East Park Greenway Underpass & Drainage Plan at the Union Pacific Railroad

September 2022

CHEYENNE MPO

SUMMIT ENGINEERING

Disclaimer Notice

The preparation of this report has been finances in part through grant(s) from the Federal Highway Administration and Federal Transit Administration, U.S. Department of Transportation, under the State Planning and Research Program, Section 505 [of Metropolitan Planning Program, Section 104(f)] of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official views or policy of the U.S. Department of Transportation.

Partners

Cheyenne Metropolitan Planning Organization
2101 O'Neil Avenue
Cheyenne, WY

City of Cheyenne
2101 O'Neil Avenue
Cheyenne, WY

Summit Engineering
5907 Townsend Place
Cheyenne, WY

GLM Design Group
P.O. Box 20505
Cheyenne, WY

Lithos Engineering
5205 S. College Ave. Ste. B
Fort Collins, CO

Martin-Martin, Wyoming
4020 Laramie St.
Cheyenne, WY

360 Rail Services
7800 E. Dorado Place, Ste. 280
Englewood, CO 80111

Contents

Appendices

Executive Summary

Purpose

The City of Cheyenne continues to expand eastward. As the City expands so should the recreational amenities. The City purchased the East Park land in 2020 with sixth-penny sales tax funds approved by Laramie County voters. In July of 2022 the park was renamed Kiwanis Park. The purpose of this study is two-fold:

- Identify a route for the Greater Cheyenne Greenway through Kiwanis Park and across the Union Pacific Railroad (UPRR) to join with the planned LEADS Trail along Campstool Road.
- Explore the potential for reducing the buildup of stormwater along the north side of the Union Pacific Railroad Embankment and improve flood mitigation for surrounding properties.

The Kiwanis Park land plays a significant role in the Lower Dry Creek Drainage Basin as it serves as a detention storage area. Runoff is detained until it is able to pass through the Union Pacific Railroad Embankment via a masonry arch structure constructed for this purpose in 1903. The figure below shows the extent of the FEMA floodplain and floodway in this area.

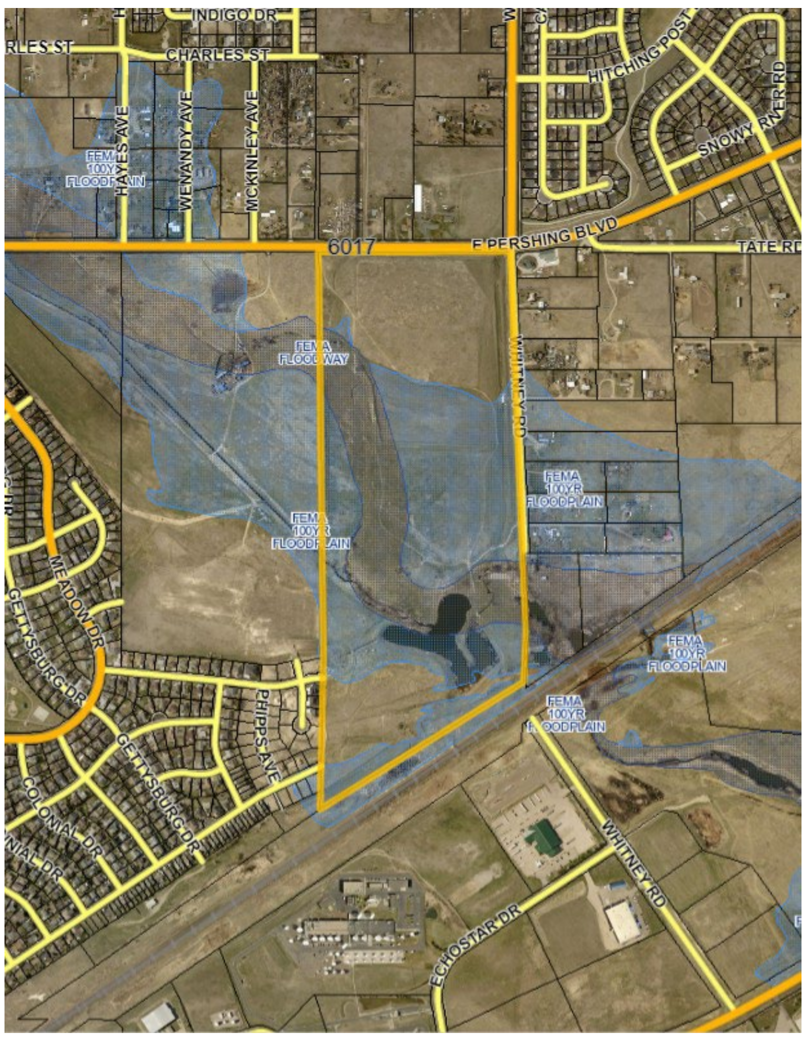


Figure 1: FEMA Floodway and Floodplain at Kiwanis Park

Considerations

Providing a route for the Greenway across the UPRR tracks requires either a pedestrian overpass or a pedestrian underpass. If the sole purpose of this project was to provide a Greenway crossing then both an overpass option and an underpass option would be equally considered. However, the purpose of this study is to also identify ways to reduce the floodway footprint and reduce the buildup of stormwater along the UPRR embankment. Impoundment of storm water against this embankment, which was neither designed nor constructed with such impoundment in mind, is a safety concern should the embankment fail during a significant storm event.

Additionally, this land holds a significant interest to history and railroad enthusiasts as the original transcontinental rail bed was constructed here in the 1870's as part of the Pacific Railroad Acts of 1862. Remnants of this original embankment are located inside Kiwanis Park.

Explored Alternatives

The alternatives explored were predicated on two main factors:

- Incorporating the existing remnants of the transcontinental rail bed into a berm to serve as the downstream side of the detention pond to keep stormwater impoundment off of the UPRR embankment.
- Utilizing the existing masonry arch structure, constructed in 1903, as a pedestrian underpass for the Greenway, thereby allowing public access to this historically significant structure. Utilizing this structure for pedestrians requires that new culverts be installed through the UPRR embankment for use as drainage conveyance. The UPRR requires that any culvert / structure that passes under their tracks be hydraulically isolated from inundation of storm water during a 100-year frequency storm event if it will be used as a pedestrian underpass.

Figure 2: 1903 Structure constructed for Drainage Conveyance

The first alternative kept the footprint of the proposed berm smaller, both within the Kiwanis Park land and including only a small portion within private property to the east. The private property which would be impacted is located within the FEMA floodplain and acts as a retention pond currently. This alternative did not provide enough stormwater storage area upstream of the UPRR tracks. It would require significantly more storm water to pass through the embankment to keep the limits of the floodplain upstream of Kiwanis Park to existing conditions. Passing the additional stormwater through the embankment would require that this flow be mitigated by improvements made to the land and culverts downstream, including within the Laramie County Conservation District Managed LEADS property; under Campstool Road; through the Cheyenne Business Parkway, 8th Filing, Lot 2, Block 1; under Interstate 80; and potentially further downstream.

The second, preferred, alternative will expand the berm into the adjacent two private properties to increase the Lower Dry Creek detention storage volume over that which was available in the first alternative. The City of Cheyenne is currently pursuing the purchase of these two properties.

Conclusion

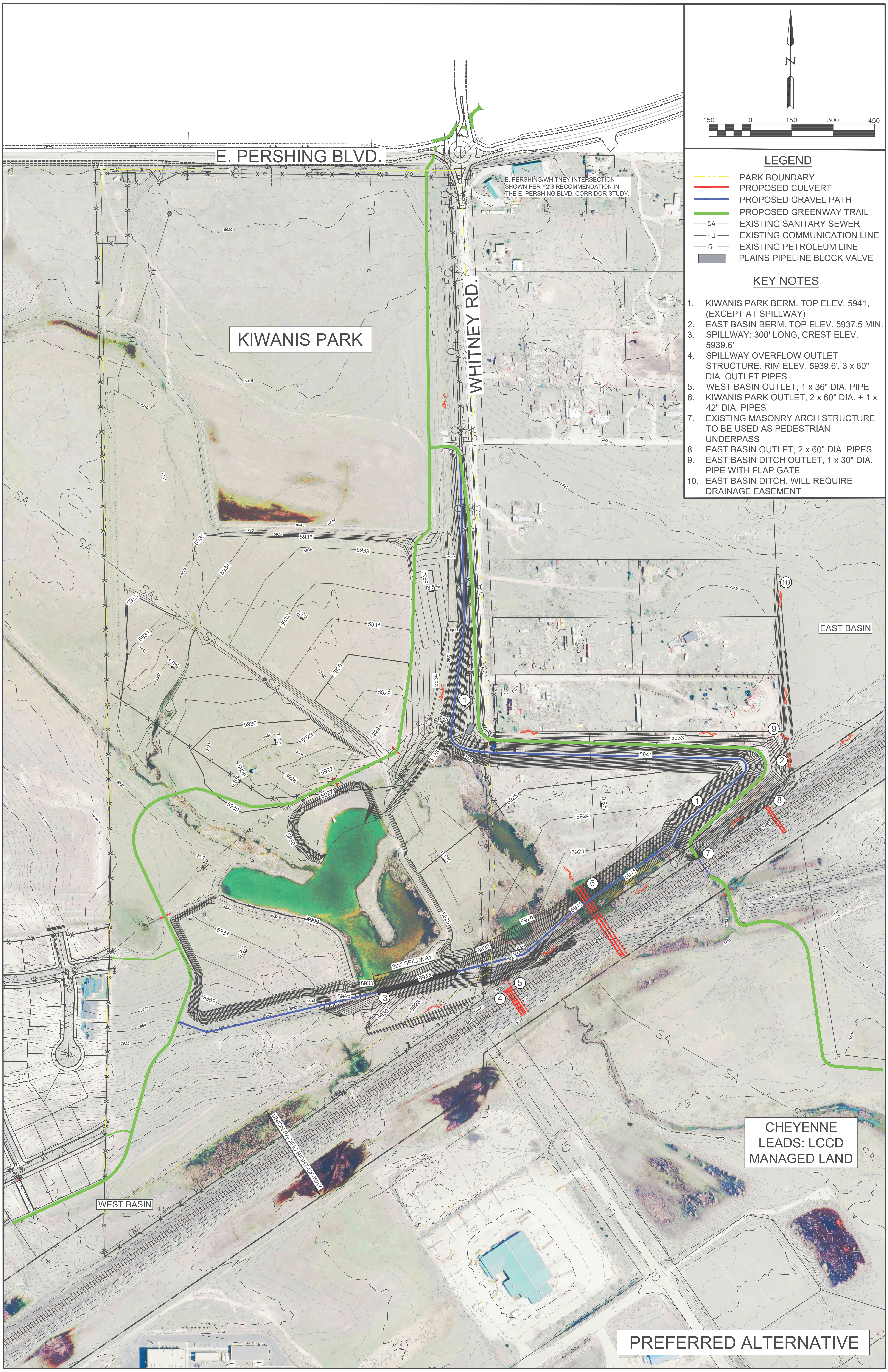
The Hydraulics and Hydrology study done by GLM Group concludes that construction of a berm within both Kiwanis Park and the adjacent properties, installation of drainage culverts through the UPRR embankment, and construction of a second berm and additional culvert to address stormwater coming to the site from east of Whitney Road, will hydraulically isolate the masonry arch structure such that it can be used as a pedestrian underpass. This design meets the project goals of removing the buildup of storm water against the UPRR embankment that comes from the Lower Dry Creek Basin north of East Pershing Boulevard. Additionally, the footprint of the floodplain, east of Whitney Road may be reduced following construction of the proposed improvements and the filing of a Letter of Map Revision with FEMA

A Greenway has been conceptually designed around East Park to connect to the existing Greenway around Saddle Ridge Subdivision at the northeast corner of the intersection of East Pershing Boulevard and Whitney Road, as well as to the proposed Greenway envisioned to enter Kiwanis Park in the southwest corner as part of the Sun Valley Connector Greenway project. The Greenway will utilize the masonry arch structure and continue through the Laramie County Conservation District Managed Cheyenne LEADS land to connect to the planned LEADS Trail along Campstool Road.

Next Steps

The implementation of this proposed design depends on the acceptance by the UPRR as it not only requires construction to take place within their right of way to construct the berm and to bore the proposed culverts through their embankment, but also to utilize the masonry arch structure as a pedestrian underpass. To move forward the City of Cheyenne must enter into a Preliminary Engineering (PE) Agreement with the UPRR. The PE Agreement will allow conceptual level plans, drainage report, geotechnical report, and culvert boring plans to be reviewed by UPRR or their subcontracted reviewers. A retainer must accompany the PE Agreement. The cost of the retainer will be determined by the UPRR Manager of Public Projects based on the scope of work. This particular project had a suggested retainer of $25,000 in 2021. The UPRR will bill the City of Cheyenne for actual review costs, which could be in excess of the retainer. Following acceptance of the conceptual plans the City of Cheyenne can proceed with final design plans, again to be reviewed by the UPRR, and ultimately construction if the plans are approved.

We believe this conceptual plan is a win-win for both the City of Cheyenne and the Union Pacific Railroad. Impoundment of stormwater on the UPRR embankment has reaches depths of 19 feet on multiple occasions in the past. A breach of the embankment in a large flood event would be catastrophic for downstream properties and the travelling public including traffic on Interstate 80, as well as catastrophic for the UPRR who relies on these mainline tracks for all railroad commerce into and out of Cheyenne to the east.



E. PERSHING BLVD.
WHITNEY RD.
KIWANIS PARK
E. PERSHING/WHITNEY INTERSECTION SHOWN PER Y2'S RECOMMENDATION IN THE E. PERSHING BLVD. CORRIDOR STUDY.
150 0 150 300 450
N
LEGEND
PARK BOUNDARY
PROPOSED CULVERT
PROPOSED GRAVEL PATH
PROPOSED GREENWAY TRAIL
SA EXISTING SANITARY SEWER
FO EXISTING COMMUNICATION LINE
GL EXISTING PETROLEUM LINE
PLAINS PIPELINE BLOCK VALVE
KEY NOTES
1. KIWANIS PARK BERM. TOP ELEV. 5941, (EXCEPT AT SPILLWAY)
2. EAST BASIN BERM. TOP ELEV. 5937.5 MIN.
3. SPILLWAY: 300' LONG, CREST ELEV. 5939.6'
4. SPILLWAY OVERFLOW OUTLET STRUCTURE. RIM ELEV. 5939.6', 3 x 60" DIA. OUTLET PIPES
5. WEST BASIN OUTLET, 1 x 36" DIA. PIPE
6. KIWANIS PARK OUTLET, 2 x 60" DIA. + 1 x 42" DIA. PIPES
7. EXISTING MASONRY ARCH STRUCTURE TO BE USED AS PEDESTRIAN UNDERPASS
8. EAST BASIN OUTLET, 2 x 60" DIA. PIPES
9. EAST BASIN DITCH OUTLET, 1 x 30" DIA. PIPE WITH FLAP GATE
10. EAST BASIN DITCH, WILL REQUIRE DRAINAGE EASEMENT
EAST BASIN
300' SPILLWAY
UNION PACIFIC RIGHT-OF-WAY
WEST BASIN
CHEYENNE LEADS: LCCD MANAGED LAND
PREFERRED ALTERNATIVE

East Park Greenway Underpass & Drainage Plan at the UPRR

Introduction

The City of Cheyenne continues to expand eastward. As the City expands so should recreational amenities, including City park facilities and the Greater Cheyenne Greenway. With that vision the City purchased the East Park land in 2020 with sixth-penny sales tax funds approved by Laramie County voters. In 2021, after some safety improvements were made, the park was opened to the public. The City of Cheyenne retained Russell + Mills to complete the East Cheyenne Community Park Master Plan in 2022. The Master Plan was done with consideration given to the drainage needs within East Park that were identified with this Drainage Plan. In July of 2022 the park was renamed Kiwanis Park when the Kiwanis Club pledged a financial contribution to the park as well as ongoing support and maintenance for the park.

In addition to being public open space, the Kiwanis Park land plays a significant role in the Lower Dry Creek Drainage Basin as it serves as a detention storage area. Runoff is detained until it is able to pass through the Union Pacific Railroad (UPRR) Embankment via a masonry arch structure constructed for this purpose in 1903. The City of Cheyenne has been proactive with its regulatory stance within the Dry Creek Basin by limiting stormwater discharge to the 20-year existing peak flow. However, even with this restriction in place, stormwater is impounded against the UPRR embankment during large storm events, with the impoundment measuring 19 feet deep on multiple occasions. When this embankment was constructed in the early 1900's it is very likely that it was not constructed with such impoundments in mind. A breach of the embankment in a large flood event would be catastrophic for downstream properties and the travelling public including traffic on Interstate 80 where multiple culverts exist to convey Dry Creek flows under the Interstate. Additionally, this would be catastrophic for the UPRR who relies on these mainline tracks for all railroad commerce into and out of the east side of Cheyenne.

History

The history of the project area begins with the passage of the Pacific Railroads Acts of 1862 that promoted the construction of the "transcontinental railroad" across the United States. Portions of the original transcontinental railbed, originally constructed in the 1870's still exist and are partially located within Kiwanis Park. Figure 3, on the following page, outlines the transcontinental railbed in aqua. The existing mainline tracks were constructed shortly after 1901 with the construction of the 6' x 8' masonry box arch culvert being completed in 1903. This arch culvert is depicted as a red line in Figure 3. As previously mentioned, its purpose is to convey storm water through the embankment. Previously a railroad trestle over Dry Creek was utilized by the transcontinental railroad.

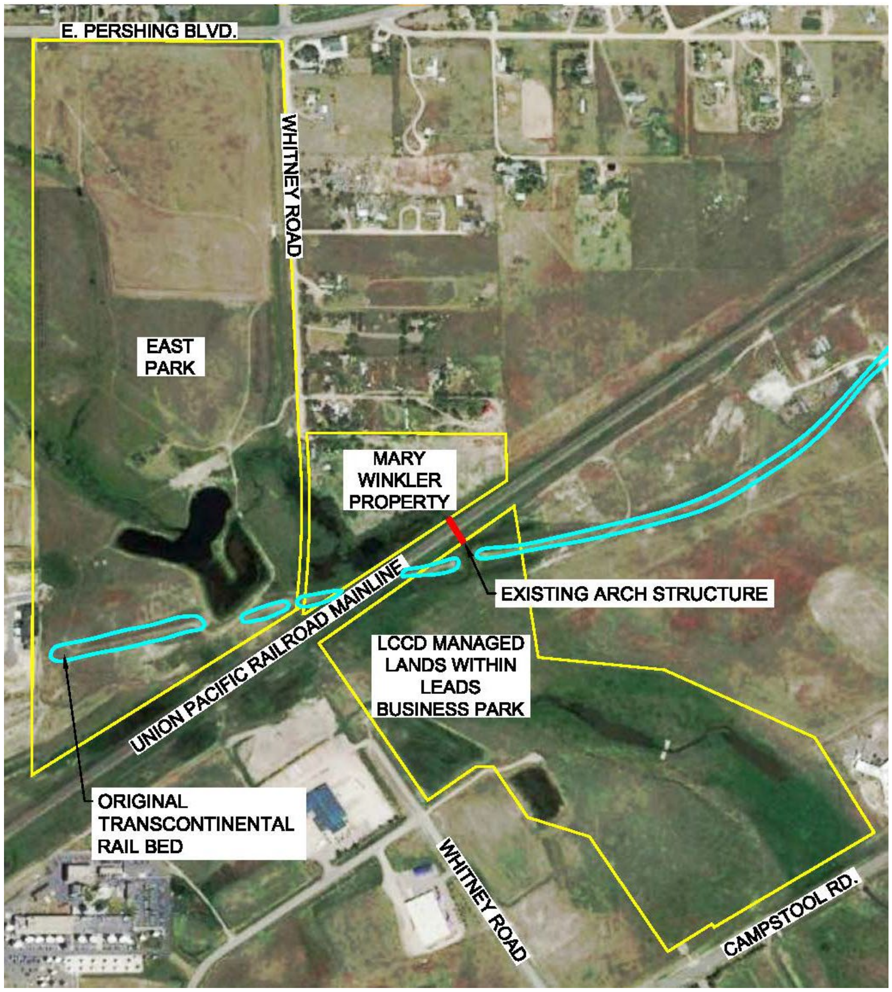


Figure 3: Vicinity Map

Purpose

The purpose of this study is two-fold:

- Identify a route for the Greater Cheyenne Greenway through Kiwanis Park and across the Union Pacific Railroad (UPRR) to join with the planned Cheyenne LEADS Trail along Campstool Road.
    - Connect the proposed Greenway through Kiwanis Park to the proposed Sun Valley Connector Greenway that will enter the park property in the southwest corner.
- Explore the potential for reducing the buildup of stormwater along the north side of the Union Pacific Railroad Embankment and improve flood mitigation for surrounding properties.

Drainage Study of UPRR Dry Creek Crossing

Overview

GLM Design Group completed the drainage study for the Union Pacific Railroad crossing of Lower Dry Creek. The complete report is included as ***Appendix A***. A summary of this report is included herein: This plan evaluated two alternatives for improvements that will remove the impoundment of storm water against the UPRR embankment by creating a bermed detention facility to detain the stormwater inside Kiwanis Park. A hydraulic analysis was done on both alternatives. In both alternatives the existing masonry arch structure was hydraulically isolated such that it could be used as a pedestrian underpass, and the north portion of Kiwanis Park was kept out of the floodplain to allow structures and park amenities to be planned in that portion of the park.

Both alternatives utilize the existing transcontinental railbed berm as the location of the new storm water detention berm. Utilizing this berm embraces the historic significance of this location. Train enthusiasts are drawn to Cheyenne because of the rich railroad history. Preserving this transcontinental railbed and incorporating it into a project that makes it publicly accessible is a great opportunity. The berm will include a gravel pathway accessible via the Greenway that will be incorporated into Kiwanis Park. From this vantage point, atop the transcontinental railbed berm, pathway users will be at the same elevation as the existing UPRR mainline tracks, but separated by a valley to the south.

Figure 4: View atop Existing Transcontinental Railbed

Alternative 1

The first alternative has a berm with a smaller footprint whereas the berm is located mainly within Kiwanis Park property and extending into the adjacent private property only within the limits of the existing low-lying ground that is almost always inundated with standing water. Figure 5 shows the extents of the berm as the magenta line; Greenway and trails are shown as orange lines; proposed culverts through the UPRR embankment are shown as red lines, the existing masonry arch structure is a dashed blue line, and a portion of the Kiwanis Park improvement area that will be outside of the floodplain is shown shaded green.

The location of the berm in this alternative restricted the amount of area available for storm water detention, and necessitated too much of an increase in flow through the culverts to Dry Creek on the south side of the UPRR embankment. This alternative causes too much water to enter the downstream system too quickly and would require extensive improvements to the downstream Dry Creek reach from the UPRR embankment to the Interstate 80 crossing and further downstream. With this alternative it isn’t feasible to simply raise the height of the berm to detain more storm water as that would cause a rise in the flood elevation on the property(ies) upstream of Kiwanis Park. For these reasons, Alternative 1 was not considered further.

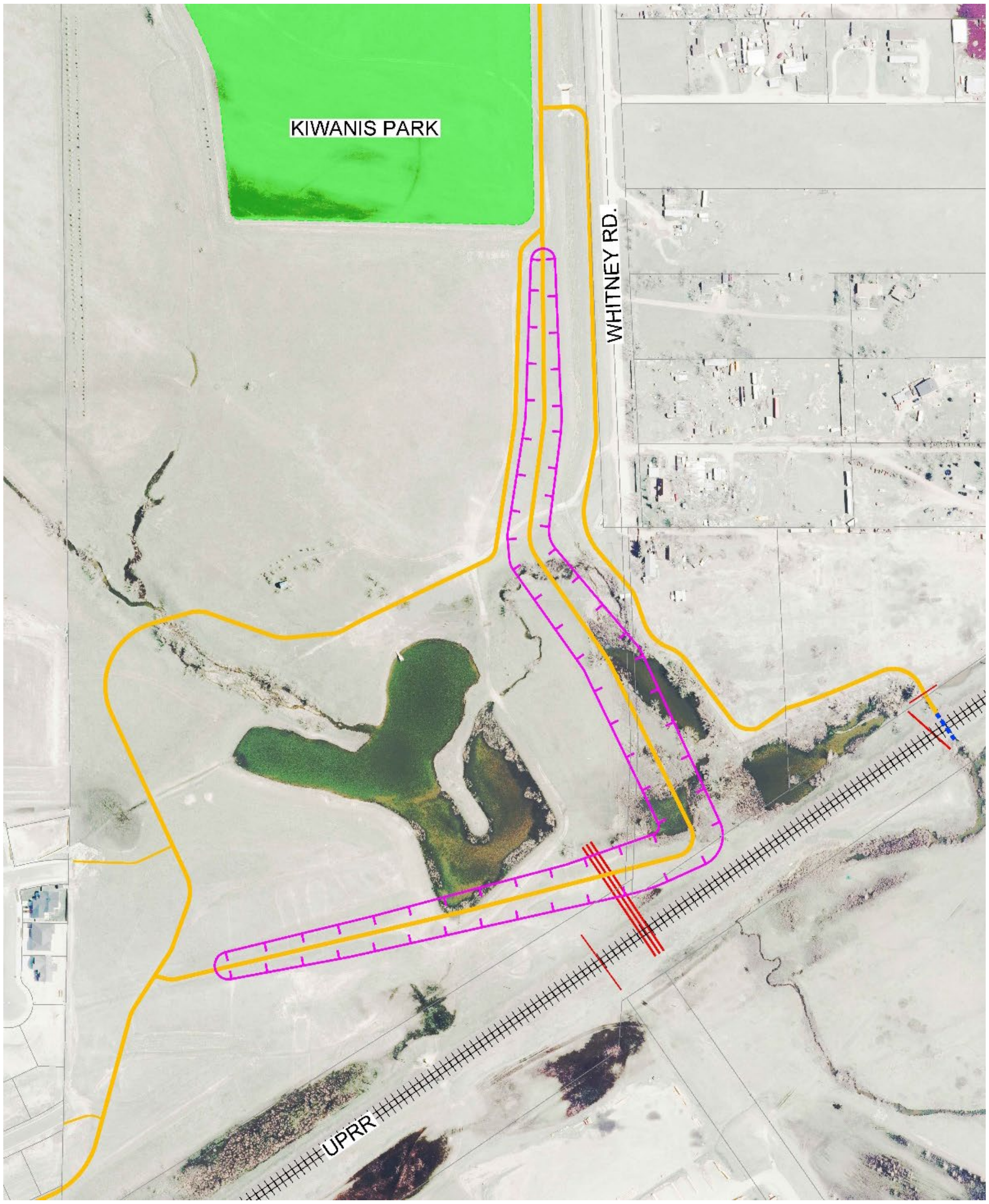


Figure 5: Alternative 1

Alternative 2

The second alternative increased the footprint of the berm by extending it almost entirely into the adjacent private properties. Both of these properties, show in Figure 6, were owned by the Mary Winkler estate. The City of Cheyenne has obtained an appraisal and is actively negotiating the purchase of these properties.

Figure 6: Privately Owned Parcels

Figure 7 shows the extents of the berm in Alternative 2 as the magenta line; Greenway and trails are shown as blue lines; culverts through the UPRR embankment are shown as red lines, and a portion of the Kiwanis Park improvement area that will be outside of the floodplain is shown shaded green.

The location of this berm increased the amount of storm water detention available and decreased the flow out of the culverts through the UPRR embankment to a manageable level. Some downstream improvements will still be required to mitigate the additional storm water flow coming through the UPRR embankment. For this reason, Alternative 2 was pursued with this plan.

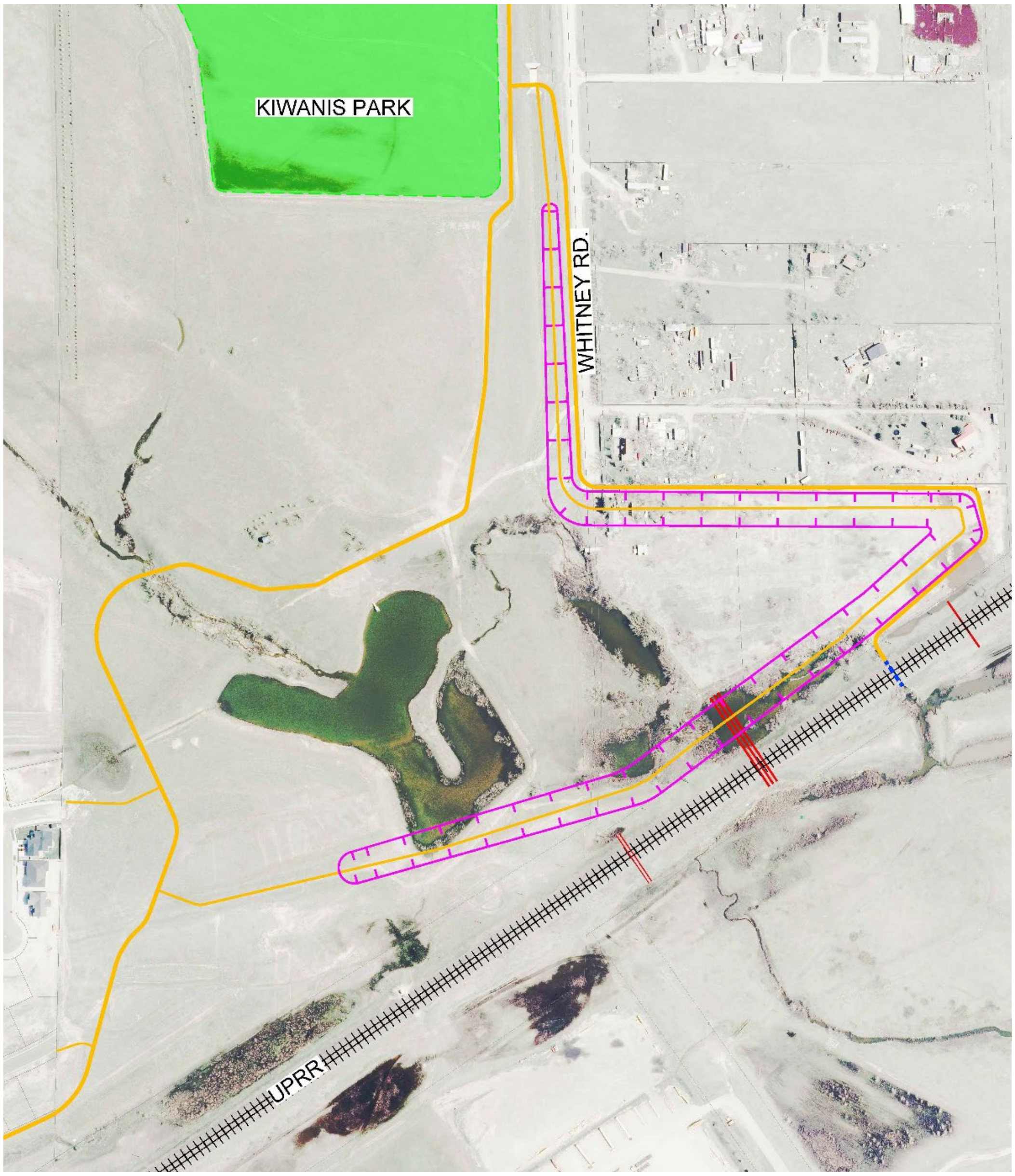


Figure 7: Alternative 2

Selected Alternative

Alternative 2 was selected because it provides a large amount of stormwater detention, it does not increase the base flood water surface elevation on upstream properties, it allows for the masonry arch structure to be hydraulically isolated for use as a pedestrian underpass, and it narrows the extents of the floodplain on adjacent properties east of Whitney Road.

The berm to be constructed will create a detention facility. This berm is an earthfill dam to be constructed using fill material that is generated from excavated on-site material as well as import structural fill. Construction of the berm will need to be monitored to ensure that it is constructed in shallow lifts of 12 inches or less, moisture conditioned, and compacted to the specifications established by a geotechnical engineer.

Two 60” diameter culverts and one 42” diameter culvert are required to be bored through the UPRR embankment to convey stormwater from Kiwanis Park to Dry Creek on the south side of the UPRR embankment. Boring large diameter pipe through a railroad embankment requires approval by the railroad, a thorough engineering evaluation of the site, and strict adherence to American Railway Engineering and Maintenance-of-Way Association (AREMA) guidelines. Lithos Engineering completed a Tunnel Feasibility Memorandum for this site. The memorandum is included as ***Appendix B***.

The height of the proposed culverts was limited to 60”. The UPRR requires continuous track monitoring during any culvert boring operation. The monitoring is done to ensure that the tracks do not settle more than ¼”. In this location there are two mainline UPRR tracks, which provide the only access to the UPRR yard from the east. Any settlement of the track or other failure during the culvert boring process would be extremely costly. The potential for settlement is reduced by increasing the distance between the top of the boring pipe and the bottom of the tracks. A suggested rule of thumb is to allow for four x the diameter of the pipe between the bottom of the track ballast and the crown of the pipe. For this reason, we have limited the pipe culverts used to a 60” diameter.

Existing conditions have stormwater directed to the masonry arch structure from not only Dry Creek, but also land to the east and west of Kiwanis Park. With the construction of a berm within Kiwanis Park stormwater from the east and west will flow toward the UPRR embankment without being detained by the proposed berm.

On the west side of the Kiwanis Park berm a detention pond will be formed between the existing UPRR embankment and the proposed berm. Storm water coming from this west basin will need to be conveyed through the UPRR embankment. A 30” diameter culvert is proposed for this purpose.

On the east side of Kiwanis Park a secondary, smaller, berm is included in the design to keep stormwater runoff from flowing onto the Greenway path from the north, east of Whitney Road. Because the masonry arch structure will need to be hydraulically isolated to be used as a pedestrian facility, it cannot be used to convey this runoff through the UPRR embankment during a 100-year frequency event. This second berm will create a smaller detention pond on the east side of the masonry arch structure. Two – 60” diameter borings are required to convey storm water from the east basin through the UPRR embankment.

As described in the drainage study completed by GLM Design Group, and included as ***Appendix A***, a spillway is also required. The spillway design must accommodate conveyance of stormwater should the culvert outlets fail or if a storm with a frequency greater than 100-year should occur.

Greater Cheyenne Greenway

Greenway Planning

The Greater Cheyenne Greenway is a recreational amenity constructed by the City of Cheyenne and developers as a 10 foot wide concrete path. The purpose is to provide a pedestrian and bicycle corridor, separated from traffic whenever feasible, to connect neighborhoods and schools around the entirety of the Greater Cheyenne area. The *Cheyenne On-Street Bicycle Plan and Greenway Plan Update*, June 2012, shows a Greenway connection at Whitney Road, East Pershing Boulevard and the Sun Valley

Connector to Kiwanis Park, as well as a Greenway connection across the UPRR between Kiwanis Park and Campstool Road.

Pedestrian Underpass of the UPRR Tracks

The City of Cheyenne will need to enter into a Professional Engineering (PE) Agreement with the UPRR to evaluate the project and to have approval to utilize the existing masonry arch structure as a pedestrian underpass. The UPRR and BNSF Railway have developed a *Guildelines for Railroad Grade Separation Projects* which provides requirements for both overpass and underpass structures for both vehicular and pedestrian use. These guidelines can be found online at https://www.bnsf.com/bnsf-resources/pdf/in-the-community/uprr-bnsf-joint-guidelines-railroad-grade-separation-projects.pdf

Figure 8: Masonry Arch Structure South Portal Looking North

The UPRR requires several items to be incorporated into the design of a pedestrian underpass structure, including lighting, fencing to keep trail users off of the tracks, and signage. 360 Rail Services has summarized these requirements in the included document *Pedestrian Underpass Requirements/Feasibility*, ***Appendix C***.

Martin/Martin completed an investigation of the masonry arch structure during this planning process to evaluate the nearly 120-year-old structure for use as a pedestrian underpass. Their investigation, *Cheyenne East Park Greenway Masonry Culvert Investigation and Assessment Report*, is included in ***Appendix D***. This investigation noted a few things that will require additional investigation including potential settlement of the southeast wingwall and a crack along the west wall face that should be monitored. They reported that the general condition of the tunnel "appears to be in good to fair condition." Patching of the masonry joints and water-proofing as needed are recommended maintenance items. The recommended clearing of overgrown vegetation at the north and south portals will occur with the construction of the Greenway. Not mentioned in their investigation, but something which needs to be done to ensure ADA accessibility through this underpass is a leveling of the floor to be in compliance with ADA slope, gap, and tripping hazard requirements.

Kiwanis Park Greenway

There is an existing Greenway located around the Saddle Ridge development at the northeast corner of the intersection of East Pershing Boulevard and Whitney Road. A Greenway is recommended with this plan to connect with that existing Greenway. The proposed Greenway will continue south from East Pershing Boulevard into Kiwanis Park where it will split at the north edge of the proposed berm. The west leg will go around the north and west sides of the existing constructed wetland and end at the western property line. From that point the Greenway is planned to continue west as the Sun Valley Connector to the existing Greenway on the east side College Drive at the Sun Valley Open Space. The east leg of the Kiwanis Park Greenway will follow the downstream side of the proposed berm around the proposed detention basin to connect to the masonry arch structure. A gravel trail is planned on top of the proposed berm around the proposed detention basin. Conceptual level plan and profiles for the concrete Kiwanis Park Greenway are included as ***Appendix E***.

The Greenway around the perimeter of the proposed berm is unique in that it will have a berm on both sides, as previously discussed, in order to hydraulically isolate the masonry arch structure from both the flow from Dry Creek as well as the storm water runoff that does not get into the proposed detention pond at Kiwanis Park but comes toward the masonry arch structure from east of Whitney Road. This section of Greenway needs to be designed to drain to one side where a small ditch is also constructed to carry stormwater that falls directly onto the Greenway or the adjacent berm slopes.   This runoff will flow through the masonry arch structure.

Consideration needs to be given to the maintenance needs of a Greenway between two berms. As shown on the plan and profile sheets a wider area has been designed where the Greenway circles around the perimeter of the berm and heads back southwest toward the masonry arch structure. This area can be used to store snow that is plowed off of the Greenway. Currently a passenger truck is used to plow snow on the Greenway. The masonry arch structure is only 6' wide and will not accommodate vehicles. Therefore, an area has been designed near the opening of the arch structure that will accommodate a Y-turn made by a passenger truck for the purpose of backing up and driving back up the Greenway toward Whitney Road.

Signage will be required along this portion of the Greenway to warn users of poor sight distance around the curves as well as to encourage them to dismount their bicycles and walk through the masonry arch structure due to the reduced width.

Cheyenne Business Parkway Greenway

The Greenway going through the masonry arch tunnel will emerge from the underpass into the Laramie County Conservation District managed lands within the LEADS Cheyenne Business Parkway. This nearly 65-acre parcel through which Dry Creek flows has been dedicated as open space. Cheyenne LEADS is planning a 10' wide concrete trail to be constructed on the north side of Campstool Road between Whitney Road and the east side of the Lowes Distribution Center. The Greenway will continue south from the masonry arch structure along the eastern side of the parcel where it will connect to the proposed LEADS trail along Campstool Road.

Next Steps

UPRR Approval

The implementation of this proposed design depends on the acceptance by the Union Pacific Railroad, as it not only requires construction to take place within their right of way to construct the berm and to bore the proposed culverts through their embankment, but also to utilize the masonry arch structure as a pedestrian underpass. To move forward the City of Cheyenne must enter into a Preliminary Engineering (PE) Agreement with the UPRR. The PE Agreement will allow conceptual level plans, drainage report, geotechnical report, and culvert boring plans to be reviewed by UPRR or their subcontracted reviewers. A monetary retainer must accompany the PE Agreement. The UPRR will bill the City of Cheyenne for actual review costs, which could be in excess of the retainer amount. Following acceptance of the conceptual plans the City of Cheyenne can proceed with final design plans, again to be reviewed by the UPRR, and ultimately construction if the plans are approved.

We believe this conceptual plan is a win-win for both the City of Cheyenne and the Union Pacific Railroad. Impoundment of stormwater on the UPRR embankment has reaches depths of 19 feet on multiple occasions in the past. A breach of the embankment in a large flood event would be catastrophic for downstream properties and the travelling public including traffic on Interstate 80, as well as catastrophic for the UPRR who relies on these mainline tracks for all railroad commerce into and out of Cheyenne to the east. The potential risk of a breach of the embankment needs to be stressed to the Union Pacific Railroad to emphasize the mutual benefit of this proposal.

Utility Investigation

There are many utilities located within the proposed project area. The scope of this study did not include utility locates. There is a potential for utilities to exist within the project area that are not shown on the conceptual design plans because they were not identified within the scope of this study. Extensive grading will be required to construct not only the berm, but to shape the land inside the detention area. The proposed grading maximizes the available storm water detention storage while preserving the north portion of Kiwanis Park for park development of structures outside of the floodplain. Impacts to existing, known utilities include:

- BOPU Sanitary Sewer Main: The intent of the proposed grading is to not remove any cover on the 30" BOPU Sanitary Sewer line. All of the existing sanitary sewer manholes within Kiwanis Park are located within the existing floodplain or floodway. These manholes will continue to be within the floodplain and should be evaluated to limit infiltration during a storm event where water is being detained in this location. Additionally, approximately 18' of fill will be placed over the 30" sanitary sewer line where the proposed berm is to be constructed over this existing main. Survey completed for the design should include invert elevations at the manholes on both the north and south side of the UPRR embankment to ensure adequate separation between the sanitary sewer main and the proposed borings through the UPRR embankment.
- Oil pipelines: two existing oil pipelines, classified as Hazardous Liquid Pipelines by the National Pipeline Mapping System, are located on the east side of the property and are depicted as the red lines in Figure 9. Fill will be placed on top of these pipelines with the construction of the berm. The location of the existing borings of these pipelines through the UPRR embankment will need to be determined to ensure adequate separation between these existing borings and

the proposed drainage culvert borings. One of these lines has existing utility markers for a petroleum pipeline owned by Plains Pipeline, L.P., the other line has existing utility markers for a crude oil pipeline owned by Suncor Energy USA Pipeline. Plains Pipeline, L.P. also has a fenced area at the south end of Whitney Road, inside an easement within Kiwanis Park containing a large valve and above ground piping. The sign on the fence says "UPRR Block Valve." The proposed berm and other grading improvements have been made to avoid this fenced area.

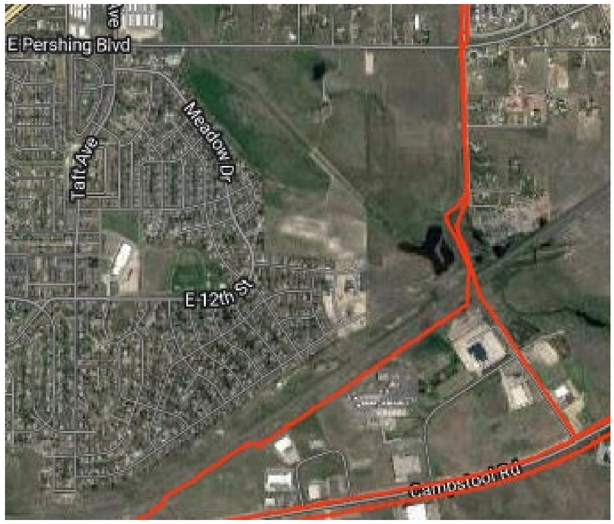


Figure 9: Hazardous Liquid Pipelines per the National Pipeline Mapping System

- Communication Lines: A portion of this property was surveyed in approximately 2010 when the constructed wetland was added to the property. The survey from that project indicates the presence of a buried communication line along the east side of the constructed wetland. There is a recorded 16' wide USWest Communications easement in this location as well as continuing north on the west side of Whitney Road to East Pershing Boulevard. Per Darrin Klawon, a Network Implementation Engineer at Lumen, this is a fiber optic line in conduit. A utility investigation and potentially potholing is recommended on this line anywhere grading will be done in its vicinity. This line is potentially located where removal of some cover is anticipated. Additionally, fill material will be placed over this potential line with the construction of the proposed berm. During final design, construction of additional conduit for future expansion by Lumen may be desired.
- Overhead Electric Lines: There in an existing overhead electric line and utility poles located within the UPRR right of way, south of Kiwanis Park property. These utility poles will be impacted by the grading proposed in this location to ensure stormwater runoff is not trapped between the proposed berm and the existing UPRR berm. Coordination with the UPRR during the PE Agreement review process to ensure these facilities remain operational for the UPRR.
- In addition to these existing utilities, the Cheyenne Board of Public Utilities (BOPU) has expressed an interest in potentially adding an additional boring through the UPRR embankment for use as a re-use water line. Coordination with the BOPU should occur during the final design process to include this boring with the UPRR Preliminary Engineering Agreement submittal. Likewise, if any improvements are desired by the BOPU on their existing 30" sanitary sewer line within the UPRR right of way, that should be included.

Projected Costs

ESTIMATE OF PROBABLE CONSTRUCTION COSTS

DESCRIPTION	UNIT	EST. QUANTITY	EST. UNIT PRICE	EST. COST
OVERALL SITE				
MOBILIZATION (ASSUME 10%)	LS	LUMP SUM	$ 794,000.00	$ 794,000.00
CONTRACT BOND (ASSUME 1%)	LS	LUMP SUM	$ 87,400.00	$ 87,400.00
INSPECTION AND TESTING	LS	LUMP SUM	$ 75,000.00	$ 75,000.00
SURVEYING	LS	LUMP SUM	$ 35,000.00	$ 35,000.00
RAILROAD FLAGGING AND SPOTTER	LS	LUMP SUM	$ 170,000.00	$ 170,000.00
STORM WATER/EROSION CONTROL	LS	LUMP SUM	$ 35,000.00	$ 35,000.00
TOPSOIL STRIPING, STORING, PLACING (1)	CY	71,000	$ 4.65	$ 330,150.00
CLEARING OF TREES/GRUBBING	LS	LUMP SUM	$ 25,000.00	$ 25,000.00
DEMOLITION OF EXISTING STRUCTURES	LS	LUMP SUM	$ 20,000.00	$ 20,000.00
UNCLASSIFIED EXCAVATION (2)	CY	247,100	$ 3.00	$ 741,300.00
EXPORT EXCESS EXCAVATION	CY	98,070	$ 14.00	$ 1,372,980.00
CRUSHED BASE GRADING 'W'	TON	2,410	$ 35.00	$ 84,350.00
RIPRAP	CY	100	$ 145.00	$ 14,500.00
4" CONCRETE GREENWAY	SF	75,000	$ 8.50	$ 637,500.00
8" CONCRETE GREENWAY	SF	2,000	$ 12.00	$ 24,000.00
4" CONCRETE SIDEWALK	SF	370	$ 8.50	$ 3,145.00
GRAVEL TRAIL	SF	26220	$ 0.45	$ 11,799.00
60" DIA. CULVERT	LF	960	$ 1,200.00	$ 1,152,000.00
42" DIA. CULVERT	LF	150	$ 900.00	$ 135,000.00
36" DIA. CULVERT	LF	140	$ 800.00	$ 112,000.00
TUNNEL INSTALL (THROUGH UPRR EMBANKMENT)	LF	1,250	$ 1,700.00	$ 2,125,000.00
GROUTING	CY	500	$ 250.00	$ 125,000.00
30" DIA. CULVERT	LF	35	$ 85.00	$ 2,975.00
30" DIA. CULVERT FLARED END	EA	1	$ 1,500.00	$ 1,500.00
30" DIA. CULVERT FLAP GATE	EA	1	$ 900.00	$ 900.00
18" DIA. CULVERT	LF	90	$ 60.00	$ 5,400.00
18" DIA. CULVERT FLARED END	EA	6	$ 1,100.00	$ 6,600.00
SANITARY SEWER MANHOLE LID ADJUSTMENT TO MAKE WATER TIGHT	EA	5	$ 500.00	$ 2,500.00
DRY LAND SEEDING	AC	110	$ 1,750.00	$ 192,500.00
HYDROMULCH SEEDING	AC	1	$ 7,840.80	$ 7,840.80
HANDRAIL	LF	70	$ 45.00	$ 3,150.00
DISMOUNT BICYCLE SIGNAGE	EA	2	$ 200.00	$ 400.00
GREENWAY WAYFINDING SIGNAGE	EA	2	$ 500.00	$ 1,000.00
FENCING (3)				
8' TALL CHAIN LINK FENCE	LF	3,000	$ 45.00	$ 135,000.00
MASONRY ARCH STRUCTURE				
4" CONCRETE FLOOR IN UNDERPASS	SF	480	$ 12.00	$ 5,760.00
HIGH STRENGTH GROUT/PATCHING	LF	70	$ 150.00	$ 10,500.00
ANTI-GRAFFITI SEALANT	LS	LUMP SUM	$ 25,000.00	$ 25,000.00
LIGHTING	LS	LUMP SUM	$ 60,000.00	$ 60,000.00
OVERHEAD PROTECTION	LS	LUMP SUM	$ 250,000.00	$ 250,000.00
			SUBTOTAL	**$ 8,821,149.80**
			10% CONTINGENCY	**$ 882,114.98**
			TOTAL ESTIMATED CONSTRUCTION COST	**$ 9,703,264.78**

See notes on following page.

Estimate of Probable Construction Costs Notes:

(1) This quantity includes the entirety of Kiwanis Park (See Note 2) and the disturbed area outside of the park boundary, at 0.4' of existing topsoil.
(2) 247,100 CY± of material will be moved to complete this project. 100,000 CY± of material is required to create the proposed berms. (A 5% fill factor has been used in the earthwork calculations.) It is assumed that 1/3 of the excess material can be placed on-site in the north portion of Kiwanis Parks that is to remain out of the floodplain. That equates to placing approximately 1' of fill within that 27 acre area. It is assumed that the remaining material will be removed from the site.
(3) For the purpose of this estimate it has been assumed that the UPRR will require that the entire south property line of Kiwanis Park/North UPRR ROW line will be fences with 8' tall chain link fence.

Estimate is based on 2022 dollars.

Estimated quantities begin south of the reconstructed Pershing/Whitney Intersection.

Estimated quantities end at the south end of the masonry arch structure and do not include any improvements south of the UPRR embankment.

Appendices

A **GLM Design Group**: Final *Lower Dry Creek Study (HEC-1 Sump 130) for Union Pacific RR Dry Creek Crossing* with Appendices

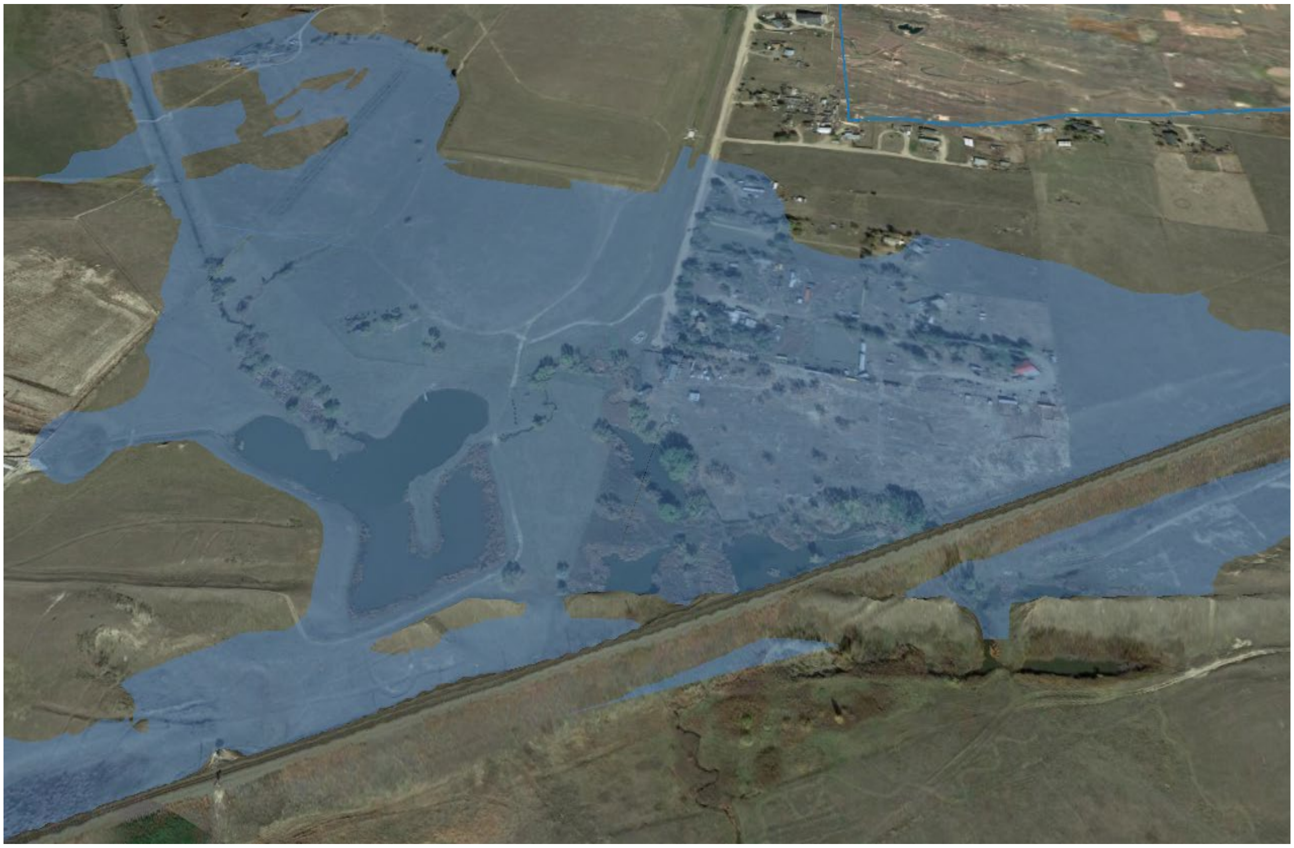
B **Lithos Engineering**: *Tunnel Feasibility Memorandum*

C **306 Rail Services**: *Pedestrian Underpass Requirements / Feasibility*

D **Martin/Martin**: *Masonry Culvert Investigation and Assessment Report*

E **Summit Engineering**: *East Park Greenway 35% Design Plan and Profiles*

Final Lower Dry Creek Study (HEC-1 Sump 130) for Union Pacific RR Dry Creek Crossing



Prepared for:

Summit Engineering
5907 Townsend Place
Cheyenne, Wyoming 82009

September 12, 2022

September 12, 2022

Ms. Darci Hendon, PE
Project Manager
Summit Engineering
5907 Townsend Place
Cheyenne, WY 82009

RE: Final Drainage Study of UPRR Dry Creek Crossing

Dear Darci:

GLM Design Group, LLC is pleased to submit the final drainage study for the Union Pacific railroad crossing of Lower Dry Creek. The preliminary study included an evaluation of alternative culverts under the UPRR embankment to replace the existing 6' x 8' masonry box arch culvert, constructed in 1903. The final study includes recommended sizes and locations required to hydraulically isolate the historic masonry culvert while protecting the UPRR embankment from impounded flood water.

The intent of this report is to provide a conceptual plan for making use of the historic masonry culvert as a part of the Greater Greenway System while taking into account UPRR design constraints and potential downstream impacts/mitigation.

If you should have any questions or comments as you review this report, please feel free to contact me at your convenience.

Sincerely,

Gene MacDonald

Gene L. MacDonald, PE
Managing Principal
GLM Design Group, LLC

TABLE OF CONTENTS

List of Figures

APPENDICES

I. General Location and Description

A. Location

The history of the project area begins with the passage of the Pacific Railroad Acts of 1862 that promoted the construction of a "transcontinental railroad" across the United States through the issuance of government bonds and grants of land to railroad companies. Transfer of land in the project area was finally patented in 1901 with the transfer of property to the Union Pacific Railroad.

Figure 1. Vicinity Map

The original transcontinental rail bed can be seen in aqua in Figure 1. The existing mainline tracks were constructed shortly after 1901 with the construction of the 6' x 8' masonry box arch culvert being completed in 1903. The original transcontinental rail bed was constructed through the project area in the 1870's and remnants of that original embankment remain today as can be identified in Figure 1. As pointed out in both our proposal and, again, in our interview, the remaining transcontinental rail bed in our project area is a key element to our proposed design approach.

B. Description of Property

Currently the project area serves as a detention storage area for stormwater runoff in Lower Dry Creek and has been modeled as such since at least the 1970's. Significant ponding up against the UPRR embankment has been noted by the USGS and others for storm events having occurred in the 1920's and 1950's. The project area is modeled as a sump in the 1988 Dry Creek Master Drainage Plan HEC-1 hydrologic model. The history of ownership of the project area immediately upstream of the UPRR Right-of-Way is a colorful one. Fred Peterson bought the property from the UPRR in 1912 and then lost it in the Great Depression. L.A. Foster acquired the property in 1939 and held it as agricultural property until 1999, when it was acquired by Dale Keizer. Mr. Keizer sold the property to the City of Cheyenne in early 2020 for the Future East Park.

Over the years since the existing UPRR main line tracks were constructed at the turn of the last century, the old transcontinental rail trestle over the historic Dry Creek channel was removed. Two oil pipelines and two fibre communication lines have been placed on the property. The Board of Public Utilities has also placed large sanitary sewer pipelines across the property. In 2010, an EPA 319 Project Grant was awarded to the County for a joint public-private constructed wetland project on Mr. Keizer's property just upstream of the original transcontinental rail bed remnants. This 5-acre feature including a 2.5-acre forebay and 2.5-acre wetland chase is now the focal point of the City's new East Park.

The following is a summary of the existing conditions:

Ground Cover - The site currently consists of native grasses in fair to good conditions. The property has historically been used for agricultural purposes including grazing of cattle. There are a few dirt roads on the property consisting of compacted earth and limited gravel. In 2021 a gravel trail was constructed around the forebay and wetland chase, connecting to a parking lot in the northwest corner of the park.

Grades – In general, the property drains to the south along moderate to shallow to moderate grades. As a part of the constructed wetland project, the northern third of the property was filled to a depth of approximately 8- to 10-feet with material excavated for the constructed wetland, effectively taking this portion of the property out of the regulatory floodplain.

Soil Type – A geotechnical study was completed in support of the constructed wetland project. The upper soils layers, based on field observations, are largely Clayey Sands. The depth to groundwater in the vicinity of the constructed wetland is approximately 8- to 12-feet. The material removed for the wetland and placed on the northern third of the property was compacted in shallow lifts and met all the required compaction test results.

Utilities – The site includes two oil pipelines and two fibre communication lines running north to south along the eastern part of the property. There are two BOPU pipelines that traverse the property east to west. There are dirt roads that have been cut in for access on the property.

Storm Drainage Facilities – Lower Dry Creek has run through this property since before the railroad was constructed and the Town of Cheyenne was incorporated. The original transcontinental rail bed bridged over the historic channel bed with a trestle bridge in the 1870's. The construction of the existing UPRR embankment at the turn of the last century, included the construction of the existing 6' x 8' box arch culvert approximately 500-feet to the east of the historic thalweg of the channel. Lower Dry Creek has been conveyed through the box arch culvert since 1903, its historic channel being abandoned. Moreover, in the early 1990's, the County completed a channel realignment of Lower Dry Creek between U.S. 30 and the UPRR embankment. Remnants of the historic channel thalweg remain in the northern third of the property and on portions of the adjacent Hess property. Local drainage is still directed to these remnants from north of Pershing Blvd.

C. Description of Overall Project Development

Russell + Mills recently prepared the East Cheyenne Community Park Master Plan. This master plan includes park amenities such as ball fields, tennis courts, pickleball courts, an indoor court building, swimming pool, open turn area, a skate park and trails.

II. Drainage Basins and Sub-Basins

A. Major Basin Description

The project area is located in the Lower Dry Creek Drainage Basin. Dry Creek is a tributary of Crow Creek and has a drainage area of 14.6 square miles, much of that upstream of the UPRR crossing. Between U.S. 30 and the UPRR crossing the average slope of this reach is 0.5 percent. The historic small, meandering low-flow channel was realigned and straightened by the County in the early 1990's. Between U.S. 30 and the East Park property, the low flow channel of Dry Creek is a man-made channel – the historic meandering channel being eliminated and/or abandoned. The historic floodplain has been narrowed somewhat by development. At the UPRR, floodwaters become ponded to a depth of nearly 19-feet for the regulatory flood event. The total storage volume estimated for Sump 130 by the 1988 study was 1,986 ac-ft with a 100-year storage volume of 868 ac-ft under existing outlet conditions. Sub-basins 110, 120 and 130 in the HEC-1 model have a more immediate impact on peak discharge to Sump 130 for the more frequent storm events. For less frequent events (higher discharges), the entire Dry Creek basin begins to contribute to ponding in Sump 130.

The rating curve used to analyze the existing UPRR 6' x 8' box arch culvert for the 1988 Dry Creek Master Drainage Plan produced slightly inaccurate results when compared with the rating curve produced by the Federal Highway Administration's HY-8 Culvert Analysis Program. HY-8 analysis indicates a maximum depth of 16.48 feet with a corresponding discharge of 770 cfs for the 100-year event. Based on the existing storage for the regulatory event from the HEC-1 model along with the more accurate outlet rating curve from the HY-8 analysis, the SWMM, Version 5.0.15 analysis produces a corresponding storage of 730 ac-ft. For the purposes of this report, we are basing our conclusions on the more accurate HY-8, UD-Culvert, and SWMM analyses while incorporating the existing storage from the 1988 HEC-1 analysis as a comparison point for proposed alternative culvert designs. For the final drainage report, we will adjust the HEC-1 analysis to more accurately reflect current conditions in the lower basin as well as separate out by-pass flow from Saddle Ridge that will not enter the re-configured storage facility.

Downstream of the UPRR crossing and Sump 130, the creek flows through the Cheyenne LEADS owned property, managed by the Laramie County Conservation District (LCCD), and the location of their new headquarters building, located between the UPRR and the Campstool Road crossing. There is a broad floodplain through this area with two ponded areas. There will be opportunity to coordinate and partner with the LCCD on expanding the existing storage areas for mitigation purposes. The proposed expansion also serves the LCCD's mission statement for the area as well. Between Campstool Road and the I-80 crossing, the channel becomes entrenched with a noticeable headcut that threatens the downstream end of the Campstool Road culverts. The LCCD has been attempting to restore this reach incorporating 'soft' engineering techniques. This reach will be evaluated as will the LCCD's headquarters property immediately upstream in the final drainage report. Near the confluence with Crow Creek, downstream of the I-80 crossing, the peak discharge for the regulatory event inundates and overtops the Campstool Road crossing (Campstool Road turns south and crosses Dry Creek a second time just upstream of the confluence with Crow Creek and near the Hereford Ranch).

B. Pre-Project Drainage Patterns

The Dry Creek Flood Control Project intercepts flow occurring in the upper Dry Creek Basin through sub-basin 70 in the HEC-1 model as well as flow from portions of the Cheyenne Regional Airport beginning with the 5-year storm event. There are four storage areas in the Dry Creek Flood Control Project which effectively attenuate peak discharges in the upper basin. This attenuation is dampened out by the time peak flows reach the U.S. 30 crossing. Peak flow downstream of the U.S. 30 crossing combined with flow from sub-catchments 120 and 130 contribute to significant ponding at the UPRR embankment for the regulatory event. Sub-basin 110 has a contributing drainage area of 0.35 sq. mi. including flow from Dakota Crossings. Sub-basin 130 has a drainage area of 2.0 sq. mi. and includes flow from Saddle Ridge and Sun Valley. Stormwater flow from newer developments east of Ridge Road such as Whitney Ranch will exacerbate the existing ponding in Sump 130 at the UPRR crossing. The existing 6' x 8' box arch culvert reaches full flow conditions beginning with a 10-year event in the basin. At this point, stormwater 'stacks' up against the UPRR embankment due to inadequate capacity at the outlet. The original transcontinental trestle bridge would have likely had significantly higher capacity than does the 6' x 8' box arch culvert. The UPRR could not have envisioned the ensuing development of Cheyenne since 1903 in the Dry Creek basin.

Runoff from sub-basins and an estimate of existing conditions for the various design points from the HEC-1 analysis are shown with Table 1. Design point DC-K is the U.S. 30 crossing; Design point DC-M is the Pershing Road crossing; and Design point DC-N is the UPRR crossing/Sump 130 in the HEC-1 model.

Table 1. Existing Conditions Runoff Summary

Catchment/ Design Point	Tributary Area (sq mi)	Basin Number	Q_{10} cfs	Q_{25} cfs	Q_{50} cfs	Q_{100} cfs
DC-K	8.68	110	-.-	-.-	-.-	2,899
DC-M	0.35	120	-.-	-.-	-.-	2,322
DC-N	2.0	130	-.-	-.-	-.-	2,736

The Pershing Road crossing is overtopped in the regulatory event. Flow from Dakota Crossings is conveyed across Pershing via culverts located east of the Dry Creek channel where it causes inundation of buildings located on the Hess property. Our analysis is focused on Basin 130 and the corresponding 130 sump in the HEC-1 model. For purposes of this analysis, we are proposing to divide Basin 130 into three smaller basins In order to evaluate a re-configured detention storage area.

III. Drainage Design Criteria

A. UPRR Guidelines

The design criteria for this study is compliant with the UPRR's ***Guidelines for Railroad Grade Separation Projects*** and with geotechnical guidance from our team partner, Lithos Engineering. Our design approach for both alternative culverts and re-configured storage for Sump 130 will result in hydraulically isolating the existing 6' x 8' box arch culvert for future use as a pedestrian trail. Moreover, our choice of potential culvert alternative sizes is based on boring guidance from our geotechnical engineer. A 60-inch diameter will be the maximum size we can bore while keeping 22 feet below the bottom of the ballast as measured from the invert of the pipe. Holding to this distance will significantly limit any possible deflection of the mainline tracks due to the boring operation. A 60-inch diameter will also provide the project with the most economical boring method, saving cost on the construction of the alternative culverts.

Our design approach also meets design standards as set forth by the State Engineer's Office – Dam Safety Program (SEO). Our approach to emergency discharge from the facility and for limiting the potential for debris blockage of the outlet structure is fully compliant with SEO Dam Safety standards and will be detailed in the final report. Both the SEO and the UPRR will require a 100-year (regulatory) design which is what we are evaluating for this report. Neither the SEO nor the UPRR will consent to ponding up against the mainline track embankment. There is a risk of breaching in this condition resulting in significant property damages and potential loss of life.

B. Development of Design Models

To be cost-effective, we are using input from the HEC-1 model to develop our SWMM model. Input from the SWMM model will be input into the HEC-RAS model. HY-8 Culvert Analysis and UD-Inlet programs are being incorporated to develop culvert rating curves for input into the SWMM model. The criteria used as the basis to analyze and design stormwater features of this project were done so according to the references noted above. Additionally, there are conveyance and storage constraints which must be considered as we select alternative culvert sizes and re-configure the existing storage. We are limiting the extents of inundation due to backwater at Sump 130 to no more than the existing condition. We are proposing an increase in downstream discharge, however, the limiting factor will be practical and cost-effective mitigation on Cheyenne LEADS property, that is managed as open space by the Laramie County Conservation District (LCCD) and downstream of the Campstool Road crossing. For the final report, identification of permitting requirements through other state and federal agencies will also be detailed.

C. Hydrological Criteria

Development (Type)	Minor Storm Design	Major Storm Design
Infrastructure	10-Year	100-Year

The proposed re-configured storage facility and new conveyance elements, including water quality allowances and downstream mitigation, will be designed using the US EPA Stormwater Management Model (SWMM, ver. 5.1.015) software along with HY-8 Culvert Analysis, HEC-RAS and HEC1.

- The 1988 HEC-1 hydrologic model will be updated with regard to sub-basins 110, 120, and 130 to reflect current conditions and the re-configured storage facility at Sump 130.
- HEC-RAS will be incorporated to delineate areas of inundation for the regulatory event using the HEC-1 information as hydrologic input for the model and starting with the Dry Creek Flood Control HEC-RAS model at U.S. 30.

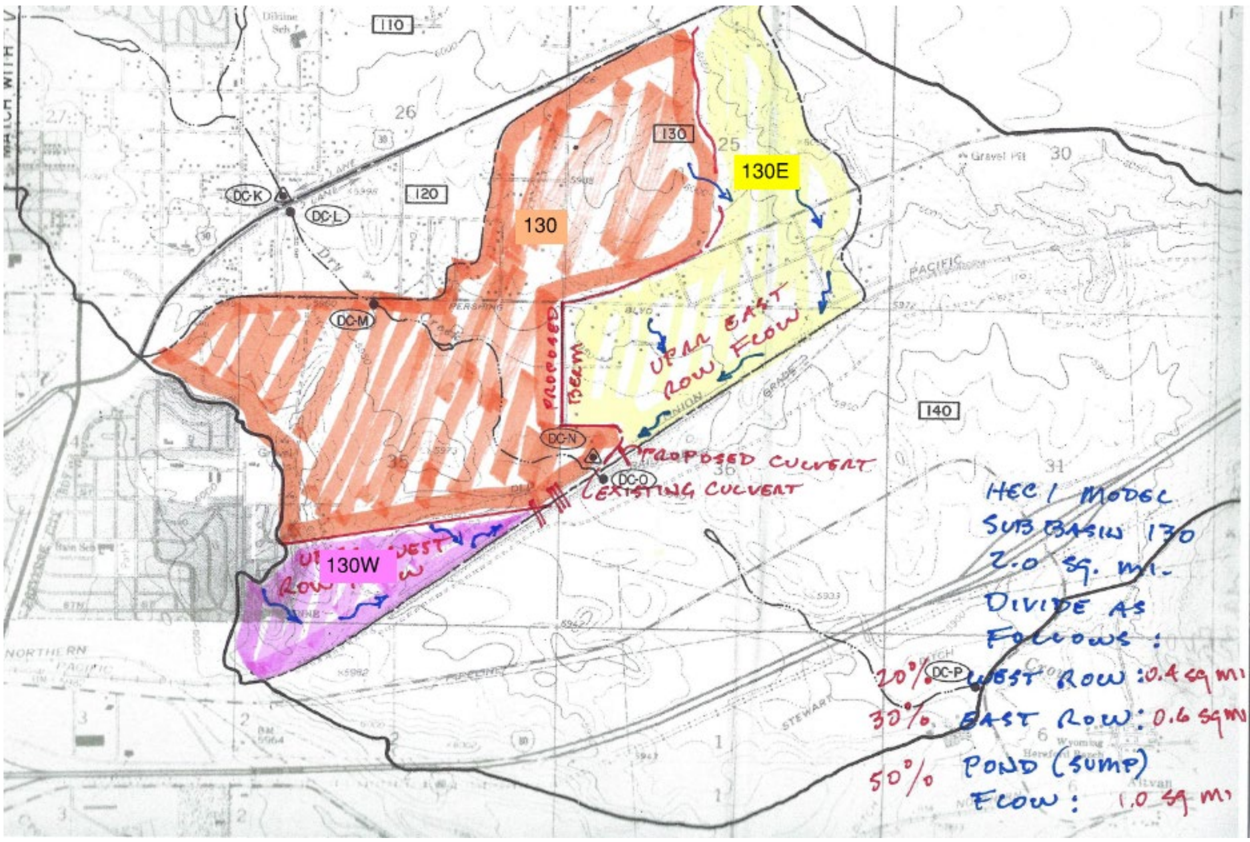
- HY-8 Culvert Analysis and UD-Culvert will be incorporated to develop rating curves for use in the EPA SWMM model.

- EPA SWMM, Version 5.0.15 will be used to evaluate alternative culvert options and storage volumes.

Hydrographs/rating curves developed in HEC-1 were input into EPA SWMM sub-catchment rainfall-to-runoff algorithms. Dynamic wave routing within the SWMM model was used to address interconnections and interactions between all collection, conveyance, storage, and regulatory elements. Detention storage volumes are based on hydrograph routing and stage-area curves developed from the HEC-1 model in conjunction with current topographical data.

Re-configured Basin Divide:

Re-configured Basin 130 marked up on original 1988 HEC-1 Basin map.



Revised Basins

Revised Basins					
Basin	Area	I%	Notes	UD	Notes
130	1	25	Changed to 25% from Gene's direction	1.74	Left alone due to basin length/size
130E	0.6	25	Changed to 25% from Gene's direction	1.74	Left alone due to basin length/size
130W	0.4	12	Mainly undeveloped area	0.75	small basin

Routing:

- Routed Basin 130 to a proposed pond (Sump_130)
- Routed Basin 130W to a proposed pond (Sump_130e)
- Combined Basin 130 and 130w and then routed to downstream side of the railroad.
- Routed Basin 130E to the downstream side of the railroad.

HEC-1 Adjustments:

```
* ------START---------START---------START--------START--------START--------START
KK  BSN_130
KO  1  1
BA  1.00
LE  0.91  1.91  1.86  0.5  25
UD  1.74
*
KK  FLW130  FLOW IN BASIN 130 PRIOR TO SUMP STORAGE BEHIND UPPR
KO  1  1
HC  2
*
KK  SUMP_130  SUMP TO ACCOUNT FOR STORAGE upstream of UPPR
RS  1 STOR 0
SV     0     2.2     8.5    18.6    32.5    50.3    70.6    94.6   124.0   159.4
SV   200.4   246.5   295.7   347.0   400.5   457.3   519.1   587.6   688.8   828.5
SQ     0      90     147     218     302     386     465     542     598     651
SQ    701     749     797     838     879     920     959     997    1032    1066
SE    5923  5924.0  5925.0  5926.0  5927.0  5928.0  5929.0  5930.0  5931.0  5932.0
SE  5933.0  5934.0  5935.0  5936.0  5937.0  5938.0  5939.0  5940.0  5941.0  5942.0
*
* --------------- basin 130w to a proposed pond---------
KK  BSN_130W
KO  1  1
BA  0.4
LE  0.91  1.91  1.86  0.5  15
UD  1.74
*
KK  DT_130w  Detention West of RR Sump
RS  1 STOR 0
SV     0   0.01   0.02    0.1    0.3    0.6    1.1    1.9    3.3    6.0
SV   10.3   21.6   43.6   70.6  103.1  142.2  198.9  399.6
SQ     0     28     42     55     67     76     84     92     99    106
SQ   113    119    125    130    135    141    146    168
SE   5923  5925.0  5926.0  5927.0  5928.0  5929.0  5930.0  5931.0  5932.0  5933.0
SE 5934.0  5935.0  5936.0  5937.0  5938.0  5939.0  5940.0  5945.0
*
* --------- Combined flow out of RR ponds (2)---------
*
KK  FLW130W  Combined RR flows
KO  1  1
HC  2
*
* ---------- basin to the east that does not get detained---------
*
KK  BSN_130E
KO  1  1
BA  0.6
LE  0.91  1.91  1.86  0.5  25
UD  0.75
*
* -------------------------------
*
KK  FLW130E  Combined RR flows and Basin 130E
KO  1  1
HC  2
*
* --------END-----------END ------------ END------------ END------------ END------------ END
```

Effective WSEL Held to Laramie County LOMR:

- WSEL=4639.6’

Pond 130:

- Max size: 5ft dia
- Contours obtained from combined_surface.dwg (August 2022 drawing)
- Flow out: HY-8
  - Inv DS: 5922 (from previous existing contour information)
  - Inv US: 5923 (from Summit's surface)
  - Length=256ft
  - Slope=0.4%
- Pond Volume obtained from HEC-1
- Hec-1 Pond: Sump_130

Summary:

- WSEL=5939.41 Q=974cfs
- Spillway at 5939.6 ft
- Volume: 547.2 acres
- Pipes: (2) 5ft dia and (1) 3.5ft dia

Overflow:

- 100-yr flow out = 974cfs
- 500-yr flow out = 2150cfs
- Culvert design: difference of 100yr out and 500yr out: Flow= +/- 1200cfs
- Spillway: $Q=CLH^{3/2}$
  - C=2.6
  - L= 110 ft
  - Q=1200 cfs
  - H = 1.4 ft (can only pond to a 41 US of spillway: 41-39.6=1.4')
  - Head = 5941.0 ft

Spillway from Pond 130	
Q =	1200
L =	278.6
H =	1.4
C =	2.6

Pond 130 Pond Rating Curve					
Contour Elev. (ft)	Surface Area (ft^2)	Contour Volume (ft^3)	Total Volume (ft^3)	Total Volume (acre-ft)	Flow (cfs)
5923	41479	0.00	0	0.0	0
5924	162361	95,301	95,301	2.2	90
5925	406068	275,066	370,367	8.5	147
5926	476385	440,759	811,126	18.6	218
5927	743253	604,893	1,416,019	32.5	302
5928	806837	774,827	2,190,847	50.3	386
5929	960035	882,327	3,073,174	70.6	465
5930	1141864	1,049,637	4,122,811	94.6	542
5931	1421595	1,279,178	5,401,989	124.0	598
5932	1661940	1,540,204	6,942,193	159.4	651
5933	1918960	1,788,911	8,731,104	200.4	701
5934	2094448	2,006,064	10,737,168	246.5	749
5935	2194028	2,144,046	12,881,214	295.7	797
5936	2274262	2,234,025	15,115,239	347.0	838
5937	2391185	2,332,479	17,447,718	400.5	879
5938	2550794	2,470,560	19,918,279	457.3	920
5939	2838152	2,693,195	22,611,474	519.1	959
5940	3137391	2,986,522	25,597,996	587.6	997
5950	15686522	86,130,783	111,728,779	2,564.9	6066

HEC-1 Info	100yr	HEC-1 Info	500yr
WSEL	5939.41	WSEL	5942.27
Flow	974	Flow	2150
Volume	547.2	Volume	1036.5

Pond 130W:

- Max size: 5ft dia
- Contours obtained from combined_surface.dwg (August 2022 drawing)
- Flow out: HY-8
    - Inv DS: 5922 (3ft below the proposed ground surface)
    - Inv US: 5923 (from Summit's surface)
    - Length=150 ft
    - Slope=0.67%
- Pond Volume obtained from HEC-1
- Hec-1 Pond: Sump_130W

Summary:

- WSEL=5933.3 Q=109cfs
- Spillway at 5933.3 ft
- Volume: 7.3 acres
- Pipes: (1) 3ft

Overflow:

- The flow from pond 130 overtops and into this pond
    - Q from 130 = +/- 1200 cfs
- Spillway at 5923 ft
- Max head allowed: 5939.6ft
- (3) 5ft pipes; Q=1200cfs, WSEL = 5938.25'
- Q at 39.3=1270cfs

Pond 130W Pond Rating Curve					
Contour Elev. (ft)	Surface Area (ft^2)	Contour Volume (ft^3)	Total Volume (ft^3)	Total Volume (acre-ft)	Flow (cfs)
5922	0	0.00	0	0.0	0
5925	172	172	172	0.0	28
5926	1169	597	769	0.0	42
5927	6422	3,444	4,213	0.1	55
5928	11761	8,958	13,171	0.3	67
5929	18336	14,927	28,098	0.6	76
5930	23317	20,777	48,875	1.1	84
5931	46668	34,324	83,199	1.9	92
5932	71879	58,822	142,021	3.3	99
5933	170957	117,896	259,917	6.0	106
5934	204606	187,530	447,447	10.3	113
5935	861743	495,417	942,864	21.6	119
5936	1057696	958,048	1,900,912	43.6	125
5937	1292712	1,173,241	3,074,153	70.6	130
5938	1542343	1,415,692	4,489,845	103.1	135
5939	1873924	1,705,445	6,195,290	142.2	141
5940	3115650	2,468,624	8,663,914	198.9	146
5945	676798	8,740,954	17,404,868	399.6	168
	HEC-1 Info	100yr	HEC-1 Info	500yr	
	WSEL	5933.3	WSEL	5935.47	
	Flow	109	Flow	122	
	Volume	7.3	Volume	32.0	

Pipe 130E:

- Pipe under RR east of the RR Sump. No detention at this site
- Max size: 5ft dia
- Based on contours from Summit, the max head upstream should be a 5639.0 before it floods structures.
- Flow: HY-8
    - Inv DS: 5928
    - Inv US: 5927….a structure will need to be added to create the drop to the existing surface (ex surface 5923)
    - Length=150ft
    - Slope=1.33%
- Basin 130E Flow = 544cfs
    - Culvert: (2) 5ft dia
        - Head=5936.94ft, Flow=544cfs
    - Culvert (2) 4.5ft dia
        - Head=5939.11ft, Flow=544cfs

Flow Summary:

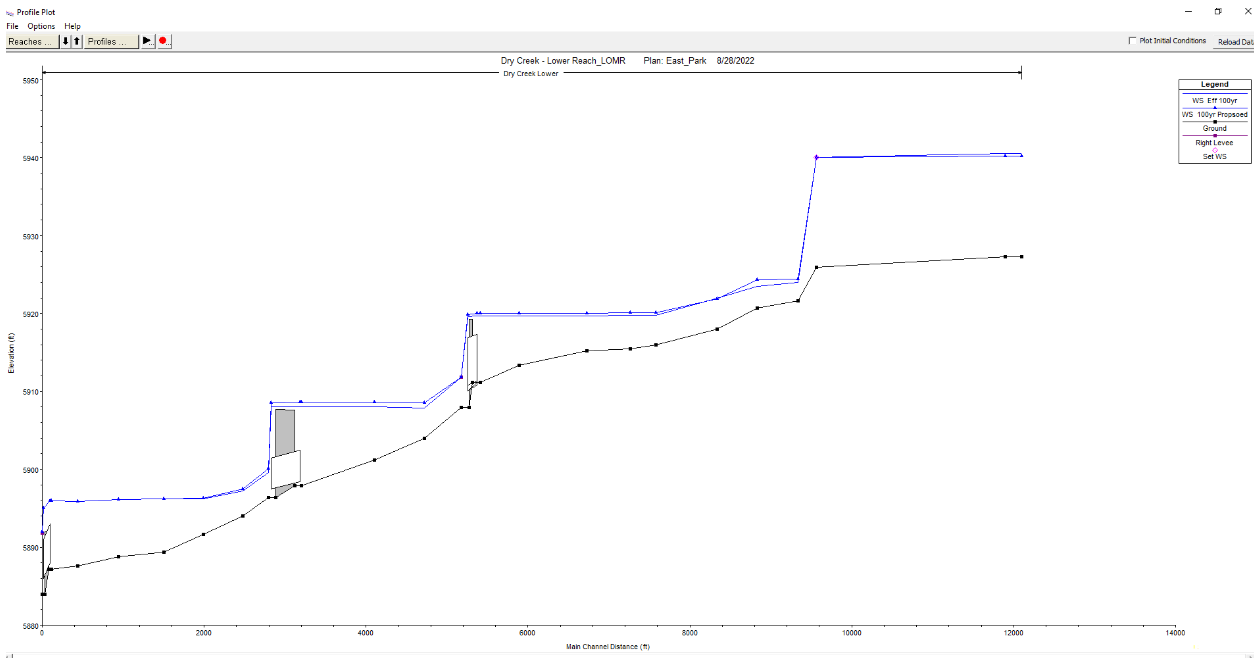
From HEC-1

Description	Hec-1 Node	100-yr Flow (cfs)	500-yr Flow (cfs)
Flow US RR Pond	Rout_130	2174	6249
Basin 130 Runoff	Bsn_130	474	876
Flow into RR Pond	Flw130	2490	6894
Flow out of RR	Sump_130	974	2150
Basin 130W Runoff	Bsn_130W	168	323
Flow out of Pond 130W	DT_130W	109	122
Combined flow out of Pond 130 and 130W	Flw130W	1014	2270
Basin 130E Runoff	Bsn_130E	544	866
Combined flow downstream of RR (all basins)	Flw130E	1015	2270

Description	100-yr			
	Flow IN (cfs)	Flow OUT (cfs)	Volume (AC-FT)	WSEL (ft)
Detention 130	2490	974	547.2	5939.41
Detention 131W	168	109	7.3	5933.3
Description	**500-yr**			
	Flow IN (cfs)	**Flow OUT (cfs)**	**Volume (AC-FT)**	**WSEL (ft)**
Detention 130	6894	2150	1036.5	5942.27
Detention 131W	323	122	32.0	5935.47

HEC-RAS Comparison:

River Sta	Corrected Effective		Proposed 100yr		Difference	
	Q Total	W.S. Elev	Q Total	W.S. Elev	Q Total	W.S. Elev
	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
90	733	5923.5	1015	5924.35	**282**	**0.85**
83.3	733	5921.96	1015	5921.92	**282**	**-0.04**
75.8	733	5919.76	1015	5920.09	**282**	**0.33**
72.7	733	5919.74	1015	5920.07	**282**	**0.33**
67.3 J	1006	5919.7	1310	5920.02	**304**	**0.32**
58.9	1006	5919.69	1310	5920.02	**304**	**0.33**
54.1 I	1006	5919.69	1310	5920.01	**304**	**0.32**
52.9	Culvert		Culvert			
51.7 H	1006	5911.81	1310	5911.81	**304**	**0**
47.2	1006	5907.88	1310	5908.57	**304**	**0.69**
41 G	1254	5908.04	1604	5908.62	**350**	**0.58**
32 F	1254	5908.01	1604	5908.58	**350**	**0.57**
30	Culvert		Culvert			
28 E	1254	5899.61	1604	5900.08	**350**	**0.47**
24.8	1254	5897.24	1604	5897.5	**350**	**0.26**
20.6	1254	5896.23	1604	5896.27	**350**	**0.04**
15 D	1563	5896.18	1899	5896.19	**336**	**0.01**
9.4	1563	5896.14	1899	5896.14	**336**	**0**
4.4 C	8500	5895.88	8500	5895.88	**0**	**0**
1.2 B	8500	5895.95	8500	5895.95	**0**	**0**
0.7	Culvert		Culvert			
0 A	8500	5892.01	8500	5892.01	**0**	**0**



IV. Drainage Facility Design

A. Preliminary Drainage Plan Overview

The design approach for selecting alternative culvert sizes and to re-configure the existing SUMP 130 has been predicated on the conveyance and storage constraints listed above, as well as, the requirement to create a hydraulically isolated condition for the existing 6' x 8' box arch culvert. We have modeled a number of culvert configurations with corresponding storage sizes including the following configurations:

B. Culvert Summaries

Given the previous discussion of UPRR and geotechnical boring constraints, the culvert diameters in excess of 5' (60-inches), are not practical solutions as they will likely cause deflection of the mainline tracks during the boring process. The 4.5' (54-inch) diameter pipes would require too many in series to be cost-effective. The 5' diameter culvert was selected as the maximum diameter that can be bored while adhering to UPRR deflection constraints. As will be discussed below, the maximum storage volume that can be realized with a re-configured storage facility appears to be 82.5% of the existing storage. An additional constraint above was the requirement to maintain or decrease the existing inundation extents resulting from backwater due to Sump 130. The culvert configurations that best meet all three criteria for the re-configured Basin 130 are as follows:

Sump 130 West:	(1) 36-inch Dia. Pipe
Sump 130 Pond:	(2) 60-inch Dia. Pipes and (1) 42-inch Dia. Pipe
Sump 130 East:	(2) 60-inch Dia. Pipes

Additionally, the following pipes are also required for emergency spill and for minor drainage conveyance upstream of the UPRR embankment:

(3) 60-inch Dia. Pipes for spillway flow and (1) 30-inch Dia. Pipe for incidental flow (upstrm. of UPRR)

C. Detention System Design

The constraints for a re-configuration of the existing Sump 130 storage is to hydraulically isolate the existing 6' x 8' box arch culvert and not impact adjacent properties with additional flood inundation in the process. The most practical way to accomplish this is to berm the floodwaters west of Whitney Road. An additional constraint for the re-configured storage is to significantly reduce impoundment of floodwaters on the UPRR embankment where ponded water can be a risk for a breach of the embankment during a flood, significantly imperiling downstream properties and people. As can be seen in the exhibit below, the existing inundation covers a significant area east of Whitney Road.

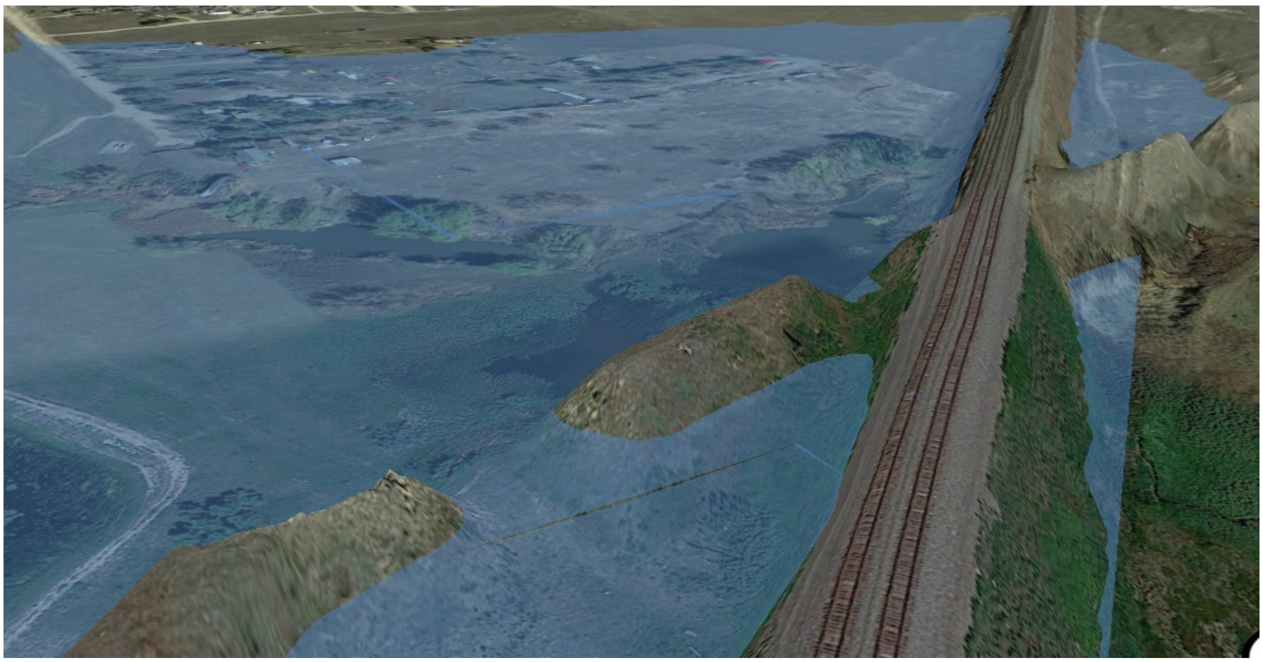


Figure 2 Existing Inundation Extents

A re-configured storage volume will need to off-set the loss of storage on the east side of Whitney Road while not increasing inundation extents upstream of the existing Sump 130 backwater curve. Our design approach to this problem is to allow some stormwater from sub-basins 120 and 130 to bypass the Sump 130 storage through a separate culvert/boring to be located east of Whitney Road and west of the 130 Pond discharge pipes, and to increase the discharge downstream of Sump 130.

Again, our proposed approach is predicated on keeping the historic masonry culvert hydraulically isolated. If we can use the historic culvert for emergency discharge more than the regulatory, 100-year event, then, we can reduce the amount of pipe borings required under the UPRR embankment. Our analysis and recommendations are based on the HEC-1 hydrologic model for cost effectiveness. The ongoing Dry Creek Drainage Master Plan update will provide a more refined analysis along with recommendations for upstream attenuation of stormwater runoff that we cannot include in our modeling efforts at this time. There is potential with the Master Plan efforts that proposed upstream attenuation will further reduce peak discharges resulting in Sump 130.

GLM Design Group

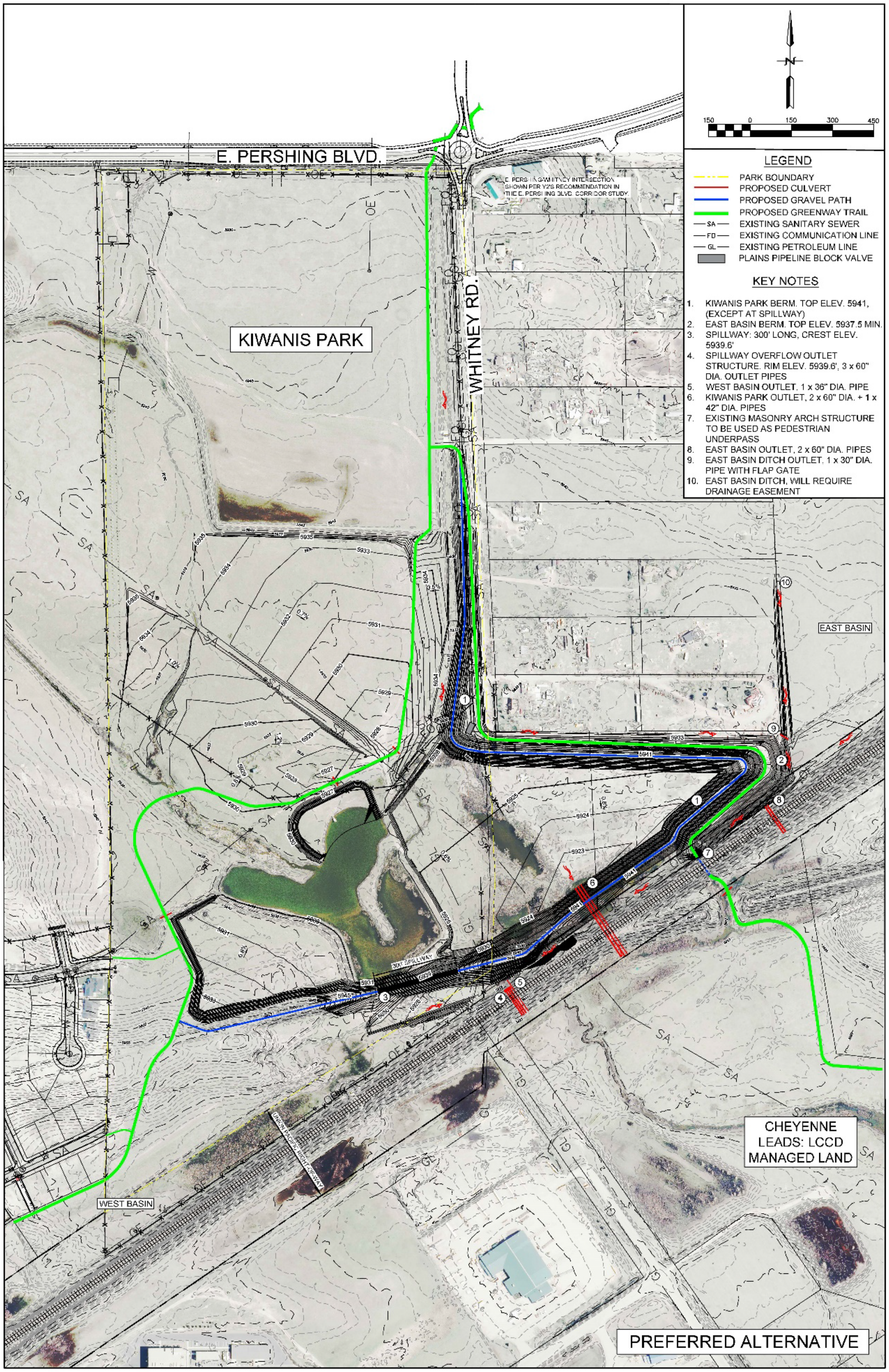


Figure 3 Proposed Berm

We are proposing to tie the remnants of the original transcontinental rail bed with connecting berms east-west and north-south to the higher ground located just to the west and to the northern third of the site. This represents a cost-effective approach in as much as less material will be required for construction of berms for the re-configured Sump 130 storage, and it maximizes the area west of Whitney Road for use for storage. Geotechnical evaluation of the existing transcontinental embankments will be required to determine the suitability for this purpose. This proposed configuration also allows for a shorter culvert under the UPRR mainline embankment which is both cost-effective and hydraulically more efficient.

The proposed solution of (2) 60-inch outlet pipes and (1) 42-inch outlet pipe in conjunction with a re-configured storage area and bypass flow for portions of Sun Valley and Saddle Ridge with their corresponding discharge pipes mirrors closely the existing inundation extent for Sump 130 backwater curve while limiting the downstream increase in discharge. There is some downstream mitigation efforts anticipated, however, the existing Campstool and I-80 crossings will require improvements regardless of changes in the downstream discharge characteristics.

D. Spillway Design

We are proposing an approximate 300-foot spillway for flood events in excess of the 0.1% chance annual flood (100-year) for compliance with the Wyoming State Engineer's Office (SEO). Again, if the historic masonry culvert can be used for flows larger than the 100-year, then, we can reduce the number of culvert borings in the UPRR embankment.

E. Impacts on Downstream Facilities.

As previously outlined, the design intent is to mitigate for an increase in the historic runoff patterns for the full range of return periods. There is opportunity to partner with the LCCD for improvements to the existing storage areas immediately downstream of the UPRR. Not only can this be a 'win-win' situation for both the City and the LCCD, as well the community at large but, this potential partnership will provide for competitive grant applications including for FEMA's BRIC2022 and 2023 grant programs. Moreover, there is significant potential with the Master Plan efforts that upstream attenuation will be recommended.

V. Sediment/Erosion Control

The site falls under the requirements the Wyoming Discharge Pollutant Prevention Discharge (WyPDES) program for a large construction site (> 5 acres). A formal state notice of coverage is not required but the site will require a Storm Water Pollution Prevention Plan (SWPPP) developed to follow the requirements of the general state permit. The SWPPP will include more detailed information on sediment and erosion control items for this project. A short summary of the recommended temporary BMP's for the site to control on-site erosion and prevent sediment from traveling off-site during construction include:

- Silt Fence – a woven synthetic fabric that filters runoff. The silt fence is a temporary barrier that is placed at the base of a disturbed area. This feature is proposed for the west, south, and east sides of the site.
- Vehicle Tracking Control – a stabilized stone pad or prefabricated metal (rattle mat) located at points of ingress and egress on a construction site. The pad is designed to reduce the amount of mud transported onto public roads by construction traffic.
- Inlet Protection – acts as a sediment filter. It is a temporary BMP and requires proper installation and regular maintenance to ensure their performance.

- The proposed detention facility would be available for temporary sediment containment if excavated with the initial grading on the site.

The contractor should store all construction materials and equipment and provide maintenance and fueling of equipment in confined areas on-site from which runoff will be contained and filtered. The temporary Best Management Practices (BMP's) are required to be inspected by the contractor at a minimum of once every two weeks and after each significant storm event.

Construction activities including excavation often increase compaction which reduces both soil hydraulic conductivity and porosity which result in standing water. Landscape planting in the base of the detention ponds should specify a tolerance for highly saturated soil conditions. As mentioned earlier in the report, permitting through state and federal agencies will be discussed in the final report with recommendations as to proceeding with design and construction.

VI. Conclusions

A. Compliance with Standards

Storm drainage calculations have followed the guidelines provided by the applicable sections of the City of Cheyenne Unified Development Code. The design approach is fully compliant with the restrictions and constraints of the UPRR, SEO, and FEMA.

B. Drainage Plan

The drainage system is designed to hydraulically isolate the existing 6' x 8' box arch culvert for potential use as a pedestrian pathway; limit the inundation due to the Sump 130 backwater curve to the existing flooding extents or less; limit the increase in downstream discharge to that which can be practically mitigated in partnership with the LCCD; provide a cost-effective approach for re-configuring the existing storage; provide a cost-effective solution for outlet pipes that meet the geotechnical/UPRR boring constraints regarding allowable deflection of the mainline tracks through the course of a boring operation; provide for a portion of sub-basins 120 and 130 to bypass the re-configured storage for a more efficient solution; and meet the requirements and constraints of the UPRR, SEO, FEMA, USACE, WDEQ, and City of Cheyenne.

VII. References

1. Urban Storm Drainage Criteria Manuals 2 and 3, Urban Drainage and Flood Control District, Denver, Colorado, November 2010 as currently (Feb 2018) amended.

2. Storm Water Management Model, Reference Manual Volume I, Hydrology, U.S. Environmental Protection Agency, January 2016.

3. Storm Water Management Model, Reference Manual Volume II, Hydraulics, U.S. Environmental Protection Agency, May 2017.

4. Conversion of Natural Watershed to Kinematic Wave Cascading Plane, Guo, J.C.Y. and Urbonas, B., Journal of Hydrologic Engineering, Vol. 14, No. 8, pp. 839-846, July/August 2009.

5. CH2M HILL 2 1988: CH2M HILL & States West Water Resources Corporation: Drainage Master Plan – Dry Creek.

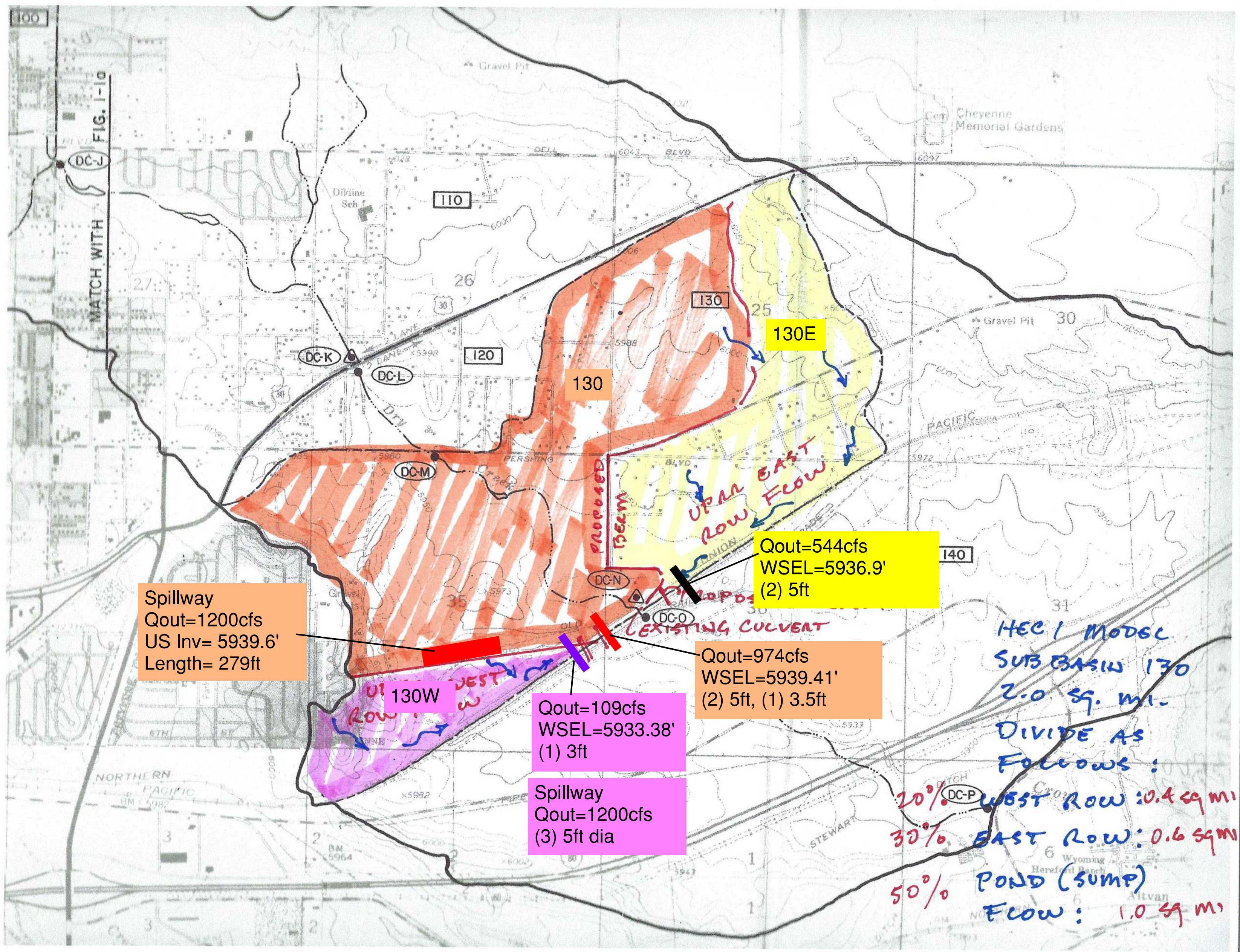
6. U.S.G.S 1988: U.S. Geological Survey: Precipitation Records and Flood-Producing Storms in Cheyenne, Wyoming, Water-Resources Investigations Report 87-4225, 1988.

VIII. Certification

"I hereby attest that the Preliminary Drainage Report for the UPRR Dry Creek crossing was prepared by me, or under my direct supervision, in accordance with the provisions of City of Cheyenne Unified Development Code for the responsible parties thereof and that I am a duly registered ProfessionalEngineer under the laws of the State of Wyoming. I understand that the City of Cheyenne does not and shall not assume liability for drainage facilities designed by others."

Gene L. MacDonald
Registered Professional Engineer
State of Wyoming # 8891

Appendix: HEC-1



MATCH WITH FIG. I-1a
100
110
120
130
130E
130W
140
DC-J
DC-K
DC-L
DC-M
DC-N
DC-O
DC-P
Gravel Pit
Cheyenne Memorial Gardens
Dildine Sch
PERSHING
BLVD
DELL
PACIFIC
UNION
NORTHERN PACIFIC
STEWART
PROPOSED BERM
PROPOSED
EXISTING CULVERT
UPRR EAST ROW FLOW
UPRR WEST ROW FLOW
Qout=544cfs
WSEL=5936.9'
(2) 5ft
Qout=974cfs
WSEL=5939.41'
(2) 5ft, (1) 3.5ft
Qout=109cfs
WSEL=5933.38'
(1) 3ft
Spillway
Qout=1200cfs
(3) 5ft dia
Spillway
Qout=1200cfs
US Inv= 5939.6'
Length= 279ft
HEC 1 MODEL
SUB BASIN 130
2.0 SQ. MI.
DIVIDE AS
FOLLOWS:
20% WEST ROW: 0.4 SQ MI
30% EAST ROW: 0.6 SQ MI
50% POND (SUMP)
FLOW: 1.0 SQ MI

Appendix: HEC-1 Input

100-year INPUT

(adjustments highlighted)

```
*FREE
ID
ID  THIS IS THE INPUT FOR THE Existing AIRPORT CONDITIONS
ID  THE PRECIPITATION IS "*"ED IN OR OUT TO GIVE THE DESIRED EVENT.
ID  CHEYENNE DRAINAGE MASTER PLAN - DRY CREEK BASIN HYDROLOGY
ID  Existing AIRPORT CONDITIONS -  STORM EVENT: 100-YEAR
ID
ID  THIS SIMULATION USES THE EXPONENTIAL LOSS RATE FUNCTION, MUSKINGUM
ID  ROUTING, AND THE SCS UNIT HYDROGRAPH OPTIONS OF HEC-1.
ID  A TWO HOUR DESIGN STORM IS USED        File Name: POST100.dat
*
IT  5,,50
IO  5
*
*
KK  BASIN10  DETENTION POND BASIN WHICH HAS ALL OUTFLOW VIA LOW FLOW/WEIR
BA  .20
PB
*    2-YEAR STORM
*  PI  .010 .010 .010 .010 .010 .010 .040 .110 .290 .150 .040 .030 .010 .010 .010
*  PI  .010 .010 .010 .010 .005 .010 .005 .005 .005
*    5-YEAR STORM
*  PI  .01 .01 .01 .01 .02 .07 .08 .40 .21 .15 .07 .02 .03 .02 .03 .02 .01 .02 .01
*  PI  .02 .01 .01 .01 .01
*   10-YEAR STORM
*  PI  .01 .02 .02 .03 .04 .10 .11 .17 .48 .25 .10 .04 .04 .04 .03 .03 .02 .03 .02
*  PI  .02 .01 .02 .01 .01
*   25-YEAR STORM
*  PI  .02 .03 .04 .06 .14 .15 .19 .58 .32 .15 .07 .06 .06 .05 .05 .04 .05 .04 .04
*  PI  .04 .04 .03 .04 .03
*   50-YEAR STORM
*  PI  .04 .06 .08 .14 .18 .18 .22 .67 .35 .18 .10 .06 .05 .06 .05 .06 .05 .06 .05
*  PI  .06 .06 .05 .06 .05
*   500-YEAR STORM (BASED ON 100-YEAR PATTERN INDEX & PERIOD PRECIP VOLUMES)
*  PI  .14 .16 .20 .22 .42 .43 .42 1.0 .55 .48 .20 .14 .18 .16 .18 .14 .16 .18 .16
*  PI  .18 .14 .14 .12 .12
*   100-YEAR STORM
PI  .09 .10 .12 .18 .22 .23 .24 .76 .39 .22 .12 .08 .09 .08 .09 .07 .08 .09 .08
PI  .09 .07 .07 .06 .06
LE  0.74  1.57  1.86  0.5   0
UD  .80
*
KK  SUMP10  DETENTION POND IN BASIN 10
RS  1  STOR  0
SV     0  0.20  1.24  3.15  6.15 10.70 17.18 26.36 38.62 51.38 52.91   56.32
SQ     0     0     0     0     0     0   108   153  177    182   268     510
SE6222.2  6224  6226  6228  6230  6232  6234  6236 6238 6239.8  6240  6240.3
*
KK  RPND10  ROUTE DETENTION POND 10 FLOW TO WESTERN HILLS DETENTION POND
RM  1  .040  .2
*
KK  BASIN_20   BASIN 20 OUTFLOW
BA  .07
LE  0.95  2.02  1.86  0.5  36
UD  .26
*
KK  COMBINE BASIN 20 WITH BASIN 10 SURFACE OUTFLOW FROM WARREN AFB POND
HC  2
*
```

```
*  KK  SUMP20  DETENTION POND IN BASIN 20 (Q=2.6*260*1^1.5)
*  RS  1   STOR  0
*  SV      0  0.45  1.06 1.80
*  SQ      0     0     0  676
*  SE 6201.5  6204  6205 6206
*
KK  RPND20  ROUTE DETENTION POND 20 FLOW TO I-25 VIA EVERS BLVD
RM  2  .146  .2
*
KK  BASIN_30
BA  .35
LE  1.08  2.43  1.86  0.5  51
UD  .46
*
KK  COMBINED FLOW ON EVERS BLVD ABOVE I-25
HC  2
*
KK  RSTR30  ROUTE BASIN 30 FLOW THROUGH BASIN 50 VIA BISHOP
RM  1  .034  .2
*
KK  BASIN_40
BA  .82
LE  0.76  1.57  1.86  0.5    0
UD  .99
*
KK  RSTR40 ROUTE BASIN 40 FLOW THROUGH BASIN 50
RM  1  .104  .2
*
KK  BASIN_50
BA  .17
LE  0.98  2.12  1.86  0.5  29
UD  .46
*
KK  COMBINED FLOW ON BISHOP ABOVE I-25
HC  2
*
KK  COMBINED FLOW ON BISHOP ABOVE I-25 (INC NORTH TRIB)
HC  2
*
KK  RSTR90  ROUTE BASIN 50 OUTFLOW THROUGH BASIN 60
RM  2  0.176  0.2
*
KK  BASIN_60
BA  .52
LE  0.95  2.02  1.86  0.5  39
UD  .59
*
KK  SURFACE INFLOW TO INTERSECTION OF DRY CREEK AND POWDERHOUSE RD
HC  2
*
KK  RSTR70  ROUTE BASIN 60 OUTFLOW THROUGH BASIN 70
RM  4  0.472  0.2
*
KK  BASIN_70
BA  1.50
LE  0.91  1.91  1.86  0.5  37
UD  0.73
*
KK  SURFACE INFLOW TO INTERSECTION OF DRY CREEK AND DELL RANGE BLVD
HC  2
KO  1   1
*
KK  SUMP70 DETENTION POND IN BASIN 70 (DELL RANGE RD AND POWDER HOUSE)
KO  1   1
```

```
RS  1  STOR  0
SV     0  1.45  5.10 13.25 27.34 46.70 73.49 106.47 123.96
SQ     0   313   586   886  1284  1687  2110   3130   4852
SE  6072  6074  6076  6078  6080  6082  6084   6086   6087
*
KK  ROUT_70 ROUTE POND OUTFLOW THROUGH DRY CREEK TO CAREY RESERVOIR
RM  1  .158 .2
*
KK  BASIN_80
BA  .61
LE  0.84  1.70  1.86  0.5  25
UD  1.11
*
KK  DRY CREEK INFLOW ABOVE CAREY RESERVOIR
HC  2
KO  1   1
*
KK  DIV1
KM  DIVERT FLOW INTO CAREY RESVR PER RESVR DIV SPILLWAY STAGE-DISCHARGE CURVE
KO  1   1
DT  DIV1
* INFLOW IN DRY CREEK PRIOR TO CAREY RESERVOIR ROUTING FOLLOWS:
DI  0  45  2700  5800
* BYPASS, WHERE (Q Dry Creek - RESERVOIR DIV)
*  Following DQ card depicts what by-passes Carey and continues in Dry Creek
DQ  0  20  290  2505
*
KK  SUMP80 CAREY RESERVOIR IN BASIN 80
KO  1   1
* FIX
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVe
RS     1    STOR       0
SV     0    9.27    22.7   37.93   54.50   72.41   91.69  109.63
SQ     0    94.0   160.0   448.0   727.0  1185.0  1605.0  1825.0
SE6033.6  6039.0 6041.00  6043.0  6045.0  6047.0  6049.0  6050.7
* FREE
*
KK  DIV2
KO   1   1
KM  DIVERT FLOW FROM CAREY RESVR LOW FLOW ORIFICE PER RESVR STAGE-DISCHARGE CURVE
DT  DIV2
* INFLOW TO CAREY RESERVOIR
DI 0  90  117  157  239  327  450  728  1429  1749  1805
* DISCHARGE FROM LOW FLOW ORIFICE, WHERE (Q - LOW FLOW OUTLET DISCHARGE)
* BYPASS, WHERE (Q - LOW FLOW DIV)
* Following DQ card depicts what by-passes Diversion system and continues in Dry Creek
DQ 0  90  99  108  118  126  134  147  172  184  187
*
KK  ROUT DIV1 AND DIV2 FLOW THROUGH OPEN CHANNEL TO PROPOSED CONVERSE CULVERTS
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1152    .005    .035            TRAP      10       3
*FREE
*
KK  BASN_6A
BA  .080
LE  0.78  1.58  1.86  0.5  35
UD  0.25
*
KK  ROUT BASIN 6A FLOW THROUGH BASIN 13A
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1600    .005    .010            CIRC     4.5
*FREE
```

```
*
KK  BASN_13A
BA  .029
LE  0.76  1.57  1.86  0.5  26
UD  0.14
*
KK  SURFACE INFLOW AND PIPE FLOW TO BASIN 13A CATCHMENT
HC  2
*
KK  ROUT BASIN 13A FLOW THROUGH BASIN 15A
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1550    .005    .010            CIRC       5
*FREE
*
KK  BASN_15A
BA  .043
LE  0.69  1.55  1.86  0.5  26
UD  0.075
*
KK  SURFACE INFLOW AND PIPE FLOW TO BASIN 15A CATCHMENT
HC  2
*
KK  ROUT BASIN 15A FLOW THROUGH BASIN 12A TO EXISTING CONVERSE CULVERTS
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1300     2.0    .050            TRAP      10       4
*FREE
*
KK  BASN_12AB
BA  .161
LE  0.76  1.57  1.86  0.5  25
UD  0.35
*
KK  SURFACE INFLOW AND PIPE FLOW TO EXISTING CONVERSE CULVERTS
KO  1   1
HC  2
*
KK  COMBINED DIVERTED FLOW WITH 12AB FLOW AT UPPER END OF DETENTION BASIN #1
HC  2
*
KK  SUMPDIV DETENTION BASIN #1
* FIX
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
RS     1    STOR       0
SV     0     0.6    6.35    17.7    33.2    51.3    72.6    98.1   119.0   130.
SQ     0    80.0   325.0   590.0   845.0   1080.   1082.   1098.   1120.  1200.
SE6024.3   6027.   6030.   6033.   6036.   6039.   6042.   6045.   6047.  6049.
* FREE
*
KK  SUMPDIV DETENTION BASIN #2
*FIX
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
RS     1    STOR       0
SV     0     1.8     7.5    17.4    29.7    44.1    60.8    79.7   142.0
SQ     0   119.0    263.    370.    478.    553.    604.    648.   666.0
SE6016.3  6020.0   6023.   6026.   6029.   6032.   6035.   6038.   6046.
*FREE
*
KK  SUMPDIV WATER QUALITY BASIN
KO  1   1
*FIX
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
RS     1    STOR       0
```

```
SV     0     1.2     2.8     4.8     7.4    10.6    14.3    18.7
SQ     0    134.    292.    413.    504.    580.    638.    648.
SE6015.6   6020.   6023.   6026.   6029.   6032.   6035.   6038.
*FREE
*
KK  ROUT DIVERTED FLOW BACK TO MAIN CHANNEL OF DRY CREEK, DOWNSTREAM OF RIDGE ROAD
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1732    .005    .016            CIRC       7
*FREE
*
KK  DIV1
KM  DIVERTED FLOW INTO DRY CREEK DIVERSION SYSTEM
DR  DIV1
*
KK  DIV2
KM  DIVERTED FLOW NOT BYPASSING CAREY RESERVOIR THROUGH LOW FLOW ORIFICE
DR  DIV2
*
KK
KO   1   1
KM  COMBINE WEIR BYPASS FLOW WITH CAREY RESERVOIR LOW FLOW ORIFICE DISCHARGE
HC  2
*
KK  ROUT_80  ROUTE CAREY RESERVOIR OUTFLOW IN DRY CREEK TO DELL RANGE BLVD
RM  1  .133 .2
*
KK  BASN_90
BA  .41
LE  0.71  1.57  1.86  0.5   6
UD  1.64
*
KK  DRY CREEK AT DELL RANGE BLVD
HC  2
*
KK  ROUT_100  ROUTE IN DRY CREEK TO RIDGE RD
RM  3  .269 .2
*
KK  BASN_100
BA  1.60
LE  0.91  1.91  1.86  0.5  29
UD  1.35
*
KK  90_100  COMBINED BASIN 90 & 100 OUTFLOW
HC  2
*
KK  BsN_100a
BA  0.22
LE  0.91  1.91  1.86  0.5  29
UD  0.508
*
KK  100_100a  COMBINED BASIN 100 & 100a OUTFLOW
HC  2
*
KK  COMBINED DIVERTED FLOW WITH BASIN 100 FLOW JUST DOWNSTREAM OF RIDGE ROAD
HC  2
*
KK  ROUT_110  ROUTE THROUGH BASIN 110 TO US 30
RM  4  .407 .2
*
KK  BASN_110
BA  2.21
LE  0.91  1.91  1.86  0.5  25
UD  0.97
```

```
*
KK   100_110   COMBINED BASIN 100 & 110 OUTFLOW
HC   2
*
KK   SUMP_110   SUMP TO ACCOUNT FOR STORAGE BEHIND US 30
RS   1 STOR 0
SV       0     0  1.12   9.96   32.09   66.45   115.72   182.49   220.72
SQ       0   452    735   1101    1492    1814     2108     2441     5320
SE  5956.8 5960   5962   5964    5966    5968     5970     5972     5973
*
KK   ROUT_120   ROUTE THROUGH BASIN 120 TO PERSHING BLVD
RM   1   .119 .2
*
KK   BASN_120
BA   0.35
LE   0.91   1.91   1.86   0.5   8
UD   0.55
*
KK   FLOW120   FLOW IN BASIN 120 AT PERSHING BLVD
HC   2
*
KK   ROUT_130   ROUTE THROUGH BASIN 130 TO UPPR
RM   5   .503 .2
KO    1    1
*
* ------START---------START---------START--------START--------START--------START
KK   BSN_130
KO    1    1
BA   1.00
LE   0.91   1.91   1.86   0.5   25
UD   1.74
*
KK   FLW130   FLOW IN BASIN 130 PRIOR TO SUMP STORAGE BEHIND UPPR
KO    1    1
HC   2
*
KK   SUMP_130   SUMP TO ACCOUNT FOR STORAGE upstream of UPPR
RS   1 STOR 0
SV         0     2.2     8.5    18.6    32.5    50.3    70.6    94.6   124.0   159.4
SV     200.4   246.5   295.7   347.0   400.5   457.3   519.1   587.6   688.8   828.5
SQ         0      90     147     218     302     386     465     542     598     651
SQ       701     749     797     838     879     920     959     997    1032    1066
SE      5923    5924    5925    5926    5927    5928    5929    5930    5931    5932
SE    5933.0    5934    5935    5936    5937    5938    5939    5940    5941    5942
*
* --------------- basin 130w to a proposed pond---------
KK   BSN_130W
KO    1    1
BA   0.4
LE   0.91   1.91   1.86   0.5   15
UD   1.74
*
KK   DT_130w   Detention West of RR Sump
RS   1 STOR 0
SV       0  0.01   0.02    0.1     0.3    0.6    1.1    1.9    3.3    6.0
SV    10.3  21.6   43.6   70.6   103.1  142.2  198.9  399.6
SQ       0    28     42     55      67     76     84     92     99    106
SQ     113   119    125    130     135    141    146    168
SE    5923  5925   5926   5927    5928   5929   5930   5931   5932   5933
SE  5934.0  5935   5936   5937    5938   5939   5940   5945
*
* --------- Combined flow out of RR ponds (2)---------
*
KK   FLW130W   Combined RR flows
```

```
KO   1   1
HC  2
*
* ---------- basin to the east that does not get detained---------
*
KK  BSN_130E
KO   1   1
BA  0.6
LE  0.91  1.91  1.86  0.5  25
UD  0.75
*
* ------------------------------
*
KK  FLW130E  Combined RR flows and Basin 130E
KO   1   1
HC  2
*
* --------END-----------END ------------ END------------ END------------ END------------ END
*
KK  ROUT_140  ROUTING SEGMENT THROUGH BASIN 140
RM  7   .698 .2
*
KK  BASN_140
BA  3.61
LE  0.95 2.02  1.86  .5   7
UD  2.30
*
KK  FLOW140  FLOW IN BASIN 140 PRIOR TO CONFLUENCE WITH CROW CREEK
HC  2
ZZ
```

500-year INPUT

(adjustments highlighted)

```
*FREE
ID
ID  THIS IS THE INPUT FOR THE Existing AIRPORT CONDITIONS
ID  THE PRECIPITATION IS "*"ED IN OR OUT TO GIVE THE DESIRED EVENT.
ID  CHEYENNE DRAINAGE MASTER PLAN - DRY CREEK BASIN HYDROLOGY
ID  Existing AIRPORT CONDITIONS -  STORM EVENT: 100-YEAR
ID
ID  THIS SIMULATION USES THE EXPONENTIAL LOSS RATE FUNCTION, MUSKINGUM
ID  ROUTING, AND THE SCS UNIT HYDROGRAPH OPTIONS OF HEC-1.
ID  A TWO HOUR DESIGN STORM IS USED        File Name: POST100.dat
*
IT  5,,50
IO  5
*
*
KK  BASIN10  DETENTION POND BASIN WHICH HAS ALL OUTFLOW VIA LOW FLOW/WEIR
BA  .20
PB
*    2-YEAR STORM
*  PI  .010 .010 .010 .010 .010 .010 .040 .110 .290 .150 .040 .030 .010 .010 .010
*  PI  .010 .010 .010 .010 .005 .010 .005 .005 .005
*    5-YEAR STORM
*  PI  .01 .01 .01 .01 .02 .07 .08 .40 .21 .15 .07 .02 .03 .02 .03 .02 .01 .02 .01
*  PI  .02 .01 .01 .01 .01
*   10-YEAR STORM
*  PI  .01 .02 .02 .03 .04 .10 .11 .17 .48 .25 .10 .04 .04 .04 .03 .03 .02 .03 .02
*  PI  .02 .01 .02 .01 .01
*   25-YEAR STORM
*  PI  .02 .03 .04 .06 .14 .15 .19 .58 .32 .15 .07 .06 .06 .05 .05 .04 .05 .04 .04
*  PI  .04 .04 .03 .04 .03
*   50-YEAR STORM
*  PI  .04 .06 .08 .14 .18 .18 .22 .67 .35 .18 .10 .06 .05 .06 .05 .06 .05 .06 .05
*  PI  .06 .06 .05 .06 .05
*   500-YEAR STORM
PI  .16 .21 .28 .28 .29 .29 .30 1.0 .40 .29 .28 .19 .19 .18 .18 .18 .17 .17 .17
PI  .17 .16 .16 .15 .15
*   100-YEAR STORM
*  PI  .09 .10 .12 .18 .22 .23 .24 .76 .39 .22 .12 .08 .09 .08 .09 .07 .08 .09 .08
*  PI  .09 .07 .07 .06 .06
LE  0.74  1.57  1.86  0.5   0
UD  .80
*
KK  SUMP10  DETENTION POND IN BASIN 10
RS  1  STOR  0
SV     0  0.20  1.24  3.15  6.15 10.70 17.18 26.36 38.62 51.38 52.91   56.32
SQ     0     0     0     0     0     0   108   153  177    182   268     510
SE6222.2  6224  6226  6228  6230  6232  6234  6236 6238 6239.8  6240  6240.3
*
KK  RPND10  ROUTE DETENTION POND 10 FLOW TO WESTERN HILLS DETENTION POND
RM  1  .040  .2
*
KK  BASIN_20   BASIN 20 OUTFLOW
BA  .07
LE  0.95  2.02  1.86  0.5  36
UD  .26
*
KK  COMBINE BASIN 20 WITH BASIN 10 SURFACE OUTFLOW FROM WARREN AFB POND
HC  2
*
```

```
*  KK  SUMP20  DETENTION POND IN BASIN 20 (Q=2.6*260*1^1.5)
*  RS  1   STOR  0
*  SV      0  0.45  1.06 1.80
*  SQ      0     0     0  676
*  SE 6201.5  6204  6205 6206
*
KK  RPND20  ROUTE DETENTION POND 20 FLOW TO I-25 VIA EVERS BLVD
RM  2  .146  .2
*
KK  BASIN_30
BA  .35
LE  1.08  2.43  1.86  0.5  51
UD  .46
*
KK  COMBINED FLOW ON EVERS BLVD ABOVE I-25
HC  2
*
KK  RSTR30  ROUTE BASIN 30 FLOW THROUGH BASIN 50 VIA BISHOP
RM  1  .034  .2
*
KK  BASIN_40
BA  .82
LE  0.76  1.57  1.86  0.5    0
UD  .99
*
KK  RSTR40 ROUTE BASIN 40 FLOW THROUGH BASIN 50
RM  1  .104  .2
*
KK  BASIN_50
BA  .17
LE  0.98  2.12  1.86  0.5  29
UD  .46
*
KK  COMBINED FLOW ON BISHOP ABOVE I-25
HC  2
*
KK  COMBINED FLOW ON BISHOP ABOVE I-25 (INC NORTH TRIB)
HC  2
*
KK  RSTR90  ROUTE BASIN 50 OUTFLOW THROUGH BASIN 60
RM  2  0.176  0.2
*
KK  BASIN_60
BA  .52
LE  0.95  2.02  1.86  0.5  39
UD  .59
*
KK  SURFACE INFLOW TO INTERSECTION OF DRY CREEK AND POWDERHOUSE RD
HC  2
*
KK  RSTR70  ROUTE BASIN 60 OUTFLOW THROUGH BASIN 70
RM  4  0.472  0.2
*
KK  BASIN_70
BA  1.50
LE  0.91  1.91  1.86  0.5  37
UD  0.73
*
KK  SURFACE INFLOW TO INTERSECTION OF DRY CREEK AND DELL RANGE BLVD
HC  2
KO  1   1
*
KK  SUMP70 DETENTION POND IN BASIN 70 (DELL RANGE RD AND POWDER HOUSE)
KO  1   1
```

```
RS  1  STOR  0
SV     0  1.45  5.10 13.25 27.34 46.70 73.49 106.47 123.96
SQ     0   313   586   886  1284  1687  2110   3130   4852
SE  6072  6074  6076  6078  6080  6082  6084   6086   6087
*
KK  ROUT_70 ROUTE POND OUTFLOW THROUGH DRY CREEK TO CAREY RESERVOIR
RM  1  .158 .2
*
KK  BASIN_80
BA  .61
LE  0.84  1.70  1.86  0.5  25
UD  1.11
*
KK  DRY CREEK INFLOW ABOVE CAREY RESERVOIR
HC  2
KO  1   1
*
KK  DIV1
KM  DIVERT FLOW INTO CAREY RESVR PER RESVR DIV SPILLWAY STAGE-DISCHARGE CURVE
KO  1   1
DT  DIV1
* INFLOW IN DRY CREEK PRIOR TO CAREY RESERVOIR ROUTING FOLLOWS:
DI  0  45  2700  4800  5800
* BYPASS, WHERE (Q Dry Creek - RESERVOIR DIV)
*  Following DQ card depicts what by-passes Carey and continues in Dry Creek
DQ  0  20  290  1860  2505
*
KK  SUMP80 CAREY RESERVOIR IN BASIN 80
KO  1   1
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
* FIX
RS     1    STOR       0
SV     0    9.27    22.7   37.93   54.50   72.41   91.69   95.00
SQ     0    94.0   160.0   448.0   727.0  1185.0  1825.0  6500.0
SE6033.6  6039.0 6041.00  6043.0  6045.0  6047.0  6049.0  6051.0
* FREE
*
KK  DIV2
KO   1   1
KM  DIVERT FLOW FROM CAREY RESVR LOW FLOW ORIFICE PER RESVR STAGE-DISCHARGE CURVE
DT  DIV2
* INFLOW TO CAREY RESERVOIR
DI 0  90  117  157  239  327  450  728  1429  1749  2000  3150
* DISCHARGE FROM LOW FLOW ORIFICE, WHERE (Q - LOW FLOW OUTLET DISCHARGE)
* BYPASS, WHERE (Q - LOW FLOW DIV)
* Following DQ card depicts what by-passes Diversion system and continues in Dry Creek
DQ 0  90  99  108  118  126  134  147  172  184  195  1280
*
KK  ROUT DIV1 AND DIV2 FLOW THROUGH OPEN CHANNEL TO PROPOSED CONVERSE CULVERTS
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1152    .005    .035            TRAP      10       3
*FREE
*
KK  BASN_6A
BA  .080
LE  0.78  1.58  1.86  0.5  35
UD  0.25
*
KK  ROUT BASIN 6A FLOW THROUGH BASIN 13A
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1600    .005    .010            CIRC     4.5
*FREE
```

```
*
KK  BASN_13A
BA  .029
LE  0.76  1.57  1.86  0.5  26
UD  0.14
*
KK  SURFACE INFLOW AND PIPE FLOW TO BASIN 13A CATCHMENT
HC  2
*
KK  ROUT BASIN 13A FLOW THROUGH BASIN 15A
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1550    .005    .010            CIRC       5
*FREE
*
KK  BASN_15A
BA  .043
LE  0.69  1.55  1.86  0.5  26
UD  0.075
*
KK  SURFACE INFLOW AND PIPE FLOW TO BASIN 15A CATCHMENT
HC  2
*
KK  ROUT BASIN 15A FLOW THROUGH BASIN 12A TO EXISTING CONVERSE CULVERTS
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1300     2.0    .050            TRAP      10       4
*FREE
*
KK  BASN_12AB
BA  .161
LE  0.76  1.57  1.86  0.5  25
UD  0.35
*
KK  SURFACE INFLOW AND PIPE FLOW TO EXISTING CONVERSE CULVERTS
KO  1   1
HC  2
*
KK  COMBINED DIVERTED FLOW WITH 12AB FLOW AT UPPER END OF DETENTION BASIN #1
HC  2
*
KK  SUMPDIV DETENTION BASIN #1
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
* FIX
RS      1    STOR       0
SV      0     0.6    6.35    17.7    33.2    51.3    72.6    98.1   119.0   250.
SQ      0    80.0   325.0   590.0   845.0   1080.   1082.   1098.   1120.  1135.
SE6024.3   6027.   6030.   6033.   6036.   6039.   6042.   6045.   6047.  6049.
* FREE
*
KK  SUMPDIV DETENTION BASIN #2
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
*FIX
RS      1    STOR       0
SV      0     1.8     7.5    17.4    29.7    44.1    60.8    79.7   230.0
SQ      0   119.0    263.    370.    478.    553.    604.    648.   690.0
SE6016.3  6020.0   6023.   6026.   6029.   6032.   6035.   6038.   6046.
*FREE
*
KK  SUMPDIV WATER QUALITY BASIN
KO  1   1
* The last value was adjusted to match the EPASWMM results - DOES NOT MATCH ACTUAL RATING CURVE
*FIX
RS      1    STOR       0
```

```
SV     0     1.2     2.8     4.8     7.4    10.6    14.3    30.
SQ     0    134.    292.    413.    504.    580.    638.    705.
SE6015.6   6020.   6023.   6026.   6029.   6032.   6035.   6038.
*FREE
*
KK  ROUT DIVERTED FLOW BACK TO MAIN CHANNEL OF DRY CREEK, DOWNSTREAM OF RIDGE ROAD
* MUSKINGHAM-CUNGE ROUTING
*FIX
RD  1732    .005    .016            CIRC       7
*FREE
*
KK  DIV1
KM  DIVERTED FLOW INTO DRY CREEK DIVERSION SYSTEM
DR  DIV1
*
KK  DIV2
KM  DIVERTED FLOW NOT BYPASSING CAREY RESERVOIR THROUGH LOW FLOW ORIFICE
DR  DIV2
*
KK
KO   1   1
KM  COMBINE WEIR BYPASS FLOW WITH CAREY RESERVOIR LOW FLOW ORIFICE DISCHARGE
HC  2
*
KK  ROUT_80  ROUTE CAREY RESERVOIR OUTFLOW IN DRY CREEK TO DELL RANGE BLVD
RM  1  .133 .2
*
KK  BASN_90
BA  .41
LE  0.71  1.57  1.86  0.5   6
UD  1.64
*
KK  DRY CREEK AT DELL RANGE BLVD
HC  2
*
KK  ROUT_100  ROUTE IN DRY CREEK TO RIDGE RD
RM  3  .269 .2
*
KK  BASN_100
BA  1.60
LE  0.91  1.91  1.86  0.5  29
UD  1.35
*
KK  90_100  COMBINED BASIN 90 & 100 OUTFLOW
HC  2
*
KK  BsN_100a
BA  0.22
LE  0.91  1.91  1.86  0.5  29
UD  0.508
*
KK  100_100a  COMBINED BASIN 100 & 100a OUTFLOW
HC  2
*
KK  COMBINED DIVERTED FLOW WITH BASIN 100 FLOW JUST DOWNSTREAM OF RIDGE ROAD
HC  2
*
KK  ROUT_110  ROUTE THROUGH BASIN 110 TO US 30
RM  4  .407 .2
*
KK  BASN_110
BA  2.21
LE  0.91  1.91  1.86  0.5  25
UD  0.97
```

```
*
KK  100_110  COMBINED BASIN 100 & 110 OUTFLOW
HC  2
*
KK  SUMP_110  SUMP TO ACCOUNT FOR STORAGE BEHIND US 30
RS  1 STOR 0
* The last value was added due to overtopping of the pond in a 500-year event
SV      0    0  1.12  9.96  32.09  66.45  115.72  182.49  220.72  230.0
SQ      0  452   735  1101   1492   1814    2108    2441    5320  8000.
SE 5956.8 5960  5962  5964   5966   5968    5970    5972    5973  5974
*
KK  ROUT_120  ROUTE THROUGH BASIN 120 TO PERSHING BLVD
RM  1  .119 .2
*
KK  BASN_120
BA  0.35
LE  0.91  1.91  1.86  0.5  8
UD  0.55
*
KK  FLOW120  FLOW IN BASIN 120 AT PERSHING BLVD
HC  2
*
KK  ROUT_130  ROUTE THROUGH BASIN 130 TO UPPR
RM  5  .503 .2
KO   1   1
*
* ------START---------START---------START--------START--------START--------START
KK  BSN_130
KO   1   1
BA  1.00
LE  0.91  1.91  1.86  0.5  25
UD  1.74
*
KK  FLW130  FLOW IN BASIN 130 PRIOR TO SUMP STORAGE BEHIND UPPR
KO   1   1
HC  2
*
KK  SUMP_130  SUMP TO ACCOUNT FOR STORAGE upstream of UPPR
RS  1 STOR 0
SV       0      2.2      8.5     18.6     32.5     50.3     70.6     94.6    124.0    159.4
SV   200.4    246.5    295.7    347.0    400.5    457.3    519.1    587.6    688.8    828.5
SQ       0       90      147      218      302      386      465      542      598      651
SQ     701      749      797      838      879      920      959      997     1032     1066
SE    5923   5924.0   5925.0   5926.0   5927.0   5928.0   5929.0   5930.0   5931.0   5932.0
SE  5933.0   5934.0   5935.0   5936.0   5937.0   5938.0   5939.0   5940.0   5941.0   5942.0
*
* --------------- basin 130w to a proposed pond---------
KK  BSN_130W
KO   1   1
BA  0.4
LE  0.91  1.91  1.86  0.5  15
UD  1.74
*
KK  DT_130w  Detention West of RR Sump
RS  1 STOR 0
SV      0    0.01    0.02     0.1      0.3     0.6     1.1     1.9      3.3     6.0
SV   10.3    21.6    43.6    70.6    103.1   142.2   198.9   399.6
SQ      0      28      42      55       67      76      84      92       99     106
SQ    113     119     125     130      135     141     146     168
SE   5923  5925.0  5926.0  5927.0   5928.0  5929.0  5930.0  5931.0   5932.0  5933.0
SE 5934.0  5935.0  5936.0  5937.0   5938.0  5939.0  5940.0  5945.0
*
* --------- Combined flow out of RR ponds (2)---------
*
```

```
KK  FLW130W  Combined RR flows
KO   1   1
HC  2
*
* ---------- basin to the east that does not get detained---------
*
KK  BSN_130E
KO   1   1
BA  0.6
LE  0.91  1.91  1.86  0.5  25
UD  0.75
*
* -------------------------------
*
KK  FLW130E  Combined RR flows and Basin 130E
KO   1   1
HC  2
*
* --------END-----------END ------------ END------------ END------------ END------------ END
*
KK  ROUT_140  ROUTING SEGMENT THROUGH BASIN 140
RM  7   .698 .2
*
KK  BASN_140
BA  3.61
LE  0.95 2.02  1.86  .5   7
UD  2.30
*
KK  FLOW140  FLOW IN BASIN 140 PRIOR TO CONFLUENCE WITH CROW CREEK
HC  2
ZZ
```

Appendix: HEC-1 Output

100-year Output

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	BASIN10	160.	1.50	37.	27.	27.	.20		
+	ROUTED TO	SUMP10	51.	2.58	15.	11.	11.	.20		
+									6232.94	2.58
+	ROUTED TO	RPND10	51.	2.58	15.	11.	11.	.20		
+	HYDROGRAPH AT	BASIN_20	133.	.92	16.	11.	11.	.07		
+	2 COMBINED AT	COMBINE	133.	.92	31.	23.	23.	.27		
+	ROUTED TO	RPND20	123.	1.08	31.	23.	23.	.27		
+	HYDROGRAPH AT	BASIN_30	507.	1.08	88.	63.	63.	.35		
+	2 COMBINED AT	COMBINED	630.	1.08	119.	86.	86.	.62		
+	ROUTED TO	RSTR30	621.	1.08	119.	86.	86.	.62		
+	HYDROGRAPH AT	BASIN_40	546.	1.67	148.	107.	107.	.82		
+	ROUTED TO	RSTR40	541.	1.75	148.	107.	107.	.82		
+	HYDROGRAPH AT	BASIN_50	214.	1.08	35.	25.	25.	.17		
+	2 COMBINED AT	COMBINED	617.	1.67	183.	132.	132.	.99		
+	2 COMBINED AT	COMBINED	1079.	1.25	302.	218.	218.	1.61		
+	ROUTED TO	RSTR90	1054.	1.42	302.	218.	218.	1.61		
+	HYDROGRAPH AT	BASIN_60	616.	1.25	122.	88.	88.	.52		
+	2 COMBINED AT	SURFACE	1635.	1.33	425.	306.	306.	2.13		
+	ROUTED TO	RSTR70	1499.	1.83	425.	306.	306.	2.13		
+	HYDROGRAPH AT	BASIN_70	1536.	1.42	355.	255.	255.	1.50		
+	2 COMBINED AT	SURFACE	2709.	1.67	779.	561.	561.	3.63		
+	ROUTED TO	SUMP70	2093.	2.17	779.	561.	561.	3.63		
+									6083.92	2.17
+	ROUTED TO	ROUT_70	2077.	2.33	779.	561.	561.	3.63		
+	HYDROGRAPH AT	BASIN_80	435.	1.83	134.	97.	97.	.61		

```
          2 COMBINED AT
+                        DRY      2442.    2.17        913.        658.        658.       4.24

          DIVERSION TO
+                       DIV1       264.    2.17        107.         77.         77.       4.24

          HYDROGRAPH AT
+                       DIV1      2178.    2.17        806.        581.        581.       4.24

          ROUTED TO
+                     SUMP80      1806.    2.92        787.        577.        577.       4.24
+                                                                                                 6050.56        2.92

          DIVERSION TO
+                       DIV2       187.    2.92        140.        110.        110.       4.24

          HYDROGRAPH AT
+                       DIV2      1619.    2.92        648.        466.        466.       4.24

          ROUTED TO
+                       ROUT      1619.    2.92        648.        466.        466.       4.24

          HYDROGRAPH AT
+                    BASN_6A       166.     .92         20.         15.         15.        .08

          ROUTED TO
+                       ROUT       163.     .92         20.         15.         15.        .08

          HYDROGRAPH AT
+                   BASN_13A        72.     .83          7.          5.          5.        .03

          2 COMBINED AT
+                    SURFACE       217.     .83         27.         20.         20.        .11

          ROUTED TO
+                       ROUT       215.     .92         27.         20.         20.        .11

          HYDROGRAPH AT
+                   BASN_15A       133.     .75         11.          8.          8.        .04

          2 COMBINED AT
+                    SURFACE       293.     .83         38.         27.         27.        .15

          ROUTED TO
+                       ROUT       293.     .83         38.         27.         27.        .15

          HYDROGRAPH AT
+                   BASN_12A       267.    1.00         38.         27.         27.        .16

          2 COMBINED AT
+                    SURFACE       522.     .92         76.         54.         54.        .31

          2 COMBINED AT
+                   COMBINED      1622.    2.92        722.        521.        521.       4.55

          ROUTED TO
+                    SUMPDIV      1096.    3.92        721.        521.        521.       4.55
+                                                                                                 6044.59        3.92

          ROUTED TO
+                    SUMPDIV       664.    5.42        611.        496.        496.       4.55
+                                                                                                 6045.07        5.42

          ROUTED TO
+                    SUMPDIV       645.    6.92        604.        485.        485.       4.55
+                                                                                                 6037.14        6.92

          ROUTED TO
+                       ROUT       645.    6.92        603.        483.        483.       4.55

          HYDROGRAPH AT
+                       DIV1       264.    2.17        107.         77.         77.        .00

          HYDROGRAPH AT
+                       DIV2       187.    2.92        140.        110.        110.        .00

          2 COMBINED AT
+                                  443.    2.25        244.        187.        187.        .00

          ROUTED TO
+                    ROUT_80       441.    2.42        243.        187.        187.        .00

          HYDROGRAPH AT
```

```
+                   BASN_90      203.    2.42        83.        60.        60.       .41

          2 COMBINED AT
+                       DRY      644.    2.42       326.       247.       247.       .41

          ROUTED TO
+                  ROUT_100      639.    2.67       325.       246.       246.       .41

          HYDROGRAPH AT
+                  BASN_100      967.    2.08       344.       249.       249.      1.60

          2 COMBINED AT
+                    90_100     1528.    2.25       664.       495.       495.      2.01

          HYDROGRAPH AT
+                  BsN_100a      272.    1.17        48.        34.        34.       .22

          2 COMBINED AT
+                  100_100a     1589.    2.25       709.       529.       529.      2.23

          2 COMBINED AT
+                  COMBINED     1969.    2.42      1226.      1012.      1012.      6.78

          ROUTED TO
+                  ROUT_110     1949.    2.75      1223.       982.       982.      6.78

          HYDROGRAPH AT
+                  BASN_110     1649.    1.67       455.       328.       328.      2.21

          2 COMBINED AT
+                   100_110     2919.    2.00      1627.      1309.      1309.      8.99

          ROUTED TO
+                  SUMP_110     2177.    3.17      1625.      1310.      1310.      8.99
+                                                                                           5970.41       3.17

          ROUTED TO
+                  ROUT_120     2175.    3.33      1624.      1307.      1307.      8.99

          HYDROGRAPH AT
+                  BASN_120      338.    1.17        57.        41.        41.       .35

          2 COMBINED AT
+                   FLOW120     2180.    3.25      1666.      1348.      1348.      9.34

          ROUTED TO
+                  ROUT_130     2174.    3.83      1660.      1331.      1331.      9.34

          HYDROGRAPH AT
+                   BSN_130      474.    2.50       203.       148.       148.      1.00

          2 COMBINED AT
+                    FLW130     2490.    3.17      1852.      1479.      1479.     10.34

          ROUTED TO
+                  SUMP_130      974.    6.92       883.       710.       710.     10.34
+                                                                                           5939.41       6.92

          HYDROGRAPH AT
+                  BSN_130W      168.    2.50        71.        52.        52.       .40

          ROUTED TO
+                   DT_130w      109.    3.50        71.        52.        52.       .40
+                                                                                           5933.38       3.50

          2 COMBINED AT
+                   FLW130W     1014.    5.17       939.       762.       762.     10.74

          HYDROGRAPH AT
+                  BSN_130E      544.    1.42       124.        89.        89.       .60

          2 COMBINED AT
+                   FLW130E     1015.    5.17       960.       851.       851.     11.34

          ROUTED TO
+                  ROUT_140     1010.    5.75       949.       770.       770.     11.34

          HYDROGRAPH AT
+                  BASN_140     1009.    3.08       521.       387.       387.      3.61

          2 COMBINED AT
+                   FLOW140     1899.    3.08      1427.      1157.      1157.     14.95
```

500-year Output

1

1

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
+	HYDROGRAPH AT	BASIN10	265.	1.50	75.	54.	54.	.20		
+	ROUTED TO	SUMP10	128.	2.58	54.	39.	39.	.20		
+									6234.89	2.58
+	ROUTED TO	RPND10	128.	2.67	54.	39.	39.	.20		
+	HYDROGRAPH AT	BASIN_20	181.	.92	30.	22.	22.	.07		
+	2 COMBINED AT	COMBINE	181.	.92	83.	60.	60.	.27		
+	ROUTED TO	RPND20	171.	1.08	83.	60.	60.	.27		
+	HYDROGRAPH AT	BASIN_30	724.	1.08	160.	115.	115.	.35		
+	2 COMBINED AT	COMBINED	894.	1.08	244.	176.	176.	.62		
+	ROUTED TO	RSTR30	890.	1.17	244.	176.	176.	.62		
+	HYDROGRAPH AT	BASIN_40	946.	1.75	304.	219.	219.	.82		
+	ROUTED TO	RSTR40	939.	1.83	304.	219.	219.	.82		
+	HYDROGRAPH AT	BASIN_50	315.	1.17	68.	49.	49.	.17		
+	2 COMBINED AT	COMBINED	1103.	1.83	372.	268.	268.	.99		
+	2 COMBINED AT	COMBINED	1707.	1.33	615.	444.	444.	1.61		
+	ROUTED TO	RSTR90	1686.	1.50	615.	444.	444.	1.61		
+	HYDROGRAPH AT	BASIN_60	922.	1.25	228.	164.	164.	.52		
+	2 COMBINED AT	SURFACE	2549.	1.42	843.	608.	608.	2.13		
+	ROUTED TO	RSTR70	2419.	1.92	843.	608.	608.	2.13		
+	HYDROGRAPH AT	BASIN_70	2382.	1.42	661.	476.	476.	1.50		
+	2 COMBINED AT	SURFACE	4420.	1.75	1503.	1084.	1084.	3.63		
+	ROUTED TO	SUMP70	4187.	2.00	1503.	1084.	1084.	3.63		
+									6086.61	2.00
+	ROUTED TO	ROUT_70	4076.	2.25	1503.	1084.	1084.	3.63		

```
           HYDROGRAPH AT
+                         BASIN_80      736.    1.92        256.        185.        185.       .61

           2 COMBINED AT
+                              DRY     4784.    2.17       1759.       1269.       1269.      4.24

           DIVERSION TO
+                             DIV1     1848.    2.17        423.        305.        305.      4.24

           HYDROGRAPH AT
+                             DIV1     2936.    2.17       1336.        963.        963.      4.24

           ROUTED TO
+                           SUMP80     3148.    1.92       1305.        956.        956.      4.24
+                                                                                                   6049.57       1.92

           DIVERSION TO
+                             DIV2     1278.    1.92        340.        260.        260.      4.24

           HYDROGRAPH AT
+                             DIV2     1870.    1.92        965.        696.        696.      4.24

           ROUTED TO
+                             ROUT     1858.    2.25        965.        696.        696.      4.24

           HYDROGRAPH AT
+                          BASN_6A      221.     .92         37.         27.         27.       .08

           ROUTED TO
+                             ROUT      218.     .92         37.         27.         27.       .08

           HYDROGRAPH AT
+                         BASN_13A       97.     .75         13.          9.          9.       .03

           2 COMBINED AT
+                          SURFACE      292.     .83         50.         36.         36.       .11

           ROUTED TO
+                             ROUT      289.     .92         50.         36.         36.       .11

           HYDROGRAPH AT
+                         BASN_15A      168.     .75         20.         14.         14.       .04

           2 COMBINED AT
+                          SURFACE      400.     .75         70.         50.         50.       .15

           ROUTED TO
+                             ROUT      393.     .75         70.         50.         50.       .15

           HYDROGRAPH AT
+                         BASN_12A      372.    1.00         71.         51.         51.       .16

           2 COMBINED AT
+                          SURFACE      728.     .92        140.        101.        101.       .31

           2 COMBINED AT
+                         COMBINED     2122.    2.00       1100.        797.        797.      4.55

           ROUTED TO
+                          SUMPDIV     1127.    4.42       1030.        797.        797.      4.55
+                                                                                                   6047.98       4.42

           ROUTED TO
+                          SUMPDIV      686.    7.00        664.        555.        555.      4.55
+                                                                                                   6045.31       7.00

           ROUTED TO
+                          SUMPDIV      669.    8.33        635.        524.        524.      4.55
+                                                                                                   6036.40       8.33

           ROUTED TO
+                             ROUT      669.    8.33        634.        521.        521.      4.55

           HYDROGRAPH AT
+                             DIV1     1848.    2.17        423.        305.        305.       .00

           HYDROGRAPH AT
+                             DIV2     1278.    1.92        340.        260.        260.       .00

           2 COMBINED AT
+                                      3008.    2.08        760.        566.        566.       .00

           ROUTED TO
+                          ROUT_80     2873.    2.33        760.        565.        565.       .00
```

```
         HYDROGRAPH AT
+                        BASN_90      373.    2.58        162.        118.        118.        .41

         2 COMBINED AT
+                            DRY     3238.    2.33        921.        683.        683.        .41

         ROUTED TO
+                       ROUT_100     3145.    2.67        921.        681.        681.        .41

         HYDROGRAPH AT
+                       BASN_100     1703.    2.25        660.        478.        478.       1.60

         2 COMBINED AT
+                         90_100     4720.    2.58       1574.       1159.       1159.       2.01

         HYDROGRAPH AT
+                       BsN_100a      404.    1.17         91.         66.         66.        .22

         2 COMBINED AT
+                       100_100a     4813.    2.58       1662.       1225.       1225.       2.23

         2 COMBINED AT
+                       COMBINED     5342.    2.58       2207.       1746.       1746.       6.78

         ROUTED TO
+                       ROUT_110     5181.    3.00       2203.       1709.       1709.       6.78

         HYDROGRAPH AT
+                       BASN_110     2760.    1.75        888.        640.        640.       2.21

         2 COMBINED AT
+                        100_110     6447.    2.92       3037.       2348.       2348.       8.99

         ROUTED TO
+                       SUMP_110     6444.    2.92       3010.       2347.       2347.       8.99
+                                                                                                   5973.42        2.92

         ROUTED TO
+                       ROUT_120     6381.    3.08       3008.       2342.       2342.       8.99

         HYDROGRAPH AT
+                       BASN_120      535.    1.25        121.         87.         87.        .35

         2 COMBINED AT
+                        FLOW120     6423.    3.00       3099.       2430.       2430.       9.34

         ROUTED TO
+                       ROUT_130     6249.    3.58       3091.       2407.       2407.       9.34

         HYDROGRAPH AT
+                        BSN_130      876.    2.67        394.        289.        289.       1.00

         2 COMBINED AT
+                         FLW130     6894.    3.50       3466.       2696.       2696.      10.34

         ROUTED TO
+                       SUMP_130     2150.    6.08       1740.       1341.       1341.      10.34
+                                                                                                   5942.27        6.08

         HYDROGRAPH AT
+                       BSN_130W      323.    2.67        145.        106.        106.        .40

         ROUTED TO
+                        DT_130w      122.    4.33        118.        100.        100.        .40
+                                                                                                   5935.47        4.33

         2 COMBINED AT
+                        FLW130W     2270.    6.08       1858.       1441.       1441.      10.74

         HYDROGRAPH AT
+                       BSN_130E      866.    1.42        241.        174.        174.        .60

         2 COMBINED AT
+                        FLW130E     2270.    6.08       1915.       1614.       1614.      11.34

         ROUTED TO
+                       ROUT_140     2268.    6.75       1829.       1441.       1441.      11.34

         HYDROGRAPH AT
+                       BASN_140     2117.    3.17       1131.        844.        844.       3.61

         2 COMBINED AT
+                        FLOW140     3398.    3.08       2838.       2285.       2285.      14.95
```

Appendix: Pond Rating Curves

Pond 130 Pond Rating Curve

Contour Elev. (ft)	Surface Area (ft^2)	Contour Volume (ft^3)	Total Volume (ft^3)	Total Volume (acre-ft)	Flow (cfs)
5923	41479	0.00	0	0.0	0
5924	162361	95,301	95,301	2.2	90
5925	406068	275,066	370,367	8.5	147
5926	476385	440,759	811,126	18.6	218
5927	743253	604,893	1,416,019	32.5	302
5928	806837	774,827	2,190,847	50.3	386
5929	960035	882,327	3,073,174	70.6	465
5930	1141864	1,049,637	4,122,811	94.6	542
5931	1421595	1,279,178	5,401,989	124.0	598
5932	1661940	1,540,204	6,942,193	159.4	651
5933	1918960	1,788,911	8,731,104	200.4	701
5934	2094448	2,006,064	10,737,168	246.5	749
5935	2194028	2,144,046	12,881,214	295.7	797
5936	2274262	2,234,025	15,115,239	347.0	838
5937	2391185	2,332,479	17,447,718	400.5	879
5938	2550794	2,470,560	19,918,279	457.3	920
5939	2838152	2,693,195	22,611,474	519.1	959
5940	3137391	2,986,522	25,597,996	587.6	997
5950	15686522	86,130,783	111,728,779	2,564.9	6066

HEC-1 Info	100yr	HEC-1 Info	500yr
WSEL	5939.41	WSEL	5942.27
Flow	974	Flow	2150
Volume	547.2	Volume	1036.5

Pond 130W Pond Rating Curve

Contour Elev. (ft)	Surface Area (ft^2)	Contour Volume (ft^3)	Total Volume (ft^3)	Total Volume (acre-ft)	Flow (cfs)
5922	0	0.00	0	0.0	0
5925	172	172	172	0.0	28
5926	1169	597	769	0.0	42
5927	6422	3,444	4,213	0.1	55
5928	11761	8,958	13,171	0.3	67
5929	18336	14,927	28,098	0.6	76
5930	23317	20,777	48,875	1.1	84
5931	46668	34,324	83,199	1.9	92
5932	71879	58,822	142,021	3.3	99
5933	170957	117,896	259,917	6.0	106
5934	204606	187,530	447,447	10.3	113
5935	861743	495,417	942,864	21.6	119
5936	1057696	958,048	1,900,912	43.6	125
5937	1292712	1,173,241	3,074,153	70.6	130
5938	1542343	1,415,692	4,489,845	103.1	135
5939	1873924	1,705,445	6,195,290	142.2	141
5940	3115650	2,468,624	8,663,914	198.9	146
5945	676798	8,740,954	17,404,868	399.6	168

HEC-1 Info	100yr	HEC-1 Info	500yr
WSEL	5933.38	WSEL	5935.47
Flow	109	Flow	122
Volume	7.6	Volume	32.0

Appendix: HY-8 Culvert Analysis Reports

HY-8 Culvert Analysis Report

Railroad Crossing: Sump 130

(main detention pond)

Crossing Discharge Data

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

Minimum Flow: 50 cfs

Design Flow: 1000 cfs

Maximum Flow: 1300 cfs

Table 1 - Summary of Culvert Flows at Crossing: RR Crossing_Sump_130

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Culvert 1 (Copy) Discharge (cfs)	Roadway Discharge (cfs)	Iterations
23.31	50.00	1.37	48.61	0.00	3
25.49	175.00	87.29	87.69	0.00	6
26.97	300.00	188.24	111.76	0.00	5
28.47	425.00	303.25	121.80	0.00	4
30.11	550.00	411.81	138.24	0.00	4
32.45	675.00	514.64	160.36	0.00	5
35.07	800.00	617.54	182.46	0.00	5
38.11	925.00	719.46	205.58	0.00	5
40.08	1000.00	780.65	219.37	0.00	3
44.23	1175.00	895.92	245.82	32.92	10
44.62	1300.00	905.93	247.10	146.83	5
44.00	1134.67	889.93	244.74	0.00	Overtopping

Rating Curve Plot for Crossing: RR Crossing_Sump_130

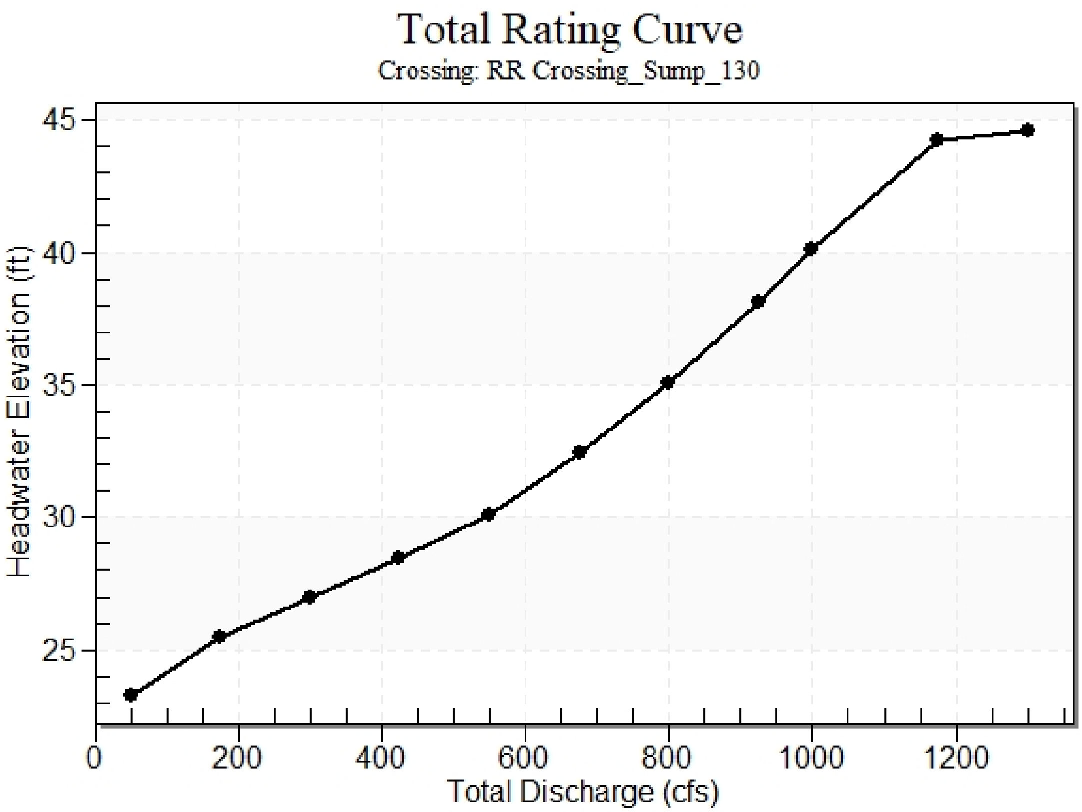


Table 2 - Culvert Summary Table: Culvert 1

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)
50.00	1.37	23.31	0.292	0.313	3-M1t	0.228	0.223	0.513	0.513	0.644	1.872
175.00	87.29	25.49	2.495	1.009	1-S2n	1.766	1.846	1.766	1.078	7.039	2.990
300.00	188.24	26.97	3.968	2.518	1-S2n	2.725	2.757	2.725	1.478	8.603	3.629
425.00	303.25	28.47	5.317	5.473	7-M2c	3.815	3.530	3.530	1.811	10.233	4.101
550.00	411.81	30.11	6.759	7.108	7-M2c	5.000	4.090	4.090	2.102	11.977	4.480
675.00	514.64	32.45	8.427	9.445	7-M2c	5.000	4.467	4.467	2.364	13.899	4.802
800.00	617.54	35.07	10.395	12.067	7-M2c	5.000	4.700	4.700	2.606	16.120	5.082
925.00	719.46	38.11	12.643	15.111	7-M2c	5.000	4.393	4.393	2.830	19.683	5.331
1000.00	780.65	40.08	14.177	17.081	6-FFc	5.000	5.000	5.000	2.958	19.879	5.468
1175.00	895.92	44.23	17.768	21.230	6-FFc	5.000	5.000	5.000	3.239	22.814	5.761
1300.00	905.93	44.62	18.111	21.617	6-FFc	5.000	5.000	5.000	3.429	23.069	5.951

****

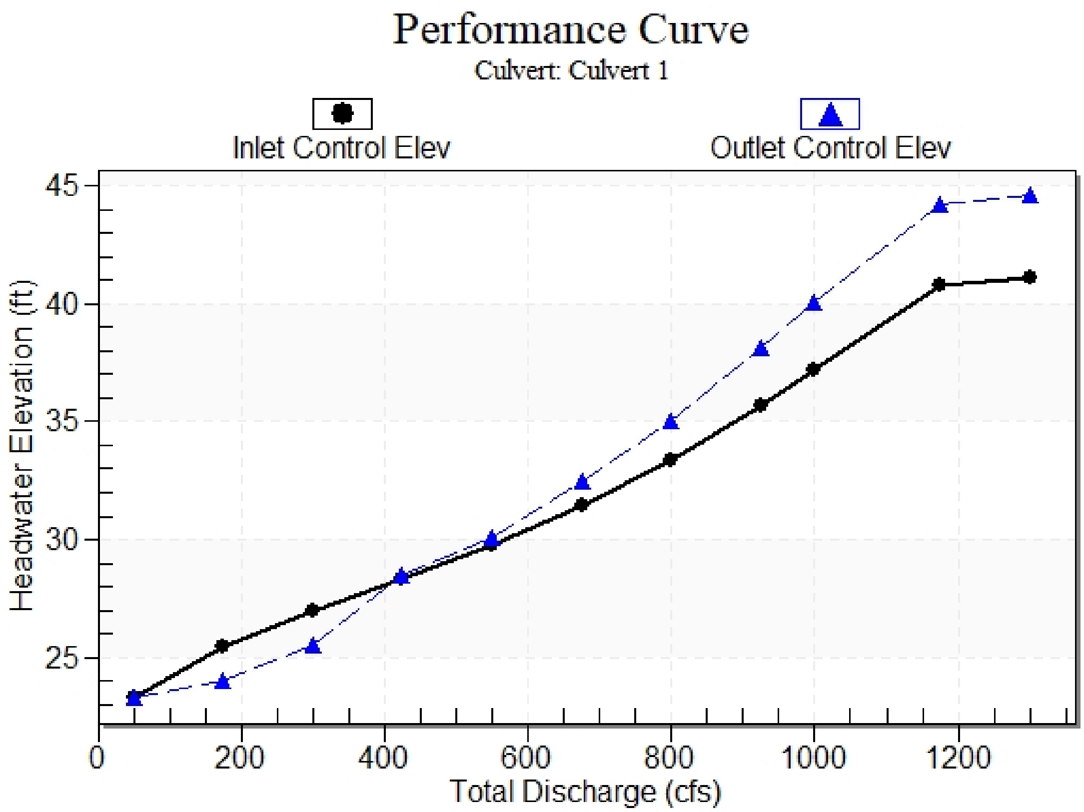
Straight Culvert

Inlet Elevation (invert): 23.00 ft, Outlet Elevation (invert): 22.00 ft

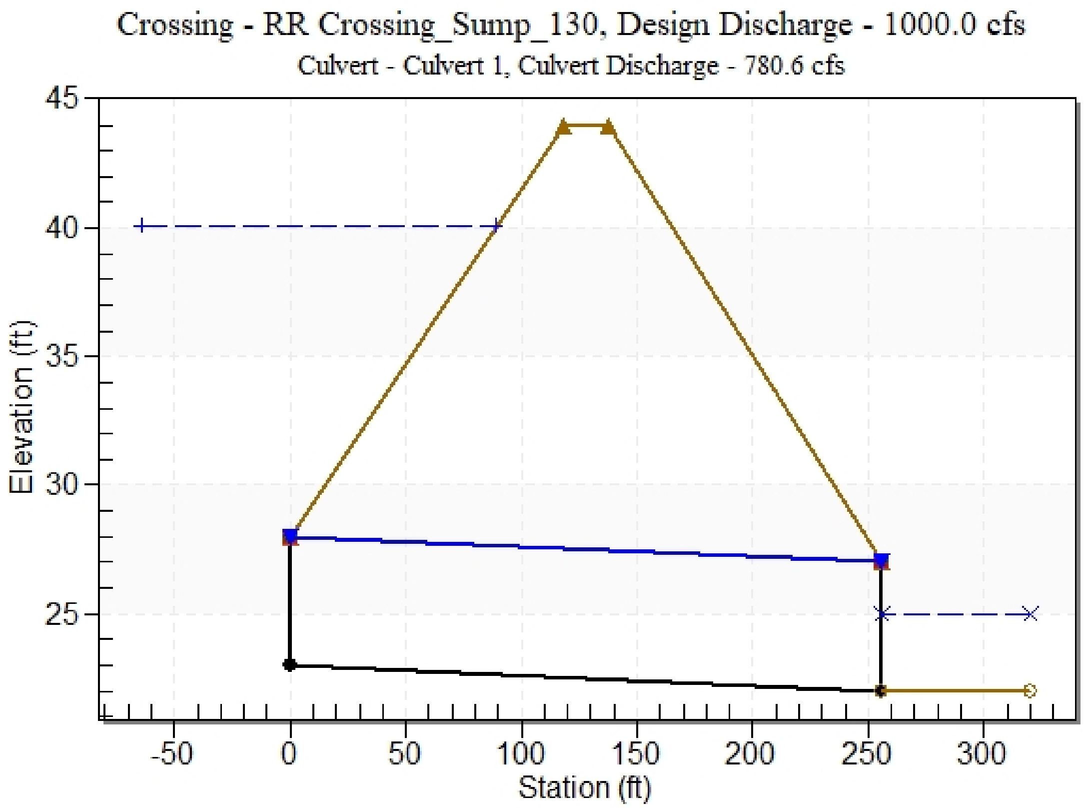
Culvert Length: 256.00 ft, Culvert Slope: 0.0039

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 23.00 ft

Outlet Station: 256.00 ft

Outlet Elevation: 22.00 ft

Number of Barrels: 2

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1.5:1)

Inlet Depression: None

Table 3 - Culvert Summary Table: Culvert 1 (Copy)

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)
50.00	48.61	23.31	3.165	3.312	1-S1f	1.587	2.177	3.500	0.513	5.052	1.872
175.00	87.69	25.49	4.883	5.494	4-FFf	2.286	2.911	3.500	1.078	9.114	2.990
300.00	111.76	26.97	6.271	3.478	5-S2n	2.780	3.185	2.849	1.478	13.327	3.629
425.00	121.80	28.47	6.931	8.473	4-FFf	3.104	3.261	3.500	1.811	12.660	4.101
550.00	138.24	30.11	8.110	10.108	4-FFf	3.500	3.338	3.500	2.102	14.368	4.480
675.00	160.36	32.45	9.938	12.446	4-FFf	3.500	3.500	3.500	2.364	16.667	4.802
800.00	182.46	35.07	12.279	15.068	4-FFf	3.500	3.500	3.500	2.606	18.965	5.082
925.00	205.58	38.11	15.116	18.112	4-FFf	3.500	3.500	3.500	2.830	21.367	5.331
1000.00	219.37	40.08	16.970	20.082	4-FFf	3.500	3.500	3.500	2.958	22.801	5.468
1175.00	245.82	44.23	20.862	24.231	4-FFf	3.500	3.500	3.500	3.239	25.550	5.761
1300.00	247.10	44.62	21.060	24.617	4-FFf	3.500	3.500	3.500	3.429	25.683	5.951

****

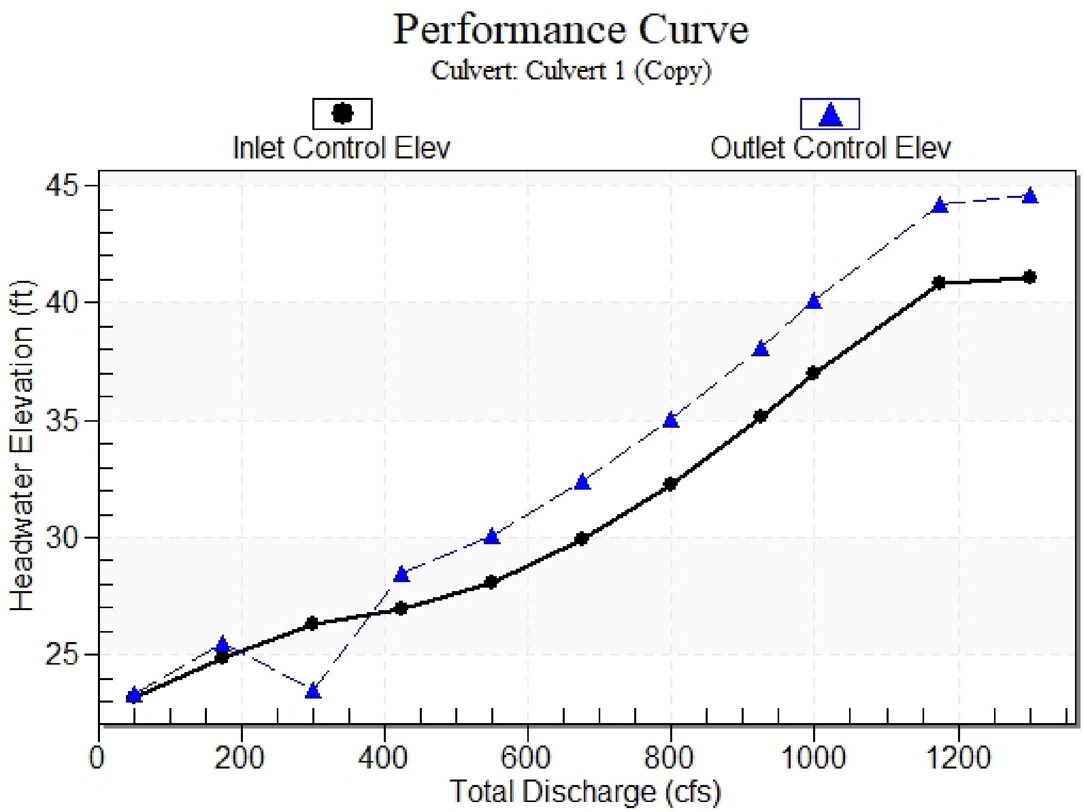
Straight Culvert

Inlet Elevation (invert): 20.00 ft,   Outlet Elevation (invert): 18.50 ft

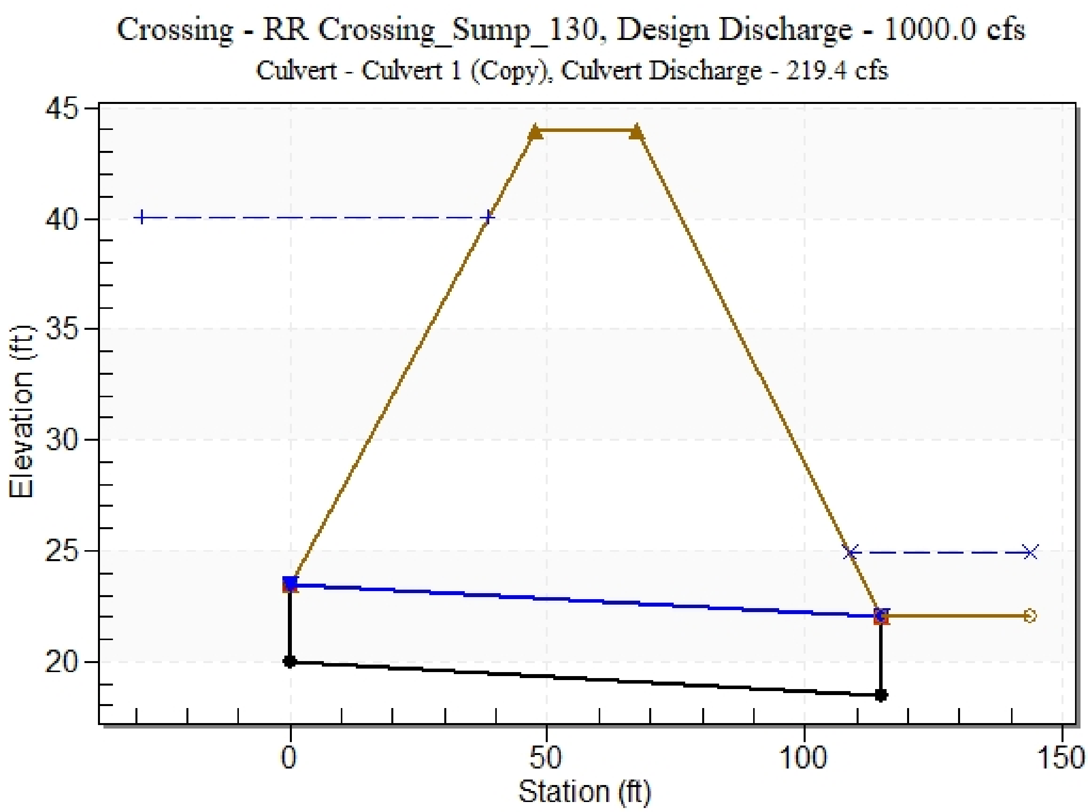
Culvert Length: 115.01 ft,   Culvert Slope: 0.0130

****

Culvert Performance Curve Plot: Culvert 1 (Copy)



Water Surface Profile Plot for Culvert: Culvert 1 (Copy)



Site Data - Culvert 1 (Copy)

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 20.00 ft

Outlet Station: 115.00 ft

Outlet Elevation: 18.50 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1 (Copy)

Barrel Shape: Circular

Barrel Diameter: 3.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1.5:1)

Inlet Depression: None

Table 4 - Downstream Channel Rating Curve (Crossing: RR Crossing_Sump_130)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
50.00	22.51	0.51	1.87	0.16	0.47
175.00	23.08	1.08	2.99	0.34	0.53
300.00	23.48	1.48	3.63	0.46	0.55
425.00	23.81	1.81	4.10	0.56	0.57
550.00	24.10	2.10	4.48	0.66	0.58
675.00	24.36	2.36	4.80	0.74	0.59
800.00	24.61	2.61	5.08	0.81	0.60
925.00	24.83	2.83	5.33	0.88	0.61
1000.00	24.96	2.96	5.47	0.92	0.61
1175.00	25.24	3.24	5.76	1.01	0.62
1300.00	25.43	3.43	5.95	1.07	0.62

Tailwater Channel Data - RR Crossing_Sump_130

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 50.00 ft

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

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 22.00 ft

Roadway Data for Crossing: RR Crossing_Sump_130

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 44.00 ft

Roadway Surface: Paved

Roadway Top Width: 20.00 ft

HY-8 Culvert Analysis Report

Railroad Crossing: Sump 130W

(smaller detention pond to the west)

Crossing Discharge Data

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

Minimum Flow: 50 cfs

Design Flow: 150 cfs

Maximum Flow: 200 cfs

Table 1 - Summary of Culvert Flows at Crossing: RR Crossing_Sump_130W

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5926.61	50.00	50.00	0.00	1
5927.75	65.00	65.00	0.00	1
5929.43	80.00	80.00	0.00	1
5931.35	95.00	95.00	0.00	1
5933.57	110.00	110.00	0.00	1
5936.07	125.00	125.00	0.00	1
5938.88	140.00	140.00	0.00	1
5940.93	150.00	150.00	0.00	1
5945.03	170.00	168.18	1.60	21
5945.14	185.00	168.65	16.18	7
5945.22	200.00	168.97	30.82	5
5945.00	168.05	168.05	0.00	Overtopping

Rating Curve Plot for Crossing: RR Crossing_Sump_130W

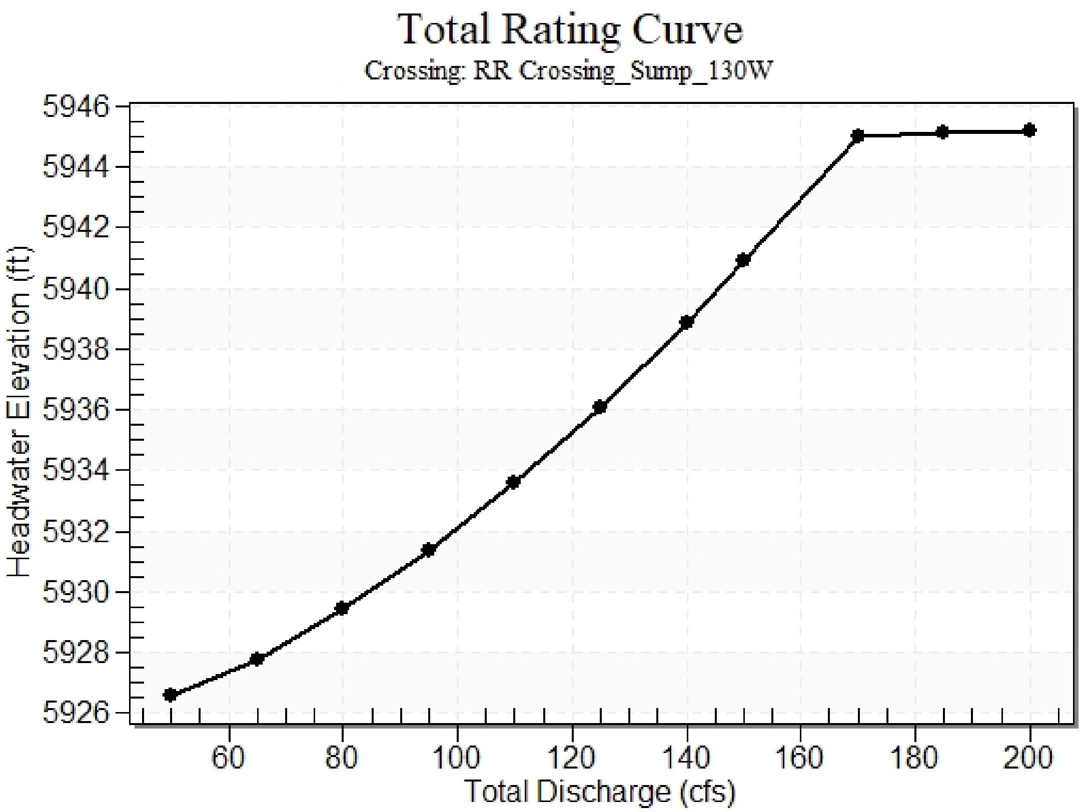


Table 2 - Culvert Summary Table: Culvert 1

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)
50.00	50.00	5926.61	3.605	3.421	5-S2n	2.260	2.301	2.260	0.513	8.754	1.872
65.00	65.00	5927.75	4.557	4.749	7-M2c	3.000	2.585	2.585	0.600	10.035	2.068
80.00	80.00	5929.43	5.710	6.433	7-M2c	3.000	2.770	2.770	0.678	11.730	2.237
95.00	95.00	5931.35	7.054	8.353	7-M2c	3.000	2.811	2.811	0.751	13.802	2.386
110.00	110.00	5933.57	8.635	10.569	6-FFc	3.000	3.000	3.000	0.819	15.562	2.520
125.00	125.00	5936.07	10.668	13.066	6-FFc	3.000	3.000	3.000	0.884	17.684	2.643
140.00	140.00	5938.88	13.000	15.881	6-FFc	3.000	3.000	3.000	0.945	19.806	2.755
150.00	150.00	5940.93	14.702	17.935	6-FFc	3.000	3.000	3.000	0.984	21.221	2.826
170.00	168.18	5945.03	18.095	22.031	6-FFc	3.000	3.000	3.000	1.059	23.792	2.958
185.00	168.65	5945.14	18.189	22.144	6-FFc	3.000	3.000	3.000	1.114	23.859	3.051
200.00	168.97	5945.22	18.252	22.221	6-FFc	3.000	3.000	3.000	1.166	23.905	3.139

****

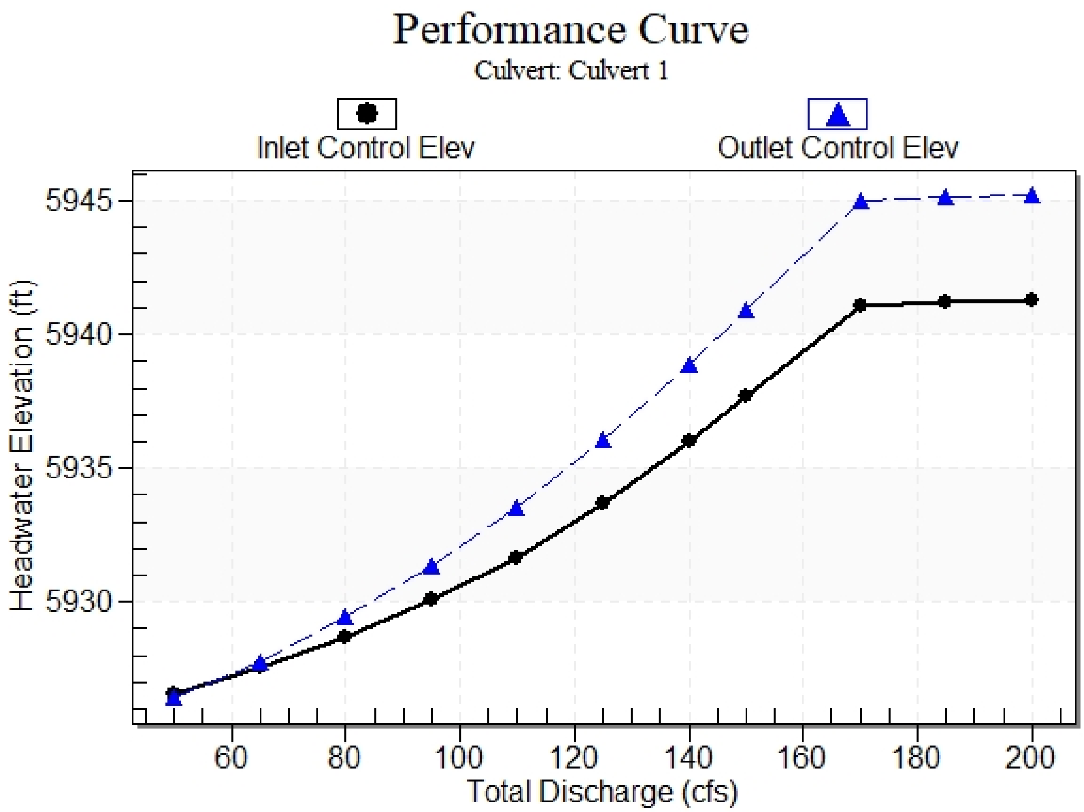
Straight Culvert

Inlet Elevation (invert): 5923.00 ft, Outlet Elevation (invert): 5922.00 ft

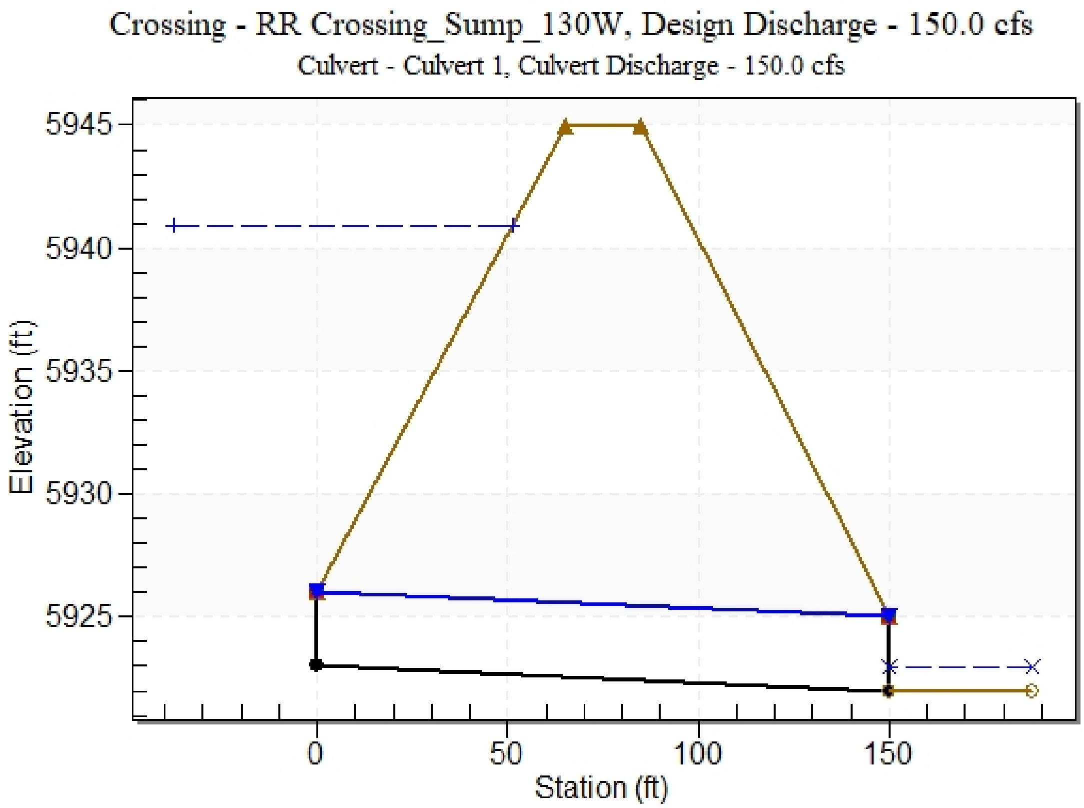
Culvert Length: 150.00 ft, Culvert Slope: 0.0067

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 5923.00 ft

Outlet Station: 150.00 ft

Outlet Elevation: 5922.00 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1.5:1)

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: RR Crossing_Sump_130W)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
50.00	5922.51	0.51	1.87	0.16	0.47
65.00	5922.60	0.60	2.07	0.19	0.48
80.00	5922.68	0.68	2.24	0.21	0.49
95.00	5922.75	0.75	2.39	0.23	0.50
110.00	5922.82	0.82	2.52	0.26	0.51
125.00	5922.88	0.88	2.64	0.28	0.51
140.00	5922.94	0.94	2.76	0.29	0.52
150.00	5922.98	0.98	2.83	0.31	0.52
170.00	5923.06	1.06	2.96	0.33	0.53
185.00	5923.11	1.11	3.05	0.35	0.53
200.00	5923.17	1.17	3.14	0.36	0.53

Tailwater Channel Data - RR Crossing_Sump_130W

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 50.00 ft

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

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 5922.00 ft

Roadway Data for Crossing: RR Crossing_Sump_130W

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 5945.00 ft

Roadway Surface: Paved

Roadway Top Width: 20.00 ft

HY-8 Culvert Analysis Report

Overflow Culverts from Sump 130W to downstream of Railroad

Crossing Discharge Data

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

Minimum Flow: 50 cfs

Design Flow: 1200 cfs

Maximum Flow: 1300 cfs

Table 1 - Summary of Culvert Flows at Crossing: RR Sump_130W Overflow

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5924.50	50.00	50.00	0.00	1
5925.98	175.00	175.00	0.00	1
5927.10	300.00	300.00	0.00	1
5928.07	425.00	425.00	0.00	1
5929.12	550.00	550.00	0.00	1
5930.34	675.00	675.00	0.00	1
5931.76	800.00	800.00	0.00	1
5933.56	925.00	925.00	0.00	1
5935.61	1050.00	1050.00	0.00	1
5938.25	1200.00	1200.00	0.00	1
5939.77	1300.00	1278.57	21.31	9
5939.60	1269.87	1269.87	0.00	Overtopping

Rating Curve Plot for Crossing: RR Sump_130W Overflow

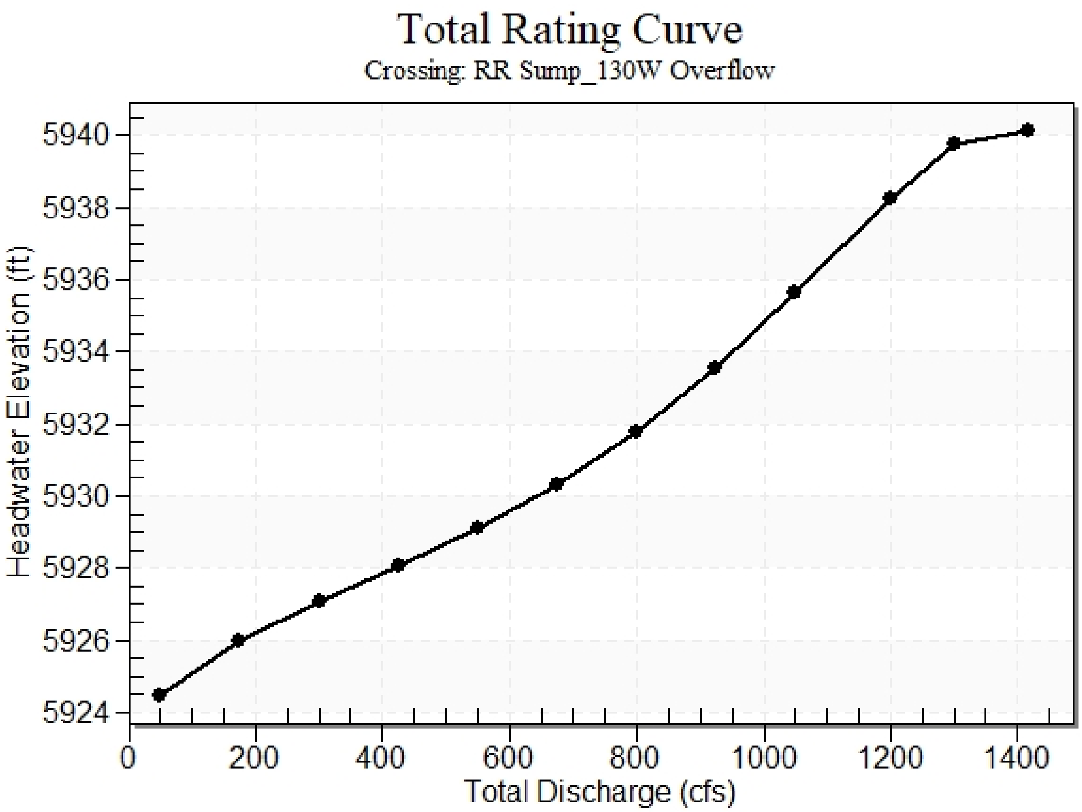


Table 2 - Culvert Summary Table: Culvert 1

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)
50.00	50.00	5924.50	1.496	0.143	1-S2n	0.944	1.124	0.944	0.513	6.468	1.872
175.00	175.00	5925.98	2.984	1.386	1-S2n	1.788	2.147	1.808	1.078	9.110	2.990
300.00	300.00	5927.10	4.103	2.549	1-S2n	2.409	2.846	2.446	1.478	10.477	3.629
425.00	425.00	5928.07	5.073	3.821	5-S2n	2.980	3.410	3.022	1.811	11.420	4.101
550.00	550.00	5929.12	6.116	5.802	5-S2n	3.575	3.876	3.600	2.102	12.115	4.480
675.00	675.00	5930.34	7.335	7.219	7-M2c	4.419	4.248	4.248	2.364	12.655	4.802
800.00	800.00	5931.76	8.756	8.756	7-M2c	5.000	4.519	4.519	2.606	14.282	5.082
925.00	925.00	5933.56	10.371	10.560	7-M2c	5.000	4.699	4.699	2.830	16.100	5.331
1050.00	1050.00	5935.61	12.181	12.614	7-M2c	5.000	4.567	4.567	3.040	18.609	5.556
1200.00	1200.00	5938.25	14.694	15.252	6-FFc	5.000	5.000	5.000	3.278	20.372	5.801
1300.00	1278.57	5939.77	16.312	16.773	6-FFc	5.000	5.000	5.000	3.429	21.706	5.951

****

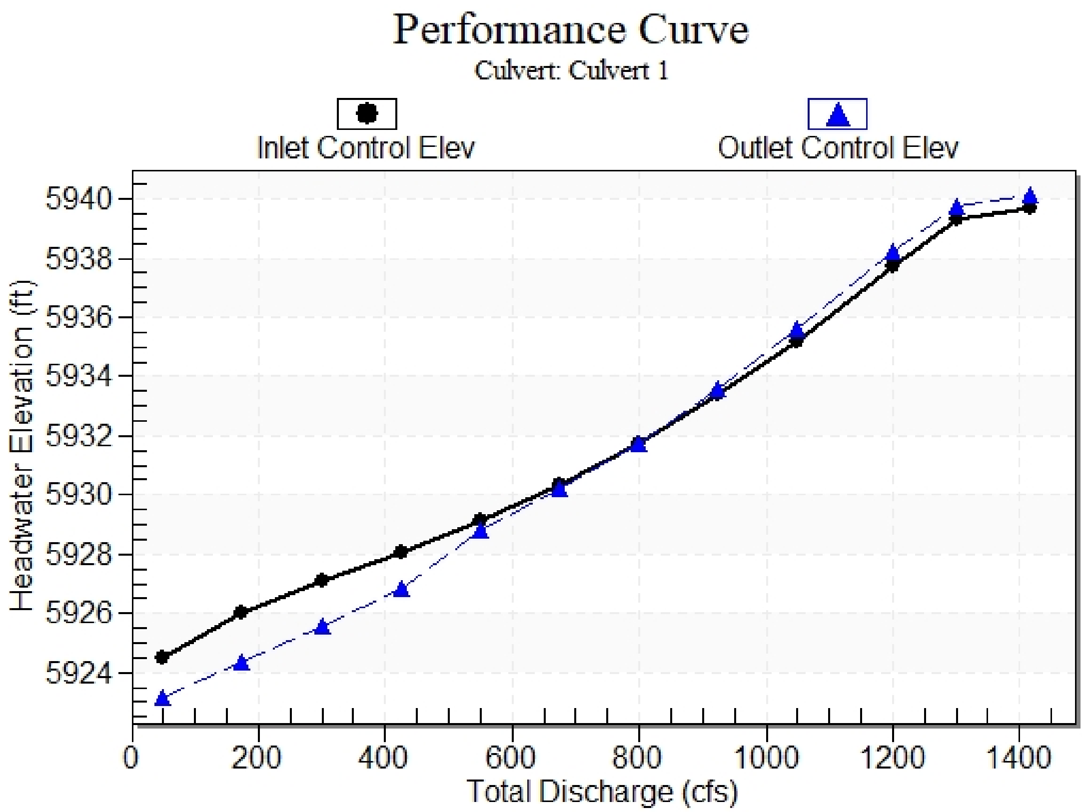
Straight Culvert

Inlet Elevation (invert): 5923.00 ft, Outlet Elevation (invert): 5922.00 ft

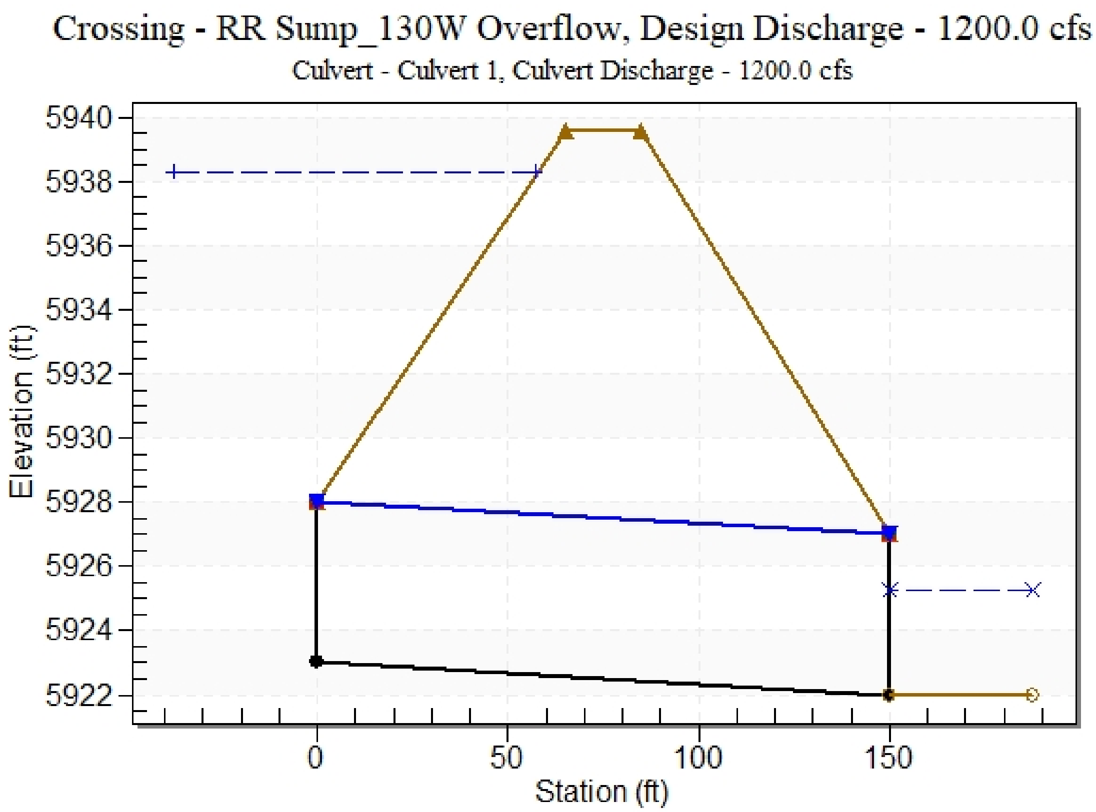
Culvert Length: 150.00 ft, Culvert Slope: 0.0067

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 5923.00 ft

Outlet Station: 150.00 ft

Outlet Elevation: 5922.00 ft

Number of Barrels: 3

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1.5:1)

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: RR Sump_130W Overflow)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
50.00	5922.51	0.51	1.87	0.16	0.47
175.00	5923.08	1.08	2.99	0.34	0.53
300.00	5923.48	1.48	3.63	0.46	0.55
425.00	5923.81	1.81	4.10	0.56	0.57
550.00	5924.10	2.10	4.48	0.66	0.58
675.00	5924.36	2.36	4.80	0.74	0.59
800.00	5924.61	2.61	5.08	0.81	0.60
925.00	5924.83	2.83	5.33	0.88	0.61
1050.00	5925.04	3.04	5.56	0.95	0.61
1200.00	5925.28	3.28	5.80	1.02	0.62
1300.00	5925.43	3.43	5.95	1.07	0.62

Tailwater Channel Data - RR Sump_130W Overflow

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 50.00 ft

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

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 5922.00 ft

Roadway Data for Crossing: RR Sump_130W Overflow

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 5939.60 ft

Roadway Surface: Paved

Roadway Top Width: 20.00 ft

HY-8 Culvert Analysis Report

Railroad Crossing: 130E

(crossing to the east pf Sump 130)

Crossing Discharge Data

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

Minimum Flow: 50 cfs

Design Flow: 544 cfs

Maximum Flow: 600 cfs

Table 1 - Summary of Culvert Flows at Crossing: RR Crossing_130E

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
5929.84	50.00	50.00	0.00	1
5930.78	105.00	105.00	0.00	1
5931.59	160.00	160.00	0.00	1
5932.26	215.00	215.00	0.00	1
5932.90	270.00	270.00	0.00	1
5933.56	325.00	325.00	0.00	1
5934.28	380.00	380.00	0.00	1
5935.08	435.00	435.00	0.00	1
5935.98	490.00	490.00	0.00	1
5936.94	544.00	544.00	0.00	1
5938.02	600.00	600.00	0.00	1
5942.00	774.85	774.85	0.00	Overtopping

Rating Curve Plot for Crossing: RR Crossing_130E

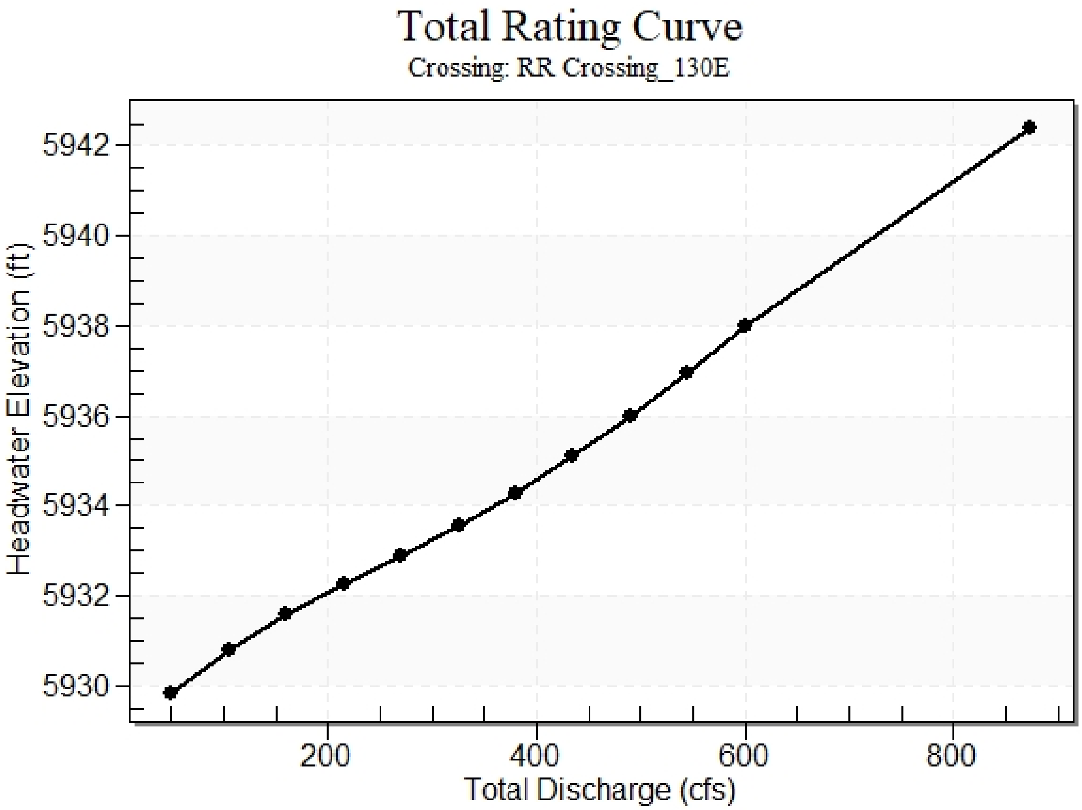


Table 2 - Culvert Summary Table: Culvert 1

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)
50.00	50.00	5929.84	1.840	0.0*	1-S2n	0.972	1.384	0.982	0.513	9.171	1.872
105.00	105.00	5930.78	2.779	0.226	1-S2n	1.412	2.032	1.457	0.797	11.034	2.477
160.00	160.00	5931.59	3.587	0.982	1-S2n	1.758	2.532	1.832	1.022	12.275	2.894
215.00	215.00	5932.26	4.264	1.768	1-S2n	2.063	2.956	2.173	1.216	13.127	3.222
270.00	270.00	5932.90	4.901	2.608	1-S2n	2.345	3.327	2.486	1.390	13.852	3.496
325.00	325.00	5933.56	5.560	3.512	5-S2n	2.615	3.655	2.784	1.549	14.467	3.733
380.00	380.00	5934.28	6.282	5.010	5-S2n	2.880	3.942	3.070	1.697	15.031	3.944
435.00	435.00	5935.08	7.084	5.921	5-S2n	3.147	4.188	3.349	1.835	15.561	4.134
490.00	490.00	5935.98	7.976	6.916	5-S2n	3.424	4.391	3.628	1.966	16.059	4.307
544.00	544.00	5936.94	8.935	7.976	5-S2n	3.718	4.547	3.907	2.089	16.526	4.464
600.00	600.00	5938.02	10.016	9.164	5-S2n	4.079	4.669	4.228	2.210	16.940	4.615

* Full Flow Headwater elevation is below inlet invert.

****

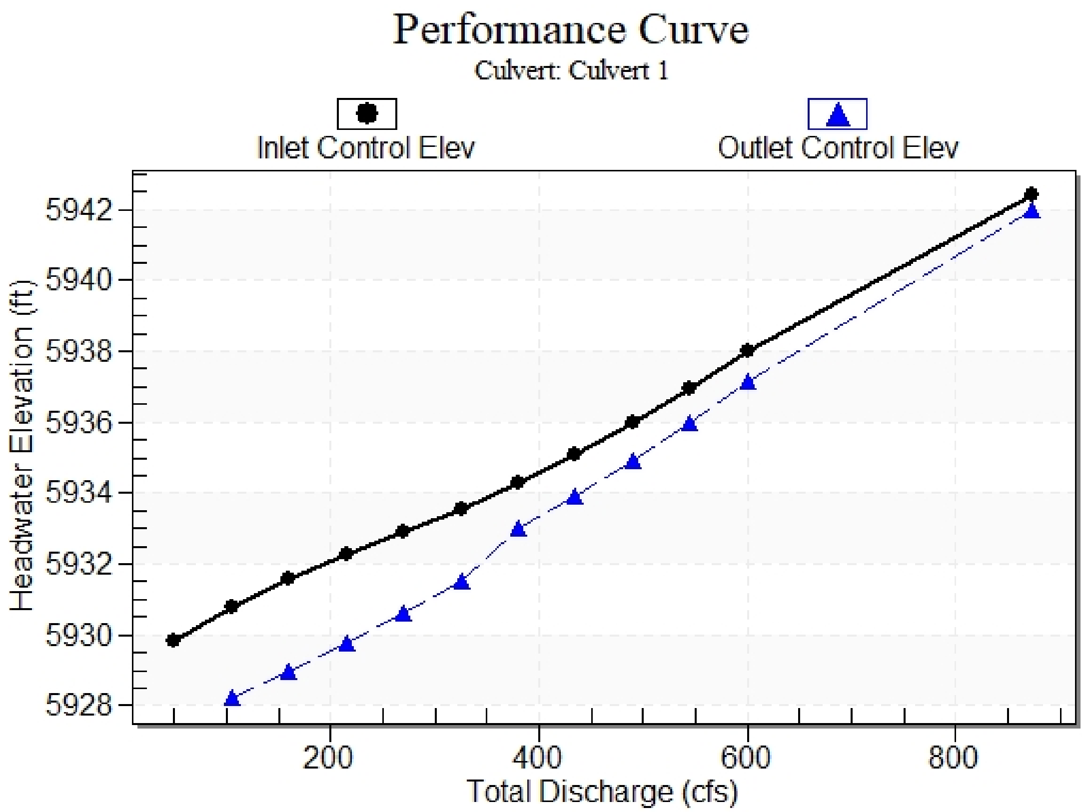
Straight Culvert

Inlet Elevation (invert): 5928.00 ft, Outlet Elevation (invert): 5926.00 ft

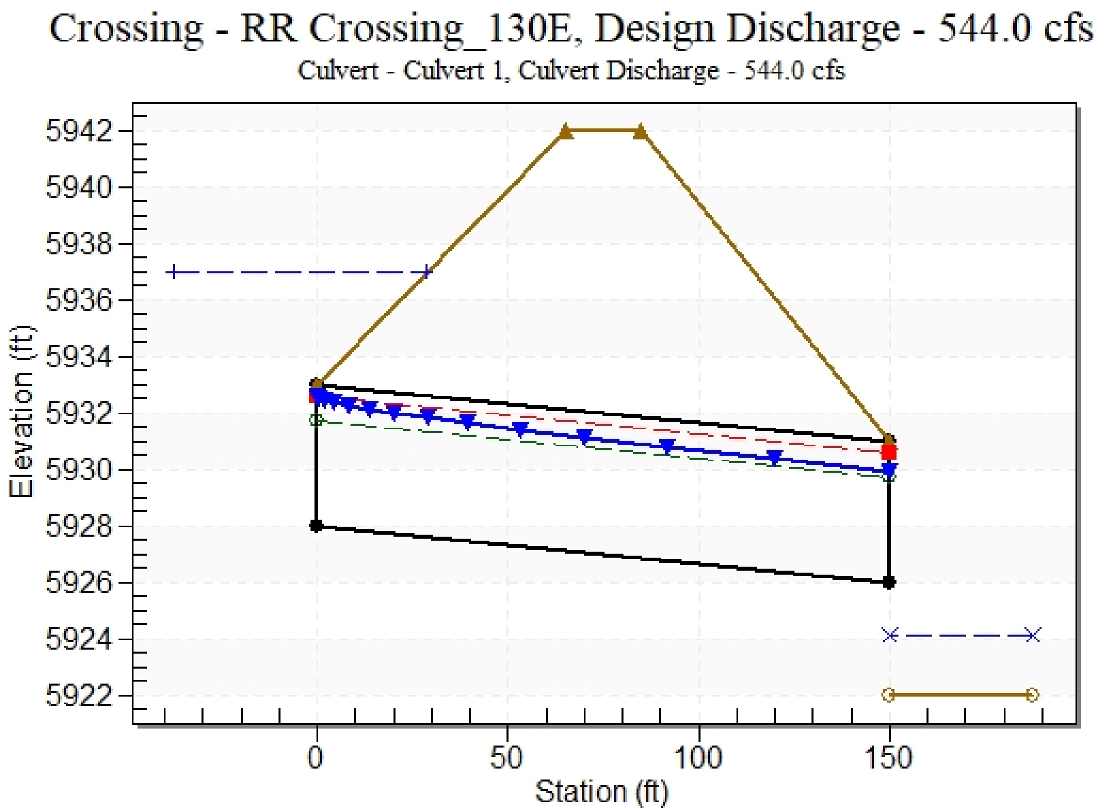
Culvert Length: 150.01 ft, Culvert Slope: 0.0133

****

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 5928.00 ft

Outlet Station: 150.00 ft

Outlet Elevation: 5926.00 ft

Number of Barrels: 2

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 5.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0130

Culvert Type: Straight

Inlet Configuration: Beveled Edge (1.5:1)

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: RR Crossing_130E)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
50.00	5922.51	0.51	1.87	0.16	0.47
105.00	5922.80	0.80	2.48	0.25	0.50
160.00	5923.02	1.02	2.89	0.32	0.52
215.00	5923.22	1.22	3.22	0.38	0.54
270.00	5923.39	1.39	3.50	0.43	0.55
325.00	5923.55	1.55	3.73	0.48	0.56
380.00	5923.70	1.70	3.94	0.53	0.56
435.00	5923.84	1.84	4.13	0.57	0.57
490.00	5923.97	1.97	4.31	0.61	0.58
544.00	5924.09	2.09	4.46	0.65	0.58
600.00	5924.21	2.21	4.61	0.69	0.59

Tailwater Channel Data - RR Crossing_130E

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 50.00 ft

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

Channel Slope: 0.0050

Channel Manning's n: 0.0350

Channel Invert Elevation: 5922.00 ft

Roadway Data for Crossing: RR Crossing_130E

Roadway Profile Shape: Constant Roadway Elevation

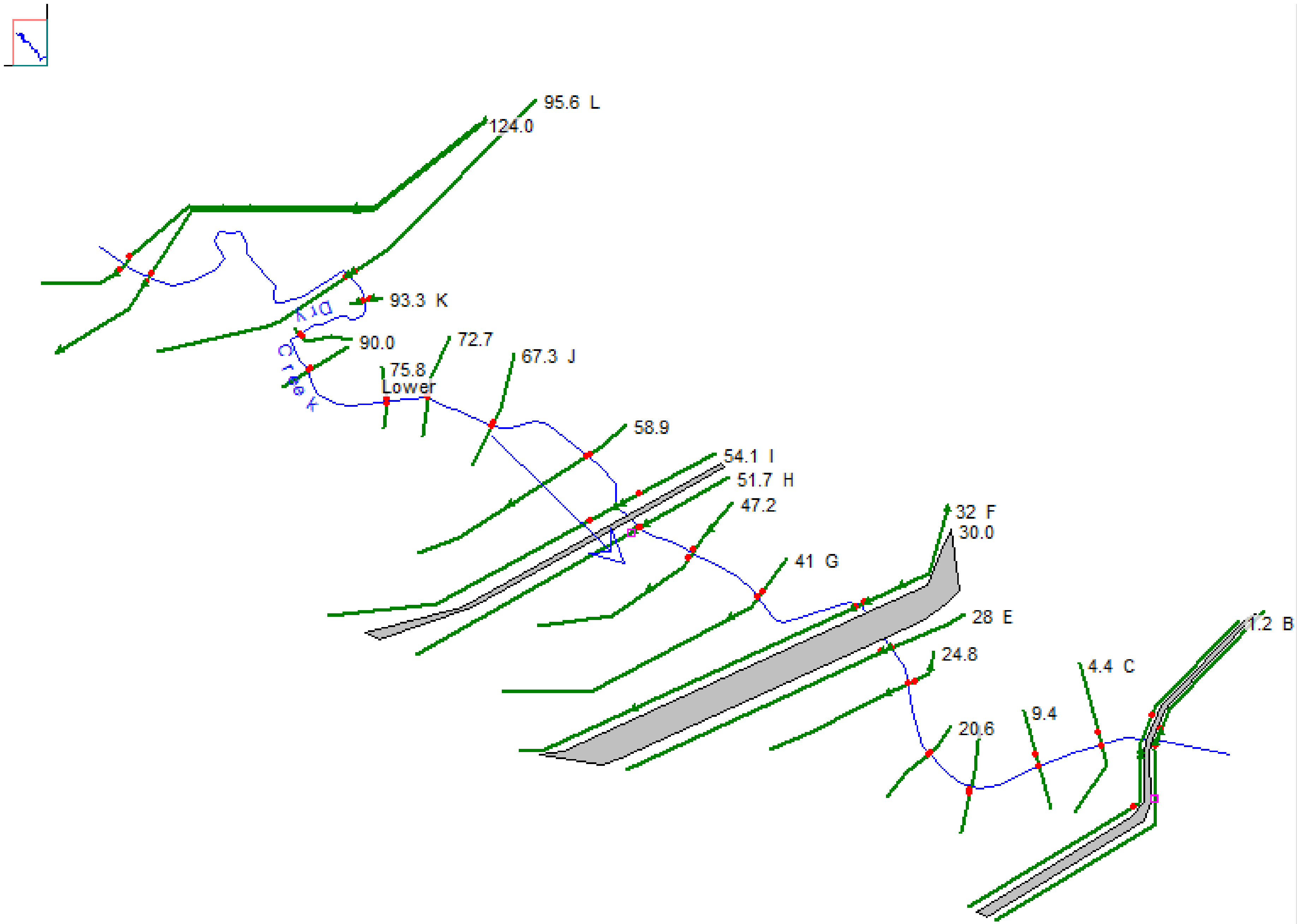
Crest Length: 100.00 ft

Crest Elevation: 5942.00 ft

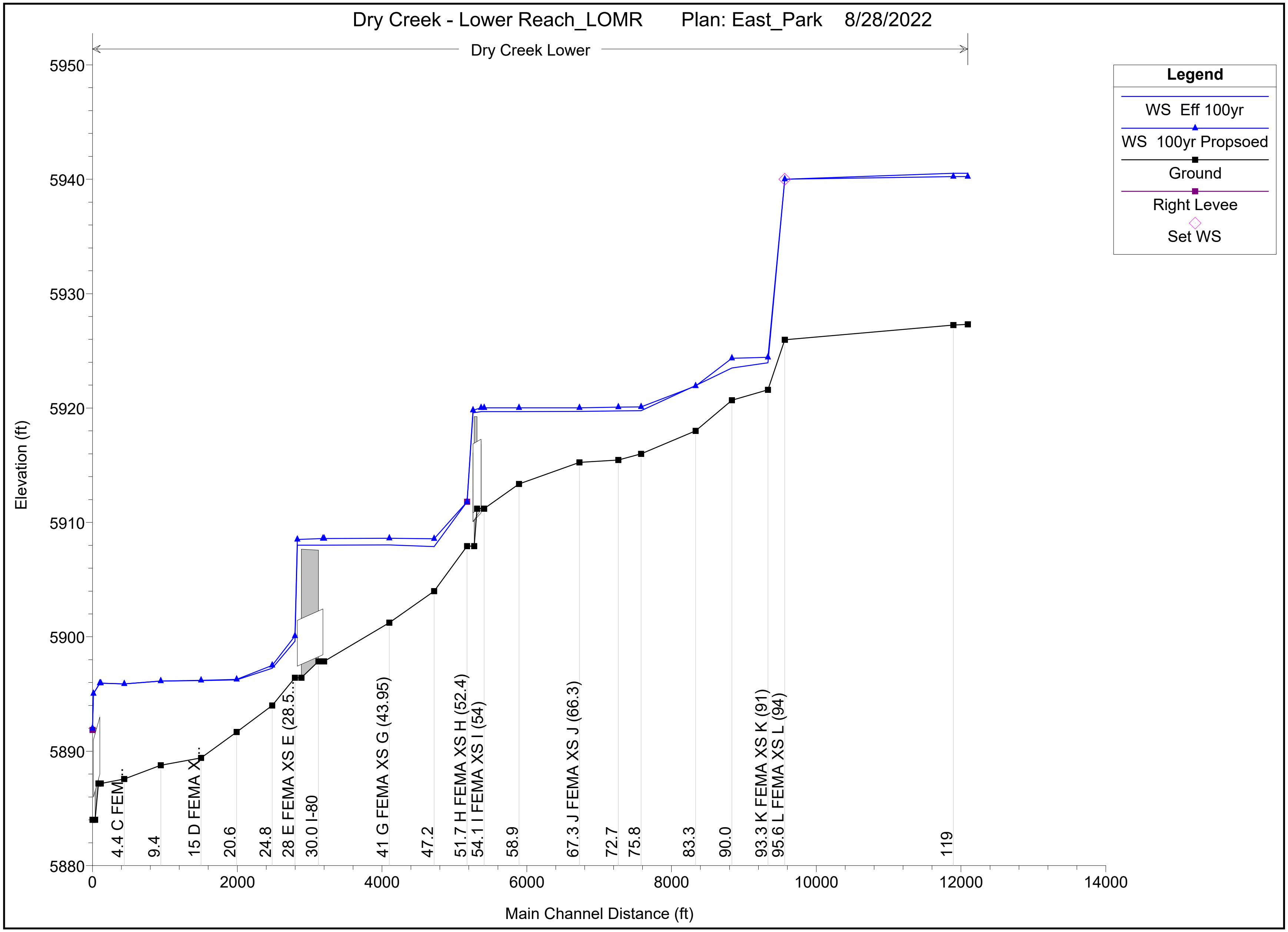
Roadway Surface: Paved

Roadway Top Width: 20.00 ft

Appendix: HEC-RAS Output



95.6 L
124.0
93.3 K
90.0
72.7
67.3 J
75.8
Lower
Dry Creek
58.9
54.1 I
51.7 H
47.2
41 G
32 F
30.0
28 E
24.8
1.2 B
4.4 C
9.4
20.6



Dry Creek - Lower Reach_LOMR Plan: East_Park 8/28/2022
Dry Creek Lower
Legend
WS Eff 100yr
WS 100yr Propsoed
Ground
Right Levee
Set WS
Elevation (ft)
Main Channel Distance (ft)
5880
5890
5900
5910
5920
5930
5940
5950
0
2000
4000
6000
8000
10000
12000
14000
4.4 C FEM...
9.4
15 D FEMA X...
20.6
24.8
28 E FEMA XS E (28.5...
30.0 I-80
41 G FEMA XS G (43.95)
47.2
51.7 H FEMA XS H (52.4)
54.1 I FEMA XS I (54)
58.9
67.3 J FEMA XS J (66.3)
72.7
75.8
83.3
90.0
93.3 K FEMA XS K (91)
95.6 L FEMA XS L (94)
119

HEC-RAS Output

HEC-RAS Adjustments:

* Adjusted cross sections to match topo
* Lidar information supplied by the City used in the updated cross sections
* Added culvert crossings into model
*

Reach	River Sta	Profile	Q Total (cfs)	Change in Flow (cfs)	W.S. Elev (ft)	Change in WSEL (ft)	Top Width (ft)	Change in Top Width (ft)
Lower	124	Eff 100yr	3798	-1308	5940.53	-0.3	3415.7	-28.99
Lower	124	100yr Proposed	2490		5940.23		3386.71	
Lower	119	Eff 100yr	3798	-1308	5940.53	-0.3	3366.01	-273.25
Lower	119	100yr Proposed	2490		5940.23		3092.76	
Lower	95.6 L	Eff 100yr	3798	-1308	5940.01	0	2419.14	0
Lower	95.6 L	100yr Proposed	2490		5940.01		2419.14	
Lower	93.3 K	Eff 100yr	733	282	5923.96	0.47	53.4	11.59
Lower	93.3 K	100yr Proposed	1015		5924.43		64.99	
Lower	90	Eff 100yr	733	282	5923.5	0.85	402.2	56.29
Lower	90	100yr Proposed	1015		5924.35		458.49	
Lower	83.3	Eff 100yr	733	282	5921.96	-0.04	79.01	-1.11
Lower	83.3	100yr Proposed	1015		5921.92		77.9	
Lower	75.8	Eff 100yr	733	282	5919.76	0.33	167.25	19.2
Lower	75.8	100yr Proposed	1015		5920.09		186.45	
Lower	72.7	Eff 100yr	733	282	5919.74	0.33	523.29	97.79
Lower	72.7	100yr Proposed	1015		5920.07		621.08	
Lower	67.3 J	Eff 100yr	1006	304	5919.7	0.32	565.77	21.42
Lower	67.3 J	100yr Proposed	1310		5920.02		587.19	
Lower	58.9	Eff 100yr	1006	304	5919.69	0.33	1424.32	21.03
Lower	58.9	100yr Proposed	1310		5920.02		1445.35	
Lower	54.1 I	Eff 100yr	1006	304	5919.69	0.32	1684.42	8.25
Lower	54.1 I	100yr Proposed	1310		5920.01		1692.67	
Lower	52.9		Culvert					
Lower	51.7 H	Eff 100yr	1006	304	5911.81	0	596.44	0
Lower	51.7 H	100yr Proposed	1310		5911.81		596.44	
Lower	47.2	Eff 100yr	1006	304	5907.88	0.69	173.16	460.4
Lower	47.2	100yr Proposed	1310		5908.57		633.56	
Lower	41 G	Eff 100yr	1254	350	5908.04	0.58	906.22	73.64
Lower	41 G	100yr Proposed	1604		5908.62		979.86	
Lower	32 F	Eff 100yr	1254	350	5908.01	0.57	2276.59	223.84
Lower	32 F	100yr Proposed	1604		5908.58		2500.43	
Lower	30		Culvert					
Lower	28 E	Eff 100yr	1254	350	5899.61	0.47	77.3	227.94
Lower	28 E	100yr Proposed	1604		5900.08		305.24	
Lower	24.8	Eff 100yr	1254	350	5897.24	0.26	183.89	13.21
Lower	24.8	100yr Proposed	1604		5897.5		197.1	
Lower	20.6	Eff 100yr	1254	350	5896.23	0.04	241.75	4.65
Lower	20.6	100yr Proposed	1604		5896.27		246.4	
Lower	15 D	Eff 100yr	1563	336	5896.18	0.01	543.03	1.15
Lower	15 D	100yr Proposed	1899		5896.19		544.18	
Lower	9.4	Eff 100yr	1563	336	5896.14	0	584.19	0
Lower	9.4	100yr Proposed	1899		5896.14		584.19	
Lower	4.4 C	Eff 100yr	8500	0	5895.88	0	886.81	0
Lower	4.4 C	100yr Proposed	8500		5895.88		886.81	
Lower	1.2 B	Eff 100yr	8500	0	5895.95	0	1806.28	0
Lower	1.2 B	100yr Proposed	8500		5895.95		1806.28	
Lower	0.7		Culvert					
Lower	0	Eff 100yr	8500	0	5892.01	0	1456.53	0
Lower	0	100yr Proposed	8500		5892.01		1456.53	

LITHOS ENGINEERING

EAST PARK GREENWAY UNDERPASS AND DRAINAGE PLAN AT THE UNION PACIFIC RAILROAD – TUNNEL FEASIBILITY MEMORANDUM

Summit Engineering, LLC

5907 Townsend Place

Cheyenne, WY 82009

September 2, 2021

Engineering from the ground down

September 2, 2021
Project No. 20116

Summit Engineering, LLC
5907 Townsend Place
Cheyenne, WY 82009

Attention: Ms. Darci Hendon, PE
Managing Member

Regarding: East Park Greenway and Drainage Tunnel Feasibility Evaluation
Cheyenne, WY

Ms. Hendon,

This memorandum presents our opinion of tunnel feasibility for the East Park Greenway and Drainage project.

1.0 Project Introduction and Background

The Cheyenne Metropolitan Planning Organization (CMPO) intends to expand trail connectivity from the East Cheyenne Community Open Space toward the southeast and under the Union Pacific Railroad (UPRR). The East Cheyenne Community Open Space is located near the corner of East Pershing and Whitney Road in Cheyenne, Wyoming. In addition, stormwater impoundment against the elevated railroad embankment in this area has been a historical issue indicating inadequate conveyance of stormwater under the tracks. An existing historic stormwater culvert is intended to be rehabilitated and used to expand the trail system and convey pedestrians. Therefore, additional stormwater conveyance will need to be constructed under the existing railroad embankment. This memorandum summarizes Lithos' opinions regarding feasibility of tunnel construction methods for the proposed stormwater infrastructure and provides an opinion of probable construction cost for feasible tunnel construction methods.

2.0 Tunnel Feasibility

Tunnel feasibility depends on a variety of factors but is largely predicated by project constraints and ground behavior. Based on the high-level feasibility study scoped, a geotechnical investigation near or through the railroad embankment where the stormwater infrastructure will be constructed has not been completed. Therefore, a detailed description of anticipated ground conditions and associated ground behavior was not possible. The following discussion of feasible tunnel construction means and methods only consider non-geologic project constraints. Feasible methods may change as project design progresses and after site-specific geotechnical information is collected.

Stormwater improvements for the project at the current feasibility-level design include the installation of seven, 60-inch diameter, one 42-inch diameter, and one 30-inch diameter steel casing pipes under the

UPRR embankment as shown in Attachment 1. The tunnel drive length is assumed to extend through the railroad embankment. We assume that stormwater culvert lengths extending away from the railroad embankment will be installed with open cut technologies and are not considered in this memorandum. The tunnel length for all of the proposed casing pipes will be between 120 and 150 feet. Based on UPRR requirements, we have assumed a single pass installation for all tunnels due to the conveyance of unpressurized stormwater. A single pass system entails that the carrier pipe will also be used as a casing pipe. In addition, tunnels will need to be installed with a high level of accuracy based on gravity flow. The following sections describe feasible tunnel construction methods based on our understanding of the proposed project.

2.1 Consideration of Feasible Tunnel Construction Methods

Geotechnical data collection, UPRR guidelines, designer or Contractor preference, and further design development may influence the proposed tunneling methods. Based on the limited information available at the time of writing this memorandum, we have identified the following feasible tunneling methods: shield mine, guided pipe ram and tunnel boring machine (TBM) for the 60-inch diameter casings; and guided pipe ram for the 42- and 30-inch diameter casings. Technically, microtunneling (MTBM) is a feasible option but has not been considered due to relatively high comparative cost. Feasible means and methods are further discussed below:

Shield Mine: Shield mining uses a jacking frame situated within a launch shaft or launch area to advance a steel casing pipe across a tunnel alignment. Manned entry is required to remove excavated muck with hand tools from near the tunnel face back through the installed casing pipe to the launch shaft or area. Accuracy of the tunnel is controlled by how much muck is removed from specific locations at the tunnel face; often excavation is completed in quadrants to control face stability and aid in preventing overmining. Shields (commonly the first steel casing pipe segment) can be retrofitted with tables and doors near the face to provide additional stability. For shield mining to be a suitable tunnel technique, ground at the tunnel face should have some inherent stability such that it does not flow or run into the casing pipe and result in over excavation. Face control with shield mining is less in comparison to guided pipe ramming and tunnel boring. Shield mining can be completed through a variety of soil or rock strength with suitable equipment and effort. In accordance with UPRR guidelines, excavation shall take place behind the tunnel face, within the steel casing pipe, such that material is never removed in advance of the leading tunnel edge.

Guided Pipe Ram: Guided pipe ramming uses a pneumatic hammer to advance a steel casing pipe through soil. Once the pipe has been installed, augers are used to remove material that accumulates inside the casing. To guide a pipe ram, a pilot tube is used to maintain line and grade. A pilot tube system generally uses an optical theodolite or laser-based instrument to set and design line and grade throughout a tunneled installation. Pilot tubes are 4- to 6-inch diameter, hollow, steel segments that allow the laser originating at the steering head to be seen at jacking frame and guidance system located in the launch shaft. Pilot tube installations are commonly accurate to within fractions of a percent and can be used in most ground conditions without large percentages of gravel or cobbles and boulders. Upsizes of pipe will be needed to achieve the proposed final diameters. At the beginning of the pipe ram, artificial face control may be needed to help create a stable plug of material inside the casing pipe. Once the ram has been advanced enough, typically the soil densifies inside the casing pipe enough to create a natural plug of stable material. Pipe ramming can be used in situations where ground conditions are sufficiently soft or where ground conditions are expected to be unstable. Contact grouting can be used after the tunnel has been installed to fill voids created during the tunneling process and limit risk of long-term settlement. Based on prior experience with the UPRR, guided pipe ramming is a preferred tunneling method due to relatively low tunnel induced settlement risk.

TBM: A TBM involves excavation of the ground with a circular cutterhead at the lead edge of the machine. The machine operator, who is positioned near the face of the tunnel, steers the TBM through the tunnel excavation. TBMs are often equipped with a conveyor system used to move excavated muck out of the tunnel to a shaft where they can be disposed of. TBMs can excavate through a variety of ground conditions and would not require casing upsizes, and no artificial face control would be needed due to the cutting head on the TBM. Similarly to guided pipe ramming, contact grouting can be used after the tunnel has been installed to fill voids created during the tunneling process and limit risk of long-term settlement. TBM is generally a higher cost alternative to a guided pipe ram. Relative to guided pipe ramming, TBMs can excavate through harder/stronger subsurface conditions and generally maintain line and grade with a higher degree of accuracy. However, they are not well suited to saturated ground conditions or unstable soil that cannot naturally maintain a vertical cut.

3.0 Required Site and Layout Considerations

Most equipment staging and operational needs for guided pipe ramming and TBM are surrounding the tunnel launch. This is estimated to be approximately 0.5 acres at launch site, and 0.25 acres at receiving site. There appears to be sufficient room on both sides of the proposed tunnel alignments to support all tunneling operations. Additionally, due to likely construction within the UPRR ROW and near the tracks, the possibility of excavation within UPRR defined Zone A or Zone B is high, which will likely require additional permits, construction considerations, and time.

4.0 Product Pipe

Steel casing is recommended due to its commonality in similar installations, high strength, and familiarity within the UPRR permitting process and within UPRR guidelines. American Railway Engineering and Maintenance-of-Way Association (AREMA) has set in place guidelines regarding minimum wall thicknesses for pipes underneath railroads, dependent upon pipe diameter. Additionally, only steel pipe can be used with pipe ramming. Table 1 below shows these requirements as coinciding within the project constraints.

Table 4.1 Minimum Wall Thickness as Required by AREMA

Tunnel Diameter	Coated or Cathodically Protected Nominal Thickness (inches)	Not Coated or Cathodically Protected Nominal Thickness (inches)
60-inch	0.781	0.844
42-inch	0.562	0.625
30-inch	0.406	0.469

Interior and exterior coatings are not common for similar installations as the coating's integrity is often damaged during the installation process. Instead, sacrificial steel (exceeding the minimums above) and/or cathodic protection using anodes is often considered.

5.0 Risks and Limitations

Risks inherent to installing casings for the subject project include over-excavation, creating a preferential flow path for water and soil piping during flood events, installation forces exceeding capacity of casing or equipment, and encountering obstructions (such as wooden trestles, train cars, or other deleterious materials used to construct the railroad embankment), . These risks along with efforts that may be taken to mitigate them are explained as follows:

1) **Over-excavation**: Over-excavation is caused by ingesting soil into the tunnel at a higher rate than tunnel advancement. This can often lead to settlement propagating to the surface. As the casing is advanced with guided pipe ramming, soil builds up inside the casing, acting as a plug to resist soil and groundwater pressures. The only time a soil plug is not present is at the beginning of the drive unless an artificial plug is placed in pipe to be rammed. Due to the nature of a TBM, no soil plug is needed, as the face of the TBM will support the face of the tunnel in most ground conditions. TBMs can be limited in their face control in flowing or running ground conditions (such as saturated sands). Shield mining is the riskiest tunnel technique presented relative to over-excavation due to the limited ability to control material at the tunnel face relative to pipe ramming and tunnel boring. Due to unknown ground conditions in the existing railroad embankment, the risk of over-excavation cannot be evaluated at this stage and should be reevaluated during future design of the project.

2) **Preferential flow path**: Pipe ramming, tunnel boring, and shield mining will create an overcut that is slightly larger than the casing pipe diameter. The overcut is generally between 0.25- and 0.75-inches, radially around the perimeter of the casing pipe. This overcut should be grouted once the casing pipe has been installed. Contact grouting will reduce risk of a preferential flow path around the outside of the casing pipe during flooding events. It also serves to reduce overall settlement of the ground above the tunnel. Although not anticipated, in the event over-excavation has occurred or contact grouting does not fill the overcut, secondary grouting could be performed to target any problem areas. Given the anticipated short-term duration and infrequent flood impoundment against the railroad embankment, this risk is relatively low for the project.

3) **Excessive jacking or installation forces**: High installation forces can be caused by difficult soil conditions, not using lubrication, misaligned pipe, and excessive steering corrections. Risk of excessive steering corrections is not considered applicable for guided pipe ramming, though is a risk for TBM. Qualified contractors should not have difficulties aligning casing for welding and can use tracks and other guides to facilitate proper pipe positioning. Lubrication should be used for this drive to follow construction best practices. The installation length is relatively short for the proposed tunnels, reducing the risk of excessive jacking forces.

4) **Obstruction**: Debris within the fill of the railroad embankment could create an obstruction stopping advancement of the guided pipe ram or TBM. Within reason, shield mining can more readily accommodate obstructions due to the ability to use various equipment at the tunnel face. The risk of encountering an obstruction within the railroad embankment should be considered high at this point and a key item to further investigate during future design phases. In our experience, railroad embankments of this size and age used any materials available to build which could include train cars, wooden trestles or ties, bricks, concrete rubble, etc. Drilling of borings through the railroad embankment will provide additional clarity as to whether an obstruction is likely.

6.0 Order-of-Magnitude Cost Estimate

Table 6.1, 6.2, and 6.3 below present the order-of-magnitude cost estimates for shield mining, guided pipe ramming and TBM, respectively. Additional permit, tunnel design, and observation costs have been estimated and included in the table below. Presented costs relied on data from previous projects in the local area and discussions with contractors. The costs below should be expected to fluctuate based on availability of materials and Contractors, and inflation. This is a Class IV cost estimate as defined by AACE 19R-97 and has an accuracy of -30 to +50 percent range.

Table 6.1 Cost Estimate for Shield Mining

Item	Unit	Quantity	Unit Cost	Total Cost
Mobilization	Each	1	$ 75,000	$ 75,000
60-inch Pipe Cost	LF	960	$ 1,200	$ 1,152,000
42-inch Pipe Cost	LF	150	$ 900	$ 135,000
30-inch Pipe Cost	LF	140	$ 600	$ 84,000
Tunnel Install (Low)	LF	1,250	$ 1,000	$ 1,250,000
Tunnel Install (High)			$1,200	$ 1,500,000
Grouting	CY	500	$ 250	$ 125,000
Railroad Permitting and Flagging	Each	1	$150,000	$150,000
Final Design and Construction Engineering	Each	1	$ 400,000	$ 400,000
			Low Estimate Task Total	**$ 3,371,000**
			High Estimate Task Total	**$ 3,621,000**

Table 6.2 Cost Estimate for Guided Pipe Ram

Item	Unit	Quantity	Unit Cost	Total Cost
Mobilization	Each	1	$ 100,000	$ 100,000
60-inch Pipe Cost	LF	960	$ 1,200	$ 1,152,000
42-inch Pipe Cost	LF	150	$ 900	$ 135,000
30-inch Pipe Cost	LF	140	$ 600	$ 84,000
Tunnel Install (Low)	LF	1,250	$ 1,400	$ 1,750,000
Tunnel Install (High)			$ 1,700	$ 2,125,000
Grouting	CY	500	$ 250	$ 125,000
Railroad Permitting and Flagging	Each	1	$150,000	$150,000
Final Design and Construction Engineering	Each	1	$ 400,000	$ 400,000
			Low Estimate Task Total	**$ 3,896,000**
			High Estimate Task Total	**$ 4,271,000**

Table 6.3 Cost Estimate for TBM

Item	Unit	Quantity	Unit Cost	Total Cost
Mobilization	Each	1	$ 140,000	$ 140,000
60-inch Pipe Cost	LF	960	$ 1,200	$ 1,152,000
42-inch Pipe Cost	LF	150	$ 900	$ 135,000
30-inch Pipe Cost	LF	140	$ 600	$ 84,000
Tunnel Install (Low)	LF	1,250	$ 1,800	$ 2,250,000
Tunnel Install (High)			$ 2,200	$ 2,750,000
Grouting	CY	500	$ 250	$ 125,000
Railroad Permitting and Flagging	Each	1	$150,000	$150,000
Final Design and Construction Engineering	Each	1	$ 400,000	$ 400,000
			Low Estimate Task Total	**$ 4,436,000**
			High Estimate Task Total	**$ 4,936,000**

Given the uncertainty of ground conditions to be tunneled in the UPRR embankment and the range in costs provided for anticipated tunneling techniques alternatives based on alignment length and diameter, we recommend considering the range in construction costs provided, but ultimately having sufficient funding to accommodate the upper end of the range.

7.0 Recommendations for Further Investigation

Lithos recommends considering guided pipe ramming or TBM as the feasible tunneling methods for installing the proposed stormwater tunnels. Risk may be further reduced in design by obtaining geotechnical information along the tunnel alignments, ideally through the railroad embankments. Ground conditions, groundwater conditions, and embankment fill material definition are key components to further understand. Lithos recommends tunnel design and specifications be completed as part of the contract documents by an engineering firm experienced in tunnel construction. Geotechnical data collection and tunnel specific design fees are estimated as part of the tables presented in Section 6.0.

8.0 Closing

Lithos is pleased to provide this feasibility memorandum for the East Park Greenway and Drainage project. Lithos would be happy to assist in future design phases of the project. If you have any questions regarding the contents of this memorandum, please contact the undersigned.

Sincerely,
Lithos Engineering

Keely Stevenson, EI
Staff Engineer

Lance Heyer, PE
Project Engineer, Associate

Nate Soule, PE, PG
Vice President

PEDESTRAIN UNDERPASS REQUIREMENTS/FEASIBILITY

The recommendations provided within the 'Guidelines for Railroad Grade Separation Projects' are intended for all Grade Separation Projects impacting the Railroad. All Grade Separation Projects shall be designed in accordance with the specific requirements of all applicable sections within these Guidelines.

Underpass Crossing (Railroad Structure over Trail)

- **Permanent Clearances (under the structure)**
  - To improve safety and sight distance all underpass structures shall be tangent without curvature. The clear width and height of pedestrian structures shall be subject to the project site and structure length. The line of sight, historical security data and lighting shall be used for determining the required size of opening.
  - Vertical Clearance shall not be less than 8 feet.
  - Protection from falling debris is required for the crossing of pedestrians safely under active rail bridges. The overhead protection shall extend a minimum of 30 feet out on each side of the Railroad structure, or further as designated by the Railroad's engineering department.
  - However, the protective cover shall not reduce the existing hydraulic opening, shall not function as a debris catcher, and shall not impact proper inspection of the structure by Railroad personnel.
  - Below are the examples of a similar underpass at UPRR track at Elgin, IL. It is a trail underpass with minimum of 30 feet horizontal overhead clearance.

Fox River Trail and Illinois Prairie Path – Elgin, IL – UPRR

Littleton, CO - UPRR

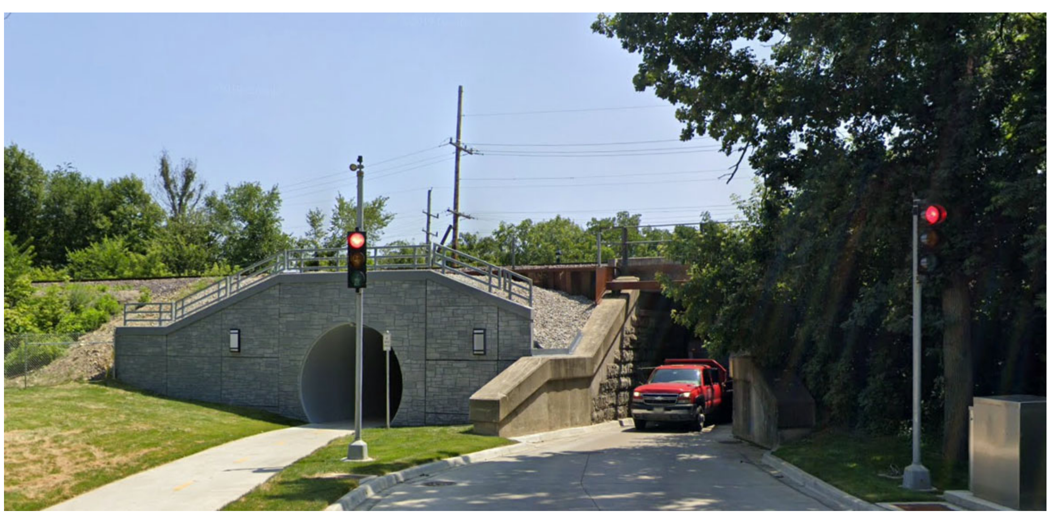
- **Crossing Under Existing Structure**

  - The existing structure in question (see below) is a historic 6’ wide x 8’ tall box arch masonry structure. The structure was built by the UPRR in 1903.
  - To repurpose this structure to be a trail underpass and bring it to the current UPRR standards, additional horizontal clearance and overhead protection with a retaining wall and wing walls may have to be added.

Existing historic Box Arch Masonry Structure

  - **Retaining wall**
    - Retained embankment within 50 feet of the centerline of Railroad tracks, supporting Railroad infrastructure and/or within the Railroad right-of-way, shall be of a type approved by the Railroad.
  - **Wingwalls**
    - Wingwalls may be cast-in-place or precast. Wingwalls shall have such slope and length as required to retain the embankment and maintain the opening. Wingwalls may be straight or flared, as local conditions and engineering design require.
    - Refer to the UPRR Standard Construction Specifications for material requirements. Items not addressed specifically in the Railroad Construction Specifications, and this document, shall be in accordance with the applicable sections of the current edition of AREMA.
    - Following are some examples of pedestrian underpasses with retaining and wing walls –

SR 89 Underpass in Truckee, CA – UPRR



Taylor Avenue Underpass in Glen Ellyn, IL – UPRR

- Per UPRR's Guidelines for Railroad Grade Separation Projects, the Railroad may reject, at its discretion, the use of any existing Underpass Structure for Trail use.
- Existing culvert pipe, box or arch structures, designed to convey water, are not permitted for trail crossing use.

Drainage

The drainage pattern of the site before and after construction shall be analyzed. Adequate drainage provisions shall be incorporated into the plans and specifications. Detailed Hydraulic Report may be required subject to site condition. The Hydraulic report must meet the Railroad Hydraulic Criteria.

When changes in the drainage system are contemplated by new or replacement construction, or because of drainage problems, the system shall be modified as required to accommodate current-condition runoff including any changes that have occurred in the drainage pattern. The size of the proposed drainage system must conform to the Railroad Hydraulic Criteria described in Section 4.5.1 and 4.5.2. of Guidelines for Railroad Grade Separation Projects.

A complete hydrologic and hydraulic study is required whenever new or additional drainage is added to the Railroad right-of-way, or when a drainage structure is scheduled to be added, removed, modified, or replaced. The Drainage Report must be in compliance with the requirements described in these Guidelines.

Please refer to the drawing below, for conceptual proposed alternate drainage plan when the existing structure is repurposed to be a trail underpass.

Fence

The Applicant shall specify the appropriate fencing to contain the Trail traffic within the Trail, crossing the Railroad right-of-way. Fence limits are subject to each project site and must be determined on a case-by-case basis.

- Fencing shall be provided to safeguard the general public and prevent trespassers from entering the Railroad right-of-way and accessing the track or other Railroad structures. Each project will be evaluated on a case-by-case basis.
- Location – Where possible, fencing shall be located outside the limits of the Railroad right-of-way. Fence may be required on top of abutments, wingwalls, retaining walls, and/or along the Railroad right-of-way.
- Height – The fencing shall be a minimum height of 8 feet.
- Length
- For projects crossing Railroad Tracks - Fencing shall extend 500 feet, or as site constraints permit, in each direction along the Railroad right-of-way, outside the Railroad right-of-way, at locations as deemed necessary by the Railroad to prevent trespassing.
- Fencing shall be located where it will not impede Railroad's access to the bridge for inspection and shall be removed and replaced at the Applicant's expense when necessary for access by the Railroad.
- Below is an example of fencing on the pedestrian path which is fully caged with chain-link fencing -

Pedestrian Path fully caged with chain-link fencing

Pedestrian Path fully caged with chain-link fencing

Signs

All access to Trails crossing railroad track shall be protected with bollard posts and signs prohibiting nonauthorized vehicular access.

All advisory and regulatory signs shall be in compliance with MUTCD and AASHTO. “No Trespassing” signs shall be posted every 500 feet.

Lighting

Maintenance of lights shall be the responsibility of the Applicant. Access to perform any maintenance for lights shall be coordinated with the local Railroad operating unit.

Structures with separation over ten (10) feet from each other shall be considered as independent structures for the purposes of lighting.

Dark, confined, and isolated Trail crossings hidden from public view may attract illegal activities. Line of sight is extremely important when visibility is a matter of safety and security.

The lighting design shall account for the impact on train operations.

Lighting shall provide visibility for the Trail without directing light toward the train traffic.

Potential Hazards

- Water is a potential hazard in tunnels and underpasses. As with any other segment of trail, proper drainage is critical and can be accomplished by digging ditches on the sides of the trail or by adding a layer of well-drained ballast in the center of the tunnel to raise the trail above any standing water. Warning signs indicating that the tunnel or underpass should not be used during high-water events are also recommended, particularly in areas prone to flooding.

- Poor lighting is another potential problem in tunnels. Tunnels should have a source of light for safety and security and to show off the interesting elements of the tunnel itself. Install lights in the tunnel, if possible, or post "flashlight-required signs" if permanent lighting is not an option.

Summary

Per UPRR's Guidelines for Railroad Grade Separation Projects, the Railroad may reject, at its discretion, the use of any existing Underpass Structure for Trail use. Existing culvert pipe, box or arch structures, designed to convey water, are not permitted for trail crossing use.

Assuming UPRR agrees to move forward, to be able to repurpose the existing arch-drainage-structure, additional construction may have to take place to bring it to the current UPRR standards for underpass as trail crossing.

Like bridges, underpass/tunnels contribute to a memorable trail experience and often act as the signature of their associated trail. Similar examples of popular tunnels on rail-trails can be found in RTC's Tunnels on Trails report, along with additional information about 78 tunnels along rail-trails across the country. This report can be found at:
https://www.railstotrails.org/resource-library/resources/tunnels-on-trails-a-study-of-78-tunnels-on-36-trails-in-the-united-states/

Cheyenne East Park Greenway

Masonry Culvert Investigation and Assessment Report

of

Tunnel

2020 Field Log

Cheyenne, Wyoming

Client: City of Cheyenne

<u>Tunnel Elements Abbreviations</u>

L1 – Liner 1
W1 – Wingwall 1
P1 – Portal 1
Pa1 – Patching 1
M1 – Masonry 1
M2- Mortar 2

Prepared for
Client: City of Cheyenne
Inspection Purpose: Special Inspection
Project Scoping
By: Martin/Martin
Ron Pierce, PE, SE, PEng, CBI
Ryan Rigg, PE

Professional Engineer (Civil)
RYAN S. RIGG
9935
Date 2/4/21
WYOMING

Milepost – Masonry Lined Tunnel

Length: 75 ft
Height: 8 ft
Span: 6 ft
Tunnel: Horseshoe Shape
Portals: Masonry
Liner: Masonry

Review Priority:

Inspection Type: Special Inspection
Inspectors: RNP, RSR
Inspection Date/Time: 12/18/20, 10:00 am
Weather: 34°F, overcast skies
Report Date: 12/18/21

Signature:

Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance

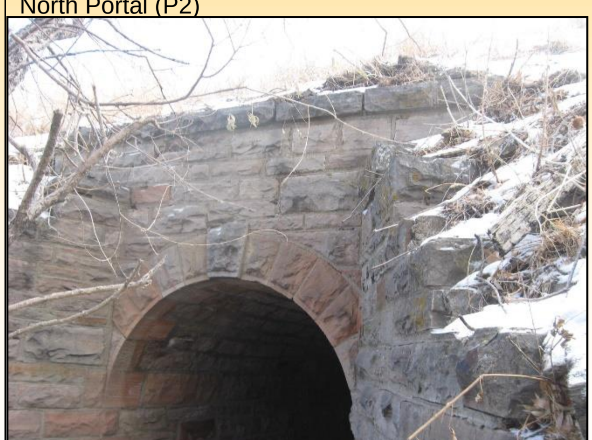
G	South Portal:
G	North Portal
F to P	Tunnel Masonry Lining Mortar Breakdown, Split/Spall, Patching, Masonry Displacement, Distortion Noted at 53 ft and 56 ft at the inside faces of masonry liner. No Efflorescence or Leakage noted at this time

Notes:

South Portal (P1)

Tunnel Masonry Lining(L1)

North Portal (P2)



Milepost – Masonry Lined Tunnel

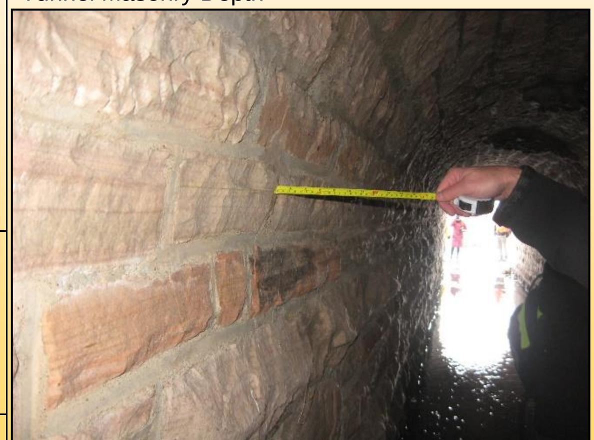
Length: 75 ft
Height: 8 ft
Span: 6 ft
Tunnel: Horseshoe Shape
Portals: Masonry
Liner: Masonry

Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance

F to p	Tunnel Masonry Liner: Efflorescence/Mortar Breakdown/Split/Spall/Patched Area/Displacement/Distortion/Leakage
F to P	Tunnel Masonry Lining Cracking Patching Noted at 53 ft and 56 ft at the inside faces of masonry liner.
F to P	Tunnel Masonry Lining Cracking Patching Noted at 53 ft and 56 ft at the inside faces of masonry liner.

Notes:

Tunnel Masonry Depth



Tunnel Masonry Depth

Tunnel Masonry Displacement

Milepost – Masonry Lined Tunnel

Length: 75 ft
Height: 8 ft
Span: 6 ft
Tunnel: Horseshoe Shape
Portals: Masonry
Liner: Masonry

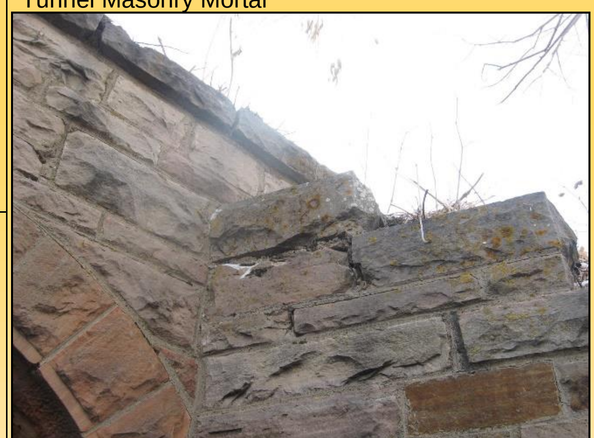
Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance

G to F	Missing Mortar South Portal
G to F	Missing Mortar North Portal
G to F	Missing Mortar North Portal

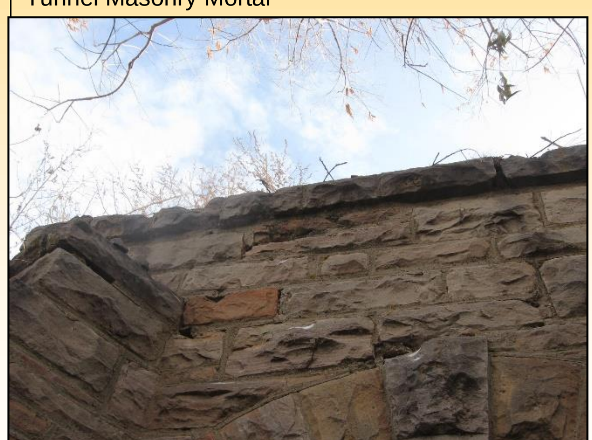
Notes:

Tunnel Masonry Mortar

Tunnel Masonry Mortar



Tunnel Masonry Mortar



Length: 75 ft
Height: 8 ft
Span: 6 ft
Tunnel: Horseshoe Shape
Portals: Masonry
Liner: Masonry

Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance

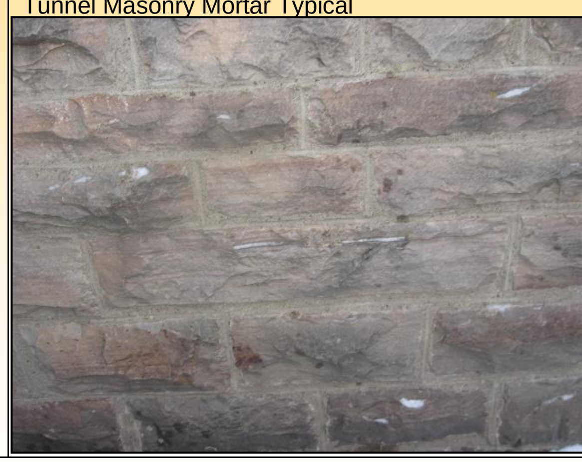
G to F	Missing Mortar North West Wing Wall
G to F	Missing Mortar North West Wing Wall
G to F	Mortar Typical

Notes:

Tunnel Masonry Mortar

Tunnel Masonry Mortar

Tunnel Masonry Mortar Typical



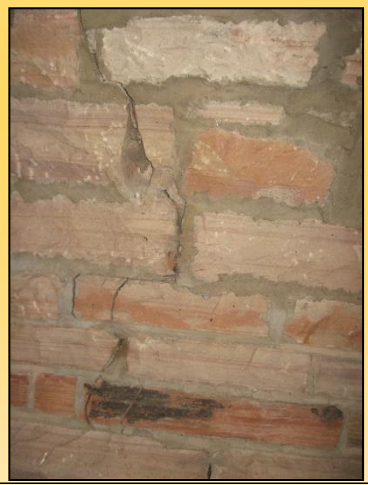
Milepost – Masonry Lined Tunnel	
Length: 75 ft Height: 8 ft Span: 6 ft Tunnel: Horseshoe Portals: Masonry	

Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance	
G to F	South Portal:
G To F	Tunnel Lining
G to F	South Portal

Notes:

Mortar Patching Ceiling

Mortar Patching Wall



Mortar Patching

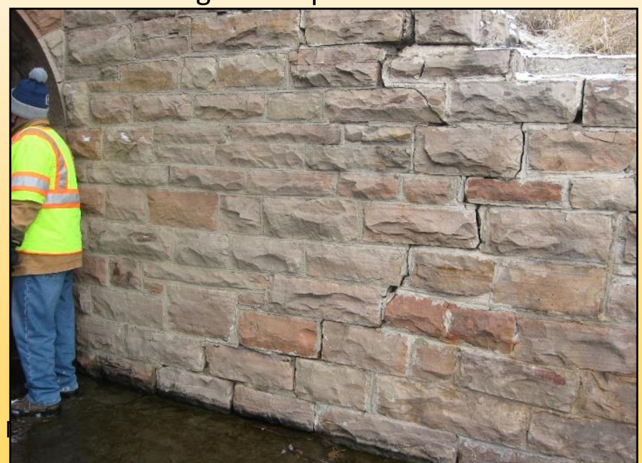
Milepost – Masonry Lined Tunnel	
Length: 75 ft Height: 8 ft Span: 6 ft Tunnel: Horseshoe Portals: Masonry	

Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance

F to P	South East Masonry Wingwall: Displacement/Mortar Breakdown/Spit/Spall/
F To P	Tunnel Lining
F to P	South Portal

Notes:

Southeast Wingwall Displacement



Southeast Wingwall

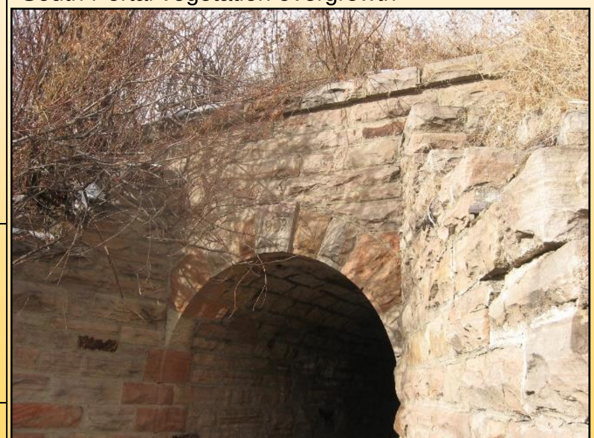
Milepost – General	
Length: 75 ft Height: 8 ft Span: 6 ft Tunnel: Horseshoe Portals: Masonry	

Element Conditions **G**ood/**F**air/**P**oor/**S**evere/**M**aintenance

M	South Portal: Vegetation
M	South Portal: Vegetation
M	South Portal: Vegetation

Notes:

South Portal vegetation overgrowth



Top South Portal Vegetation overgrowth

South Portal West side Vegetation overgowth

Summary of Recommendations

Cheyenne Masonry Tunnel inspection

Tunnel inspection was performed on December 18, 2020 in Cheyenne Wyoming. This masonry lined Tunnel has an opening/installation year of 1903. It is single barrel horseshoe shaped tunnel that is under approximately 30 feet of fill and supports two train tracks for the Union Pacific railroad. It is located approximately ½ mile southwest of the Cheyenne Station No. 4 Fire/Rescue Training center parking lot. The tunnel is 75-feet length, 6-feet wide opening, 8-feet tall opening and is owned by the Union Pacific railroad.

We arrived onsite at approximately 10 am, the sky was overcast and temperature was 34 degrees. The Martin/Martin Wyoming project team of Ron Pierce and Ryan Rigg met the client's team from Summit Engineering, GLM Design, Railpros and the City of Cheyenne.

The general condition of the tunnel appears to be in good to fair condition. A few noteworthy things were observed.

1. The southeast masonry wingwall shows signs of possible settlement. This separation of masonry blocks is noted in the pictures provided. It appears that the wall is vertically settling, and no miss alignment i.e. distortion was noted in the horizontal plane.

2. A crack that is full depth of the tunnel was noted approximately ¾ of its length (53 to 56 feet from the south entrance east and west wall faces, respectively).

Some investigations from geotechnical engineer to establish is a monitoring program to determine if the settlement and cracking/separations has finalized or if further remediation is needed to stabilize this structure.

Recommendations:

Secure a geotechnical engineer to do site investigations of the southeast wingwall and the main tunnel. Geotech to determine the number of boreholes to properly characterize the possible movement of the Tunnel and SE wingwall.

Further Engineering investigation

1. Obtain previous inspection reports for Union Pacific Railroad

2. Mortar patches effectiveness and stability i.e. sounding.

3. Review geotechnical data following investigation to establish if the remediation is required.

4. Confirm if southeast Wingwalls and Tunnel are stable in their current time.

5. Perform NTIS Tunnel inspection and gather inspection elements.

6. Determine the tunnel current conditions Good, Fair or Poor.

Maintenance Items.

1. Clearing of overgrown vegetation and South and North Portals
2. Patching of masonry joints
3. Water-proofing as needed