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Drainage Report
QuikTrip Store 0313 – 31st & K-15, Wichita, KS

City of Wichita/Sedgwick County
Subdivision Drainage Plan Checklist

Submit completed forms to:
City of Wichita Public Works & Utilities, 455 N. Main 8th Floor, Wichita KS 67202; or
Sedgwick County Stormwater Management, 1144 S. Seneca, Wichita KS 67213.

Project Name:	QuikTrip No. 0313R, K-15 and 31st Streets				
Total Area of Project:	2.4	acres			
Development Type:	Commercial		Other:		
Developer Name:	QuikTrip Corporation	**Contact:**	Joe Kim	**Phone:**	918.615.7140
Email:	jkim@quiktrip.net				
Engineer Name:	Schwab Eaton	**Contact:**	Anne Stephens	**Phone:**	316.722.4472
Email:	astephens@schwab-eaton.com				

Directions:

(1) Fill-out this checklist completely and include it with the Drainage Plan submittal. This checklist should be included in the bound copy, behind the cover sheet for the submittal. Incomplete Drainage Plans and checklists will not be accepted.

*(2) Indicate whether a plan element is included or not included in the submittal by choosing "**Yes**" or "**No**" from the dropdown list in the **"Element Included?"** column. The question must be answered for every plan element for this checklist to be considered complete. An explanation must be provided for all **"No"** answers.*

Drainage Plan Checklist			
#	Plan Element Description	Element Included?	Explanation/Notes
1.0	**General**		
1.1	Digital copy of drainage plan, including preliminary Master Grading Plan, preliminary plat and proposed plat, in PDF format and one half size, bound, paper copy.	Yes	
1.2	Professional Engineer's seal, signature and date on plan cover.	Yes	
1.3	Site location map, using color ortho-imagery and showing the project boundaries, a north arrow and an accurate scale.	Yes	See site plan and drainage report.
1.4	Narrative of the development type, existing conditions and proposed impacts on stormwater runoff, wetlands, riparian zones and floodplains/floodways.	Yes	See drainage report.
1.5	Discussion of off-site conditions surrounding the proposed development.	Yes	See drainage report.
1.6	Summary table of runoff calculations (pre/post development).	Yes	See drainage report.
1.7	Narrative description of the type and function of the permanent structural stormwater management facilities.	Yes	See drainage report.
2.0	**Existing Conditions Information**		
2.1	**Existing Conditions Drainage Map**		
2.1.1	On-site and off-site topography: NAVD 88 datum, one-foot contours with spot elevations	Yes	
2.1.2	On-site and off-site drainage features, including perennial and intermittent streams (with names labeled), conveyance systems such as open channels, ditches, swales and areas of overland flow. Flow direction must be indicated by arrows.	Yes	
2.1.3	Storm sewer system components, including storm drains, inlets, catch basins, gutters, manholes, headwalls, pipes and culverts. Material and size must be noted for all pipes and culverts.	Yes	
2.1.4	Location and boundaries of natural features such as wetlands, lakes, ponds with the normal water elevation noted, rock outcroppings, wooded areas and tree rows.	Yes	
2.1.5	Location, dimensions and elevations of existing bridges and culvert crossings.	Yes	
2.1.6	Location of existing utilities (e.g., water, sewer, gas, electric, cable, etc.) with labels and easement boundaries.	Yes	
2.1.7	Groundwater elevations, if applicable.	No	Not applicable.
2.1.8	Delineation of predominant soil based on USDA soil surveys and/or on-site soil borings; indicate NRCS soil name and Hydrologic Soil Group for undisturbed surface soils.	Yes	
2.1.9	Land use types per NRCS nomenclature.	Yes	
2.1.10	Footprint of existing impervious areas (labeled, area given in acres).	Yes	
2.1.11	Internal drainage subbasin boundaries used for hydrologic calculations (labeled with ID, total area in acres, impervious area in acres and curve number).	Yes	
2.1.12	Time of concentration flow paths: Indicate and label each segment separately (i.e., overland flow, shallow concentrated, channel1, channel2, etc.). For each segment, provide the appropriate data to calculate Tc (e.g., length, slope, cover type, paved/unpaved, roughness parameters, geometric properties, etc.).	Yes	

Drainage Plan Checklist			
#	Plan Element Description	Element Included?	Explanation/Notes
2.2	**Existing Conditions Hydrology and Hydraulics Analysis**		
2.2.1	Narrative of the hydrologic analysis methodology used (e.g., unit hydrograph or other approved methods).	Yes	
2.2.2	A summary table of drainage subbasin hydrologic parameters (subbasin ID, area in acres, curve number, Tc, etc.).	Yes	
2.2.3	Table of existing condition runoff curve numbers with supporting data and calculations.	Yes	
2.2.4	Table of existing condition times of concentration with supporting data and calculations.	Yes	
2.2.5	A summary table of rainfall data used in the hydrologic analysis, and a reference for the source of the data.	Yes	
2.2.6	Cross-sections and other diagrams of existing open channels, bridge and culvert sections and other hydraulic features as required to illustrate the basis for hydraulic analysis.	No	Not applicable.
2.2.7	Hydrologic and hydraulic analyses for runoff rates, volumes, velocities and elevations. Provide supporting data not specified above and identify assumptions. Include detailed calculations for the 2, 5, 10, 25 & 100-year, 24-hour storm events. Provide results in a tabular form. Provide digital copies of any computer files and models used.	No	Not applicable - pre-development meeting did not require detention. 10-year and 100-year rates provided.
3.0	**postdevelopment Conditions Information**		
3.1	**postdevelopment Conditions Drainage Map**		
3.1.1	Proposed project boundary.	Yes	
3.1.2	on-site and off-site topography: NAVD 88 datum, one-foot contours with spot elevations.	Yes	
3.1.3	Existing on-site and off-site drainage features that are to remain after development, including perennial and intermittent streams (with names labeled), conveyance systems such as open channels, ditches, swales and areas of overland flow. Flow direction must be indicated by arrows.	Yes	
3.1.4	Location and description of off-site through-drainage conveyances which are confined to an easement, dedication and/or reserve.	Yes	
3.1.5	Footprint of proposed impervious areas, including roads, parking lots, buildings and other structures.	Yes	
3.1.6	Location of proposed utilities (e.g., water, sewer, gas, electric, cable, etc.) with labels and easement boundaries.	Yes	
3.1.7	Delineation of predominant soils, based on anticipated soil textures and NRCS guidelines if different from predevelopment soil conditions; indicate NRCS soil name and Hydrologic Soil Group for surface soils.	Yes	
3.1.8	Land use cover per NRCS nomenclature.	Yes	
3.1.9	Internal drainage subbasin boundaries used for hydrologic calculations (labeled with ID, total area in acres, impervious area in acres and curve number).	Yes	
3.1.10	Proposed limits of land disturbing activity (i.e., grading limits).	Yes	
3.1.11	Time of concentration flow paths. Indicate and label each segment separately (i.e., overland flow, shallow concentrated, channel1, channel2, etc.). For each segment, provide the appropriate data to calculate Tc (e.g., length, slope, cover type, paved/unpaved, roughness parameters, geometric properties, etc.).	Yes	
3.2	**Proposed Conveyances Map**		
3.2.1	on-site and off-site drainage features, including perennial and intermittent streams (with names labeled), proposed conveyance systems (such as open channels, ditches, swales and areas of overland flow, including backyard drainage). Flow direction must be indicated by arrows.	Yes	
3.2.2	Storm sewer system components, including storm drains, inlets, catchbasins, gutters, manholes, headwalls, pipes and culverts. Material and size must be noted for all pipes and culverts.	Yes	
3.2.3	For any subbasin or drainage area > 40 acres, show that the stormwater flow is confined to an open channel with required side benches and freeboard, or conformance to applicable policy and design requirements if partially enclosed.	No	
3.2.4	Location(s) of stormwater management facilities and any associated drainage easements.	Yes	
3.2.5	Proposed energy dissipaters and other channel protection devices.	No	Not required per pre-development meeting.
3.2.6	Location(s) and dimension(s) of proposed channel, bridge and culvert crossings.	No	Not applicable
3.2.7	Normal pool and 100-year pool elevations for ponds and lakes.	No	
3.2.8	Permanent concrete outfall control structure(s) for ponds.	No	N/A
3.2.9	Emergency overflow spillways and top of berm elevations for ponds and other volume/peak discharge control facilities.	No	N/A
3.2.10	Floodplains, ponds, and stormwater management facilities located in reserves.	No	N/A - Zone X
3.3	**postdevelopment Conditions Hydrology & Hydraulics**		

Drainage Plan Checklist			
#	Plan Element Description	Element Included?	Explanation/Notes
3.3.1	Narrative of the hydrologic analysis methodology used (e.g., unit hydrograph or other approved methods).	Yes	
3.3.2	A summary table of drainage subbasin hydrologic parameters (subbasin ID, area in acres; curve number, Tc, etc.).	Yes	
3.3.3	Table of postdevelopment condition runoff curve numbers with supporting data and calculations.	Yes	
3.3.4	Table of postdevelopment condition times of concentration with supporting data and calculations.	Yes	
3.3.5	Cross-sections and other diagrams of existing open channels; bridge and culvert sections and other hydraulic features as	Yes	
3.3.6	Hydrologic and hydraulic analyses for runoff rates, volumes, velocities and elevations. Provide supporting data not specified above and identify assumptions. Include detailed calculations for the 2, 5, 10, 25 & 100-year, 24-hour storm events. Provide results in a tabular form. Provide digital copies of any computer files and models used.	No	Pre-development meeting did not require detention. 10 year and 100-year rates are provided.
3.3.7	Downstream peak discharge assessment (10% Rule) results and supporting data and calculations. Provide digital copies of any computer files and models used.	Yes	Pre-development meeting did not require.
3.3.8	Stage-storage-discharge or other outlet rating curves and inflow/outflow hydrographs for all ponds.	No	N/A
3.3.9	Demonstrate that the pond contours on the master grading plan and the stage-storage-discharge data are consistent for all ponds.	No	N/A
3.3.10	Demonstrate that all ponds have one foot of freeboard above the 100-year, 24-hour high water level.	No	N/A
3.3.11	Demonstrate that runoff from the proposed project site is discharged in the same manner as prior to development, using level spreaders, energy dissipaters, other devices or grading as required, or identify an appropriate flowage easement.	No	N/A
3.4	**Stormwater Quantity Control Sizing**		
3.4.1	Hydraulic sizing calculations for all stormwater management controls.	Yes	
3.4.2	Table(s) listing all stormwater management controls. Present the types, sizes, elevations, flows, velocities and depths for each control, as applicable. Verify that velocities are self-cleaning and non-erosive.	Yes	
3.4.3	Typical details (including cross-sections where applicable) for outlet structures, embankments, spillways, grade control structures, conveyance channels, etc.	No	N/A
3.5	**Stormwater Quality Management Facilities**		
3.5.1	Table(s) listing all stormwater management facilities. Present the description, % TSS removal value, water quality volume handled, contributing drainage area in acres and contributing impervious area in acres.	Yes	
3.5.2	Indicate the responsible party for maintenance, as shown in the plat text (i.e., Home Owners Association, Lot Owners Association, property owner, etc.).	Yes	
3.5.3	Water quality volume (total and by facility), with supporting data and calculations.	Yes	
3.5.4	% TSS removal value (total and by facility) with supporting data and calculation. Must be equal to or greater than 80%.	Yes	
3.5.5	Channel protection volume with supporting data and calculations.	No	Not Applicable
3.5.6	Water quality volume and channel protection volume orifice size calculations.	No	Not Applicable
3.5.7	Other calculations required for each stormwater management facility as specified in the Wichita/Sedgwick County Stormwater Manual.	No	Not Applicable
3.5.8	Typical details (including cross-sections where applicable) for outlet structures, embankments, internal grading, forebays and other siltation prefilters, filtration/infiltration media, vegetation, check dams, operational controls, etc.	Yes	
4.0	**Floodplains**		
4.1	Reference the source of flood profile, floodplain, floodway and stream discharge information.	No	Not applicable - FEMA FIRM Map No. 20173C0368E
4.2	Delineation of nearest base flood elevations.	No	
4.3	Delineation of predevelopment regulatory floodplain/floodway limits using FEMA's current GIS database; limits to be per elevation and scaled location.	No	Not applicable
4.4	Delineation of postdevelopment regulatory floodplain/floodway limits; limits to be per elevation and scaled location, with project limits shown.	No	Not applicable
4.5	Floodway data table and discharges.	No	Not applicable
4.6	Hydrologic and hydraulic study information for local floodplain analysis, unnumbered Zone A elevation determinations and floodplain map revisions or required permits.	No	Not applicable
4.7	Regulatory floodway and four natural profile models (10, 50, 100 and 500-year) for existing and postdevelopment conditions.	No	Not applicable
4.8	Floodplains and floodways located within a reserve, where necessary.	No	Not applicable

Drainage Plan Checklist			
#	Plan Element Description	Element Included?	Explanation/Notes
4.9	Floodplain cut and fill calculations for volume sensitive basins.	No	Not applicable
4.10	Demonstrate that floodway elevations and velocities do not increase due to construction in the floodway ("No Rise Certification").	No	Not applicable
5.0	**Federal, State and Local Permits**		
5.1	US Army Corps of Engineers regulatory program permits (Section 404 permit)	No	Not applicable
5.2	Kansas Department of Agriculture - Division of Water Resources Permits (Stream Obstruction, Channel Change, Floodplain Fill, Levee, Water Appropriations, Dam Safety permit, etc.).	No	
5.3	FEMA letters of map change/revision - LOMA, LOMR, LOMR-f, CLOMR, etc.; shall be included and approved when project modifies the limits of the floodplain/floodway.	No	Not applicable
6.0	**Half Scale Preliminary Master Grading Plan**		
6.1	One set of plans and associated PDF of plans.	Yes	
6.2	Professional Engineer's seal, signature and date.	Yes	
6.3	Title block including subdivision name and phase and dated revision documentation.	Yes	
6.4	Future phases shown but cross-hatched as information only.	Yes	
6.5	Scale, not greater than 1-inch = 60 feet.	Yes	
6.6	North arrow.	Yes	
6.7	Index or legend key.	Yes	
6.8	Benchmarks (minimum of 2) used for site control (NAVD 88 vertical datum).	Yes	
6.9	Existing contours of entire site with contour interval of one foot.	Yes	
6.10	Proposed contours for channels, ponds, and other permanent stormwater management facilities, with contour interval of one foot.	Yes	
6.11	Spot elevations shown to the nearest tenth of a foot for critical locations, including lot and property boundaries.	Yes	
6.12	Proposed lot and street layout.	Yes	
6.13	Locations of underground storm drains.	Yes	
6.14	Overflow locations for storms exceeding storm drain capacity, with elevations.	No	
6.15	Top elevations of storm drains at all inlets, manholes, and flow line elevations for all outfalls.	Yes	
6.16	Locations of open ditches and lakes.	Yes	
6.17	Flow direction arrows.	Yes	
6.18	Proposed flow line elevations of all open ditches at maximum 100 foot intervals, and 100-year flood elevations thereon.	No	Not applicable
6.19	Ponds: Location, bottom elevation, normal pool elevation, 100-year flood elevation, emergency overflow elevation.	No	Not applicable
6.20	Proposed top-of-curb elevations at points where drainage will be required to flow over the curb.	No	Not applicable
6.21	Platted minimum building opening elevation for each lot, in table form for all lots (excluding basement floor elevations).	Yes	
6.22	Standard foundation and elevation detail for slab on grade, full basement, view-out, partial view-out and/or walk-out construction.	No	
6.23	Top of foundation elevation for each lot.	No	Not applicable
6.24	Notation for builders for each lot as to the type of structure that may be constructec and the view-out, walk-out or pad elevation, as applicable.	No	Not applicable
6.25	Indicate that all lots are above the 100-year flood elevation.	No	Not applicable
6.26	Indicate that grading around structures conforms to perimeter drainage requirements.	No	Not applicable
6.27	Indicate that backyard drainage grading conforms to backyard drainage requirements.	No	Not applicable
6.28	Adjacent subdivision lot lines, with lot labels and subdivision names.	Yes	
6.29	Boundaries and labels for all easements, rights-of-way and reserves	Yes	
6.30	Statement on proposed final plat: *"A drainage plan has been developed for the subdivision and all drainage easements, rights-of-way, or reserves shall remain at the established grades and remain unobstructed to allow for the conveyance of stormwater."*	No	Not applicable - By others
End of Checklist			

Schwab Eaton

QuikTrip No. 0313R
K-15 & 31st Street South
Wichita, Kansas

DRAINAGE STUDY

August 16, 2013

I. INTRODUCTION:

QuikTrip Corporation has proposed a new store and gas station at the intersection of K-15 and 31st Street South in Wichita, KS. The new project site is located on a portion of a K&R RV Park LLC. The current zoning of the site is LC – Limited Commercial District with no overlay districts.

QuikTrip has retained Schwab-Eaton to provide Drainage Private Project plans for the site. Addressing storm water management issues relative to the QuikTrip site is an integral part of such plans. Schwab Eaton has performed an analysis of the existing and proposed drainage conditions relative to the proposed site development and has prepared this study.

QuikTrip was not required by the City of Wichita to provide storm water detention for the site since it is located at the lower reaches of the surrounding watershed. Detaining water in the lower reaches could increase the risk of area flooding. Therefore, storm water detention was not designed for this project.

II. METHODOLOGY:

The intent of this study is to review the existing and proposed conditions of storm water flow through the project site in order to appropriately design a storm drainage system for the proposed store and gas station. This study follows the requirements and guidelines established by the city of Wichita, Kansas in their Stormwater Manual volumes 1-3. Proposed storm water management strategies are intended to manage and control storm water runoff from the project site and storm water runoff flowing to the site from adjacent watersheds. The 10-Year and 100-Year storm recurrence intervals were both considered in the design of proposed storm water structures and pipes. QuickTrip West has requested that no ponding would occur on proposed pavement areas in the 100-Year event. Providing adequate diversions of off-site runoff from adjacent lots to the downstream storm water system was also a design consideration.

The Rational Formula Method was used in this study, based on the formula:

$Q = ciA$, where:

Q = the peak rate of discharge in cubic feet per second for the given design storm.
c = the runoff coefficient
i = the rainfall intensity in inches per hour for the given design storm based on the determined Time of Concentration (Tc).
A = the watershed area in acres.

Watershed maps are included in the Appendix.

III. EXISTING CONDITIONS:

The existing site conditions are based on a topographic survey conducted by Savoy Company P.A. on February 1st, 2013. In addition, LiDAR data was used to generate information regarding the runoff from adjacent upstream development that drains through the project site. The project site currently consists of moderately wooded RV parking areas with three asphalt drives. Soil conditions appear to have a Hydrological Soil Classification "B."

See Pre-Development Drainage Map at the end of this report for a graphic depiction of the watershed areas. Two basic watersheds have been identified based on the receiving infrastructure. Watershed "A" drains to an existing 24"x80" box culvert crossing K-15 approximately 230 feet southeast of the K-15/31st Street intersection delivering a majority of site runoff across the highway. It is also subdivided into subareas based on the existing drives/valley flumes. Watershed "B" is smaller portion of the site that fronts along 31st Street and drains to an inlet on the south side of 31st that is connected with a 36" dia. pipe to a 48" dia. storm sewer trunk line. The 48" trunk line runs southwest along 31st and crosses K-15 parallel to the aforementioned RCB.

The following is a summary of the drainage conditions for each watershed (including both the on-site and off-site portions).

A. Existing Watershed "A": This watershed totals 6.5 acres (consisting of 2.2 acres on-site and 4.3 acres off-site), has a runoff coefficient of 0.51 for the 10-year and 0.59 for the 100-year, and an estimated Tc of 14 minutes. The peak discharges for each design storm are estimated to be:

10-Year: $Q = ciA = (0.51)(5.37)(6.5) = 17.8$ cfs
100-Year: $Q = ciA = (0.59)(7.57)(6.5) = 29.0$ cfs

B. Existing Watershed "B": This watershed totals 0.2 acre (has no significant off-site drainage passing through), has a runoff coefficient of 0.33 for the 10-year and 0.44 for the 100-year, and an estimated Tc of 5 minutes. The peak discharges for each design storm are estimated to be:

10-Year: $Q = ciA = (0.33)(7.41)(0.2) = 0.5$ cfs
100-Year: $Q = ciA = (0.44)(10.32)(0.2) = 0.9$ cfs

IV. PROPOSED CONDITIONS:

See Post-Development Drainage Map at the end of this report for a graphic depiction of the watershed areas under proposed conditions. Under post-developed conditions, most of the on-site drainage is redirected toward 31st Street as a part of Watershed "B". Most

of the perimeter unpaved areas within the site will remain in Watershed "A". Off-site drainage within Watershed "A" is diverted around the east and south side of the site through a flume, crossing the proposed southwest site entrance by means of a 14"x23" elliptical RCP culvert. The culvert will discharge into the existing K-15 highway ditch that drains to the 24"x80" RCB. Most of the off-site drainage will generally enter the site at dead end streets with inverted crowns functioning as valley gutters. Off-site drainage within Watershed "A" was divided into subareas to assess storm water flows along various segments of the flume. The following is a summary of the proposed drainage conditions for each watershed:

A. Proposed Watershed "A": This watershed will total 4.9 acres (0.6 acre on-site and 4.3 acres off-site), have a runoff coefficient of 0.54 for the 10-year and 0.63 for the 100-year, and an estimated Tc of 14 minutes. The peak discharges for each design storm are estimated to be:

10-Year: $Q = ciA = (0.54)(5.37)(4.9) = 14.2$ cfs
100-Year: $Q = ciA = (0.63)(7.57)(4.9) = 23.4$ cfs

This watershed was subdivided, as previously described, to evaluate off-site drainage entering the site along various segments of a proposed flume. The Watershed Map indicates four subareas – A1 through A4. The breakdown of the subarea hydrological characteristics may be found on watershed maps within the Drainage Private Project Plans.

B. Proposed Watershed "B": This watershed totals 1.61 acre (has no significant off-site drainage passing through), has a runoff coefficient of 0.85 for the 10-year and 0.87 for the 100-year, and an estimated time of concentration of 5 minutes. The peak discharges from each design storm are estimated to be:

10-Year: $Q = ciA = (0.85)(7.41)(1.6) = 10.1$ cfs
100-Year: $Q = ciA = (0.87)(10.32)(1.6) = 14.4$ cfs

This watershed was also subdivided to size the storm sewer network within the site. The Watershed Map indicates nine subareas – B1 through B9. The breakdown of the subarea hydrological characteristics may be found on watershed maps within the Drainage Private Project Plans.

V. STORMWATER QUALITY:

Temporary storm water quality measures (BMPs) will be installed at the site perimeter and other points of discharge to protect the surrounding drainage ways from silt and sediment discharges during site demolition, preparation and construction. Said requirements will be in accordance with City of Wichita standards and the NPDES program administered by KDHE. An NOI will be submitted to KDHE for a construction permit prior to on-site disturbances.

Since essentially all of the developed impervious surfaces will be discharged at a common point, that location appears to be the optimum location for providing a permanent BMP improvement for protecting post-development storm water quality. A pre-manufactured hydrodynamic separator is proposed at that location (immediately south of the point of connection to the existing 31st Street curb inlet) to capture and retain suspended pollutants. The separator will be a KriStar FlowGard Dual-Vortex separator, Model #DVS-72S. It has effective treatment of flows up to 4.25 cfs and will handle total flows (treatment and bypass) of 27 cfs.

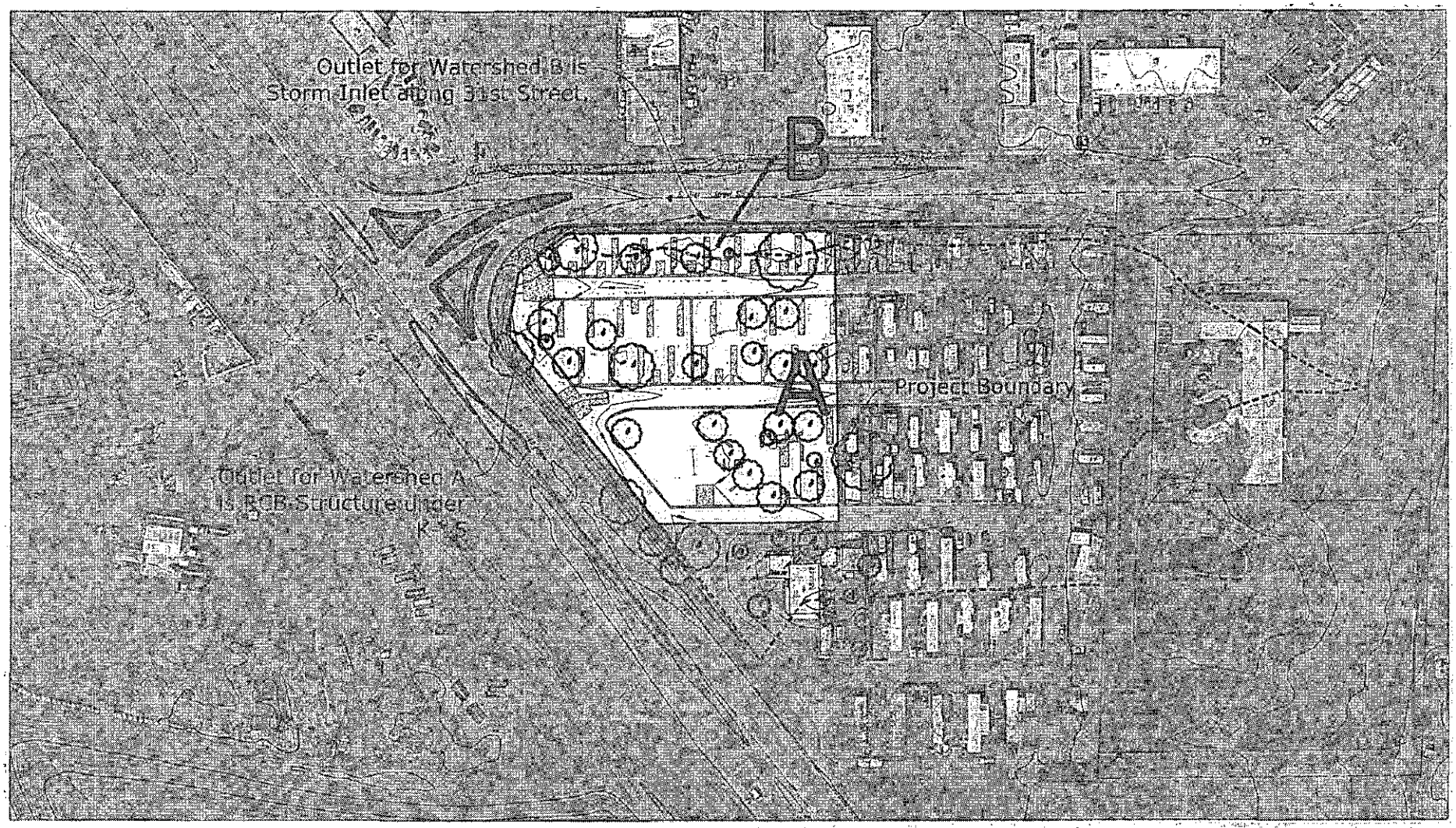
VI. SUMMARY AND CONCLUSIONS:

There will be a change in the watershed areas and respective discharges to the two receiving points described herein. The flows to the existing 24"x80" RCB will be reduced in the 100-year event from 29.0 cfs to 23.4 cfs. The flows to the inlet structure on 31st Street will be increased in the 100-year event from 0.9 cfs to 14.4 cfs. Schwab-Eaton does not have complete information on the capacity of the downstream system. Since the connecting pipe between the inlet and the 48" trunk line is a 36" diameter pipe, it is assumed to have a reasonable carrying capacity.

Respectfully submitted,

Anne Stephens, PE
Schwab Eaton

ANNE STEPHENS
LICENSED
19299
KANSAS
PROFESSIONAL ENGINEER

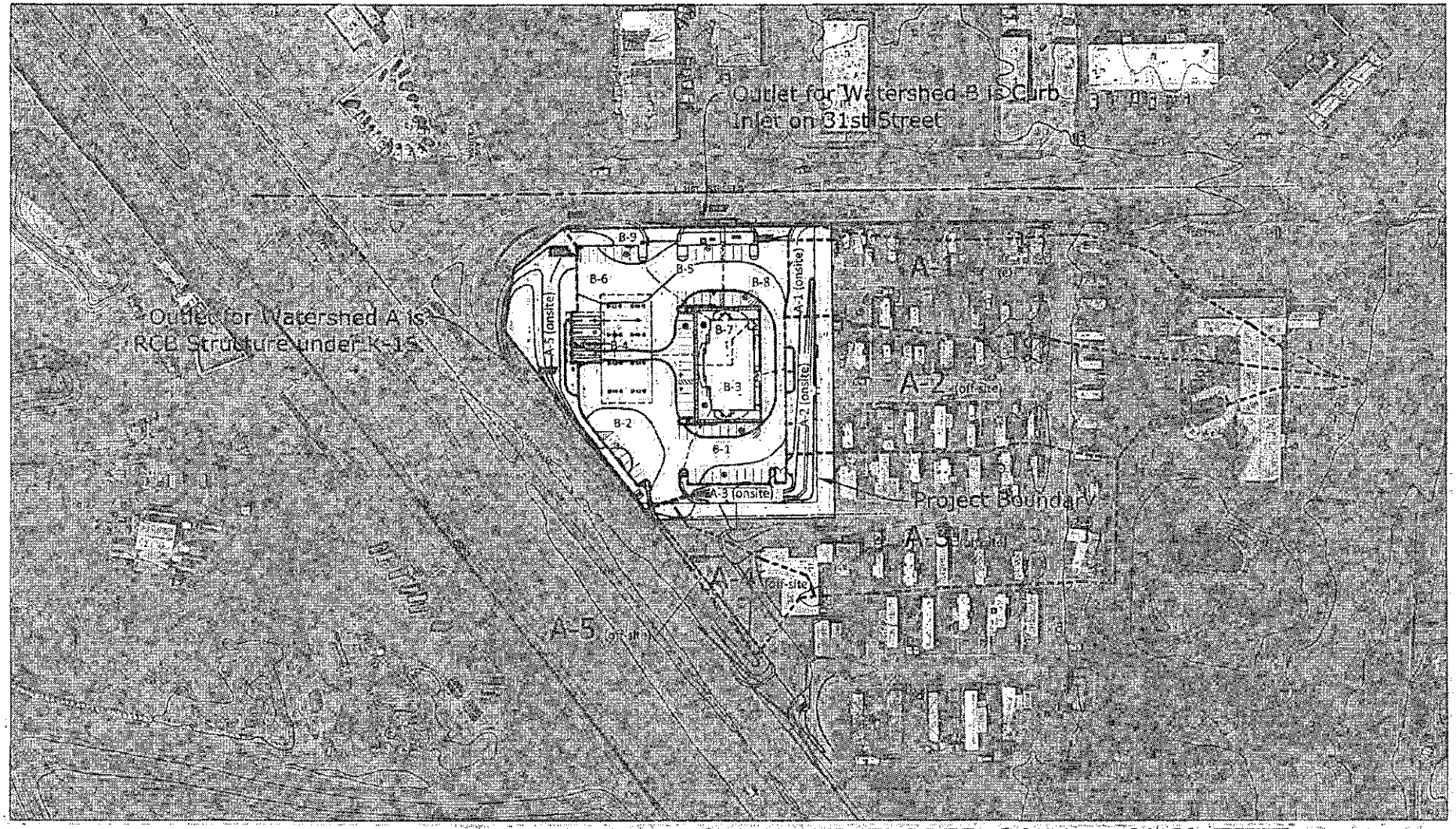


Watershed Map (PREDEVELOPED CONDITIONS)

QT Store #0313R

Date: 08/19/2013

Schwab Eaton



Watershed Map (POST DEVELOPED CONDITIONS)

QT Store #0313R

Date: 08/19/2013

Schwab Eaton

QuikTrip No. 0313R
K-15 & 31st Street South
Wichita, Kansas

SUPPLEMENTAL CULVERT ANALYSIS

October 22, 2013

I. INTRODUCTION

The purpose of this supplemental report is to analyze the existing K-15 culvert south of the QuikTrip entrance in combination with the new entrance pipe for the 100 year storm. The Rational Method was used to develop peak flows for the culvert analysis. HY-8 Culvert Analysis Program was then utilized for the hydraulic analysis.

II. EXISTING CONDITIONS

The existing K-15 culvert is a composite structure consisting of (upstream to downstream) an 8' long – 32" x 24" corrugated metal arch pipe (CMAP) with end section, a 90' long 3' x 2' reinforced concrete box (RCB), and a 10' long 32" x 24" CMAP with end section, resulting in a structure 108' long at a 0.23%. This structure is currently separated from the K&R RV Park by a berm with an approximate elevation of 1284.25. If the capacity of this structure was exceeded the additional flow would overtop the berm and surface flow to and existing RCB near K-15 and 31st Street.

The drainage area to the culvert is approximately 12.85 acres, has a runoff coefficient of 0.45, and an estimated time of concentration of 42 minutes. The peak flow is 26.3 cfs.

The culvert discharges into an open ditch on the west side of K-15. The ditch has an approximate 18' wide bottom with 8:1 side slopes and a manning's n of 0.035. The downstream ditch collects and additional 5.74 acres of drainage area with a runoff coefficient of 0.51, and an estimated time of concentration of 33 minutes. The peak flow is 15.0 cfs. The average ditch slope is approximately 0.28%.

III. PROPOSED CONDITION

A new entrance, off of K-15 is being constructed for the QuikTrip store. This entrance essentially blocks runoff from a portion of the RV Park and any overflow from the K-15 culvert from reaching the RCB near K-15 and 31st Street. To address this, an entrance pipe will be constructed under the new entrance. This pipe has been sized to pass the Q_{100} from the portion of the RV Park that has been cut off (10.2 cfs) and any excess from the K-15 culvert should its capacity be exceeded (4.8cfs) for a total of 15.0 cfs.

The attached HY-8 reports show that the capacity of the extended K-15 structure (remove the upstream 8' CMMAC and replace it with a 13' long HERCP extension) prior to topping the berm at 1284.25 is 21.5 cfs.

Analysis of the HERCP entrance pipe with a Q=15.0 cfs results in a headwater elevation of 1282.93, which is below the adjacent existing structures.

HY-8 Culvert Analysis Report

K-15 Crossing

10.22.13

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 21.45 cfs

Design Flow: 21.5 cfs

Maximum Flow: 21.55 cfs

Table 1 - Summary of Culvert Flows at Crossing: CMMAC

Headwater Elevation (ft)	Total Discharge (cfs)	CMMAC 36x22 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1283.89	21.45	21.45	0.00	1
1283.89	21.46	21.46	0.00	1
1283.89	21.47	21.47	0.00	1
1283.89	21.48	21.48	0.00	1
1283.89	21.49	21.49	0.00	1
1283.89	21.50	21.50	0.00	1
1283.90	21.51	21.51	0.00	1
1283.90	21.52	21.52	0.00	1
1283.90	21.53	21.53	0.00	1
1283.90	21.54	21.54	0.00	1
1283.90	21.55	21.55	0.00	1
1285.50	35.95	35.95	0.00	Overtopping

Note: A 36" x 22" CMMAC was chosen to represent the 32" x 24" CMMAC identified by survey based on culvert cross sectional area.

Rating Curve Plot for Crossing: CMMAC

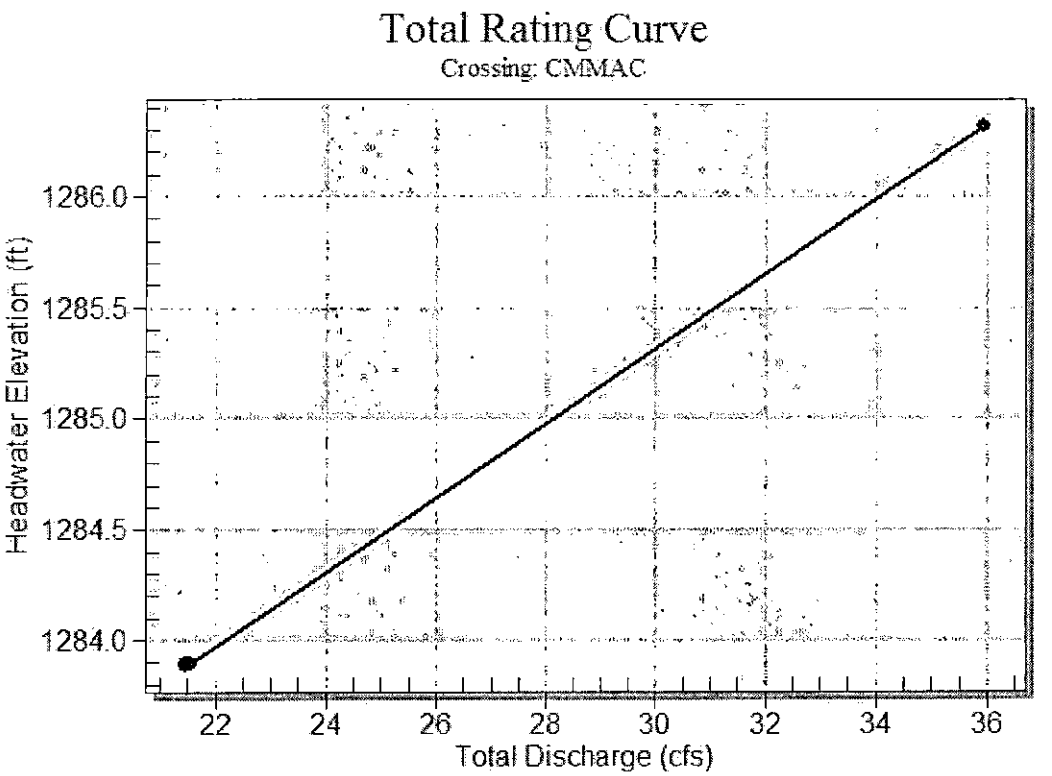


Table 2 - Culvert Summary Table: CMMAC 36x22

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
21.45	21.45	1283.89	2.151	2.220	3-M2t	1.850	1.206	1.270	0.850	6.269	0.000
21.46	21.46	1283.89	2.152	2.221	3-M2t	1.850	1.206	1.270	0.850	6.272	0.000
21.47	21.47	1283.89	2.153	2.222	3-M2t	1.850	1.207	1.270	0.850	6.275	0.000
21.48	21.48	1283.89	2.153	2.223	3-M2t	1.850	1.207	1.270	0.850	6.278	0.000
21.49	21.49	1283.89	2.154	2.224	3-M2t	1.850	1.207	1.270	0.850	6.281	0.000
21.50	21.50	1283.89	2.155	2.224	3-M2t	1.850	1.208	1.270	0.850	6.284	0.000
21.51	21.51	1283.90	2.156	2.225	3-M2t	1.850	1.208	1.270	0.850	6.287	0.000
21.52	21.52	1283.90	2.157	2.226	3-M2t	1.850	1.208	1.270	0.850	6.290	0.000
21.53	21.53	1283.90	2.158	2.227	3-M2t	1.850	1.208	1.270	0.850	6.293	0.000
21.54	21.54	1283.90	2.159	2.228	3-M2t	1.850	1.209	1.270	0.850	6.296	0.000
21.55	21.55	1283.90	2.160	2.228	3-M2t	1.850	1.209	1.270	0.850	6.299	0.000

****

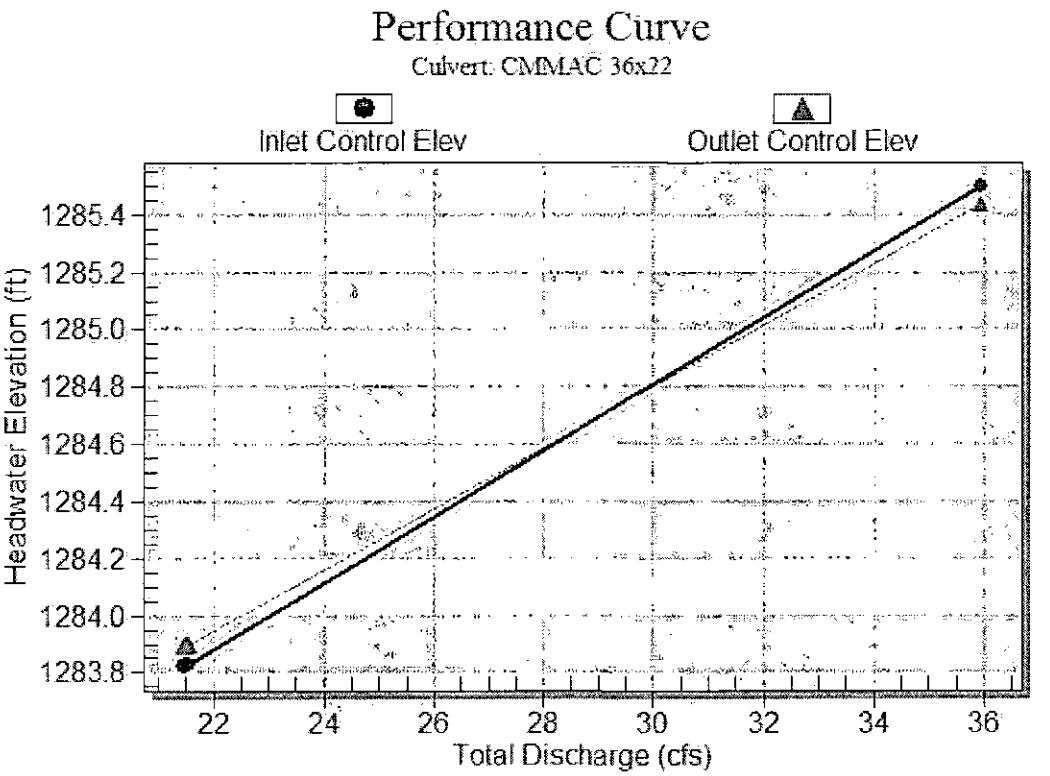
Straight Culvert

Inlet Elevation (invert): 1281.67 ft, Outlet Elevation (invert): 1281.64 ft

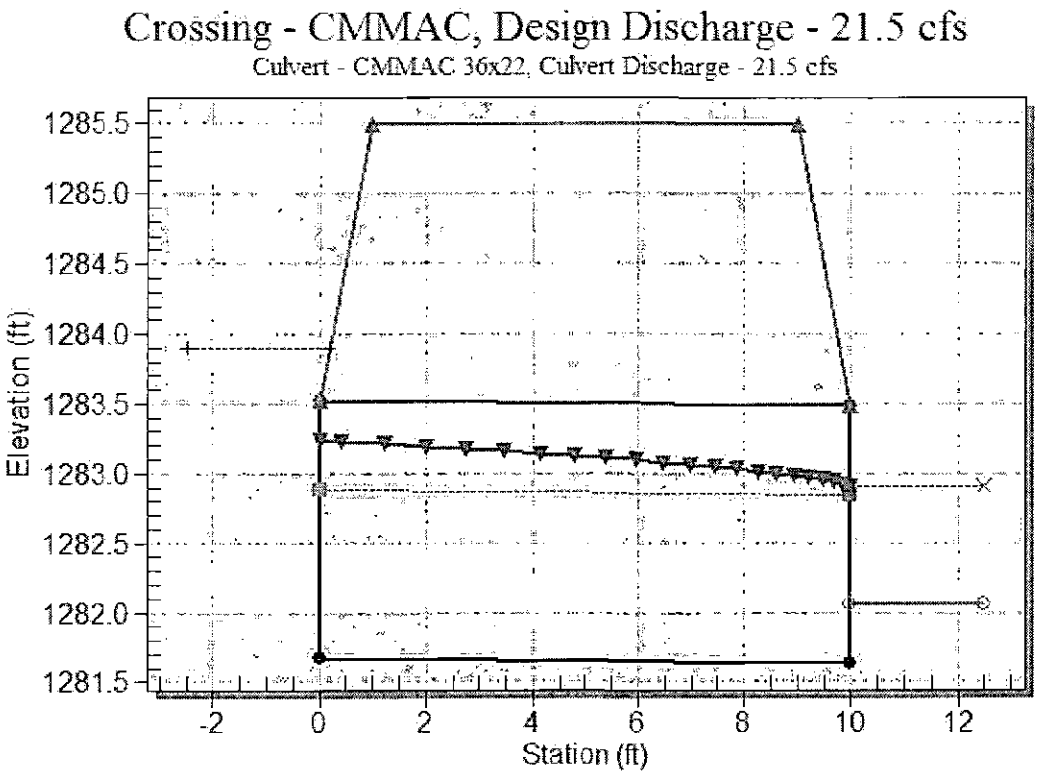
Culvert Length: 10.00 ft, Culvert Slope: 0.0030

****

Culvert Performance Curve Plot: CMMAC 36x22



Water Surface Profile Plot for Culvert: CMMAC 36x22



Site Data - CMMAC 36x22

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1281.67 ft

Outlet Station: 10.00 ft

Outlet Elevation: 1281.64 ft

Number of Barrels: 1

Culvert Data Summary - CMMAC 36x22

Barrel Shape: Pipe Arch

Barrel Span: 36.10 in

Barrel Rise: 22.20 in

Barrel Material: Steel or Aluminum

Embedment: 0.00 in

Barrel Manning's n: 0.0250

Culvert Type: Straight

Inlet Configuration: Headwall

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: CMMAC)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
21.45	1282.91	0.85
21.46	1282.91	0.85
21.47	1282.91	0.85
21.48	1282.91	0.85
21.49	1282.91	0.85
21.50	1282.91	0.85
21.51	1282.91	0.85
21.52	1282.91	0.85
21.53	1282.91	0.85
21.54	1282.91	0.85
21.55	1282.91	0.85

Tailwater Channel Data - CMMAC

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 1282.91 ft

Roadway Data for Crossing: CMMAC

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 ft

Crest Elevation: 1285.50 ft

Roadway Surface: Paved

Roadway Top Width: 8.00 ft

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 21.5 cfs

Design Flow: 21.5 cfs

Maximum Flow: 21.5 cfs

Table 4 - Summary of Culvert Flows at Crossing: RCB

Headwater Elevation (ft)	Total Discharge (cfs)	RCB 3x2 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1284.16	21.50	21.50	0.00	1
1285.50	33.48	33.48	0.00	Overtopping

Rating Curve Plot for Crossing: RCB

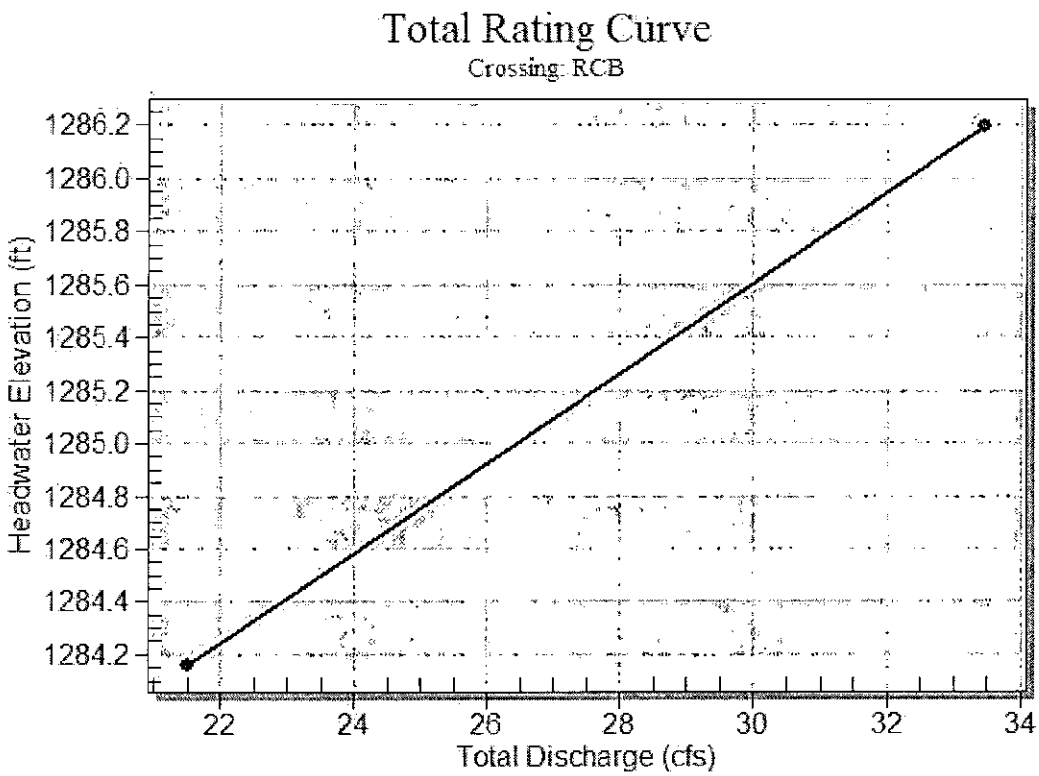


Table 5 - Culvert Summary Table: RCB 3x2

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926
21.50	21.50	1284.16	1.980	2.271	4-FFf	1.436	1.168	2.000	2.216	3.583	4.926

****

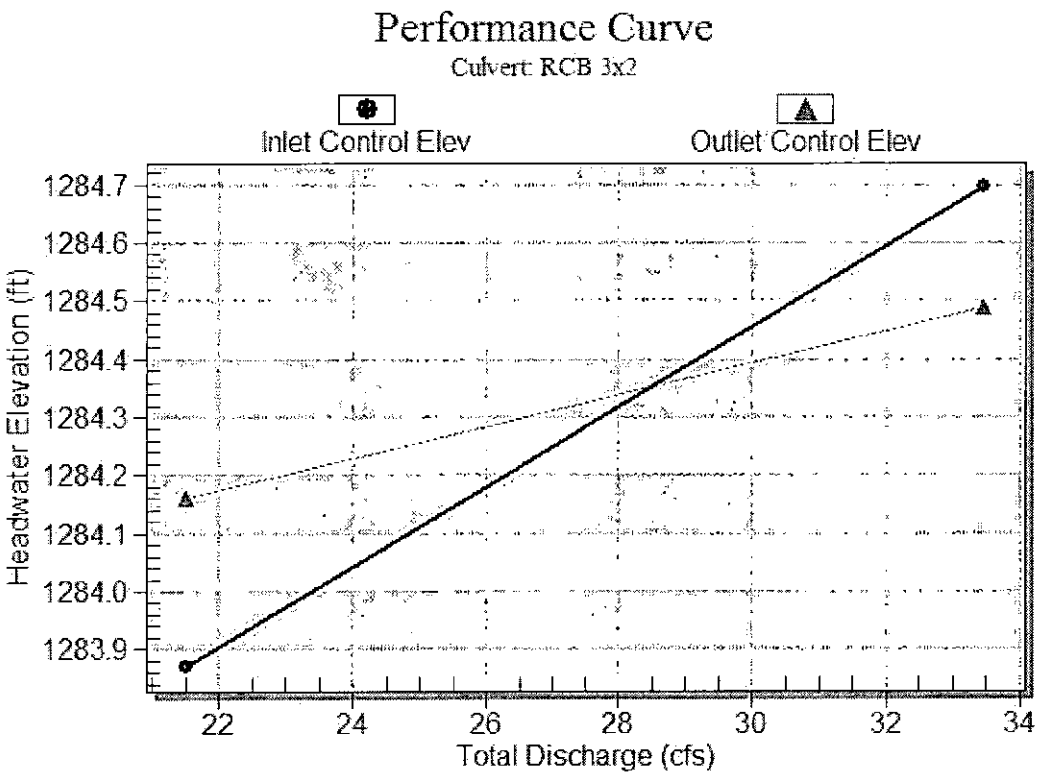
Straight Culvert

Inlet Elevation (invert): 1281.89 ft, Outlet Elevation (invert): 1281.67 ft

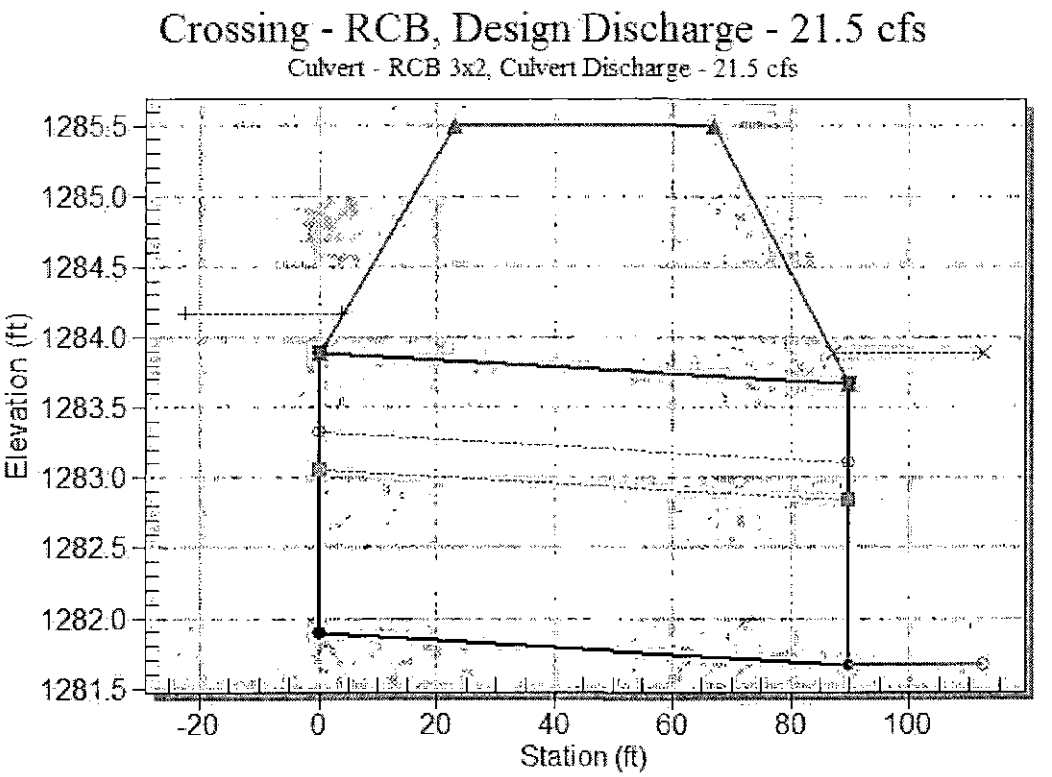
Culvert Length: 90.00 ft, Culvert Slope: 0.0024

****

Culvert Performance Curve Plot: RCB 3x2



Water Surface Profile Plot for Culvert: RCB 3x2



Site Data - RCB 3x2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1281.89 ft

Outlet Station: 90.00 ft

Outlet Elevation: 1281.67 ft

Number of Barrels: 1

Culvert Data Summary - RCB 3x2

Barrel Shape: Concrete Box

Barrel Span: 3.00 ft

Barrel Rise: 2.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: NONE

Table 6 - Downstream Channel Rating Curve (Crossing: RCB)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58
21.50	1283.89	2.22	4.93	0.41	0.58

Tailwater Channel Data – RCB*

Tailwater Channel Option: Rectangular Channel

Bottom Width: 1.97 ft

Channel Slope: 0.0030

Channel Manning's n: 0.0128

Channel Invert Elevation: 1281.67 ft

Roadway Data for Crossing: RCB

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 ft

Crest Elevation: 1285.50 ft

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

*NOTE:

The tailwater channel data listed above was created to mimic the actual HW elevation and velocity in the downstream CMMAC. In order for HY-8 to correctly calculate the outlet losses at the intermediate culvert junctions an upstream velocity and downstream velocity are needed. Current limitations within the program require the tailwater data to be input as a channel section for calculation of the downstream velocity. Therefore a rectangular channel was selected and the channel width and manning's "n" were manipulated to result in a downstream tailwater elevation and velocity that matched the HW and velocity from the downstream CMMAC, by continuity, at the selected flow rate of 21.5 cfs.

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 21.45 cfs

Design Flow: 21.5 cfs

Maximum Flow: 21.55 cfs

Table 7 - Summary of Culvert Flows at Crossing: Elliptical

Headwater Elevation (ft)	Total Discharge (cfs)	Elliptical 36x24 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1284.25	21.45	21.45	0.00	1
1284.25	21.46	21.46	0.00	1
1284.25	21.47	21.47	0.00	1
1284.25	21.48	21.48	0.00	1
1284.25	21.49	21.49	0.00	1
1284.25	21.50	21.50	0.00	1
1284.25	21.51	21.51	0.00	1
1284.25	21.52	21.52	0.00	1
1284.25	21.53	21.53	0.00	1
1284.26	21.54	21.54	0.00	1
1284.26	21.55	21.55	0.00	1
1285.50	33.52	33.52	0.00	Overtopping

Rating Curve Plot for Crossing: Elliptical

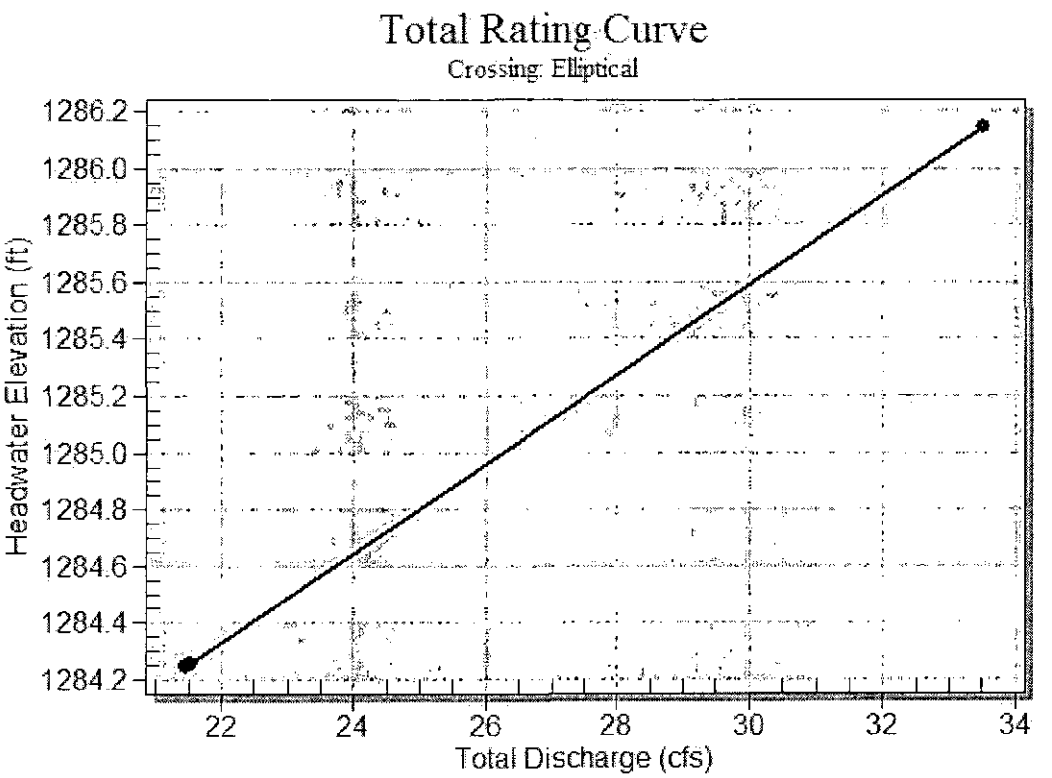


Table 8 - Culvert Summary Table: Elliptical 36x24

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
21.45	21.45	1284.25	1.928	2.327	4-FFf	1.552	1.302	2.000	2.264	4.389	3.575
21.46	21.46	1284.25	1.928	2.328	4-FFf	1.553	1.302	2.000	2.265	4.391	3.576
21.47	21.47	1284.25	1.929	2.329	4-FFf	1.553	1.302	2.000	2.266	4.393	3.576
21.48	21.48	1284.25	1.930	2.330	4-FFf	1.554	1.302	2.000	2.267	4.395	3.576
21.49	21.49	1284.25	1.930	2.331	4-FFf	1.554	1.303	2.000	2.267	4.398	3.577
21.50	21.50	1284.25	1.931	2.332	4-FFf	1.555	1.303	2.000	2.268	4.400	3.577
21.51	21.51	1284.25	1.931	2.333	4-FFf	1.556	1.303	2.000	2.269	4.402	3.577
21.52	21.52	1284.25	1.932	2.334	4-FFf	1.556	1.304	2.000	2.270	4.404	3.578
21.53	21.53	1284.25	1.932	2.335	4-FFf	1.557	1.304	2.000	2.271	4.406	3.578
21.54	21.54	1284.26	1.933	2.336	4-FFf	1.558	1.304	2.000	2.272	4.408	3.578
21.55	21.55	1284.26	1.933	2.337	4-FFf	1.558	1.305	2.000	2.272	4.410	3.579

****

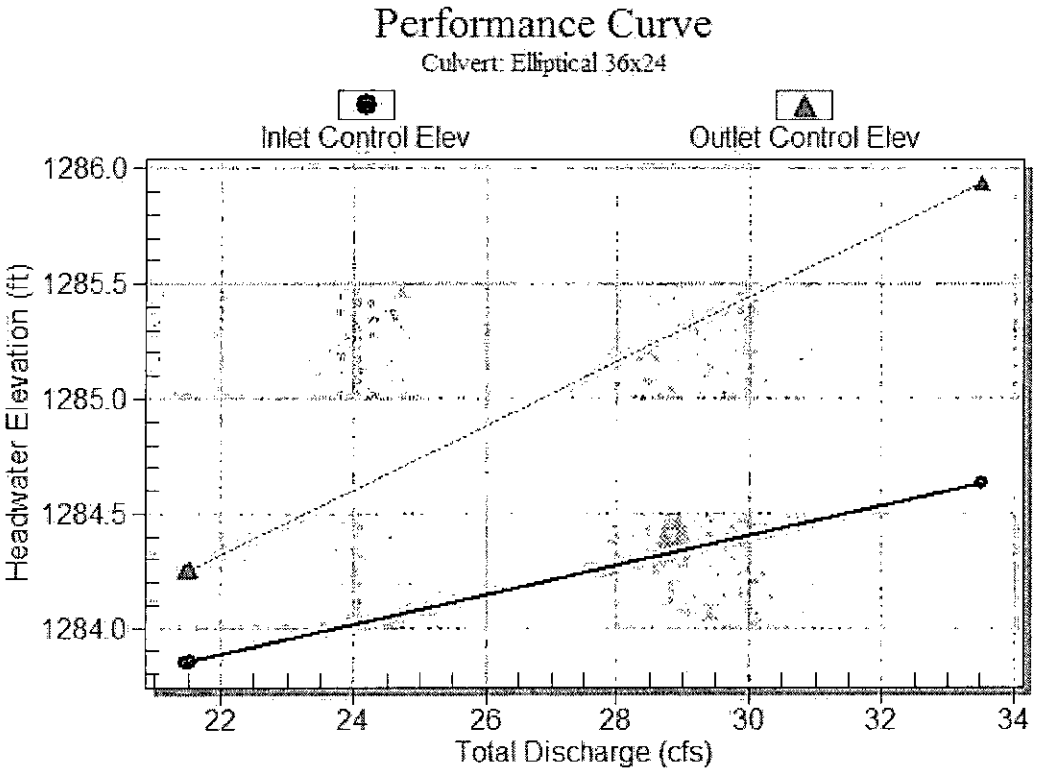
Straight Culvert

Inlet Elevation (invert): 1281.92 ft, Outlet Elevation (invert): 1281.89 ft

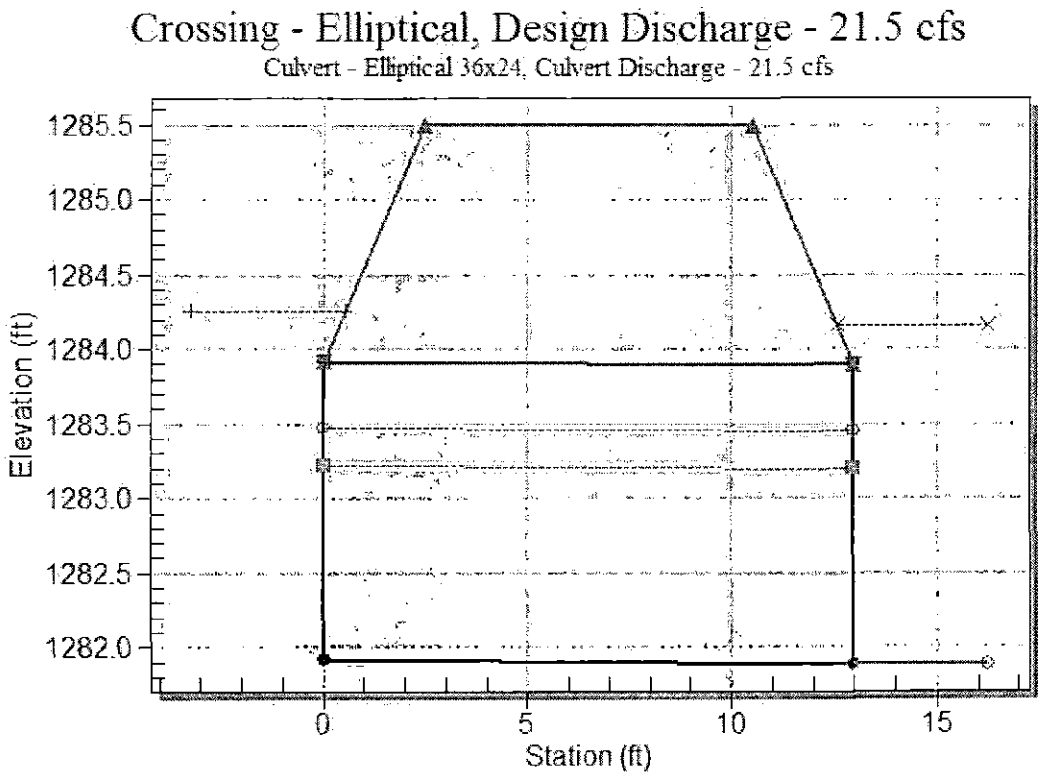
Culvert Length: 13.00 ft, Culvert Slope: 0.0023

****

Culvert Performance Curve Plot: Elliptical 36x24



Water Surface Profile Plot for Culvert: Elliptical 36x24



Site Data - Elliptical 36x24

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1281.92 ft

Outlet Station: 13.00 ft

Outlet Elevation: 1281.89 ft

Number of Barrels: 1

Culvert Data Summary - Elliptical 36x24

Barrel Shape: Elliptical

Barrel Span: 38.00 in

Barrel Rise: 24.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Grooved Edge Projecting

Inlet Depression: NONE

Table 9 - Downstream Channel Rating Curve (Crossing: Elliptical)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
21.45	1284.15	2.26	3.58	0.42	0.42
21.46	1284.15	2.26	3.58	0.42	0.42
21.47	1284.16	2.27	3.58	0.42	0.42
21.48	1284.16	2.27	3.58	0.42	0.42
21.49	1284.16	2.27	3.58	0.42	0.42
21.50	1284.16	2.27	3.58	0.42	0.42
21.51	1284.16	2.27	3.58	0.42	0.42
21.52	1284.16	2.27	3.58	0.42	0.42
21.53	1284.16	2.27	3.58	0.43	0.42
21.54	1284.16	2.27	3.58	0.43	0.42
21.55	1284.16	2.27	3.58	0.43	0.42

Tailwater Channel Data – Elliptical*

Tailwater Channel Option: Rectangular Channel

Bottom Width: 2.65 ft

Channel Slope: 0.0030

Channel Manning's n: 0.0202

Channel Invert Elevation: 1281.89 ft

Roadway Data for Crossing: Elliptical

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 20.00 ft

Crest Elevation: 1285.50 ft

Roadway Surface: Paved

Roadway Top Width: 8.00 ft

*NOTE:

The tailwater channel data listed above was created to mimic the actual HW elevation and velocity in the downstream RCB. In order for HY-8 to correctly calculate the outlet losses at the intermediate culvert junctions an upstream velocity and downstream velocity are needed. Current limitations within the program require the tailwater data to be input as a channel section for calculation of the downstream velocity. Therefore a rectangular channel was selected and the channel width and manning's "n" were manipulated to result in a downstream tailwater elevation and velocity that matched the HW and velocity from the downstream RCB, by continuity, at the selected flow rate of 21.5 cfs.

HY-8 Culvert Analysis Report

QuikTrip Entrance

10.22.13

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 0 cfs

Design Flow: 10.2 cfs

Maximum Flow: 15 cfs

Note: The drainage basin for this culvert produces a Q_{100} = 10.2 cfs. The adjacent basin produces a Q100 = 26.3 cfs of which 21.5 cfs passes under K-15 prior to topping the berm separating the K-15 basin from the residential basin. Therefore the entrance culvert was sized to handle Q100=15.0 cfs {10.2 + (26.3 – 21.5)}.

Table 1 - Summary of Culvert Flows at Crossing: Crossing 1

Headwater Elevation (ft)	Total Discharge (cfs)	ent3824_5 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1281.27	0.00	0.00	0.00	1
1281.75	1.50	1.50	0.00	1
1281.95	3.00	3.00	0.00	1
1282.12	4.50	4.50	0.00	1
1282.26	6.00	6.00	0.00	1
1282.38	7.50	7.50	0.00	1
1282.50	9.00	9.00	0.00	1
1282.59	10.20	10.20	0.00	1
1282.72	12.00	12.00	0.00	1
1282.83	13.50	13.50	0.00	1
1282.93	15.00	15.00	0.00	1
1285.50	46.04	46.04	0.00	Overtopping

Rating Curve Plot for Crossing: Crossing 1

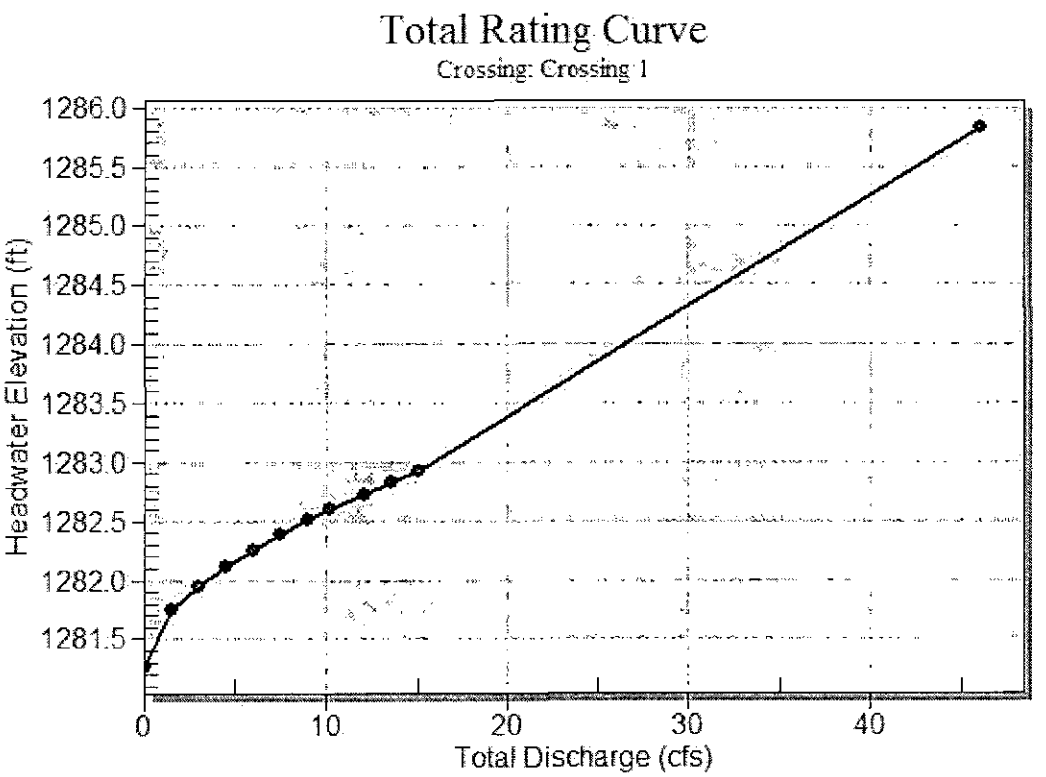


Table 2 - Culvert Summary Table: ent3824_5

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
0.00	0.00	1281.27	0.000	0.000	0-NF	0.000	0.000	0.000	0.000	0.000	0.000
1.50	1.50	1281.75	0.413	0.483	2-M2c	0.420	0.319	0.319	0.191	2.733	1.652
3.00	3.00	1281.95	0.595	0.683	2-M2c	0.598	0.453	0.453	0.282	3.320	2.072
4.50	4.50	1282.12	0.742	0.847	2-M2c	0.742	0.563	0.563	0.353	3.698	2.351
6.00	6.00	1282.26	0.865	0.986	2-M2c	0.866	0.654	0.654	0.413	4.034	2.567
7.50	7.50	1282.38	0.979	1.114	2-M2c	0.983	0.736	0.736	0.466	4.315	2.743
9.00	9.00	1282.50	1.114	1.233	2-M2c	1.096	0.815	0.815	0.514	4.532	2.894
10.20	10.20	1282.59	1.217	1.324	2-M2c	1.183	0.874	0.874	0.549	4.703	3.000
12.00	12.00	1282.72	1.356	1.453	2-M2c	1.315	0.954	0.954	0.597	4.954	3.143
13.50	13.50	1282.83	1.461	1.556	2-M2c	1.428	1.015	1.015	0.635	5.167	3.250
15.00	15.00	1282.93	1.558	1.656	2-M2c	1.555	1.072	1.072	0.670	5.372	3.348

****

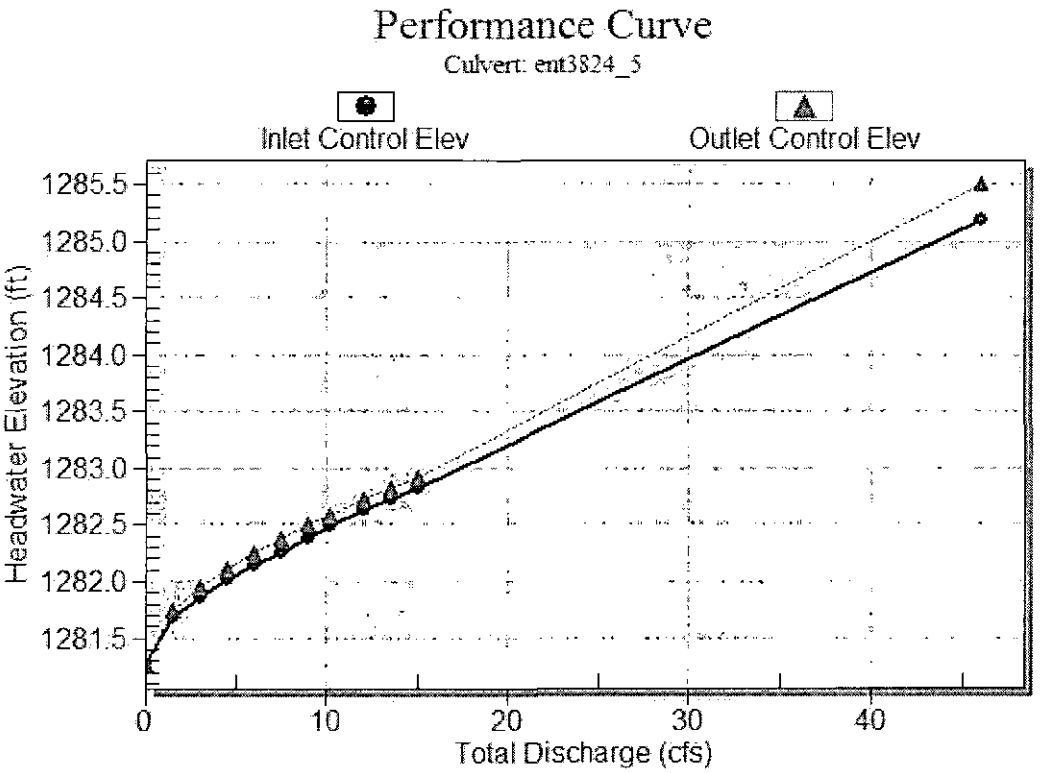
Straight Culvert

Inlet Elevation (invert): 1281.27 ft, Outlet Elevation (invert): 1281.17 ft

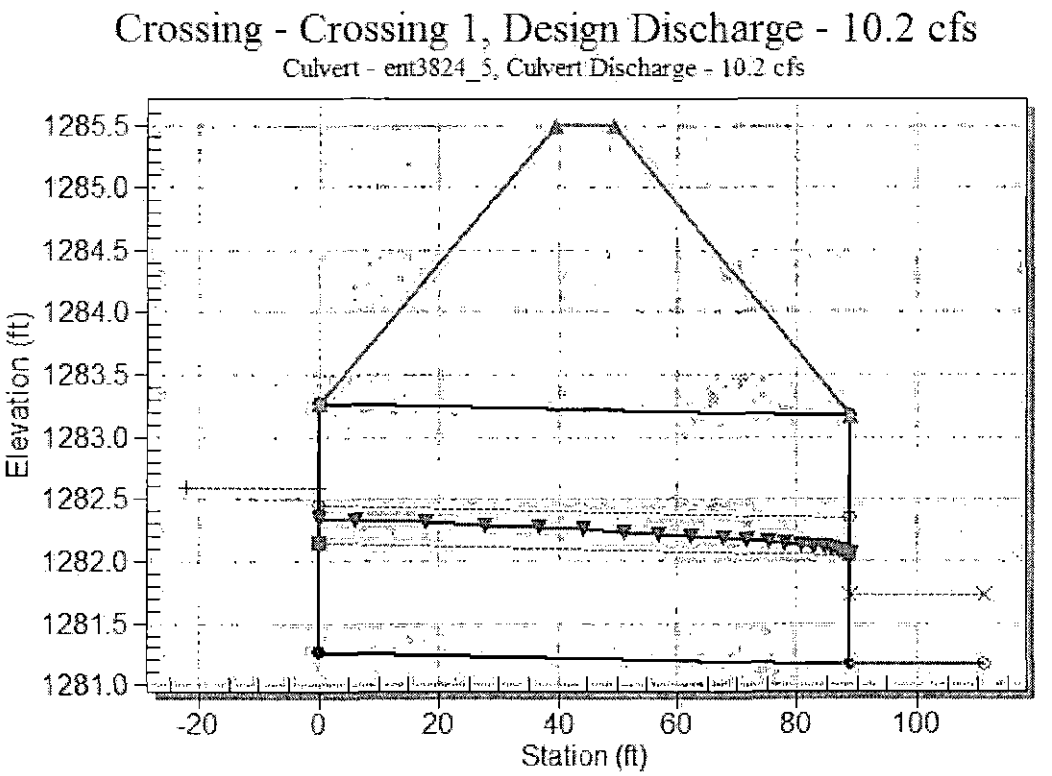
Culvert Length: 89.00 ft, Culvert Slope: 0.0011

****

Culvert Performance Curve Plot: ent3824_5



Water Surface Profile Plot for Culvert: ent3824_5



Site Data - ent3824_5

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1281.27 ft

Outlet Station: 89.00 ft

Outlet Elevation: 1281.17 ft

Number of Barrels: 1

Culvert Data Summary - ent3824_5

Barrel Shape: Elliptical

Barrel Span: 38.00 in

Barrel Rise: 24.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Grooved Edge Projecting

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: Crossing 1)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
0.00	1281.17	0.00	0.00	0.00	0.00
1.50	1281.36	0.19	1.65	0.02	0.72
3.00	1281.45	0.28	2.07	0.04	0.76
4.50	1281.52	0.35	2.35	0.04	0.78
6.00	1281.58	0.41	2.57	0.05	0.80
7.50	1281.64	0.47	2.74	0.06	0.81
9.00	1281.68	0.51	2.89	0.06	0.82
10.20	1281.72	0.55	3.00	0.07	0.83
12.00	1281.77	0.60	3.14	0.07	0.84
13.50	1281.81	0.64	3.25	0.08	0.85
15.00	1281.84	0.67	3.35	0.08	0.85

Tailwater Channel Data - Crossing 1

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.00 ft

Side Slope (H:V): 4.00 (_:1)

Channel Slope: 0.0020

Channel Manning's n: 0.0120

Channel Invert Elevation: 1281.17 ft

Roadway Data for Crossing: Crossing 1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 50.00 ft

Crest Elevation: 1285.50 ft

Roadway Surface: Gravel

Roadway Top Width: 10.00 ft