Innovative approaches
Practical results
Outstanding service



Trophy Club Storm Water Master Plan – Phase I

Prepared for:

Town of Trophy Club

Prepared by:

FREESE AND NICHOLS, INC.
4055 International Plaza, Suite 200
Fort Worth, Texas 76109
817-735-7300
TRO11171

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DRAFT
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LIST OF EXHIBITS

1.0 EXECUTIVE SUMMARY

The Town has contracted FNI to perform a Storm Water Master Plan conducted in three phases. Phase I is a detailed study of five known drainage issues within the Town. Phase II will be a review, analysis and provision of recommendations for all remaining drainage systems in the Town. Phase II will also include development and ranking of proposed drainage improvement alternatives for a Town-wide Storm Water Capital Improvement Plan (CIP). Phase III will be coordination of regional drainage concerns with neighboring communities and pursuit of grant funding opportunities to fund drainage studies and improvements. This report summarizes the findings of the first phase of the Master Plan. The study analyzes and proposes improvements for the five (5) identified drainage focus areas:

- Marshall Branch at Trophy Club Drive
- Skyline (Indian) Creek
- Overhill/Timber Ridge Drives
- Fresh Meadows Drive
- Cypress Creek

A Project Location Map is included as Figure 1.

Marshall Branch at Trophy Club Drive

Calculations indicate that the road currently offers 2-Year return event flood protection and may act as a low-water crossing during larger return event storms due to depth of inundation. For 5-Year return event flows, the road is expected to be overtopped by approximately 1.8-feet. This depth increases to an expected 6.2-feet for 100-Year return event flows. Currently the channel flows north from Highway 114 through 3-8'x10' reinforced box culverts (RBC) at Trophy Club Drive and continues north through the golf course to its confluence with Lake Grapevine as shown on Figure 1. Initial analysis of the crossing revealed a necessity to provide additional channel capacity upstream and downstream of the crossing to adequately carry expected design flows. Three (3) improvement alternatives were considered:

1. Bridge crossing sized to accommodate 100-Year return event flows,
2. Culvert crossing sized to accommodate 100-Year return event flows, and
3. Culvert crossing size to accommodate 25-Year return event flows, with possible consideration given to phasing for future construction to achieve 100-Year capacity.

Based on the discussion of alternatives provided in this report, Alternative 1, the 100-Year solution which consists of a 500-foot long bridge with piers accompanied by upstream and downstream channel excavation, with an OPCC of $5.3 million is the preferred alternative.

Skyline (Indian) Creek

Skyline (Indian) Creek flows from the upper reaches of the watershed through a pond on the golf course. The channel originates at the pond outfall and drains north through the golf course between residential properties for about 3,000 linear feet before draining into the Town of Southlake and eventually into Lake Grapevine as shown on Figure 1. Proposed improvements include channel modification and roadway improvements. The proposed channel section has an average depth of 5-feet, average bottom width of 30-feet and average top width of 30-feet. Typical sections are shown on an inset of the floodplain maps in Figures 8A through 8C. It is recommended that the concrete block wall have a stone finish to give the channel an aesthetic appeal. In addition to placing a rectangular section, approximately four (4) grade control structures are proposed. Greenleaf Drive currently has 3-7' X 3.5' box culverts and the proposed improvements consist of 4-7' X 5' box culverts. Indian Creek Drive currently has 3-7'X 3' box culverts and the proposed improvements consist of 4-7' X 6'box culverts. An approximate 35-foot clear span bridge will be required at T.W. King Road in lieu of the 6-48 inch culverts to pass the 100-Year storm event. Figures 8 and 8A, 8B and 8C show the extents of the proposed improvements to Skyline (Indian) Creek. The OPCC for these proposed improvements is approximately $5.9 million including T.W. King Road improvements and is included as an appendix to this report. The OPCC for these proposed improvements without T.W. King Road improvements is approximately $5.9 million.

Overhill/Timber Ridge Drives

The watershed for the Overhill Drive storm drain system is approximately 30 acres. The watershed is considered fully developed, consisting of approximately 80 percent residential and 20 percent open space (golf course). The upper half of the watershed drains into a detention pond located at the south end of the golf course. The detention pond was constructed as a part of the Knolls development in 2006 in an effort to mitigate the expected increased runoff from development of the subdivision. Improvements to the detention pond were constructed in 2008. The recommended improvements consist of approximately 300 linear feet of 30-inch pipe on Timber Ridge Drive and 500 linear feet of 36-inch pipe on Skyline Drive and Indian Creek Drive as described above and shown graphically on Figure 9. The OPCC for these proposed improvements is $240,000 and is included as an appendix to this report.

Fresh Meadows Drive

The watershed for the Fresh Meadow/Inverness storm drain systems is approximately 114 acres in size. Similar to the previous study location, this watershed is also considered fully developed. The lower half of the watershed drains into a retention pond located on the golf course (see Figure 5). The storm drain system along Fresh Meadow also appears to be undersized. The proposed improvements for this location include reconstructing the pond outfall and increasing the storm drain system capacity along Fresh Meadow. The OPCC for these proposed improvements is $451,000 and is included as an appendix to this report.

Cypress Creek

The Cypress Creek Channel hydraulic analysis results and comments from residents indicate that the primary problem for Cypress Creek Channel is erosion. FNI recommends further and more detailed geomorphic and geotechnical investigation. Possible hard armoring may be required and the OPCC for this conceptual improvement is approximately $1.3 million.

2.0 INTRODUCTION

The Town of Trophy Club has contracted with FNI to perform a Storm Water Master Plan conducted in three phases. Phase I is a detailed study of five known drainage issues within the Town. Phase II will be a review, analysis and provision of recommendations for all remaining drainage systems in the Town. Phase II will also include development and ranking of proposed drainage improvement alternatives for a Town-wide Storm Water Capital Improvement Plan (CIP). Phase III will be coordination of regional drainage concerns with neighboring communities and pursuit of grant funding opportunities to fund drainage studies and improvements. A map showing the location of the five (5) identified focus areas is shown in Figure 1. This report summarizes the findings of the first phase of the Master Plan. The study analyzes and proposes improvements for the five (5) identified drainage focus areas:

- Marshall Branch at Trophy Club Drive
- Skyline (Indian) Creek
- Overhill/Timber Ridge Drives
- Fresh Meadows Drive
- Cypress Creek

In the preliminary stages of this study, FNI conducted a public meeting with Town staff and residents on May 16, 2011. At the meeting, a presentation was given to describe the intent and locations for the study in Phase I. Individual comment forms were distributed to obtain resident input. The same comment form also was posted on the Town's website for residents unable to attend the public meeting. To date, FNI has incorporated all 28 comments received into a database for use in Phase I as well as Phases II and III and by Town staff.

3.0 HYDROLOGY

3.1 METHODOLOGY

The *Integrated Storm Water Management (iSWM™) Manua*l, 2010, developed by North Central Texas Council of Governments (NCTCOG) was used for drainage criteria. The hydrologic analyses of the study areas used three (3) different hydrologic methodologies: Snyder's Unit Hydrograph Method, Soil Conservation Service (SCS) Unit Hydrograph Method, and the Rational Method. Guidance from *iSWM™* recommends different methods based on drainage basin size. For basins with drainage areas up to 200 acres, the Rational Method is appropriate. Larger drainage areas can use either the SCS Unit Hydrograph Method or Snyder's Unit Hydrograph Method. Drainage areas for the sites were delineated using 2001 NCTCOG 2-foot contour data and were supplemented by engineering site visits and site specific survey from Brittain & Crawford, LLC (B&C) (2011). The drainage area delineations for each of the Phase I sites are

shown in Figures 2 through 6 Drainage Area Maps. Drainage areas were delineated based on B&C's field survey, supplemented with 2001 NCTCOG two-foot topographic contour data (Captured November 2000 – January 2001 by Vargis, LLC).

For SCS hydrologic calculations, existing (2011) and ultimate land use curve numbers "CN" values were developed for each site, based on inspection of aerial photography and assumptions for future development within the Town of Westlake. Weighted averages of the "CN" values were taken to calculate a composite "CN" value for each drainage area. A similar approach was used to obtain watershed characteristics for Snyder's calculations and to obtain "C" values (runoff coefficients) for the Rational Method calculations. Rational Method calculations for Overhill Drive were used from a previous study performed by Teague Nall and Perkins, Inc. (TNP), dated November 2008 entitled "Timber Ridge Drainage Study."

Rainfall intensities were obtained from the U.S. Geological Survey (USGS) intensity-duration-frequency data for Denton County. Time of concentration calculations were performed using the National Resources Conservation Service (NRCS) TR-55 methodology on each of the basins, except for the Marshall Branch basin. Due to its size, the Marshall Branch basin time of concentration was developed using Snyder's Lag Time calculations.

3.2 RESULTS

Peak flows were calculated for the 2-, 5-, 10-, 25-, 50- and 100-Year frequency rainfall events. Table 1 includes the existing (2011) land use conditions peak flows for the 5- and 100-Year rainfall events. Flow values are shown in units of cubic feet per second (cfs). The ultimate land use conditions were determined assuming the undeveloped property south of 114 in Westlake was developed with 1-acre residential lots. Table 2 shows the peak flows for each basin with ultimate land use conditions for the 5- and 100-Year rainfall events. Peak flows for Skyline (Indian) Creek, Overhill/Timber Ridge and Fresh Meadows did not change in ultimate conditions because the watersheds are considered fully developed. As noted in Table 2, full development of the Marshall Branch watershed only produces a 5.6 percent increase in expected flow because the majority of the 11-square mile basin is currently in a developed condition. The only study area showing significant change with full development is the Cypress Court watershed. Full development of the watershed, south of Highway 114 is expected to produce an approximately 30 percent increase in 100-Year flow. Contributing drainage areas to each of the study locations are shown on Figures 2 through 6.

Table 1. Existing Flows Per Basin

Basin	Area (acres)	5-Year (cfs)	100-Year (cfs)
Trophy Club Drive	6918.4	2477.7	14390.8
Skyline (Indian) Creek	322.2	919.1	2207.8
Overhill/Timber Ridge	27.1	25.03	41.48
Fresh Meadows Drive	114.2	230.5	535.0
Cypress Court	102.6	249.8	613.4

Table 2. Ultimate Flows Per Basin

Basin	Area (acres)	5-Year (cfs)	100-Year (cfs)	Percent Increase*
Trophy Club Drive	6918.4	2564.5	15427.7	7.2%
Skyline (Indian) Creek	322.2	919.1	2207.8	0.0%
Overhill/Timber Ridge	27.1	25.0	41.5	0.0%
Fresh Meadows Drive	114.2	230.5	535.0	0.0%
Cypress Court	102.6	333.5	801.3	30.6%

* Percent Increase based on 100-Year Flows

As studied streams, Marshall Branch and Skyline (Indian) Creek each had published Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) flows. These flows are compared in Table 3 to FNI's calculation of ultimate flows.

Table 3. FIS 100-Year Flow Comparison

			FNI (Existing Conditions)		Percent Difference	
	Drainage Area (Sq. Mi)	Flow Flow (cfs)	Contributing Drainage Area (Sq. Mi)	Flow Flow (cfs)	Contributing Drainage Area (Sq. Mi)	Flow (cfs)
Trophy Club Drive	11.93	11050	10.81	14390.8	9%	30%
Skyline (Indian) Creek	0.53	1740	0.5	2207.8	6%	27%

4.0 HYDRAULICS

4.1 METHODOLOGY

Closed Systems

The closed conduit hydraulic analysis used Manning's equation methodology and Bentley's StormCAD V8i software. Criteria used for evaluation of sufficient storm drain capacity includes containment of 5-Year return event flow within storm drain pipes, 100-Year return event flow capacity for rights-of-way above storm drain pipes and for storm drain inlets and positive

overflow routes for 100-Year return event flows. Analysis of inlets for study areas were conceptually sized based on design flows. Storm drain pipes were also assumed to be in clean working order and to have full flow capacity. The pipe sizes and alignments of the existing storm drain system were modeled based on Town-provided data. This data did not contain flowlines or profiles so pipe slopes were assumed.

Open Channels

The open channel hydraulic analyses used backwater calculations and the United States Army Corps of Engineers' (USACE) Hydraulic Engineering Center-River Analysis System (HEC-RAS) Version 4.1. The geometry for the HEC-RAS model was extracted using a GIS pre-processor, HEC-GeoRAS Version 4.3.93. NCTCOG 2001 2-foot contours were used for channel data and supplemented with field survey data obtained by B&C for this project. Channel data for Marshall Branch was also supplemented using the 2008 Carter and Burgess Tract J LOMR. The criteria used to analyze the performance of the existing open channels considered both flood and erosion protection. Flood protection was evaluated based on 1-foot of freeboard between the 100-Year floodplain and residential structures. NCTCOG iSWM criteria states that roadway crossings should be sized to contain the 100-Year rainfall event with 1.5-feet of freeboard to the top of road for culverts and 2-feet of freeboard to the low chord elevation for bridges. While NCTCOG *iSWM™* recommends 2-feet of freeboard to the low chord of bridges, guidance from NCTCOG *iSWM™* criteria indicates that based on site specific conditions, freeboard requirements can be lowered. Erosion protection was based on NCTCOG *iSWM™* erosion criteria.

5.0 EXISTING CONDITIONS

5.1 MARSHALL BRANCH AT TROPHY CLUB DRIVE

The watershed for Marshall Branch lies southwest of Lake Grapevine and extends into the Town of Trophy Club, the Town of Westlake and the Cities of Roanoke, Keller and Fort Worth. The total area of the watershed above Lake Grapevine is 13.7 square miles. Of that area, approximately 11.2 square miles is located outside of the corporate limits of the Town of Trophy Club. The existing area in Westlake is approximately 58 percent low density residential development and 16 percent open space. The undeveloped area resides primarily in Westlake. Given the current largely one (1) acre plus residential development located in Westlake, FNI assumed the remaining open space in Westlake would be developed similarly. Detention policies can have a large impact on peak flows; therefore, FNI took adjacent communities' detention policies into account. The City of Keller's detention policy, which contributes approximately 1,950 acres to Marshall Branch at Trophy Club Drive and is fully developed, did not factor into hydrologic calculations. The Town of Westlake, which contributes approximately 2,600 acres to Marshall Branch at Trophy Club Drive, has a regional detention policy. This policy discourages site by site detention in favor of a regional detention effort. To

account for this policy, FNI assumed that all future development within the Town of Westlake will occur without detention.

The watershed at Trophy Club Drive is 10.8 square miles. Trophy Club Drive is the main thoroughfare connecting the east and west portions of town. When this roadway is closed at Marshall Branch due to high water, the only connection between the two portions of town is Highway 114, which is outside the Town limits. A detour of 2.5 miles is required when the roadway is closed.

According to information from Town Staff, Trophy Club Drive has been overtopped on several occasions, requiring barricades to prevent traffic flow during storm events. Calculations indicate that the road currently offers 2-Year return event flood protection and may act as a low-water crossing during larger return event storms due to depth of inundation. For 5-Year return event flows, the road is expected to be overtopped by approximately 1.8 feet. This depth increases to an expected 6.2 feet for 100-Year return event flows. Currently the channel flows north from Highway 114 through 3-10'x8' (10 feet wide by 8 feet high) reinforced box culverts (RBC) at Trophy Club Drive and continues north through the golf course to its confluence with Lake Grapevine as shown on Figure 1. Visual evidence indicates that erosion along the banks and sedimentation on the upstream side of the culverts has partially blocked conveyance through the culverts. Marshall Branch is a FEMA studied stream in this location. As a result, the channel has calculated Base Flood Elevations (BFEs), and lettered cross-sections. Figure 2 shows the contributing drainage area for Marshall Branch at Trophy Club Drive. Figure 2 also compares the FEMA-effective and FNI-computed existing conditions of the 100-Year floodplain for Marshall Branch at Trophy Club Drive.

Exhibit 1. Existing Conditions of Marshall Branch at Trophy Club Drive

Erosion in channel

Sedimentation blocking culverts

5.2 SKYLINE (INDIAN) CREEK

The watershed for Skyline (Indian) Creek is approximately 322 acres (0.5 square miles) at the town limit line, T.W. King Road, and is located on the southeast side of the Town of Trophy Club. While the channel is officially termed Indian Creek in FEMA documentation, Town staff members refer to the channel as Skyline Creek due to its proximity to the residential roadway of the same name. Skyline (Indian) Creek flows from the upper reaches of the watershed through a pond on the golf course. The pond is located west of Pebble Beach Drive, north of Inverness Drive and southeast of Fresh Meadows Drive. The channel originates at the pond outfall and drains north through the golf course between residential properties for about 3,000 linear feet before draining into the Town of Southlake and eventually into Lake Grapevine as shown on Figure 1. Skyline (Indian) Creek crosses three (3) roadway crossing within the town limits: Greenleaf Drive, Indian Creek Drive and T.W. King Road. The center line of T.W. King Road serves as the corporate boundary between Southlake and Trophy Club in this location. Reports from Town staff and residents indicate that these road crossings have been inundated during past rain events. Results of the hydraulic channel analysis indicate that the (3 – 7'x3.5' RCB) Greenleaf Drive culverts currently have 5-Year return event flow protection while Indian Creek Drive (3 – 7'x3' RCB) and T.W. King Road (6 – 48-inch Reinforced Concrete Pipe (RCP)) only have 2-Year return event flow protection. Visual evidence indicates that significant erosion has undermined retaining walls along the creek banks in its entirety and has exposed an encased sewer line from downstream of Indian Creek Drive to T.W. King Road. The creek is heavily vegetated with trees and thick brush, limiting channel capacity and generally causing increases in water surface elevations throughout the channel. Since the channel is not contained within a platted drainage easement, adjacent property owners have constructed various bank stabilization measures along each of their segments of the channel. As a result, the channel geometry is highly variable from one property to the next. Results indicate that several houses and appurtenant structures are inundated by 100-Year event flows. Figure 3 shows the contributing drainage area and the existing conditions 100-Year FEMA and FNI floodplains of Skyline (Indian) Creek. The floodplain in this location has a FEMA Zone AE designation indicating the floodplain limits have been determined by detailed study methods.

Exhibit 2. Existing Conditions in Skyline (Indian) Creek

Undermined retaining wall

Exposed sanitary sewer

5.3 OVERHILL DRIVE

The watershed for the Overhill Drive storm drain system is approximately 30 acres. The watershed is considered fully developed, consisting of approximately 80 percent residential and 20 percent open space (golf course). The upper half of the watershed drains into a detention pond located at the south end of the golf course. The detention pond was constructed as a part of the Knolls development in 2006 in an effort to mitigate the expected increased runoff from development of the subdivision. Improvements to the detention pond were constructed in 2008. Exhibit 3 shows the existing detention pond.

Flow from the surrounding Knolls development is conveyed through the golf course in a series of open swales to the outlet of the detention pond, a 3'x3' square concrete drop inlet located behind the residential homes along Overhill Drive and Timber Ridge Drive. The detention pond drop inlet drains to an 18-inch pipe between 548 and 550 Timber Ridge Drive then to the existing storm drain system located beneath Timber Ridge Drive and Skyline Drive. The existing storm drain system begins with an 18-inch pipe at the pond and terminates at the creek with a 36-inch pipe. There are curb inlets in the streets ranging from 10-feet to 20-feet in length, draining the adjacent neighborhood to the closed system. The existing system sizes and alignments are shown in more detail on Figure 4.

Information from Town staff and residents, obtained during the public meeting indicates that runoff from The Knoll previously exceeded the capacity of the surface drainage features in the golf course and entered residential structures on the west side over Overhill Drive north of Timber Ridge Drive. Remediation efforts were constructed in 2006 with additional grading of the golf course and of the existing detention pond. However, manhole covers along Timber Ridge Drive continue to be forced open by excess flow during heavy rain events, causing

significant runoff to drain to the intersection of Timber Ridge Drive and Skyline Drive where the intersection becomes inundated. Excess drainage at the flooded intersection overtops the south curbline and inundates the residences at 4 and 6 Skyline Drive before discharging into Skyline (Indian) Creek. Movement of the manhole covers during storm events confirms calculations indicating that the existing system is undersized for design storm events.

Exhibit 3. Existing Conditions of Golf Course Drainage Features Upstream of Overhill Drive

Photo showing existing detention pond with 3' inlet

Existing swale leading to pond

5.4 FRESH MEADOWS DRIVE

The watershed for the Fresh Meadow/Inverness storm drain systems is approximately 114 acres in size. Similar to the previous study location, this watershed is also considered fully developed with approximately 80 percent residential and 20 percent open space (golf course). The lower half of the watershed drains into a retention pond located on the golf course (see Figure 5). The retention pond provides a limited amount of storage capacity for excess runoff, but the majority of the capacity in the pond is used by the constant water surface elevation in this golf course water feature. This drainage area serves as the headwaters of the Skyline (Indian) Creek Channel watershed described above.

Based on comments received at the public meeting from adjacent residents, it was discovered that several homes northwest of the pond experience high water and the potential for residential inundation during rain events. A site investigation by the study team revealed a natural swales running behind the homes from 218 through 222 Fresh Meadows Drive and Fresh Meadows Court and outfalling into the golf course pond. The pond has an outfall structure comprised of 2-24-inch diameter High Density Polyethylene (HDPE) pipes and an overflow path draining to the swale behind the properties at 224 and 226 Fresh Meadows

Court. This swale serves as the upstream end of Skyline (Indian) Creek (Figure 5). Exhibit 4 shows existing condition photographs.

Exhibit 4. Existing Conditions of Fresh Meadows

Existing overflow swale

Existing outfall structure (2-24-inch HDPE) and overflow

5.5 CYPRESS CREEK

This unnamed tributary to Golf Course Creek was identified as Cypress Creek for the purposes of this study. The watershed for Cypress Creek is approximately 103 acres and is located on the south side of the Town. Approximately 40 percent of the watershed is located in Westlake. Visual inspection of recent aerial photographs indicates that approximately 53 percent of the watershed is developed with Medium Density Residential, third acre lots-type land use. It was assumed that the remainder of the watershed would develop as Low Density Residential acre lots. The creek enters the Town of Trophy Club from Highway 114 through 2-60-inch concrete pipe culverts, crosses Indian Creek Drive, continues north behind residential properties for about 1,300 linear feet to its confluence at a pond on Golf Course Creek as shown on Figure 6. Visual evidence indicates that significant erosion has undermined retaining walls along the creek banks and has exposed several utility lines. The hydraulic results indicate that the primary problem on Cypress Creek is erosion. Comments from Town residents along Cypress Creek confirm that erosion and not flood control is the primary concern.

A preliminary site visit was made to Cypress Creek on June 8, 2011 to locations of bank erosion that may affect residential property. FNI staff and Town staff walked approximately 1,100 linear feet of channel, beginning at Indian Creek Drive and continuing downstream to the confluence at the pond on the golf course. The purpose of the preliminary site visit was to identify erosion problems.

EXISTING CONDITIONS

The channel encompasses a small earthen section capable of carrying lower return event flows. This low-flow channel is in a state of downcutting (lowering flowline and widening banks) along

the majority of the length observed. Areas that were incised (width/depth ratios less than 10) had generally steep banks and were undercut in some locations. The creek banks on the outside of meanders were scoured and near-vertical. Tree roots were exposed, indicating bank erosion and channel widening. Multiple knickpoints (headcuts) were observed on the channel bed. Knickpoints are natural drops in elevation which are characteristic of channels that are actively downcutting (see Exhibit 5). Bank failures in the form of rotational slides (slumps) were observed. Leaning trees on the creek banks indicate slow moving creep failures. Causes of stream bank failure may include improper drainage from residential properties, existing geologic conditions and geotechnical properties of the slope, and removal of the bank toe following channel downcutting and/or widening. Prior to design of bank stabilization improvements, it is recommended that a detailed geotechnical investigation be conducted to determine the cause (or causes) of slope failures. The instabilities observed in the unnamed creek did not appear to pose an immediate threat to existing municipal infrastructure.

BACKGROUND

Stream flow (flow) typically increases following watershed development and urbanization. In the Dallas/Fort Worth (DFW) area, watershed development began as open prairie that was converted to agricultural land. Overland roughness was decreased and natural drainage patterns were altered to increase drainage rates. Stream flow increased as a result of this development, and stream channels adjusted their dimensions (width, depth, and slope) by enlarging to convey the higher flows.

When the watershed of the unnamed creek became urbanized, impervious surfaces decreased times of concentration and increased peak flows once again. The channel of the unnamed creek is now in the process of adjusting to the increase in flow. Channels adjust by the principles proposed by Lane (1955). Lane's relationship explains that flow and channel slope (stream power) are in a balance with sediment flow and the size of the sediment particles (D_{50}). When one of the variables of Lane's balance changes, the others change in order to maintain the balance.

When the flow of the unnamed creek increased as a result of urbanization, the erosive power of the creek was increased, more sediment was eroded, and the channel dimensions began to adjust to decrease stream power. The creek appears to be following the stages of the Incised Channel Evolution Model (ICEM) (Schuum, 1977). The channel of the unnamed creek was in Stage II (downcutting) of the ICEM.

Channels downcut to decrease channel slope and reach an equilibrium slope. The equilibrium slope is considered a stable channel slope that is in balance with stream flow and sediment. It is the slope that allows the channel to convey water and sediment downstream without net aggradation or degradation under the current flow regime. Channels in the DFW area typically downcut to reach an equilibrium slope, instead of increasing meander length. Downcutting in the channel of the unnamed creek appears to be occurring as headward migrating knickpoints

decreasing the channel slope. This process will continue until the channel has reached a new equilibrium slope or until preventive measures are constructed in areas of active erosion.

The downstream end of the unnamed creek (near the golf course) showed indications of widening (ICEM stage III). This suggests that the downstream end of the creek was adjusting to the increase in flow. At this downstream end, the channel was wider, the slopes were less steep and the flow had connection to a terraced floodplain. These geomorphic features allowed for the erosive power of higher flows to dissipate. The channel has widened by eroding the toe of the bank slope, causing bank failures. Unless stabilized by construction, widening can be expected to continue in the upstream direction until channel dimensions are able to convey the flow and sediment of the system without any net aggradation or degradation.

Exhibit 5. Photos from Site Visit Showing Geomorphic Features of the Cypress Creek

Channel downcutting

Knickpoint migrating in the upstream direction

Channel incision, knickpoint and slow moving creep

Incised channel, toe erosion, creeps, leaning trees, exposed roots

Bank scour on a meander

Vertical banks, soil loss, exposed roots

6.0 PROPOSED IMPROVEMENTS

Following analysis of existing conditions in the five focus areas, hydraulic models were completed for each area to recommend improvements that meet current design criteria, while considering cost effective solutions. The following sections describe those recommendations.

6.1 MARSHALL BRANCH AT TROPHY CLUB DRIVE

Because the size of the existing floodplain relative to the size of the existing hydraulic opening at the Trophy Club Drive crossing, it was acknowledged that recommended improvements might be financially prohibitive. As a result, three improvement alternatives were considered:

1. Bridge crossing sized to accommodate 100-Year return event flows,
2. Culvert crossing sized to accommodate 100-Year return event flows, and
3. Culvert crossing size to accommodate 25-Year return event flows, with possible consideration given to phasing for future construction to achieve 100-Year capacity.

Initial analysis of the crossing revealed a necessity to provide additional channel capacity upstream and downstream of the crossing to adequately carry expected design flows. Proposed grading downstream of the Trophy Club Drive crossing serves two main functions, both related to a decrease in water surface elevation. One benefit to this reduction in water surface elevation is the removal of approximately seven (7) residential structures from the 100-Year floodplain (see Figure 7). A lower downstream water surface elevation also maximizes the efficiency of the roadway crossing.

In addition to increased channel carrying capacity to reduce the downstream water surface elevation, the roadway must be raised to match adjacent grades in order to eliminate the low water crossing effect of the current configuration. It is recommended that the roadway elevation be increased by as much as 5.8 feet at its lowest point. Preliminary review of existing adjacent grades indicates that the roadway increase can be tied into existing roadway grades

prior to the intersections with Meadow Creek Court to the East and Trophy Lake Drive to the west. Figure 7 provides a graphic concept for the 527 linear feet of roadway reconstruction and typical sections for the recommended channel grading limits. The commercial access driveway west of the channel and the intersection of Trophy Club Drive and Meadow Creek Court will require reconstruction as part of this project. The proposed sizes shown in this report balance the limits of grading downstream, increase in roadway elevation and the hydraulic opening of the structure to create an optimal solution.

As described in the existing conditions section of this report, sedimentation upstream of the crossing has occurred over time, partially blocking the existing opening and further reducing the hydraulic carrying capacity of the 3-8'x10' RCBs. Grading limits upstream of Trophy Club Drive serve to eliminate this blockage and to further reduce the width of the 100-Year floodplain between Trophy Club Drive and Highway 114. It is estimated that the upstream grading will remove eight (8) residential properties from the floodplain as shown on Figure 7. The total grading effort both upstream and downstream will remove a total of 15 structures from the floodplain; seven (7) structures will be removed due to the downstream grading and eight (8) structures due to the upstream grading.

The downstream impacts of these recommended roadway crossing improvements were an important consideration in this study. Because the crossing was truly serving as a low-water crossing in larger design storms, such as the 100-Year return event, flow values did not change before and after the recommended improvements were incorporated into the hydraulic model. The change is the method of conveyance. Before improvements, a majority of the flow goes over the roadway. After the improvements, the flows pass underneath the roadway. In lower return event storms such as the 2-Year and 5-Year storms, there is no negative impact on the rate of flow downstream of the project. In the 2-Year and lower events, the flow passes through the existing structure without detention. The 5-Year event overtops the existing structure by approximately 1.83 feet and is not detained. Velocities downstream of the proposed improvements are actually decreased as a result of the improvements. The reason for the decrease in velocities is due to the increased channel area. With the same flow, the proposed downstream grading provides a large flow area, causing the velocities to decrease. The proposed limits of grading are intended to gradually transition flows from the improved section to the golf course without creating locations of erosive velocities. This will be an important consideration during design of the improvements. Downstream of the crossing, the majority of the floodplain is contained within the golf course. The three (3) eastern most buildings of the Quorum Townhomes apartment complex on 350 Quorum Drive and the residences on Oakmont Drive are within the limits of the floodplain. The proposed channel crossing improvements do not change the 100-Year water surface elevation impact to these structures.

As summarized above, our analyses indicate that the proposed improvements are not expected to create a negative impact to downstream velocities or 100-Year water surface elevations. The three crossing alternative considered are summarized below.

Bridge Crossing

Alternative 1

This alternative includes installation of a bridge with piers and channel excavation upstream and downstream of Trophy Club Drive. A bridge, approximately 500-feet in length, is needed to replace the existing 3-10'x8' box culverts to span across Marshall Branch. Trophy Club Drive will be raised approximately 6-feet in order for the bridge to pass the 100-Year storm event. This proposed improvement will provide approximately 0.8-feet of freeboard to the top chord of the roadway. NCTCOG *iSWM™* design guidance indicates that the crossing should include 2-feet of freeboard to the low chord of a bridge. During final design of the proposed improvements, modifications to grading, bridge height and hydraulic opening should be finalized to achieve this result or to determine if the criteria should be changed. Channel excavation upstream and downstream of Trophy Club Drive on the west side of the channel will provide additional valley storage, lowering the tailwater at Trophy Club Drive and removing the residential structures on the east side of Marshall Branch from the 100-Year floodplain. Typical cross sections can be seen in Exhibits 6 and 7 for the proposed excavation upstream and downstream of Trophy Club Drive. The OPCC for this alternative is approximately $5.3 Million and is included as an appendix to this report. The proposed improvements can be seen in Figure 7.

Exhibit 6. Typical Cross Section Upstream of Trophy Club Drive

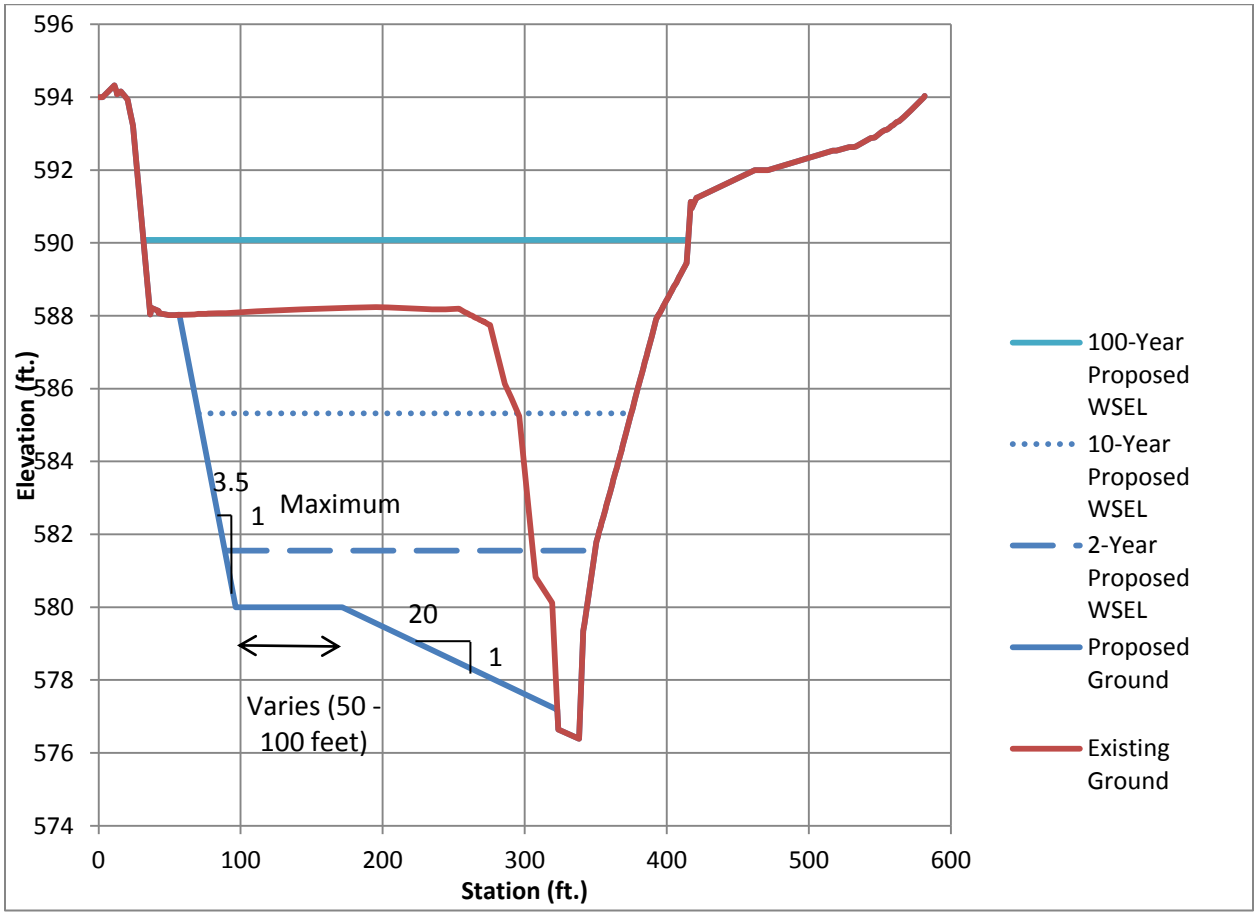
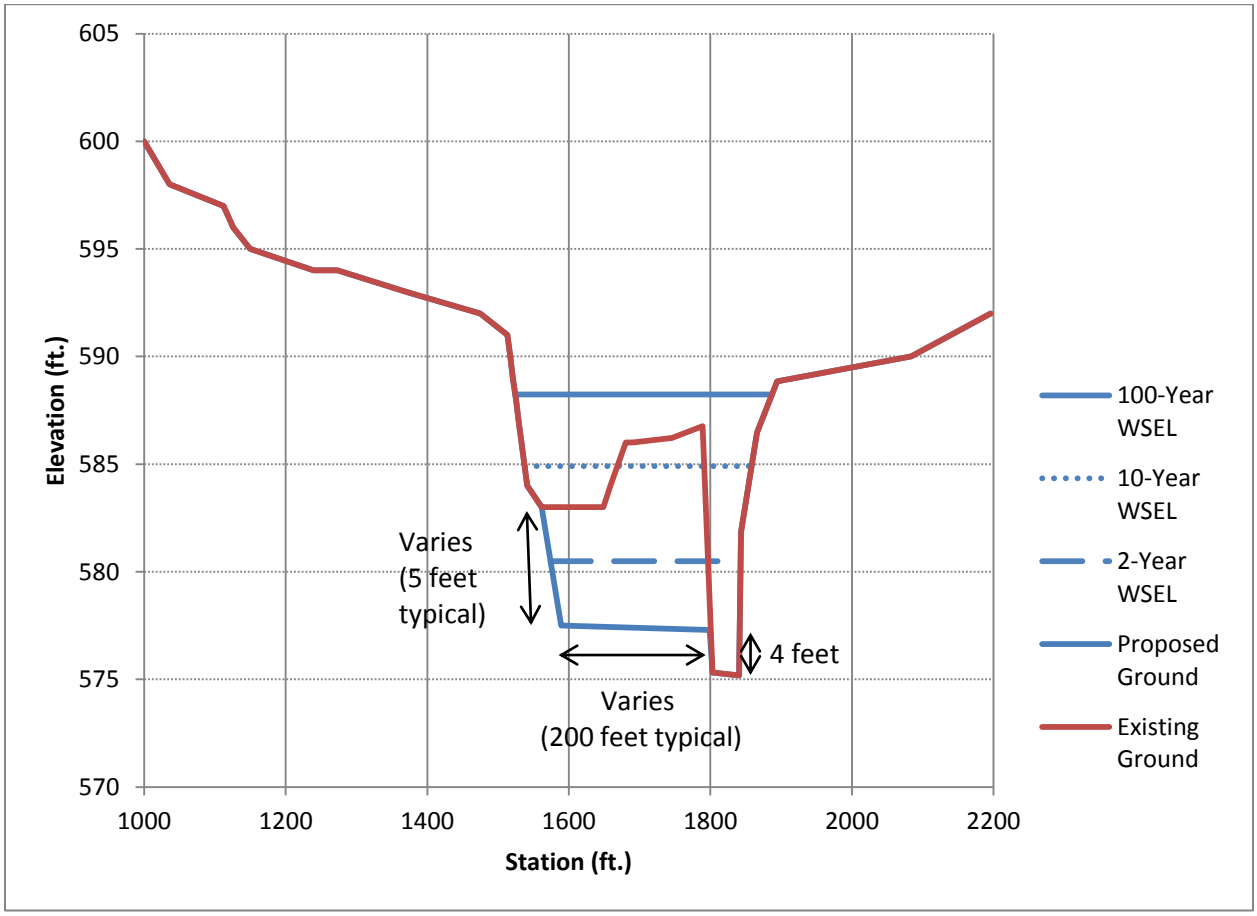


Exhibit 7. Typical Cross Section Downstream of Trophy Club Drive



Alternative 2

A phased improvement scenario using multi-box culverts was also considered. An improvement scenario that meets 100-Year design criteria consists of raising Trophy Club Drive approximately 6 feet and installing 18—12' x 10' box culverts. Upstream and downstream excavation is also required for this solution. The OPCC for this improvement alternative is approximately $5 Million. To reduce the initial outlay of construction costs, a first phase improvement can be considered. The first phase includes raising Trophy Club Drive and installing eight (8) of the 18 box culverts. This first phase solution would provide 10-Year flood protection for the roadway but would raise the 100-Year water surface elevation upstream of Trophy Club Drive by 1.2-feet at Trophy Club Drive and 0.27-feet at the Westbound 114 Service Road. This solution would have a negative impact on the residential structures on the east side of the channel upstream of crossing and is therefore not recommended. The second phase of construction consists of upstream and downstream excavation and constructing the remaining 10-12' x 10' box culverts. The ten (10) box culverts could be constructed by means of boring to eliminate the need for open cutting Trophy Club Drive. The OPCC for the first phase of this proposed improvement is approximately $2.3 Million. However, this alternative is not

recommended. While it does reduce the initial outlay of construction cost, the negative impact to upstream water surface elevations and the high cost of second phase construction reduce the benefit.

Alternative 3

A 25-Year flood protection alternative was also analyzed. This solution consists of raising Trophy Club Drive approximately 6 feet and installing 8—12' x 10' box culverts. Upstream and downstream excavation is required for this solution as well. While the road would pass the 25-Year flood, this solution would not remove all of the residential structures from the 100-Year floodplain that the full solution would. Approximately 100-feet downstream of Trophy Club Drive the 100-Year water surface elevation would be reduced by approximately 2.4 feet. This decrease in water surface elevation is approximately 0.1 foot less than the full solution. Preliminary floodplain delineations indicate that the houses on Riviera Court and Trophy Club Drive that are in the FNI existing 100-Year floodplain are removed from the 100-Year floodplain. The 100-Year water surface elevation is reduced at the most by approximately 2.2 feet at a location 975 linear feet upstream of Trophy Club Drive. Immediately upstream of Trophy Club Drive the 100-Year water surface elevation is increased by approximately 0.75 feet. Upstream of Trophy Club Drive, 8, 7, 6 and 5 Meadow Creek Court as well as 8 Crooked Creek Court are not removed from the 100-Year floodplain. The OPCC for this proposed improvement is approximately $4 Million. This option is not a preferred alternative because the benefit provided by this solution is considerably less than the 100-Year solution but the cost is not proportionally lower than the cost of the 100-Year solution. This solution increases the 100-Year water surface elevation immediately upstream of Trophy Club Drive and allows five (5) structures to remain in the floodplain.

Based on the discussion of alternatives provided above, Alternative 1, the 100-Year solution which consists of a 500-foot long bridge with piers accompanied by upstream and downstream channel excavation, with an OPCC of $5.3 million is the preferred alternative.

6.2 SKYLINE (INDIAN) CREEK

Because existing improvements are inconsistent and existing residential structures are located so close to the channel banks, a complete reconstruction of the channel is recommended for this focus area. Proposed improvements include a uniform channel section with vertical side slopes and a bottom width varying from 15-feet to 50-feet. The uniform section recommended is a structural concrete block wall from T.W. King Road upstream and approximately 3,000 linear feet to the northern edge of the golf course adjacent to Timberline Drive (see Figure 8). The three roadway crossings encompassed within these limits, Greenleaf Drive, Indian Creek Drive and T.W. King Road are also recommended for upgrade. The approximately 240 linear feet of Skyline (Indian) Creek, through the golf course between the upstream end of this Skyline (Indian) Creek focus area and the downstream end of the Fresh Meadows focus area, are not recommended for improvement. This 240 linear feet of channel is not limited by existing

residential structures and does not show erosive velocities based on the models created for this analysis.

Channel Improvements

The proposed channel section has an average depth of 5-feet, average bottom width of 30-feet and average top width of 30-feet. Typical sections are shown on an inset of the floodplain maps in Figures 8A through 8C. It is recommended that the concrete block wall have a stone finish to give the channel an aesthetic appeal. In addition to placing a rectangular section, approximately four (4) grade control structures are proposed. Exhibit 8 below shows the proposed channel profile for Skyline (Indian) Creek.

Exhibit 8. Proposed Skyline (Indian) Creek Profile

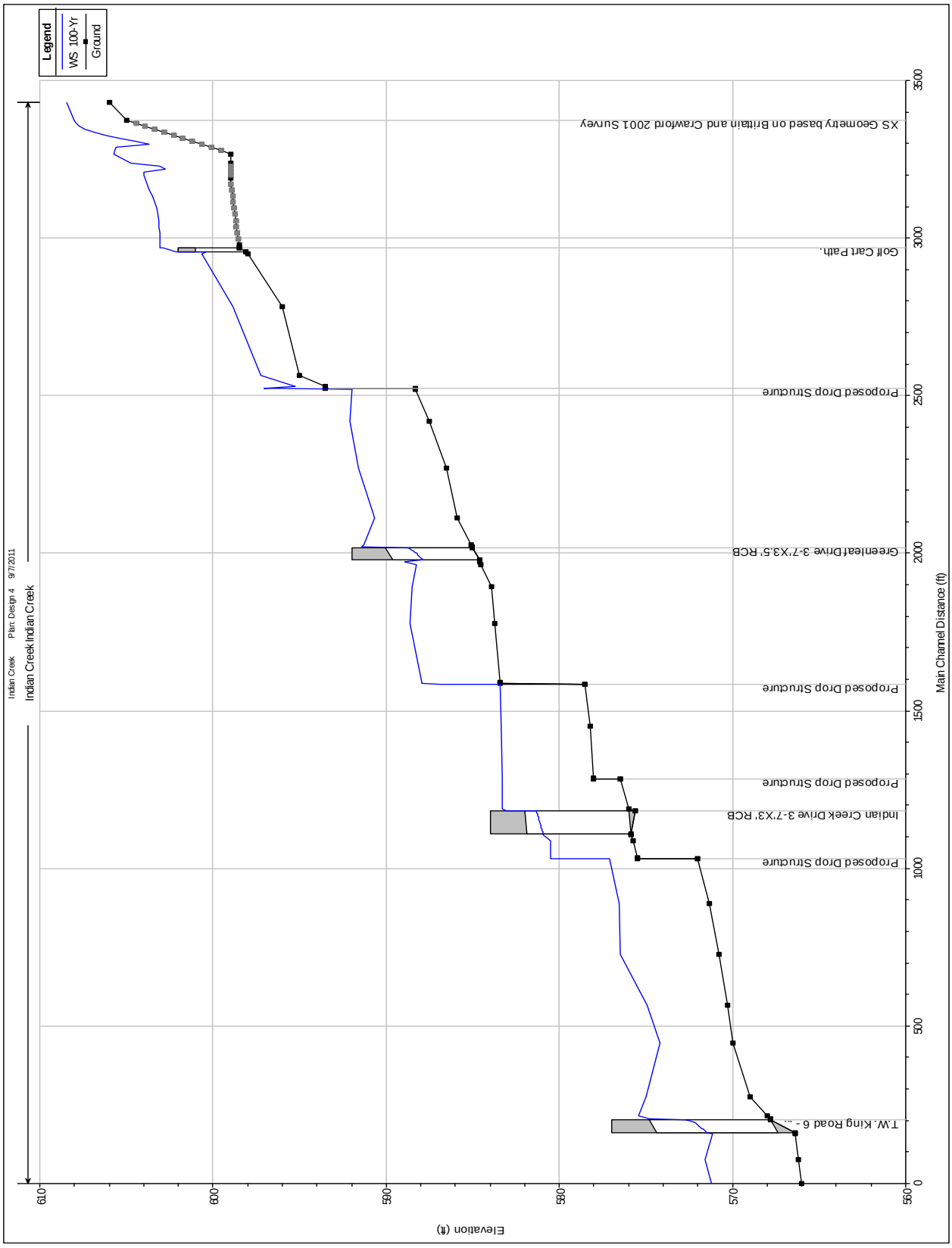


Exhibit 9 shows an example of the proposed channel improvements and Exhibit 10 shows a typical cross section. Downstream of Indian Creek Drive, utility coordination will be required to relocate an existing sanitary sewer line, which runs parallel to the existing creek center line. An articulated concrete block is planned in the flowline of the channel to prevent erosion, while still promoting vegetative growth. Vegetation that grows within the channel should be monitored to ensure that the roots system and stem diameter do not exceed a threshold value based on product specifications. Large diameter stems and large root systems could crack or dislodge the articulated concrete block system. The articulated concrete block could be replaced by either a concrete lining or a natural channel bottom as needed during final design.

Roadway Crossing Improvements

Greenleaf Drive currently has 3-7' X 3.5' box culverts and the proposed improvements consist of 4-7' X 5' box culverts. Indian Creek Drive currently has 3-7'X 3' box culverts and the proposed improvements consist of 4-7' X 6'box culverts. An approximate 35-foot clear span bridge will be required at T.W. King Road in lieu of the 6-48-inch culverts to pass the 100-Year storm event. Table 4 summarizes the proposed improvements:

Table 4. Skyline (Indian) Creek Roadway Improvements

Road	Existing	Proposed	OPCC
Greenleaf Drive	3 – 7' X 3.5' RCB	4 -7' X 5' RCB	$ 137,160.00
Indian Creek Drive	3 – 7' X 3' RCB	4 -7' X 6' RCB	$ 234,360.00
T.W. King Road	6- 48- inch RCP	1 – 35-foot Clear Span Bridge	$ 189,000.00

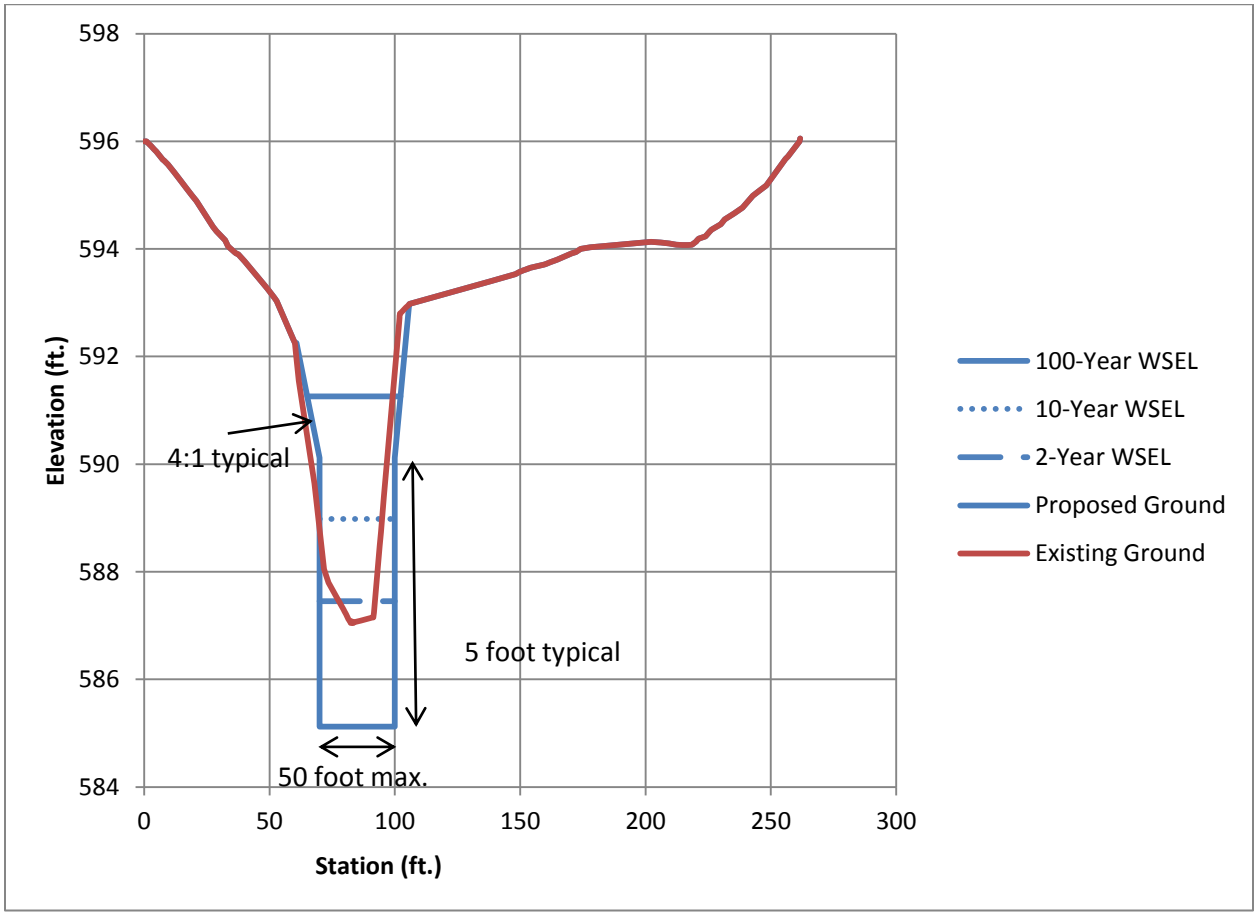
It is acknowledged that the crossing at T.W. King Road is owned by both Trophy Club and Southlake, as the corporate boundary is the centerline of the road. In addition, it is acknowledged that the roadway was recently reconstructed to its current section, 6-48-inch reinforced concrete pipe (RCP) culverts in July of 2005 by Cheatham and Associates. However, the construction plans obtained by FNI during this study do not include either design calculations or intended design return event. The hydraulic models prepared by FNI indicate that the existing structure has a 2-Year return event capacity without overtopping the road. Calculations indicate that the road would overtop by approximately 0.2 feet in the 5-Year storm event and approximately 3.6 feet in the 100-Year storm event. However, it is possible to leave the existing 6-48-inch culverts in place without including any residential structures in Trophy Club in the 100-Year floodplain. The impact of the increased water surface elevation from the undersized roadway crossing attenuates approximately 500 feet upstream of T.W. King. Improving T.W. King causes an increase in velocities immediately downstream of the crossing in the 2-Year return event. This increase in velocity will require erosion protection in this area. Storms larger than the 2-Year event actually experience a decrease in velocities with improvements to T.W. King Road.

Figures 8 and 8A, 8B and 8C show the extents of the proposed improvements to Skyline (Indian) Creek. The OPCC for these proposed improvements is approximately $5.9 Million including

T.W. King Road improvements and is included as an appendix to this report. The OPCC for these proposed improvements without T.W. King Road improvements is approximately $5.6 million. It should be noted that this construction cost can be phased over multiple projects. In general, improvement projects should be constructed from downstream to upstream. The existing roadway crossings are located such that the project could easily be constructed in three discrete projects: Phase I – T.W. King to Indian Creek, Phase II – Indian Creek to Greenleaf, and Phase III – Greenleaf to the golf course. Roadway crossing improvements can be divided with the phases. For example, the Indian Creek Drive crossing can be constructed as the upstream limit of Phase I or delayed and included as the downstream limit of the Phase II project.

Exhibit 9. Example of a Similar Design in Garland Texas

Exhibit 10. Typical Cross Section of Proposed Improvements



6.3 OVERHILL DRIVE

Unlike the previous two open channel focus areas, this project included analysis of needed improvements to the closed storm drain system serving a local neighborhood. The analysis combines calculations for the operation of the Knoll golf course detention structure with the operation of the Timber Ridge Drive/Skyline Drive closed storm drain system. Calculations were performed using Infoworks SD 11.5 modeling software. This dynamic calculation package allows for the computation of the hydrologic function of the detention basin as well as the hydraulic function of the storm drain system in one combined model, creating greater accuracy in the obtained results. A previous analysis of the Timber Ridge/Skyline system was performed by Teague Nall and Perkins (TNP) in November 2008 using StormCAD V5.6 software/methodology. The TNP recommended improvements were used in this analysis exercise.

As mentioned earlier in this report, the existing detention feature on the golf course was constructed in 2006 and improvements to the detention pond were constructed in 2008. Storage calculations were performed for the existing detention pond structure based on field

survey of the existing topography, performed by B&C for this study. Calculations indicate that the pond has sufficient storage volume to attenuate a 100-Year storm event. The existing outfall structure, a 3'x3' drop inlet, is suitable to constrict flow in all storm events, backing up water into the pond, and releasing it at a slower rate into the downstream system.

Proposed improvements include removing and replacing section of the storm drain along Timber Ridge Drive and Skyline Drive. The existing storm drain consists of pipes ranging from 18-inches in Timber Ridge Drive to 33-inches (at low point in Skyline). The proposed storm drain consists of proposed pipes ranging from 30-inches to 36-inches (see Figure 9).

The recommended improvement alignments sought to utilize the existing system where possible and to minimize impacts to adjacent residential structures by limiting construction in side-yards between two residential properties. As a result, the 18-inch outfall pipe between the detention pond and Timber Ridge Drive is proposed to remain in place. However, based on field survey performed by TNP, the 36-inch pipe connecting Skyline Drive to the channel outfall has experienced settling, creating an adverse slope grade (away from the creek). As a result, water ponds in the pipe and reduces the system's capacity. In order to avoid construction between the two residential lots at 4 and 6 Skyline, an option of building a diversion system along Skyline Drive and Indian Creek Drive is proposed. The proposed diversion system would be a continuation of the existing system that drains south on Skyline Drive, then turns southeast down Indian Creek Drive (west-bound lane) and outfalls into Skyline (Indian) Creek at the existing roadway crossing. The existing 36-inch outfall between 4 and 6 Skyline Drive will still be utilized to carry flows in higher return-event storms.

The recommended improvements consist of approximately 300 linear feet of 30-inch pipe on Timber Ridge Drive and 500 linear feet of 36-inch pipe on Skyline Drive and Indian Creek Drive as described above and shown graphically on Figure 9. The OPCC for these proposed improvements is $240,000 and is included as an appendix to this report. The OPCC assumes the pavement repair will be limited to trench width and does not include the cost of complete pavement repair.

It should be noted that the proposed improvements outfall to Skyline (Indian) Creek within the limits of the improvements recommended in Section 5.2. However, because these improvements do not significantly change the location of the outfall of existing drainage, it is not considered a requirement to construct the Skyline (Indian) Creek channel improvements prior to construction of these improvements. However, it should be noted that some channel improvements at the point of outfall near Indian Creek Drive will be required to reduce the likelihood of erosion if the Overhill improvements are constructed before the Skyline (Indian) Creek improvements.

6.4 FRESH MEADOWS DRIVE

A majority of the storm drain system along Fresh Meadows Drive and Seminole Drive is sized appropriately to carry design flows. Existing storm drain consists of pipes ranging from 18-inches to 27-inches. The proposed storm drain consists of new pipes, ranging from 24-inches to 42-inches. Proposed improvements include removing and replacing the upstream section of storm drain along Fresh Meadows Drive and adding inlets to collect street flows and to convey them to the closed system. In addition to upgrades along the system, it is recommended that the outfall be relocated from the south side to the north side of 226 Fresh Meadows Drive. The relocation of the outfall serves to reduce erosion in the sinuous section of Skyline (Indian) Creek behind 226 Fresh Meadows Court. Design and construction of the improvements should include consideration of bank stabilization measures along this portion of the channel to remediate existing erosion and protect the outfall location from future erosion. Figure 10 shows the extents of pipes to be removed and replaced.

Pond outfall modifications are proposed to control normal pool elevations in the golf course pond. As noted earlier, the current pond grading and outfall configuration do not allow significant storage of rainfall flows prior to overtopping the spillway. In addition, the current outfall structure of 2-18-inch grate inlets from the pond is undersized to convey design flows without engaging the spillway, the low portion of the bank on the north side of the pond. The grading between the spillway and the adjacent residential structures at 222 and 224 Fresh Meadows Court does not direct runoff away from the residences and toward the outfall channel. The finished floor elevations at 222 and 224 Fresh Meadows Court are approximately at the same elevation as the top of bank on the downstream side of the pond. As a result, overtopping in the pond places the adjacent homes at risk of inundation. Resident information provided at the public meeting confirms these calculations. Calculations indicate that a 2-Year return event storm will engage the spillway of the pond. In addition, a 25-Year return event storm may result in flooding of adjacent residential structures.

Other resident information obtained at the public meeting indicates that runoff drains from south to north across the properties between 218 and 222 Fresh Meadows Drive. This area is intended to drain east through an open “feeder” channel on the south side of the properties into the golf course pond. A visual inspection of the outfall channel and golf course pond suggest that the lack of available storage in the pond causes runoff to backup into the feeder channel and overflow through residential properties to the closed system in Fresh Meadows Drive. The proposed spillway modification of the pond should allow the pond to operate appropriately to prevent backup into the feeder channel.

Proposed modifications to the pond include a turf reinforced grass-lined weir to release flows from the pond. The pond spillway will outfall to a more clearly defined outfall channel, with grading to direct flows downstream and away from residential structures (Figure 10). The natural grass-lined weir will provide aesthetic appeal while also protecting the bed and banks from erosion. Velocities discharging from the weir range from 0.75 feet per second (fps) for 2-

Year return event flows to 1.75 feet per second (fps) 100-Year velocity. Grading downstream of the weir will be designed to maintain low velocities and non-erosive conditions. The proposed overflow weir releases an increased flow to Skyline (Indian) Creek, from 200 cubic feet per second (cfs) to 225 cfs in the 100-Year storm event. The increased flow is not expected to create erosive conditions or to produce a negative impact on downstream residential structures. As with most of the other focus areas described in this report, coordination with the golf course will be required for coordination and approval of construction on the golf course. In this instance, the resultant normal pool in the golf course pond will be lower following construction to allow additional storage capacity for use during rainfall runoff events. The OPCC for these proposed improvements is $451,000 and is included as an appendix to this report.

6.5 CYPRESS CREEK

The site visit made on June 8, 2011 was a preliminary geomorphic site investigation that allowed for identification of 15 areas of interest (Figure 11). The areas of interest include observed areas of erosion and channel instability. This preliminary investigation provided concept locations for potential improvement alternatives (areas of interest), as opposed to a traditional approach that might include full channel armoring. Based on the site visit, it is our opinion that pinpointing specific repair locations will provide a cost-effective approach that minimizes channel disturbance and maintains as much as possible the existing natural habitat in areas where the channel is stable. A full geomorphic stream assessment is recommended during the design phase of this focus area to pinpoint areas that may require protection or stabilization, to gain an understanding of how the channel is reacting to the increased flows, and to understand how it might change in response to future increases in flows at the existing areas of interest and at other locations.

The channel of Cypress Creek can be expected to continue degrading in response to urbanization. The channel forming flow is the flow that is responsible for forming the channel dimensions. In the DFW area, the channel forming flow is typically between the 0.5-Year and 2-Year peak flow and can be expected to increase as development in the watershed increases. The existing channel dimensions and sediment characteristics will be collected during a field investigation as part of the geomorphic stream assessment. The geomorphic stream assessment would use modeled future flows (full build-out conditions), channel dimensions and sediment characteristics to perform an equilibrium slope analysis, incipient motions analysis, and estimate future channel dimensions.

Observations of similar channels in the area suggest that the slope of the channel will continue to downcut until the equilibrium slope is reached. An equilibrium slope analysis provides an estimate of the amount of potential downcutting that could occur before the equilibrium slope is reached. This will allow for calculation of the number of engineered drop structured needed or grade control to achieve the equilibrium slope. An incipient motional analysis would be conducted as part of a geomorphic stream assessment to estimate sediment transport under

future flow regimes and give an indication of potential deposition. Future stable channel dimensions (width and depth) would also be investigated. There is potential for the channel to continue to widen once the slopes stabilize, and estimation of future channel dimensions would indicate the potential necessity for bank stabilization measures. It is recommended that geotechnical investigations be conducted on any slopes during design of stabilization measures.

Proposed improvements for Cypress Creek include installing approximately 1,500 linear feet of gabion baskets in specific point repair locations along the banks of the channel. The gabion baskets would be approximately 6 feet tall and would leave a natural channel bottom in place. In order to implement the proposed improvements, a detailed geomorphological and geotechnical investigation, along with design level survey is recommended. The OPCC for this conceptual improvement scenario is approximately $1.3 Million and is included as an appendix to this report.

7.0 CONCLUSIONS AND RECOMMENDATIONS

FNI studied five (5) sites for Phase I of the Trophy Club Master Plan and developed proposed improvements for each site. Although it was assumed that existing channels are not platted into easements, OPCCs do not include property acquisition costs. In addition, all costs are in 2011 dollars, without any inflation factors included. Table 5 below summarizes the findings, recommendations and opinion of probable cost for each location.

Table 5. Phase I Summary

Site	Description	Issue Found	Proposed Improvement	OPCC (M)
Trophy Club Drive	Marshall Branch at Trophy Club Drive	Road overtopping in 5-Year event, residential structures flooding.	Excavation upstream and downstream of Trophy Club Drive, replace crossing with a bridge	$ 5.3
Skyline (Indian) Creek	Skyline (Indian) Creek from downstream of the golf course to T.W. King Road	Capacity and erosion problems	Hard Armored rectangular channel	$ 5.9
Overhill/Timber Ridge	Detention pond in golf course and storm drain system along Overhill Drive and Timber Ridge Drive	Storm drain system capacity problems	Increase storm drain system capacity	$ 0.24
Fresh Meadows	Pond in golf course that outfalls in to Skyline (Indian) Creek and a storm drain system along Fresh Meadows Drive	Inadequate pond outfall and storm drain system capacity	Turf reinforced overflow weir and increase storm drain system capacity	$ 0.45
Cypress Court	Cypress Creek from downstream of Indian Creek drive to confluence with Golf Course Creek	Erosion	Further geomorphic and geotechnical investigation and gabion channel armoring	$ 1.3

The summary cost to complete all of the recommended improvements, based on 2011 construction cost values, is approximately $13 million. OPCCs and electronic models are included as an appendix to this report.

OPINION OF PROBABLE CONSTUCTION COST

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Town of Trophy Club-Storm Water Master Plan

Marshall Branch Channel Improvements — **September 15, 2011**

ESTIMATOR	CHECKED BY	ACCOUNT NO
DCS		

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	STORM DRAIN IMPROVEMENTS				**$3,544,000.00**
	SITE PREPARATION	1	LS	$10,000.00	$10,000.00
	EXCAVATION	115000	CY	$10.00	$1,150,000.00
	BRIDGE	1	EA	$2,250,000.00	$2,250,000.00
	RETAINING WALL	1000	SF	$60.00	$60,000.00
	SODDING	6000	SY	$5.00	$30,000.00
	MISC. GRADING	6000	SY	$4.00	$24,000.00
	REMOVE EXISTING CULVERTS	1	EA	$15,000.00	$15,000.00
	RESTORATION AND CLEANUP	1	LS	$5,000.00	$5,000.00
		SUBTOTAL			**$3,544,000.00**
		CONTINGENCY		**30%**	**$1,063,200**
		SUBTOTAL			**$4,607,200.00**
		MOBILIZATION		**5%**	**$230,360**
		SUBTOTAL			$4,838,000.00
		ENG,SUR,GEO		**8%**	**$387,040**
PROJECT TOTAL					**$5,225,000**

OPINION OF PROBABLE CONSTUCTION COST

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Town of Trophy Club-Storm Water Master Plan

Indian Creek Channel Improvements — **September 15, 2011**

ESTIMATOR	CHECKED BY	ACCOUNT NO
DCS		

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	STORM DRAIN IMPROVEMENTS				**$3,977,000.00**
	SITE PREPARATION	1	LS	$50,000.00	$50,000.00
	CONCRETE SEGMENTAL CHANNEL WALL	3000	LF	$600.00	$1,800,000.00
	ARTICULATED CONCRETE CHANNEL BOTTOM	3000	LF	$400.00	$1,200,000.00
	EXCAVATION	16000	CY	$10.00	$160,000.00
	4-7'X5' RCB CULVERT (GREEN LEAF)	40	LF	$3,000.00	$120,000.00
	4-7'X6' RCB CULVERT (INDIAN CREEK)	70	LF	$3,000.00	$210,000.00
	35' SPAN BRIDGE (TW KING)	1	EA	$175,000.00	$175,000.00
	HEADWALL (GREENLEAF)	2	EA	$3,500.00	$7,000.00
	HEADWALL (INDIAN CREEK)	2	EA	$3,500.00	$7,000.00
	6" REINFORCED CONCRETE PAVEMENT	1600	SY	$75.00	$120,000.00
	REMOVE EXISTING CULVERTS	3	EA	$5,000.00	$15,000.00
	REMOVE HEADWALLS	6	EA	$2,500.00	$15,000.00
	MISC. RETAINING WALL DEMO	1	LS	$15,000.00	$15,000.00
	SODDING	4000	SY	$5.00	$20,000.00
	MISC. GRADING	12000	SY	$4.00	$48,000.00
	RESTORATION AND CLEANUP	1	LS	$15,000.00	$15,000.00
		SUBTOTAL			**$3,977,000.00**
		CONTINGENCY		**30%**	**$1,193,100**
		SUBTOTAL			**$5,170,100.00**
		MOBILIZATION		**5%**	**$258,505**
		SUBTOTAL			$5,429,000.00
		ENG,SUR,GEO		**8%**	**$434,320**
PROJECT TOTAL					**$5,863,000**

OPINION OF PROBABLE CONSTUCTION COST

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

Town of Trophy Club-Storm Water Master Plan

Timber Ridge Drive- w/ Diversion — **September 15, 2011**

ESTIMATOR	CHECKED BY	ACCOUNT NO
DCS		

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	STORM DRAIN IMPROVEMENTS				**$162,775.00**
	SITE PREPARATION	1	EA	$5,000.00	$5,000.00
	30" RCP	300	LF	$75.00	$22,500.00
	36" RCP	500	LF	$90.00	$45,000.00
	10 CURB INLET	1	EA	$3,500.00	$3,500.00
	MANHOLE	6	EA	$4,000.00	$24,000.00
	30" HEADWALL	1	EA	$275.00	$275.00
	6" REINFORCED CONCRETE PAVEMENT	700	SY	$75.00	$52,500.00
	UTILITY ADJUSTMENT	1	LS	$5,000.00	$5,000.00
	RESTORATION AND CLEANUP	1	LS	$5,000.00	$5,000.00
		SUBTOTAL			**$162,775.00**
		CONTINGENCY		**30%**	**$48,833**
		SUBTOTAL			**$211,607.50**
		MOBILIZATION		**5%**	**$10,580**
		SUBTOTAL			$222,000.00
		ENG,SUR,GEO		**8%**	**$17,760**
PROJECT TOTAL					**$240,000**

OPINION OF PROBABLE CONSTUCTION COST

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

Town of Trophy Club-Storm Water Master Plan

Fresh Meadows Drive Storm Drain — **September 15, 2011**

ESTIMATOR	CHECKED BY	ACCOUNT NO
DCS		

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	STORM DRAIN IMPROVEMENTS				**$305,900.00**
	SITE PREPARATION	1	LS	$5,000.00	$5,000.00
	24" RCP	490	LF	$75.00	$36,750.00
	42" RCP	255	LF	$130.00	$33,150.00
	20' CURB INLET	8	EA	$5,000.00	$40,000.00
	5' MANHOLE	1	EA	$4,500.00	$4,500.00
	6" REINFORCED CONCRETE PAVEMENT	1300	SY	$75.00	$97,500.00
	CONCRETE DRIVEWAY REPAIR	550	SY	$60.00	$33,000.00
	UTILITY ADJUSTMENT	1	LS	$2,000.00	$2,000.00
	POND OUTFALL GRADING	4000	SY	$8.00	$32,000.00
	TURF REINFORCMENT	4000	SY	$5.00	$20,000.00
	RESTORATION AND CLEANUP	1	LS	$2,000.00	$2,000.00
		SUBTOTAL			**$305,900.00**
		CONTINGENCY		**30%**	**$91,770**
		SUBTOTAL			**$397,670.00**
		MOBILIZATION		**5%**	**$19,884**
		SUBTOTAL			$418,000.00
		ENG,SUR,GEO		**8%**	**$33,440**
PROJECT TOTAL					**$451,000**

OPINION OF PROBABLE CONSTUCTION COST

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

Town of Trophy Club-Storm Water Master Plan

Cypress Creek Channel Improvements — **September 15, 2011**

ESTIMATOR	CHECKED BY	ACCOUNT NO
DCS		

ITEM	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	STORM DRAIN IMPROVEMENTS				**$853,000.00**
	SITE PREPARATION	1	LS	$50,000.00	$50,000.00
	EXCAVATION	3000	CY	$10.00	$30,000.00
	SODDING	2000	SY	$5.00	$10,000.00
	MISC. GRADING	2000	SY	$4.00	$8,000.00
	GABION WALL	3000	CY	$250.00	$750,000.00
	RESTORATION AND CLEANUP	1	LS	$5,000.00	$5,000.00
		SUBTOTAL			**$853,000.00**
		CONTINGENCY		**30%**	**$255,900**
		SUBTOTAL			**$1,108,900.00**
		MOBILIZATION		**5%**	**$55,445**
		SUBTOTAL			$1,164,000.00
		ENG,SUR,GEO		**8%**	**$93,120**
PROJECT TOTAL					**$1,257,000**