branch Watershed

Return Period	**Point Rainfall Depths (inches)**							
(years)	**5-min**	**15-min**	**1-hr**	**2-hr**	**3-hr**	**6-hr**	**12-hr**	**24-hr**
2 yr	0.49	1.04	1.85	2.22	2.45	2.91	3.45	3.95
5 yr	0.57	1.22	2.45	3.00	3.30	3.90	4.70	5.40
10 yr	0.63	1.36	2.86	3.55	3.85	4.65	5.50	6.40
25 yr	0.73	1.56	3.35	4.15	4.55	5.45	6.50	7.50
50 yr	0.80	1.71	3.82	4.65	5.15	6.20	7.35	8.52
100 yr	0.87	1.87	4.25	5.20	5.70	6.92	8.40	9.55
500 yr	1.00	2.20	5.40	6.60	7.40	8.80	10.50	12.00
Ref: City of Grand Prairie Storm Design Manual (December 2010) Table 5.4B								

I. FLOOD ROUTING

The Modified Puls routing method was utilized for reaches modeled in HEC-RAS. The routing was used to establish storage-outflow relationships from steady-flow water surface profiles using the HEC-RAS hydraulic analyses. Storage-outflow relationships were determined for existing channel and floodplain conditions.

J. DETENTION & DIVERSIONS

One (1) private pond located just southwest of the Beltline Road and Sunnybrook Street intersection was identified within the Henry Branch watershed. This pond is located on-channel and does not appear to be designed specifically for detention. The pond was evaluated as part of this study and the results are included in Section X.

There were no diversions identified or modeled in the Henry Branch watershed.

III. Hydraulic Studies

III. HYDRAULIC STUDIES

A. HYDRAULIC ANALYSES

Halff Associates developed detailed hydraulic models using existing and ultimate conditions hydrology for Henry Branch using the City of Grand Prairie LiDAR data (2009), aerial digital photography (2010), Marshall Lancaster & Associates, Inc. provided field surveys (July 2011), and field observations.

Computed flood profiles for Henry Branch were developed using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS, Version 4.1). Halff Associates developed HEC-RAS models for existing (2011) channel and bridge conditions with existing and ultimate land use conditions discharges.

Hydraulic cross-sections were extracted from the City of Grand Prairie one-foot contour interval LiDAR data using the USACE HEC-GeoRAS (Version 4.2.92) computer program. Where detailed survey was available, the survey data was incorporated into the City of Grand Prairie LiDAR data to obtain composite cross sections with surveyed channel data and LiDAR overbank data. Flowlines and channels of non-surveyed hydraulic cross sections were interpolated based on nearby channel surveys when the LiDAR data was not sufficient to define the channels. The locations of hydraulic cross-sections for Henry Branch are displayed in the Floodplain Workmaps included in Appendix A.

Bridge data was input to the hydraulic models for Skyline Drive, Grand Prairie Road, and an inline structure based on survey data. Expansion and contraction coefficients of 0.3 and 0.5 were applied upstream and downstream of structures or other abrupt changes in floodplain width as appropriate. Ineffective flow areas were entered upstream and downstream of structures to account for loss of conveyance due to the structures. Ineffective flow limits were also used in situations where there was storage without conveyance. Normal depth was used as the starting boundary condition for the hydraulic model.

Channel roughness factors (Manning's "n"values) were selected based on standard references, engineering judgment, aerial and field photographs, and field observations of the streams and floodplain areas. References included Chow's 1959 Open Channel Hydraulics, the City's Drainage Design Manual, and the HEC-RAS program built-in references dialog windows. Manning's "n" values for Henry Branch range form 0.02 – 0.08 in the channel and 0.06 – 0.10 in the overbank. Computed peak discharges from the Henry Branch HEC-HMS model for the existing 2-, 5-, 10-, 25-, 50-, 100-, and 500-year and ultimate 100-year frequency floods were included in the existing conditions and ultimate conditions hydraulic models, respectively. The hydraulic results, including computed water surface elevations and profiles, are also discussed in Section IV.B, Hydraulic Study Results.

A floodway was not calculated as a part of this Henry Branch study.

A DVD containing copies of all hydraulic computer models, GIS shapefiles, and figures used in preparation of this report is included in Appendix F.

IV. Hydrologic and Hydraulic Study Results

IV. HYDROLOGIC AND HYDRAULIC STUDY RESULTS

A. HYDROLOGIC STUDY RESULTS

This section of the supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek compiles the results of the detailed hydrologic computer model for the Henry Branch watershed.

Hydrologic parameter data for all sub-basins modeled in the Henry Branch watershed is included in Appendix B. Detailed times of concentration calculations are included in Appendix B and on the DVD in Appendix F of this report.

A detailed HEC-HMS hydrologic computer model has been prepared for the Henry Branch watershed. The existing and ultimate land use conditions were analyzed with channel flood routing data based on existing channels and bridges. Table IV-1 contains available peak flood discharge information for existing and ultimate conditions at key locations along Henry Branch for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood frequencies.

Table IV-1 – Summary of Discharges for Henry Branch

Location	Area	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year		500-Year
	(mi2)	Existing	Existing	Existing	Existing	Existing	Existing	Ultimate	Existing
At Dallas Street	0.15	225	325	375	450	500	550	700	650
Approximately 370 feet upstream of Skyline Road	0.28	300	475	550	700	800	900	1,050	1,100
Approximately 950 feet downstream of Skyline Road	0.35	375	600	700	850	950	1,100	1,300	1,400
At confluence with Indian Hills Branch	0.37	375	600	750	900	1,000	1,150	1,300	1,450

B. HYDRAULIC STUDY RESULTS

This section of the supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek compiles the results of the detailed hydraulic computer model for the Henry Branch watershed.

The computed peak flood discharges from Henry Branch were used in the HEC-RAS hydraulic model to compute existing water surface elevations for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood frequencies and ultimate water surface elevations for the 100-year flood frequency. 100-year water surface elevations increased on average by one-half foot between existing and ultimate conditions for the Henry Branch watershed.

The HEC-RAS hydraulic computer model for Henry Branch and the City of Grand Prairie LiDAR data (2009) were used to delineate the existing conditions 100-year floodplain (Refer to the Floodplain Workmaps in Appendix A of this report). A DVD included in Appendix F contains the hydraulic model and mapping shapefiles developed as part of this report. Flood profiles are included in Appendix B of this report. The water surface elevations for the existing 10-, 50-, 100-, and 500-year frequency events and the ultimate 100-year frequency event are shown for all profiles.

C. QUALITY ASSURANCE / QUALITY CONTROL

Quality assurance / quality control for the 2011 hydrologic and hydraulic studies was performed by Halff Associates, Inc. as part of the City of Grand Prairie – Y#0882 FEMA FY10 CTP Project. Storm events were added to the models during the preparation of this report and were also reviewed by Halff Associates, Inc.

V. Floodplain Mapping

V. FLOODPLAIN MAPPING

A. OVERVIEW

Halff Associates re-mapped the existing 100-year floodplain for Henry Branch as part of the 2011 City of Grand Prairie Cooperating Technical Partners Flood Study. The floodplains are connected through bridges whether the bridge is overtopped or not per FEMA Mapping guidance. The profile should be referenced to determine if a bridge is overtopped as the mapping will always be connected. The floodplains through culverts were delineated based on the modeled conditions through the culvert. If the culvert is not overtopped, the floodplain will be disconnected on either side of the culvert. Base Flood Elevations (BFEs) along Henry Branch were generated based on the HEC-RAS model output data. The BFEs were finalized per the FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix C, dated November 2009. Floodways were not delineated for Henry Branch as part of the CTP study. The results of the CTP Risk Map project were submitted to FEMA in October 2011. Refer to the Appendix A for Floodplain Workmaps of Henry Branch. Floodplain shapefiles are included on the DVD in Appendix F.

VI. Roadway Crossings

Grand Prairie
TEXAS

Figure VI-1
Existing Roadway Crossings

Legend

- 10% Event Overtops Road
- 1% Event Does Not Overtop Road
- Stream Centerline
- Cottonwood CTP 100yr FP
- Henry Existing 100yr FP

N S E W

0 150 300 600 Feet

1 inch = 300 feet

HALFF

VI. ROADWAY CROSSINGS

A. EVALUATION OF EXISTING ROADWAY CROSSINGS

Existing roadway crossings along Henry Branch were evaluated on their level of protection against the existing 10%, 2%, and 1% (10-year, 50-year, and 100-year) chance flood events. Table VI-1 below includes the current hydraulic model, the station and description of the roadway crossing, and if the roadway crossing is overtopped by the existing 10%, 2%, or 1% chance flood event. Water Surface Elevations (WSEL) refer to the upstream face of the structure. Refer to Appendix A for a location map of existing bridge crossings along Henry Branch.

Table VI-1 - Existing Bridge Crossings

Stream: Henry Branch							
Model: Henry_Branch_Watershed.prj (HEC-RAS)							
River Station		**Roadway Crossing**	**Min. Top of Road Elev.**	**10% Event Overtops Road**	**2% Event Overtops Road**	**1% Event Overtops Road**
63.	43+50	*Grand Prairie Road*	510.67	No WSEL=504.84	No WSEL=505.59	No WSEL=505.88
64.	22+00	*Skyline Drive*	485.47	Yes WSEL=485.84	Yes WSEL=486.64	Yes WSEL=486.82

Overtopped roadways were resized for the ultimate 1% (100-year) annual chance flood event. A summary of the roadway improvement alternatives is included in Table VI-2. Refer to Section VII for detailed descriptions of conceptual existing roadway crossing improvements.

Table VI-2 – Existing Roadway Proposed Alternatives

Stream Name	Roadway	Approx. River Station	100-Year Ultimate Discharge	Existing Crossing	Minimum Top of Road Elevation		Approx. Bridge Span/Improvement	100-Year Ult WSEL at US XS	Change in WSEL
					Existing	Proposed			
			(cfs)	(ft)			(ft)	(ft)	(ft)
Henry Branch	Skyline Drive	22+00	1,050	3-5’x3’ Box Culverts	485.47	486.25	3-9’x6’ Box Culverts	484.46	-2.61

B. EVALUATION OF PROPOSED AND FUTURE ROADWAY CROSSINGS

According to the City of Grand Prairie's Master Thoroughfare Plan, there are no planned major thoroughfares within the Henry Branch watershed. The current Master Thoroughfare Plan includes existing crossings at Grand Prairie Road and Skyline Drive along Henry Branch. The existing roadway classifications match the planned roadway classifications indicating there is no intention to resize these roadways in the future at this time.

VII. Alternatives for Streams and Open Channels

VII. ALTERNATIVES FOR STREAMS AND OPEN CHANNELS

Halff Associates considered proposed bridge alternatives for Skyline Road since it was shown to be overtopped by the existing 100-year flood event. The proposed bridge alternative was sized to pass the 100-year ultimate discharge so that the roadway was not overtopped. Mitigation was not considered for proposed bridge alternatives but could be used to reduce the required bridge span and/or height for the final design. A detailed cost estimate for the flood control alternative can be found in Section XII of this report. The total annual cost given with the cost estimate is based on a 50-year project life and a 7% discount rate.

The City of Grand Prairie 2009 LiDAR data deliverables included a shapefile for buildings that were identified during the data acquisition. This building shapefile was intersected with the delineated existing 100-year floodplain for Henry Branch to identify potentially flooded structures. A total of four (4) structures were identified within the existing 100-year floodplain. Of these structures, one (1) was considered a significant, enclosed structure that would qualify as an insurable structure. Flood protection alternatives were not considered economically feasible and buyouts are not recommended for these structures.

Henry Branch is considered waters of the United States. Construction of improvements within the waters of the United States requires permitting by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act. Bridge improvements can typically be permitted under Nationwide Permit 14 (NWP 14) for Linear Transportation Crossings to satisfy the USACE requirements. Refer to Appendix E for more information regarding Section 404 Permits.

The following is a brief description of the proposed conceptual improvement within the Henry Branch watershed. Refer to Table VI-2 for a summary of conceptual existing bridge crossing improvements.

1. SKYLINE DRIVE AT HENRY BRANCH (STREAM STATION 22+00)

The bridge crossing at Skyline Drive consists of three 5’x 3’ box culverts. The existing culverts at Skyline Drive have the capacity to pass the 5-year storm event without the roadway being overtopped. Skyline Drive is overtopped by the existing 10-year storm event with the ultimate 100-year storm event overtopping the roadway by more than 1.5 feet. Table VII-1 below shows the level of protection for Skyline Drive.

Table VII-1 – Skyline Drive Level of Protection

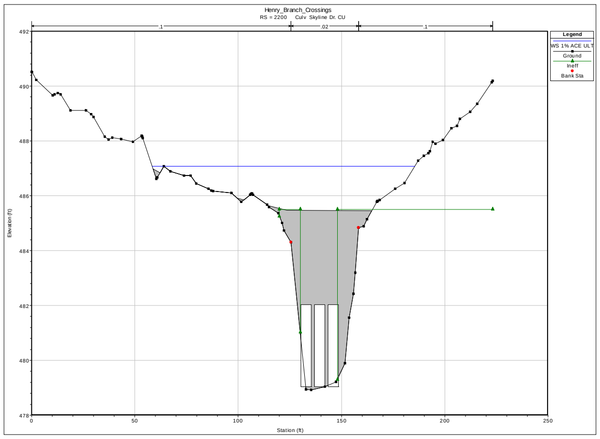
Stream: Henry Branch										
Model: Henry_Branch_Watershed.prj (HEC-RAS)										
River Station		**Roadway Crossing**	**Min. Top of Road Elev.**	**Ex. 50% Event Overtops Road**	**Ex. 20% Event Overtops Road**	**Ex. 10% Event Overtops Road**	**Ex. 4% Event Overtops Road**	**Ex. 2% Event Overtops Road**	**Ex. 1% Event Overtops Road**
64.	22+00	*Skyline Drive*	485.47	No WSEL= 482.98	No WSEL= 484.26	Yes WSEL= 485.84	Yes WSEL= 486.38	Yes WSEL= 486.64	Yes WSEL= 486.82

<u>Alternative 1</u>

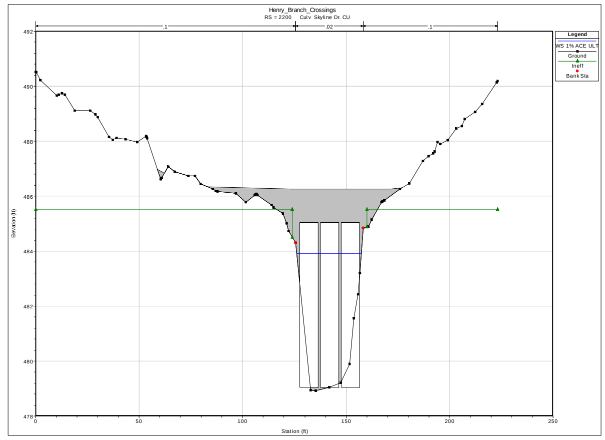
- Elevate minimum Top of Road to 486.25’
- Construct 3 – 9’x 6’ Concrete Box Culverts

STATEMENT OF PROBABLE COST - 2012	
Subtotal	$202,000
25% Contingency	$50,500
CONSTRUCTION TOTAL	**$253,000**
10% for Engineering and Survey	$25,300
TOTAL	**$280,000**

Refer to Section XII of this report for a detailed breakdown of the preliminary cost estimate. If the Alternative 1 improvements at Skyline Drive were implemented, the roadway would no longer be overtopped by the ultimate 100-year storm event. The ultimate 100-year water surface elevations are lowered up to 1.62’ upstream of Skyline Drive as a result of the proposed improvements; however, no existing structures benefit from the decrease in water surface elevations. Valley storage loss should be minimal, but will need to be checked for the final bridge design and mitigation plan prior to construction. A FEMA Letter of Map Revision (LOMR) will be necessary after construction of the improvements to incorporate floodplain mapping revisions into the FEMA mapping. Alternative 1 would require construction within the waters of the United States which can be permitted under Nationwide Permit 14 for Linear Transportation Crossings to satisfy the USACE requirements from Section 404 of the Clean Water Act.



Skyline Road Existing Conditions



Skyline Road Proposed Conditions

VIII. Storm Water Infrastructure Analysis

VIII. STORM WATER INFRASTRUCTURE ANALYSIS

A. OVERVIEW

Storm water infrastructure analysis was not performed as part of the FEMA CTP and Road Map Drainage Master Plan (Y#0882) contract. Halff Associates was contracted in March 2012 by the City of Grand Prairie to analyze the limitations and deficiencies of the drainage system for portions of the Hot Spot Study Area #4 watershed through the use of detailed hydraulic analysis and to provide improvement recommendations that are effective both functionally and financially. Hot Spot Study Area #4 is located in the upper Henry Branch watershed, upstream of Dallas Street. Analysis for this master plan will be performed using the InfoWorks SD modeling package and should be included as an attachment to this report upon completion.

IX. Channel Stability Assessment & Erosion Hazard Analysis

IX. CHANNEL STABILITY ASSESSMENT & EROSION HAZARD ANALYSIS

A. INTRODUCTION

Halff Associates was tasked to prepare an analysis of stream bank restoration improvement alternatives along with preliminary quantities/estimates of probable cost for Henry Branch. The critical data utilized for this analysis comes from the Henry Branch Geomorphic Stream Assessment that was prepared by Freese and Nichols, Inc. (FNI) included in Appendix C of this report. Only alternatives considered to be a public benefit were proposed as part of this study. The City of Grand Prairie Resolution 3919 found in Appendix E addresses the City policy concerning public and private benefits. The following sections will describe standard erosion prevention measures (structural and non-structural) for stream bank and channel stabilization and recommended alternatives at key locations along Henry Branch.

B. EROSION HAZARD SETBACKS (NON-STRUCTURAL)

As defined by the City's Drainage Design Manual, an Erosion Hazard Setback (EHS) is defined as the minimum horizontal distance from the toe of the slope of the bank of a watercourse that a structure must be constructed or placed to be outside the erosion hazard area. It is recommended that no building, fence, wall, deck, swimming pool or other structure should be located, constructed, or maintained within the area encompassing the setback. Stream bank erosion hazard setbacks may be required to extend beyond the limits of the regulatory floodplain.

The procedure for determining the stream bank erosion hazard setback zone per Section 2.6.F of the City's Drainage Design Manual is as follows:

1. Locate the toe of the natural stream bank.
2. From this toe, construct a line sloping at 4 horizontal to 1 vertical towards the bank until it intersects natural ground.
3. From this intersection, add 10 feet in the direction away from the stream to locate the outer edge of the erosion hazard setback.

As previously stated, setbacks established for the purposes of stream bank erosion hazard protection may extend beyond the limits of the regulatory floodplain limits. If the exercise above yields an erosion setback limit within the regulatory floodplain limits, then Halff recommends utilizing the limits of the regulatory floodplain (as shown in Appendix A) at a minimum as the outer limits of the erosion setback zone.

Potential situations may occur where stream bank erosion hazard setback lines could be reduced where stream banks consist entirely or partly of rock. In these areas, the interface of the stream bank with the top of the unweathered rock strata should be located with the assistance of a qualified geotechnical engineer. This point on the surface of the slope will be the toe of a 3:1 slope intersecting natural ground. The actual setback line should then be located 25 feet beyond this intersection (City standard criteria is 10 feet beyond this intersection), assuming it is beyond the regulatory floodplain limits. Once again, setback lines should take into account future widening and downcutting of existing channels.

As an alternative to the setback, the developer or landowner may submit to the City Engineer a plan to stabilize and protect stream banks threatened by erosion. Stabilization shall be of a permanent nature, consistent with the guidelines established in this study and by the City of Grand Prairie, and shall be designed and sealed by a licensed professional engineer. It is recommended that these limited erosion protection measures be used as a guideline to plan erosion protection alternatives in the Henry Branch watershed.

C. EROSION CONTROL MEASURES (STRUCTURAL)

Halff Associates identified several structural erosion control methods that could be used to help control the effects of erosion on Henry Branch. Typically, grade control structures are used to help prevent channel erosion and the corresponding downstream deposition. Following is a brief description of the different erosion control methods included in this report.

1. Grade Control Structures

i. Purpose

Grade control structures are utilized to provide stability to the streambed (refer to Appendix D). The most common method of establishing grade control is the construction of in-channel grade control structures or “hard points.” Two basic types of grade control structures exist. One type is a “bed control” structure as it is designed to provide a hard point in the streambed that is capable of resisting the erosive forces of a degradational zone. The second type is referred to as a "hydraulic control" structure since it functions by reducing the energy slope along the degradational zone to the point that the stream is no longer capable of scouring the bed. Important factors must be considered when siting grade control structures.

ii. Hydraulic Considerations

Hydraulic siting of grade control structures is a critical element of the design process, especially determining the anticipated drop at the structure. Procedures for hydraulic siting of these structures are also described in Appendix D. The primary factors affecting the final equilibrium slope upstream of a structure include sediment concentration and load, the channel characteristics (slope, width, depth, roughness, etc.), and the hydraulic effect of the structure. Also important is the time it takes for the equilibrium slope to develop, which could be over a period of a few hydrographs or over many years.

iii. Other Considerations

In some cases, traditional bank stabilization measures may not be feasible where system-wide instabilities exist. In these instances, grade control structures may be more of an appropriate solution. Grade control structures can enhance the bank stability of the bed, can reduce bank heights due to sediment deposition, and can reduce velocities and scouring potential by creating a backwater situation. For flood control, considerations should be given to the potential to cause overbank flooding. Grade control structures are often designed to be hydraulically submerged at flows less than bank-full so the frequency of overbank flooding is not significantly affected. Final siting of grade control structures should also try to minimize adverse environmental impacts to the system and instead provide direct environmental benefits to streams (scour holes and man-made pools provide fish habitat).

iv. *Existing Structures*

Grade control structures can have adverse as well as beneficial effects on existing structures. For structures upstream of hydraulic control measures, the potential exists for increased stages within the structure and also for sediment deposition. Many structures already provide some measure of grade control (usually culverts), however they may not be able to be relied on to provide long-term grade control. Grade control structures can also be implemented during planned improvements to existing structures and as new structures are being built.

v. *Local Site Conditions*

When planning grade control structures, the final siting is often adjusted to accommodate local site conditions or local drainage situations. A stable upstream alignment that provides a straight approach for a grade control structure is critical. In a very sinuous channel, this could require straightening the channel to provide an adequate approach (with considerations for USACE jurisdictional waters). Upstream meanders should also be stabilized prior to implementing a downstream grade control structure.

vi. *Downstream Channel Response*

Since grade control structures affect the sediment delivery to downstream reaches, it is necessary to consider the potential impacts to the downstream channel when grade control structures are planned. Bed control structures reduce the downstream sediment loading by preventing the erosion of the bed and banks, while hydraulic control structures have the added effect of trapping sediments. The concern is that reduced sediment loads to downstream areas will cause degradational problems downstream. A solution would be to reduce the number of grade control structures upstream or add additional grade control structures in the downstream reach.

vii. *Typical Grade Control Structures for Henry Branch*

Examples of typical grade control structures are included in Appendix D, including hydraulic grade control structures such as Loose Rock Dams and bed control structures such as Rock Chutes and Gabion Check Dams. Various other grade control structure types do exist; however, the typical structures included in this report are the basis for cost estimating purposes. The City of Grand Prairie is not required to solely utilize these typical structures since actual channel/site conditions may require different structure types, and Halff would recommend that other cost-effective solutions be evaluated prior to actual design of the grade control structures.

D. U.S. ARMY CORPS OF ENGINEERS SECTION 404 PERMITS

For any future channel or slope improvements to Henry Branch, considerations must be made to impacts to jurisdictional waters of the United States. A wetland investigation and determination should be performed prior to construction of any proposed improvements within the channel. Minor improvements to jurisdictional waters may fall into a Nationwide Permit category, where more extensive modifications of jurisdictional waters would require an extensive Individual Permit process. Refer to Appendix E to locate current Nationwide Permit descriptions and descriptions of and an application for a USACE Individual Permit. Nationwide Permits that could apply to potential channel and development improvements include:

- Nationwide Permit 3 – Maintenance
- Nationwide Permit 13 – Bank Stabilization
- Nationwide Permit 14 – Linear Transportation
- Nationwide Permit 27 – Stream and Wetland Restoration Activities
- Nationwide Permit 29, 39 – Residential, Commercial, and Institutional Activities
- Nationwide Permit 41 – Reshaping of Existing Drainage Ditches

The USACE web-site has more information on the current permits. Please visit http://www.swf.usace.army.mil/ for additional information.

E. OVERVIEW OF ALTERNATIVES TO HELP STABILIZE STREAM BEDS AND BANKS ALONG HENRY BRANCH

Based on the Henry Branch Stream Assessment report, Halff Associates has prepared the following alternatives to help stabilize stream beds and banks along Henry Branch. Erosion sites identified in the Stream Assessment report were ranked based on severity of erosion and likelihood of impending slope failure with consideration to the project cost of each proposed alternative. Halff Associates utilized these rankings to establish a prioritization of erosion sites as illustrated in Table IX-1 below. See Appendix A for a location map of erosion sites.

Table IX-1 – Stream Stability and Erosion Hazard Alternatives for Henry Branch

Rank	Location	Proposed Alternative	Owner
1	Station 22+70	Remove Concrete Dam Structure; Install Rock Chute	Private
2	Just Downstream of Skyline Road	Place 24" Rock Rip-Rap	Public
3	Stations 6+50 & 36+00	Install Rock Chutes	Public

1. CONCRETE DAM STRUCTURE REMOVAL/MAINTENANCE (STREAM STATION 22+70)

A privately owned concrete dam structure is currently located in-channel at approximate stream station 22+70 just upstream of Skyline Road. The dam structure has been almost completely undercut by the channel and could potentially be washed downstream and block the culverts at Skyline Road during a storm event. Due to the severely compromised condition of this structure, Halff recommends immediate action to protect the roadway and structure crossing downstream. From discussions with the City, it appears that the structure is on private property and the function of the structure is unknown. Halff recommends further coordination with the owner of this structure to determine its function and decide whether it can be removed. Although the dam is a privately owned structure, this alternative was considered a public benefit. If the dam structure were to fail and be washed downstream, the culverts across Skyline Drive could be blocked causing potential roadway flooding and/or structure flooding.

2. ROCK RIP-RAP PLACEMENT (STREAM STATION 20+00)

Halff recommends the placement of 24" rock rip-rap downstream of the concrete lined channel at approximate stream station 20+00. The end of the concrete channel is undercut and the channel is severely eroding immediately downstream of the concrete lining. The rock rip-rap should extend a minimum of twenty-five (25) feet downstream of the concrete channel.

3. ROCK CHUTES ALONG HENRY BRANCH (STREAM STATIONS 6+50 & 36+00)

Rock Chutes are proposed as a stream bed stabilization alternative along Henry Branch to serve as hard points and help control the down-cutting effects of the stream in these areas. Two (2) rock chutes were strategically located at approximate stream stations 6+50 and 36+00 where existing "knickpoints" were observed during the field inspection of Henry Branch as part of the Stream Assessment. Knickpoints are locations along the creek where there is a short, steep slope in the active channel. The proposed rock chutes would consist of 3'x3' gabion baskets across the channel at the upstream and downstream ends to act as toe walls to prevent lifting, undermining, and/or sliding of the rock chutes. The remainder of the rock chute would consist of 24” rock rip-rap across the bottom of the channel and along the bank side slopes up to the bankfull elevation. A typical section of the proposed rock chutes is illustrated in Appendix D of this report. “Bankfull” can be described as the area immediately above the down-cutting location. The gabion mattress and rock rip-rap would be situated along the channel side slopes and tied in at the bankfull elevation. Minimum 2:1 side slopes for placement of rock rip-rap is recommended for a stable rock slope. Each proposed rock chute location will need to be evaluated on a case-to-case basis to determine the bankfull elevation and side slope gradients. The length of each rock chute will need to be determined in the field and dictated by the depth of each knickpoint.

X. Dams/Levees/Detention/Drainage Reviews

X. DAMS / LEVEES / DETENTION / DRAINAGE REVIEWS

A. DAMS/LEVEES

One (1) small private pond was identified within the Henry Branch watershed located just southwest of the Beltline Road and Skyline Road intersection. The spillway of the dam is in poor condition as a result of heavy erosion occurring around the concrete spillway outlet. Figure X-1 shows the location of the pond and Figures X-2 and X-3 show pictures of the spillway structure taken during the Henry Branch Stream Assessment performed by Freese and Nichols in June 2012.

Figure X-1 – Henry Branch On-Channel Pond (Private)

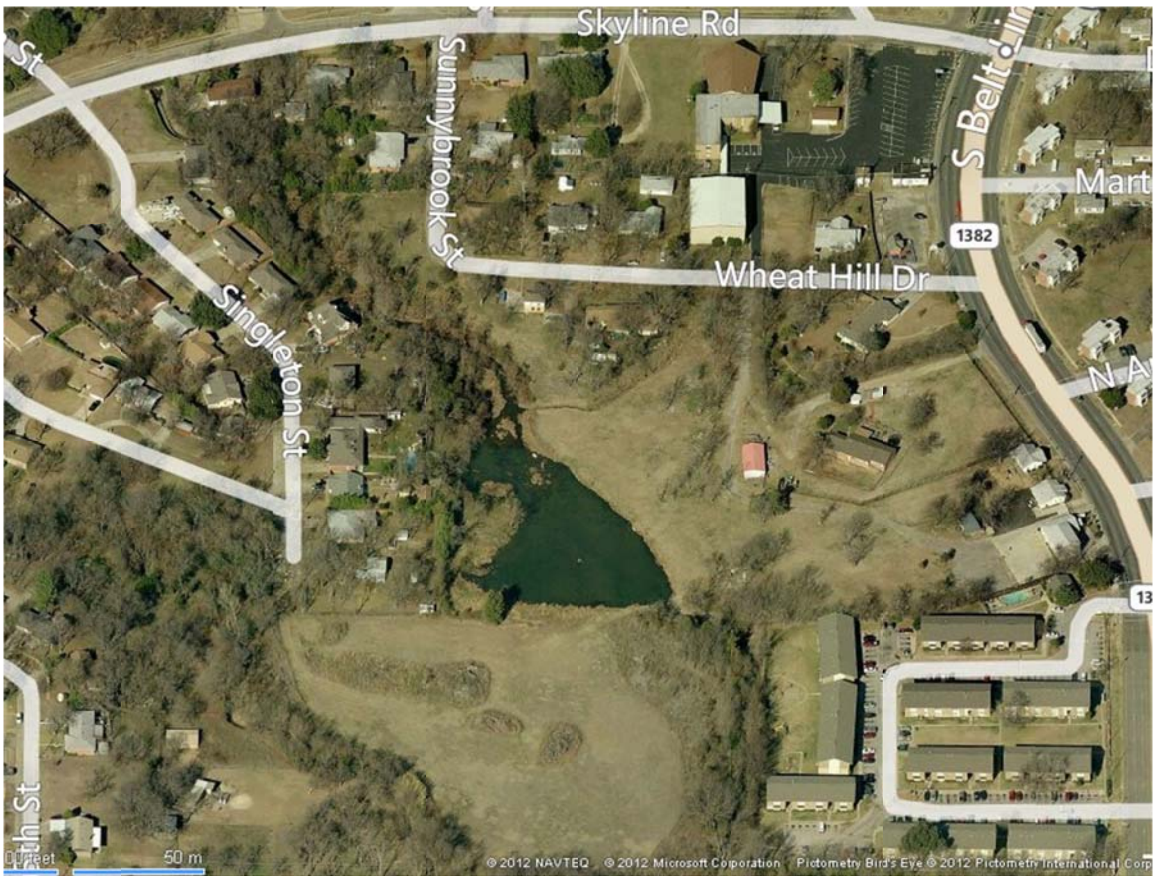


Figure X-2 – On-Channel Pond: Spillway Upstream

Figure X-3 – On-Channel Pond: Spillway Downstream

B. DETENTION PONDS

There are no detention ponds located within the Henry Branch watershed.

C. POND MAINTENANCE

The on-channel pond located along Henry Branch was visually inspected by RPS Espey Consultants as part of the City-wide Drainage Master Plan for Cottonwood Creek. Please reference Section X.C Pond #1 from the Cottonwood Creek CWDMP for the maintenance report for this pond.

D. DRAINAGE REVIEWS

There are no drainage reviews located within the Henry Branch watershed.

XI. Storm Drain Outfall Assessment

XI. STORM DRAIN OUTFALL ASSESSMENT

RPS Espey Consultants examined photographs provided by the City of Grand Prairie of each storm drain outfall located within the Cottonwood Creek watershed as part of the City-wide Drainage Master Plan for Cottonwood Creek. All storm drain outfalls within the Henry Branch watershed were included within this review. Please reference Section XI of the Cottonwood Creek CWDMP for the condition of each outfall located within the Henry Branch watershed.

XII. Preliminary Quantities/ Estimates of Probable Cost

XII. PRELIMINARY QUANTITIES/ESTIMATES OF PROBABLE COST

Preliminary quantities and estimates of probable cost were calculated for stream and open channel alternatives from Section VII of this report.

The roadway improvement cost estimates were based on the existing roadway widths. Any future expansion of these roadways will need to be accounted for with an update to the included cost estimates.

The following estimates of probable cost were prepared using standard cost estimate practices and it is understood and agreed that these statements are estimates only.

HALFF ASSOCIATES, Inc.

4000 Fossil Creek Boulevard
Fort Worth, Texas 76137
(817) 847-1422

CLIENT:	City of Grand Prairie	**DATE:**	8/30/2012
PROJECT	Supplemental CWDMP for Cottonwood Creek	**PREPARED BY:**	bp/sr
	Henry Branch at Skyline Drive	**AVO:**	27930
	Total Replacement (stream station 22+00)		

ESTIMATE OF PROBABLE COST

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
	Henry Branch at Skyline Drive Improvements				
1	Mobilization	LS	1	$20,000	$20,000
2	Traffic Control	LS	1	$25,000	$25,000
3	Remove and Dispose Existing Bridge	SF	1,200	$15	$18,000
4	Three - 9'x6' CBC	LF	190	$325	$61,750
5	Sawcut for Removal of Pavement	FT	120	$5	$600
6	Pavement Repair	SF	5,400	$7	$37,800
7	Compacted Backfill (Select Material)	CY	1,000	$20	$20,000
8	Furnish and Install 24" Rock Rip-Rap	CY	100	$120	$12,000
9	Furnish and Install Turf Reinforcing Mat	SY	1,000	$10	$10,000
10	Furnish and Install Seeding	SY	1,000	$2	$2,000
				Subtotal	$207,000
				25% Contingency	$51,800
				CONSTRUCTION TOTAL	**$259,000**
	Engineering, Surveying, and Environmental			10% of Construction	$25,900
				TOTAL	**$280,000**
				TOTAL ANNUAL	**$20,000**

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and that the Engineer shall not be liable to Owner or to a third party for any failure to accurately estimate the cost of the project, or any part thereof.

HALFF ASSOCIATES, Inc.
4000 Fossil Creek Boulevard
Fort Worth, Texas 76137
(817) 847-1422

CLIENT: City of Grand Prairie
PROJECT: Supplemental CWDMP for Cottonwood Creek
Henry Branch - Remove Concrete Dam Structure
Install Rock Chute (Station 22+70)

DATE: 8/30/2012
PREPARED BY: bp/sr
AVO: 27930

ESTIMATE OF PROBABLE COST

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
	Remove Concrete Dam Structure				
1	Site Preparation/Access/Care of Water	LS	1	$10,000	$10,000
2	Remove/Dispose Concrete Dam Structure	LS	1	$15,000	$15,000
	Install Rock Chute				
1	Site Preparation/Access/Care of Water	LS	1	$5,000	$5,000
2	Furnish and Install 24" Rock Rip-Rap	CY	120	$120	$14,400
3	Filter Fabric for 24" Rock Rip-Rap	SY	240	$2	$480
4	3 'x 3' Gabions (PVC Wiring)	CY	20	$250	$5,000
5	Filter Fabric for 3 'x 3' Gabions	SY	60	$2	$120
6	Channel Excavation	CY	150	$12	$1,800
7	Grass Sodding	SY	50	$10	$500
				Subtotal	$52,300
			25% Contingency		$13,100
			CONSTRUCTION TOTAL		**$65,000**
	Engineering, Surveying, and Environmental Design		10% of Construction		$6,500
				TOTAL	**$72,000**
			TOTAL ANNUAL		**$5,000**

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and that the Engineer shall not be liable to Owner or to a third party for any failure to accurately estimate the cost of the project, or any part thereof.

HALFF ASSOCIATES, Inc.
4000 Fossil Creek Boulevard
Fort Worth, Texas 76137
(817) 847-1422

CLIENT:	City of Grand Prairie	**DATE:**	8/30/2012
PROJECT:	Supplemental CWDMP for Cottonwood Creek	**PREPARED BY:**	bp/sr
	Henry Branch - Place 24" Rock Rip-Rap	**AVO:**	27930
	Downstream of Concrete Channel (Station 20+00)		

ESTIMATE OF PROBABLE COST

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Site Preparation/Access/Care of Water	LS	1	$7,500	$7,500
2	Furnish and Install 24" Rock Rip-Rap	CY	30	$120	$3,600
3	Filter Fabric for 24" Rock Rip-Rap	SY	500	$2	$1,000
				Subtotal	$12,100
			25% Contingency		$3,000
			CONSTRUCTION TOTAL		**$15,000**
	Engineering, Surveying, and Environmental Design		10% of Construction		$1,500
				TOTAL	**$17,000**
			TOTAL ANNUAL		**$1,000**

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and that the Engineer shall not be liable to Owner or to a third party for any failure to accurately estimate the cost of the project, or any part thereof.

HALFF ASSOCIATES, Inc.

4000 Fossil Creek Boulevard
Fort Worth, Texas 76137
(817) 847-1422

CLIENT: City of Grand Prairie
PROJECT: Supplemental CWDMP for Cottonwood Creek
Henry Branch - Install Two Rock Chutes

DATE: 8/30/2012
PREPARED BY: bp/sr
AVO: 27930

ESTIMATE OF PROBABLE COST

Item No.	Description	Unit	Total Quantity	Unit Cost	Total Amount
1	Site Preparation/Access/Care of Water	LS	1	$10,000	$10,000
2	Furnish and Install 24" Rock Rip-Rap	CY	120	$120	$14,400
3	Filter Fabric for 24" Rock Rip-Rap	SY	240	$2	$480
4	3 'x 3' Gabions (PVC Wiring)	CY	20	$250	$5,000
5	Filter Fabric for 3 'x 3' Gabions	SY	60	$2	$120
6	Channel Excavation	CY	150	$12	$1,800
7	Grass Sodding	SY	50	$10	$500
				Subtotal	$32,300
			25% Contingency		$8,100
			CONSTRUCTION TOTAL		**$40,000**
	Engineering, Surveying, and Environmental Design		10% of Construction		$4,000
		TOTAL for Individual Rock Chute			**$44,000**
		TOTAL for Two Rock Chutes			**$88,000**
			TOTAL ANNUAL		**$6,000**

This statement was prepared utilizing standard cost estimate practices. It is understood and agreed that this is an estimate only, and that the Engineer shall not be liable to Owner or to a third party for any failure to accurately estimate the cost of the project, or any part thereof.

XIII. Evaluation & Prioritization/ Phasing & Implementation

XIII. EVALUATION & PRIORITIZATION/PHASING & IMPLEMENTATION

A. EVALUATION & PRIORITIZATION

Halff Associates developed one (1) stream and open channel alternative for Henry Branch that is described in detail in Section VII of this report. A process of assigning ranking factors is typically utilized to rank short-term and long-term priority projects based on criteria from Section II.G of the City of Grand Prairie City-Wide Drainage Master Plan Road Map. Even though there is only one open channel alternative included in this watershed, ranking criteria was still assigned to allow this project to be incorporated into the overall City-wide implementation plan. Table XIII-1 at the end of Section XIII shows the ranking criteria assigned to Skyline Drive. The following is a brief summary of the criteria and methodology utilized to rank short-term and long-term priority projects.

1. Ranking Criteria:

v. *Number of properties/structures benefited* – The number of structures benefited by the reduction in flood damage was determined for each proposed CIP. Due to the lack of development at the majority of proposed CIP locations, there were no structures benefited by the reduction in flood damage.

vi. *Estimates of probable cost* – A preliminary cost-estimate was determined for each proposed CIP and then categorized as follows:

- **Small Projects** – Less than $500,000
- **Medium Projects** - $500,000 to $1,500,000
- **Large Projects** – $1,500,000 to $5,000,000
- **Extra-Large Projects** – $5,000,000 to $10,000,000
- **Super Size Projects** – Greater than $10,000,000

vii. *Roadway Type Benefited* – Each proposed CIP roadway was categorized based on existing roadway type. Categories include **HWY, P7U, P6D, P4D, P3U, M5U, M4U, M3U, C2U,** and **No Roadway** (if no roadway benefits are included with project).

viii. *Roadway Flood Event Protection* – The level of flood protection, if no improvements were made, was determined for each proposed CIP roadway crossing. Halff Associates described existing roadway crossing protection based on the following storm events: 2-year, 5-year, 10-year, 25-year, 50-year, or 100-year (existing).

ix. *Roadway Citizens Protected/Impacted* – Per Ranking Factor #3 below, an approximate percentage of total roadway citizens impacted was determined for each proposed CIP if no improvements were made.

x. *Ultimate 100-Year Discharge* – The ultimate 100-year discharge was determined for each proposed CIP location.

2. Ranking Methodology:

i. *Ranking Factor #1*- The initial ranking factor was based on the estimate of probable cost versus the number of properties/structures benefited:

<table>
<tr><th colspan="2" rowspan="2">Determine Initial Ranking Factor</th><th colspan="3">No. of Properties/Structures Benefited</th></tr>
<tr><th>High
> 10</th><th>Medium
5 to 10</th><th>Small
< 5</th></tr>
<tr><td rowspan="5">Estimate of Probable Cost ($)</td><td>Small
< $500k</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Medium
$500k - $1.5Mil</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>Large
> $1.5Mil</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>X-Large (> $5M)</td><td>6</td><td>7</td><td>8</td></tr>
<tr><td>Super-Size
(>$10M)</td><td>9</td><td>10</td><td>11</td></tr>
</table>

ii. *Ranking Factor #2* - A second ranking factor was determined based on the number of citizens impacted, by potential for roadway shutdowns if no improvements were made on existing roadways, and by a cost to benefit ratio of proposed improvements per roadway citizens impacted.

Step 1 – Determine Existing Roadway Type

Roadway Type
HWY
P7U
P6D
P4D
P3U
M5U
M4U
M3U
C2U

Step 2 – Determine Existing Conditions Roadway Flood Event Protection and Percentage of Roadway Citizens Protected

Roadway Flood Event Protection	Percentage of Citizens Protected [1]
1-Year	0%
2-Year	15%
5-Year	35%
10-Year	50%
25-Year	70%
50-Year	85%
100-Year	100%

[1]Based on approximation, using logarithmic chart, with 1-Year Event coverage protecting 0% and with 100-Year Event protecting 100%

Step 3 – Determine Percentage of Roadway Citizens Impacted
100% minus percentage of citizens protected

Step 4 – Determine Number of Roadway Citizens Impacted

Roadway Type Benefited	Percentage of Citizens Protected [1]
HWY	20800
P7U	12740
P6D	11700
P4D	7800
P3U	5460
M5U	8450
M4U	6760
M3U	5070
C2U	2730

[1]Based on percentage of citizens impacted multiplied by [No. Lanes * 4 hours impacted *hourly volume per lane * Level of Service C Traffic Volume (see table below)]

Grand Prairie Classification	NCTCOG Classification	Lanes	Hourly Service Vol./lane	NCTCOG LOS*			Current UDC "LOS C" Traffic Volume
				Roadway Capacity LOS E	LOS D	LOS C	
P7U	Principal Arterial-Undiv.	7	700	49,000	39,200	31,850	42,000
P6D	Principal Arterial-Divided	6	750	45,000	36,000	29,250	42,000
P4D	Principal Arterial-Divided	4	750	30,000	24,000	19,500	28,000
P3U	Principal Arterial-Undiv.	3	700	21,000	16,800	13,650	18,000
M5U	Minor Arterial	5	650	32,500	26,000	21,125	28,000
M4U	Minor Arterial	4	650	26,000	20,800	16,900	22,000
M3U	Minor Arterial	3	650	19,500	15,600	12,675	18,000
C2U	Collector	2	525	10,500	8,400	6,825	10,000
L2U	Local Street	2	525	10,500	8,400	6,825	8,000
LU	Local Street	1	525	5,250	4,200	3,413	8,000
R2U	Rural Street	2	525	10,500	8,400	6,825	8,000

* = from the Dallas-Fort Worth Regional Travel Model Manual, Exhibits 23 and 24
NCTCOG capacity: LOS E = (# lanes) * 10 * (NCTCOG Hourly Service Volume per Lane)
NCTCOG capacity: LOS D = (LOS E) * .8
NCTCOG capacity: LOS C = (LOS E) * .65

Step 5 – Divide Cost to Benefit of Roadway Number of Citizens Impacted
Divide the estimate of probable cost by the results from Step 4 to determine the cost to benefit ratio (in dollars)

Step 6 – Develop Second Ranking Factor with highest rank being the lowest cost to benefit ratio

iii. *Ranking Factor #3* – A third ranking factor was determined based on the total tax value of all the properties with structures that are benefited by the project from Ranking Factor #1. The Third Ranking Factor was based on the table below.

Total Tax Value of Properties with Structures Benefited	Third Ranking Factor
$2,000,000 +	1
≥ $1,900,000	2
≥ $1,800,000	3
≥ $1,700,000	4
≥ $1,600,000	5
≥ $1,500,000	6
≥ $1,400,000	7
≥ $1,300,000	8
≥ $1,200,000	9
≥ $1,100,000	10
≥ $1,000,000	11
≥ $900,000	12
≥ $800,000	13
≥ $700,000	14
≥ $600,000	15
≥ $500,000	16
≥ $400,000	17
≥ $300,000	18
≥ $200,000	19
$0 to $199,999	20

iv. *Initial Ranking* - A total ranking factor was determined using the summation of Ranking Factors #1, #2, and #3. The initial ranking of proposed CIPs was determined with the top ranked (#1) project having the lowest total ranking factor.

v. *Final Ranking* - If two or more projects had the same initial ranking, the projects were sorted further using the ultimate 100-year discharge at each project location. The higher ranked of these projects was the one with the greatest ultimate 100-year discharge at the project location. If two projects in different watersheds had the same initial ranking and similar ultimate 100-year discharges (within 500 cfs) then the projects were ranked in order of the lowest estimate of probable cost.

B. PHASING & IMPLEMENTATION

1. Final Short-term Priorities Implementation

Short-term Priority CIPs could generally be described as those projects with an initial ranking factor of 1, 2, or 3 from the matrix under Ranking Factor #1 above. The Short-term Priority projects would become the City's key Capital Improvement Projects for immediate implementation, contingent upon City Council approval and allocated funding. Prior to beginning the construction process on these projects, the following key issues may need to be examined:

- Public or private participation in funding and implementation
- Drainage right-of-way or easement needs
- Permitting – FEMA, NCTCOG, U.S. Army Corps of Engineers, Texas Commission on Environmental Quality , or Environmental Protection Agency
- Public or neighborhood meetings to describe project and receive citizen feedback
- Adherence of project to City's ordinances and standards for construction

2. Final Long-term Plan Implementation

All other CIPs not classified as Short-term priorities will be considered **Long-term CIPs**. These need to be planned properly with funding allocated for future construction, contingent on City Council approval. Projects that could be constructed by phasing (i.e., will phasing provide immediate benefits or does the whole project need to be constructed for benefits to occur) would need to be re-evaluated by each Phase and re-ranked accordingly with the other CIPs.

For the Long-term projects, the following key issues may need to be examined:

- All the Short-term issues listed above
- Longer range funding plans for larger projects, including phasing (look into State and Federal grants and construction loans)
- More global view, watershed-wide or regional type projects (look into cooperative efforts with U.S. Army Corps of Engineers, NCTCOG, or adjacent communities)
- Examine how increased development of the City's flood warning system could provide further benefits to these areas until funding is allocated for project implementation
- Non-structural measures including:
    - **Buy-out program –** City would need to decide on perpetual maintenance of property or re-selling property after measures are taken to remove lot from flood hazard. Recommend pursuit of City funding, if available, or associated

grants (see CWDMP Roadmap Section II.D – Funding Opportunities), if applicable

- Enforce **new and/or improved development standards** to restrict future development in flood hazard areas

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Figure XIII-1
CIP Location Map

Legend

- Roadway Improvement
- Erosion Alternative Locations
- Stream Centerline
- Cottonwood CTP 100yr FP
- Henry Existing 100yr FP

N
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0 150 300 600 Feet

1 inch = 300 feet

HALFF

Table XIII-1 Stream and Open Channel Capital Improvement Projects

Preliminary Short-Term Priorities & Long-Term Implementation

	Capital Improvement Project	Project Size & Short-Term/Long-Term	Step 1 - Initial Ranking Factor - Estimate of Probable Cost vs. # Structures Benefited [1]			Step 2 - Second Ranking Factor - Cost to Benefit of Roadway Number of Citizens Impacted [2]							Step 3 - Tax Value of Benefited Property Structures [7]		Sum of 1st, 2nd, and 3rd Factors - Step 4	Initial Rank - Step 4	100-Year Ultimate Discharge at CIP Location - Step 5		Final Rank - Step 6
			# Structures	Cost	1st Factor [1]	Type	Roadway Flood Event Protection	Roadway % Citizens Protected [3]	Roadway % Citizens Impacted [4]	Roadway # Citizens Impacted [5]	Cost to Benefit Roadway # Citizens Impacted [6]	2nd Factor	Tax Value of Property Structures Benefited	3rd Factor	Total	Rank [8]	Ultimate Q_{100}	Sorting [9]	Rank [10]
1	**Alt. 1 -** Skyline Drive at Henry Branch	Small/Long-Term	0	$280,000	**3**	M4U	5	35%	65%	4394	$63.72	**1**	$0	**20**	**24**	**1**	1,050		1

1 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 1
2 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 2
3 Based on approximation, using logarithmic chart, with 1-Year Event coverage protecting 0% of traffic volume and 100-Year Event coverage protecting 100% of traffic volume
4 Percent Impacted = 100% minus % of Roadway Citizens Protected (approximate)
5 Number Impacted = % Impacted multiplied by [No. Lanes * 4 Hours Impacted * Hourly Volume Per Lane * Level of Service "C" Traffic Volume]
6 Cost of CIP divided by Roadway # Citizens Impacted
7 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 3
8 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 4
9 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 5
10 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 6

Additional Notes:
a. Phased projects shall be ranked in order of Phasing (i.e. Phase 1 shall be ranked higher than Phase 2, etc.)
b. In Step 5, when comparing projects between two different watersheds: If two projects have same rank in Step 4 and need to be sorted, but have similar 100-Year Ultimate Discharges, then projects should be ranked in order of lowest cost estimate

Table XIII-2 Stream Stability Capital Improvement Projects

Preliminary Short-Term Priorities & Long-Term Implementation

Rank	Stream	Capital Improvement Project	Short-Term/Long-Term	Public/Private	Probable Cost
1	Henry Branch	Remove Concrete Dam Structure & Install Rock Chute (Approximate Station 22+70)	Short-Term	Public	$72,000
2	Henry Branch	Place 24" Rock Rip-Rap Downstream of Concrete Channel (Approximate Station 20+00)	Short-Term	Public	$17,000
3	Henry Branch	Install Rock Chutes (Approximate Stations 6+50 & 36+00)	Short-Term	Public	$88,000

XIV. Short Term Priorities & Long Term Plan

XIV. SHORT TERM PRIORITIES & LONG TERM PLAN

A. SHORT-TERM PRIORITIES IMPLEMENTATION

There are three (3) short-term capital improvement projects located in the Henry Branch watershed. All three short-term CIPs are stream stability alternatives intended to protect public infrastructure and prevent future erosion to stream beds and stream banks. The erosion hazard setback zone referenced in Section IX of this report has been delineated by Halff Associates and is included on the DVD in Appendix F of this report. It is recommended that the setback shapefile be utilized to help manage future development in the watershed.

B. LONG-TERM PLAN IMPLEMENTATION

There is one (1) long-term CIP located in the Henry Branch watershed. The proposed re-sizing of the Skyline Drive culvert crossing along Henry Branch should be considered by the City as a long-term project since the proposed alternative does not directly benefit any structures. A benefit-to-cost ratio could not be calculated because there are no directly quantifiable benefits from the roadway improvement alternatives at this time.

Prior to implementation of this long-term CIP, Halff Associates recommends a "passive" approach to warning citizens of potential danger due to flooding at Skyline Drive. A passive flood warning approach involves the placement of flood warning signage at potentially overtopped roadway crossings. An "active" approach involves incorporating a roadway crossing into the City's flood warning system; however, this is not recommended at this time for Skyline Drive since the time from the rainfall event to the peak discharge at Skyline does not allow enough lead time to be included in the City's current active flood warning system. Improved methods of incorporating this crossing to the active flood warning system could be evaluated.

XV. Master Plan Study Wrap-up & Recommendations

XV. MASTER PLAN STUDY WRAP-UP & RECOMMENDATIONS

This supplemental report to the City-wide Drainage Master Plan for Cottonwood Creek provides comprehensive, updated technical data for the management of the Henry Branch watershed and its tributaries. This report addresses existing flooding, erosion, and sedimentation problems within the watershed and provides planning alternatives and design concepts to help alleviate potential flood damages. The information presented in this report will provide the City of Grand Prairie with the necessary updated drainage information to coordinate future development and help minimize existing and potential flood damages within the Henry Branch watershed.

Based on the findings of this report, Halff Associates recommends the following actions:

A. STREAMS AND OPEN CHANNELS

A relatively small number of structures are currently inundated by the 100-year floodplain in the Henry Branch watershed. The proposed re-sizing of the Skyline Drive culvert crossing along Henry Branch serves to mitigate roadway flooding and does not mitigate the flooding of any homes or businesses. Halff recommends that the City include this alternative in the evaluation of future Capital Improvement Projects and place flood warning signage at Skyline Drive until this alternative can be implemented.

B. STREAM BANK STABILITY

Three (3) stream stability alternatives were developed by Halff Associates along Henry Branch intended to protect public infrastructure and help control future erosion to stream beds and stream banks. Halff recommends that the City implement these alternatives in order of their ranking provided in Section IX of this report. Halff also recommends that the City utilize the Erosion Hazard Setbacks delineated as part of this study to manage new development in the Henry Branch watershed.

C. MAINTENANCE

Maintenance should be considered an ongoing task in the Henry Branch watershed and should follow the recommendations of the City of Grand Prairie City-Wide Drainage Master Plan Road Map Section F.6.

1. Storm Drain Outfalls

Please reference Section XI of the Cottonwood Creek Drainage Master Plan developed by RPS Espey Consultants for the condition of each outfall located within the Henry Branch watershed. Halff Associates recommends the City proceed with maintenance and repairs for the outfalls with a condition of poor as soon as possible. Remedial maintenance of the fair outfalls and continued field inspection for the good outfalls should be conducted in a regularly scheduled cycle determined by the City.

2. Detention Ponds

There were no detention ponds identified within the Henry Branch watershed. One (1) small private pond was identified on-channel along Henry Branch and was considered to be in poor condition as a result of heavy erosion occurring around the concrete spillway outlet. This pond was not considered with the other stream and open channel alternatives since it is privately owned and does not appear to serve as flood protection for any downstream structures.

D. FUTURE STUDIES & REPORT UPDATES

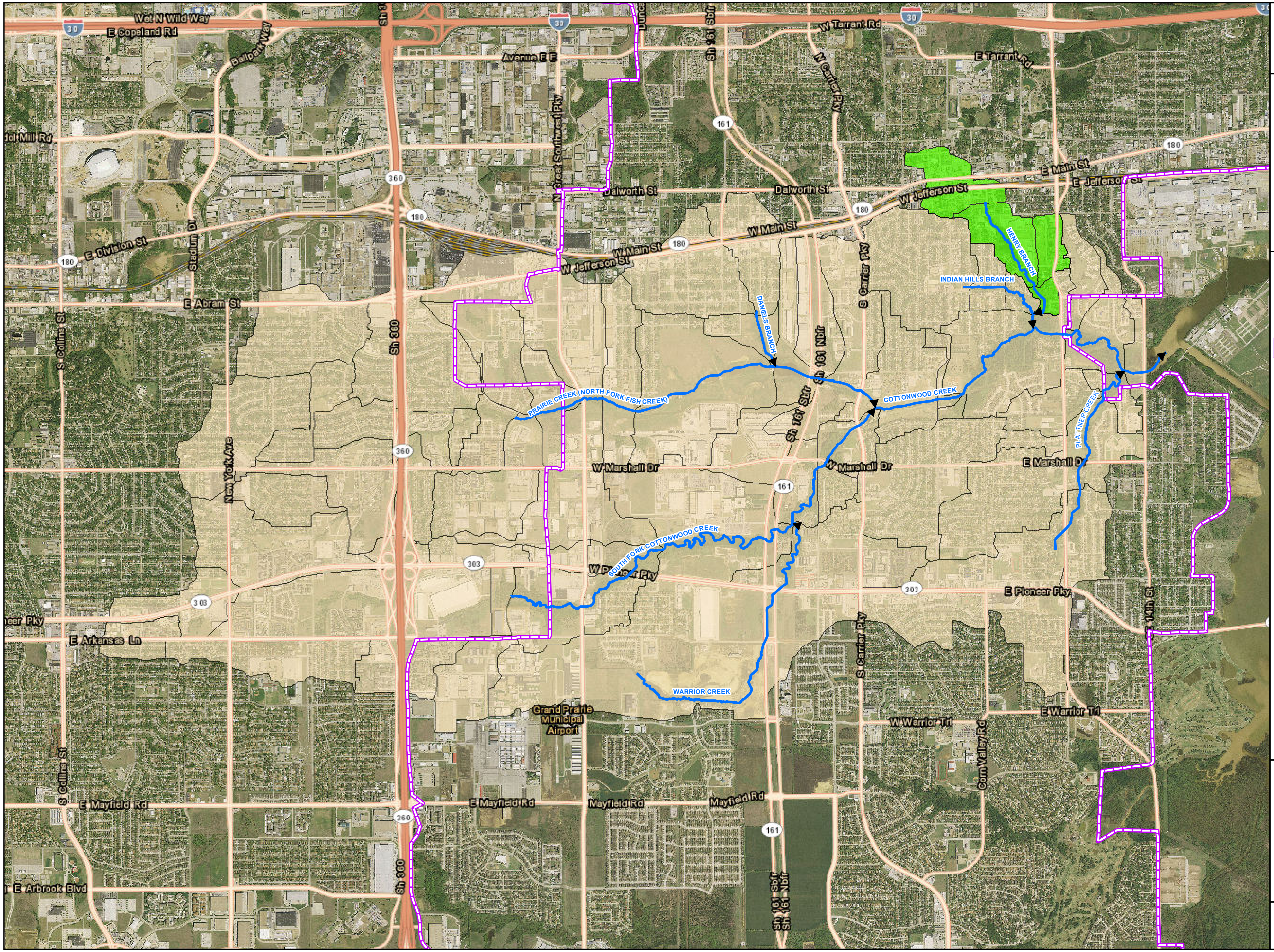
Future studies and technical data should be incorporated into this report as they become available. The following watershed studies are known to be ongoing and should be incorporated into this report once they become final.

- **Cottonwood & Lakeview Watershed Internal Storm Drain Master Plan Detail Study –** Incorporate alternative recommendations for the drainage system at Hot Spot Study Area #4 located in the upper Henry Branch watershed

Maintenance of this CWDMP document will be critical to keeping the document accurate and current. Future LOMRs and watershed studies should be included as attachments in this same document. Final hydrology and hydraulic models should be added to Appendix F.

Appendix A
Figures

Overall Watershed Map



GRand PRaiRie
TEXAS

Overall Watershed Map

Legend

- Stream Centerline
- Grand Prairie City Limit
- Henry Branch Watershed
- Cottonwood Creek Watershed

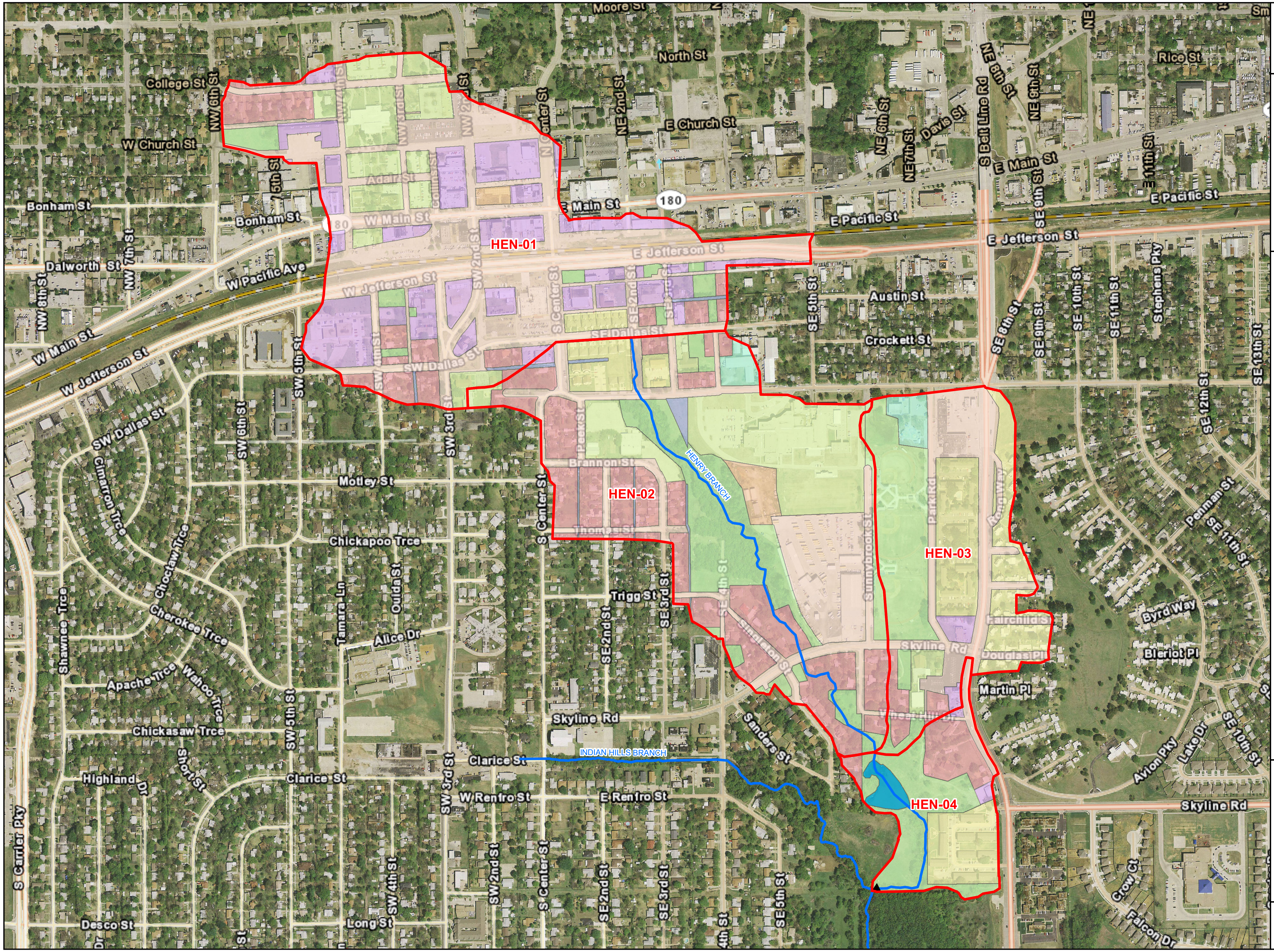
N E S W

0 1,500 3,000 6,000 Feet

1 inch = 3,000 feet

HALFF

Existing Landuse Map



Grand Prairie
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Existing Landuse Map

Legend

- Henry Branch Watershed
- Stream Centerline

Existing Landuse

- Commercial
- Impervious
- Industrial
- Institutional
- Multi Family
- Open Space
- Single Family
- Under Construction
- Utilities
- Water

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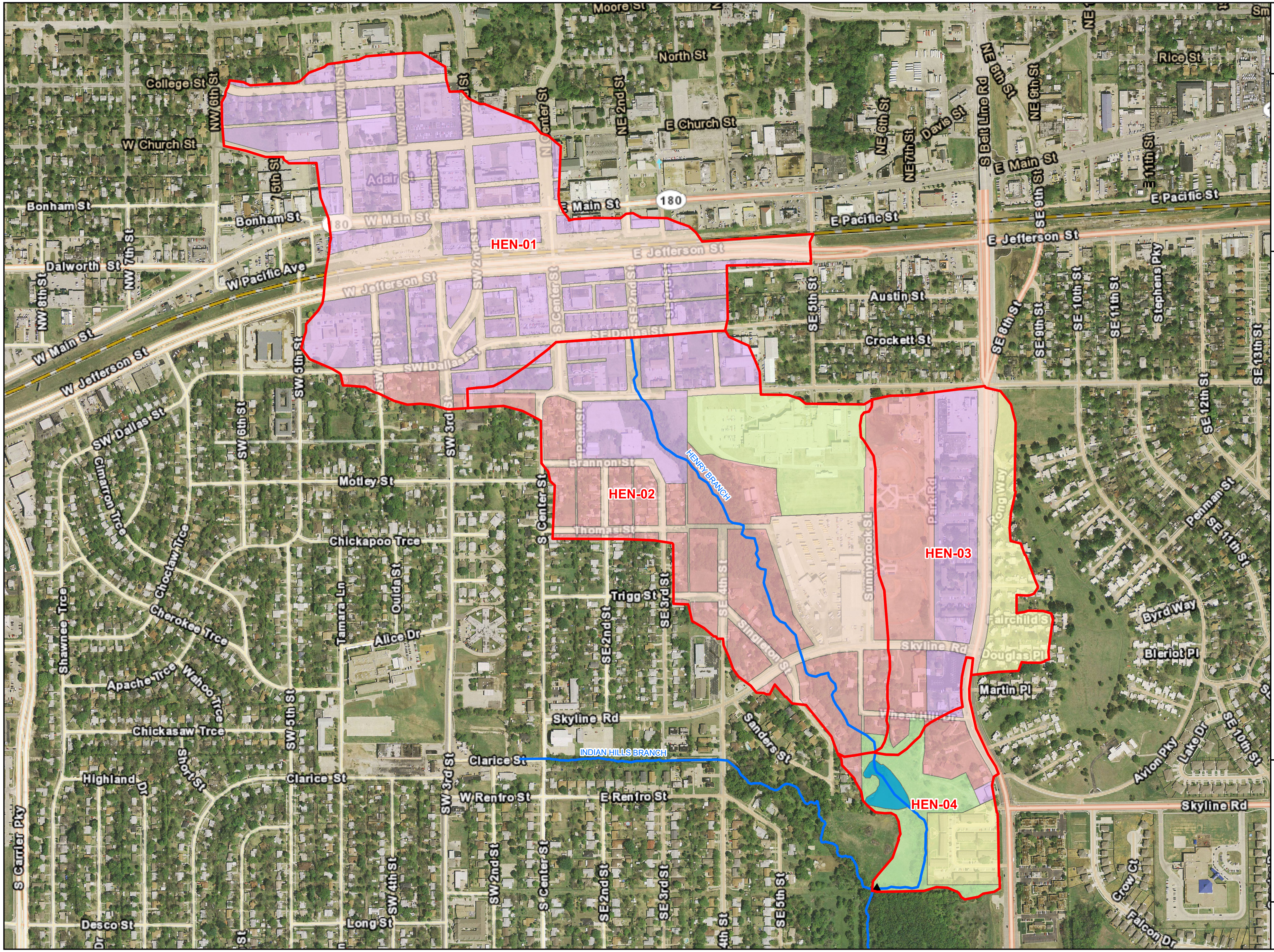
0 300 600 1,200 Feet

1 inch = 600 feet

HALFF

Ultimate Landuse Map



Grand Prairie TEXAS

Ultimate Landuse Map

Legend

Henry Branch Watershed

Stream Centerline

Ultimate Landuse

- Commercial
- Impervious
- Institutional
- Multi Family
- Open Space
- Single Family
- Water

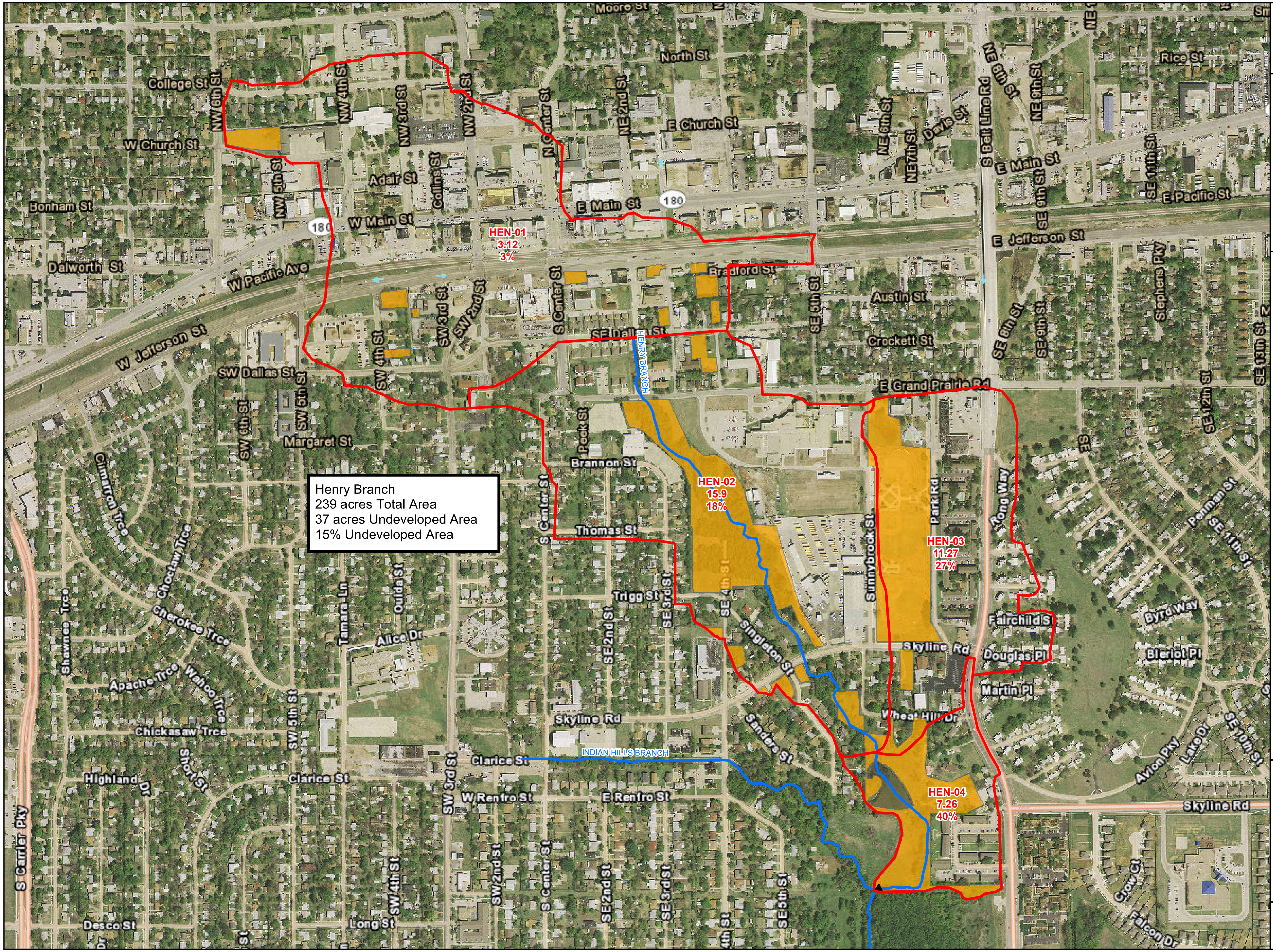
N W E S

Feet 0 300 600 1,200

1 inch = 600 feet

HALFF

Undeveloped Area Map



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Undeveloped Areas Map

Legend

- Henry Branch Watershed
- Stream Centerline
- Undeveloped Area

N W E S

0 300 600 1,200 Feet

1 inch = 600 feet

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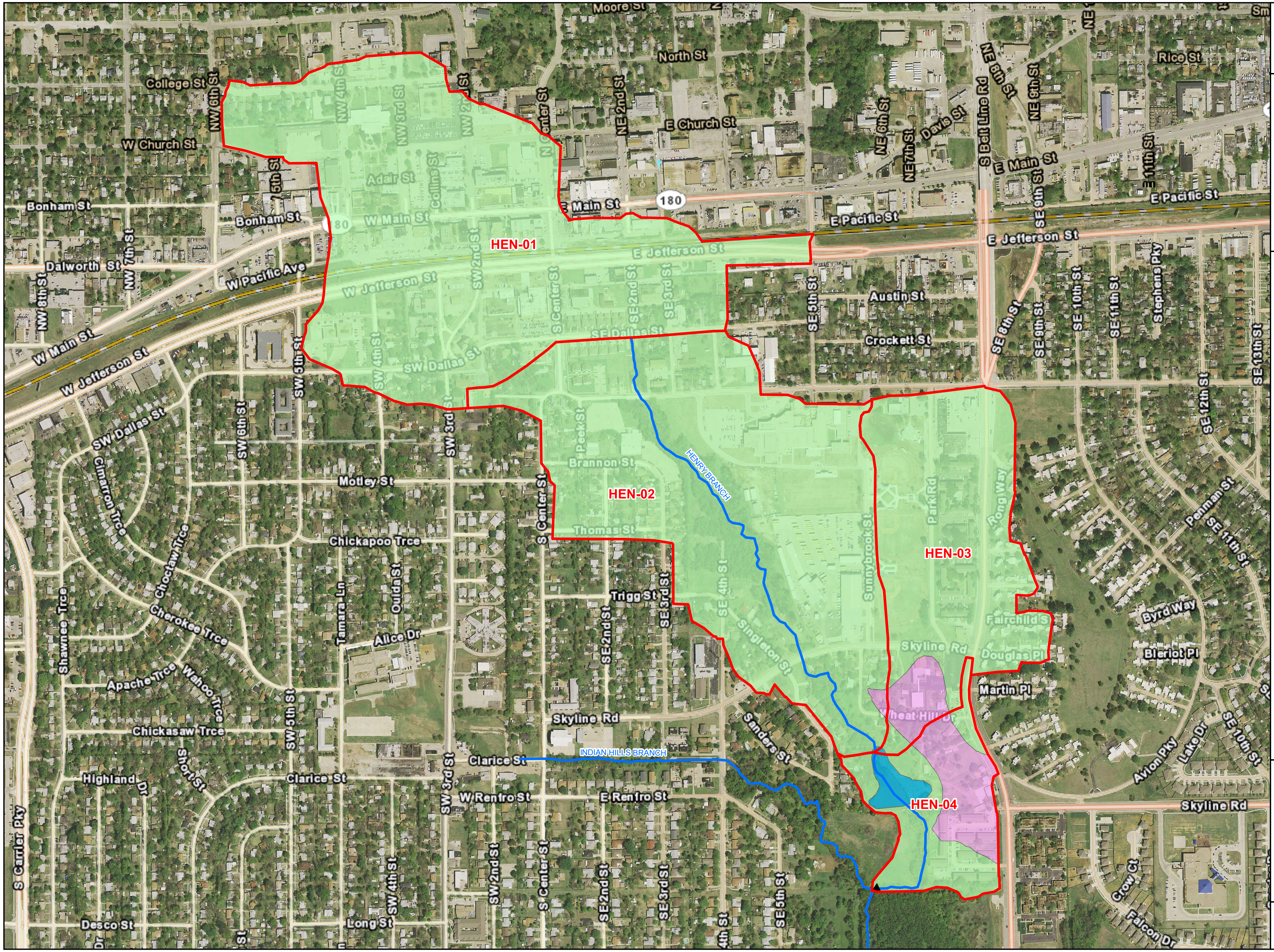
Hydrologic Soils Map



Hydrologic Soils Map

Legend

- Henry Branch Watershed
- Stream Centerline

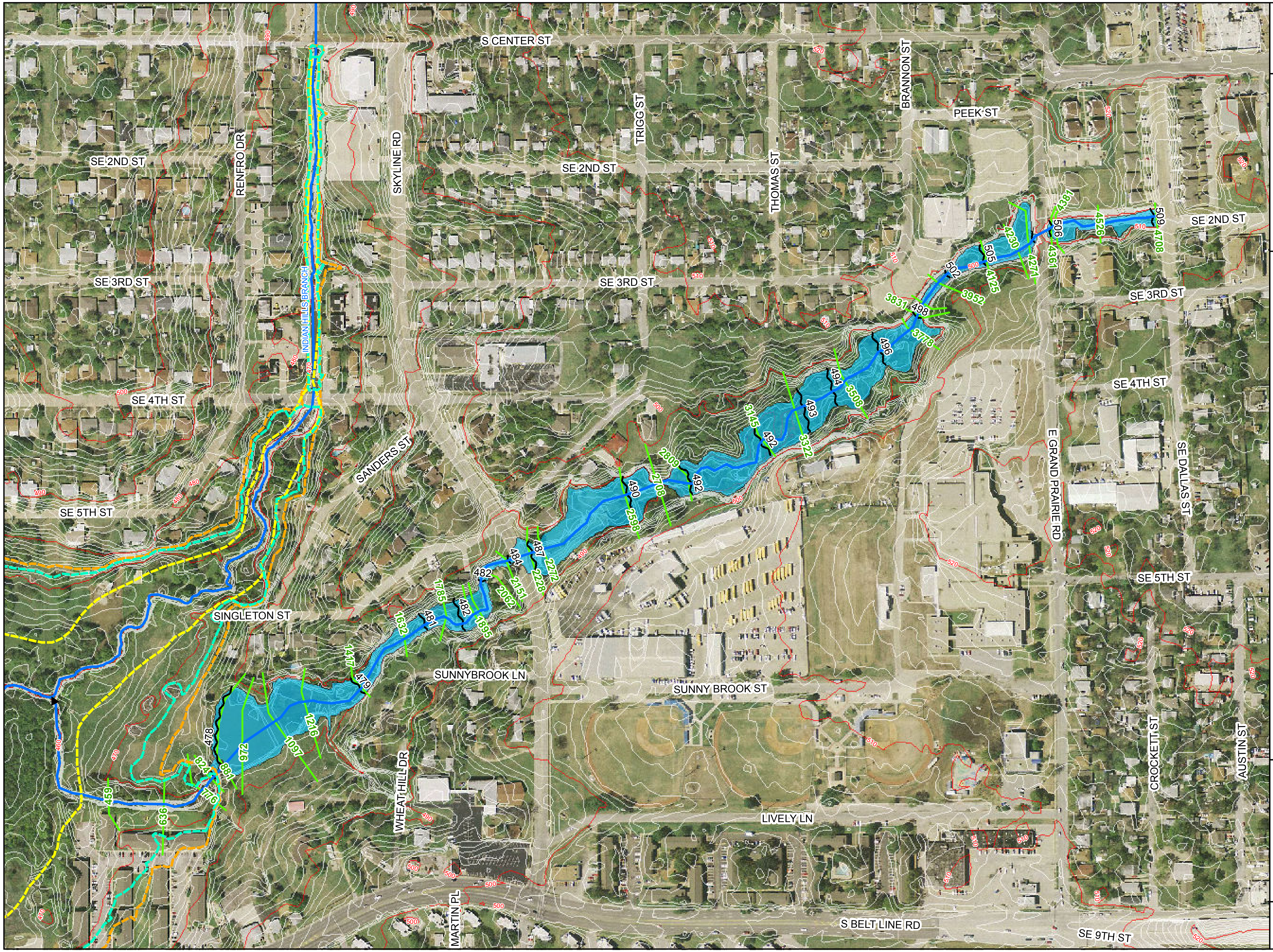
Hydrologic Soil Group

- B
- D
- Water

0 300 600 1,200 Feet

1 inch = 600 feet

Floodplain Workmaps



Floodplain Workmap
Henry Branch

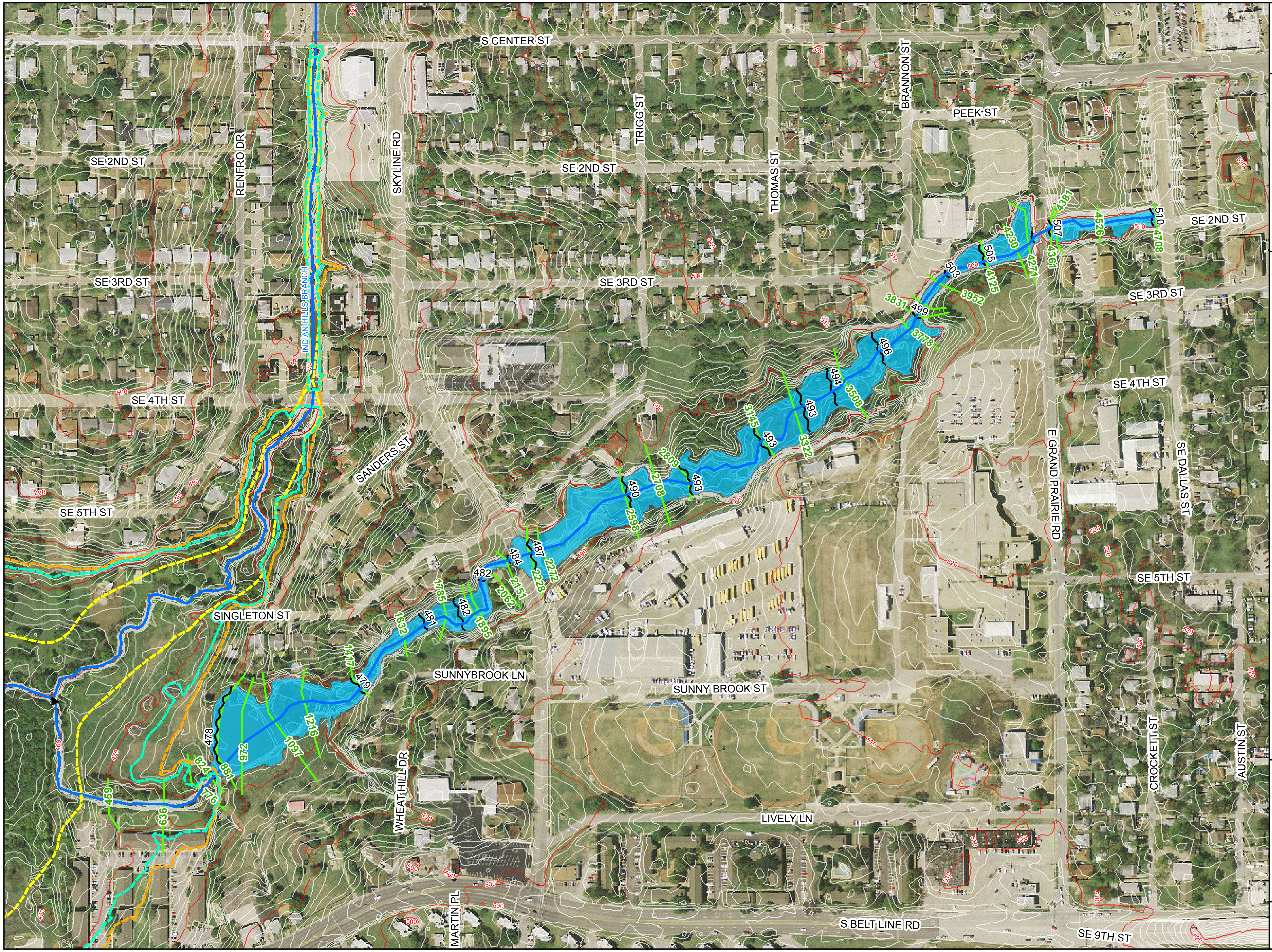
Legend

- Cottonwood CTP 100yr FP
- Cottonwood CTP Floodway
- Cottonwood CTP 500yr FP
- Henry Existing 100yr FP
- Henry Branch BFE
- Cross Section
- Stream Centerline
- GP_Roads

Notes:
1) Contours reflect the City of Grand Prairie 2009 Lidar Data.

1 inch = 300 feet

Ultimate Floodplain Workmaps



Grand Prairie
TEXAS

Ultimate Floodplain Workmap
Henry Branch

Legend

- Cottonwood CTP 100yr FP
- Cottonwood CTP Floodway
- Cottonwood CTP 500yr FP
- Stream Centerline
- Henry Ultimate BFE
- Cross Section
- Henry Ultimate 100yr FP

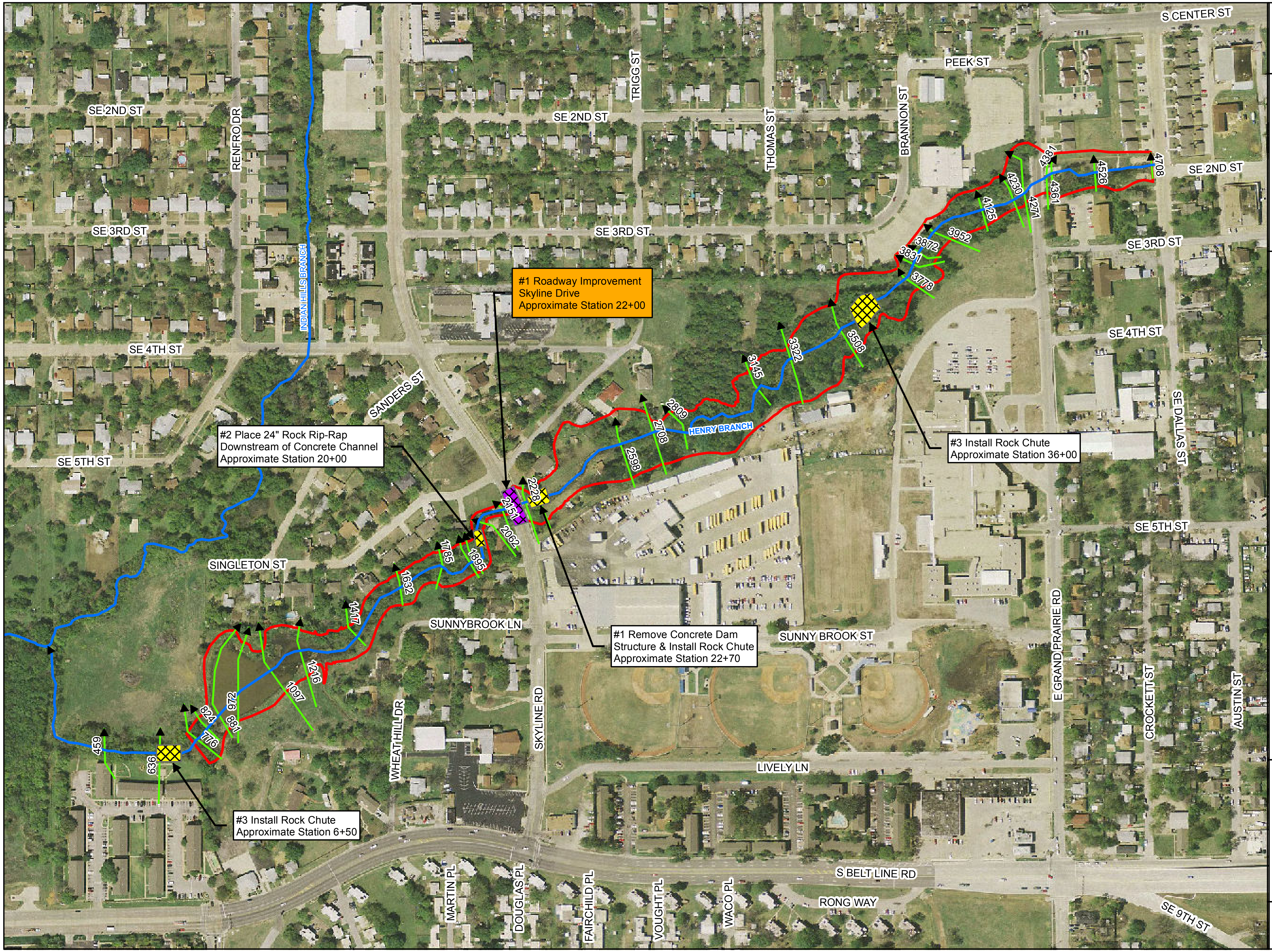
Notes:
1) Contours reflect the City of Grand Prairie 2009 Lidar Data.

0 150 300 600 Feet

1 inch = 300 feet

HALFF

CIP Workmaps



Grand Prairie
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CIP Workmap
Henry Branch

Legend

Erosion

- Grade Stabilization
- Roadway Improvement
- Erosion Hazard Setback
- Cross Section
- Stream Centerline
- GP_Roads

Notes:
1. Halff recommends further coordination with the owner of the dam structure just upstream of Skyline Drive to determine its function and decide whether it can be removed.

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0 150 300 600 Feet

1 inch = 300 feet

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Appendix B
Hydrologic and Hydraulic Data

Hydrologic Parameters

Appendix B - Hydrologic Parameter Data

HEC-HMS Basin Name (1)	Area (ac) (2)	Area (mi2) (3)	**Lag Time Exist (min) (4)	Ultimate (min) (5)	% Soil Type A (6)	% Soil Type B (7)	% Soil Type C (8)	% Soil Type D (9)	Composite CN (10)	*Initial Abstraction (11)	% Impervious Existing (12)	Ultimate (13)
Henry Branch		**0.344**										
B_HEN_01	93	0.145	17	9	0.0	0.0	0.0	100.0	80	0.50	83	90
B_HEN_02	86	0.134	16	12	0.0	0.4	0.0	9.6	80	0.50	57	72
B_HEN_03	42	0.065	16	16	0.0	7.8	0.0	92.2	79	0.53	57	68
B_HEN_04	18	0.028	6	6	0.0	35.9	0.0	64.1	75	0.67	40	41

Times of Concentration Spreadsheets

TR-55: Existing Lag Time Calculations for Henry Branch

HMS Program Basin Name	Longest Flowpath (ft) (1)	Overland Flow Length (ft) (2)	Slope (ft/ft) (3)	Surface Type (4)	Velocity (f/s)	Manning's n (5)	T_O (hr) (6)	Shallow Concentrated Flow Length (ft) (7)	Slope (ft/ft) (8)	Surface Type (9)	Velocity (f/s)	K (10)	T_S (hr) (11)	Channel Flow Length (ft) (12)	Slope (ft/ft) (13)	Channel Velocity (f/s) (14)	Flow Type (15)	T_h (hr) (16)	Total Time of Conc. (hr) (17)	Total Lag Time (hr) (18)	Total Lag Time (min)	Time Step (min) (19)
Henry Basins																						
HEN-01	4,191	100	0.0050	Short Grass	0.11	0.15	0.256	634	0.0235	Paved	3.11	20.3	0.057	3,457	0.0110	6.00	Stormdrain	0.160				
						T_O Total	**0.256**					**T_S Total**	**0.057**				**T_C Total**	**0.160**	**0.473**	**0.284**	**17**	**4.9**
HEN-02	4,131	100	0.0393	Short Grass	0.25	0.15	0.112	991	0.0208	Paved	2.93	20.3	0.094	3,040	0.0112	3.74	Main Channel	0.226				
						T_O Total	**0.112**					**T_S Total**	**0.094**				**T_C Total**	**0.226**	**0.432**	**0.259**	**16**	**4.5**
HEN-03	2,687	100	0.0148	Short Grass	0.17	0.15	0.166	406	0.0109	Unpaved	1.68	16.1	0.067	579	0.0250	6.00	Stormdrain	0.027				
								1,202	0.0099	Paved	2.02	20.3	0.165	400	0.0156	4.96	Open Channel	0.022				
						T_O Total	**0.166**					**T_S Total**	**0.232**				**T_C Total**	**0.049**	**0.447**	**0.268**	**16**	**4.7**
HEN-04	2,026							738	0.0108	Paved	2.11	20.3	0.097	176	0.0436	6.00	Stormdrain	0.008				
														377	0.0555	4.38	Open Channel	0.024				
														735	0.0070	5.97	Main Channel	0.034				
												T_S Total	**0.097**				**T_C Total**	**0.066**	**0.163**	**0.098**	**6**	**1.7**

Notes:
(1) GeoHMS Longest Flowpath
(2) Overland flow length (Maximum allowed in WinTR55 is 100 ft.)
(3) Slope of the ground
(4) WinTR55 surface type
(5) WinTR55 Manning's n
(6) WinTR55 Overland time of concentration: $T_O=0.42(nL)^{0.8}/(3.95^{0.5}S^{0.4}60)$
(7) Shallow concentrated flow length
(8) Slope of the ground
(9) WinTR55 surface type
(10) 16.1 for unpaved and 20.3 for paved soil cover
(11) WinTR55 Shallow Concentrated time of concentration: $T_S=L/(60^2KS^{0.5})$
(12) Channelized flow length
(13) Slope of the ground
(14) Channel velocity taken from HECRAS model for main channel flow and Flowmaster was used to approximate velocities for open channel flow. Assumed 6 ft/s for all storm drains
(15) Type of channel flow
(16) Channelized time of concentration = Channel Length/Channel Velocity/3600
(17) Total time of concentration: $T_C=T_O+T_S+T_h$
(18) Total lag time: $T_L=0.6T_C$
(19) Time Step : $T=0.29T_L$

TR-55: Ultimate Lag Time Calculations for Henry Branch

		Overland Flow						Shallow Concentrated Flow						Channel Flow					Total			
HMS Program Basin Name	Longest Flowpath (ft) (1)	Length (ft) (2)	Slope (ft/ft) (3)	Surface Type (4)	Velocity (f/s)	Manning's n (5)	T_O (hr) (6)	Length (ft) (7)	Slope (ft/ft) (8)	Surface Type (9)	Velocity (f/s)	K (10)	T_S (hr) (11)	Length (ft) (12)	Slope (ft/ft) (13)	Channel Velocity (f/s) (14)	Flow Type (15)	T_h (hr) (16)	Time of Conc. (hr) (17)	Total Lag Time (hr) (18)	Total Lag Time (min)	Time Step (min) (19)
Henry Basins																						
HEN-01	4,191	50	0.0050	Smooth Surface	0.76	0.011	0.018	684	0.0235	Paved	3.11	20.3	0.061	3,457	0.0110	6.00	Stormdrain	0.160				
						T_O Total	**0.018**					**T_S Total**	**0.061**				**T_C Total**	**0.160**	**0.239**	**0.144**	**9**	**2.5**
HEN-02	4,131	50	0.0393	Smooth Surface	1.74	0.011	0.008	1041	0.0208	Paved	2.93	20.3	0.099	3,040	0.0112	3.74	Main Channel	0.226				
						T_O Total	**0.008**					**T_S Total**	**0.099**				**T_C Total**	**0.226**	**0.333**	**0.200**	**12**	**3.5**
HEN-03	2,687	100	0.0148	Short Grass	0.17	0.15	0.166	406	0.0109	Paved	2.12	20.3	0.053	579	0.0250	6.00	Stormdrain	0.027				
								1,202	0.0099	Paved	2.02	20.3	0.165	400	0.0156	4.96	Open Channel	0.022				
						T_O Total	**0.166**					**T_S Total**	**0.219**				**T_C Total**	**0.049**	**0.434**	**0.260**	**16**	**4.5**
HEN-04	2,026							738	0.0108	Paved	2.11	20.3	0.097	176	0.0436	6.00	Stormdrain	0.008				
														377	0.0555	4.38	Open Channel	0.024				
														735	0.0070	5.97	Main Channel	0.034				
												T_S Total	**0.097**				**T_C Total**	**0.066**	**0.163**	**0.098**	**6**	**1.7**

Notes:
(1) GeoHMS Longest Flowpath
(2) Overland flow length (Maximum allowed in WinTR55 is 100 ft.)
(3) Slope of the ground
(4) WinTR55 surface type
(5) WinTR55 Manning's n
(6) WinTR55 Overland time of concentration: $T_O=0.42(nL)^{0.8}/(3.95^{0.5}S^{0.4}60)$
(7) Shallow concentrated flow length
(8) Slope of the ground
(9) WinTR55 surface type
(10) 16.1 for unpaved and 20.3 for paved soil cover
(11) WinTR55 Shallow Concentrated time of concentration: $T_S=L/(60^2KS^{0.5})$
(12) Channelized flow length
(13) Slope of the ground
(14) Channel velocity taken from HECRAS model for main channel flow and Flowmaster was used to approximate velocities for open channel flow. Assumed 6 ft/s for all storm drains
(15) Type of channel flow
(16) Channelized time of concentration = Channel Length/Channel Velocity/3600
(17) Total time of concentration: $T_C=T_O+T_S+T_h$
(18) Total lag time: $T_L=0.6T_C$
(19) Time Step : $T=0.29T_L$

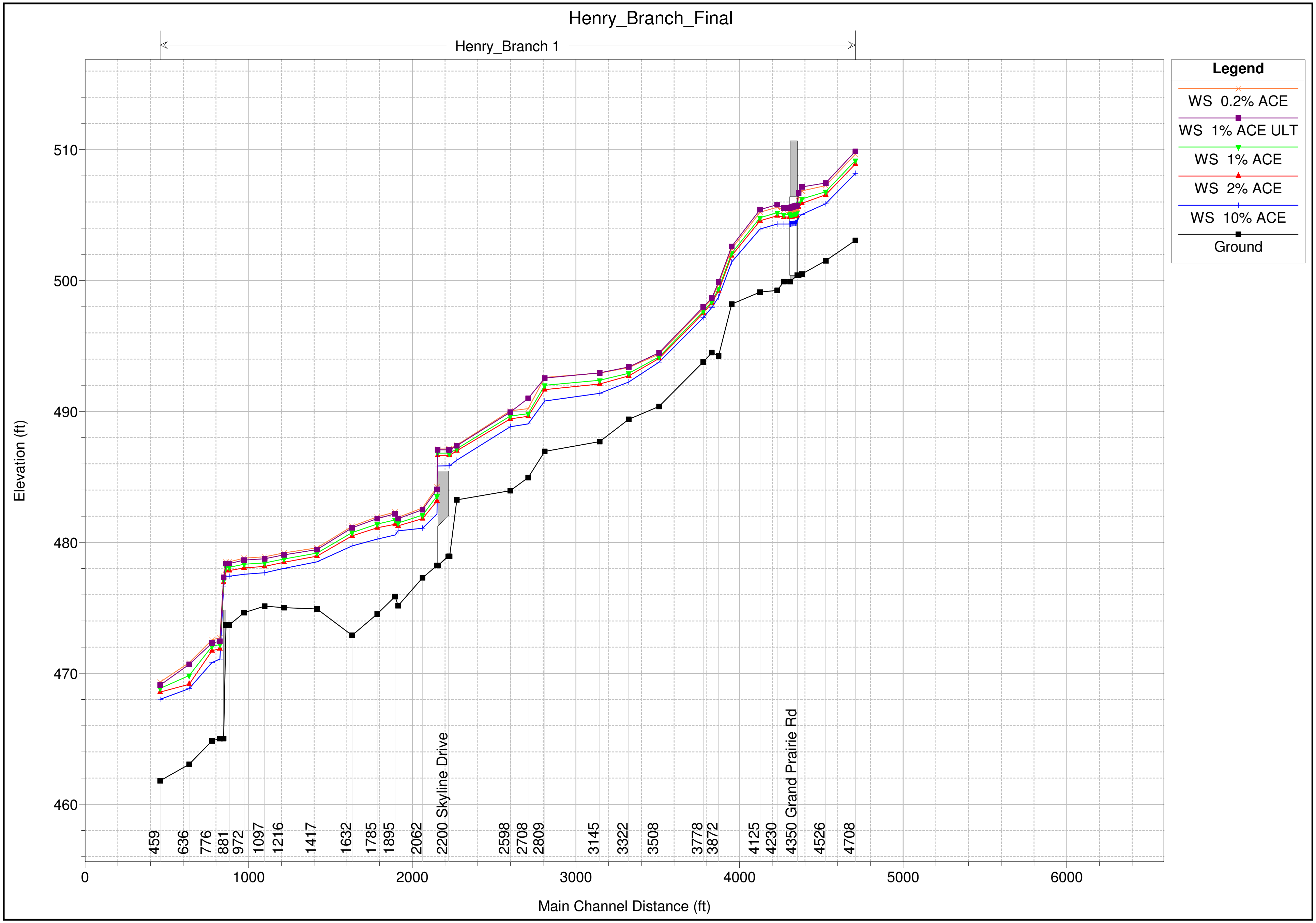
Technical Release 55, Table 2-2c

Table 2-2c Runoff curve numbers for other agricultural lands 1/

Cover description — Cover type	Hydrologic condition	Curve numbers for hydrologic soil group — A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. 2/	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. 3/	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 4/	48	65	73
Woods—grass combination (orchard or tree farm). 5/	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. 6/	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 4/	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Profiles



1 in Horiz. = 800 ft 1 in Vert. = 10 ft

Appendix C
Geomorphic Stream Assessment

Innovative approaches
Practical results
Outstanding service

Henry Branch
Stream Condition Assessment

Prepared for:

City of Grand Prairie

August 6, 2012

Prepared by:

FREESE AND NICHOLS, INC.
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Fort Worth, Texas 76109
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HAF12272

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EXECUTIVE SUMMARY

Bed	The channel of Henry Branch was composed of soil and Quaternary alluvial and terrace deposits of gravel, sand, silt, and clay. The channel bed was predominately clay with depositional features composed of sands and fine gravels. There was one location where channel erosion exposed the underlying Woodbine Formation. The formation consisted of weathered silty shale.
Bed Stability	Knickpoints were observed at two locations in Henry Branch. Knickpoints suggest channel instability. Table 4.1 provides locations and descriptions of the knickpoints observed in Henry Branch during the stream condition assessment. It is recommended that the knickpoints be stabilized to decrease future channel degradation and/or monitored (surveyed) to identify actual migration rates in order to prioritize stabilization efforts.
Banks	The alluvial soils that form the channel banks are mapped as the Houston Black-Urban land complex and the Trinity-Urban land complex by the Natural Resources Conservation Service (NRCS). There was one location where the underlying silty shale of the Upper Woodbine was exposed in the channel banks.
Bank Stability	The majority of the channel was stable. The most unstable areas were noted in areas where development had occurred directly on the channel banks or where the riparian corridor had been altered by other activity. These locations showed severe erosion, exposed tree roots, and were threatening infrastructure.
Channel Evolution	The Henry Branch study reach has been disturbed by development in the watershed. The channel has downcut and widened in some areas as a result of the increased flows resulting from urbanization. It appeared that the channel had come back into equilibrium with the urban flow regime in some locations. If flows increase due to future watershed disturbances, it can be expected that the channel of Henry Branch will respond with increased instability.

1.0 INTRODUCTION

Fluvial Geomorphology is the study of river related landforms. It investigates how the complex behaviors of streams respond to land use change in a watershed. This dynamic relationship determines the shape of a stream channel. Fluvial Geomorphologists are trained to identify how a stream channel will adjust its physical characteristics in response to land use changes; and consequently, how these adjustments will affect the physical stream system, habitat availability/function, and infrastructure.

On June 1, 2012, FNI Hydrologists/Fluvial Geomorphologists performed a stream condition assessment on the channel of Henry Branch in the City of Grand Prairie (Figure 1.1). The City of Grand Prairie selected this assessment study area to evaluate and document the locations of erosive conditions, channel instability issues, and potential erosion threats to private property and infrastructure adjacent to the channel. Existing conditions of Henry Branch were observed and recorded. This report documents the data collected during the field visit, locations of erosive channel conditions and channel instabilities. The locations may be considered for channel improvement projects.

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City of Grand Prairie
Henry Branch Stream Condition Assessment

Location Map

FN JOB NO	HAF12272
FILE	location.mxd
DATE	July 06 2012
SCALE	1:5,000
DESIGNED	SVC
DRAFTED	DKC

1.1
FIGURE

2.0 FIELD ASSESSMENT METHODOLOGY

The stream condition assessment entailed a walking survey of the study reach of Henry Branch, making detailed field notes that included a visual summary of channel conditions and identification of definitive characteristics of channel erosion. For convenience in referencing locations, the study reach was divided into segments and numbered the same as the cross sections in the hydrologic and hydraulic model of Henry Branch (Halff Associates, 2012). Channel geometry was measured with a survey rod and digital range finder at each cross section. All locations were photographed with a GPS-enabled digital camera. Representative photographs are provided in Appendix A. All digital photographs contain a GPS tag and image direction and are included on a DVD as Attachment 1. The entire reach was sketched on an aerial photograph mapbook to capture the channel morphology. Copies of the sketches are provided in Appendix B. The geology of the reach was noted considering rock type, degree of weathering, and thickness of alluvial soils. Bank stability and degree of erosion were recorded. Bed and bank geomorphic processes were noted using the methodologies developed by Thorne, 1998; Montgomery and Buffington, 1998; Henshaw and Booth, 2000; Rosgen and Silvey, 1995; and Johnson et al., 1999. Streambank stability and bank erosion characteristics used in this evaluation are shown in Table 2.1. This fluvial geomorphologic study also included a review of the Channel Evolution Model (CEM) (Schumm, 1977) and the potential for change over time.

Table 2.1 Factors affecting stream bank stability

VARIABLES

- Top width, bottom width, active channel depth and width
- Bed material, bedload size, and depositional features
- Knickpoints and log jams (drops in elevation)
- Gullies and tributaries
- Pools, runs, riffles, and glides
- Channel type (alluvium or rock) and height of soil or rock

STABLE

- Perennial vegetation to waterline
- No raw or undercut banks (some erosion on outside of meander bends OK)
- No recently exposed roots
- No recent tree falls

SLIGHTLY UNSTABLE

- Perennial vegetation to waterline in most places
- Some scalloping of banks
- Minor erosion and/or bank undercutting
- Recently exposed tree roots rare but present
- Minimal scour less than 50 percent of the bank

MODERATELY UNSTABLE

- Perennial vegetation to waterline sparse (mainly scoured or stripped by lateral erosion)
- Bank held by hard points (trees, boulders) and eroded back elsewhere
- Extensive erosion and bank undercutting
- Recently exposed tree roots and fine root hairs common
- Moderate erosion scour from 50 to 75 percent of the bank

SEVERELY UNSTABLE

- No perennial vegetation at waterline
- Banks held by hard points
- Banks are near vertical
- Recently exposed tree roots common
- Tree falls and/or severely undercut banks common
- High erosion greater than 75 percent of the active channel is scoured

3.0 WATERSHED CHARACTERISTICS

The following sections describe the existing conditions of the study area including the geographic setting, climate, topography, geology and soils, and channel morphology. The information was developed from a desktop analysis of available data including topographic maps, aerial photographs, soil survey reports, and geologic maps and reports. Additional information was obtained from the field investigation, where visual observations, photographs and field measurements were collected. Appendix C shows areas of concern and items of interest along the channel of the study reach on a 2011 aerial photograph. Appendix D shows the channel erosion rating given to the channel banks throughout the study reach on a 2011 aerial photograph.

3.1 GEOGRAPHIC SETTING

The stream condition assessment was conducted on the channel of Henry Branch in the City of Grand Prairie in Dallas County, Texas (Figure 1.1). The study reach of Henry Branch is in the Cottonwood Creek watershed. Henry Branch is a tributary of Indian Hills Branch, which confluences with Cottonwood Creek upstream of the Belt Line Road Bridge crossing on Cottonwood Creek. The assessment reach extended from an outfall at Dallas Street, near Crockett Elementary School, downstream to the confluence with Indian Hills Branch.

The Henry Branch watershed is mostly developed and landuse types include single family residential, multi-family residential, industrial, and the City's Central Business District. Residential development in the watersheds began prior to 1958. The watershed was nearly fully developed by 1989. See section 4.1 for Historical Watershed Development.

3.2 CLIMATE

The study reach of Henry Branch occupies the extreme northern part of the humid subtropical belt which extends inland from the Gulf of Mexico. Average annual temperatures range from 52°F to 77°F. Annual precipitation averages 36 inches. Rainfall in October to March is triggered by southward moving continental polar fronts, which produce low intensity, long duration storms (National Weather Service, 2012). The most common storms in April to September are thunderstorms which are responsible for most of the serious flooding (100- year peak flows) in small watersheds (1-10 square miles).

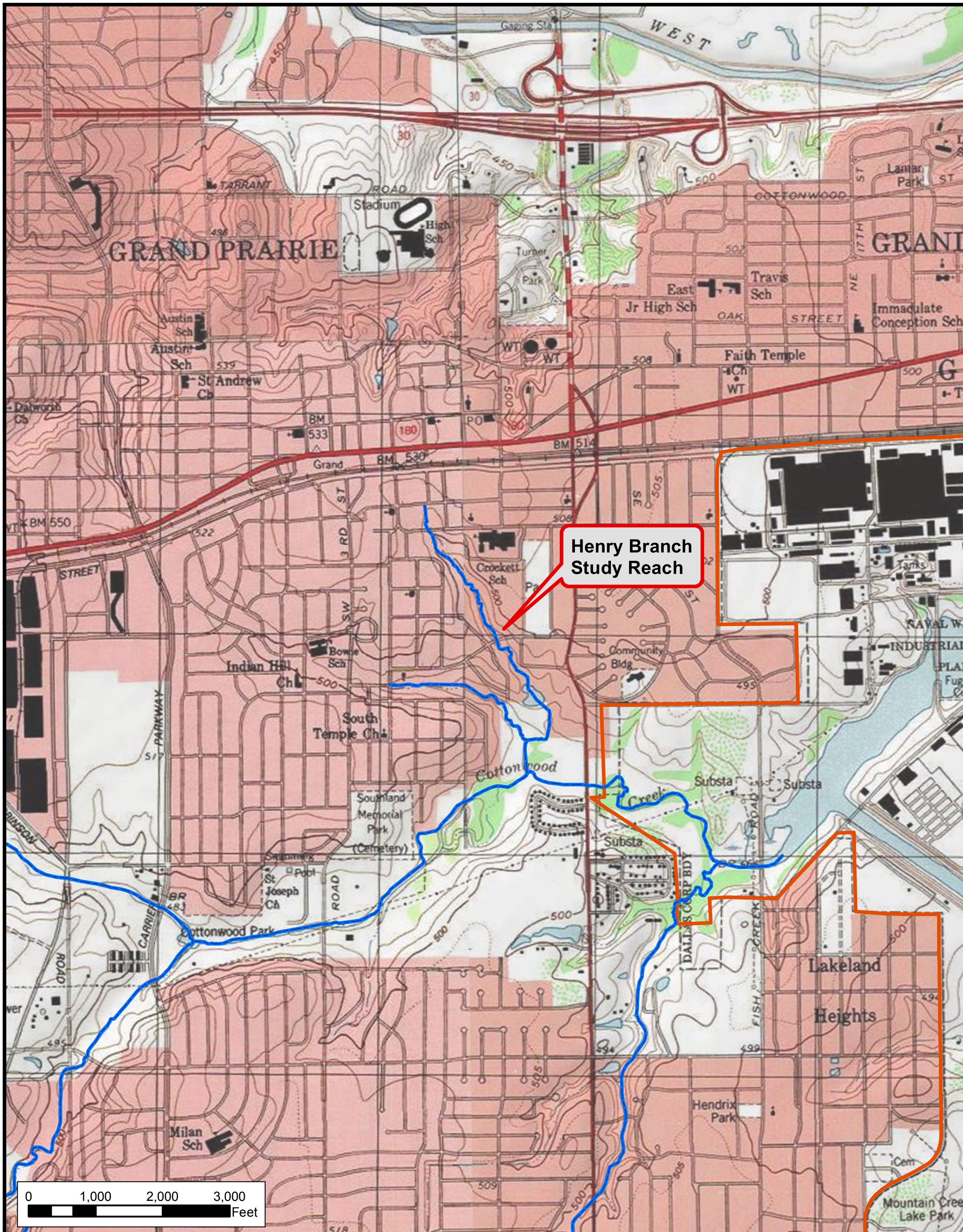
3.3 TOPOGRAPHY

Elevations in the Henry Branch study area ranged from 500 feet (ft.) above mean sea level (msl) to 460 ft. msl (Figure 3.1). The average study reach channel slopes was 0.009 ft./ft. The drainage area of Henry Branch upstream of the confluence with Indian Hills Branch was approximately 0.4 square mile.

3.4 GEOLOGY AND SOILS

The study area is located in the Blackland Prairie physiographic subprovince of the Texas Gulf Coastal Plain. The Blackland Prairie is underlain by Cretaceous age limestones, shales, and sandstones, which dip gently to the southeast at 0.54 degrees (Allen and Flannigan, 1985). Stream valleys are mapped as Quaternary Terrace deposits (Figure 3.2), however field observations confirmed that the channel of Henry Branch was underlain by soil and Quaternary Alluvium composed of gravel, sand, silt, and clay. The channel bed was predominately clay with depositional features composed of sands and fine gravels. There was one location where channel erosion exposed the underlying Woodbine Formation. The formation consisted of weathered silty shale.

The alluvial soils that form the channel banks are mapped as the Houston Black-Urban land complex and the Trinity-Urban land complex by the Natural Resources Conservation Service (NRCS) (Figure 3.3). The Houston Black-Urban land complex is composed of approximately 40% Houston Black soils and the remainder of the complex is land that has been disturbed by urban activity. The Houston Black is made up of deep moderately well drained clayey soils. These soils were derived from clayey marine sediment on uplands. The hazard of surface erosion of the Houston Black-Urban land complex is moderate. The Trinity-Urban land complex is composed of approximately 60% Trinity clay soils and the remainder is land that has been disturbed by urban development. The Trinity clay is a deep nearly level clayey soil on floodplains of major streams. The hazard of surface erosion of the Trinity clay is slight.



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City of Grand Prairie
Henry Branch Stream Condition Assessment

Topographic Map

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FILE	topo.mxd
DATE	July 24 2012
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3.1
FIGURE

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N
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City of Grand Prairie
Henry Branch Stream Condition Assessment

Geologic Map

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SCALE	1:10,000
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3.2
FIGURE

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City of Grand Prairie
Henry Branch Stream Condition Assessment

Soils Map

FN JOB NO	HAF12272
FILE	soils.mxd
DATE	July 06 2012
SCALE	1:5,030
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3.3

FIGURE

3.5 STREAM MORPHOLOGY

The channel of Henry Branch had low sinuosity (ratio of channel length to valley length was 1.11), was slightly entrenched (ratio of flood-prone width to bankfull width greater than 2.2) and had a low width/depth ratio (less than 12).

Some segments of the Henry Branch channel have been altered to increase flow conveyance to reduce flooding during high-flow events. A retention pond has historically been present on the channel upstream of the Indian Hills Branch confluence. Locations of existing channel protection/stabilization structures are presented in Appendix C. The meandering segments of the study reaches contained multiple geomorphic units including scour pools, pools, runs, riffles, bars, stable undercut banks, knickpoints, benches, erosion ledges, and large woody debris. Henry Branch contained multiple anabranches (multiple semi-stable channels that are interconnected, separated by vegetated islands, and convey flow at all but the lowest stages [Coffman et al., 2011) between cross sections 3872 and 3145. Segments of Henry Branch have floodplain connectivity, which allows flows to spread out and dissipate during high flow events. At the time of the field investigation, there was a dense riparian corridor established along the majority of the study reach. The most unstable areas were noted in areas where development had occurred directly on the channel banks, or where the riparian corridor had been altered by other activity.

4.0 RESULTS

4.1 HISTORICAL WATERSHED DEVELOPMENT

A historical aerial photograph analysis was performed to assess channel conditions prior to urban development. Historical aerial photographs from 1958 and 1964 were obtained from Texas Natural Resources Information System (TNRIS). Historical aerial photographs from 2004, 2009, and 2011 were obtained from North Central Texas Council of Governments, Landiscor, and Bing, respectively. The following photographs are examples from the Henry Branch watersheds at 1:10,000 scale (Figure 4.1).

In 1958 (Figure 4.1), the watershed of Henry Branch was being developed. The photograph shows a non-developed riparian buffer containing the headwater channel. There was a one and a half acre retention pond feature on the drainage channel. Prior to 1958, it is likely that the drainage was impacted by agricultural land practices. In 1996, the drainage was fully developed and still contained a riparian buffer that had grown in with vegetation. By 2011, the majority of the channel remained the same. During the field investigation in June 2012, it was observed that the retention pond had been realigned and engineered into its present configuration.

Figure 4.1 Historical aerial photographs from 1958 and 2011

4.2 KNICKPOINT MIGRATION

As part of the stream condition assessment, knickpoints (headcuts) in the streambed were identified. A knickpoint is a break in slope in the long profile of the stream which is marked by a sharp change in channel slope (drop in elevation) resulting in a waterfall. Figure 4.2 shows an upstream view of a knickpoint on Henry Branch near cross section 636. Figure 4.3 shows a downstream view of another knickpoint near cross section 3778. Table 4.1 provides descriptions of the knickpoints identified during the stream condition assessment.

Figure 4.2 Looking upstream near cross section 636, there was a knickpoint with a 1.5-foot drop in elevation.

Figure 4.3 Looking downstream near cross section 3778, there was a knickpoint with a 2-foot drop in elevation.

Table 4.1 Locations of knickpoints and movement

Knickpoint Location	Description and Movement
Between XS 3778 and 3508	There was a two-foot knickpoint downstream of XS 3778. Field observations suggest the potential for upstream movement, however the channel was inset within a floodplain and the knickpoint did not appear to be a major threat to the system. There was a second segment of channel that had tried to lower its base level, but encountered tree roots. Field observations suggest the advance of the knickpoint may have been halted by the roots.
Between XS 776 and 636	There were two knickpoints; one with a 1.5 foot drop and one with a two-foot drop. Field observations suggest minimal upstream migration. If the knickpoints do migrate upstream, they may pose an additional threat to the undercut and scoured concrete spillway at cross section 881.

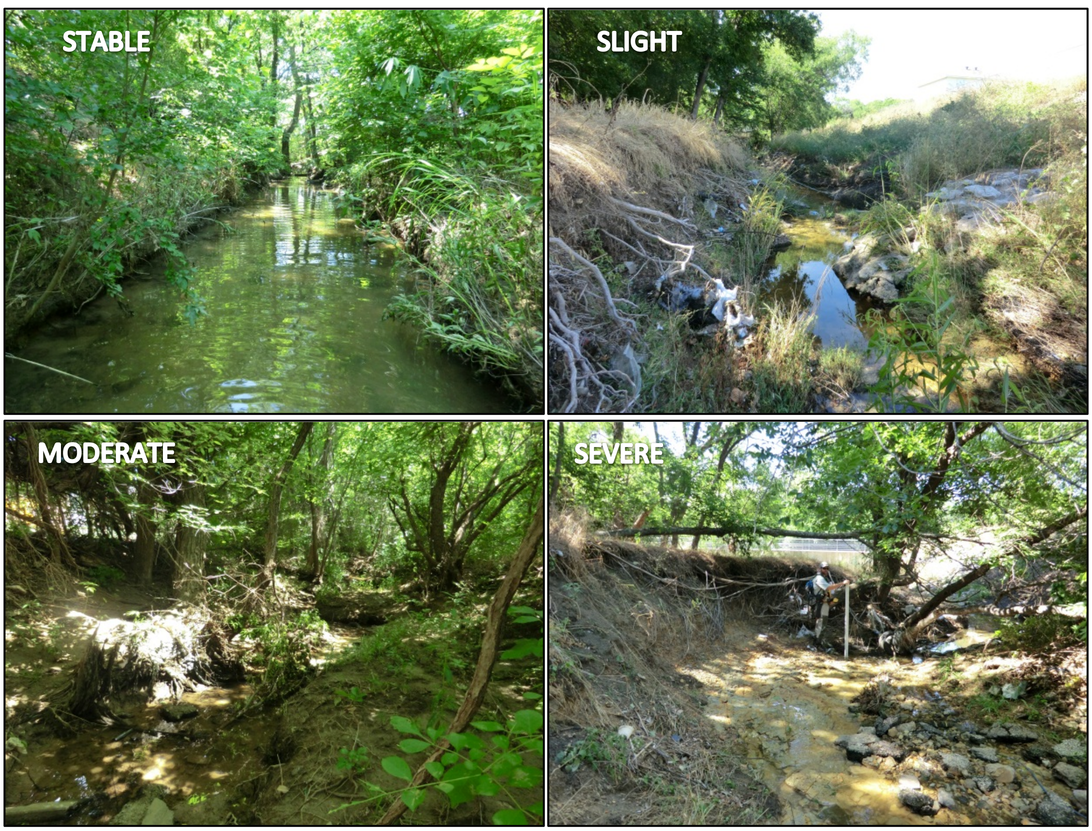
XS is the abbreviation for cross section. Cross section numbers reference the cross sections used in the HEC-RAS modeling.

4.3 CHANNEL EROSION AND INSTABILITY

The stream condition assessment documented the existing channel processes of bank erosion and channel instability. Channel segments were rated “stable”, “slight”, “moderate”, and “severe” using the criteria in Table 2.1. Examples are shown in Figure 4.4. In addition, the following channel processes were observed and recorded:

- bank undercutting by flowing water
- ratio of bankfull height to bank height (incised channel and steep bank angles)
- rooting depth
- channel scour and collapsed banks (failures)
- newly-fallen large woody debris
- human-induced alteration (retaining walls, culverts, and retention ponds)

Figure 4.4 Example of channel condition ranking



The following sections describe the erosion and instabilities observed in the study reach. Example photographs are provided. Please note that left and right bank views assume downstream direction. Henry Branch was a small channel set within a riparian buffer surrounded by urban development. The majority of the channel ranked stable with short segments that ranked as having moderate and severe erosion. This section of the report highlights the moderate and severe erosion segments observed during the stream assessment. Appendix D illustrates the channel erosion ranking for Henry Branch.

The first moderate to severe erosion location was upstream of Grand Prairie Road. There was bend scour exposing shale of the Woodbine Formation, exposed roots and tree falls (Figure 4.5). The eroding bank was not threatening infrastructure, but was contributing sediment from erosion.

Figure 4.5 Looking downstream at bank erosion on the left bank near cross section 4526

The second erosion severe location was near cross section 2272, upstream of Skyline Road. The channel had completely undercut a concrete structure that may have originally been a drop structure. At the time of the stream assessment, water was flowing underneath the concrete structure. It appeared that high flows may flow over the concrete structure (Figure 4.6).

Figure 4.6 Looking upstream at the severely undercut concrete structure near cross section 2272

The third severe erosion location was near cross section 2062, downstream of Skyline Road. The channel was lined with concrete. The end of the concrete channel was undercut. Immediately downstream of the concrete lining, the channel was severely eroding. Both banks had exposed roots, leaning trees and soil loss. Directly downstream there was a building with an undercut footer wall on the outside of a 90-degree bend in the channel (Figure 4.7).

Figure 4.7 Looking downstream at the undercut concrete channel and severe erosion near cross section 2062

The fourth severe erosion location was near cross section 881. The channel upstream was engineered into a retention pond with a spillway. Downstream of the spillway there was severe scour and bank erosion. The scour was causing the channel to erode. The erosion undercut the spillway and the concrete had collapsed (Figure 4.8).

Figure 4.8 Looking downstream at the undercut concrete spillway and severe erosion near cross section 881

Specific areas of concern, severe instability, and items of interest observed during the Henry Branch field assessment are called out and described on a 2011 aerial photograph in Appendix C. Digital photographs representing each cross section location are shown in Appendix A. Copies of digital photographs taken during the field assessment along with image direction are provided on a DVD (Attachment 1). The areas experiencing channel erosion along the study reach is shown on a 2011 aerial photograph of the study area in Appendix D.

Processes of bank erosion and instability are important in the development and natural evolution of channel forms. The migration of a channel across a floodplain involves a combination of bank erosion and deposition. Bank erosion, however, can also create management problems when bridges, buildings and roads are undermined or destroyed. Excess sediment deposition can cause problems by filling channels and culverts with sediment, potentially increasing flood risk. Sediment that is not deposited in the channel may be carried downstream to a detention structure, reducing its total capacity over time.

Bank failures occur when bank material becomes unstable and falls or slides to the base of the bank. Several types of failures and different failure mechanisms were observed for cohesive and non-cohesive bank materials. In addition, bank height, bank angle, moisture content, groundwater, vegetation, climatic cycles, and duration of stream flow affects bank stability.

Note that bank stability is a complex process; geotechnical engineers should be consulted and a detailed geotechnical analysis should be conducted to provide data for any bank stabilization designs.

4.4 CHANNEL FORMING FLOW

Research has shown that in many streams and rivers, a single discharge can be used to estimate stable channel geometry (Copeland et al, 2000). This single representative discharge is known as the channel forming or effective discharge. The channel forming discharge has been defined as the flow that determines particular channel parameters, such as cross-sectional capacity (Wolman and Leopold, 1957) and performs most of the work, where work is defined in terms of sediment transport (Wolman and Miller, 1960). Theoretically, it is the discharge that if maintained indefinitely would produce the same channel geometry as the natural long-term hydrograph in an undisturbed watershed. The channel-forming discharge is a function of both the magnitude of the event and its frequency of occurrence (Wolman and Miller, 1960). Leopold and Wolman (1957) suggest that the channel forming discharge has an approximate return period between one and two years. In stable perennial alluvial channels, the channel-forming discharge typically reflects the 2-year frequency peak discharge (Thomas et al., 1996; NRCS, 2007). Allen et al. (2002) suggest that the channel forming discharge in urbanized watersheds of the Dallas-Fort Worth area corresponds to a recurrence interval less than the 1.25-year frequency flow.

Based on field observations and review of the Henry Branch hydrologic and hydraulic model (Halff, 2012), the modeled 2-year peak discharge appeared to be greater than the channel forming flow for the majority of Henry Branch.

4.5 CHANNEL EVOLUTION

There is an important balance between the supply of bedload at the upstream end of a channel reach and the stream power available to transport it. This is known as Lane's Balance. Based on extensive field observations, E.W. Lane formulated a qualitative expression for stream equilibrium (Lane, 1955):

$$Qw\ S \propto Qs\ D50$$

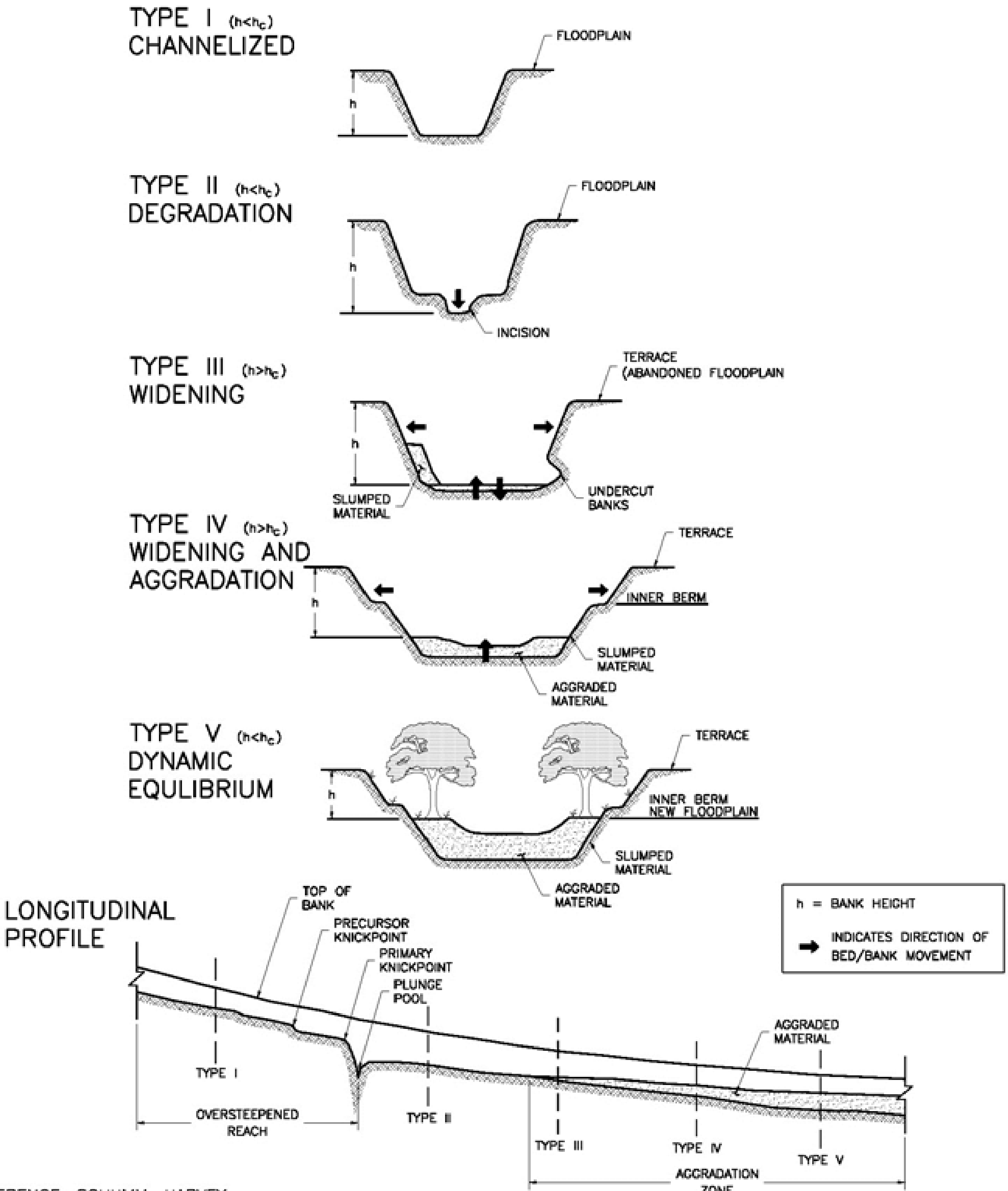
where Qw is the water discharge (ft3/s), S is the channel slope (ft./ft.), Qs is the bed material discharge (tons/day), and D_{50} is the average particle size (50 percent) of the bed material (inches).

An imbalance will occur if there is an increase in the volume of sediment load in relation to the available stream power. If the stream power is insufficient to transport all of the sediment in the reach, then the balance tips towards aggradation, with net deposition occurring along the reach. Aggradation occurs when sediment supply is increased by upstream channel erosion, mass movement, or human activities. Deposition in the channel may lead to the channel bed becoming elevated above the floodplain surface, and reduced channel capacity due to deposition increases flooding and promotes channel migration (Charlton, 2008).

If the water discharge is increased, over time the channel slope would increase by degrading. Harvey and Watson (1986) showed that channel evolution occurs as a result of increased discharge and can be assessed in terms of the Channel Evolution Model (CEM) (Schumm, 1977, Figure 4.9). The following is a synopsis of the channel evolution of Henry Branch:

- Between Dallas Street and Grand Prairie Road (cross sections 4708 to 4361), the channel was straight with a constructed floodplain. The channel ranked as having slight to moderate erosion induced by flows from the outfall locations. Channel evolution is not applicable for this engineered channel

- Between Grand Prairie Road and Skyline Road, Henry Branch was a small pilot channel within a riparian floodplain. Multiple anabranches were present between cross sections 3872 and 3145. A knickpoint was observed during the field visit near cross section 3778. The majority of the system appeared stable (Stage I). The knickpoint near cross section 3788 indicated that this section of the reach may be transitioning to Stage II (downcutting).
- Downstream of Skyline Road to cross section 1216 the channel was more incised. The channel banks were built up with fill material. Downstream of the concrete channel at cross section 2062 the channel was wider and incised from local scour, not channel evolution. The majority of this segment was stable and ponded (Stage I to II).
- Between cross sections 1216 and 881 the channel was engineered into a retention pond. Channel evolution is not applicable.
- Between cross sections 881 and 459, Henry Branch was a pilot channel within a riparian corridor (Stage IV). The channel contained vegetated benches, erosion on meander bends and depositional point bars. The series of knickpoints indicated instability in the system. The instability likely occurred as Henry Branch was trying to lower its slope to meet the elevation of Indian Hills Branch. Additional downcutting downstream of the knickpoints is not likely to occur because the channel downstream of cross section 459 has been armored with grouted riprap. Downcutting may occur upstream cross section 636 if the knickpoints migrate upstream.



REFERENCE: SCHUMM, HARVEY
AND WATSON (1984)

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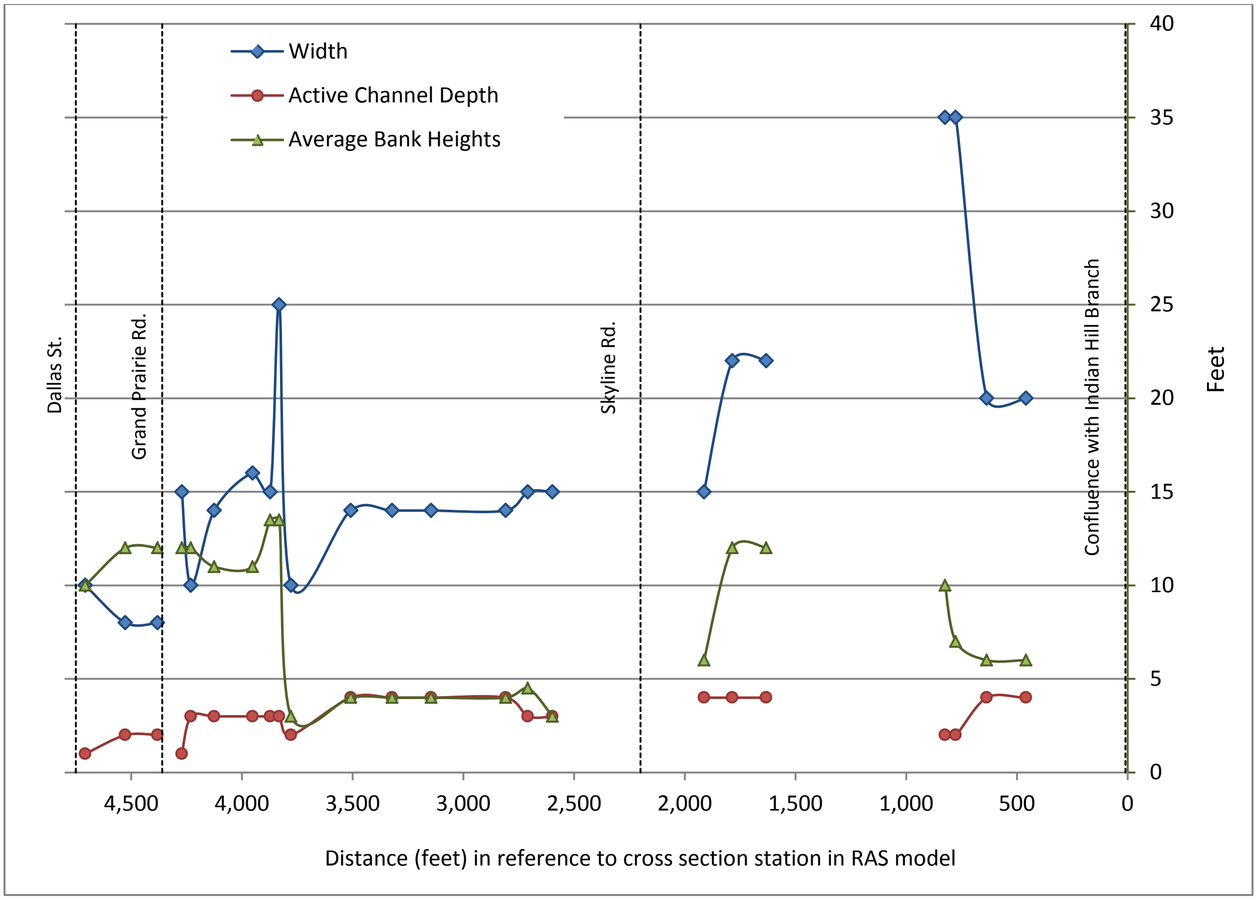
		Channel Evolution Model	SCALE 1:0 DESIGNED SVC DRAFTED SVC	FIGURE

4.6 EXISTING CONDITION CHANNEL GEOMETRY

The existing condition geometry assessment included measurement and evaluation of the channel morphology of the study reach of Henry Branch at each cross section location. The bottom width, active channel width, active channel depth, left bank height and right bank heights were analyzed based on field measurements to identify where possible changes were occurring in the channel. The active channel contains the flow that is responsible for forming the channel of the study reach. The active channel is defined as the portion of the channel in which flows occur frequently enough to keep vegetation from becoming established (Wood-Smith and Buffington 1996). Another active channel indicator was the top of depositional bars, which is indicative of the bankfull elevation in incised channels (Simon and Castro, 2003).

Channel dimensions varied throughout the study reach. Variation is likely due in part to local changes in flow resulting from stormwater inflows from the surrounding urban areas. Valley morphology also affected the channel dimensions. Generally, channel-floodplain connectivity was noted when the creek valley was wide and channel depth was relatively shallow. The channel anabranched across a broad floodplain between cross sections 3872 and 3145. High flows are able to spread onto the floodplain, decreasing the erosive power of the stream. If discharges are increased as a result of future increases in impervious surfaces, the erosive power of the stream will increase and the channel may become larger. Results of measurements taken in the study area are shown in Figure 4.10. The blank areas on the graph signify areas where channel dimensions have been altered. The water is ponded upstream of an undermined drop structure upstream of Skyline Road, and the channel is lined with concrete downstream of Skyline Road (between cross sections 2598 and 1913). There is a retention pond located between cross sections 1632 and 824.

Figure 4.10 Channel geometry of Henry Branch



5.0 CONCLUSIONS

5.1 HISTORICAL WATERSHED DEVELOPMENT

The historical aerial photograph analysis showed that the Henry Branch watershed was already mostly developed as residential by 1958. The watershed was fully developed by the time of the June 2012 field assessment, and there was a vegetated riparian buffer that bordered the channel throughout the study reach. If the amount of impervious cover in the watershed increases, or the riparian buffer is removed, the channel will likely become unstable. Increased instability will lead to increased erosion, downstream sedimentation, and potential threats to infrastructure.

5.2 KNICKPOINT MIGRATION

As part of the stream condition assessment, knickpoints (headcuts) in the streambed were identified. Table 4.1 provides locations and descriptions of the knickpoints observed in Henry Branch during the stream condition assessment. It is recommended that the knickpoints be stabilized to decrease future channel degradation and/or monitored (surveyed) to identify actual migration rates in order to prioritize stabilization efforts.

5.3 CHANNEL EROSION AND INSTABILITY

Stream bank protection and bank stabilization should be considered at all locations categorized as severely unstable and priority should be given to the areas in closest proximity to homes and infrastructure. Locations with severe erosion and actively migrating knickpoints should be addressed to decrease excess sediment loading. Appendix C provides maps describing specific areas of concern, items of interest, and severe instability along the study reach of Henry Branch. Erosion severity along the study reach is categorized in Appendix D.

5.4 CHANNEL FORMING FLOW

Based on field observations and review of the Henry Branch hydrologic and hydraulic model (Halff Associates, 2012), the modeled 2-year peak discharge appeared to be greater than the channel forming flow in the majority of the modeled cross sections in the study area.

5.5 CHANNEL EVOLUTION

The Henry Branch study reach has been disturbed by development in the watershed. The channel has downcut and widened in some areas as a result of the increased flows resulting from urbanization. It appeared that the channel had come back into equilibrium with the urban flow regime in some locations. If flows increase due to future watershed disturbances, it can be expected that the channel of Henry Branch will respond with increased instability.

6.0 REFERENCES

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APPENDIX A
Representative Photographs of Henry Branch

	
Upstream view towards 4708.	Right bank downstream of 4708.
	
Downstream view towards 4526, bank scour on the left bank from a riprap slope (outfall).	Upstream view from 4526, scour on the banks and the erosion matting was showing.
	
Left bank downstream of 4526 the bank had gully erosion.	Downstream of 4526, the left bank was scoured and had tree falls.

Henry Branch: Between SE Dallas St. and E. Grand Prairie Rd. (cross sections 7325 – 6384)

Left and right bank views assume downstream direction

	
Upstream view from 4381 showing an armored right bank.	Upstream view from 4271, dense, early succession vegetation along the channel
	
Downstream from 4230 shows a low flow channel, with trash debris along the banks.	Downstream of 4230, shows the banks armored with concrete rubble.
	
Downstream view from 4125 shows a stable channel.	Downstream view from 3952 shows a channel protected with concrete rubble.

Henry Branch: Downstream of E. Grand Prairie Rd. (cross sections 4381 – 3925)

Left and right bank views assume downstream direction

	
Upstream view from 3925 shows the creek cut around the concrete rubble and exposed the erosion control fabric.	Upstream view from 3872 shows a channel protected with slabs of concrete rubble.
	
Upstream view from 3831 shows wider low flow channel.	Downstream of 3831 the channel splits creating an islet.
	
Downstream of 3778 there was a debris jam.	Downstream of 3778 there was a 2-foot knickpoint.

Henry Branch: Downstream E. Grand Prairie Rd. (cross sections 3925 – 3778)

Left and right bank views assume downstream direction

	
Downstream of 3778 downstream of the knick point the channel bed showed exposed roots that formed a root mat.	At 3508 the channel was pooled.
	
Upstream of 3145 there was trash in the channel.	Downstream view from 3145, the channel meandered through the riparian corridor.
	
Downstream of 3145 the channel became wide once again.	Downstream of 3145 there was a piece of a concrete pipe in the channel.

Henry Branch: Downstream of E. Grand Prairie Rd. (3778 – 3145)

Left and right bank views assume downstream direction


Downstream from 2809 there was concrete rubble in the channel below a pedestrian bridge.


Downstream of 2708 the channel becamenarrow.


Downstream of 2598 there was a beaver pond on the channel; adjacent landowner said this location floods.


Downstream of 2598 there was a beaver dam on the channel.


At 2272 there was a concrete low water crossing that was severely undercut.

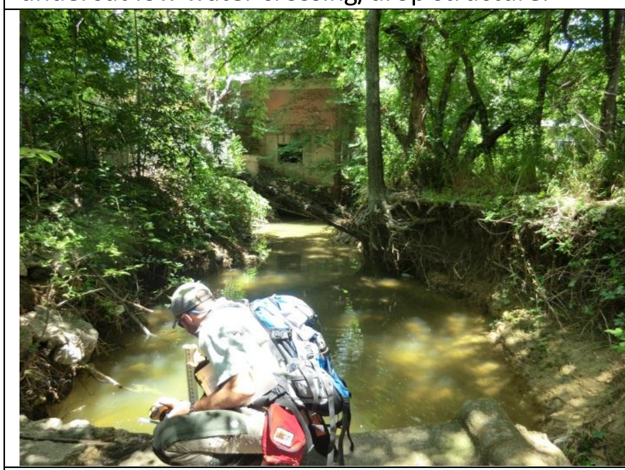

At 2272 there was a concrete low water crossing that was severely undercut.

Henry Branch: Upstream of Skyline Road (2809 – 2272)

Left and right bank views assume downstream direction

Upstream view from 2228 shows a cracked and undercut low water crossing/drop structure.

Upstream view from 2151 shows a concrete channel.



Downstream view from 2062 shows a 4-foot drop from the concrete to the channel bed and severe erosion downstream.

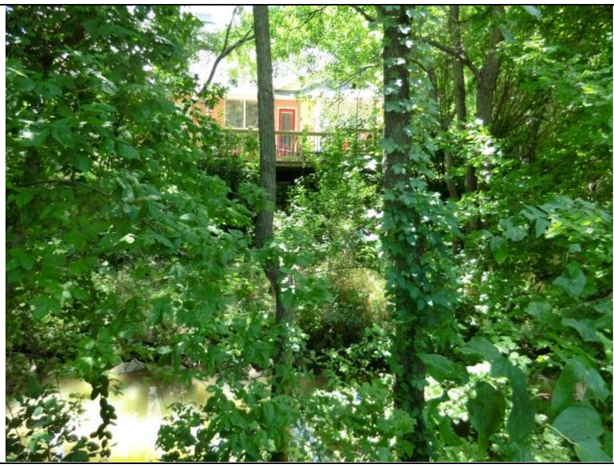
Left bank at 2062 has rusty drums on private property.

Right bank at 2062 there was a debris jam.

Downstream view from 1913 at a debris jam.

Henry Branch: Downstream of Skyline Road (2228 – 1913)

Left and right bank views assume downstream direction

	
Left bank near the vicinity of 1895 was armored with concrete rubble.	View from the left bank at 1785 looking downstream. The channel was incised.
	
View from the left bank at 1632.	View from the left bank looking at the right bank shows a house on the bank.
	
Upstream view from 1417 the stream was ponded.	Left bank view at 1417 shows a swale entering the channel.

Henry Branch: Downstream of Skyline Road (1895 – 1417)

Left and right bank views assume downstream direction

	
Left bank at 1417 shows gully erosion at the swale location.	Downstream from 1417 shows the ponded stream. The stream has been channelized.
	
Looking at the right bank near 1216.	Upstream view from 1097.
	
Downstream view from 1097.	Upstream view from 972.

Garden Branch: Downstream of Kingswood Blvd (2112 – 1443)

	
Downstream view from 972	Looking towards the right bank at 881. There was concrete drop at this location.
	
At 881 the concrete drop was severely eroded.	Looking towards the right bank at 824. The banks were armored with concrete rubble.
	
Upstream view from 776 shows a wide channel.	Right bank at 776 shows vegetation to the toe of the bank slope.

Henry Branch: Downstream of Skyline Road (972 – 776)

Left and right bank views assume downstream direction

Looking downstream at a knickpoint in the channel upstream of 636.

Looking upstream at a headcut upstream of 636.

Upstream view from 459.

Downstream view from 459.

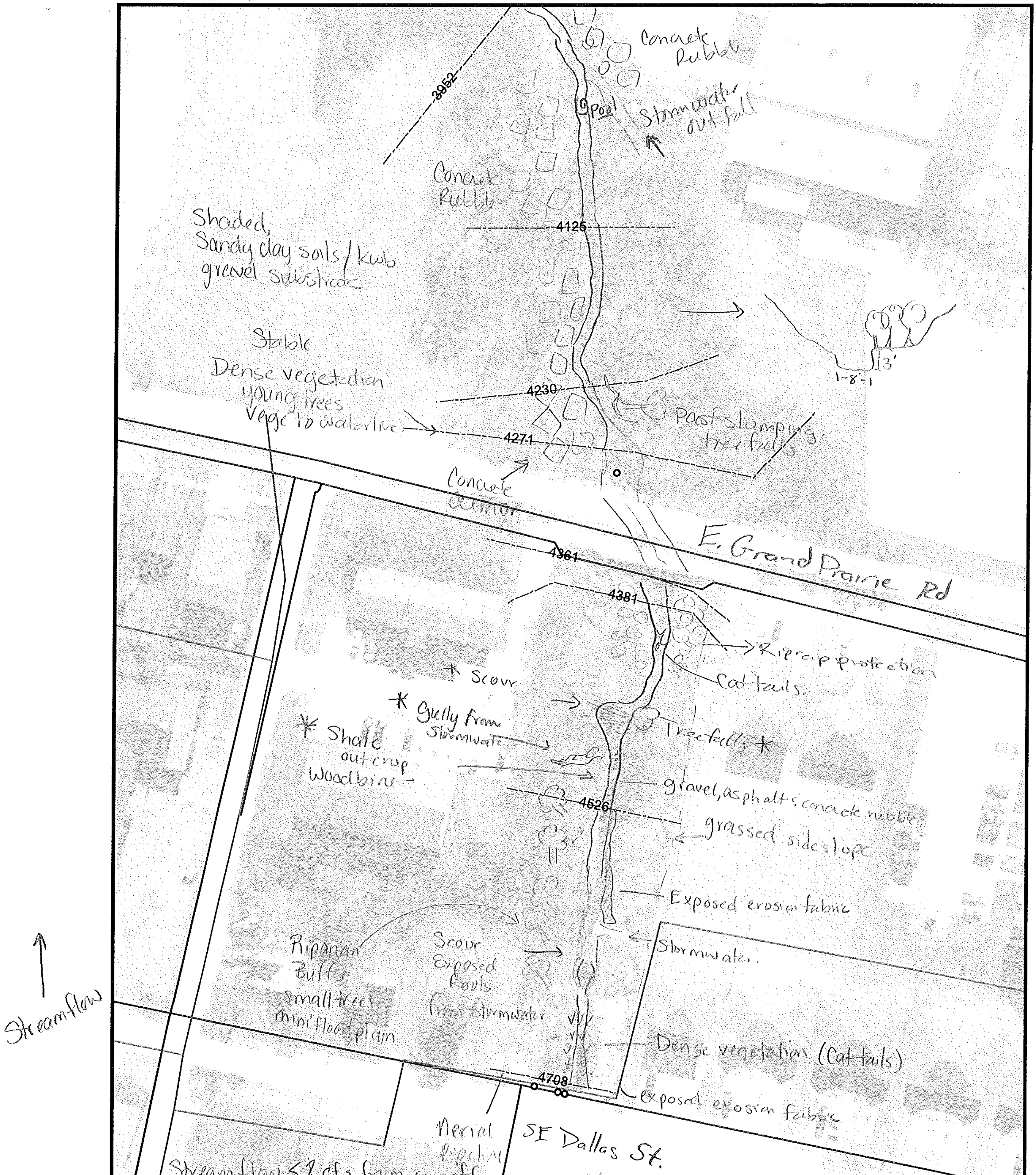
Downstream of the study reach the channel was armored with grouted riprap. Photo looking upstream at the study reach.

Downstream of the study reach the channel was armored with riprap and shotcrete. Photo looking downstream from the study reach.

Henry Branch: Downstream of Skyline Road(636 - 459)

Left and right bank views assume downstream direction

APPENDIX B
Stream Assessment Field Sketches



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Henry Branch Stream Condtion Assessment
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Field Assessment

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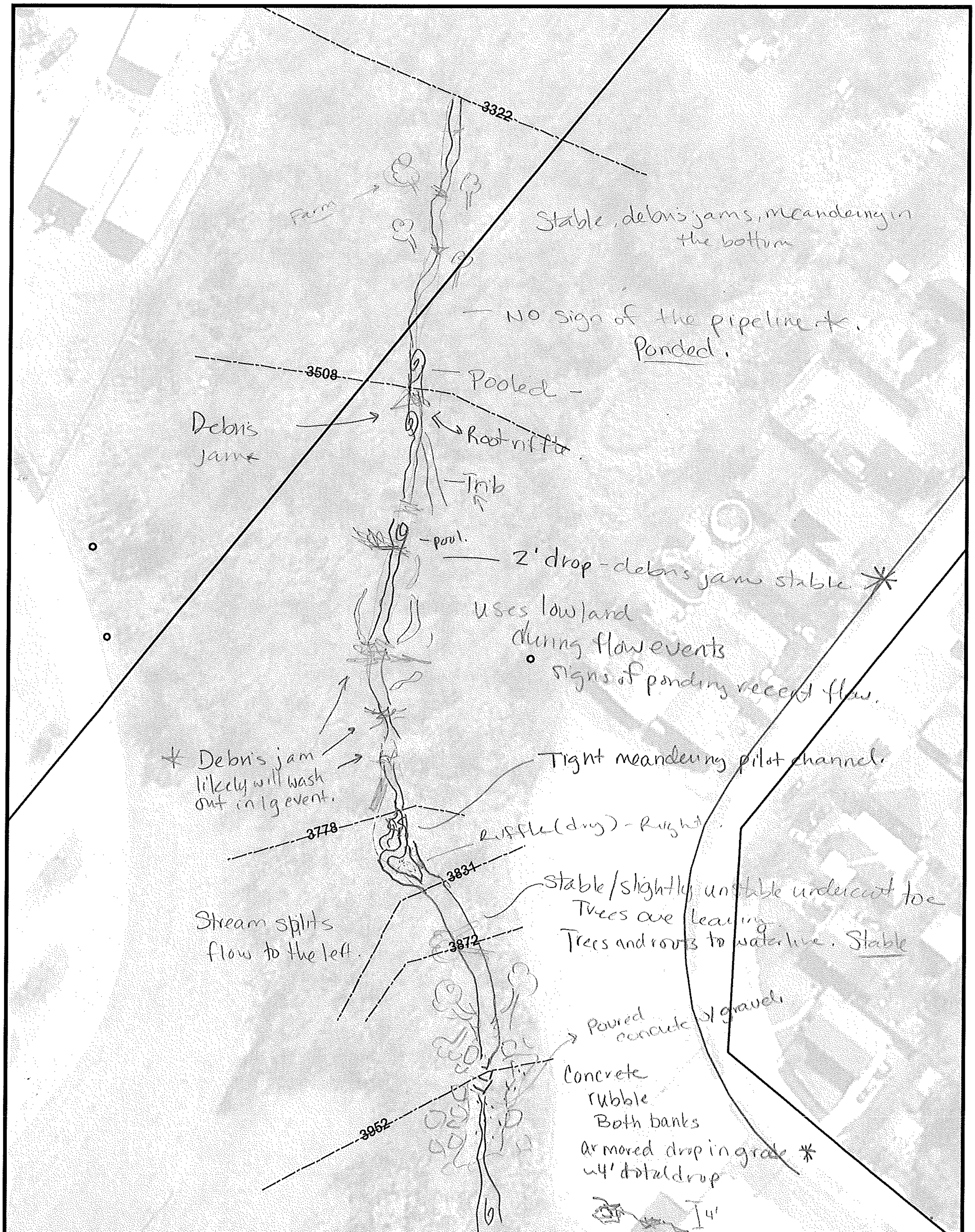
FIGURE

Channel does not follow flow line



Stream flow

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S W N E

Henry Branch Stream Condtion Assessment
City ~~Ciyt~~ of Grand Prairie

Field Assessment

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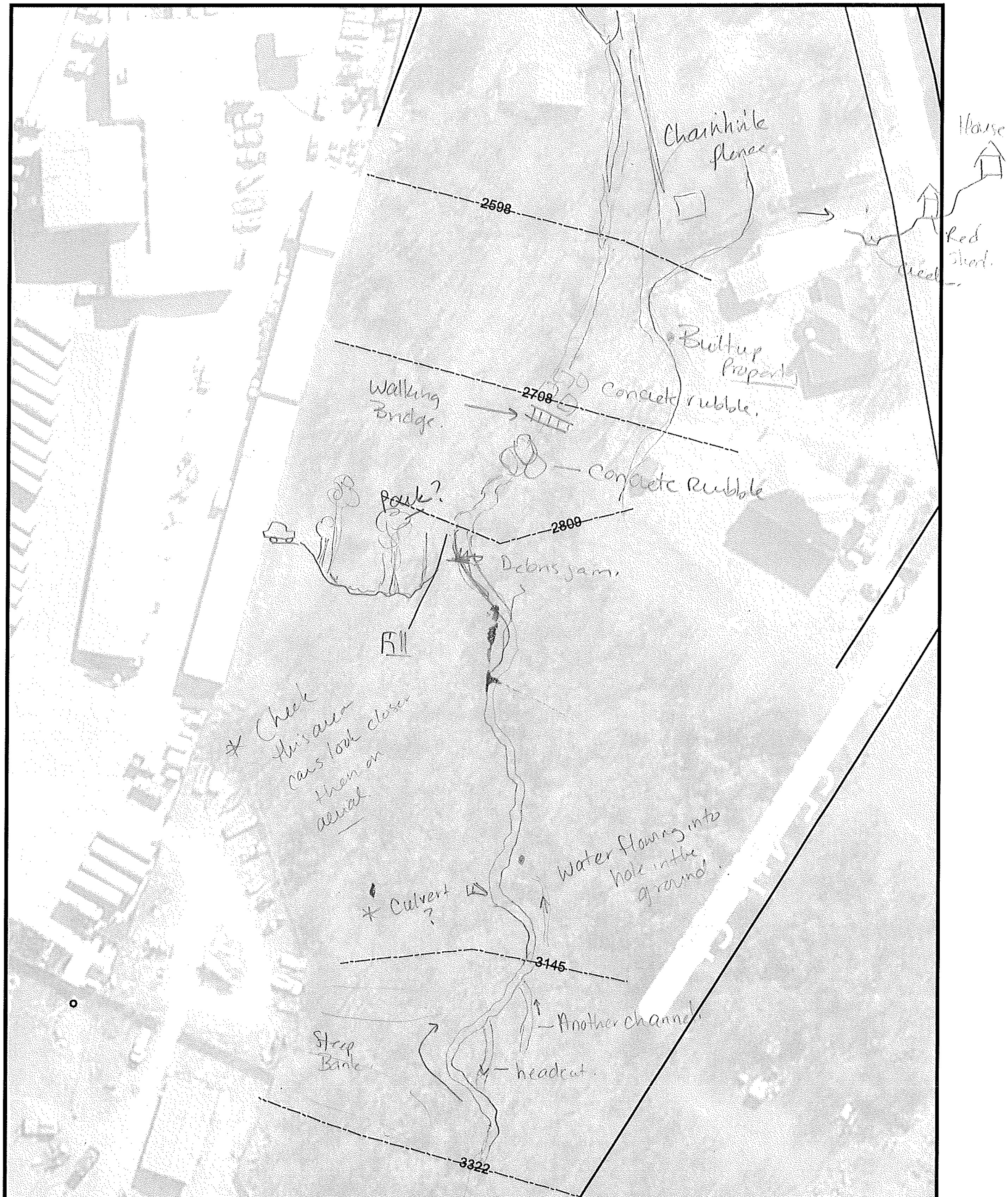

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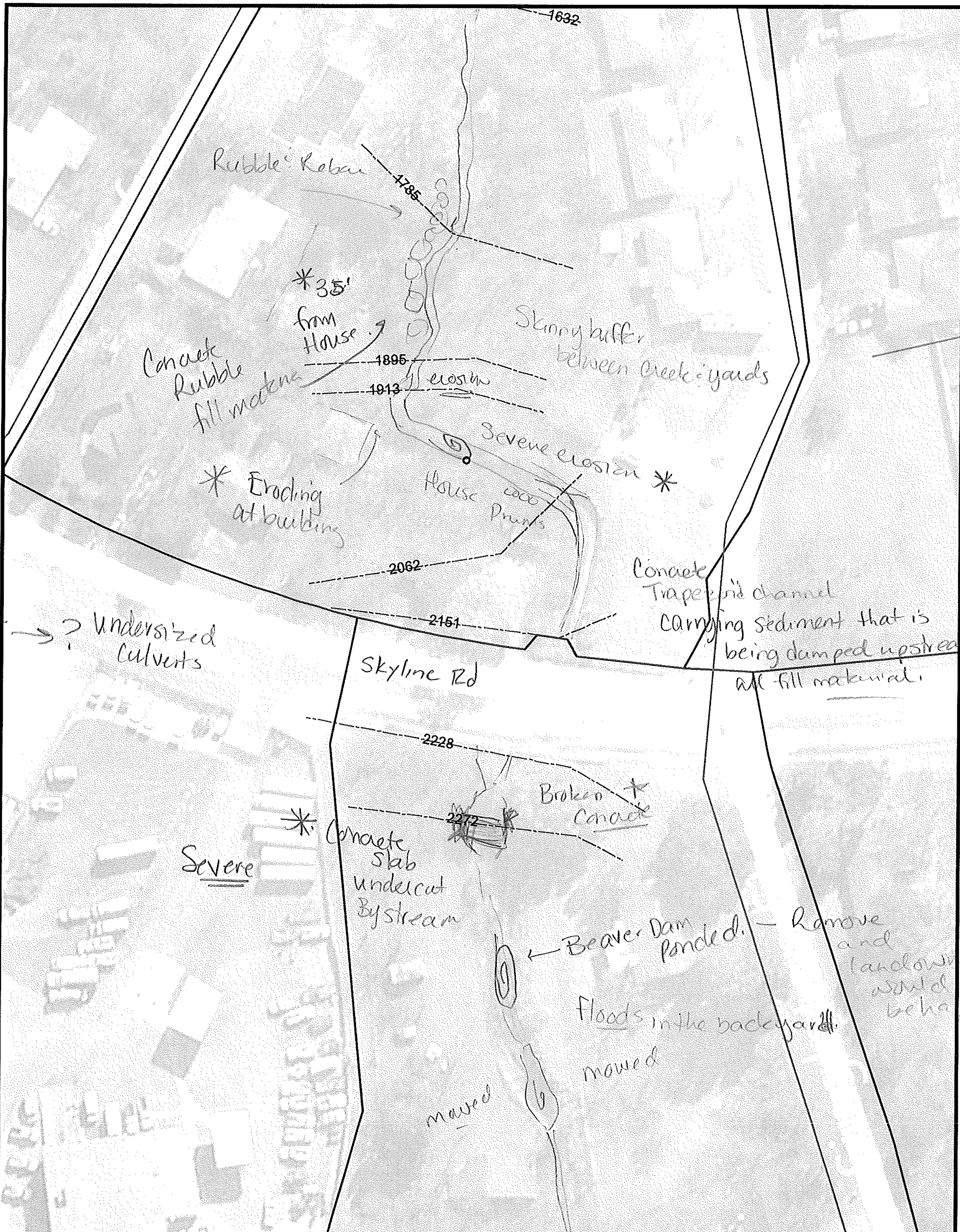
3
FIGURE

Slight to no flow



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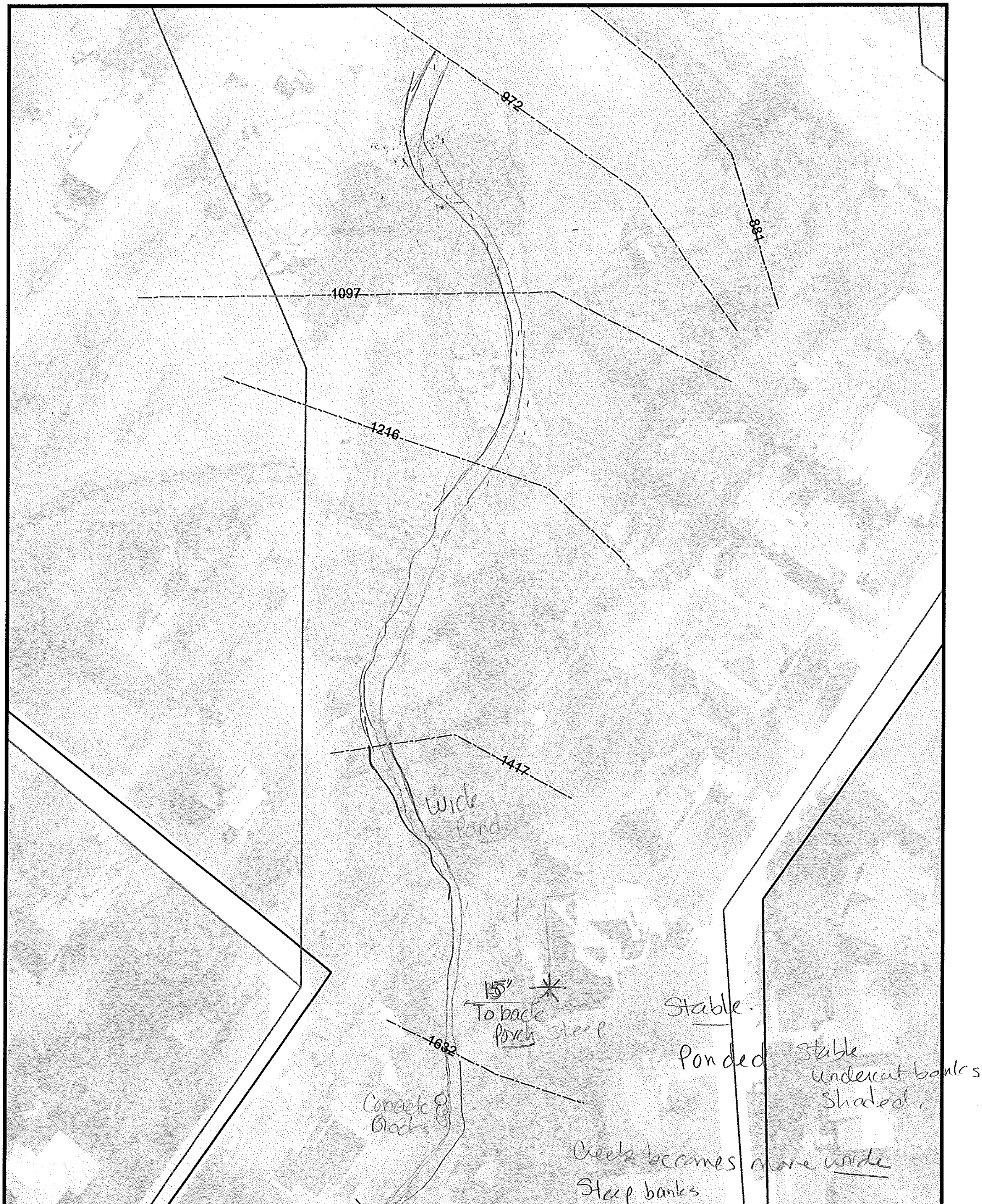

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Field Assessment

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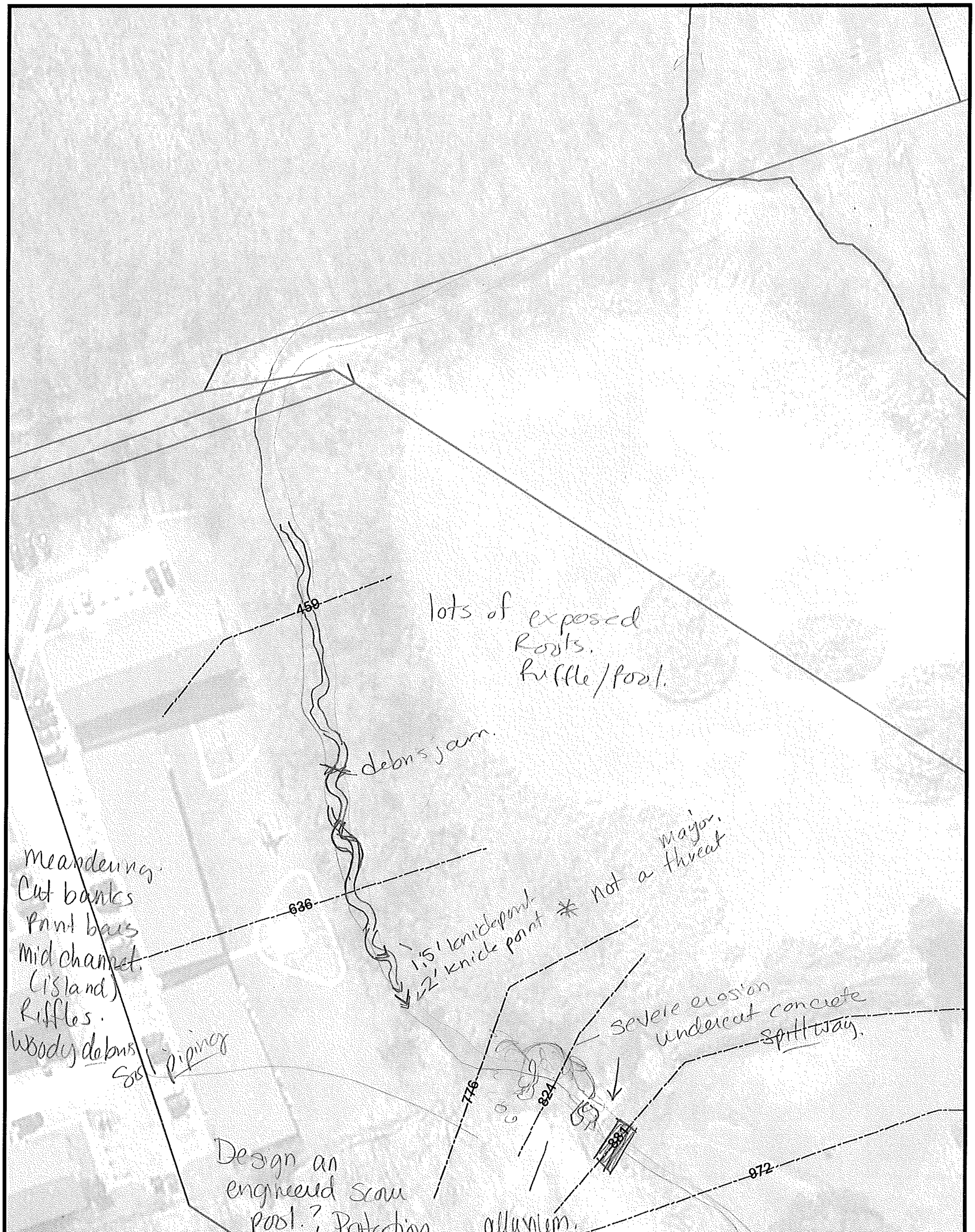
FIGURE



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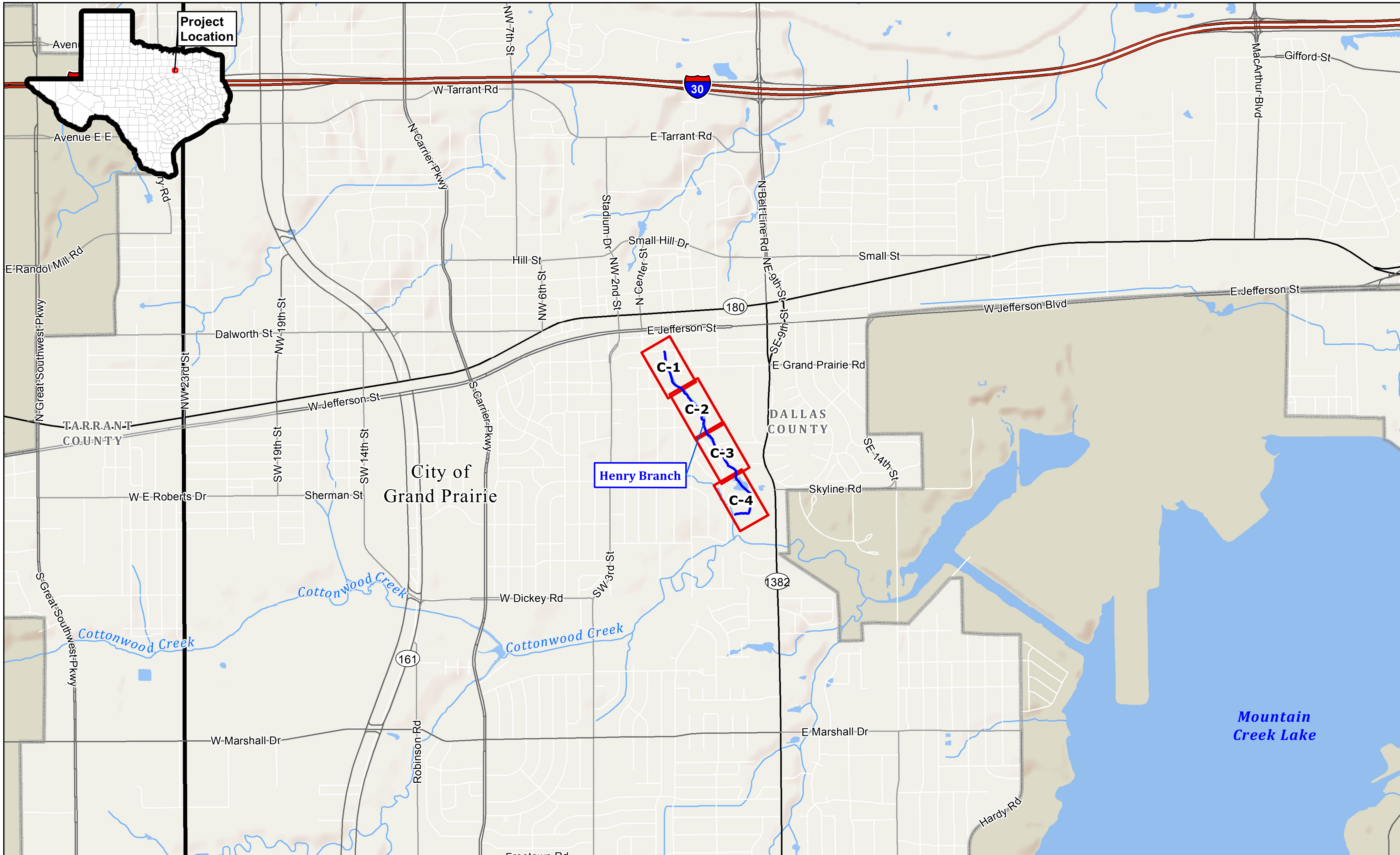
APPENDIX C
Areas of Interest



Grand Prairie | Index | County Boundary | Henry Branch | NHD Flowline | NHD Waterbody

1:24,000
1 inch equals 2,000 feet
0 1,000 2,000 4,000 Feet

N W E S

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DATE CREATED 7/24/2012
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Henry_Branch_AOI_Index
PREPARED BY SSJ

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Henry Branch Stream Condition Assessment

Areas of Interest - Index

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FIGURE C

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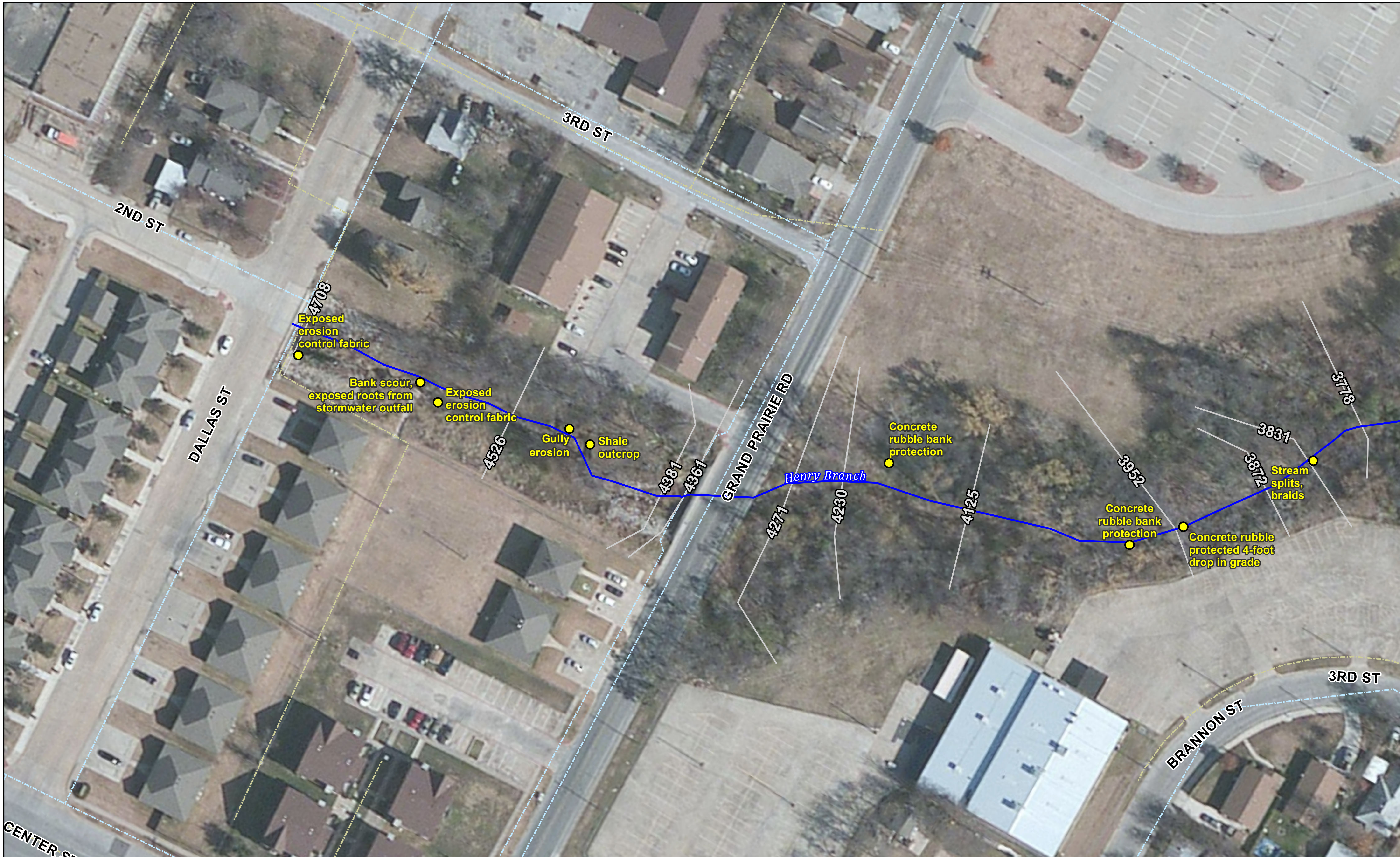


Henry Branch AOI

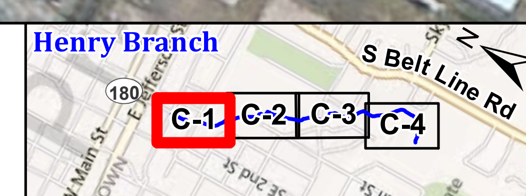
Henry Branch

NHD Flowline

Cross Section

Water Line

Wastewater Line



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1 inch = 75 feet

0 37.5 75 150 Feet

CITY OF GRAND PRAIRIE

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Areas of Interest

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C-1

FIGURE

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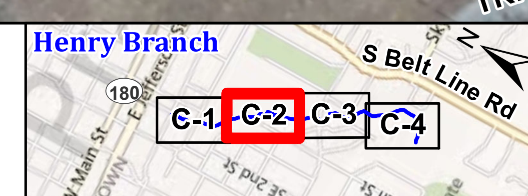
Henry Branch AOI
Henry Branch
NHD Flowline
Cross Section
Water Line
Wastewater Line



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1 inch = 75 feet
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Henry Branch Stream Condition Assessment
Areas of Interest

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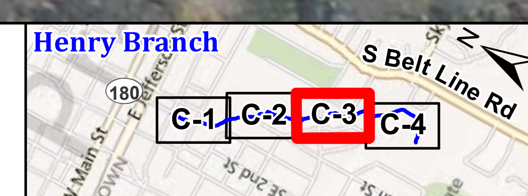
C-2
FIGURE

Henry Branch AOI
Henry Branch
NHD Flowline
Cross Section
Water Line
Wastewater Line



1:900
1 inch = 75 feet
0 37.5 75 150 Feet

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DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
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FIGURE

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Henry Branch AOI

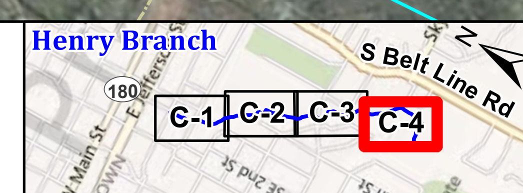
Henry Branch

NHD Flowline

Cross Section

Water Line

Wastewater Line



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1 inch = 75 feet

0 37.5 75 150 Feet

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Henry Branch Stream Condition Assessment

Areas of Interest

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DATE CREATED	7/24/2012
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
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C-4

FIGURE

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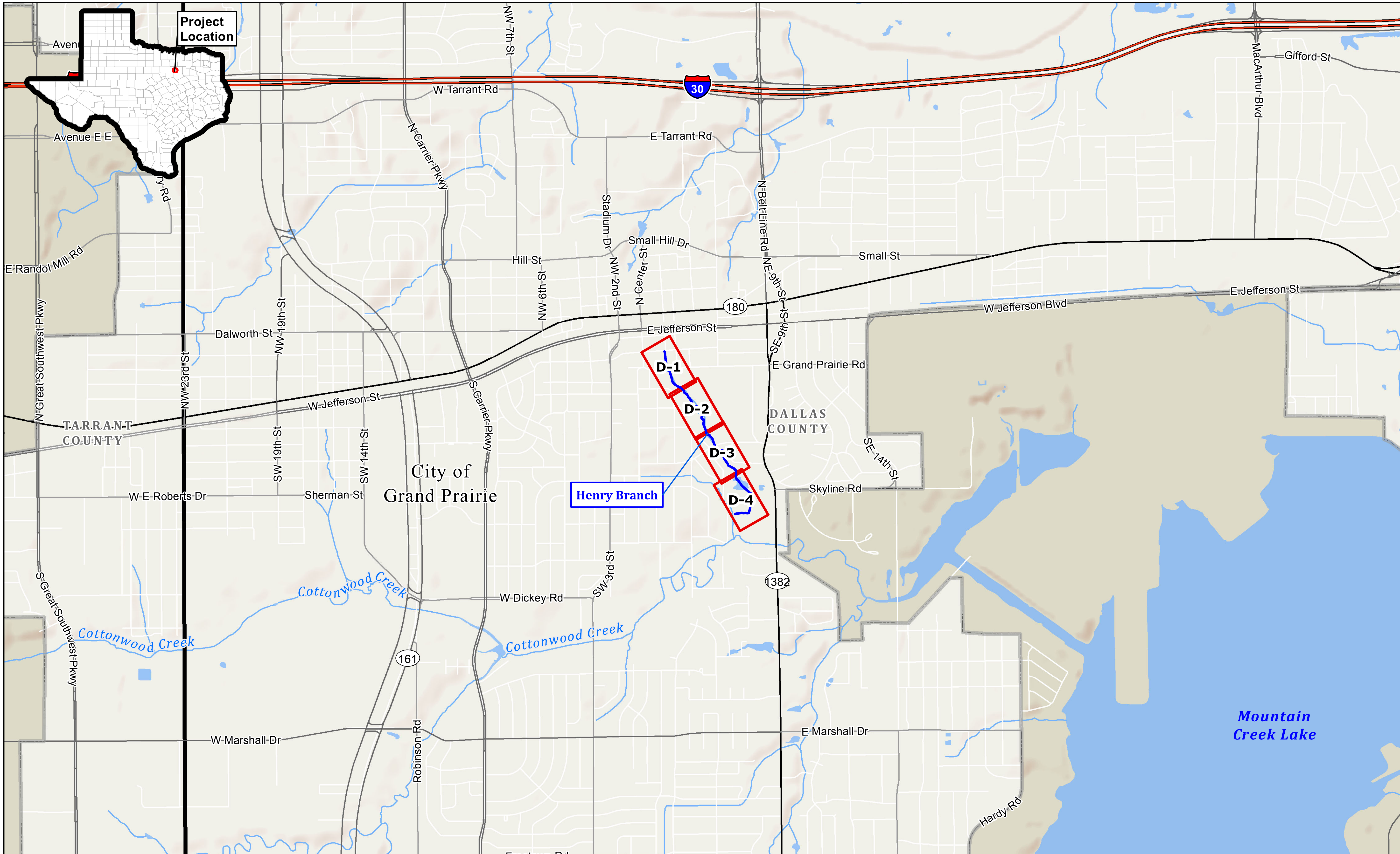
APPENDIX D
Channel Erosion Rating



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DATE CREATED 7/24/2012
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FILE NAME Henry_Branch_Erosion_index
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Henry Branch Stream Condition Assessment

Channel Erosion Rating - Index

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Henry Branch
Grand Prairie
Index
County Boundary
NHD Flowline
NHDWaterbody

1:24,000
1 inch equals 2,000 feet
0 1,000 2,000 4,000 Feet

N S E W

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FIGURE

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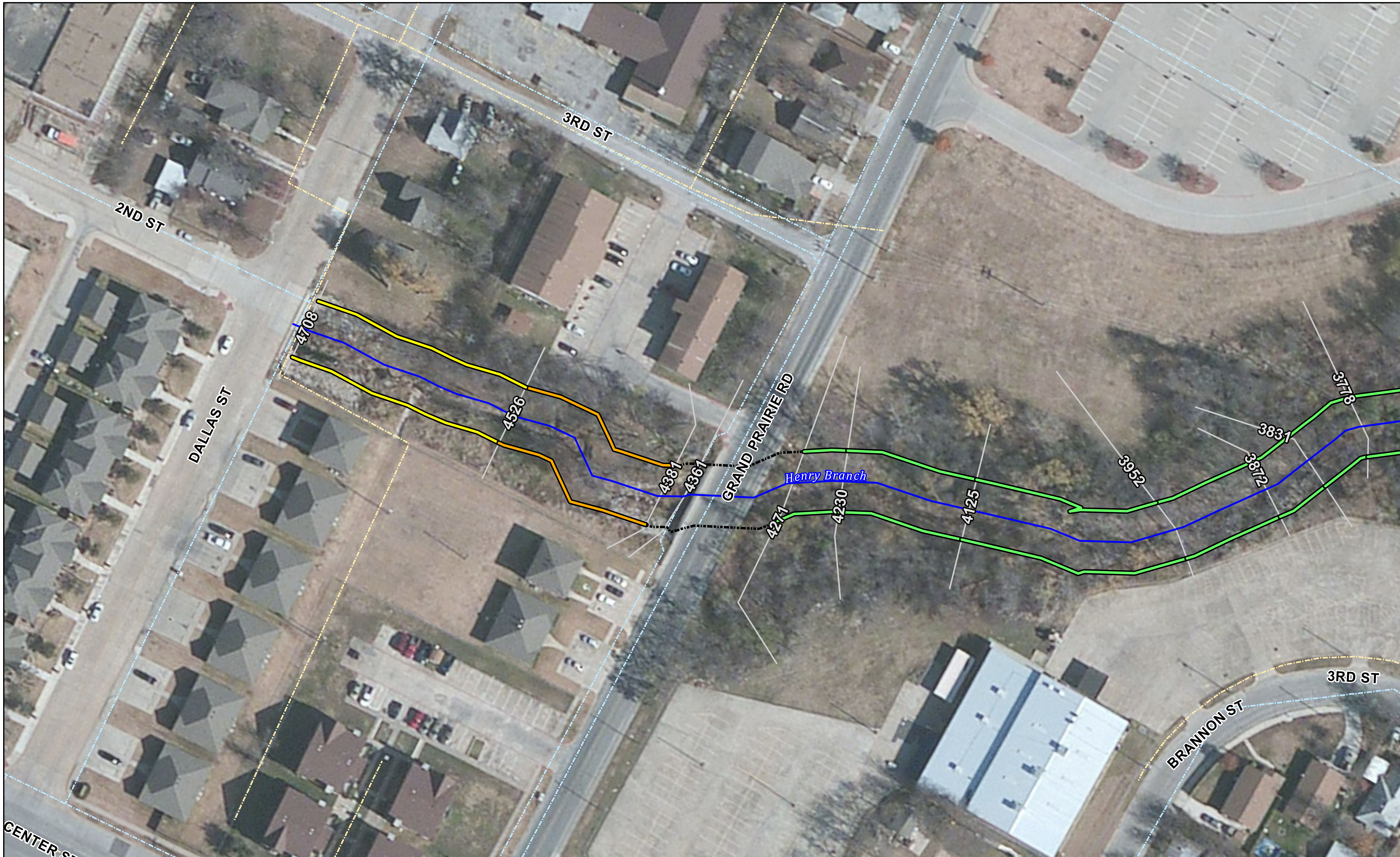

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DATE CREATED	7/24/2012
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
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Henry Branch Stream Condition Assessment

Channel Erosion Rating

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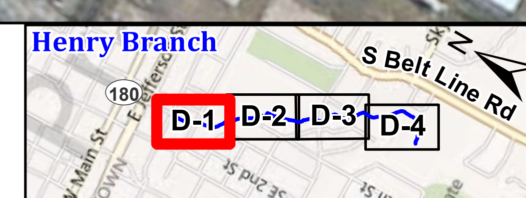
Concrete
Road
Stable
Slight
Moderate
Severe
Henry Branch
Cross Section
Water Line
Wastewater Line

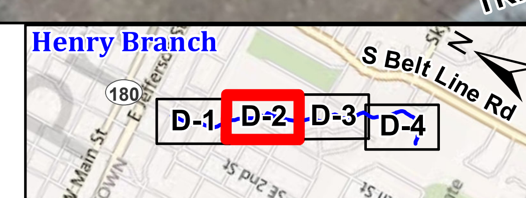


1:900
1 inch = 75 feet
0 37.5 75 150 Feet

D-1
FIGURE

Path: H:\ENVIRONMENTAL\FINAL_EXHIBITS\Henry_Branch_Erosion.mxd

Concrete
Road
Stable
Slight
Moderate
Severe
Henry Branch
Cross Section
Water Line
Wastewater Line



1:900
1 inch = 75 feet
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Channel Erosion Rating

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DATE CREATED	7/24/2012
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Henry_Branch_Erosion
PREPARED BY	SSJ

D-2
FIGURE

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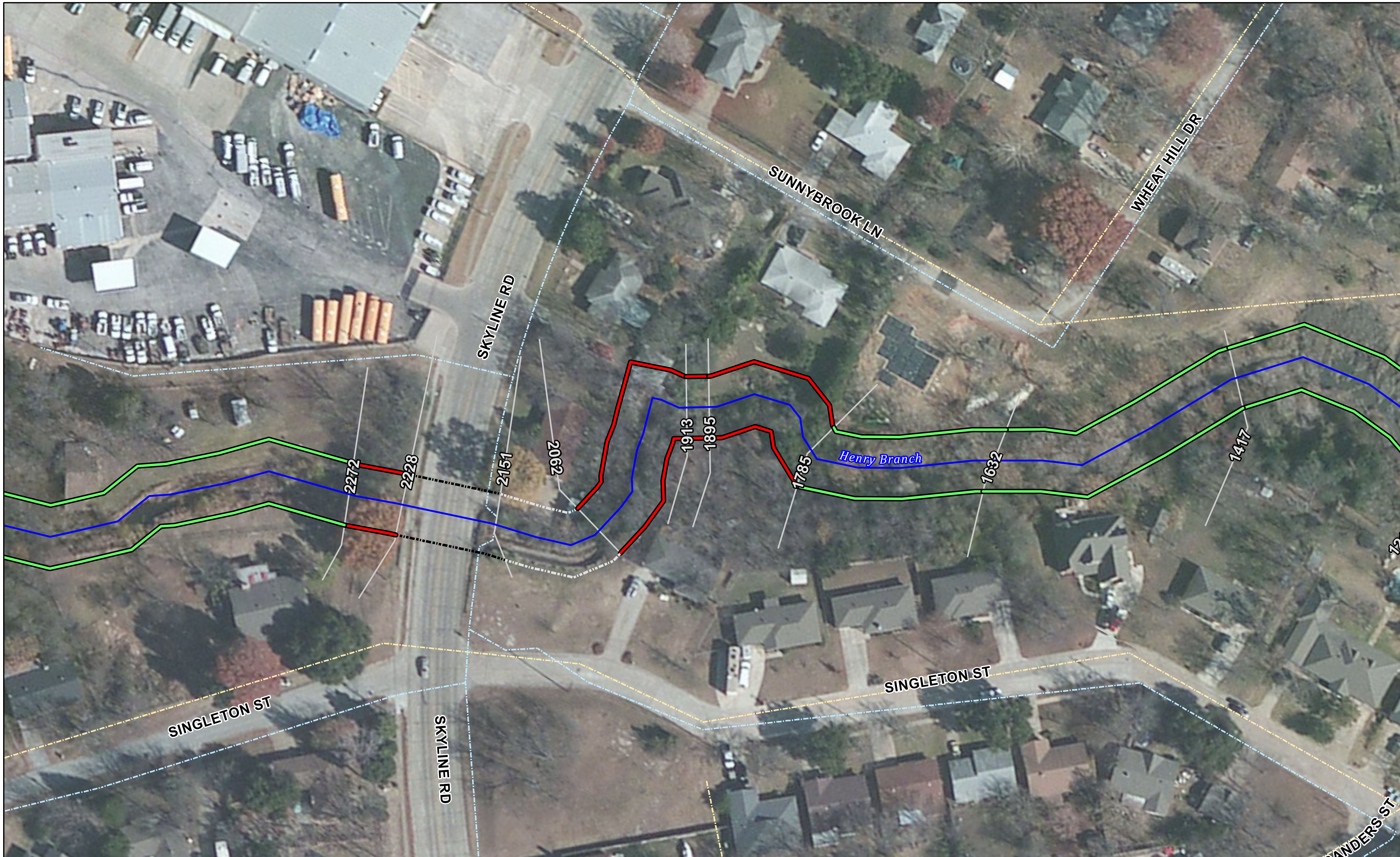
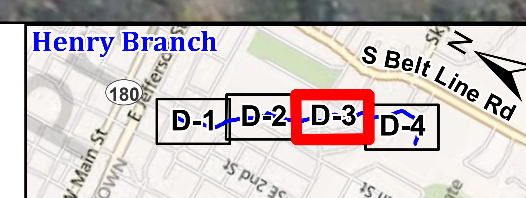


Concrete	Slight
Road	Moderate
Stable	Severe
Henry Branch	Water Line
Cross Section	Wastewater Line



1:900
1 inch = 75 feet
0 37.5 75 150 Feet

D-3
FIGURE

CITY OF GRAND PRAIRIE
Henry Branch Stream Condition Assessment
Channel Erosion Rating

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DATE CREATED 7/24/2012
DATUM & COORDINATE SYSTEM NAD83 State Plane (feet) Texas North Central
FILE NAME Henry_Branch_Erosion
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FN PROJECT NO.	HAF12272
DATE CREATED	7/24/2012
DATUM & COORDINATE SYSTEM	NAD83 State Plane (feet) Texas North Central
FILE NAME	Henry_Branch_Erosion
PREPARED BY	SSJ

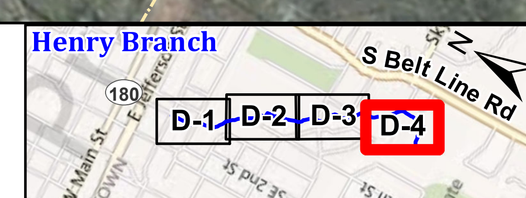
CITY OF GRAND PRAIRIE

Henry Branch Stream Condition Assessment

Channel Erosion Rating

FREESE NICHOLS
4500 International Plaza Suite 200
Fort Worth, Texas 76109-4895
(817) 735-7300

Legend: Concrete; Road; Stable; Slight; Moderate; Severe; Henry Branch; Cross Section; Water Line; Wastewater Line



1:900
1 inch = 75 feet
0 37.5 75 150 Feet

D-4
FIGURE

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ATTACHMENT 1
Digital photographs, GPS and image direction shapefile

Appendix D
Channel Stability Alternatives

Design Considerations for Siting Grade Control Structures

Design Considerations for Siting Grade Control Structures

by David S. Biedenharn and Lisa C. Hubbard

PURPOSE: The purpose of this Coastal and Hydraulics Engineering Technical Note (CHETN) is to provide guidance and highlight possible areas of concern that may require consideration before siting grade control structures.

INTRODUCTION: In the widest sense, the term grade control can be applied to any alteration in the watershed which provides stability to the streambed. By far the most common method of establishing grade control is the construction of in-channel grade control structures. There are two basic types of grade control structures. One type can be referred to as a bed control structure as it is designed to provide a hard point in the streambed that is capable of resisting the erosive forces of the degradational zone. The second type can be referred to as a hydraulic control structure as it is designed to function by reducing the energy slope along the degradational zone to the point that the stream is no longer capable of scouring the bed. The distinction between the operating processes of these two types is important whenever grade control structures are considered.

Design considerations for siting grade control structures include determination of the type, location, and spacing of structures along the stream, along with the elevation and dimensions of structures. Siting grade control structures is often considered a simple optimization of hydraulics and economics. However, these factors alone are usually not sufficient to define the optimum siting conditions for grade control structures. In practice, hydraulic considerations must be integrated with a host of other factors, which vary from site to site, to determine the final structure plan. Some of the more important factors to be considered when siting grade control structures are discussed in the following paragraphs.

HYDRAULIC CONSIDERATIONS: One of the most important steps in the siting of a grade control structure or a series of structures is the determination of the anticipated drop at the structure. This requires some knowledge of the ultimate channel morphology, both upstream and downstream of the structure, which involves assessment of sediment transport and channel morphologic processes.

The hydraulic siting of grade control structures is a critical element of the design process, particularly when a series of structures is planned. The design of each structure is based on the anticipated tailwater or downstream bed elevation which, in turn, is a function of the next structure downstream. Heede and Mulich (1973) suggested that the optimum spacing of structures is such that the upstream structure does not interfere with the deposition zone of the next downstream structure. Mussetter (1982) showed that the optimum spacing should be the length of the deposition above the structure, which is a function of the deposition slope (Figure 1). Figure 1 also illustrates the recommendations of Johnson and Minaker (1944) that the most desirable spacing can be determined by extending a line from the top of the first structure at a slope equal to the maximum equilibrium slope of sediment upstream until it intersects the original streambed.

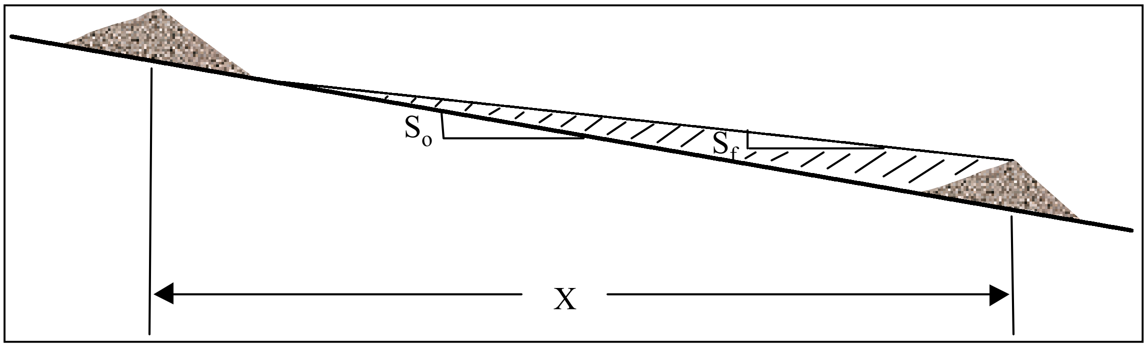


Figure 1. Spacing of grade control structure (adapted from Mussetter 1982)

Theoretically, the hydraulic siting of grade control structures is straightforward and can be determined by:

$$H = (S_o - S_f)X \qquad (1)$$

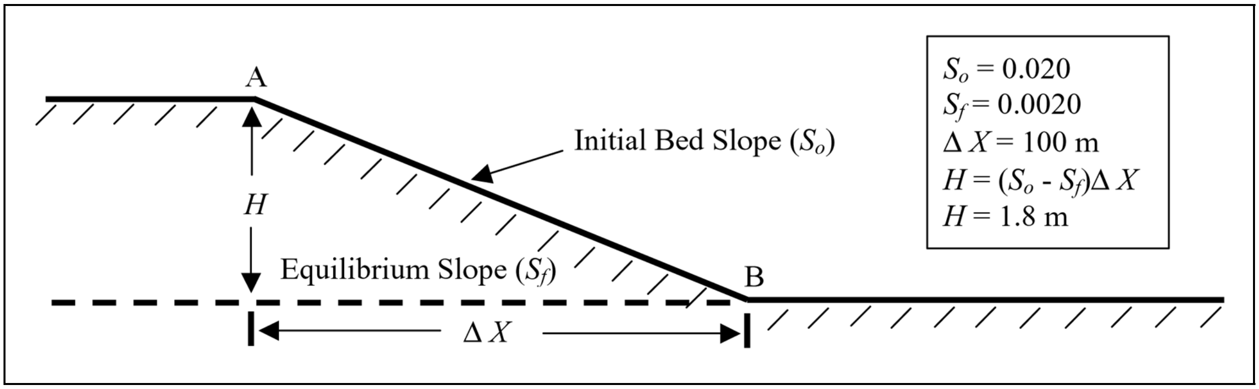
where H is the amount of drop to be removed from the reach, S_o is the original bed slope, S_f is the final, or equilibrium slope, and X is the length of the reach (Goitom and Zeller 1989). The number of structures (N) required for a given reach can then be determined by:

$$N = H/h \qquad (2)$$

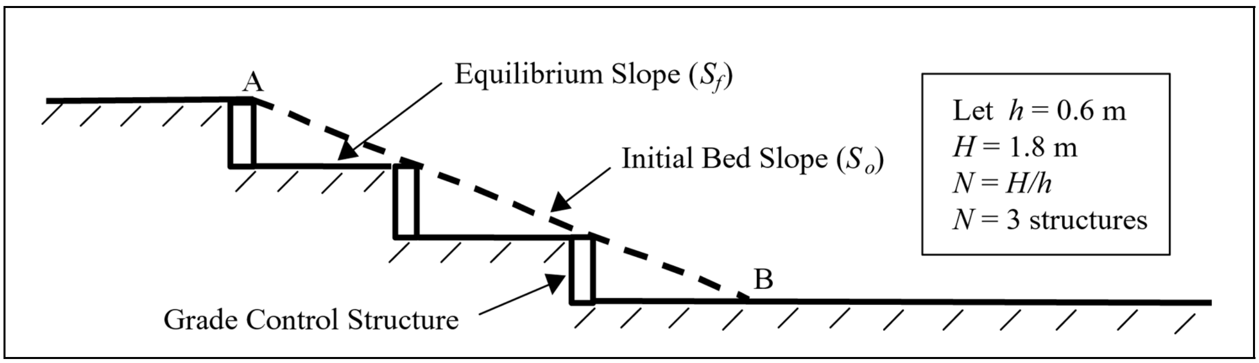
where h is the selected drop height of the structure.

The hydraulic siting of a series of bed control structures using the preceding procedure is illustrated in Figure 2. In contrast to bed control structures which are built at grade and the bed allowed to degrade between them (Figure 2b), hydraulic control structures are constructed with a raised and possibly constricted weir crest that drowns out the degradational zone (Figure 3b). It follows from Equation 1 that one of the most important factors to consider when siting grade control structures is the determination of the equilibrium slope (S_f). Unfortunately, this is also one of the most difficult parameters to define with any reliability. Failure to properly define the equilibrium slope can lead to costly, overly conservative designs, or inadequate design resulting in continued maintenance problems and possible complete failure of the structures.

The primary factors affecting the final equilibrium slope upstream of a structure include the incoming sediment concentration and load, the channel characteristics (slope, width, depth, roughness, etc.), and the hydraulic effect of the structure. Another complicating factor is the amount of time it takes for the equilibrium slope to develop. In some instances, the equilibrium slope may develop over a period of a few hydrographs while in others, it may take many years.



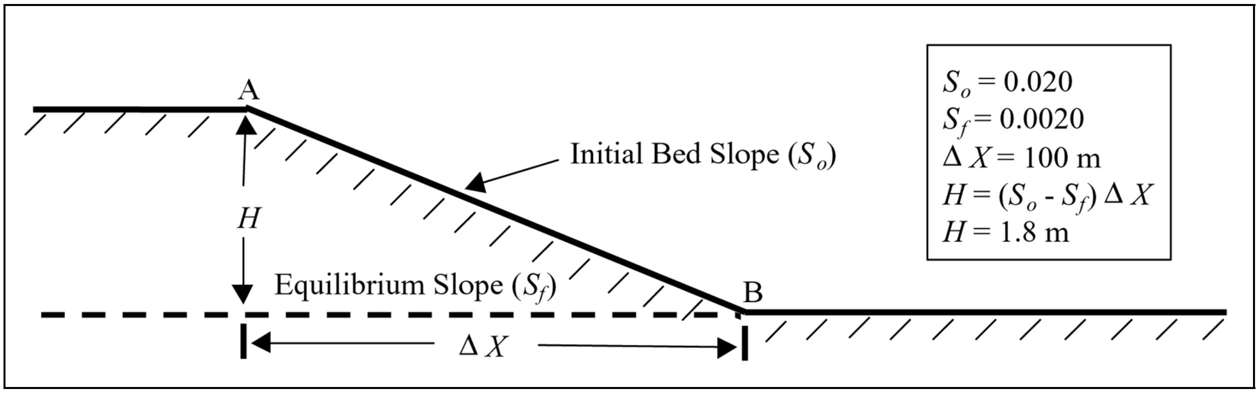
a. Initial condition of streambed showing degradational zone between points A and B. Total anticipated drop in reach is calculated to be 1.8 m



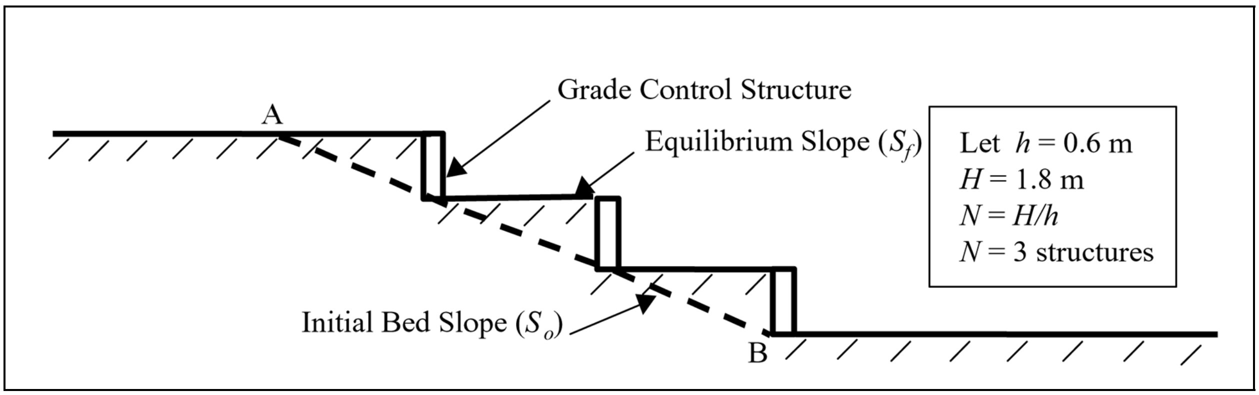
b. Stabilization of degradational zone using three bed control structures. Each structure has a design drop of 0.6 m

Figure 2. Hydraulic siting of bed control structures

There are many different methods for determining the equilibrium slope in a channel (Mussetter 1982; Federal Interagency Stream Restoration Working Group 1988; Watson, Biedenharn, and Scott 1999). These can range from detailed sediment transport modeling (Thomas et al. 1994; HQUSACE 1993) to less elaborate procedures involving empirical or process-based relationships such as regime analysis (Lacey 1931; Simons and Albertson 1963), tractive stress (Lane 1953a,b; Simons 1957; Simons and Sentürk 1992; HQUSACE 1994), or minimum permissible velocity (USDA 1977). In some cases, the equilibrium slope may be based solely on field experience with similar channels in the area. Regardless of the procedure used, the engineer must recognize the uses and limitations of that procedure before applying it to a specific situation. The decision to use one method or another depends upon several factors such as the level of study (reconnaissance or detail design), availability and reliability of data, project objectives, and time and cost constraints.



a. Initial condition of streambed showing degradational zone between points A and B. Total anticipated drop in reach is calculated to be 1.8 m



b. Stabilization of degradational zone using three hydraulic control structures. Each structure has a design drop of 0.6 m

Figure 3. Hydraulic siting of hydraulic control structures

GEOTECHNICAL CONSIDERATIONS: The preceding discussion focused only on the hydraulic aspects of siting grade control structures. However, in some cases, the geotechnical stability of the reach may be an important or even the primary factor to consider when siting grade control structures. This is often the case where channel degradation has caused, or is anticipated to cause, severe bank instability due to exceedance of the critical bank height (Thorne and Osman 1988). When this occurs, bank instability may be widespread throughout the system rather than restricted to the concave banks in bendways. Traditional bank stabilization measures may not be feasible in situations where system-wide bank instabilities exist. In these instances, grade control may be the more appropriate solution.

Grade control structures can enhance the bank stability of a channel in several ways. Bed control structures indirectly affect the bank stability by stabilizing the bed, thereby reducing the length of bank line that achieves an unstable height. With hydraulic control structures, two additional advantages with respect to bank stability are: (a) bank heights are reduced due to sediment deposition, which increases the stability of the banks with regard to mass failure; and (b) by creating a backwater situation, velocities and scouring potential are reduced, which reduces or eliminates the severity and extent of basal cleanout of the failed bank material, thereby promoting self-healing of the banks.

FLOOD CONTROL IMPACTS: Channel improvements for flood control and channel stability often appear to be mutually exclusive objectives. For this reason, it is important to ensure that any increased postproject flood potential is identified. This is particularly important when hydraulic control structures are considered. In these instances, the potential for causing overbank flooding may be the limiting factor with respect to the height and amount of constriction at the structure. Grade control structures are often designed to be hydraulically submerged at flows less than bank-full so that the frequency of overbank flooding is not affected. However, if the structure exerts control through a wider range of flows including overbank, then the frequency and duration of overbank flows may be impacted. When this occurs, the impacts must be quantified and appropriate provisions such as acquiring flowage easements or modifying structure plans should be implemented.

Another factor that must be considered is the safe return of overbank flows back into the channel. This is particularly a problem when the flows are out of bank upstream of the structure but still within bank downstream. The resulting head differential can cause damage to the structure as well as severe erosion of the channel banks depending upon where the flow re-enters the channel. Some means of controlling the overbank return flows must be incorporated into the structure design. One method is simply to design the structure to be submerged below the top bank elevation, thereby reducing the potential for a head differential to develop across the structure during overbank flows. If the structure exerts hydraulic control throughout a wider range of flows including overbank, then a more direct means of controlling the overbank return flows must be provided. One method is to ensure that all flows pass only through the structure. This may be accomplished by building an earthen dike or berm extending from the structure to the valley walls which prevents any overbank flows from passing around the structure (Forsythe 1985). Another means of controlling overbank flows is to provide an auxiliary high-flow structure which will pass the overbank flows to a specified downstream location where the flows can re-enter the channel without causing significant damage (Hite and Pickering 1982).

ENVIRONMENTAL CONSIDERATIONS: In today's environment, projects must work in harmony with the natural system to meet the needs of the present without compromising the ability of future generations to meet their needs. Engineers and geomorphologists are responding to this challenge by trying to develop new and innovative methods for incorporating environmental features into channel projects. The final siting and design of a grade control structure is often modified to minimize adverse environmental impacts to the system.

Grade control structures can produce positive environmental impacts on a channel system in a number of ways. Grade control structures are typically placed in severely unstable stream reaches. By preventing the headward migration of zones of degradation, grade control structures provide vertical stability to the stream and reduce the amount of sediment eroded from the streambed and banks. This not only protects the upstream reaches from the destabilizing effects of bed lowering, but can also minimize sedimentation problems in the downstream reaches.

Therefore, the impacts of grade control structures are not restricted to a local area around the structure, but can have far-reaching impacts on the whole channel system.

Grade control structures can provide direct environmental benefits to a stream. Cooper and Knight (1987) conducted a study of fisheries resources below natural scour holes and man-made pools below grade control structures in north Mississippi. They concluded that, although there was greater species diversity in the natural pools, there was increased growth of game fish and a larger percentage of harvestable-size fish in the man-made pools. They also observed that the man-made pools provided greater stability of reproductive habitat. Shields et al. (1990) reported that the physical aquatic habitat diversity was higher in stabilized reaches of Twentymile Creek, MS, than in reaches without grade control structures. They attributed the higher diversity values to the scour holes and low-flow channels created by the grade control structures. The use of grade control structures as environmental features is not limited to the low-gradient sand bed streams of the southeastern United States. Jackson (1974) documented the use of gabion grade control structures to stabilize a high-gradient trout stream in New York. She observed that, following construction of a series of bed sills, there was a significant increase in the density of trout. The increase in trout density was attributed to the accumulation of gravel between the sills which improved the spawning habitat for various species of trout.

Adverse environmental impacts can also be associated with grade control structures. During the construction of any structure there is always the potential for the destruction of riparian habitat. However, with grade control structures, these impacts are usually limited to a localized area at the structure as opposed to other types of channel improvement features (levees, bank stabilization, or channelization) where habitat destruction may occur continuously over long reaches of stream.

Perhaps the most serious negative environmental impact of grade control structures is the obstruction to fish passage. In many instances, fish passage is one of the primary considerations and may lead the engineer to select several small fish passable structures in lieu of one or more high drops that would restrict fish passage. In some cases, particularly when drop heights are small, fish are able to migrate upstream past a structure during high flows (Cooper and Knight 1987). However, in situations where structures are impassable, and where the migration of fish is an important concern, openings, fish ladders, or other passageways must be incorporated into the design of the structure to address the fish movement problems (Nunnally and Shields 1985). The various methods of accomplishing fish movement through structures are not discussed here. Interested readers are referred to Nunnally and Shields (1985); Clay (1961); and Smith (1985) for a more detailed discussion.

Other potentially adverse impacts associated with grade control structures include changed substrate character due to sediment deposition, increased water temperature, altered energy and transport characteristics, general habitat modification, and reduction in stream dynamics including riparian succession. There may also be social considerations that should be considered, especially safety.

The environmental aspects of the project must be an integral component of the design process when siting grade control structures. A detailed study of all environmental features in the project area should be conducted early in the design process. This will allow these factors to be incorporated into the initial plan rather than having to make costly and often less environmentally effective last minute modifications to the final design. Unfortunately, there is very little published guidance concerning the incorporation of environmental features into the design of grade control structures. One source of useful information can be found in the following technical reports published by the U.S. Army Engineer Research and Development Center (ERDC) Environmental Laboratory: Shields and Palermo (1982); Henderson and Shields (1984); and Nunnally and Shields (1985).

EXISTING STRUCTURES: Bed degradation can cause significant damage to bridges, culverts, pipelines, utility lines, and other structures along the channel perimeter. Grade control structures can prevent this degradation and thereby provide protection to these structures. For this reason, it is important to locate all potentially impacted structures when siting grade control structures. The final siting should be modified, as needed, within project restraints, to ensure protection of existing structures.

It must also be recognized that grade control structures can have adverse as well as beneficial effects on existing structures. This is a concern upstream of hydraulic control structures due to the potential for increased stages and sediment deposition. In these instances, the possibility of submerging upstream structures such as water intakes or drainage structures may become a deciding factor in the siting of grade control structures.

Whenever possible, the designer should take advantage of any existing structures which may already be providing some measure of grade control. This usually involves culverts or other structures that provide a nonerodible surface across the streambed. Unfortunately, these structures are usually not initially designed to accommodate any significant bed lowering and, therefore, cannot be relied on to provide long-term grade control. However, it may be possible to modify these structures to protect against the anticipated degradation. These modifications may be accomplished by simply adding some additional riprap with launching capability at the downstream end of the structure. In other situations, more elaborate modifications such as providing a sheet pile cutoff wall or energy dissipation devices may be required. Damage to and failure of bridges is the natural consequence of channel degradation. Consequently, it is not uncommon in a channel stabilization project to have several bridges that are in need of repair or replacement. In these situations it is often advantageous to integrate the grade control structure into the planned improvements at the bridge. If the bridge is not in immediate danger of failing and only needs some additional erosion protection, the grade control structure can be built at or immediately downstream of the bridge with the riprap from the structure tied into the bridge for protection. If the bridge is to be replaced, then it may be possible to construct the grade control structure concurrently with the road crossing.

LOCAL SITE CONDITIONS: When planning grade control structures, the final siting is often adjusted to accommodate local site conditions, such as the planform of the stream or local drainage. A stable upstream alignment that provides a straight approach into the structure is critical. Since failure to stabilize the upstream approach may lead to excessive scour and possible flanking of the structure, it is desirable to locate the structure in a straight reach. If this is not possible (as in the case in a very sinuous channel), it may be necessary to realign the channel to provide an adequate approach. Stabilization of the realigned channel may be required to ensure that the approach is maintained. Even if the structure is built in a straight reach, the possibility of upstream meanders migrating into the structure must be considered. In this case, the upstream meanders should be stabilized prior to, or concurrent with, the construction of the grade control structure.

Local inflows from tributaries, field drains, roadside ditches, or other sources often play an important part in the siting of grade control structures. Failure to provide protection from local drainage can result in severe damage to a structure (U.S. Army Corps of Engineers 1981). During the initial siting of the structure, all local drainage should be identified. Ideally, the structure should be located to avoid local drainage problems. However, there may be some situations where this is not possible. In these instances, the local drainage should either be redirected away from the structure or incorporated into the structure design in such a manner that there will be no damage to the structure.

DOWNSTREAM CHANNEL RESPONSE: Since grade control structures affect the sediment delivery to downstream reaches, it is necessary to consider the potential impacts to the downstream channel when grade control structures are planned. Bed control structures reduce the downstream sediment loading by preventing the erosion of the bed and banks, while hydraulic control structures have the added effect of trapping sediments. The ultimate response of the channel to the reduction in sediment supply will vary from site to site. In some instances, the effects of grade control structures on sediment loading may be so small that downstream degradational problems may not be encountered. However, in some situations such as when a series of hydraulic control structures is planned, the cumulative effects of sediment trapping may become significant. In these instances, it may be necessary to modify the plan to reduce the amount of sediment being trapped or to consider placing additional grade control structures in the downstream reach to protect against the induced degradation.

GEOLOGIC CONTROLS: Geologic controls often provide grade control in a similar manner to a bed control structure. In some cases, a grade control structure can actually be eliminated from the plan if an existing geologic control can be utilized to provide a similar level of bed stability. However, caution must always be used when relying on geologic outcrops to provide long- term grade control. In situations where geologic controls are to be used as permanent grade control structures, a detailed geotechnical investigation of the outcrop is needed to determine its vertical and lateral extent. This is necessary to ensure that the outcrop will neither be eroded, undermined, or flanked during the project life.

EFFECTS ON TRIBUTARIES: The effect of main stem structures on tributaries should be considered when siting grade control structures. As degradation on a main stem channel migrates upstream it may branch up into the tributaries. Therefore, the siting of grade control structures should consider effects on the tributaries. If possible, main stem structures should be placed downstream of tributary confluences. This will allow one structure to provide grade control to both the main stem and the tributary. This is generally a more cost-effective procedure than having separate structures on each channel.

SUMMARY: The preceding discussion illustrates that the siting of grade control structures is not simply a hydraulic exercise, and there are many other factors that must be included in the design process. For any specific situation, some or all of the factors discussed in this section may be critical elements in the final siting of grade control structures. It is recognized that this does not represent an all inclusive list since there may be other factors not discussed here that may be locally important. For example, in some cases, maintenance requirements, debris passage, ice conditions, esthetics or safety considerations may be controlling factors. Consequently, there is no definitive cookbook procedure for siting grade control structures that can be applied universally. Rather, each situation must be assessed on an individual basis.

ADDITIONAL INFORMATION: Questions about this CHETN can be addressed to David S. Biedenharn (601-634-4653), e-mail: *David.S.Biedenharn@erdc.usace.army.mil* or Lisa C. Hubbard (601-634-4150), e-mail: *Lisa.C.Hubbard@erdc.usace.army.mil*. This CHETN should be referenced as follows:

> Biedenharn, D. S., and Hubbard, L. C. (2001). "Design considerations for siting grade control structures," Coastal and Hydraulics Engineering Technical Note CHETN-VII-3 U.S. Army Engineer Research and Development Center, Vicksburg, MS. *http://chl.wes.army.mil/library/publications/chetn/*

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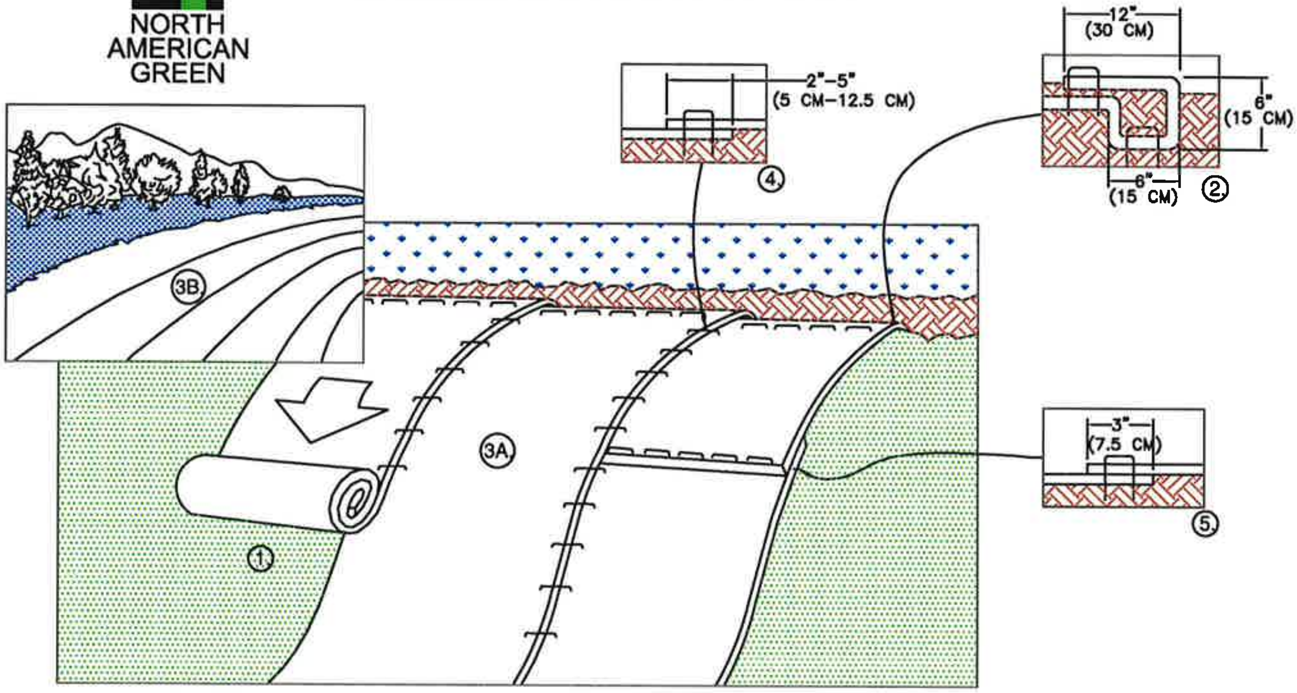
Slope Installation

SLOPE INSTALLATION

APLICACIONES PARA TALUDES

NORTH AMERICAN GREEN



1. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING ANY NECESSARY APPLICATION OF LIME, FERTILIZER, AND SEED. NOTE: WHEN USING CELL-O-SEED DO NOT SEED PREPARED AREA. CELL-O-SEED MUST BE INSTALLED WITH PAPER SIDE DOWN.
2. BEGIN AT THE TOP OF THE SLOPE BY ANCHORING THE BLANKET IN A 6" (15 CM) DEEP X 6" (15 CM) WIDE TRENCH WITH APPROXIMATELY 12" (30cm) OF BLANKET EXTENDED BEYOND THE UP-SLOPE PORTION OF THE TRENCH. ANCHOR THE BLANKET WITH A ROW OF STAPLES/STAKES APPROXIMATELY 12" (30 CM) APART IN THE BOTTOM OF THE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING. APPLY SEED TO COMPACTED SOIL AND FOLD REMAINING 12" (30 CM) PORTION OF BLANKET BACK OVER SEED AND COMPACTED SOIL. SECURE BLANKET OVER COMPACTED SOIL WITH A ROW OF STAPLES/STAKES SPACED APPROXIMATELY 12" (30 CM) APART ACROSS THE WIDTH OF THE BLANKET.
3. ROLL THE BLANKETS (A.) DOWN OR (B.) HORIZONTALLY ACROSS THE SLOPE. BLANKETS WILL UNROLL WITH APPROPRIATE SIDE AGAINST THE SOIL SURFACE. ALL BLANKETS MUST BE SECURELY FASTENED TO SOIL SURFACE BY PLACING STAPLES/STAKES IN APPROPRIATE LOCATIONS AS SHOWN IN THE STAPLE PATTERN GUIDE. WHEN USING THE DOT SYSTEM™, STAPLES/STAKES SHOULD BE PLACED THROUGH EACH OF THE COLORED DOTS CORRESPONDING TO THE APPROPRIATE STAPLE PATTERN.
4. THE EDGES OF PARALLEL BLANKETS MUST BE STAPLED WITH APPROXIMATELY 2" – 5" (5 CM – 12.5 CM) OVERLAP DEPENDING ON BLANKET TYPE.
5. CONSECUTIVE BLANKETS SPLICED DOWN THE SLOPE MUST BE PLACED END OVER END (SHINGLE STYLE) WITH AN APPROXIMATE 3" (7.5 CM) OVERLAP. STAPLE THROUGH OVERLAPPED AREA, APPROXIMATELY 12" (30 CM) APART ACROSS ENTIRE BLANKET WIDTH.

NOTE:
*IN LOOSE SOIL CONDITIONS, THE USE OF STAPLE OR STAKE LENGTHS GREATER THAN 6" (15 CM) MAY BE NECESSARY TO PROPERLY SECURE THE BLANKETS.

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1. PREPARE EL TERRENO ANTES DE INSTALAR LAS MANTAS, INCLUYENDO LA APLICACION DE CAL, FERTILIZANTE Y SEMILLA. NOTA: CUANDO ESTE USANDO CELL-O-SEED NO SIEMBRE EL AREA PREPARADA. CELL-O-SEED TIENE QUE INSTALARSE CON EL LADO DE PAPEL HACIA ABAJO.
2. COMIENCE EN LA CABECERA DEL TALUD SUJETANDO LA MANTA EN UNA ZANJA DE 6' (15 CM) DE PROFUNDIDAD FOR 6' (15 CM) DE ANCHO CON APROXIMADAMENTE 12" (30 CM) DE LA MANTA EXTENDIDA MAS ALLA DE LA PENDIENTE ALTA DE LA ZANJA. SUJETE LA MANTA AL FONDO DE LA ZANJA CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE 12" (30 CM) UNA DE LA OTRA. RELLENE Y COMPACTE LA ZANJA DESPUES DEL ENGRAPE. RIEGE LA SEMILLA EN EL SUELO COMPACTADO Y DOBLE LAS 12" (30 CM) REMANENTES DE MANTA SOBRE LA SEMILLA EL SUELO COMPACTADO. ASEGURE LA MANTA SOBRE EL SUELO CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE 12" (30 CM) UNA DE LA OTRA A TRAVES DEL ANCHO DE LA MANTA.
3. DESENROLLE LAS MANTAS (3A) HACIA ABAJO U (3B) HORIZONTALMENTE A TRAVES DEL TALUD CON EL LADO APROPIADO HACIA LA SUPERFICIE DEL SUELO. TODAS LAS MANTAS DEBERAN ASEGURARSE A LA SUPERFICIE DEL SUELO POR MEDIO DE GRAPAS O ESTACAS EN LUGARES APROPIADOS TAL Y COMO SE INDICA EN EL PATRON GUIA DE ENGRAPADO. CUANDO ESTE USANDO EL DOT SYSTEM™. LAS GRAPAS O ESTACAS DEBEN COLOCARSE A TRAVES DE CADU UNDO DE LOS PUNTOS CON COLOR CORRESPONDIENTES AL PATRON DE ENGRAPADO APROPIADO.
4. LOS BORDES DE LAS MANTAS PARALELAS TIENEN QUE ENGRAPARSE CON UN TRASLAPE DE APROXIMADAMENTE 2" – 5" (5 CM – 12.5 CM) DEPENDIENDO DEL TIPO DE MANTA.
5. MANTAS CONSECUTIVAS UNIDAS EN LA BAJADA DE LOS TALUDES, DEBEN COLOCARSE ORILLA SOBRE ORILLA (TIPO EXCALONADO) CON UN TRASLAPE DE APROXIMADAMENTE 3" (7.5 CM). ENGRAPE EL AREA TRASLAPADA CON UNA SEPARACION DE APROXIMADAMENTE 12" (30 CM) A TRAVES DE TODO EL ANCHO DE LA MANTA.

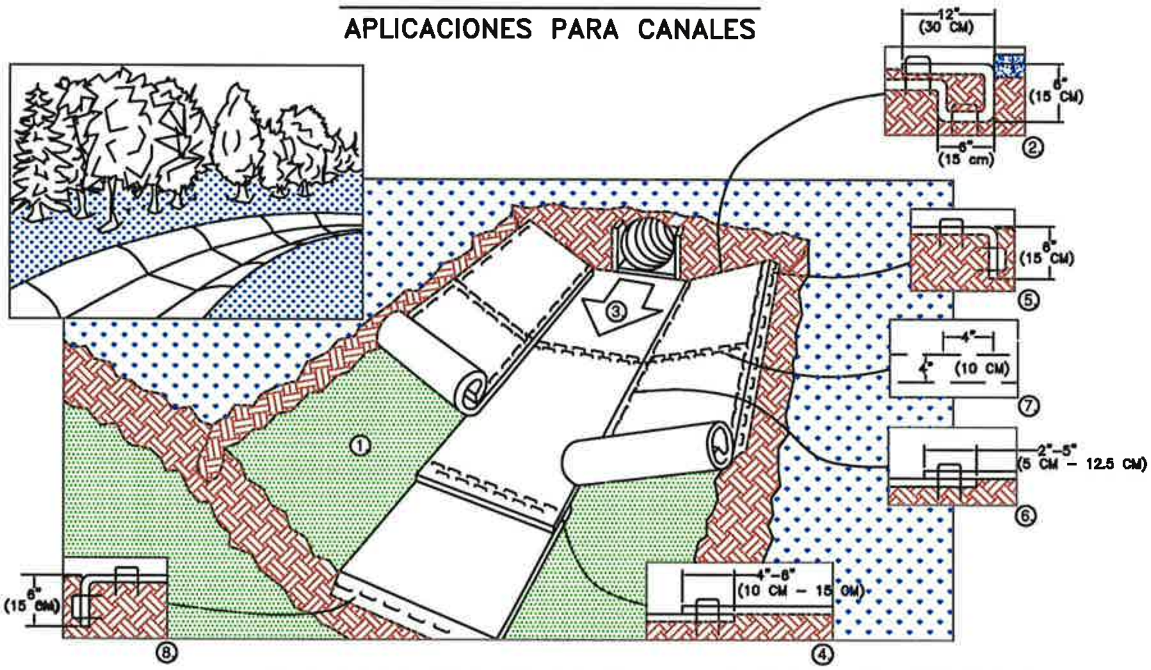
NOTA:
* EN CONDICIONES DE SUELTO, PUEDE QUE SE NECESITEN GRAPAS O ESTACAS DE MAS DE 6" (15 CM) DE LARGO PARA ASEGURAR LAS MANTAS CORRECTAMENTE.

REV. 1/2004

NORTH AMERICAN GREEN

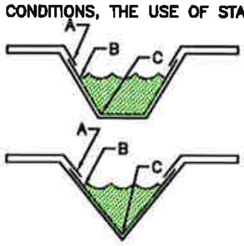
CHANNEL INSTALLATION

APLICACIONES PARA CANALES



1. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING ANY NECESSARY APPLICATION OF LIME, FERTILIZER, AND SEED. NOTE: WHEN USING CELL-O-SEED DO NOT SEED PREPARED AREA. CELL-O-SEED MUST BE INSTALLED WITH PAPER SIDE DOWN.
2. BEGIN AT THE TOP OF THE CHANNEL BY ANCHORING THE BLANKET IN A 6" (15 CM) DEEP X 6" (15 CM) WIDE TRENCH WITH APPROXIMATELY 12" (30 CM) OF BLANKET EXTENDED BEYOND THE UP-SLOPE PORTION OF THE TRENCH. ANCHOR THE BLANKET WITH A ROW OF STAPLES/STAKES APPROXIMATELY 12" (30 CM) APART IN THE BOTTOM OF THE TRENCH. BACKFILL AND COMAPCT THE TRENCH AFTER STAPLING. APPLY SEED TO COMPACTED SOIL AND FOLD REMAINING 12" (30 CM) PORTION OF BLANKET BACK OVER SEED AND COMPACTED SOIL. SECURE BLANKET OVER COMPACTED SOIL WITH A ROW OF STAPLES/STAKES SPACED APPROXIMATELY 12" (30 CM) ACROSS THE WIDTH OF THE BLANKET.
3. ROLL CENTER BLANKET IN DIRECTION OF WATER FLOW IN BOTTOM OF CHANNEL. BLANKETS WILL UNROLL WITH APPROPRIATE SIDE AGAINST THE SOIL SURFACE. ALL BLANKETS MUST BE SECURELY FASTENED TO SOIL SURFACE BY PLACING STAPLES/STAKES IN APPROPRIATE LOCATIONS AS SHOWN IN THE STAPLE PATTERN GUIDE. WHEN USING THE DOT SYSTEM™, STAPLES/STAKES SHOULD BE PLACED THROUGH EACH OF THE COLORED DOTS CORRESPONDING TO THE APPROPRIATE STAPLE PATTERN.
4. PLACE CONSECUTIVE BLANKETS END OVER END (SHINGLE STYLE) WITH A 4" - 6" (10 CM -15 CM) OVERLAP. USE A DOUBLE ROW OF STAPLES STAGGERED 4" (10 CM) APART AND 4" (10 CM) ON CENTER TO SECURE BLANKETS.
5. FULL LENGTH EDGE OF BLANKETS AT TOP OF SIDE SLOPES MUST BE ANCHORED WITH A ROW OF STAPLES/STAKES APPROXIMATELY 12" (30 CM) APART IN A 6" (15 CM) DEEP X 6" (15 CM) WIDE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING.
6. ADJACENT BLANKETS MUST BE OVERLAPPED APPROXIMATELY 2" - 5" (5 CM -12.5 CM) (DEPENDING ON BLANKET TYPE) AND STAPLED.
7. IN HIGH FLOW CHANNEL APPLICATIONS, A STAPLE CHECK SLOT IS RECOMMENDED AT 30 TO 40 FOOT (9 M - 12 M) INTERVALS. USE A DOUBLE ROW OF STAPLES STAGGERED 4" (10 CM) APART AND 4" (10 CM) ON CENTER OVER ENTIRE WIDTH OF THE CHANNEL.
8. THE TERMINAL END OF THE BLANKETS MUST BE ANCHORED WITH A ROW OF STAPLES/STAKES APPROXIMATELY 12" (30 CM) APART IN A 6" (15 CM) DEEP X 6" (15 CM) WIDE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING.

NOTE:
* IN LOOSE SOIL CONDITIONS, THE USE OF STAPLE OR STAKE LENGTHS GREATER THAN 6" (15 CM) MAY BE NECESSARY TO PROPERLY ANCHOR THE BLANKETS.



CRITICAL POINTS

A. OVERLAPS AND SEAMS
B. PROJECTED WATER LINE
C. CHANNEL BOTTOM/SIDE SLOPE VERTICES

NOTE:
* HORIZONTAL STAPLE SPACING SHOULD BE ALTERED IF NECESSARY TO ALLOW STAPLES TO SECURE THE CRITICAL POINTS ALONG THE CHANNEL SURFACE.

** IN LOOSE SOIL CONDITIONS, THE USE OF STAPLE OR STAKE LENGTHS GREATER THAN 6" (15 cm) MAY BE NECESSARY TO PROPERLY ANCHOR THE BLANKETS.

PUNTOS CRITICOS

A. TRASLAPES Y JUNTAS
B. LINEAS DE AGUA PROYECTADA
C. FONDO DEL CANAL/VERTICES DE LAS PENDIENTES LATERALES

NOTA:
* LA SEPARACION HORIZONTAL DE LAS GRAPAS SE DEBE ALTERAR SI SE NECESITA, PARA PERMITIR QUE LAS GRAPAS ASEGUREN LOS PUNTOS CRITICOS A LO LARGO DE LA SUPERFICIE DEL CANAL.

** EN CONDICIONES DE SUELO SUELTO, PUEDE QUE SE NECESITEN GRAPAS O ESTACAS DE MAS DE 6" (15 CM) DE LARGO PARA ASEGURAR LAS MANTAS CORRECTAMENTE.

1. PREPARE EL SUELO DE COLOCAR LAS MANTAS, INCLUYENDO LA APLICASION DE CAL, FERTILIZANTE SEMILLA. NOTA: CUANDO ESTE USANDO CELL-O-SEED NO SIEMBRE EL AREA PREPARADA. CELL-O-SEED TIENE QUE INSTALARSE CON EL LADO DE PAPEL HACIA ABAJO.
2. COMIENCE EN LA CABECERA DEL CANAL SUJETANDO LA MANTA EN UNA ZANJA DE 6" (15 CM) DE PROFUNDIDAD POR 6" (15 CM). DE ANCHO CON APROXIMADAMENTE 12" (30 CM) DE LA MANTA EXTENDIDA MAS ALLA DE LA PENDIENTE ALTA DE LA ZANJA. SUJETE RELLENE Y COMPACTE LA ZANJA DESPUES DEL ENGRAPE. RIEGUE LA SEMILLA EN EL SUELO COMPACTADO Y DOBLE LAS 12" (30 CM) REMANENTES DE MANTA SOBRE LA SEMILLA Y EL SUELO COMPACTADO. ASEGURE LA MANTA SOBRE EL SUELO CON UNA LINEADE GRAPAS O ESTACAS APROXIMADAMENTE 12" (30 CM) UNA DE LA OTRA A TRAVES DEL ANCHO DE LA MANTA.
3. DESENROLLE LA MANTA DEL MEDIO EN EL FONDO DEL CANAL Y EN LA DIRECCION DEL FLUJO DE AGUA CON EL LADO APROPIADO HACIA LA SUPERFICIE DEL SUELO. TODAS LAS MANTAS DEBERAN ASEGURARSE A LA SUPERFICIE DEL SUELO POR MEDIO DE GRAPAS O ESTACAS EN LUGARESAPROPIADOS TAL Y COMO SE INDICA EN EL PATRON GUIA DE ENGRAPADO. CUANDO ESTE USANDO EL DOT SYSTEM™. LAS GRAPAS O ESTACAS DEBEN COLOCARSE A TRAVES DE CADA UNO DE LOS PUNTOS CON COLOR CORRESPONDIENTES AL PATRON DE ENGRAPADO APROPIADO.
4. COLOQUE LAS MANTAS CONSECUTIVAS BORDE SOBRE BORDE (TIPO ESCALONADO) CON UN TRASLAPE DE 4" - 6" (10 CM - 15 CM). USE UNA LINEA DOBLE DE GRAPAS ESCALONADAS, SEPARADAS POR 4" (10 CM) Y CADA 4" (10 CM) SOBRE EL CENTRO PARA ASEGURAR LAS MANTAS.
5. EN EL TOPE DE LAS DOS PENDIENTES LATERALES DEL CANAL, SE DEBE SUJETAR TODO EL LARGO DE LA ORILLA DE LAS MANTAS CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE CADA 12" (30 CM) UNA DE LA OTRA EN UNA ZANJA DE 6" (15 CM) DE PROFUNDIDAD POR 6" (15 CM) DE ANCHO. RELLENE Y COMPACTE LA ZANJA DESPUES DEL ENGRAPE.
6. LAS MANTAS ADYACENTES DEBEN TRASLAPARSE APROXIMADAMENTE DE 2" - 5" (5 CM- 12.5 CM) (DEPENDIENDO DEL TIPO DE. MANTA) Y ENGRAPPARSE.
7. EN APLICACIONES PARA CANALES DE FLUJO ALTO, SE RECOMIENDA DEJAR UNA RANURA PARA EL CHEQUEO DE LAS GRAPAS A INTERVALOS DE 30 A 40 PIES (9 M - 12 M). USE UNA LINEA DOBLE DE PRAPAS ESCALONADAS, SEPARADAS POR 4" (10 CM) Y CADA 4" (10 CM) SOBRE EL CENTRO A TRAVES DE TODO EL ANCHO DEL CANAL.
8. LOS BORDES FINALES DE LAS MANTAS DEBEN SUJETARSE CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE CADA 12" 30 CM) UNA DE LA OTRA EN UNA ZANJA DE 6" (15 CM) DE PROFUNDIDAD POR 6" (15 CM) DE ANCHO. RELLENE Y COMPACTE DESPUES DEL ENGRAPADO.

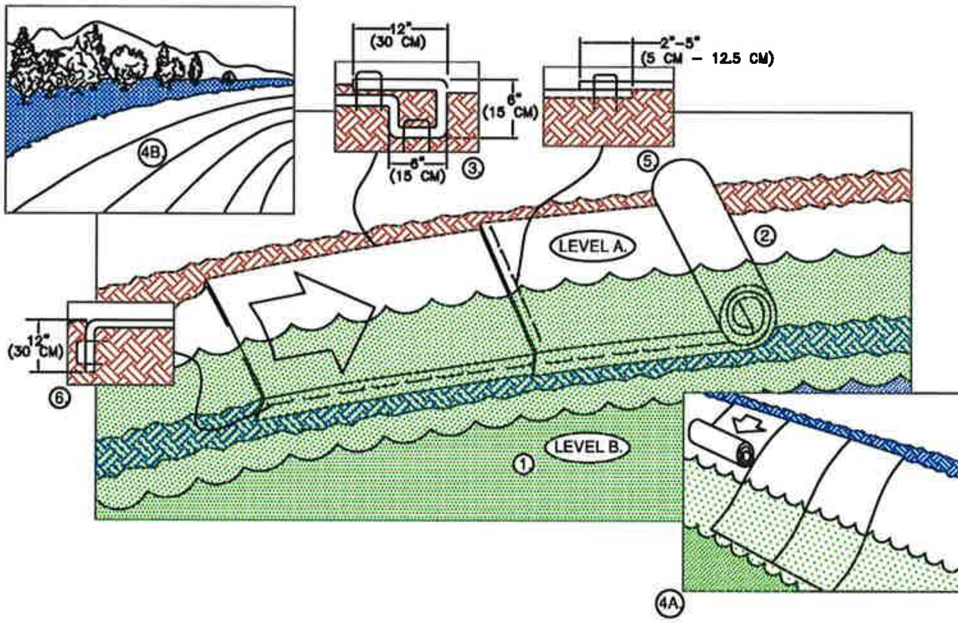
NOTA:
* EN CONDICIONES DE SUELTO, PUEDE QUE SE NECESITEN GRAPAS O ESTACAS DE MAS DE 6" (15 CM) DE LARGO PARA ASEGURAR LAS MANTAS CORRECTAMENTE.

REV. 1/2004

SHORELINE INSTALLATION

APLICACIONES PARA LAS LINEAS COSTERAS

NORTH AMERICAN GREEN



1. FOR EASIER INSTALLATION, LOWER WATER FROM LEVEL A TO LEVEL B BEFORE INSTALLATION.
2. PREPARE SOIL BEFORE INSTALLING BLANKETS, INCLUDING ANY NECESSARY APPLICATION OF LIME, FERTILIZER, AND SEED NOTE: WHEN USING CELL-O-SEED, DO NOT SEED PREPARED AREA. CELL-O-SEED MUST BE INSTALLED WITH PAPER SIDE DOWN.
3. BEGIN AT THE TOP OF THE SHORELINE BY ANCHORING THE BLANKET IN A 6" (15 CM) DEEP X 6" (15 CM) WIDE TRENCH WITH APPROXIMATELY 12" (30 CM) OF BLANKET EXTENDED BEYOND THE UP-SLOPE PORTION OF THE TRENCH. ANCHOR THE BLANKET WITH A ROW OF STAPLES/STAKES APPROXIMATELY 12" (30 CM) APART IN THE BOTTOM OF THE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING. APPLY SEED TO COMPACTED SOIL AND FOLD REMAINING 12" (30 CM) PORTION OF BLANKET BACK OVER SEED AND COMPACTED SOIL. SECURE BLANKET OVER COMPACTED SOIL WITH A ROW OF STAPLES/STAKES SPACED APPROXIMATELY 12" (30 CM) APART ACROSS THE WIDTH OF THE BLANKET.
4. ROLL BLANKETS EITHER (A.) DOWN THE SHORELINE FOR LONG BANKS, (TOP TO BOTTOM) OR (B.) HORIZONTALLY ACROSS THE SHORELINE SLOPE. BLANKETS WILL UNROLL WITH APPROPRIATE SIDE AGAINST THE SOIL SURFACE. ALL BLANKETS MUST BE SECURELY FASTENED TO SOIL SURFACE BY PLACING STAPLES/STAKES IN APPROPRIATE LOCATIONS AS SHOWN IN THE STAPLE PATTERN GUIDE. WHEN USING THE DOT SYSTEM™, STAPLES/STAKES SHOULD BE PLACED THROUGH EACH OF THE COLORED DOTS CORRESPONDING TO THE APPROPRIATE STAPLE PATTERN.
5. THE EDGES OF ALL HORIZONTAL AND VERTICAL BLANKET SEAMS MUST BE STAPLED WITH APPROXIMATELY 2" - 5" (5 CM - 12.5 CM) OVERLAP.

   NOTE:
   * SEAM OVERLAP SHOULD BE SHINGLED ACCORDING TO PREDOMINANT EROSIVE ACTION.
6. THE EDGE OF THE BLANKET AT OR BELOW NORMAL WATER LEVEL MUST BE ANCHORED BY PLACING THE BLANKET IN A 12" (30 CM) DEEP X 6" (15 CM) WIDE ANCHOR TRENCH. ANCHOR THE BLANKET WITH A ROW OF STAPLES/STAKES SPACED APPROXIMATELY 12" (30 CM) APART IN THE TRENCH. BACKFILL AND COMPACT THE TRENCH AFTER STAPLING (STONE OR SOIL MAY BE USED AS BACKFILL.)

   NOTE:
   * IN LOOSE SOIL CONDITIONS, THE USE OF STAPLE OR STAKE LENGTHS GREATER THAN 6" (15 CM) MAY BE NECESSARY TO PROPERLY ANCHOR THE BLANKETS.

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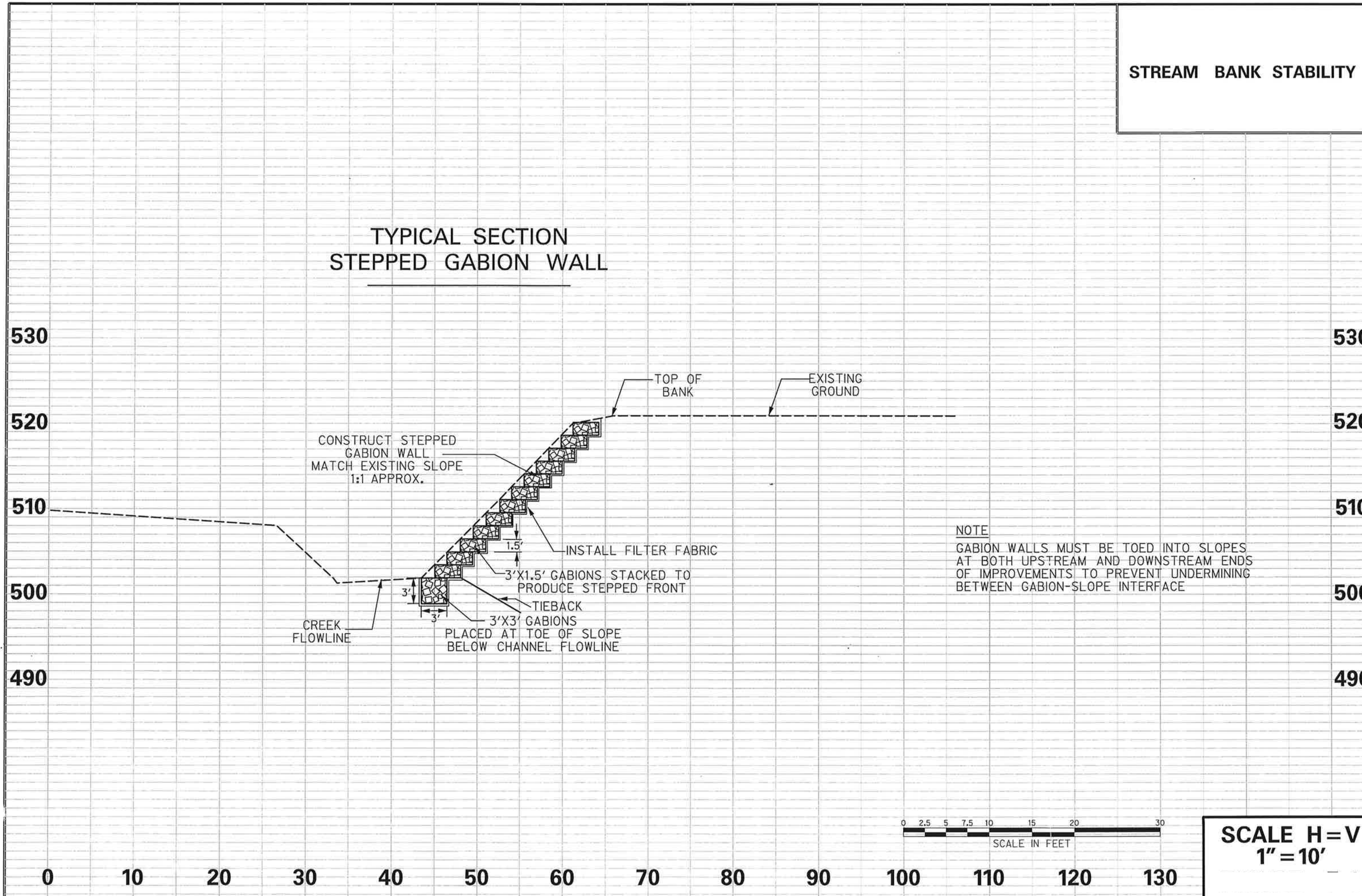
1. PARA UNA INSTALACION MAS FACIL, BAJE EL NIVEL DEL AGUA DEL PUNTO A AL PUNTO B, ANTES DE LA INSTALACION.
2. PREPARE EL TERRENO ANTES DE LA INSTALACION DE LAS MANTAS, INCLUYENDO APLICACION DE CAL, FERTILIZANTE Y SEMILLA. NOTA: CUANDO ESTE USANDO CELL-O-SEED NO SIEMBRE EL AREA PREPARADA. CELL-O-SEED TIENE QUE INSTALARSE CON EL LADO DE PAPEL HACIA ABAJO.
3. COMIENCE EN LA CABECERA DE LA LINEA COSTERA SUJETANDO LA MANTA EN UNA ZANJA DE 6" (15 CM) DE PROFUNDIDAD POR 6" (15 CM) DE ANCHO CON APROXIMADAMENTE 12" (30 CM) DE LA MANTA EXTENDIDA MAS ALLA DE LA PENDIENTE ALTA DE LA ZANJA. SUJETE LA MANTA AL FONDO DE LA ZANJA CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE 12" (30cm) UNA BACKFILL AND COMPACT THE TRENCH AFTER STAPLING. APPLY SEED TO COMPACTED SOIL AND FOLD REMAINING 12" (30cm) DE LA ORTA. RELLENE Y COMPACTE LA ZNAJA DESPUES DEL ENGRAPE. RIEGUE LA SEMILLA EN EL SUELO COMPACTADO Y DOBLE LAS 12" (30 CM) REMANENTES DE MANTA SOBRE LA SEMILLA Y EL SUELO COMPACTADO. ASEGURE LA MANTA SOBRE EL SUELO CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE 12" (30 CM) UNA DE LA ORTA A TRAVES DEL ANCHO DE LA MANTA.
4. DESENROLLE LAS MANTAS (4A) HACIA ABAJO EN LA LINEA COSTERA PARA RIBERAS LARGAS U (4B) HORIZONTALMENTE A TRAVES DE LA PENDIENTE DE ESTA CON EL LADO APROPIADO HACIA LA SUPERFICIE DEL SUELO. TODAS LAS MANTAS DEBERAN ASEGURARSE A LA SUPERFICIE DEL SUELO POR NEDIO DE GRAPAS O ESTACAS EN LUGARES APROPIADOS TAL Y COMO SE INDICA EN EL PATRON GUIA DE ENGRAPADO. CUANDO ESTE USANDO EL DOT SYSTEM™, LAS GRAPAS O ESTACAS DEBEN COLOCARSE A TRAVES DE CADA UNO DE LOS PUNTOS CON COLOR CORRESPONDIENTES AL PATRON DE ENGRAPADO APROPIADO.
5. LOS BORDES DE LAS COSTURAS DE LAS MANTAS HORIZONTALES Y VERTICALES DEBEN ENGRAPARSE CON UN TRASLAPE DE APROXIMADAMENTE 2" - 5" (5 CM - 12.5 CM).

   NOTA:
   * LA COSTURA DEL TRASLAPE DEBE CUBRIRSE DE ACUERDO A LA ACCION PREDOMINANTE DE EROSION.
6. EL BORDE DE LA MANTA QUE ESTA AL O POR DEBAJO DEL NIVEL DE AGUA NORMAL DEBE ASEGURARSE COLOCANDOLO EN UNA ZANJA DE ANCLAJE DE 12" (30 CM) DE PROFUNDIDAD POR 6" (15 CM) DE ANCHO. ASEGURE LA MANTA EN LA ZANJA CON UNA LINEA DE GRAPAS O ESTACAS APROXIMADAMENTE A 12" (30 CM) UNA DE LA OTRA. RELLENE Y COMPACTE LA ZANJA DESPUES DE ENGRAPAR (PIEDRAS O SUELO PUEDE USARSE COMO RELLENO).

   NOTA:
   * EN CONDICIONES DE SUELO SUELTO, PUEDE QUE SE NECESITEN GRAPAS O ESTACAS DE MAS DE 6" (15 CM) DE LARGO PARA ASEGURAR LAS MANTAS CORRECTAMENTE.

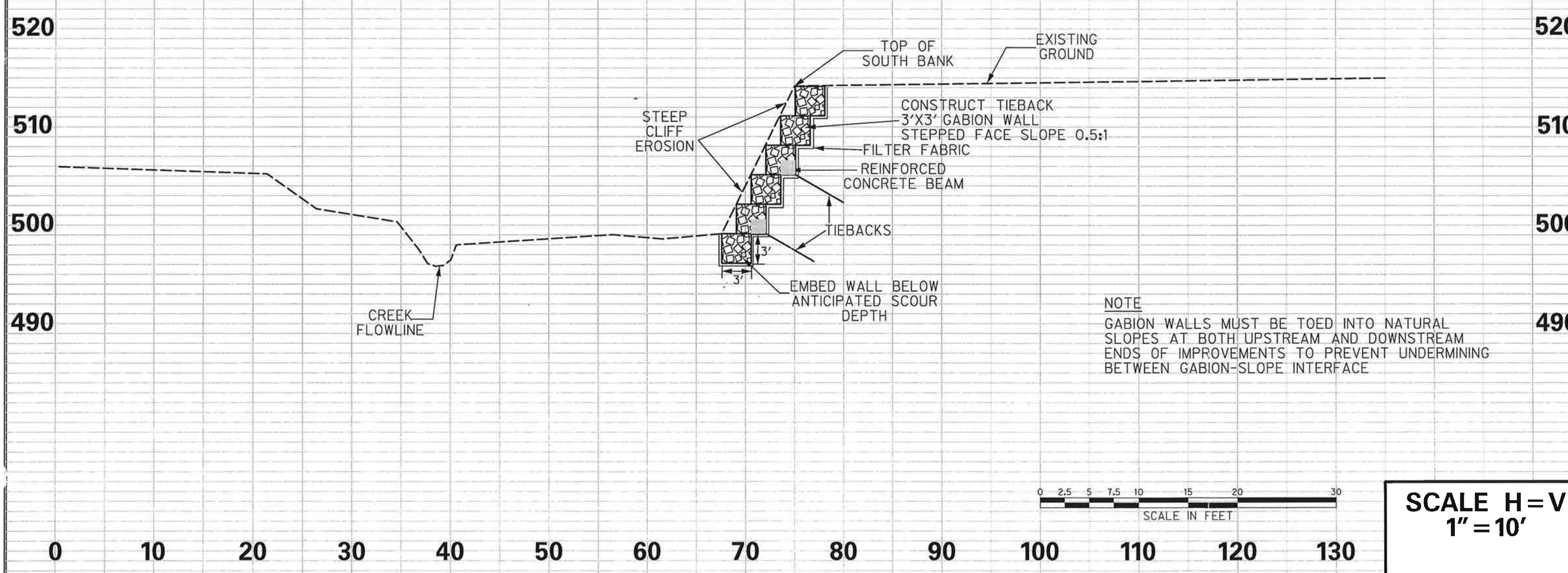
REV. 1/2004

Hard Armor Solutions


STREAM BANK STABILITY
TYPICAL SECTION
STEPPED GABION WALL
TOP OF BANK
EXISTING GROUND
CONSTRUCT STEPPED GABION WALL MATCH EXISTING SLOPE 1:1 APPROX.
INSTALL FILTER FABRIC
1.5'
3'X1.5' GABIONS STACKED TO PRODUCE STEPPED FRONT
TIEBACK
3'
3'
3'X3' GABIONS PLACED AT TOE OF SLOPE BELOW CHANNEL FLOWLINE
CREEK FLOWLINE
NOTE
GABION WALLS MUST BE TOED INTO SLOPES AT BOTH UPSTREAM AND DOWNSTREAM ENDS OF IMPROVEMENTS TO PREVENT UNDERMINING BETWEEN GABION-SLOPE INTERFACE
530
520
510
500
490
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0 2.5 5 7.5 10 15 20 30
SCALE IN FEET
SCALE H=V
1"=10'

STREAM BANK STABILITY

TYPICAL SECTION
TIEBACK GABION WALL

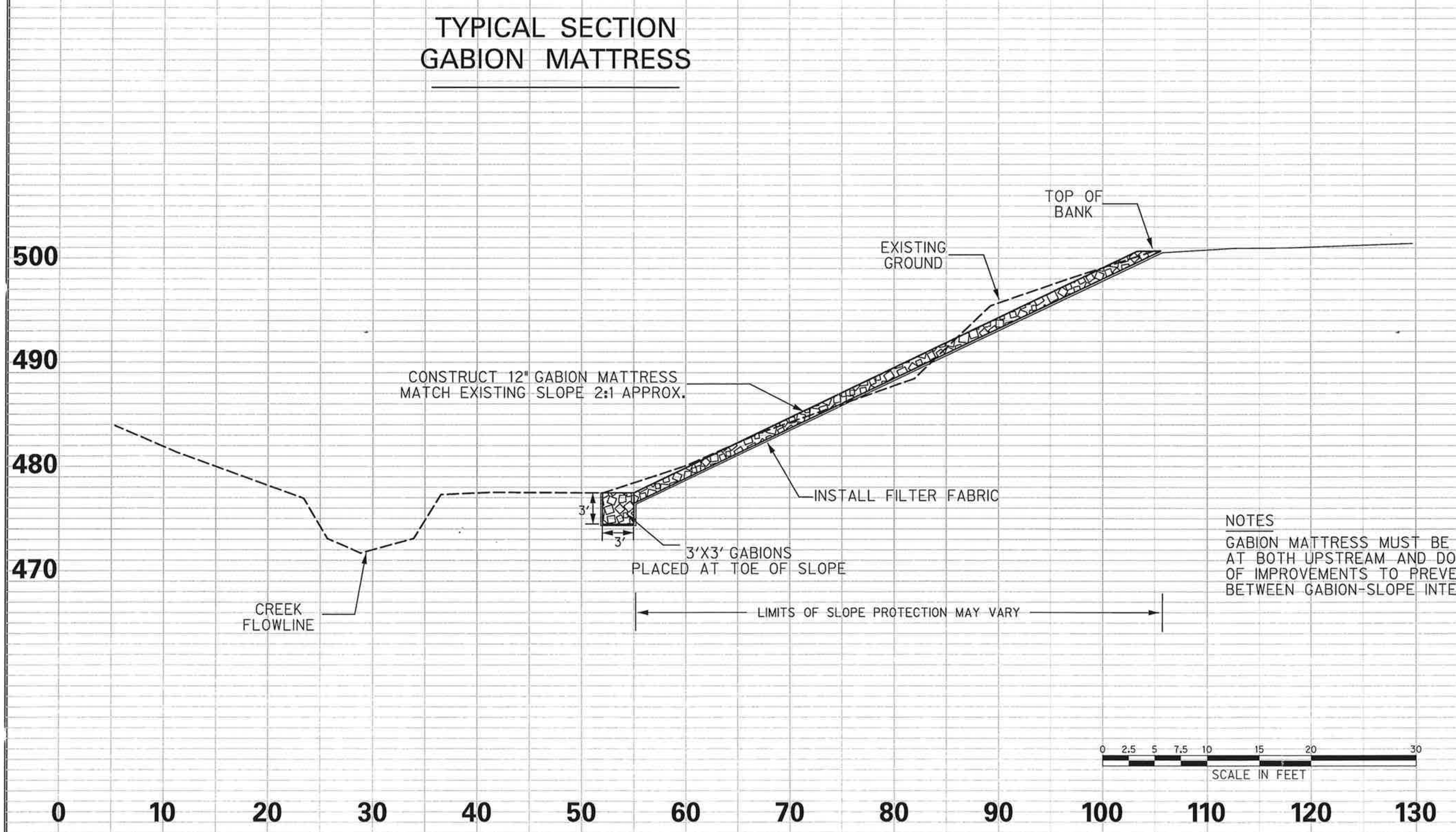


NOTE

GABION WALLS MUST BE TOED INTO NATURAL SLOPES AT BOTH UPSTREAM AND DOWNSTREAM ENDS OF IMPROVEMENTS TO PREVENT UNDERMINING BETWEEN GABION-SLOPE INTERFACE

SCALE H=V
1"=10'

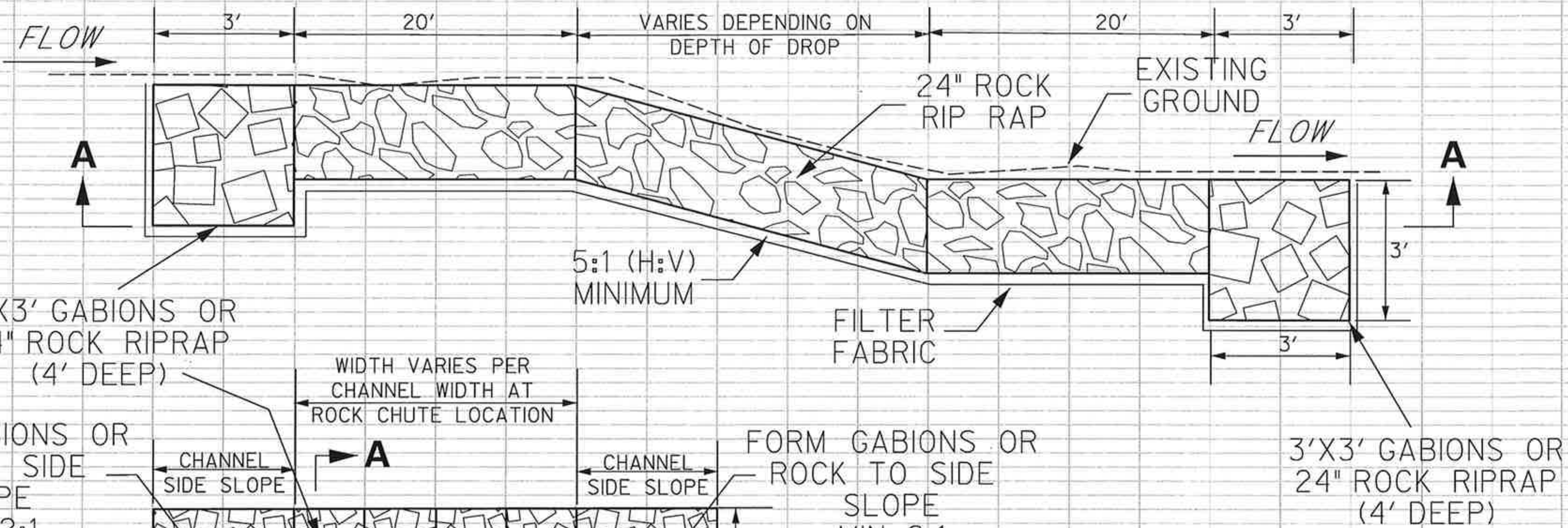
STREAM BANK STABILITY

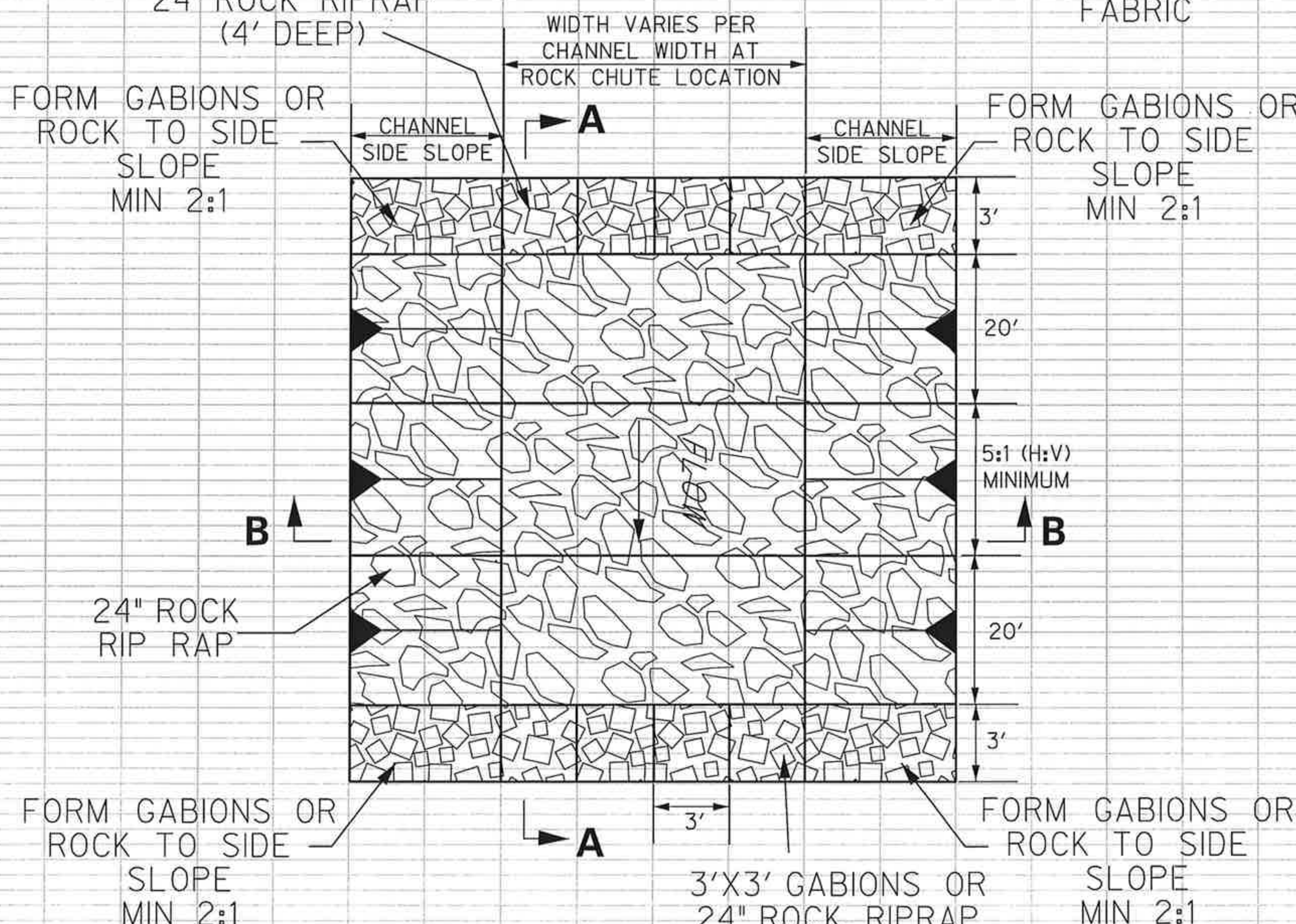


SCALE H=V
1"=10'

ROCK CHUTE TYPICAL SECTION

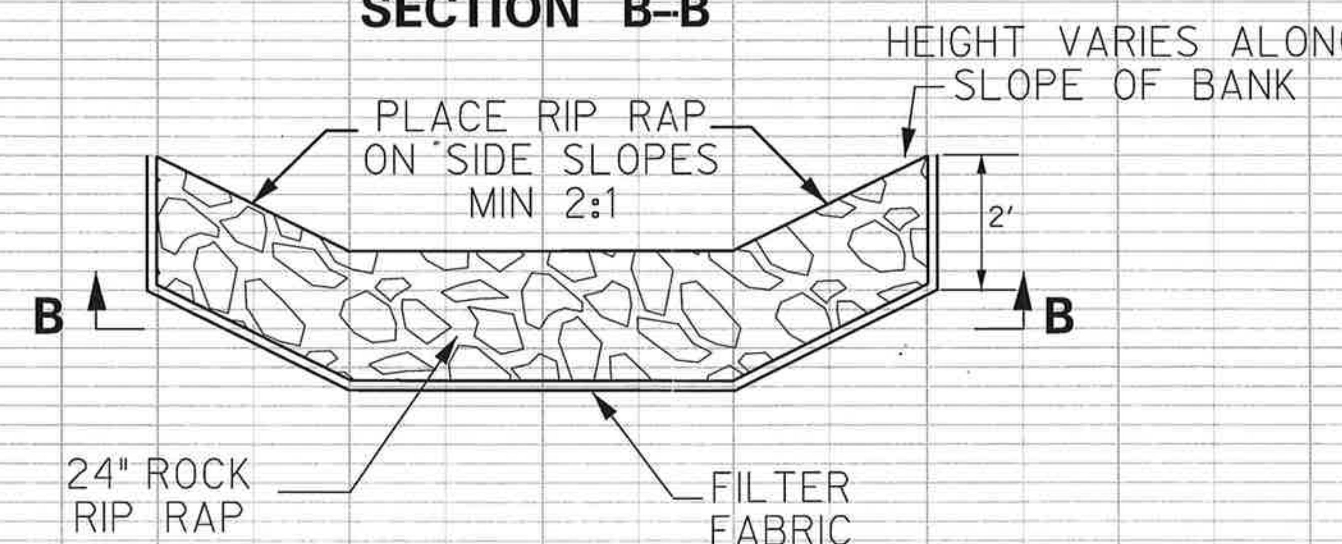
PROFILE VIEW SECTION A–A





PLAN VIEW

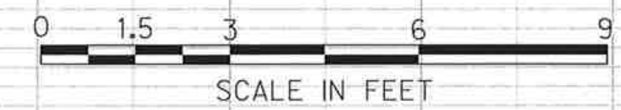
FRONT VIEW SECTION B–B

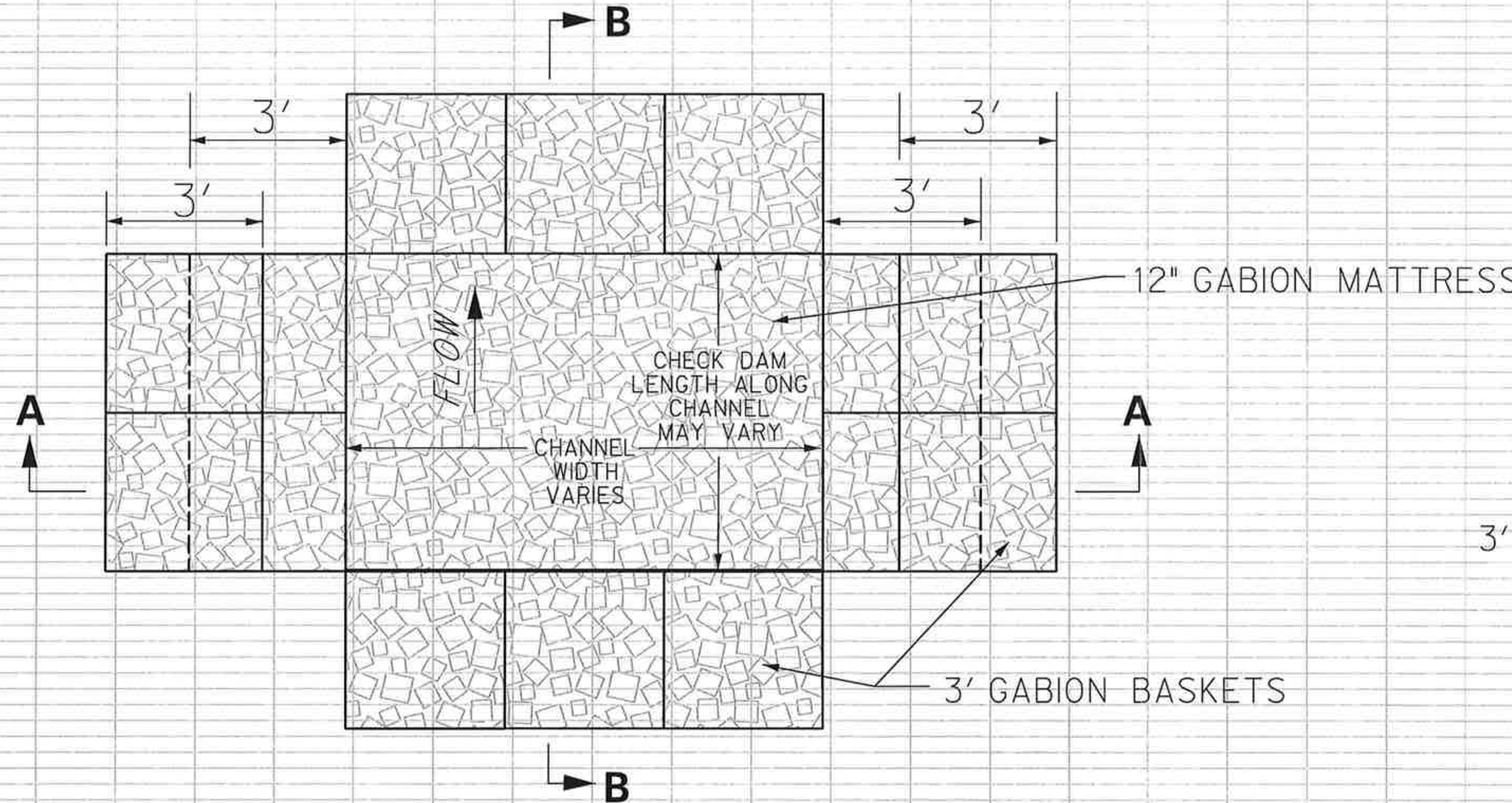


NOTE:
1. HEIGHT OF ROCK CHUTES WILL VARY ACCORDING TO BANKFULL ELEVATION AT SPECIFIC LOCATIONS.
2. IF NO GRADE CHANGE EXISTS, "DROP" PORTION OF CHUTE CAN BE REMOVED.

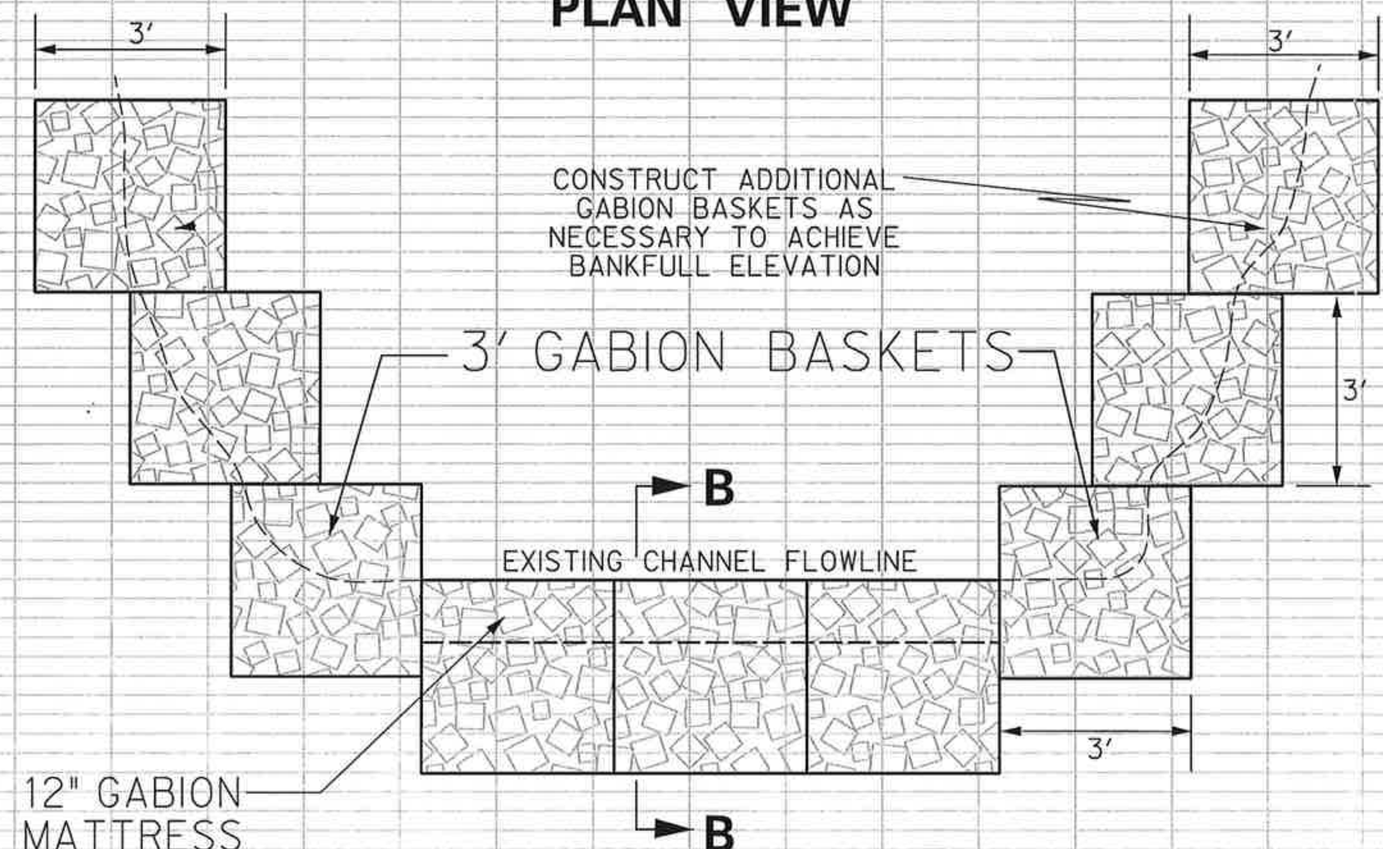
SCALE H=V 1"=3′

GABION CHECK DAM TYPICAL SECTION



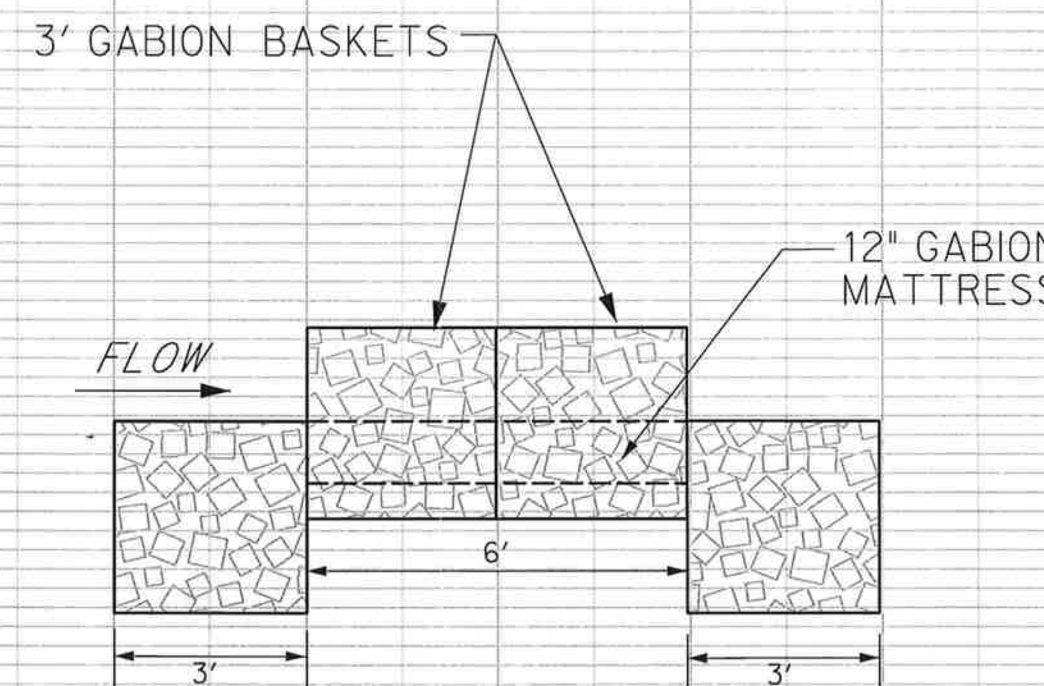


PLAN VIEW



CHANNEL VIEW

SECTION A-A

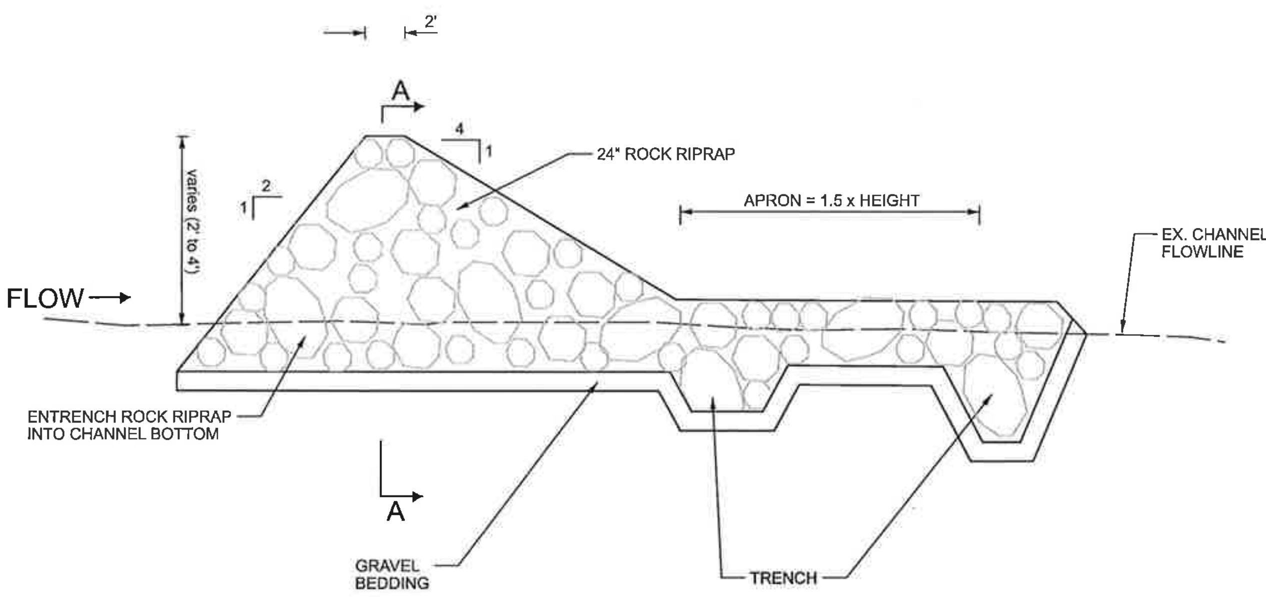


SIDE VIEW

SECTION B-B

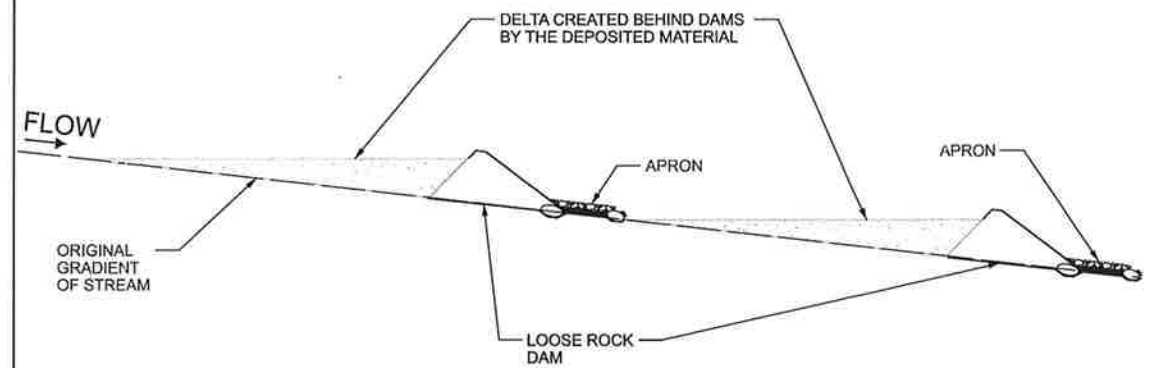
SCALE H=V
1"=3'

LOOSE ROCK DAM PROFILE



PROFILE VIEW SECTION A-A

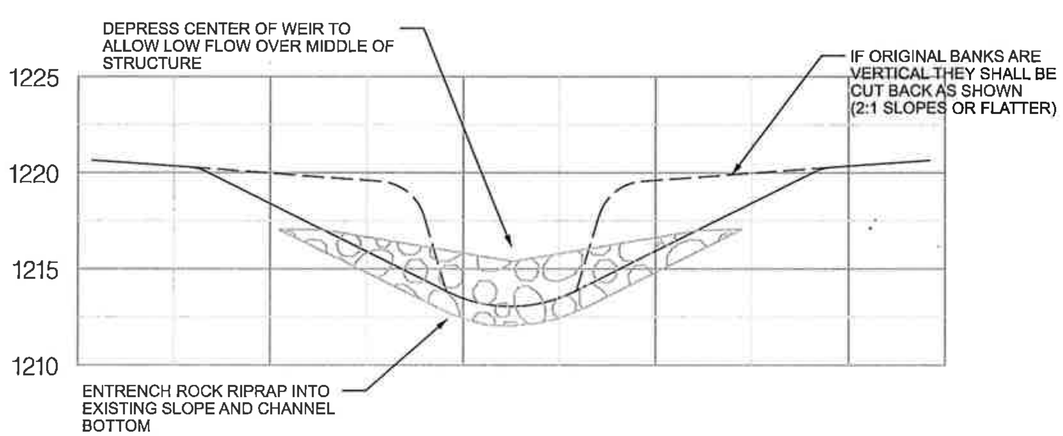
SCALE:
1" = 10' HORIZ.
1" = 4' VERT.



LOOSE ROCK DAMS

NO SCALE

LOOSE ROCK DAM PROFILE



SECTION A-A

SCALE:
1" = 10' HORIZ.
1" = 10' VERT.

GENERAL NOTES:

18" ROCK RIPRAP SHALL BE USED FOR LOOSE ROCK DAM CONSTRUCTION.

CUT A 4- TO 6-INCH TRENCH ACROSS THE GULLY AND UP THE SIDES TO ANCHOR LARGER HEAVY ROCKS ON THE DOWNSTREAM TOE OF THE DAM. PLACE A ROW OF LARGE ROCKS ALONG THIS TRENCH TO FORM THE DOWNSTREAM TOE. PROVIDE APRON WITH ADDITIONAL TOE DOWNSTREAM.

Symbol	Description	Tracking Action	Date

Date: APR 2007
Proj. No. 23159
Work Order No. W.O. #540.26
Rev.

Designed by:
Dwn by: BBP
Reviewed by: SBC
Submitted by: SBC

Halff Associates
ENGINEERS • ARCHITECTS • SCIENTISTS • PLANNERS • SURVEYORS

LOOSE ROCK DAM

Appendix E
Miscellaneous

City Resolution No. 3919

RESOLUTION NO. 3919

A RESOLUTION ESTABLISHING A POLICY CONCERNING EROSION AND OTHER DRAINAGE PROBLEMS RELATING TO WATERWAYS.

WHEREAS, the City Council has determined that Erosion problems along the Trinity River and Creeks in the city are of concern to the City.

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF GRAND PRAIRIE, TEXAS:

SECTION 1. That it is hereby determined to be in the best interests of the City of Grand Prairie, Texas and its inhabitants to adopt the following drainage policy:

Erosion and/or flooding problems on private property will be investigated on a case-by-case basis. The City will focus on improvements to the waterways that will result in a general public benefit, such as lowering erosive velocities and increasing flow capacities in proximate streams for the general prevention of erosion and flooding.

Remedy of private property issues, such as flooding due to lot-to-lot drainage (no involvement of City property) and construction projects to protect specific private property due to proximate stream erosion, will not be undertaken by the City unless a general public benefit or public safety concern can be demonstrated, and the undertaking of such are approved by the City Council. Individual projects will be evaluated and prioritized based on available funding.

SECTION 2. That this resolution shall become effective immediately upon its passage and approval.

PASSED AND APPROVED BY THE CITY COUNCIL OF THE CITY OF GRAND PRAIRIE, TEXAS, this 17th day of June, 2003.

Charles England

Mayor, Grand Prairie, Texas

ATTEST:

Karan J. Barrett

for Catherine E. DiMaggio, City Secretary

APPROVED AS TO FORM:

Donald R. Postell

Donald R. Postell, City Attorney

U.S. Army Corps of Engineers
Nationwide Permits
Individual Permit Application

US Army Corps of Engineers

Regulatory Program Information

- National Regulatory Program Home Page: http://www.usace.army.mil/inet/functions/cw/cecwo/reg/
- Fort Worth District Regulatory Home Page: http://www.swf.usace.army.mil/pubdata/environ/regulatory/index.asp
- Galveston District Regulatory Home Page: www.swg.usace.army.mil/reg/
- Tulsa District Regulatory Home Page: www.swt.usace.army.mil/permits/permits.cfm
- Albuquerque District Regulatory Home Page: www.spa.usace.army.mil/reg/

One Corps Serving The Army and the Nation

US Army Corps of Engineers

Corps Contacts in Texas and Southwestern Division

Fort Worth District	(817) 886-1731
Little Rock District	(501) 324-5296
Galveston District	(409) 766-3930
Tulsa District	(918) 669-7400
Albuquerque District	(915) 568-1359

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Appendix F
DVD