***FINAL - HYDRAULIC DESIGN REPORT FOR***
***I-70 OVER SAND CREEK***

Project No. FBR 0704 220

***Prepared for:***

**David Evans and Associates, Inc.**
**and**
**CDOT Region 6**

March 2011

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# Table of Contents

# 1.0 INTRODUCTION

This report outlines the floodplain modeling, scour results, minor drainage requirements and proposed permanent stormwater quality facilities (PSQFs) for the I-70 over Sand Creek project. These improvements will help protect against scour at the bridge abutments for the 100-year event, safely convey runoff from the I-70 pavement to a stable outfall and provide water quality improvements to the improved roadway runoff prior to discharging into Sand Creek.

The project is located in the City and County of Denver, on I-70 between Quebec Street and I-270. Please see Figure 1 below for the project location.

Figure 1:
Project Location


# 2.0 EXISTING CONDITIONS

According to the CDOT plans, the I-70 Bridges at Sand Creek are approximately 330 feet long and 100 feet wide combined. The upstream low girder elevation is 5246.39 feet at 2/3rds across the structure. The bridge has five multi-column bent piers with web walls. The bridges are on grade and consist of three travel lanes in the westbound direction and four travel lanes in the eastbound direction.

# 3.0 PROPOSED CONDITIONS

The proposed bridge will be lengthened approximately to 345 feet and the width will be increased 164 feet to accommodate future widening of I-70.

Hydraulic criteria that were satisfied included:

- Safely convey the 100-year event under I-70 through the bridge and design riprap revetment to handle the corresponding velocity.
- Maintain proper freeboard.
- Safely convey runoff from the 100-year event from the I-70 pavement
- Obtain 100% water quality capture volume or 80% TSS removal for the entire project.

The existing and proposed bridge section can be located in the Appendix.

# 4.0 SITE VISIT

A site visit was performed on March 22, 2010. The purpose of this initial visit was to gather information on the existing drainage structure and site conditions, in particular the bridge. Please see the photos contained in the Appendix illustrate the existing conditions.

# 5.0 GENERAL HYDROLOGY

## 5.1 Sand Creek

The Sand Creek watershed tributary to the I-70 Bridge is approximately 175 square miles. The anticipated 100-year event is 30,000 cfs while the anticipated 500-year event is 33,000 cfs.

## 5.2 Roadway Runoff

Runoff from the improved I-70 roadway, ramps, and bridge was calculated based on a total of 6.84 acres of pavement being affected by this project. The peak flows were developed using the rational method with one hour rainfall data from the City and County of Denver Storm Drainage Design & Technical Criteria.

Supporting information for the hydrology is shown in the Appendix.

### *5.2.1 Bridge Drainage*

In order to size the bridge inlets, CDOT criteria was reviewed. The 5-year event needs to be captured before the expansion joint. A copy of the criteria is provided in the Appendix.

Double vane grate inlet (specials) are placed within the moment and approach slab of the bridge to intercept the 5-year event from running over the expansion joint per CDOT criteria. The spreadwidth was checked along the bridge for the 100-year event and no deck drains were required.

### *5.2.2 Roadway Inlet Interception*

In order to size the storm drains along the interstate CDOT criteria was reviewed. The allowable spread is the shoulder plus 4 feet. A copy of the criteria is provided in the Appendix.

The capacity of the shoulder plus 4 feet was calculated for the various longitudinal and cross slopes. Inlet interception curves were developed to determine interception rates and bypass. The roadway geometry (carrying capacity) and the inlet interception were used to determine the inlet type and spacing.

All inlets on the project consist of a double vane grate inlets or double vane grate inlet (specials) because all inlet locations have a spreadwidth of at least 9 feet. Double vane grate inlet (specials) were developed for the bridge to be able to fit within the approach slab and near the retaining wall.

A Type D inlet was originally placed in the median at the sump location near 88+00, however at CDOTs request the inlet was changed to a double vane grate in the sump and additional inlets were added on both the east and west sides to intercept runoff before reaching the low point. Still, the double vane grate within the sump may have a tendency to clog and should be monitored carefully to ensure its functionality during a major storm event.

Inlet interception calculations are provided in the Appendix.

### *5.2.3 Storm Sewer*

Storm sewer will be placed throughout the project. All pipe called out on the plans is reinforced concrete pipe (RCP) per CDOT criteria since there are only storm sewer systems (except for an existing RCP cross culvert to be extended 24.8') within this project. There are also soil sulfrate resistance concerns which require the use of RCP.

Peak flows were calculated within the storm sewer systems to assure that the pipe sizes shown would be adequate. The HGL calculations were performed using NeoUDSewer and are located in the Appendix.

The pipe slopes were designed to minimize sediment accumulation within the system. The minimum velocity within a pipe is 5 ft/s for the 2-year event. The only exceptions are the ditches above pipes E-42 and E-44, which have velocities approximately 1 fps during the 100-year event. As a result sediment will likely fall out in the shoulder / drainage ditch to the inlet before getting into the pipe and therefore be monitored for sediment accumulation.

### *5.2.4 Outlet Protection*

The riprap calculations are provided in the Appendix.

## 6.0 FLOODPLAIN INFORMATION

The only cross section which was changed from the effective model was sections 2618, and then sections 2449 and 2475 were removed to account for the wider bridge and replaced with cross section 2400. The effective model showed a 0.00% longitudinal channel profile that we revised to better reflect the actual slope of 0.1%. The existing and proposed cross section locations are included. Please see the floodplain section ion the appendix, Figure 1 illustrates the Effective and Pre-Project cross section locations and Figure 2 illustrates the Post-Project cross section locations with the new bridge and proposed grading.

There was also some minor grading that was accounted for underneath the bridge, which is labeled on the proposed cross sections and shown on a plan view of the bridge which is attached.

We adjusted the n values slightly on the proposed upstream cross section at the bridge (2618), to better reflect the existing and proposed conditions with a wider section of n = 0.035 than shown on the existing model. Also, in our estimation of n values on the new downstream section of the proposed bridge, we kept similar n values to the existing model, however we reduced the width of n = 0.022 to account for the reduced sand channel bottom near the downstream drop structure since we feel this is a more conservative approach. I have attached both the existing and proposed cross sections, with the n values highlighted, for your information / review.

The table below, Table 1, compares the Pre-Project, the Post-Project and the Effective Model WSELs. As you can see the Post-Project model is less than or equal to the Pre-Project model at all cross sections.

Table 1.
Floodplain Summary Model

| Location | Cross Section ID | Effective WSEL | Pre-Project WSEL | Post-Project WSEL | Difference Post-Pre |
|---|---|---|---|---|---|
| | 3302 | 5242.74 | 5242.67 | 5242.49 | -0.18 |
| | 3273 | 5242.73 | 5242.61 | 5242.41 | -0.2 |
| | 2857 | 5241.91 | 5241.85 | 5241.84 | -0.01 |
| | 2680 | 5241.42 | 5241.51 | 5241.20 | -0.31 |
| I-70 Pedestrian Bridge | 2665 | | | | - |
| | 2651 | 5240.30 | 5240.29 | 5239.47 | -0.82 |
| | 2618 | 5240.21 | 5240.22 | 5239.45 | -0.77 |
| I-70 Bridge | 2546 | | | | - |
| Cross section removed in Post-Project model | 2475 | 5238.37 | 5238.45 | | - |
| Cross section removed in Post-Project model | 2449 | 5237.82 | 5238.54 | | - |
| New Cross Section DS of Proposed Bridge | 2400 | | | 5236.40 | - |
| | 2358 | 5236.08 | 5235.60 | 5235.60 | 0 |
| | 2319 | 5234.66 | 5234.82 | 5234.82 | 0 |
| | 2102 | 5233.87 | 5233.91 | 5233.91 | 0 |
| | 2063 | 5233.89 | 5234.00 | 5234.00 | 0 |
| | 1884 | 5233.56 | 5233.56 | 5233.56 | 0 |

Figure 3 illustrates our floodplain delineation, in addition profiles have been added illustrating the effective, pre-project and post-project conditions. As the table above shows, the water surface elevations are very close between the effective and the pre and post-project conditions.

### 6.1 Freeboard

Freeboard was calculated according to CDOT criteria. A review of the upstream watershed found Sand Creek to be considered a low debris stream. Our review showed that there are several locations where any large debris would be "screened" prior to reaching the I-70 over Sand Creek Bridge. See Figure 2 next page. A detention pond

# SAND CREEK
# DEBRIS EVALUATION

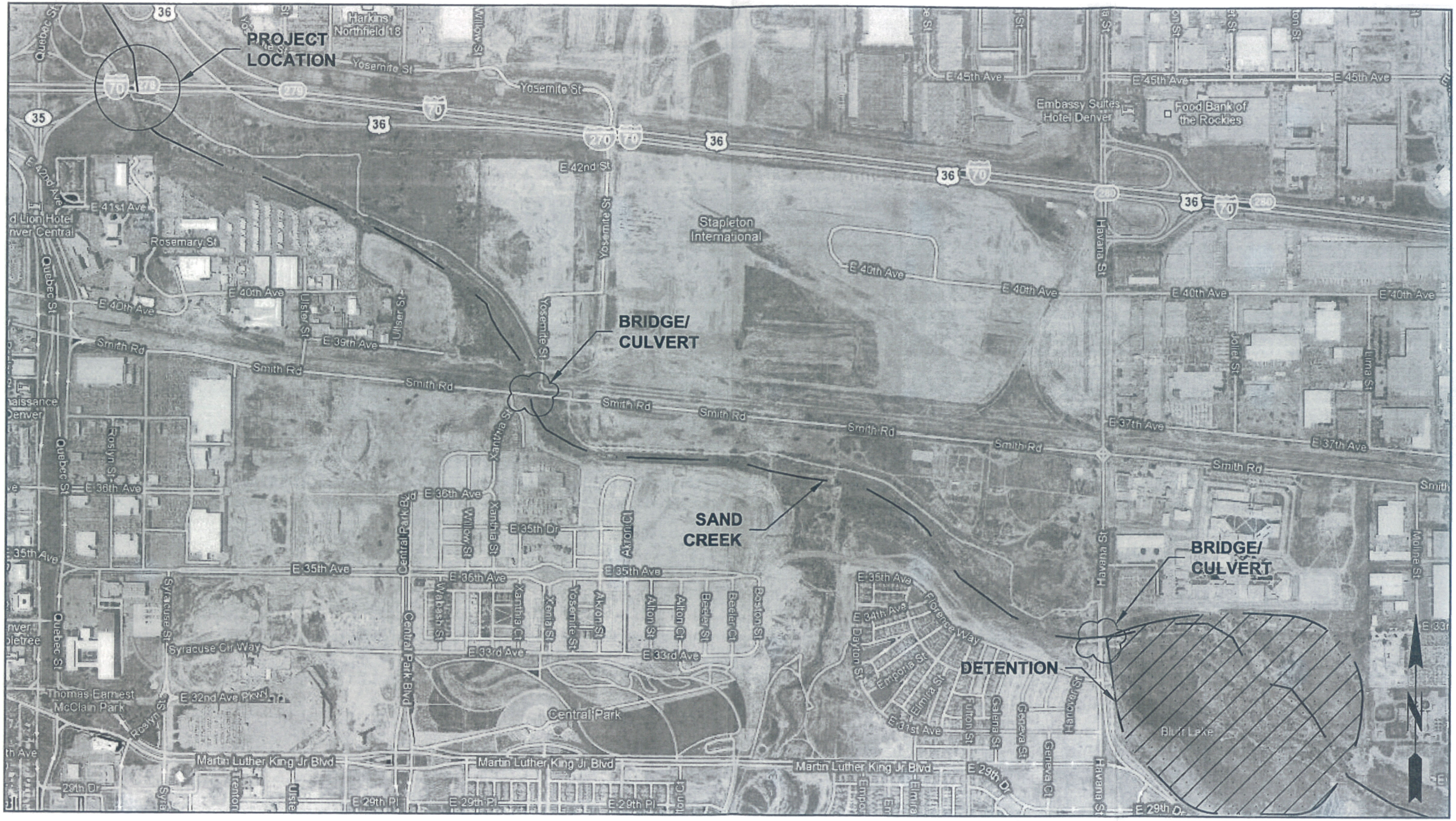



FIGURE 2

and multiple bridges upstream will filter any material and prevent most of the debris from heading downstream to the bridge for I-70. Section 2680 was used from the hydraulic model since it was sufficiently upstream of both the I-70 bridge and the pedestrian bridge and used the velocity through the bridge as outlined in CDOT criteria. The freeboard calculations and backup information are located in the Appendix.

### 6.2 Sand Creek

Required freeboard was calculated according to CDOT criteria using the 100-year peak flow and water surface elevation from the upstream cross section from HEC-RAS, Section 2680 and the velocity from within the bridge. The proposed bridge girder type is U-72 which allows a 1 foot reduction in the freeboard requirements for a "tapered" upstream girder per CDOT criteria, however the reduction was not included in the freeboard calculations in order to be conservative. For the proposed I-70 Bridge over Sand Creek, the freeboard required is 3.82 feet (neglecting girder shape) and the freeboard available is 3.95 feet. The actual upstream low cord elevation at 0.67W is 5245.15 feet.

See the Appendix for floodplain information, freeboard calculations and a description of the backwater calculations.

## 7.0 BRIDGE SCOUR ANALYSIS

Scour is the erosion of streambed or bank material due to flowing water. There are three types of scour which were calculated for Sand Creek at the I-70 bridge. Contraction scour results from the contraction of the flow area at the bridge, which causes an increase in velocity and shear stress on the stream bed at the bridge and is divided further into live bed and clear water scour. Local scour at piers and abutments results in the removal of material around the piers and abutments caused by an acceleration of flow and the resulting vortices induced by obstructions to the flow.

A scour analysis was performed and scour depths were calculated for both the 100-year and 500-year peak flows per CDOT criteria using HEC-RAS 4.0 which utilizes the equations from the latest edition of HEC-18. The 500-yr peak flow scour analysis was also run assuming the downstream drop structure failed. The scour input data and results for all three scenarios can be found in the Appendix.

Table 2 summarizes the findings regarding contraction, pier, and abutment scour at the I-70 bridge.

Table 2:
Scour Analysis Results

| Scour Type | Depth (ft) | |
|---|---|---|
| | 100-Year | 500-Year |
| Contraction | 1.5 | 7.2 |
| Pier | 6.0 | 11.0 |
| Left Abutment | 4.6 | 11.6 |
| Right Abutment | 27.3 | 30.3 |

With the results shown in Table 2 it is apparent that the bridge abutment scour occurs for the right abutment only. This is the anticipated result because the left abutment is aligned with the flow, due to construction of a guidebank when the bridge was first built, whereas the left abutment encroaches into the flow path.

Prior to the analysis it was determined if there was live bed (material transported) or if it was clear water (no material transport) scour. The velocity compared to the bed material shows that live bed scour is likely to occur.

The analysis showed that riprap bank protection along the abutments was sufficient since the velocities are relatively low (less than 14 fps) for the 100-year event. Since little field data on abutment scour exists, equations for predicting abutment scour are based entirely on laboratory data. As a result, the analysis calculated the scour depths from both the HIRE and the Froehlich equations and reported the more conservative results.

For the pier scour since there is anticipated little debris in the stream we left the pier widths at 2.5 feet and did not increase the width due to excess debris.

CDOT requested that we consider the scour potential if the drop structure immediately downstream of the bridge were to fail. As the output shows, the loss of the drop structure only lowers the channel invert, simulating contraction scour, by the drop height (roughly five feet) and does not increase the relative depths of scour.

The Appendix contains the results of the updated HEC-RAS model, showing the results for the 100-year and 500-year scour for contraction, pier and abutment.

## 8.0 WATER QUALITY

Permanent stormwater quality facilities (PSQFs) were evaluated and considered for feasibility of implementation for the entire project. The PSQFs will capture 100 percent of the project highway runoff and treat it with a water quality capture volume (WQCV) or by removal of 80% of the total suspended solids (TSS) as required by CDOTs MS4 permit.

The PSQFs consist of dry swales and ecology embankments. Since CDOT has numerous dry swales throughout the Denver region, they have found them to be maintenance intensive. The frequently plug up, fill with water and do not drain. For this project it was desired to not pond the water to be treated but perform the 80% TSS removal by allowing the runoff to infiltrate and be partially stored within the granular matrix below ground.

The dry swales will infiltrate the WQCV and the ecology embankments are intended to remove 80% of the TSS. At the dry swales there will not be ponding water above finished grade and will not store the WQCV above the invert of the dry swale. Each of the water quality features has a granular bedding material and underdrains even though the soils are classified as Hydrologic Soil Group A. The runoff will infiltrate through the granular bedding to the underdrain where it will pass through the Class 1 geotextile to the 4" perforated pipe underdrain. In addition to the significant infiltration of the granular material there will be some inadvertent storage within the voids of the Class A material. These improvements are intended to infiltrate the WQCV within the bed and remove 80% TSS.

Another water quality improvement feature is the ecology embankments. These are currently used in the State of Washington for TSS removal. A description from their criteria manual is included in the Appendix.

The I-70 Water Quality Figure Sheets 1-2 illustrate the locations of the PSQF's and the tributary treatment area to each, the impervious area and the required WQCV if necessary.

Table 3, summarizes the location, the type of permanent BMP, the drainage area, the % imperviousness, required capture volume and the actual capture volume.

Table 3:
PSQF Summary Table

| ID | Station | Type | Drainage Area (acres) | % Imperviousness | WQCV |
|---|---|---|---|---|---|
| EE-1 | 74+26.29 | Ecology Embankment 1 | 0.33 | 100 | N/A |
| EE-2 | 75+36.78 | Ecology Embankment 2 | 0.51 | 100 | N/A |
| EE-3 | 82+64.03 | Ecology Embankment 3 | 0.34 | 100 | N/A |
| EE-4 | 83+25.02 | Ecology Embankment 4 | 1.42 | 100 | N/A |
| DS-1 | 74+65.21 | Dry Swale 1 | 1.46 | 100 | 0.06 |
| DS-2 | 75+26.63 | Dry Swale 2 | 0.47 | 100 | 0.02 |
| DS-3 | 86+27.22 | Dry Swale 3 | 2.33 | 100 | 0.10 |

Maintenance of the PSQFs is expected to occur on an "as-needed" basis and shall be inspected once a year per the MS4 requirement. All of the facilities have a maintenance road for access to ease sediment removal. CDOT will handle all maintenance.

## 9.0 CONCLUSION

This report presents the supporting information for the final scour, floodplain evaluation, minor drainage and water quality assessment for the proposed improvements for I-70 Bridge over Sand Creek.

Included are the final results from the HEC-RAS modeling for the proposed bridge over Sand Creek for the scour analysis and to evaluate the effects on the floodplain.

Based on the scour calculations, the extents and size of riprap revetment for the scour countermeasure is shown on the bridge hydraulic information sheets.

In addition drainage infrastructure has been designed to safely convey runoff from the highway to a permanent stormwater quality facility.

These proposed improvements will be further refined based on comments received at the FIR.

# Appendix

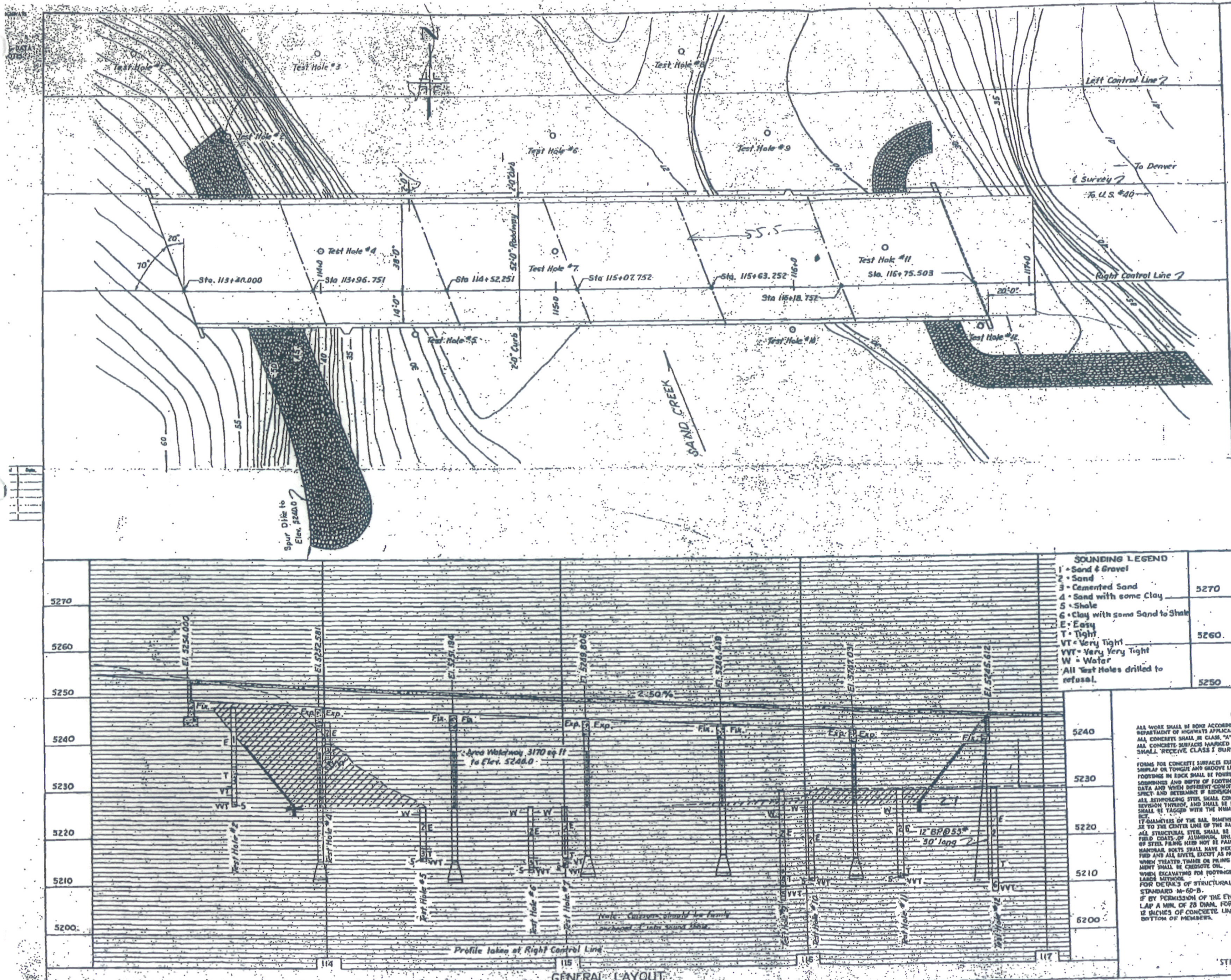
# Bridge Information

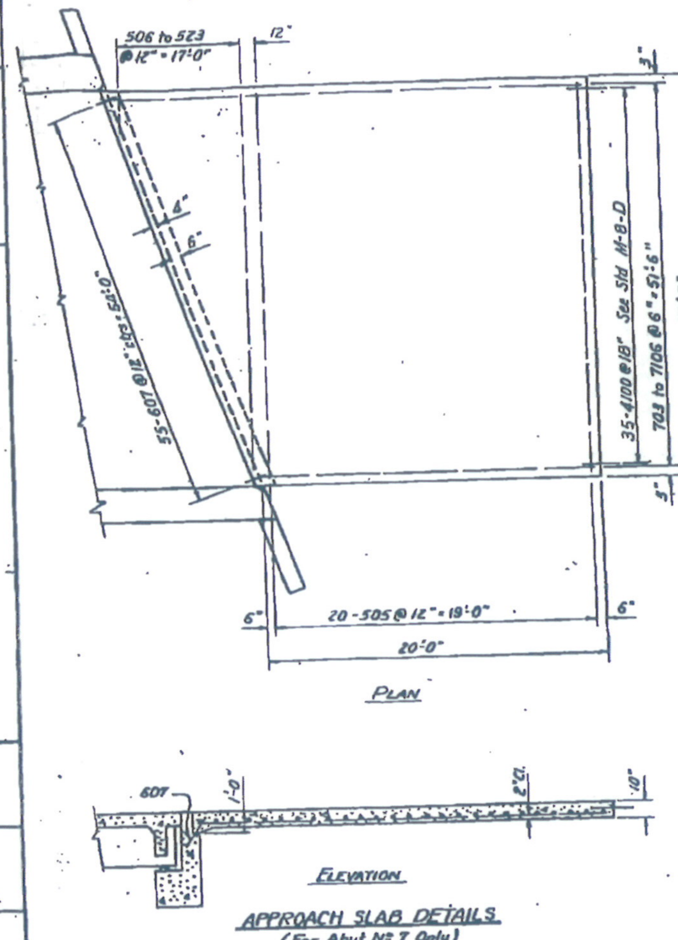
335'

| FED. ROAD REG. NO. | DIVISION | PROJECT NO. | SHEET NO. | TOTAL SHEETS |
|---|---|---|---|---|
| 8 | COLO. | I-70-4(12)288 | 21 | |

6-6-60 = Rev. Appr. Slab. P.C.

EB




APPROACH SLAB DETAILS
(For Abut Nº 7 Only)

## GENERAL NOTES

ALL WORK SHALL BE DONE ACCORDING TO THE STANDARD SPECIFICATIONS OF THE COLORADO DEPARTMENT OF HIGHWAYS APPLICABLE TO THE PROJECT.

ALL CONCRETE SHALL BE CLASS "A" AND AIR ENTRAINED AS SPECIFIED.

ALL CONCRETE SURFACES MARKED WITH THE SYMBOL "F" AS SHOWN ON SHEET No. 22 SHALL RECEIVE CLASS I SURFACE FINISH.

FORMS FOR CONCRETE SURFACES EXPOSED IN THE FINISHED WORK SHALL BE CONSTRUCTED OF SHIPLAP OR TONGUE AND GROOVE LUMBER S 2 S UNLESS FACED WITH PANEL BOARD.

FOOTINGS IN ROCK SHALL BE POURED OUT TO ROCK AND NOT FORMED.

SOUNDINGS AND DEPTH OF FOOTING SHOWN ARE IN ACCORDANCE WITH THE BEST AVAILABLE DATA AND WHEN DIFFERENT CONDITIONS ARE ENCOUNTERED THE BRIDGE ENGINEER WILL INSPECT AND DETERMINE IF REDESIGN IS NECESSARY.

ALL REINFORCING STEEL SHALL CONFORM TO ASTM SPECIFICATION A 305-56T OR THE LATEST REVISION THEREOF, AND SHALL BE INTERMEDIATE GRADE STEEL OF A DEFORMED TYPE. EACH BAR SHALL BE TAGGED WITH THE NUMBER DESIGNATION AND THE STATION NUMBER OF THE PROJECT. SECONDARY BARS WHEN SPLICED SHALL LAP 17 DIAMETERS OF THE BAR. DIMENSIONS FOR REINFORCING STEEL NOT SHOWN AS CLEAR SHALL BE TO THE CENTER LINE OF THE BAR.

ALL STRUCTURAL STEEL SHALL BE PAINTED ONE SHOP COAT OF ZINC CHROMATE AND TWO FIELD COATS OF ALUMINUM, UNLESS OTHERWISE NOTED, EXCEPT THE UNEXPOSED PORTION OF STEEL PILING NEED NOT BE PAINTED.

HANDRAIL BOLTS SHALL HAVE HEX HEADS, NUTS, AND LOCK WASHERS UNLESS OTHERWISE SPECIFIED AND ALL RIVETS, EXCEPT AS NOTED ARE ¾" DIA, AND SHALL BE POWER DRIVEN.

WHEN TREATED TIMBER OR PILING IS SHOWN ON THE DRAWING THE PRESERVATIVE FOR TREATMENT SHALL BE CREOSOTE OIL.

WHEN EXCAVATING FOR FOOTINGS THE FINAL ONE FOOT IN DEPTH SHALL BE DONE BY HAND LABOR METHODS.

FOR DETAILS OF STRUCTURAL EXCAVATION AND STRUCTURAL BACKFILL, SEE STANDARD M-60-B.

IF BY PERMISSION OF THE ENGINEER PRIMARY BARS ARE SPLICED, THEY SHALL LAP A MIN. OF 28 DIAM. FOR BARS NEAR TOP OF BEAMS HAVING MORE THAN 12 INCHES OF CONCRETE UNDER THE BARS, AND 17 DIAM. FOR BARS NEAR BOTTOM OF MEMBERS.

STRUCTURE NO. E-17-BY

LOADING DATA 'Interstate Alternate

LIVE LOAD — A.A.S.H.O. (H20-S16-44)

DEAD LOAD ASSUMES 15 LBS. PER SQ. FT. ADDITIONAL WEARING SURFACE WHICH INCLUDES THE ½ INCH CONCRETE MONOLITHIC WEARING SURFACE SHOWN.

DESIGNING DATA

A.A.S.H.O. 1953 UNIT STRESSES, EXCEPT AS NOTED.

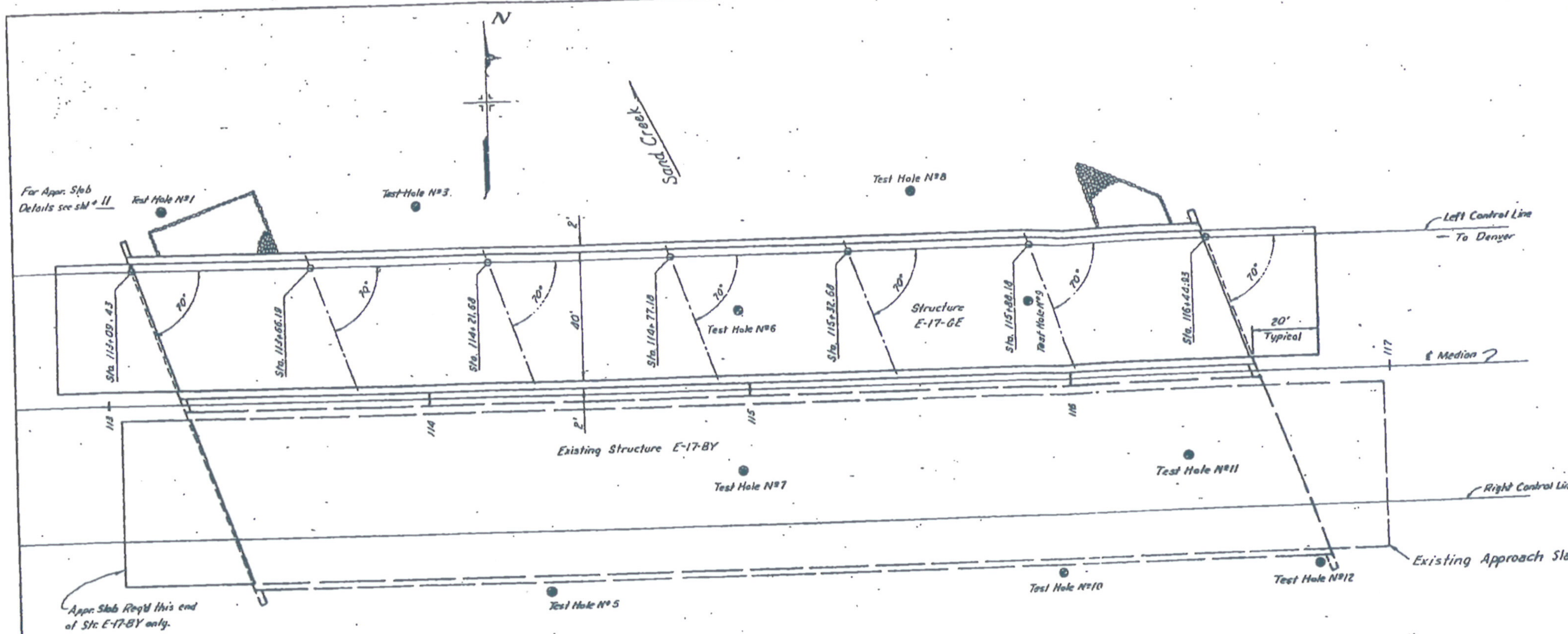
Reinforcing Steel $f_s$ = 20000 lbs. per sq. in.
Structural Steel $f_s$ = 18000 lbs. per sq. in.
$f_c$ = 1200 lbs. per sq. in.
$n$ = 10

COLORADO
DEPARTMENT OF HIGHWAYS
6 SPANS @ 54'-0" CONC. SLAB & GIRDER BRIDGE
52' RDWY 2' CURB 70° SKEW
General Layout, General Notes & Loading Data
Across Sand Creek
Sta. 113+40.000 to 116+75.503
Near Denver Sec. 21 T. 3S R. 67W

| | |
|---|---|
| Designed by WWD | Approved by [signature] |
| Made by JRJ | Bridge Engineer |
| Checked by | Date: March 17, 1960 |

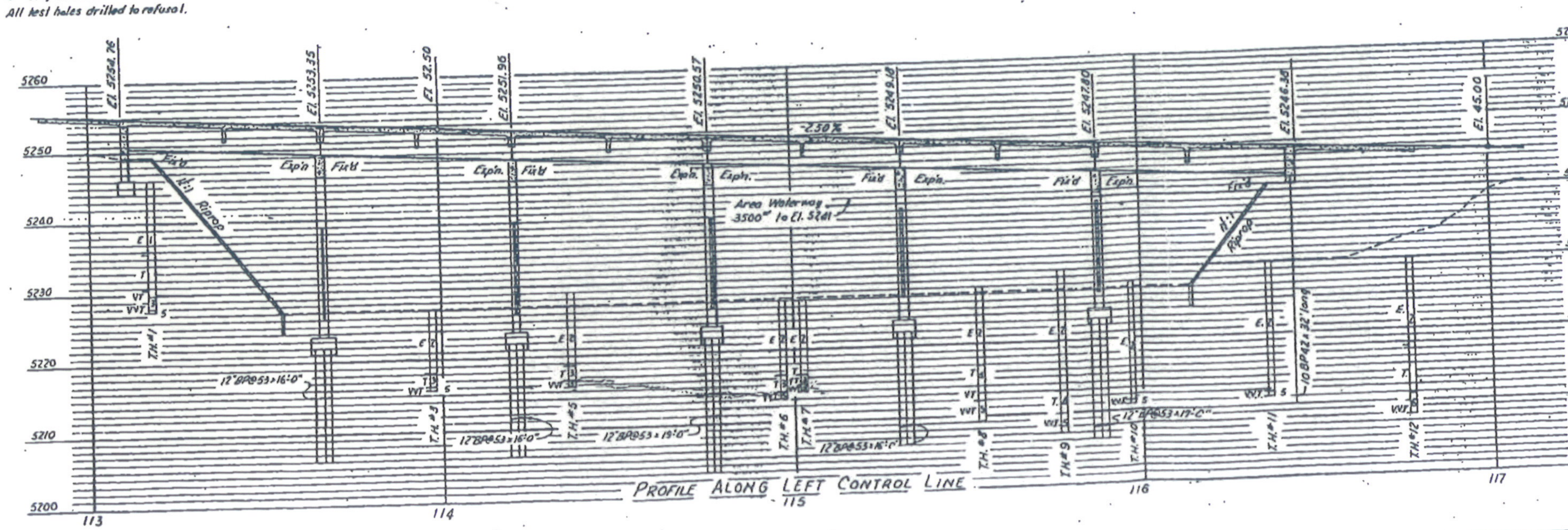
| FED. ROAD REG. NO. | DIVISION | PROJECT NO. | SHEET NO. | TOTAL SHEETS |
|---|---|---|---|---|
| 9 | COLO. | I 70-4(33)288 | 97 | |

REVISIONS



**SOUNDING LEGEND**

1 = Sand & Gravel — E. = Easy
2 = Sand — T. = Tight
3 = Cemented Sand — VT. = Very Tight
4 = Sand with some Clay — VVT. = Very Very Tight
5 = Shale
6 = Clay with some Sand to Shale
All test holes drilled to refusal.



PROFILE ALONG LEFT CONTROL LINE

## SUMMARY OF QUANTITIES

| Item | Description | Unit | Super-structure | Abut. No. 1 | Pier No. 2 | Pier No. 3 | Pier No. 4 | Pier No. 5 | Pier No. 6 | Abut. No. 7 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Unclassified Structural Excavation (Bridge) | Cu.Yd. | | | 60 | 60 | 62 | 67 | 48 | 10 | 365 |
| 16 | Structure Backfill (Class X) | Cu.Yd. | | | 42 | 42 | 44 | 50 | 27 | 5 | 250 |
| | | | | | | | | | | | |
| 46 | Class A Concrete | Cu.Yd. | 721.0 | | 53.5 | 52.8 | 52.0 | 31.3 | 50.0 | 19.7 | 1,032 |
| 47 | Reinforcing Steel (Incl. 1% ± for Overrun) | Lb. | 202,449 | 3,230 | 10,195 | 10,200 | 9,950 | 9,675 | 9,220 | 1,410 | 256,665 |
| 48 • | Structural Steel (Incl. ½% ± for Paint) | Lb. | 33,230 | 325 | 610 | 610 | 610 | 610 | 610 | 325 | 36,930 |
| 61 | Steel Piling (10" BP@42#) | Lin.Ft. | | | | | | | | 288 | 288 |
| 61 | Steel Piling (12" BP@53#) | Lin.Ft. | | | 288 | 288 | 342 | 288 | 306 | | 1,512 |
| 67 ⊕ | Riprap (1'-6" Thick) | Cu.Yd. | | 120 | | | | | | 105 | 225 |
| | | | | | | | | | | | |
| 80 | Sheet Copper (32 ounce) | Lb. | 40 | | | | | | | | 40 |
| 89 | Drain Pipe (4" ø x 2'-0") Concrete Floor | Ea. | 12 | | | | | | | | 12 |
| 90 | 1½" Electrical Conduit with Junction Boxes | Lin.Ft. | 385 | | | | | | | | 385 |
| * | 1" Exp'n Jt. Mat'l (Type I)(AASHO M-153-54) | Sq.Ft. | 180 | | | | | | | | 180 |

* To be incl. in Bid Price of Item 46.
• Includes 22,005 Lbs of Handrail.
⊕ Note: Approximately 20 Cu.Yd. available from N.E. Corner of Structure E-17-BY.

**ⓐ Quantities for One Approach Slab – Str. E-17-BY (One Req'd)**

| Item | Description | Unit | Totals |
|---|---|---|---|
| 37 | Concrete Paving (10" Thick) | Sq.Yd. | 170 |
| 47 | Reinforcing Steel (Incl. 1% ± for Overrun) | Lb. | 7,905 |

**ⓐ Quantities for One Approach Slab – Str. E-17-GE (2 Req'd)**

| Item | Description | Unit | Total |
|---|---|---|---|
| 37 | Concrete Paving (10" Thick) | Sq.Yd. | 121 |
| 47 | Reinforcing Steel (Incl. 1% ± for Overrun) | Lb. | 3,610 |
| | 1" Exp'n Joint Mat'l. (Type I)(AASHO M-153-54) | Sq.Ft. | 35 |

ⓐ Not incl. in Summary of Bridge Quantities. To be included with Roadway Quantities.

## GENERAL NOTES

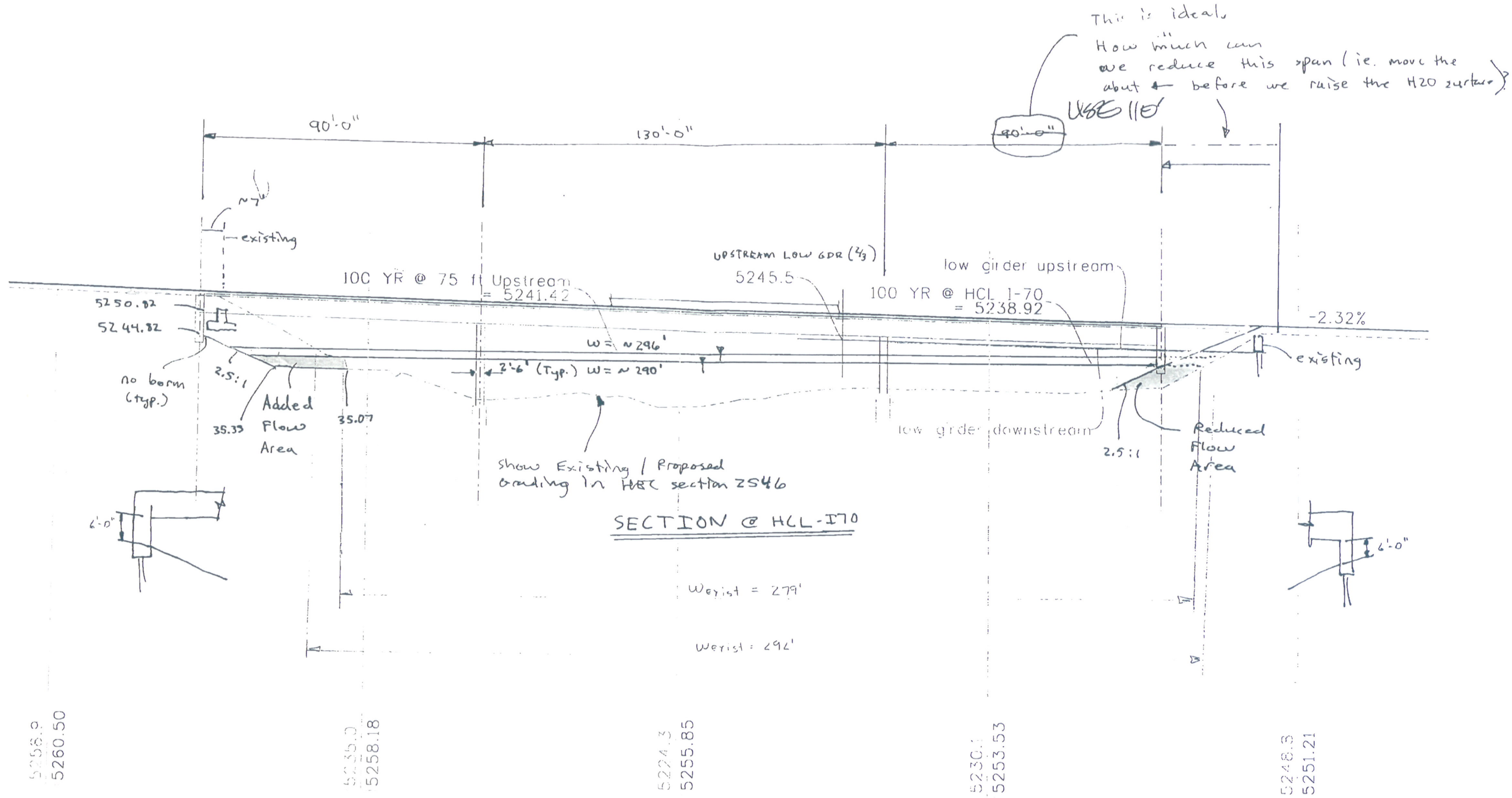
ALL WORK SHALL BE DONE ACCORDING TO THE STANDARD SPECIFICATIONS OF THE COLORADO DEPARTMENT OF HIGHWAYS APPLICABLE TO THE PROJECT.
ALL CONCRETE SHALL BE CLASS "A".
ALL REINFORCING STEEL SHALL BE INTERMEDIATE GRADE STEEL OF A DEFORMED TYPE. EACH BAR SHALL BE TAGGED WITH THE BAR DESIGNATION AND STATION NUMBER OF THE PROJECT.
IF BY PERMISSION OF THE ENGINEER PRIMARY BARS ARE SPLICED, THEY SHALL LAP A MINIMUM OF 22 DIAMETERS FOR BARS NEAR TOPS OF BEAMS HAVING MORE THAN 12 INCHES OF CONCRETE UNDER THE BARS, AND 17 DIAMETERS FOR BARS NEAR BOTTOM OF MEMBERS. SECONDARY BARS WHEN SPLICED SHALL LAP 17 DIAMETERS OF THE BAR.
DIMENSIONS FOR REINFORCING STEEL NOT SHOWN AS CLEAR SHALL BE TO THE CENTERLINE OF THE BAR.
SOUNDINGS AND DEPTH OF FOOTINGS ARE IN ACCORDANCE WITH THE BEST AVAILABLE DATA. AND WHEN DIFFERENT CONDITIONS ARE ENCOUNTERED THE BRIDGE ENGINEER WILL INSPECT AND DETERMINE IF REDESIGN IS NECESSARY.
FOOTINGS IN ROCK SHALL BE POURED OUT TO ROCK AND NOT FORMED.
WHEN EXCAVATING FOR FOOTINGS THE FINAL ONE FOOT IN DEPTH SHALL BE DONE BY HAND LABOR METHODS.
FOR DETAILS OF STRUCTURAL EXCAVATION AND STRUCTURE BACKFILL, SEE STANDARD M-16-A
ALL CONCRETE SURFACES MARKED WITH THE SYMBOL / AS SHOWN ON SHEET NO. 92 SHALL RECEIVE CLASS "1" SURFACE FINISH.
ALL STRUCTURAL STEEL SHALL BE PAINTED WITH ONE SHOP COAT OF ZINC CHROMATE AND TWO FIELD COATS OF ALUMINUM PAINT UNLESS OTHERWISE NOTED.
ALL RIVETS SHALL BE ¾ INCH DIAMETER UNLESS OTHERWISE NOTED.
HIGH TENSILE BOLTS MAY BE SUBSTITUTED FOR FIELD RIVETS AT THE CONTRACTORS OPTION. BOLTS SHALL BE FURNISHED IN THE AMOUNT OF FIVE PERCENT IN EXCESS OF THE NOMINAL NUMBER REQUIRED FOR EACH SIZE AND LENGTH.
WELDING SHALL CONFORM TO THE LATEST EDITION OF THE A.W.S. STANDARD SPECIFICATIONS FOR WELDING HIGHWAY BRIDGES.
FOR WELDED GIRDERS ALL SHOP BUTT WELDS IN FLANGES AND WEBS SHALL BE MADE BEFORE WELDING INTO GIRDER.
WHEN CALLED FOR IN THE SPECIAL PROVISIONS, SHOP WELDS SHALL BE INSPECTED RADIOGRAPHICALLY AND BY THE PENETRANT DYE METHOD.
WHEN TREATED TIMBER PILING IS SHOWN ON THE PLANS, THE PRESERVATIVE FOR TREATMENT SHALL BE CREOSOTE OIL.
ALL STRUCTURAL STEEL NOT OTHERWISE NOTED SHALL BE ASTM A36-62T

**LOADING DATA.** *(Interstate Alternate)*
LIVE LOAD A. A. S. H. O. H20 S16-44
DEAD LOAD—ASSUMES 15 LBS. PER SQ. FT. ADDITIONAL WEARING SURFACE WHICH INCLUDES THE ½ INCH CONCRETE MONOLITHIC WEARING SURFACE SHOWN.

**DESIGNING DATA.**
A. A. S. H. O. — UNIT STRESSES.
$f_c$ = 1,200 Lbs. per Sq. In.
$f_s$ = 20,000 Lbs. per Sq. In. (Reinf. & A36 Struct.)
n = 10.
$f_s$ = 18,000 Lbs. per Sq. In. (A7 Struct.)

STRUCTURE NO. E-17-GE (W. bound)

**COLORADO DEPARTMENT OF HIGHWAYS**
6 SPAN CONC. SLAB & GIRDER BRIDGE
40' RDWY – 2' CURBS – 70° SKEW
Summary of Quantities, General Layout, and General Notes
Across: SAND CREEK
Sta: 113+09.427 to 116+44.930
Near: Denver — Sec. 21 T. 33 R. 67W
Designed by WWD — Made by B.D.E. — Checked by RRA/MEP
Approved by [signature] Bridge Engineer — Date: June 17, 1963




\ Sand Creek \ Bridge\Reference_Files\ 17537BRDG_Prof.dgn

# Photos

**Site Photos**
**I-70 Over Sand Creek**

I-70 looking west from I-270 flyover.

I-70 Bridge and Pedestrian Bridge, looking north.

I-70 Bridge looking south from Quebec St. Pedestrian Bridge

I-70 Bridge Scour

# Hydrology

I-70 Over Sand Creek

**Runoff and Peak Flow Calculations**
**Developed Condition**
(Rational Method Procedure)

Calculated by LDR
5/22/2010

| Basin ID | Tc | A, acre | $C_{100}$ | $I_{100}$, in/hr | $I_{wq}$, in/hr | $Q_{100}$, cfs | $Q_{wq}$, cfs |
|---|---|---|---|---|---|---|---|
| 1 | 5.0 | 0.34 | 0.96 | 8.72 | 1.70 | 2.9 | 0.6 |
| 2 | 5.0 | 0.35 | 0.96 | 8.72 | 1.70 | 2.9 | 0.6 |
| 3 | 5.0 | 0.29 | 0.96 | 8.72 | 1.70 | 2.4 | 0.5 |
| 4 | 5.0 | 0.47 | 0.96 | 8.72 | 1.70 | 3.9 | 0.8 |
| 5 | 5.0 | 0.33 | 0.96 | 8.72 | 1.70 | 2.7 | 0.5 |
| 6 | 5.0 | 0.27 | 0.96 | 8.72 | 1.70 | 2.2 | 0.4 |
| 7 | 5.0 | 0.48 | 0.96 | 8.72 | 1.70 | 4.0 | 0.8 |
| 8 | 5.0 | 0.24 | 0.96 | 8.72 | 1.70 | 2.0 | 0.4 |
| 9 | 5.0 | 0.68 | 0.96 | 8.72 | 1.70 | 5.7 | 1.1 |
| 10 | 5.0 | 0.56 | 0.96 | 8.72 | 1.70 | 4.7 | 0.9 |
| 11 | 5.0 | 0.34 | 0.96 | 8.72 | 1.70 | 2.8 | 0.5 |
| 12 | 5.0 | 0.48 | 0.96 | 8.72 | 1.70 | 4.0 | 0.8 |
| 13 | 5.0 | 0.78 | 0.96 | 8.72 | 1.70 | 6.5 | 1.3 |
| 14 | 8.8 | 0.62 | 0.96 | 7.30 | 1.42 | 4.3 | 0.8 |
| 15 | 5.0 | 0.64 | 0.96 | 8.72 | 1.70 | 5.4 | 1.0 |

Intensity = (28.5*P)/(10+Tc)^0.786

| Return Period | One-hour Rainfall (inches) |
|---|---|
| 2-year | 0.95 |
| 5-year | 1.34 |
| 10-year | 1.55 |
| 50-year | 2.25 |
| 100-year | 2.57 |
| Water Quality | 0.5 |

# 5.0 RAINFALL

## 5.1 Introduction

The design rainfall data to be used to complete hydrologic analyses described in the RUNOFF chapter of these DENVER CRITERIA are presented in this section. More specifically, this chapter provides: 1) point precipitation values for Denver, 2) information on the Colorado Urban Hydrograph Procedure (CUHP), and 3) an intensity-duration-frequency table for use with the Rational Method. All hydrological analyses within Denver shall use the rainfall data presented herein for calculating storm runoff. There may be cases where the designer needs to consider events more extreme than the 100-year storm (e.g., for public safety).

The design storms and intensity-frequency-duration tables for Denver were developed using the rainfall data and procedures presented in the DISTRICT MANUAL and are presented herein for convenience.

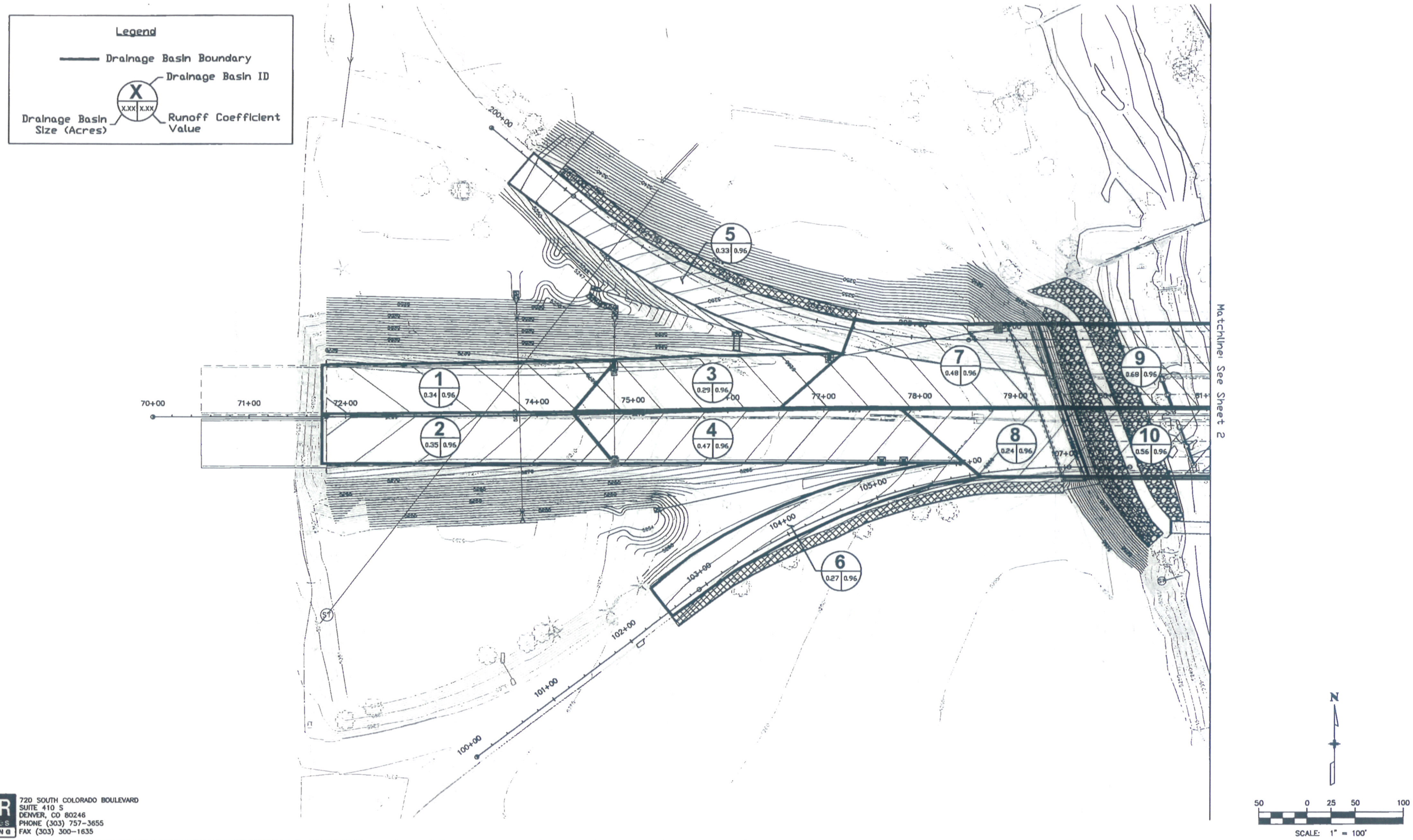
## 5.2 Rainfall Depth-Duration-Frequency Values

A review of the isopluvial maps presented in the *Precipitation-Frequency Atlas of the Western United States, Volume III-Colorado* (National Oceanic and Atmospheric Administration [NOAA] Atlas) shows that all of Denver can be included in one rainfall zone. The precipitation values for various return periods and duration storms were found to have minimal variation.

The 1-hour point rainfall is necessary for use with both the Rational Method and CUHP and is also the basis for deriving durations less than one hour. For watersheds greater than 10 square miles, the 3-hour rainfall depth is required, and for watersheds 20 square miles and larger, the 6-hour rainfall depth is required for use with CUHP. One-hour point rainfall values are summarized in Table 5.1. To obtain durations less than 1 hour, the factors in Table 5.2 are applied to the 1-hour point rainfall.

**Table 5.1. One-hour Point Rainfall Depths**

| Return Period | One-hour Point Rainfall (inches) |
|---|---|
| 2-Year | 0.95 |
| 5-Year | 1.34 |
| 10-Year | 1.55 |
| 50-Year | 2.25 |
| 100-Year | 2.57 |
| Date: July, 1992<br>Revised: | Reference: Wastewater Management Division, 1987, as determined based on NOAA Atlas 2, Volume IIII. |




NAME: Z:\Region 6\FASTER Bridges\I-70 over Sand Creek\CAD_I-70 at Sand Creek\DWG\FOR Drainage Plan\X - I-70 Drainage Basins.dwg
PLOT DATE: Aug 17, 2010 3:29pm


MOSER & associates ENGINEERING
720 SOUTH COLORADO BOULEVARD
SUITE 410 S
DENVER, CO 80246
PHONE (303) 757-3655
FAX (303) 300-1635


Print Date: 8/20/2010
File Name: DRAINAGE BASINS
Horiz. Scale: 1"=100' Vert. Scale: N/A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Denver Colorado 80202
Phone: 720.946.0969


| Sheet Revisions | | |
|---|---|---|
| Date: | Comments | Init. |
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Region 6 DJH

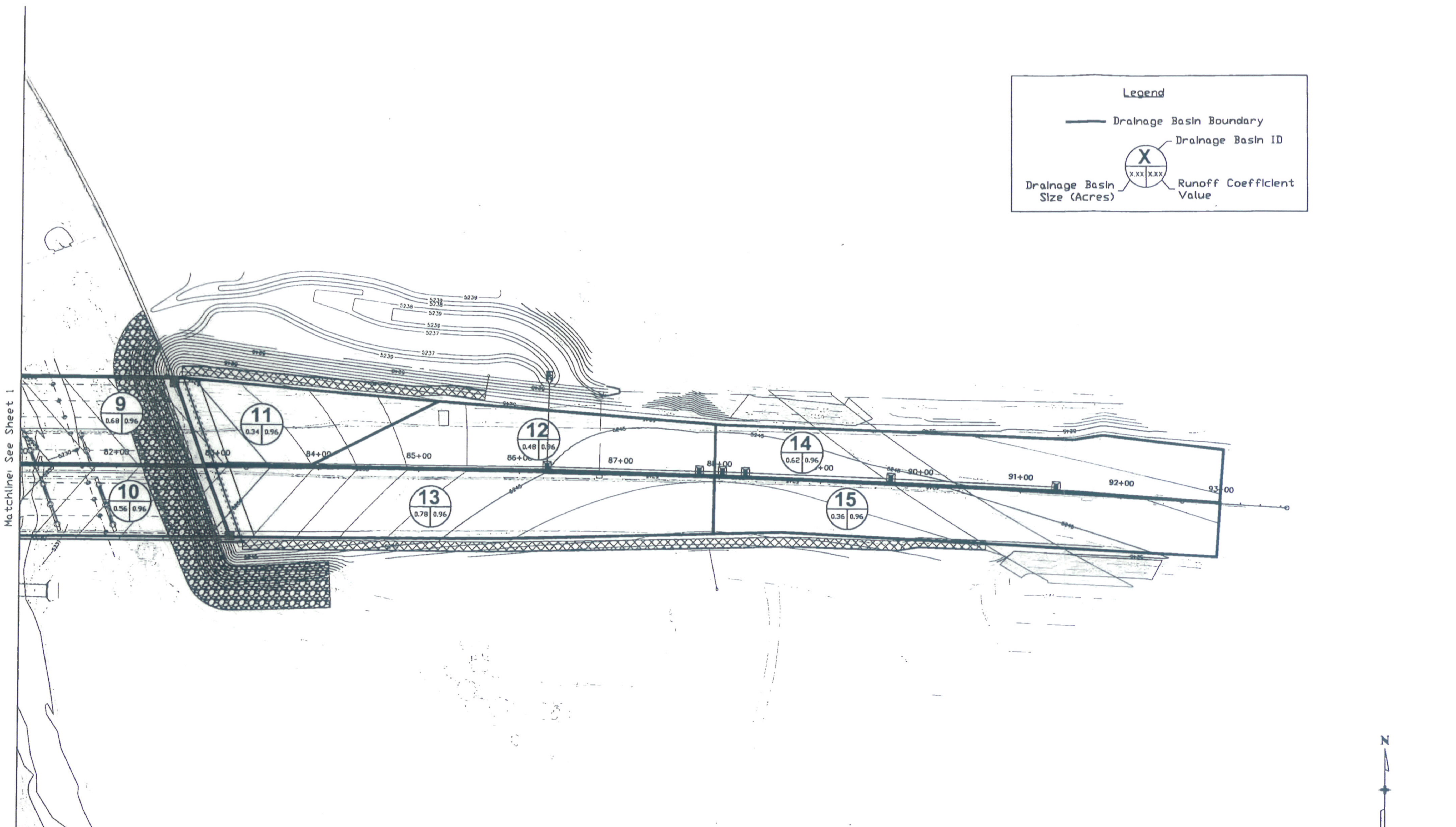

As Constructed
No Revisions:
Revised:
Void:

# I-70 DRAINAGE BASIN FIGURE

| | | | |
|---|---|---|---|
| Designer: | LDR | Structure Numbers | E-17-AER |
| Detailer: | RWM | | |
| Sheet Subset: | DRAINAGE | Subset Sheets: | 1 of 2 |

Project No./Code
C 0704-220
17537
Sheet Number 1

NAME: Z:\Region 6\FASTER Bridges\I-70 over Sand Creek\CAD_I-70 at Sand Creek\DWG\FOR Drainage Plan\X - I-70 Drainage Basins.dwg
PLOT DATE: Aug 09, 2010 11:59am




50 0 25 50 100
SCALE: 1" = 100'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| File Name: DRAINAGE BASINS | Date: | Comments | Init. | |
| Horiz. Scale: 1"=100' Vert. Scale: N/A | | | | |


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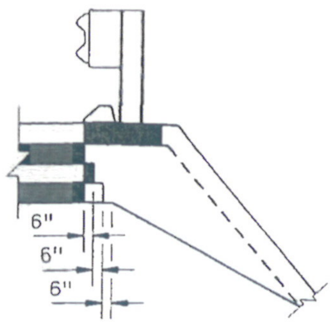
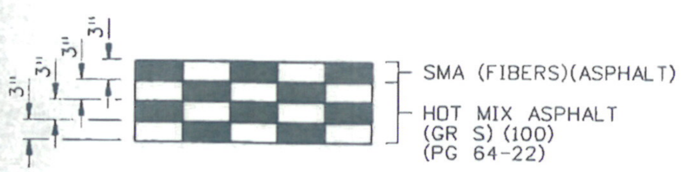
| As Constructed | I-70 DRAINAGE BASIN FIGURE | | | Project No./Code |
|---|---|---|---|---|
| No Revisions: | | | | C 0704-220 |
| Revised: | Designer: LDR | Structure Numbers | E-17-AER | 17537 |
| | Detailer: RWM | | | |
| Void: | Sheet Subset: DRAINAGE | Subset Sheets: 2 of 2 | | Sheet Number 2 |

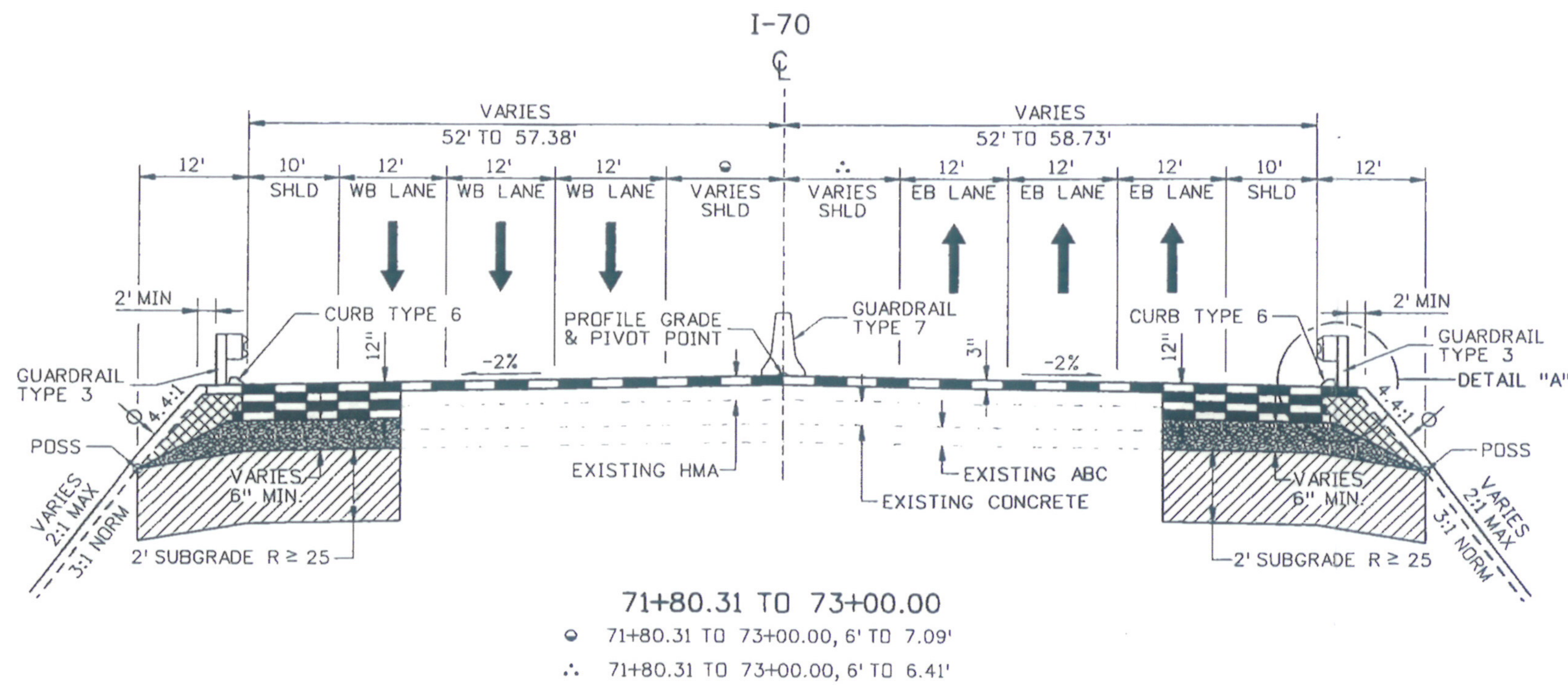
Know what's below.
Call before you dig.




DETAIL "A" TYPICAL




HOT MIX ASPHALT




71+80.31 TO 73+00.00

⊖ 71+80.31 TO 73+00.00, 6' TO 7.09'

∴ 71+80.31 TO 73+00.00, 6' TO 6.41'

## NOTES AND LEGEND

TYPICAL SECTIONS ARE REPRESENTATIVE ONLY.
PLAN SHEETS ARE TO BE USED FOR CONSTRUCTION.

ϕ = MINIMUM 4" TOPSOIL

= HOT MIX ASPHALT

= AGGREGATE BASE COURSE (CLASS 6)

= SUBGRADE R ≥ 25

= EMBANKMENT MATERIAL

dmma 7:15:41 AM C:\Work\ProjectWise\dmma\FASTER Bridges\dms00583\17537DES_TyplSec01.dgn

Print Date: 8/16/2010
File Name: 17537DES_TyplSect01.dgn
Horiz. Scale: 1:20 Vert. Scale: As Noted

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| Revised: |
| Void: |

I-70
TYPICAL SECTIONS

| | | | |
|---|---|---|---|
| Designer: | M. GRANT | Structure Numbers | |
| Detailer: | D. MADDOCK | | |
| Sheet Subset: TYPICALS | | Subset Sheets: | 1 of 18 |

| Project No./Code |
|---|
| FBR 0704-220 |
| 17537 |
| Sheet Number 13 |

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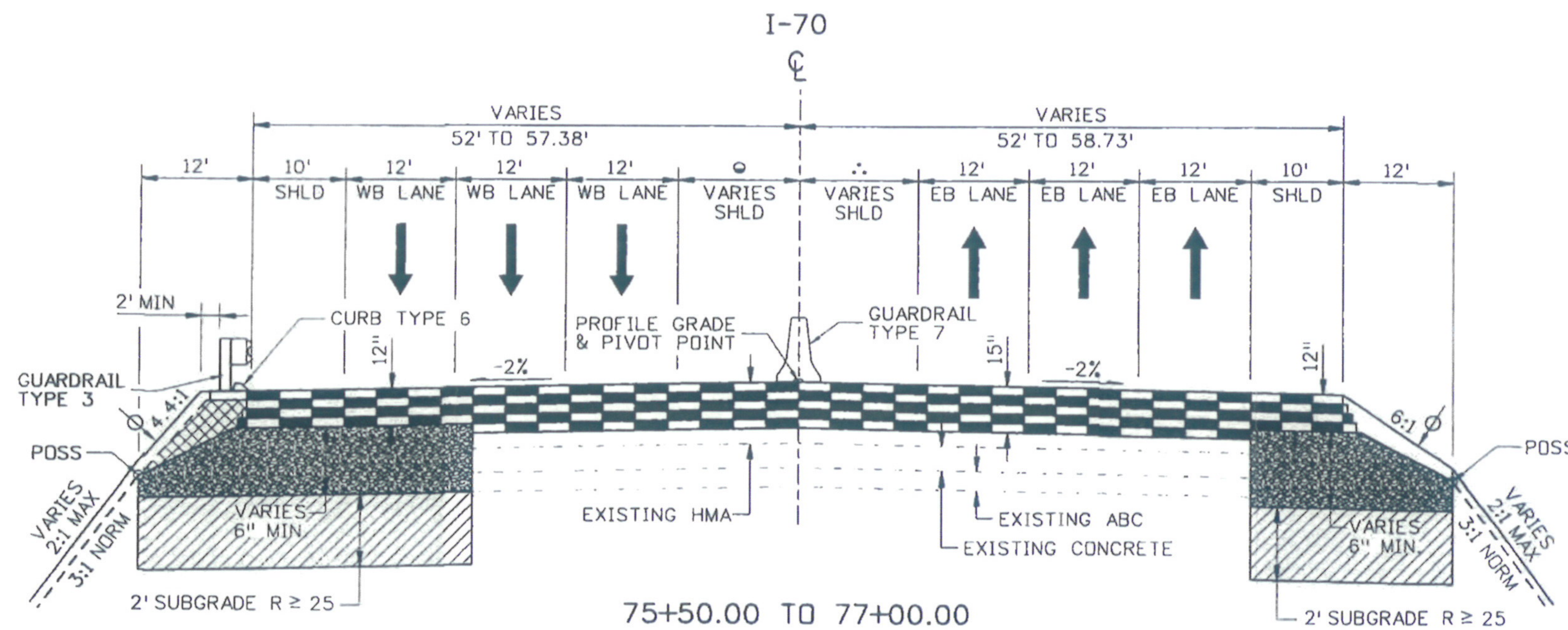
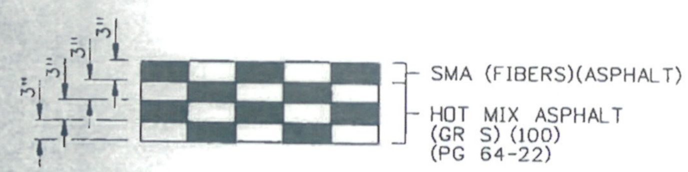



75+50.00 TO 77+00.00

⊖ 75+50.00 TO 77+00.00, 9.44' TO 11.08'

∴ 75+50.00 TO 77+00.00, 10.38' TO 12.52'




HOT MIX ASPHALT

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= EMBANKMENT MATERIAL

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I-70
TYPICAL SECTIONS

Designer: M. GRANT
Detailer: D. MADDOCK
Sheet Subset: TYPICALS
Structure Numbers
Subset Sheets: 5 of 18

Project No./Code
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17537
Sheet Number 17

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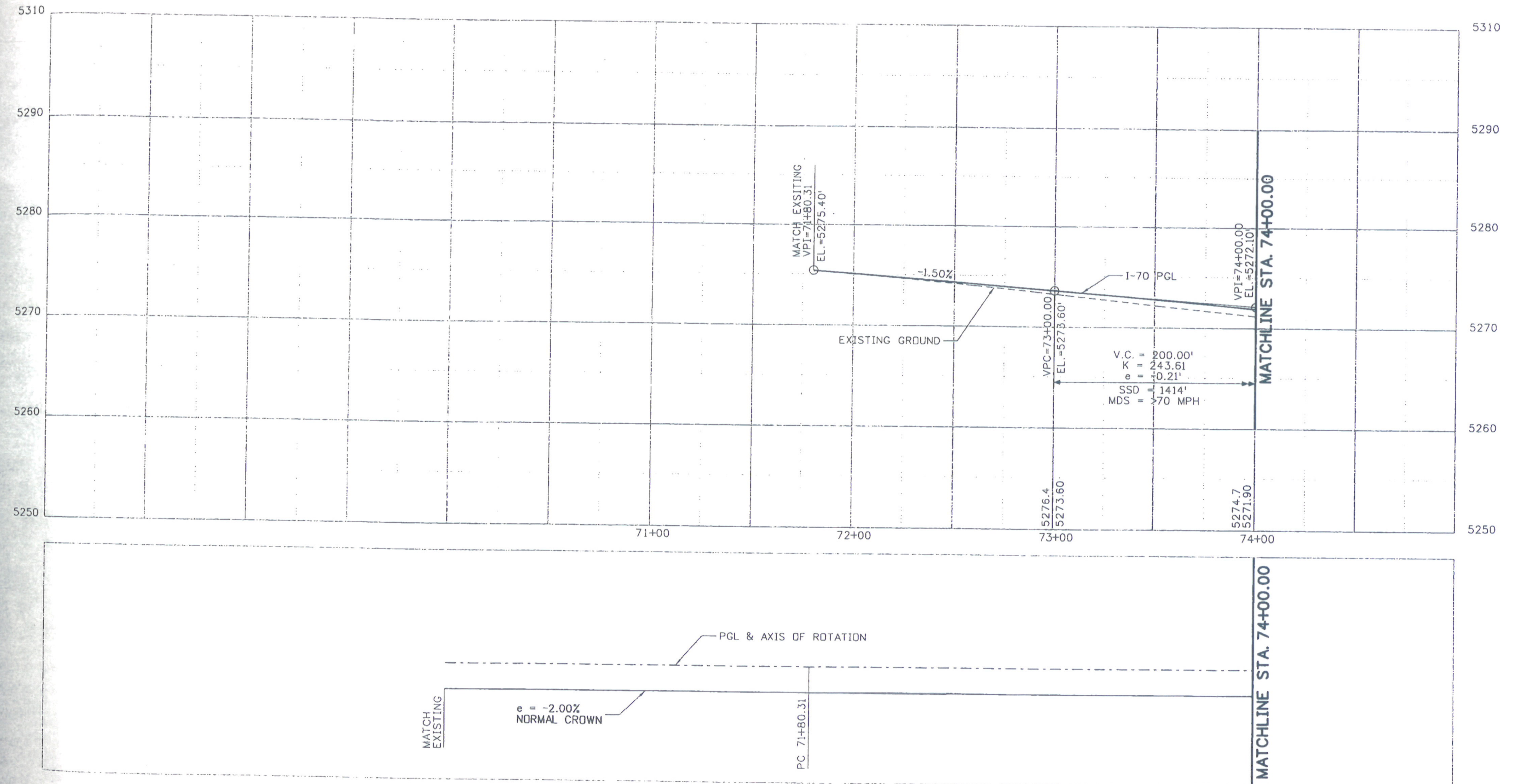


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ROADWAY PROFILE SHEET
71+80.31 TO 74+00.00

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| Designer: | M. GRANT | Structure Numbers | |
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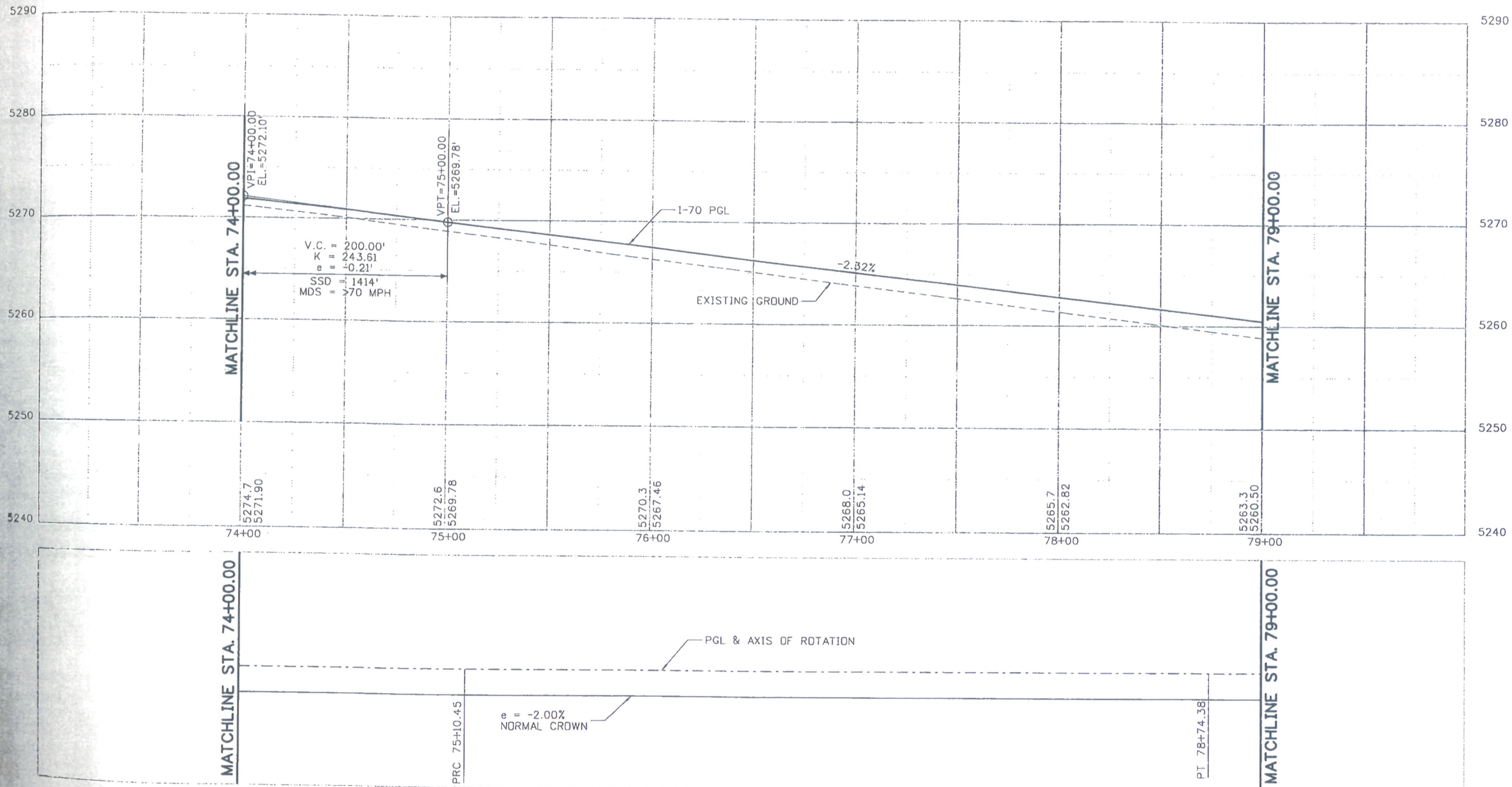


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ROADWAY PROFILE SHEET
74+00.00 TO 79+00.00

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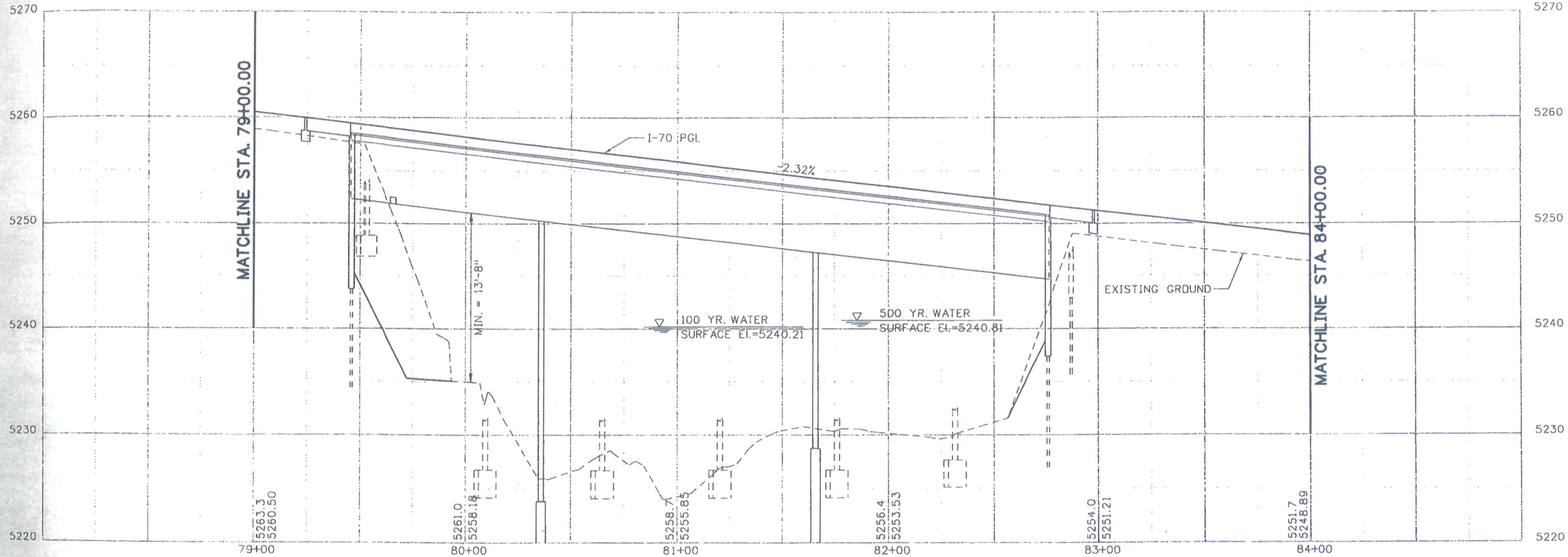


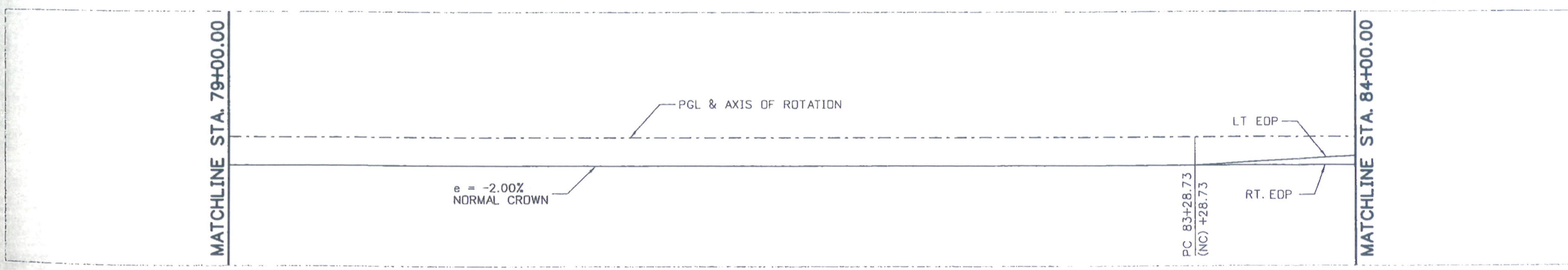


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| Print Date: 8/16/2010 | Sheet Revisions | Colorado Department of Transportation | As Constructed |
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| Designer: M. GRANT | Structure Numbers | FBR 0704-220 |
| Detailer: D. SPORING | | 17537 |
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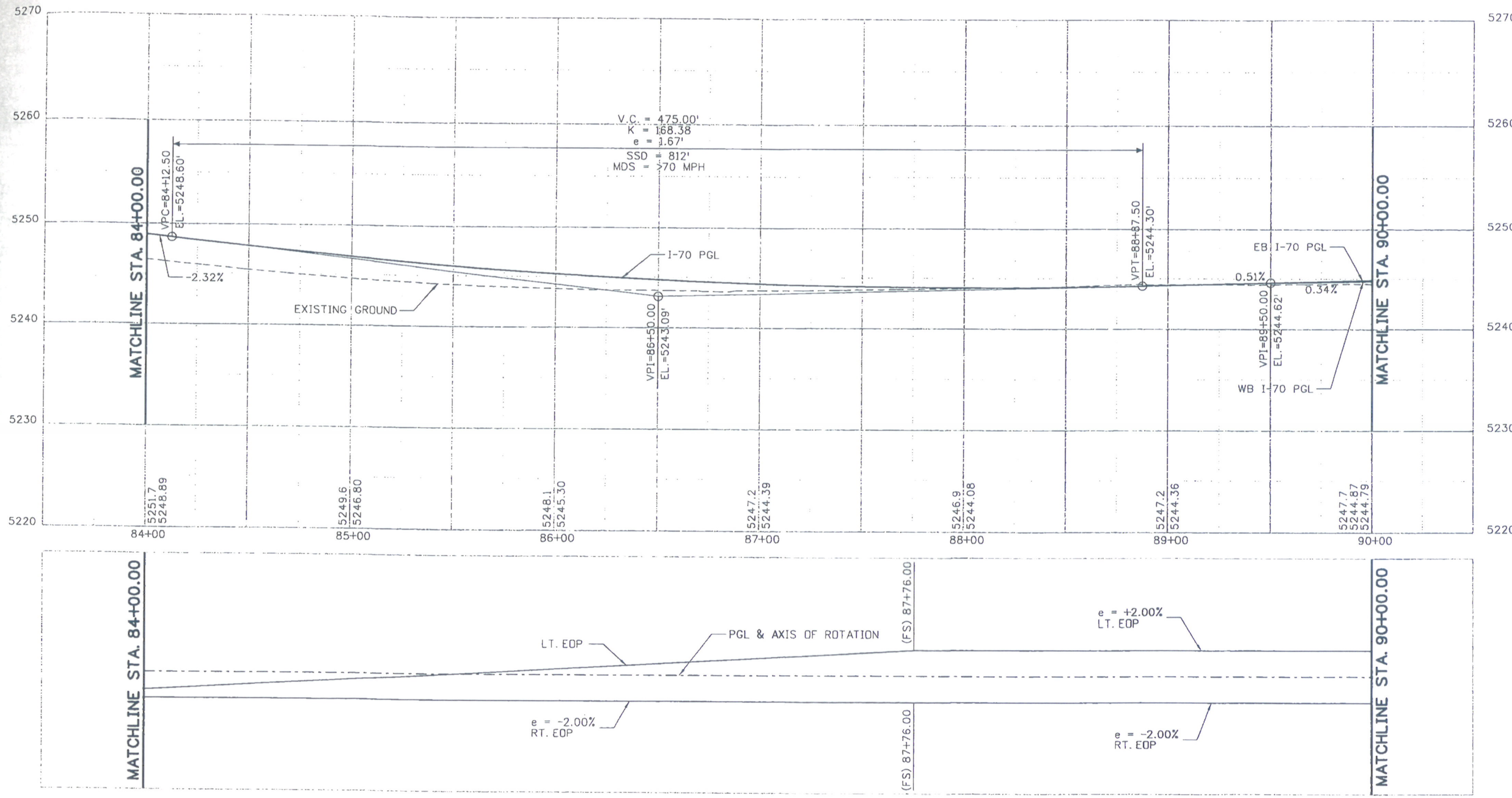


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ROADWAY PROFILE SHEET
84+00.00 TO 90+00.00

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|---|---|---|---|
| Designer: | M. GRANT | Structure Numbers | |
| Detailer: | D. SPORING | | |
| Sheet Subset: | PROFILE | Subset Sheets: | 4 of 7 |

| Project No./Code |
|---|
| FBR 0704-220 |
| 17537 |
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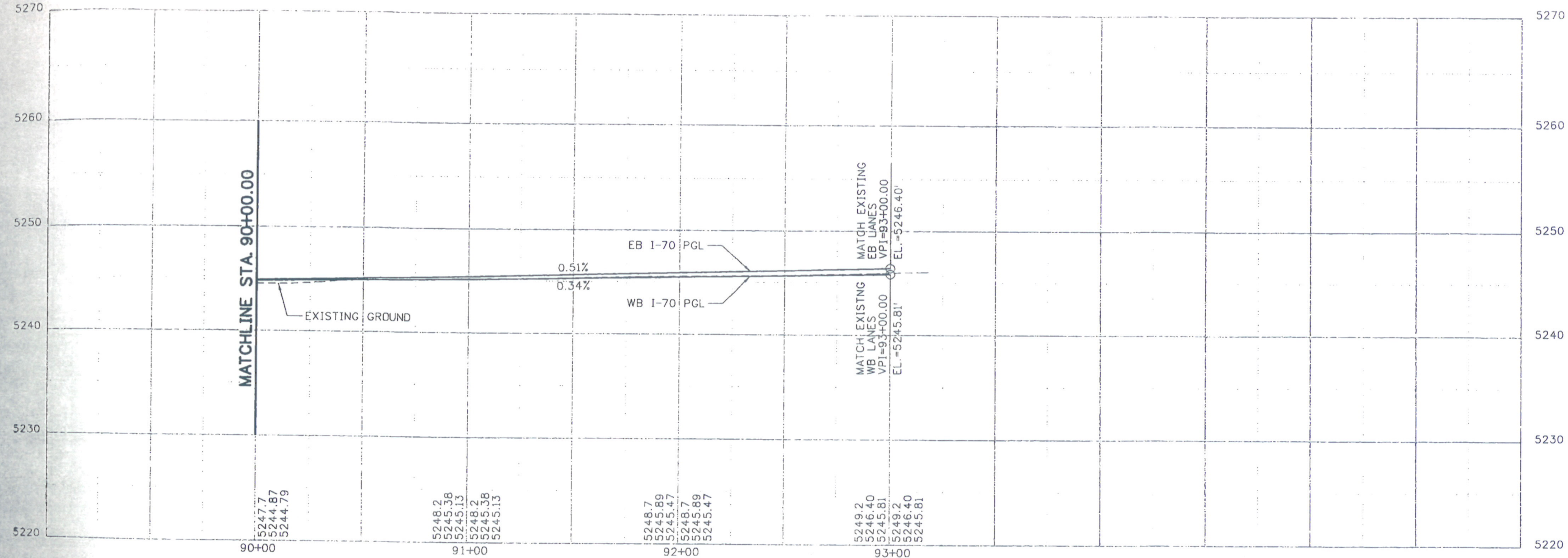


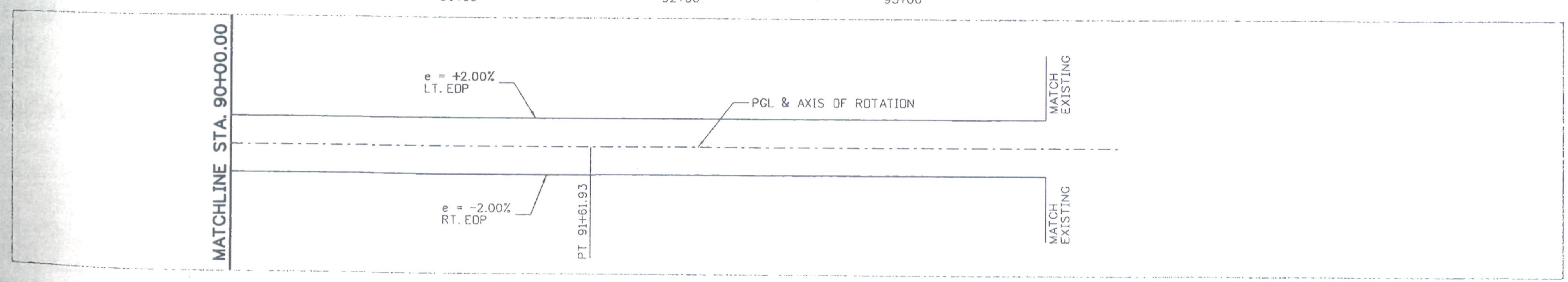


Print Date: 8/16/2010
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ROADWAY PROFILE SHEET
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Designer: M. GRANT
Detailer: D. SPORING
Structure Numbers
Sheet Subset: PROFILE
Subset Sheets: 5 of 7

Project No./Code
FBR 0704-220
17537
Sheet Number 48

SPREADWIDTH CALCULATIONS

Maximum Spreadwidth
Worksheet for Triangular Channel

I-70 BRIDGE
OVER SAND CREEK

| Project Description | |
|---|---|
| Project File | untitled.fm2 |
| Worksheet | Spreadwidth |
| Flow Element | Triangular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

| Input Data | | |
|---|---|---|
| Mannings Coefficient | 0.015 | |
| Channel Slope | 0.023200 | ft/ft |
| Depth | 0.32 | ft |
| Left Side Slope | 0.000000 | H : V |
| Right Side Slope | 50.000000 | H : V |

| Results | | |
|---|---|---|
| Discharge | 11.23 | cfs |
| Flow Area | 2.56 | ft² |
| Wetted Perimeter | 16.32 | ft |
| Top Width | 16.00 | ft |
| Critical Depth | 0.42 | ft |
| Critical Slope | 0.005680 | ft/ft |
| Velocity | 4.39 | ft/s |
| Velocity Head | 0.30 | ft |
| Specific Energy | 0.62 | ft |
| Froude Number | 1.93 | |
| Flow is supercritical. | | |

Discharge → I-70 EB: $Q_{100}$ = 4.7 CFS
I-70 WB: $Q_{100}$ = 5.9 CFS

Top Width → 12' SHOULDER + 4' INTO TRAVEL LANE

## Table
## Rating Table for Triangular Channel

| Project Description | |
|---|---|
| Project File | untitled.fm2 |
| Worksheet | Spreadwidth |
| Flow Element | Triangular Channel |
| Method | Manning's Formula |
| Solve For | Discharge |

| Constant Data | |
|---|---|
| Mannings Coefficient | 0.015 |
| Channel Slope | 0.023200 ft/ft |
| Left Side Slope | 0.000000 H : V |
| Right Side Slope | 50.000000 H : V |

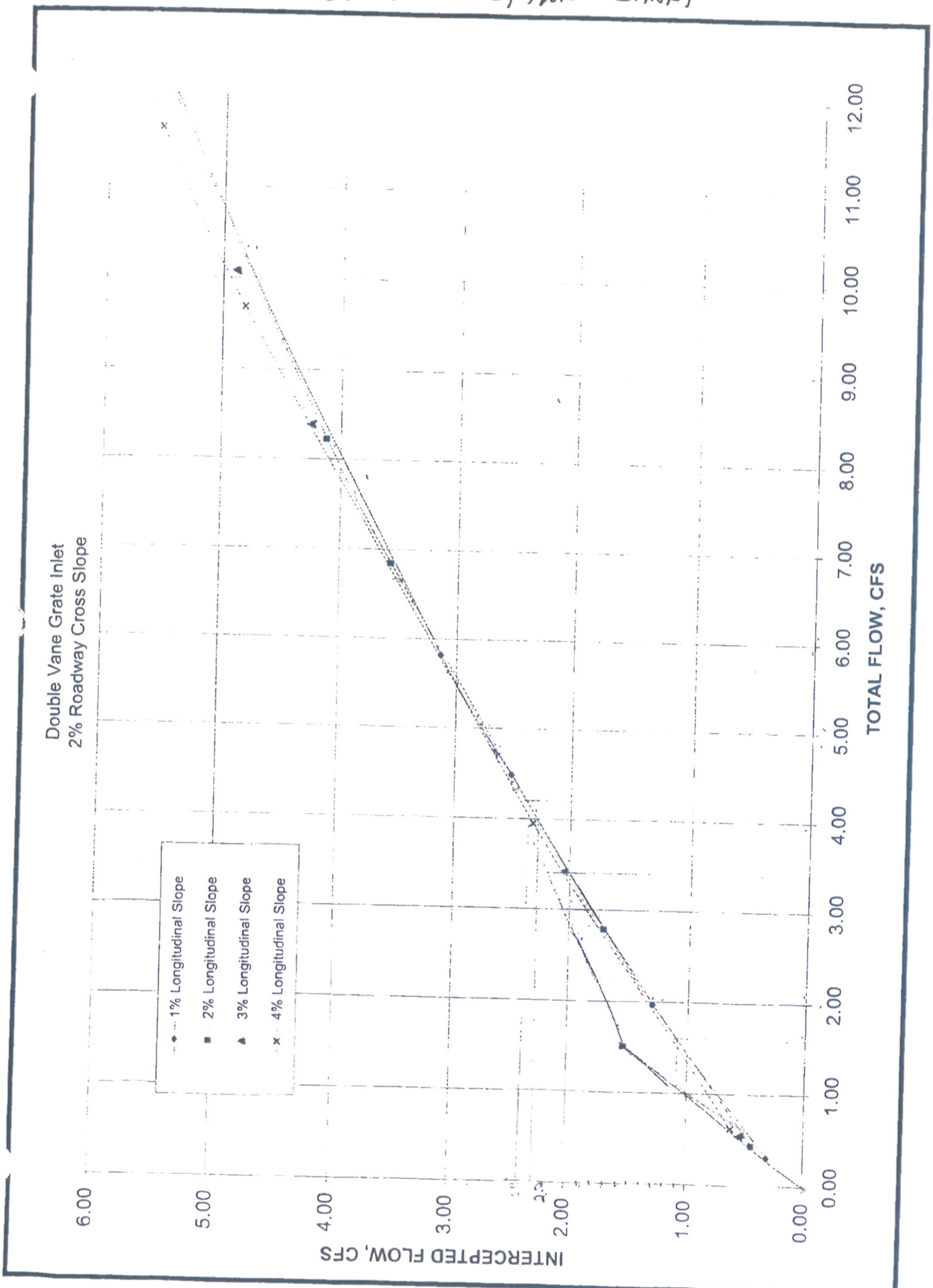
Input Data

| | Minimum | Maximum | Increment |
|---|---|---|---|
| Depth | 0.20 | 0.32 | 0.02 ft |

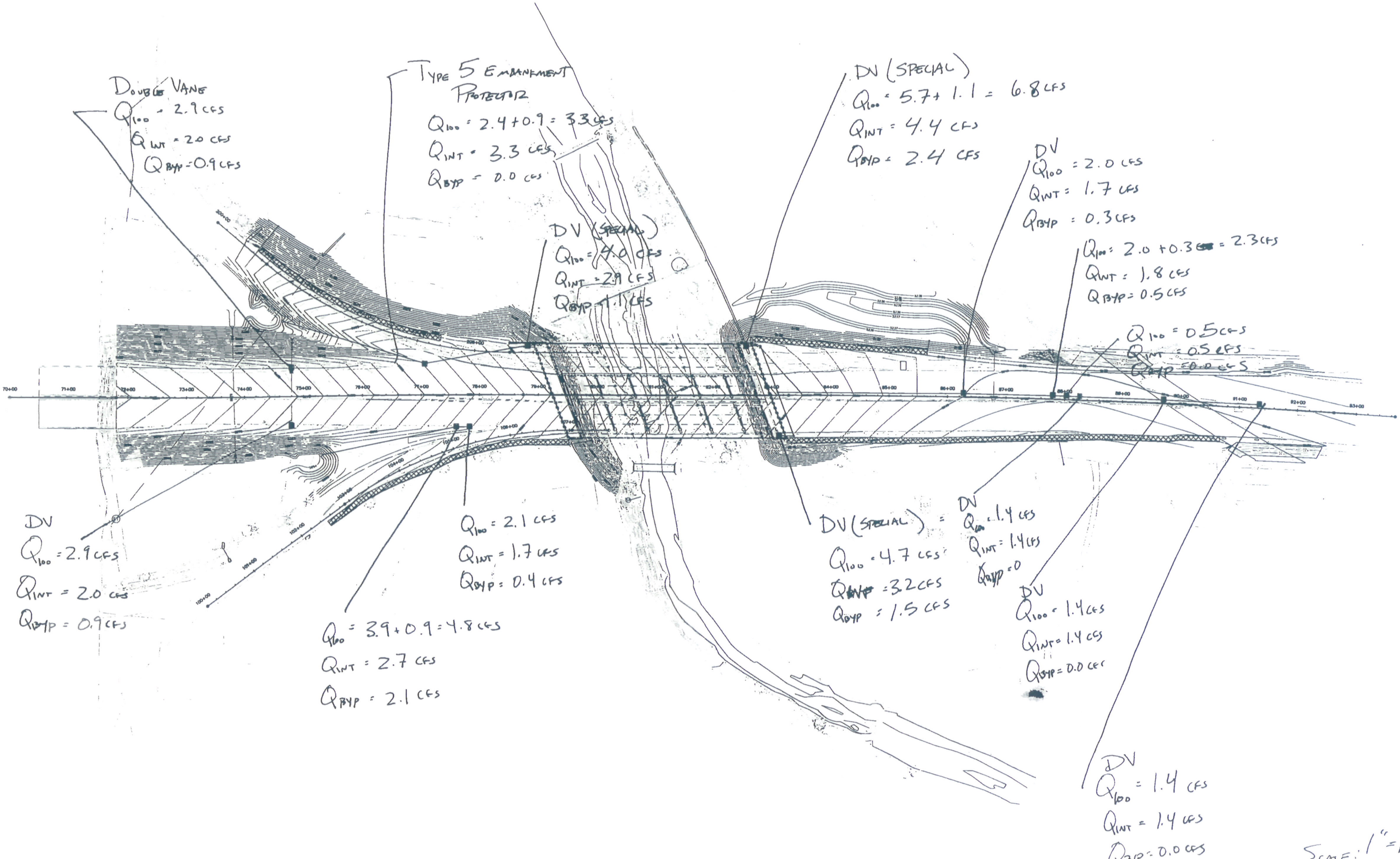
Rating Table

| Depth (ft) | Discharge (cfs) | Velocity (ft/s) |
|---|---|---|
| 0.20 | 3.21 | 3.21 |
| 0.22 | 4.14 | 3.42 |
| 0.24 | 5.22 | 3.62 |
| 0.26 | 6.46 | 3.82 |
| 0.28 | 7.87 | 4.01 |
| 0.30 | 9.46 | 4.20 |
| 0.32 | 11.23 | 4.39 |

# INLET INTERCEPTION CHART



# Inlet Interception
## 100-yr Event



# DOUBLE VANE GRATE (SPECIAL)

$Q_S = 2.79$ cfs **INLET INTERCEPTION @ BRIDGE**

TOP WIDTH = 10.5'

$V = 2.53$ ft/s

$S = 0.024$

$S_x = 0.02$

DEPTH = 0.21 ft

$$R_{FF} = \left(1 - \left(1 - \frac{\text{GRATE TOPWIDTH}}{\text{TOPWIDTH}}\right)^{2.67}\right)\left(1 - \text{CLOGGING FACTOR}\right)$$

$$= \left(1 - \left(1 - \frac{6}{10.5}\right)^{2.67}\right)(1 - 0.4)$$

$$= 0.54$$

$$Q_{FL} = (0.54)(2.79) = 1.51 \text{ cfs}$$

$$Q_{BYP} = 2.79 - 1.51 = 1.28 \text{ cfs}$$

$$R_{SF} = 1/\left(1 + \left(K_u \times V^{1.8}\right)\right)/\left(S_x \times \text{GRATE LENGTH}^{2.3}\right)$$

$$= 1/\left(1 + \left(0.15 + 2.53^{1.8}\right)\right)/\left(0.02 \times 5^{2.3}\right)$$

$$= 0.50$$

$$Q_{SF} = (0.50)(1.28) = 0.64$$

$$Q_{TOTAL} = 1.51 - 0.64 = 2.15 \text{ cfs}$$

$Q_{RATIO} = 2.15/2.79 = 77\%$ OF STR FLOW CAPTURED

MATERIAL SELECTION
CORRESPONDENCE



**Lee Rosen**

**From:** Rich Ommert [ommert@moser-eng.com]
**Sent:** Wednesday, May 26, 2010 2:51 PM
**To:** 'Lee Rosen'; Robert Mitchell
**Subject:** FW: FASTER Pipe Material Selection

-----Original Message-----
**From:** Hendrickson, Duane (Jay) [mailto:Duane.Hendrickson@dot.state.co.us]
**Sent:** Wednesday, May 26, 2010 2:35 PM
**To:** 'Ridley Moorman'; 'Jennifer Wood'; John Guenther; Bill.Beams; 'Kurt.Kellogg'; Rich Ommert; moser@moser-eng.com
**Cc:** Kloska, Jeff; Werdel, Justin
**Subject:** FW: FASTER Pipe Material Selection

fyi:

---

lay 26, 2010 1:51 PM
uane (Jay)

R Pipe Material Selection

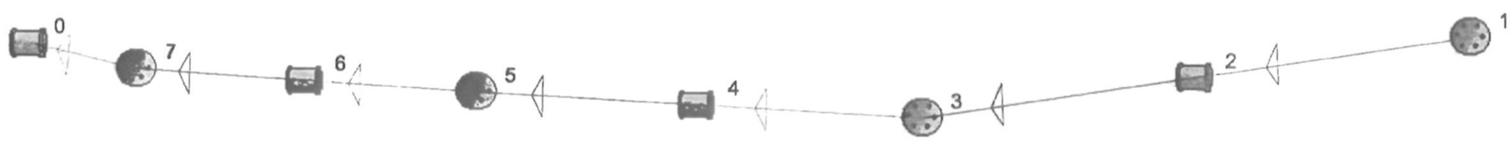
Jay,

Here is the location of CDOT's pipe material selection guidelines. Basically, the current guidelines specify concrete for storm sewers. For culverts, alternative pipe materials are allowed. Could you send this to the appropriate people for each the FASTER projects? Thanks.

http://www.dot.state.co.us/DesignSupport/Design%20Bulletins/Design%20Bulletins.htm

Jeff Kloska
Colorado Department of Transportation
Region 6 Hydraulics
(303) 757-9737

# Storm Sewer B
# HGL Calculations



# NeoUDS Results Summary

Storm Sewer B

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 1:20:52 PM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 100 **Years.**

100 Year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| **Manhole ID #** | **Basin Area * C** | **Overland (Minutes)** | **Gutter (Minutes)** | **Basin (Minutes)** | **Rain I (Inch/Hour)** | **Peak Flow (CFS)** | **Comments** |
| 1 | 96.00 | 32459.4 | 0.0 | 0.0 | 0.02 | 2.0 | |
| 3 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |
| 5 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |
| 7 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| Manhole ID # | Contributing Area * C | Rainfall Duration (Minutes) | Rainfall Intensity (Inch/Hour) | Design Peak Flow (CFS) | Ground Elevation (Feet) | Water Elevation (Feet) | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 96 | 32459.4 | 0.02 | 2.0 | 5269.05 | 5266.15 | |
| 3 | 192 | 32459.4 | 0.02 | 4.0 | 5269.01 | 5261.93 | |
| 5 | 288 | 54378.8 | 0.01 | 4.0 | 5261.16 | 5251.01 | |
| 7 | 0 | 0.0 | 0.00 | 4.0 | 5251.00 | 5251.00 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 6 | 5 | 7 | Round | 15.1 | 18 | 24 | N/A |
| 4 | 3 | 5 | Round | 6.9 | 18 | 24 | N/A |
| 2 | 1 | 3 | Round | 9.7 | 18 | 24 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.
Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 4.0 | 13.9 | 0.73 | 3.8 | 0.72 | 3.9 | 1.3 | 0.91 | |
| 4 | 4.0 | 111.3 | 0.26 | 16.7 | 0.72 | 3.9 | 1.3 | 6.99 | |
| 2 | 2.0 | 22.8 | 0.40 | 4.5 | 0.52 | 3.1 | 0.6 | 1.48 | |

A Froude number = 0 indicated that a pressured flow occurs.

---

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 6 | 0.50 | 5249.22 | 5249.04 | 9.94 | -0.04 | Sewer Too Shallow |
| 4 | 32.03 | 5261.21 | 5252.31 | 5.80 | 6.85 | |
| 2 | 1.34 | 5265.63 | 5264.34 | 1.42 | 2.67 | Sewer Too Shallow |

---

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID | Sewer | Surcharged | Upstream | Downstream | Upstream | Downstream | |

| # | Length (Feet) | Length (Feet) | (Feet) | (Feet) | (Feet) | (Feet) | Condition |
|---|---|---|---|---|---|---|---|
| 6 | 36 | 0 | 5249.22 | 5249.04 | 5251.01 | 5249.77 | Subcritical |
| 4 | 27.8 | 0 | 5261.21 | 5252.31 | 5261.93 | 5252.56 | Jump |
| 2 | 96.6 | 0 | 5265.63 | 5264.34 | 5266.15 | 5264.74 | Jump |

---

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 6 | 5 | 5251.04 | 0.04 | 0.05 | 0.00 | 0.00 | 0.00 | 7 | 5251.00 |
| 4 | 3 | 5262.17 | 11.13 | 0.05 | 0.00 | 0.00 | 0.00 | 5 | 5251.04 |
| 2 | 1 | 5266.30 | 4.13 | 0.05 | 0.00 | 0.00 | 0.00 | 3 | 5262.17 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

---

## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 1 | 5269.05 | 5265.63 | 3.42 |
| 3 | 5269.01 | 5261.21 | 7.80 |
| 5 | 5261.16 | 5249.22 | 11.94 |
| 7 | 5251.00 | 5249.04 | 1.96 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Earth |

| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Volume (Cubic Yards) |
|---|---|---|---|---|---|---|---|
| 6 | 23.4 | 4.5 | 3.4 | 4.5 | 36 | 3.00 | 107 |
| 4 | 15.1 | 4.5 | 17.2 | 4.5 | 27.8 | 3.00 | 78 |
| 2 | 6.3 | 4.5 | 8.8 | 4.5 | 96.6 | 3.00 | 91 |

Total earth volume for sewer trenches = 277 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.

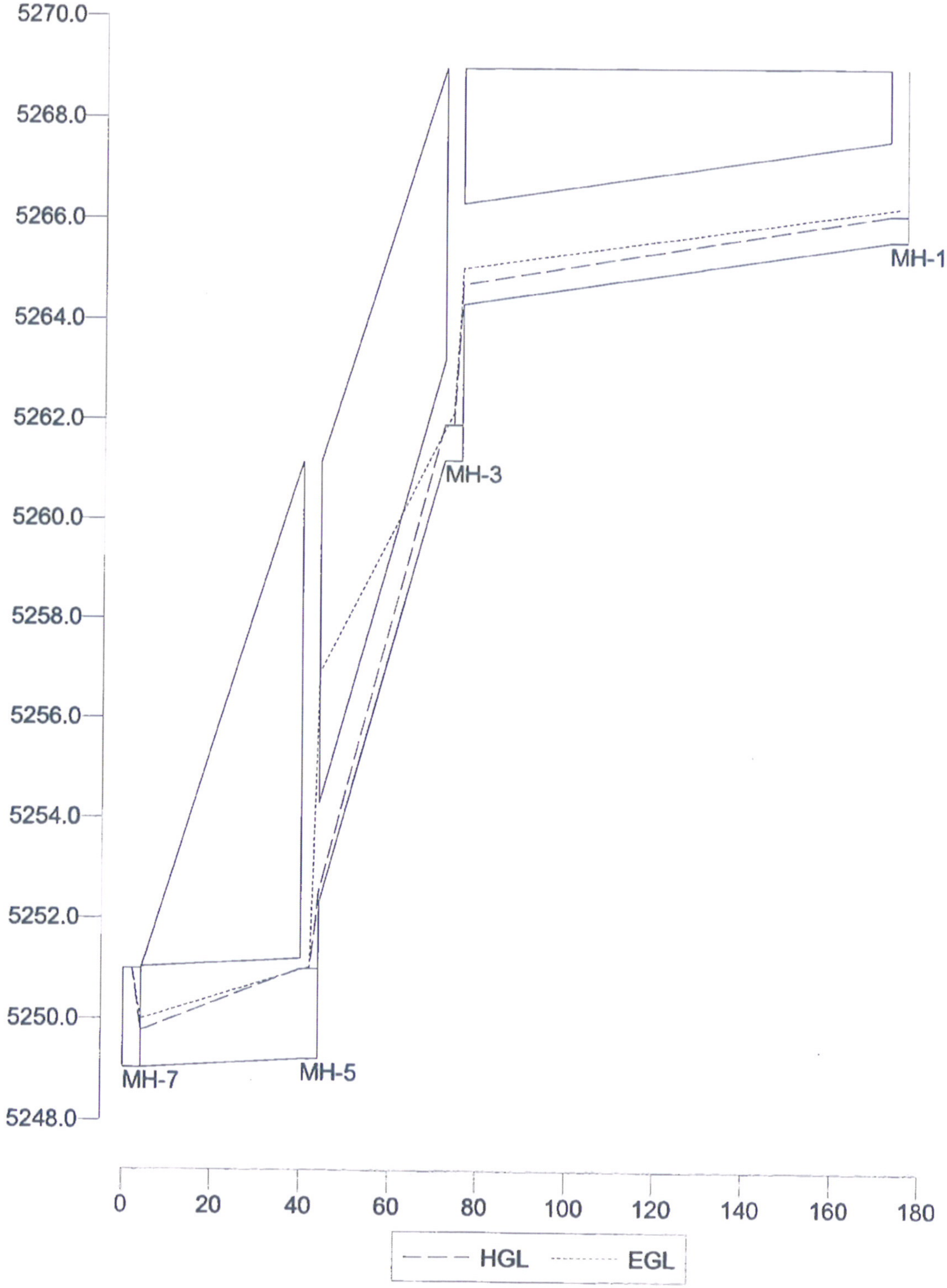
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

100 Year Event

# B1 to B-7



# NeoUDS Results Summary

Storm Sewer B

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 1:19:09 PM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 5 **Years.**

5 year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| Manhole ID # | Basin Area * C | Overland (Minutes) | Gutter (Minutes) | Basin (Minutes) | Rain I (Inch/Hour) | Peak Flow (CFS) | Comments |
| 1 | 96.00 | 51105.3 | 0.0 | 0.0 | 0.01 | 1.4 | |
| 3 | 96.00 | 21152.2 | 0.0 | 0.0 | 0.03 | 2.8 | |
| 5 | 96.00 | 21152.2 | 0.0 | 0.0 | 0.03 | 2.8 | |
| 7 | 96.00 | 21152.2 | 0.0 | 0.0 | 0.03 | 2.8 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| Manhole ID # | Contributing Area * C | Rainfall Duration (Minutes) | Rainfall Intensity (Inch/Hour) | Design Peak Flow (CFS) | Ground Elevation (Feet) | Water Elevation (Feet) | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 96 | 51105.3 | 0.01 | 1.4 | 5269.05 | 5266.08 | |
| 3 | 192 | 51105.3 | 0.01 | 2.8 | 5269.01 | 5261.82 | |
| 5 | 288 | 85612.1 | 0.01 | 2.8 | 5261.16 | 5251.01 | |
| 7 | 0 | 0.0 | 0.00 | 2.8 | 5251.00 | 5251.00 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 6 | 5 | 7 | Round | 13.2 | 18 | 24 | N/A |
| 4 | 3 | 5 | Round | 6.0 | 18 | 24 | N/A |
| 2 | 1 | 3 | Round | 8.4 | 18 | 24 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.
Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 2.8 | 13.9 | 0.61 | 3.5 | 0.61 | 3.5 | 0.9 | 0.92 | |
| 4 | 2.8 | 111.3 | 0.22 | 15.0 | 0.61 | 3.5 | 0.9 | 6.87 | |
| 2 | 1.4 | 22.8 | 0.34 | 4.0 | 0.45 | 2.7 | 0.4 | 1.47 | |

A Froude number = 0 indicated that a pressured flow occurs.

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 6 | 0.50 | 5249.22 | 5249.04 | 9.94 | -0.04 | Sewer Too Shallow |
| 4 | 32.03 | 5261.21 | 5252.31 | 5.80 | 6.85 | |
| 2 | 1.34 | 5265.63 | 5264.34 | 1.42 | 2.67 | Sewer Too Shallow |

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID | Sewer | Surcharged | Upstream | Downstream | Upstream | Downstream | |

| # | Length (Feet) | Length (Feet) | (Feet) | (Feet) | (Feet) | (Feet) | Condition |
|---|---|---|---|---|---|---|---|
| 6 | 36 | 0 | 5249.22 | 5249.04 | 5251.01 | 5249.65 | Subcritical |
| 4 | 27.8 | 0 | 5261.21 | 5252.31 | 5261.82 | 5252.52 | Jump |
| 2 | 96.6 | 0 | 5265.63 | 5264.34 | 5266.08 | 5264.67 | Jump |

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 6 | 5 | 5251.02 | 0.02 | 0.05 | 0.00 | 0.00 | 0.00 | 7 | 5251.00 |
| 4 | 3 | 5262.00 | 10.98 | 0.05 | 0.00 | 0.00 | 0.00 | 5 | 5251.02 |
| 2 | 1 | 5266.19 | 4.18 | 0.05 | 0.00 | 0.00 | 0.00 | 3 | 5262.00 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 1 | 5269.05 | 5265.63 | 3.42 |
| 3 | 5269.01 | 5261.21 | 7.80 |
| 5 | 5261.16 | 5249.22 | 11.94 |
| 7 | 5251.00 | 5249.04 | 1.96 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Earth |

| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Volume (Cubic Yards) |
|---|---|---|---|---|---|---|---|
| 6 | 23.4 | 4.5 | 3.4 | 4.5 | 36 | 3.00 | 107 |
| 4 | 15.1 | 4.5 | 17.2 | 4.5 | 27.8 | 3.00 | 78 |
| 2 | 6.3 | 4.5 | 8.8 | 4.5 | 96.6 | 3.00 | 91 |

Total earth volume for sewer trenches = 277 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.

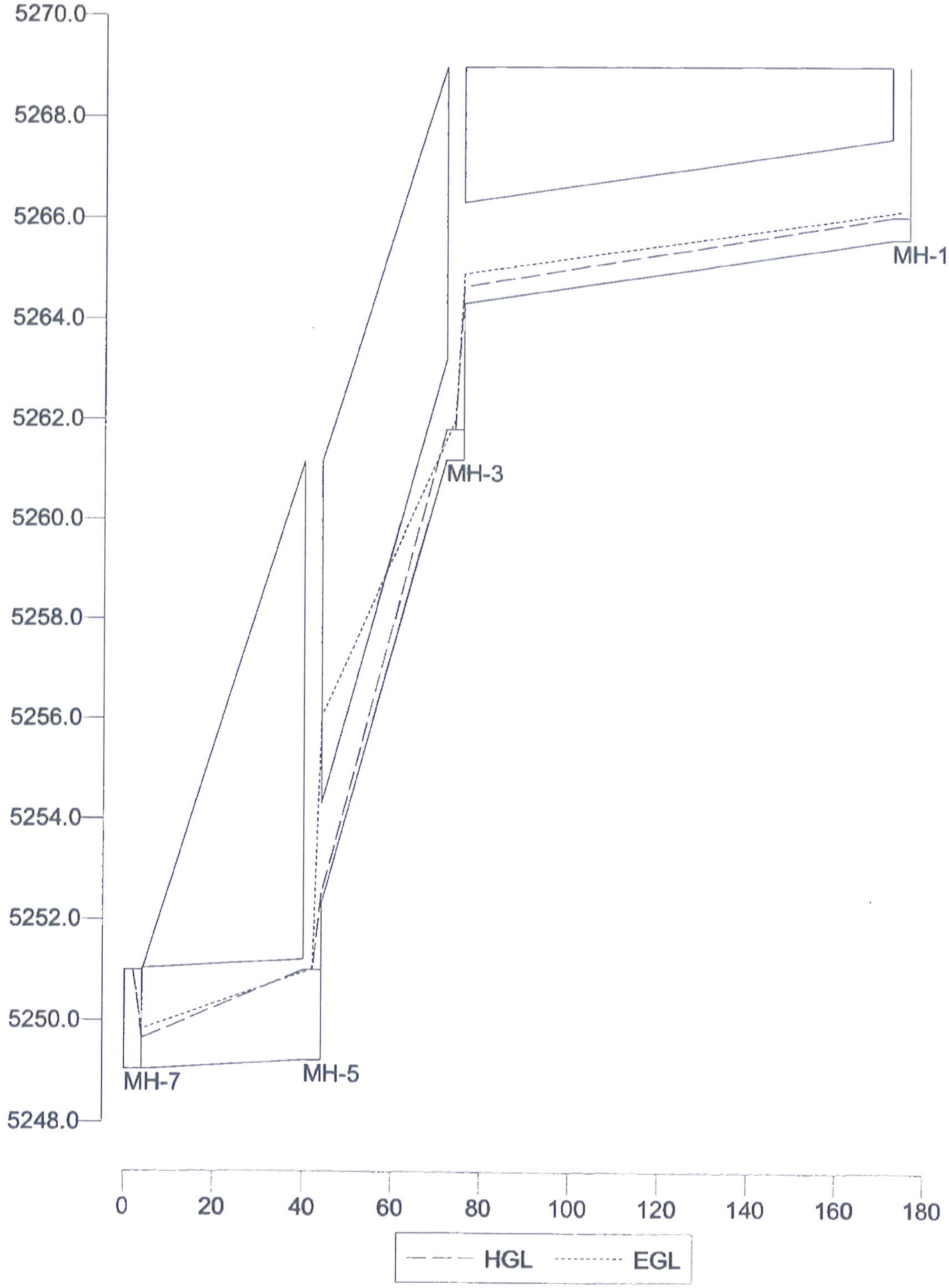
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

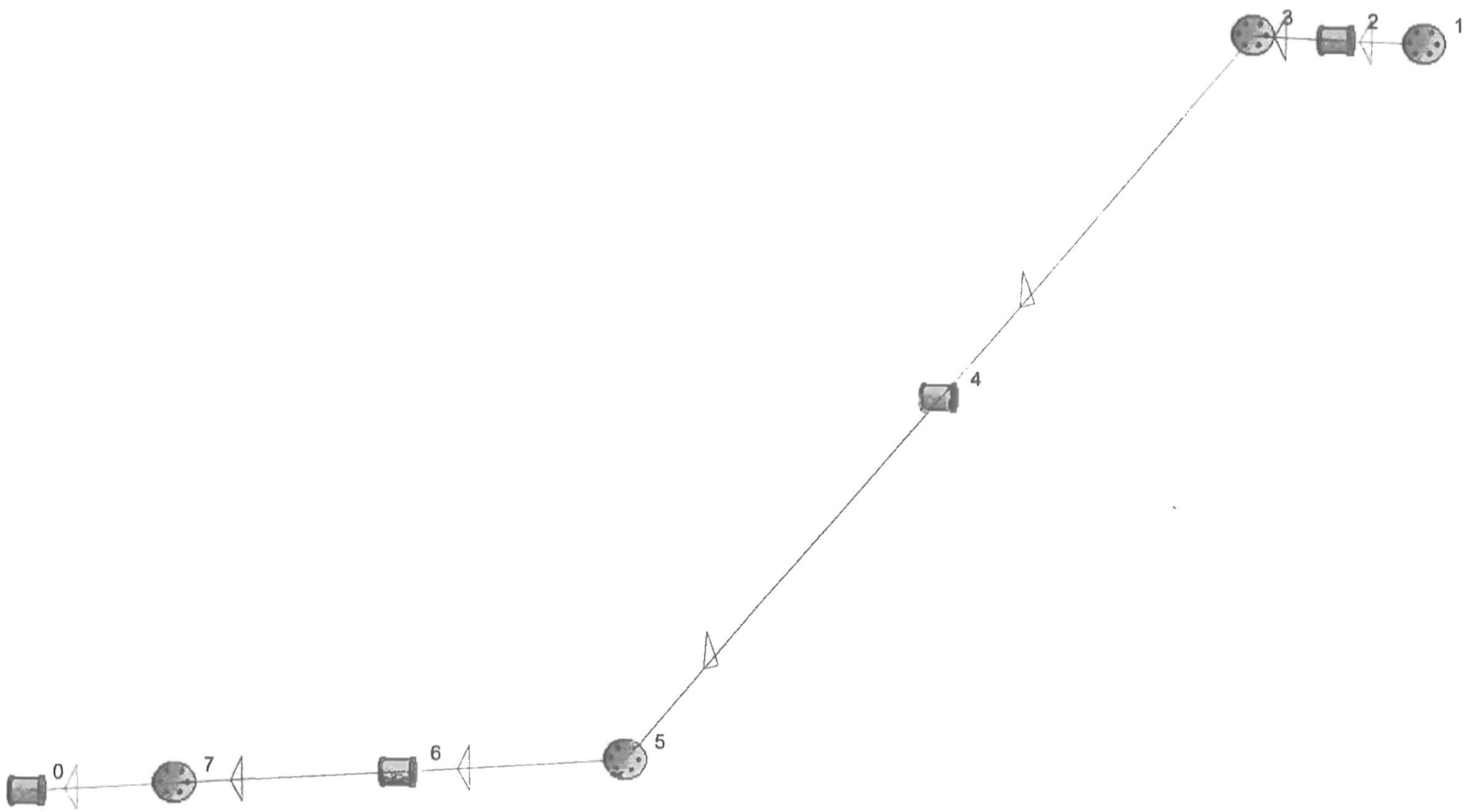
The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

5year Event

# B1 to B-7



# Storm Sewer C
# HGL Calculations



# NeoUDS Results Summary

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 11:35:08 AM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 100 **Years.**

PROFILE C
100 Year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| **Manhole ID #** | **Basin Area * C** | **Overland (Minutes)** | **Gutter (Minutes)** | **Basin (Minutes)** | **Rain I (Inch/Hour)** | **Peak Flow (CFS)** | **Comments** |
| 1 | 96.00 | 32459.4 | 0.0 | 0.0 | 0.02 | 2.0 | |
| 3 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |
| 5 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |
| 7 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| Manhole ID # | Contributing Area * C | Rainfall Duration (Minutes) | Rainfall Intensity (Inch/Hour) | Design Peak Flow (CFS) | Ground Elevation (Feet) | Water Elevation (Feet) | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 96 | 32459.4 | 0.02 | 2.0 | 5269.05 | 5266.15 | |
| 3 | 192 | 32459.4 | 0.02 | 4.0 | 5269.01 | 5261.93 | |
| 5 | 288 | 54378.8 | 0.01 | 4.0 | 5261.16 | 5252.84 | |
| 7 | 0 | 0.0 | 0.00 | 4.0 | 5251.00 | 5251.00 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 2 | 1 | 3 | Round | 8.6 | 18 | 18 | N/A |
| 4 | 3 | 5 | Round | 12.5 | 18 | 18 | N/A |
| 6 | 5 | 7 | Round | 12.5 | 18 | 18 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.
Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 1.7 | 12.3 | 0.38 | 4.9 | 0.51 | 3.2 | 1.0 | 1.66 | |
| 4 | 4.4 | 11.7 | 0.64 | 6.1 | 0.81 | 4.5 | 2.5 | 1.56 | |
| 6 | 4.4 | 11.7 | 0.64 | 6.1 | 0.81 | 4.5 | 2.5 | 1.56 | |

A Froude number = 0 indicated that a pressured flow occurs.

---

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 2 | 1.81 | 5259.03 | 5258.67 | 1.50 | 2.40 | Sewer Too Shallow |
| 4 | 1.64 | 5258.48 | 5255.53 | 2.59 | 6.86 | |
| 6 | 1.64 | 5255.32 | 5254.15 | 7.07 | -0.10 | Sewer Too Shallow |

---

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID | Sewer | Surcharged | Upstream | Downstream | Upstream | Downstream | |

| # | Length (Feet) | Length (Feet) | (Feet) | (Feet) | (Feet) | (Feet) | Condition |
|---|---|---|---|---|---|---|---|
| 2 | 20 | 0 | 5259.03 | 5258.67 | 5259.59 | 5259.04 | Jump |
| 4 | 180.1 | 0 | 5258.48 | 5255.53 | 5259.29 | 5256.16 | Jump |
| 6 | 71.5 | 0 | 5255.32 | 5254.15 | 5256.13 | 5254.79 | Jump |

---

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 2 | 1 | 5259.61 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 3 | 5259.61 |
| 4 | 3 | 5259.61 | 3.16 | 0.05 | 0.00 | 0.00 | 0.00 | 5 | 5256.45 |
| 6 | 5 | 5256.45 | 0.90 | 0.08 | 0.00 | 0.00 | 0.00 | 7 | 5255.55 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

---

## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 5 | 5263.89 | 5255.32 | 8.57 |
| 3 | 5262.57 | 5258.48 | 4.09 |
| 1 | 5262.03 | 5259.03 | 3.00 |
| 7 | 5255.55 | 5254.15 | 1.40 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Earth |

| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Volume (Cubic Yards) |
|---|---|---|---|---|---|---|---|
| 2 | 6.1 | 3.9 | 7.9 | 3.9 | 20 | 2.50 | 15 |
| 4 | 8.3 | 3.9 | 16.8 | 3.9 | 180.1 | 2.50 | 343 |
| 6 | 17.2 | 3.9 | 2.9 | 3.9 | 71.5 | 2.50 | 121 |

Total earth volume for sewer trenches = 479.05 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.

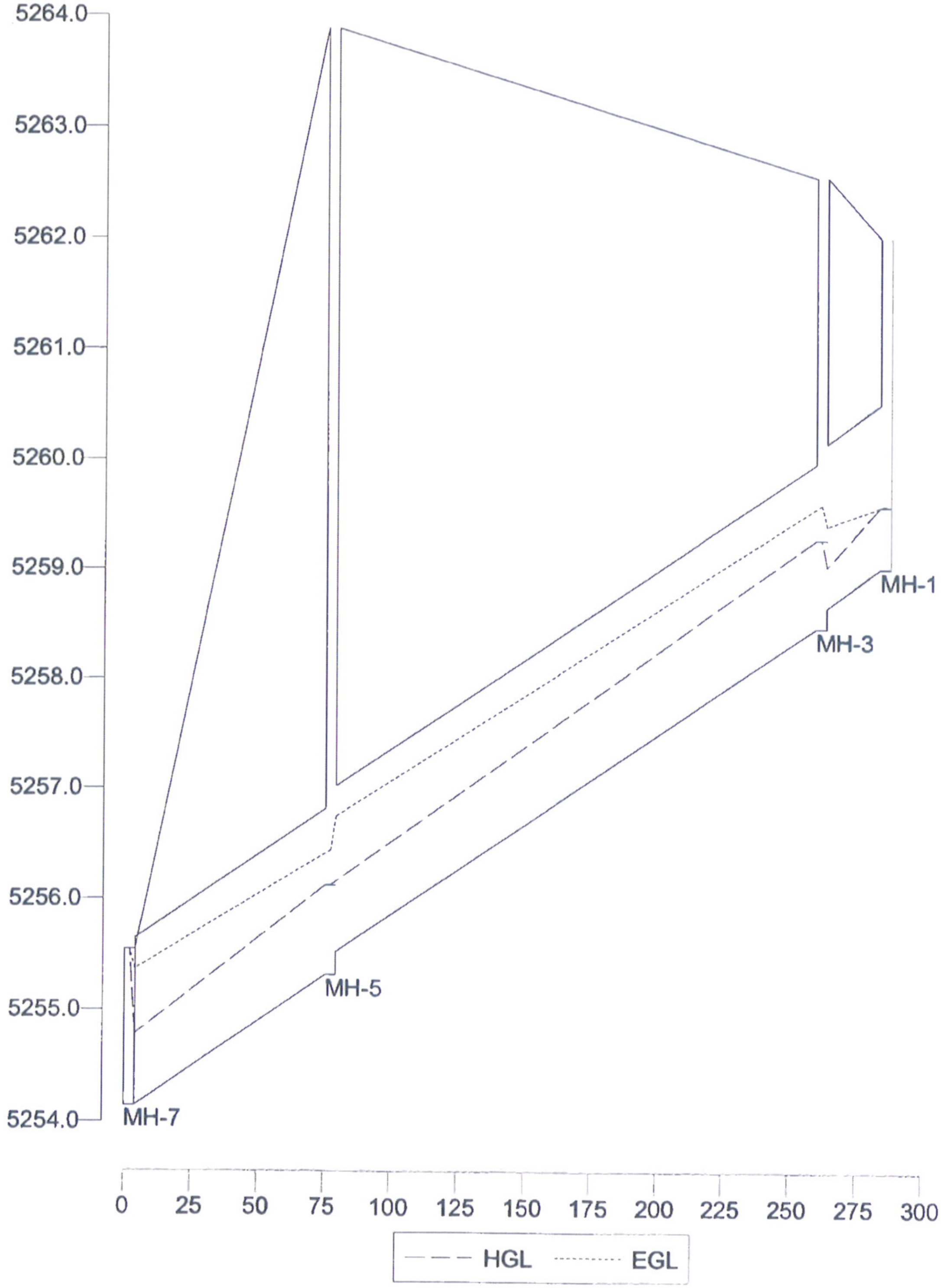
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

100 Year Event

# C-1 to C-7



# NeoUDS Results Summary

Storm Sewer C

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 1:26:57 PM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 5 **Years.**

5 year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| **Manhole ID #** | **Basin Area * C** | **Overland (Minutes)** | **Gutter (Minutes)** | **Basin (Minutes)** | **Rain I (Inch/Hour)** | **Peak Flow (CFS)** | **Comments** |
| 5 | 96.00 | 34649.0 | 0.0 | 0.0 | 0.02 | 1.9 | |
| 3 | 96.00 | 34649.0 | 0.0 | 0.0 | 0.02 | 1.9 | |
| 1 | 96.00 | 362821.2 | 0.0 | 0.0 | 0.00 | 0.3 | |
| 7 | 96.00 | 34649.0 | 0.0 | 0.0 | 0.02 | 1.9 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| **Manhole ID #** | **Contributing Area * C** | **Rainfall Duration (Minutes)** | **Rainfall Intensity (Inch/Hour)** | **Design Peak Flow (CFS)** | **Ground Elevation (Feet)** | **Water Elevation (Feet)** | **Comments** |
|---|---|---|---|---|---|---|---|
| 5 | 288 | 140219.9 | 0.01 | 1.9 | 5263.89 | 5255.85 | |
| 3 | 192 | 83705.5 | 0.01 | 1.9 | 5262.57 | 5259.01 | |
| 1 | 96 | 362821.2 | 0.00 | 0.3 | 5262.03 | 5259.27 | |
| 7 | 0 | 0.0 | 0.00 | 1.9 | 5255.55 | 5255.55 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 2 | 1 | 3 | Round | 4.5 | 18 | 18 | N/A |
| 4 | 3 | 5 | Round | 9.1 | 18 | 18 | N/A |
| 6 | 5 | 7 | Round | 9.1 | 18 | 18 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.
Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 0.3 | 12.3 | 0.16 | 2.9 | 0.24 | 1.6 | 0.2 | 1.55 | |
| 4 | 1.9 | 11.7 | 0.41 | 4.9 | 0.53 | 3.4 | 1.1 | 1.59 | |
| 6 | 1.9 | 11.7 | 0.41 | 4.9 | 0.53 | 3.4 | 1.1 | 1.59 | |

A Froude number = 0 indicated that a pressured flow occurs.

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 2 | 1.81 | 5259.03 | 5258.67 | 1.50 | 2.40 | Sewer Too Shallow |
| 4 | 1.64 | 5258.48 | 5255.53 | 2.59 | 6.86 | |
| 6 | 1.64 | 5255.32 | 5254.15 | 7.07 | -0.10 | Sewer Too Shallow |

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID | Sewer | Surcharged | Upstream | Downstream | Upstream | Downstream | |

| # | Length (Feet) | Length (Feet) | (Feet) | (Feet) | (Feet) | (Feet) | Condition |
|---|---|---|---|---|---|---|---|
| 2 | 20 | 0 | 5259.03 | 5258.67 | 5259.27 | 5258.83 | Jump |
| 4 | 180.1 | 0 | 5258.48 | 5255.53 | 5259.01 | 5255.94 | Jump |
| 6 | 71.5 | 0 | 5255.32 | 5254.15 | 5255.85 | 5254.56 | Jump |

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 2 | 1 | 5259.31 | 0.12 | 0.05 | 0.00 | 0.00 | 0.00 | 3 | 5259.19 |
| 4 | 3 | 5259.19 | 3.16 | 0.05 | 0.00 | 0.00 | 0.00 | 5 | 5256.03 |
| 6 | 5 | 5256.03 | 0.48 | 0.08 | 0.00 | 0.00 | 0.00 | 7 | 5255.55 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 5 | 5263.89 | 5255.32 | 8.57 |
| 3 | 5262.57 | 5258.48 | 4.09 |
| 1 | 5262.03 | 5259.03 | 3.00 |
| 7 | 5255.55 | 5254.15 | 1.40 |

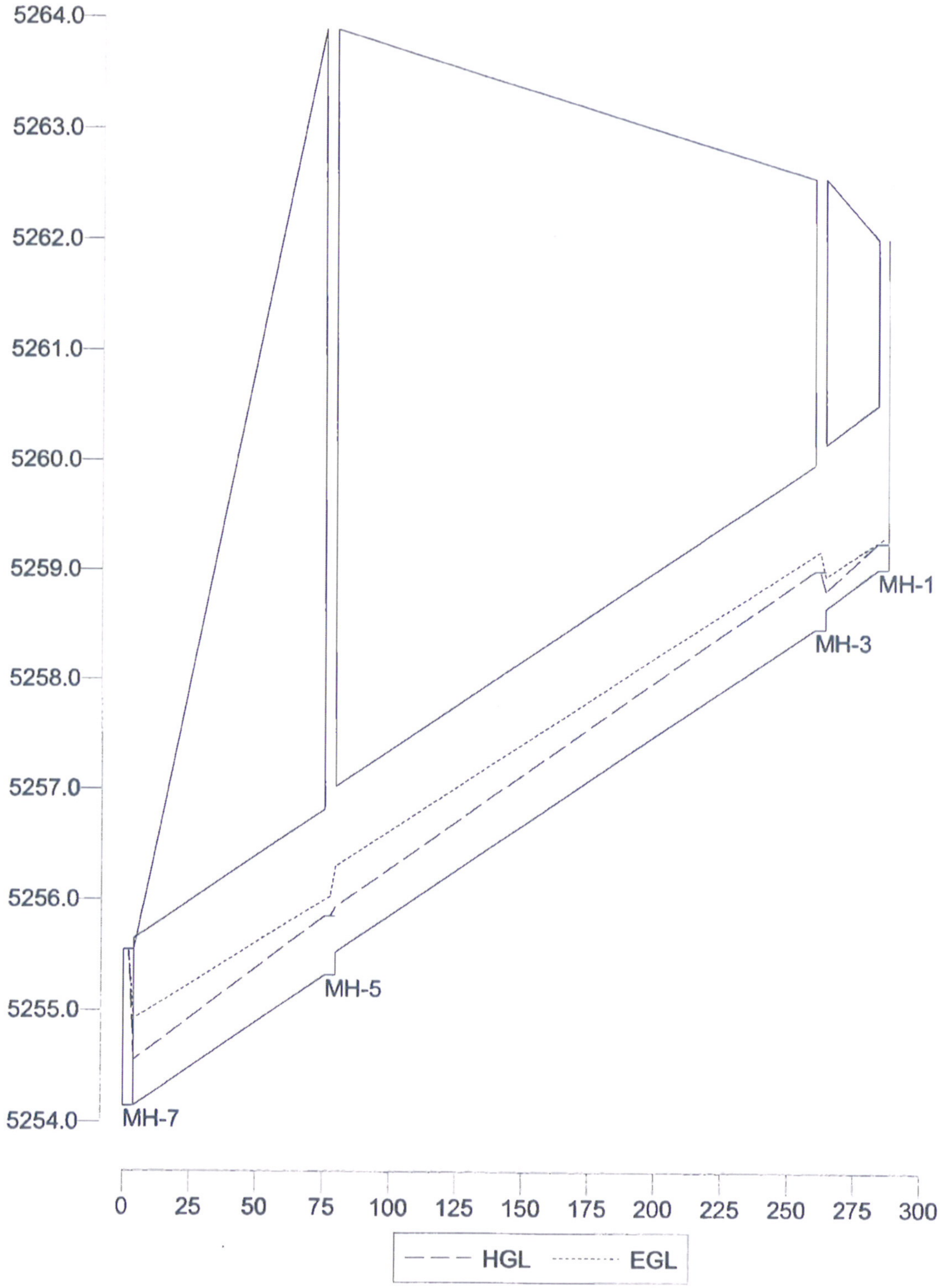
| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Earth |

| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Volume (Cubic Yards) |
|---|---|---|---|---|---|---|---|
| 2 | 6.1 | 3.9 | 7.9 | 3.9 | 20 | 2.50 | 15 |
| 4 | 8.3 | 3.9 | 16.8 | 3.9 | 180.1 | 2.50 | 343 |
| 6 | 17.2 | 3.9 | 2.9 | 3.9 | 71.5 | 2.50 | 121 |

Total earth volume for sewer trenches = 479.05 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.
If the bottom width is less than the minimum width, the minimum width was used.
The backfill depth under the sewer was assumed to be 1 foot.
The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

5 year Event

# C-1 to C-7



# Storm Sewer D
# HGL Calculations

# NeoUDS Results Summary

Storm sewer D

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 11:57:50 AM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 100 **Years.**

100 Year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| Manhole ID # | Basin Area * C | Overland (Minutes) | Gutter (Minutes) | Basin (Minutes) | Rain I (Inch/Hour) | Peak Flow (CFS) | Comments |
| 1 | 96.00 | 20228.2 | 0.0 | 0.0 | 0.03 | 2.9 | |
| 3 | 96.00 | 20228.2 | 0.0 | 0.0 | 0.03 | 2.9 | |
| 5 | 96.00 | 20228.2 | 0.0 | 0.0 | 0.03 | 2.9 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| Manhole ID # | Contributing Area * C | Rainfall Duration (Minutes) | Rainfall Intensity (Inch/Hour) | Design Peak Flow (CFS) | Ground Elevation (Feet) | Water Elevation (Feet) | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 96 | 20228.2 | 0.03 | 2.9 | 5259.06 | 5256.71 | |
| 3 | 192 | 48873.4 | 0.02 | 2.9 | 5263.81 | 5253.54 | |
| 5 | 0 | 0.0 | 0.00 | 2.9 | 5250.12 | 5250.12 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 2 | 1 | 3 | Round | 10.6 | 18 | 18 | N/A |
| 4 | 3 | 5 | Round | 10.6 | 18 | 18 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.
Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 2.9 | 11.9 | 0.50 | 5.6 | 0.65 | 3.9 | 1.6 | 1.61 | |
| 4 | 2.9 | 11.9 | 0.50 | 5.6 | 0.65 | 3.9 | 1.6 | 1.61 | |

A Froude number = 0 indicated that a pressured flow occurs.

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 2 | 1.70 | 5256.06 | 5253.08 | 1.50 | 9.23 | Sewer Too Shallow |
| 4 | 1.70 | 5252.89 | 5248.70 | 9.42 | -0.08 | Sewer Too Shallow |

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Sewer Length (Feet) | Surcharged Length (Feet) | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Condition |
| 2 | 175.2 | 0 | 5256.06 | 5253.08 | 5256.71 | 5253.59 | Jump |
| 4 | 246.2 | 0 | 5252.89 | 5248.70 | 5253.54 | 5249.21 | Jump |

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 2 | 1 | 5256.95 | 3.17 | 0.05 | 0.00 | 0.00 | 0.00 | 3 | 5253.78 |
| 4 | 3 | 5253.78 | 3.66 | 0.05 | 0.00 | 0.00 | 0.00 | 5 | 5250.12 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

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## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 1 | 5259.06 | 5256.06 | 3.00 |
| 3 | 5263.81 | 5252.89 | 10.92 |
| 5 | 5250.12 | 5248.70 | 1.42 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Earth Volume (Cubic Yards) |
| 2 | 6.1 | 3.9 | 21.5 | 3.9 | 175.2 | 2.50 | 456 |
| 4 | 21.9 | 3.9 | 2.9 | 3.9 | 246.2 | 2.50 | 627 |

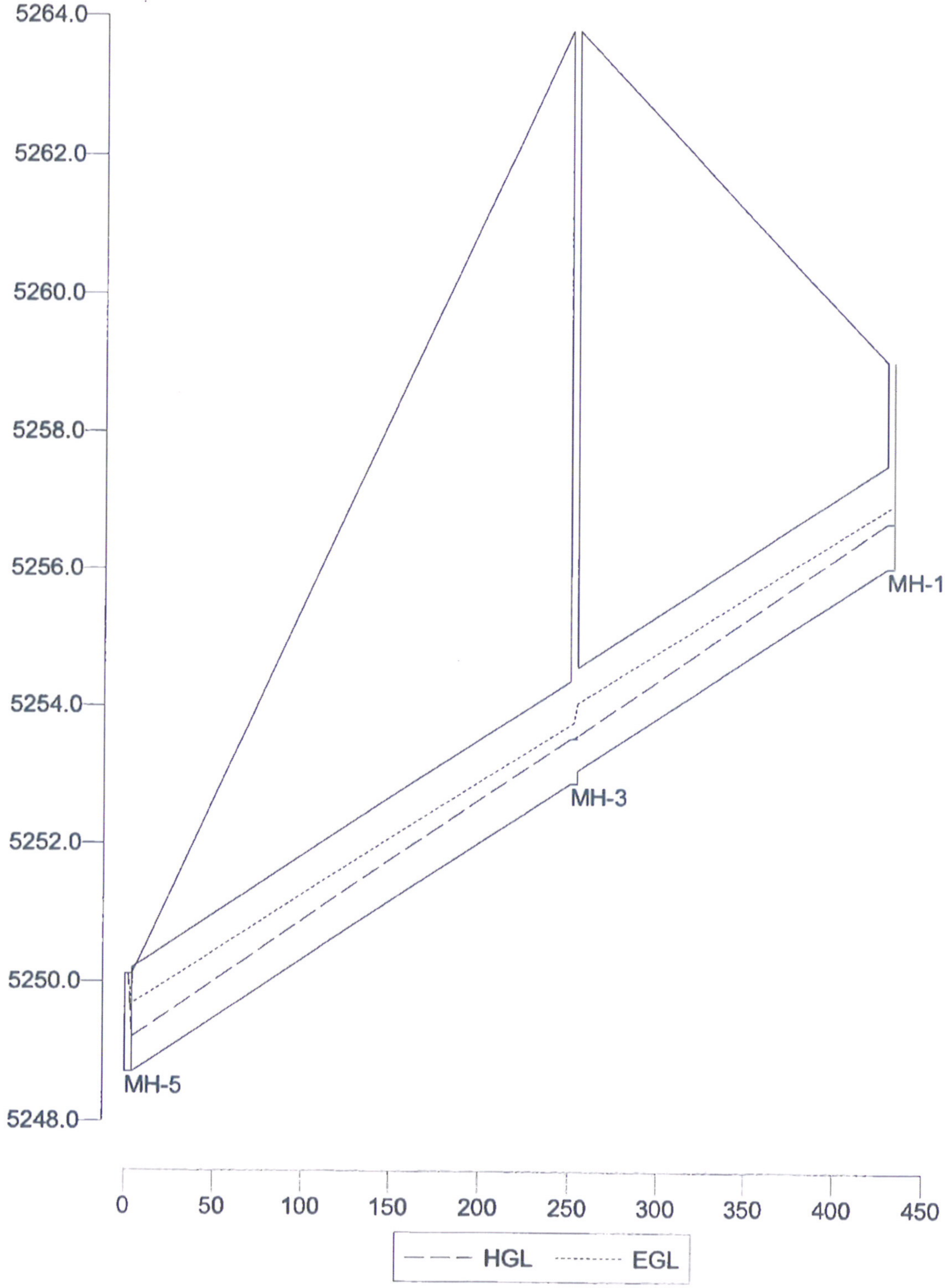
Total earth volume for sewer trenches = 1082.3 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

100 Year Event

# D-1 to D-5



# NeoUDS Results Summary

Storm Sewer D

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 1:27:35 PM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 5 **Years.**

5year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| **Manhole ID #** | **Basin Area * C** | **Overland (Minutes)** | **Gutter (Minutes)** | **Basin (Minutes)** | **Rain I (Inch/Hour)** | **Peak Flow (CFS)** | **Comments** |
| 1 | 96.00 | 39917.5 | 0.0 | 0.0 | 0.02 | 1.7 | |
| 3 | 96.00 | 39917.5 | 0.0 | 0.0 | 0.02 | 1.7 | |
| 5 | 96.00 | 39917.5 | 0.0 | 0.0 | 0.02 | 1.7 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| **Manhole ID #** | **Contributing Area * C** | **Rainfall Duration (Minutes)** | **Rainfall Intensity (Inch/Hour)** | **Design Peak Flow (CFS)** | **Ground Elevation (Feet)** | **Water Elevation (Feet)** | **Comments** |
|---|---|---|---|---|---|---|---|
| 1 | 96 | 39917.5 | 0.02 | 1.7 | 5259.06 | 5256.57 | |
| 3 | 192 | 96431.1 | 0.01 | 1.7 | 5263.81 | 5253.40 | |
| 5 | 0 | 0.0 | 0.00 | 1.7 | 5250.12 | 5250.12 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 2 | 1 | 3 | Round | 8.7 | 18 | 18 | N/A |
| 4 | 3 | 5 | Round | 8.7 | 18 | 18 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.
Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 1.7 | 11.9 | 0.38 | 4.8 | 0.51 | 3.2 | 1.0 | 1.61 | |
| 4 | 1.7 | 11.9 | 0.38 | 4.8 | 0.51 | 3.2 | 1.0 | 1.61 | |

A Froude number = 0 indicated that a pressured flow occurs.

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 2 | 1.70 | 5256.06 | 5253.08 | 1.50 | 9.23 | Sewer Too Shallow |
| 4 | 1.70 | 5252.89 | 5248.70 | 9.42 | -0.08 | Sewer Too Shallow |

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Sewer Length (Feet) | Surcharged Length (Feet) | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Condition |
| 2 | 175.2 | 0 | 5256.06 | 5253.08 | 5256.57 | 5253.46 | Jump |
| 4 | 246.2 | 0 | 5252.89 | 5248.70 | 5253.40 | 5249.09 | Jump |

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 2 | 1 | 5256.73 | 3.17 | 0.05 | 0.00 | 0.00 | 0.00 | 3 | 5253.56 |
| 4 | 3 | 5253.56 | 3.44 | 0.05 | 0.00 | 0.00 | 0.00 | 5 | 5250.12 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

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## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 1 | 5259.06 | 5256.06 | 3.00 |
| 3 | 5263.81 | 5252.89 | 10.92 |
| 5 | 5250.12 | 5248.70 | 1.42 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Earth Volume (Cubic Yards) |
| 2 | 6.1 | 3.9 | 21.5 | 3.9 | 175.2 | 2.50 | 456 |
| 4 | 21.9 | 3.9 | 2.9 | 3.9 | 246.2 | 2.50 | 627 |

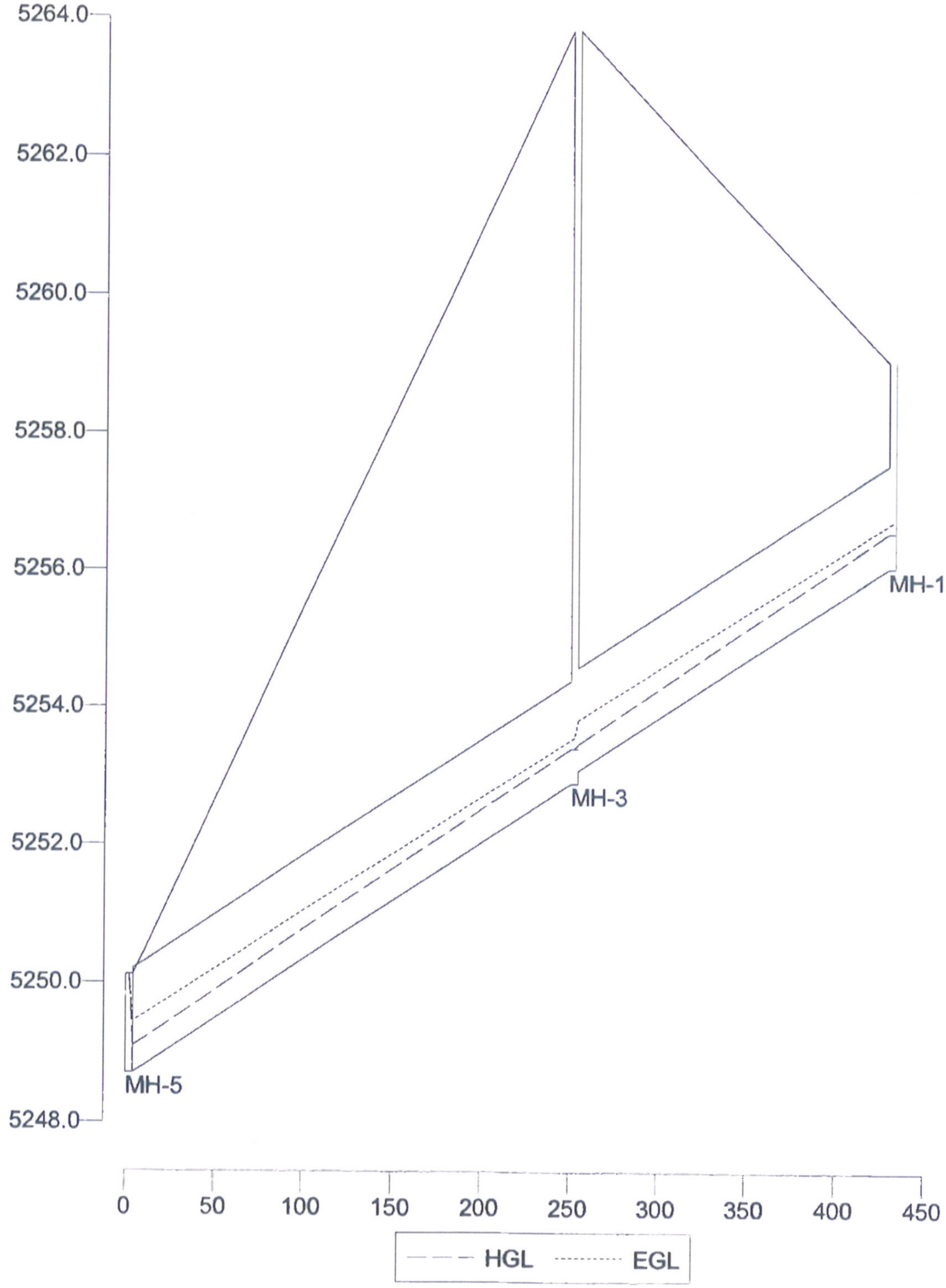
Total earth volume for sewer trenches = 1082.3 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

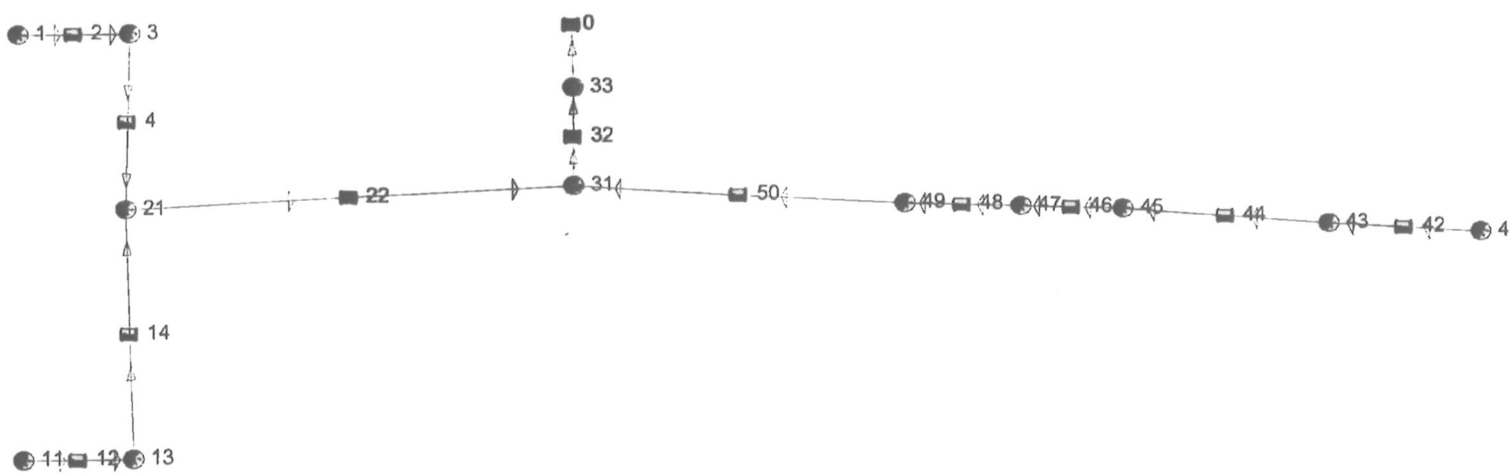
The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

5year Event

# D-1 to D-5



# Storm Sewer E
# HGL Calculations



# NeoUDS Results Summary

Storm Sewer E

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 2:36:54 PM
**Using** NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 100 **Years.**

100 Year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| Manhole ID # | Basin Area * C | Overland (Minutes) | Gutter (Minutes) | Basin (Minutes) | Rain I (Inch/Hour) | Peak Flow (CFS) | Comments |
| 33 | 96.00 | 2312.6 | 0.0 | 0.0 | 0.17 | 15.9 | |
| 31 | 96.00 | 2312.6 | 0.0 | 0.0 | 0.17 | 15.9 | |
| 49 | 96.00 | 7098.7 | 0.0 | 0.0 | 0.07 | 6.6 | |
| 47 | 96.00 | 10649.7 | 0.0 | 0.0 | 0.05 | 4.8 | |
| 45 | 96.00 | 12251.0 | 0.0 | 0.0 | 0.04 | 4.3 | |
| 43 | 96.00 | 21152.2 | 0.0 | 0.0 | 0.03 | 2.8 | |
| 41 | 96.00 | 51105.3 | 0.0 | 0.0 | 0.01 | 1.4 | |
| 21 | 96.00 | 5930.7 | 0.0 | 0.0 | 0.08 | 7.6 | |
| 3 | 96.00 | 11897.6 | 0.0 | 0.0 | 0.05 | 4.4 | |
| 1 | 96.00 | 11897.6 | 0.0 | 0.0 | 0.05 | 4.4 | |
| 13 | 96.00 | 17845.8 | 0.0 | 0.0 | 0.03 | 3.2 | |
| 11 | 96.00 | 17845.8 | 0.0 | 0.0 | 0.03 | 3.2 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| | | Rainfall | Rainfall | Design | Ground | Water | |
|---|---|---|---|---|---|---|---|

| Manhole ID # | Contributing Area * C | Duration (Minutes) | Intensity (Inch/Hour) | Peak Flow (CFS) | Elevation (Feet) | Elevation (Feet) | Comments |
|---|---|---|---|---|---|---|---|
| 33 | 0 | 0.0 | 0.00 | 15.9 | 5239.54 | 5239.54 | |
| 31 | 1056 | 49069.1 | 0.02 | 15.9 | 5244.94 | 5239.88 | |
| 49 | 480 | 55078.7 | 0.01 | 6.6 | 5244.11 | 5241.11 | |
| 47 | 384 | 62180.6 | 0.01 | 4.8 | 5244.10 | 5241.23 | |
| 45 | 288 | 49597.7 | 0.01 | 4.3 | 5244.12 | 5241.60 | |
| 43 | 192 | 51105.3 | 0.01 | 2.8 | 5244.71 | 5242.28 | |
| 41 | 96 | 51105.3 | 0.01 | 1.4 | 5245.26 | 5243.08 | |
| 21 | 480 | 46027.5 | 0.02 | 7.6 | 5250.23 | 5243.91 | |
| 3 | 192 | 28751.6 | 0.02 | 4.4 | 5250.01 | 5245.29 | |
| 1 | 96 | 11897.6 | 0.05 | 4.4 | 5250.34 | 5245.74 | |
| 13 | 192 | 43119.1 | 0.02 | 3.2 | 5248.95 | 5244.42 | |
| 11 | 96 | 17845.8 | 0.03 | 3.2 | 5249.33 | 5244.89 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 32 | 31 | 33 | Round | 23.5 | 24 | 24 | N/A |
| 50 | 49 | 31 | Round | 16.0 | 18 | 18 | N/A |
| 48 | 47 | 49 | Round | 13.9 | 18 | 18 | N/A |
| 46 | 45 | 47 | Round | 13.3 | 18 | 18 | N/A |
| 44 | 43 | 45 | Round | 12.8 | 18 | 18 | N/A |
| 42 | 41 | 43 | Round | 10.4 | 18 | 14 | N/A |
| 22 | 21 | 31 | Round | 17.2 | 18 | 18 | N/A |
| 4 | 3 | 21 | Round | 13.1 | 18 | 18 | N/A |
| 2 | 1 | 3 | Round | 13.1 | 18 | 18 | N/A |
| 14 | 13 | 21 | Round | 11.3 | 18 | 18 | N/A |
| 12 | 11 | 13 | Round | 11.3 | 18 | 18 | N/A |

Round and arch sewers are measured in inches.

Box sewers are measured in feet.

Calculated diameter was determined by sewer hydraulic capacity.

Suggested diameter was rounded up to the nearest commercially available size

All hydraulics where calculated using the existing parameters.

If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 15.9 | 16.8 | 1.55 | 6.1 | 1.42 | 6.7 | 5.1 | 0.86 | |
| 50 | 6.6 | 9.0 | 0.95 | 5.6 | 0.99 | 5.3 | 3.7 | 1.08 | |
| 48 | 4.8 | 9.6 | 0.75 | 5.4 | 0.84 | 4.7 | 2.7 | 1.24 | |
| 46 | 4.3 | 9.6 | 0.71 | 5.3 | 0.80 | 4.5 | 2.4 | 1.26 | |
| 44 | 2.8 | 7.0 | 0.66 | 3.7 | 0.64 | 3.9 | 1.6 | 0.93 | |
| 42 | 1.4 | 3.1 | 0.55 | 2.8 | 0.49 | 3.3 | 1.3 | 0.76 | |
| 22 | 7.6 | 8.6 | 1.10 | 5.5 | 1.06 | 5.7 | 4.3 | 0.94 | |
| 4 | 4.4 | 10.2 | 0.69 | 5.6 | 0.81 | 4.5 | 2.5 | 1.35 | |
| 2 | 4.4 | 10.2 | 0.69 | 5.6 | 0.81 | 4.5 | 2.5 | 1.35 | |
| 14 | 3.2 | 11.1 | 0.55 | 5.4 | 0.68 | 4.1 | 1.8 | 1.5 | |
| 12 | 3.2 | 11.2 | 0.55 | 5.5 | 0.68 | 4.1 | 1.8 | 1.51 | |

A Froude number = 0 indicated that a pressured flow occurs.

## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 32 | 0.55 | 5238.31 | 5237.87 | 4.63 | -0.33 | Sewer Too Shallow |
| 50 | 0.97 | 5239.96 | 5238.50 | 2.65 | 4.94 | |
| 48 | 1.10 | 5240.38 | 5240.16 | 2.22 | 2.45 | |
| 46 | 1.10 | 5240.80 | 5240.58 | 1.82 | 2.02 | Sewer Too Shallow |
| 44 | 0.44 | 5241.62 | 5241.00 | 1.59 | 1.62 | Sewer Too Shallow |
| 42 | 0.44 | 5242.53 | 5241.82 | 1.56 | 1.72 | Sewer Too Shallow |
| 22 | 0.88 | 5242.44 | 5239.95 | 6.29 | 3.49 | |
| 4 | 1.25 | 5244.48 | 5243.28 | 4.03 | 5.45 | |
| 2 | 1.25 | 5244.93 | 5244.68 | 3.91 | 3.83 | |
| 14 | 1.48 | 5243.70 | 5242.64 | 3.75 | 6.09 | |
| 12 | 1.50 | 5244.20 | 5243.90 | 3.63 | 3.55 | |

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Sewer Length (Feet) | Surcharged Length (Feet) | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Condition |
| 32 | 79.6 | 0 | 5238.31 | 5237.87 | 5239.88 | 5239.42 | Subcritical |
| 50 | 150 | 113.46 | 5239.96 | 5238.50 | 5241.11 | 5239.46 | Jump |
| 48 | 20 | 0 | 5240.38 | 5240.16 | 5241.23 | 5240.91 | Jump |
| 46 | 20 | 0 | 5240.80 | 5240.58 | 5241.60 | 5241.28 | Jump |
| 44 | 141.6 | 0 | 5241.62 | 5241.00 | 5242.28 | 5241.66 | Subcritical |
| 42 | 161.2 | 0 | 5242.53 | 5241.82 | 5243.08 | 5242.37 | Subcritical |
| 22 | 283.5 | 0 | 5242.44 | 5239.95 | 5243.91 | 5241.04 | Subcritical |
| 4 | 95.9 | 0 | 5244.48 | 5243.28 | 5245.29 | 5243.97 | Jump |
| 2 | 20 | 0 | 5244.93 | 5244.68 | 5245.74 | 5245.37 | Jump |
| 14 | 71.4 | 18.87 | 5243.70 | 5242.64 | 5244.42 | 5243.19 | Jump |
| 12 | 20 | 0 | 5244.20 | 5243.90 | 5244.89 | 5244.45 | Jump |

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 32 | 31 | 5240.44 | 0.90 | 0.05 | 0.00 | 0.00 | 0.00 | 33 | 5239.54 |
| 50 | 49 | 5241.32 | 0.59 | 1.32 | 0.29 | 0.00 | 0.00 | 31 | 5240.44 |
| 48 | 47 | 5241.34 | 0.02 | 0.05 | 0.01 | 0.00 | 0.00 | 49 | 5241.32 |
| 46 | 45 | 5241.91 | 0.56 | 0.05 | 0.00 | 0.00 | 0.00 | 47 | 5241.34 |
| 44 | 43 | 5242.50 | 0.58 | 0.05 | 0.00 | 0.00 | 0.00 | 45 | 5241.91 |
| 42 | 41 | 5243.21 | 0.71 | 0.05 | 0.00 | 0.00 | 0.00 | 43 | 5242.50 |
| 22 | 21 | 5244.38 | 3.56 | 1.32 | 0.38 | 0.00 | 0.00 | 31 | 5240.44 |
| 4 | 3 | 5245.61 | 1.10 | 1.32 | 0.13 | 0.00 | 0.00 | 21 | 5244.38 |
| 2 | 1 | 5246.06 | 0.32 | 1.32 | 0.13 | 0.00 | 0.00 | 3 | 5245.61 |
| 14 | 13 | 5244.47 | 0.02 | 1.32 | 0.07 | 0.00 | 0.00 | 21 | 5244.38 |
| 12 | 11 | 5245.14 | 0.60 | 1.32 | 0.07 | 0.00 | 0.00 | 13 | 5244.47 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 33 | 5239.54 | 5237.87 | 1.67 |
| 31 | 5244.94 | 5238.31 | 6.63 |
| 49 | 5244.11 | 5239.96 | 4.15 |
| 47 | 5244.10 | 5240.38 | 3.72 |
| 45 | 5244.12 | 5240.80 | 3.32 |
| 43 | 5244.71 | 5241.62 | 3.09 |
| 41 | 5245.26 | 5242.53 | 2.73 |
| 21 | 5250.23 | 5242.44 | 7.79 |
| 3 | 5250.01 | 5244.48 | 5.53 |
| 1 | 5250.34 | 5244.93 | 5.41 |
| 13 | 5248.95 | 5243.70 | 5.25 |
| 11 | 5249.33 | 5244.20 | 5.13 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Earth Volume (Cubic Yards) |
| 32 | 12.8 | 4.5 | 2.8 | 4.5 | 79.6 | 3.00 | 94 |
| 50 | 8.4 | 3.9 | 13.0 | 3.9 | 150 | 2.50 | 207 |
| 48 | 7.5 | 3.9 | 8.0 | 3.9 | 20 | 2.50 | 17 |
| 46 | 6.7 | 3.9 | 7.1 | 3.9 | 20 | 2.50 | 15 |
| 44 | 6.3 | 3.9 | 6.3 | 3.9 | 141.6 | 2.50 | 92 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 42 | 5.9 | 3.5 | 6.3 | 3.5 | 161.2 | 2.17 | 90 |
| 22 | 15.7 | 3.9 | 10.1 | 3.9 | 283.5 | 2.50 | 535 |
| 4 | 11.1 | 3.9 | 14.0 | 3.9 | 95.9 | 2.50 | 169 |
| 2 | 10.9 | 3.9 | 10.7 | 3.9 | 20 | 2.50 | 27 |
| 14 | 10.6 | 3.9 | 15.3 | 3.9 | 71.4 | 2.50 | 134 |
| 12 | 10.3 | 3.9 | 10.2 | 3.9 | 20 | 2.50 | 25 |

Total earth volume for sewer trenches = 1405.28 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.

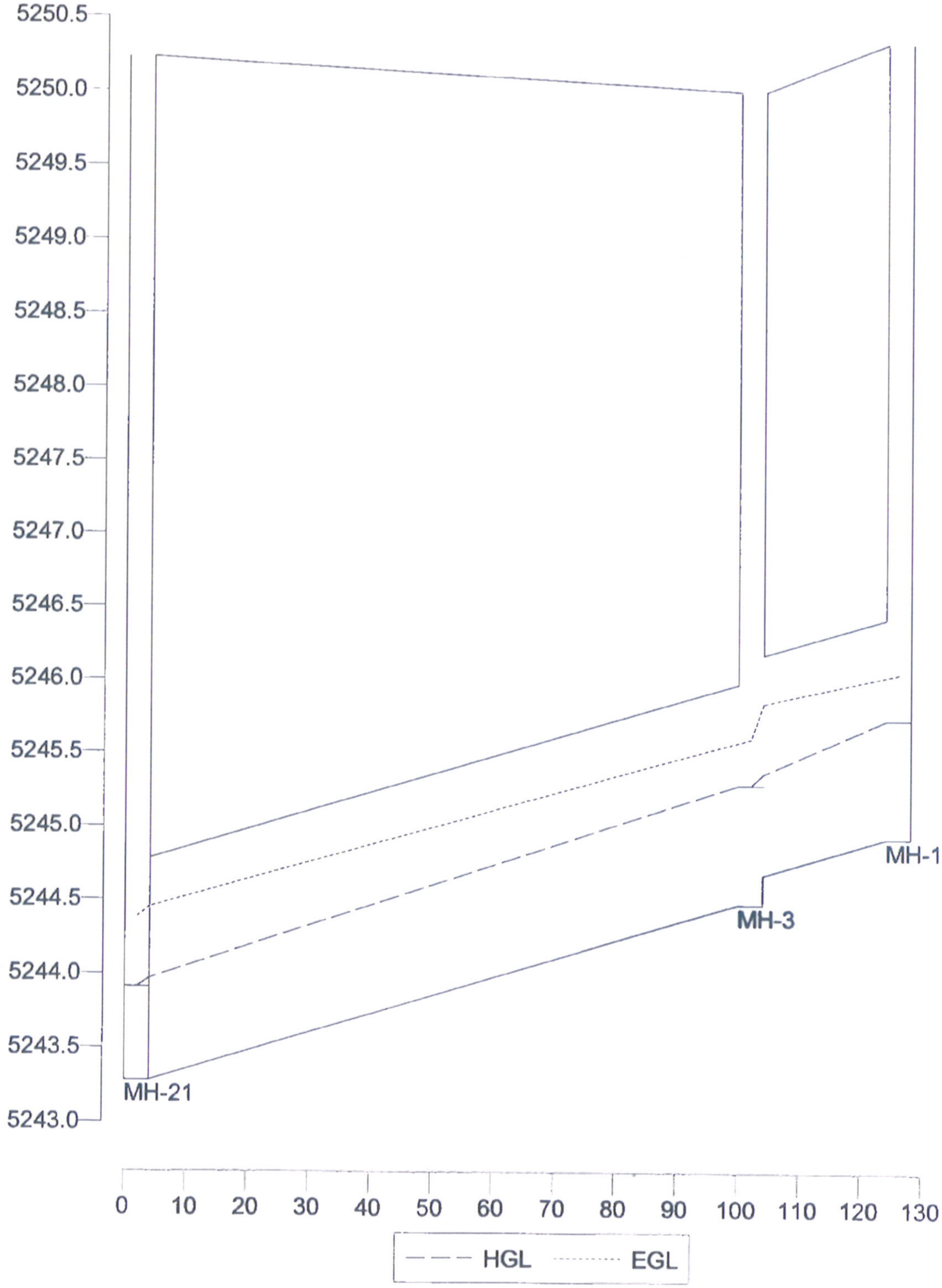
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

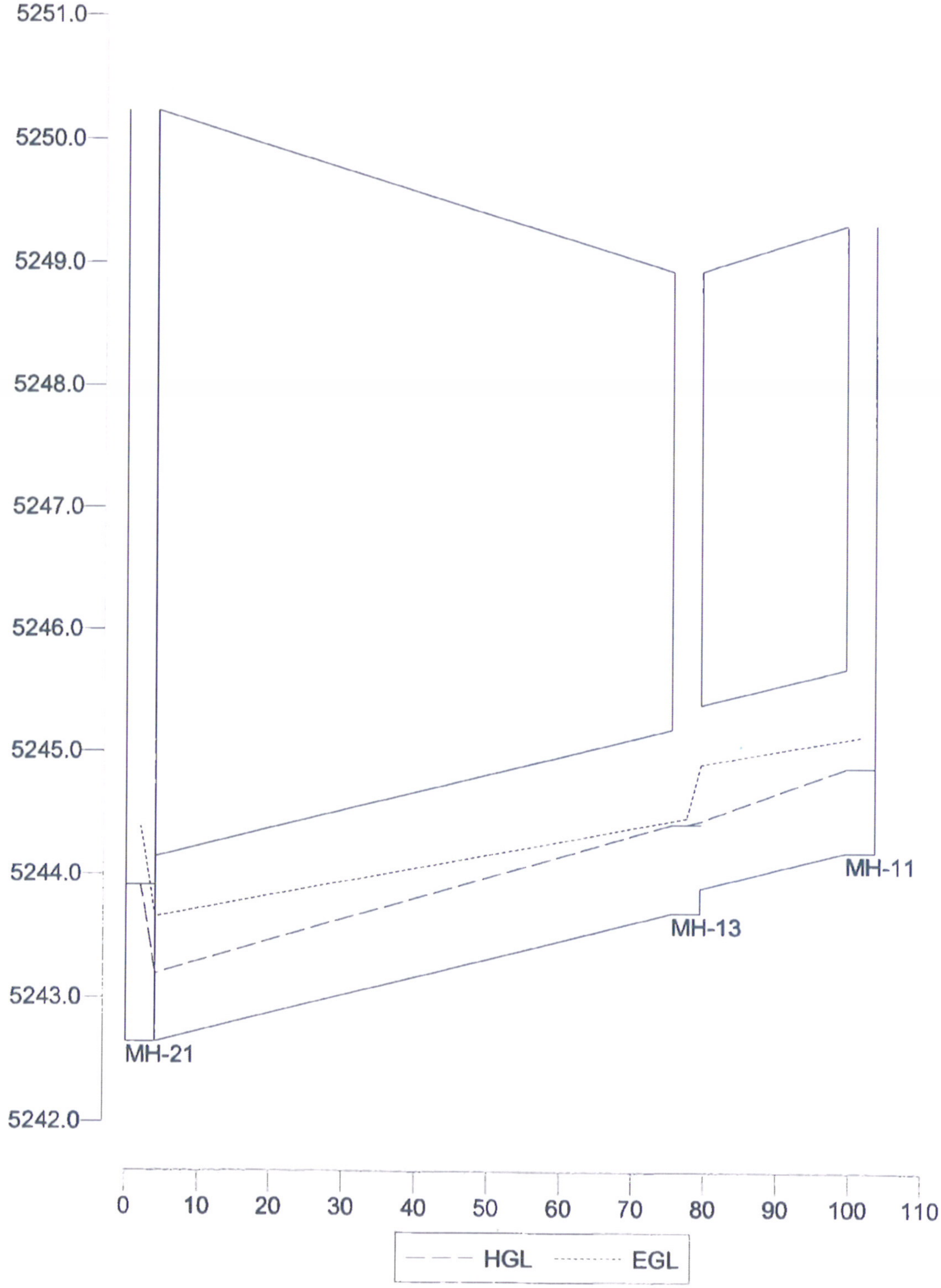
100 Year Event

# E-1 to E-21



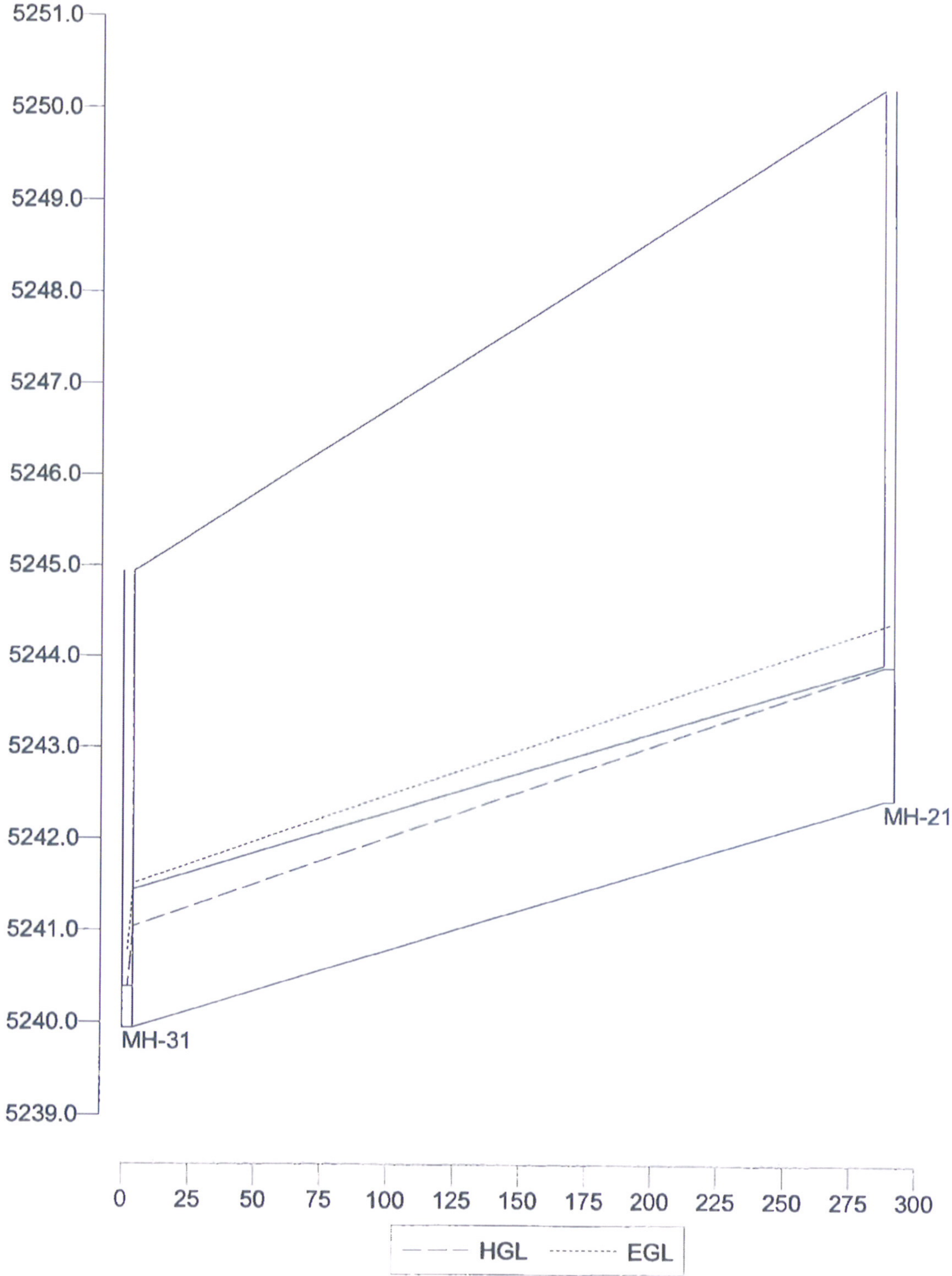
100 Year Event

# E-11 to E-14



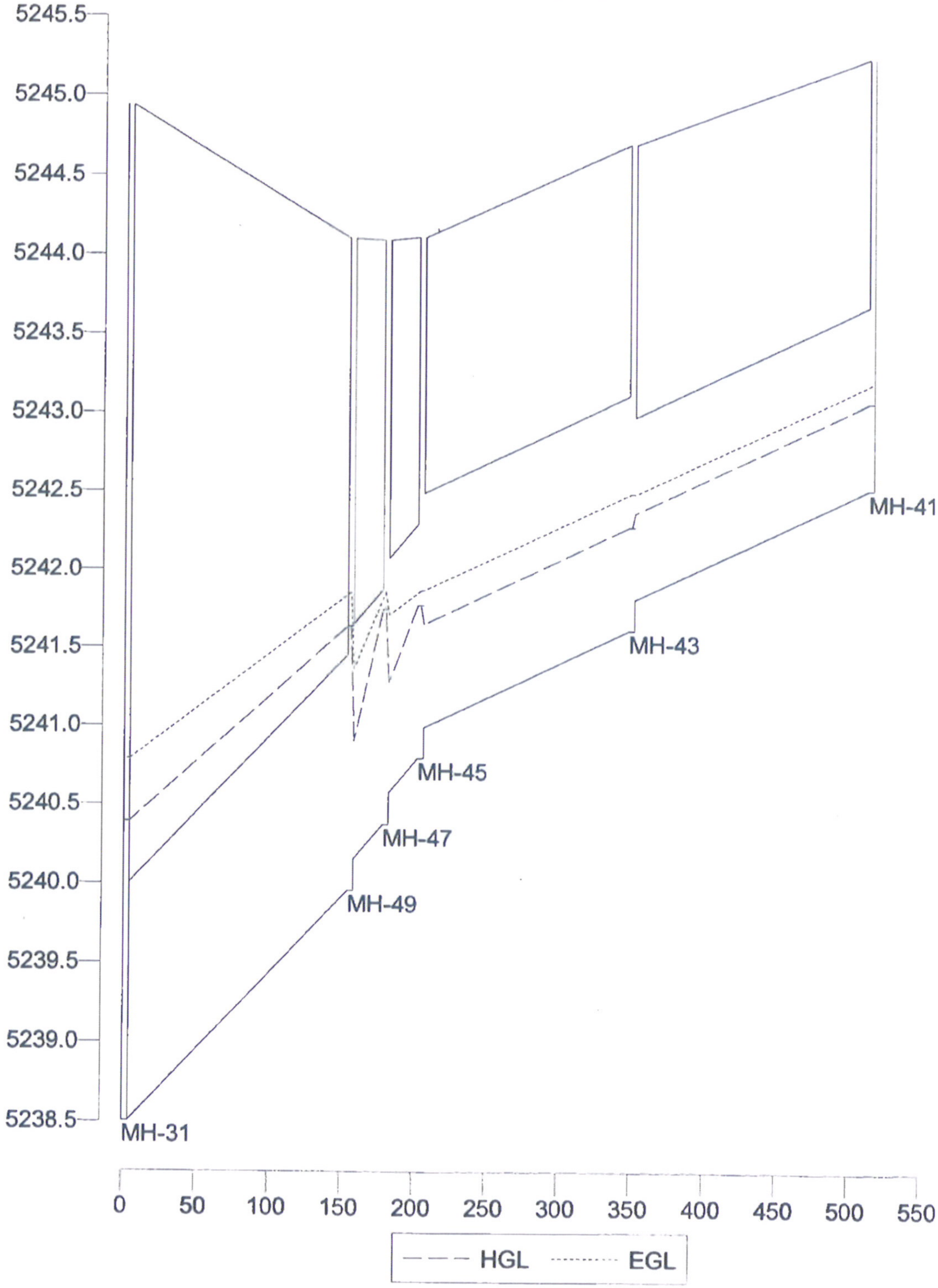
100 Year Event

# E-21 to E-31



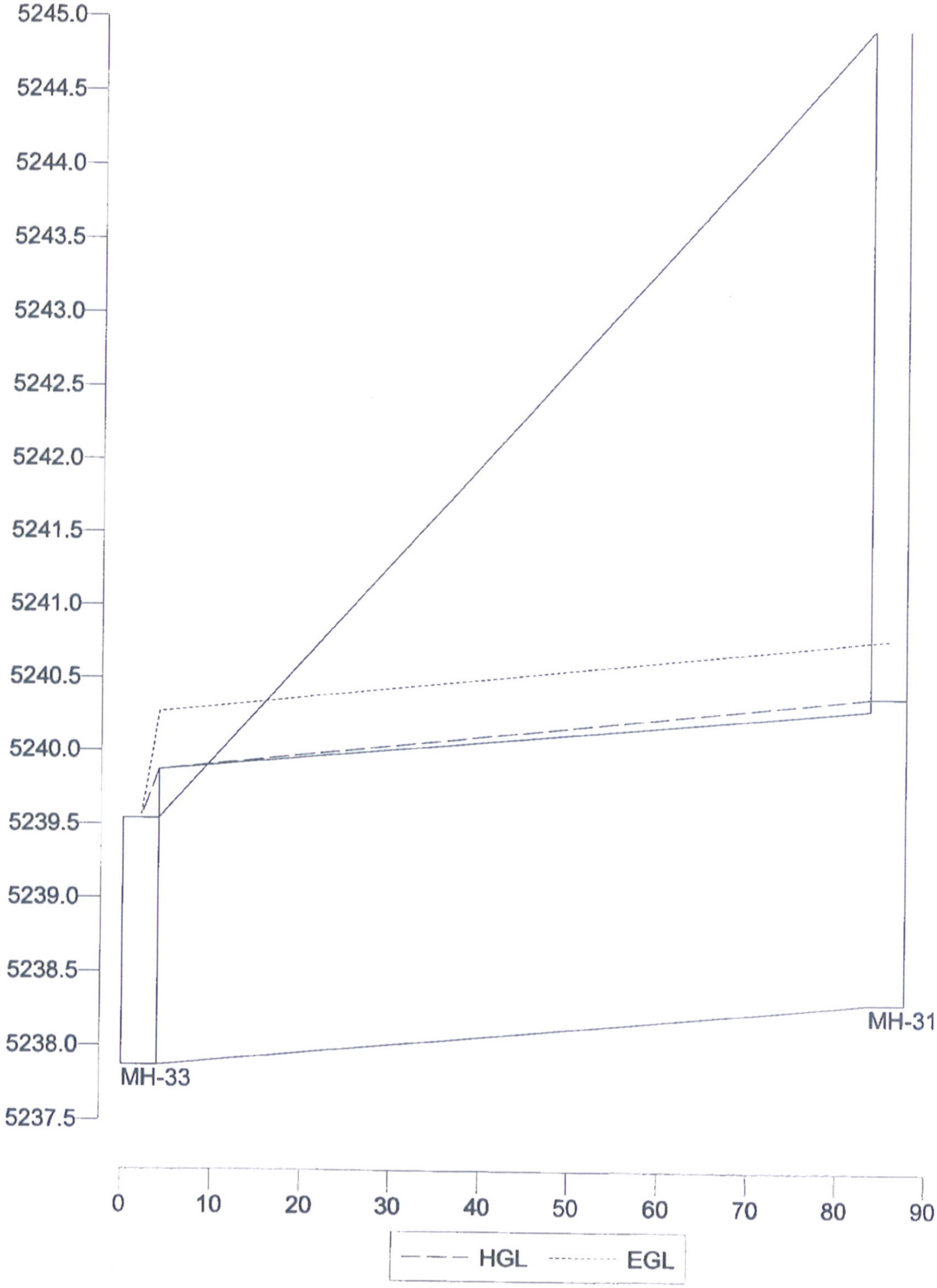
100 Year Event

# E-41 to E-31



100 Year Event

# E-31 to E-33



# NeoUDS Results Summary

Storm Sewer E

**Project Title:**
**Project Description:**
**Output Created On:** 3/10/2011 at 1:39:46 PM
Using NeoUDSewer Version 1.6.7 Beta Release.
**Rainfall Intensity** Formula **Used.**
**Return Period of Flood is** 5 **Years.**

5 Year Event

## Sub Basin Information

| | | Time of Concentration | | | | | |
|---|---|---|---|---|---|---|---|
| Manhole ID # | Basin Area * C | Overland (Minutes) | Gutter (Minutes) | Basin (Minutes) | Rain I (Inch/Hour) | Peak Flow (CFS) | Comments |
| 33 | 96.00 | 5468.1 | 0.0 | 0.0 | 0.08 | 8.1 | |
| 31 | 96.00 | 5468.1 | 0.0 | 0.0 | 0.08 | 8.1 | |
| 49 | 96.00 | 18581.8 | 0.0 | 0.0 | 0.03 | 3.1 | |
| 47 | 96.00 | 30505.2 | 0.0 | 0.0 | 0.02 | 2.1 | |
| 45 | 96.00 | 30505.2 | 0.0 | 0.0 | 0.02 | 2.1 | |
| 43 | 96.00 | 123454.1 | 0.0 | 0.0 | 0.01 | 0.7 | |
| 41 | 96.00 | 123454.1 | 0.0 | 0.0 | 0.01 | 0.7 | |
| 21 | 96.00 | 13432.7 | 0.0 | 0.0 | 0.04 | 4.0 | |
| 3 | 96.00 | 28751.6 | 0.0 | 0.0 | 0.02 | 2.2 | |
| 1 | 96.00 | 28751.6 | 0.0 | 0.0 | 0.02 | 2.2 | |
| 13 | 96.00 | 37117.0 | 0.0 | 0.0 | 0.02 | 1.8 | |
| 11 | 96.00 | 37117.0 | 0.0 | 0.0 | 0.02 | 1.8 | |

The shortest design rainfall duration is 5 minutes.
For rural areas, the catchment time of concentration is always => 10 minutes.
For urban areas, the catchment time of concentration is always => 5 minutes.
At the first design point, the time constant is <= (10+Total Length/180) in minutes.
When the weighted runoff coefficient => 0.2, then the basin is considered to be urbanized.
When the Overland Tc plus the Gutter Tc does not equal the catchment Tc, the above criteria supersedes the calculated values.

## Summary of Manhole Hydraulics

| | | Rainfall | Rainfall | Design | Ground | Water | |
|---|---|---|---|---|---|---|---|

| Manhole ID # | Contributing Area * C | Duration (Minutes) | Intensity (Inch/Hour) | Peak Flow (CFS) | Elevation (Feet) | Elevation (Feet) | Comments |
|---|---|---|---|---|---|---|---|
| 33 | 0 | 0.0 | 0.00 | 8.1 | 5239.54 | 5239.54 | |
| 31 | 1056 | 115749.9 | 0.01 | 8.1 | 5244.94 | 5239.62 | |
| 49 | 480 | 144067.9 | 0.01 | 3.1 | 5244.11 | 5240.63 | |
| 47 | 384 | 178021.1 | 0.01 | 2.1 | 5244.10 | 5240.94 | |
| 45 | 288 | 123454.1 | 0.01 | 2.1 | 5244.12 | 5241.36 | |
| 43 | 192 | 298205.8 | 0.00 | 0.7 | 5244.71 | 5241.94 | |
| 41 | 96 | 123454.1 | 0.01 | 0.7 | 5245.26 | 5242.91 | |
| 21 | 480 | 104164.1 | 0.01 | 4.0 | 5250.23 | 5243.22 | |
| 3 | 192 | 69460.8 | 0.01 | 2.2 | 5250.01 | 5245.07 | |
| 1 | 96 | 28751.6 | 0.02 | 2.2 | 5250.34 | 5245.52 | |
| 13 | 192 | 89666.8 | 0.01 | 1.8 | 5248.95 | 5244.22 | |
| 11 | 96 | 37117.0 | 0.02 | 1.8 | 5249.33 | 5244.72 | |

## Summary of Sewer Hydraulics

Note: The given depth to flow ratio is 0.9.

| | Manhole ID Number | | | Calculated | Suggested | Existing | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Upstream | Downstream | Sewer Shape | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Diameter (Rise) (Inches) (FT) | Width (FT) |
| 32 | 31 | 33 | Round | 19.3 | 21 | 24 | N/A |
| 50 | 49 | 31 | Round | 12.1 | 18 | 18 | N/A |
| 48 | 47 | 49 | Round | 10.2 | 18 | 18 | N/A |
| 46 | 45 | 47 | Round | 10.2 | 18 | 18 | N/A |
| 44 | 43 | 45 | Round | 7.6 | 18 | 18 | N/A |
| 42 | 41 | 43 | Round | 8.0 | 18 | 14 | N/A |
| 22 | 21 | 31 | Round | 13.5 | 18 | 18 | N/A |
| 4 | 3 | 21 | Round | 10.1 | 18 | 18 | N/A |
| 2 | 1 | 3 | Round | 10.1 | 18 | 18 | N/A |
| 14 | 13 | 21 | Round | 9.1 | 18 | 18 | N/A |
| 12 | 11 | 13 | Round | 9.1 | 18 | 18 | N/A |

Round and arch sewers are measured in inches.
Box sewers are measured in feet.
Calculated diameter was determined by sewer hydraulic capacity.

Suggested diameter was rounded up to the nearest commercially available size
All hydraulics where calculated using the existing parameters.
If sewer was sized mathematically, the suggested diameter was used for hydraulic calculations.

| Sewer ID | Design Flow (CFS) | Full Flow (CFS) | Normal Depth (Feet) | Normal Velocity (FPS) | Critical Depth (Feet) | Critical Velocity (FPS) | Full Velocity (FPS) | Froude Number | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 8.1 | 14.6 | 1.06 | 4.8 | 1.03 | 5.0 | 2.6 | 0.91 | |
| 50 | 3.1 | 9.0 | 0.61 | 4.6 | 0.67 | 4.0 | 1.8 | 1.21 | |
| 48 | 2.1 | 9.6 | 0.48 | 4.3 | 0.56 | 3.5 | 1.2 | 1.3 | |
| 46 | 2.1 | 9.6 | 0.48 | 4.3 | 0.56 | 3.5 | 1.2 | 1.3 | |
| 44 | 0.7 | 7.0 | 0.32 | 2.5 | 0.34 | 2.4 | 0.4 | 0.94 | |
| 42 | 0.7 | 3.1 | 0.38 | 2.3 | 0.35 | 2.6 | 0.7 | 0.79 | |
| 22 | 4.0 | 8.6 | 0.72 | 4.8 | 0.78 | 4.3 | 2.3 | 1.12 | |
| 4 | 2.2 | 10.2 | 0.47 | 4.6 | 0.59 | 3.4 | 1.2 | 1.39 | |
| 2 | 2.2 | 10.2 | 0.47 | 4.6 | 0.59 | 3.4 | 1.2 | 1.39 | |
| 14 | 1.8 | 11.1 | 0.41 | 4.6 | 0.52 | 3.3 | 1.0 | 1.51 | |
| 12 | 1.8 | 11.2 | 0.41 | 4.6 | 0.52 | 3.3 | 1.0 | 1.52 | |

A Froude number = 0 indicated that a pressured flow occurs.

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## Summary of Sewer Design Information

| | | Invert Elevation | | Buried Depth | | |
|---|---|---|---|---|---|---|
| Sewer ID | Slope % | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Comment |
| 32 | 0.55 | 5238.31 | 5237.87 | 4.63 | -0.33 | Sewer Too Shallow |
| 50 | 0.97 | 5239.96 | 5238.50 | 2.65 | 4.94 | |
| 48 | 1.10 | 5240.38 | 5240.16 | 2.22 | 2.45 | |
| 46 | 1.10 | 5240.80 | 5240.58 | 1.82 | 2.02 | Sewer Too Shallow |
| 44 | 0.44 | 5241.62 | 5241.00 | 1.59 | 1.62 | Sewer Too Shallow |
| 42 | 0.44 | 5242.53 | 5241.82 | 1.56 | 1.72 | Sewer Too Shallow |
| 22 | 0.88 | 5242.44 | 5239.95 | 6.29 | 3.49 | |
| 4 | 1.25 | 5244.48 | 5243.28 | 4.03 | 5.45 | |
| 2 | 1.25 | 5244.93 | 5244.68 | 3.91 | 3.83 | |
| 14 | 1.48 | 5243.70 | 5242.64 | 3.75 | 6.09 | |
| 12 | 1.50 | 5244.20 | 5243.90 | 3.63 | 3.55 | |

## Summary of Hydraulic Grade Line

| | | | Invert Elevation | | Water Elevation | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | Sewer Length (Feet) | Surcharged Length (Feet) | Upstream (Feet) | Downstream (Feet) | Upstream (Feet) | Downstream (Feet) | Condition |
| 32 | 79.6 | 0 | 5238.31 | 5237.87 | 5239.62 | 5238.94 | Subcritical |
| 50 | 150 | 0 | 5239.96 | 5238.50 | 5240.63 | 5239.11 | Jump |
| 48 | 20 | 0 | 5240.38 | 5240.16 | 5240.94 | 5240.64 | Jump |
| 46 | 20 | 0 | 5240.80 | 5240.58 | 5241.36 | 5241.06 | Jump |
| 44 | 141.6 | 0 | 5241.62 | 5241.00 | 5241.94 | 5241.32 | Subcritical |
| 42 | 161.2 | 0 | 5242.53 | 5241.82 | 5242.91 | 5242.20 | Subcritical |
| 22 | 283.5 | 0 | 5242.44 | 5239.95 | 5243.22 | 5240.67 | Jump |
| 4 | 95.9 | 0 | 5244.48 | 5243.28 | 5245.07 | 5243.75 | Jump |
| 2 | 20 | 0 | 5244.93 | 5244.68 | 5245.52 | 5245.15 | Jump |
| 14 | 71.4 | 0 | 5243.70 | 5242.64 | 5244.22 | 5243.05 | Jump |
| 12 | 20 | 0 | 5244.20 | 5243.90 | 5244.72 | 5244.31 | Jump |

## Summary of Energy Grade Line

| | Upstream Manhole | | | Juncture Losses | | | | Downstream Manhole | |
|---|---|---|---|---|---|---|---|---|---|
| Sewer ID # | Manhole ID # | Energy Elevation (Feet) | Sewer Friction (Feet) | Bend K Coefficient | Bend Loss (Feet) | Lateral K Coefficient | Lateral Loss (Feet) | Manhole ID # | Energy Elevation (Feet) |
| 32 | 31 | 5239.84 | 0.30 | 0.05 | 0.00 | 0.00 | 0.00 | 33 | 5239.54 |
| 50 | 49 | 5240.89 | 0.99 | 1.32 | 0.06 | 0.00 | 0.00 | 31 | 5239.84 |
| 48 | 47 | 5241.13 | 0.24 | 0.05 | 0.00 | 0.00 | 0.00 | 49 | 5240.89 |
| 46 | 45 | 5241.55 | 0.42 | 0.05 | 0.00 | 0.00 | 0.00 | 47 | 5241.13 |
| 44 | 43 | 5242.04 | 0.49 | 0.05 | 0.00 | 0.00 | 0.00 | 45 | 5241.55 |
| 42 | 41 | 5242.99 | 0.95 | 0.05 | 0.00 | 0.00 | 0.00 | 43 | 5242.04 |
| 22 | 21 | 5243.51 | 3.57 | 1.32 | 0.11 | 0.00 | 0.00 | 31 | 5239.84 |
| 4 | 3 | 5245.25 | 1.71 | 1.32 | 0.03 | 0.00 | 0.00 | 21 | 5243.51 |
| 2 | 1 | 5245.70 | 0.42 | 1.32 | 0.03 | 0.00 | 0.00 | 3 | 5245.25 |
| 14 | 13 | 5244.39 | 0.86 | 1.32 | 0.02 | 0.00 | 0.00 | 21 | 5243.51 |
| 12 | 11 | 5244.89 | 0.48 | 1.32 | 0.02 | 0.00 | 0.00 | 13 | 5244.39 |

Bend loss = Bend K * Flowing full vhead in sewer.
Lateral loss = Outflow full vhead - Junction Loss K * Inflow full vhead.
A friction loss of 0 means it was negligible or possible error due to jump.
Friction loss includes sewer invert drop at manhole.
Notice: Vhead denotes the velocity head of the full flow condition.
A minimum junction loss of 0.05 Feet would be introduced unless Lateral K is 0.
Friction loss was estimated by backwater curve computations.

## Summary of Earth Excavation Volume for Cost Estimate

The user given trench side slope is 1.

| Manhole ID # | Rim Elevation (Feet) | Invert Elevation (Feet) | Manhole Height (Feet) |
|---|---|---|---|
| 33 | 5239.54 | 5237.87 | 1.67 |
| 31 | 5244.94 | 5238.31 | 6.63 |
| 49 | 5244.11 | 5239.96 | 4.15 |
| 47 | 5244.10 | 5240.38 | 3.72 |
| 45 | 5244.12 | 5240.80 | 3.32 |
| 43 | 5244.71 | 5241.62 | 3.09 |
| 41 | 5245.26 | 5242.53 | 2.73 |
| 21 | 5250.23 | 5242.44 | 7.79 |
| 3 | 5250.01 | 5244.48 | 5.53 |
| 1 | 5250.34 | 5244.93 | 5.41 |
| 13 | 5248.95 | 5243.70 | 5.25 |
| 11 | 5249.33 | 5244.20 | 5.13 |

| | Upstream Trench Width | | Downstream Trench Width | | | | |
|---|---|---|---|---|---|---|---|
| Sewer ID # | On Ground (Feet) | At Invert (Feet) | On Ground (Feet) | At Invert (Feet) | Trench Length (Feet) | Wall Thickness (Inches) | Earth Volume (Cubic Yards) |
| 32 | 12.8 | 4.5 | 2.8 | 4.5 | 79.6 | 3.00 | 94 |
| 50 | 8.4 | 3.9 | 13.0 | 3.9 | 150 | 2.50 | 207 |
| 48 | 7.5 | 3.9 | 8.0 | 3.9 | 20 | 2.50 | 17 |
| 46 | 6.7 | 3.9 | 7.1 | 3.9 | 20 | 2.50 | 15 |
| 44 | 6.3 | 3.9 | 6.3 | 3.9 | 141.6 | 2.50 | 92 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 42 | 5.9 | 3.5 | 6.3 | 3.5 | 161.2 | 2.17 | 90 |
| 22 | 15.7 | 3.9 | 10.1 | 3.9 | 283.5 | 2.50 | 535 |
| 4 | 11.1 | 3.9 | 14.0 | 3.9 | 95.9 | 2.50 | 169 |
| 2 | 10.9 | 3.9 | 10.7 | 3.9 | 20 | 2.50 | 27 |
| 14 | 10.6 | 3.9 | 15.3 | 3.9 | 71.4 | 2.50 | 134 |
| 12 | 10.3 | 3.9 | 10.2 | 3.9 | 20 | 2.50 | 25 |

Total earth volume for sewer trenches = 1405.28 Cubic Yards. The earth volume was estimated to have a bottom width equal to the diameter (or width) of the sewer plus two times either 1 foot for diameters less than 48 inches or 2 feet for pipes larger than 48 inches.

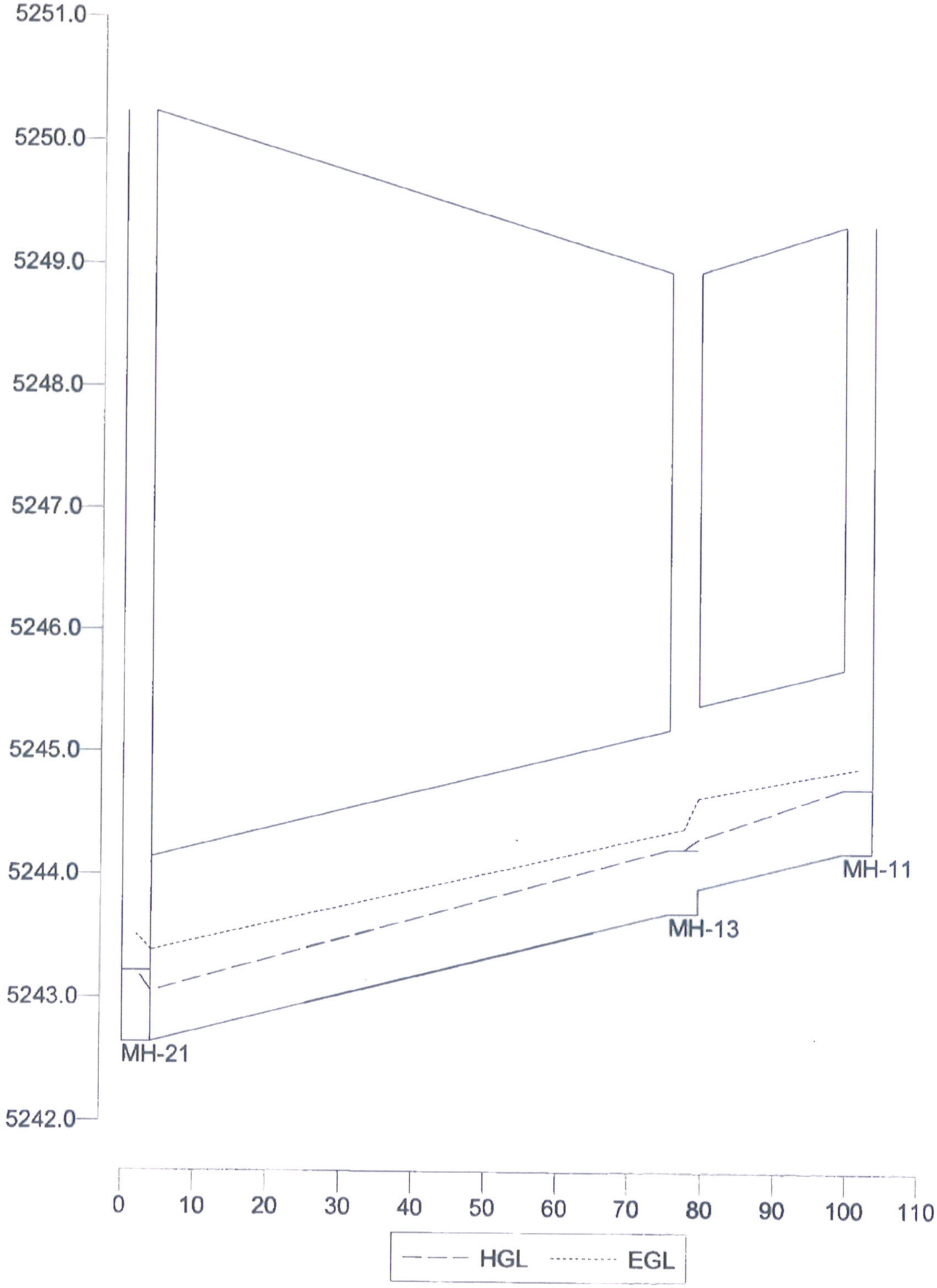
If the bottom width is less than the minimum width, the minimum width was used.

The backfill depth under the sewer was assumed to be 1 foot.

The sewer wall thickness is equal to: (equivalent diameter in inches/12)+1

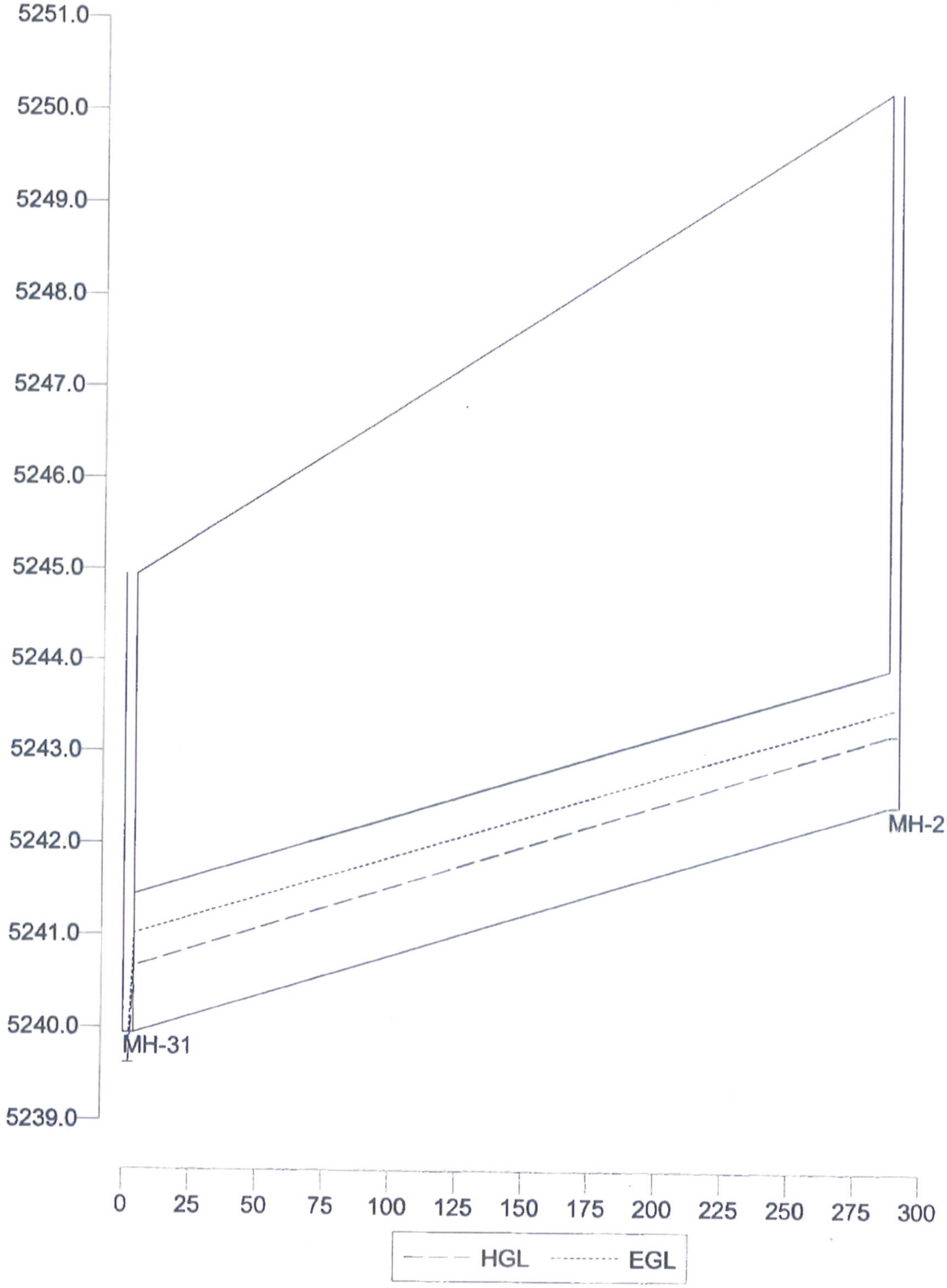
5 Year Event

# E-11 to E-14



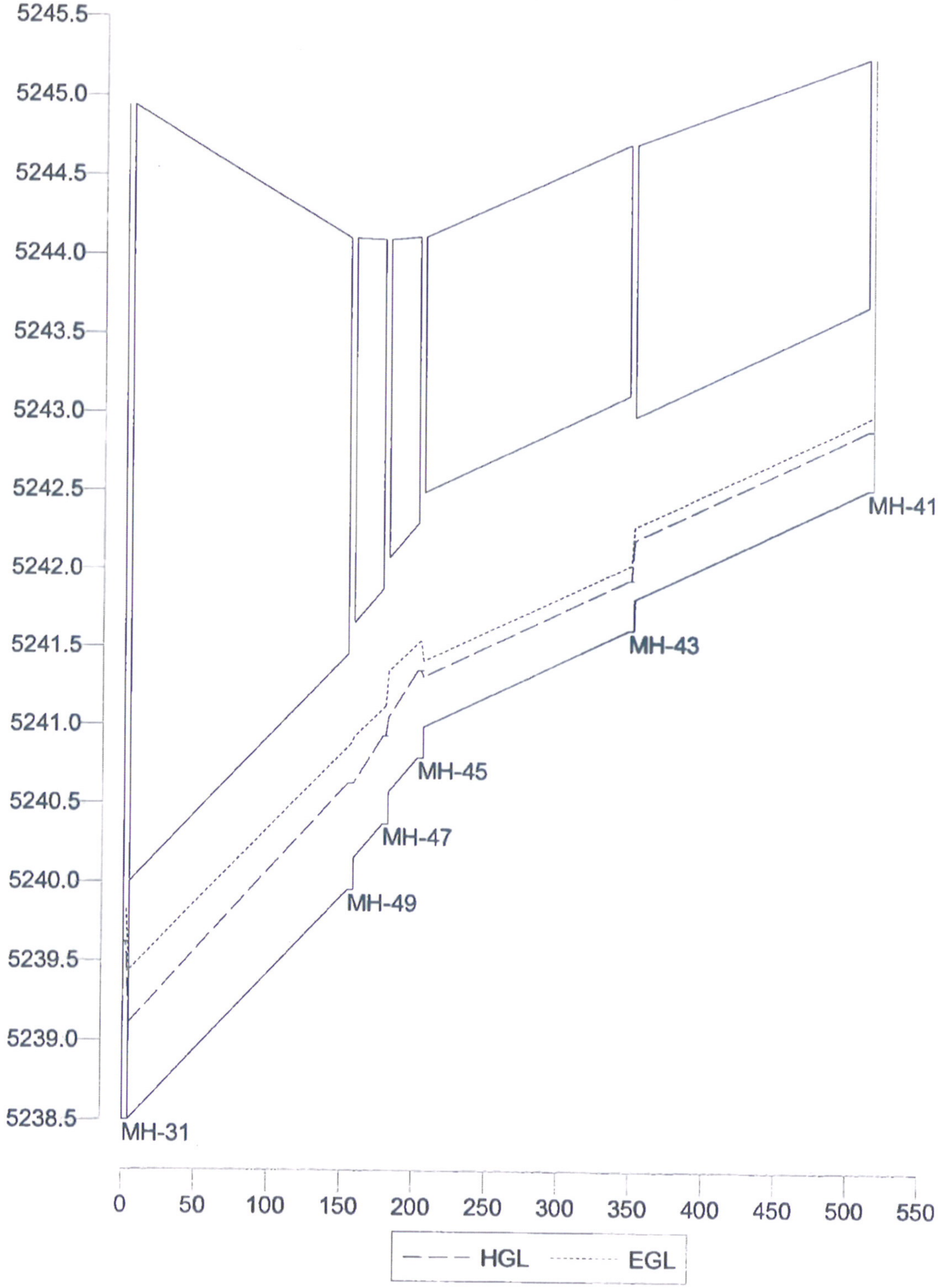
5 Year Event

# E-21 to E-31



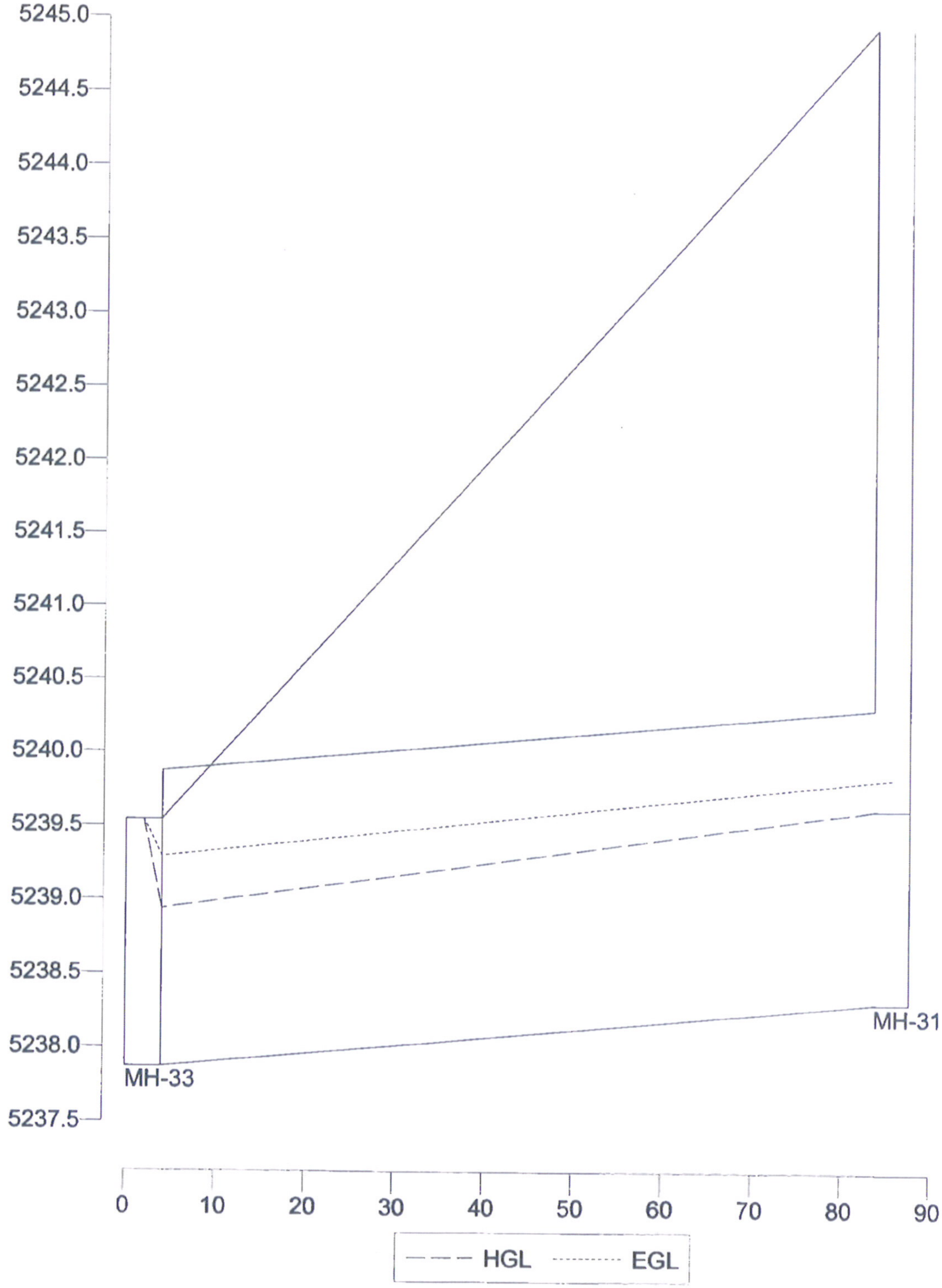
5 Year Event

# E-41 to E-31



5 Year Event

# E-31 to E-33



# Riprap Outlet Protection Calculations

**Location:** A-5

**Notes:**

**Date:** 8/9/2010

**By:** LDR

| | | | |
|---|---|---|---|
| (0) D (ft) = | 1.8 | Yn (ft)= | 1.6 |
| Q (cfs) = | 28.26 | Dpipe (ft) = | 2 |
| (1) V (f/s) = | 10.5 | Da (ft) = | 1.8 |

**Culvert Protection Eq. 5-5**

| | |
|---|---|
| Q | 28.26 |
| D | 1.8 |

| | |
|---|---|
| d50 (Inches) = | 9.7 |

Q/D^1.5 11.702089

| Riprap Designation | d50 (INCHES) |
|---|---|
| L | 9 |
| M | 12 |
| H | 18 |
| VH | 24 |

**Length of Protection Eq. 5-9**

| | |
|---|---|
| D | 1.8 |
| (1/(2 tan e) [Fig 5-9] | 1 |
| Q | 28.26 |
| (2) V (fps) | 5 |
| Yt | 0.72 |

| | |
|---|---|
| (3) L = | 6.1 |
| Lmin = | 6.0 |
| Lmax = | 20.0 |

| | |
|---|---|
| (4) Q/D^2.5 = | 6.50 |

(0) If Yn is less than D then use Da for D, Da = 1/2(D + Yn)
(1) Velocity used in calculating stable channel lining
(2) allowable velocity in downstream channel between 5.0 - 7.0 fps. Not pipe outlet velocity
(3) L less than or equal to 10D or at least 3D
(4) Assume Yt/D=0.4 and calcualte Q/D^2.5 and go to the scanned chart and calculate the expansion factor 1/2tan e

**Recommendations:** Type M Riprap, ~~[illegible]~~ L= 8.0'

Location: B-8

Notes:

Date: 8/9/2010

By: LDR

| | |
|---|---|
| (0) D (ft) = | 1.425 |
| Q (cfs) = | 5.8 |
| (1) V (f/s) = | 4.6 |

| | |
|---|---|
| Yn (ft)= | 0.85 |
| Dpipe (ft) = | 2 |
| Da (ft) = | 1.425 |

**Culvert Protection Eq. 5-5**

| | |
|---|---|
| Q | 5.8 |
| D | 1.425 |

| | |
|---|---|
| d50 (Inches) = | 2.8 |

Q/D^1.5 3.4096178

| Riprap Designation | d50 (INCHES) |
|---|---|
| L | 9 |
| M | 12 |
| H | 18 |
| VH | 24 |

**Length of Protection Eq. 5-9**

| | |
|---|---|
| D | 1.425 |
| (1/(2 tan e) [Fig 5-9] | 5.5 |
| Q | 5.8 |
| (2) V (fps) | 5 |
| Yt | 0.57 |

| | |
|---|---|
| (3) L = | 3.4 |
| Lmin = | 6.0 |
| Lmax = | 20.0 |

| | |
|---|---|
| (4) Q/D^2.5 = | 2.39 |

(0) If Yn is less than D then use Da for D, Da = 1/2(D + Yn)
(1) Velocity used in calculating stable channel lining
(2) allowable velocity in downstream channel between 5.0 - 7.0 fps. Not pipe outlet velocity
(3) L less than or equal to 10D or at least 3D
(4) Assume Yt/D=0.4 and calcualte Q/D^2.5 and go to the scanned chart and calculate the expansion factor 1/2tan e

**Recommendations:** Type L Riprap, L = 8.0'

**Location:** D-6

**Notes:**

**Date:** 8/9/2010

**By:** LDR

| | | | |
|---|---|---|---|
| (0) D (ft) = | 1.05 | Yn (ft)= | 0.6 |
| Q (cfs) = | 4.4 | Dpipe (ft) = | 1.5 |
| (1) V (f/s) = | 6.98 | Da (ft) = | 1.05 |

**Culvert Protection Eq. 5-5**

| | |
|---|---|
| Q | 4.4 |
| D | 1.05 |

| | |
|---|---|
| d50 (Inches) = | 3.4 |

Q/D^1.5 4.089486

| Riprap Designation | d50 (INCHES) |
|---|---|
| L | 9 |
| M | 12 |
| H | 18 |
| VH | 24 |

**Length of Protection Eq. 5-9**

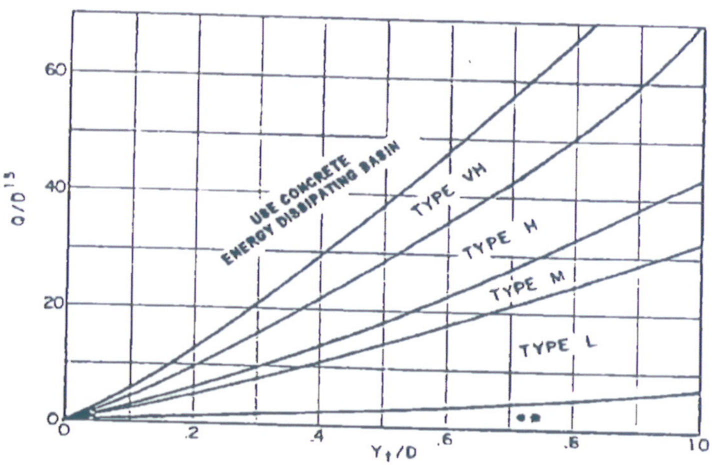
| | |
|---|---|
| D | 1.05 |
| (1/(2 tan e) [Fig 5-9] | 3.6 |
| Q | 4.4 |
| (2) V (fps) | 5 |
| Yt | 0.42 |

| | |
|---|---|
| (3) L = | 3.8 |
| Lmin = | 4.5 |
| Lmax = | 15.0 |

| | |
|---|---|
| (4) Q/D^2.5 = | 3.89 |

(0) If Yn is less than D then use Da for D, Da = 1/2(D + Yn)
(1) Velocity used in calculating stable channel lining
(2) allowable velocity in downstream channel between 5.0 - 7.0 fps. Not pipe outlet velocity
(3) L less than or equal to 10D or at least 3D
(4) Assume Yt/D=0.4 and calcualte Q/D^2.5 and go to the scanned chart and calculate the expansion factor 1/2tan e

**Recommendations:** TYPE L RIPRAP, L= 6.0'




Use $D_o$ instead of D whenever flow is supercritical in the barrel.
** Use Type L for a distance of 3D downstream

**Figure MD-21—Riprap Erosion Protection at Circular Conduit Outlet Valid for $Q/D^{2.5} \leq 6.0$**

# Floodplain Information

720 S. Colorado Boulevard, Suite 410 S
Denver, Colorado 80246
phone (303) 757-3655
fax (303) 300-1635

February 16, 2011

To: Jeremy Hamer, P.E., CFM, LEED AP |
Project Controls Office
Public Works Department
City and County of Denver

From: Richard Ommert, PE, CFM
Moser & Associates Engineering
720 South Colorado Boulevard
Denver, Colorado 80246

CC:

**Re: Permit Number 201101041**
**Floodplain Permit Response to Comments**

Mr. Hamer,
Please see the response to your comments below in sub-bullets.

Comments provided by Jeremy Hamer, PE, CFM, in response to "Floodplain Analysis Results", provided by Richard Ommert @ Moser and Associates.

1. Provide information regarding effective model (effective date, associated LOMR, etc...) and verify that your models are utilizing the current FIS/FIRM information (Feb. 12, 2010).
   - We verified that the model we are using is the current effective model. WSEL matches those in the floodway data table.
2. Convert cross section numbering to reflect FEMA river stationing.
   - Completed
3. Also add FEMA cross section locations to plans and profiles, for reference only.
   - Completed
4. It is unclear whether your models take into account the pedestrian bridge upstream of I-70 and the drop structure just downstream. If not, revise the models accordingly.
   - Our model takes these structures into account, please see the profile and models.
5. Label structures (pedestrian bridge, I-70 bridge, drop structure, etc...) on plan and profile sheets and provide river stations for each.
   - Completed
6. For all three models, provide HEC-RAS cross sections for all of the sections used, including structures.
   - Completed
7. Provide profile sheets that show the ground profile, cross section labels, structures, and WSEL's for all three models.
   - Completed

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8. Provide justification for the use of a 0.1% channel slope. If the topo supports this, provide the associated slope calculation(s).
- CDOT survey shows slope 0.001005ft/ft

9. Why are the Effective WSEL's higher than the Pre and/or Post-Project WSEL's at times? Please explain/justify the increase.
- Updated CDOT mapping, we added cross sections, they used 2' contour mapping and results are still pretty close to the effective.

10. Provide HEC-RAS input and output files for each model.
- Included

11. Side slopes of 2.5:1 are steeper than recommended, be advised that this will need to be approved by the maintaining entity (CDOT and/or UDFCD).
- 2.5:1 is an acceptable slope for riprap and is allowed per UDFCD criteria. Actually 2:1 are allowed at bridge abutments

12. You will need to obtain an Erosion Control Permit from the City & County of Denver before we can issue the Floodplain Permit.
- CDOT to obtain

13. This project will also require the approval of UDFCD as they are responsible for maintenance of Sand Creek.
- UDFCD was already notified, the email and response from the UDFCD are included in the appendix.

14. Full hydraulic calculations should be sent to CDOT for approval. We request to be copied on the approved report, for our records.
- Report has been sent to CDOT. We will request an approval letter from CDOT to be sent to you.

Table 1. Floodplain Summary Table – It is important to note that the pre-project values have changed slightly from those submitted previously. The pre-project geometry file was somehow corrupted, we have the copied HEC-RAS output but the geometry is gone, so a new pre-project model was created. So, while the values are different they are still greater than the post-project model and only slightly different than those previously submitted.

Regards,

Richard Ommert, P.E., CFM
Moser and Associates Engineering, Inc.

MOSER & associates ENGINEERING

720 S. Colorado Boulevard, Suite 410 S
Denver, Colorado 80246
phone (303) 757-3655
fax (303) 300-1635

Date: February 16, 2011

To: Jeremy Hamer, P.E., CFM, LEED AP
Project Controls Office
Public Works Department
City and County of Denver
PW-PCO, City and County of Denver
201 W Colfax, Dept. 507
Denver, CO 80202

From: Richard Ommert, PE, CFM
Moser & Associates Engineering
720 South Colorado Boulevard
Denver, Colorado 80246

**Re: I-70 Over Sand Creek Bridge Replacement – Floodplain Analysis Results**

Mr. Hamer;

I wanted to write you to give you an update on our progress on the floodplain modeling. Since our meeting about a month ago, we have updated the effective HEC-RAS model with our topo from the project survey.

The only cross section which was changed from the effective model was sections 2618, and then sections 2449 and 2475 were removed to account for the wider bridge and replaced with cross section 2400. The effective model showed a 0.00% longitudinal channel profile that we revised to better reflect the actual slope of 0.1%. The existing and proposed cross section locations are included. Figure 1 illustrates the Effective and Pre-Project cross section locations and Figure 2 illustrates the Post-Project cross section locations with the new bridge and proposed grading.

There was also some minor grading that was accounted for underneath the bridge, which is labeled on the proposed cross sections and shown on a plan view of the bridge which is attached.

We adjusted the n values slightly on the proposed upstream cross section at the bridge (2618), to better reflect the existing and proposed conditions with a wider section of n = 0.035 than shown on the existing model. Also, in our estimation of n values on the new downstream section of the proposed bridge, we kept similar n values to the existing model, however we reduced the width of n = 0.022 to account for the reduced sand channel bottom near the downstream drop structure since we feel this is a more conservative approach. I have attached both the existing and proposed cross sections, with the n values highlighted, for your information / review.

The table below, Table 1, compares the Pre-Project, the Post-Project and the Effective Model WSELs. As you can see the Post-Project model is less than or equal to the Pre-Project model at all cross sections.

Table 1.
Floodplain Summary Model

| Location | Cross Section ID | Effective WSEL | Pre-Project WSEL | Post-Project WSEL | Difference Post-Pre |
|---|---|---|---|---|---|
| | 3302 | 5242.74 | 5242.67 | 5242.49 | -0.18 |
| | 3273 | 5242.73 | 5242.61 | 5242.41 | -0.2 |
| | 2857 | 5241.91 | 5241.85 | 5241.84 | -0.01 |
| | 2680 | 5241.42 | 5241.51 | 5241.20 | -0.31 |
| I-70 Pedestrian Bridge | 2665 | | | | - |
| | 2651 | 5240.30 | 5240.29 | 5239.47 | -0.82 |
| | 2618 | 5240.21 | 5240.22 | 5239.45 | -0.77 |
| I-70 Bridge | 2546 | | | | - |
| Cross section removed in Post-Project model | 2475 | 5238.37 | 5238.45 | | - |
| Cross section removed in Post-Project model | 2449 | 5237.82 | 5238.54 | | - |
| New Cross Section DS of Proposed Bridge | 2400 | | | 5236.40 | - |
| | 2358 | 5236.08 | 5235.60 | 5235.60 | 0 |
| | 2319 | 5234.66 | 5234.82 | 5234.82 | 0 |
| | 2102 | 5233.87 | 5233.91 | 5233.91 | 0 |
| | 2063 | 5233.89 | 5234.00 | 5234.00 | 0 |
| | 1884 | 5233.56 | 5233.56 | 5233.56 | 0 |

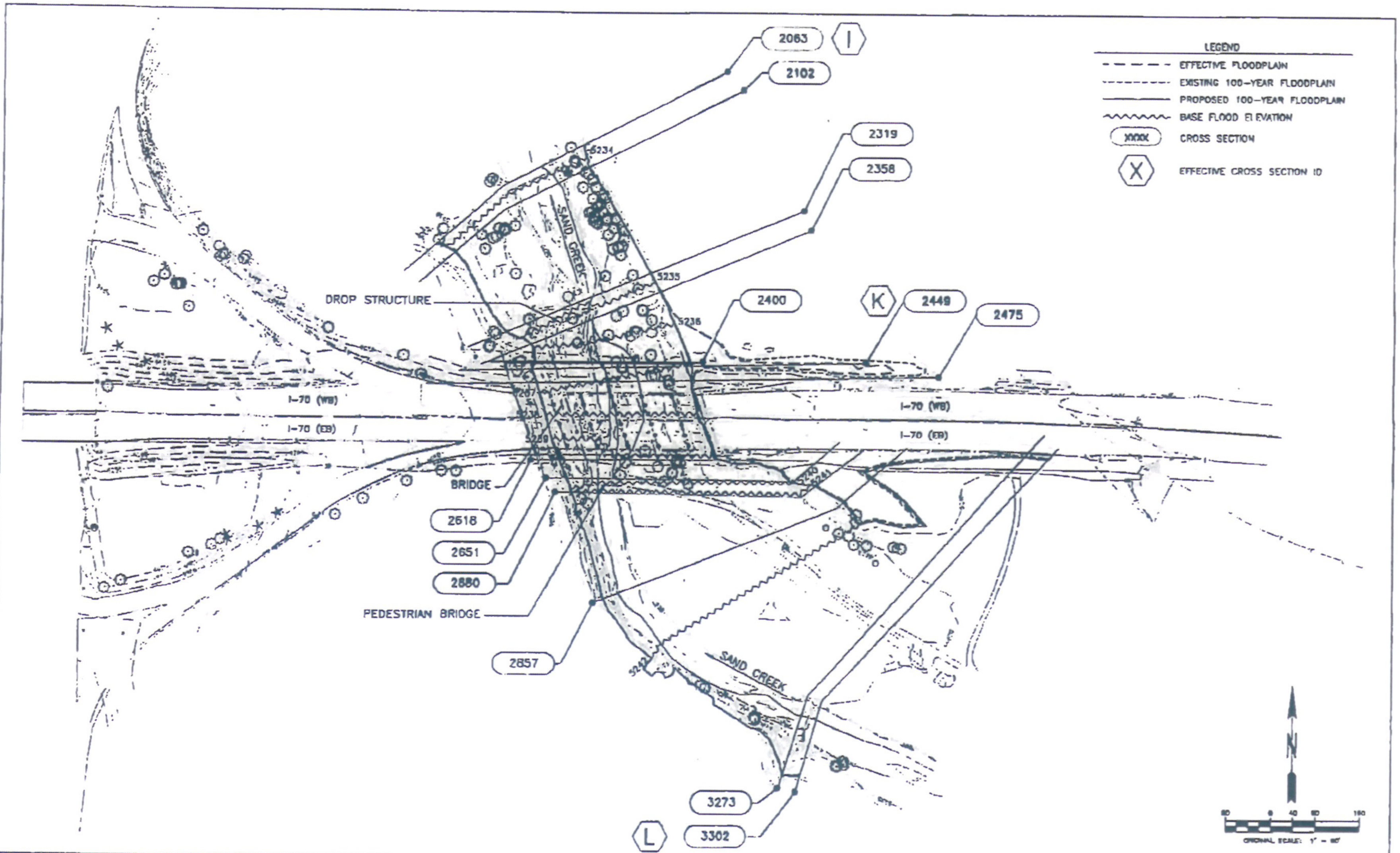
Figure 3 illustrates our floodplain delineation, in addition profiles have been added illustrating the effective, pre-project and post-project conditions. As the table above shows, the water surface elevations are very close between the effective and the pre and post-project conditions.

In addition, a response has been included that covers all of the comments received in January from the CCD.

If you would like to get together to discuss or review the model please let me know.

Best regards,
Moser & Associates Engineering

Richard Ommert, PE, CFM
Project Manager




MOSER ENGINEERING
720 S. COLORADO BLVD.
SUITE 410S
DENVER, CO 80246
PH: (303) 757-3486

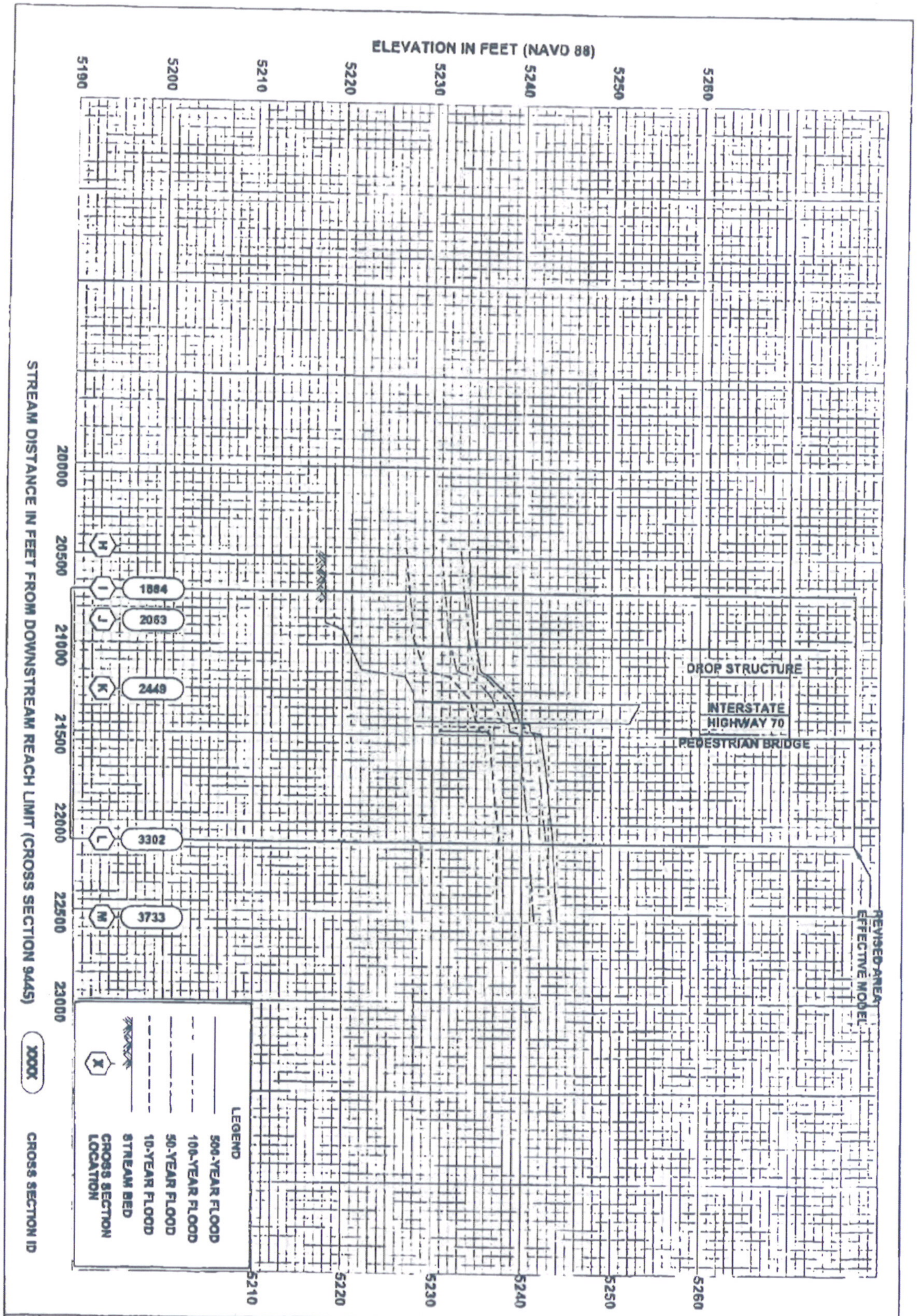
PROJECT NO.

Colorado Department of Transportation

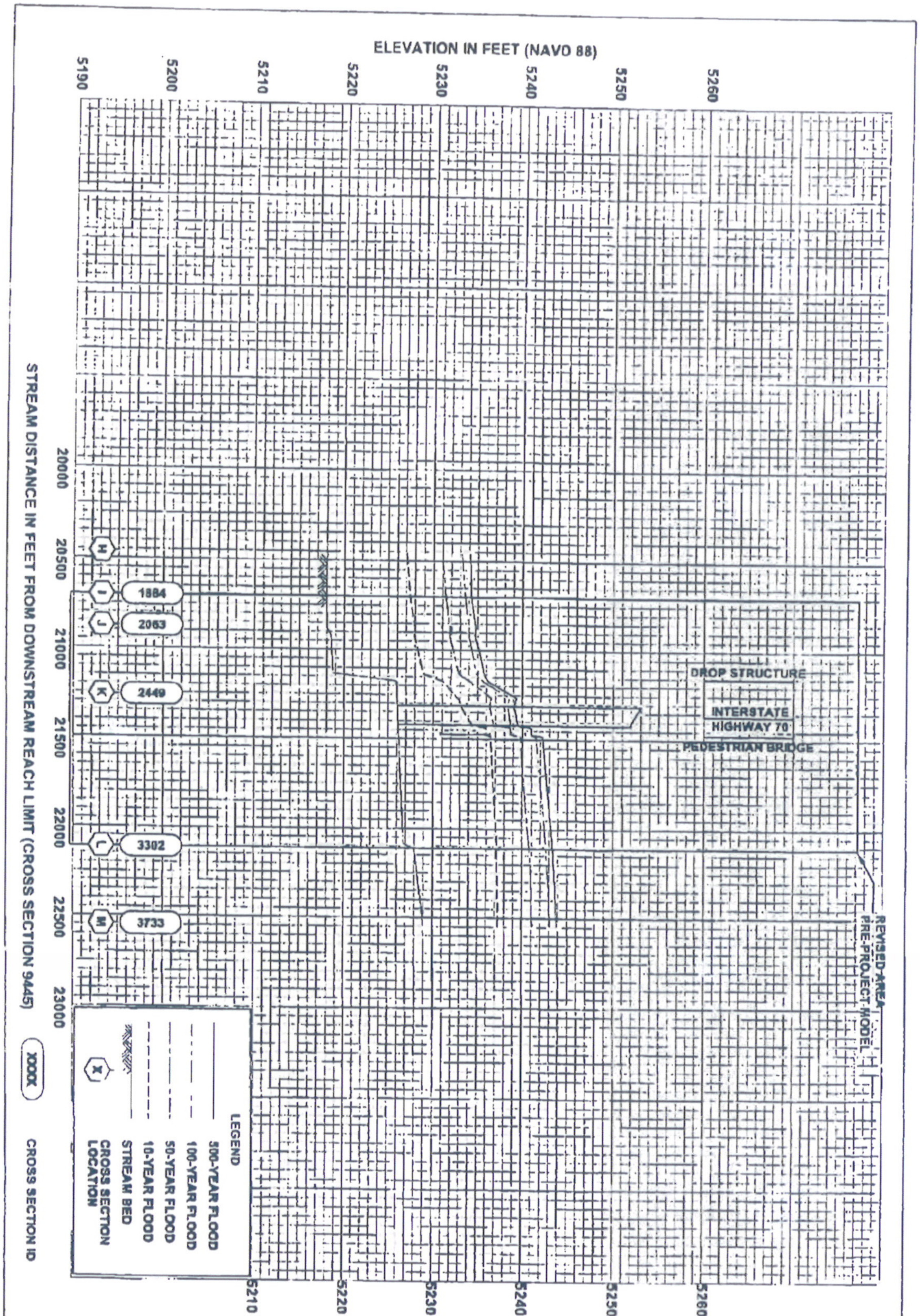
I-70 at Sand Creek Bridge Replacement

Floodplain Delineations

FIGURE 3




| 05P | FEDERAL EMERGENCY MANAGEMENT AGENCY<br>CITY AND COUNTY OF DENVER, CO | FLOOD PROFILES<br>SAND CREEK |
|---|---|---|



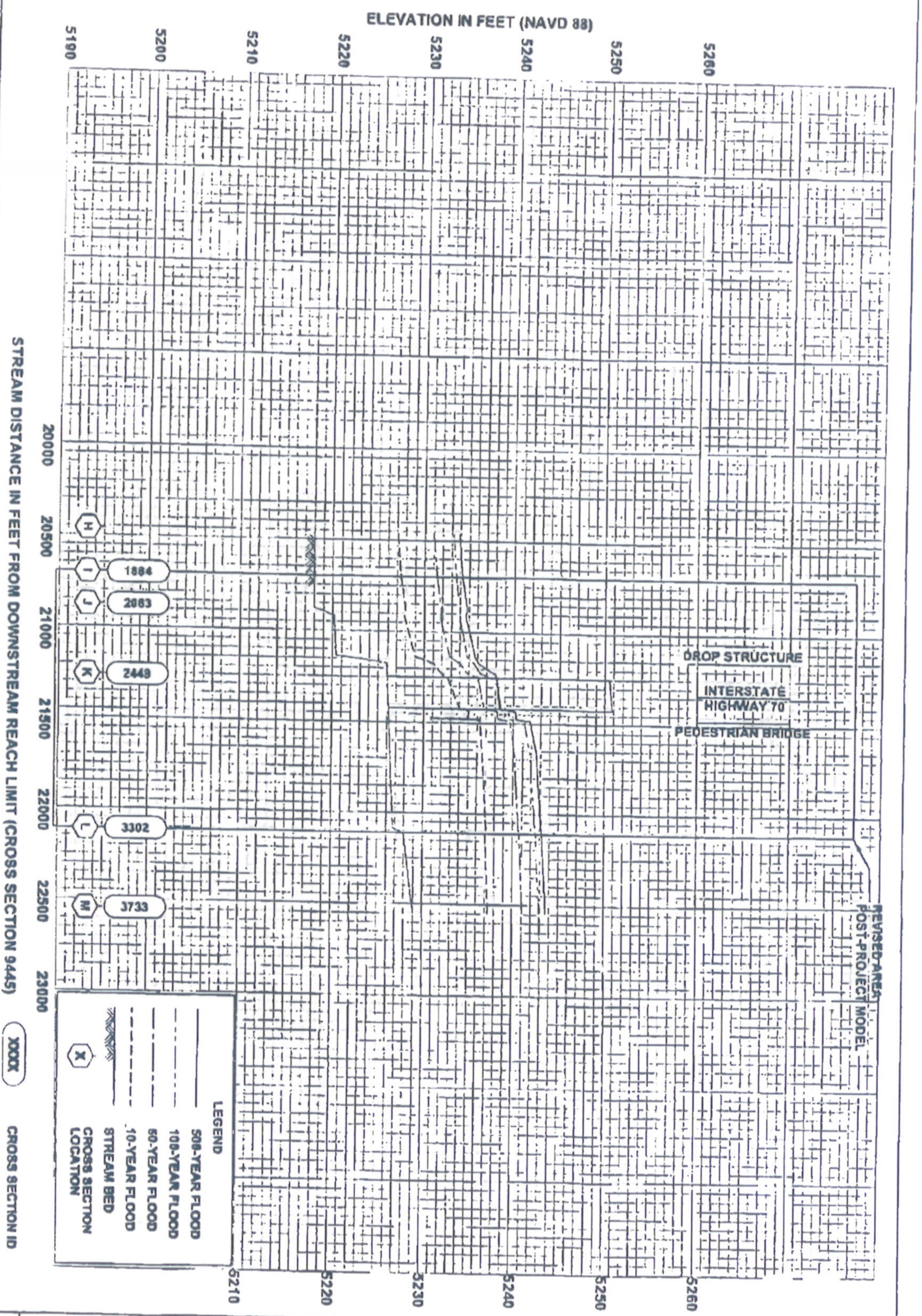

FEDERAL EMERGENCY MANAGEMENT AGENCY

**CITY AND COUNTY OF DENVER, CO**

**FLOOD PROFILES**

# SAND CREEK

05P

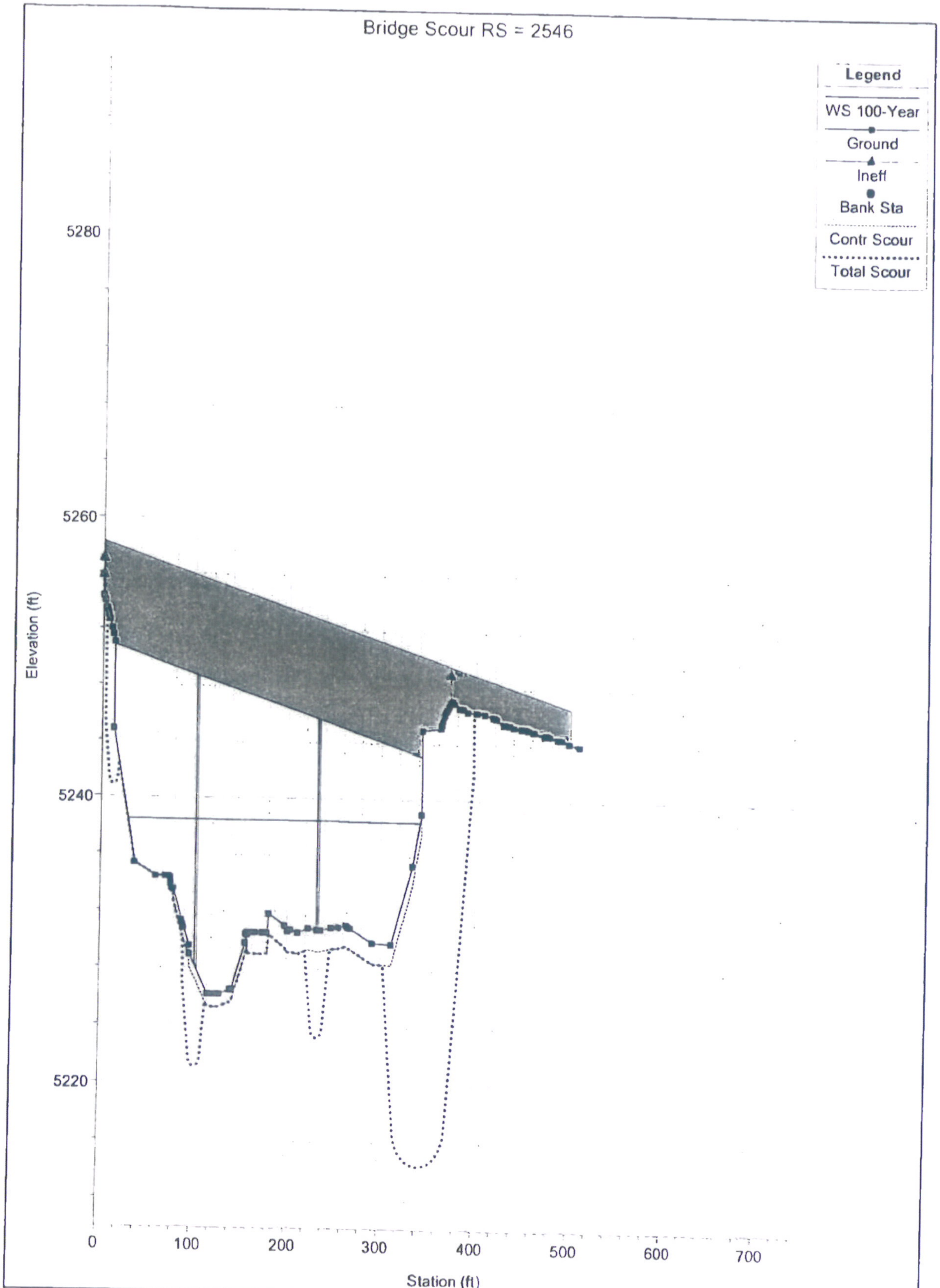



| FEDERAL EMERGENCY MANAGEMENT AGENCY<br>CITY AND COUNTY OF DENVER, CO | FLOOD PROFILES<br>SAND CREEK |
|---|---|

05P

# Bridge Scour

100-YR Scour




1 in Horiz. = 150 1 in Vert. = 10

Contraction Scour

Input Data

| | Left | Channel | Right |
|---|---|---|---|
| Average Depth (ft): | 4.26 | 10.95 | 8.12 |
| Approach Velocity (ft/s): | 8.64 | 15.93 | 9.93 |
| Br Average Depth (ft): | 3.44 | 10.21 | 7.25 |
| BR Opening Flow (cfs): | 910.88 | 12794.27 | 16294.85 |
| BR Top WD (ft): | 49.94 | 73 | 181.20 |
| Grain Size D50 (mm): | 0.67 | 0.67 | 0.67 |
| Approach Flow (cfs): | 1185.12 | 12203.30 | 16611.57 |
| Approach Top WD (ft): | 32.20 | 69.96 | 206.08 |
| K1 Coefficient: | 0.690 | 0.690 | 0.690 |

Results

| | Left | Channel | Right |
|---|---|---|---|
| Scour Depth Ys (ft): | 0.00 | 0.86 | 1.48 |
| Critical Velocity (ft/s): | | | |
| Equation: | Live | Live | Live |

Pier Scour

All piers have the same scour depth

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.67000 |
| Depth Upstream (ft): | 13.29 |
| Velocity Upstream (ft/s): | 16.04 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 174.50 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 1.38000 |
| K4 Armouring Coef: | 1.00 |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | 6.00 |
| Froude #: | 0.78 |
| Equation: | CSU equation |

Pier Scour Limited to Maximum of Ys = 2.4 * a

Abutment Scour

Input Data

| | Left | Right |
|---|---|---|
| Station at Toe (ft): | 12.99 | 343.07 |
| Toe Sta at appr (ft): | 3.91 | 325.23 |
| Abutment Length (ft): | 0.00 | 122.99 |
| Depth at Toe (ft): | 1.00 | 8.00 |
| K1 Shape Coef: | 0.55 - Spill-through abutment | |
| Degree of Skew (degrees): | 90.00 | 90.00 |
| K2 Skew Coef: | 1.00 | 1.00 |
| Projected Length L' (ft): | 0.00 | 122.99 |
| Avg Depth Obstructed Ya (ft): | | 6.05 |
| Flow Obstructed Qe (cfs): | | 1638.95 |
| Area Obstructed Ae (sq ft): | | 744.28 |

Results

| | Left | Right |
|---|---|---|
| Scour Depth Ys (ft): | 4.60 | 27.31 |

| | | |
|---|---|---|
| Froude #: | 1.52 | 0.62 |
| Equation: | HIRE | HIRE |

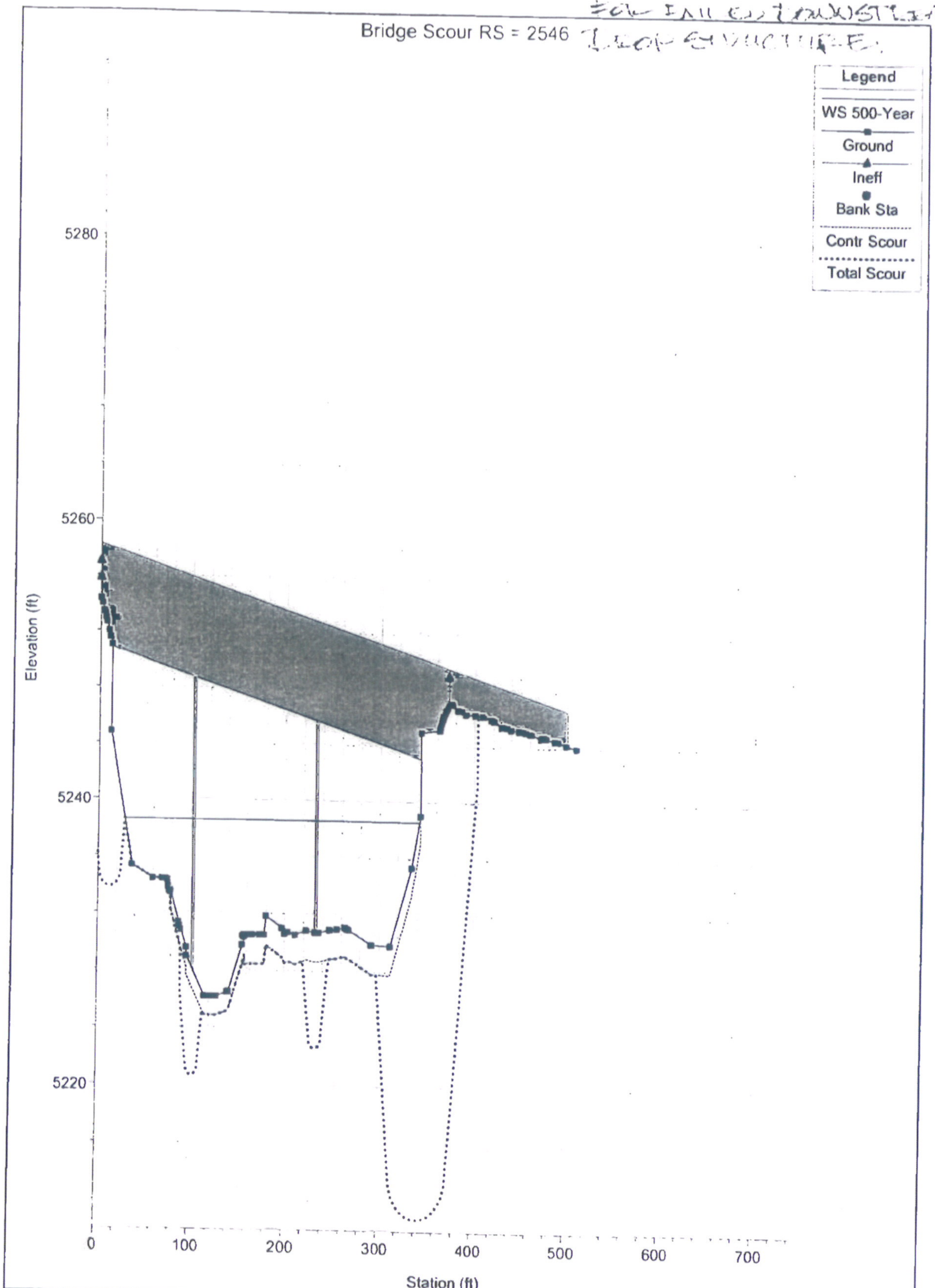
Combined Scour Depths

Pier Scour + Contraction Scour (ft):

| | | |
|---|---|---|
| Channel: | 6.86 | |
| Right Bank: | 7.48 | |

| | |
|---|---|
| Left abutment scour + contraction scour (ft): | 4.60 |
| Right abutment scour + contraction scour (ft): | 28.79 |

[illegible] Scour
New Contraction & Pier Scour will be increased to account for fill [illegible] downstream [illegible] structure.




1 in Horiz. = 150 1 in Vert. = 10

Contraction Scour

**Input Data**

| | Left | Channel | Right |
|---|---|---|---|
| Average Depth (ft): | 4.82 | 11.71 | 8.88 |
| Approach Velocity (ft/s): | 8.96 | 15.94 | 10.10 |
| Br Average Depth (ft): | 3.57 | 10.37 | 7.40 |
| BR Opening Flow (cfs): | 1041.88 | 13978.16 | 17979.96 |
| BR Top WD (ft): | 50.34 | 76.22 | 181.60 |
| Grain Size D50 (mm): | 0.67 | 0.67 | 0.67 |
| Approach Flow (cfs): | 1452.84 | 13063.26 | 18483.90 |
| Approach Top WD (ft): | 33.68 | 69.96 | 206.08 |
| K1 Coefficient: | 0.690 | 0.690 | 0.690 |

**Results**

| | Left | Channel | Right |
|---|---|---|---|
| Scour Depth Ys (ft): | 0.00 | 1.33 | 2.06 |
| Critical Velocity (ft/s): | 1.89 | 2.19 | 2.10 |
| Equation: | Live | Live | Live |

Pier Scour

All piers have the same scour depth

INCREASE 5' FOR FAILED DOWNSTREAM BRG.

**Input Data**

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.67000 |
| Depth Upstream (ft): | 14.04 |
| Velocity Upstream (ft/s): | 16.11 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 174.50 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |

**Results**

| | |
|---|---|
| Scour Depth Ys (ft): | 6.00 |
| Froude #: | 0.76 |
| Equation: | CSU equation |

INCREASE 6' FOR FAILED DOWNSTREAM BRG

Pier Scour Limited to Maximum of Ys = 2.4 * a

Abutment Scour

**Input Data**

| | Left | Right |
|---|---|---|
| Station at Toe (ft): | 12.99 | 343.07 |
| Toe Sta at appr (ft): | 3.91 | 325.23 |
| Abutment Length (ft): | 0.00 | 128.03 |
| Depth at Toe (ft): | 3 | 9 |
| K1 Shape Coef: | 0.55 - Spill-through abutment | |
| Degree of Skew (degrees): | 90.00 | 90.00 |
| K2 Skew Coef: | 1.00 | 1.00 |
| Projected Length L' (ft): | 0.00 | 128.03 |
| Avg Depth Obstructed Ya (ft): | | 6.56 |
| Flow Obstructed Qe (cfs): | | 1828.19 |
| Area Obstructed Ae (sq ft): | | 839.68 |

**Results**

| | Left | Right |
|---|---|---|
| Scour Depth Ys (ft): | 11.64 | 30.30 |

| | | |
|---|---|---|
| Froude #: | 0.91 | 0.59 |
| Equation: | HIRE | HIRE |

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

| | | |
|---|---|---|
| | Channel: | 7.33 |
| | Right Bank: | 8.06 |

| | |
|---|---|
| Left abutment scour + contraction scour (ft): | 11.64 |
| Right abutment scour + contraction scour (ft): | 32.37 |

## Bridge Hydraulic Information Transmittal Sheet for Spillthrough Abutments

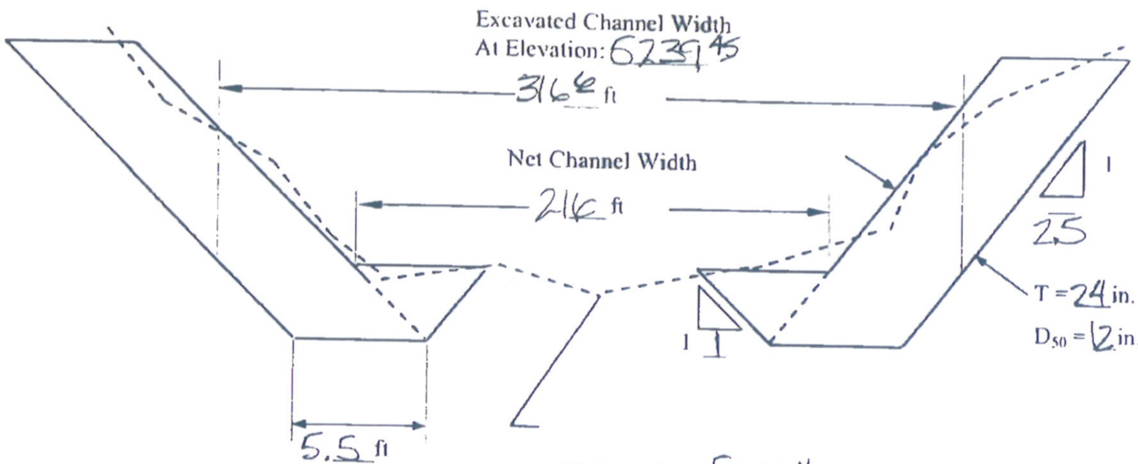
Here is the structure opening and hydraulic information required for the bridge across Sand Creek on SH I-70 at/near I-270.

**PROJECT INFORMATION**

| | |
|---|---|
| Date: 7/9/2010 | Construction Project Number: C 0704 220 |
| To: Josh Warren (T-EA) | P.E. Project No.: |
| From: Richard Pruett | Project Name: CDOT R6 Faster Bridges I-70 over Sand Creek |

**BRIDGE INFORMATION**

| | |
|---|---|
| Existing Structure Number: | E-17-BY |
| Station at Centerline of Channel: | 81+00 @ HCL |
| Skew: | 30° |
| Minimum Low Girder Elevation: | 5245.15 |
| Design Year Event: | 100 year recurrence. |




**HYDRAULIC INFORMATION**

| | | | |
|---|---|---|---|
| D.A. = 175 sq. miles | $Q_{(Design)}$ = 3000 cfs | $Q_{(100)}$ = 3000 cfs | $Q_{(500)}$ = 3300 cfs |
| OHW = 5230.41 ft | $DHW_{(Design)}$ = 5239.45 | $HW_{(100)}$ = 5239.45 | $HW_{(500)}$ = 5240.20 |
| | $V_{(Design)}$ = 14.23 fs | $V_{(100)}$ = 14.23 fps | $V_{(500)}$ = 14.33 fps |

Please submit to Staff Bridge the information required by CDOT Drainage Design Manual so they may proceed with design. Bridge Layout requested: yes ☐ no ☒

Comments:

See Bridge Hydraulic Information Sheets for more information

Figure 10.6 Transmittal of Bridge Hydraulic Information Sheet for Spillthrough Abutments.

UPSTREAM BRIDGE FAILE

HEC-RAS River: SandCreek Reach 04

| Reach | River Sta | Profile | Plan | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Sta W.S. Lft (ft) | Sta W.S. Rgt (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04 | 3733 | 100-Year | BC Nat | 30000.00 | 5226.00 | 5243.15 | | 5244.26 | 0.001959 | 12.45 | 4839.35 | 722.57 | 285.71 | 1006.26 |
| 04 | 3733 | 100-Year | sc rw brdge grd2 | 30000.00 | 5226.00 | 5242.85 | | 5244.15 | 0.002143 | 12.89 | 4694.85 | 721.08 | 286.20 | 1007.28 |
| 04 | 3733 | 600-Year | BC Nat | 33000.00 | 5229.00 | 5243.81 | | 5244.86 | 0.001790 | 12.27 | 5316.21 | 727.48 | 284.10 | 1011.58 |
| 04 | 3733 | 600-Year | sc rw brdge grd2 | 33000.00 | 5229.00 | 5243.66 | | 5244.77 | 0.001905 | 12.57 | 5206.54 | 726.35 | 284.47 | 1010.82 |
| | | | | | | | | | | | | | | |
| 04 | 3302 | 100-Year | BC Nat | 30000.00 | 5228.80 | 5242.57 | 5239.88 | 5243.46 | 0.001541 | 10.95 | 4638.95 | 736.98 | 30.07 | 767.05 |
| 04 | 3302 | 100-Year | sc rw brdge grd2 | 30000.00 | 5227.69 | 5242.49 | 5239.45 | 5243.31 | 0.001395 | 9.83 | 4738.46 | 748.95 | 30.82 | 779.77 |
| 04 | 3302 | 600-Year | BC Nat | 33000.00 | 5228.80 | 5243.23 | 5240.16 | 5244.13 | 0.001459 | 11.00 | 5018.21 | 753.28 | 24.52 | 777.76 |
| 04 | 3302 | 600-Year | sc rw brdge grd2 | 33000.00 | 5227.89 | 5243.19 | 5239.79 | 5244.02 | 0.001316 | 9.86 | 5139.57 | 757.64 | 27.45 | 785.09 |
| | | | | | | | | | | | | | | |
| 04 | 3273 | 100-Year | BC Nat | 30000.00 | 5228.00 | 5242.55 | 5239.10 | 5243.42 | 0.001121 | 9.85 | 4986.88 | 749.31 | 6.68 | 756.00 |
| 04 | 3273 | 100-Year | sc rw brdge grd2 | 30000.00 | 5226.82 | 5242.41 | 5239.53 | 5243.27 | 0.001237 | 10.46 | 4783.91 | 739.34 | 25.63 | 764.97 |
| 04 | 3273 | 600-Year | BC Nat | 33000.00 | 5228.00 | 5243.22 | 5239.42 | 5244.09 | 0.001077 | 9.95 | 5354.96 | 759.40 | 5.35 | 764.75 |
| 04 | 3273 | 600-Year | sc rw brdge grd2 | 33000.00 | 5226.82 | 5243.12 | 5239.90 | 5243.98 | 0.001172 | 10.49 | 5186.48 | 750.56 | 21.86 | 772.42 |
| | | | | | | | | | | | | | | |
| 04 | 2857 | 100-Year | BC Nat | 30000.00 | 5228.00 | 5241.67 | 5238.98 | 5242.85 | 0.002110 | 12.57 | 3949.77 | 536.20 | 13.55 | 606.40 |
| 04 | 2857 | 100-Year | sc rw brdge grd2 | 30000.00 | 5226.40 | 5241.84 | 5238.16 | 5242.76 | 0.001638 | 9.65 | 4260.55 | 544.88 | 17.97 | 606.78 |
| 04 | 2857 | 600-Year | BC Nat | 33000.00 | 5228.00 | 5242.37 | 5239.33 | 5243.54 | 0.002050 | 12.80 | 4231.98 | 614.54 | 12.73 | 627.27 |
| 04 | 2857 | 600-Year | sc rw brdge grd2 | 33000.00 | 5226.40 | 5242.53 | 5238.51 | 5243.48 | 0.001807 | 9.84 | 4557.48 | 601.20 | 16.99 | 618.19 |
| | | | | | | | | | | | | | | |
| 04 | 2856 | 100-Year | sc rw brdge grd2 | 30000.00 | 5226.22 | 5241.20 | 5237.79 | 5242.39 | 0.002133 | 11.50 | 3645.34 | 452.63 | 30.54 | 483.16 |
| 04 | 2856 | 600-Year | sc rw brdge grd2 | 33000.00 | 5226.22 | 5241.85 | 5238.19 | 5243.12 | 0.002107 | 11.78 | 3884.98 | 459.33 | 29.87 | 524.98 |
| | | | | | | | | | | | | | | |
| 04 | 2851 | 100-Year | sc rw brdge grd2 | 30000.00 | 5226.19 | 5239.47 | 5238.36 | 5241.96 | 0.006117 | 15.93 | 2578.32 | 410.45 | 37.76 | 446.21 |
| 04 | 2851 | 600-Year | sc rw brdge grd2 | 33000.00 | 5226.19 | 5240.23 | 5238.85 | 5242.73 | 0.005616 | 15.94 | 2811.67 | 416.98 | 36.28 | 453.26 |
| | | | | | | | | | | | | | | |
| 04 | 2818 | 100-Year | sc rw brdge grd2 | 30000.00 | 5226.16 | 5239.45 | 5237.92 | 5241.75 | 0.002076 | 14.23 | 2643.64 | 318.56 | 26.44 | 343.01 |
| 04 | 2818 | 600-Year | sc rw brdge grd2 | 33000.00 | 5226.16 | 5240.20 | 5238.30 | 5242.54 | 0.001932 | 14.33 | 2883.79 | 318.47 | 24.55 | 343.02 |
| | | | | | | | | | | | | | | |
| 04 | 2478 | 100-Year | BC Nat | 30000.00 | 5228.00 | 5238.37 | 5237.43 | 5241.09 | 0.007302 | 14.19 | 2317.04 | 486.52 | 187.19 | 878.95 |
| 04 | 2478 | 600-Year | BC Nat | 33000.00 | 5228.00 | 5238.96 | 5237.94 | 5241.79 | 0.007052 | 14.52 | 2493.13 | 522.96 | 185.68 | 896.28 |
| | | | | | | | | | | | | | | |
| 04 | 2449 | 100-Year | BC Nat | 30000.00 | 5228.00 | 5237.82 | 5237.17 | 5240.79 | 0.010106 | 14.79 | 2221.03 | 573.94 | 123.02 | 752.62 |
| 04 | 2449 | 600-Year | BC Nat | 33000.00 | 5228.00 | 5238.45 | 5237.67 | 5241.51 | 0.009484 | 15.01 | 2409.06 | 692.59 | 119.17 | 811.77 |
| | | | | | | | | | | | | | | |
| 04 | 2400 | 100-Year | sc rw brdge grd2 | 30000.00 | 5225.96 | 5236.40 | 5236.40 | 5240.33 | 0.003885 | 16.80 | 2035.80 | 263.94 | 78.12 | 342.06 |
| 04 | 2400 | 600-Year | sc rw brdge grd2 | 33000.00 | 5225.96 | 5237.99 | 5236.94 | 5241.28 | 0.002510 | 15.45 | 2495.82 | 308.92 | 37.11 | 348.03 |
| | | | | | | | | | | | | | | |
| 04 | 2368 | 100-Year | BC Nat | 30000.00 | 5226.94 | 5236.08 | 5236.08 | 5239.77 | 0.010421 | 14.37 | 1951.71 | 261.26 | 82.89 | 344.15 |
| 04 | 2368 | 100-Year | sc rw brdge grd2 | 30000.00 | 5225.90 | 5235.60 | 5235.60 | 5239.83 | 0.011572 | 15.87 | 1824.42 | 216.52 | 42.13 | 258.65 |
| 04 | 2368 | 600-Year | BC Nat | 33000.00 | 5226.94 | 5236.54 | 5236.54 | 5240.50 | 0.010427 | 14.90 | 2072.57 | 263.21 | 81.23 | 344.44 |
| 04 | 2368 | 600-Year | sc rw brdge grd2 | 33000.00 | 5225.90 | 5236.16 | 5236.16 | 5240.66 | 0.011385 | 16.40 | 1946.48 | 217.84 | 41.45 | 259.29 |
| | | | | | | | | | | | | | | |
| 04 | 2319 | 100-Year | BC Nat | 30000.00 | 5222.00 | 5234.66 | | 5236.58 | 0.004223 | 12.09 | 2840.15 | 287.96 | 50.93 | 338.88 |
| 04 | 2319 | 100-Year | sc rw brdge grd2 | 30000.00 | 5220.40 | 5234.82 | | 5236.37 | 0.003000 | 10.55 | 3117.20 | 289.79 | 73.75 | 365.23 |
| 04 | 2319 | 600-Year | BC Nat | 33000.00 | 5222.00 | 5235.39 | | 5237.42 | 0.004182 | 12.49 | 3052.80 | 298.64 | 45.73 | 344.37 |
| 04 | 2319 | 600-Year | sc rw brdge grd2 | 33000.00 | 5220.40 | 5235.65 | | 5237.27 | 0.002900 | 10.79 | 3361.88 | 298.85 | 88.76 | 367.61 |
| | | | | | | | | | | | | | | |
| 04 | 2102 | 100-Year | BC Nat | 30000.00 | 5220.00 | 5233.87 | | 5235.89 | 0.003788 | 11.98 | 2852.21 | 298.00 | 73.22 | 371.22 |
| 04 | 2102 | 100-Year | sc rw brdge grd2 | 30000.00 | 5220.18 | 5233.91 | | 5235.65 | 0.003605 | 11.56 | 2912.12 | 291.88 | 85.10 | 376.76 |
| 04 | 2102 | 600-Year | BC Nat | 33000.00 | 5220.00 | 5234.61 | | 5236.53 | 0.003756 | 12.37 | 3083.96 | 329.64 | 57.53 | 387.17 |
| 04 | 2102 | 600-Year | sc rw brdge grd2 | 33000.00 | 5220.18 | 5234.66 | | 5236.54 | 0.003663 | 12.09 | 3148.16 | 346.10 | 64.21 | 410.31 |
| | | | | | | | | | | | | | | |
| 04 | 2083 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5233.89 | 5230.11 | 5235.52 | 0.002497 | 11.62 | 3240.87 | 325.38 | 66.15 | 391.53 |
| 04 | 2083 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5234.00 | 5229.60 | 5235.45 | 0.002333 | 10.88 | 3381.90 | 346.23 | 75.31 | 427.16 |
| 04 | 2083 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5234.62 | 5230.67 | 5236.36 | 0.002570 | 12.15 | 3525.00 | 412.69 | 36.45 | 463.11 |
| 04 | 2083 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5234.80 | 5230.17 | 5236.33 | 0.002326 | 11.21 | 3694.58 | 392.88 | 47.21 | 440.09 |
| | | | | | | | | | | | | | | |
| 04 | 1884 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5233.56 | | 5235.03 | 0.002529 | 11.52 | 3419.03 | 342.11 | 231.25 | 846.57 |
| 04 | 1884 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5233.56 | | 5235.03 | 0.002529 | 11.52 | 3419.03 | 342.11 | 231.25 | 846.57 |
| 04 | 1884 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5234.21 | | 5235.86 | 0.002782 | 12.42 | 3714.11 | 630.99 | 90.57 | 837.46 |
| 04 | 1884 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5234.21 | | 5235.86 | 0.002782 | 12.42 | 3714.11 | 630.99 | 90.57 | 837.46 |
| | | | | | | | | | | | | | | |
| 04 | 1844 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5233.19 | 5228.42 | 5234.45 | 0.001882 | 9.69 | 3431.36 | 446.36 | 315.72 | 762.08 |
| 04 | 1844 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5233.19 | 5228.42 | 5234.45 | 0.001882 | 9.69 | 3431.36 | 446.36 | 315.72 | 762.08 |
| 04 | 1844 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5234.11 | 5228.91 | 5235.27 | 0.001714 | 9.63 | 3988.07 | 663.13 | 104.54 | 767.67 |
| 04 | 1844 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5234.11 | 5228.91 | 5235.27 | 0.001714 | 9.63 | 3988.07 | 663.13 | 104.54 | 767.67 |
| | | | | | | | | | | | | | | |
| 04 | 1419 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5232.91 | 5228.76 | 5234.02 | 0.001755 | 9.16 | 3646.61 | 782.29 | 161.22 | 943.51 |
| 04 | 1419 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5232.91 | 5228.76 | 5234.02 | 0.001755 | 9.16 | 3646.61 | 782.29 | 161.22 | 943.51 |
| 04 | 1419 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5233.78 | 5229.19 | 5234.91 | 0.001839 | 9.21 | 3955.33 | 826.42 | 120.25 | 946.66 |
| 04 | 1419 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5233.78 | 5229.19 | 5234.91 | 0.001839 | 9.21 | 3955.33 | 826.42 | 120.25 | 946.66 |
| | | | | | | | | | | | | | | |
| 04 | 1330 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5232.29 | 5228.31 | 5233.74 | 0.002561 | 10.94 | 3242.07 | 310.71 | 660.39 | 971.09 |
| 04 | 1330 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5232.29 | 5228.31 | 5233.74 | 0.002561 | 10.94 | 3242.07 | 310.71 | 660.39 | 971.09 |
| 04 | 1330 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5233.13 | 5228.81 | 5234.64 | 0.002474 | 11.18 | 3506.91 | 319.42 | 653.37 | 972.79 |
| 04 | 1330 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5233.13 | 5228.81 | 5234.64 | 0.002474 | 11.18 | 3506.91 | 319.42 | 653.37 | 972.79 |
| | | | | | | | | | | | | | | |
| 04 | 1313 | | | Bridge | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 04 | 1296 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5232.25 | 5227.52 | 5233.50 | 0.002117 | 9.95 | 3439.22 | 310.54 | 285.21 | 595.76 |
| 04 | 1296 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5232.25 | 5227.52 | 5233.50 | 0.002117 | 9.95 | 3439.22 | 310.54 | 285.21 | 595.76 |
| 04 | 1296 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5233.10 | 5228.02 | 5234.40 | 0.002057 | 10.20 | 3706.76 | 317.96 | 279.17 | 597.13 |
| 04 | 1296 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5233.10 | 5228.02 | 5234.40 | 0.002057 | 10.20 | 3706.76 | 317.96 | 279.17 | 597.13 |
| | | | | | | | | | | | | | | |
| 04 | 1279 | 100-Year | BC Nat | 30000.00 | 5218.00 | 5232.17 | 5227.45 | 5233.45 | 0.001711 | 10.16 | 3413.52 | 307.55 | 293.17 | 600.72 |
| 04 | 1279 | 100-Year | sc rw brdge grd2 | 30000.00 | 5218.00 | 5232.17 | 5227.45 | 5233.45 | 0.001711 | 10.16 | 3413.52 | 307.55 | 293.17 | 600.72 |
| 04 | 1279 | 600-Year | BC Nat | 33000.00 | 5218.00 | 5233.00 | 5227.97 | 5234.35 | 0.001669 | 10.43 | 3645.54 | 313.45 | 288.99 | 602.44 |
| 04 | 1279 | 600-Year | sc rw brdge grd2 | 33000.00 | 5218.00 | 5233.00 | 5227.97 | 5234.35 | 0.001669 | 10.43 | 3645.54 | 313.45 | 288.99 | 602.44 |
| | | | | | | | | | | | | | | |
| 04 | 1216 | | | Bridge | | | | | | | | | | |

The consideration of the potential impacts constitutes an assessment of risk for the specific site. The least total expected cost (LTEC) alternative should be developed in accordance with FHWA HEC-17 (3) when the conventional design frequency in Chapter 7, Hydrology is not used. This analysis provides a comparison between other alternatives developed in response to environmental, regulatory, and political considerations.

**Backwater Increases Over Existing Conditions**

The backwater increase will be defined as the difference in water surface elevations between the natural case with no bridge and the case with the proposed bridge.

The new structure will conform to FEMA regulations for sites covered by the NFIP.

For sites not covered by NFIP, the backwater increase during the passage of the 100-year flood will be limited to no more than one foot above the backwater corresponding to natural conditions that existed prior to the construction of the bridge. For sites not covered by NFIP, a greater than one foot increase in backwater is acceptable if there is adequate justification showing that the design is the only practical alternative and that the design will only cause minimal impacts. For these sites, a risk analysis (LTEC) design should be considered. Any impacted property owner must agree to the changed flood condition.

Hydraulic evaluation must include channel conditions pertaining to: i) natural channel condition prior to the construction of the existing bridge; ii) the existing bridge; and iii) the proposed bridge.

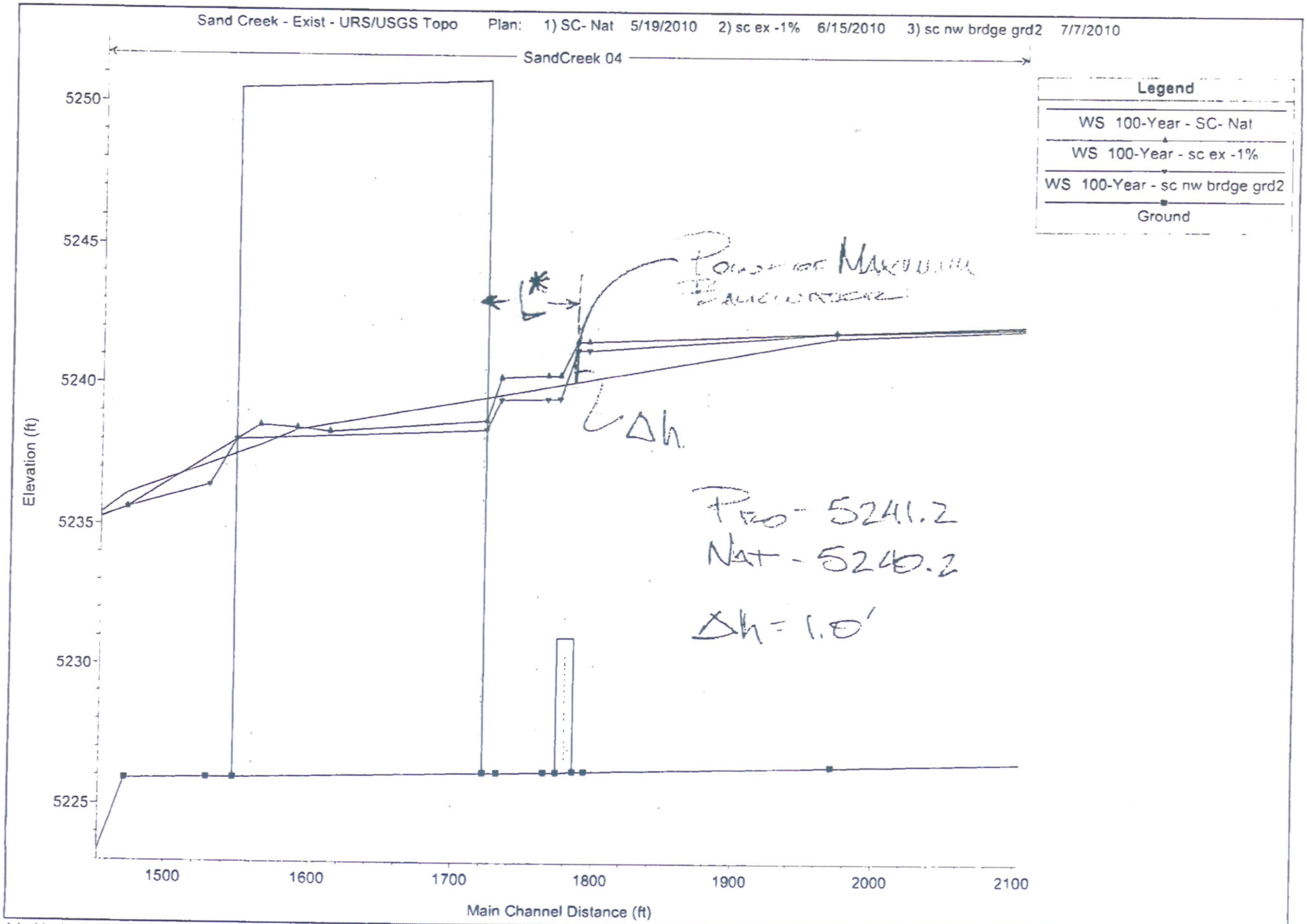
**Distance to point of maximum backwater**

In backwater computations, it will be found necessary in some cases to locate the point or points of maximum backwater with respect to the bridge. The maximum backwater in line with the midpoint of, the bridge occurs at point *A* (figure 10.1A), this point being a distance, $L^*$, from the waterline on the upstream side of the embankment. Where floodplains are inundated and embankments constrict the flow, the elevation of the water surface throughout the areas *ABCD* and *AEFG* will be essentially the same as at point *A*, where the backwater measurement was made on the models. This characteristic has been verified from field measurements made by the U.S. Geological Survey on bridges where the flood plains on each side of the main channel were no wider than twice the bridge length and hydraulic roughness was relatively low.

For crossings with exceptionally wide, rough floodplains, this essentially level ponding may not occur. Flow gradients may exist along the upstream side of the embankments due to borrow pits, ditches and cleared areas along the right-of-way. These flow gradients along embankments are likely to be more pronounced on the falling than on the rising stage of a flood. A correlation is needed between the water level along the upstream side of embankments and point *A* since it is difficult to obtain water surface elevations at point *A* in the field during floods. For the purpose of design and field verification, it has been assumed that the average water surface elevation along the upstream side of embankments, for as much as two bridge lengths adjacent to each abutment (*F* to *G* and *D* to *C*), is the same as at point *A* (figure 10.1B).

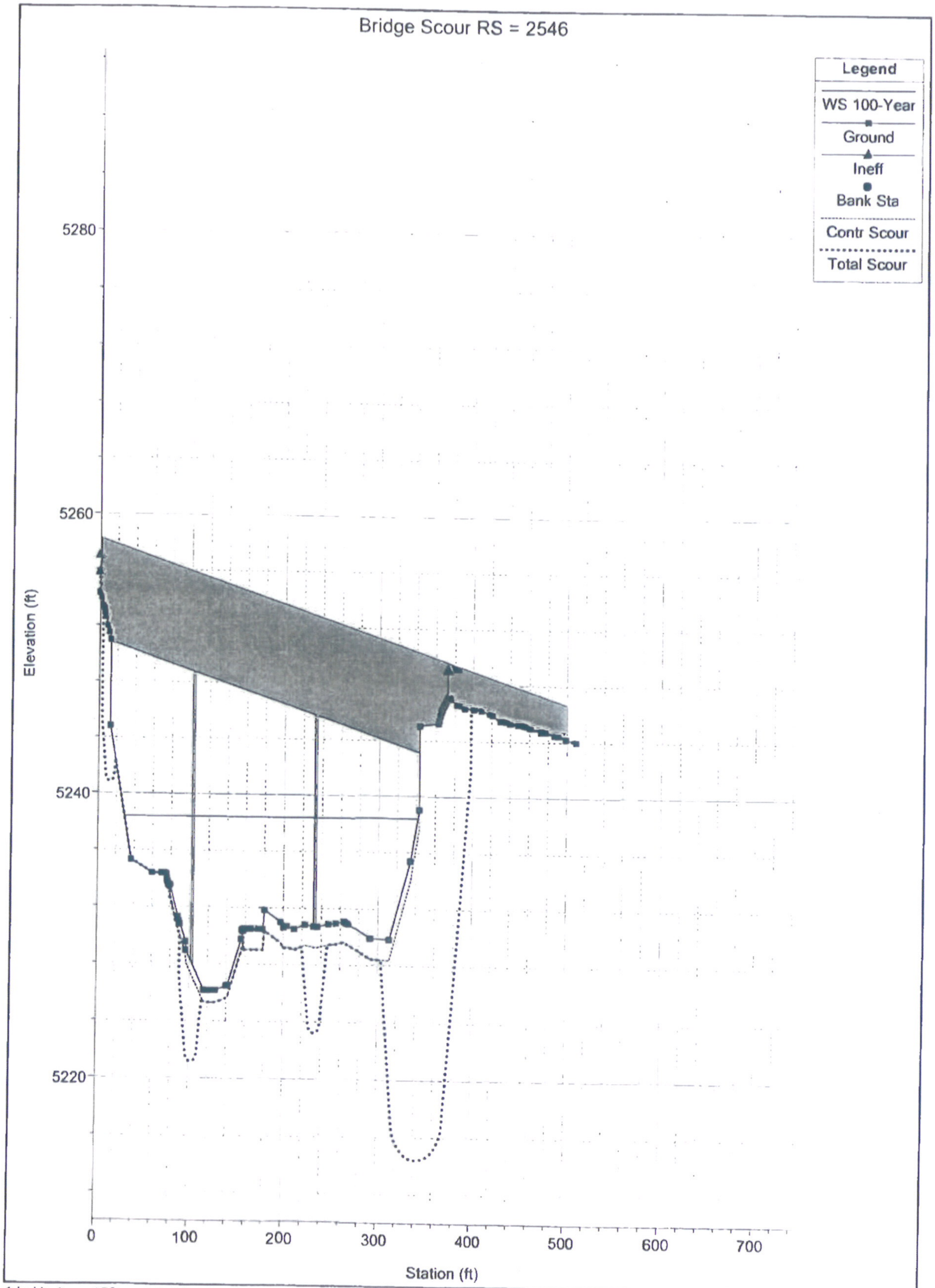
*Normal crossings*

Figure 10.1 has been prepared for determining distance to point of maximum backwater, measured normal to centerline of bridge. The curves on figure 10.1 were developed from information supplied by the U.S. Geological Survey on a number of field structures during floods. Referring to figure 10.1, the normal depth of flow under a bridge is defined here as $\bar{y} = A_{n2} / b$, where $A_{n2}$ is the cross sectional area under the bridge, referred to normal water surface, and $b$ is the width of waterway. A trial solution is re-



1 in Horiz. = 100 ft 1 in Vert. = 5 ft

100-Yr Scour




1 in Horiz. = 150    1 in Vert. = 10

## Contraction Scour

### Input Data

| | Left | Channel | Right |
|---|---|---|---|
| Average Depth (ft): | 4.26 | 10.95 | 8.12 |
| Approach Velocity (ft/s): | 8.64 | 15.93 | 9.93 |
| Br Average Depth (ft): | 3.44 | 10.21 | 7.25 |
| BR Opening Flow (cfs): | 910.88 | 12794.27 | 16294.85 |
| BR Top WD (ft): | 49.94 | 73 | 181.20 |
| Grain Size D50 (mm): | 0.67 | 0.67 | 0.67 |
| Approach Flow (cfs): | 1185.12 | 12203.30 | 16611.57 |
| Approach Top WD (ft): | 32.20 | 69.96 | 206.08 |
| K1 Coefficient: | 0.690 | 0.690 | 0.690 |

### Results

| | Left | Channel | Right |
|---|---|---|---|
| Scour Depth Ys (ft): | 0.00 | 0.86 | 1.48 |
| Critical Velocity (ft/s): | | | |
| Equation: | Live | Live | Live |

## Pier Scour

All piers have the same scour depth

### Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.67000 |
| Depth Upstream (ft): | 13.29 |
| Velocity Upstream (ft/s): | 16.04 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 174.50 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 1.38000 |
| K4 Armouring Coef: | 1.00 |

### Results

| | |
|---|---|
| Scour Depth Ys (ft): | 6.00 |
| Froude #: | 0.78 |
| Equation: | CSU equation |

Pier Scour Limited to Maximum of Ys = 2.4 * a

## Abutment Scour

### Input Data

| | Left | Right |
|---|---|---|
| Station at Toe (ft): | 12.99 | 343.07 |
| Toe Sta at appr (ft): | 3.91 | 325.23 |
| Abutment Length (ft): | 0.00 | 122.99 |
| Depth at Toe (ft): | 1.00 | 8.00 |
| K1 Shape Coef: | 0.55 - Spill-through abutment | |
| Degree of Skew (degrees): | 90.00 | 90.00 |
| K2 Skew Coef: | 1.00 | 1.00 |
| Projected Length L' (ft): | 0.00 | 122.99 |
| Avg Depth Obstructed Ya (ft): | | 6.05 |
| Flow Obstructed Qe (cfs): | | 1638.95 |
| Area Obstructed Ae (sq ft): | | 744.28 |

### Results

| | Left | Right |
|---|---|---|
| Scour Depth Ys (ft): | 4.60 | 27.31 |

| | | |
|---|---|---|
| Froude #: | 1.52 | 0.62 |
| Equation: | HIRE | HIRE |

Combined Scour Depths

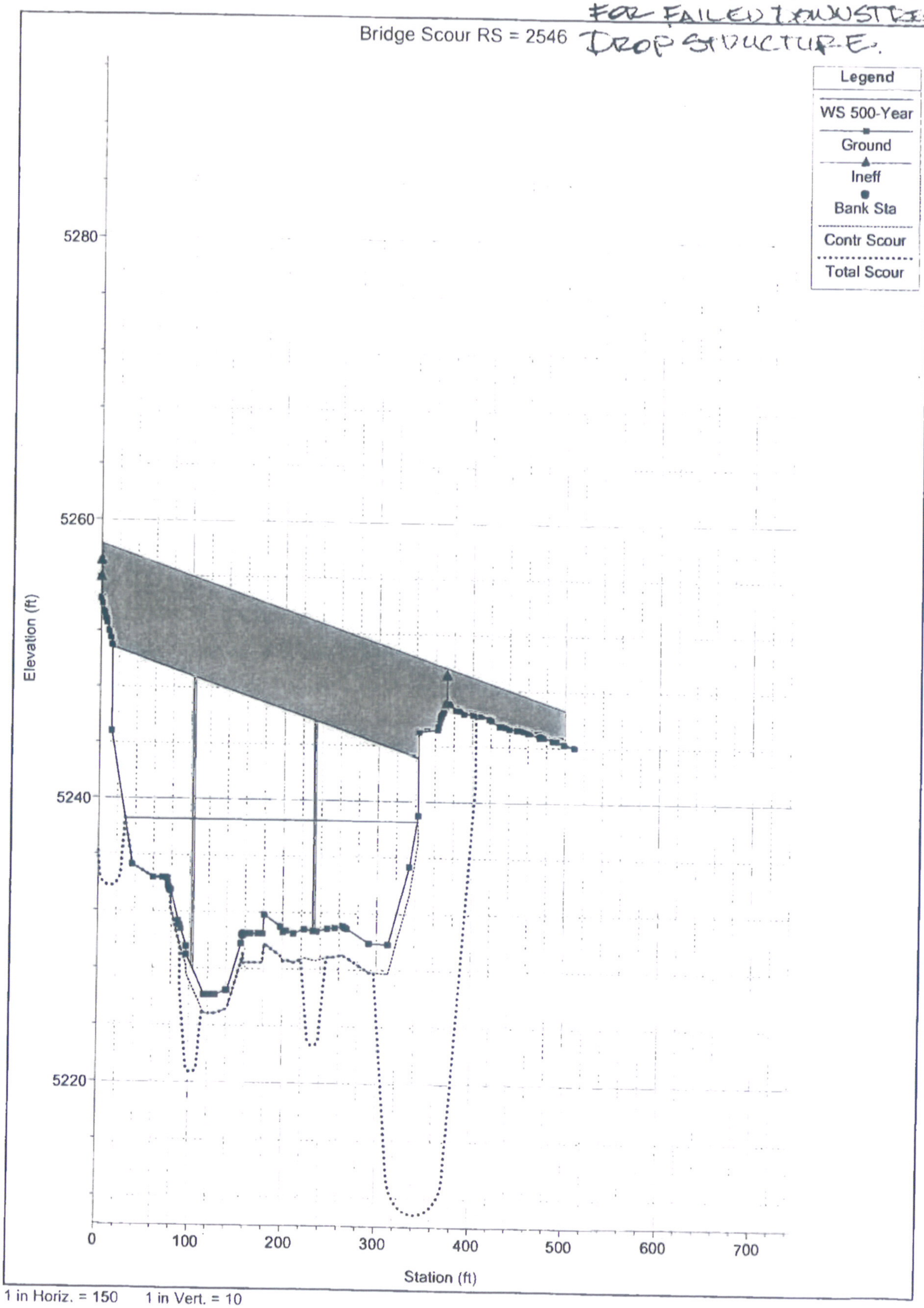
Pier Scour + Contraction Scour (ft):

| | |
|---|---|
| Channel: | 6.86 |
| Right Bank: | 7.48 |

| | |
|---|---|
| Left abutment scour + contraction scour (ft): | 4.60 |
| Right abutment scour + contraction scour (ft): | 28.79 |

500-YR SCOUR

NOTE: CONTRACTION & PIER SCOUR WILL BE INCREASED TO ACCOUNT FOR FAILED DOWNSTREAM DROP STRUCTURE.



## Contraction Scour

### Input Data

| | Left | Channel | Right |
|---|---|---|---|
| Average Depth (ft): | 4.82 | 11.71 | 8.88 |
| Approach Velocity (ft/s): | 8.96 | 15.94 | 10.10 |
| Br Average Depth (ft): | 3.57 | 10.37 | 7.40 |
| BR Opening Flow (cfs): | 1041.88 | 13978.16 | 17979.96 |
| BR Top WD (ft): | 50.34 | 76.22 | 181.60 |
| Grain Size D50 (mm): | 0.67 | 0.67 | 0.67 |
| Approach Flow (cfs): | 1452.84 | 13063.26 | 18483.90 |
| Approach Top WD (ft): | 33.68 | 69.96 | 206.08 |
| K1 Coefficient: | 0.690 | 0.690 | 0.690 |

### Results

| | Left | Channel | Right |
|---|---|---|---|
| Scour Depth Ys (ft): | 0.00 | 1.33 | 2.06 |
| Critical Velocity (ft/s): | 1.89 | 2.19 | 2.10 |
| Equation: | Live | Live | Live |

## Pier Scour

All piers have the same scour depth

INCREASE 5' FOR FAILED DOWNSTREAM DROP

### Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.67000 |
| Depth Upstream (ft): | 14.04 |
| Velocity Upstream (ft/s): | 16.11 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 174.50 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |

### Results

(INCREASE 6' FOR FAILED DOWNSTREAM DROP

| | |
|---|---|
| Scour Depth Ys (ft): | 6.00 |
| Froude #: | 0.76 |
| Equation: | CSU equation |

Pier Scour Limited to Maximum of Ys = 2.4 * a

## Abutment Scour

### Input Data

| | Left | Right |
|---|---|---|
| Station at Toe (ft): | 12.99 | 343.07 |
| Toe Sta at appr (ft): | 3.91 | 325.23 |
| Abutment Length (ft): | 0.00 | 128.03 |
| Depth at Toe (ft): | 3 | 9 |
| K1 Shape Coef: | 0.55 - Spill-through abutment | |
| Degree of Skew (degrees): | 90.00 | 90.00 |
| K2 Skew Coef: | 1.00 | 1.00 |
| Projected Length L' (ft): | 0.00 | 128.03 |
| Avg Depth Obstructed Ya (ft): | | 6.56 |
| Flow Obstructed Qe (cfs): | | 1828.19 |
| Area Obstructed Ae (sq ft): | | 839.68 |

### Results

| | Left | Right |
|---|---|---|
| Scour Depth Ys (ft): | 11.64 | 30.30 |

| | | |
|---|---|---|
| Froude #: | 0.91 | 0.59 |
| Equation: | HIRE | HIRE |

Combined Scour Depths

Pier Scour + Contraction Scour (ft):

| | |
|---|---|
| Channel: | 7.33 |
| Right Bank: | 8.06 |

| | |
|---|---|
| Left abutment scour + contraction scour (ft): | 11.64 |
| Right abutment scour + contraction scour (ft): | 32.37 |

## Bridge Hydraulic Information Transmittal Sheet for Spillthrough Abutments

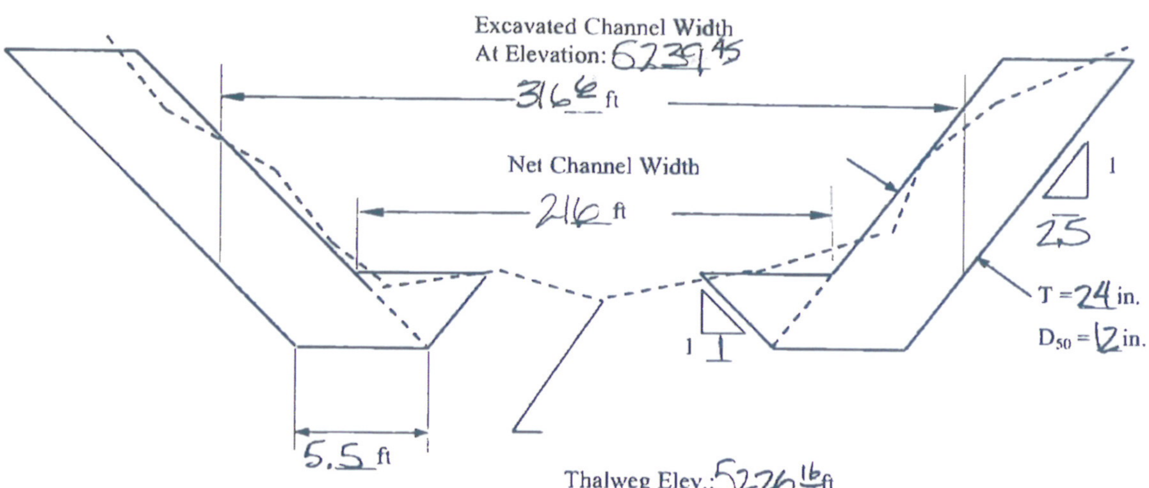
Here is the structure opening and hydraulic information required for the bridge across Sand Creek on SH I-70 at/near I-270.

**PROJECT INFORMATION**

| | |
|---|---|
| Date: 7/9/2010 | Construction Project Number: C 0704 220 |
| To: Josh Warren (TEA) | P.E. Project No.: |
| From: Richard Prulett | Project Name: CDOT R6 Faster Bridges I-70 over Sand Creek |

**BRIDGE INFORMATION**

| | |
|---|---|
| Existing Structure Number: | E-17-BY |
| Station at Centerline of Channel: | 81+00 @ HCL |
| Skew: | 30° |
| Minimum Low Girder Elevation: | 5245.15 |
| Design Year Event: | 100 year recurrence. |




**HYDRAULIC INFORMATION**

| | | | |
|---|---|---|---|
| D.A. = 175 sq. miles | $Q_{(Design)}$ = 3000 cfs | $Q_{(100)}$ = 3000 cfs | $Q_{(500)}$ = 3300 cfs |
| OHW = 5230.41 ft | $DHW_{(Design)}$ = 5239.45 | $HW_{(100)}$ = 5239.45 | $HW_{(500)}$ = 5240.20 |
| | $V_{(Design)}$ = 14.23 cfs | $V_{(100)}$ = 14.23 fps | $V_{(500)}$ = 14.33 fps |

Please submit to Staff Bridge the information required by CDOT Drainage Design Manual so they may proceed with design. Bridge Layout requested: yes ☐ no ☒

Comments:

See Bridge Hydraulic Information Sheets for more information

Figure 10.6 Transmittal of Bridge Hydraulic Information Sheet for Spillthrough Abutments.

UPSTREAM BRIDGE FACE

HEC-RAS River: SandCreek Reach: 04

| Reach | River Sta | Profile | Plan | Q Total (cfs) | Min Ch El (ft) | W.S. Elev (ft) | Crit W.S. (ft) | E.G. Elev (ft) | E.G. Slope (ft/ft) | Vel Chnl (ft/s) | Flow Area (sq ft) | Top Width (ft) | Sta W.S. Lft (ft) | Sta W.S. Rgt (ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 04 | 3733 | 100-Year | SC- Nat | 30000.00 | 5229.00 | 5243.15 | | 5244.26 | 0.001959 | 12.45 | 4839.35 | 722.57 | 285.71 | 1008.29 |
| 04 | 3733 | 100-Year | sc nw brdge grd2 | 30000.00 | 5229.00 | 5242.95 | | 5244.15 | 0.002143 | 12.69 | 4694.85 | 721.08 | 286.20 | 1007.28 |
| 04 | 3733 | 500-Year | SC- Nat | 33000.00 | 5229.00 | 5243.81 | | 5244.86 | 0.001790 | 12.27 | 5316.21 | 727.48 | 284.10 | 1011.58 |
| 04 | 3733 | 500-Year | sc nw brdge grd2 | 33000.00 | 5229.00 | 5243.66 | | 5244.77 | 0.001905 | 12.57 | 5206.54 | 726.35 | 284.47 | 1010.82 |
| | | | | | | | | | | | | | | |
| 04 | 3302 | 100-Year | SC- Nat | 30000.00 | 5228.80 | 5242.57 | 5239.88 | 5243.46 | 0.001541 | 10.95 | 4638.95 | 736.98 | 30.07 | 767.05 |
| 04 | 3302 | 100-Year | sc nw brdge grd2 | 30000.00 | 5227.99 | 5242.49 | 5239.45 | 5243.31 | 0.001395 | 9.83 | 4736.46 | 748.95 | 30.82 | 779.77 |
| 04 | 3302 | 500-Year | SC- Nat | 33000.00 | 5228.80 | 5243.23 | 5240.16 | 5244.13 | 0.001459 | 11.00 | 5016.21 | 753.28 | 24.52 | 777.79 |
| 04 | 3302 | 500-Year | sc nw brdge grd2 | 33000.00 | 5227.99 | 5243.19 | 5239.79 | 5244.02 | 0.001316 | 9.86 | 5139.57 | 757.64 | 27.45 | 785.09 |
| | | | | | | | | | | | | | | |
| 04 | 3273 | 100-Year | SC- Nat | 30000.00 | 5228.00 | 5242.55 | 5239.10 | 5243.42 | 0.001121 | 9.85 | 4966.88 | 749.31 | 6.68 | 756.00 |
| 04 | 3273 | 100-Year | sc nw brdge grd2 | 30000.00 | 5226.82 | 5242.41 | 5239.53 | 5243.27 | 0.001237 | 10.46 | 4783.91 | 739.34 | 25.63 | 764.97 |
| 04 | 3273 | 500-Year | SC- Nat | 33000.00 | 5228.00 | 5243.22 | 5239.42 | 5244.09 | 0.001077 | 9.95 | 5354.96 | 759.40 | 5.35 | 764.75 |
| 04 | 3273 | 500-Year | sc nw brdge grd2 | 33000.00 | 5226.82 | 5243.12 | 5239.90 | 5243.98 | 0.001172 | 10.49 | 5186.48 | 750.56 | 21.86 | 772.42 |
| | | | | | | | | | | | | | | |
| 04 | 2867 | 100-Year | SC- Nat | 30000.00 | 5228.00 | 5241.67 | 5238.98 | 5242.85 | 0.002110 | 12.57 | 3949.77 | 536.20 | 13.55 | 606.40 |
| 04 | 2867 | 100-Year | sc nw brdge grd2 | 30000.00 | 5226.40 | 5241.84 | 5238.16 | 5242.76 | 0.001636 | 9.65 | 4260.55 | 544.68 | 17.97 | 606.78 |
| 04 | 2867 | 500-Year | SC- Nat | 33000.00 | 5228.00 | 5242.32 | 5239.33 | 5243.54 | 0.002050 | 12.80 | 4231.98 | 614.54 | 12.73 | 627.27 |
| 04 | 2867 | 500-Year | sc nw brdge grd2 | 33000.00 | 5226.40 | 5242.53 | 5238.51 | 5243.46 | 0.001607 | 9.84 | 4557.48 | 601.20 | 16.99 | 618.19 |
| | | | | | | | | | | | | | | |
| 04 | 2680 | 100-Year | sc nw brdge grd2 | 30000.00 | 5226.22 | 5241.20 | 5237.79 | 5242.39 | 0.002133 | 11.50 | 3645.34 | 452.63 | 30.54 | 483.16 |
| 04 | 2680 | 500-Year | sc nw brdge grd2 | 33000.00 | 5226.22 | 5241.85 | 5238.19 | 5243.12 | 0.002107 | 11.78 | 3884.98 | 459.33 | 29.67 | 524.98 |
| | | | | | | | | | | | | | | |
| 04 | 2651 | 100-Year | sc nw brdge grd2 | 30000.00 | 5226.19 | 5239.47 | 5238.38 | 5241.96 | 0.006117 | 15.93 | 2576.32 | 410.45 | 37.76 | 448.21 |
| 04 | 2651 | 500-Year | sc nw brdge grd2 | 33000.00 | 5226.19 | 5240.23 | 5238.85 | 5242.73 | 0.005616 | 15.94 | 2811.67 | 416.98 | 36.28 | 453.26 |
| | | | | | | | | | | | | | | |
| 04 | 2618 | 100-Year | sc nw brdge grd2 | 30000.00 | 5226.16 | 5239.45 | 5237.92 | 5241.75 | 0.002076 | 14.23 | 2643.64 | 316.56 | 26.44 | 343.01 |
| 04 | 2618 | 500-Year | sc nw brdge grd2 | 33000.00 | 5226.16 | 5240.20 | 5238.30 | 5242.54 | 0.001932 | 14.33 | 2883.79 | 318.47 | 24.55 | 343.02 |
| | | | | | | | | | | | | | | |
| 04 | 2476 | 100-Year | SC- Nat | 30000.00 | 5228.00 | 5238.37 | 5237.43 | 5241.09 | 0.007302 | 14.19 | 2317.04 | 486.52 | 187.19 | 876.95 |
| 04 | 2476 | 500-Year | SC- Nat | 33000.00 | 5228.00 | 5238.96 | 5237.94 | 5241.79 | 0.007052 | 14.52 | 2493.13 | 522.96 | 185.66 | 896.28 |
| | | | | | | | | | | | | | | |
| 04 | 2449 | 100-Year | SC- Nat | 30000.00 | 5228.00 | 5237.82 | 5237.17 | 5240.79 | 0.010106 | 14.79 | 2221.03 | 573.94 | 123.02 | 752.62 |
| 04 | 2449 | 500-Year | SC- Nat | 33000.00 | 5228.00 | 5238.45 | 5237.67 | 5241.51 | 0.009484 | 15.01 | 2409.06 | 692.59 | 119.17 | 811.77 |
| | | | | | | | | | | | | | | |
| 04 | 2400 | 100-Year | sc nw brdge grd2 | 30000.00 | 5225.96 | 5236.40 | 5236.40 | 5240.33 | 0.003685 | 16.80 | 2035.60 | 263.94 | 78.12 | 342.06 |
| 04 | 2400 | 500-Year | sc nw brdge grd2 | 33000.00 | 5225.96 | 5237.99 | 5236.94 | 5241.28 | 0.002510 | 15.45 | 2495.82 | 308.92 | 37.11 | 348.03 |
| | | | | | | | | | | | | | | |
| 04 | 2358 | 100-Year | SC- Nat | 30000.00 | 5226.94 | 5236.08 | 5236.08 | 5239.77 | 0.010421 | 14.37 | 1951.71 | 261.26 | 82.89 | 344.15 |
| 04 | 2358 | 100-Year | sc nw brdge grd2 | 30000.00 | 5225.90 | 5235.60 | 5235.60 | 5239.83 | 0.011572 | 15.87 | 1824.42 | 216.52 | 42.13 | 258.65 |
| 04 | 2358 | 500-Year | SC- Nat | 33000.00 | 5226.94 | 5236.54 | 5236.54 | 5240.50 | 0.010427 | 14.90 | 2072.57 | 263.21 | 81.23 | 344.44 |
| 04 | 2358 | 500-Year | sc nw brdge grd2 | 33000.00 | 5225.90 | 5236.16 | 5236.16 | 5240.66 | 0.011365 | 16.40 | 1946.48 | 217.84 | 41.45 | 259.29 |
| | | | | | | | | | | | | | | |
| 04 | 2319 | 100-Year | SC- Nat | 30000.00 | 5222.00 | 5234.66 | | 5236.58 | 0.004223 | 12.09 | 2840.15 | 287.96 | 50.93 | 338.88 |
| 04 | 2319 | 100-Year | sc nw brdge grd2 | 30000.00 | 5220.40 | 5234.82 | | 5236.37 | 0.003000 | 10.55 | 3117.20 | 289.79 | 73.75 | 365.23 |
| 04 | 2319 | 500-Year | SC- Nat | 33000.00 | 5222.00 | 5235.39 | | 5237.42 | 0.004182 | 12.49 | 3052.80 | 298.64 | 45.73 | 344.37 |
| 04 | 2319 | 500-Year | sc nw brdge grd2 | 33000.00 | 5220.40 | 5235.65 | | 5237.27 | 0.002900 | 10.79 | 3361.88 | 298.65 | 68.76 | 367.61 |
| | | | | | | | | | | | | | | |
| 04 | 2102 | 100-Year | SC- Nat | 30000.00 | 5220.00 | 5233.67 | | 5235.69 | 0.003768 | 11.98 | 2652.21 | 298.00 | 73.22 | 371.22 |
| 04 | 2102 | 100-Year | sc nw brdge grd2 | 30000.00 | 5220.18 | 5233.91 | | 5235.65 | 0.003605 | 11.56 | 2912.12 | 291.68 | 85.10 | 376.78 |
| 04 | 2102 | 500-Year | SC- Nat | 33000.00 | 5220.00 | 5234.61 | | 5236.53 | 0.003758 | 12.37 | 3063.96 | 329.64 | 57.53 | 387.17 |
| 04 | 2102 | 500-Year | sc nw brdge grd2 | 33000.00 | 5220.18 | 5234.66 | | 5236.64 | 0.003663 | 12.09 | 3146.16 | 346.10 | 64.21 | 410.31 |
| | | | | | | | | | | | | | | |
| 04 | 2063 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5233.89 | 5230.11 | 5235.52 | 0.002497 | 11.62 | 3240.87 | 325.38 | 66.15 | 391.53 |
| 04 | 2063 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5234.00 | 5229.60 | 5235.45 | 0.002333 | 10.86 | 3381.90 | 348.23 | 75.31 | 427.18 |
| 04 | 2063 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5234.62 | 5230.67 | 5236.36 | 0.002570 | 12.15 | 3525.00 | 412.69 | 36.45 | 463.11 |
| 04 | 2063 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5234.80 | 5230.17 | 5236.33 | 0.002326 | 11.21 | 3694.58 | 392.88 | 47.21 | 440.09 |
| | | | | | | | | | | | | | | |
| 04 | 1884 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5233.56 | | 5235.03 | 0.002529 | 11.52 | 3419.03 | 342.11 | 231.25 | 646.57 |
| 04 | 1884 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5233.56 | | 5235.03 | 0.002529 | 11.52 | 3419.03 | 342.11 | 231.25 | 646.57 |
| 04 | 1884 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5234.21 | | 5235.86 | 0.002782 | 12.42 | 3714.11 | 630.99 | 90.57 | 837.46 |
| 04 | 1884 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5234.21 | | 5235.86 | 0.002782 | 12.42 | 3714.11 | 630.99 | 90.57 | 837.46 |
| | | | | | | | | | | | | | | |
| 04 | 1844 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5233.19 | 5228.42 | 5234.45 | 0.001882 | 9.69 | 3431.36 | 446.36 | 315.72 | 762.08 |
| 04 | 1844 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5233.19 | 5228.42 | 5234.45 | 0.001882 | 9.69 | 3431.36 | 446.36 | 315.72 | 762.08 |
| 04 | 1844 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5234.11 | 5228.91 | 5235.27 | 0.001714 | 9.63 | 3988.07 | 663.13 | 104.54 | 767.67 |
| 04 | 1844 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5234.11 | 5228.91 | 5235.27 | 0.001714 | 9.63 | 3988.07 | 663.13 | 104.54 | 767.67 |
| | | | | | | | | | | | | | | |
| 04 | 1419 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5232.91 | 5228.76 | 5234.02 | 0.001755 | 9.16 | 3648.61 | 782.29 | 161.22 | 943.51 |
| 04 | 1419 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5232.91 | 5228.76 | 5234.02 | 0.001755 | 9.16 | 3648.61 | 782.29 | 161.22 | 943.51 |
| 04 | 1419 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5233.78 | 5229.19 | 5234.91 | 0.001639 | 9.21 | 3955.33 | 826.42 | 120.25 | 946.68 |
| 04 | 1419 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5233.78 | 5229.19 | 5234.91 | 0.001639 | 9.21 | 3955.33 | 826.42 | 120.25 | 946.68 |
| | | | | | | | | | | | | | | |
| 04 | 1330 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5232.29 | 5228.31 | 5233.74 | 0.002561 | 10.94 | 3242.07 | 310.71 | 660.39 | 971.09 |
| 04 | 1330 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5232.29 | 5228.31 | 5233.74 | 0.002561 | 10.94 | 3242.07 | 310.71 | 660.39 | 971.09 |
| 04 | 1330 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5233.13 | 5228.81 | 5234.64 | 0.002474 | 11.18 | 3506.91 | 319.42 | 653.37 | 972.79 |
| 04 | 1330 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5233.13 | 5228.81 | 5234.64 | 0.002474 | 11.18 | 3506.91 | 319.42 | 653.37 | 972.79 |
| | | | | | | | | | | | | | | |
| 04 | 1313 | | | Bridge | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 04 | 1295 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5232.25 | 5227.52 | 5233.50 | 0.002117 | 9.95 | 3439.22 | 310.54 | 285.21 | 595.76 |
| 04 | 1295 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5232.25 | 5227.52 | 5233.50 | 0.002117 | 9.95 | 3439.22 | 310.54 | 285.21 | 595.76 |
| 04 | 1295 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5233.10 | 5228.02 | 5234.40 | 0.002057 | 10.20 | 3706.76 | 317.96 | 279.17 | 597.13 |
| 04 | 1295 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5233.10 | 5228.02 | 5234.40 | 0.002057 | 10.20 | 3706.76 | 317.96 | 279.17 | 597.13 |
| | | | | | | | | | | | | | | |
| 04 | 1279 | 100-Year | SC- Nat | 30000.00 | 5218.00 | 5232.17 | 5227.45 | 5233.45 | 0.001711 | 10.16 | 3413.52 | 307.55 | 293.17 | 600.72 |
| 04 | 1279 | 100-Year | sc nw brdge grd2 | 30000.00 | 5218.00 | 5232.17 | 5227.45 | 5233.45 | 0.001711 | 10.16 | 3413.52 | 307.55 | 293.17 | 600.72 |
| 04 | 1279 | 500-Year | SC- Nat | 33000.00 | 5218.00 | 5233.00 | 5227.97 | 5234.35 | 0.001669 | 10.43 | 3645.54 | 313.45 | 288.99 | 602.44 |
| 04 | 1279 | 500-Year | sc nw brdge grd2 | 33000.00 | 5218.00 | 5233.00 | 5227.97 | 5234.35 | 0.001669 | 10.43 | 3645.54 | 313.45 | 288.99 | 602.44 |
| | | | | | | | | | | | | | | |
| 04 | 1215 | | | Bridge | | | | | | | | | | |

**Stable Channel Lining Eq. 5-4**

| | |
|---|---|
| V (fps) | 14.23 |
| S ft/ft | 0.001 |
| Ss = 2.5 | 2.5 |

| | |
|---|---|
| d50 (ft) = | 0.6 |

VELOCITY AT BRIDGE
CHANNEL SLOPE

9" MIN d50, USE 12" d50

REUSE EXISTING RIPRAP IF MIN d50 = 12"
VERIFY 24" THICKNESS

**Stable Channel Lining Eq. 5-4**

| | |
|---|---|
| V (fps) | 14.23 |
| S ft/ft | 0.001 |
| Ss = 2.5 | 2.5 |

| | |
|---|---|
| d50 (ft) = | 0.6 |

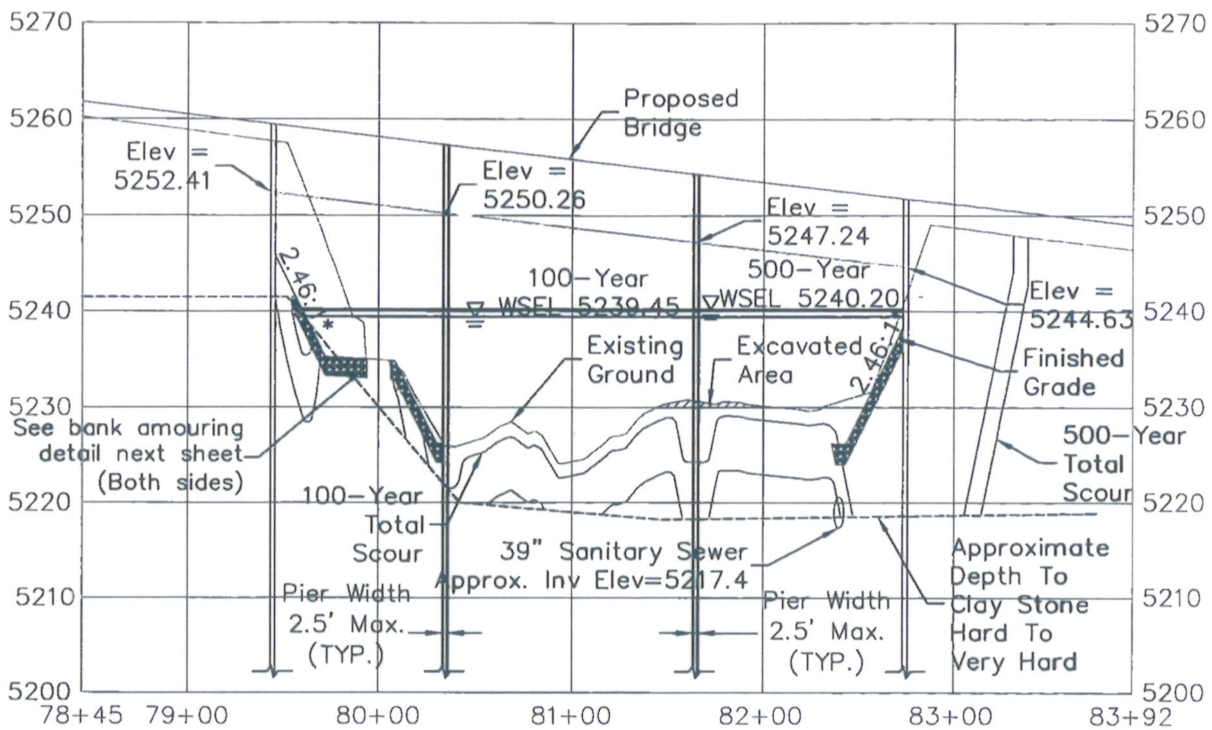
VELOCITY AT [illegible]
CHANNEL SLOPE

9" MIN d50, USE 12" d50

REUSE EXISTING RIPRAP IF MIN d50=12"
VERIFY 24" THICKNESS

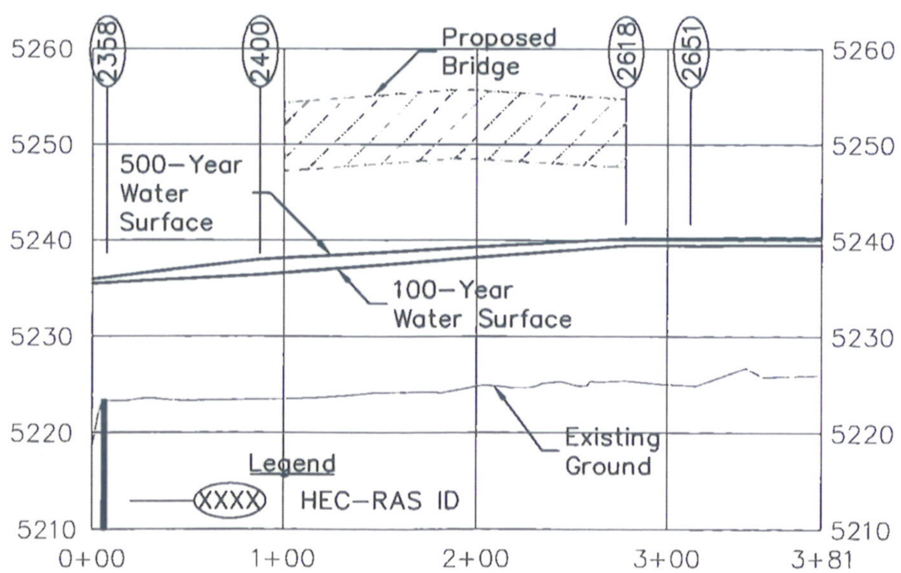
## SECTION THROUGH HCL I-70

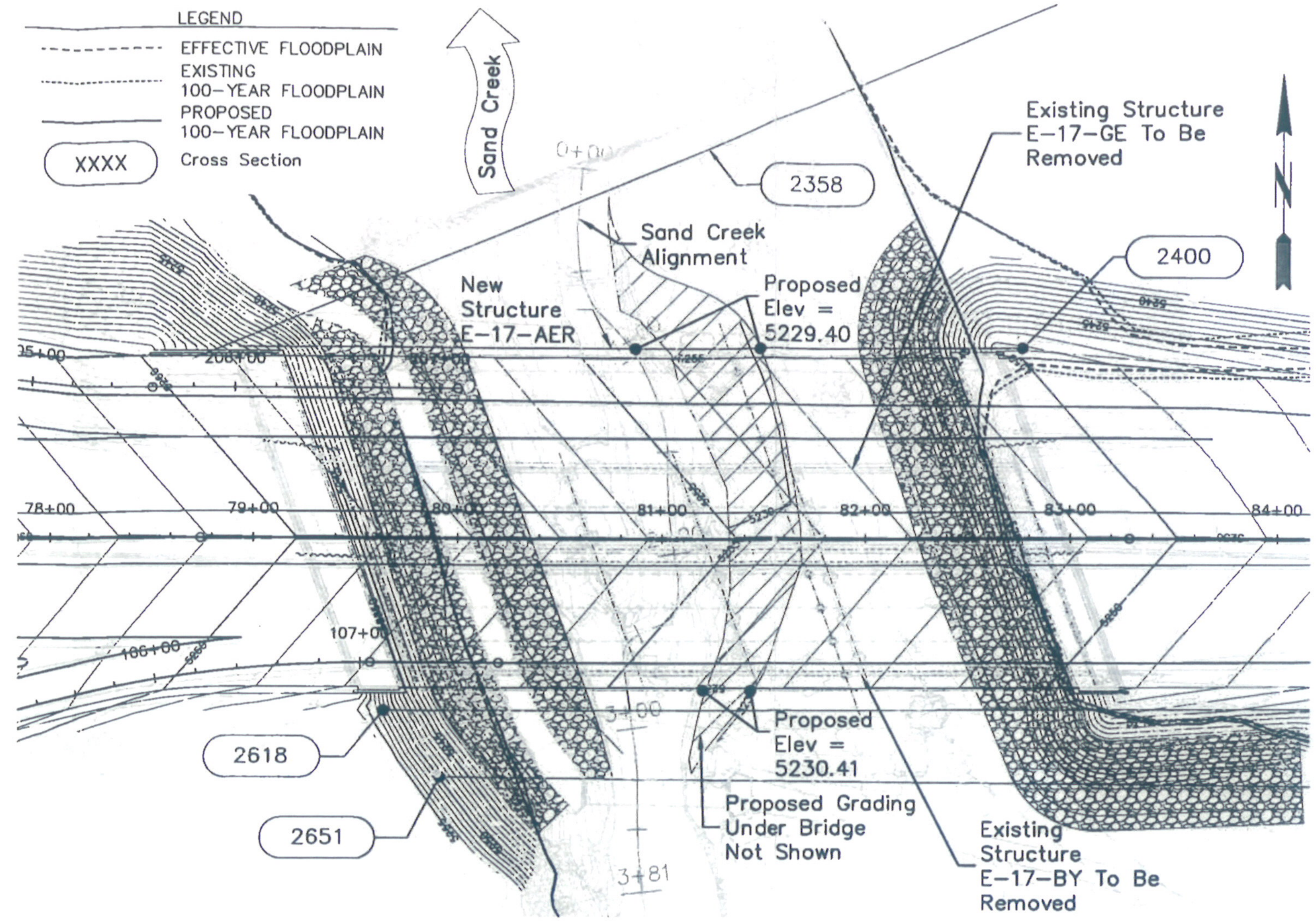
Note: Section Shown Left To Right Looking Downstream.




* Embankment slopes shown on the section above are skewed due to the HCL. Actual slopes (normal to the embankment) are 2.5:1

## SAND CREEK ALIGNMENT




## PLAN VIEW FOR PROPOSED I-70 BRIDGE OVER SAND CREEK

SCALE: 1" = 80'

### SCOUR ANALYSIS RESULTS

| Scour Type | Depth (ft) 100-Year | 500-Year |
|---|---|---|
| Contraction | 1.5 | 7.2 |
| Pier | 6.0 | 11.0 |
| Left Abutment | 4.6 | 11.6 |
| Right Abutment | 27.3 | 30.3 |

Manning's "n" for design - Channel = 0.03
Overbank varies 0.035 to 0.045
Debris - Brush [X] Trees/Logs [ ] Ice [ ] Other [ ]
Drainage Area = 175 sq. mi.

### COMPARISON OF HYDRAULICS (2)

| HEC-RAS Model | Velocity (avg) (fps) | Required Freeboard (ft) | Actual Freeboard (ft) | Maximum Backwater (ft) |
|---|---|---|---|---|
| Natural | 12.6 | - | - | 1.0 |
| Existing | 11.9 | 3.6 | 5.0 | - |
| Proposed | 9.7 | 3.8 | 4.0 | - |

(2) AT PROPOSED BRIDGE LOCATION DURING 100-YEAR EVENT

### CHANNEL DESCRIPTION

Bottom Material - Cohesive [ ] Non-Cohesive [X]
Bottom Material - Size - Clay [ ] Silt [ ] Sand [X] Gravel [ ]
Cobbles [ ] Other [ ]
Stream Form - Straight [X] Meandering [ ] Braided [ ]

Note: All Elevations Are Based On Datum NAVD88.


MOSER & Associates ENGINEERING
720 SOUTH COLORADO BOULEVARD SUITE 410 S
DENVER, CO 80246
PHONE (303) 757-3655
FAX (303) 300-1635


Print Date: 08/10/2010
File Name: 17537BRDG_BRHYD01
Horiz. Scale: As Noted Vert. Scale: As Noted


DAVID EVANS AND ASSOCIATES INC.
1331 17th Street, Suite 900
Denver Colorado 80202
Phone: 720.946.0969


| Sheet Revisions | | |
|---|---|---|
| Date: | Comments | Init. |
| | | |
| | | |
| | | |


Colorado Department of Transportation
4670 Holly Street
Denver, CO 80216-6408
Phone: 303-398-6780 FAX: 720-945-1028
Region 6
DJH

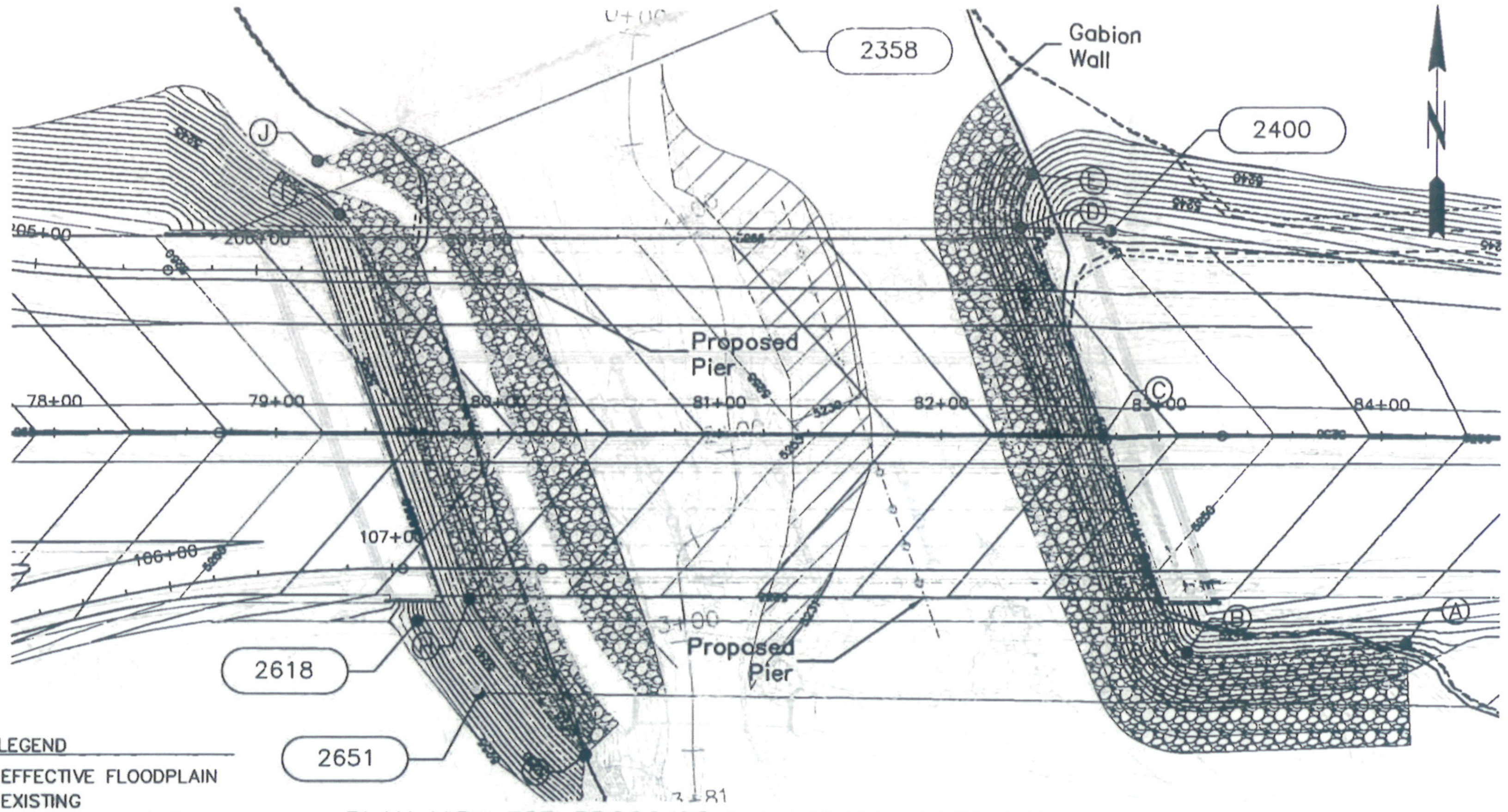

As Constructed
No Revisions:
Revised:
Void:

I-70 OVER SAND CREEK
BRIDGE HYDRAULIC INFORMATION (1)

| | | | |
|---|---|---|---|
| Designer: | R. Ommert | Structure Numbers | E-17-AER |
| Detailer: | R. Mitchell | | E-17-BY |
| Sheet Subset: | BRIDGE | Subset Sheets: | B10 of B50 |

Project No./Code
FBR 0704 220
17537
Sheet Number

Z:\Region 6\FASTER Bridges\I-70 over Sand Creek\CAD_J-70 at Sand Creek\DWG\FOR Bridge Hydraulic Information\17537BRDG_BRHYD01.dwg

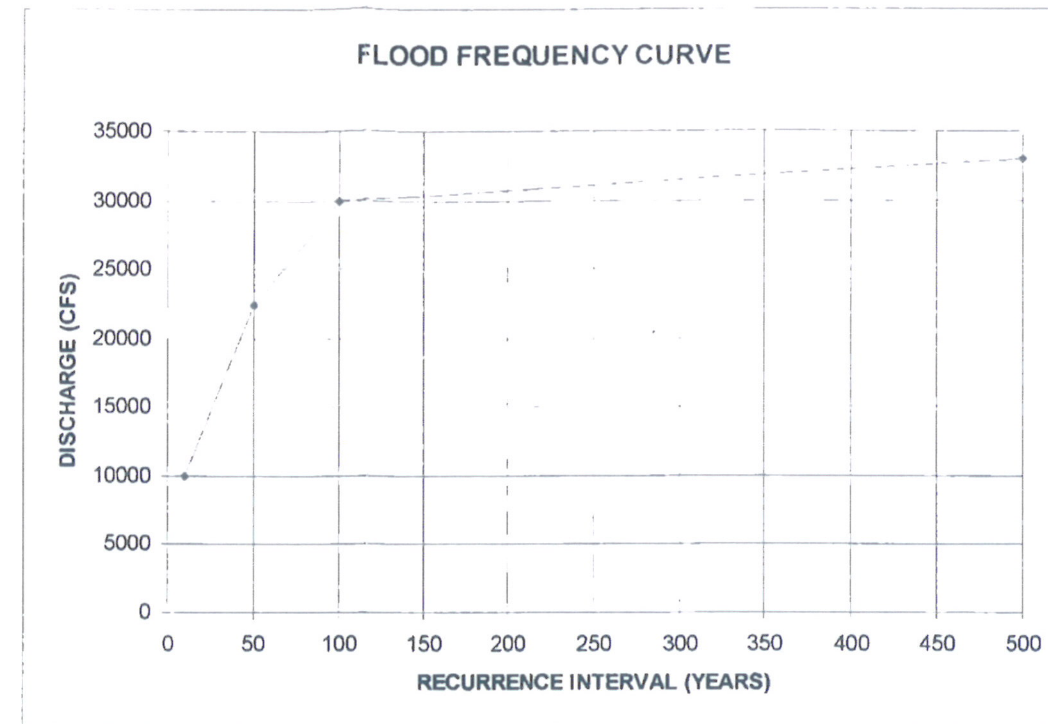


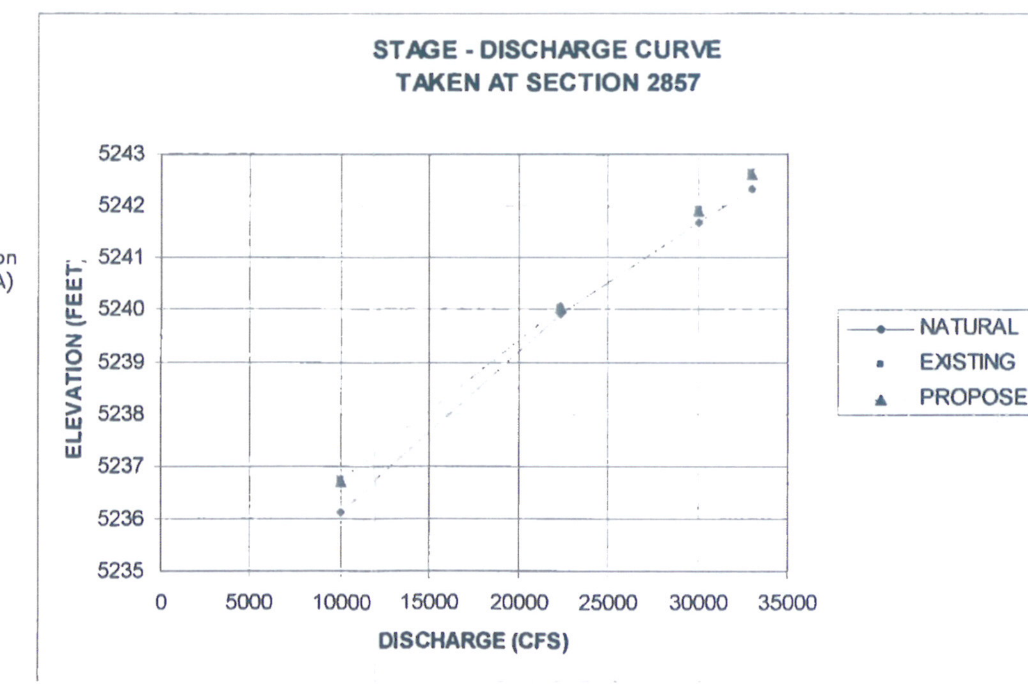

LEGEND

- - - - - - EFFECTIVE FLOODPLAIN
EXISTING 100-YEAR FLOODPLAIN
PROPOSED 100-YEAR FLOODPLAIN
XXXX Cross Section

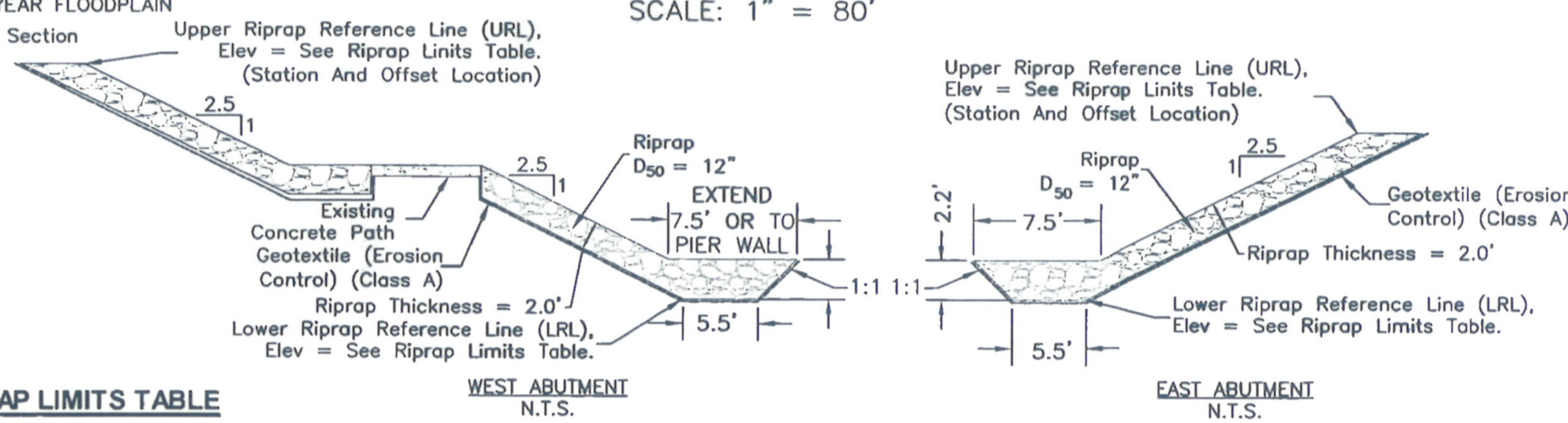
PLAN VIEW FOR PROPOSED I-70 BRIDGE OVER SAND CREEK
STATION AND OFFSETS BASED ON I-70 HCL
SCALE: 1" = 80'

## BRIDGE HYDRAULIC INFORMATION




Water Surface Taken At HEC-RAS Cross Section 2857




### RIPRAP LIMITS TABLE

| POINT | STATION | OFFSET | URL ELEV. | LRL ELEV. |
|---|---|---|---|---|
| A | 84+11.68 | 93.98 Rt | 5241.50 | 5224.00 |
| B | 83+12.96 | 97.91 Rt | 5241.50 | 5224.00 |
| C | 82+73.63 | 0.00 | 5241.50 | 5224.00 |
| D | 82+35.79 | 93.22 Lt | 5238.50 | 5224.00 |
| E | 82+41.57 | 116.98 Lt | 5238.50 | 5224.00 |
| G | 80+40.07 | 145.04 Rt | 5241.50 | 5224.00 |
| H | 79+87.20 | 74.59 Rt | 5241.50 | 5224.00 |
| I | 79+27.85 | 98.68 Lt | 5238.50 | 5224.00 |
| J | 79+12.49 | 124.59 Lt | 5237.73 | 5224.00 |

Notes:

1. Section Shown Normal To The Slope From The Station And Offset Point Shown In The Riprap Limits Table.

2. Field Adjustment Of The Riprap Thickness And Shape From The Typical Detail May Be Required To Take Into Account The Existing Bank Protection And Proposed Ground Shown On The Plan.

3. Existing Riprap On The West Abutment May Be Re-used If It Is Of The Proper Size, Gradation And Thickness.

TYPICAL CHANNEL BANK ARMOURING DETAIL
N.T.S.

Note: All Elevations Are Based On Datum NAVD88.

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Print Date: 08/10/2010
File Name: 17537BRDG_BRHYD02
Horiz. Scale: As Noted Vert. Scale: As Noted

DAVID EVANS AND ASSOCIATES INC.
1331 17th Street, Suite 900
Denver Colorado 80202
Phone: 720.946.0969

Sheet Revisions

| Date: | Comments | Init. |
|---|---|---|
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Colorado Department of Transportation
4670 Holly Street
Denver, CO 80216-6408
Phone: 303-398-6780 FAX: 720-945-1028
Region 6 DJH

As Constructed
No Revisions:
Revised:
Void:

I-70 OVER SAND CREEK
BRIDGE HYDRAULIC INFORMATION (2)

| | | | |
|---|---|---|---|
| Designer: | R. Ommert | Structure Numbers | E-17-AER |
| Detailer: | R. Mitchell | | E-17-BY |
| Sheet Subset: | BRIDGE | Subset Sheets: | B11 of B50 |

Project No./Code
FBR 0704 220
17537
Sheet Number

Revision Dates (Preliminary Stage Only)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Design | Designed By | Checked By | INITIAL | DATE | Detail | Detailed By | Checked By | INITIAL | DATE | Quantities | Quantities By | Checked By | INITIAL | DATE |

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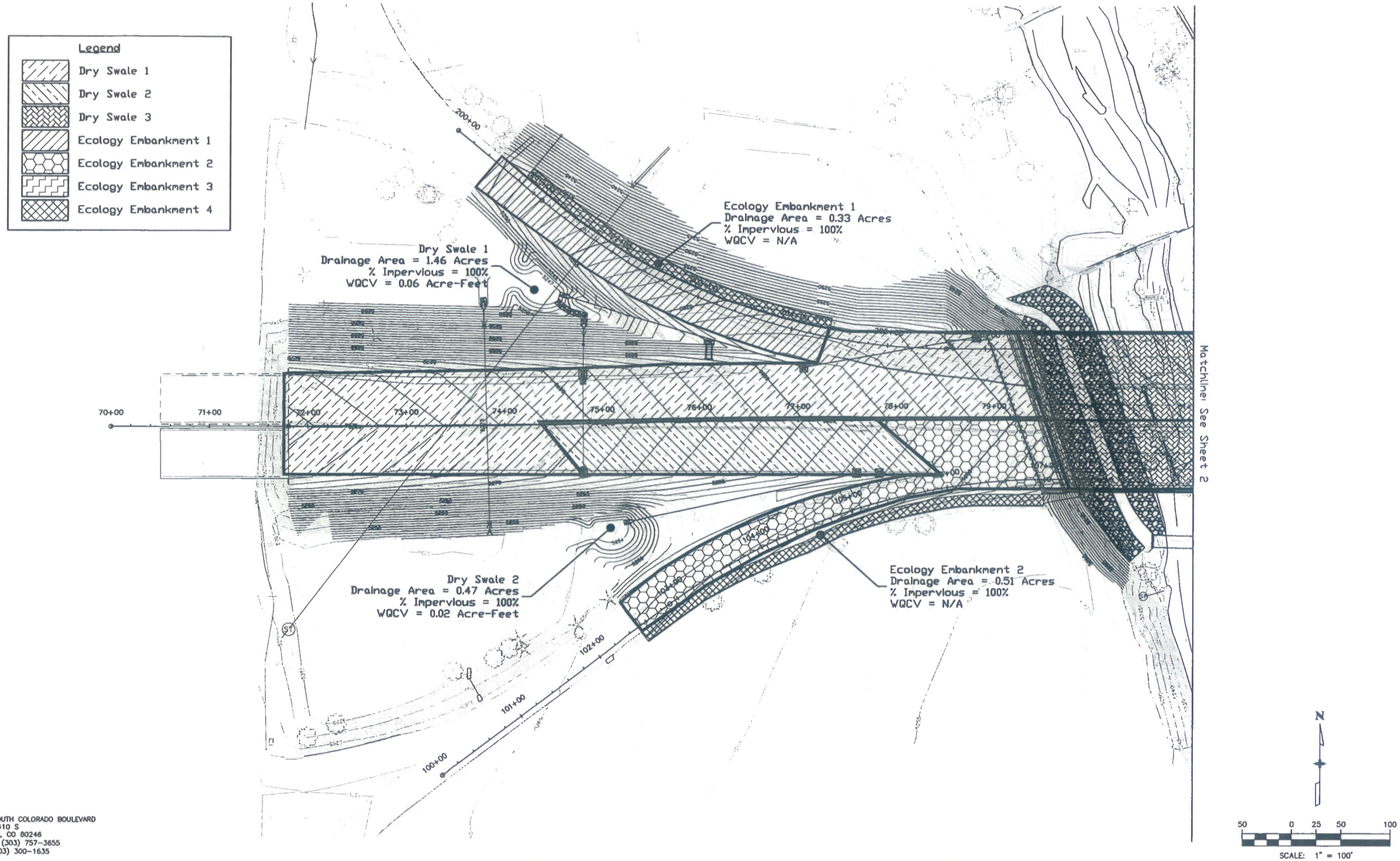
# Water Quality




NAME: Z:\Region 6\FASTER Bridges\I-70 over Sand Creek\CAD_I-70 at Sand Creek\DWG\FOR Drainage Plan\X - I-70 WQ Basins.dwg
PLOT DATE: Aug 17, 2010 4:16pm

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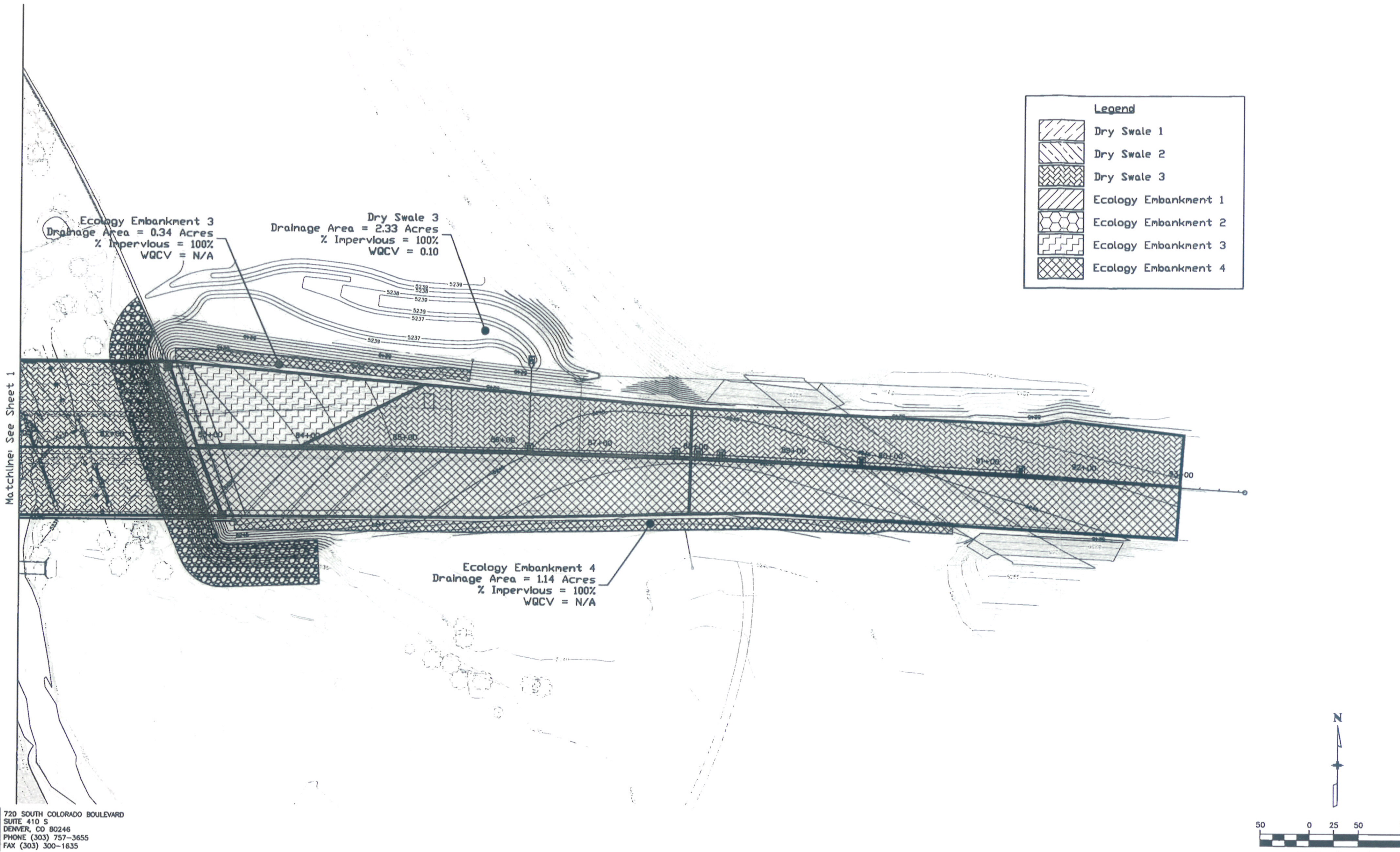
| | | | | | |
|---|---|---|---|---|---|
| Print Date: 8/20/2010 | Sheet Revisions | | | Colorado Department of Transportation | As Constructed |
| File Name: WQ Basins | Date: | Comments | Init. | | No Revisions: |
| Horiz. Scale: 1"=100' Vert. Scale: N/A | | | | 4670 Holly Street<br>Denver, CO 80216-6408<br>Phone: 303-398-6780 FAX: 720-945-1028 | Revised: |
| DAVID EVANS AND ASSOCIATES INC.<br>1331 17th Street, Suite 900<br>Denver Colorado 80202<br>Phone: 720.946.0969 | | | | Region 6 DJH | Void: |

| | | | |
|---|---|---|---|
| I-70 WATER QUALITY FIGURE | | | Project No./Code |
| | | | C 0704-220 |
| Designer: LDR | Structure Numbers | E-17-AER | 17537 |
| Detailer: RWM | | | |
| Sheet Subset: DRAINAGE | Subset Sheets: 1 of 2 | | Sheet Number 1 |

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NAME: Z:\Region 6\FASTER Bridges\I-70 over Sand Creek\CAD_I-70 at Sand Creek\DWG\FOR Drainage Plan\X - I-70 WQ Basins.dwg
PLOT DATE: Aug 17, 2010 4:16pm

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|---|---|---|---|---|---|---|---|
| Print Date: 8/20/2010 | Sheet Revisions | | | Colorado Department of Transportation | As Constructed | I-70 WATER QUALITY FIGURE | Project No./Code |
| File Name: WQ Basins | Date: | Comments | Init. | 4670 Holly Street<br>Denver, CO 80216-6408<br>Phone: 303-398-6780 FAX: 720-945-1028 | No Revisions: | | C 0704-220 |
| Horiz. Scale: 1"=100' Vert. Scale: N/A | | | | | Revised: | Designer: LDR / Structure Numbers: E-17-AER | 17537 |
| DAVID EVANS AND ASSOCIATES INC.<br>1331 17th Street, Suite 900<br>Denver Colorado 80202<br>Phone: 720.946.0969 | | | | Region 6 DJH | Void: | Detailer: RWM | |
| | | | | | | Sheet Subset: DRAINAGE / Subset Sheets: 2 of 2 | Sheet Number 2 |

## RT.07 – Media Filter Drain (previously referred to as the Ecology Embankment)

*Media Filter Drain Along SR 167 in King County.*

### Introduction

#### *General Description*

The media filter drain (MFD), previously referred to as the *ecology embankment,* is a linear flow-through stormwater runoff treatment device that can be sited along highway side slopes (conventional design) and medians (dual media filter drains), borrow ditches, or other linear depressions. Cut-slope applications may also be considered. The media filter drain can be used where available right of way is limited, sheet flow from the highway surface is feasible, and lateral gradients are generally less than 25% (4H:1V). The media filter drain has a General Use Level Designation (GULD) for basic, enhanced, and phosphorus treatment. Updates/changes to the use-level designation and any design changes will be posted in the *Postpublication Updates* section of the HRM Resource web page.

Media filter drains (MFDs) have four basic components: a gravel no-vegetation zone, a grass strip, the MFD mix bed, and a conveyance system for flows leaving the MFD mix. This conveyance system usually consists of a gravel-filled underdrain trench or a layer of crushed surfacing base course (CSBC). This layer of CSBC must be porous enough to allow treated flows to freely drain away from the MFD mix.

Typical MFD configurations are shown in Figures RT.07.1, RT.07.2, and RT.07.3.

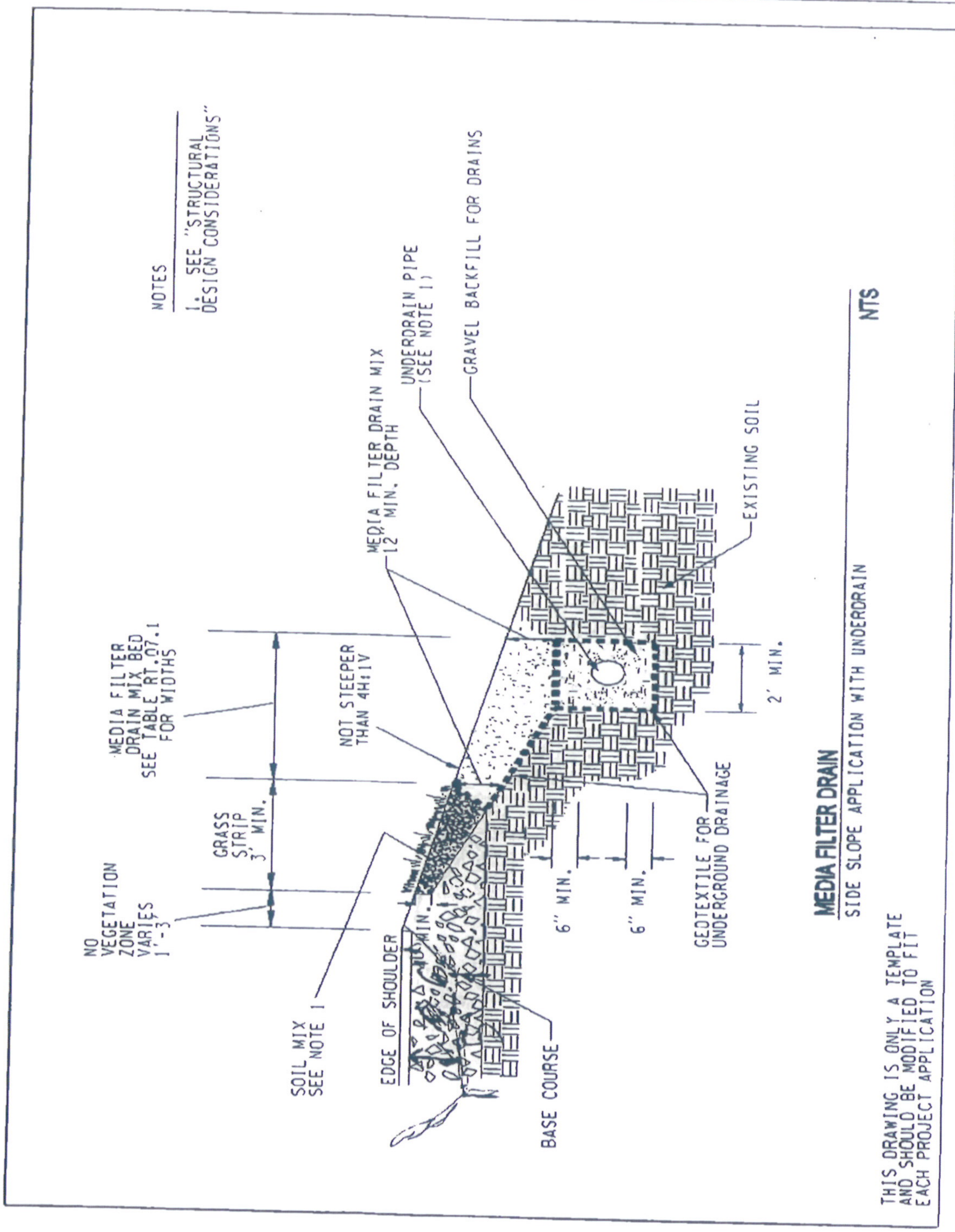


**Figure RT.07.1.** <u>Media filter drain</u>: **Cross section.**

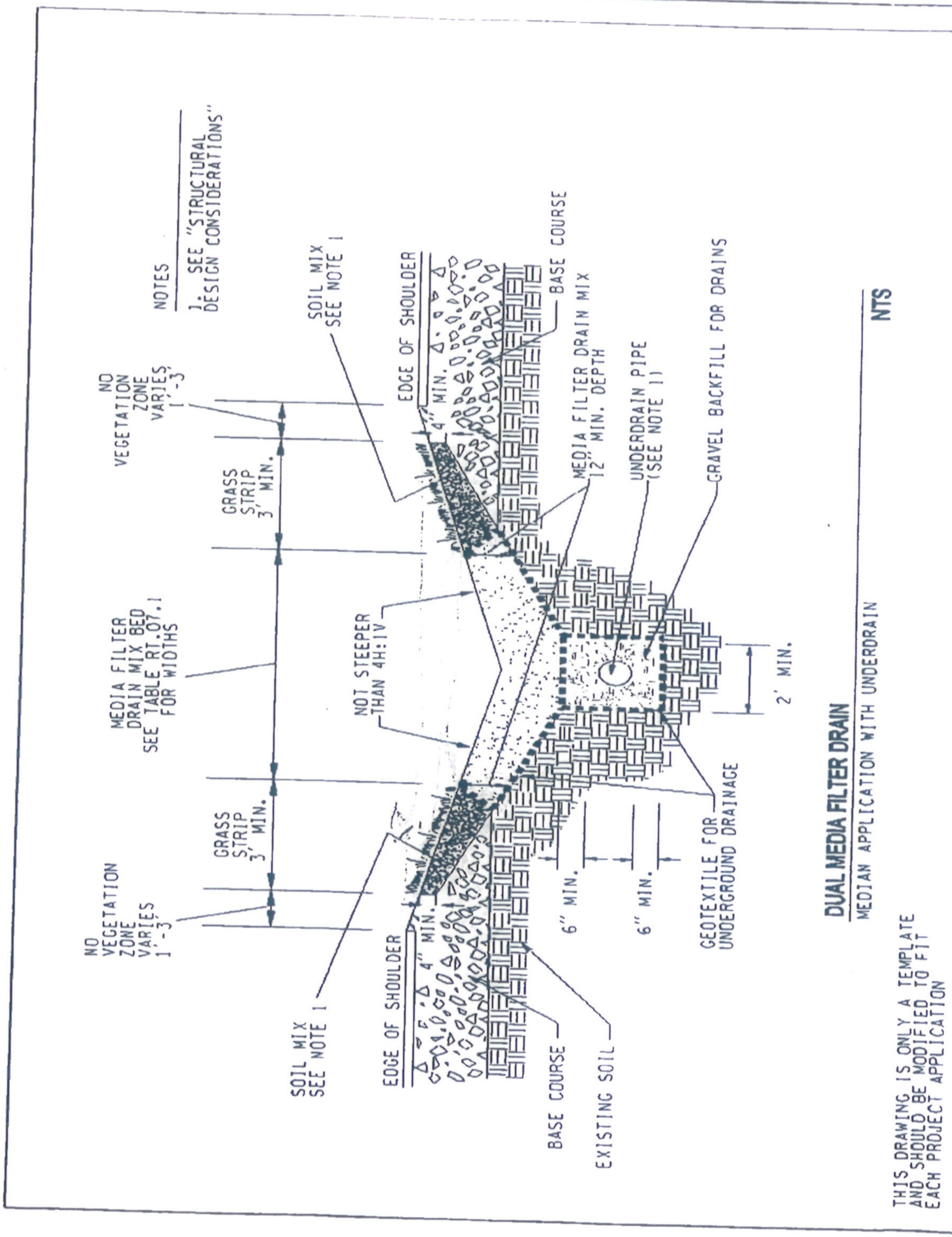


**Figure RT.07.2. Dual media filter drain: Cross section.**

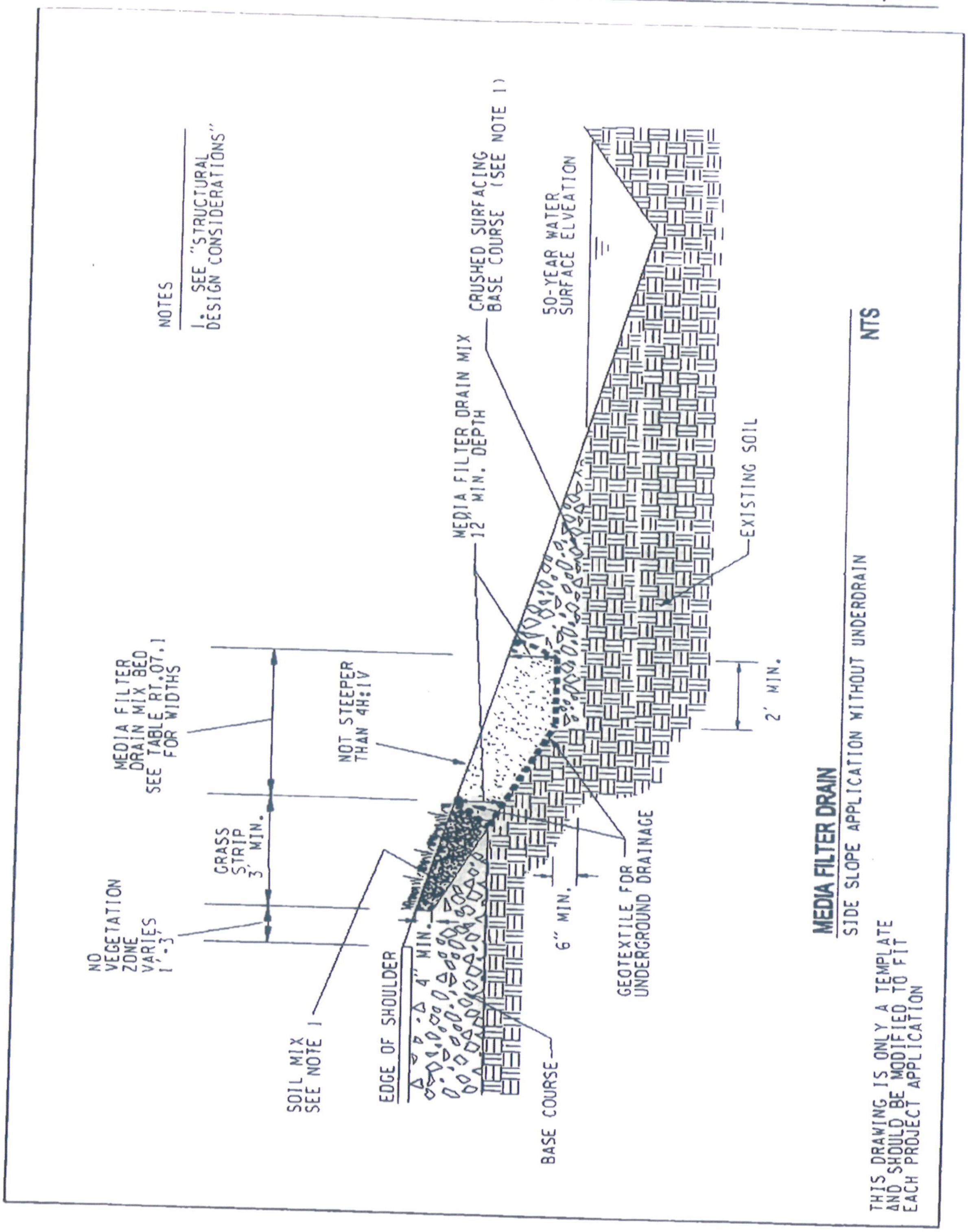


Figure RT.07.3. Media filter drain without underdrain trench.

### Functional Description

The media filter drain removes suspended solids, phosphorus, and metals from highway runoff through physical straining, ion exchange, carbonate precipitation, and biofiltration.

Stormwater runoff is conveyed to the media filter drain via sheet flow over a vegetation-free gravel zone to ensure sheet dispersion and provide some pollutant trapping. Next, a grass strip, which may be amended with compost, is incorporated into the top of the fill slope to provide pretreatment, further enhancing filtration and extending the life of the system. The runoff is then filtered through a bed of porous, alkalinity-generating granular medium—the media filter drain mix. Media filter drain mix is a fill material composed of crushed rock (sized by screening), dolomite, gypsum, and perlite. The dolomite and gypsum additives serve to buffer acidic pH conditions and exchange light metals for heavy metals. Perlite is incorporated to improve moisture retention, which is critical for the formation of biomass epilithic biofilm to assist in the removal of solids, metals, and nutrients. Treated water drains from the media filter drain mix bed into the conveyance system below the media filter drain mix. Geotextile lines the underside of the media filter drain mix bed and the conveyance system.

The underdrain trench is an option for hydraulic conveyance of treated stormwater to a desired location, such as a downstream flow control facility or stormwater outfall. The trench's perforated underdrain pipe is a protective measure to ensure free flow through the media filter drain mix. It may be possible to omit the underdrain pipe if it can be demonstrated that the pipe is not necessary to maintain free flow through the media filter drain mix and underdrain trench.

It is critical to note that water should sheet flow across the media filter drain. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

### Applications and Limitations

In many instances, conventional runoff treatment is not feasible due to right of way constraints (such as adjoining wetlands and geotechnical considerations). The media filter drain and the dual media filter drain designs are runoff treatment options that can be sited in most right of way confined situations. In many cases, a media filter drain or a dual media filter drain can be sited without the acquisition of additional right of way needed for conventional stormwater facilities or capital-intensive expenditures for underground wet vaults.

#### *Applications*

Media Filter Drains

The media filter drain can achieve basic, phosphorus, and enhanced water quality treatment. Since maintaining sheet flow across the media filter drain is required for its proper function, the ideal locations for media filter drains in highway settings are highway side slopes or other long, linear grades with lateral side slopes less than 4H:1V and longitudinal slopes no steeper than 5%. As side slopes approach 3H:1V, without design modifications, sloughing may become a problem due to friction limitations between the separation geotextile and underlying soils. The longest flow path from the contributing area delivering sheet flow to the media filter drain should not exceed 150 feet.

Dual Media Filter Drain for Highway Medians

The dual media filter drain is fundamentally the same as the side-slope version. It differs in siting and is more constrained with regard to drainage options. Prime locations for dual media filter drains in a highway setting are medians, roadside drainage or borrow ditches, or other linear depressions. It is especially critical for water to sheet flow across the dual media filter drain. Channelized flows or ditch flows running down the middle of the dual media filter drain (continuous off-site inflow) should be minimized.

*Limitations*

Media Filter Drains

- **Steep slopes**. Avoid construction on longitudinal slopes steeper than 5%. Avoid construction on 3H:1V lateral slopes, and preferably use less than 4H:1V slopes. In areas where lateral slopes exceed 4H:1V, it may be possible to construct terraces to create 4H:1V slopes or to otherwise stabilize up to 3H:1V slopes. (For details, see *Geometry, Components* and *Sizing Criteria, Cross Section* in the Structural Design Considerations section below).
- **Wetlands**. Do not construct in wetlands and wetland buffers. In many cases, a media filter drain (due to its small lateral footprint) can fit within the highway fill slopes adjacent to a wetland buffer. In those situations where the highway fill prism is located adjacent to wetlands, an interception trench/underdrain will need to be incorporated as a design element in the media filter drain.
- **Shallow groundwater**. Mean high water table levels at the project site need to be determined to ensure the media filter drain mix bed and the underdrain (if needed) will not become saturated by shallow groundwater.
- **Unstable slopes**. In areas where slope stability may be problematic, consult a geotechnical engineer.

Dual Media Filter Drains for Highway Medians

In addition to the above limitations on the media filter drain:

- **Wetlands**. Do not construct in wetlands and wetland buffers.
- **Areas of seasonal groundwater inundations or basement flooding**. The hydraulic and runoff treatment performance of the dual media filter drain may be compromised due to backwater effects and lack of sufficient hydraulic gradient.

## Design Flow Elements

### *Flows to Be Treated*

The basic design concept behind the media filter drain and dual media filter drain is to fully filter all runoff through the media filter drain mix. Therefore, the infiltration capacity of the medium and drainage below needs to match or exceed the hydraulic loading rate.

## Structural Design Considerations

### *Geometry*

#### *Components*

No-Vegetation Zone

The no-vegetation zone (vegetation-free zone) is a shallow gravel trench located directly adjacent to the highway pavement. The no-vegetation zone is a crucial element in a properly functioning media filter drain or other BMPs that use sheet flow to convey runoff from the highway surface to the BMP. The no-vegetation zone functions as a level spreader to promote sheet flow and a deposition area for coarse sediments. The no-vegetation zone should be between 1 foot and 3 feet wide. Depth will be a function of how the roadway section is built from subgrade to finish grade; the resultant cross section will typically be triangular to trapezoidal. Within these bounds, width varies depending on WSDOT maintenance spraying practices. Contact the area maintenance office for this information.

Grass Strip

The width of the grass strip is dependent on the availability of space within the highway side slope. The baseline design criterion for the grass strip within the media filter drain is a 3-foot-minimum-width, but wider grass strips are recommended if the additional space is available. The designer should consult with the Region Landscape Architect for soil mix recommendations. The designer may consider adding aggregate to the soil mix to help minimize rutting problems from errant vehicles. The soil mix should ensure grass growth for the design life of the media filter drain.

Media Filter Drain Mix Bed

The media filter drain mix is a mixture of crushed rock (screened to 3/8" to #10 sieve), dolomite, gypsum, and perlite. The crushed rock provides the support matrix of the medium; the dolomite and gypsum add alkalinity and ion exchange capacity to promote the precipitation and exchange of heavy metals; and the perlite improves moisture retention to promote the formation of biomass within the media filter drain mix. The combination of physical filtering, precipitation, ion exchange, and biofiltration enhances the water treatment capacity of the mix. The media filter drain mix has an estimated initial filtration rate of 50 inches per hour and a long-term filtration rate of 28 inches per hour due to siltation. With an additional safety factor, the rate used to size the length of the media filter drain should be 10 inches per hour.

Conveyance System Below Media Filter Drain Mix

The gravel underdrain trench provides hydraulic conveyance when treated runoff needs to be conveyed to a desired location such as a downstream flow control facility or stormwater outfall.

In Group C and D soils, an underdrain pipe would help to ensure free flow of the treated runoff through the media filter drain mix bed. In some Group A and B soils, an underdrain pipe may be unnecessary if most water percolates into subsoil from the underdrain trench. The need for underdrain pipe should be evaluated in all cases. The underdrain trench should be a minimum of 2 feet wide for either the conventional or dual media filter drain.

The gravel underdrain trench may be eliminated if there is evidence to support that flows can be conveyed laterally to an adjacent ditch or onto a fill slope that is properly vegetated to protect against erosion. The media filter drain mix should be kept free draining up to the 50-year storm event water surface elevation represented in the downstream ditch.

*Sizing Criteria*

Width

The width of the media filter drain mix bed is determined by the amount of contributing pavement routed to the embankment. The surface area of the media filter drain mix bed needs to be sufficiently large to fully infiltrate the runoff treatment design flow rate using the long-term filtration rate of the media filter drain mix. For design purposes, a 50% safety factor is incorporated into the long-term media filter drain mix filtration rate to accommodate variations in slope, resulting in a design filtration rate of 10 inches per hour. The media filter drain mix bed should have a bottom width of at least 2 feet in contact with the conveyance system below the media filter drain mix.

Length

In general, the length of a media filter drain or dual media filter drain is the same as the contributing pavement. Any length is acceptable as long as the surface area media filter drain mix bed is sufficient to fully infiltrate the runoff treatment design flow rate.

Cross Section

In profile, the surface of the media filter drain should preferably have a lateral slope less than 4H:1V (<25%). On steeper terrain, it may be possible to construct terraces to create a 4H:1V slope, or other engineering may be employed if approved by Ecology, to ensure slope stability up to 3H:1V. If sloughing is a concern on steeper slopes, consideration should be given to incorporating permeable soil reinforcements, such as geotextiles, open-graded/permeable pavements, or commercially available ring and grid reinforcement structures, as top layer components to the media filter drain mix bed. Consultation with a geotechnical engineer is required.

Inflow

Runoff is conveyed to a media filter drain using sheet flow from the pavement area. The longitudinal pavement slope contributing flow to a media filter drain should be less than 5%. Although there is no lateral pavement slope restriction for flows going to a media filter drain, the designer should ensure flows remain as sheet flow.

Media Filter Drain Mix Bed Sizing Procedure

The media filter drain mix should be a minimum of 12 inches deep, including the section on top of the underdrain trench.

For runoff treatment, sizing the media filter drain mix bed is based on the requirement that the runoff treatment flow rate from the pavement area, $Q_{Highway}$, cannot exceed the long-term infiltration capacity of the media filter drain, $Q_{Infiltration}$:

$$Q_{Highway} \leq Q_{Infiltration}$$

For western Washington, $Q_{Highway}$ is the flow rate at or below which 91% of the runoff volume for the developed TDA will be treated, based on a 15-minute time step (see Section 4-3.1.1), and can be determined using the water quality data feature in MGSFlood. For eastern Washington, $Q_{Highway}$ is the peak flow rate predicted for the 6-month, short-duration storm under post-developed conditions for each TDA (see Appendix 4C), and can be determined by selecting the short-duration storm option in StormSHED.

The long-term infiltration capacity of the media filter drain is based on the following equation:

$$\frac{LTIR * L * W}{C * SF} = Q_{Infiltration}$$

where: $LTIR$ = Long-term infiltration rate of the media filter drain mix (use 10 inches per hour for design) (in/hr)

$L$ = Length of media filter drain (parallel to roadway) (ft)

$W$ = Width of the media filter drain mix bed (ft)

$C$ = Conversion factor of 43200 ((in/hr)/(ft/sec))

$SF$ = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is expected)

Assuming that the length of the media filter drain is the same as the length of the contributing pavement, solve for the width of the media filter drain:

$$W \geq \frac{Q_{Highway} * C * SF}{LTIR * L} \qquad \text{(RT.07-1)}$$

Western Washington project applications of this design procedure have shown that, in almost every case, the calculated width of the media filter drain does not exceed 1.0 foot. Therefore, Table RT.07.1 was developed to simplify the design steps and should be used to establish an appropriate width.

**Table RT.07.1. Western Washington design widths for media filter drains.**

| Pavement width that contributes runoff to the media filter drain | Minimum media filter drain width* |
|---|---|
| ≤ 20 feet | 2 feet |
| ≥ 20 and ≤ 35 feet | 3 feet |
| > 35 feet | 4 feet |

* Width does not include the required 1 3 foot gravel vegetation-free zone or the 3-foot filter strip width (see Figure RT.07.1).

### *Materials*

*Media Filter Drain Mix*

The media filter drain mix used in the construction of media filter drains consists of the amendments listed in Table RT.07.2. Mixing and transportation must occur in a manner that ensures the materials are thoroughly mixed prior to placement and that separation does not occur during transportation or construction operations.

These materials should be used in accordance with the following *Standard Specifications*:

- Gravel Backfill for Drains, 9-03.12(4)
- Underdrain Pipe, 7-01.3(2)
- Construction Geotextile for Underground Drainage, 9-33.1

*Crushed Surfacing Base Course (CSBC)*

If the design is configured to allow the media filter drain to drain laterally into a ditch (see Figure RT.07.3), the crushed surfacing base course below the media filter drain should conform to Section 9-03.9(3) of the *Standard Specifications.*

### *Berms, Baffles, and Slopes*

See *Geometry, Components* and *Sizing Criteria, Cross Section* under Structural Design Considerations above.

Table RT.07.2. Media filter drain mix.

| Amendment | Quantity |
|---|---|
| **Mineral aggregate: Crushed screenings 3/8-inch to #10 sieve**<br>Crushed screenings shall be manufactured from ledge rock, talus, or gravel in accordance with Section 3-01 of the *Standard Specifications for Road, Bridge, and Municipal Construction* (2002), which meets the following test requirements:<br>Los Angeles Wear, 500 Revolutions — 35% max.<br>Degradation Factor — 30 min.<br>Crushed screenings shall conform to the following requirements for grading and quality:<br>**Sieve Size** — **Percent Passing (by weight)**<br>1/2" square — 100<br>3/8" square — 90-100<br>U.S. No. 4 — 30-56<br>U.S. No. 10 — 0-10<br>U.S. No. 200 — 0-1.5<br>% fracture, by weight, min. — 75<br>Static stripping test — Pass<br>The fracture requirement shall be at least one fractured face and will apply to material retained on the U.S. No. 10 if that sieve retains more than 5% of the total sample.<br>The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.<br>Crushed screenings shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50% of the surface area of any size between successive laboratory sieves. | 3 cubic yards |
| Perlite:<br>▪ Horticultural grade, free of any toxic materials)<br>▪ 0-30% passing US No. 18 Sieve<br>▪ 0-10% passing US No. 30 Sieve | 1 cubic yard per 3 cubic yards of mineral aggregate |
| Dolomite: CaMg(CO3)2 (calcium magnesium carbonate)<br>▪ Agricultural grade, free of any toxic materials)<br>▪ 100% passing US No. 8 Sieve<br>▪ 0% passing US No. 16 Sieve | 10 pounds per cubic yard of perlite |
| Gypsum: Noncalcined, agricultural gypsum CaSO4•2H2O (hydrated calcium sulfate)<br>▪ Agricultural grade, free of any toxic materials)<br>▪ 100% passing US No. 8 Sieve<br>▪ 0% passing US No. 16 Sieve | 1.5 pounds per cubic yard of perlite |

## Site Design Elements

### *Landscaping (Planting Considerations)*

Landscaping is the same as for biofiltration swales (see BMP RT.04) unless otherwise specified in the special provisions for the project's construction documents.

### *Operations and Maintenance*

Maintenance will consist of routine roadside management. While herbicides will not be applied directly over the media filter drain, it may be necessary to periodically control noxious weeds with herbicides in areas around the media filter drain as part of WSDOT's roadside management program. The use of pesticides may be prohibited if the media filter drain is in a critical aquifer recharge area for drinking water supplies. The designer should check with the local area water purveyor or local health department. Areas of the media filter drain that show signs of physical damage will be replaced by local maintenance staff in consultation with region hydraulics/water quality staff.

### *Signing*

Nonreflective guideposts will delineate the media filter drain. This practice allows WSDOT personnel to identify where the system is installed and to make appropriate repairs should damage occur to the system. If the media filter drain is in a critical aquifer recharge area for drinking water supplies, signage prohibiting the use of pesticides must be provided.