F O R   R E P O R T

SH 92 Final Design

Austin to Hotchkiss, Colorado
CDOT Project 14934

Hydrology & Hydraulics Report

Prepared for

CDOT
Region 3

April 2012

URS

URS Corporation
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Project No. 22241827

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1.1 GENERAL

This report presents proposed drainage improvements for the State Highway 92 project along with the analysis that forms the basis of the design. The primary project goal of this document is to provide engineering support to the design documents describing the proposed structures for review by CDOT Region 3. Analysis of the on-site and off-site drainage basins affecting the project has been conducted to estimate runoff peak discharges for use in design of structures to convey stormwater off the roadway and under the roadway.

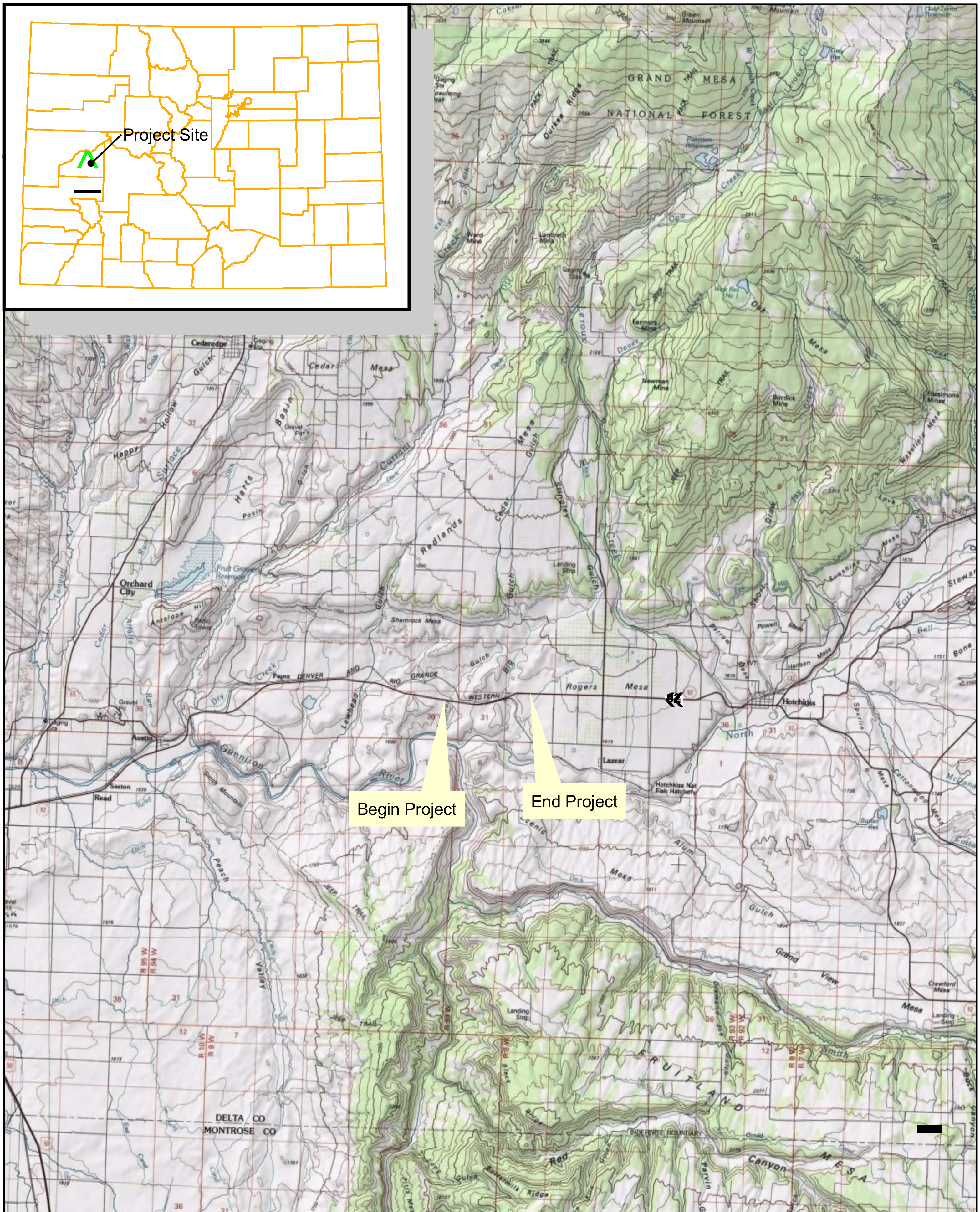
1.2 SITE LOCATION AND DESCRIPTION

The project alignment location is shown in Figure 1-1.

Roadway, Stationing & Length:	SH 92 / Shamrock Road to 3000 Road, Station 364+00 to Station 451+00, approx. 1.7 miles
Major Roadway Structures:	Big Gulch 8' Arch Culvert, Bridge at Union Pacific Railroad
Intersections:	Pleasure Park, Shamrock Rd.
Drainageways:	Big Gulch
County:	Delta County
Legal Description:	The project limits extend from Section 36 of Township 15S, Range 94W to Section 32 of Township 14S, Range 93W West of the 6th Principal Meridian.

1.3 PROJECT MAPPING

URS surveyed the project site in 2006 to 1-foot contour interval accuracy. This mapping was supplemented for drainage purposes with publicly available maps, aerial photographs, and digital terrain model data from the US Geological Survey (USGS).



CDOT State Highway 92 Construction Project 14934 URS Project No. 22241827	Location Map	Figure 1.1

2.1 BASIN DESCRIPTION

The proposed roadway improvements start approximately 7 miles east of Austin, Colorado and extend east 1.7 miles toward Hotchkiss, Colorado. Drainageways within the project corridor primarily run south to the Gunnison River. Consequently, all of the contributing sub-catchments lie on the north side of the road, and all of the final outfalls are on the south side of the road. All of the project catchment area is within the Gunnison River basin, which lies in Division 4 of the Colorado Water Conservation Board divisions.

The largest drainageway crossing is the Big Gulch crossing at Mile Post (MP) 14.92 (roadway sta 429+88). There is an historical arch culvert at this location. This crossing has a 9.3-square mile contributing area that rises from 5,380 feet to 7,320 feet in elevation. The basin map for Big Gulch is shown in Figure 2.1. The culvert extends underneath the existing roadway and Union Pacific Railroad that is adjacent to the road to the south.

All other drainageways have contributing areas of less than 1 square mile, and are currently serviced by corrugate steel pipe (CSP) culverts, most of which are less than 36-inches in diameter. The basin map for the other drainageways is shown in Figure 2.2.

Contributing areas were delineated using methods required by each hydrologic approach. These methods are discussed at greater length in subsequent sections. The basins varied greatly in size, length, width, shape, and elevation range. The landforms are predominately plateau and canyon (or gully), with some broad alluvial fans and a few broad valleys separated by narrow ridges.

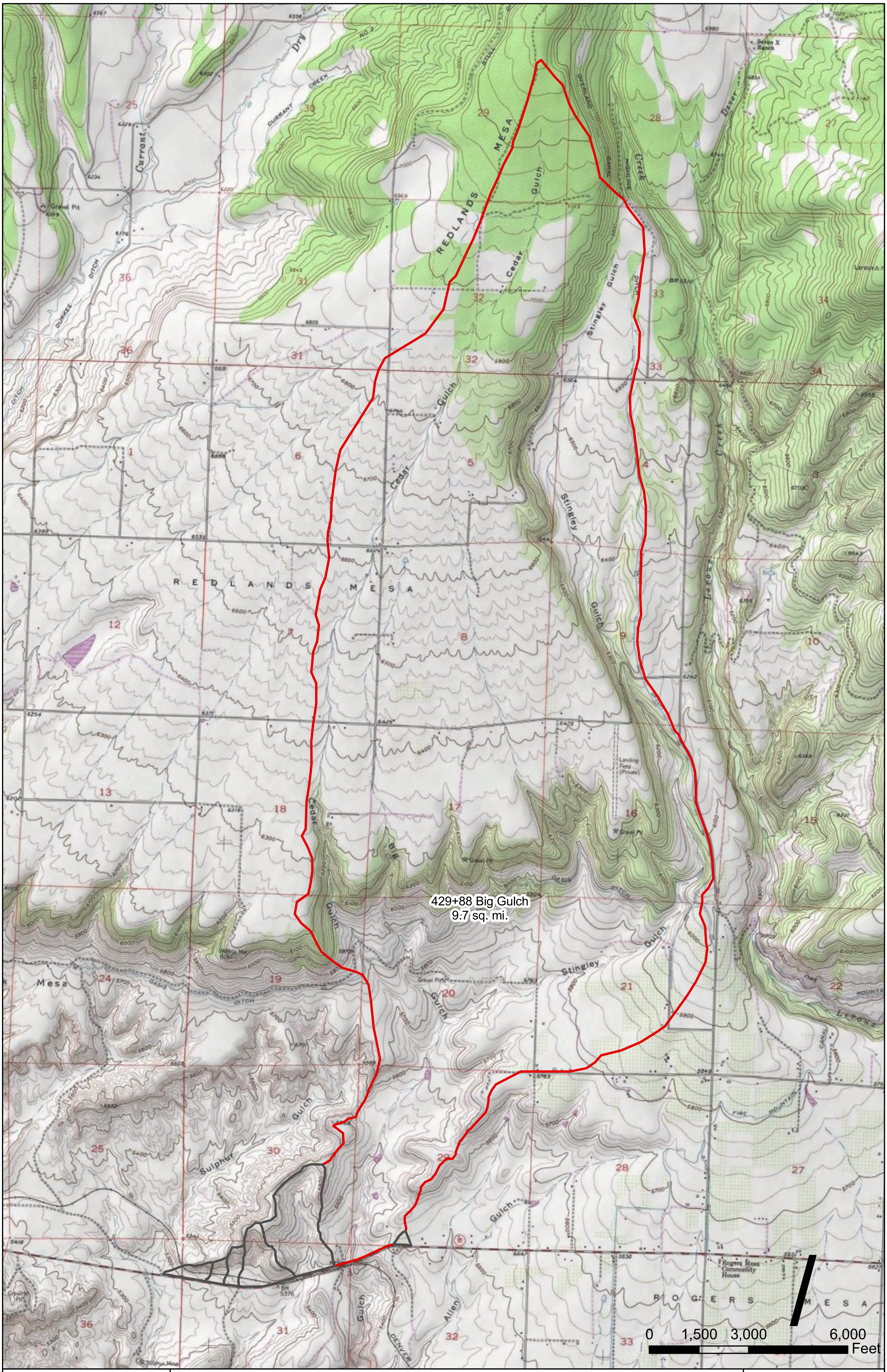
Soils data was obtained from the NRCS data gateway as Soil Survey Geographic Database (SSURGO) data for use in ArcGIS. The soils are predominantly hydrologic soil group type D, with some type C and B soils. Land cover information was derived from digital land use data that is also available from the NRCS data Gateway. The principle land use for basins other than Big Gulch is shrub and brush rangeland.

The average slope of the land is 17 percent, and the average channel slope measured was 8 percent. Less than 1 percent of the drainage area is developed.

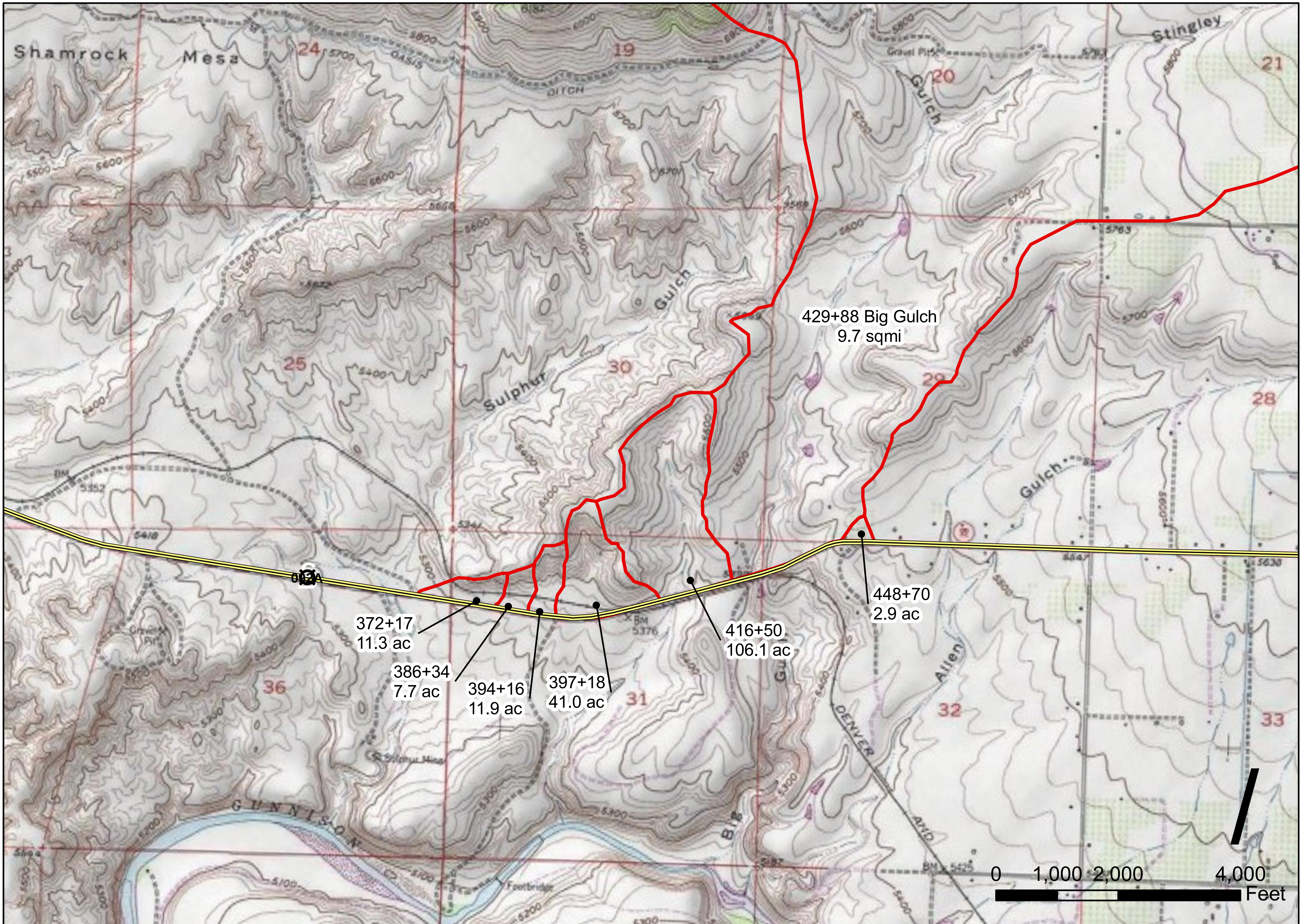
2.2 CHANNEL DESCRIPTION

From the photographic record in Appendix A and observations in the field by URS personnel, the channels for the contributing offsite basins tended to be steep, ephemeral, and sandy bottomed. The Big Gulch channel is steep, intermittent, and sandy bottomed. Channel side slopes vary from vertical to very gentle, and are predominately about 2H:1V where they intersect the roadway. The channel shape tends to be trapezoidal, as is typical with semi-arid regions. Banks in the lowlands near the road appear to be unstable and degrading, with head-cutting visible from the road in some areas.

Informal interviews of the State water commissioner and deputy state water commissioner for the region, along with ditch operators and other locals have indicated that runoff water typically carries a moderate to heavy sediment load and significant amounts of debris.



CDOT State Highway 92 Construction Project 14934 URS Project No. 22241827	Big Gulch Basin Boundary	Figure 2.1



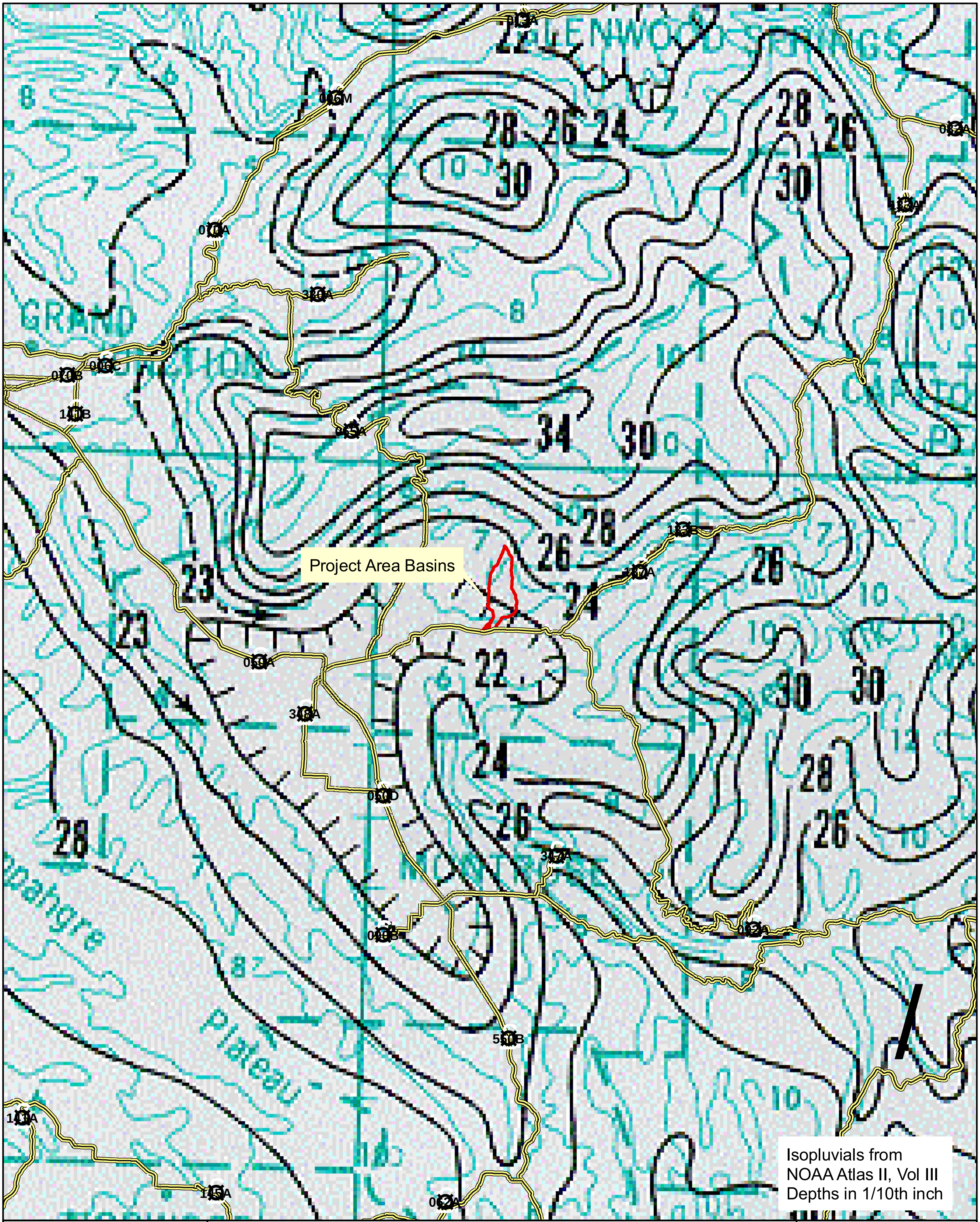
CDOT State Highway 92 Construction Project 14934 URS Project No. 22241827	NRCS Method Basin Boundaries	Figure 2.2

2.3 PRECIPITATION DATA

Although precipitation data was not needed for the regression method, the rainfall for the NRCS method was estimated using the National Oceanic and Atmospheric Administration's (NOAA's) Atlas II, as available from the NOAA website:

http://www.nws.noaa.gov/ohd/hdsc/noaaatlas2.htm.

The 50-year, 24-hour event map in this atlas was used to determine rainfall for each basin. The project precipitation is presented in Figure 2.3. The 50-year, 24-hour precipitation for this project is 2.15 inches.



CDOT State Highway 92 Construction Project 14934 URS Project No. 22241827	Project Precipitation 50 year, 24-hour Rainfall Depth	Figure 2.3

2.4 FLOOD HISTORY

There is no known history of the existing structures on the site creating flooding problems.

URS performed a search of the FEMA website:

http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1 map service center, which showed that no detailed FEMA studies have been performed for the project area. All areas of interest are noted as Zone X. FEMA FIRMettes are included in Appendix B.

2.5 DESIGN FLOOD FREQUENCY

The overall approach to selecting the design flood frequency followed the Colorado Department of Transportation's (CDOT's) Drainage Design Manual (DDM), 2004 (Reference 3).

Crossing structures for SH92 are designed to safely pass the storm events shown in Table 7.2 of Chapter 7 of the DDM, which indicates a 50-year storm (or a 2% chance event) for rural multilane roads.

Parallel structures are designed to safely pass the storm events shown in Table 7.2 of Chapter 7 of the DDM, which indicates a 2 – 10 year storm for side drains and a 50-year storm (or a 2% chance event) where overtopping or revetment is concerned. The DDM does not mention duration, so a 24-hour duration was used for all design storms.

2.6 PREDICTION OF DESIGN DISCHARGES

Using recommendations from the DDM, three approaches were used to analyze the basin hydrology within the project area. On the large basin of Big Gulch (Sta. 429+88), a regression analysis, a basin transposition method and deterministic NRCS analysis were performed. For the remaining basins, flow rates are estimated using deterministic NRCS methods consistent with the DDM. Peak design flows are summarized in Table 2.1.

Table 2.1
Summary of Cross Drain Design Flows

Crossing Station	Drainage Area (Square Miles)	Curve Number	Peak 50-year Flow Rate (cfs)
STA 386+34	0.012	70	3.5
STA 394+16	0.0180	70	5.3
STA 397+18	0.0580	68	9.7
STA 416+50	0.1660	67	20.1
STA 429+88 (Big Gulch)	9.26	68	553*
STA 448+70	0.0050	51	0.2

*Design Point flow rates of 2200 cfs (regression method) and 823 cfs (NRCS method) were not used.

Many of the side drain basins are within crossing drain basins as well. For these side drains, the flow rate was assumed to be proportional to the ratio of the side drain basin area to the crossing drain basin area. An NRCS analysis was used to estimate flow rates for side drains that did not reside in a crossing drainage basin. Peak design flows are summarized in Table 2.2.

Table 2.2
Summary of Side Drain Design Flows

Centerline Access Station	Drainage Area (ac)	Curve Number	Peak 10-year Flow Rate (cfs)	Method	Road Crossing
STA. 372+17	3.82	69.7	0.34	Ratio	Shamrock Rd
STA. 390+90	14.61	69.5	1.47	Ratio	Day Dr
STA. 421+46	4.43	66.5	0.15	Ratio	Unnamed
STA. 437+89	15.10	51.0	0.60	NRCS	Unnamed
STA. 437+80	11.3	51.0	0.10	NRCS	Unnamed
STA. 446+51	0.06	53.6	0.10	Ratio	Unnamed
STA. 450+16	0*	51.0	0.10	Ratio	Unnamed

*The crossing at STA 450+16 is at a high point.

No flow rates were reported on the as-built drawings of the existing road that were provided to URS.

The upstream land use for the proposed structures is not expected to change significantly within the design life of the structures. It is CDOT policy to design hydraulic structures to the existing conditions, and the existing conditions were used for all structure designs.

2.6.1 Colorado Regional Regression Equations

Analysis of gage data and use of empirical regression equations are both acceptable methods for estimating flow rates for larger basins. The regression method is a statistical method for flow estimation. The equations were updated by the USGS for Colorado in 2009 (Reference 14).

The regression method was completed for Big Gulch using the StreamStats online tool from USGS, (http://water.usgs.gov/osw/streamstats/colorado.html). This tool delineates the catchment, computes the necessary basin parameters, and estimates the flow rates for different recurrence intervals. The tool is newly implemented (2009) in Colorado, so the results were compared with a hand calculation of the regression equations. The remaining smaller basins did not fall within range of areas that were used to generate the method, so the method is not considered applicable to the small basins.

The USGS National Flood Frequency Program (NFF) uses different equations in different areas. The Big Gulch sub-catchment, lies within the Northwest region. The Northwest region requires the sub-catchment area and the average annual precipitation. These parameters were estimated by StreamStats, and for comparison, the sub-catchment area was also estimated using ArcGIS and the average annual precipitation was estimated using data from the Colorado Decision Support System available at http://cdss.state.co.us/DNN/Home/tabid/36/Default.aspx. This data references the Colorado Climate Center report 84-4, and “Values represent average annual precipitation in inches from 1951-1980”.

The regression method basin is shown in Figure 2.1 and the calculations are detailed in Appendix C. The 50-year peak discharge predicted by this method is 2,200 cfs and was not considered reasonable.

2.6.2 Basin Transposition Method

Since there is no stream gage record for Big Gulch, basins with gages with more than 25 years of record were transposed using USGS methods in order to estimate a design flow rate for Big Gulch. The 3 basins selected were within a 20-mile radius, and are shown in Figure 2.4. These basins are all larger and higher in elevation. Since rainfall on the western slope of Colorado is well known to occur more frequently and intensely at higher elevations, using these gages is conservative.

The selected basins were analyzed using the US Army Corps of Engineers software Flood Frequency Analysis (FFA) (Reference 5) and/or the US Geological Survey's software PeakFq (Reference 8). Both apply a regression analysis to set of daily high peak flows from the data record. These methods require supplying FFA or PeakFq software with the annual peak flow data from the gage station to be analyzed. The resulting flows from PeakFQ and FFA were used in the transposition calculation, using the methods in Blakemore et al. 1994 (Reference 16). Areas for the transposition method were delineated and measured in ArcGIS.

The basin transposition method calculations are detailed in Appendix C. The 50-year peak discharge for Big Gulch predicted by this method is 553 cfs.

2.6.3 Natural Resources Conservation Service Methods

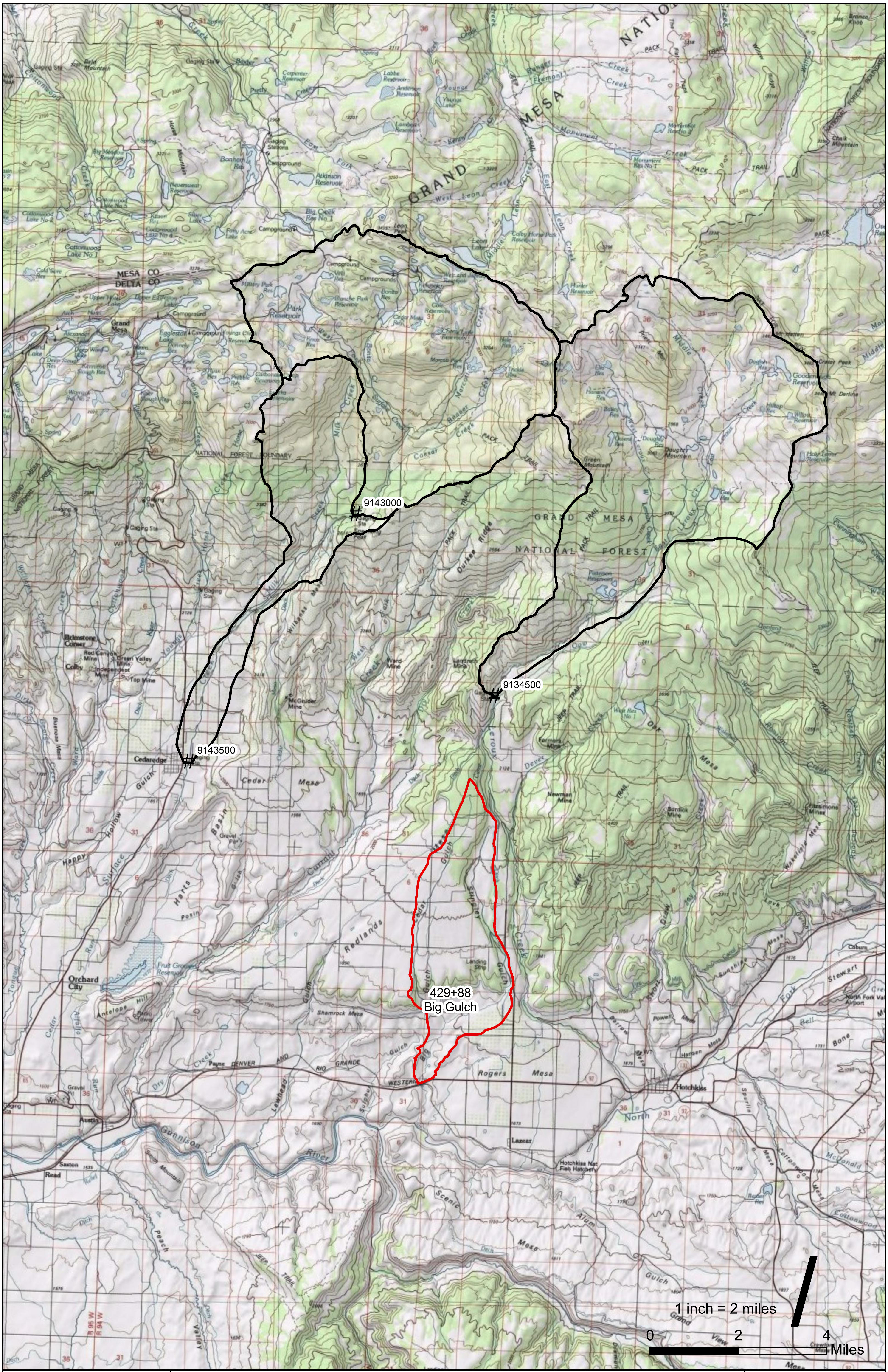
Sub-catchments for the culvert crossings, including Big Gulch, were delineated in ArcGIS from drainage divides shown on the USGS 7.5 minute quadrangles for the basin. The Natural Resources Conservation Service (NRCS) method sub-catchments are shown in Figure 2.2.

The NRCS method is deterministic. The NRCS curve number is used to determine the loss of rainfall due to soil infiltration, evaporation, and loss due to ground cover. This method is described in Technical Release No. 55 (TR-55) (NRCS, 1986) (Reference 9). A single curve number was determined for each sub-catchment using a combination of land use and soils data, both of which were obtained from the NRCS data gateway (NRCS, 2007). The land use data was divided into primary land use types that were correlated with the land cover types that are presented in TR-55. The soils data is a digital version of the soil survey from the NRCS, and each soil type identified was associated with a hydrologic soil group designation. A curve number (CN) was assigned to each combination of land use and soil type, based on the tables in TR-55.

The sub-catchments delineated, using the GIS methods, were intersected with the land-use areas and with the soils type areas. Using this data, an area-weighted average of the curve number for each sub-catchment was calculated in a Microsoft Excel workbook. CN calculations are summarized in Appendix C.

The other component to the NRCS method described in TR-55 is the time of concentration. This parameter was calculated using land slope, flow length, and land use information. This information was likewise obtained from the NRCS data gateway (NRCS, 2007). More detail on the NRCS hydrologic calculations for each sub-catchment is contained in Appendix C.

The NRCS method was completed using the US Army Corps of Engineer’s software HEC-HMS (Reference 11). The NRCS flow rates were used for all basins except for Big Gulch. For Big Gulch, the 50-year peak discharge predicted by this method is 823 cfs. This flow rate was not used because this method is best applied to small basins. At nearly 10 square miles, the Big Gulch basin is near the upper end of the range of applicability.



CDOT State Highway 92 Construction Project 14934 URS Project No. 22241827	Basin Transposition Method Basin Boundaries	Figure 2.4

3.1 EXISTING STRUCTURE DESCRIPTIONS

Cross Culverts: There are approximately 13 culverts crossing the existing highway and its approach roads including storm drainage as well as an irrigation siphon. A photographic log of existing culverts documented by URS during their survey is included in Appendix A.

Verbal reports from CDOT indicate that the culverts are old and some are near failure. They have reported that many of the culverts were extended with larger diameter pipe in the past. They have also reported that many of the CSPs are corroded to the point of structural failure due to corrosive soils. Subsequent testing by CDOT Region 3 indicates a value of CR5 for the corrosion resistance level for the corridor. For these reasons, CDOT has requested that all of the pipes be replaced with reinforced concrete pipe (RCP) or new structures.

No adequacy problems have been reported, however there are several culverts that have one end buried, and some have both ends buried. No major scour holes were observed on the surveyed existing culverts.

Big Gulch Culvert: The existing Big Gulch culvert is a historic structure that will be extended in kind. Plans made available from CDOT dated July 1940, show the existing Big Gulch culvert as an 8 foot by 8 foot arch culvert. The historical stone arch was extended in 1940 using reinforced concrete. There is a pond on the downstream end of the culvert that causes water to stand in the culvert.

3.2 CULVERT DESIGN

3.2.1 Big Gulch

The existing and proposed conditions for the Big Gulch culvert were analyzed using HEC-RAS computer software from the USACE (USACE 2001) (Reference 12). The software uses standard step backwater techniques to solve for flow depth. Selection of Manning's n values follows CDOT recommendations in Table 9.2 of Chapter 9 of the DDM. Manning's n values used in the model can be seen in Table 3.1. HEC-RAS calculations are in Appendix D.

Table 3.1
Manning's n Selection

Manning's n value	Description
0.013	Concrete pipe
0.030	Natural stream, gravel and cobbles
0.035	Floodplains, high grass and weeds

The HEC-RAS evaluation process for Big Gulch indicated that the existing headwater to depth (HW/D) ratio is 1.2. The proposed extension to the culvert increases the HW/D ratio to 1.3 which is slightly over the allowable HW/D ratio of 1.2 (per CDOT DDM Chapter 9, Section 9.2.2). However, in order to keep the historical structure and at the request of CDOT, the design includes an extension of the culvert as opposed to a replacement, and the HW/D ratio of 1.3 will be accepted as a variance.

The exit velocity in the design condition is 17.7 fps which is lower than the existing exit velocity of 19.4 fps. The reduction in velocity can be attributed to the addition of a bend in the culvert, which will dissipate some energy within the culvert barrel. The culvert outlets into an existing pond of unknown depth. No outlet riprap is being provided because all improvements will be made at the upstream end only, and CDOT has historically had no problems with downstream degradation.

3.2.2 Cross Culverts

Because the roadway is being relocated away from the existing alignment through the majority of the project area, all existing culverts, except at Sta. 370 and Big Gulch, will be removed or abandoned in place. All new minor and irrigation culverts are designed using the CulvertMaster Software from Bentley (Reference 1) and checked against the AASHTO nomographs. The designs meet the criteria presented in the CDOT DDM. The CulvertMaster calculations are presented in Appendix D.

The minimum pipe size for this project is 24 inches. All new pipe culverts will have a diameter equal to or greater than 24 inches in diameter and will be Reinforced Concrete Pipe (RCP). End treatments will include concrete end sections.

Channel geometry downstream of the culverts for use in CulvertMaster was taken from the existing ground survey. Special ditches will be required upstream and downstream of certain culverts, as shown on the drawings. Culverts are designed to match the flow lines at both upstream and downstream ends.

One inlet will be required at Station 416+51, right side. The inlet is connected to the cross culvert at that station. The inlet will receive flow from Special Ditch 419R and no additional areas. The drainage area the inlet will be receiving is small and only produces 1.2 cfs in the 10 year storm. A Type D inlet is recommended however, because the crossing culvert size is 36”, and too big for a smaller sized inlet.

In order to handle flows on the bridge crossing over the railroad, a hydraulic analysis following the method described in HEC 21, Design of Bridge Deck Drains was performed. The results of the analysis indicate that no deck drains are needed. Riprap rundowns will be installed to prevent erosion on the northeast and northwest embankments after water exits the bridge. The results of the analysis are in Appendix E.

3.3 CULVERT OUTLET PROTECTION

Culvert outlet riprap is provided for all proposed culverts. In general, outlet protection design is consistent with the DDM and its recommendation to design riprap consistent with the guidance in FHWA’s HEC-14 (Reference 15). At a minimum riprap blankets are sized according to M-601-12, Headwalls and Culvert Outlet Paving, in CDOT’s M&S Standards. The riprap design calculation is provided in Appendix E.

3.4 PARALLEL DRAINAGE DESIGN

Roadside ditches are typically triangular shaped with a 1.5-foot depth, and 4:1 or 3:1 side slopes.

A hydrologic analysis has been performed for all ditches. In some cases, peak flow is based on runoff from roadway pavement and in other cases a larger peak is realized from offsite areas.

Ditch hydrology is based on a 10-year return period. The 100-year return period was calculated to ensure that ditches have adequate capacity.

The 10-year return period ditch hydraulics were evaluated using Bentley FlowMaster assuming the steepest longitudinal slope in the analyzed reach and a Manning's "n" value of 0.03. Ditches will be lined with soil retention blanket to provide protection until vegetation is developed. Ditch hydrology and hydraulics are provided in Appendix C.

Side drain culverts will be placed under approach roads where the road blocks a drainage path. Side drains were designed for the 10 year storm flow rate. The minimum pipe size for side drains is 18 inches. All new pipe culverts will have a diameter equal to or greater than 18 inches in diameter and will be Reinforced Concrete Pipe (RCP). End treatments will include concrete end sections.

Channel geometry downstream of the culverts for use in CulvertMaster was taken from the existing ground survey. Culverts are designed to match the flow lines at both upstream and downstream ends.

3.5 DESIGN DOCUMENTS

The design drawings in Appendix F present the recommended designs for this project.

4.1 EROSION CONTROL PLAN

The primary source of wind and water erosion will be from denuded and disturbed areas during construction of the project. Best Management Practices (BMP), consisting of hay bale inlet protection, silt fence on earth embankments and silt sock on paved embankments, and permanent seeding will be utilized to reduce the impact of grading. Once permanent seeding and paving is complete, the potential for wind and water erosion will be reduced.

Erosion and Sediment Control plans prepared for this project show the location and type of temporary erosion control measures to be installed during construction. 0These BMPs will be installed according to Colorado Department of Transportation's Erosion Control Manual (Reference 13) and specifications in Section 208 of the Standard Specifications.

Active areas of earthwork operations will be watered and compacted according to the earthwork specifications contained in the contract. Disturbed areas where construction activities will not occur for long periods shall be stabilized. Throughout construction, as unpaved areas are completed, topsoil placement and permanent seeding or landscaping operations will follow.

Mud and dirt carryout onto existing paved streets will be prevented by construction of gravel entryways. Cleanup of paved surfaces will occur as necessary by sweeping.

Wind erosion from all active unpaved roads for this project will be controlled through sprinkling.

4.2 POST CONSTRUCTION WATER QUALITY

Treatment of highway runoff will be provided through the use of topsoil placement and seeding the entire project corridor.

5.1 CONCLUSION

The roadway grade, like the surrounding grade, is rolling to steep. Adequate grade for positive drainage is available in all locations.

The Union Pacific Railroad (UPRR) parallels the roadway in areas on the north and south. Where the railroad lies upstream of the highway, URS has designed facilities as though the railway does not block or attenuate flow in any drainage ways. This is done to anticipate any improvements that the railroad may make. The improvements to SH 92 are expected to maintain and in some cases reduce the risk of flooding. The case is similar for the approach roadways.

URS contacted the Delta County Engineer, and requested and received the Delta County Road Standards. Upon review, the standards for Delta County Road Drainage match or do not exceed the CDOT standards.

1. Bentley Haestad Methods, *Culvertmaster*, Version 3.1, Service Pack 1, Storm Drain Hydraulics Computer Software

2. Blakemore E. Thomas, H. W. Hjalmarson, and S. D. Waltemeyer, USGS Geological Survey, Open Fille Report 93-419, Tucson, Arizona, 1994

3. Colorado Department of Transportation; *Drainage Design Manual*; CDOT; 2004.

4. NRCS, 2007, Geospatial Data Gateway (Website, http://datagateway.nrcs.usda.gov/)

5. US Army Corps of Engineers. Feb. 1995 *Flood Frequency Analysis (FFA).* Version 3.1 Computer Software.

6. US Geological Survey. 1984 *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains.* United States Geological Survey Water-supply Paper 2339.

7. US Geological Survey. 05/22/2004. *The National Flood Frequency Program, Version 3: A Computer Program For Estimating Magnitude And Frequency Of Floods For Ungaged Sites.* Version 3.2. From Water-Resources Investigations Report 02-4168. Computer Software.

8. US Geological Survey. 05/06/2005. *Program PeakFq, Annual peak flow frequency analysis following Bulletin 17b Guidelines.* Version 5.0 Beta 8. Computer Software.

9. United States Department of Agriculture Natural Resources Conservation Service Conservation, Engineering Division, Technical Release 55 (TR-55), June 1986. *Urban Hydrology for Small Watersheds.*

10. Federal Emergency Management Agency. January 16, 1981. *Flood Insurance Study, City of Orchard City, Colorado, Delta County*. Community No. 080258.

11. U.S.Army Corps of Engineers. Hydraulic Modeling System (HEC-HMS). (Computer Software) Version 3.0.1. Build 1169.

12. U.S.Army Corps of Engineers. May 2005. HEC-RAS River Analysis System. (Computer Software) Version 3.0.3.

13. Colorado Department of Transportation; Erosion Control and Stormwater Quality Guide; CDOT; 2002.

14. Capesius, J.P., and Stephens, V.C., 2009, Regional regression equations for estimation of natural streamflow statistics in Colorado: U.S. Geological Survey Scientific Investigations Report 2009–5136, 46 p

15. Federal Highway Administration. Hydraulic Engineering Circular No. 14, Third Edition. Hydraulic Design of Energy Dissipators for Culverts and Channels.

16. Blakemore E. Thomas, H. W. Hjalmason, and S> D> Waltemeyer, US Geological Survey. 1994. Open File Report 93-419 Methods for Estimating magnitude and Frequency of Floods in the Southwestern United States.

17. Federal Highway Administration. Hydraulic Engineering Circular No. 21. Design of Bridge Deck Drainage.

Appendix A

Photographs of Existing Pipes from URS Ground Survey

Mile Post 13.89
18" CSP
South End

Drainage Looking South

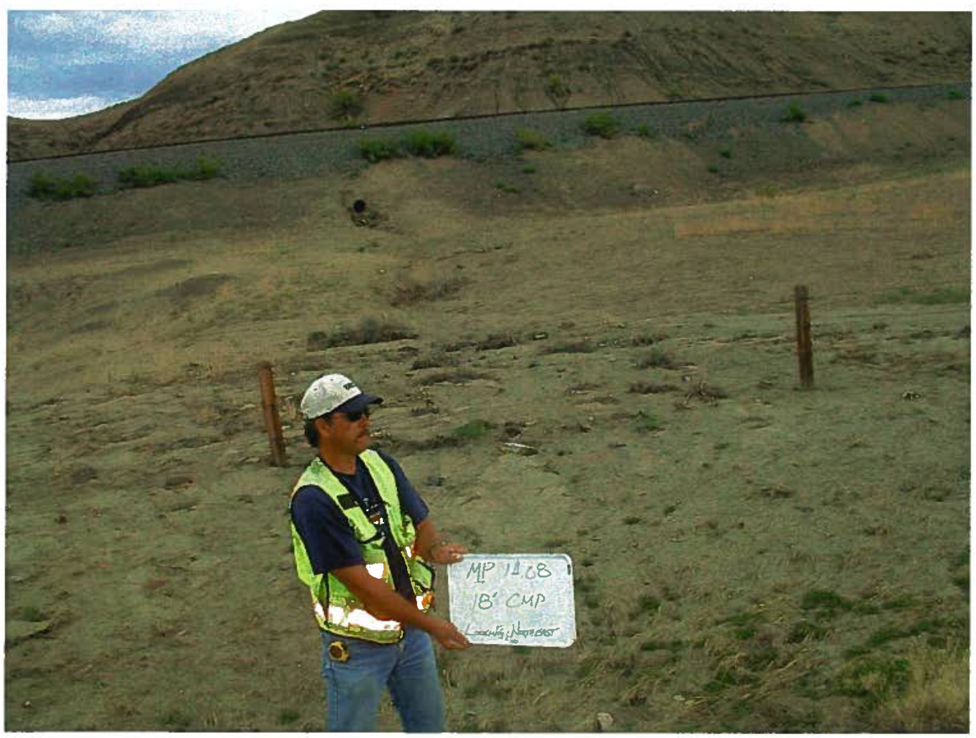
Mile Post 14.00
18" CSP
North End

Drainage Looking East

Mile Post 14.00
18" CSP
South End

Drainage Looking South

Mile Post 14.08
18" CSP
North End



Drainage Looking Northeast

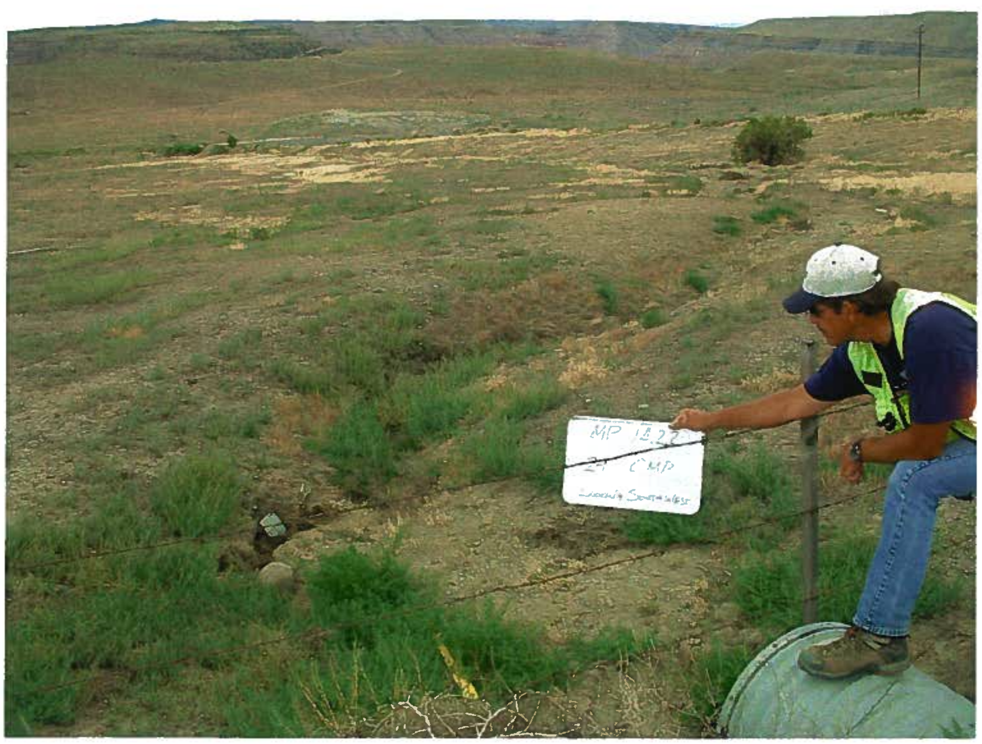
Mile Post 14.08
18" CSP
South End

Drainage Looking South

Mile Post 14.22
24" CSP
North End

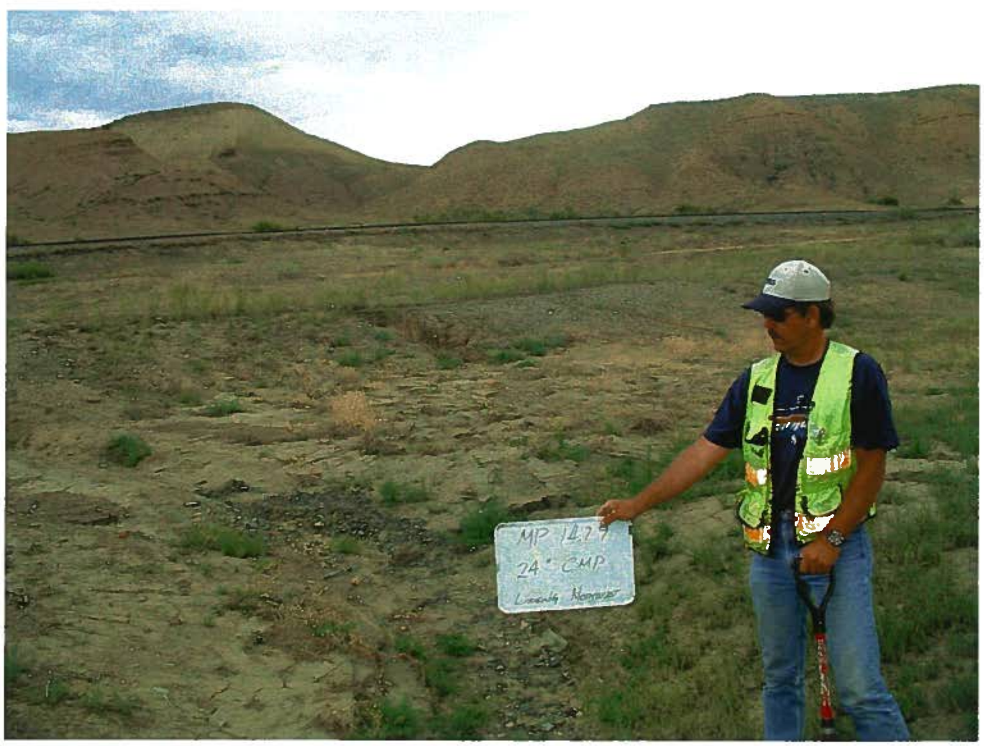
Drainage Looking East

Mile Post 14.22
24" CSP
South End



Drainage Looking Southwest

Mile Post 14.29
24" CSP
North End



Drainage Looking Northeast

Mile Post 14.29
24" CSP
South End

Drainage Looking South

Mile Post 14.51
24" CSP
North End

Drainage Looking East

Mile Post 14.51
24" CSP
South End

Drainage Looking South

Mile Post 14.65
36" CSP
North End

Drainage Looking East

Mile Post 14.65
36" CSP
South End

Drainage Looking West

Mile Post 14.75
18" CSP
East End

Drainage Looking Northeast

Mile Post 14.75
18" CSP
West End

Drainage Looking Southwest

Mile Post 14.92
7' CBC
North End

Drainage Looking North

Mile Post 14.92
7' CBC
South End

Drainage Looking South

Mile Post 15.05
18" CSP
East End

Drainage Looking Southwest

Mile Post 15.05
18" CSP
West End

Drainage Looking Northeast

Mile Post 15.07
10" CPP
North End

Drainage Looking Northeast

Mile Post 15.07
10" CPP
South End

Drainage Looking Southwest

Mile Post 15.24
18" CSP
North End

Drainage Looking Northeast

Mile Post 15.24
18" CSP
South End

Drainage Looking South

Mile Post 15.28
30" CSP
North End

Drainage Looking North

Mile Post 15.28
30" CSP
South End

Drainage Looking South

Appendix B

FEMA Firmettes

MAP SCALE 1" = 2000'

1000 0 2000 4000 FEET

METERS

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0475D

FIRM

FLOOD INSURANCE RATE MAP

DELTA COUNTY, COLORADO

AND INCORPORATED AREAS

PANEL 475 OF 725

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
DELTA COUNTY, Unincorporated Areas	080041	0475	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
08029C0475D

EFFECTIVE DATE
AUGUST 19, 2010

Federal Emergency Management Agency

Appendix C

Hydrology

State Highway 92 Hydrology

OBJECTIVE:

The purpose of this calculation is to determine peak flow rates for use of cross culvert design within the SH 92 study area.

GIVEN:

CDOT Drainage Design Manual states in Table 7.2 Table of Design Frequencies, that for rural multilane roads, the design frequency shall be the 50 year storm event.

REFERENCES:

- Basins and time on concentration paths were delineated based on USGS 7.5 minute quadrangles or Right of Way survey, where available.
- Rainfall data is from NOAA Atlas 2, Volume III available at: http://www.nws.noaa.gov/ohd/hdsc/noaaatlas2.htm
- Soil type, land use, and annual rainfall are from the CDSS Division 4.available at: http://cdss.state.co.us/DNN/Home/tabid/36/Default.aspx
- NRCS methods are from USDA (1986) *Urban Hydrology for Small Watersheds.,* 210-VI-TR-55, Second Ed.,
- Regression Methods are from Capesius, J.P., and Stephens, V.C., 2009, Regional regression equations for estimation of natural streamflow statistics in Colorado: U.S. Geological Survey Scientific Investigations Report 2009–5136, 46 p. Available at: http://water.usgs.gov/osw/streamstats/colorado.html
- Colorado Department of Transportation. (2004) Drainage Design Manual (DDM).
- The transposed flow rates are computed below using the methods in "Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States by "Blakemore E. Thomas, H. W. Hjalmarson, and S. D. Waltemeyer, USGS Geological Survey, Open Fille Report 93-419, Tucson, Arizona, 1994.

ASSUMPTIONS:

NRCS methods were used for all basins with an area less than 2000 acres. Basin 429+88 (Big Gulch) had an area greater than 2000 acres, and the regression equation method was compared to a basin transposition method and the basin transposition method result was used. This choice is consistent with the previous study and for an earlier phase of SH 92. The regression results indicate a flow that would overtop the road, and there is no evidence that the current culvert (dated to pre-1940) has been overtopped.

For the NRCS Method, maximum sheet flow length is 100 ft. Minimum time of concentration is 10 minutes. Impervious values are assumed to be 2%.

ANALYSIS / CALCULATIONS:

HEC-HMS was used to calculate peak flows for the NRCS Basins. Time of concentration and curve number were calculated using an Excel spreadsheet, attached. The Regression equations were calculated using and Excel spreadsheet, attached.

Calculation Notes URS

Subject: Hydrology

By: Betsy Young and Joel Jones   Date: Apr. 26, 12

Checked By: : ________   Date: ________

Project Name: State Highway 92

Project No: 22241827

Task No. 00007   File No.:

CONCLUSIONS:

The table below presents the 50 year flow rate for each basin.

Cross Drains

Basin	Q_{50} (cfs)
372+00	4.6
386+34	3.5
394+16	5.3
397+18	9.7
416+50	20.1
429+88	553
448+70	0.2

ATTACHMENTS:

- HECHMS output
- Time of concentration and curve number calculation
- Basin, soil, land use maps
- Regression calculation
- Regression region map

Electronic Files:

GIS Maps:

I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\7.0_CAD_GIS\GIS\Maps

Calculations:

I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\8.0_Design\8.01 Drainage\Calculations

Cross Drain - NRCS Method

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations - SCS Methods
Calculations for Time of Concentration and Lag Time

	Upland (Sheet) Flow Travel Time						Shallow Concentrated Flow					Channel Flow																
	Basin Area	2yr 24 hr Rainfall, P2	Manning's n	Length, L	Slope, s	Upland T_1	Length	Surface*	Slope	Velocity	Shallow T_2	Length	El @Top	El @Bot	Slope	Bottom Width	annel Side Slo	Mannings n	Depth	Q	Flow Area	Wetted Per.	Hydraulic Rad,	Velocity	Channel T_3	T_c	L	ercent Im
Subcatchment ID	(ac)	(in)		(ft)	pct	(hr)	(ft)	P or U	pct	(ft/s)	(hr)	(ft)	(ft)	(ft)	(ft/ft)	(ft)			(ft)	(cfs)	(ft2)			(ft/s)	(hr)	hr	min	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
372+17	11.3	1.05	0.13	100	35	0.08	768	U	17	6.64	0.0321	909	5310	5270	0.044	4.000	4.000	0.030	0.300	6	1.560	6.474	0.241	4.02	0.063	0.176	6.33	2
386+34	7.7	1.05	0.13	100	35	0.08	872	U	19	7.12	0.0340	0														0.115	4.14	2
394+16	11.9	1.05	0.13	100	50	0.07	220	U	10	5.06	0.0121	0														0.100	3.60	2
397+18	41.0	1.05	0.13	100	5	0.18	1686	U	8	4.48	0.1046	580	5470	5350	0.207	4.000	4.000	0.030	0.300	14	1.560	6.474	0.241	8.72	0.018	0.299	10.77	2
416+50	106.1	1.05	0.13	100	10	0.13	1237	U	11	5.43	0.0633	2352	5480	5280	0.085	10.000	3.000	0.030	0.350	26	3.868	12.214	0.317	6.71	0.097	0.294	10.59	2
430+00	6226.0	1.05	0.13	100	5	0.18	2032	U	5	3.61	0.1565	41740	7229	5398	0.044	50.000	2.000	0.030	2.000	1712	112.000	62.649	1.788	15.28	0.759	1.097	39.51	3
448+70	2.9	1.05	0.13	100	5	0.18	315	U	6	4.07	0.0215															0.198	7.12	2

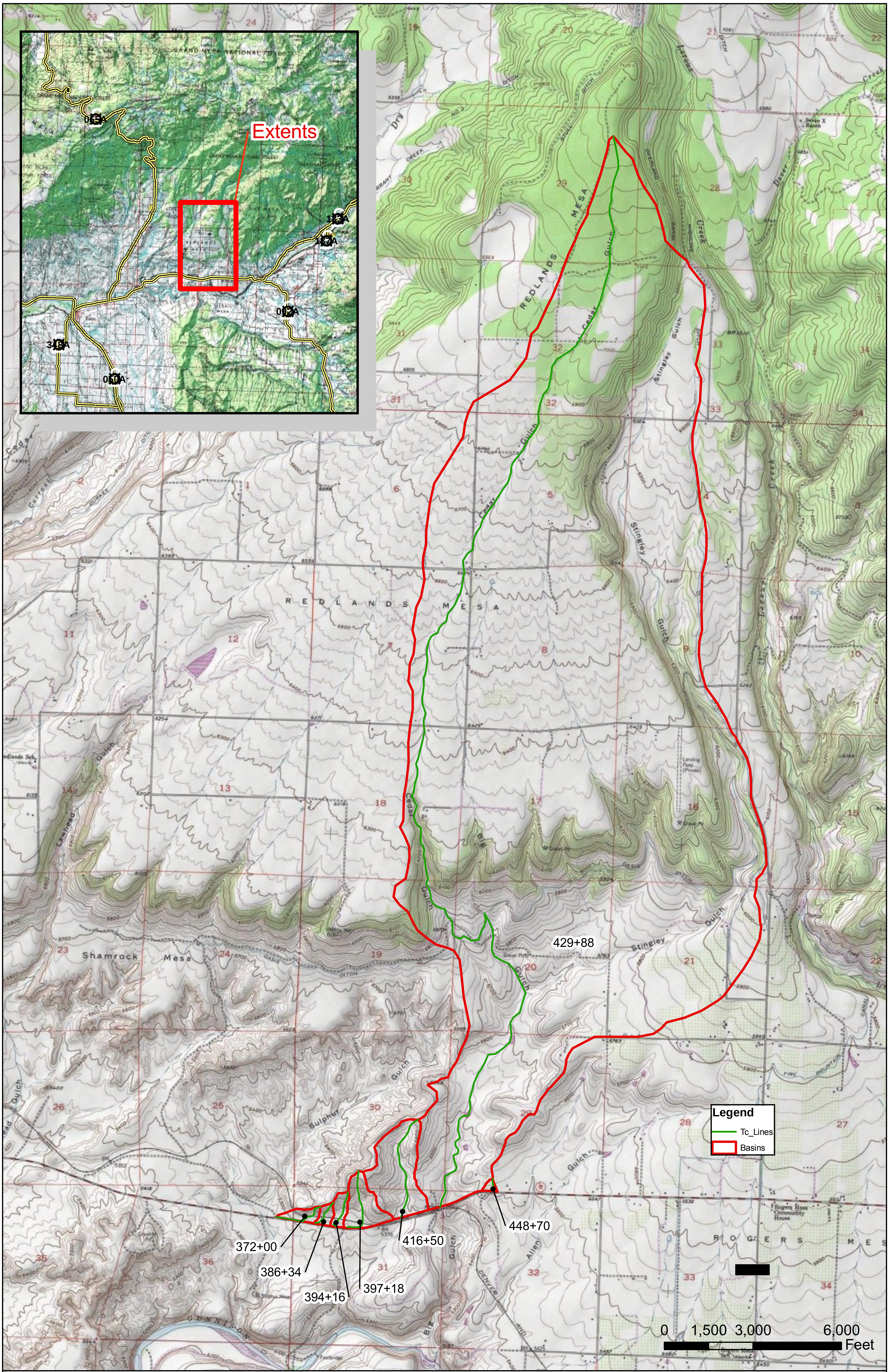
3.6 min
39.5 max
11.7 average

Column Explanation

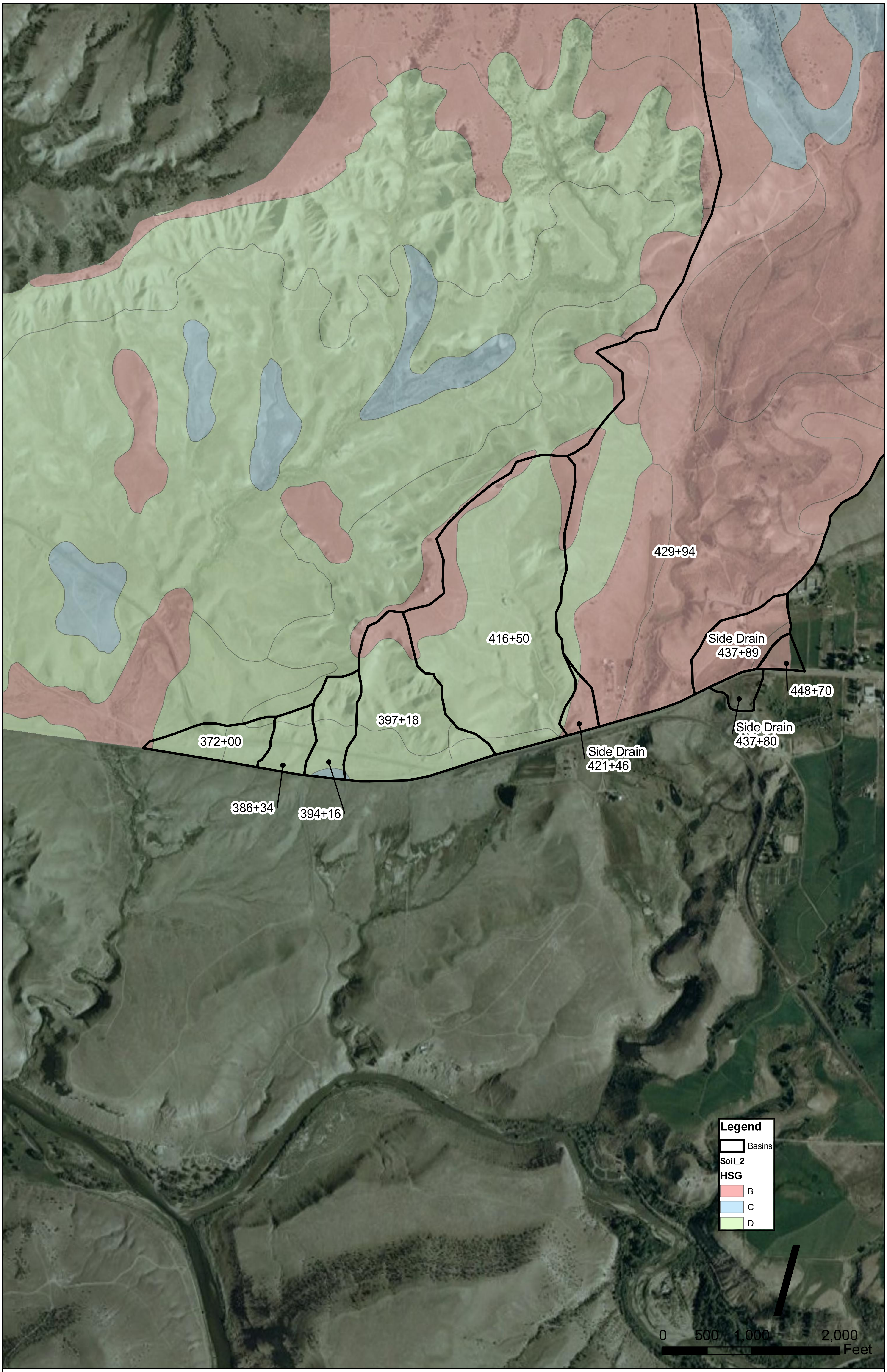
1 Subcatchment name. Names correspond to the station of the crossing structure
2 Basin area in acres
3 2 year, 24 hour rainfall from NOAA Atlas II, Vol III 2yr 24hr rainfall map
4 Upland flow Manning's n based on areas consisting of Shrub & Brush Rangeland
5 Travel length of sheet flow
6 Slope of sheet flow path. Determined by dividing the USGS quad contour elevation difference by the length
7 Travel time for upland flow $Tt = 0.007(nL)^{0.8}/((P_2)^{0.5} s^{0.4})$
8 Length of shallow concentrated flow. Determined by dividing the USGS quad contour elevation difference by the length
9 An unpaved surface was assumed for all subcatchments.
10 Shallow concentrated slopes. Determined by dividing the USGS quad contour elevation difference by the length
11 Velocities were calculated using the equations provided in appendix F of TR-55. Unpaved: $V = 16.1345 (s)^{0.5}$, Paved: $V = 20.3282 (s)^{0.5}$
12 Travel time for Shallow Concentrated Flow Tt = Length/Velocity/(3600sec/hr)
13 Length of channel, if applicable
14 The channel elevation at the top of the channel
15 The channel elevation at the bottom of the channel and basin.
16 Channel slope
17 Channel bottom width estimated from aerial photo
18 Channel bottom width estimated from USGS quad contours
19 Manning's n for channel
20 A guess at the flow depth
21 Q=VA, value corresponds to the flow calculated by HEC-HMS
22 Channel flow cross section area calculated using the depth guess, Depth*Bottom Width + Depth*Depth*Channel Side Slope
23 Wetted perimeter for Manning's Equation. In Columns: Bottom Width + $(Depth^2 + (Depth*Channel\ side\ slope)^2)^{0.5}$
24 Hydraulic Radius = Area / Wetted Perimeter
25 Channel Velocity using Manning's. In Columns: =1.486/Manning's n for channels * Hydraulic $Radius^{2/3}$ * Channel $Slope^{0.5}$
26 Travel time for channel flow T3 = Length/Velocity/(3600sec/hr)
27 Time of Concentration = sum of the travel times or 5 minutes, whichever is greater.
28 Time lag = Time of Concentration * 0.6 * 60 minutes/hour

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations - SCS Methods
Basin Curve Number Calculations

NRCS Land Code	Cropland and Pasture					Evergreen Forest Land					Shrub and Brush Rangeland					Total weighted CN for subcatchment (sum of values to the left)
TR-55 Land Cover from CN tables	Row crops, Straght Row and Crop Residue Cover, Poor condition					Woods, Fair condition					Sage-grass-fair					
Hydrologic Soil Group	A	B	B/D	C	D	A	B	B/D	C	D	A	B	B/D	C	D	
TR-55 CN from Tables	71	80	80	87	90	36	60	60	73	79	-	51	51	63	70	
Subcatchment ID																
372+17												0.68			69.1	69.7
386+34															70	70.0
394+16														4.2	65.4	69.5
397+18												5.0			63.0	68.0
416+50												9.3			57.3	66.5
420+94														28.2	38.6	66.9
430+00		8.4		9.2			14		26				7	3.7	0.3	68.4
448+70												51.0				51.0



Cross Drain Basin Delineation and Time of Concentration



Land Use and Soil Type

Project: Offsite_Basins Simulation Run: 50yr_24hr

Start of Run: 01Jan2000, 00:00 Basin Model: Offsite_Basins
End of Run: 02Jan2000, 01:00 Meteorologic Model: 50yr_24hr
Compute Time: 02Apr2012, 20:32:30 Control Specifications: Control 1

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
416+50	0.166000	20.1	01Jan2000, 12:07	0.27
397+18	0.064000	9.7	01Jan2000, 12:07	0.30
394+16	0.018000	5.3	01Jan2000, 11:59	0.36
386+34	0.012000	3.5	01Jan2000, 12:00	0.36
372+00	0.018000	4.6	01Jan2000, 12:02	0.36
448+70	0.005000	0.2	01Jan2000, 12:00	0.05
372+17	0.018000	4.4	01Jan2000, 12:02	0.35
430+00	9.700000	661.0	01Jan2000, 12:41	0.31
SD403R	0.000656	0.2	01Jan2000, 12:03	0.36
SD419R	0.002800	2.0	01Jan2000, 11:58	0.88
sd437+89	0.023600	0.8	01Jan2000, 12:00	0.05
sd437+80	0.006080	0.2	01Jan2000, 12:01	0.05
sd446+51	0.000156	0.0	01Jan2000, 11:58	0.07

Big Gulch - Regression Method

Basin Characteristics Report

Date: Mon Aug 15 2011 11:29:09 Mountain Daylight Time
NAD27 Latitude: 38.7988 (38 47 56)
NAD27 Longitude: -107.8189 (-107 49 08)
NAD83 Latitude: 38.7988 (38 47 56)
NAD83 Longitude: -107.8195 (-107 49 10)

Parameter	Value
6-hour, 100-year precipitation, in inches	1.85
Mean basin slope computed from 10 m DEM, in percent	11.1
Area that drains to a point on a stream in square miles	9.26
Mean Basin Elevation in feet	6350
Mean annual precipitation, in inches	13.67
Percentage of basin above 7500 ft elevation	0

USGS
Colorado StreamStats

Streamstats Ungaged Site Report

Date: Mon Aug 15 2011 11:29:58 Mountain Daylight Time
Site Location: Colorado
NAD27 Latitude: 38.7988 (38 47 56)
NAD27 Longitude: -107.8189 (-107 49 08)
NAD83 Latitude: 38.7988 (38 47 56)
NAD83 Longitude: -107.8195 (-107 49 10)
Drainage Area: 9.26 mi2

Peak-Flows Basin Characteristics			
100% Northwest Region Peak Flow (9.26 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	9.26	1	5250
Percent above 7500 ft (percent)	0	0	99
Mean Annual Precipitation (inches)	13.67	8	49

Low-Flows Basin Characteristics			
100% Northwest Region Min Flow (9.26 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	9.26	5	5250
Mean Basin Elevation (feet)	6350 (below min value 6880)	6880	10480

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Flow-Duration Basin Characteristics			
100% Northwest Region Flow Duration (9.26 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	9.26	1	5250
Mean Annual Precipitation (inches)	13.71	8	49

Maximum-Flows Basin Characteristics			
100% Northwest Region Max Flow (9.26 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	9.26	5	5250
Mean Annual Precipitation (inches)	13.67	8	49
Percent above 7500 ft (percent)	0	0	99

Mean-Flows Basin Characteristics			
100% Northwest Region Mean Flow (9.26 mi2)			
Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	9.26	1	5250
Mean Annual Precipitation (inches)	13.71	8	49

Peak-Flows Streamflow Statistics					
Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
PK2	104	110			
PK5	328	88			

PK10	656	79			
PK25	1390	74			
PK50	2200	74			
PK100	3310	75			
PK200	4760	76			
PK500	7270	79			

Low-Flows Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
M7D2Y	0.0421				
M7D10Y	0.0149				
M7D50Y	0.0122				

Flow-Duration Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
D10	0.6	52			
D25	0.24	56			
D50	0.11	66			
D75	0.0446	91			
D90	0.0145	220			

Maximum-Flows Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
V7D2Y	0.00784	86			
V7D10Y	0.0271	59			
V7D50Y	0.11	51			

Mean-Flows Streamflow Statistics

Statistic	Flow (ft^3/s)	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
				Minimum	Maximum
Q1	0.18	66			
Q2	0.19	56			
Q3	0.25	43			
Q4	0.49	66			
Q5	1.79	47			
Q6	0.4	61			
Q7	0.88	52			
Q8	1.08	78			
Q9	1.08	99			
QA	0.52	29			
Q10	0.35	85			
Q11	0.22	66			
Q12	0.2	61			

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations
Regression Method Northwest Region

Northwest Region

return interval	constant_K	exponent_a	exponent_b	exponent_c	exponent_d
2		-1.150	0.750	-0.41	2.15
5		-0.490	0.760	-0.54	2
10		-0.010	0.750	-0.63	1.93
25		0.350	0.750	-0.72	1.82
50		0.650	0.740	-0.77	1.74
100		0.930	0.74	-0.81	1.65
200		1.200	0.73	-0.85	1.56
500		1.530	0.72	-0.88	1.44

Northwest Region Method Results Summary

Catchment ID	Catchment Area (mi^2)	Average Annual Rain (in)	Percent of Area above 7500 ft (	2yr Q (cfs)	5yr Q (cfs)	10yr Q (cfs)	25yr Q (cfs)	50yr Q (cfs)	100yr Q (cfs)	200yr Q (cfs)	500yr Q (cfs)
430+00	9.26	13.7	1.0	104	330	811	1392	2204	3318	4774	7292

Big Gulch - Basin Transposition Method

14934 State Highway 92

Statistical Methods applied to Gauging Station Data for Cedar Gulch Crossing

Prepared by JAJ
Date 12-Sep-11

Cedar Gulch has no stream gauges operating on it. The basins selected were within a 20 mile radius and had similar size and elevation characteristics.
Flows in grey do not meet the 25 years of data required for use by Bulletin 17b. But are included as context because of their proximity and similarity to the site basin.
Blue columns are for sourced data, all others are calculated.

The selected basins were analyzed using the US Army Corps of Engineers software Flood Frequency Analysis (FFA) and/or the US Geological Survey's software PeakFq. Both apply a regression analysis to set of daily high peak flows from the data record. Bulletin 17b flows were used from PeakFq and computed curve flows were used from FFA.

Summary of Results from FFA runs on the selected USGS gauges near to Currant Creek (by others)

Site Name	Catchment Area (mi^2)	Catchment Area (ac)	Basin Aspect	Years of Record	Maximum Basin Elevation (ft)	Mean Basin Elevation (ft)	Gauge Elevation (ft)	FFA 50yr Q (cfs)	FFA 100yr Q (cfs)	FFA 200yr Q (cfs)	FFA 500yr Q (cfs)
USGS 09137050 CURRANT CREEK NEAR READ, CO.	56.90	36416	South	12	10879	7054	5035	1140	1220	1260	1300
USGS 09143000 SURFACE CREEK NEAR CEDAREDGE, CO.	27.40	17536	South	67	11333	9727	8261	830	957	1090	1280
USGS 09143500 SURFACE CREEK AT CEDAREDGE, CO.	39.00	24960	South	90	11115	9415	6220	1010	1220	1460	1820

Summary of Results from PeakFq runs by URS on the selected USGS gauges near to Currant Creek

Site Name	Catchment Area (mi^2)	Catchment Area (ac)	Basin Aspect	Years of Record	Maximum Basin Elevation (ft)	Mean Basin Elevation (ft)	Gauge Elevation (ft)	PeakFq 50yr Q (cfs)	PeakFq 100yr Q (cfs)	PeakFq 200yr Q (cfs)	PeakFq 500yr Q (cfs)
USGS 09134500 LEROUX CREEK NEAR CEDAREDGE, CO.	34.50	22080	South	29	11115	8262	7255	1355	1476	1594	1750
USGS 09135900 LEROUX CREEK AT HOTCHKISS, CO.	66.70	42688	South	21			5315	1676	1981	2297	2731
USGS 09137050 CURRANT CREEK NEAR READ, CO.	56.90	36416	South	12	10879	7054	5035	2045	2603	3179	4025
USGS 09143000 SURFACE CREEK NEAR CEDAREDGE, CO.	27.40	17536	South	67	11333	9727	8261	808	923	1042	1204
USGS 09143500 SURFACE CREEK AT CEDAREDGE, CO.	39.00	24960	South	90	11115	9415	6220	998	1206	1435	1774
USGS 09144000 SURFACE CREEK AT ECKERT, CO.	43.60	27904	South	11			5450	765	912	1067	1286
USGS 09144200 TONGUE CREEK AT CORY, CO.	197.00	126080	South	23			5030	1811	2135	2465	2908

The transposed flow rates are computed below using the methods in "Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States by "Blakemore E. Thomas, H. W. Hjalmarson, and S. D. Waltemeyer, USGS Geological Survey, Open Fille Report 93-419, Tucson, Arizona, 1994.

Use Equation 2, page 15:

$$Q_{T(u)} = Q_{T(g)}(A_u / A_g)^x$$

$Q_{T(u)}$ peak discharge in cfs at ungauged site for T-year recurrence interval

$Q_{T(g)}$ weighted peak discharge in cfs at gauged site for T-year recurrence interval. We will use the values above which were calculated by the USGS PeakFq program.

A_u drainage area in square miles at the ungauged site = 9.26

A_g drainage area in square miles at the gauged site

x exponent for each flood region as shown on table on page 16. This site is in a region that uses x = 0.5

Transposed Estimated Peak Flow Rates

Site Name								FFA 50yr Q (cfs)	FFA 100yr Q (cfs)	FFA 200yr Q (cfs)	FFA 500yr Q (cfs)
USGS 09134500 LEROUX CREEK NEAR CEDAREDGE, CO.								702	765	826	907
USGS 09143000 SURFACE CREEK NEAR CEDAREDGE, CO.								470	537	606	700
USGS 09143500 SURFACE CREEK AT CEDAREDGE, CO.								486	588	699	864
USGS 09144200 TONGUE CREEK AT CORY, CO.								393	463	534	630

USGS 09135900 LEROUX CREEK AT HOTCHKISS, CO.								624	738	856	1018
							Standard Deviation:	130	120	110	109
							Average:	553	**630**	710	824
							Average including basins with 20+ events	125	130	138	157
							Average including basins with 20+ events	535	618	704	824

Side Drain Hydrology

State Highway 92 Hydrology

OBJECTIVE:

The purpose of this calculation is to determine peak flow rates for use of side culvert design within the SH 92 study area.

GIVEN:

CDOT Drainage Design Manual states in Table 7.2 Table of Design Frequencies, that for side drains, the design frequency shall be the 10 year storm event.

REFERENCES:

- *Crossing Basin Hydrology Calc Package,* Betsy Young, April 2012
- Basins and time of concentration paths were delineated based on USGS 7.5 minute quadrangles or Right of Way survey, where available.
- Rainfall data is from NOAA Atlas 2, Volume III available at: http://www.nws.noaa.gov/ohd/hdsc/noaaatlas2.htm
- Soil type, land use, and annual rainfall are from the CDSS Division 4.available at: http://cdss.state.co.us/DNN/Home/tabid/36/Default.aspx
- NRCS methods are from USDA (1986) *Urban Hydrology for Small Watersheds.,* 210-VI-TR-55, Second Ed.,
- Colorado Department of Transportation. *Drainage Design Manual (DDM).* (2004)

ASSUMPTIONS:

Many of the side drains reside within a basin where the flow rate has already been calculated by the NRCS method. For these side drains, the flow rate was assumed to be proportional to the ratio of the side drain basin area to the crossing drain basin area.

An NRCS analysis was used to estimate flow rates for side drains that did not reside in a crossing drainage basin.

See Table 1 in the Conclusions Section for which Method was used for each culvert.

ANALYSIS / CALCULATIONS:

HEC-HMS was used to calculate peak flows for the NRCS Basins. Time of concentration and curve number were calculated using an Excel spreadsheet, attached. The ratio method was calculated using a spreadsheet, attached.

Calculation Notes URS

Subject: Hydrology

By: Betsy Young and Joel Jones Date: Apr. 26, 12

Checked By: : Date:

Project Name: State Highway 92

Project No: 22241827

Task No. 00007 File No.:

CONCLUSIONS:

The table below presents the 10 year flow rate for each basin.

Table 1- Side Drain Summary

Centerline Access Station	Drainage Area (ac)	Curve Number	Peak 10-year Flow Rate (cfs)	Method	Road Crossing
STA. 372+17	3.82	69.7	0.34	Ratio	Shamrock Rd
STA. 390+90	14.61	69.5	1.47	Ratio	Day Dr
STA. 421+46	4.43	66.5	0.15	Ratio	Unnamed
STA. 437+89	15.10	51.0	0.60	NRCS	Unnamed
STA. 437+80	11.3	51.0	0.10	NRCS	Unnamed
STA. 446+51	0.06	53.6	0.10	Ratio	Unnamed
STA. 450+16	0*	51.0	0.10	Ratio	Unnamed

*The crossing at STA 450+16 is at a high point.

ATTACHMENTS:

- Time of concentration and curve number calculation
- HECHMS output
- Ratio Method Spreadsheet

SH 92
Side Drain Calculations

	ID	Within Basin	Big Basin Area (ac)	10 yr Major Basin Flow (cfs)	50 yr Major Basin Flow (cfs)	Start		End		Size (in)	Basin Area (ac)	10 yr Flow (cfs)[1]	50 yr Flow (cfs)[1]	Length (ft)	Long. Slope	**HW/D**	**Velocity (fps)**
						Start STA	Elevation (ft)	End STA	Elevation (ft)								
1	STA. 372+17 LT	372+17	11.3	1	3.5	37262	5282.5	37167	5278	24	3.82	0.34	1.18	95	0.047	**0.15**	**4.5**
2	STA. 390+90 RT	394+16	11.9	1.2	5.3	39153	5344	39028	5340	24	14.61	1.47	6.51	125	0.032	**0.32**	**6.1**
3	STA. 421+46 LT	416+50	106.1	3.6	20.1	42177	5386	42114	5385	18	4.43	0.15	0.84	63	0.016	**0.14**	**2.5**
4	STA. 437+89 LT[3]	430+00	6226.0	-	553	43768	5448	43807	5446	18	15.10	0.60	1.34	39	0.051	**0.29**	**5.72**
5	STA. 437+80 RT[2]	-	-	-	-	43751	5452	43850	5448	18	11.3	0.10	0.20	99	0.040	**0.11**	**3.07**
6	STA. 446+51 RT[2]	-	-	-	-	44615	5503	44688	5500.5	18	0.06	0.10	0.20	73	0.034	**0.11**	**2.88**
7	STA. 450+16 LT[4]	448+70	2.9	0.1	0.2	45036	5508	44997	5507.5	18	0	0.10	0.20	39	0.013	**0.11**	**2.05**

[1]Flow was calculated by taking the ratio of the Special Ditch Basin area to the Existing Offsite Basin area that the ditch resides in. The ratio was then applied to the flow.
For example, if a ditch basin was half the size of the existing offsite basin, then it receives half the flow.

[2] Hydrology for 437+80RT and 446+51 was calculated using NRCS method, because it does not reside in any of the major basins

[3] Hydrology for 437+89 a was calculated using NRCS method, because2 and 10 yr flow was not calculated for Big Gulch

[4] STA 450+1+ LT sits at a high point, and will be replaced in kind. The full basin flow was modeled to determine the velocity and HW/D.

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations - SCS Methods
Calculations for Time of Concentration and Lag Time

	Upland (Sheet) Flow Travel Time						Shallow Concentrated Flow					Channel Flow																
	Basin Area	2yr 24 hr Rainfall, P2	Manning's n	Length, L	Slope, s	Upland T_1	Length	Surface*	Slope	Velocity	Shallow T_2	Length	El @Top	El @Bot	Slope	Bottom Width	annel Side Slo	Mannings n	Depth	Q	Flow Area	Wetted Per.	Hydraulic Rad,	Velocity	Channel T_3	T_c	L	ercent Im
Subcatchment ID	(ac)	(in)		(ft)	pct	(hr)	(ft)	P or U	pct	(ft/s)	(hr)	(ft)	(ft)	(ft)	(ft/ft)	(ft)			(ft)	(cfs)	(ft2)			(ft/s)	(hr)	hr	min	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
sd437+89	15.1	1.05	0.13	100	10	0.13	607	U	10	5.07	0.0332	896	5500	5440	0.067	10.000	3.000	0.030	0.350	23	3.868	12.214	0.317	5.95	0.042	0.209	7.51	2
sd437+80	3.9	1.05	0.13	100	4	0.19	582	U	10	5.10	0.0317	582														0.224	8.08	3
sd446+51	0.1	1.05	0.13	46	2	0.14	42	U	7	4.27	0.0027															0.139	5.02	4

3.6 min
39.5 max
11.7 average

Column Explanation
1 Subcatchment name. Names correspond to the station of the crossing structure
2 Basin area in acres
3 2 year, 24 hour rainfall from NOAA Atlas II, Vol III 2yr 24hr rainfall map
4 Upland flow Manning's n based on areas consisting of Shrub & Brush Rangeland
5 Travel length of sheet flow
6 Slope of sheet flow path. Determined by dividing the USGS quad contour elevation difference by the length
7 Travel time for upland flow $Tt = 0.007(nL)^{0.8}/((P_2)^{0.5}\ s^{0.4})$
8 Length of shallow concentrated flow. Determined by dividing the USGS quad contour elevation difference by the length
9 An unpaved surface was assumed for all subcatchments.
10 Shallow concentrated slopes. Determined by dividing the USGS quad contour elevation difference by the length
11 Velocities were calculated using the equations provided in appendix F of TR-55. Unpaved: $V = 16.1345\ (s)^{0.5}$, Paved: $V = 20.3282\ (s)^{0.5}$
12 Travel time for Shallow Concentrated Flow Tt = Length/Velocity/(3600sec/hr)
13 Length of channel, if applicable
14 The channel elevation at the top of the channel
15 The channel elevation at the bottom of the channel and basin.
16 Channel slope
17 Channel bottom width estimated from aerial photo
18 Channel bottom width estimated from USGS quad contours
19 Manning's n for channel
20 A guess at the flow depth
21 Q=VA, value corresponds to the flow calculated by HEC-HMS
22 Channel flow cross section area calculated using the depth guess, Depth*Bottom Width + Depth*Depth*Channel Side Slope
23 Wetted perimeter for Manning's Equation. In Columns: Bottom Width + $(Depth^2 + (Depth*Channel\ side\ slope)^2)^{0.5}$
24 Hydraulic Radius = Area / Wetted Perimeter
25 Channel Velocity using Manning's. In Columns: =1.486/Manning's n for channels * Hydraulic $Radius^{2/3}$ * Channel $Slope^{0.5}$
26 Travel time for channel flow T3 = Length/Velocity/(3600sec/hr)
27 Time of Concentration = sum of the travel times or 5 minutes, whichever is greater.
28 Time lag = Time of Concentration * 0.6 * 60 minutes/hour

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations - SCS Methods
Basin Curve Number Calculations

NRCS Land Code	Cropland and Pasture					Evergreen Forest Land					Shrub and Brush Rangeland					Total weighted CN for subcatchment (sum of values to the left)
TR-55 Land Cover from CN tables	Row crops, Straght Row and Crop Residue Cover, Poor condition					Woods, Fair condition					Sage-grass-fair					
Hydrologic Soil Group	A	B	B/D	C	D	A	B	B/D	C	D	A	B	B/D	C	D	
TR-55 CN from Tables	71	80	80	87	90	36	60	60	73	79	-	51	51	63	70	
Subcatchment ID																
sd437+89												51.0				51.0
sd437+80												51.0				51.0
sd446+51												44.0			9.5	53.6

Project: Offsite_Basins Simulation Run: 10 yr

Start of Run: 01Jan2000, 00:00 Basin Model: Offsite_Basins
End of Run: 02Jan2000, 01:00 Meteorologic Model: 10yr_24hr
Compute Time: 02Apr2012, 20:31:38 Control Specifications: Control 1

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
416+50	0.166000	3.6	01Jan2000, 12:04	0.09
397+18	0.064000	1.8	01Jan2000, 12:07	0.11
394+16	0.018000	1.2	01Jan2000, 12:01	0.14
386+34	0.012000	0.8	01Jan2000, 12:02	0.14
372+00	0.018000	1.0	01Jan2000, 12:04	0.14
448+70	0.005000	0.1	01Jan2000, 12:00	0.03
372+17	0.018000	1.0	01Jan2000, 12:04	0.14
430+00	9.700000	159.3	01Jan2000, 12:44	0.12
SD403R	0.000656	0.0	01Jan2000, 12:04	0.14
SD419R	0.002800	1.2	01Jan2000, 11:57	0.56
sd437+89	0.023600	0.6	01Jan2000, 12:00	0.03
sd437+80	0.006080	0.1	01Jan2000, 12:01	0.03
sd446+51	0.000156	0.0	01Jan2000, 11:58	0.03

Special Ditch Hydrology

State Highway 92 Hydrology

OBJECTIVE:

The purpose of this calculation is to determine peak flow rates for use of side culvert design within the SH 92 study area.

GIVEN:

CDOT Drainage Design Manual states in Table 7.2 Table of Design Frequencies, that for side drains, the design frequency shall be the 10 year storm event. Special Ditches were also designed to the 10 year event.

REFERENCES:

- *Crossing Basin Hydrology Calc Package,* Betsy Young, April 2012
- *Side Drain Hydrology Calc Package*, Betsy Young, April 2012
- Basins and time of concentration paths were delineated based on USGS 7.5 minute quadrangles or Right of Way survey, where available.
- Rainfall data is from NOAA Atlas 2, Volume III available at: http://www.nws.noaa.gov/ohd/hdsc/noaaatlas2.htm
- Soil type, land use, and annual rainfall are from the CDSS Division 4.available at: http://cdss.state.co.us/DNN/Home/tabid/36/Default.aspx
- NRCS methods are from USDA (1986) *Urban Hydrology for Small Watersheds.,* 210-VI-TR-55, Second Ed.,
- Colorado Department of Transportation. *Drainage Design Manual (DDM).* (2004)

ASSUMPTIONS:

Many of the special ditches reside within a basin where the flow rate has already been calculated by the NRCS method. For these side drains, the flow rate was assumed to be proportional to the ratio of the side drain basin area to the crossing drain basin area.

An NRCS analysis was used to estimate flow rates for side drains that did not reside in a crossing drainage basin.

See Table 1 in the Conclusions Section for which Method was used for each ditch.

ANALYSIS / CALCULATIONS:

HEC-HMS was used to calculate peak flows for the NRCS Basins. Time of concentration and curve number were calculated using an Excel spreadsheet, attached. The ratio method was calculated using a spreadsheet, attached.

Calculation Notes URS

Subject: Hydrology

By: Betsy Young Date: Apr. 26, 12

Checked By: : Date:

Project Name: State Highway 92

Project No: 22241827

Task No. 00007 File No.:

CONCLUSIONS:

The table below presents the 10 year flow rate for each basin.

Table 1- Side Drain Summary

Centerline Access Station	Drainage Area (ac)	Peak 10-year Flow Rate (cfs)	Method
SD403R	0.42	0.01	NRCS
SD407L	0.21	0.01	Ratio
SD411L	1.50	0.07	Ratio
SD419R	1.75	1.2	NRCS

ATTACHMENTS:

- Time of concentration and curve number calculation
- HECHMS output
- Ratio Method Spreadsheet

SH 92
Special Ditch Calculations

	ID	Within Basin	Big Basin Area (ac)	10 yr Major Basin Flow (cfs)	100 yr Major Basin Flow (cfs)	Start Ditch Start STA	Elevation (ft)	End Ditch End STA	Elevation (ft)	Type	Basin Area (ac)	10 yr Flow (cfs) [1]	100 yr Flow (cfs) [1]	Length (ft)	Long. Slope
1	SD403R	-	-	-	-	40366	5470	40366	5469.5	V	0.42	0.01 [2]	0.20	78	0.006
2	SD407L	397+18	40.96	1.8	13.6	40711	5410	40760	5409.5	V	0.21	0.01	0.07	49	0.010
3	SD411L	397+18	40.96	1.8	13.6	40926	5400	41100	5399	V	1.50	0.07	0.50	174	0.006
4	SD419R	-	-	-	-	41900	5384	41651	5383	V	1.75	1.20	2.30	249	0.004

[1]Flow was calculated by taking the ratio of the Special Ditch Basin area to the Existing Offsite Basin area that the ditch resides in. The ratio was then applied to the flow.
For example, if a ditch basin was half the size of the existing offsite basin, then it receives half the flow.

[2] Hydrology for SD403R and SD419R was calculated using NRCS method, because it does not reside in any of the major basins

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations - SCS Methods
Calculations for Time of Concentration and Lag Time

	Upland (Sheet) Flow Travel Time						Shallow Concentrated Flow				
	Basin Area	2yr 24 hr Rainfall, P2	Manning's n	Length, L	Slope, s	Upland T_1	Length	Surface*	Slope	Velocity	Shallow T_2
Subcatchment ID	(ac)	(in)		(ft)	pct	(hr)	(ft)	P or U	pct	(ft/s)	(hr)
1	2	3	4	5	6	7	8	9	10	11	12
SD403R	0.4	1.05	0.13	100	2	0.25	178	U	5	3.63	0.0136
SD419R	1.8	1.05	0.01	60	7	0.01	150	U	4	3.23	0.0129

	Channel Flow																
	Length	El @Top	El @Bot	Slope	Bottom Width	annel Side Slo|	Mannings n	Depth	Q	Flow Area	Wetted Per.	Hydraulic Rad,	Velocity	Channel T_3	T_c	L	ercent Im|
Subcatchment ID	(ft)	(ft)	(ft)	(ft/ft)	(ft)			(ft)	(cfs)	(ft2)			(ft/s)	(hr)	hr	min	
1	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
SD403R															0.268	9.64	2
SD419R	1010	5396	5384	0.012	4.000	4.000	0.030	0.750	17	4.688	8.743	0.536	3.56	0.079	0.106	3.82	30
																3.6 min	
																39.5 max	
																11.7 average	

Column Explanation

1 Subcatchment name. Names correspond to the station of the crossing structure
2 Basin area in acres
3 2 year, 24 hour rainfall from NOAA Atlas II, Vol III 2yr 24hr rainfall map
4 Upland flow Manning's n based on areas consisting of Shrub & Brush Rangeland
5 Travel length of sheet flow
6 Slope of sheet flow path. Determined by dividing the USGS quad contour elevation difference by the length
7 Travel time for upland flow $Tt = 0.007(nL)^{0.8}/((P_2)^{0.5} s^{0.4})$
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24 Hydraulic Radius = Area / Wetted Perimeter
25 Channel Velocity using Manning's. In Columns: =1.486/Manning's n for channels * Hydraulic $Radius^{2/3}$ * Channel $Slope^{0.5}$
26 Travel time for channel flow T3 = Length/Velocity/(3600sec/hr)
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28 Time lag = Time of Concentration * 0.6 * 60 minutes/hour

14934 State Highway 92 - Austin to Hotchkiss
Proposed Roadway Basin Calculations - SCS Methods
Basin Curve Number Calculations

NRCS Land Code	Cropland and Pasture					Evergreen Forest Land					Shrub and Brush Rangeland					Total weighted CN for subcatchment (sum of values to the left)
TR-55 Land Cover from CN tables	Row crops, Straght Row and Crop Residue Cover, Poor condition					Woods, Fair condition					Sage-grass-fair					
Hydrologic Soil Group	A	B	B/D	C	D	A	B	B/D	C	D	A	B	B/D	C	D	
TR-55 CN from Tables	71	80	80	87	90	36	60	60	73	79	-	51	51	63	70	
Subcatchment ID																
SD403R															70.0	70.0
SD419R															70.0	70.0

Project: Offsite_Basins Simulation Run: 10 yr

Start of Run: 01Jan2000, 00:00 Basin Model: Offsite_Basins
End of Run: 02Jan2000, 01:00 Meteorologic Model: 10yr_24hr
Compute Time: 02Apr2012, 20:31:38 Control Specifications: Control 1

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
416+50	0.166000	3.6	01Jan2000, 12:04	0.09
397+18	0.064000	1.8	01Jan2000, 12:07	0.11
394+16	0.018000	1.2	01Jan2000, 12:01	0.14
386+34	0.012000	0.8	01Jan2000, 12:02	0.14
372+00	0.018000	1.0	01Jan2000, 12:04	0.14
448+70	0.005000	0.1	01Jan2000, 12:00	0.03
372+17	0.018000	1.0	01Jan2000, 12:04	0.14
430+00	9.700000	159.3	01Jan2000, 12:44	0.12
SD403R	0.000656	0.0	01Jan2000, 12:04	0.14
SD419R	0.002800	1.2	01Jan2000, 11:57	0.56
sd437+89	0.023600	0.6	01Jan2000, 12:00	0.03
sd437+80	0.006080	0.1	01Jan2000, 12:01	0.03
sd446+51	0.000156	0.0	01Jan2000, 11:58	0.03

Appendix D
Hydraulics

State Highway 92 Hydraulics

OBJECTIVE:

The purpose of this calculation is to determine crossing culvert pipe sizes and locations.

GIVEN:

Design flow rates. See *SH 92 Basin Calc Package*, Betsy Young, Aug 2011

REFERENCES:

- Roadway plan and profile, attached
- Structure cross sections, attached
- Contours and cross sections used for HECRAS model are located at: I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\6.0 Project Deliverables\14934\Hydraulics\Working\Betsy

ASSUMPTIONS:

Minimum culvert size is 24”. All pipes will be RCP.

ANALYSIS / CALCULATIONS:

CulvertMaster was used for all cross drains except for at STA 429+33. The culvert at STA 429+33 was analyzed with HECRAS because of the downstream hydraulic conditions at this location.

CONCLUSIONS:

The existing and proposed pipes can be seen in the table below:

STA	Peak Discharge (cfs)	Ex Pipe (size, mat’l)	Proposed Pipe (size,mat’l)
386+34	3.5	18" CMP	24” RCP
394+16	5.3	24" CMP	24” RCP
397+18	9.7	24" CMP	24” RCP
416+50	20.1	36" CMP	36” RCP
429+88	553	8’ Arch	Extend in kind
448+70	0.2	30" CMP	30” RCP

ATTACHMENTS:

- CulvertMaster output
- HECRAS input/ output

<u>Electronic Files:</u>
GIS Maps:
I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\7.0_CAD_GIS\GIS\Maps

Calculations:
I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\8.0_Design\8.01 Drainage\Calculations\Cross Drains.cvm

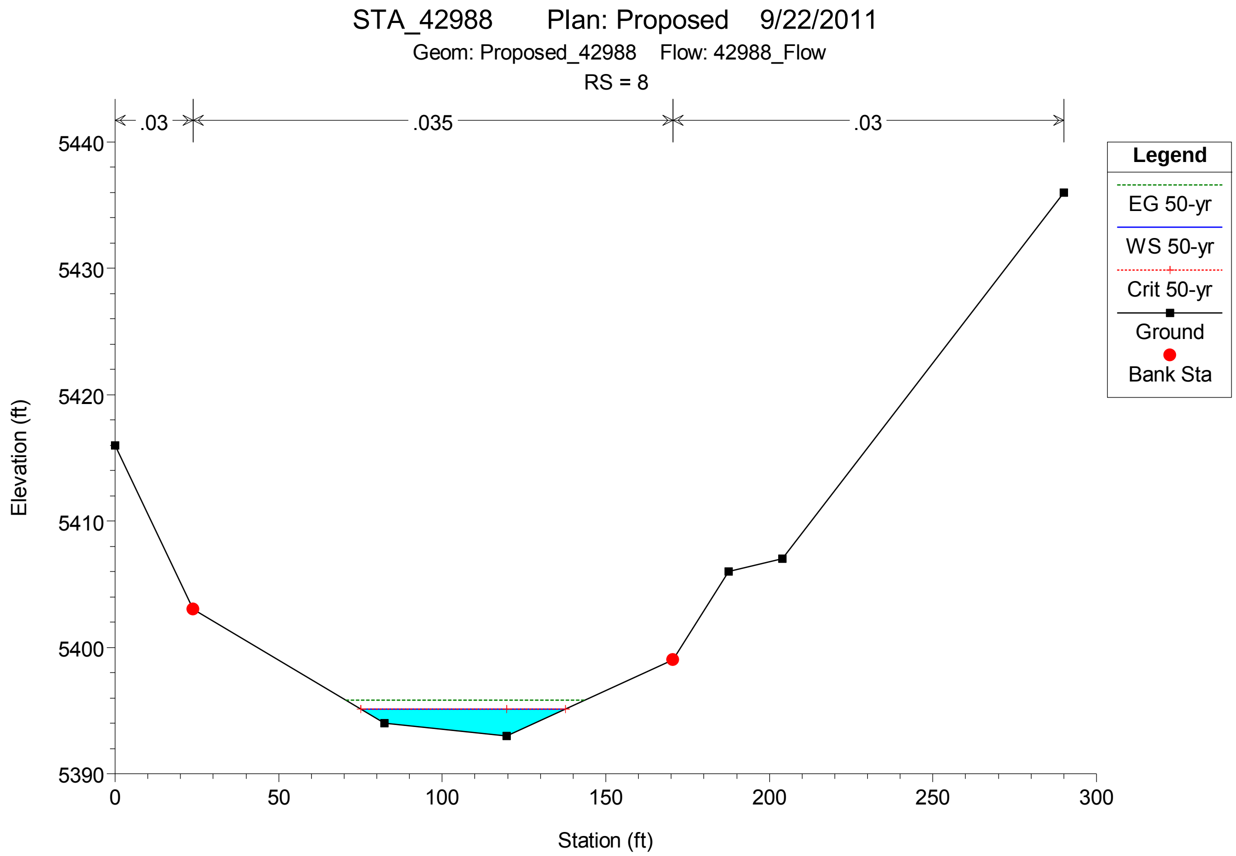
Big Gulch - HECRAS

HEC-RAS Plan: Exist River: Big Gulch Reach: Big Gulch Profile: 50-yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Big Gulch	8	50-yr	553.00	5393.00	5395.15	5395.15	5395.80	0.015708	6.50	85.13	62.88	0.98
Big Gulch	7	50-yr	553.00	5386.00	5388.76	5388.76	5389.43	0.015566	6.55	84.40	61.08	0.98
Big Gulch	6	50-yr	553.00	5372.00	5375.78	5375.78	5377.30	0.012334	9.90	55.87	51.69	0.99
Big Gulch	5.5		Culvert									
Big Gulch	5	50-yr	553.00	5363.00	5366.83	5366.83	5368.39	0.012290	10.01	55.26	65.71	1.00
Big Gulch	4	50-yr	553.00	5365.00	5367.54		5367.57	0.000316	1.41	402.48	171.11	0.16
Big Gulch	3	50-yr	553.00	5366.00	5367.18	5367.18	5367.50	0.019377	4.57	121.13	180.31	0.98
Big Gulch	2	50-yr	553.00	5352.00	5354.42	5354.42	5355.29	0.014861	7.49	73.79	41.75	0.99
Big Gulch	1	50-yr	553.00	5336.00	5338.82	5338.82	5339.65	0.014870	7.31	75.61	44.43	0.99

HEC-RAS Plan: Prop River: Big Gulch Reach: Big Gulch Profile: 50-yr

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Big Gulch	8	50-yr	553.00	5393.00	5395.12	5395.12	5395.80	0.016540	6.61	83.63	62.52	1.01
Big Gulch	7	50-yr	553.00	5386.00	5388.73	5388.73	5389.43	0.016619	6.71	82.35	60.33	1.01
Big Gulch	6	50-yr	553.00	5372.00	5382.25	5375.74	5382.41	0.000289	3.21	172.21	104.80	0.18
Big Gulch	5.5		Culvert									
Big Gulch	5	50-yr	553.00	5363.00	5366.82	5366.82	5368.39	0.012437	10.04	55.07	65.58	1.00
Big Gulch	4	50-yr	553.00	5365.00	5367.54		5367.57	0.000315	1.40	402.73	171.12	0.16
Big Gulch	3	50-yr	553.00	5366.00	5367.17	5367.17	5367.50	0.020736	4.66	118.67	180.12	1.01
Big Gulch	2	50-yr	553.00	5352.00	5354.40	5354.40	5355.29	0.015311	7.57	73.03	41.61	1.01
Big Gulch	1	50-yr	553.00	5336.00	5338.79	5338.79	5339.65	0.015641	7.44	74.31	44.20	1.01



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.035
.03
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Bank Sta
Elevation (ft)
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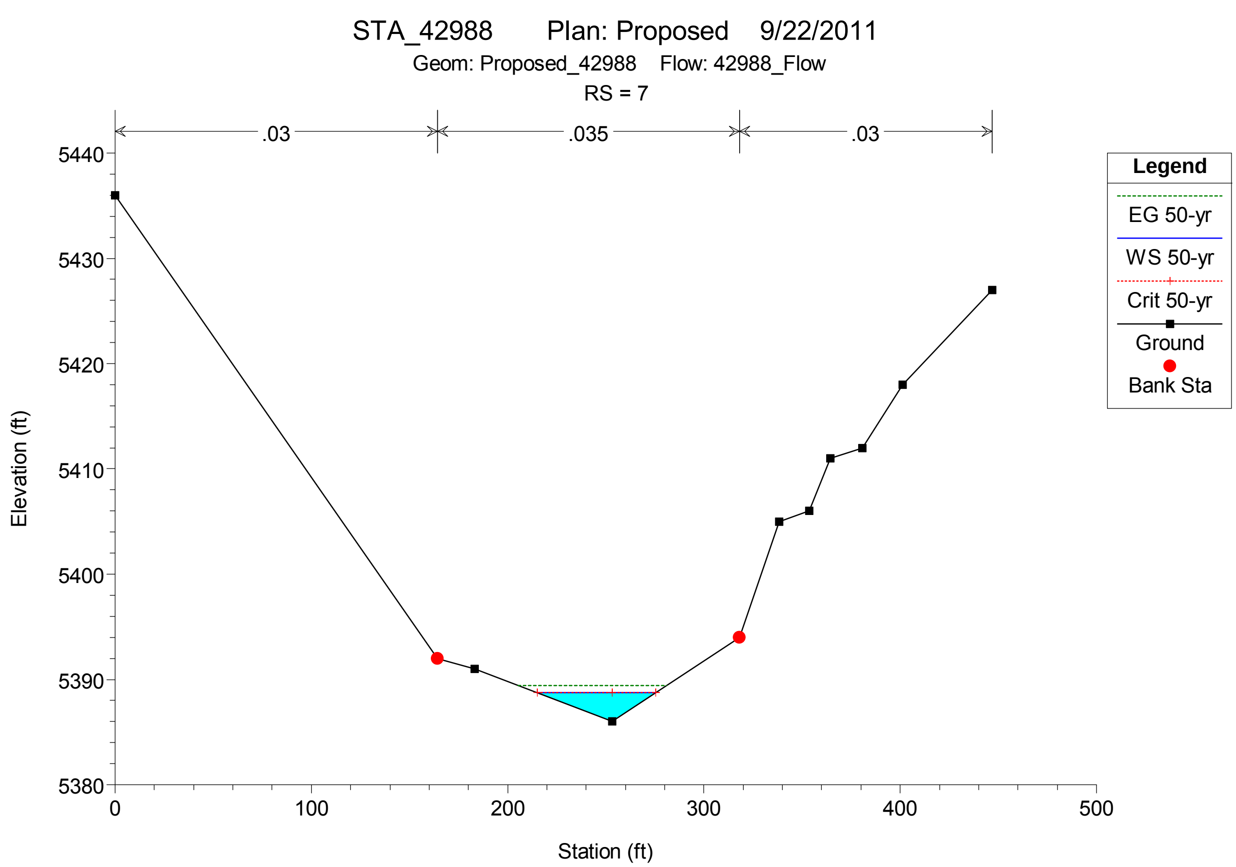
5430
5420
5410
5400
5390
0
50
100
150
200
250
300
Station (ft)



STA_42988 Plan: Proposed 9/22/2011
Geom: Proposed_42988 Flow: 42988_Flow
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.035
.03
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Bank Sta
Elevation (ft)
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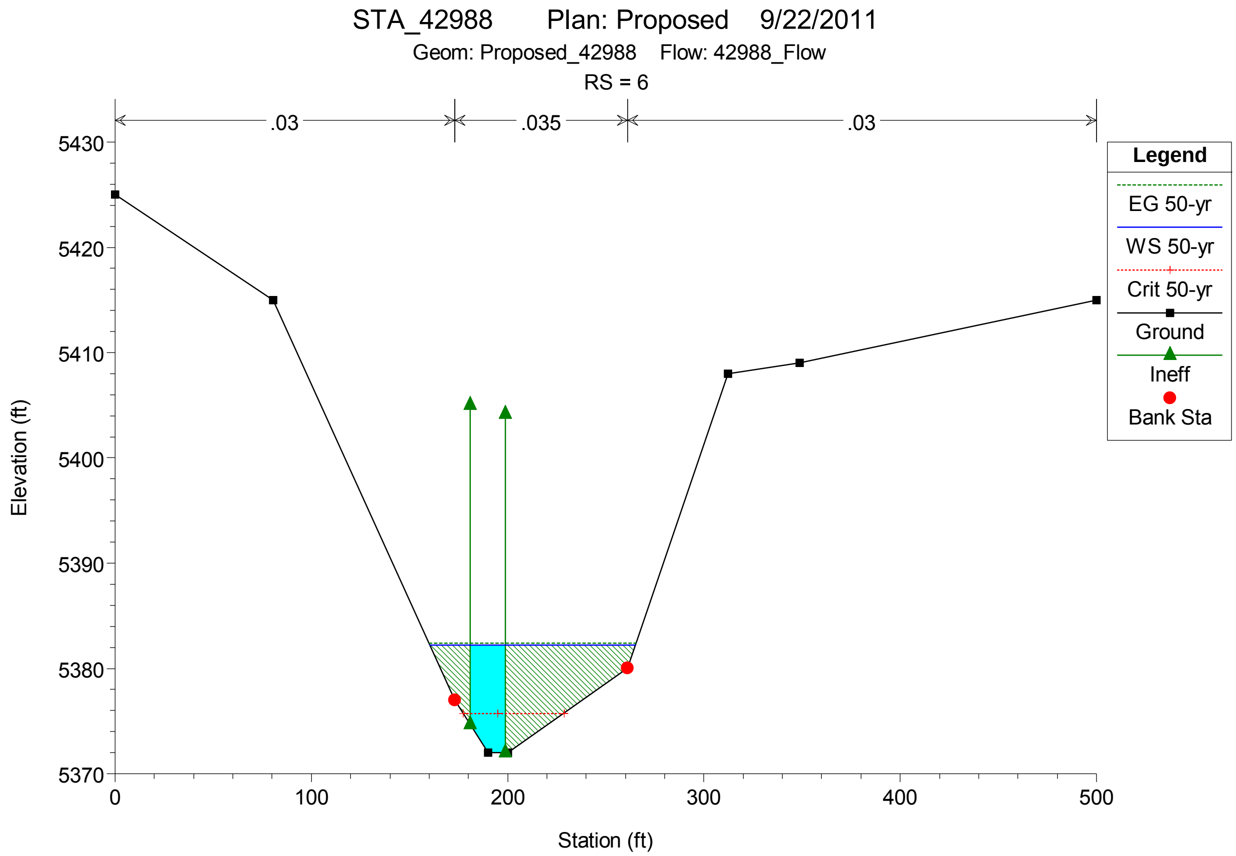
5430
5420
5410
5400
5390
5380
0
100
200
300
400
500
Station (ft)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.035
.03
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Ineff
Bank Sta
Elevation (ft)
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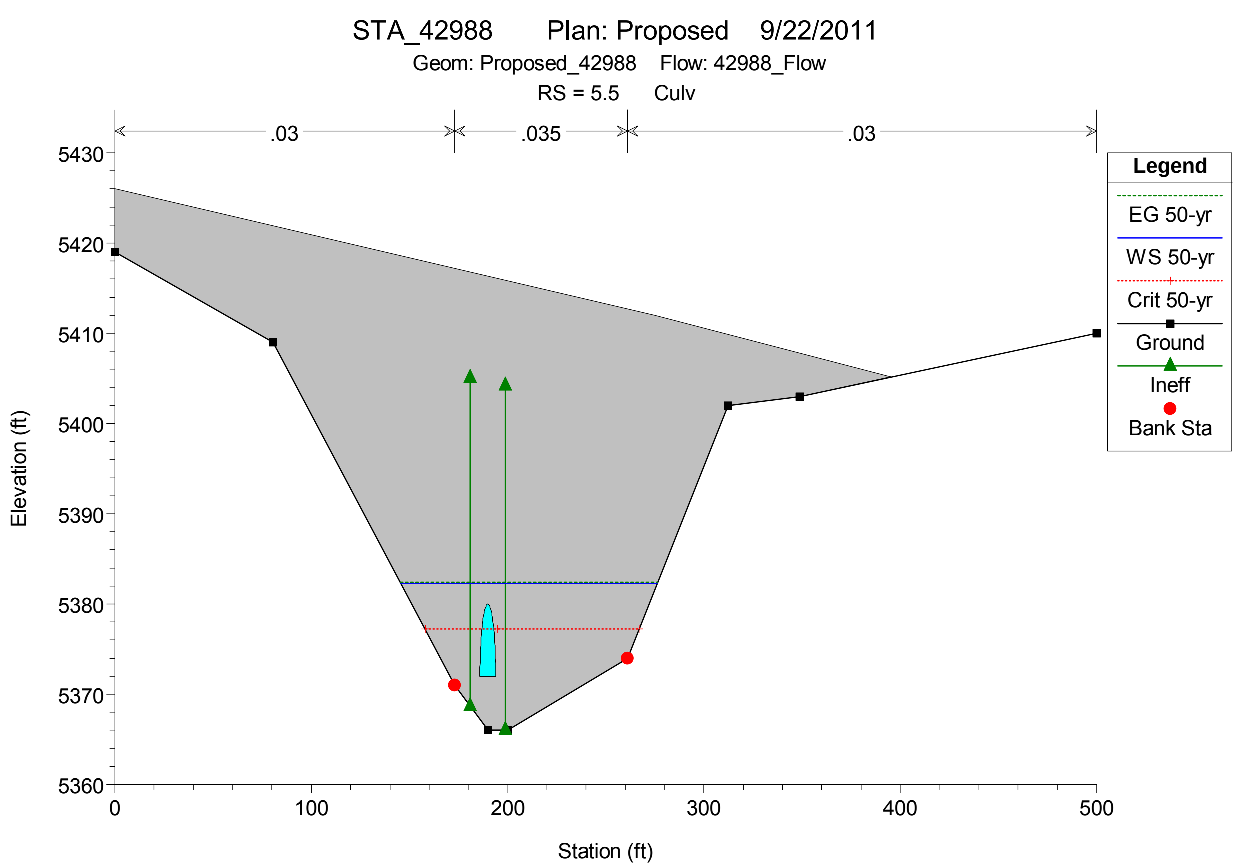
5420
5410
5400
5390
5380
5370
0
100
200
300
400
500
Station (ft)


STA_42988 Plan: Proposed 9/22/2011
Geom: Proposed_42988 Flow: 42988_Flow
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Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Ineff
Bank Sta
Elevation (ft)
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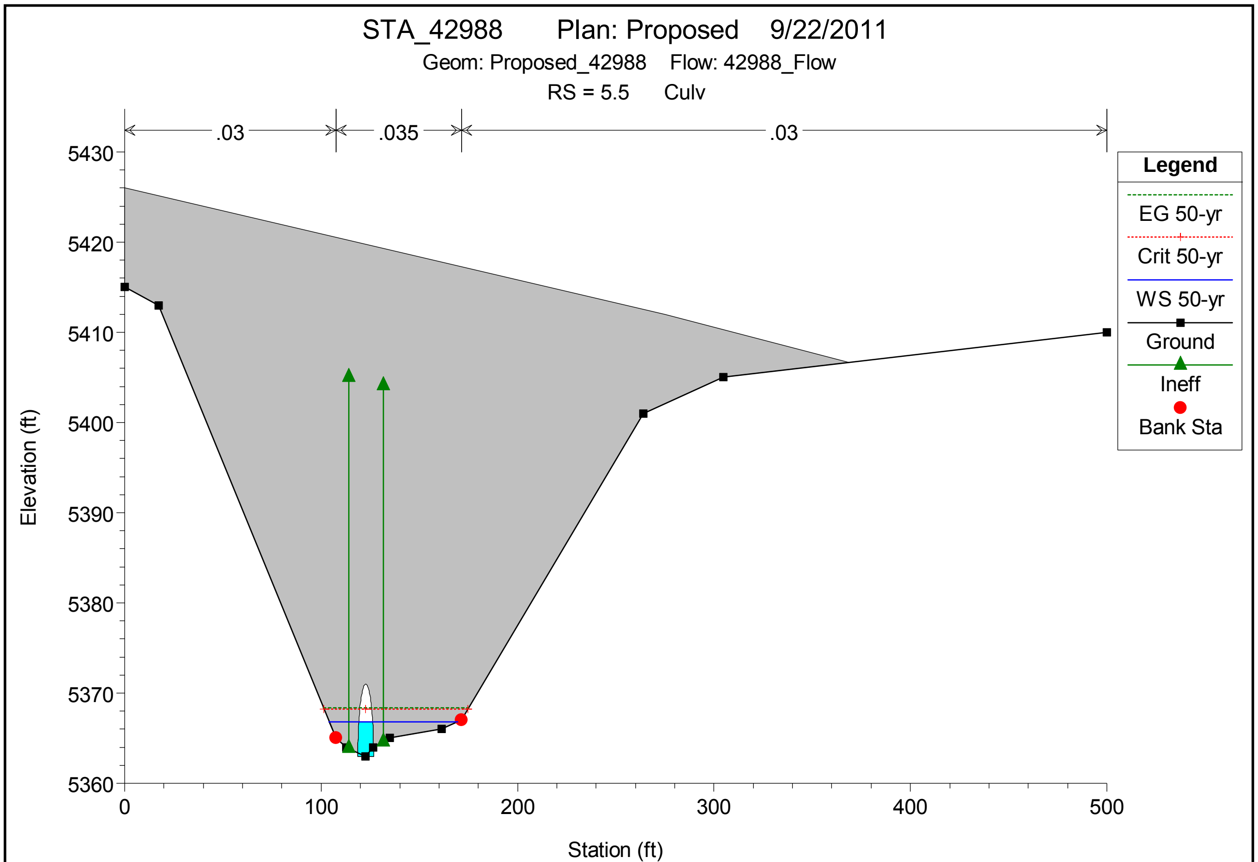
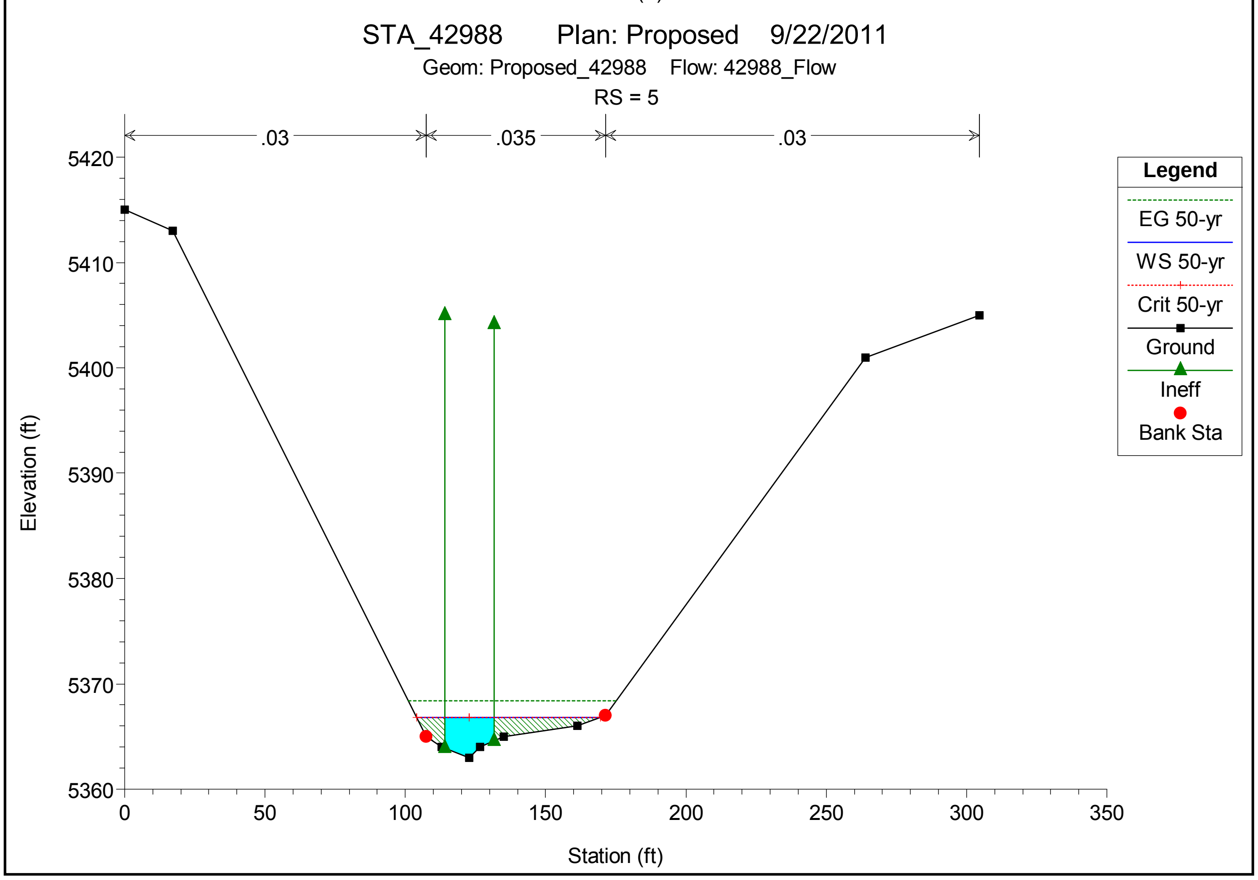
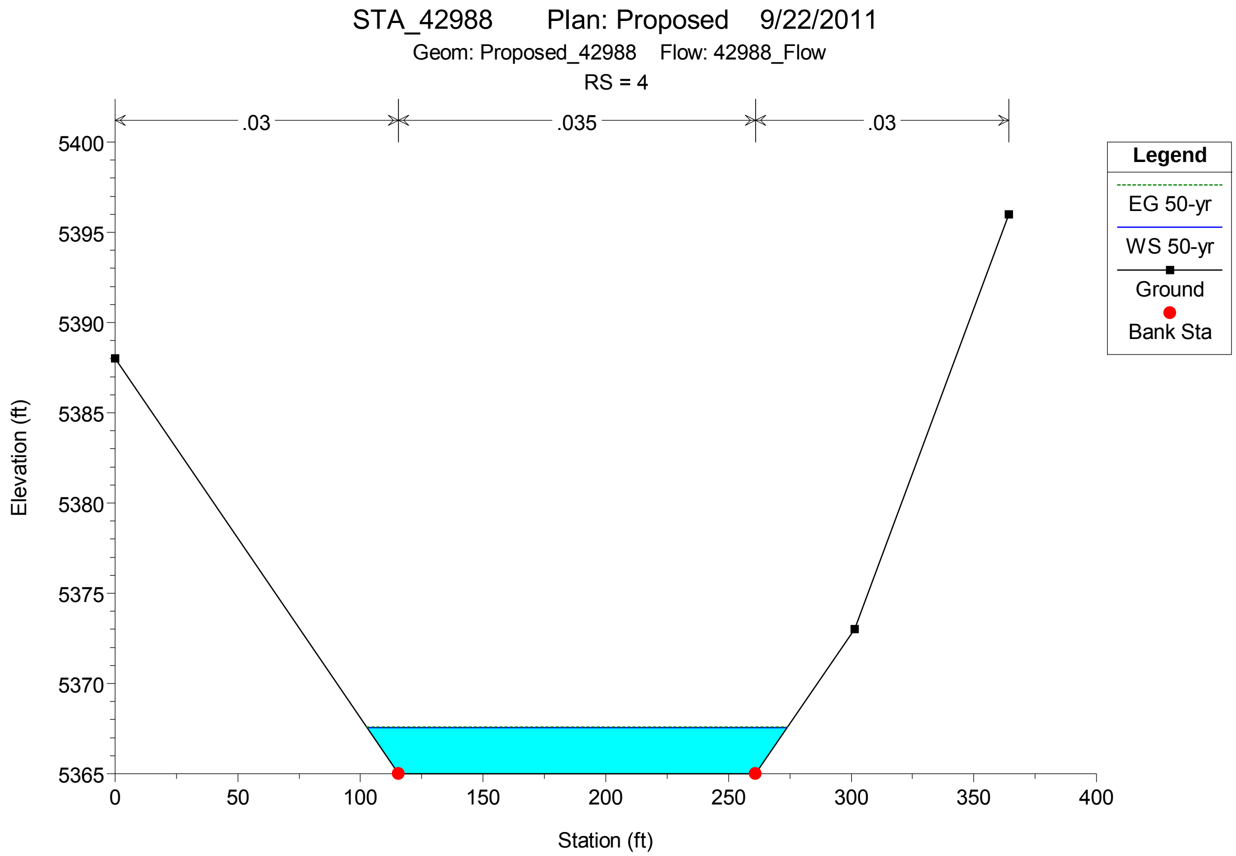
5410
5400
5390
5380
5370
5360
0
100
200
300
400
500
Station (ft)


STA_42988 Plan: Proposed 9/22/2011
Geom: Proposed_42988 Flow: 42988_Flow
RS = 5.5 Culv
.03
.035
.03
Legend
EG 50-yr
Crit 50-yr
WS 50-yr
Ground
Ineff
Bank Sta
Elevation (ft)
5430
5420
5410
5400
5390
5380
5370
5360
0
100
200
300
400
500
Station (ft)


STA_42988 Plan: Proposed 9/22/2011
Geom: Proposed_42988 Flow: 42988_Flow
RS = 5
.03
.035
.03
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Ineff
Bank Sta
Elevation (ft)
5420
5410
5400
5390
5380
5370
5360
0
50
100
150
200
250
300
350
Station (ft)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Geom: Proposed_42988 Flow: 42988_Flow
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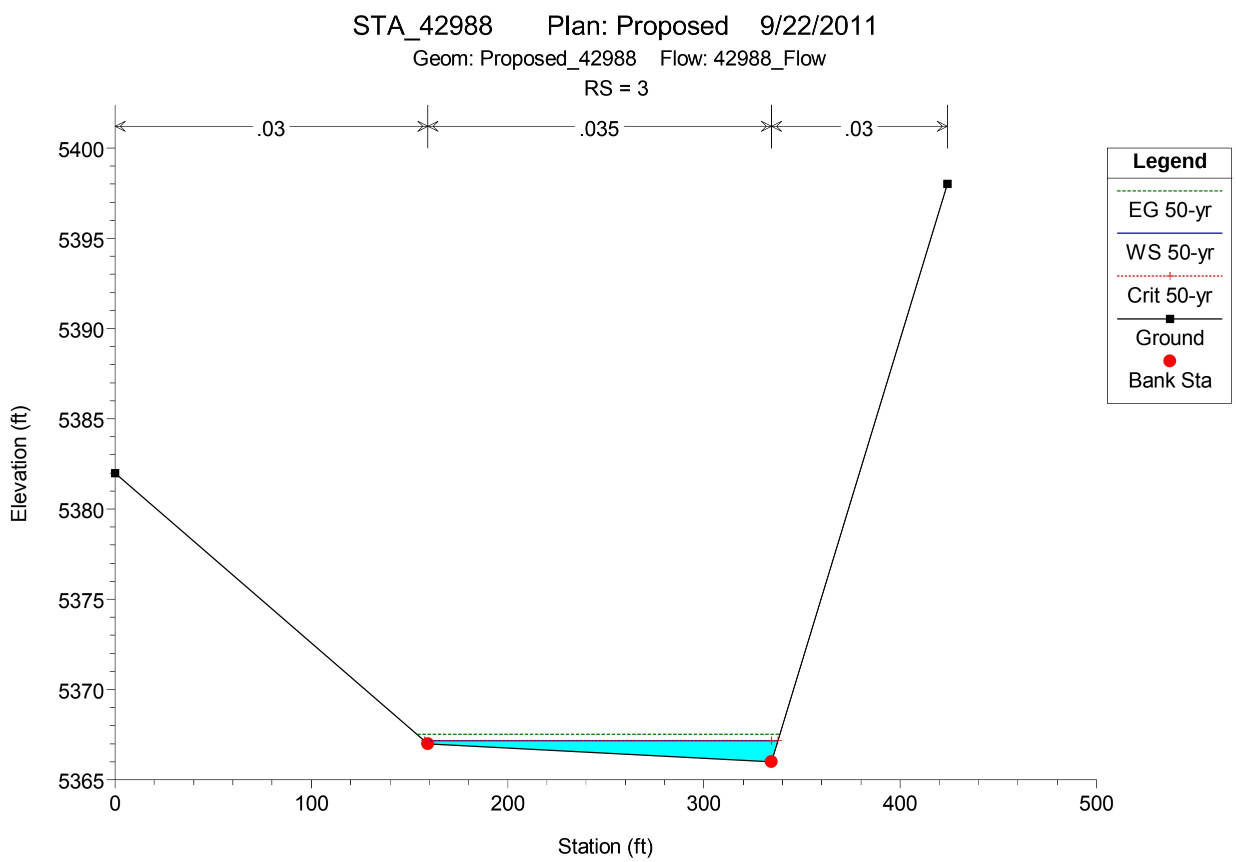
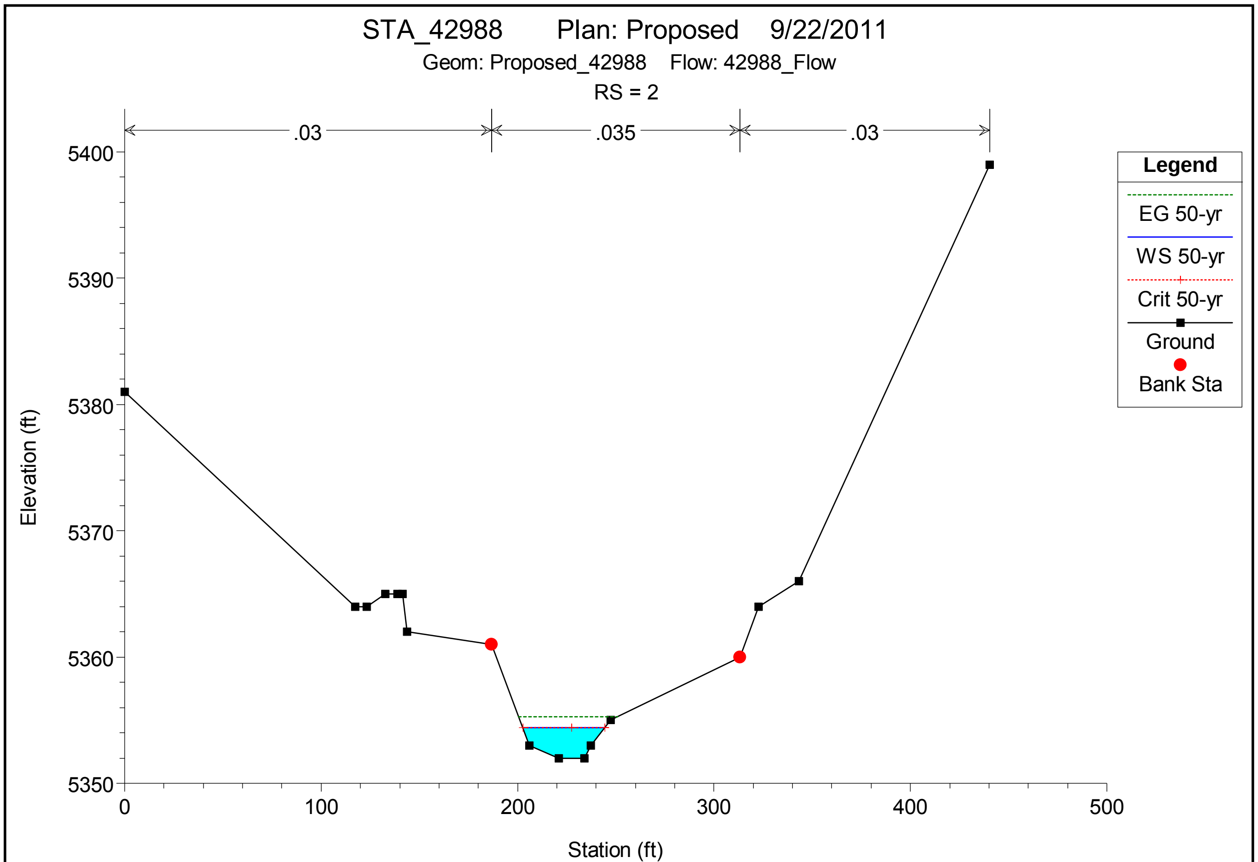
.03
.035
.03
Legend
EG 50-yr
WS 50-yr
Ground
Bank Sta
Elevation (ft)
5400
5395
5390
5385
5380
5375
5370
5365
0
50
100
150
200
250
300
350
400
Station (ft)


STA_42988 Plan: Proposed 9/22/2011
Geom: Proposed_42988 Flow: 42988_Flow
RS = 3
.03
.035
.03
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Bank Sta
Elevation (ft)
5400
5395
5390
5385
5380
5375
5370
5365
0
100
200
300
400
500
Station (ft)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Geom: Proposed_42988 Flow: 42988_Flow
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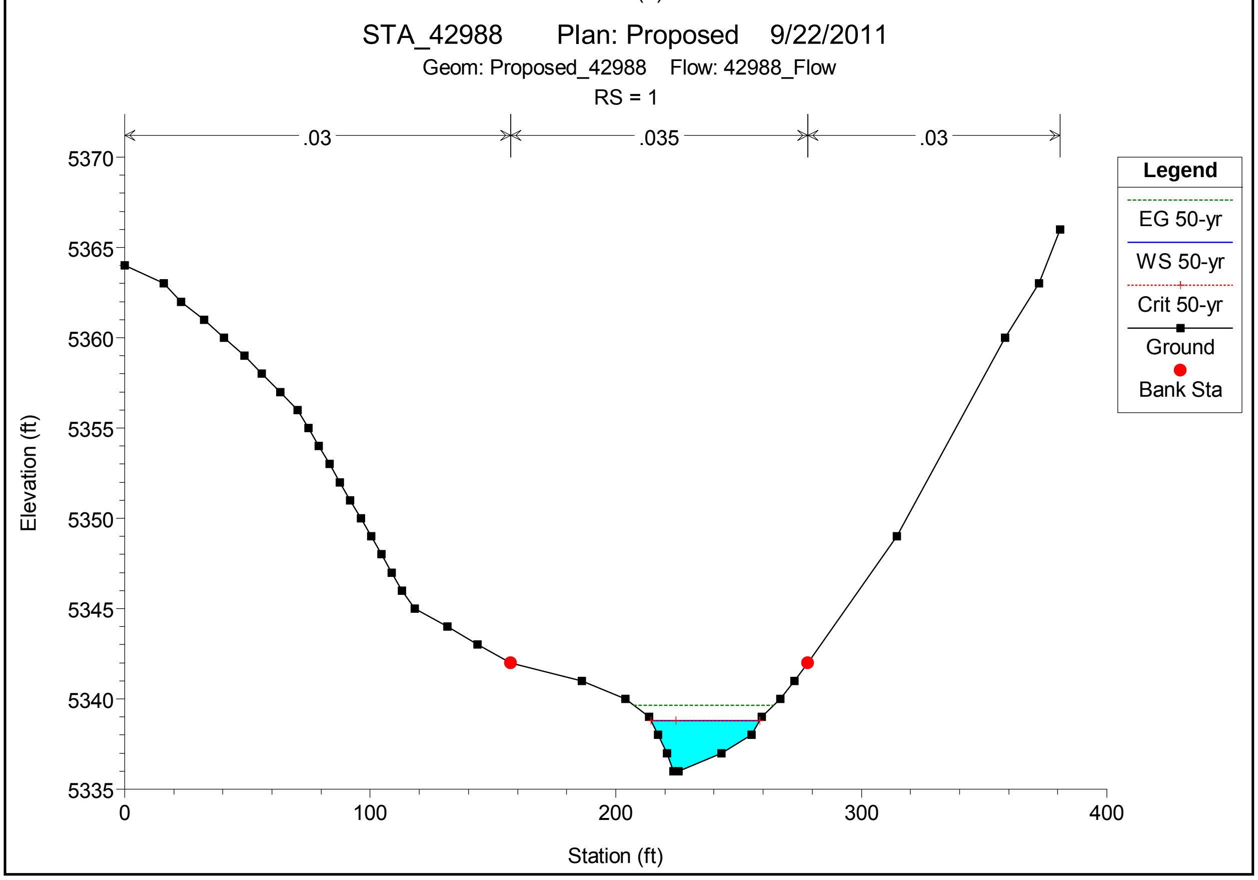
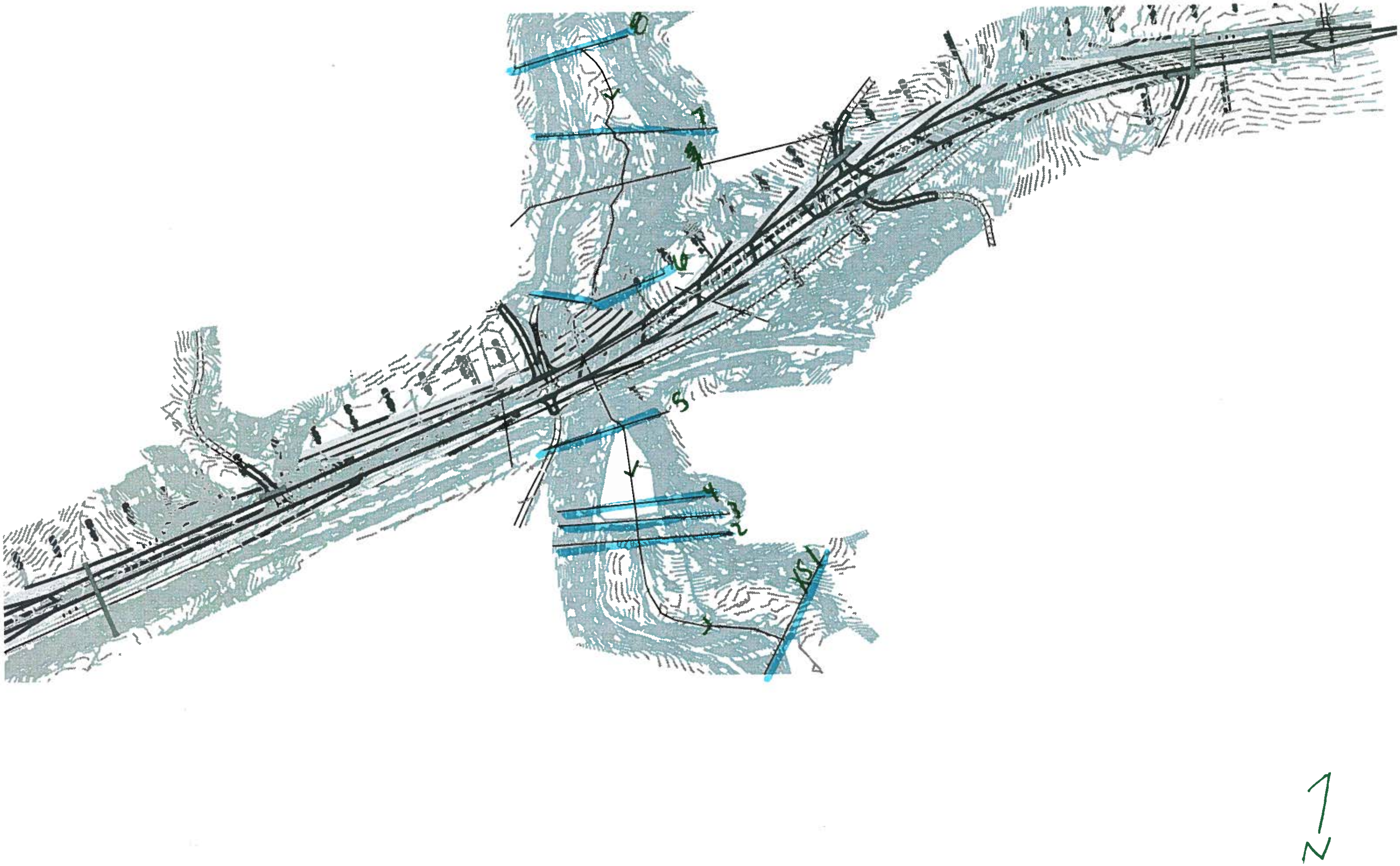
.03
.035
.03
Elevation (ft)
5400
5390
5380
5370
5360
5350
0
100
200
300
400
500
Station (ft)
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Bank Sta


STA_42988 Plan: Proposed 9/22/2011
Geom: Proposed_42988 Flow: 42988_Flow
RS = 1
.03
.035
.03
Elevation (ft)
5370
5365
5360
5355
5350
5345
5340
5335
0
100
200
300
400
Station (ft)
Legend
EG 50-yr
WS 50-yr
Crit 50-yr
Ground
Bank Sta

Cross Section Locations



Cross Drains - CulvertMaster

Culvert Calculator Report
397+22

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	58.60 ft	Headwater Depth/Height	0.90
Computed Headwater Eleva	57.39 ft	Discharge	9.70 cfs
Inlet Control HW Elev.	57.22 ft	Tailwater Elevation	46.50 ft
Outlet Control HW Elev.	57.39 ft	Control Type	Entrance Control

Grades

Upstream Invert	55.60 ft	Downstream Invert	42.50 ft
Length	300.00 ft	Constructed Slope	0.043667 ft/ft

Hydraulic Profile

Profile	CompositePressureProfileS1S2	Depth, Downstream	4.00 ft
Slope Type	N/A	Normal Depth	0.61 ft
Flow Regime	N/A	Critical Depth	1.11 ft
Velocity Downstream	3.09 ft/s	Critical Slope	0.005151 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.013
Section Material	Concrete	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	1		

Outlet Control Properties

Outlet Control HW Elev.	57.39 ft	Upstream Velocity Head	0.45 ft
Ke	0.50	Entrance Loss	0.23 ft

Inlet Control Properties

Inlet Control HW Elev.	57.22 ft	Flow Control	Unsubmerged
Inlet Type	Square edge w/headwall	Area Full	3.1 ft²
K	0.00980	HDS 5 Chart	1
M	2.00000	HDS 5 Scale	1
C	0.03980	Equation Form	1
Y	0.67000		

Culvert Calculator Report
416+51

Comments: 50 yr

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	79.70	ft	Headwater Depth/Height	0.76	
Computed Headwater Eleva	77.48	ft	Discharge	20.10	cfs
Inlet Control HW Elev.	77.21	ft	Tailwater Elevation	66.70	ft
Outlet Control HW Elev.	77.48	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	75.20	ft	Downstream Invert	70.50	ft
Length	113.00	ft	Constructed Slope	0.041593	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.79	ft
Slope Type	Steep		Normal Depth	0.78	ft
Flow Regime	Supercritical		Critical Depth	1.44	ft
Velocity Downstream	13.60	ft/s	Critical Slope	0.004188	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	3.00	ft
Section Size	36 inch		Rise	3.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	77.48	ft	Upstream Velocity Head	0.56	ft
Ke	0.50		Entrance Loss	0.28	ft

Inlet Control Properties					
Inlet Control HW Elev.	77.21	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	7.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
448+77

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	7.75	ft	Headwater Depth/Height	0.09	
Computed Headwater Eleva	4.22	ft	Discharge	0.20	cfs
Inlet Control HW Elev.	4.18	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	4.22	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	4.00	ft	Downstream Invert	3.50	ft
Length	77.00	ft	Constructed Slope	0.006494	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.14	ft
Slope Type	Steep		Normal Depth	0.14	ft
Flow Regime	Supercritical		Critical Depth	0.14	ft
Velocity Downstream	1.86	ft/s	Critical Slope	0.005631	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.50	ft
Section Size	30 inch		Rise	2.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	4.22	ft	Upstream Velocity Head	0.05	ft
Ke	0.50		Entrance Loss	0.02	ft

Inlet Control Properties					
Inlet Control HW Elev.	4.18	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	4.9	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
386+33

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	29.00	ft	Headwater Depth/Height	0.51	
Computed Headwater Eleva	27.01	ft	Discharge	3.50	cfs
Inlet Control HW Elev.	26.89	ft	Tailwater Elevation	26.00	ft
Outlet Control HW Elev.	27.01	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	26.00	ft	Downstream Invert	25.00	ft
Length	77.00	ft	Constructed Slope	0.012987	ft/ft

Hydraulic Profile					
Profile	CompositeS1S2		Depth, Downstream	1.00	ft
Slope Type	Steep		Normal Depth	0.50	ft
Flow Regime	N/A		Critical Depth	0.65	ft
Velocity Downstream	2.23	ft/s	Critical Slope	0.004466	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	27.01	ft	Upstream Velocity Head	0.24	ft
Ke	0.50		Entrance Loss	0.12	ft

Inlet Control Properties					
Inlet Control HW Elev.	26.89	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	3.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
394+16

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	60.80	ft	Headwater Depth/Height	0.63	
Computed Headwater Eleva	59.07	ft	Discharge	5.30	cfs
Inlet Control HW Elev.	58.86	ft	Tailwater Elevation	44.50	ft
Outlet Control HW Elev.	59.07	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	57.80	ft	Downstream Invert	44.60	ft
Length	162.00	ft	Constructed Slope	0.081481	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.39	ft
Slope Type	Steep		Normal Depth	0.39	ft
Flow Regime	Supercritical		Critical Depth	0.81	ft
Velocity Downstream	12.40	ft/s	Critical Slope	0.004579	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	59.07	ft	Upstream Velocity Head	0.30	ft
Ke	0.50		Entrance Loss	0.15	ft

Inlet Control Properties					
Inlet Control HW Elev.	58.86	ft	Flow Control	Unsubmerged	
Inlet Type	Square edge w/headwall		Area Full	3.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Side Drain Hydraulics

State Highway 92 Hydraulics

OBJECTIVE:

The purpose of this calculation is to determine side drain culvert pipe sizes and locations.

GIVEN:

Design flow rates. See *SH 92 Basin Calc Package*, Betsy Young, Aug 2011

REFERENCES:

- Design contours, existing contours. Located in Microstation file. (Electronic location below)

ASSUMPTIONS:

Minimum culvert size is 18”. All pipes will be RCP.

ANALYSIS / CALCULATIONS:

CulvertMaster was used for all side drains.

CONCLUSIONS:

The existing and proposed pipes can be seen in the table below:

STA	10 yr Discharge (cfs)	Ex Pipe (size, mat’l)	Proposed Pipe (size,mat’l)
STA. 372+17 LT	0.34	NA	24” RCP
STA. 390+90 RT	1.47	NA	24” RCP
STA. 421+46 LT	0.15	18” CSP	18” RCP
STA. 437+89 LT	0.60	10” Plastic	18” RCP
STA. 437+80 RT	0.1	NA	18” RCP
STA. 446+51 RT	0.1	NA	18” RCP
STA. 450+16 LT	0.1	18” CSP	18” RCP

ATTACHMENTS:

- Summary Table
- CulvertMaster output

<u>Electronic Files:</u>

Microstation:
I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\6.0 Project Deliverables\17772\Hydraulics\Working\Betsy

Calculations:
I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\8.0_Design\8.01 Drainage\Calculations\Side Drains

SH 92
Side Drain Calculations

	ID	Within Basin	Big Basin Area (ac)	10 yr Major Basin Flow (cfs)	50 yr Major Basin Flow (cfs)	Start STA	Start Elevation (ft)	End STA	End Elevation (ft)	Size (in)	Basin Area (ac)	**10 yr Flow (cfs)**[1]	50 yr Flow (cfs)[1]	Length (ft)	Long. Slope	**HW/D**	**Velocity (fps)**
1	STA. 372+17 LT	372+17	11.3	1	3.5	37262	5282.5	37167	5278	24	3.82	**0.34**	1.18	95	0.047	**0.15**	**4.5**
2	STA. 390+90 RT	394+16	11.9	1.2	5.3	39153	5344	39028	5340	24	14.61	**1.47**	6.51	125	0.032	**0.32**	**6.1**
3	STA. 421+46 LT	416+50	106.1	3.6	20.1	42177	5386	42114	5385	18	4.43	**0.15**	0.84	63	0.016	**0.14**	**2.5**
4	STA. 437+89 LT	430+00	6226.0	-	553	43768	5448	43807	5446	18	15.10	**0.60**	1.34	39	0.051	**0.29**	**5.72**
5	STA. 437+80 RT	-	-	-	-	43751	5452	43850	5448	18	11.3	**0.10**	0.20	99	0.040	**0.11**	**3.07**
6	STA. 446+51 RT	-	-	-	-	44615	5503	44688	5500.5	18	0.06	**0.10**	0.20	73	0.034	**0.11**	**2.88**
7	STA. 450+16 LT	448+70	2.9	0.1	0.2	45036	5508	44997	5507.5	18		**0.10**	0.20	39	0.013	**0.11**	**2.05**

[1]Flow was calculated by taking the ratio of the Special Ditch Basin area to the Existing Offsite Basin area that the ditch resides in. The ratio was then applied to the flow.
For example, if a ditch basin was half the size of the existing offsite basin, then it receives half the flow.

[2] Hydrology for 437+80RT and 446+51 was calculated using NRCS method, because it does not reside in any of the major basins

[3] Hydrology for 437+89 a was calculated using NRCS method, because 10 yr flow was not calculated for Big Gulch

Culvert Calculator Report
sd 372+17 LT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	5,285.50	ft	Headwater Depth/Height	0.15	
Computed Headwater Eleva	5,282.80	ft	Discharge	0.34	cfs
Inlet Control HW Elev.	5,282.72	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,282.80	ft	Control Type	Entrance Control	

Grades

Upstream Invert	5,282.50	ft	Downstream Invert	5,278.00	ft
Length	95.00	ft	Constructed Slope	0.047368	ft/ft

Hydraulic Profile

Profile	S2		Depth, Downstream	0.12	ft
Slope Type	Steep		Normal Depth	0.12	ft
Flow Regime	Supercritical		Critical Depth	0.20	ft
Velocity Downstream	4.50	ft/s	Critical Slope	0.005243	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	5,282.80	ft	Upstream Velocity Head	0.07	ft
Ke	0.50		Entrance Loss	0.03	ft

Inlet Control Properties

Inlet Control HW Elev.	5,282.72	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	3.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
sd 390+90 RT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	5,347.00	ft	Headwater Depth/Height	0.32	
Computed Headwater Eleva	5,344.64	ft	Discharge	1.47	cfs
Inlet Control HW Elev.	5,344.54	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,344.64	ft	Control Type	Entrance Control	

Grades

Upstream Invert	5,344.00	ft	Downstream Invert	5,340.00	ft
Length	125.00	ft	Constructed Slope	0.032000	ft/ft

Hydraulic Profile

Profile	S2		Depth, Downstream	0.26	ft
Slope Type	Steep		Normal Depth	0.26	ft
Flow Regime	Supercritical		Critical Depth	0.42	ft
Velocity Downstream	6.10	ft/s	Critical Slope	0.004559	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	2.00	ft
Section Size	24 inch		Rise	2.00	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	5,344.64	ft	Upstream Velocity Head	0.15	ft
Ke	0.50		Entrance Loss	0.07	ft

Inlet Control Properties

Inlet Control HW Elev.	5,344.54	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	3.1	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
sd 421+46 LT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	5,388.25	ft	Headwater Depth/Height	0.14	
Computed Headwater Eleva	5,386.21	ft	Discharge	0.15	cfs
Inlet Control HW Elev.	5,386.18	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,386.21	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	5,386.00	ft	Downstream Invert	5,385.00	ft
Length	63.00	ft	Constructed Slope	0.015873	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.11	ft
Slope Type	Steep		Normal Depth	0.11	ft
Flow Regime	Supercritical		Critical Depth	0.14	ft
Velocity Downstream	2.50	ft/s	Critical Slope	0.005846	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	5,386.21	ft	Upstream Velocity Head	0.05	ft
Ke	0.50		Entrance Loss	0.02	ft

Inlet Control Properties					
Inlet Control HW Elev.	5,386.18	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	1.8	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
sd 437+80 RT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	5,454.25	ft	Headwater Depth/Height	0.12	
Computed Headwater Eleva	5,452.17	ft	Discharge	0.10	cfs
Inlet Control HW Elev.	5,452.12	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,452.17	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	5,452.00	ft	Downstream Invert	5,448.00	ft
Length	99.00	ft	Constructed Slope	0.040404	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.07	ft
Slope Type	Steep		Normal Depth	0.07	ft
Flow Regime	Supercritical		Critical Depth	0.12	ft
Velocity Downstream	3.07	ft/s	Critical Slope	0.006210	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	5,452.17	ft	Upstream Velocity Head	0.04	ft
Ke	0.50		Entrance Loss	0.02	ft

Inlet Control Properties					
Inlet Control HW Elev.	5,452.12	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	1.8	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
sd 437+89 LT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary					
Allowable HW Elevation	5,450.25	ft	Headwater Depth/Height	0.29	
Computed Headwater Eleva	5,448.44	ft	Discharge	0.60	cfs
Inlet Control HW Elev.	5,448.35	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,448.44	ft	Control Type	Entrance Control	

Grades					
Upstream Invert	5,448.00	ft	Downstream Invert	5,446.00	ft
Length	39.00	ft	Constructed Slope	0.051282	ft/ft

Hydraulic Profile					
Profile	S2		Depth, Downstream	0.16	ft
Slope Type	Steep		Normal Depth	0.16	ft
Flow Regime	Supercritical		Critical Depth	0.29	ft
Velocity Downstream	5.72	ft/s	Critical Slope	0.005076	ft/ft

Section					
Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties					
Outlet Control HW Elev.	5,448.44	ft	Upstream Velocity Head	0.10	ft
Ke	0.50		Entrance Loss	0.05	ft

Inlet Control Properties					
Inlet Control HW Elev.	5,448.35	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	1.8	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
sd 446+51 RT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	5,505.25	ft	Headwater Depth/Height	0.12	
Computed Headwater Eleva	5,503.17	ft	Discharge	0.10	cfs
Inlet Control HW Elev.	5,503.13	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,503.17	ft	Control Type	Entrance Control	

Grades

Upstream Invert	5,503.00	ft	Downstream Invert	5,500.50	ft
Length	73.00	ft	Constructed Slope	0.034247	ft/ft

Hydraulic Profile

Profile	S2		Depth, Downstream	0.08	ft
Slope Type	Steep		Normal Depth	0.08	ft
Flow Regime	Supercritical		Critical Depth	0.12	ft
Velocity Downstream	2.88	ft/s	Critical Slope	0.006210	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	5,503.17	ft	Upstream Velocity Head	0.04	ft
Ke	0.50		Entrance Loss	0.02	ft

Inlet Control Properties

Inlet Control HW Elev.	5,503.13	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	1.8	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Culvert Calculator Report
sd 450+16 LT

Comments: 10 yr

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	5,510.25	ft	Headwater Depth/Height	0.12	
Computed Headwater Eleva	5,508.17	ft	Discharge	0.10	cfs
Inlet Control HW Elev.	5,508.15	ft	Tailwater Elevation	0.00	ft
Outlet Control HW Elev.	5,508.17	ft	Control Type	Entrance Control	

Grades

Upstream Invert	5,508.00	ft	Downstream Invert	5,507.50	ft
Length	39.00	ft	Constructed Slope	0.012821	ft/ft

Hydraulic Profile

Profile	S2		Depth, Downstream	0.10	ft
Slope Type	Steep		Normal Depth	0.10	ft
Flow Regime	Supercritical		Critical Depth	0.12	ft
Velocity Downstream	2.05	ft/s	Critical Slope	0.006210	ft/ft

Section

Section Shape	Circular		Mannings Coefficient	0.013	
Section Material	Concrete		Span	1.50	ft
Section Size	18 inch		Rise	1.50	ft
Number Sections	1				

Outlet Control Properties

Outlet Control HW Elev.	5,508.17	ft	Upstream Velocity Head	0.04	ft
Ke	0.50		Entrance Loss	0.02	ft

Inlet Control Properties

Inlet Control HW Elev.	5,508.15	ft	Flow Control	N/A	
Inlet Type	Square edge w/headwall		Area Full	1.8	ft²
K	0.00980		HDS 5 Chart	1	
M	2.00000		HDS 5 Scale	1	
C	0.03980		Equation Form	1	
Y	0.67000				

Special Ditch Hydraulics

State Highway 92 Hydrology and Hydraulics

OBJECTIVE:

The purpose of this calculation is to determine special ditch sizes and locations.

GIVEN:

Design flow rates. See *SH 92 Basin Calc Package*, Betsy Young, Aug 2011

REFERENCES:

- Design contours, existing contours. Located in Microstation file. (Electronic location below)

ASSUMPTIONS:

Minimum freeboard is 1 foot. Manning's n value is assumed to be 0.03.

ANALYSIS / CALCULATIONS:

Ditch flow was calculated by taking the ratio of the special ditch basin area to the existing offsite basin area that the ditch resides in. The ratio was then applied to the flow For example, if a ditch basin was half the size of the existing offsite basin, then it receives half the flow. Hydrology for SD403R was calculated using NRCS method, because it does not reside in any of the major basins. FlowMaster was used for hydraulics on all ditches.

CONCLUSIONS:

All ditches will be triangular with 4:1 or 3:1 side slopes, with a longitudinal slope of at least 0.3%. See attached table and FlowMaster output for results.

ATTACHMENTS:

- Summary Table
- FlowMaster output
- HECHMS output

<u>Electronic Files:</u>
Microstation:
I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\6.0 Project Deliverables\17772\Hydraulics\Working\Betsy

Calculations:
I:\PROJECTS\22239666_SH92_Master\22241827_TO5_Final_Design\8.0_Design\8.01 Drainage\Calculations\Special Ditches

SH 92
Special Ditch Calculations

	ID	Within Basin	Big Basin Area (ac)	10 yr Major Basin Flow (cfs)	100 yr Major Basin Flow (cfs)	Start Ditch Start STA	Elevation (ft)	End Ditch End STA	Elevation (ft)	Type	Basin Area (ac)	10 yr Flow (cfs) [1]	100 yr Flow (cfs) [1]	Length (ft)	Long. Slope	10 yr Depth (ft)	Left Side Slope	Right SS	10 yr Velocity (fps)
1	SD403R	-	-	-	-	40366	5470	40366	5469.5	V	0.42	0.01 [2]	0.20	78	0.006	0.08	4	4	0.43
2	SD407L	397+18	40.96	1.8	13.6	40711	5410	40760	5409.5	V	0.21	0.01	0.07	49	0.010	0.07	4	4	0.52
3	SD411L	397+18	40.96	1.8	13.6	40926	5400	41100	5399	V	1.50	0.07	0.50	174	0.006	0.16	4	4	0.69
4	SD419R	-	-	-	-	41900	5384	41651	5383	V	1.75	1.20	2.30	249	0.004	0.5	4	4	1.21

[1]Flow was calculated by taking the ratio of the Special Ditch Basin area to the Existing Offsite Basin area that the ditch resides in. The ratio was then applied to the flow.
For example, if a ditch basin was half the size of the existing offsite basin, then it receives half the flow.

[2] Hydrology for SD403R and SD419R was calculated using NRCS method, because it does not reside in any of the major basins

378+40

SD403R - 10yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00600	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	0.01	ft³/s

Results

Normal Depth	0.08	ft
Flow Area	0.02	ft²
Wetted Perimeter	0.63	ft
Hydraulic Radius	0.04	ft
Top Width	0.61	ft
Critical Depth	0.05	ft
Critical Slope	0.04598	ft/ft
Velocity	0.43	ft/s
Velocity Head	0.00	ft
Specific Energy	0.08	ft
Froude Number	0.39	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.08	ft
Critical Depth	0.05	ft
Channel Slope	0.00600	ft/ft
Critical Slope	0.04598	ft/ft

SD403R - 100yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00600	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	0.20	ft³/s

Results

Normal Depth	0.24	ft
Flow Area	0.22	ft²
Wetted Perimeter	1.94	ft
Hydraulic Radius	0.11	ft
Top Width	1.88	ft
Critical Depth	0.17	ft
Critical Slope	0.03087	ft/ft
Velocity	0.90	ft/s
Velocity Head	0.01	ft
Specific Energy	0.25	ft
Froude Number	0.46	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.24	ft
Critical Depth	0.17	ft
Channel Slope	0.00600	ft/ft
Critical Slope	0.03087	ft/ft

SD407L - 10yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.01000	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	0.01	ft³/s

Results

Normal Depth	0.07	ft
Flow Area	0.02	ft²
Wetted Perimeter	0.57	ft
Hydraulic Radius	0.03	ft
Top Width	0.56	ft
Critical Depth	0.05	ft
Critical Slope	0.04601	ft/ft
Velocity	0.52	ft/s
Velocity Head	0.00	ft
Specific Energy	0.07	ft
Froude Number	0.49	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.07	ft
Critical Depth	0.05	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.04601	ft/ft

SD407L - 100yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.01000	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	0.70	ft³/s

Results

Normal Depth	0.34	ft
Flow Area	0.47	ft²
Wetted Perimeter	2.82	ft
Hydraulic Radius	0.17	ft
Top Width	2.74	ft
Critical Depth	0.29	ft
Critical Slope	0.02612	ft/ft
Velocity	1.50	ft/s
Velocity Head	0.03	ft
Specific Energy	0.38	ft
Froude Number	0.64	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.34	ft
Critical Depth	0.29	ft
Channel Slope	0.01000	ft/ft
Critical Slope	0.02612	ft/ft

SD411L - 10yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00600	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	0.07	ft³/s

Results

Normal Depth	0.16	ft
Flow Area	0.10	ft²
Wetted Perimeter	1.31	ft
Hydraulic Radius	0.08	ft
Top Width	1.27	ft
Critical Depth	0.11	ft
Critical Slope	0.03550	ft/ft
Velocity	0.69	ft/s
Velocity Head	0.01	ft
Specific Energy	0.17	ft
Froude Number	0.43	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.16	ft
Critical Depth	0.11	ft
Channel Slope	0.00600	ft/ft
Critical Slope	0.03550	ft/ft

SD411L - 100yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00600	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	0.50	ft^3/s

Results

Normal Depth	0.33	ft
Flow Area	0.44	ft^2
Wetted Perimeter	2.74	ft
Hydraulic Radius	0.16	ft
Top Width	2.65	ft
Critical Depth	0.25	ft
Critical Slope	0.02733	ft/ft
Velocity	1.14	ft/s
Velocity Head	0.02	ft
Specific Energy	0.35	ft
Froude Number	0.49	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.33	ft
Critical Depth	0.25	ft
Channel Slope	0.00600	ft/ft
Critical Slope	0.02733	ft/ft

SD419R - 10yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00400	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	1.20	ft³/s

Results

Normal Depth	0.50	ft
Flow Area	0.99	ft²
Wetted Perimeter	4.10	ft
Hydraulic Radius	0.24	ft
Top Width	3.98	ft
Critical Depth	0.35	ft
Critical Slope	0.02431	ft/ft
Velocity	1.21	ft/s
Velocity Head	0.02	ft
Specific Energy	0.52	ft
Froude Number	0.43	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.50	ft
Critical Depth	0.35	ft
Channel Slope	0.00400	ft/ft
Critical Slope	0.02431	ft/ft

SD419R - 100yr

Project Description

Friction Method	Manning Formula
Solve For	Normal Depth

Input Data

Roughness Coefficient	0.030	
Channel Slope	0.00400	ft/ft
Left Side Slope	4.00	ft/ft (H:V)
Right Side Slope	4.00	ft/ft (H:V)
Discharge	2.30	ft³/s

Results

Normal Depth	0.63	ft
Flow Area	1.61	ft²
Wetted Perimeter	5.23	ft
Hydraulic Radius	0.31	ft
Top Width	5.08	ft
Critical Depth	0.46	ft
Critical Slope	0.02229	ft/ft
Velocity	1.43	ft/s
Velocity Head	0.03	ft
Specific Energy	0.67	ft
Froude Number	0.45	
Flow Type	Subcritical	

GVF Input Data

Downstream Depth	0.00	ft
Length	0.00	ft
Number Of Steps	0	

GVF Output Data

Upstream Depth	0.00	ft
Profile Description		
Profile Headloss	0.00	ft
Downstream Velocity	Infinity	ft/s
Upstream Velocity	Infinity	ft/s
Normal Depth	0.63	ft
Critical Depth	0.46	ft
Channel Slope	0.00400	ft/ft
Critical Slope	0.02229	ft/ft

Appendix E

Bridge and Deck Drainage

State Highway 92

OBJECTIVE:

The purpose of this calculation is to determine number and locations of deck drains, if any, that are needed on the SH 92 bridge crossing over the Union Pacific Rail Road.

GIVEN:

- Bridge Plans

REFERENCES:

- *Design of Bridge Deck Drainage* HEC 21, Army Corp of Engineers, May 1993

ANALYSIS / CALCULATIONS:

The method outlined in HEC 21 was used. The steps are as follows:

1) Determine flow rate over bridge end, using Rational Method
2) Determine L_0, the distance to the first inlet.
3) Determine L_c, the spacing between inlets.

CONCLUSIONS:

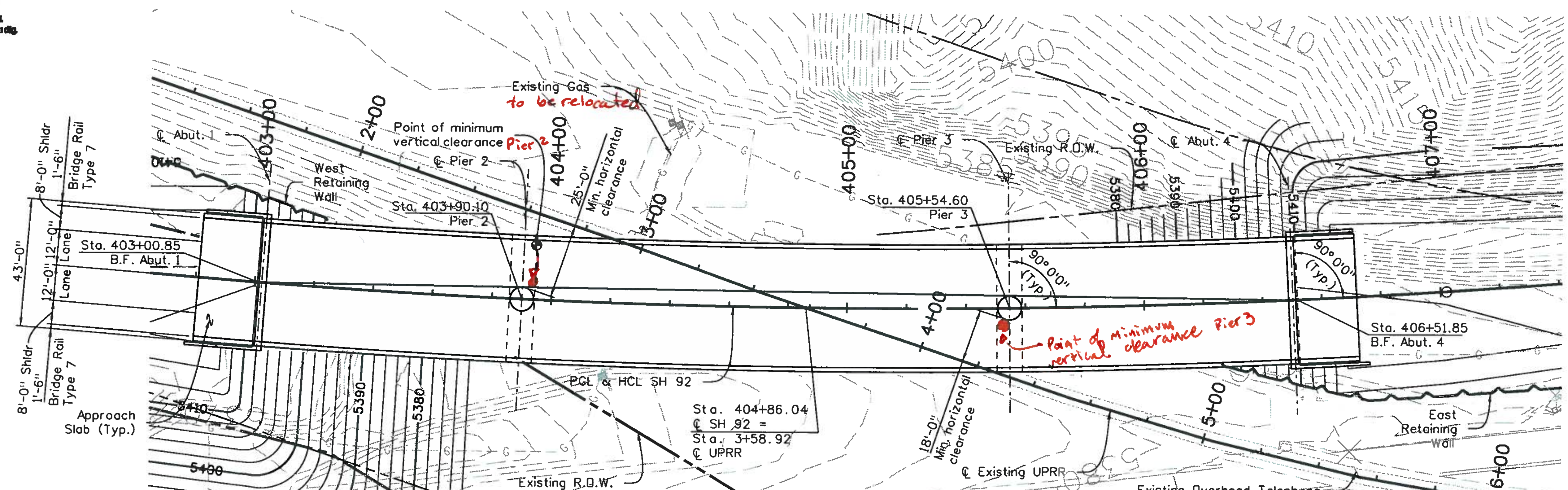
HEC 21 states that if L_0 is greater than the length of the bridge, then no inlets are needed. This calculation estimated L_0 = 341ft, which is less than the length of the bridge high point to the bridge end. Therefore, only bridge end design will be considered. See attached for more details.

ATTACHMENTS:

- Rational Method Calculation
- 10 yr-1 hr rainfall map
- Bridge Plans
- HEC21 Chart 5 – Inlet Spacing
- HEC21 Inlet Spacing Equation

File Path: I:\PROJECTS\22239666_SH92_Master\22241827_T05_Final_Design\6.0 Project Deliverables\17772\Bridge\Drawings\17772BridgeGeneralLayout 1.dgn

811 Know what's below. Call before you dig.



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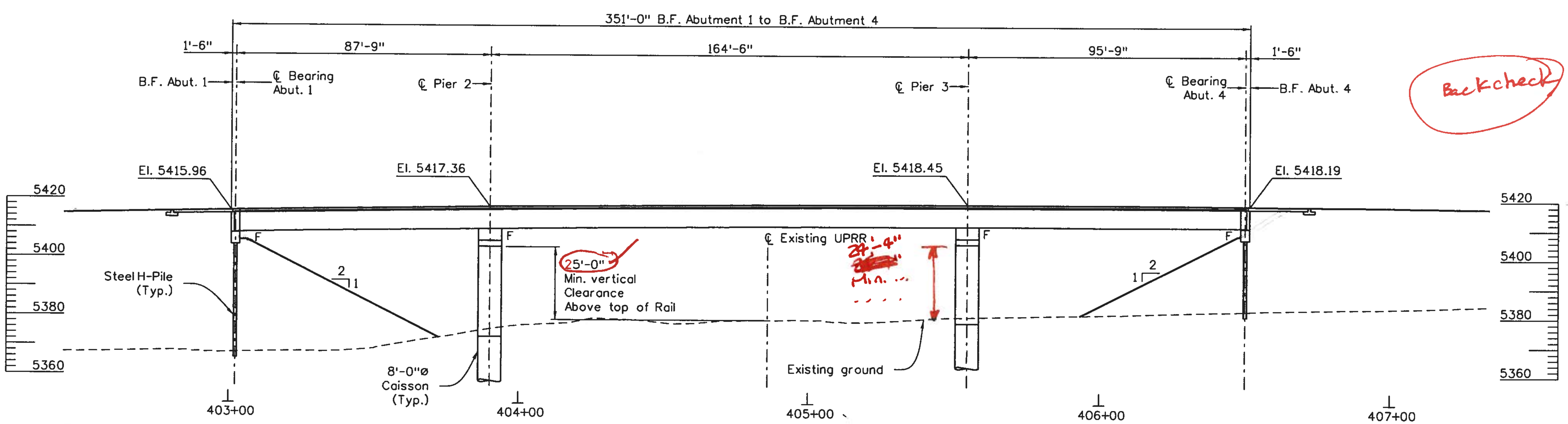

SECTION

Taken along PGL & HCL SH 92

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File Name: 17772BridgeGeneralLayout 1.dgn	
Horiz. Scale: 1:40	Vert. Scale:
Unit Information	Unit Leader Initials
URS	

Sheet Revisions

Date:	Comments	Init.
	FOR PLANS XXX 2012	

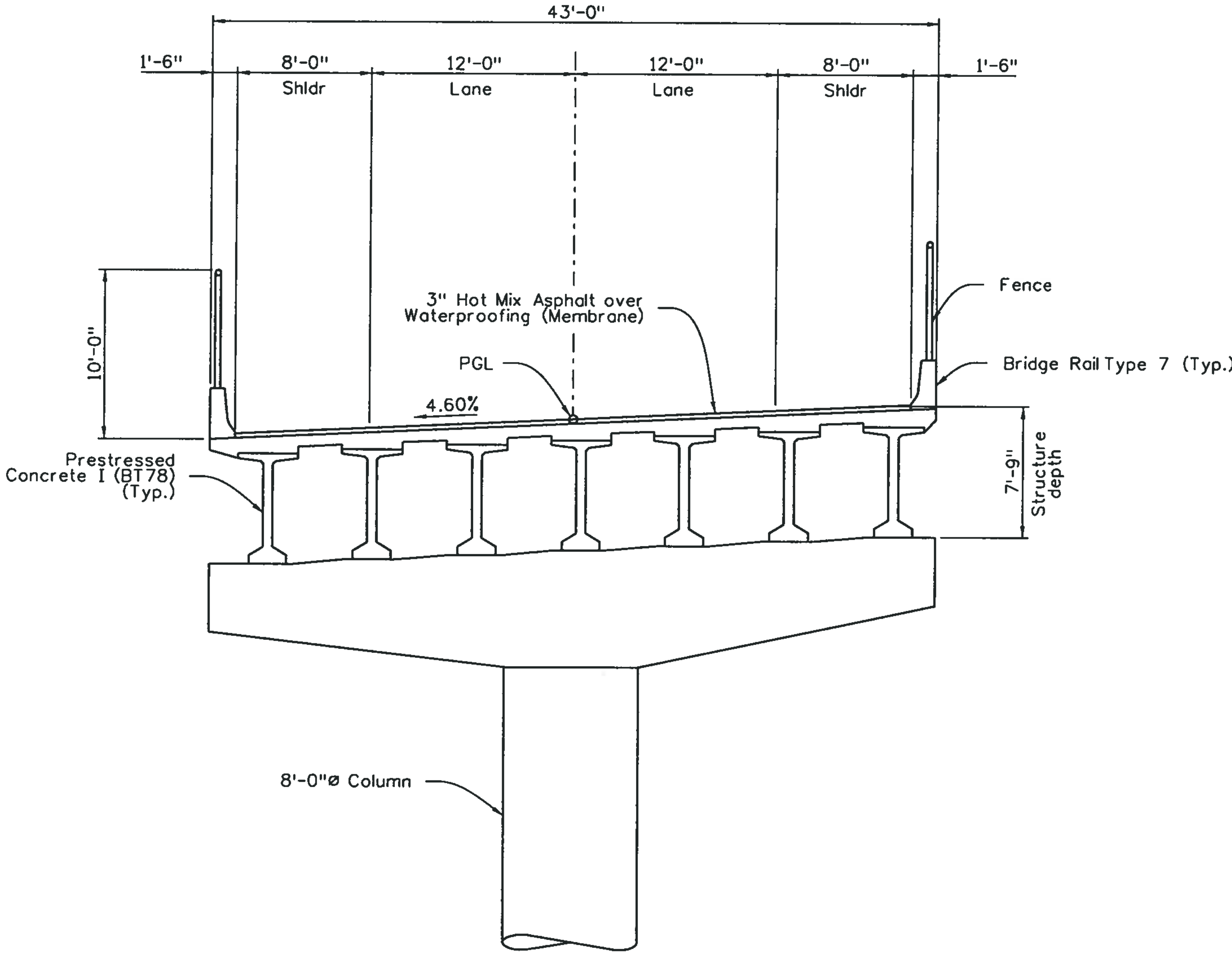
Colorado Department of Transportation
2424 North Townsend Avenue
Montrose, CO 81401
Phone: 972-249-5285 FAX: 970-249-6018
Region 3 RA

As Constructed
No Revisions:
Revised:
Void:

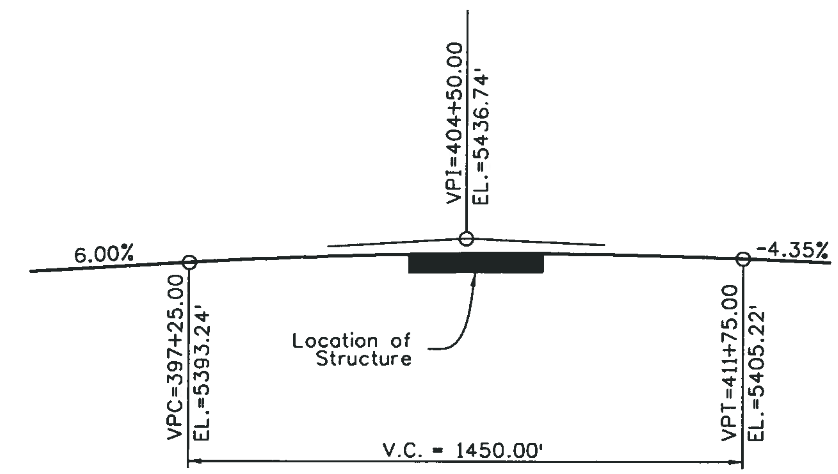
GENERAL LAYOUT (1)

Designer:	C. PARENT	Structure Numbers	I-05-Z
Detailer:	D. STRONG		
Sheet Subset:	BRIDGE	Subset Sheets: B103 of B104	

Project No./Code
HB 092A-024
17772
Sheet Number

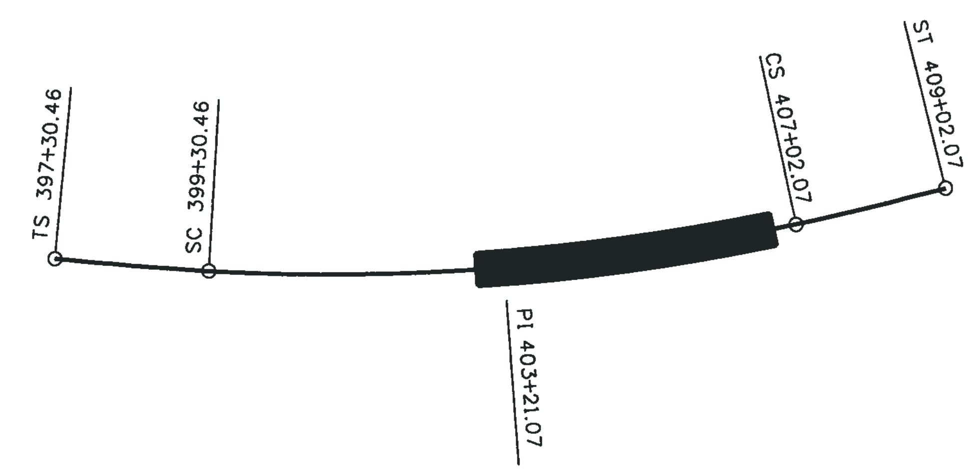


TYPICAL SECTION



SH 92 PROFILE GRADE

needs UPRR Profile then backcheck



TOTAL CURVE

Δ = 19° 25'51" LT
T = 590.61'
E = 42.28'

CIRCULAR CURVE

Δ = 15° 25'52" LT
D = 1° 59'59"
T = 388.15'
L = 771.61'
R = 2865.00'

SPIRAL CURVE

Δ = 1° 59'59" LT
L = 200.00'
L = 133.34'
S = 66.67'

SH 92 PROFILE GRADE

File Path: I:\PROJECTS\22239666_SH92_Master\22241827_T05_Final_Design\6.0 Project Deliverables\17772\Bridge\Drawings\17772BridgeGeneralLayout 2.dgn

Print Date: 3/29/2012
File Name: 17772BridgeGeneralLayout 2.dgn
Horiz. Scale: 1:10 Vert. Scale:
Unit Information Unit Leader Initials
URS

Sheet Revisions

Date:	Comments	Init.
	FOR PLANS XXX 2012	

Colorado Department of Transportation
DOT DEPARTMENT OF TRANSPORTATION
2424 North Townsend Avenue
Montrose, CO 81401
Phone: 972-249-5285 FAX: 970-249-6018
Region 3 RA

As Constructed
No Revisions:
Revised:
Void:

GENERAL LAYOUT (2)

Designer: C. PARENT
Detailer: D. STRONG
Sheet Subset: BRIDGE
Structure Numbers I-05-Z
Subset Sheets: B104 of B104

Project No./Code
HB 092A-024
17772
Sheet Number

State Highway 92
Bridge Basin - Rational Method
Proposed Time of Concentration

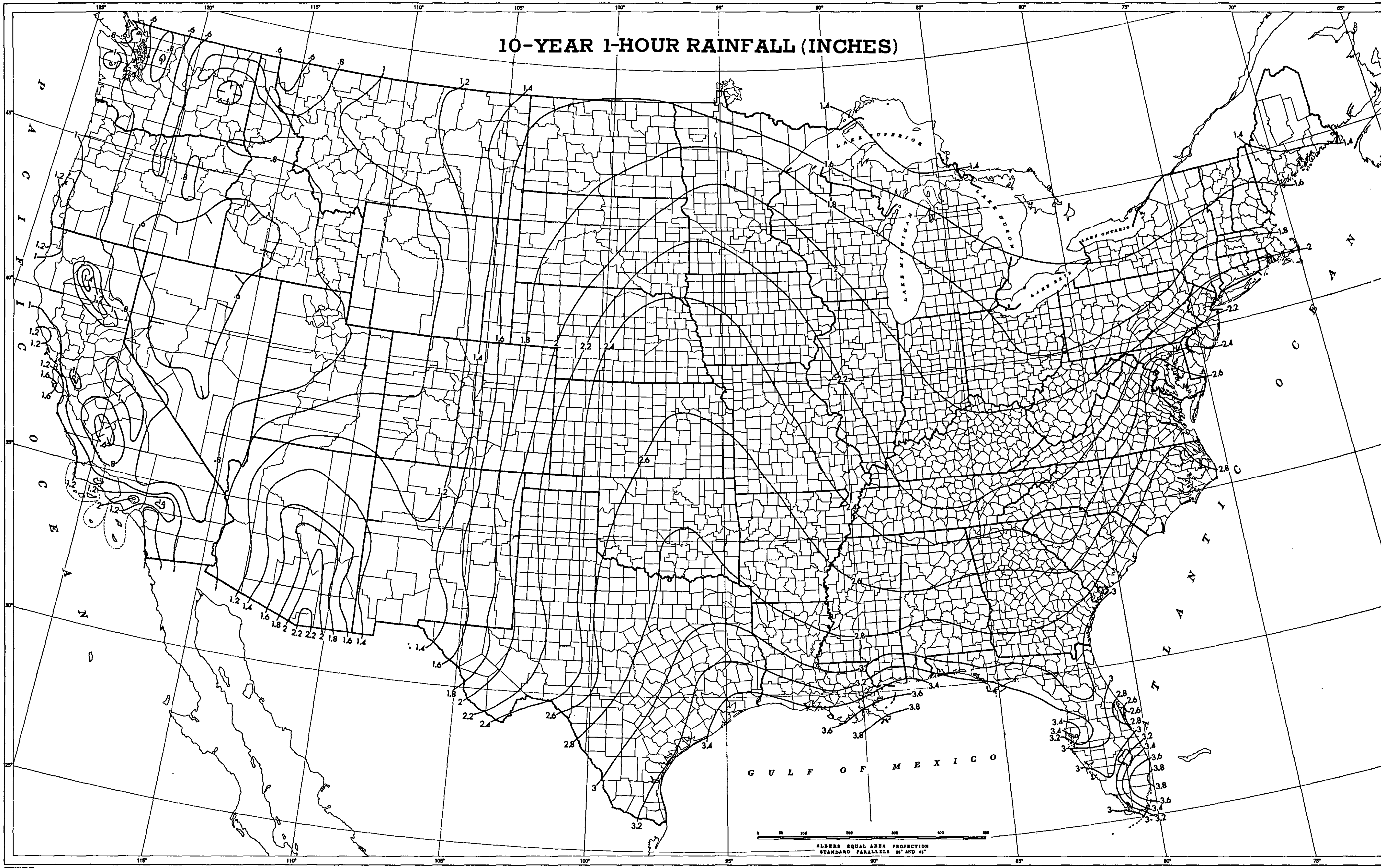
TIME OF CONCENTRATION																	
SUB-BASIN DATA								TRAVEL TIME (Tt)									TOTAL
BASIN ID	C	AREA (acre)	constant, k_w	Overland Flow Length, l_o (ft)	SLOPE (ft/ft)	Manning's n	To (Min)	LENGTH (ft)	ELEV. START (ft)	ELEV. END (ft)	Gutter Slope, Sx (ft/ft)	Spread, T (ft)	Width of Pavement, Wp (ft)	constant, Kg	Tg (Min)		To+Tg (Min.)
Bridge Area	0.90	0.3	0.93	40	0.05	0.016	1.058	252	5418.45	5415.96	0.010	8.0000	40.0000	484.0	2.0472		3.10525

State Highway 92
Bridge Basin - Rational Method
Proposed Basin Runoff

		RATIONAL FLOWS		
BASIN ID	**AREA (acre)**	**C_{10}**	**I_{10} (in/hr)[1]**	**Q_{10} (cfs)**
Bridge Area	0.3	0.900	4.15	1.3

[1] I = (28.5 x P1) / (10 +Tc)^0.786 , Eq. (RA-3) Urban Drainage, Where P1(10-yr)=4.15

N/A - Not Applicable


10-YEAR 1-HOUR RAINFALL (INCHES)
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS 29° AND 45°

Go to Appendix C

Go to Chart 6

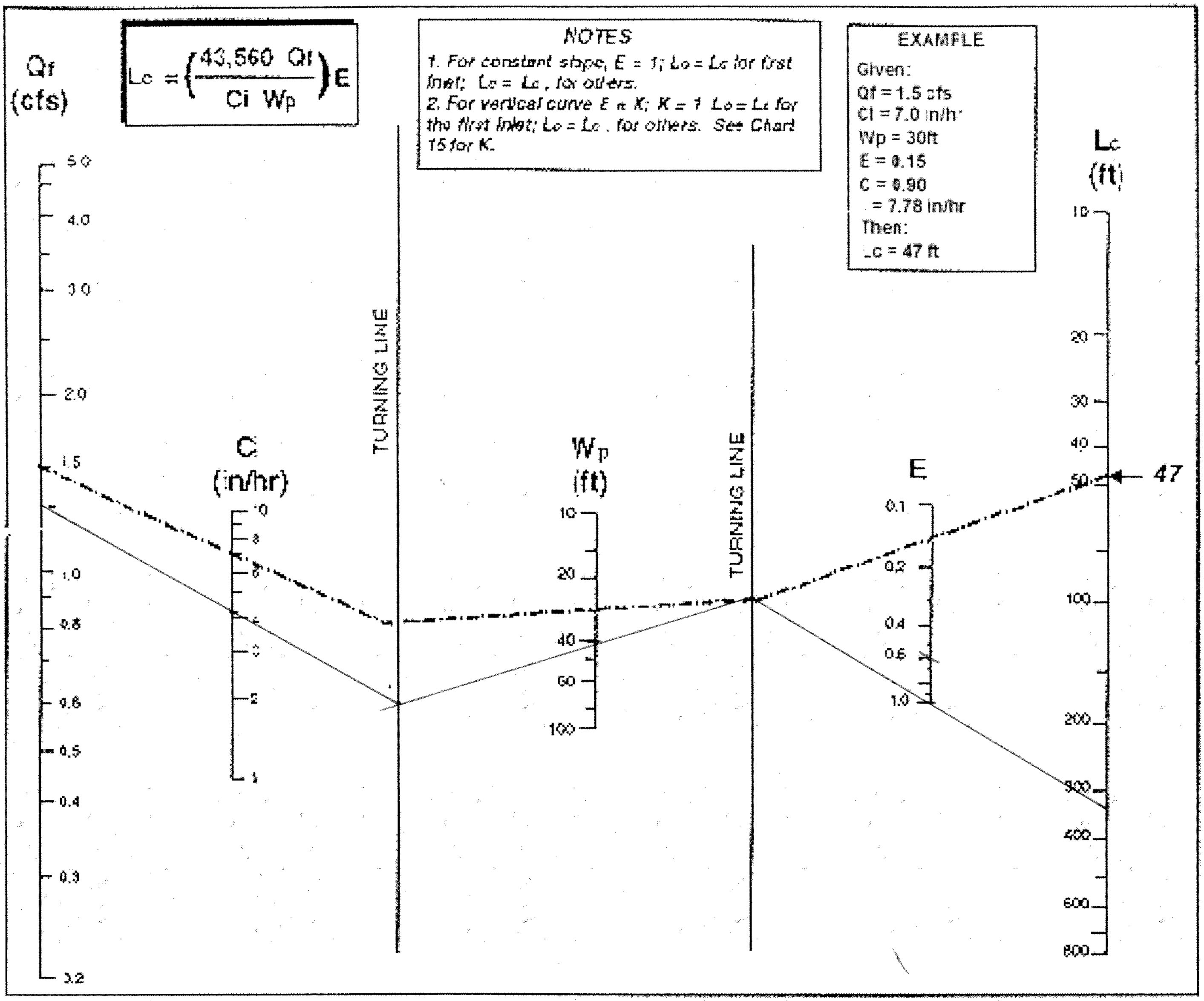


Chart 5. Inlet spacing.

Q = 1.3 cfs

Ci = 4.15 in/hr

Wp = 40'

E = 1

$$L_o = \frac{(43,560)(1.3)}{(4.15)(40)}(1) = 341.1 \text{ ft}$$

⇒ less than length of high point to abutment

only bridge end design is considered

or between inlets as,

$$L_c = \frac{43560\,Q}{C\,i\,W_p}\,E\,, \text{ for the general case,} \qquad (22b)$$

where:

i = Design rainfall intensity, in/hr, (step 1).
Q = Gutter flow, ft^3/s, (step 2).
L_c = Constant distance between inlets, feet.
L_0 = Distance to first inlet, feet.
C = Rational runoff coefficient.
W_p = Width of pavement contributing to gutter flow, feet.
E = Constant, which is equal to 1 for first inlets in all cases and is equal to capture efficiency for subsequent inlets of constant-slope bridges.[3]

Since the first inlet receives virtually no bypass flow from upslope inlets, the constant **E** can be assumed to be equal to 1. The computed distance, $\mathbf{L_0}$, is then compared with the length of the bridge. If $\mathbf{L_0}$ is greater than the length of the bridge, then inlets are not needed and only bridge end treatment design need be considered.

4. If inlets are required, then the designer should proceed to calculate the constant inlet spacing, $\mathbf{L_c}$, for the subsequent inlets.

4a. Inlet interception efficiencies for particular inlets or scuppers can often be found in the manufacturers' literature. If such information is not available, then Chart 6, Chart 7, Chart 8, Chart 9, and Chart 10 can be used to estimate efficiency.

For **circular scuppers**, Chart 6 summarizes results from a laboratory study conducted at the University of South Florida (Anderson, 1973). Efficiency curves are provided for grades of 0.2, 2.0, and 5 percent. To use the figure, calculate the ratio of inlet diameter, **D**, to gutter spread, **T**, and enter the graph at the appropriate value along the x-axis. It should be noted that one cross bar across the circular scupper did not significantly reduce efficiency for a diameter of 4 inches. Upon intersection with the applicable curve (or appropriate interpolated curve), read efficiency, **E**, from the y-axis.

For **rectangular inlets**, several steps are necessary to calculate flow interception efficiency, **E**, which is the ratio of intercepted to total deck flow. Note that such grates in bridge decks need to be consistent with reinforcing bar spacing. Additional structural details are needed to transfer the load from the imbedded grate to the reinforced deck slab.

- Find the ratio of frontal flow bound by width of grate, **W**, to total deck flow, $\mathbf{E_o}$, using Chart 7.
- Find the flow intercepted by the inlet as a percent of the frontal flow. Identify the grate

Appendix F

Riprap Calculations

State Highway 92 Hydrology

OBJECTIVE:

The purpose of this calculation is to determine riprap and geotextile quantities for culvert outlet protection.

GIVEN:

Outlet protection will follow the CDOT standard detail M-601-12.

REFERENCES:

- Colorado Department of Transportation. *Drainage Design Manual (DDM)* (2004).
- Federal Highway Administration, *Hydraulic Design of Energy Dissipators for Culverts and Channels HEC 14,* July 2006

ASSUMPTIONS:

A minimum riprap rock size of 9" was used.

ANALYSIS / CALCULATIONS:

The method outlined in HEC14 was used. The calculation was done in an Excel Spreadsheet.

CONCLUSIONS:

See the attached spreadsheet for areas and volumes of outlet protection.

ATTACHMENTS:

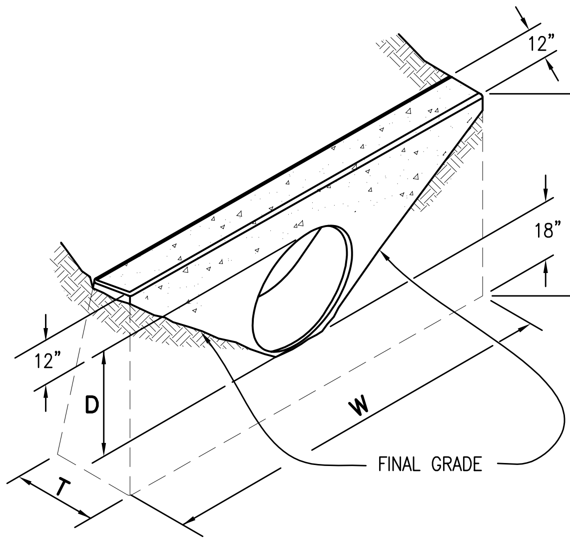
- Calculation Spreadsheet
- CDOT Detail M-601-12

SH 92 **RIPRAP DESIGN**

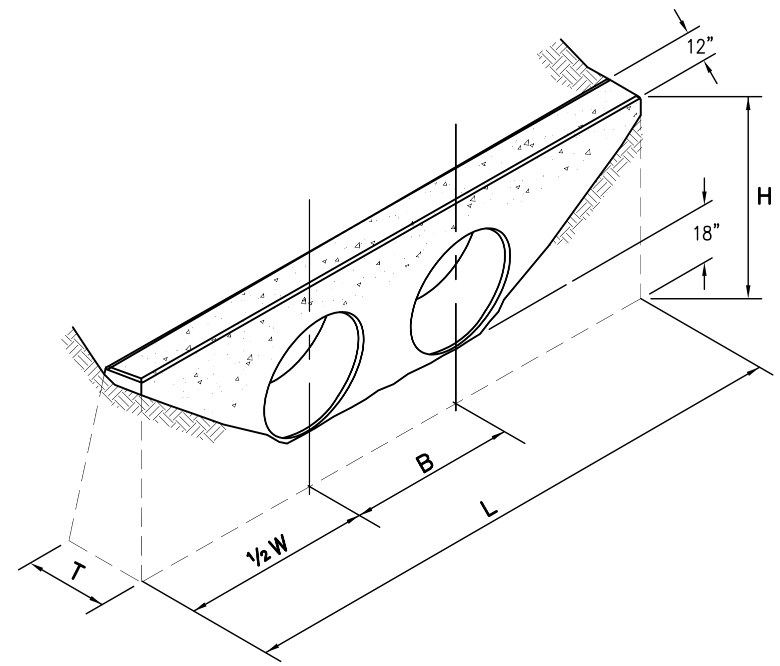
									Check for reasonableness									
Culvert	Size	Design Q	ye (depth)	Vo	Assume D50	D50	Right Side of Eqn	Compute hs	greater or eq to 2	>0.1		Recommendations			Rip Rap		Geotextile	Comment
	(in)	(cfs)	(feet)	(ft/sec)	(feet)	(inch)	HEC-14 Eqn 10.1	(feet)	hs/D50	D50/ye		D50 (inch)	L (feet)	W (feet)	Vol (CY)	SA (SF)	SA (SY)	
Cross Drains																		
386+34	24	3.5	1	2.23	0.06	0.72	0.188	0.188	3.136	0.060		9	10.0	6.0	3.5	60.0	6.7	
394+16	24	5.3	1	3.37	0.11	1.32	0.320	0.320	2.906	0.110		9	10.0	6.0	3.5	60.0	6.7	
397+18	24	9.7	0.65	11.05	0.4	4.8	1.313	0.853	2.134	0.615		9	10.0	6.0	3.5	60.0	6.7	
416+50	36	20.1	0.7	16.08	0.6	7.2	1.771	1.239	2.066	0.857		9	15.0	9.0	7.8	135.0	15.0	
429+88																		Big Gulch - no outlet protection
448+70	30	0.2	0.14	1.86	0.02	0.24	0.797	0.112	5.579	0.143		9	12.5	7.5	5.4	93.8	10.4	
Side Drains																		
372+17	24	1.18	0.21	6.55	0.12	1.44	1.547	0.325	2.707	0.571		9	10.0	6.0	3.5	60.0	6.7	
390+90	24	6.51	0.54	9.45	0.3	3.6	1.293	0.698	2.327	0.556		9	10.0	6.0	3.5	60.0	6.7	
421+46	18	0.84	0.26	4.19	0.09	1.08	0.832	0.216	2.404	0.346		9	7.5	4.5	2.0	33.8	3.8	
437+80	18	0.2	0.1	3.77	0.05	0.6	1.245	0.125	2.491	0.500		9	7.5	4.5	2.0	33.8	3.8	
437+89	18	0.6	0.16	5.72	0.1	1.2	1.407	0.225	2.250	0.625		9	7.5	4.5	2.0	33.8	3.8	
446+51	18	0.2	0.11	3.56	0.05	0.6	1.110	0.122	2.442	0.455		9	7.5	4.5	2.0	33.8	3.8	
450+16	18	0.2	0.14	2.53	0.04	0.48	0.641	0.090	2.244	0.286		9	7.5	4.5	2.0	33.8	3.8	

GENERAL NOTES

1. FOR SIZE AND LOCATION OF PIPES, SEE THE PLANS.
2. ALL CONCRETE SHALL BE CLASS B.
3. FOOTINGS IN ROCK SHALL BE POURED OUT TO ROCK AND NOT FORMED IN ACCORDANCE WITH SUBSECTION 601.09(b).
4. EXPOSED CONCRETE CORNERS SHALL BE CHAMFERED 3/4 IN.



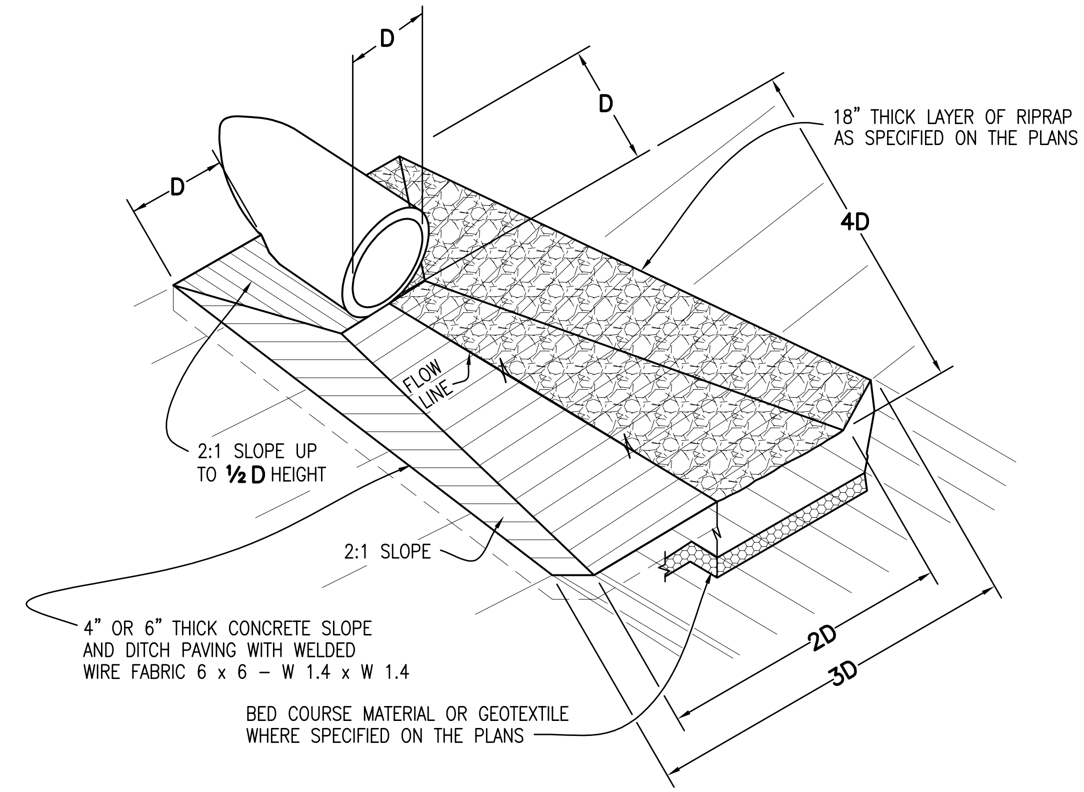
SINGLE PIPE



DOUBLE PIPE

CONCRETE HEADWALL INSTALLATIONS

SEE STANDARD PLAN M-601-10 FOR REINFORCING DETAILS.



PIPE OUTLET PAVING

MAY BE USED WITH MULTIPLE PIPES.

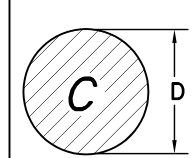
PIPE		PIPE DIAMETER (AND EQUIVALENT DIAMETER) (IN.)											
		18		24		30		36		42		48	
TYPE	MATERIAL	SINGLE	DOUBLE	SINGLE	DOUBLE	SINGLE	DOUBLE	SINGLE	DOUBLE	SINGLE	DOUBLE	SINGLE	DOUBLE
CIRCULAR	RIGID	1.0	1.3	1.5	2.0	2.0	2.7	2.8	3.6	3.6	4.6	4.6	6.0
	FLEXIBLE	1.1	1.4	1.6	2.1	2.2	3.0	3.0	4.0	3.9	5.3	5.0	6.8
ELLIPTICAL	RIGID	23 x 14		30 x 19		38 x 24		45 x 29		53 x 34		60 x 38	
		0.9	1.2	1.3	1.6	1.7	2.2	2.3	2.9	2.9	3.7	3.5	4.4
ARCH	METAL	22 x 13		29 x 18		36 x 22		43 x 27		50 x 31		58 x 36	
		0.9	1.3	1.4	1.9	1.8	2.4	2.4	3.4	3.2	4.4	3.4	5.0

CONCRETE QUANTITIES FOR ONE CONCRETE HEADWALL (CUBIC YARDS)

THICKNESS	MATERIAL	PIPE DIAMETER (IN.)					
		18	24	30	36	42	48
4"	CONCRETE	0.4	0.8	1.2			
6"	CONCRETE				2.6	3.6	4.7
18"	RIPRAP	2.0	3.5	5.4	7.8	10.7	13.9

PIPE OUTLET PAVING (CUBIC YARDS)

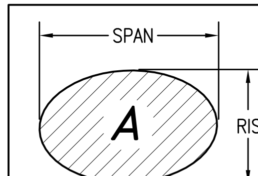
NOTE: VOLUME OCCUPIED BY PIPE HAS BEEN DEDUCTED.



CIRCULAR

D = PIPE DIAMETER (INSIDE)
H = D + 30"
W = 3D + 18"
T = 0.4 H (NEAREST IN.)
B = 1.5 D (30" MINIMUM)
L = W + B

TYPE OF PIPE — HEADWALL DIMENSIONS



ARCH OR ELLIPTICAL

D = EQUIVALENT CIRCULAR DIAMETER (INSIDE)
H = RISE + 30"
W = 3D + 18"
T = 0.4 H (NEAREST IN.)
B = 1.5 D (30" MINIMUM)
L = W + B

TYPE OF PIPE — HEADWALL DIMENSIONS

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Last Modification Date: 07/04/06	Initials: LTA
Full Path: www.dot.state.co.us/DesignSupport/	
Drawing File Name: 6010120101.dwg	
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Sheet Revisions		
	Date:	Comments
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(R-X)		
(R-X)		
(R-X)		

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Denver, Colorado 80222
Phone: (303) 757-9083
Fax: (303) 757-9820
Project Development Branch SRJ/LTA

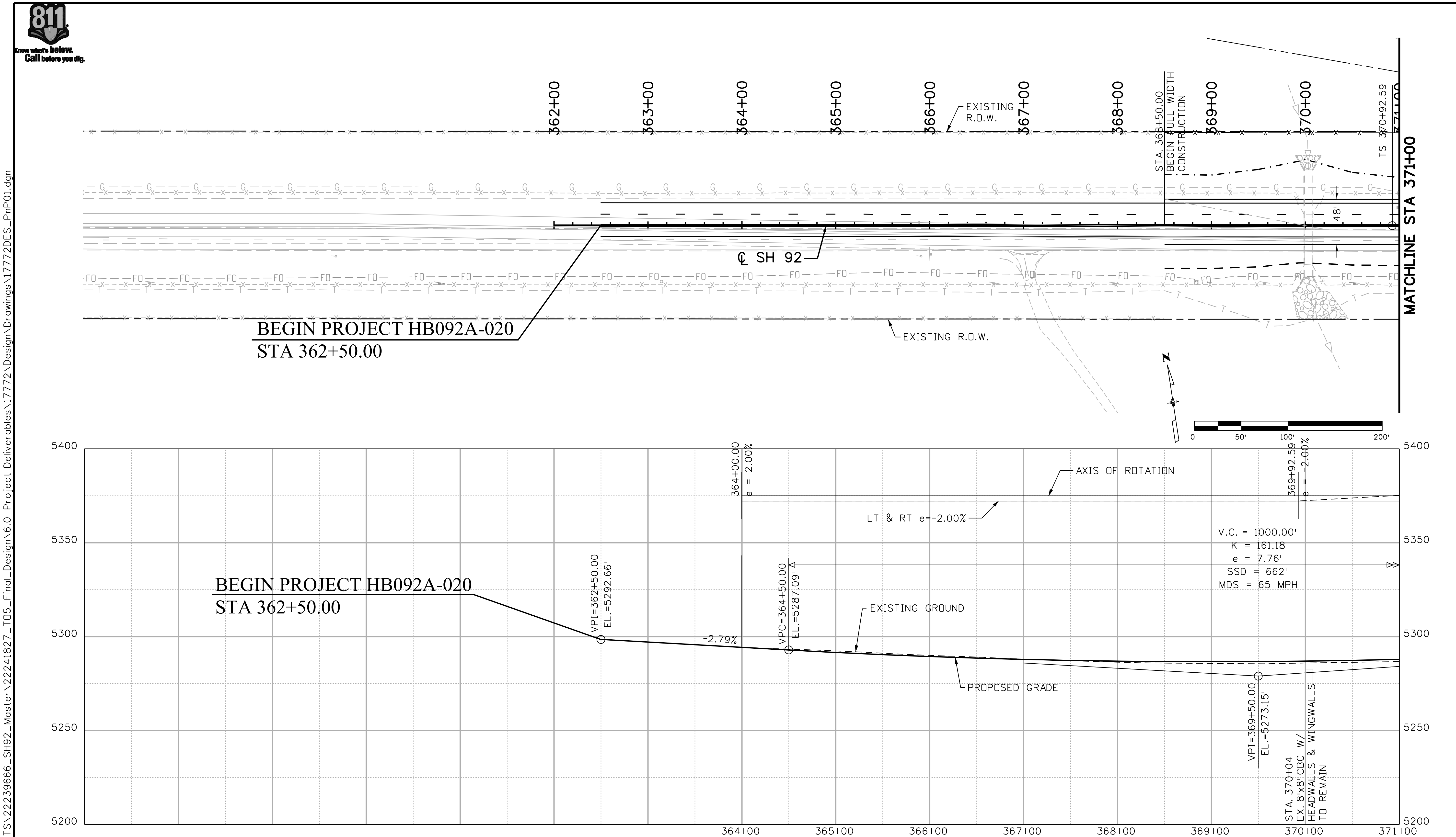
HEADWALLS AND PIPE OUTLET PAVING

Issued By: Project Development Branch on July 04, 2006

STANDARD PLAN NO.
M-601-12
Sheet No. 1 of 1

Appendix G

Roadway Plan and Profile Sheets



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ROADWAY PLAN AND PROFILE
Designer: P.WELLS
Detailer: B.TENNANT
Structure Numbers
Sheet Subset: SH92 P&P
Subset Sheets: 01 of 07

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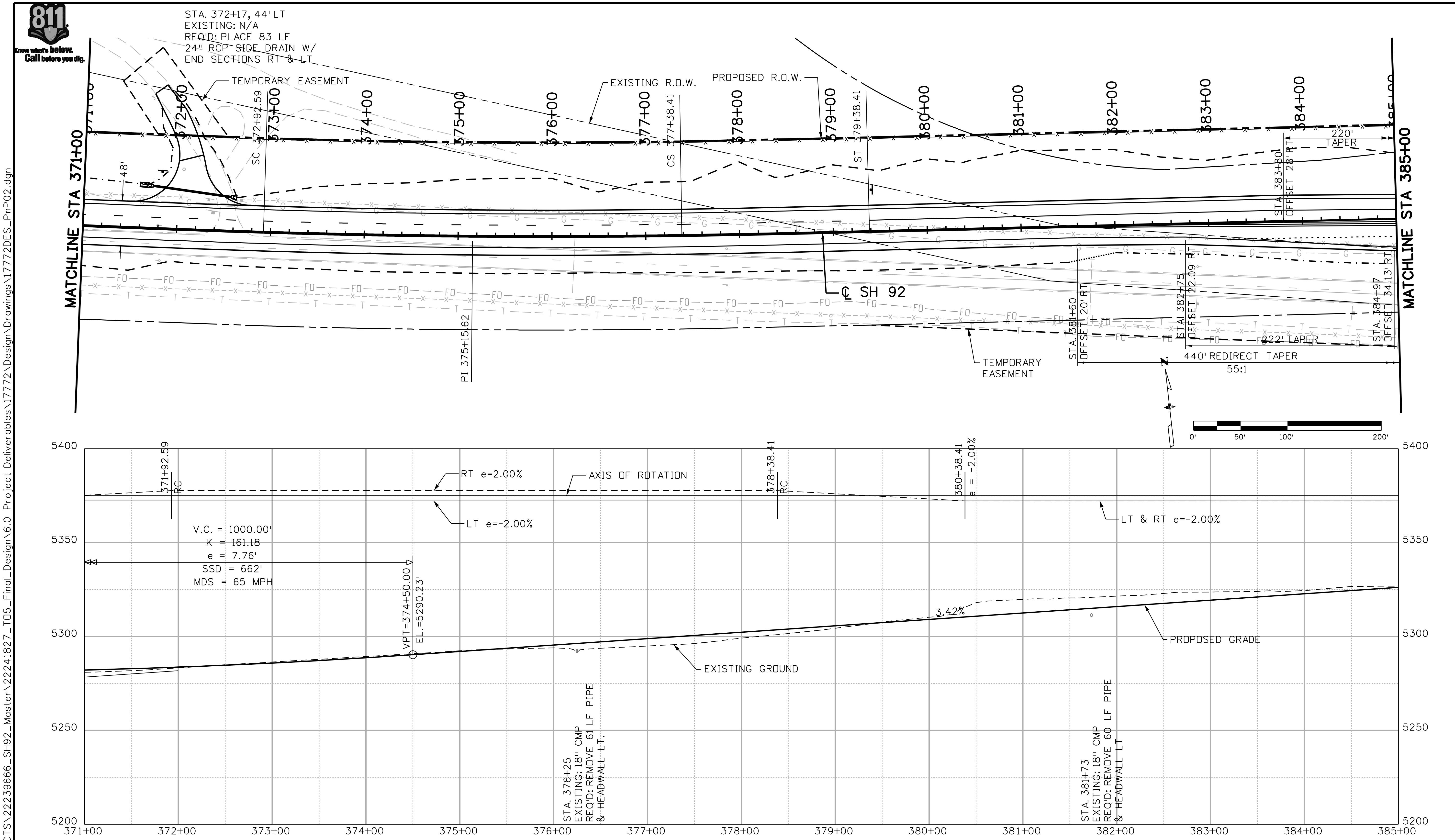
STA 092A-024
17772
Sheet Number



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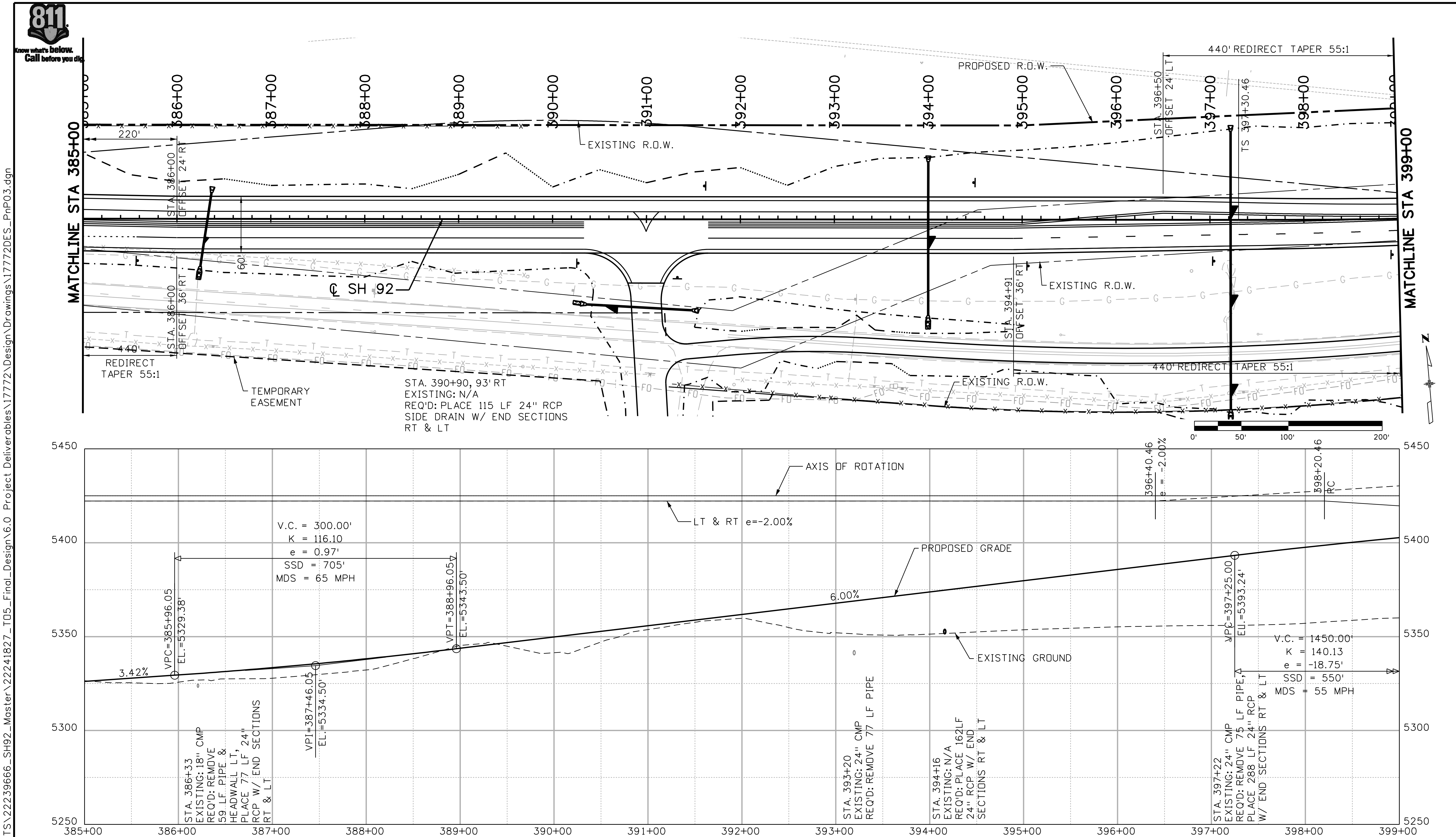

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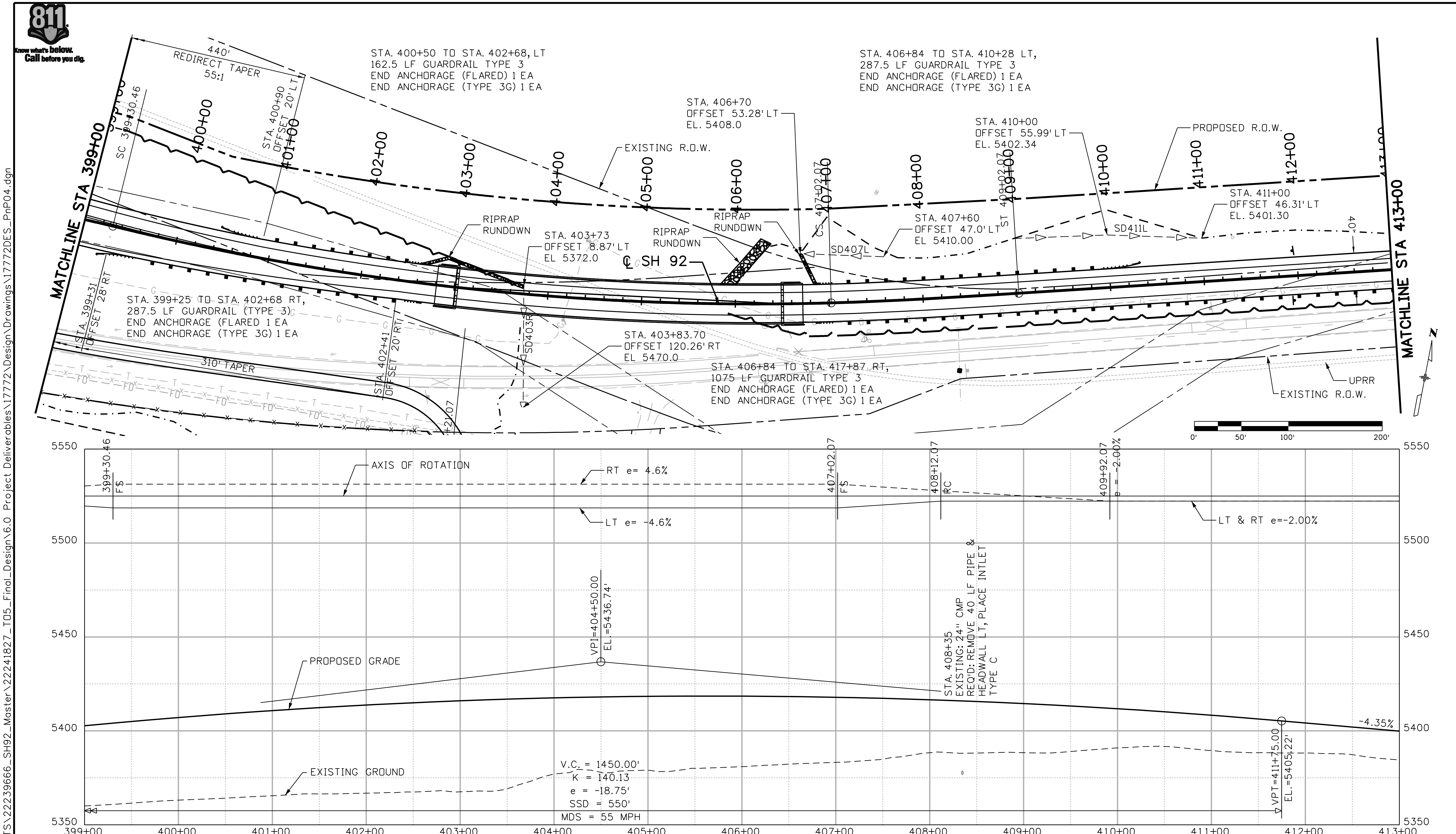

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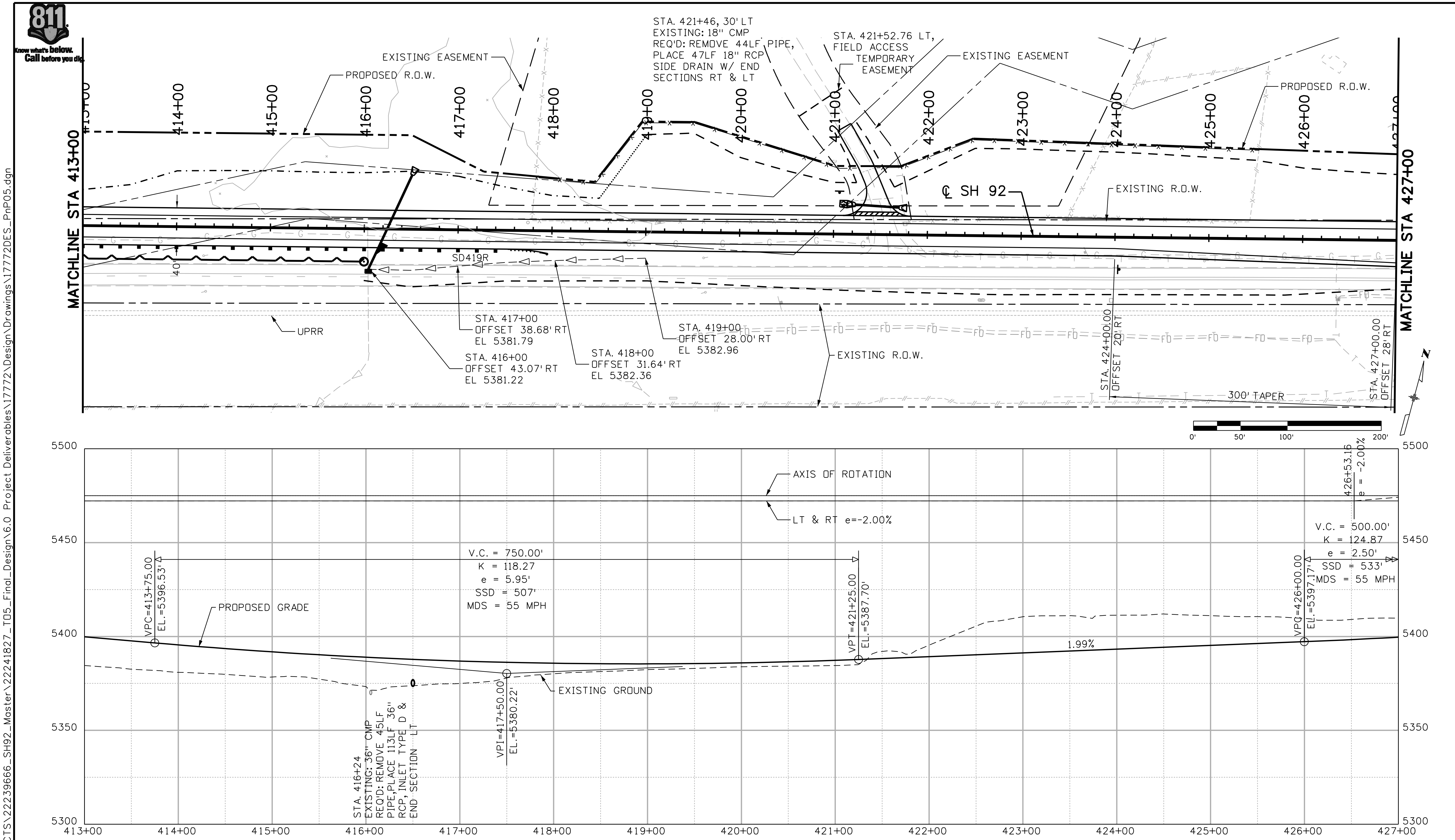

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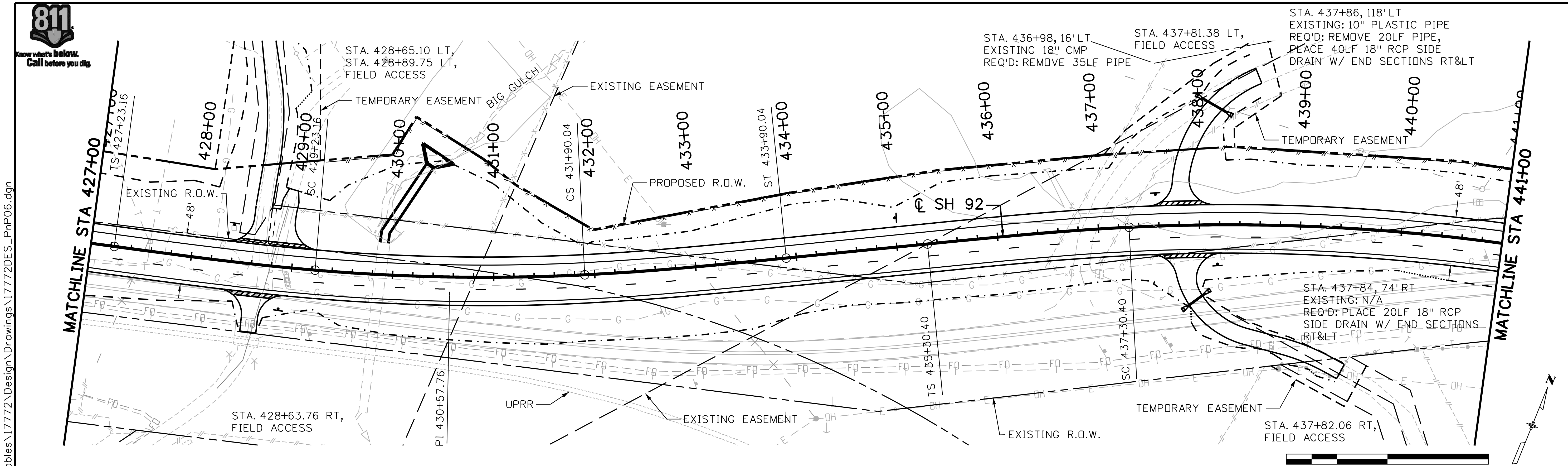

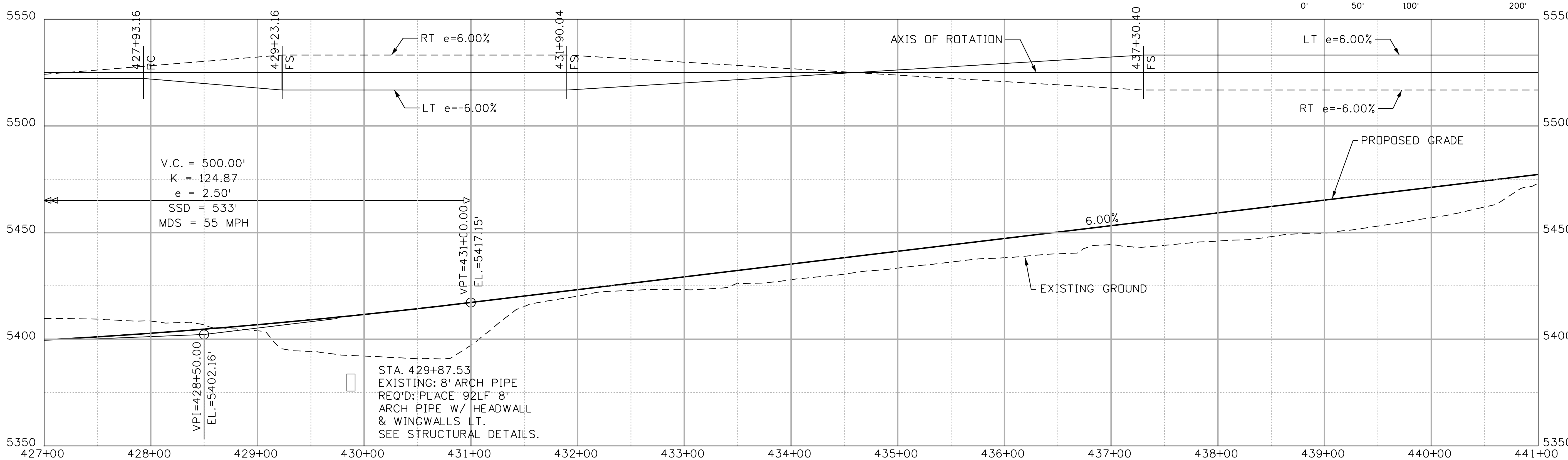

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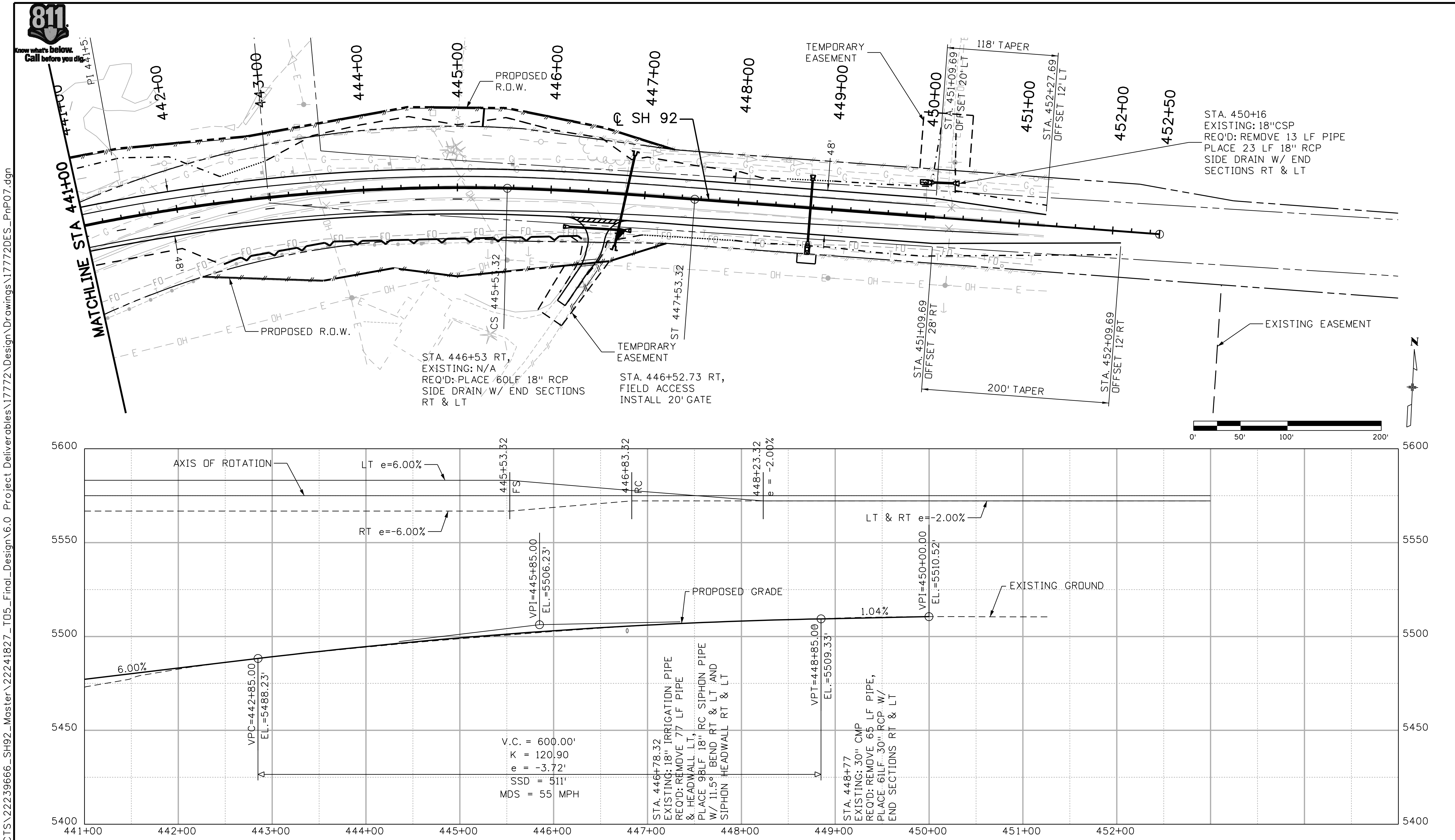

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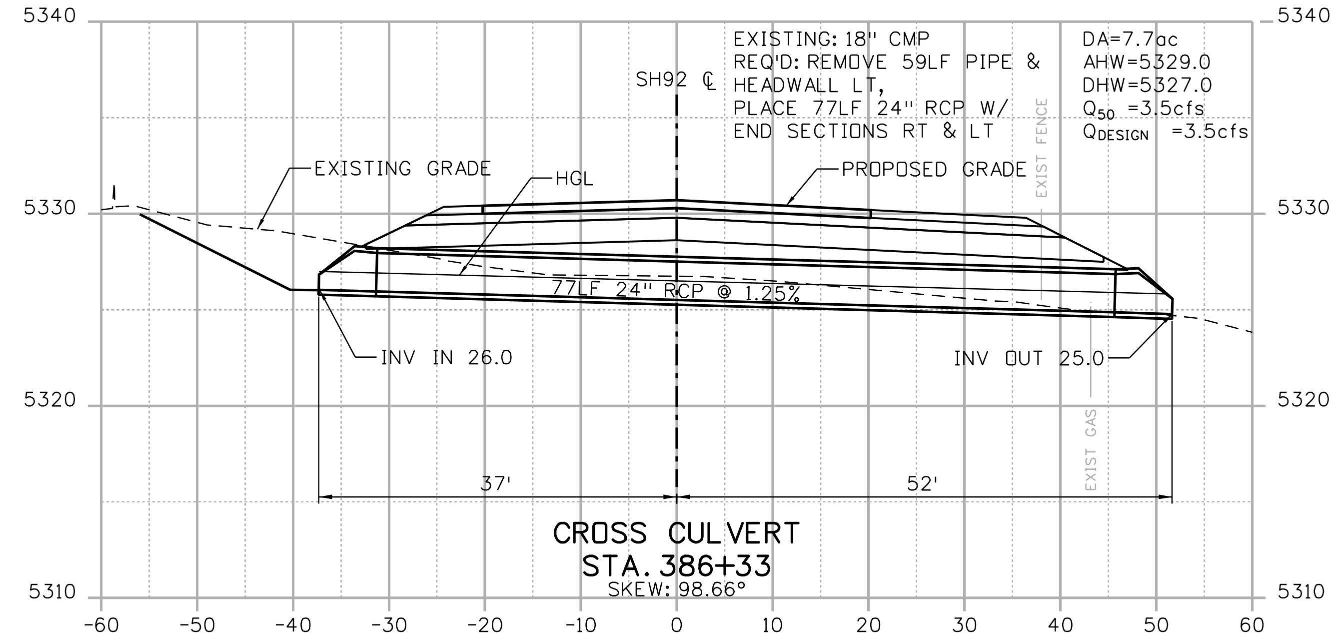

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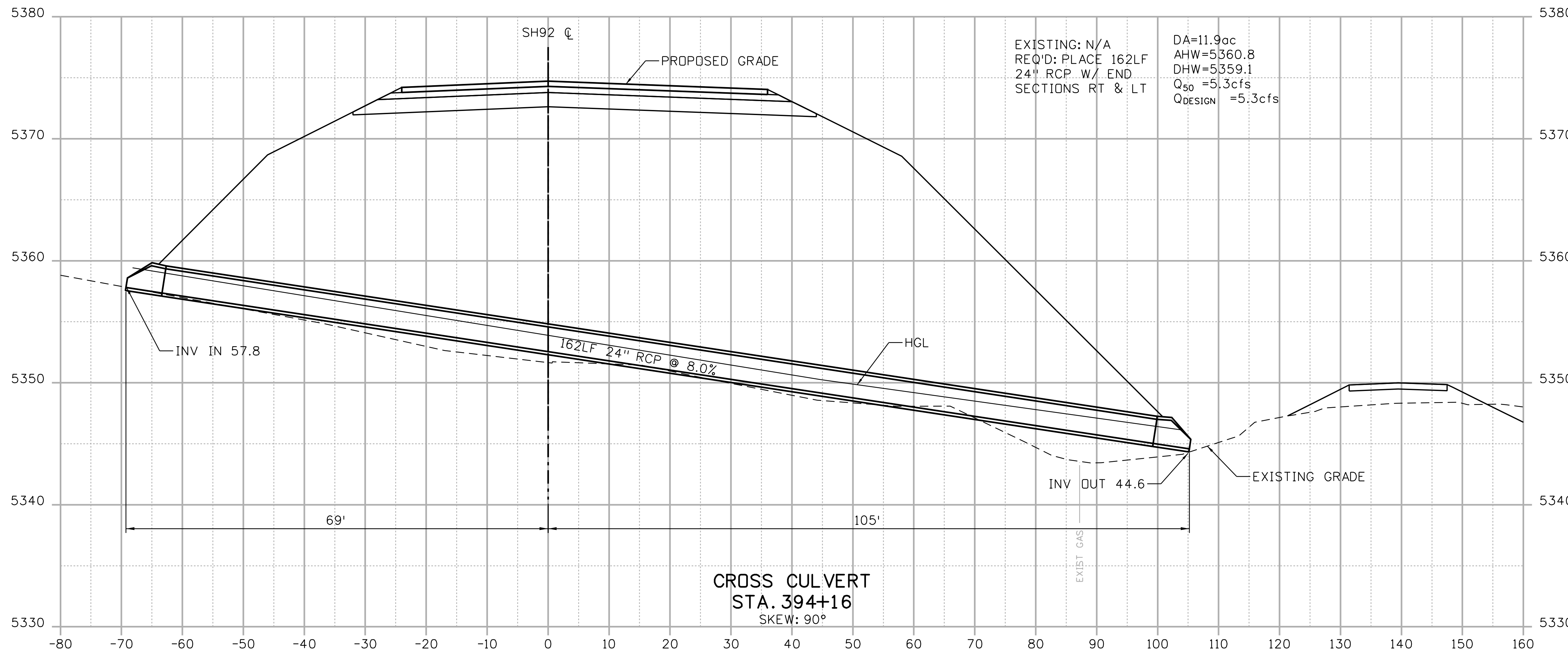

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STRUCTURE CROSS SECTIONS

Designer: M. MORGAN
Detailer: B. TENNANT
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Sheet Subset: SH92 STR
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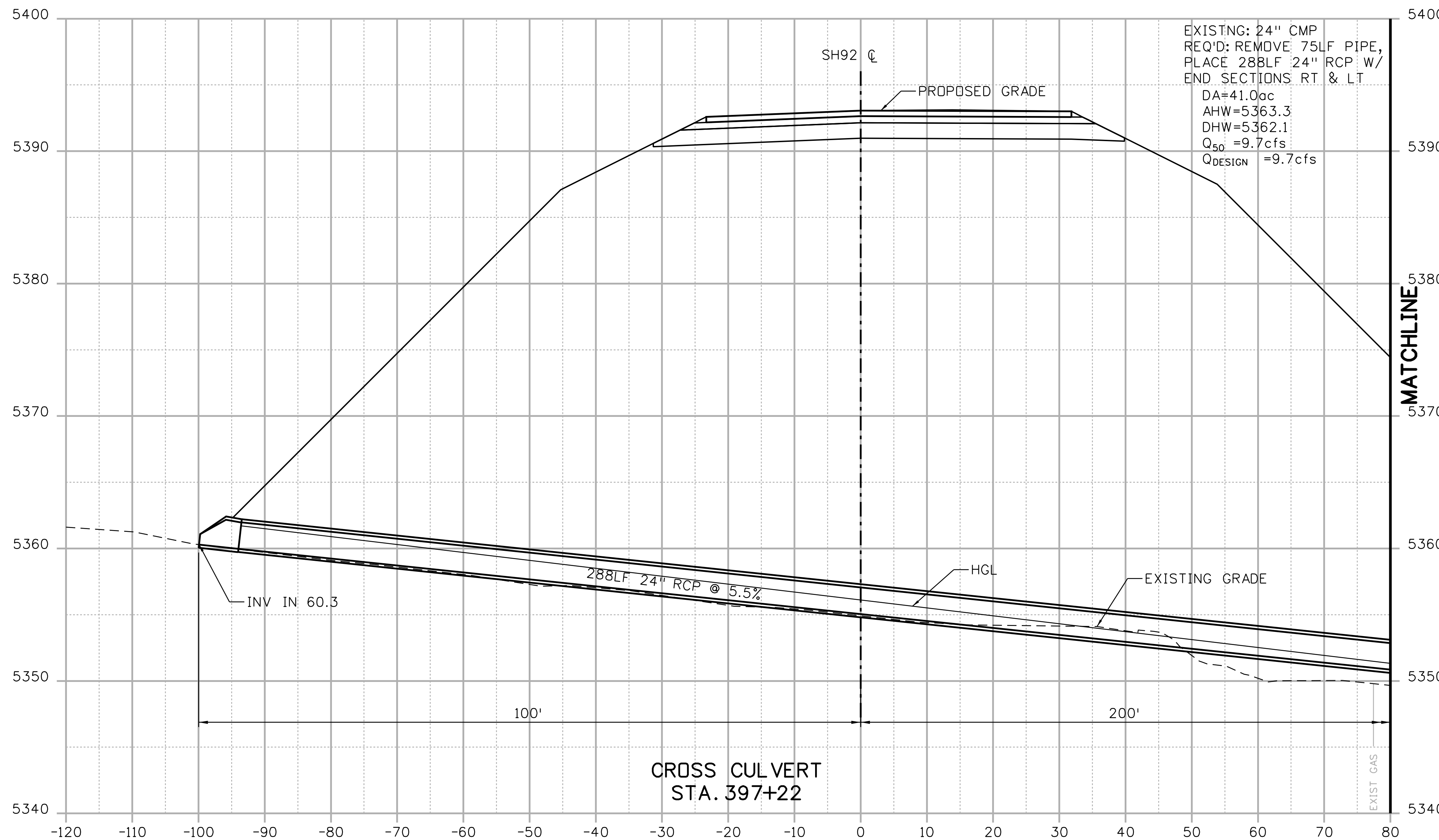

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Detailer:	B. TENNANT		
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Sheet Number

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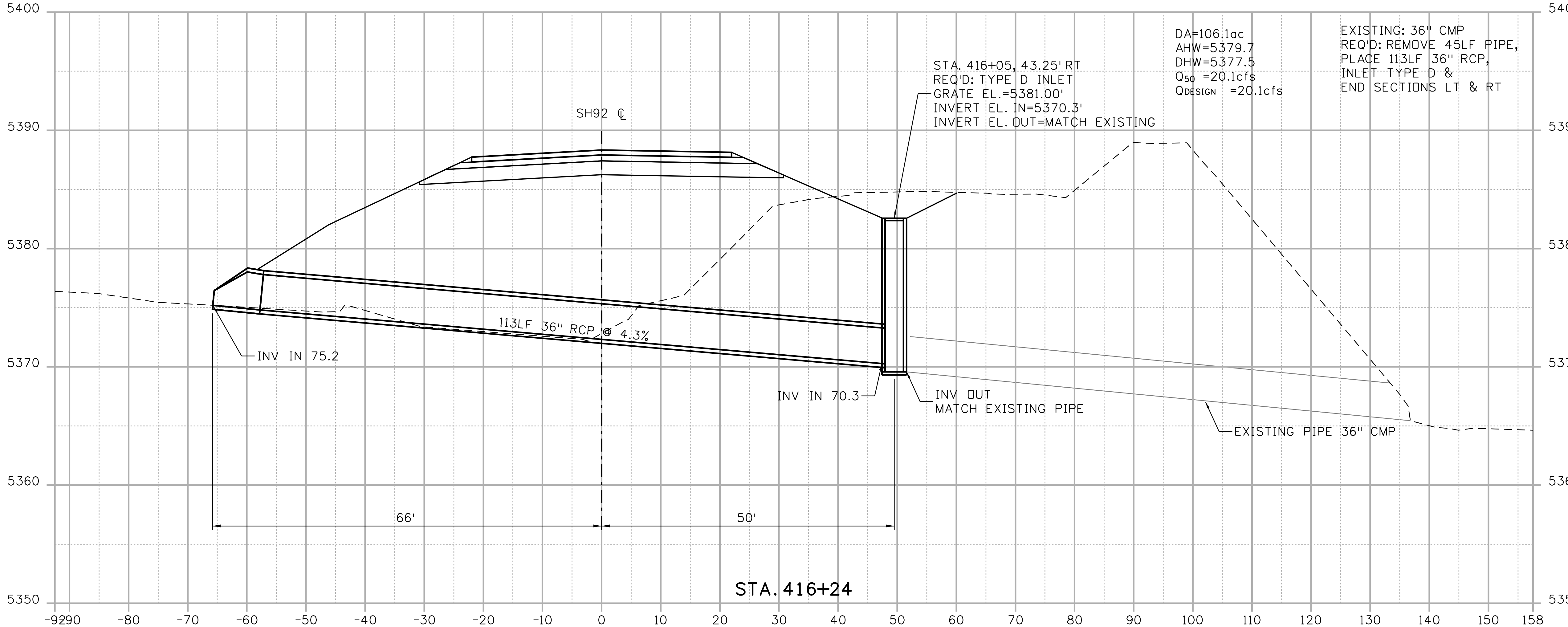

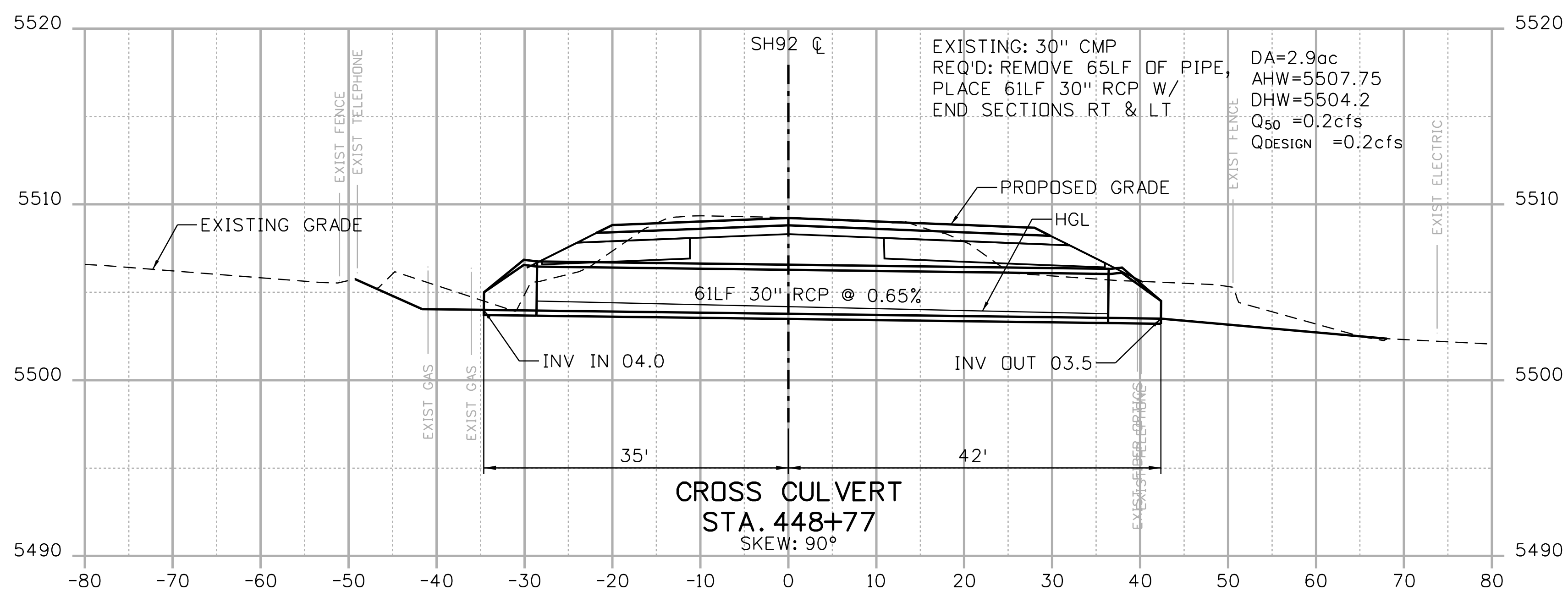

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Unit Information Unit Leader Initials
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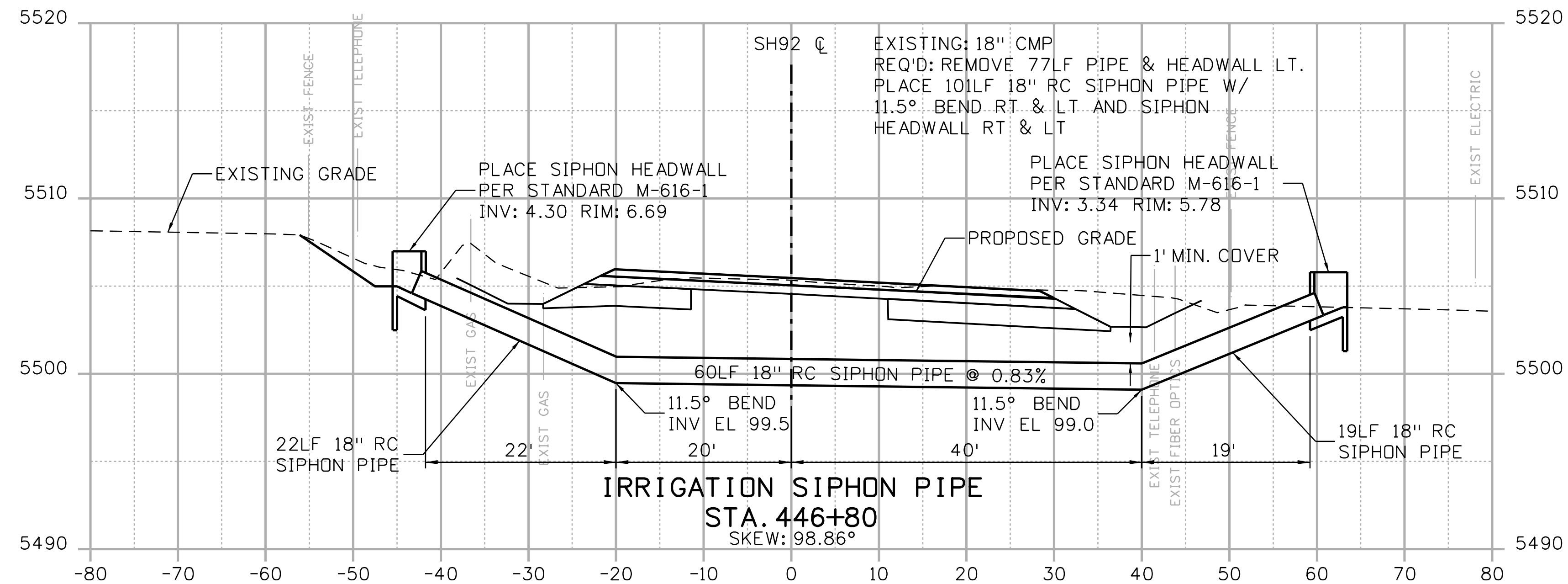

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Unit Information	Unit Leader Initials		
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IRRIGATION CROSS SECTIONS

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