

FINAL  
LOCATION HYDRAULICS REPORT

The City of Palm Bay  
Malabar Road Project Development and Environment (PD&E) Study  
Limits of Project: St. Johns Heritage Parkway to Minton Road  
Brevard County, Florida  
Financial Management Number: 437210-1-28-01  
ETDM Number: 14396  
Date: October 2023

The environmental review, consultation, and other actions required by applicable federal environmental laws for this project are being, or have been, carried out by the Florida Department of Transportation (FDOT) pursuant to 23 U.S.C. § 327 and a Memorandum of Understanding dated May 26, 2022, and executed by the Federal Highway Administration and FDOT.

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# PROFESSIONAL ENGINEER CERTIFICATION

## LOCATION HYDRAULICS REPORT

**Project:** Malabar Road PD&E Study

**ETDM Number:** N/A

**Financial Project ID:** 437210-1-28-01

**Federal Aid Project Number:** N/A

This Location Hydraulics Report contains engineering information that fulfills the purpose and need for Malabar Road Project Development & Environment Study from St. Johns Heritage Parkway to Minton Road in Brevard County, Florida. I acknowledge that the procedures and references used to develop the results contained in this report are standard to the professional practice of transportation engineering as applied through professional judgment and experience.

I hereby certify that I am a registered professional engineer in the State of Florida practicing with Inwood Consulting Engineers, and that I have prepared or approved the evaluation, findings, opinions, conclusions or technical advice for this project.



This item has been digitally signed and sealed by Renato Chuw, PE on the date adjacent to the seal.

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# Malabar Road PD&E Study

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## Executive Summary

The Malabar Road Project Development and Environment (PD&E) Study evaluated capacity, safety, and multi-modal improvements on Malabar Road from St. Johns Heritage Parkway to Minton Road, a distance of approximately four miles. This project involves the widening of Malabar Road from two lanes to four lanes to meet future travel demands, improve safety and provide for bicycle and pedestrian features, such as sidewalks and a shared use path.

The purpose of this Location Hydraulics Report is to address base floodplain encroachments resulting from the roadway improvements evaluated in the PD&E Study. In accordance with Executive Order 11988 “Floodplain Management”, U.S.DOT Order 5650.2, “Floodplain Management Protection”, and Federal-Aid Policy Guide 23 CFR 650A, floodplains must be protected. The intent of these regulations is to avoid or minimize highway encroachments within the 100-year (base) floodplains and to avoid supporting land use development incompatible with floodplain values.

Floodplain encroachments areas resulting from the proposed Malabar Road widening were quantified. It is determined that impacts will occur to the floodplain associated with the proposed widening at the western end of the project. Floodplains are not present throughout the remainder of the project.

According to the FEMA FIRMs, portions of the project are within Zone AE of the 100-year floodplain. These areas are located toward the western end of the project and are associated with the Three Forks Conservation Area and C-8 Canal. The established flood water elevation is 20.0 feet NAVD.

It was concluded that the project will impact approximately 1.41 ac-ft of floodplain based on the proposed roadway alignment and an additional 0.50 ac-ft for the recommended preferred pond alternative (total of 1.91 ac-ft). These impacts are minimal compared to the overall extent of the floodplain, therefore, it was determined that the floodplain encroachment is classified as “minimal”. Minimal encroachments on a floodplain occur when there is a floodplain involvement, but the impacts on human life, transportation facilities, and natural and beneficial floodplain values are not significant and can be resolved with minimal efforts. Please refer to **Section 4.4** for additional information.

In conclusion, the following floodplain statement is a slightly modified version of statement Number 4 in the FDOT PD&E Manual (Part 2, Chapter 13 “Floodplains”), tailored for this project:

*“The proposed cross drains and floodplain compensation areas will perform hydraulically in a manner equal to or greater than the existing condition, and backwater surface elevations are not expected to increase. As a result, there will be no significant change in flood risk, and there will not be a significant change in the potential for interruption or termination of emergency service or in emergency evacuation routes. Therefore, it has been determined that this encroachment is not significant.”*

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## 1.0 Project Summary

Initiated in November 2019, this Project Development and Environment (PD&E) Study has been conducted to assess various widening alternatives for Malabar Road. This Preliminary Engineering Report (PER) documents the project's purpose and need, the alternatives developed, the process of selecting the preferred alternative, and presents the preliminary design analysis for the preferred alternative.

### 1.1 Project Description

The Malabar Road Project Development and Environment (PD&E) Study evaluated capacity, safety, and multi-modal improvements on Malabar Road from St. Johns Heritage Parkway to Minton Road, a distance of approximately four miles, in the City of Palm Bay and Brevard County, Florida. Malabar Road is an east-west regional roadway connecting western Brevard County/City of Palm Bay to US 1 in Malabar. The roadway's maintaining jurisdiction is Brevard County at its western edge, before transitioning to the City of Palm Bay for several miles, and then becoming a state road (S.R. 514) between I-95 and US 1. Malabar Road has an existing diamond interchange with I-95. Within the study area, Malabar Road is an urban minor arterial. The study area is shown in **Figure 1-1**.

Malabar Road within the project limits is a two-lane roadway. The section from St. Johns Heritage Parkway to Garvey Road is undivided, whereas the section from Garvey Road to Minton Road has median turn lanes. An 8' sidewalk is present on Malabar Road's north side for the entirety of the project limits. Minimal sidewalk is present on the south side. No on road bicycle facilities are present along the study limit's length.

There are currently four signalized intersections and numerous unsignalized intersections along the study corridor. The four signalized intersections are located at Krassner Drive/Bending Branch Lane, Jupiter Boulevard, the Plaza Shopping Center, and Minton Road.

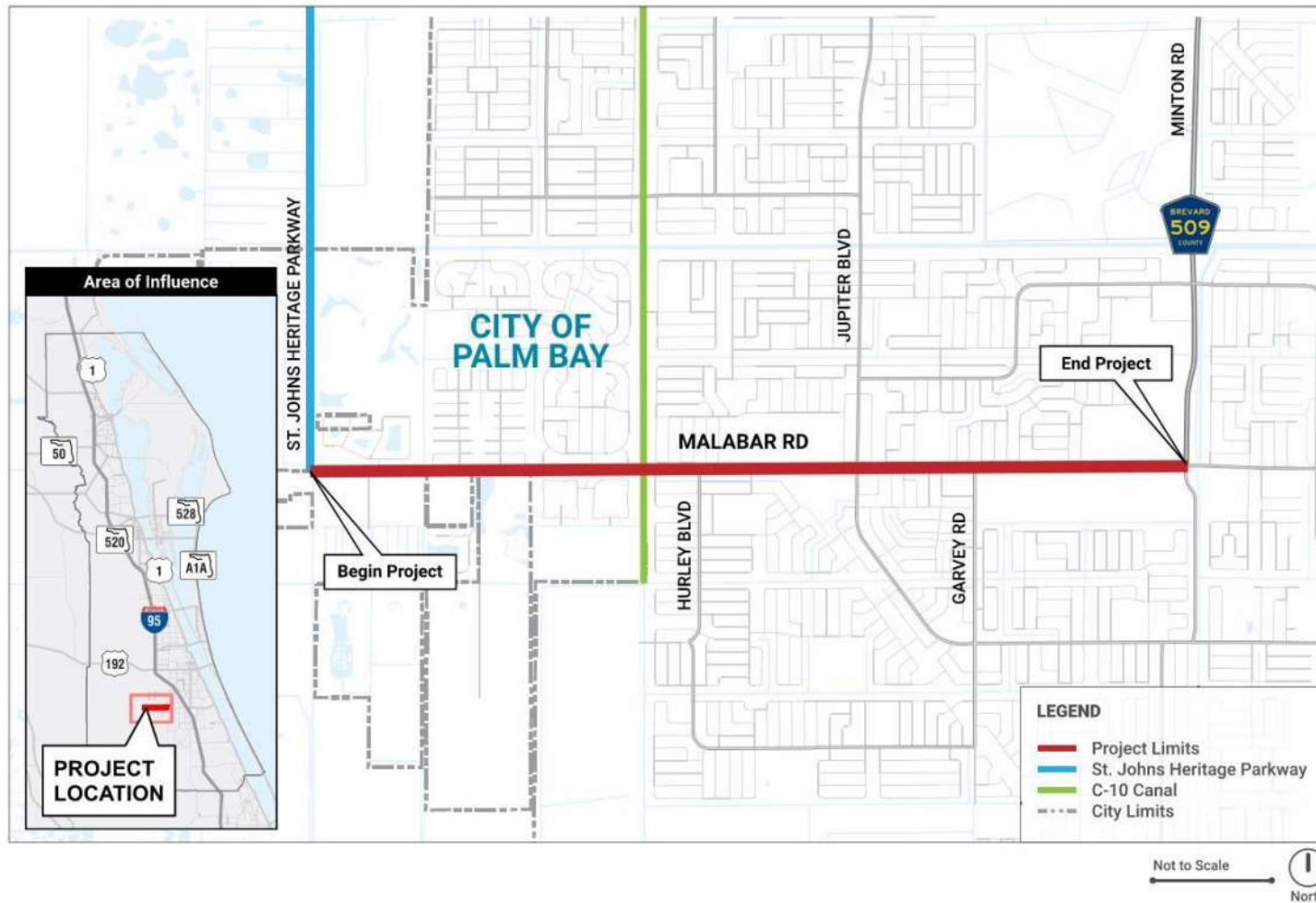
This roadway is unique due to the surrounding canal system that is operated/maintained by the Melbourne-Tillman Water Control District (MTWCD). Malabar Road within the project limits crosses over four canals (C-7, C-8, C-9, and C-10). Canal C-20 runs parallel to Malabar Road on the north side from Canal C-10 (250' west of Bavarian Avenue) to approximately 0.30 miles west of Minton Road. One bridge, crossing over Canal C-10, is located within the project limits.

The proposed improvements will widen Malabar Road from two to four lanes from the St. Johns Heritage Parkway to Minton Road. The preferred alternative's typical section along the study corridor will include two 11' lanes in each direction, a 22' wide median, a 10' shared-use path on the north side, and an 8' sidewalk on the south side. The intersections at St. Johns Heritage Parkway, Krassner Drive/Bending Branch Lane, Hurley Boulevard, and Maywood Avenue/Daffodil Drive are proposed as roundabouts while Jupiter Boulevard, the Plaza Shopping Center, and Minton Road are proposed to remain signalized.

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Figure 1-1: Study Roadway



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STUDY ROADWAY

FIGURE 1

# Malabar Road PD&E Study

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## 1.2 Purpose and Need

The purpose of this project is to evaluate the need for capacity improvements (roadway widening) to relieve existing congestion and accommodate projected future traffic demand. The project's secondary goals are to 1) Enhance safety conditions; 2) Improve multi-modal facilities; and 3) Enhance regional and local mobility. The need for these improvements is described in this section.

### 1.2.1 Transportation Demand/Capacity

The existing (2020) traffic analysis shows the four signalized intersections and 13 unsignalized intersections operated with an overall Level of Service (LOS) of E or better and no overcapacity movements. Even though the intersections were operating acceptably, the existing traffic analysis for the segments shows multiple segments of the Malabar Road corridor operated worse than the City standard of LOS C, with traffic volumes ranging from 7,200 to 16,000 Annual Average Daily Traffic (AADT). As population and employment growth are expected to continue in western Palm Bay, the east-west traffic volumes along Malabar Road are anticipated to increase. This will ultimately lead to unacceptable segment and intersection operations.

### 1.2.2 Safety

Crash records were obtained for Malabar Road from 900' west of the St. Johns Heritage Parkway to ¼ mile east of Minton Road for the most recent five-year period on record (2016 through 2020). There was a total of 642 reported crashes during this period, 202 (32 percent) resulted in at least one injury. There were no reported fatal crashes along the study corridor during the five-year period. As displayed in **Figure 1-2**, the crashes per year along the corridor generally increased between 2016 (123 crashes) and 2019 (137 crashes). The 2020 crash data saw a decrease to 113 crashes, likely due to decreases in traffic volumes related to the COVID-19 pandemic. While the overall total crashes decreased in 2020, the total number of injury crashes was the second highest behind 2017. This could be attributed to higher travel speeds along the corridor due to the lower volume, which leads to more severe crashes. It is important to note the traffic counts for this project were performed in January 2020, prior to the beginning of the pandemic restrictions in March 2020.

The highest crash type observed was rear end, comprising 54 percent of the total crashes. Left turn (14 percent) and sideswipe crashes (12 percent) were the second and third highest crash types.

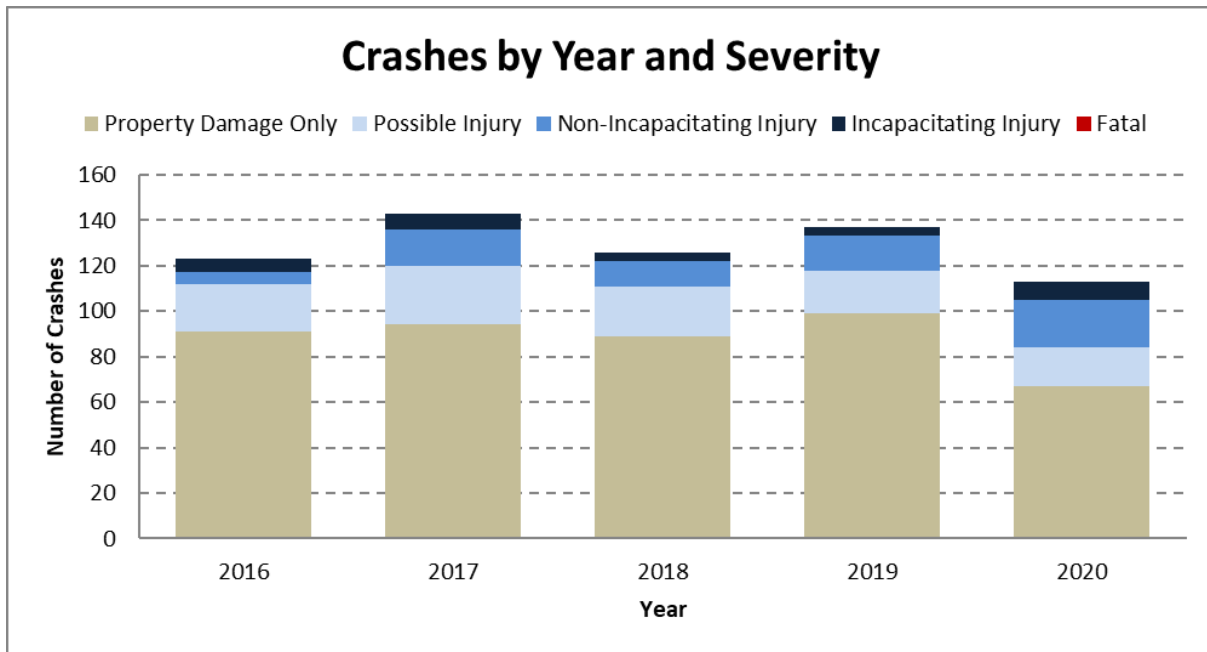
Three existing signalized intersections at Jupiter Boulevard, the Plaza Shopping Center, and Minton Road were the highest crash locations along the study corridor, accounting for 330 of the 642 total reported crashes (51 percent). The four highest crash unsignalized intersections are St. Johns Heritage Parkway, Hurley Boulevard, Hillock Avenue, and Maywood Avenue/Daffodil Drive accounting for 90 total crashes (14 percent). Two high crash segments from 0.05 miles east of Jupiter Boulevard to 0.05 west of Santa Rosa Avenue (1,400 feet in length) and from 0.05 miles east of Maywood Avenue/Daffodil Drive to 0.05 west of the Plaza Shopping Center (1,175 feet in length) accounted for 61 total crashes (10 percent). A crash rate analysis was performed on the 2016 to 2018 crash data because average crash rates were not

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available for 2019 and 2020. Only one segment of Malabar Road, between Jupiter Boulevard and the Plaza Shopping Center, had a higher than average crash rate for one year of analysis. While the segments had low safety ratios, the three signalized intersections at Jupiter Boulevard, the Plaza Shopping Center, and Minton Road each had higher crash rates than statewide or districtwide averages for similar roadways in at least two of the three analysis years.

Figure 1-2: Crashes per Year (Corridor Wide)



## 1.2.3 Modal Interrelationships

An 8' sidewalk is present on the north side of Malabar Road for the entirety of the project limits. Where Canal C-20 exists, this facility is on the north side of the canal. Sidewalk is present for approximately 40 percent of the project limits on the south side. No on-road bicycle facilities are present along the length of the project limits.

The Office of Greenways and Trails (OGT) and the Space Coast Transportation Planning Organization (SCTPO) identified trail opportunities in the vicinity of Malabar Road. The St. Johns River Eco-Heritage Trail will align with the St. Johns Heritage Parkway and connect the Brevard Zoo Linear Trail to Malabar Road. The St. Johns River Eco-Heritage Trail will extend south where it will connect to existing trail facilities. In addition to OGT and SCTPO identified trails, two local trails are in the study vicinity. One local trail runs east-west along Malabar Road from St. John Heritage Parkway to west of Minton Road as previously discussed. The second local trail called the Cross City Trail ends just south of Malabar Road near the City of Palm Bay Public Works Department. The trail is located adjacent to the power lines and starts at Walpole Road and ends just south of Malabar Road. There is no connection between Cross City Trail and the trail paralleling Malabar Road's north side due to the presence of Canal C-20. The existing

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trails and trail opportunities are displayed in **Figure 15** of the *Malabar Road Preliminary Engineering Report*.

Two transit routes with 16 total transit stops (six eastbound and 10 westbound) operate along Malabar Road within the study corridor. Space Coast Area Transit Route 20 connects Heritage and West Melbourne and Route 23 provides service to the West Palm Bay area. Route 20 operates along the entire corridor and Route 23 operates between Jupiter Boulevard and Minton Road. Both routes operate from approximately 6:30 AM to 8:30 PM on weekdays and 7:30 AM to 5:30 PM on Saturdays with hour long headways. The eastbound bus stop in front of the Madalyn Landing Apartments is the only stop with a bus shelter. The existing transit routes and shelters are displayed in **Figure 15** of the *Malabar Road Preliminary Engineering Report*.

## 1.2.4 System Linkage

The western Palm Bay area is anticipated to experience population and traffic growth in the next 30 years, leading to increased travel on facilities west of I-95 and south of US 192. The St. Johns Heritage Parkway is providing a “beltway” facility to accommodate the forecasted increase in traffic in western Palm Bay. The St. Johns Heritage Parkway is already constructed from Malabar Road to US 192, and a study is being performed for the extension of the Parkway from Babcock Street north to Malabar Road.

Malabar Road is one of three primary east-west roadways connecting to the Parkway and is the only one of those roadways that has an interchange with I-95. Malabar Road from Minton Road to Corporate Circle is four lanes and the section from Corporate Circle to I-95 is six lanes. The Malabar Road four-lane alternative proposed from the St. Johns Heritage Parkway to Minton Road would tie into the existing four-lane section starting at Minton Road.

A PD&E study was completed in 2021 for Malabar Road from Babcock Street to US 1 with a preferred alternative to widen from two to four lanes. Design and right-of-way for the Babcock Street to US 1 project is planned in the SCPTO’s 2045 Long Range Transportation Plan (LRTP) Cost Feasible Plan for the 2026 to 2030 time period and construction is planned for the 2031 to 2035 time period.

## 1.3 Alternatives Analysis Summary

### 1.3.1 Roadway Typical Sections

Two initial typical section alternatives were developed to support the Malabar Road purpose and need for capacity and safety improvements:

- Alternative A – Minimum right-of-way alternative
  - 89.5’ right-of-way alternative from the St. Johns Heritage Parkway to Canal C-10 (**Figure 1-3**)
  - 92.5’ right-of-way alternative from Canal C-10 to Sta. 256+80 (**Figure 1-4**)



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- Alternative B – Desired right-of-way alternative
  - 100' right-of-way alternative from the St. Johns Heritage Parkway to Canal C-10 (**Figure 1-5**)
  - 103' right-of-way alternative from Canal C-10 to Sta. 256+80 (**Figure 1-6**)

Each of the initial typical sections were applied from the St. Johns Heritage Parkway to Sta. 256+80, which is just west of the Plaza Shopping Center where Malabar Road begins to transition to a four-lane roadway. The posted speed for each typical section alternative is 35 mph from St. Johns Heritage Parkway to Championship Circle, 45 mph from Championship Circle to east of Maywood Avenue/Daffodil Drive, and 35 mph from east of Maywood Avenue/Daffodil Drive to Minton Road. This maintains the existing posted speed limits.

The initial Malabar Road typical section alternatives were developed using design provisions from the Florida Greenbook and the FDOT Design Manual (FDM). Alternative A was developed to minimize the right-of-way impacts to residential properties on the south side of Malabar Road and minimize Canal C-20 impacts on the north side of Malabar Road east of Canal C-10. The following features are common between the 89.5' and the 92.5' typical sections:

- Two 11' travel lanes in each direction;
- 15.5' wide median, including Type E curb and gutter;
- Type F curb and gutter outside of the travel lanes; and
- 10' shared-use path on the north side and 6' sidewalk on the south side.
  - The inside edge of the 6' sidewalk is at the back of curb.

The primary difference between the 89.5' and 92.5' typical sections is the presence of Canal C-20 on the north side of Malabar Road east of Canal C-10. In the 92.5' typical, an extra 3' is added on the north side for guardrail protection between the roadway and Canal C-20.

Alternative A utilized a smaller median width of 15.5' and a 6' south side sidewalk at the back of curb to reduce the overall right-of-way needed for the study corridor. A 15.5' median does not meet the minimum 22' Florida Greenbook or FDM median widths for a 45 mph facility, thus a design variation would be needed if this alternative was to move forward. Alternative B increases the median width to a standard 22' median (including Type E curb and gutter) per FDM criteria. Alternative B also provides a 4' grass buffer between the south side curb and the sidewalk, which was not provided in Alternative A. The additional 6.5' in the median and 4' grass buffer on the south side equates to the 10.5' difference between the 89.5'/92.5' Alternative A typical sections and the 100'/103' Alternative B typical sections. The following features are common between the 100' and the 103' typical section alternatives:

- Two 11' travel lanes in each direction;
- 22' wide median, including Type E curb and gutter;
- Type F curb and gutter outside of the travel lanes;
- 10' shared-use path on the north side and 6' sidewalk on the south side; and
- 4' grass buffer between the back of the curb and the 6' south side sidewalk.



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Similar to Alternative A, the 3' difference between the 100' and 103' typical sections is north side guardrail protection between the roadway and Canal C-20.

The Alternative A and Alternative B typical sections were presented at the Alternatives Public Meeting conducted on Thursday, September 24, 2020 and subsequent local jurisdiction meetings in October 2020. During these meetings, discussion was held regarding the lack of on-road bicycle facilities being provided in the typical section alternatives. While adding on-road bicycle facilities was deemed not feasible by the study team due to the right-of-way and Canal C-20 impacts, widening the south side sidewalk to 8' was explored. A 10' shared-use path is already being proposed on the north side, so widening the south side sidewalk to 8' would provide a wider facility accommodating both pedestrians and bicycles. The 8' south side sidewalk was incorporated into the preferred alternative.

## 1.3.2 Bridge Typical Sections

One bridge structure is present over Canal C-10 at approximately Sta. 142+00. Four bridge typical sections were developed in support of the initial typical section alternatives discussed in the previous section:

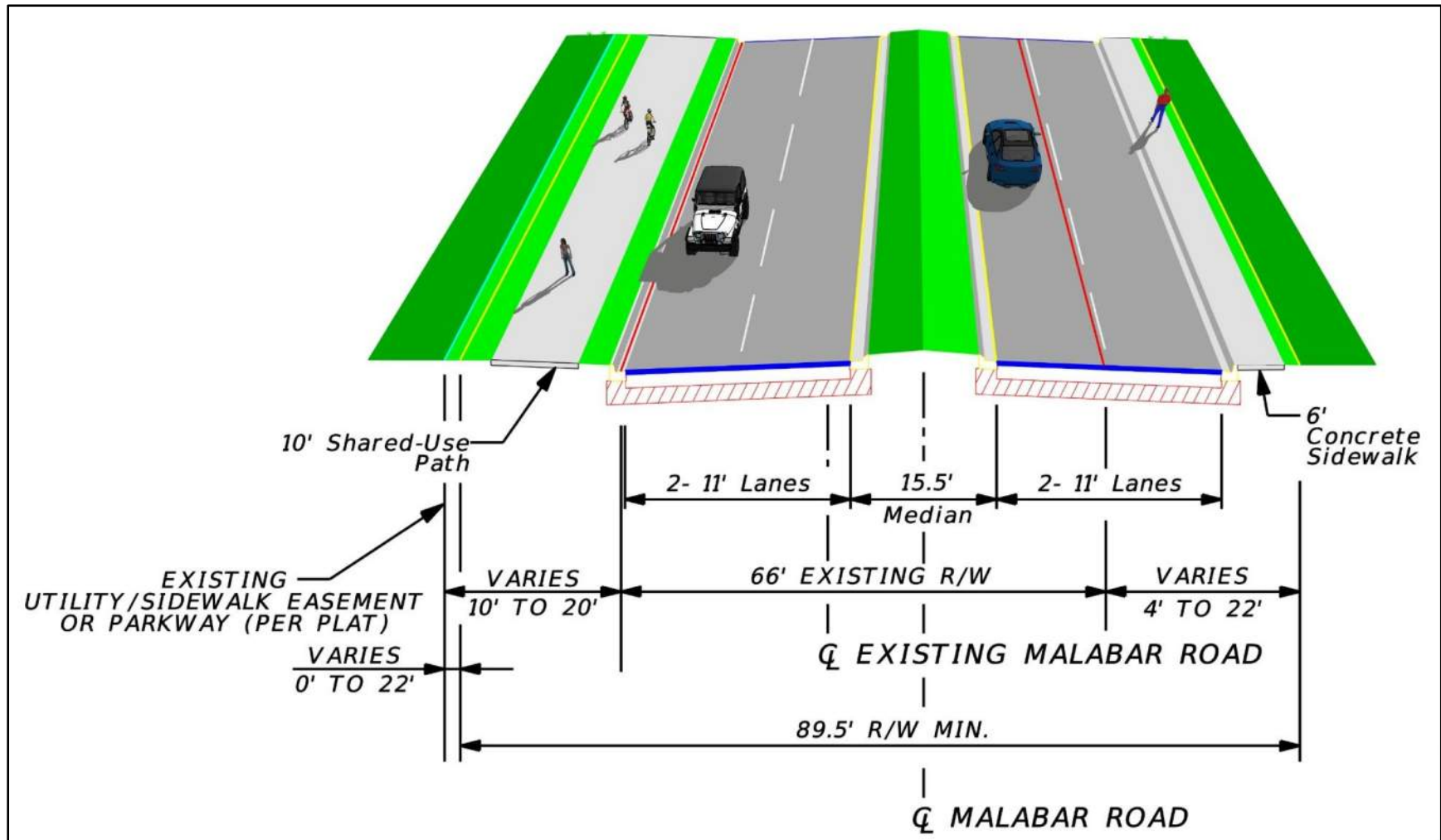
- Alternative A – Minimum right-of-way bridge typical sections
  - Raised sidewalk alternative
  - Flush sidewalk with traffic separator alternative
- Alternative B – Desired right-of-way bridge typical sections
  - Raised sidewalk alternative
  - Flush sidewalk with traffic separator alternative

The Alternative A bridge typical sections have a 15.5' median consistent with the Alternative A roadway typical section. The Alternative B bridge typical sections have a 22' median consistent with Alternative B roadway typical section. The raised sidewalk bridge typical section (both Alternatives A and B) incorporates a 10' shared-use path on the north side and 6' sidewalk on the south side that is raised above the travel lanes and separated by a 1.5' paved shoulder. A traffic railing with a pedestrian/bicycle railing on top is present to the outside of the bridge structure. The flush sidewalk bridge typical section (both Alternatives A and B) provides the same 10' shared-use path and 6' sidewalk, but the facilities are flush with the bridge deck and separated from the travel lanes by a 2.5' paved shoulder and 1'4" traffic railing. A pedestrian/bicycle railing is present to the outside of the bridge structure.

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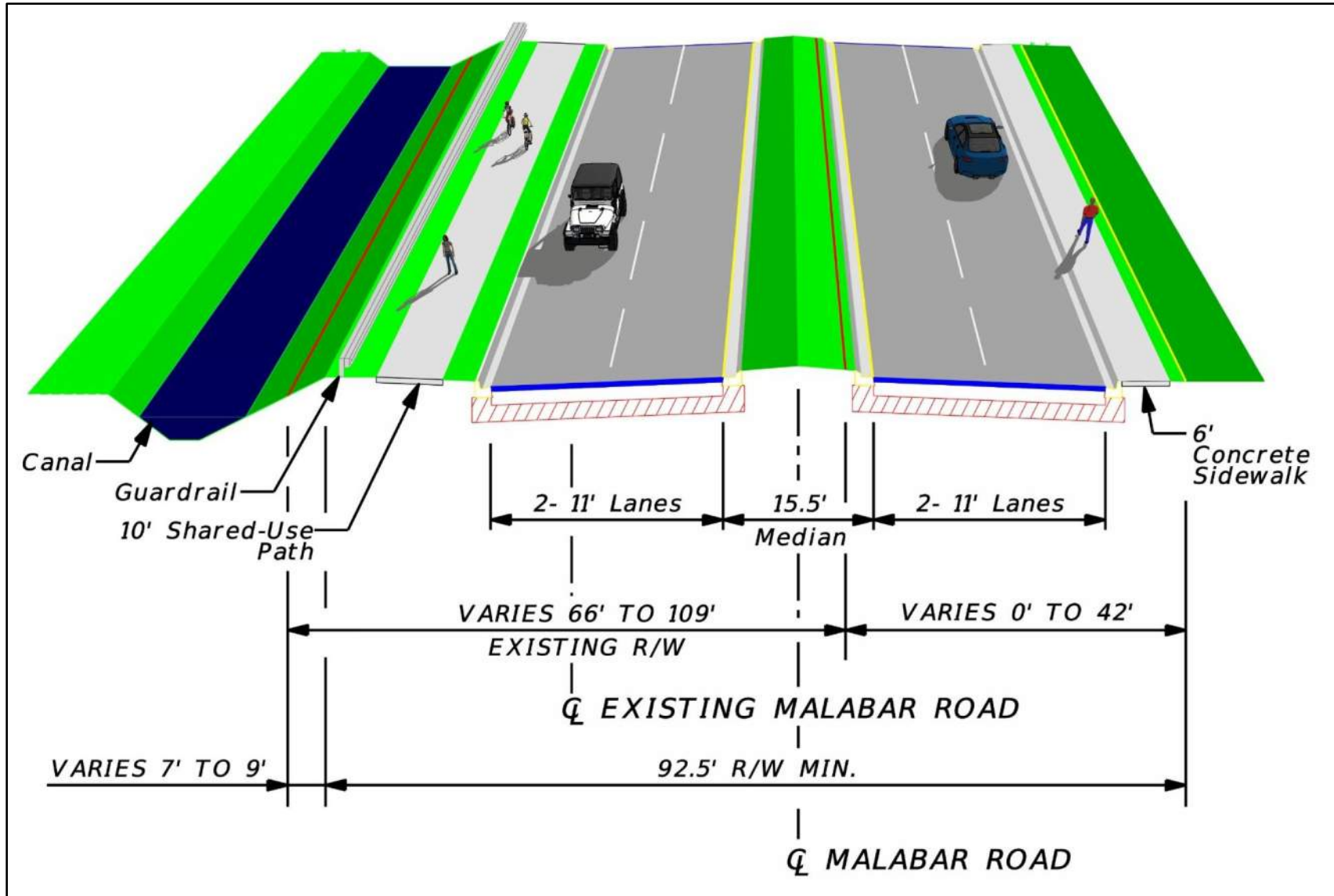
Figure 1-3: 89.5' Alternative A – St. Johns Heritage Parkway to Canal C-10



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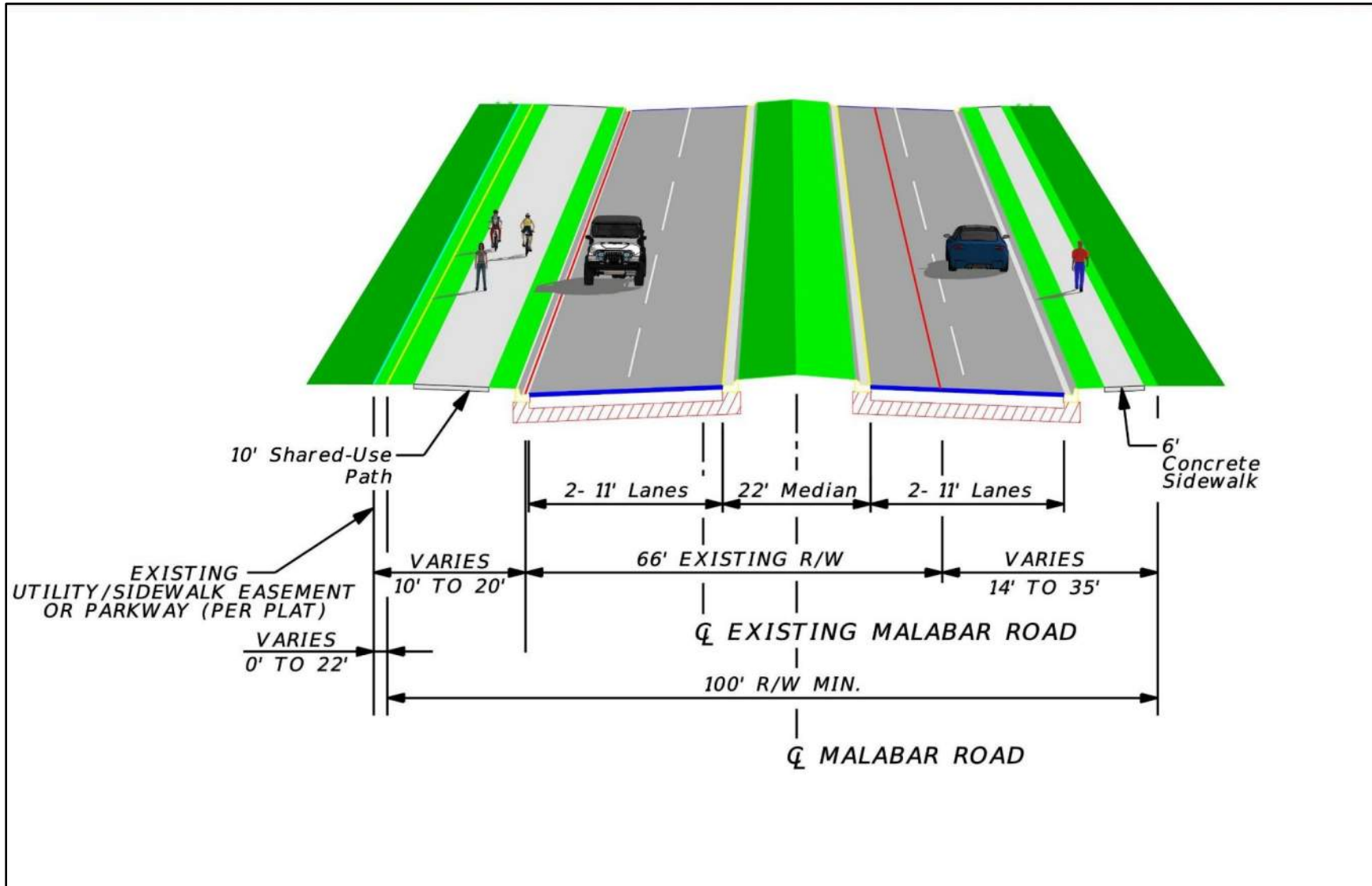
Figure 1-4: 92.5' Alternative A – Canal C-10 to Sta. 256+80



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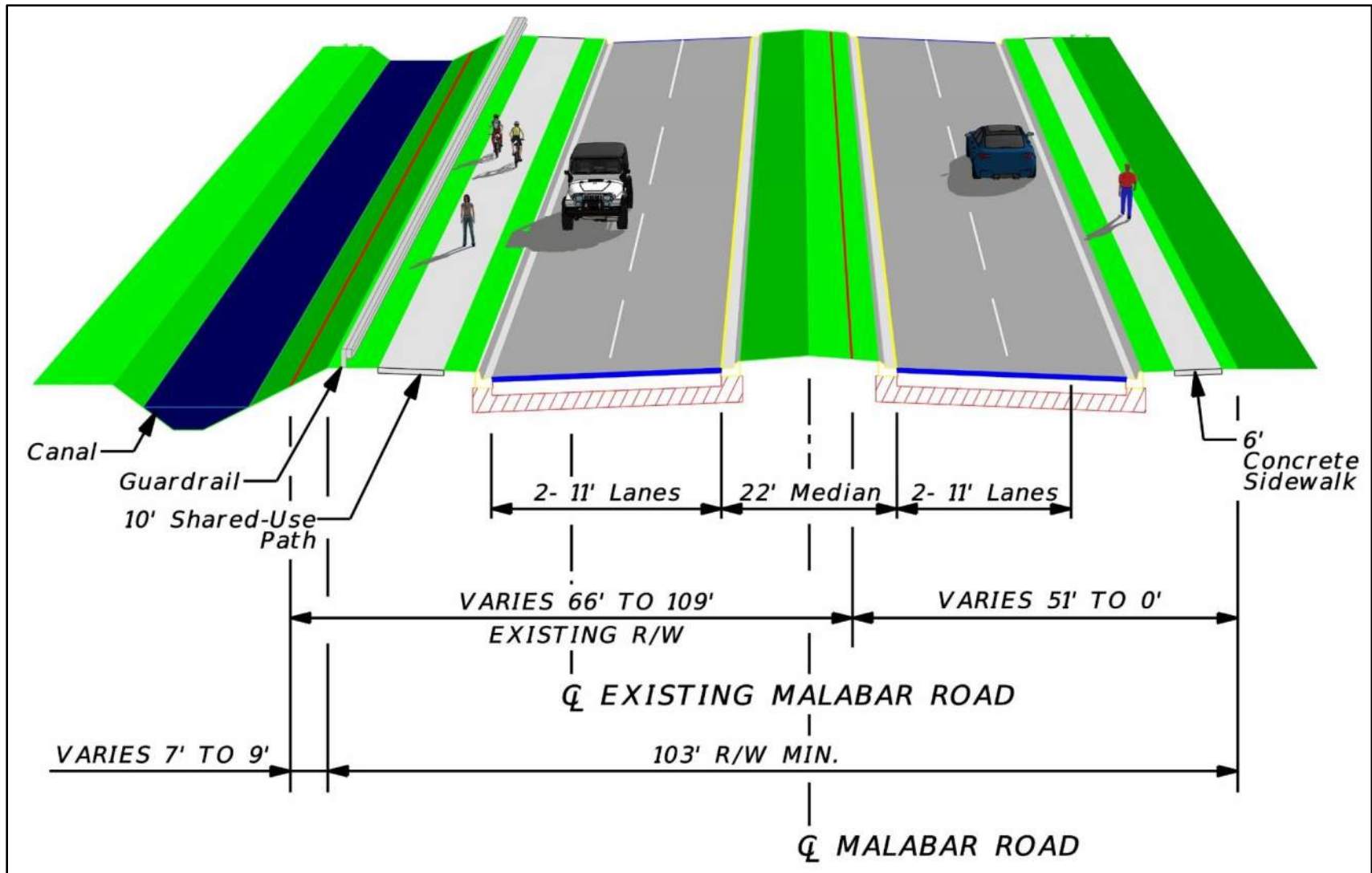
Figure 1-5: 100' Alternative B – St. Johns Heritage Parkway to Canal C-10



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Figure 1-6: 103' Alternative B – Canal C-10 to Sta. 256+80



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## 1.3.3 Intersection Alternatives

The following intersections were reviewed for either a traffic signal/unsignalized intersection or a roundabout:

- Traffic Signal vs Roundabout Evaluation –
  - Malabar Road & St. Johns Heritage Parkway;
  - Malabar Road & Wisteria Avenue/Abilene Drive;
  - Malabar Road & Krassner Drive/Bending Branch Lane;
  - Malabar Road & Jupiter Boulevard; and
  - Malabar Road & Garvey Road.
- Unsignalized Intersection vs Roundabout Evaluation –
  - Malabar Road & Hurley Boulevard; and
  - Malabar Road & Maywood Avenue/Daffodil Drive.

In order to analyze and compare the signalized/unsignalized alternatives to the roundabouts at each location, an intersection operational analysis and safety analysis were performed. Based on this analysis, roundabouts are anticipated to operate better or the same as the signalized/unsignalized intersection at every location except Garvey Road. Roundabouts have been shown to reduce fatal/injury crash types versus signalized/unsignalized intersections, and the results show the roundabout has lower predicted fatal/injury crashes at every intersection.

During the intersection alternatives analysis, it was determined that the following intersections would remain signalized in the preferred alternative due to operational limitations and right-of-way impacts of a roundabout configuration:

- Malabar Road & Plaza Shopping Center; and
- Malabar Road & Minton Road.

## 1.4 Description of Preferred Alternative

### 1.4.1 Selection of Preferred Alternative

The purpose of this project is to evaluate the need for capacity improvements (roadway widening) to relieve existing congestion and accommodate projected future traffic demand. The project's secondary goals are to 1) Enhance safety conditions; 2) Improve multi-modal facilities; and 3) Enhance regional and local mobility.

Alternative B with 8' south side sidewalks was selected as the preferred alternative by the City of Palm Bay and Brevard County. Alternative B was selected because it provides the wider median plus the 4' grass buffer, both meeting 2023 FDM standards, while having a negligible impact on right-of-way and only a slighter higher project cost when compared to Alternative A. A wider median would facilitate U-turn movements at directional median openings not having a bulb-out. The 4-ft grass buffer between the back of curb and the sidewalk enhances pedestrian safety from an errant vehicle and provides more comfort to the pedestrian in the sidewalk. The following bullets summarize how the preferred alternative meets the primary and secondary purpose and need goals noted above:



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- Transportation Demand/Capacity
  - In the 2050 build condition, each roadway segment is anticipated to operate at LOS C or better, except the segment from the Plaza Shopping Center to Minton Road.
    - This segment is anticipated to operate at LOS F due to the short distance (approximately 750') between the signalized intersections at the Plaza Shopping Center and Minton Road, and the effect of the overlapping delays of these two adjacent signals.
    - The signals at the Plaza Shopping Center and Minton Road will be optimized as one system in the future build condition to enhance operations between the two signals.
  - Each of the signalized intersections are anticipated to perform at LOS E or better and no intersections operated with a V/C ratio greater than 1.0 in either the 2050 AM or PM peak hour.
- Safety
  - Using the predictive safety analysis methods provided in the Highway Safety Manual (HSM), as traffic volumes increase in the no-build condition, crashes are predicted to increase by over 120 percent between 2020 and 2050.
  - By providing a four-lane facility, the 2050 crashes are predicted to be up to 40 percent less than a two-lane facility with the same traffic volumes.
- Modal Interrelationships
  - A 10' shared-use path will be provided on the north side of Malabar Road.
  - An 8' sidewalk will be provided on the south side of Malabar Road.
  - Existing transit stop access will be enhanced as part of the four-lane widening and sidewalk improvements.
- System Linkage
  - Providing a four-lane Malabar Road from the St. Johns Heritage Parkway to Minton Road would provide at least four travel lanes from the St. Johns Heritage Parkway to US 1 once the planned projects are constructed.
  - The project will also enhance the access to St. Johns Heritage Parkway, a critical north/south arterial in western Brevard County.

## 1.4.2 Typical Sections

The preferred alternative typical sections were designed using 2023 FDM criteria as discussed in **Section 4.2** of the *Malabar Road Preliminary Engineering Report*. The following describes the typical section elements:

- Two 11' travel lanes in each direction;
- 22' wide median, including Type E curb and gutter;
- Type F curb and gutter outside of the travel lanes;
- 10' shared-use path on the north side and 8' sidewalk on the south side; and
- 4' grass buffer between the back of the curb and the 8' south side sidewalk.

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The following highlights key differences in typical section elements along the Malabar Road study corridor:

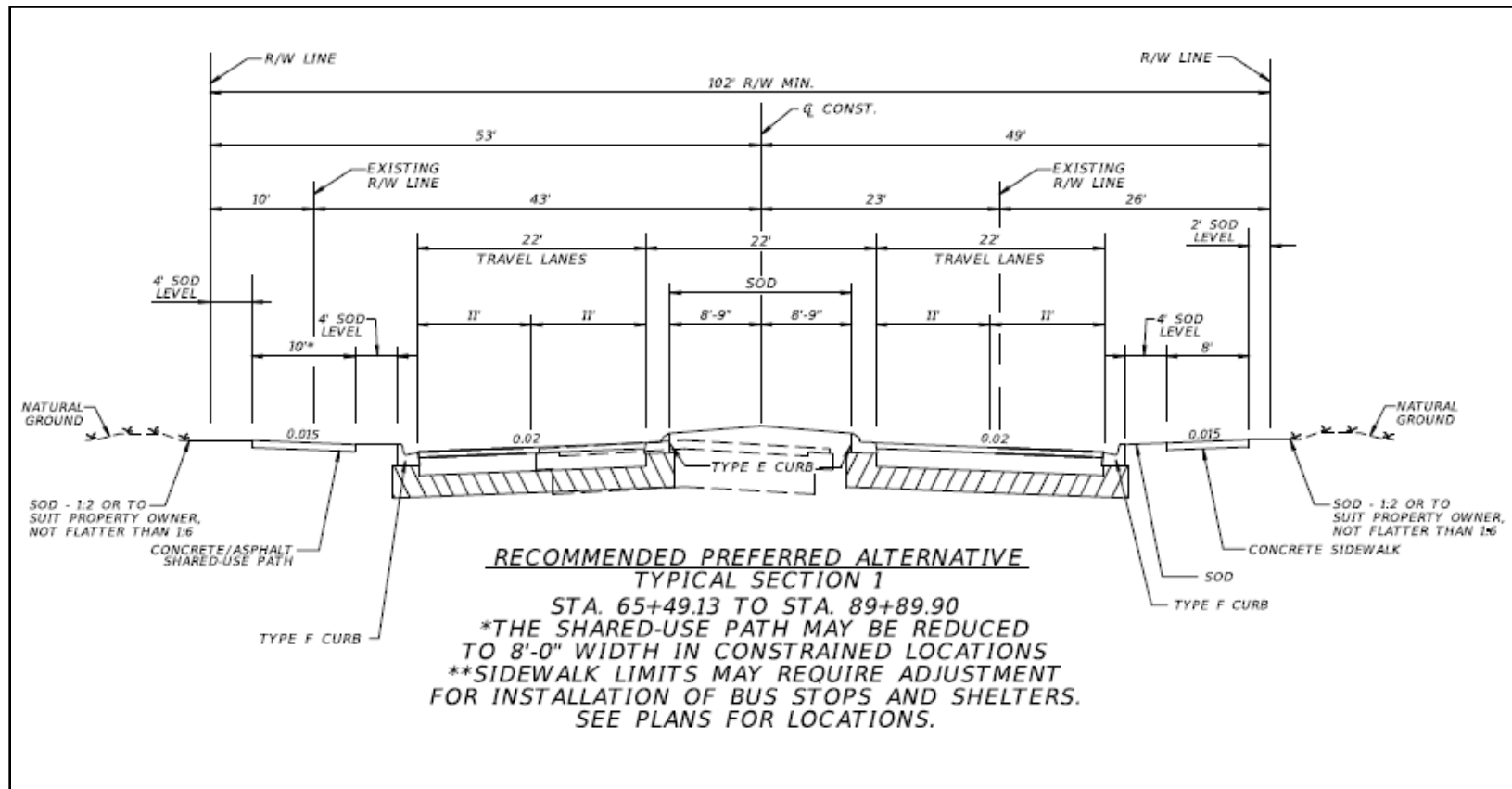
- St. Johns Heritage Parkway to Canal C-10 (**Figure 1-7**) –
  - Primarily contained within 102' to 106' of right-of-way.
    - Between Bending Branch Lane/Krassner Drive and the bridge over Canal C-10, the proposed roadway alignment is generally in the same location as the existing roadway. This was done to maintain the alignment of the westbound travel lanes coming from the bridge. The roadway in this section is positioned further south than the section from St. Johns Heritage Parkway to and Bending Branch Lane/Krassner Drive, resulting in the 106' right-of-way.
    - In front of the Tillman Lakes development (Abilene Drive), the right-of-way expands to 136'.
  - No roadside drainage swales are present within this section.
- Malabar Road over Canal C-10 (**Figure 1-8**) –
  - Two 11' travel lanes in each direction, a 10' barrier separated shared-use path on the north side and an 8' barrier separated sidewalk on the south side.
  - 19' mountable raised median on the bridge with two 1.5' inside shoulders.
  - The overall bridge width is 93.25' with the roadway crowned at 2 percent at the centerline of construction.
- Canal C-10 to West of Jupiter Boulevard (**Figure 1-9**) –
  - Proposed right-of-way width varies between 100' west of Jupiter Boulevard to 194' in the areas where dry retention linear swales are present.
  - Canal C-20 runs parallel to Malabar Road on the north side for this entire section.
- West of Jupiter Boulevard to East of Jupiter Boulevard (**Figure 1-10**) –
  - Widening is primarily contained within a 101.5' proposed right-of-way footprint.
  - In front of the USPS, the proposed right-of-way reduces to 94.5', and the south side sidewalk is reduced to 6' and brought adjacent to the back of curb.
  - Canal C-20 is being relocated to the north and retaining walls are proposed for the north and south sides of the canal.
- East of Jupiter Boulevard to Maywood Avenue/Daffodil Drive (**Figure 1-11**) –
  - Proposed right-of-way width is typically 101.5' in this section but does widen to 191' in the area where dry retention linear swales are present.
  - Canal C-20 runs parallel to Malabar Road on this section's north side.
- Note the preferred typical section varies through the Maywood Avenue/Daffodil Drive roundabout.
- West of Plaza Shopping Center (**Figure 1-12**) –
  - Widening is primarily contained within a 107' proposed right-of-way.
  - A third lane is added in the eastbound direction to accommodate turn lane improvements on the Minton Road intersection's western leg.
- The section between the Plaza Shopping Center and Minton Road intersections varies due to the turn lane configurations.



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Figure 1-7: Representative Preferred Alternative Typical Section – St. Johns Heritage Parkway to Canal C-10

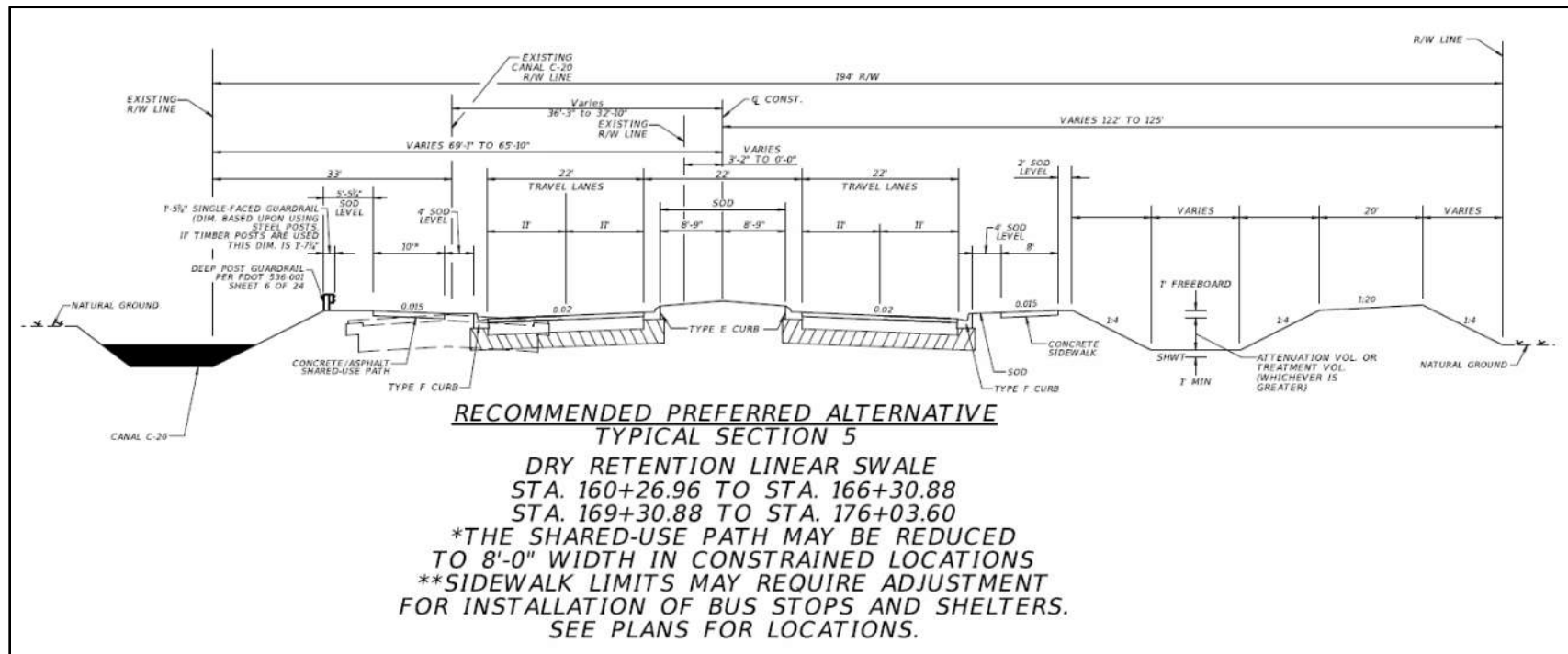




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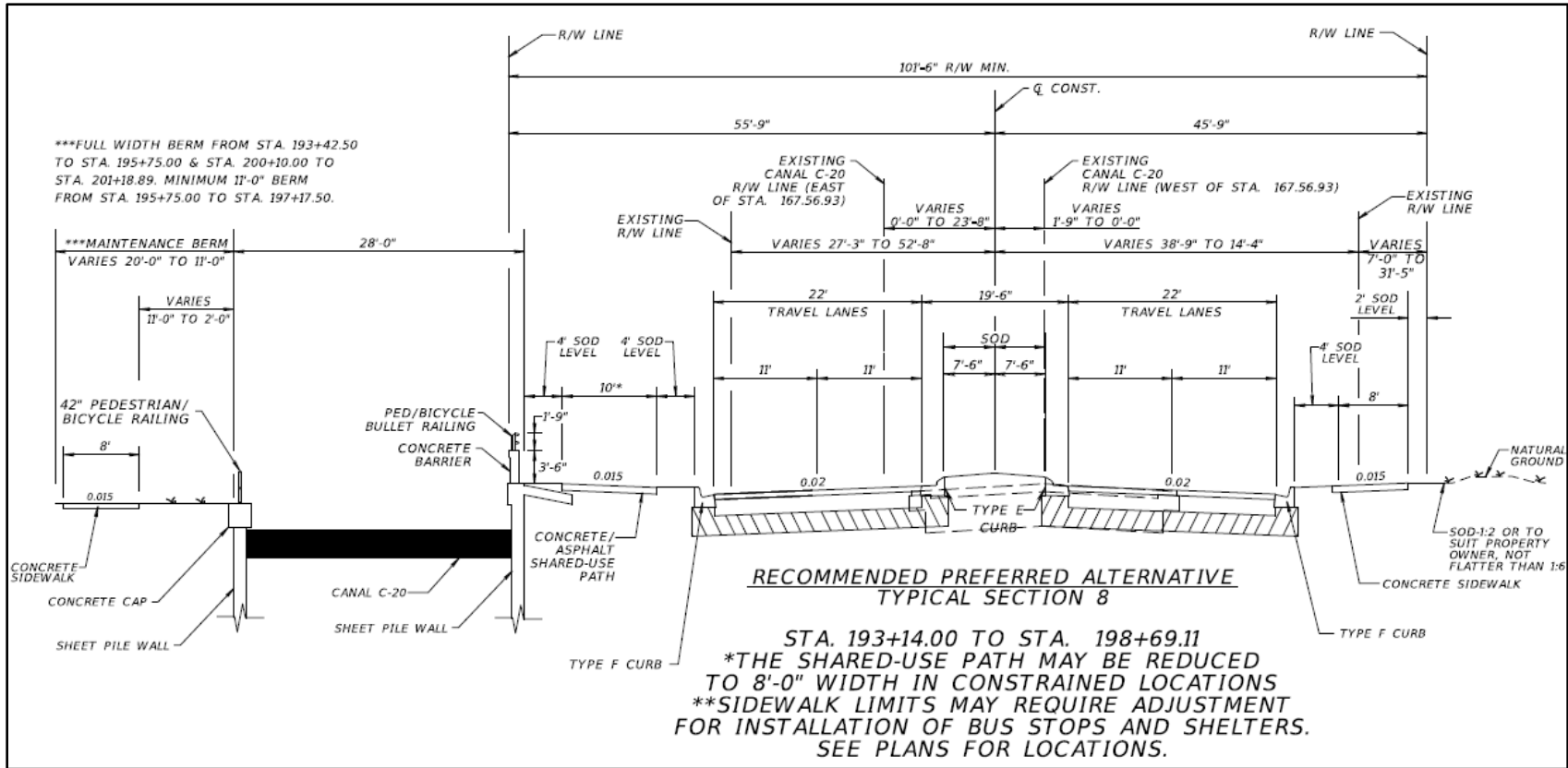
Figure 1-9: Representative Preferred Alternative Typical Section – Canal C-10 to West of Jupiter Boulevard



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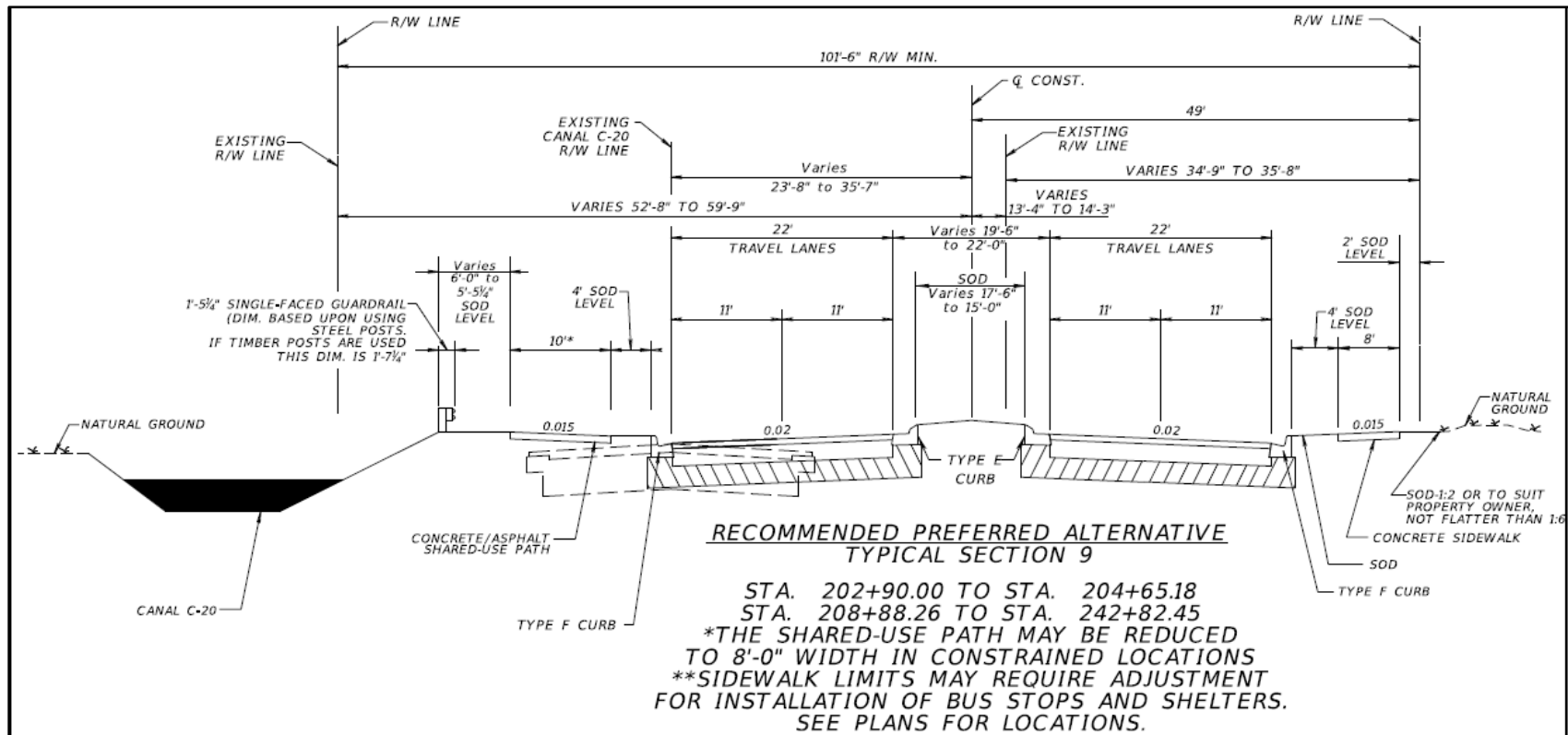
Figure 1-10: Representative Preferred Alternative Typical Section – West of Jupiter Boulevard to East of Jupiter Boulevard



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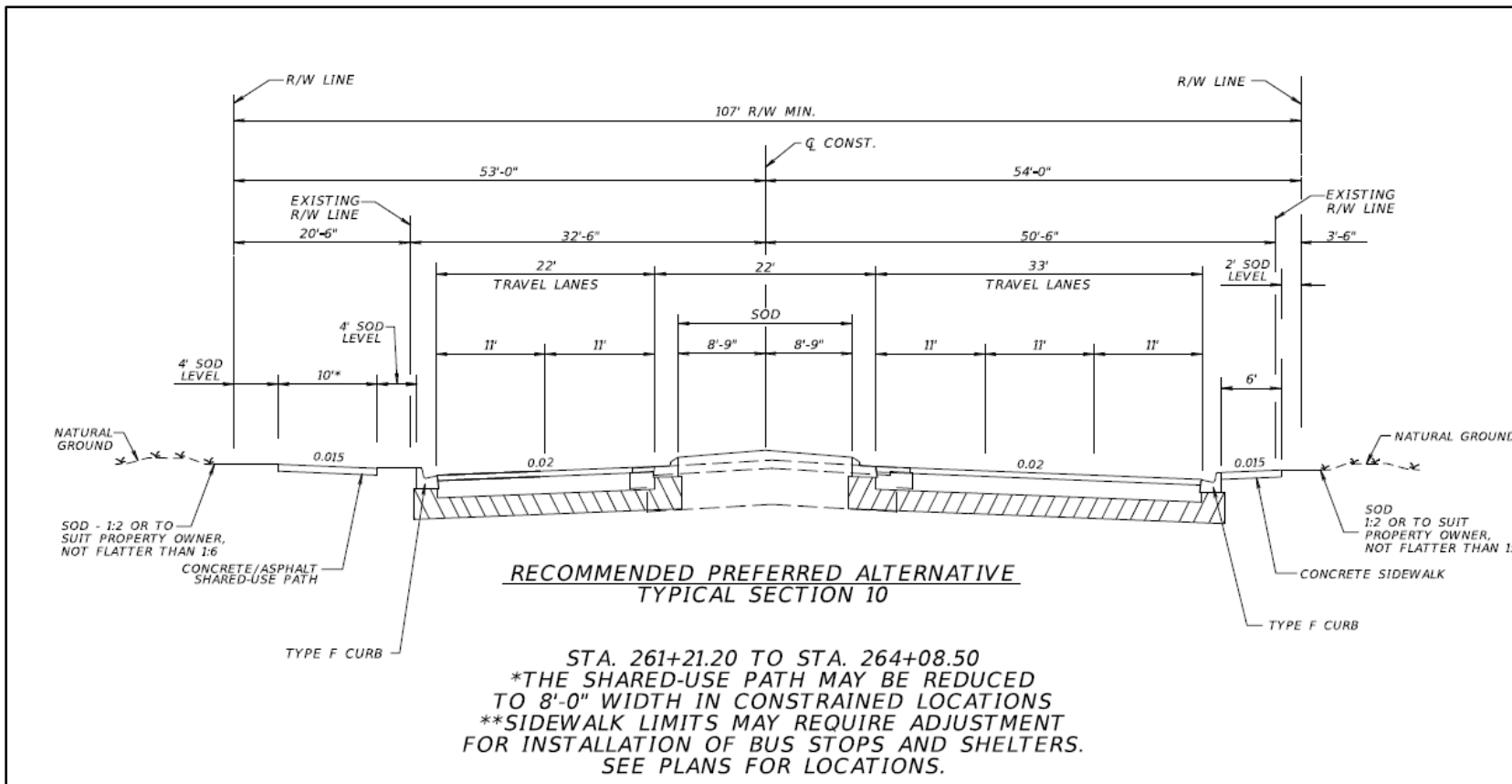
Figure 1-11: Representative Preferred Alternative Typical Section – East of Jupiter Boulevard to Maywood Avenue/Daffodil Drive



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Figure 1-12: Representative Preferred Alternative Typical Section – West of Plaza Shopping Center



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## 1.4.3 Intersections

Based on the intersection alternatives analysis, the following intersection control types are recommended for the preferred alternative:

- Traffic Signals –
  - Malabar Road & Jupiter Boulevard\*;
  - Malabar Road & Garvey Road;
  - Malabar Road & Plaza Shopping Center; and
  - Malabar Road & Minton Road.
- Roundabouts –
  - Malabar Road & St. Johns Heritage Parkway;
  - Malabar Road & Krassner Drive/Bending Branch Lane;
  - Malabar Road & Hurley Boulevard; and
  - Malabar Road & Maywood Avenue/Daffodil Drive.
- Two-Way Stop Control –
  - Malabar Road & Snapdragon Drive;
  - Malabar Road & Championship Circle;
  - Malabar Road & Wisteria Avenue/Abilene Drive;
  - Malabar Road & Bavarian Avenue;
  - Malabar Road & Watoga Avenue/Avery Springs;
  - Malabar Road & Palm Bay Public Works Driveways;
  - Malabar Road & Post Office;
  - Malabar Road & Santa Rosa Avenue;
  - Malabar Road & Madalyn Landing; and
  - Malabar Road & Sutherland Drive.

\* While the intersection of Malabar Road and Jupiter Boulevard would have improved operations and safety as a roundabout, the signal alternative was selected due to constrained right-of-way. The US Post Office in the intersection's southwest corner is federal property and cannot be impacted, shifting the alignment to the north requiring the Canal C-20 to be relocated even as a signalized intersection. The roundabout's larger footprint would require additional Canal C-20 relocation impacting nearby residences.

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## 2.0 Data Collection

The design team collected and reviewed data from the following sources:

- Palm Bay Code of Ordinances Title XVII, Chapter 174.068 – Stormwater Management and Conservation – Design Standards (August 2020)
- Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) Panel Nos. 12009C0590G, 12009C0595G, 12009C0655G, and 12009C0660G, Effective Date 3/17/2014, in Brevard County, Florida.
- United States Geological Survey (USGS) Quadrangle Maps
- United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) Soils Survey of Brevard County, Florida, 2016
- Field Reconnaissance (June 2020)
- Melbourne-Tillman Water Control District (MTWCD) Permitting Policy, February 2021
- City of Palm Bay Basin Maps
- Existing Permit Databases (SJRWMD)
- 1-ft LIDAR Data Source: Florida Division of Emergency Management (FDEM), Brevard County, 2007
- Total Maximum Daily Load (TMDL) for the Indian River Lagoon (March 2009)



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## 3.0 Existing Drainage Conditions

### 3.1 Topography & Hydrologic Features

Topography throughout the project is relatively flat with a very gradual uphill slope from the western end of the corridor to the east. Roadway elevations begin at 19.0 feet and increase to 26.0 feet. All elevations mentioned in this report are in reference to the North American Vertical Datum of 1988 (NAVD) unless otherwise stated. Where information was available only in the National Geodetic Vertical Datum of 1929 (NGVD), it was converted to NAVD using the conversion  $NAVD = NGVD - 1.38$  feet. Please refer to the **USGS Quadrangle Map, Figure 2 in Appendix A**. Malabar Road does not traverse any OFWs. It is within one (1) Waterbody ID (WBID) – 3090 Melbourne-Tillman (C-1) Canal, which is not impaired for nutrients, but is within the established TMDL for nutrients for the Indian River Lagoon. There are ten (10) existing cross drains underneath Malabar Road and one (1) bridge within the project limits. The cross drains and bridge allow for conveyance of offsite and onsite runoff beneath the road toward its historical path, including the conveyance of several canals. The size and geometry of all cross drains and bridges have been estimated from 1-foot LiDAR contours, existing plans, and during field reconnaissance but should be verified during design. Please refer to **Table 3-1 for a Summary of Existing Cross Drains and Bridges**.

**Table 3-1: Summary of Existing Cross Drains and Bridges**

Structure No.	Station	Description	Remarks
CD-1	62+80	Double 96" RCP	C-7
CD-2	89+18	8' x 6' CBC	C-8
CD-3	114+67	18" CMP	
CD-4	115+71	Single 54" RCP	C-9
Bridge	142+00	#704004	C-10
CD-5	155+75	Single 13" x 21" RCP	
CD-6	176+84	Single 14" x 23" RCP	
CD-7	188+40	Single 21" x 28" RCP	
CD-8	224+58	Single 18" x 30" RCP	
CD-9	238+72	Single 19" x 30" RCP	
CD-10	248+33	Single 19" x 30" RCP	

### 3.2 Soils Data and Geotechnical Investigations

The soil survey of Brevard County, Florida (dated 2016) published by the USDA NRCS has been reviewed within the project vicinity. USDA Soil Survey Geographic database (SSURGO) data was also obtained from NRCS to create a soils map for the project limits using GIS ArcMap. The soil survey map for the project vicinity is illustrated in **Figure 3 of Appendix A**.

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**Table 3-2: USDA NRCS Soil Survey Information for Brevard County**

Soil No.	USDA Soil Name	Seasonal High Ground Water		HSG	Soil Classification		
		Depth* (feet)	Duration (months)		Depth (inches)	Unified	AASHTO
2	Anclote Sand, Depressional, 0 to 1 percent slopes	0-1.0	---	A/D	0-19	SP, SP-SM	A-3
					19-72	SP, SP-SM	A-3
11	Canova Mucky Peat	0-1.0	---	B/D	0-13	SP, SP-SM	A-3
					13-57	SC, SM-SC	A-2, A-6
17	EauGallie Sand	0-1.0	---	A/D	0-22	SP, SP-SM	A-3
					22-35	SP-SM, SM	A-2-4, A-3
					35-55	SP, SP-SM	A-3
					55-61	SM, SM-SC, SC	A-2-4
					61-84	SM, SM-SC	A-2-4
18	EauGallie, Winder, and Riviera Soils, Depressional	0-1.0	---	A/D	N/A	N/A	N/A
19	Riviera Sand	0.25-1.5	---	C/D	N/A	N/A	N/A
22	Floridana Sand, Frequently Poned, 0 to 1 percent slopes	0-0.5	---	C/D	0-12	SP-SM	A-3
					12-29	SP-SM, SP	A-3
					29-62	SM-SC, SC	A-2
24	Floridana, Chobee, and Felda Soils, Frequently Flooded	0-1.0	---	B/D	N/A	N/A	N/A
30	Malabar Sand	0-1.0	---	A/D	0-45	SP	A-3
					45-61	SM-SC, SC	A-2-4, A-2-6
					61-65	SP-SM	A-3, A-2-4
31	Malabar, Holopaw, and Pineda Soils	0-1.0	---	A/D	N/A	N/A	N/A
33	Micco Mucky Peat, Frequently Flooded	0-1.0	---	A/D	0-30	PT	Organic
					30-38	SP, SP-SM	A-3
					38-55	SC, SM-SC	A-2, A-6
47	Pineda Sand, 0 to 2 percent slopes	0-1.0	---	C/D	0-19	SP, SP-SM	A-3
					19-35	SP, SP-SM	A-3
					35-38	SP-SM, SM	A-2-4
					38-60	SM, SM-SC, SC	A-2-4
					60-64	SM, SP-SM	A-2-4, A-3
71	Wabasso Sand	0-1.0	---	C/D	0-23	SP, SP-SM	A-3
					23-28	SP-SM	A-2-4, A-3
					28-34	SM, SP-SM	A-2-4, A-3
					34-62	SC, SM-SC	A-2
73	Winder Loamy Sand	0-1.0	---	B/D	0-12	SM	A-2
					12-17	SM	A-2
					17-31	SC, SM-SC	A-2, A-6
					31-47	SC, SM-SC, SM	A-2
					47-65	SC, SM-SC, SM	A-2

\*Seasonal High Ground Water Table: Depth is referenced below existing grade, except where indicated as "+".

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The soils encountered along the project limits are mostly Hydrologic Soil Group (HSG) A/D and C/D. Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sand or gravel and have a high rate of water transmission. Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission. If a soil is assigned to a dual HSG, the first letter is for drained areas and the second is for un-drained areas. Soils are only assigned a dual class if they are group D in their natural condition. According to the Soil Survey, there are 13 different soil types located along the project limits within Brevard County. **Table 3-2: USDA NRCS Soil Survey Information for Brevard County** summarizes and lists the soil types and relevant information. The ground water depth varies from 0' to 5' along the project per the NRCS Soil Survey information.

A preliminary geotechnical investigation was performed by Geotechnical and Environmental Consultants, Inc. (GEC) for the pond site alternatives. A copy of the report is provided in Appendix K of the Pond Siting Report. The geotechnical investigation estimated the seasonal high water depths at each pond site. However, SJRWMD allows controlling stormwater ponds at the average wet seasonal water elevations (AWSWE). Reasonable assumptions are made to set the control elevations of the pond site alternatives that are based on the results of the preliminary geotechnical investigation, existing permitted control elevations of nearby ponds, and NRCS information. A more detailed geotechnical investigation should be supplemented during the design phase for the selected stormwater ponds.

## 3.3 Existing Bridge

The existing bridge over Canal C-10 was constructed in 1972 and consists of five (5) concrete spans, each 27.9 feet in length. Information gathered from the National Bridge Inventory was used to provide some of the parameters as summarized in **Table 3-3**. Per the bridge inspection reports, there is no significant known scour at the bridge. The National Bridge Inventory Data can be found in Appendix F.

**Table 3-3: Existing Bridge Data**

Category	Bridge No. 704004
Year Constructed	1972
Structure Name	Malabar Rd over Canal
Facility Carried	Malabar Road
Approximate Location	2.5 Miles West of CR-509
Owner/Maintenance Agency	County Highway Agency
Crossing/Waterway/ Canal ID	C-10 Canal (MTWCD)
Bridge Length	140.1 ft
Number of Traffic Lanes	2
Number of Spans	5
Structure Type	Pre-Stressed Concrete
Pile Type	Concrete

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Category	Bridge No. 704004
Deck Type	Concrete Precast Panels
Deck Condition	7 - Good
Superstructure Condition	7 - Good
Substructure Condition	7 - Good
Sufficiency Rating	77.6

## 3.4 Environmental Characteristics

### 3.4.1 Land Use Data

The project corridor is predominantly forest and residential for the majority of the project length, with some commercial properties clustered around Jupiter Boulevard and Garvey Road. At Daffodil Drive, the land use transitions to commercial for the remainder of the project limits. Please see **Figure 4** for the **Land Use Map** in **Appendix A**. The widening of Malabar Road does not alter the existing or future land uses in the area.

### 3.4.2 Natural and Biological Features

The proposed project has potential to involve several State and/or Federally listed protected wildlife species. These species and their anticipated involvement are identified in the **Natural Resources Evaluation Report** located in Appendix I of the Pond Siting Report.

The project corridor was evaluated for the presence of potentially occurring protected species. The western most portion of the proposed project corridor occurs within the secondary protection zone (1,500 meters) of two Audubon’s crested caracara nests, the preferred alternative “may affect, but is not likely to adversely affect” the continued existence of the caracara. Due to the lack of suitable habitat or defined conservation measures for the species, the preferred alternative “may affect, but is not likely to adversely affect” the continued existence of the Florida scrub-jay, wood stork, American alligator, eastern indigo snake, gopher tortoise, and federally protected plant species. The project is considered to have “no effect” on the Everglades snail kite, Florida grasshopper sparrow, red-cockaded woodpecker, and bald eagle. Similarly, “no adverse effect is anticipated” for the Florida burrowing owl, Florida pine snake, Florida sandhill crane, southeastern American kestrel, wading birds, state listed plant species, Florida black bear, and southern fox squirrel.

Wetlands and other surface waters with potential to be affected by the proposed project were identified within the study area. A wetland assessment was performed for these wetlands and other surface waters in accordance with the Uniform Mitigation Assessment Method (UMAM) as described in Chapter 62-345, FAC to determine the functional value provided by the wetlands and other surface waters. Other surface waters classified as upland cut ditches and permitted reservoirs were included in the assessment; however, mitigation will not be required for impacts to these other surface waters. Based on the wetland assessment, no direct wetland impacts are associated with the preferred alternative; however, approximately 2.20 acres of direct impacts to other surface waters are associated with the preferred alternative. Direct impacts of 0.61 acres to wetlands and 0.04 acres to other surface waters are associated with the preferred floodplain compensation site. Direct impacts to wetlands of 0.28 acres are associated with the preferred pond alternatives.

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## 3.5 Floodplains/Floodways

According to the Federal Emergency Management Agency (FEMA), the relevant Flood Insurance Rate Map (FIRM) panel numbers are 12009C0590G, 12009C0595G, 12009C0655G, and 12009C0660G, dated 3/17/2014.

According to the FEMA FIRMs, portions of the project intersect Zone AE of the 100-year floodplain at the western end of the project limits. These areas are associated with the Three Forks Conservation Area and C-8 Canal and have a 1% probability of flooding every year. The established flood water elevation is 20.0 feet NAVD. There are no federally regulated floodways within the project limits. Please refer to **Appendix A – Figure 5** for the **FEMA Floodplains Map**.

The MTWCD has a watershed model that includes the canals along the project. Additionally, a Stormwater Management Model (SWMM) was developed for Canal C-1 by SJRWMD and the MTWCD. This model includes data for Canals C-7 and C-8 which outfall directly to Canal C-1. Results of this model were also utilized for data collection.

General comments relating to floodplains include the fact that any development within the 100-year floodplain has the potential for placing citizens and property at risk of flooding and producing changes in floodplain elevations and plan view extent. Development (such as roadways, housing developments, strip malls and other commercial facilities) within floodplains increases the potential for flooding by limiting flood storage capacity and exposing people and property to flood hazards. Development also reduces vegetated buffers that protect water quality and destroys important habitats for fish and wildlife. The area surrounding the proposed roadway widening project has and will continue to experience growth.

Any floodplain impacts will be mitigated for in an offsite floodplain compensation site on a cup for cup basis. From the available data, one (1) Floodplain Impact Area (FIA) has been determined based on areas in which the 100-year floodplain lies within the proposed right-of-way. **Figure 3-1** illustrates the location of the FIA. The FIA is approximately 3400 feet long and is located in a Zone AE floodplain with BFE 20.0 feet. The estimated floodplain impact volume is 1.41 ac-ft for the proposed roadway improvements. Additionally, the recommended preferred pond, C-7 Alt. 3, has an estimated floodplain impact of 0.50 ac-ft. The total floodplain impacts are anticipated to be 1.91 ac-ft.

Floodplain impacts were quantified by identifying areas in which the floodplain will potentially be impacted by proposed roadway fill. These areas were multiplied by an estimated average depth of impact to calculate an impact volume. In most areas, this depth was estimated to be 0.25 feet between the average ground elevation contours and the floodplain elevation of 20.00 feet. In canals, the depth was estimated to be 2.00 feet between the normal water level and floodplain elevation of 20.00 feet. For the C-7 Alt. 3 pond berm, the area of the berm between the existing ground elevation (18.00) and floodplain elevation was estimated to be 0.50 acres with an average depth of impact of 1.00 feet.

For the purpose of this study, a cup for cup approach was taken to provide the City of Palm Bay with right-of-way estimates for offsite floodplain compensation area (FPCA) sites for funding projections. Compensation volumes were calculated to be the available volume between the Seasonal High Water Table (SHWT) of the proposed compensation site and the 100-year flood elevation of the FIA. Initially, one (1) Floodplain Compensation Area (FPCA) site was identified. However, recent coordination with the City of Palm Bay has

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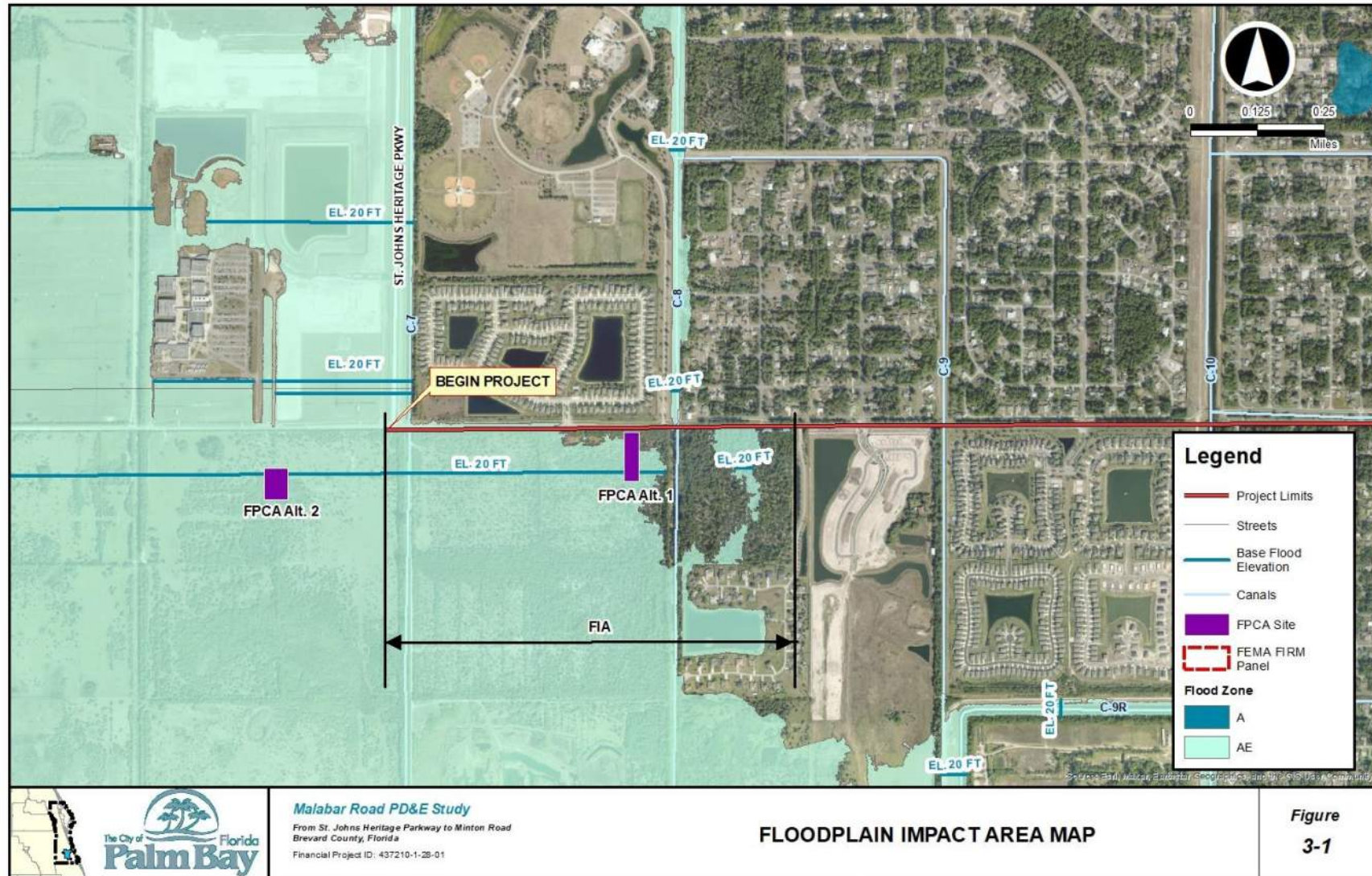
indicated that the site selected for Alt. 1 is planned for new development. It was requested that a second alternative be investigated west of the C-7 Canal utilizing a property already owned by the City (FPCA Alt. 2). The recommended preferred Floodplain Compensation Area (FPCA) site (Alt. 2) is shown in **Figure 3-1** and provides 1.91 ac-ft of compensation volume. Refer to the Pond Siting Report prepared for the study for further information. During the design phase, it is recommended that alternative approaches to traditional FPCAs be considered. Alternative approaches include creating a floodplain model or modifying the existing SJRWMD SWMM model with the proposed improvements to demonstrate no increase in the 100-year floodplain elevations or providing floodplain compensation within the stormwater management ponds.



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Figure 3-1: Floodplain Impact Area Map (FIA)



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## 3.5.1 Flooding History and Maintenance Concern

Discussions were held with Palm Bay, MTWCD, and SJRWMD regarding drainage issues along the project corridor. Mike McCabe from MTWCD indicated that flooding occurs around Belvedere Road during large storm events, where Canal C-20 overtops into nearby streets and yards. These areas are not located within an established FEMA Floodzone. A review of the MTWCD data indicates that two of the downstream culverts (located at the entrances to the Hoyle property and Davis property) are undersized relative to the upstream culverts, which is likely contributing to the overtopping. We recommend replacement of the undersized culverts to alleviate some of the flooding concern. The culvert sizes in this vicinity can be seen in **Figure 3-2** below. Additionally, cross drain analysis indicates that several of the cross drains in this area overtop during a 25-year or higher storm. It is recommended that these be upsized.

Figure 3-2: Flooding History



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## 4.0 Proposed Drainage Conditions

The stormwater runoff from the project limits will be collected and conveyed via curb and gutter to the preferred pond alternative for each basin. The various pond alternatives consist of dry retention ponds, wet detention ponds, and dry linear swales. The ponds will discharge at or near the same cross drains that carry the roadway runoff in the existing condition, or directly into canals where appropriate. The proposed ponds have been sized to achieve the required water quality treatment and water quantity attenuation and serve as a budget tool for right-of-way estimation for the project to the City of Palm Bay. Please refer to the Pond Siting Report prepared for this study for more information.

A preliminary analysis of the cross drains has been performed to determine whether the existing cross drains can be extended or would require a replacement. Replacement may be required due to an increase in headwater elevations caused by extension of the pipe, the need to relocate the pipe due to the proposed roadway configuration, or existing damage to the cross drain that necessitates replacement. Please note that the hydraulic analysis is based on providing adequate conveyance capacity. Any culverts with velocities exceeding 5 feet per second (fps) will require installation of splash pads on adjacent and opposite slopes to prevent scour per MTWCD requirements. **Table 4-1** below provides a **Summary of Cross Drains**. The locations of the cross drains can be seen in the basin maps in **Appendix B**.

**Table 4-1: Summary of Cross Drains**

Structure No.	Station	Existing Condition				Proposed Condition				Remarks
		# of Barrels	Size	Type	Length (ft)	# of Barrels	Size	Type	Length (ft)	
CD-1	62+80	2	96"	RCP	140	2	96"	RCP	194	Extend
CD-2	89+18	1	8' x 6'	CBC	45	1	8' x 6'	RCP	102	Extend
CD-3	114+67	1	18"	CMP	44	Remove or Plug*				
CD-4	115+71	1	54"	RCP	44	1	54"	RCP	102	Extend
CD-5	155+75	1	13" x 21"	ERCP	78	1	14" X 23"	ERCP	190	Replace
CD-6	176+84	1	14" X 23"	ERCP	62	1	14" X 23"	ERCP	117	Extend
CD-7	188+40	1	21" X 28"	ERCP	60	1	19" X 30"	ERCP	85	Extend
CD-8	224+58	1	18" X 30"	ERCP	78	1	29" X 45"	ERCP	124	Upsize
CD-9	238+72	1	19" X 30"	ERCP	94	1	24" X 38"	ERCP	126	Upsize
CD-10	248+33	1	19" X 30"	ERCP	73	1	24" X 38"	ERCP	144	Upsize

\*In the current condition, CD-3 only collects runoff from a small portion of Malabar Road. Previously, it collected runoff from a large section of agricultural land, but these parcels have been redeveloped into the Chapparral subdivision with its own stormwater detention system and therefore this area no longer produces significant runoff. CD-3 is therefore defunct and the runoff from Malabar Road will be directed to the closed drainage system that is constructed as part of the widening.

The hydrologic analyses for the existing and proposed cross drains were based on the Velocity Method for a 50-year, 100-year, and 500-year storm frequencies using a maximum full-flow velocity of 5 fps per MTWCD requirements. Recommended pipe sizes are based on certain assumptions for the hydraulic analyses such as roadway crest elevation and tailwater conditions. These assumptions were derived from the best available information at the time. Where available, the MTWCD ICPR and SJRWMD SWMM models were used to determine tailwater elevations, pipe inverts, and discharge. Cross drain sizes and inverts were taken from the

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best available existing plans and verified during field reconnaissance. During the design phase, more accurate information regarding the tailwater conditions and roadway profile will be available to the designer. The cross drains were analyzed using the Federal Highway Administration HY-8 (v. 7.60) cross drain modeling software. For more information regarding the Cross Drain Analysis please refer to **Appendix D**.

In addition to the analysis for cross drains, a preliminary hydraulic analysis was performed for the proposed side drain culverts that would enclose Canal C-20 at various locations from its outfall at Canal C-10 to Jupiter Boulevard. Canal C-20 will be crossed or impacted in several locations due to new or modified neighborhood access, roundabouts, and u-turn bulbs. Additionally, a segment of the canal is proposed to be relocated from approximately station 179+77 to 202+90 which will require relocation of two existing culverts. The following locations were analyzed: new side street crossing at Hoffer Avenue, roundabout at Hurley Avenue, new side street crossing at Hillcrest Avenue, u-turn bulb at Public Works Department entrance, existing culvert at Methodist Church entrance (across from United States Post Office), and existing culvert at Jupiter Boulevard. Per the MTWCD Permitting Policy, only single barrel culverts, box culverts, or bridges are permitted within canals. Based on the flows and a recently permitted and installed 8' x 6' CBC at the Avery Springs Subdivision entrance (SJRWMD Permit No. 149645-2), it was determined that an 8' x 6' CBC would be recommended at each of these locations. Modeling was performed in HY-8 (v. 7.60) for each of the locations with discharge, invert elevations, and tailwater data collected from the MTWCD ICPR model. The locations of the culverts can be seen in the basin maps in **Appendix B**. For more information regarding this analysis, please refer to **Appendix D**.

## 4.1 Longitudinal & Transverse Floodplain Impacts

The project will impact the 100-year floodplain in two (2) different ways;

- 1) Longitudinal impacts resulting from filling the floodplain areas associated with proposed roadway widening within the project limits, isolated wetlands, wetland systems, and depressional areas.
- 2) Transverse impacts resulting from the extension and replacement of the existing cross drain culverts.

The longitudinal impacts cannot be avoided since the floodplains extend both north and south of Malabar Road within the study limits. The floodplain impact area was quantified based on the FEMA FIRMs and established 100-year base flood elevation, and the existing ground elevations were established from 1-foot LIDAR contours. To be conservative, it was assumed that any fill from the proposed roadway outside of the existing roadway was quantified as floodplain impacts.

The transverse impacts resulting from the extension or replacement of the culverts have not been analyzed in this report. To minimize upstream impacts, FDOT design criteria for conveyance systems (e.g. culverts) allow no significant rise in flood stages at the upstream end of the structures. During design, efforts should be made to show that proposed base headwater elevations will not surpass 0.1 feet of rise from the existing condition, and every necessary action should be taken to minimize upstream impacts. A preliminary hydraulic analysis of the cross drains has been performed as part of this study and included in this report.

A Bridge Hydraulics Report (BHR) will be required during the design phase to evaluate the hydraulic impacts to Canal C-10 associated with the bridge improvements. Preliminary proposed bridge information, such as proposed length, width, number of spans, and vertical clearance, is discussed in the *Preliminary Engineering*

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Report prepared for this study. A scour evaluation should also be performed as part of the Bridge Hydraulics Report for the proposed bridge. Potential bridge scour considerations include the long-term aggradation and degradation of the channel, contraction scour at the bridge and local scour at the piers and abutments. Minimum vertical clearance required between the design flood stage (50-year storm) and the low member of the bridge is 2 feet. This clearance is necessary to allow the majority of debris to pass without causing damage to the structure. In addition, a minimum vertical clearance of 12 feet above the Mean High Water (MHW) is required for concrete superstructures classified as moderately aggressive due to chloride content. A minimum of 10 feet of horizontal clearance is required for crossings subject to boat traffic or consistent with debris conveyance needs and structure economy where no boat traffic is anticipated. Further, the BHR should include clearance requirements for MTWCD equipment and boat traffic during normal water elevation conditions.

## 4.2 Project Classification

The floodplain is located in a low density, non-urbanized area, and the encroachment area is classified as “minimal”. Minimal encroachments on a floodplain occur when there is a floodplain involvement, but the impacts on human life, transportation facilities, and natural and beneficial floodplain values are not significant and can be resolved with minimal efforts. Normally, these minimal efforts to address the impacts will consist of applying the Department’s and the City’s drainage design standards and following the Water Management District’s procedures to achieve results that will not increase or significantly change the flood elevations and/or limits.

## 4.3 Risk Evaluation

There is no change in flood “risk” associated with this project. The encroachments will not have a significant potential for interruption or termination of transportation facilities needed for emergency vehicles or used as an evacuation route. In addition, no significant adverse impacts on natural and beneficial floodplain values are anticipated and no significant impacts to highway users are expected.

## 4.4 PD&E Manual Requirements with Minimal Encroachment

Chapter 13 Floodplains of the FDOT’s PD&E Manual, Part 2, defines four categories of encroachments as they pertain to base floodplain involvement; significant, minimal, none and no involvement, and also lists the report criteria corresponding to these encroachment categories. The FDOT has different requirements based on the category of encroachment. The proposed Malabar Road widening project was determined to have minimal encroachments and as a result, the requirements for this category are listed as follows:

- a) **General description of the project including location, length, existing and proposed typical sections, drainage basins, and cross drains.**

*See Sections 1.0 through 4.2 of this LHR for general project information and the Pond Siting Report for drainage basin descriptions.*

- b) **Determination of whether the proposed action is in the base floodplain.**

*It has been determined that improvements associated with the widening of Malabar Road will encroach on the Zone AE 100-year floodplain as established by the most recent FEMA maps dated 3/17/2014.*



# Malabar Road PD&E Study

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- c) The history of flooding of the existing facilities and/or measures to minimize any impacts due to the proposed project improvements.**

*According to local agencies, Malabar Road has experienced minor flooding during major storm events, particularly around Belvedere Road and Canal C-20. A review of the MTWCD data indicated that some of the culverts within this area are constricting flow, and it is recommended that these be reviewed during design for resizing. A Floodplain Compensation area will be constructed to mitigate loss of storage in the floodplain at the beginning of the corridor due to the project improvements. In addition, stormwater treatment areas are proposed to attenuate runoff. The project will have no adverse impact on the existing condition.*

- d) Determination of whether the encroachment is longitudinal or transverse, and if it is a longitudinal encroachment an evaluation and discussion of practicable avoidance alternatives.**

*With the increase in the number of travel lanes proposed, there will be longitudinal and transverse impacts to the floodplain. Longitudinal impacts will be minimized by utilizing the maximum allowable roadway embankment slope.*

*The transverse floodplain impacts from the project occur due to the lengthening of the existing cross drains. The impacts at these locations are not analyzed during this study and will need to be addressed during the design phase. A preliminary hydraulic analysis for the longer cross drains has been performed for this study and included in this report.*

*The existing roadway bisects the floodplain. There are no economically feasible avoidance alternatives.*

- e) The practicability of avoidance alternatives and/or measures to minimize impacts.**

*The project will take every effort to minimize floodplain impacts resulting from the roadway fill. The maximum allowable roadway embankment slope will be used within the floodplain area to minimize the floodplain impacts.*

- f) Impact of the project on emergency services and evacuation.**

*The proposed cross drains and bridge will perform hydraulically in a manner equal to or greater than the existing condition, and backwater elevations are not expected to increase. As a result, there will be no significant change in flood risk, and there will not be a significant change in the potential for interruption or termination of emergency service or in emergency evacuation routes.*

- g) Impacts of the project on the base flood, likelihood of flood risk, overtopping, location of overtopping, backwater.**

*The proposed cross drains and bridge will perform hydraulically in a manner equal to or greater than the existing condition. As a result, there will be no significant change in flood risk or overtopping.*

# Malabar Road PD&E Study

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- h) Determination of the impact of the proposed improvements on regulatory floodways, if any, and documentation of coordination with FEMA and local agencies to determine the project's consistency with the regulatory floodway.**

*There is no involvement with regulatory floodways on this project.*

- i) The impacts on natural and beneficial floodplain values, and measures to restore and preserve these values (this information may also be addressed as part of the wetland impact evaluation and recommendations).**

*Addressed as part of the Natural Resource Evaluation Report.*

- j) Consistency of the project with the local floodplain development plan or the land use elements in the Comprehensive Plan, and the potential impacts of encouraging development within the 100-year base floodplain.**

*The project will remain consistent with local floodplain development plans. The project will not support base floodplain development that is incompatible with existing floodplain management programs.*

- k) Measures to minimize floodplain impacts associated with the project, and measures to restore and preserve the natural and beneficial floodplain values impacted by the project.**

*The project will take every effort to minimize floodplain impacts resulting from the roadway fill. The maximum allowable roadway embankment slope will be used within the floodplain area to minimize the floodplain impacts and floodplain compensation will be provided as needed.*

- l) A map showing project, location and impacted floodplains. Copies of applicable maps should be included in the appendix.**

*See Figure 5 in **Appendix A** and Figure 3-1.*

- m) Results of any and all project risk assessments performed.**

*The proposed cross drains and bridge will perform hydraulically in a manner equal to or greater than the existing condition. As a result, there will be no significant change in flood risk.*

# Malabar Road PD&E Study

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## 5.0 Conclusion and Recommendations

The modification to the drainage structures included in the project will result in an insignificant change in their capacity to carry floodwater. This change will cause minimal increases in flood heights and flood limits. An alternative encroachment location is not considered in this category as it defeats the project purpose or is economically unfeasible. The proposed structures should be hydraulically equivalent to or greater than the existing structures, and backwater surface elevations are not expected to increase. As a result, the project will not affect existing flood heights or floodplain limits. This project will not result in any new or increased adverse environmental impacts. There will be no significant change in the potential for interruption or termination of emergency service or emergency evacuation routes. Therefore, it has been determined that these encroachments are not significant.

Although a floodplain compensation site has been conservatively sized for floodplain impact compensation for this project, it is recommended that additional alternatives be considered involving a modeling approach or use of stormwater treatment ponds to provide floodplain compensation. These alternatives should be further evaluated during the design phase.

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# Malabar Road PD&E Study

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## ***APPENDIX A***

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**Exhibits**

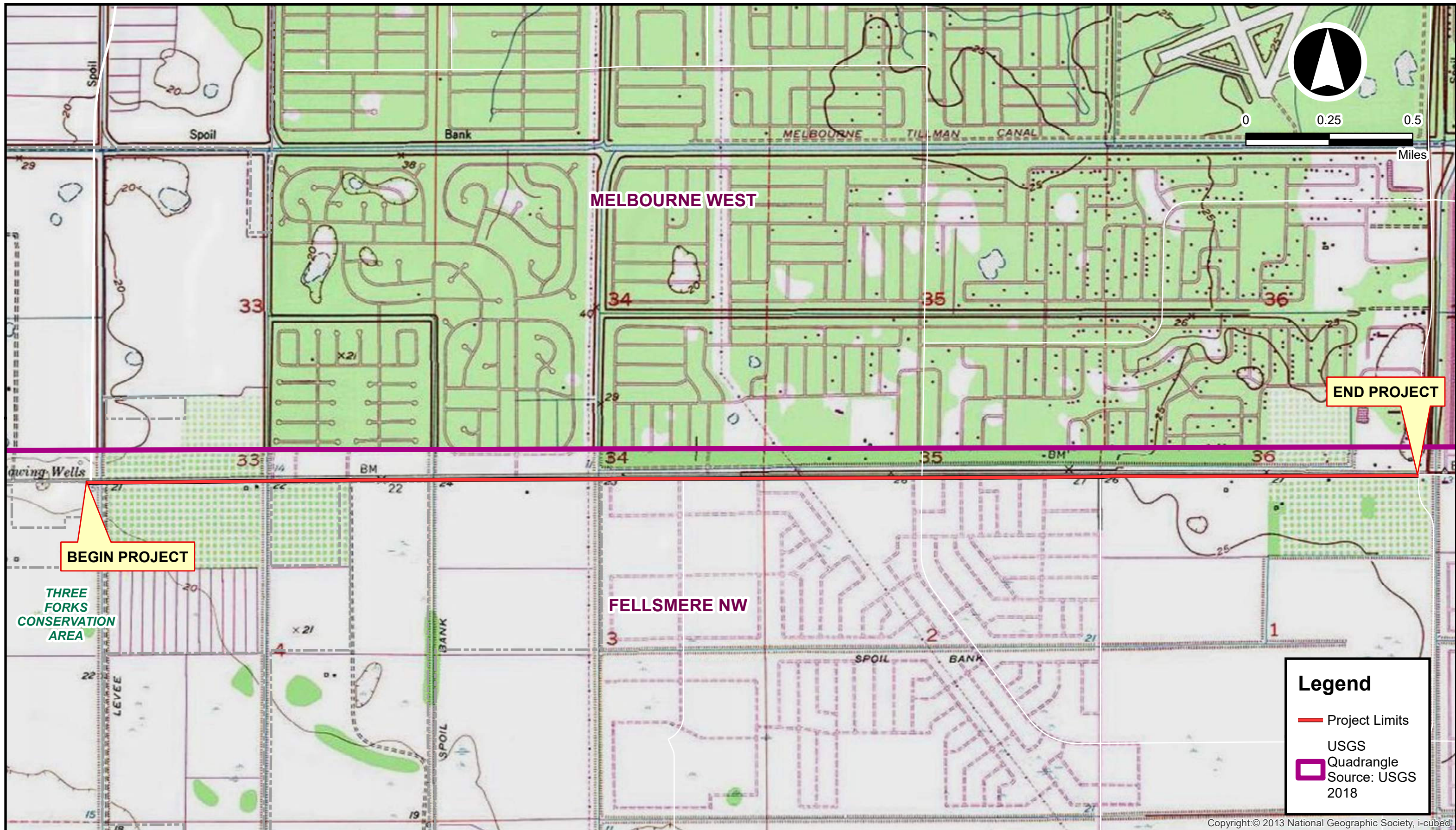
# Malabar Road PD&E Study

FM No. 437210-1-28-01

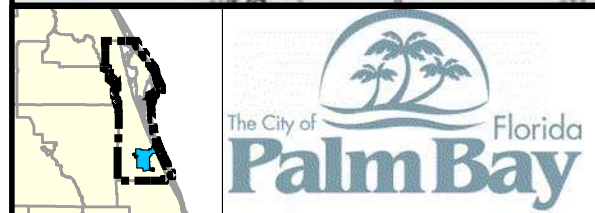
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**Malabar Road PD&E Study**  
 From St. Johns Heritage Parkway to Minton Road  
 Brevard County, Florida  
 Financial Project ID: 437210-1

**USGS QUADRANGLE MAP**

**Figure**  
**2**



# Brevard County Soil Descriptions

2: Anclote sand, depressional, 0 to 1 percent slopes

11: Canova mucky peat, undrained

17: EauGallie sand

18: EauGallie, Winder, and Riviera soils, depressional

19: Riviera sand, 0 to 2 percent slopes

22: Floridana sand, frequently ponded, 0 to 1 percent slopes

24: Floridana, Chobee, and Felda soils, frequently flooded

30: Malabar sand

31: Malabar, Holopaw, and Pineda soils

33: Micco mucky peat, frequently flooded

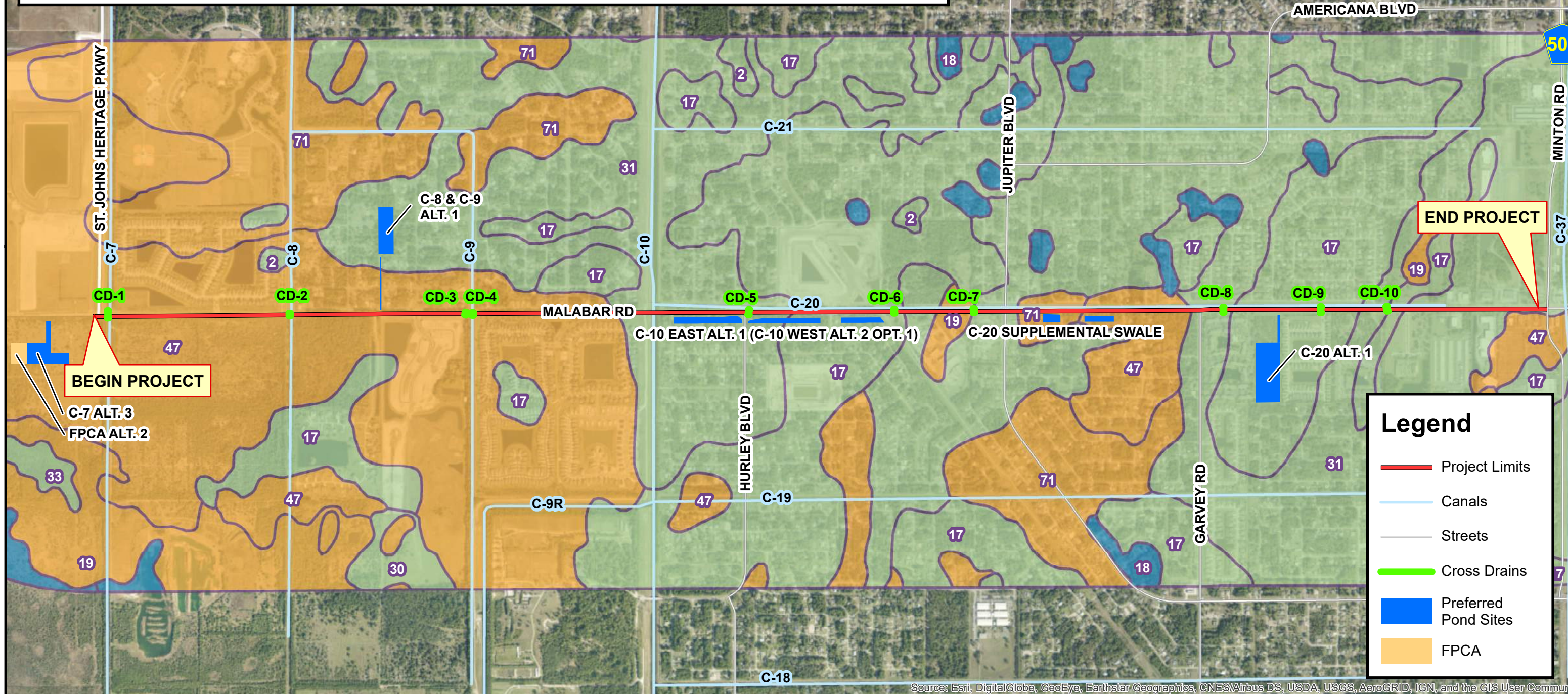
47: Pineda sand, 0 to 2 percent slopes

71: Wabasso sand

73: Winder loamy sand

## Soil Group

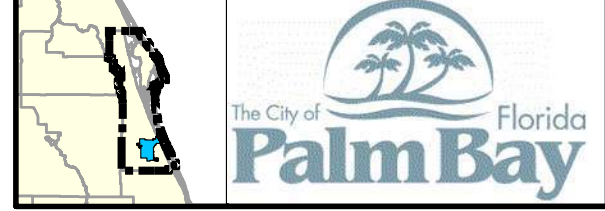
- A/D
- B/D
- C/D



### Legend

- Project Limits
- Canals
- Streets
- Cross Drains
- Preferred Pond Sites
- FPCA

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



**Malabar Road PD&E Study**  
 From St. Johns Heritage Parkway to Minton Road  
 Brevard County, Florida  
 Financial Project ID: 437210-1-28-01

## NRCS SOILS MAP

**Figure 3**



# Brevard County Land Use

## URBAN AND BUILT UP

- 1100: Residential, low density - less than 2 dwelling units/acre
- 1200: Medium density residential - 2-5 units/acre
- 1300: Residential, high density - 6 units/acre
- 1400: Commercial and services
- 1700: Institutional

## AGRICULTURE

- 1890: Other recreation
- 1900: Open land
- 1920: Inactive land with street patterns, no structures
- 2110: Improved pastures
- 2120: Unimproved pastures
- 2130: Woodland pastures

## UPLAND NONFORESTED

- 2150: Field crops
- 2430: Ornamentals
- 2600: Other open lands - rural
- 3100: Herbaceous upland (non-forested)
- 3200: Shrub and brushland
- 3300: Mixed upland (non-forested)

## UPLAND FORESTS

- 4110: Pine flatwoods
- 4200: Upland hardwood
- 4340: Upland mixed coniferous/hardwood

## WATER

- 5100: Streams and waterways
- 5300: Reservoirs - pits, ponds, dammed systems

## WETLANDS

- 6182: Cabbage palm savannah
- 6410: Freshwater marsh
- 6430: Wet prairies
- 6460: Mixed scrub-shrub wetland

## BARREN LAND

- 7430: Spoil areas

## TRANSPORTATION, COMMUNICATIONS, AND UTILITIES

- 8140: Roads
- 8200: Communications
- 8320: Electrical power transmission lines
- 8370: Surface water collection basins



0 0.25 0.5 Miles

AMERICANA BLVD

509

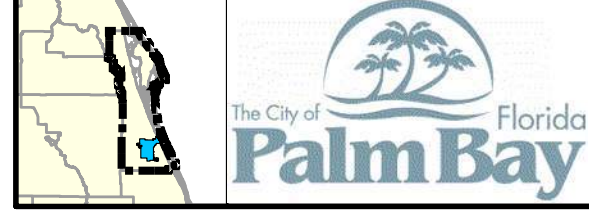
END PROJECT

BEGIN PROJECT

### Legend

- Project Limits
- Canals
- Streets
- Cross Drains
- Preferred Pond Sites
- FPCA

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

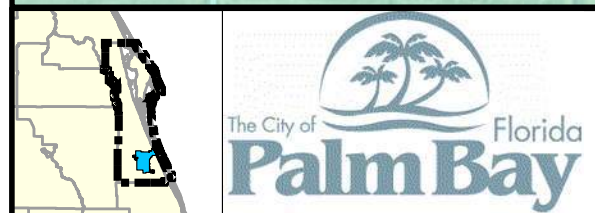
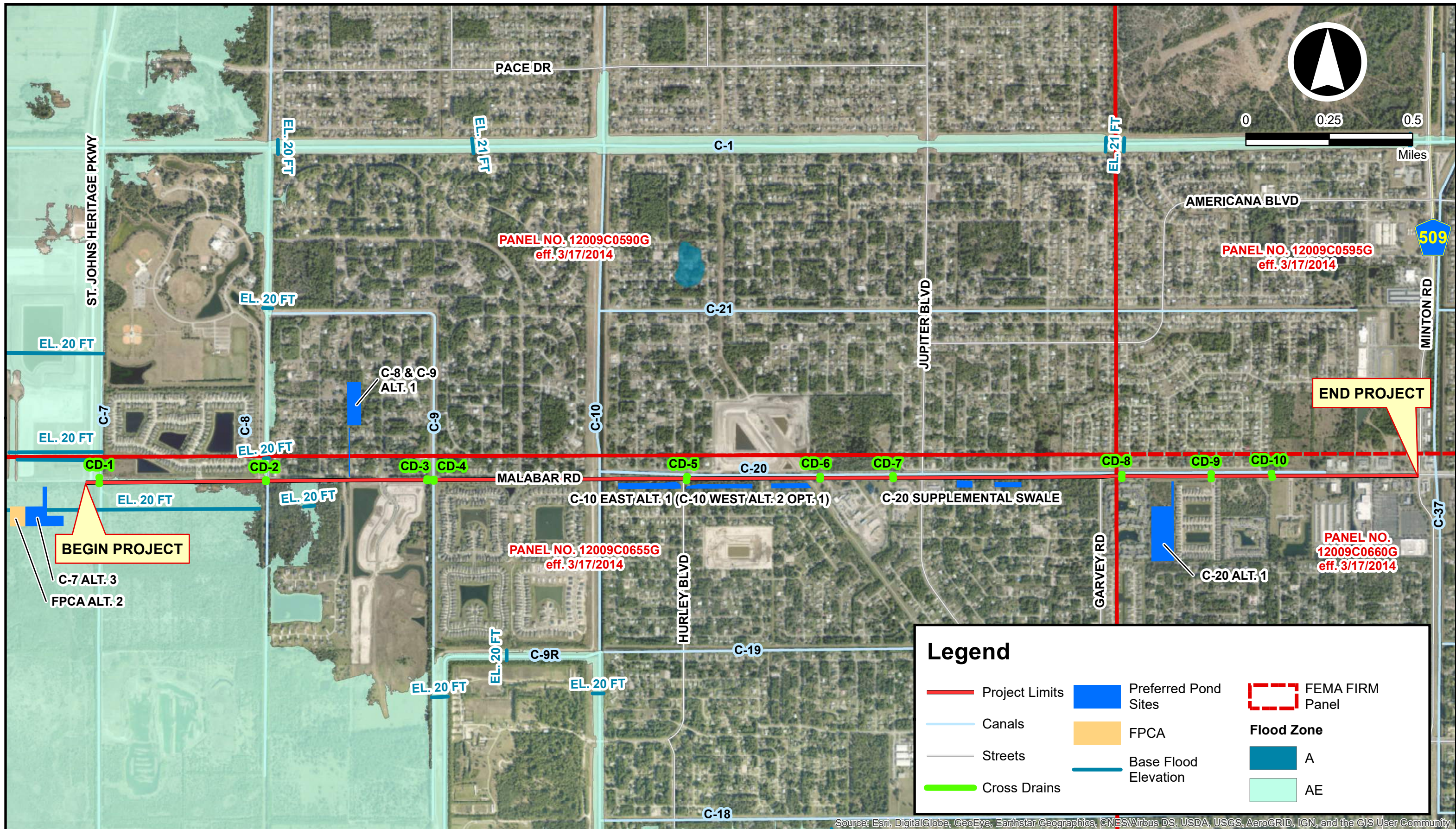


**Malabar Road PD&E Study**  
 From St. Johns Heritage Parkway to Minton Road  
 Brevard County, Florida  
 Financial Project ID: 437210-1-28-01

## LAND USE MAP

Figure  
4





**Malabar Road PD&E Study**  
 From St. Johns Heritage Parkway to Minton Road  
 Brevard County, Florida  
 Financial Project ID: 437210-1-28-01

**FEMA FLOODPLAINS MAP**

**Figure 5**



**Malabar Road PD&E Study**

FM No. 437210-1-28-01

***APPENDIX B***

---

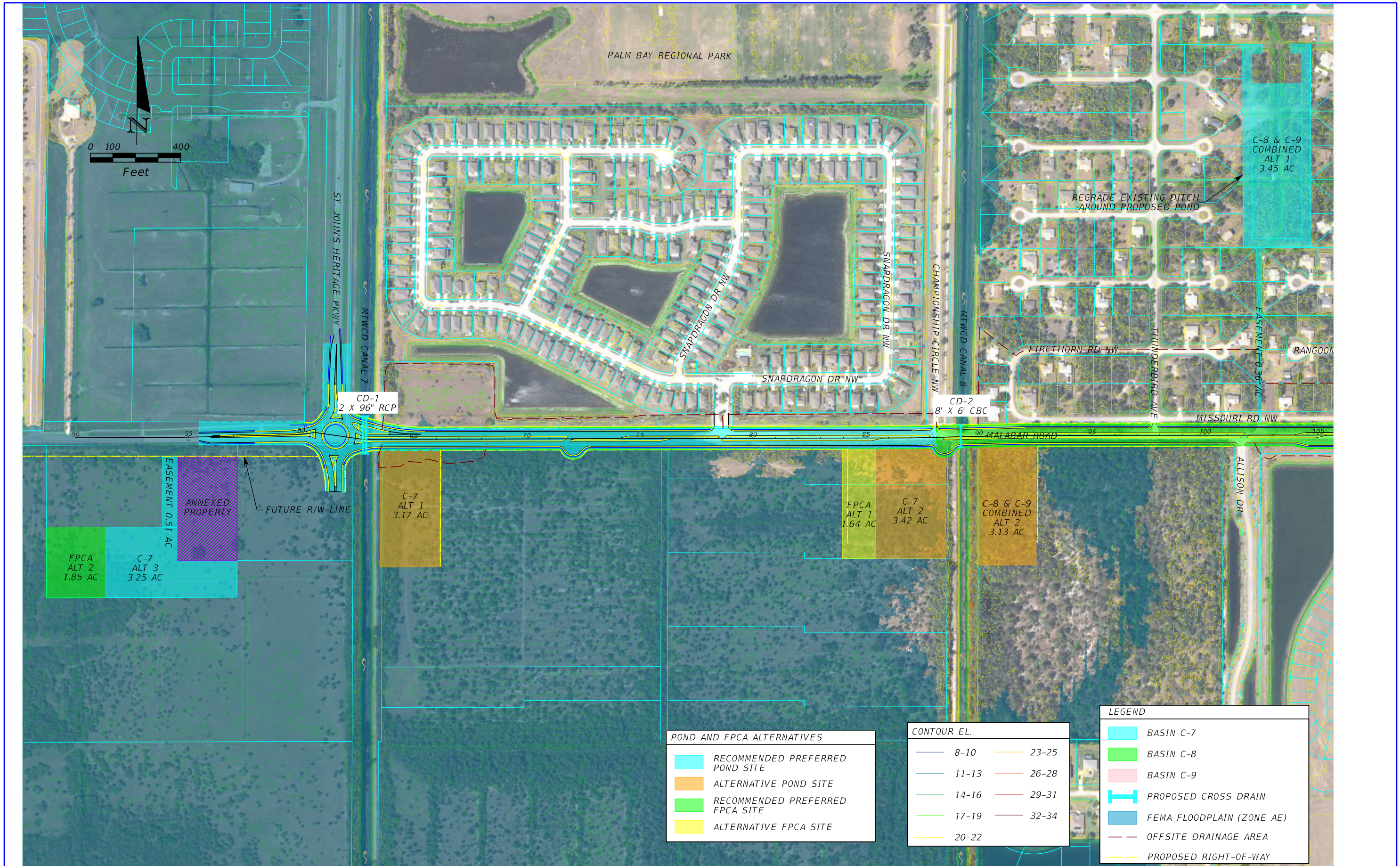
**Basin Maps**

# Malabar Road PD&E Study

FM No. 437210-1-28-01

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POND AND FPCA ALTERNATIVES	
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<span style="color: orange;">■</span>	ALTERNATIVE POND SITE
<span style="color: green;">■</span>	RECOMMENDED PREFERRED FPCA SITE
<span style="color: yellow;">■</span>	ALTERNATIVE FPCA SITE

CONTOUR EL.	
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<span style="color: blue;">—</span>	11-13
<span style="color: green;">—</span>	14-16
<span style="color: green;">—</span>	17-19
<span style="color: yellow;">—</span>	20-22
<span style="color: orange;">—</span>	23-25
<span style="color: red;">—</span>	26-28
<span style="color: red;">—</span>	29-31
<span style="color: brown;">—</span>	32-34

LEGEND	
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<span style="color: green;">■</span>	BASIN C-8
<span style="color: pink;">■</span>	BASIN C-9
<span style="color: cyan;">—</span>	PROPOSED CROSS DRAIN
<span style="color: blue;">—</span>	FEMA FLOODPLAIN (ZONE AE)
<span style="color: red;">—</span>	OFFSITE DRAINAGE AREA
<span style="color: yellow;">—</span>	PROPOSED RIGHT-OF-WAY

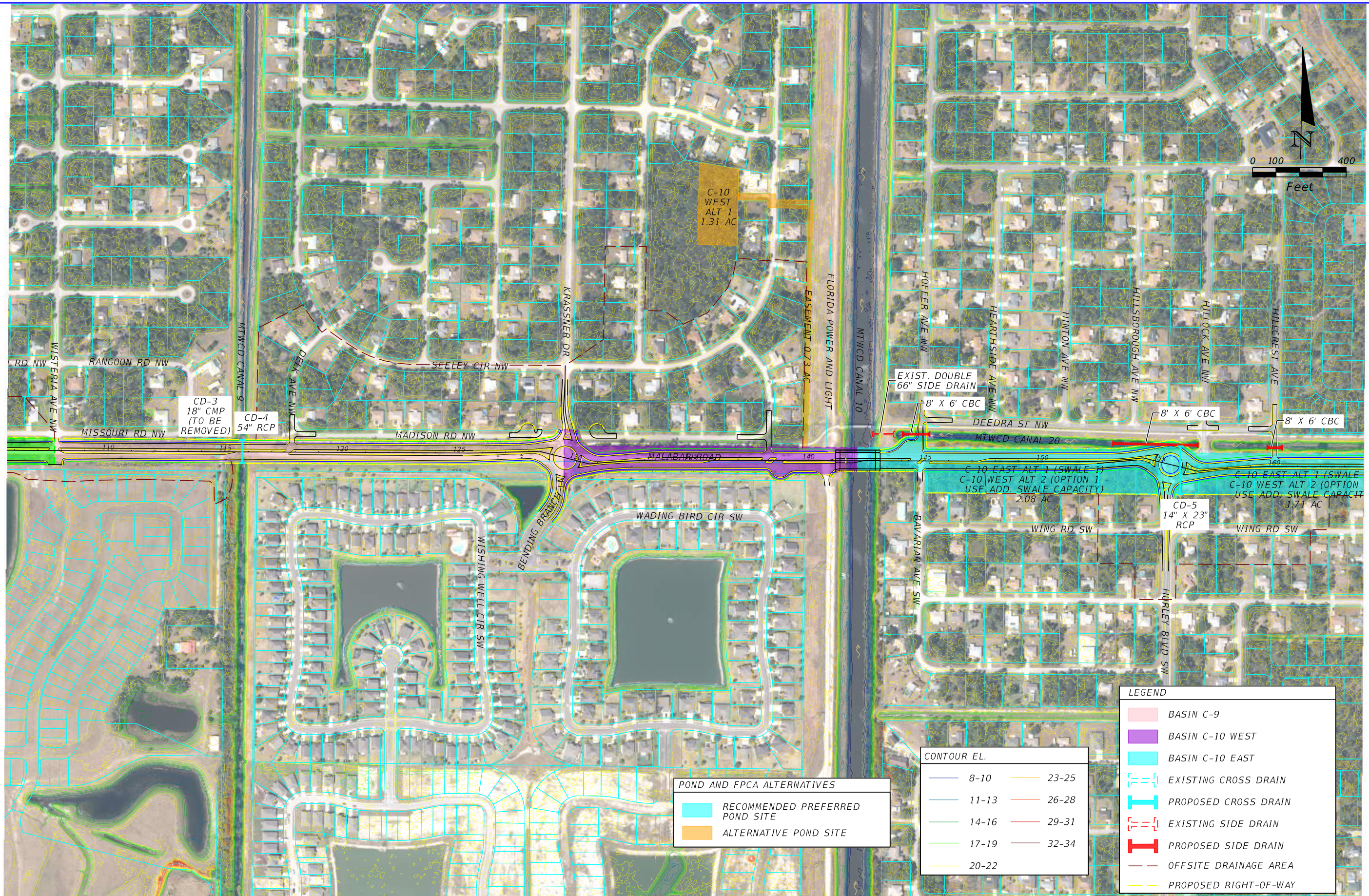
REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION		
ROAD NO.	COUNTY	FINANCIAL PROJECT ID

# BASIN MAPS

SHEET NO. 1





**POND AND FPCA ALTERNATIVES**

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--	---

**CONTOUR EL.**

8-10	23-25
11-13	26-28
14-16	29-31
17-19	32-34
20-22	

**LEGEND**

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<span style="display:inline-block; width:15px; height:15px; background-color:cyan;"></span> BASIN C-10 EAST
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<span style="display:inline-block; width:15px; height:15px; border:1px solid black;"></span> PROPOSED SIDE DRAIN
<span style="display:inline-block; width:15px; height:15px; border:1px dashed black;"></span> OFFSITE DRAINAGE AREA
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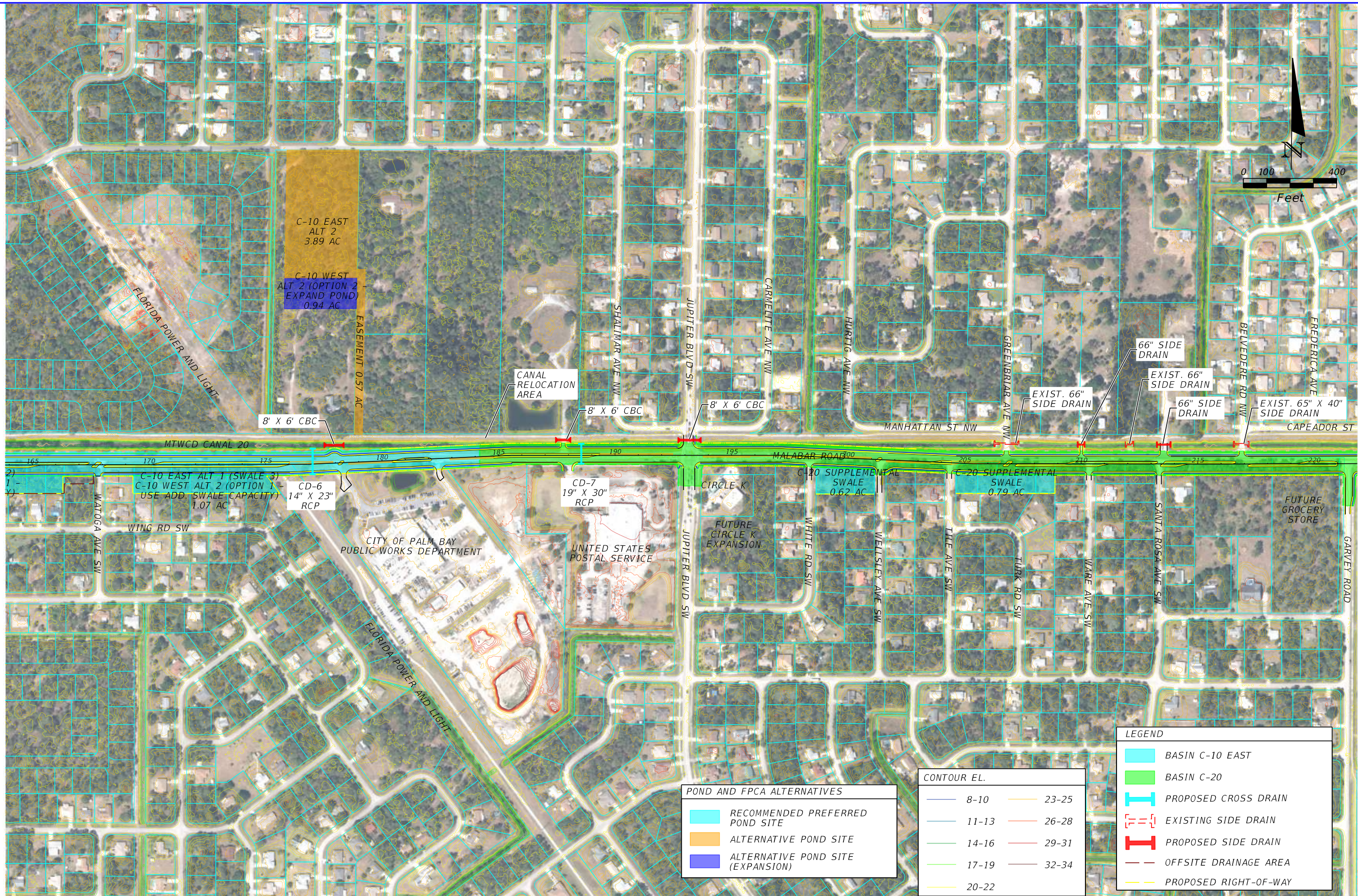
REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION		
ROAD NO.	COUNTY	FINANCIAL PROJECT ID

# BASIN MAPS

SHEET NO.
2





**POND AND FPCA ALTERNATIVES**

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<span style="color: purple;">■</span>	ALTERNATIVE POND SITE (EXPANSION)

**CONTOUR EL.**

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11-13	26-28
14-16	29-31
17-19	32-34
20-22	

**LEGEND**

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<span style="color: green;">■</span>	BASIN C-20
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<span style="color: red;">- - -</span>	EXISTING SIDE DRAIN
<span style="color: red;">┌─┐</span>	PROPOSED SIDE DRAIN
<span style="color: red;">---</span>	OFFSITE DRAINAGE AREA
<span style="color: yellow;">---</span>	PROPOSED RIGHT-OF-WAY

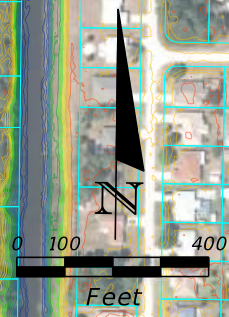
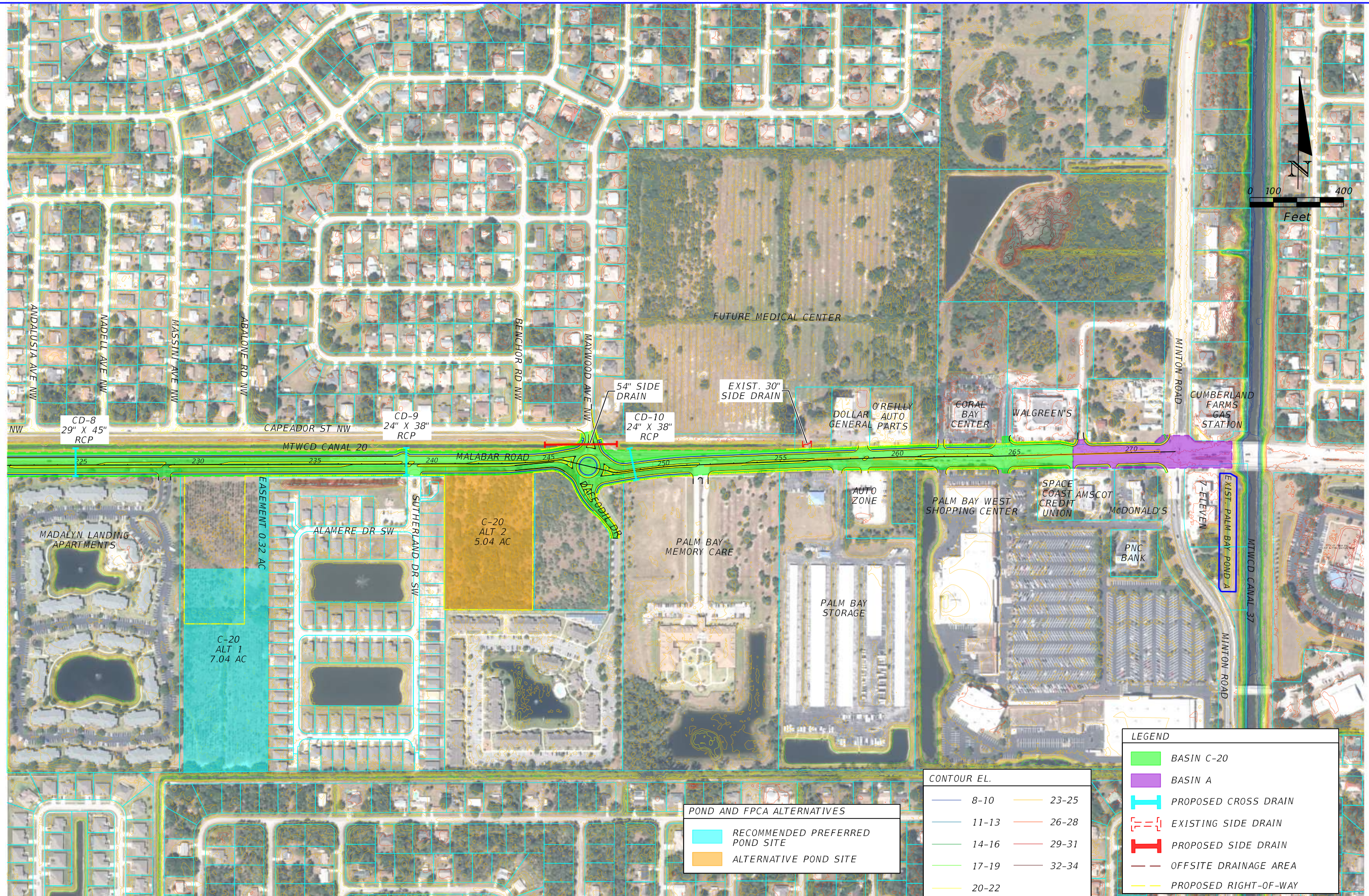
REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION		
ROAD NO.	COUNTY	FINANCIAL PROJECT ID

# BASIN MAPS

SHEET NO.  
3





**POND AND FPCA ALTERNATIVES**

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**CONTOUR EL.**

8-10	23-25
11-13	26-28
14-16	29-31
17-19	32-34
20-22	

**LEGEND**

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REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION		
ROAD NO.	COUNTY	FINANCIAL PROJECT ID

BASIN MAPS

SHEET NO.  
4



**Floodplain Impact & Compensation Calculations**



# Malabar Road PD&E Study

FM No. 437210-1-28-01

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**Malabar Road PD&E Study**

Summary Floodplain Impact Areas (FIA)							
FIA Name	Station	-	Station	Total Length of Impact (ft)	Estimated Fill Area Not Within Canals (0.25' Depth) (ac)	Estimated Fill Area Within Canals (2.00' Depth) (ac)	Estimated Fill Volume (ac-ft)
C-7	55+48.00	-	101+00.00	4,552	4.26	0.17	1.41

Summary Floodplain Compensation Areas (FPCA)									
FPCA	SHWT Elevation (ft)	Pond TOB Elevation (ft)	100-yr Flood Elevation (ft)	Required Compensation Volume (ac-ft)	Width (ft)	Length (ft)	Provided Compensation Volume (ac-ft)	Provided Compensation Area (ac)	Provided FPCA Area (20% FS) (ac)
C-7 Alt. 1	17.00	20.00	20.00	1.41	124.00	480.00	2.15	1.37	1.64

**Malabar Road PD&E Study**

Summary Floodplain Impact Areas (FIA)							
FIA Name	Station	-	Station	Total Length of Impact (ft)	Estimated Fill Area Not Within Canals (0.25' Depth) (ac)	Estimated Fill Area Within Canals (2.00' Depth) (ac)	Estimated Fill Volume (ac-ft)
C-7	55+48.00	-	101+00.00	4,552	4.26	0.17	1.41
Pond C-7 Impacts	N/A						0.50

Summary Floodplain Compensation Areas (FPCA)									
FPCA	SHWT Elevation (ft)	Pond TOB Elevation (ft)	100-yr Flood Elevation (ft)	Required Compensation Volume (ac-ft)	Width (ft)	Length (ft)	Provided Compensation Volume (ac-ft)	Provided Compensation Area (ac)	Provided FPCA Area (20% FS) (ac)
C-7 Alt. 2	16.20	18.00	20.00	1.91	232.00	290.00	1.91	1.54	1.85

# Malabar Road PD&E Study

FM No. 437210-1-28-01

## ***APPENDIX D***

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### **Cross Drain Analysis**

# Malabar Road PD&E Study

FM No. 437210-1-28-01

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**Malabar Road PD&E Study**  
**CD-1: 2 - 96" RCP (Sta. 62+80) (Existing)**

**HYDROLOGIC ANALYSIS**

**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)

A = Existing Culvert Cross Section Area

V = 5 feet per second (maximum)

Pipe Size= **96.0 in.**      Barrels= **2**

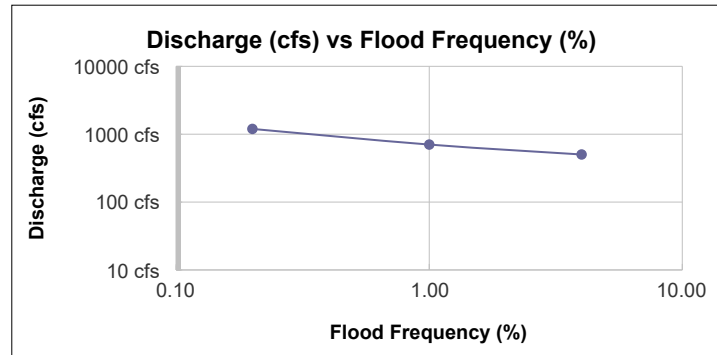
A<sub>1</sub>= **100.53 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V = **503 cfs**

Q<sub>50yr</sub> = 734.72(2)<sup>-0.291</sup> = **601 cfs**

Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> = **704 cfs**

Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> = **1196 cfs**



**Overtopping Frequency Determination for CD-1 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-1	62+80	96" RCP	2	Round	96"	96"	100.53	503	601	704	1333.1	1196

\*OT = Overtopping

**Sample Calculations:**

$Q_{(OT)} = 734.72x^{-0.291}$  (from curve fitting equation)  
 x = 0.13 %

Storm Event = 1/Storm Freq  
 775-yr

Storm Event			
50-yr	100-yr	775-yr	500-yr
Storm Frequency (%)			
2	1	0.13	0.2

**Malabar Road PD&E Study**  
**CD-2: 1 - 8'x6' CBC (Sta. 89+18) (Existing)**

**HYDROLOGIC ANALYSIS**

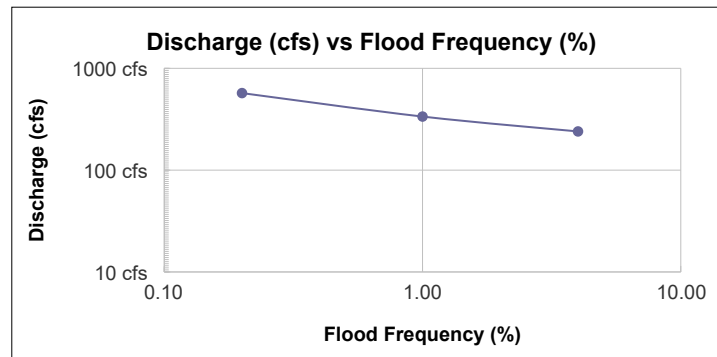
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= **72"x96"**      Barrels= **1**  
 A<sub>1</sub>= **48.00 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V = **240 cfs**  
 Q<sub>50yr</sub> = 350.80(2)<sup>-0.291</sup> = **287 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> = **336 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> = **571 cfs**



**Overtopping Frequency Determination for CD-2 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-2	89+18	8'x6' CBC	1	Rectangle	72"	96"	48.00	240	287	336	528.4	571

\*OT = Overtopping

**Sample Calculations:**

$Q_{(OT)} = 350.80x^{-0.291}$  (from curve fitting equation)  
 x = 0.24 %

Storm Event = 1/Storm Freq  
 409-yr

Storm Event			
50-yr	100-yr	409-yr	500-yr
Storm Frequency (%)			
2	1	0.24	0.2



**Malabar Road PD&E Study**  
**CD-4: 1 - 54" RCP (Sta. 115+71) (Existing)**

**HYDROLOGIC ANALYSIS**

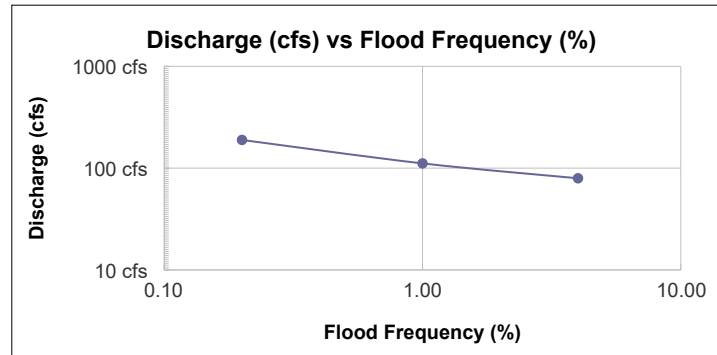
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= **54.0 in.**      Barrels= **1**  
 A<sub>1</sub>= **15.90 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V = **80 cfs**  
 Q<sub>50yr</sub> = 116.23(2)<sup>-0.291</sup> = **95 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> = **111 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> = **189 cfs**



**Overtopping Frequency Determination for CD-4 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-4	115+71	54" RCP	1	Round	54"	54"	15.90	80	95	111	197.3	189

\*OT = Overtopping

**Sample Calculations:**

$Q_{(OT)} = 116.23x^{-0.291}$  (from curve fitting equation)  
 x = 0.16 %

Storm Event = 1/Storm Freq  
 616-yr

Storm Event			
50-yr	100-yr	616-yr	500-yr
Storm Frequency (%)			
2	1	0.16	0.2

**Malabar Road PD&E Study**  
**CD-5: 1 - 13"x21" RCP (Sta. 155+75) (Existing)**

**HYDROLOGIC ANALYSIS**

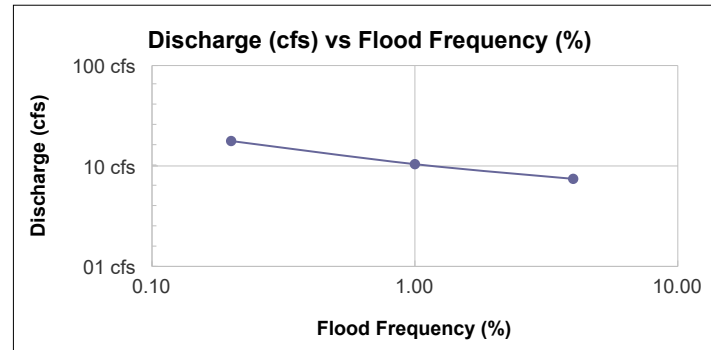
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= **13"x21"**      Barrels= **1**  
 A<sub>1</sub>= **1.49 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V =      **07 cfs**  
 Q<sub>50yr</sub> = 10.882(2)<sup>-0.291</sup> =      **09 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> =      **10 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> =      **18 cfs**



**Overtopping Frequency Determination for CD-5 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-5	155+75	13"x21" RCP	1	Elliptical	13"	21"	1.49	7	9	10	15.6	18

\*OT = Overtopping

**Sample Calculations:**

Q<sub>(OT)</sub> = 10.882x<sup>-0.291</sup> (from curve fitting equation)  
 x      0.29      %

Storm Event = 1/Storm Freq  
 346-yr

Storm Event			
50-yr	100-yr	346-yr	500-yr
Storm Frequency (%)			
2	1	0.29	0.2

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 3000 Dovera Drive, Suite 200, Oviedo, FL 32765  
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 Ch'd by: REC      PROJECT #: KIT-009-01

**Malabar Road PD&E Study**  
**CD-6: 1 - 14"x23" RCP (Sta. 176+84) (Existing)**

**HYDROLOGIC ANALYSIS**

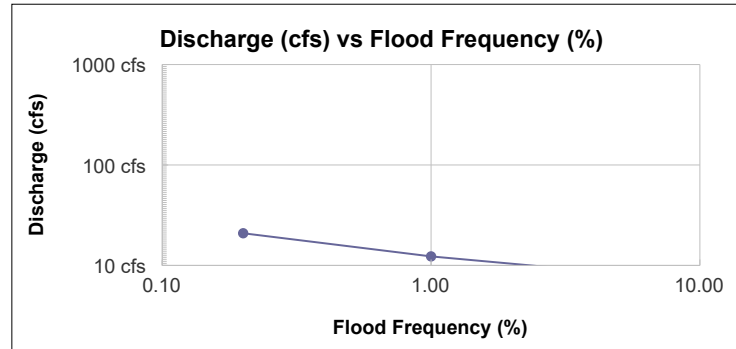
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= 14"x23"      Barrels= 1  
 A<sub>1</sub>= 1.76 sq.ft.

Q<sub>25yr</sub> = A<sub>1</sub>V =      **09 cfs**  
 Q<sub>50yr</sub> = 12.835(2)<sup>-0.291</sup> =      **10 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> =      **12 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> =      **21 cfs**



**Overtopping Frequency Determination for CD-6 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-6	176+84	14"x23" RCP	1	Elliptical	14"	23"	1.76	9	10	12	16.1	21

\*OT = Overtopping

**Sample Calculations:**

Q<sub>(OT)</sub> = 12.835x<sup>-0.291</sup> (from curve fitting equation)  
 x      0.46      %  
 Storm Event = 1/Storm Freq  
 218-yr

Storm Event			
50-yr	100-yr	218-yr	500-yr
Storm Frequency (%)			
2	1	0.46	0.2



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**Malabar Road PD&E Study**  
**CD-8: 1 - 18"x30" RCP (Sta. 224+58) (Existing)**

**HYDROLOGIC ANALYSIS**

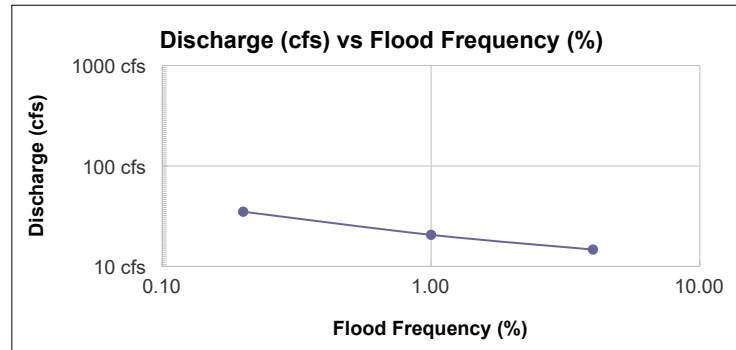
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= **18"x30"**      Barrels= **1**  
 A<sub>1</sub>= **2.95 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V = **15 cfs**  
 Q<sub>50yr</sub> = 21.525(2)<sup>-0.291</sup> = **18 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> = **21 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> = **35 cfs**



**Overtopping Frequency Determination for CD-8 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-8	224+58	18"x30" RCP	1	Elliptical	18"	30"	2.95	15	18	21	31.1	35

\*OT = Overtopping

**Sample Calculations:**

Q<sub>(OT)</sub> = 21.525x<sup>-0.291</sup> (from curve fitting equation)  
 x      0.28      %

Storm Event = 1/Storm Freq  
 355-yr

Storm Event			
50-yr	100-yr	355-yr	500-yr
Storm Frequency (%)			
2	1	0.28	0.2

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**Malabar Road PD&E Study**  
**CD-9: 1 - 19"x30" RCP (Sta. 238+72) (Existing)**

**HYDROLOGIC ANALYSIS**

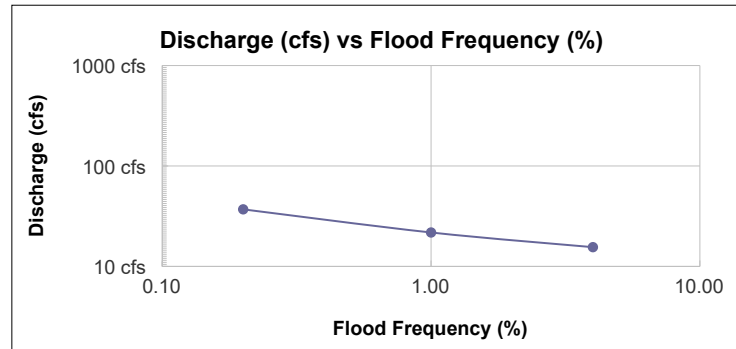
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= **19"x30"**      Barrels= **1**  
 A<sub>1</sub>= **3.11 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V = **16 cfs**  
 Q<sub>50yr</sub> = 22.721(2)<sup>-0.291</sup> = **19 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> = **22 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> = **37 cfs**



**Overtopping Frequency Determination for CD-9 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-9	238+72	19"x30" RCP	1	Elliptical	19"	30"	3.11	16	19	22	27.5	37

\*OT = Overtopping

**Sample Calculations:**

Q<sub>(OT)</sub> = 22.721x<sup>-0.291</sup> (from curve fitting equation)  
 x      0.52      %

Storm Event = 1/Storm Freq  
 192-yr

Storm Event			
50-yr	100-yr	192-yr	500-yr
Storm Frequency (%)			
2	1	0.52	0.2

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**Malabar Road PD&E Study**  
**CD-10: 1 - 19"x30" RCP (Sta. 248+33) (Existing)**

**HYDROLOGIC ANALYSIS**

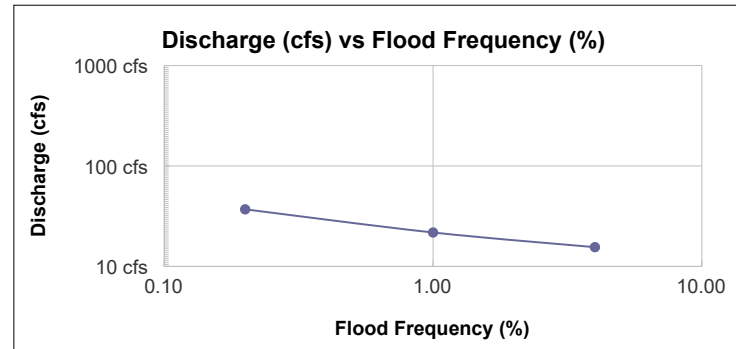
**VELOCITY METHOD :**

$Q = AV$

Q = Peak Runoff for Return Period T (cfs)  
 A = Existing Culvert Cross Section Area  
 V = 5 feet per second (maximum)

Pipe Size= **19"x30"**      Barrels= **1**  
 A<sub>1</sub>= **3.11 sq.ft.**

Q<sub>25yr</sub> = A<sub>1</sub>V = **16 cfs**  
 Q<sub>50yr</sub> = 22.721(2)<sup>-0.291</sup> = **19 cfs**  
 Q<sub>100yr</sub> = 1.4Q<sub>25yr</sub> = **22 cfs**  
 Q<sub>500yr</sub> = 1.7Q<sub>100yr</sub> = **37 cfs**



**Overtopping Frequency Determination for CD-10 (Proposed)**

Name	Approximate Location	Description	Barrel	Geometry	Pipe Size			Q <sub>(25)</sub>	Q <sub>(50)</sub>	Q <sub>(100)</sub>	Q <sub>(OT)</sub>	Q <sub>(500)</sub>
					Height	Width	Total Area (sf)					
CD-10	248+33	19"x30" RCP	1	Elliptical	19"	30"	3.11	16	19	22	39.0	37

\*OT = Overtopping

**Sample Calculations:**

Q<sub>(OT)</sub> = 22.721x<sup>-0.291</sup> (from curve fitting equation)  
 x 0.16 %  
 Storm Event = 1/Storm Freq  
 642-yr

Storm Event			
50-yr	100-yr	642-yr	500-yr
Storm Frequency (%)			
2	1	0.16	0.2



**Malabar Road PD&E Study**

**TABLE – CROSS DRAIN FLOOD DATA SHEET - EXISTING VS. PROPOSED**

Structure Number	Approximate Location	Design Flood (50-yr Storm Event)					Base Flood (100-yr Storm Event)					Overtopping Flood				Greatest Flood (500-yr Storm Event)					
		Existing (A)		Proposed (B)		B-A	Existing (A)		Proposed (B)		B-A	Existing (A)		Proposed (B)		B-A	Existing (A)		Proposed (B)		B-A
		Discharge (cfs)	Stage (ft)	Discharge (cfs)	Stage (ft)	Stage (ft)	Discharge (cfs)	Stage (ft)	Discharge (cfs)	Stage (ft)	Stage (ft)	Discharge (cfs)	Stage (ft)	Discharge (cfs)	Stage (ft)	Discharge (cfs)	Stage (ft)	Discharge (cfs)	Stage (ft)	Discharge (cfs)	Stage (ft)
CD-1	Sta. 62+80	601	15.55	601	15.60	0.05	704	15.95	704	16.02	0.07	1347.04	20.00	1333.14	20.00	1196	18.73	1196	18.92	0.19	
CD-2	Sta. 89+18	287	16.30	287	16.36	0.06	336	16.88	336	16.94	0.06	584.86	21.00	528.40	21.00	571	20.72	571	20.77	0.05	
CD-3	Sta. 114+67	CD-3 to be removed or plugged																			
CD-4	Sta. 115+71	95	17.06	95	17.15	0.09	111	17.56	111	17.67	0.11	197.74	21.50	197.30	21.50	189	20.97	189	21.00	0.03	
CD-5	Sta. 155+75	9	19.92	9	19.55	-0.37	10	20.26	10	19.77	-0.49	14.89	22.50	15.61	22.50	18	22.55	18	22.54	-0.01	
CD-6	Sta. 176+84	10	22.03	10	22.06	0.03	12	22.56	12	22.58	0.02	16.17	24.00	16.10	24.00	21	24.06	21	24.06	0.00	
CD-7	Sta. 188+40	19	21.89	19	21.82	-0.07	22	22.34	22	22.29	-0.05	32.40	24.50	32.47	24.50	38	24.57	38	24.57	0.00	
CD-8	Sta. 224+58	18	24.57	18	24.09	-0.48	21	24.59	21	24.16	-0.43	11.80	24.50	31.11	24.50	35	24.67	35	24.54	-0.13	
CD-9	Sta. 238+72	19	25.03	19	24.41	-0.62	22	25.06	22	24.60	-0.46	17.12	25.00	27.49	25.00	37	25.16	37	25.09	-0.07	
CD-10	Sta. 248+33	19	25.13	19	24.45	-0.68	22	25.51	22	24.64	-0.87	21.60	25.50	39.03	25.50	37	25.63	37	25.27	-0.36	

Cross Drain Upsizing Summary			
Structure Number	Existing Pipe Size	Proposed Pipe Size	Proposed Change
CD-1	Double 96" RCP	Double 96" RCP	Extend
CD-2	Single 8' x 6' CBC	Single 8' x 6' CBC	Extend
CD-3	Single 18" CMP	None	Remove or Plug
CD-4	Single 54" RCP	Single 54" RCP	Extend
CD-5	Single 13" x 21" RCP	Single 14" x 23" RCP	Replace
CD-6	Single 14" x 23" RCP	Single 14" x 23" RCP	Extend
CD-7	Single 21" x 28" RCP*	Single 19" x 30" RCP	Extend
CD-8	Single 18" x 30" RCP	Single 29" x 45" RCP	Upsize
CD-9	Single 19" x 30" RCP	Single 24" x 38" RCP	Upsize
CD-10	Single 19" x 30" RCP	Single 24" x 38" RCP	Upsize

\*While existing plans indicate that this cross drain is 21" x 28", it is likely that it is a standard 19" x 30" pipe, therefore, the proposed pipe has been modeled using the standard size.

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 601.00 cfs

Design Flow: 704.00 cfs

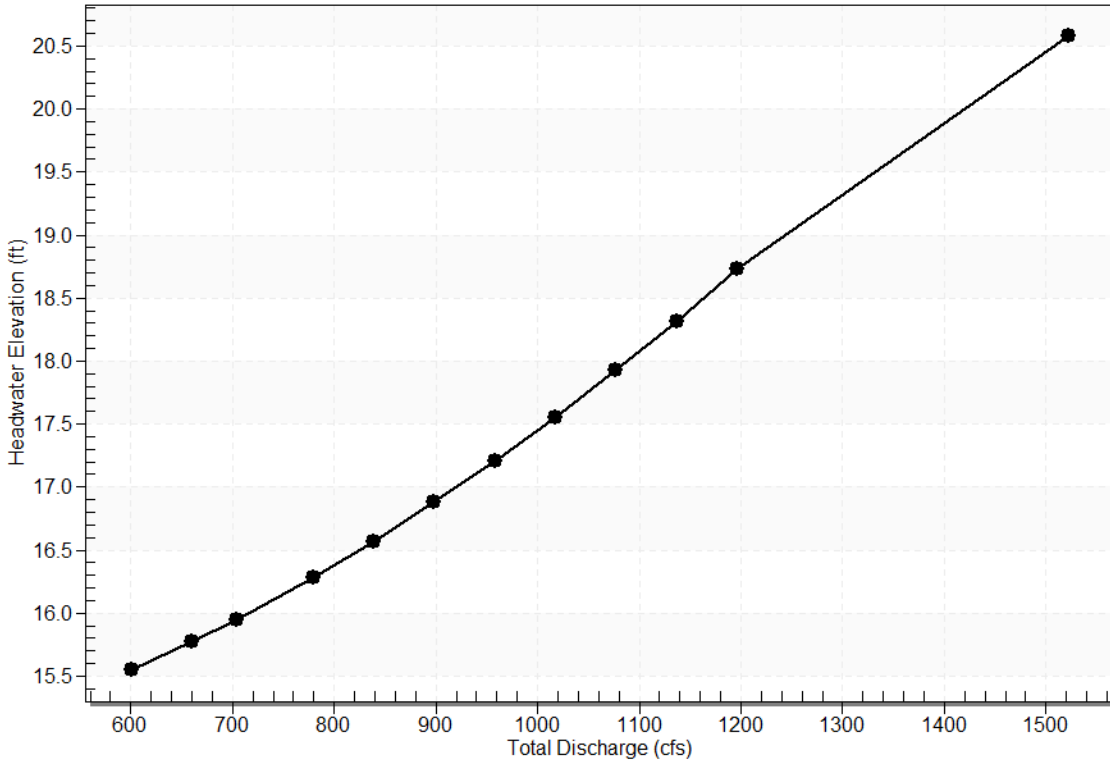
Maximum Flow: 1196.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-1**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-1 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
15.55	601.00	601.00	0.00	1
15.78	660.50	660.50	0.00	1
15.95	704.00	704.00	0.00	1
16.28	779.50	779.50	0.00	1
16.57	839.00	839.00	0.00	1
16.88	898.50	898.50	0.00	1
17.20	958.00	958.00	0.00	1
17.55	1017.50	1017.50	0.00	1
17.92	1077.00	1077.00	0.00	1
18.31	1136.50	1136.50	0.00	1
18.73	1196.00	1196.00	0.00	1
20.00	1347.04	1347.04	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-1**

**Total Rating Curve**  
Crossing: EX. CD-1



**Culvert Data: EX. CD-1**

**Table 2 - Culvert Summary Table: EX. CD-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)
601.0	601.0	15.55	6.57	9.53	4-2	8.00	4.38	8.0	8.56	5.98	0.00
660.5	660.5	15.78	6.99	9.75	4-5	8.00	4.60	8.0	8.56	6.57	0.00
704.0	704.0	15.95	7.31	9.93	4-1	8.00	4.76	8.0	8.56	7.00	0.00
779.5	779.5	16.28	7.88	10.2	4-64	8.00	5.02	8.0	8.56	7.75	0.00
839.0	839.0	16.57	8.37	10.5	4-50	8.00	5.21	8.0	8.56	8.35	0.00
898.5	898.5	16.88	8.89	10.8	4-56	8.00	5.40	8.0	8.56	8.94	0.00

<b>958.0</b> <b>0 cfs</b>	958.0 0 cfs	17.20	9.44	11.1 84	4- FFf	8.00	5.58	8.0 0	8.56	9.53	0.00
<b>1017.</b> <b>50 cfs</b>	1017. 50 cfs	17.55	10.0 3	11.5 33	4- FFf	8.00	5.75	8.0 0	8.56	10.1 2	0.00
<b>1077.</b> <b>00 cfs</b>	1077. 00 cfs	17.92	10.6 6	11.9 03	4- FFf	8.00	5.91	8.0 0	8.56	10.7 1	0.00
<b>1136.</b> <b>50 cfs</b>	1136. 50 cfs	18.31	11.3 2	12.2 94	4- FFf	8.00	6.07	8.0 0	8.56	11.3 0	0.00
<b>1196.</b> <b>00 cfs</b>	1196. 00 cfs	18.73	12.0 3	12.7 06	4- FFf	8.00	6.22	8.0 0	8.56	11.9 0	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

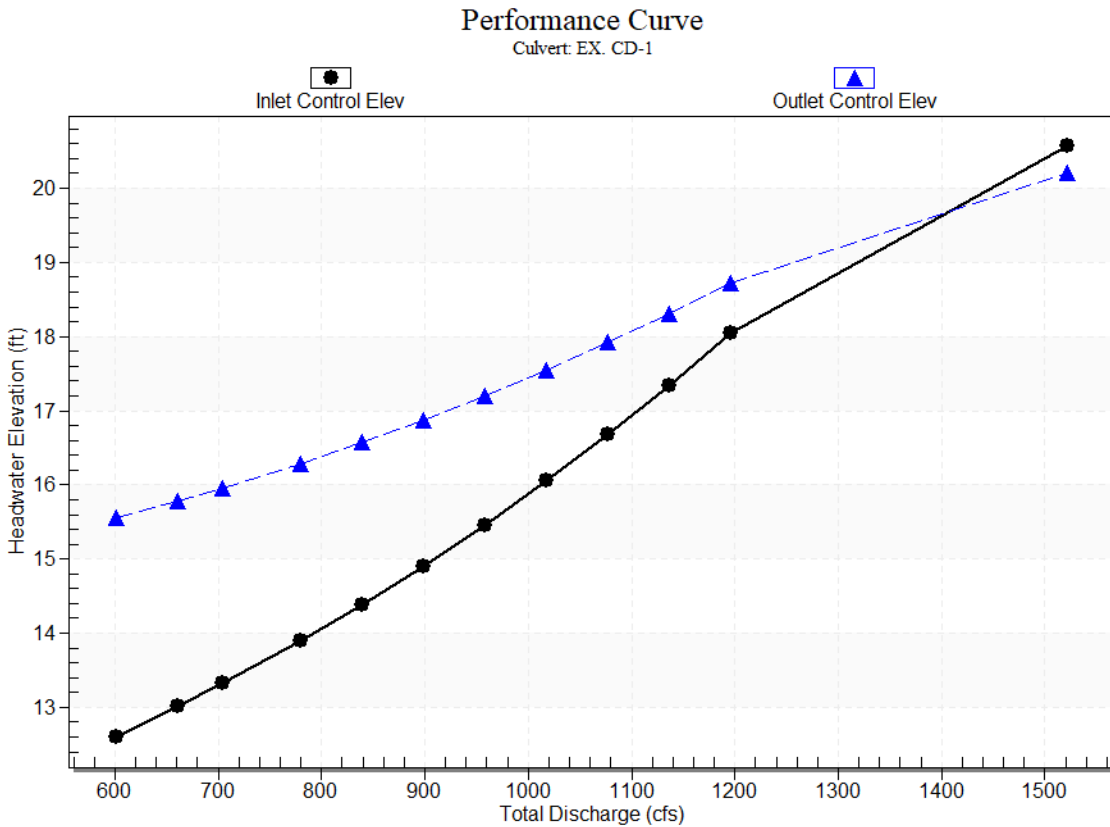
Inlet Elevation (invert): 6.02 ft,

Outlet Elevation (invert): 5.92 ft

Culvert Length: 140.00 ft,

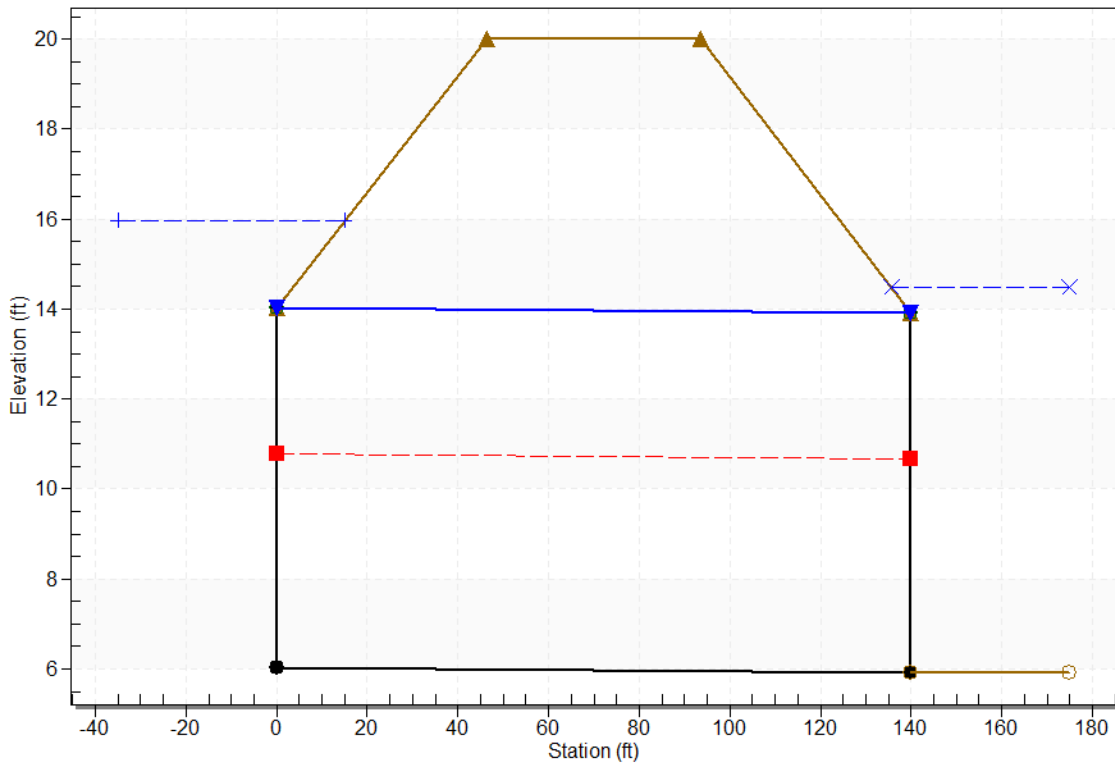
Culvert Slope: 0.0007

### Culvert Performance Curve Plot: EX. CD-1



### Water Surface Profile Plot for Culvert: EX. CD-1

Crossing - EX. CD-1, Design Discharge - 704.0 cfs  
Culvert - EX. CD-1, Culvert Discharge - 704.0 cfs



### Site Data - EX. CD-1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 6.02 ft

Outlet Station: 140.00 ft

Outlet Elevation: 5.92 ft

Number of Barrels: 2

### Culvert Data Summary - EX. CD-1

Barrel Shape: Circular

Barrel Diameter: 8.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope (Ke=0.7)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-1

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

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
601.00	14.48	8.56
660.50	14.48	8.56
704.00	14.48	8.56
779.50	14.48	8.56
839.00	14.48	8.56
898.50	14.48	8.56
958.00	14.48	8.56
1017.50	14.48	8.56
1077.00	14.48	8.56
1136.50	14.48	8.56
1196.00	14.48	8.56

### Tailwater Channel Data - EX. CD-1

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.48 ft

### Roadway Data for Crossing: EX. CD-1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 20.00 ft

Roadway Surface: Paved

Roadway Top Width: 47.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 287.00 cfs

Design Flow: 336.00 cfs

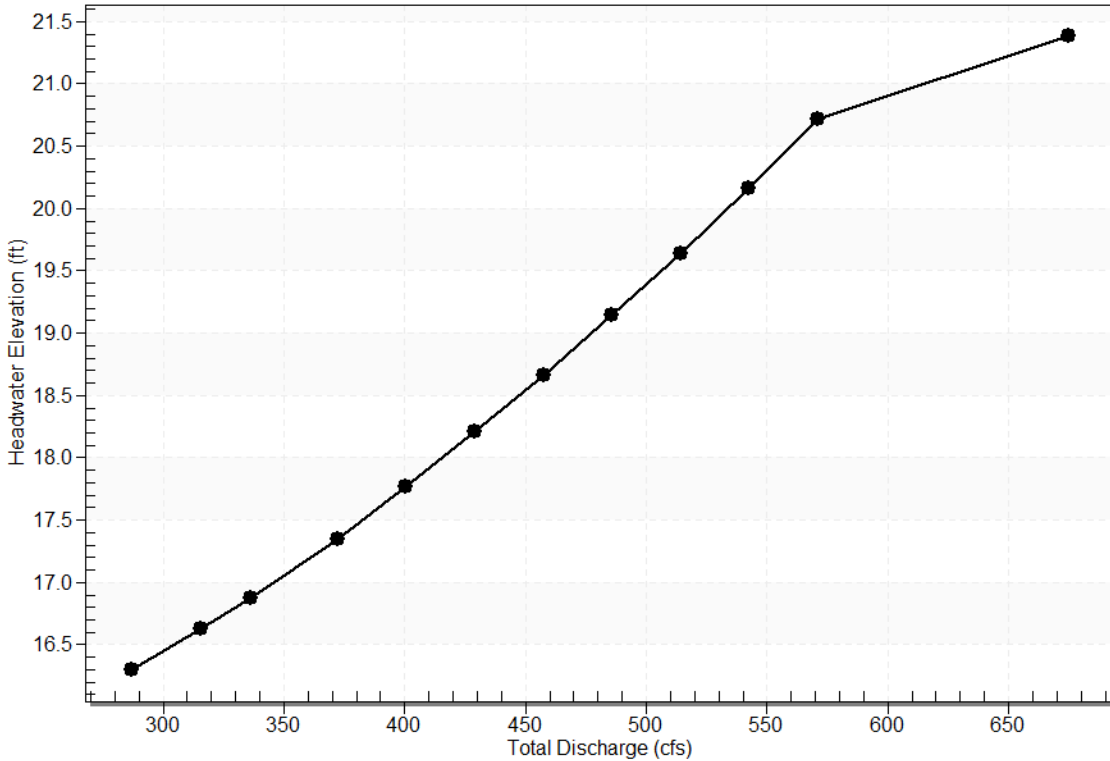
Maximum Flow: 571.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-2**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-2 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
16.30	287.00	287.00	0.00	1
16.63	315.40	315.40	0.00	1
16.88	336.00	336.00	0.00	1
17.35	372.20	372.20	0.00	1
17.77	400.60	400.60	0.00	1
18.21	429.00	429.00	0.00	1
18.66	457.40	457.40	0.00	1
19.14	485.80	485.80	0.00	1
19.64	514.20	514.20	0.00	1
20.17	542.60	542.60	0.00	1
20.72	571.00	571.00	0.00	1
21.00	584.86	584.86	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-2**

**Total Rating Curve**  
Crossing: EX. CD-2



**Culvert Data: EX. CD-2**

**Table 2 - Culvert Summary Table: EX. CD-2**

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)
287.0	287.0	16.30	5.79	5.95	3-M1	4.24	3.42	4.4	4.42	8.12	0.00
315.4	315.4	16.63	6.19	6.27	3-M2	4.55	3.64	4.4	4.42	8.92	0.00
336.0	336.0	16.88	6.48	6.52	3-M2	4.78	3.80	4.4	4.42	9.50	0.00
372.2	372.2	17.35	7.00	6.98	3-M2	5.17	4.07	4.4	4.42	10.5	0.00



<b>400.6 0 cfs</b>	400.6 0 cfs	17.77	7.42	7.34 7	3- M2 t	5.47	4.27	4.4 2	4.42	11.3 3	0.00
<b>429.0 0 cfs</b>	429.0 0 cfs	18.21	7.86	7.69 3	7- M2 c	5.78	4.47	4.4 7	4.42	12.0 0	0.00
<b>457.4 0 cfs</b>	457.4 0 cfs	18.66	8.31	8.02 9	7- M2 c	6.00	4.67	4.6 7	4.42	12.2 6	0.00
<b>485.8 0 cfs</b>	485.8 0 cfs	19.14	8.79	8.35 8	7- M2 c	6.00	4.86	4.8 6	4.42	12.5 0	0.00
<b>514.2 0 cfs</b>	514.2 0 cfs	19.64	9.29	8.68 1	7- M2 c	6.00	5.04	5.0 4	4.42	12.7 4	0.00
<b>542.6 0 cfs</b>	542.6 0 cfs	20.17	9.82	8.99 7	7- M2 c	6.00	5.23	5.2 3	4.42	12.9 7	0.00
<b>571.0 0 cfs</b>	571.0 0 cfs	20.72	10.3 7	9.30 9	7- M2 c	6.00	5.41	5.4 1	4.42	13.2 0	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 10.35 ft,

Outlet Elevation (invert): 10.27 ft

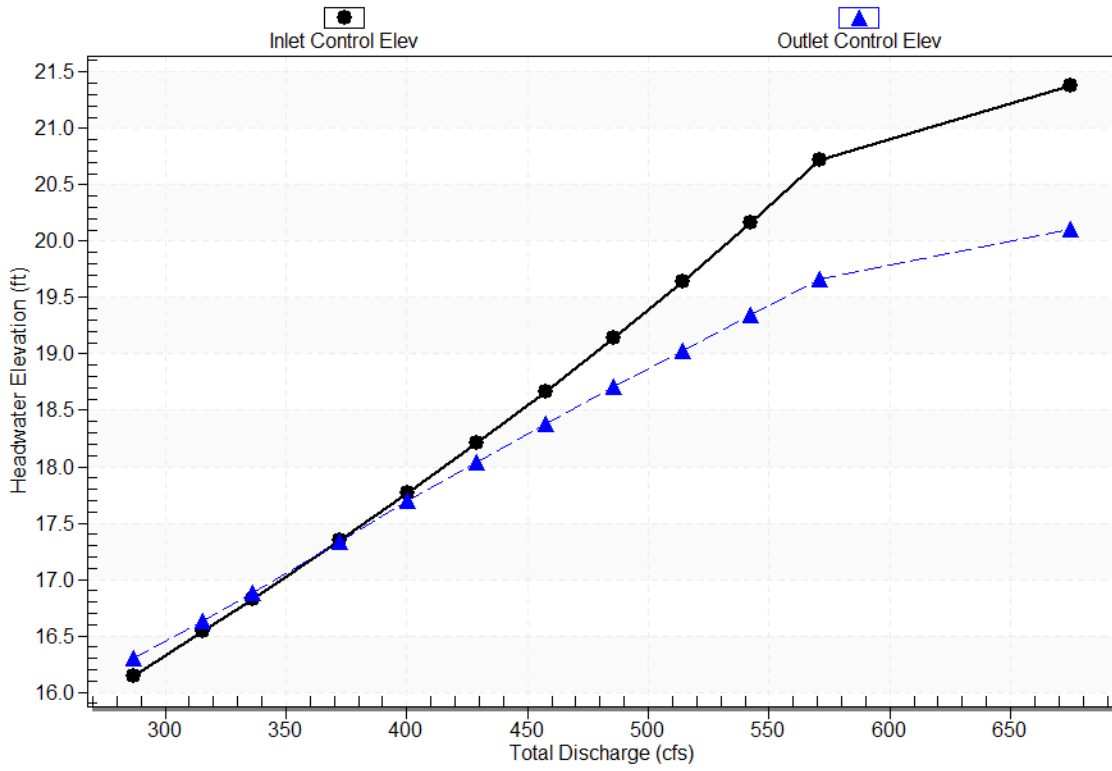
Culvert Length: 45.00 ft,

Culvert Slope: 0.0018

### Culvert Performance Curve Plot: EX. CD-2

#### Performance Curve

Culvert: EX. CD-2





Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-2

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-2 )

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
287.00	14.69	4.42
315.40	14.69	4.42
336.00	14.69	4.42
372.20	14.69	4.42
400.60	14.69	4.42
429.00	14.69	4.42
457.40	14.69	4.42
485.80	14.69	4.42
514.20	14.69	4.42
542.60	14.69	4.42
571.00	14.69	4.42

### Tailwater Channel Data - EX. CD-2

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.69 ft

### Roadway Data for Crossing: EX. CD-2

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 21.00 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 95.00 cfs

Design Flow: 111.00 cfs

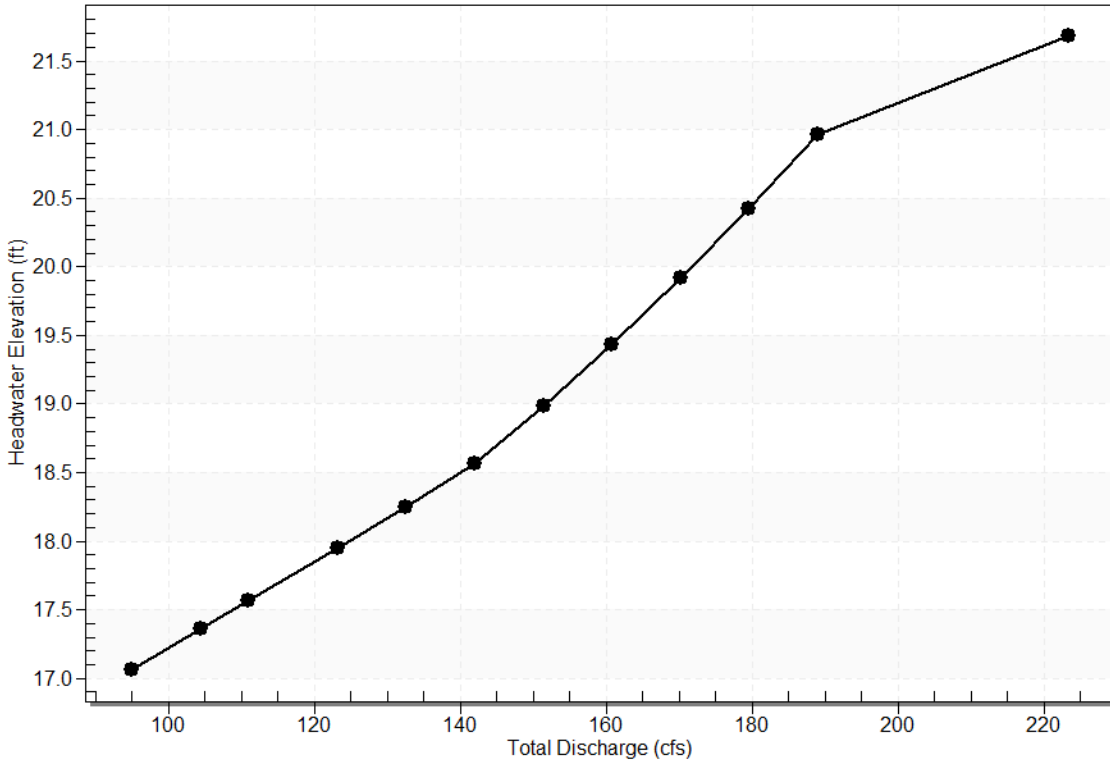
Maximum Flow: 189.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-4**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-4 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
17.06	95.00	95.00	0.00	1
17.36	104.40	104.40	0.00	1
17.56	111.00	111.00	0.00	1
17.95	123.20	123.20	0.00	1
18.25	132.60	132.60	0.00	1
18.56	142.00	142.00	0.00	1
18.98	151.40	151.40	0.00	1
19.43	160.80	160.80	0.00	1
19.91	170.20	170.20	0.00	1
20.43	179.60	179.60	0.00	1
20.97	189.00	189.00	0.00	1
21.50	197.74	197.74	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-4**

**Total Rating Curve**  
Crossing: EX. CD-4



**Culvert Data: EX. CD-4**

**Table 2 - Culvert Summary Table: EX. CD-4**

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)
95.00 cfs	95.00 cfs	17.06	4.45	4.684	7-c A2	- 1.00	2.86	2.86	2.24	8.91	0.00
104.40 cfs	104.40 cfs	17.36	4.76	4.976	7-c A2	- 1.00	3.00	3.00	2.24	9.26	0.00
111.00 cfs	111.00 cfs	17.56	4.98	5.182	7-c A2	- 1.00	3.10	3.10	2.24	9.50	0.00
123.20 cfs	123.20 cfs	17.95	5.43	5.566	7-c A2	- 1.00	3.27	3.27	2.24	9.96	0.00

<b>132.6</b> <b>0 cfs</b>	132.6 0 cfs	18.25	5.79	5.86 8	7- A2 c	- 1.00	3.39	3.3 9	2.24	10.3 2	0.00
<b>142.0</b> <b>0 cfs</b>	142.0 0 cfs	18.56	6.18	6.17 9	7- JA 2c	- 1.00	3.50	3.5 0	2.24	10.7 0	0.00
<b>151.4</b> <b>0 cfs</b>	151.4 0 cfs	18.98	6.60	6.50 2	7- JA 2c	- 1.00	3.61	3.6 1	2.24	11.0 8	0.00
<b>160.8</b> <b>0 cfs</b>	160.8 0 cfs	19.43	7.05	6.84 1	7- JA 2c	- 1.00	3.71	3.7 1	2.24	11.4 7	0.00
<b>170.2</b> <b>0 cfs</b>	170.2 0 cfs	19.91	7.53	7.17 0	7- JA 2t	- 1.00	3.80	3.8 0	2.24	11.8 8	0.00
<b>179.6</b> <b>0 cfs</b>	179.6 0 cfs	20.43	8.05	7.47 3	7- A2 t	- 1.00	3.88	3.8 8	2.24	12.3 1	0.00
<b>189.0</b> <b>0 cfs</b>	189.0 0 cfs	20.97	8.59	7.79 2	7- A2 t	- 1.00	3.96	3.9 6	2.24	12.7 6	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 12.38 ft,

Outlet Elevation (invert): 12.45 ft

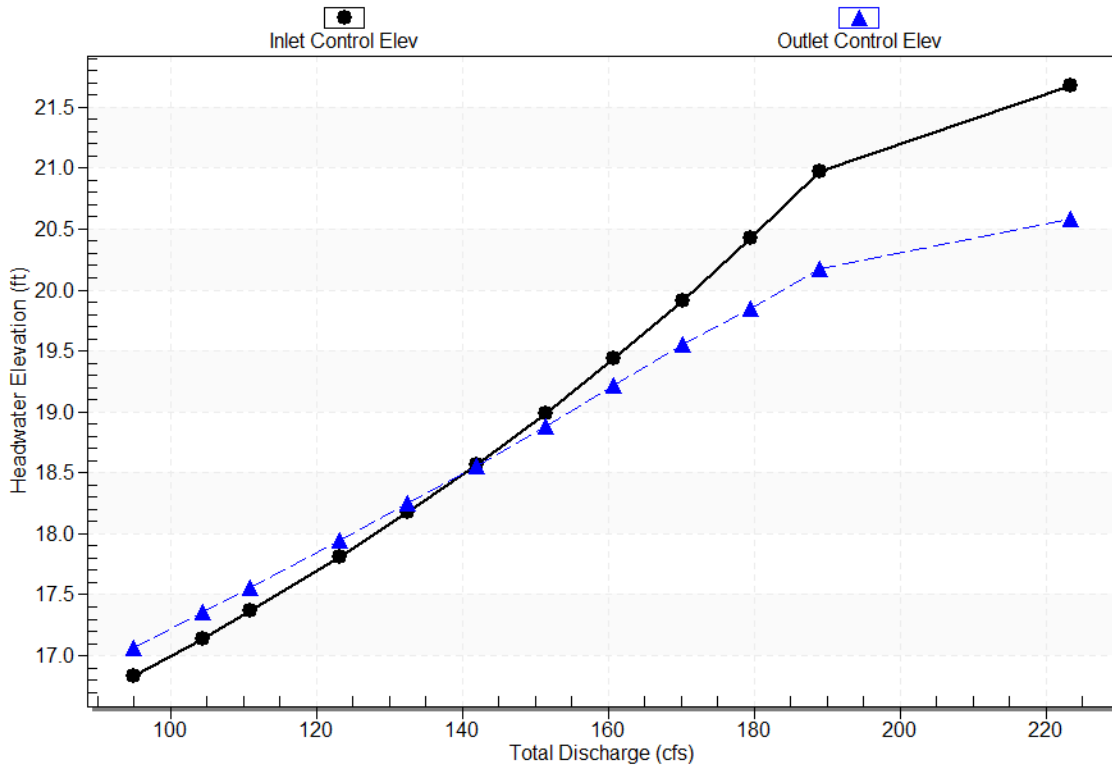
Culvert Length: 44.00 ft,

Culvert Slope: -0.0016

### Culvert Performance Curve Plot: EX. CD-4

#### Performance Curve

Culvert: EX. CD-4

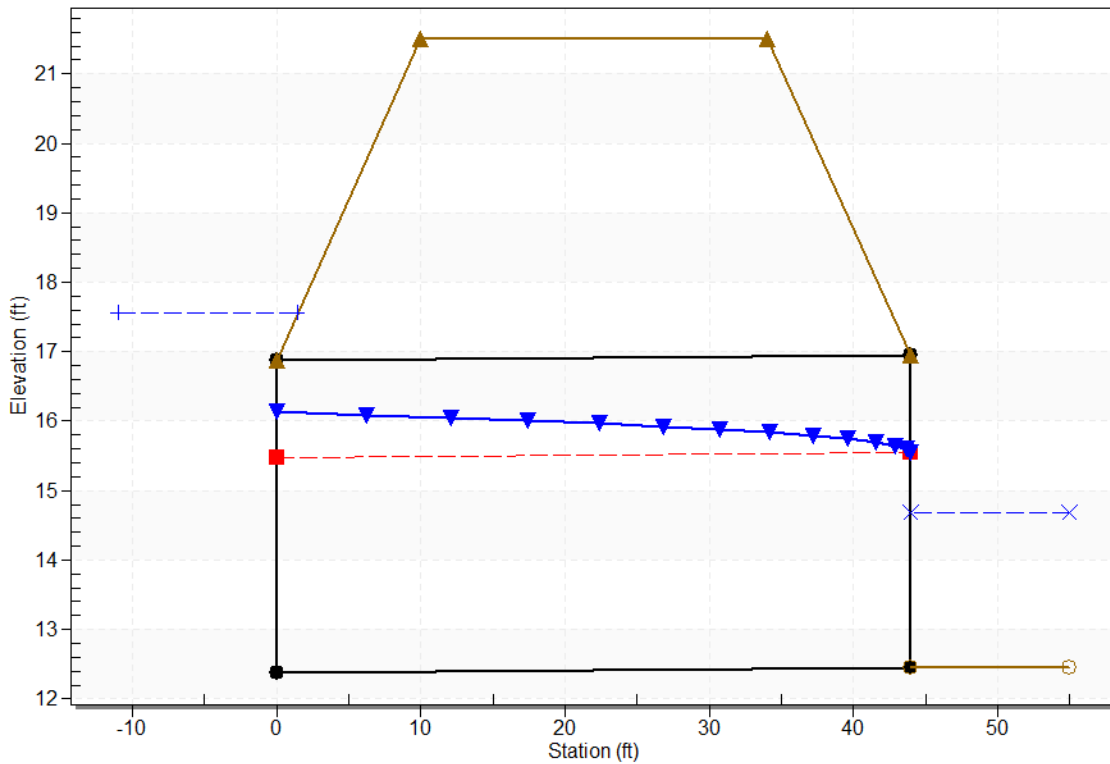




## Water Surface Profile Plot for Culvert: EX. CD-4

Crossing - EX. CD-4, Design Discharge - 111.0 cfs

Culvert - EX. CD-4, Culvert Discharge - 111.0 cfs



## Site Data - EX. CD-4

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 12.38 ft

Outlet Station: 44.00 ft

Outlet Elevation: 12.45 ft

Number of Barrels: 1

## Culvert Data Summary - EX. CD-4

Barrel Shape: Circular

Barrel Diameter: 4.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall ( $K_e=0.5$ )

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-4

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-4)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
95.00	14.69	2.24
104.40	14.69	2.24
111.00	14.69	2.24
123.20	14.69	2.24
132.60	14.69	2.24
142.00	14.69	2.24
151.40	14.69	2.24
160.80	14.69	2.24
170.20	14.69	2.24
179.60	14.69	2.24
189.00	14.69	2.24

### Tailwater Channel Data - EX. CD-4

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.69 ft

### Roadway Data for Crossing: EX. CD-4

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 21.50 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 9.00 cfs

Design Flow: 10.00 cfs

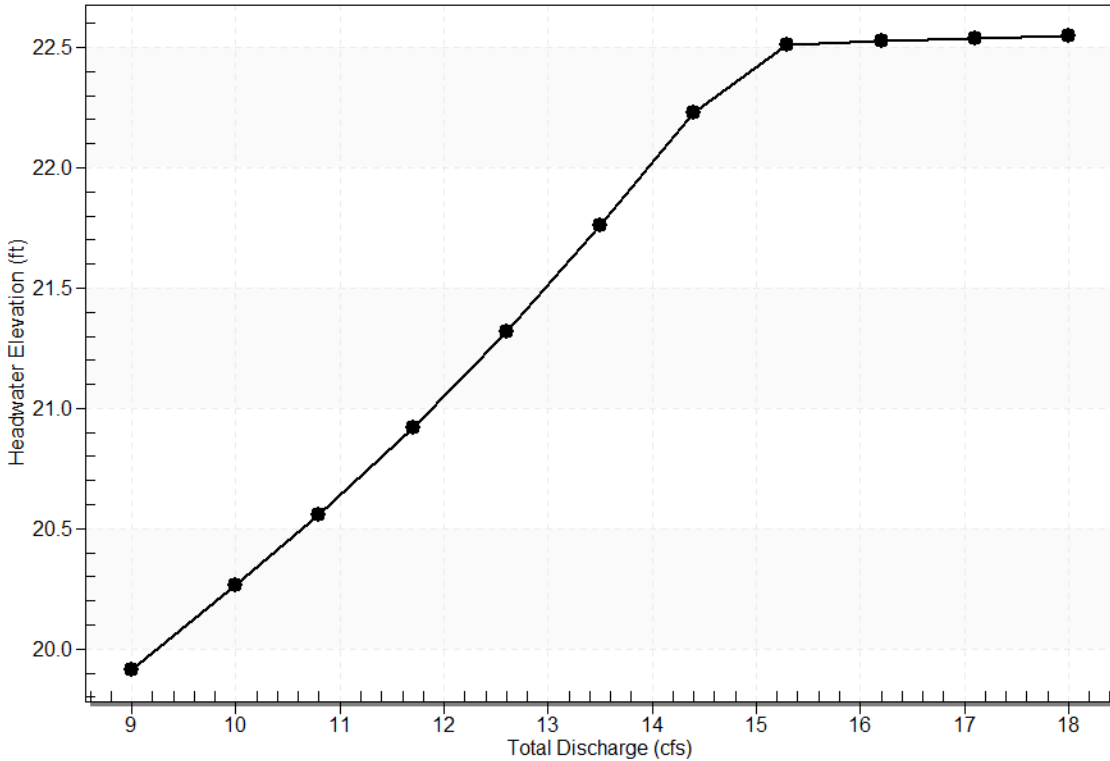
Maximum Flow: 18.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-5**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-5 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
19.92	9.00	9.00	0.00	1
20.26	10.00	10.00	0.00	1
20.56	10.80	10.80	0.00	1
20.92	11.70	11.70	0.00	1
21.32	12.60	12.60	0.00	1
21.76	13.50	13.50	0.00	1
22.23	14.40	14.40	0.00	1
22.51	15.30	14.91	0.27	36
22.53	16.20	14.94	1.19	5
22.54	17.10	14.96	2.08	4
22.55	18.00	14.98	2.90	3
22.50	14.89	14.89	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-5**

**Total Rating Curve**  
Crossing: EX. CD-5



**Culvert Data: EX. CD-5**

**Table 2 - Culvert Summary Table: EX. CD-5**

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
9.00 cfs	9.00 cfs	19.92	2.12	0.949	5- JS1 f	0.55	0.96	1.08	5.90	6.16	0.00
10.00 cfs	10.00 cfs	20.26	2.46	1.358	5- S2 n	0.59	0.99	0.61	5.90	11.83	0.00
10.80 cfs	10.80 cfs	20.56	2.76	1.715	5- S2 n	0.61	1.01	0.64	5.90	12.06	0.00
11.70 cfs	11.70 cfs	20.92	3.12	2.151	5- S2 n	0.64	1.03	0.67	5.90	12.31	0.00

<b>12.60</b> cfs	12.60 cfs	21.32	3.52	2.62 1	5- S2 n	0.67	1.04	0.7 0	5.90	12.5 1	0.00
<b>13.50</b> cfs	13.50 cfs	21.76	3.96	3.12 6	4- FFf	0.70	1.08	1.0 8	5.90	9.24	0.00
<b>14.40</b> cfs	14.40 cfs	22.23	4.43	3.66 6	4- FFf	0.74	1.08	1.0 8	5.90	9.85	0.00
<b>15.30</b> cfs	14.91 cfs	22.51	4.71	3.98 7	4- FFf	0.75	1.08	1.0 8	5.90	10.2 0	0.00
<b>16.20</b> cfs	14.94 cfs	22.53	4.73	4.00 6	4- FFf	0.75	1.08	1.0 8	5.90	10.2 2	0.00
<b>17.10</b> cfs	14.96 cfs	22.54	4.74	4.01 9	4- FFf	0.76	1.08	1.0 8	5.90	10.2 4	0.00
<b>18.00</b> cfs	14.98 cfs	22.55	4.75	4.03 0	4- FFf	0.76	1.08	1.0 8	5.90	10.2 5	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 17.80 ft,

Outlet Elevation (invert): 14.64 ft

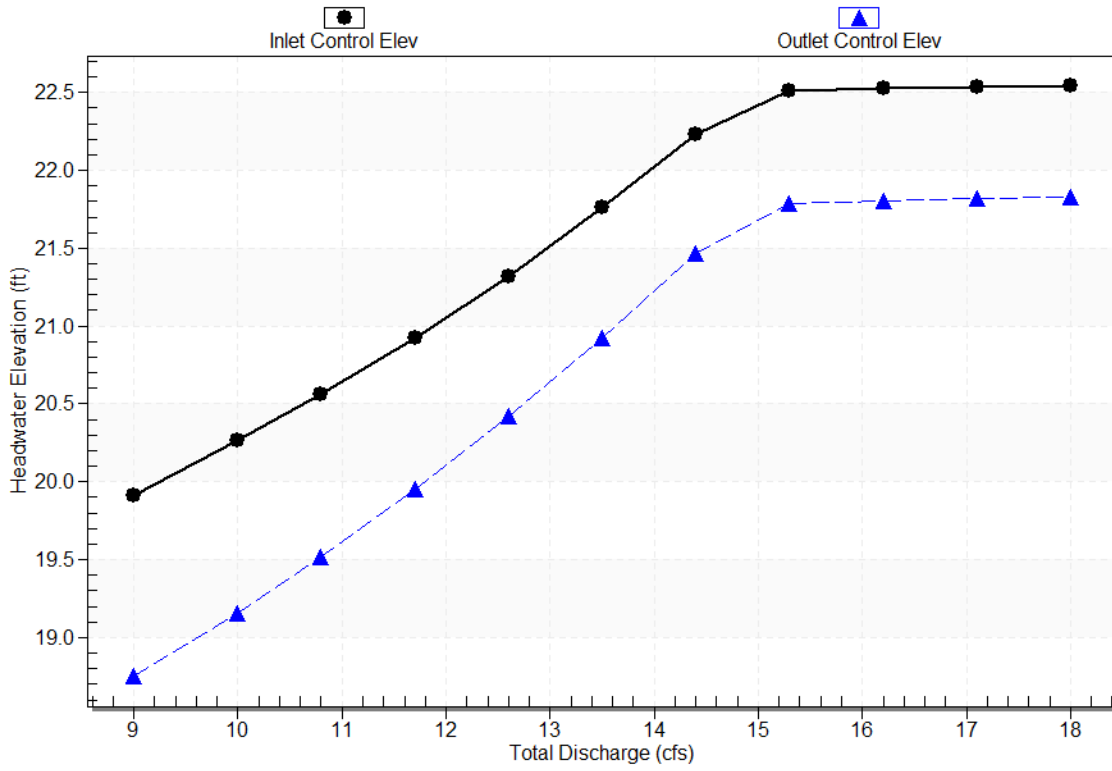
Culvert Length: 78.06 ft,

Culvert Slope: 0.0405

### Culvert Performance Curve Plot: EX. CD-5

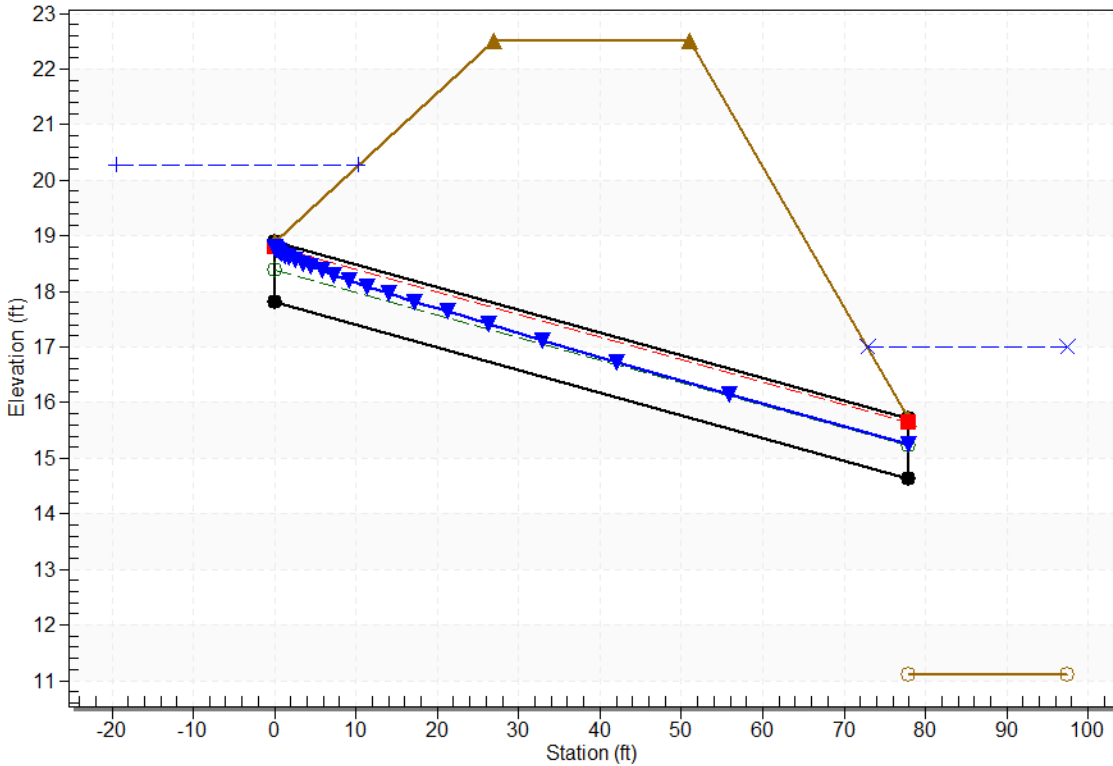
#### Performance Curve

Culvert: EX. CD-5



### Water Surface Profile Plot for Culvert: EX. CD-5

Crossing - EX. CD-5, Design Discharge - 10.0 cfs  
Culvert - EX. CD-5, Culvert Discharge - 10.0 cfs



### Site Data - EX. CD-5

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 17.80 ft

Outlet Station: 78.00 ft

Outlet Elevation: 14.64 ft

Number of Barrels: 1

### Culvert Data Summary - EX. CD-5

Barrel Shape: User Defined

Barrel Span: 1.75 ft

Barrel Rise: 1.08 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0120 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-5

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-5)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
9.00	17.01	5.90
10.00	17.01	5.90
10.80	17.01	5.90
11.70	17.01	5.90
12.60	17.01	5.90
13.50	17.01	5.90
14.40	17.01	5.90
15.30	17.01	5.90
16.20	17.01	5.90
17.10	17.01	5.90
18.00	17.01	5.90

### Tailwater Channel Data - EX. CD-5

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 17.01 ft

### Roadway Data for Crossing: EX. CD-5

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 22.50 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft



# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 10.00 cfs

Design Flow: 12.00 cfs

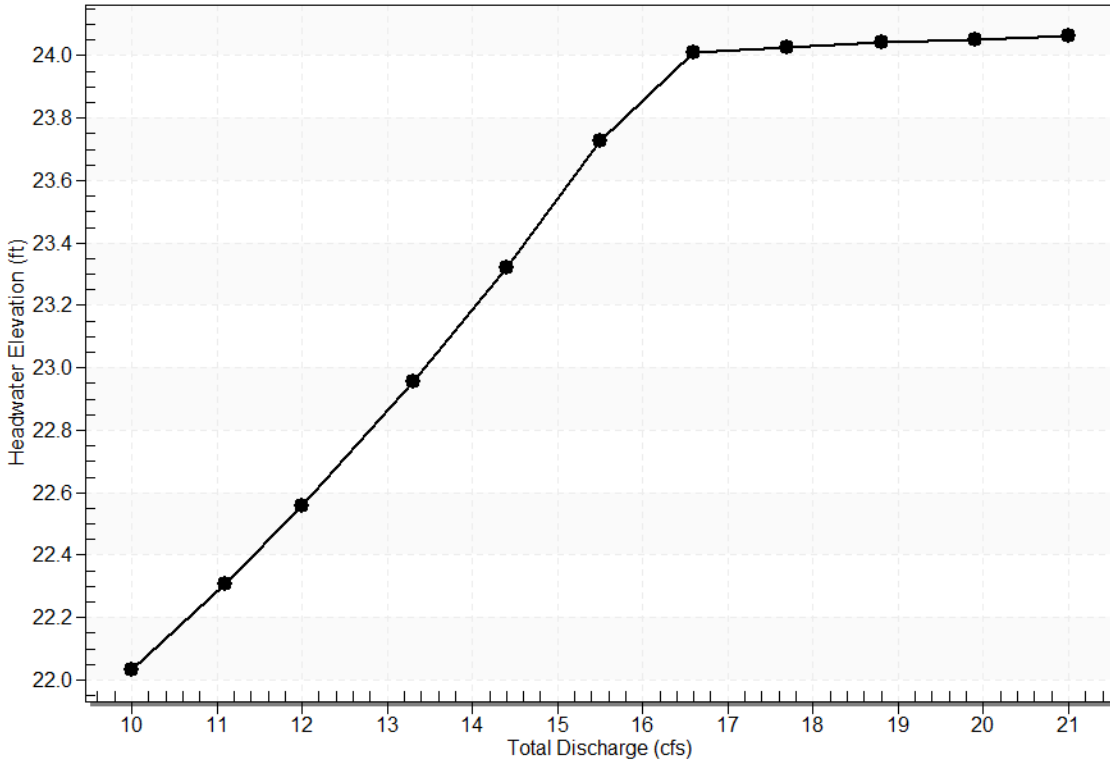
Maximum Flow: 21.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-6**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-6 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
22.03	10.00	10.00	0.00	1
22.31	11.10	11.10	0.00	1
22.56	12.00	12.00	0.00	1
22.95	13.30	13.30	0.00	1
23.32	14.40	14.40	0.00	1
23.73	15.50	15.50	0.00	1
24.01	16.60	16.19	0.28	35
24.03	17.70	16.24	1.37	5
24.04	18.80	16.27	2.45	4
24.05	19.90	16.30	3.46	3
24.06	21.00	16.32	4.56	3
24.00	16.17	16.17	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-6**

**Total Rating Curve**  
Crossing: EX. CD-6



**Culvert Data: EX. CD-6**

**Table 2 - Culvert Summary Table: EX. CD-6**

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)
10.00 cfs	10.00 cfs	22.03	1.96	0.724	5-S2n	0.62	1.01	0.65	5.86	9.76	0.00
11.10 cfs	11.10 cfs	22.31	2.24	1.031	5-S2n	0.66	1.05	0.70	5.86	10.01	0.00
12.00 cfs	12.00 cfs	22.56	2.49	1.298	5-S2n	0.70	1.07	0.74	5.86	10.22	0.00
13.30 cfs	13.30 cfs	22.95	2.88	1.718	5-S2n	0.75	1.10	0.79	5.86	10.49	0.00

<b>14.40</b> <b>cfs</b>	14.40 cfs	23.32	3.25	2.10 1	5- S2 n	0.79	1.11	0.8 3	5.86	10.7 1	0.00
<b>15.50</b> <b>cfs</b>	15.50 cfs	23.73	3.66	2.47 4	5- S2 n	0.83	1.04	0.8 7	5.86	10.9 7	0.00
<b>16.60</b> <b>cfs</b>	16.19 cfs	24.01	3.94	2.80 8	5- S2 n	0.86	1.17	0.9 3	5.86	10.7 4	0.00
<b>17.70</b> <b>cfs</b>	16.24 cfs	24.03	3.96	2.82 6	5- S2 n	0.86	1.17	0.9 3	5.86	10.7 5	0.00
<b>18.80</b> <b>cfs</b>	16.27 cfs	24.04	3.97	2.83 8	5- S2 n	0.86	1.17	0.9 3	5.86	10.7 6	0.00
<b>19.90</b> <b>cfs</b>	16.30 cfs	24.05	3.98	2.84 9	5- S2 n	0.86	1.17	0.9 3	5.86	10.7 7	0.00
<b>21.00</b> <b>cfs</b>	16.32 cfs	24.06	3.99	2.85 9	5- S2 n	0.86	1.17	0.9 3	5.86	10.7 8	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 20.07 ft,

Outlet Elevation (invert): 18.47 ft

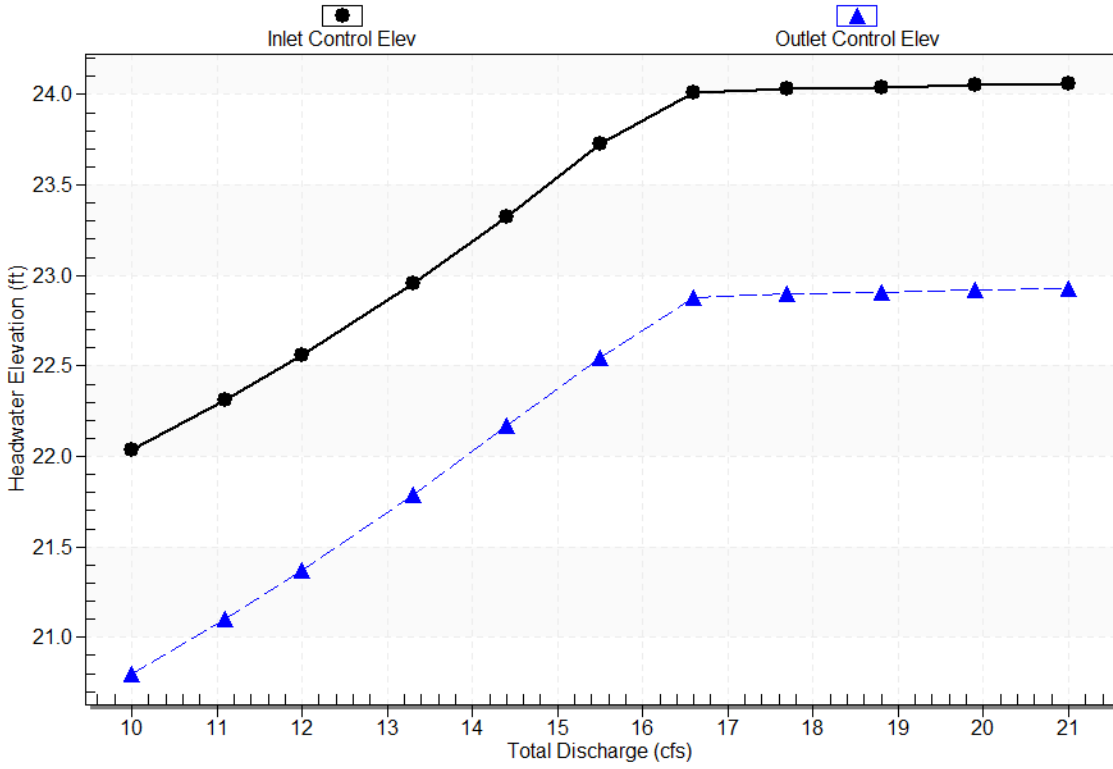
Culvert Length: 62.02 ft,

Culvert Slope: 0.0258

Culvert Performance Curve Plot: EX. CD-6

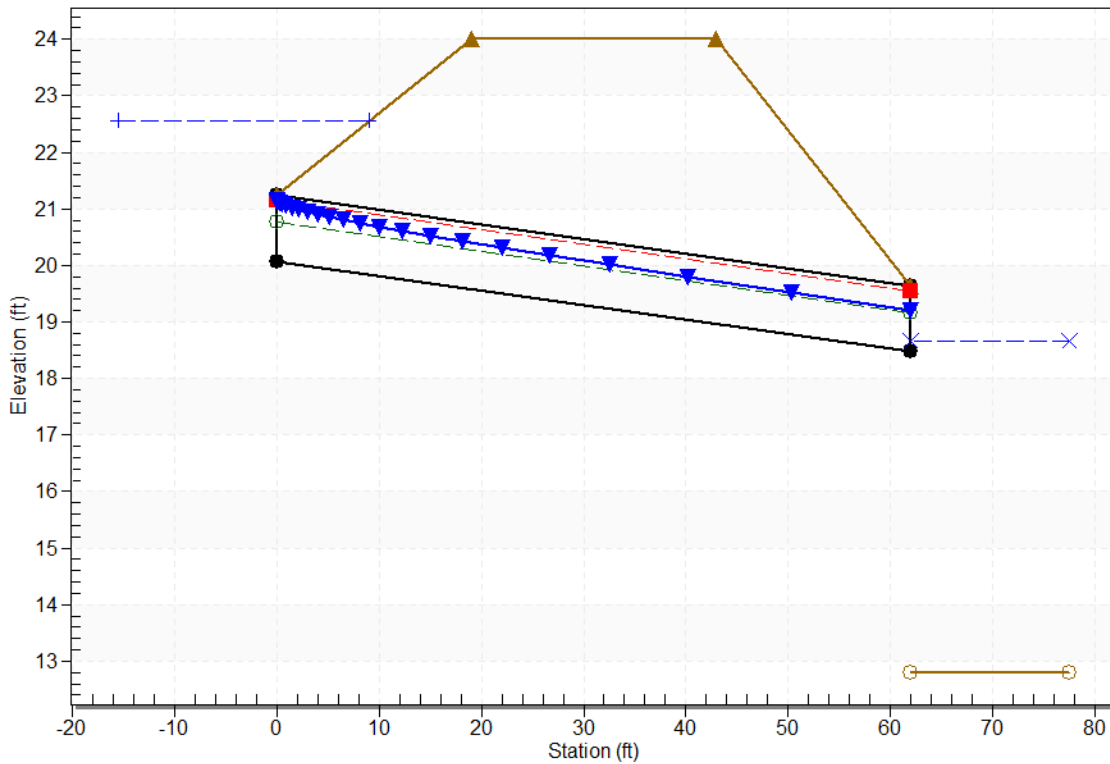
Performance Curve

Culvert: EX. CD-6



### Water Surface Profile Plot for Culvert: EX. CD-6

Crossing - EX. CD-6, Design Discharge - 12.0 cfs  
Culvert - EX. CD-6, Culvert Discharge - 12.0 cfs



### Site Data - EX. CD-6

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 20.07 ft

Outlet Station: 62.00 ft

Outlet Elevation: 18.47 ft

Number of Barrels: 1

### Culvert Data Summary - EX. CD-6

Barrel Shape: Elliptical

Barrel Span: 23.00 in

Barrel Rise: 14.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-6

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-6)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
10.00	18.66	5.86
11.10	18.66	5.86
12.00	18.66	5.86
13.30	18.66	5.86
14.40	18.66	5.86
15.50	18.66	5.86
16.60	18.66	5.86
17.70	18.66	5.86
18.80	18.66	5.86
19.90	18.66	5.86
21.00	18.66	5.86

### Tailwater Channel Data - EX. CD-6

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 18.66 ft

### Roadway Data for Crossing: EX. CD-6

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 24.00 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 19.00 cfs

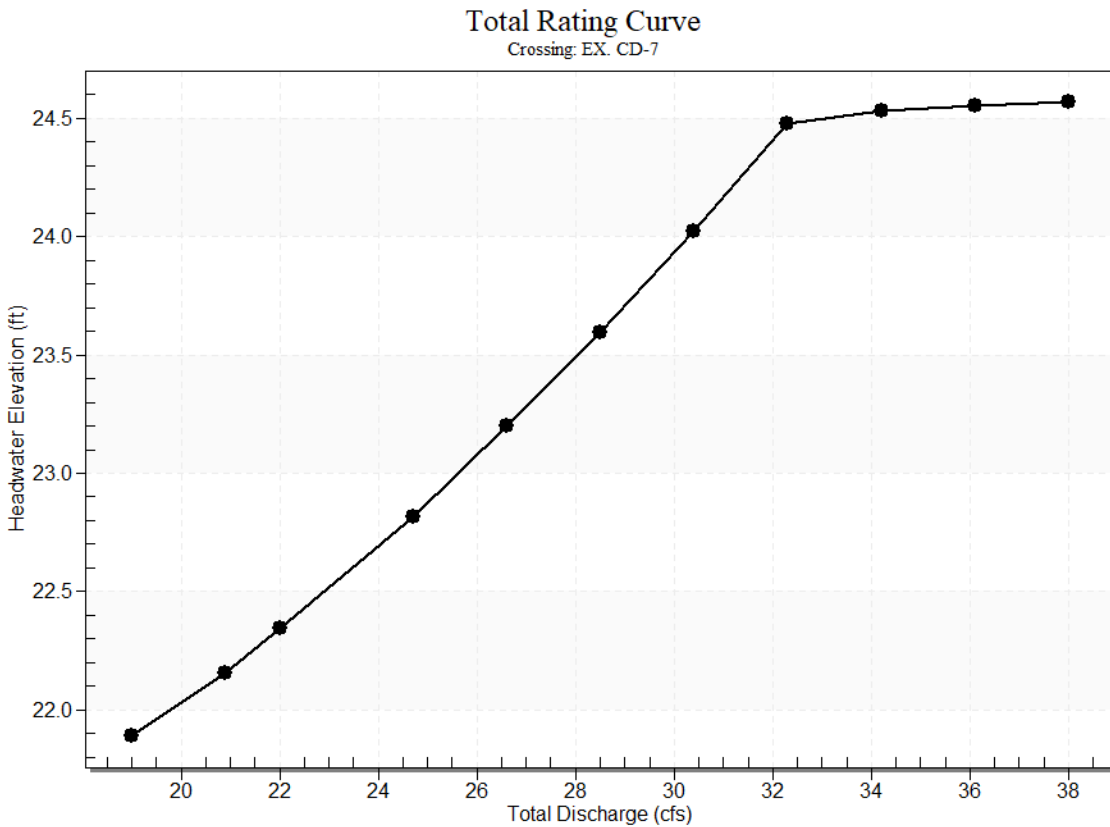
Design Flow: 22.00 cfs

Maximum Flow: 38.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-7**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-7 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
21.89	19.00	19.00	0.00	1
22.15	20.90	20.90	0.00	1
22.34	22.00	22.00	0.00	1
22.82	24.70	24.70	0.00	1
23.20	26.60	26.60	0.00	1
23.60	28.50	28.50	0.00	1
24.02	30.40	30.40	0.00	1
24.48	32.30	32.30	0.00	1
24.53	34.20	32.53	1.54	8
24.55	36.10	32.62	3.40	5
24.57	38.00	32.69	5.22	4
24.50	32.40	32.40	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-7**



**Culvert Data: EX. CD-7**

**Table 2 - Culvert Summary Table: EX. CD-7**

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)
19.00 cfs	19.00 cfs	21.89	2.49	1.228	5-S2n	0.88	1.41	0.95	5.91	10.77	0.00
20.90 cfs	20.90 cfs	22.15	2.75	1.628	5-S2n	0.93	1.47	1.01	5.91	11.02	0.00
22.00 cfs	22.00 cfs	22.34	2.94	1.801	5-S2n	0.95	1.50	1.04	5.91	11.16	0.00
24.70 cfs	24.70 cfs	22.82	3.42	2.249	5-S2n	1.02	1.56	1.12	5.91	11.50	0.00



<b>26.60</b> <b>cfs</b>	26.60 cfs	23.20	3.80	2.58 8	5- S2 n	1.07	1.59	1.1 8	5.91	11.7 2	0.00
<b>28.50</b> <b>cfs</b>	28.50 cfs	23.60	4.20	2.94 9	5- S2 n	1.12	1.62	1.2 3	5.91	11.9 8	0.00
<b>30.40</b> <b>cfs</b>	30.40 cfs	24.02	4.62	3.33 3	5- S2 n	1.17	1.64	1.2 8	5.91	12.2 1	0.00
<b>32.30</b> <b>cfs</b>	32.30 cfs	24.48	5.08	3.73 9	5- S2 n	1.22	1.67	1.3 3	5.91	12.4 4	0.00
<b>34.20</b> <b>cfs</b>	32.53 cfs	24.53	5.13	3.78 9	5- S2 n	1.23	1.67	1.3 4	5.91	12.4 7	0.00
<b>36.10</b> <b>cfs</b>	32.62 cfs	24.55	5.15	3.80 9	5- S2 n	1.23	1.67	1.3 4	5.91	12.4 8	0.00
<b>38.00</b> <b>cfs</b>	32.69 cfs	24.57	5.17	3.82 4	5- S2 n	1.23	1.67	1.3 4	5.91	12.4 9	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 19.40 ft,

Outlet Elevation (invert): 17.97 ft

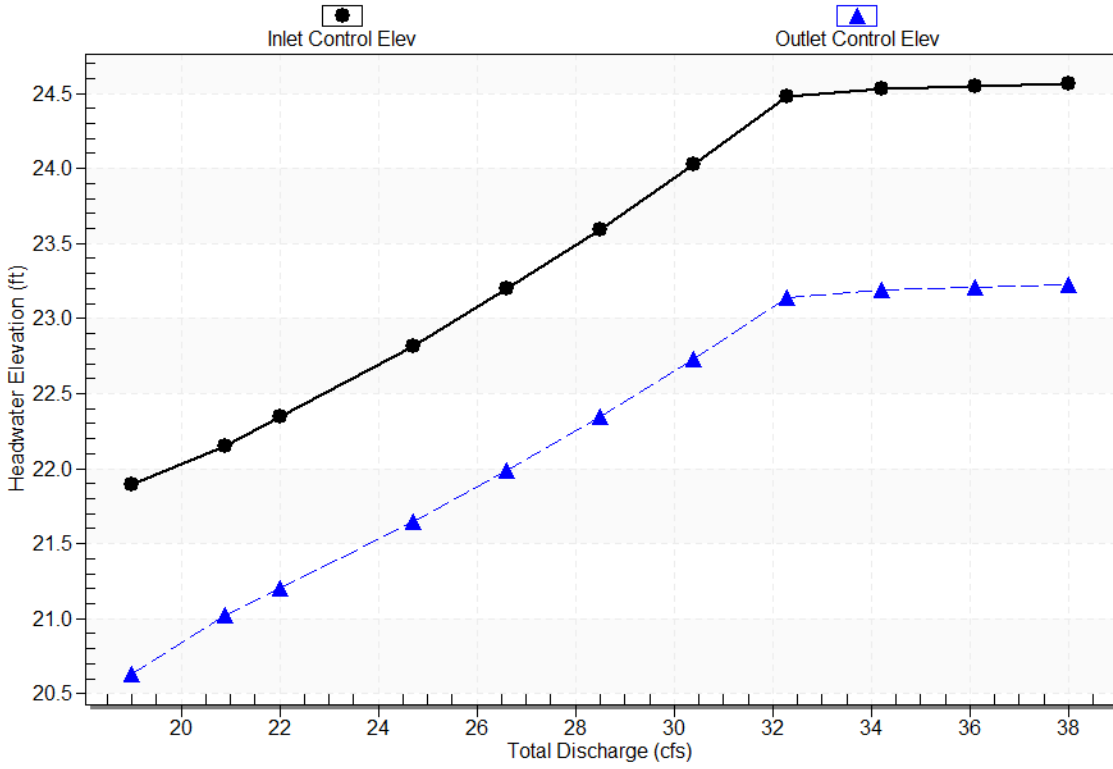
Culvert Length: 60.02 ft,

Culvert Slope: 0.0238

Culvert Performance Curve Plot: EX. CD-7

Performance Curve

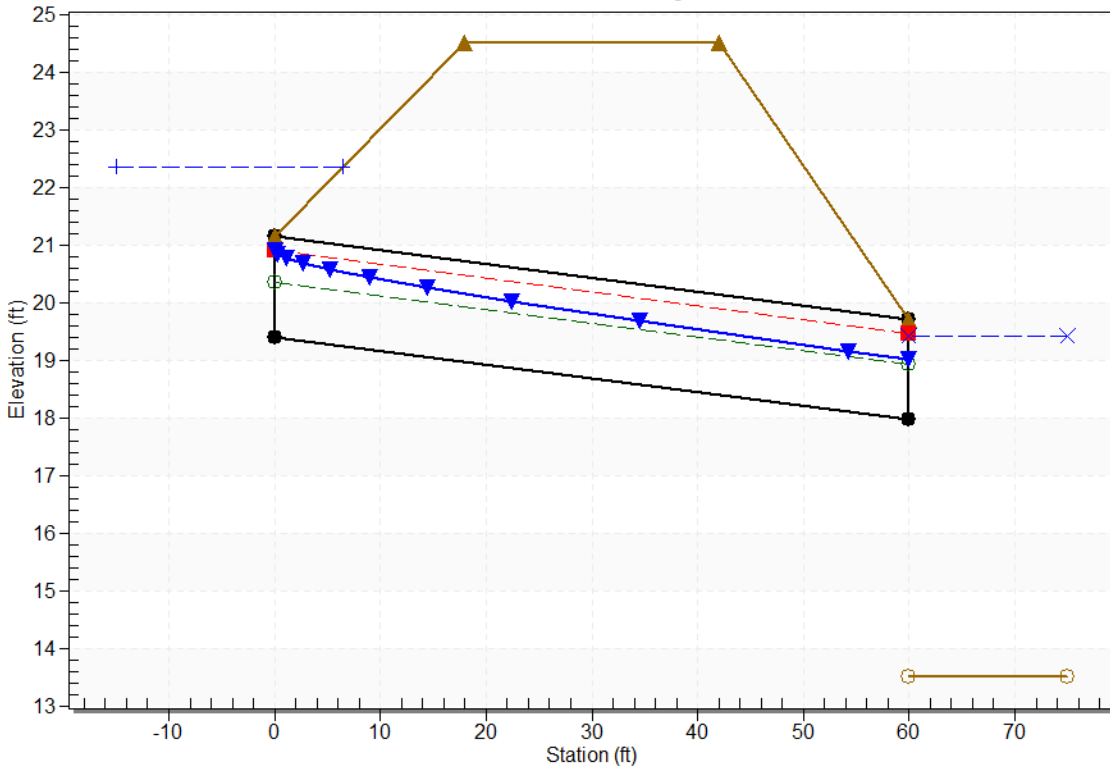
Culvert: EX. CD-7



### Water Surface Profile Plot for Culvert: EX. CD-7

Crossing - EX. CD-7, Design Discharge - 22.0 cfs

Culvert - EX. CD-7, Culvert Discharge - 22.0 cfs



### Site Data - EX. CD-7

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 19.40 ft

Outlet Station: 60.00 ft

Outlet Elevation: 17.97 ft

Number of Barrels: 1

### Culvert Data Summary - EX. CD-7

Barrel Shape: User Defined

Barrel Span: 2.34 ft

Barrel Rise: 1.75 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0120 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-7

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-7)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
19.00	19.43	5.91
20.90	19.43	5.91
22.00	19.43	5.91
24.70	19.43	5.91
26.60	19.43	5.91
28.50	19.43	5.91
30.40	19.43	5.91
32.30	19.43	5.91
34.20	19.43	5.91
36.10	19.43	5.91
38.00	19.43	5.91

### Tailwater Channel Data - EX. CD-7

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 19.43 ft

### Roadway Data for Crossing: EX. CD-7

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 24.50 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft



# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 18.00 cfs

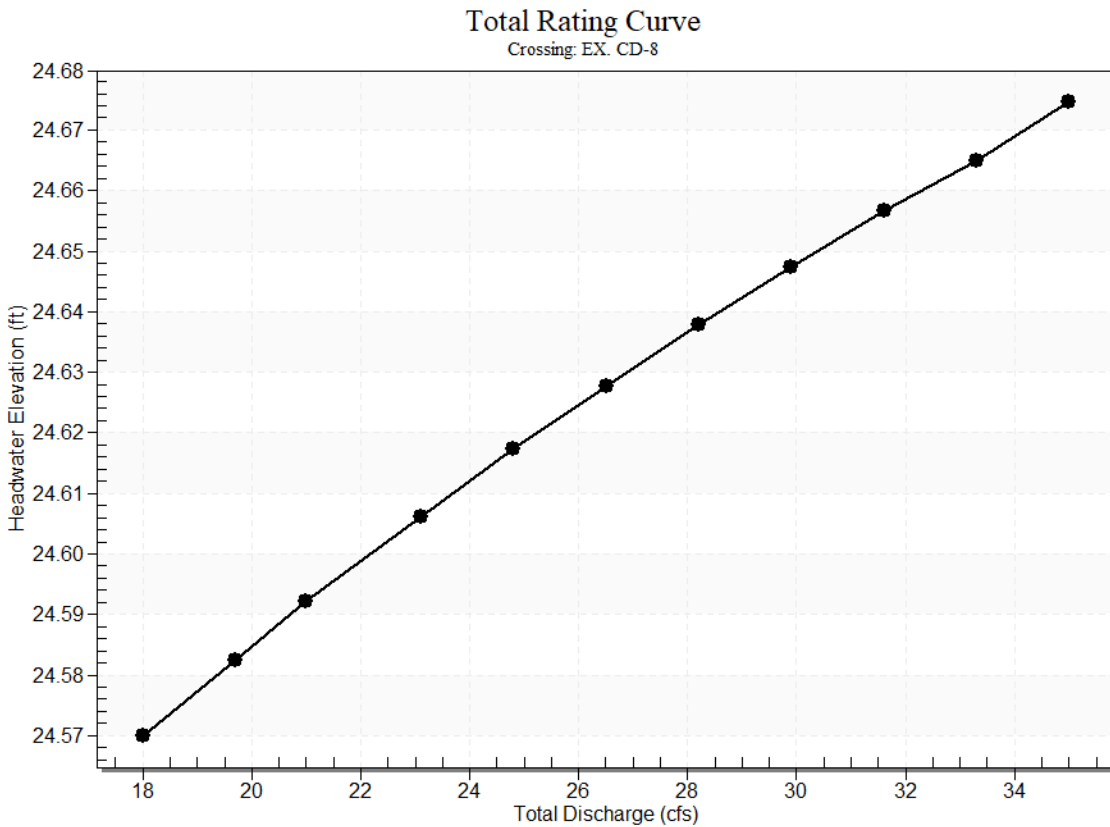
Design Flow: 21.00 cfs

Maximum Flow: 35.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-8**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-8 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
24.57	18.00	12.46	5.46	11
24.58	19.70	12.57	6.98	3
24.59	21.00	12.66	8.23	3
24.61	23.10	12.78	10.20	3
24.62	24.80	12.88	11.84	3
24.63	26.50	12.97	13.48	3
24.64	28.20	13.05	15.10	3
24.65	29.90	13.14	16.73	3
24.66	31.60	13.22	18.36	3
24.66	33.30	13.29	19.83	2
24.67	35.00	13.37	21.61	3
24.50	11.80	11.80	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-8**



**Culvert Data: EX. CD-8**

**Table 2 - Culvert Summary Table: EX. CD-8**

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)
18.00 cfs	12.46 cfs	24.57	1.65	3.560	4-FFf	0.68	1.07	1.50	8.36	4.28	0.00
19.70 cfs	12.57 cfs	24.58	1.66	3.572	4-FFf	0.68	1.07	1.50	8.36	4.32	0.00
21.00 cfs	12.66 cfs	24.59	1.67	3.582	4-FFf	0.69	1.07	1.50	8.36	4.35	0.00
23.10 cfs	12.78 cfs	24.61	1.69	3.596	4-FFf	0.69	1.08	1.50	8.36	4.39	0.00
24.80 cfs	12.88 cfs	24.62	1.70	3.607	4-FFf	0.69	1.08	1.50	8.36	4.43	0.00
26.50 cfs	12.97 cfs	24.63	1.71	3.618	4-FFf	0.69	1.09	1.50	8.36	4.46	0.00

<b>28.20</b> cfs	13.05 cfs	24.64	1.72	3.62 8	4- FFf	0.70	1.09	1.5 0	8.36	4.49	0.00
<b>29.90</b> cfs	13.14 cfs	24.65	1.73	3.63 7	4- FFf	0.70	1.09	1.5 0	8.36	4.51	0.00
<b>31.60</b> cfs	13.22 cfs	24.66	1.74	3.64 7	4- FFf	0.70	1.10	1.5 0	8.36	4.54	0.00
<b>33.30</b> cfs	13.29 cfs	24.66	1.75	3.65 5	4- FFf	0.70	1.10	1.5 0	8.36	4.57	0.00
<b>35.00</b> cfs	13.37 cfs	24.67	1.76	3.66 5	4- FFf	0.71	1.10	1.5 0	8.36	4.59	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

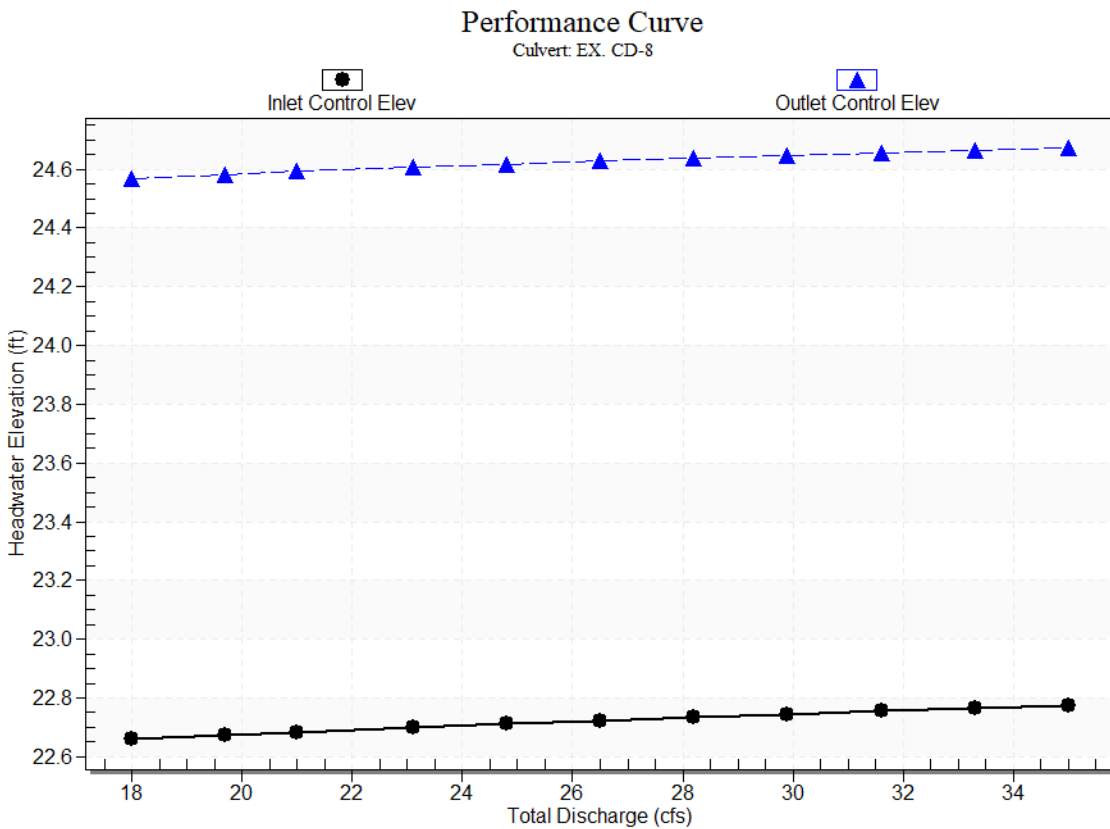
Inlet Elevation (invert): 21.01 ft,

Outlet Elevation (invert): 19.49 ft

Culvert Length: 78.01 ft,

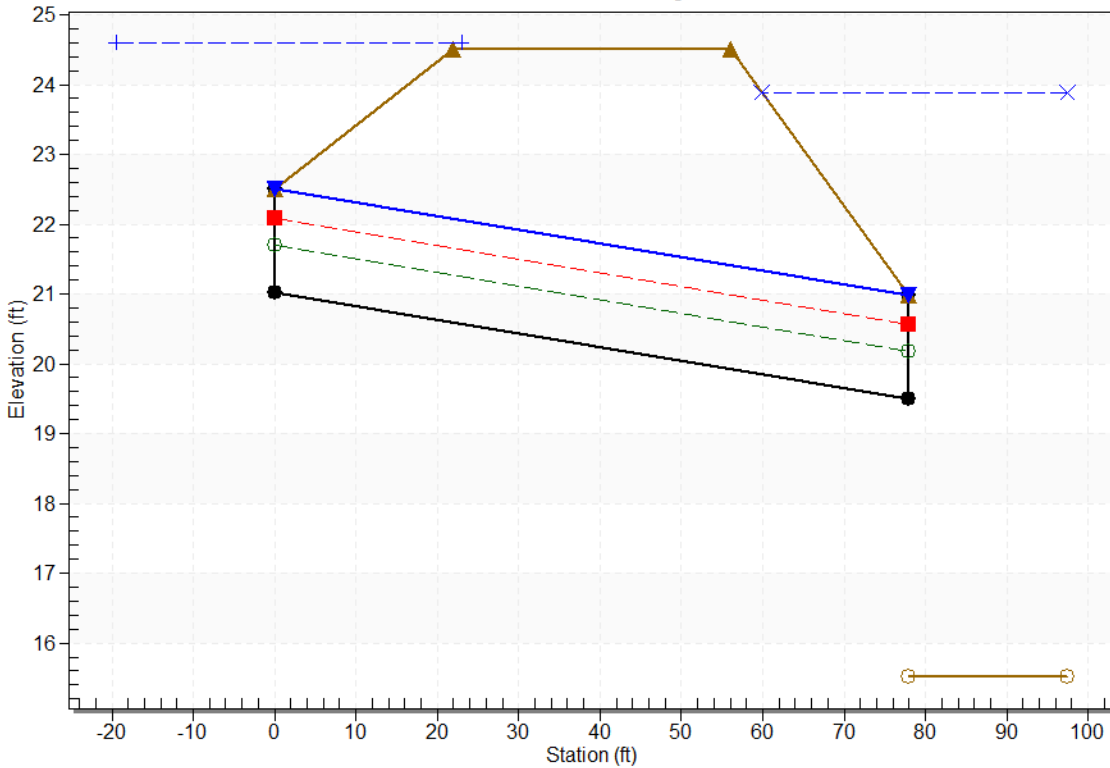
Culvert Slope: 0.0195

### Culvert Performance Curve Plot: EX. CD-8



### Water Surface Profile Plot for Culvert: EX. CD-8

Crossing - EX. CD-8, Design Discharge - 21.0 cfs  
Culvert - EX. CD-8, Culvert Discharge - 12.7 cfs



### Site Data - EX. CD-8

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 21.01 ft

Outlet Station: 78.00 ft

Outlet Elevation: 19.49 ft

Number of Barrels: 1

### Culvert Data Summary - EX. CD-8

Barrel Shape: User Defined

Barrel Span: 2.50 ft

Barrel Rise: 1.50 ft

Barrel Material: Concrete

Embedment: 0.00 in



Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0120 (bottom)

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-8

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-8)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
18.00	23.88	8.36
19.70	23.88	8.36
21.00	23.88	8.36
23.10	23.88	8.36
24.80	23.88	8.36
26.50	23.88	8.36
28.20	23.88	8.36
29.90	23.88	8.36
31.60	23.88	8.36
33.30	23.88	8.36
35.00	23.88	8.36

### Tailwater Channel Data - EX. CD-8

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 23.88 ft

### Roadway Data for Crossing: EX. CD-8

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 24.50 ft

Roadway Surface: Paved

Roadway Top Width: 34.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 19.00 cfs

Design Flow: 22.00 cfs

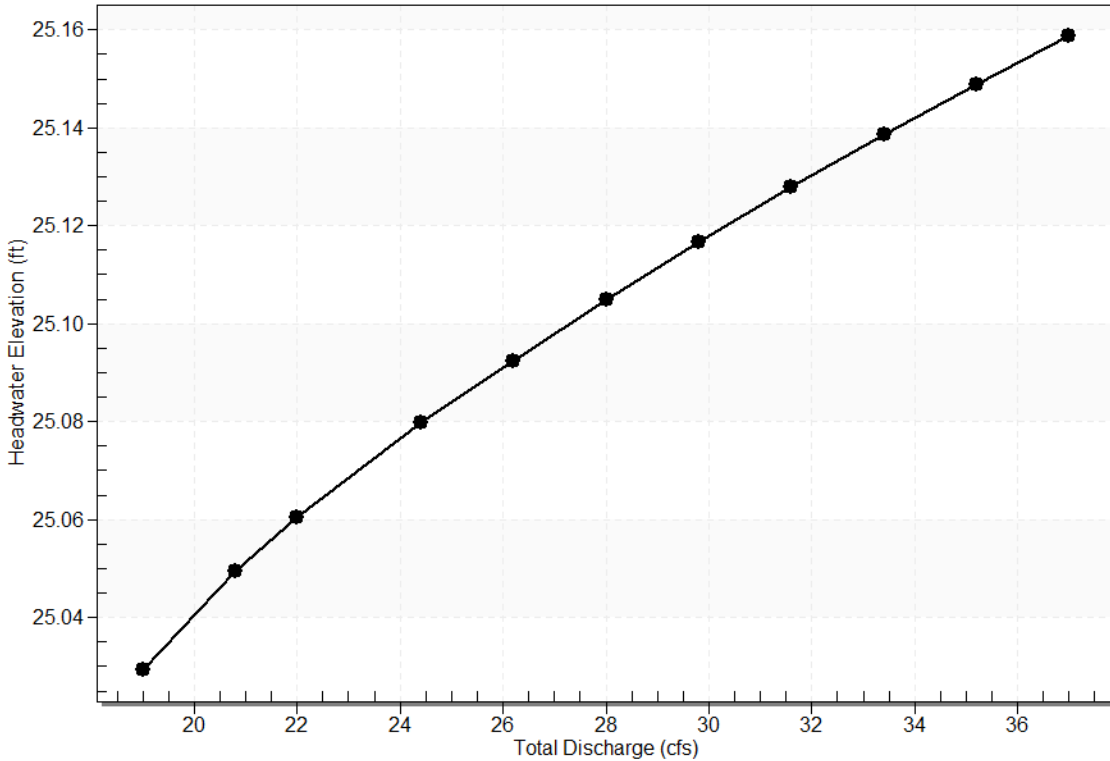
Maximum Flow: 37.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-9**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-9 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
25.03	19.00	17.35	1.49	13
25.05	20.80	17.50	3.23	5
25.06	22.00	17.58	4.35	4
25.08	24.40	17.73	6.60	4
25.09	26.20	17.82	8.24	3
25.10	28.00	17.91	9.96	3
25.12	29.80	18.00	11.71	3
25.13	31.60	18.08	13.45	3
25.14	33.40	18.15	15.19	3
25.15	35.20	18.23	16.94	3
25.16	37.00	18.30	18.67	3
25.00	17.12	17.12	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-9**

**Total Rating Curve**  
Crossing: EX. CD-9



**Culvert Data: EX. CD-9**

**Table 2 - Culvert Summary Table: EX. CD-9**

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)
19.00 cfs	17.35 cfs	25.03	2.21	5.159	4-FFf	0.84	1.26	1.58	8.41	5.41	0.00
20.80 cfs	17.50 cfs	25.05	2.23	5.179	4-FFf	0.84	1.26	1.58	8.41	5.46	0.00
22.00 cfs	17.58 cfs	25.06	2.24	5.190	4-FFf	0.84	1.26	1.58	8.41	5.49	0.00
24.40 cfs	17.73 cfs	25.08	2.25	5.210	4-FFf	0.85	1.27	1.58	8.41	5.53	0.00
26.20 cfs	17.82 cfs	25.09	2.27	5.222	4-FFf	0.85	1.27	1.58	8.41	5.56	0.00
28.00 cfs	17.91 cfs	25.10	2.28	5.235	4-FFf	0.85	1.28	1.58	8.41	5.59	0.00

<b>29.80</b> cfs	18.00 cfs	25.12	2.29	5.24 7	4- FFf	0.86	1.28	1.5 8	8.41	5.61	0.00
<b>31.60</b> cfs	18.08 cfs	25.13	2.30	5.25 8	4- FFf	0.86	1.28	1.5 8	8.41	5.64	0.00
<b>33.40</b> cfs	18.15 cfs	25.14	2.31	5.26 9	4- FFf	0.86	1.28	1.5 8	8.41	5.66	0.00
<b>35.20</b> cfs	18.23 cfs	25.15	2.32	5.27 9	4- FFf	0.86	1.29	1.5 8	8.41	5.69	0.00
<b>37.00</b> cfs	18.30 cfs	25.16	2.33	5.28 9	4- FFf	0.86	1.29	1.5 8	8.41	5.71	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

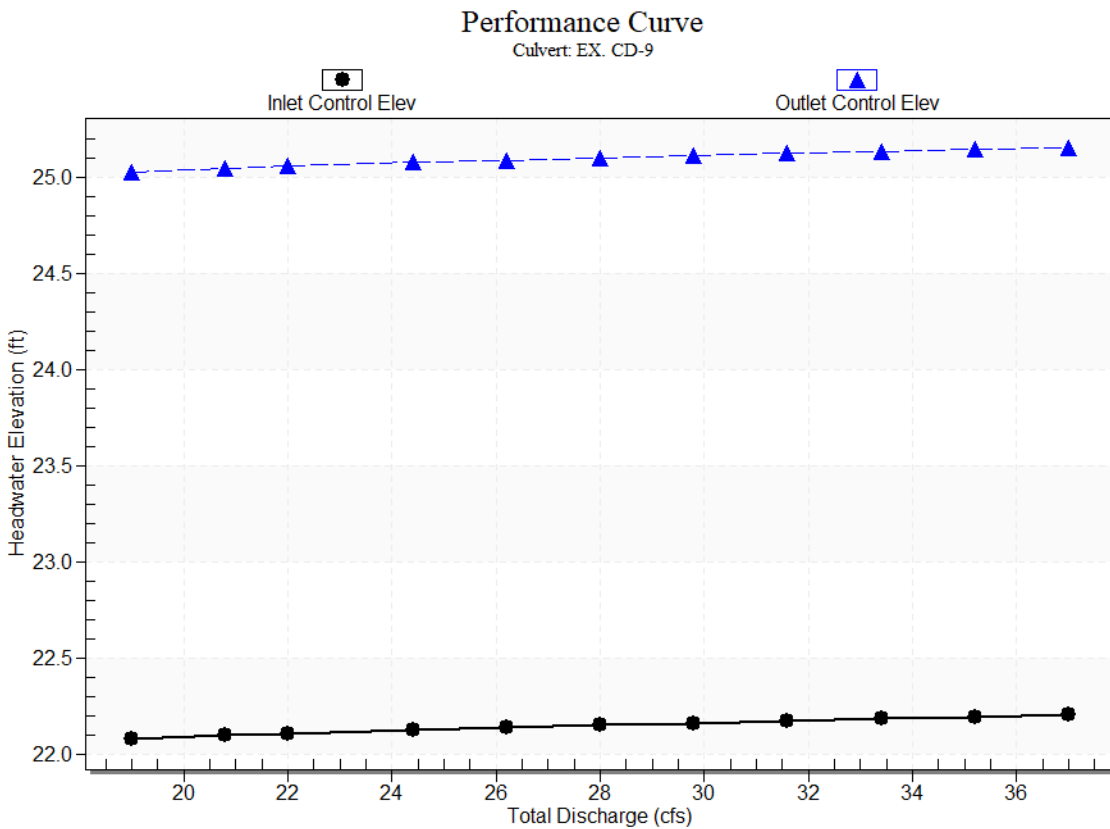
Inlet Elevation (invert): 19.87 ft,

Outlet Elevation (invert): 18.32 ft

Culvert Length: 94.01 ft,

Culvert Slope: 0.0165

### Culvert Performance Curve Plot: EX. CD-9

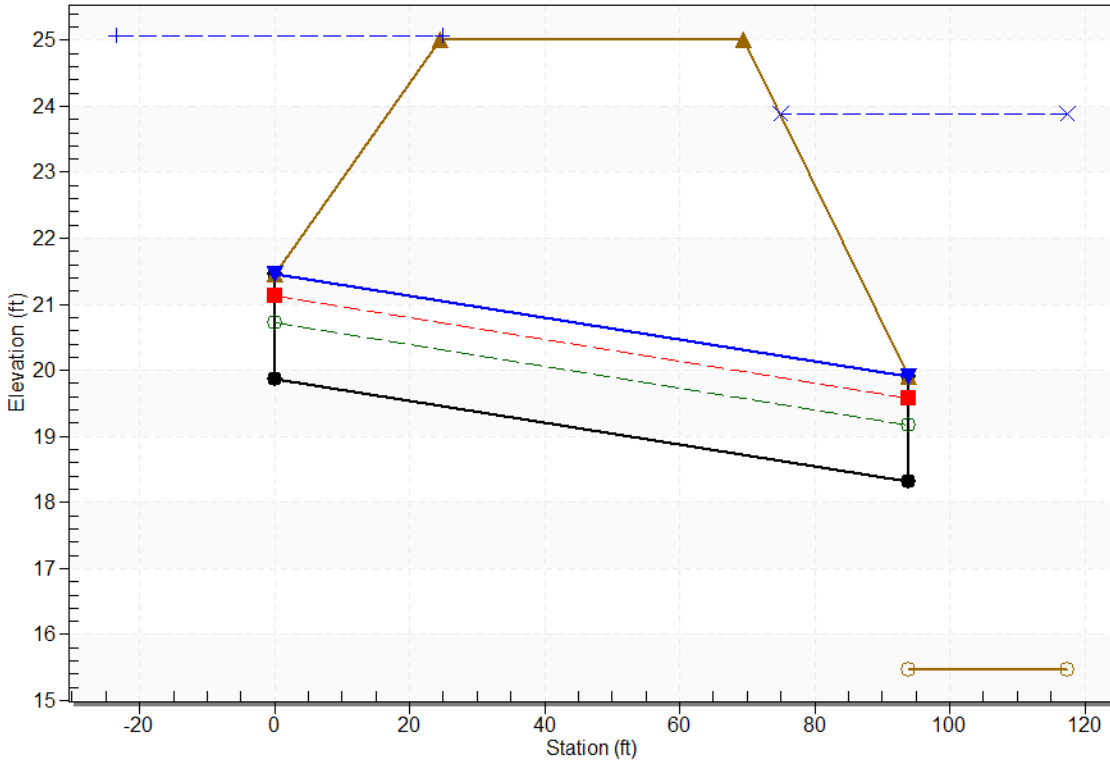




### Water Surface Profile Plot for Culvert: EX. CD-9

Crossing - EX. CD-9, Design Discharge - 22.0 cfs

Culvert - EX. CD-9, Culvert Discharge - 17.6 cfs



### Site Data - EX. CD-9

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 19.87 ft

Outlet Station: 94.00 ft

Outlet Elevation: 18.32 ft

Number of Barrels: 1

### Culvert Data Summary - EX. CD-9

Barrel Shape: Elliptical

Barrel Span: 30.00 in

Barrel Rise: 19.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-9

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-9)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
19.00	23.88	8.41
20.80	23.88	8.41
22.00	23.88	8.41
24.40	23.88	8.41
26.20	23.88	8.41
28.00	23.88	8.41
29.80	23.88	8.41
31.60	23.88	8.41
33.40	23.88	8.41
35.20	23.88	8.41
37.00	23.88	8.41

### Tailwater Channel Data - EX. CD-9

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 23.88 ft

### Roadway Data for Crossing: EX. CD-9

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 25.00 ft

Roadway Surface: Paved

Roadway Top Width: 45.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 19.00 cfs

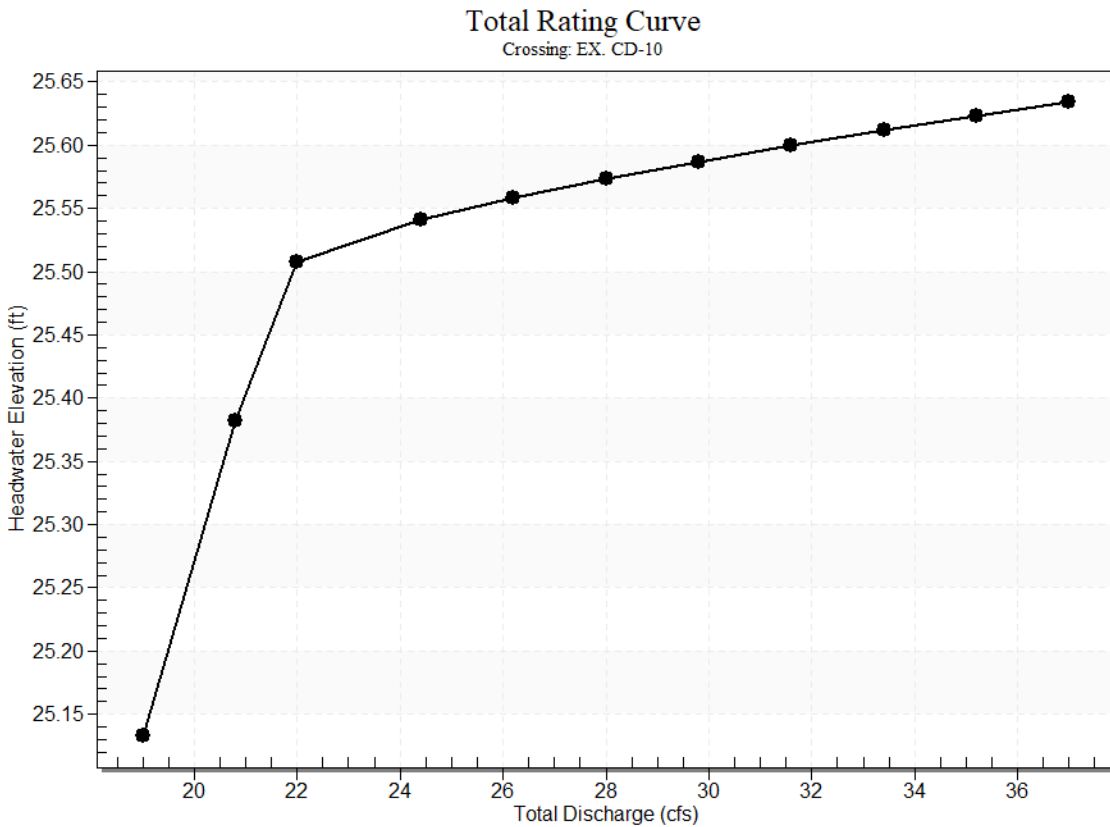
Design Flow: 22.00 cfs

Maximum Flow: 37.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: EX. CD-10**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>EX. CD-10 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
25.13	19.00	19.00	0.00	1
25.38	20.80	20.80	0.00	1
25.51	22.00	21.65	0.21	26
25.54	24.40	21.87	2.45	6
25.56	26.20	21.99	4.10	4
25.57	28.00	22.08	5.84	4
25.59	29.80	22.17	7.46	3
25.60	31.60	22.25	9.20	3
25.61	33.40	22.33	10.95	3
25.62	35.20	22.41	12.71	3
25.63	37.00	22.48	14.46	3
25.50	21.60	21.60	0.00	Overtopping

**Rating Curve Plot for Crossing: EX. CD-10**



**Culvert Data: EX. CD-10**

**Table 2 - Culvert Summary Table: EX. CD-10**

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)
19.00 cfs	19.00 cfs	25.13	2.43	3.283	4-FFf	0.80	1.31	1.58	7.89	5.93	0.00
20.80 cfs	20.80 cfs	25.38	2.70	3.532	4-FFf	0.84	1.37	1.58	7.89	6.49	0.00
22.00 cfs	21.65 cfs	25.51	2.83	3.658	4-FFf	0.86	1.39	1.58	7.89	6.76	0.00
24.40 cfs	21.87 cfs	25.54	2.87	3.691	4-FFf	0.87	1.39	1.58	7.89	6.82	0.00
26.20 cfs	21.99 cfs	25.56	2.89	3.708	4-FFf	0.87	1.40	1.58	7.89	6.86	0.00
28.00 cfs	22.08 cfs	25.57	2.90	3.723	4-FFf	0.88	1.40	1.58	7.89	6.89	0.00

<b>29.80</b> cfs	22.17 cfs	25.59	2.92	3.73 7	4- FFf	0.88	1.40	1.5 8	7.89	6.92	0.00
<b>31.60</b> cfs	22.25 cfs	25.60	2.93	3.75 0	4- FFf	0.88	1.40	1.5 8	7.89	6.94	0.00
<b>33.40</b> cfs	22.33 cfs	25.61	2.95	3.76 2	4- FFf	0.88	1.40	1.5 8	7.89	6.97	0.00
<b>35.20</b> cfs	22.41 cfs	25.62	2.96	3.77 3	4- FFf	0.88	1.40	1.5 8	7.89	6.99	0.00
<b>37.00</b> cfs	22.48 cfs	25.63	2.97	3.78 4	4- FFf	0.88	1.41	1.5 8	7.89	7.01	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

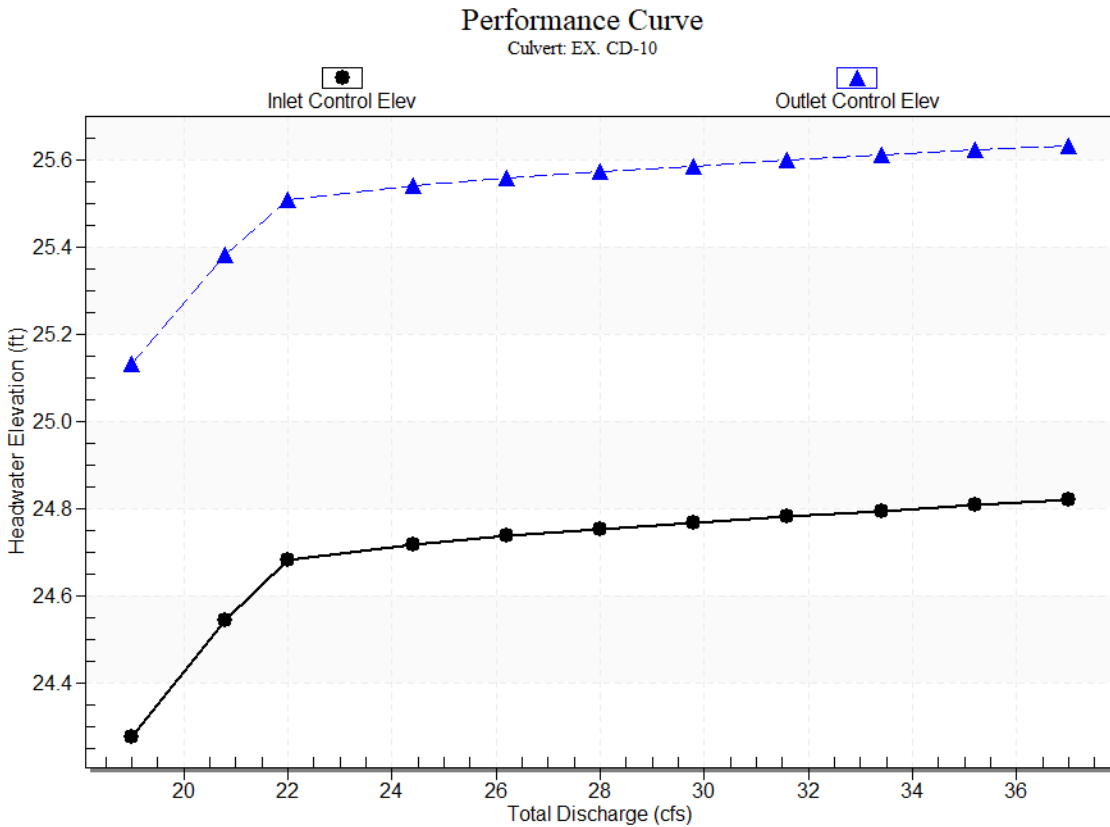
Inlet Elevation (invert): 21.85 ft,

Outlet Elevation (invert): 20.17 ft

Culvert Length: 73.02 ft,

Culvert Slope: 0.0230

### Culvert Performance Curve Plot: EX. CD-10

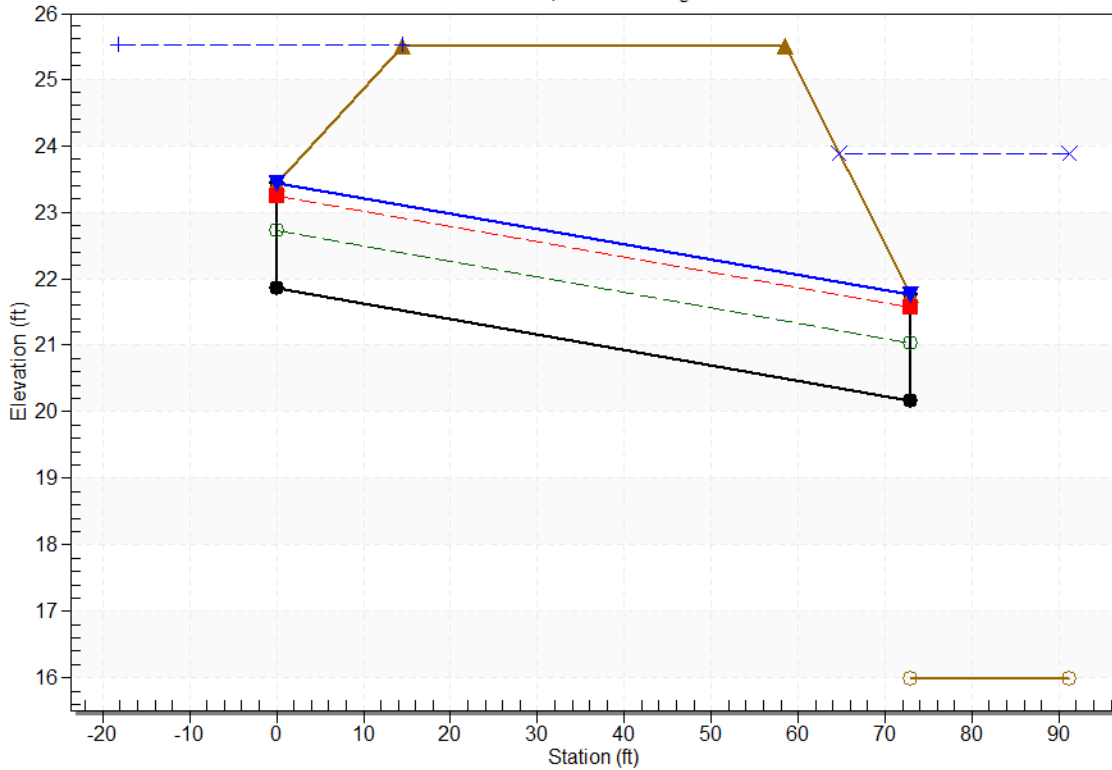




### Water Surface Profile Plot for Culvert: EX. CD-10

Crossing - EX. CD-10, Design Discharge - 22.0 cfs

Culvert - EX. CD-10, Culvert Discharge - 21.7 cfs



### Site Data - EX. CD-10

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 21.85 ft

Outlet Station: 73.00 ft

Outlet Elevation: 20.17 ft

Number of Barrels: 1

### Culvert Data Summary - EX. CD-10

Barrel Shape: Elliptical

Barrel Span: 30.00 in

Barrel Rise: 19.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: EX. CD-10

Table 3 - Downstream Channel Rating Curve (Crossing: EX. CD-10)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
19.00	23.88	7.89
20.80	23.88	7.89
22.00	23.88	7.89
24.40	23.88	7.89
26.20	23.88	7.89
28.00	23.88	7.89
29.80	23.88	7.89
31.60	23.88	7.89
33.40	23.88	7.89
35.20	23.88	7.89
37.00	23.88	7.89

### Tailwater Channel Data - EX. CD-10

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 23.88 ft

### Roadway Data for Crossing: EX. CD-10

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 25.50 ft

Roadway Surface: Paved

Roadway Top Width: 44.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 601.00 cfs

Design Flow: 704.00 cfs

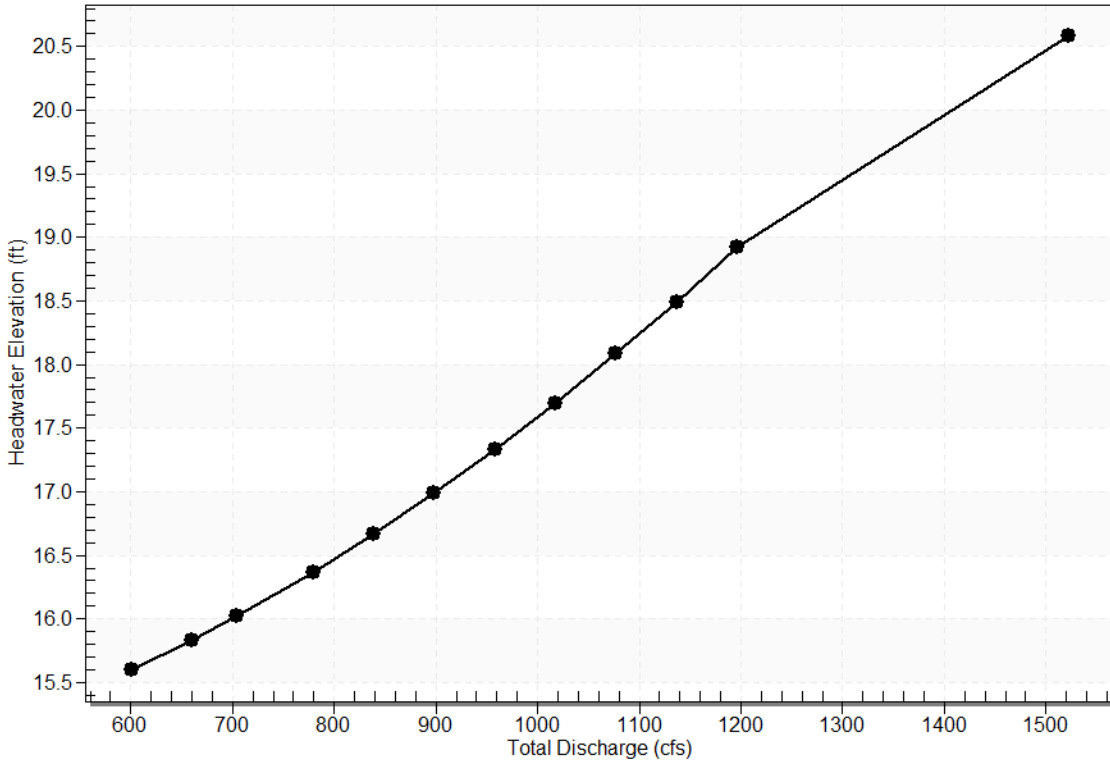
Maximum Flow: 1196.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-1**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-1 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
15.60	601.00	601.00	0.00	1
15.83	660.50	660.50	0.00	1
16.02	704.00	704.00	0.00	1
16.37	779.50	779.50	0.00	1
16.67	839.00	839.00	0.00	1
16.99	898.50	898.50	0.00	1
17.33	958.00	958.00	0.00	1
17.70	1017.50	1017.50	0.00	1
18.08	1077.00	1077.00	0.00	1
18.49	1136.50	1136.50	0.00	1
18.92	1196.00	1196.00	0.00	1
20.00	1333.14	1333.14	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-1**

**Total Rating Curve**  
Crossing: PR. CD-1



**Culvert Data: PR. CD-1**

**Table 2 - Culvert Summary Table: PR. CD-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)
601.0	601.0	15.60	6.57	9.56	4-2	8.00	4.38	8.0	8.58	5.98	0.00
660.5	660.5	15.83	6.99	9.79	4-5	8.00	4.60	8.0	8.58	6.57	0.00
704.0	704.0	16.02	7.31	9.97	4-9	8.00	4.76	8.0	8.58	7.00	0.00
779.5	779.5	16.37	7.88	10.3	4-27	8.00	5.02	8.0	8.58	7.75	0.00
839.0	839.0	16.67	8.37	10.6	4-26	8.00	5.21	8.0	8.58	8.35	0.00
898.5	898.5	16.99	8.89	10.9	4-47	8.00	5.40	8.0	8.58	8.94	0.00

<b>958.0</b> <b>0 cfs</b>	958.0 0 cfs	17.33	9.44	11.2	4-	8.00	5.58	8.0	8.58	9.53	0.00
<b>1017.</b> <b>50 cfs</b>	1017. 50 cfs	17.70	10.0	11.6	4-	8.00	5.75	8.0	8.58	10.1	0.00
<b>1077.</b> <b>00 cfs</b>	1077. 00 cfs	18.08	10.6	12.0	4-	8.00	5.91	8.0	8.58	10.7	0.00
<b>1136.</b> <b>50 cfs</b>	1136. 50 cfs	18.49	11.3	12.4	4-	8.00	6.07	8.0	8.58	11.3	0.00
<b>1196.</b> <b>00 cfs</b>	1196. 00 cfs	18.92	12.0	12.8	4-	8.00	6.22	8.0	8.58	11.9	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

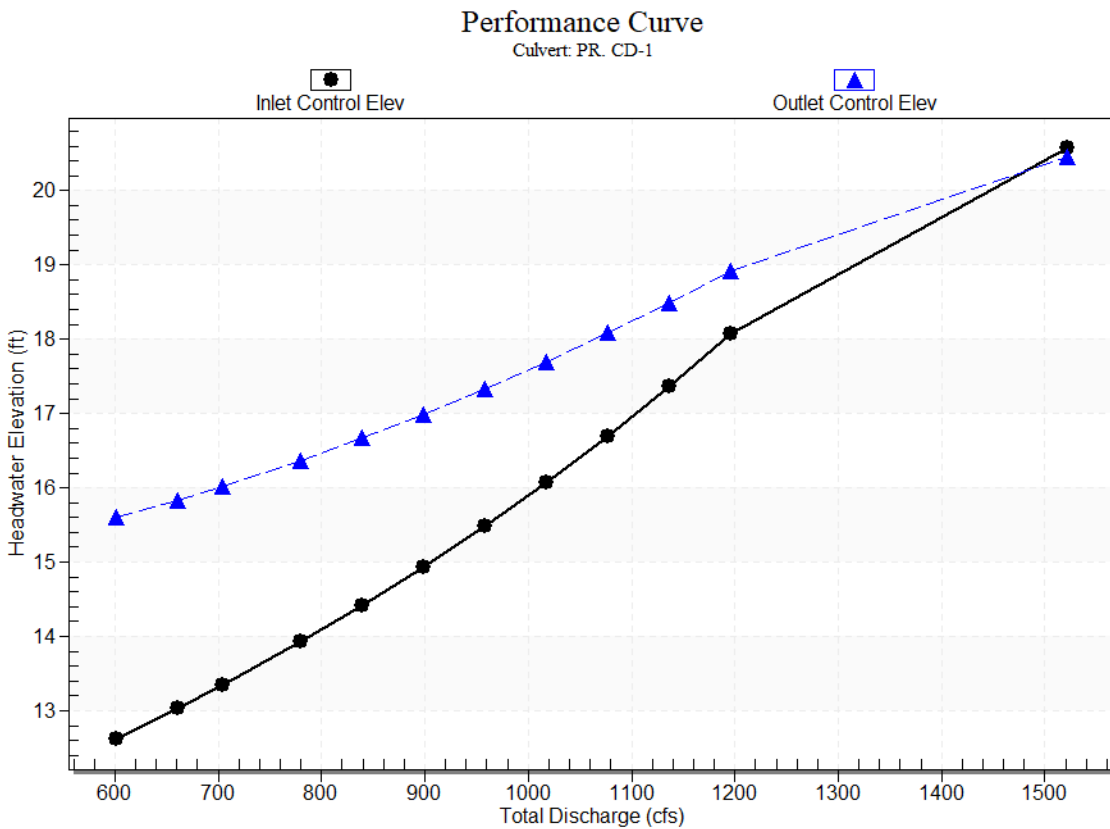
Inlet Elevation (invert): 6.04 ft,

Outlet Elevation (invert): 5.90 ft

Culvert Length: 194.00 ft,

Culvert Slope: 0.0007

### Culvert Performance Curve Plot: PR. CD-1

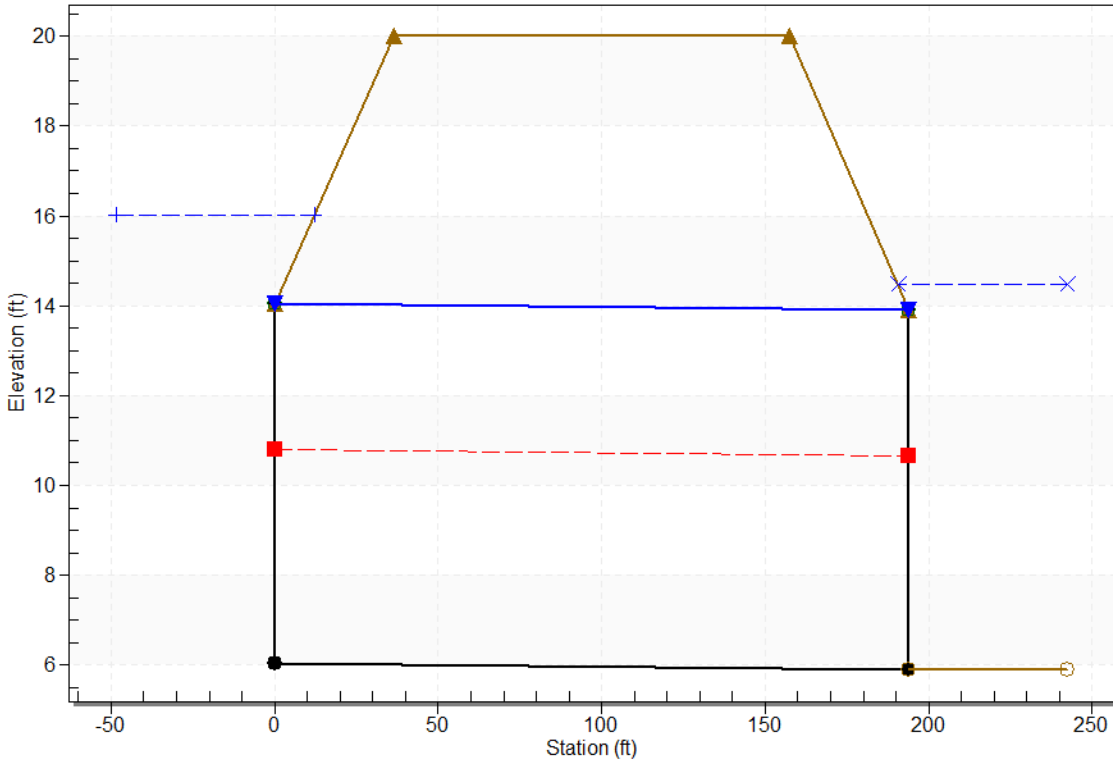




### Water Surface Profile Plot for Culvert: PR. CD-1

Crossing - PR. CD-1, Design Discharge - 704.0 cfs

Culvert - PR. CD-1, Culvert Discharge - 704.0 cfs



### Site Data - PR. CD-1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 6.04 ft

Outlet Station: 194.00 ft

Outlet Elevation: 5.90 ft

Number of Barrels: 2

### Culvert Data Summary - PR. CD-1

Barrel Shape: Circular

Barrel Diameter: 8.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Mitered to Conform to Slope (Ke=0.7)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-1

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

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
601.00	14.48	8.58
660.50	14.48	8.58
704.00	14.48	8.58
779.50	14.48	8.58
839.00	14.48	8.58
898.50	14.48	8.58
958.00	14.48	8.58
1017.50	14.48	8.58
1077.00	14.48	8.58
1136.50	14.48	8.58
1196.00	14.48	8.58

### Tailwater Channel Data - PR. CD-1

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.48 ft

### Roadway Data for Crossing: PR. CD-1

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 20.00 ft

Roadway Surface: Paved

Roadway Top Width: 121.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 287.00 cfs

Design Flow: 336.00 cfs

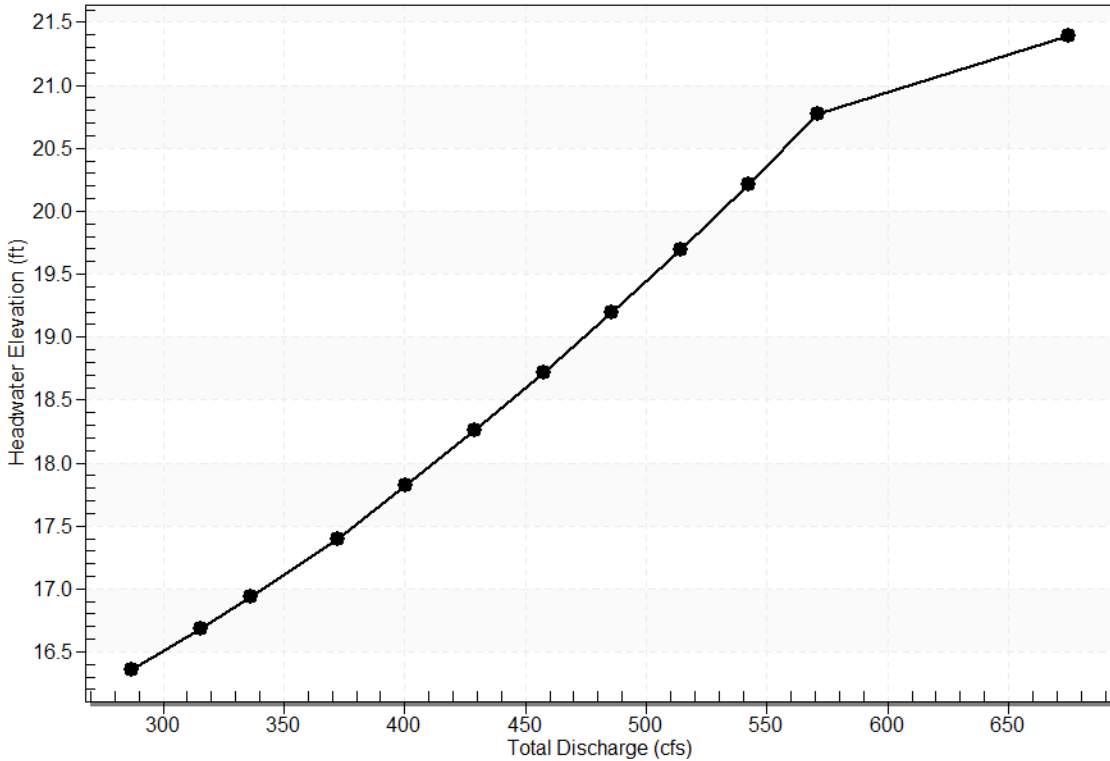
Maximum Flow: 571.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-2**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-2 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
16.36	287.00	287.00	0.00	1
16.69	315.40	315.40	0.00	1
16.94	336.00	336.00	0.00	1
17.40	372.20	372.20	0.00	1
17.82	400.60	400.60	0.00	1
18.26	429.00	429.00	0.00	1
18.71	457.40	457.40	0.00	1
19.19	485.80	485.80	0.00	1
19.69	514.20	514.20	0.00	1
20.22	542.60	542.60	0.00	1
20.77	571.00	571.00	0.00	1
21.00	582.40	582.40	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-2**

**Total Rating Curve**  
Crossing: PR. CD-2



**Culvert Data: PR. CD-2**

**Table 2 - Culvert Summary Table: PR. CD-2**

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)
287.0	287.0	16.36	5.79	5.96	3-M1	4.25	3.42	4.47	4.47	8.03	0.00
315.4	315.4	16.69	6.19	6.28	3-M2	4.57	3.64	4.47	4.47	8.82	0.00
336.0	336.0	16.94	6.48	6.53	3-M2	4.79	3.80	4.47	4.47	9.40	0.00
372.2	372.2	17.40	7.00	6.98	3-M2	5.19	4.07	4.47	4.47	10.41	0.00

<b>400.6 0 cfs</b>	400.6 0 cfs	17.82	7.42	7.33 5	3- M2 t	5.49	4.27	4.4 7	4.47	11.2 0	0.00
<b>429.0 0 cfs</b>	429.0 0 cfs	18.26	7.86	7.67 8	3- M2 t	5.79	4.47	4.4 7	4.47	12.0 0	0.00
<b>457.4 0 cfs</b>	457.4 0 cfs	18.71	8.31	8.01 3	7- M2 c	6.00	4.67	4.6 7	4.47	12.2 6	0.00
<b>485.8 0 cfs</b>	485.8 0 cfs	19.19	8.79	8.34 1	7- M2 c	6.00	4.86	4.8 6	4.47	12.5 0	0.00
<b>514.2 0 cfs</b>	514.2 0 cfs	19.69	9.29	8.66 3	7- M2 c	6.00	5.04	5.0 4	4.47	12.7 4	0.00
<b>542.6 0 cfs</b>	542.6 0 cfs	20.22	9.82	8.97 9	7- M2 c	6.00	5.23	5.2 3	4.47	12.9 7	0.00
<b>571.0 0 cfs</b>	571.0 0 cfs	20.77	10.3 7	9.41 5	7- M2 c	6.00	5.41	5.4 1	4.47	13.2 0	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 10.40 ft,

Outlet Elevation (invert): 10.22 ft

Culvert Length: 102.00 ft,

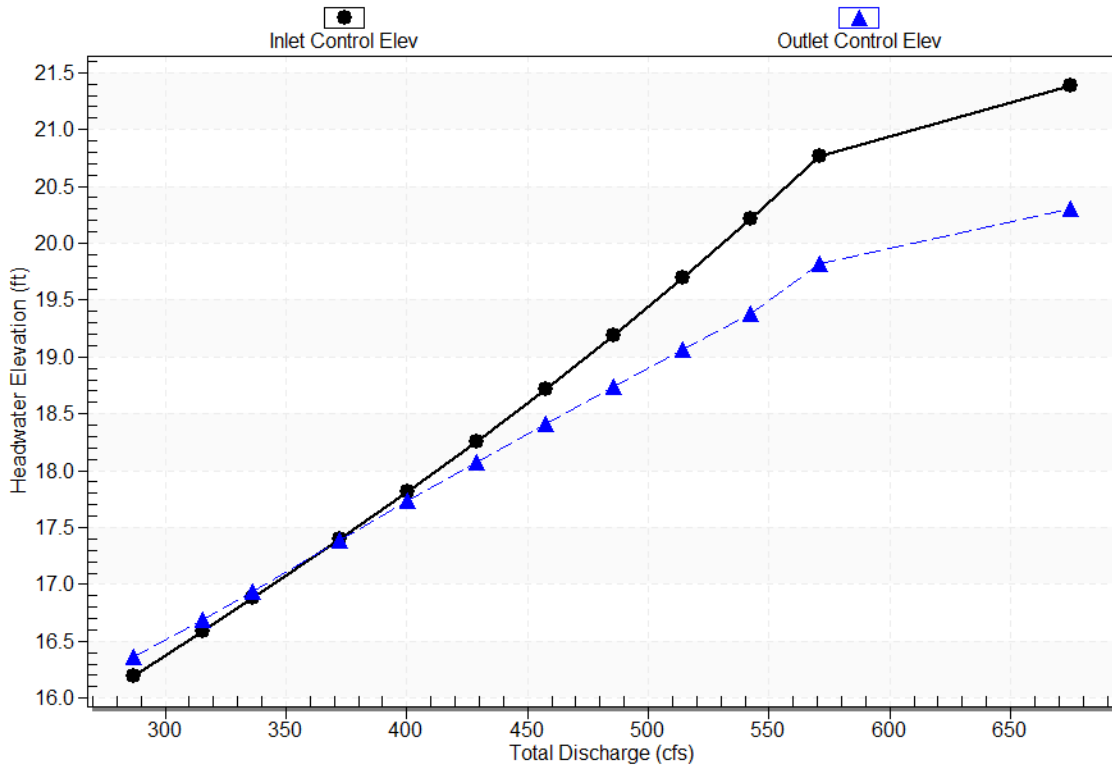
Culvert Slope: 0.0018



### Culvert Performance Curve Plot: PR. CD-2

#### Performance Curve

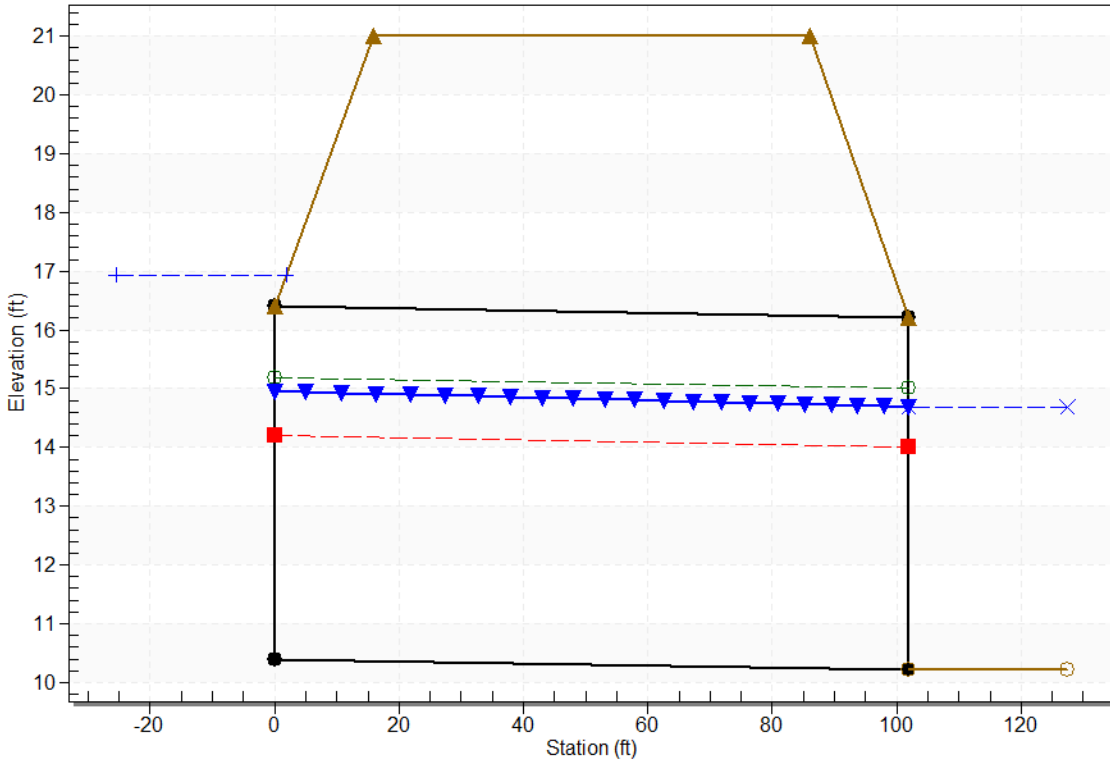
Culvert: PR. CD-2



### Water Surface Profile Plot for Culvert: PR. CD-2

Crossing - PR. CD-2, Design Discharge - 336.0 cfs

Culvert - PR. CD-2, Culvert Discharge - 336.0 cfs



### Site Data - PR. CD-2

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 10.40 ft

Outlet Station: 102.00 ft

Outlet Elevation: 10.22 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-2

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-2

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-2)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
287.00	14.69	4.47
315.40	14.69	4.47
336.00	14.69	4.47
372.20	14.69	4.47
400.60	14.69	4.47
429.00	14.69	4.47
457.40	14.69	4.47
485.80	14.69	4.47
514.20	14.69	4.47
542.60	14.69	4.47
571.00	14.69	4.47

### Tailwater Channel Data - PR. CD-2

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.69 ft

### Roadway Data for Crossing: PR. CD-2

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 21.00 ft

Roadway Surface: Paved

Roadway Top Width: 70.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 95.00 cfs

Design Flow: 111.00 cfs

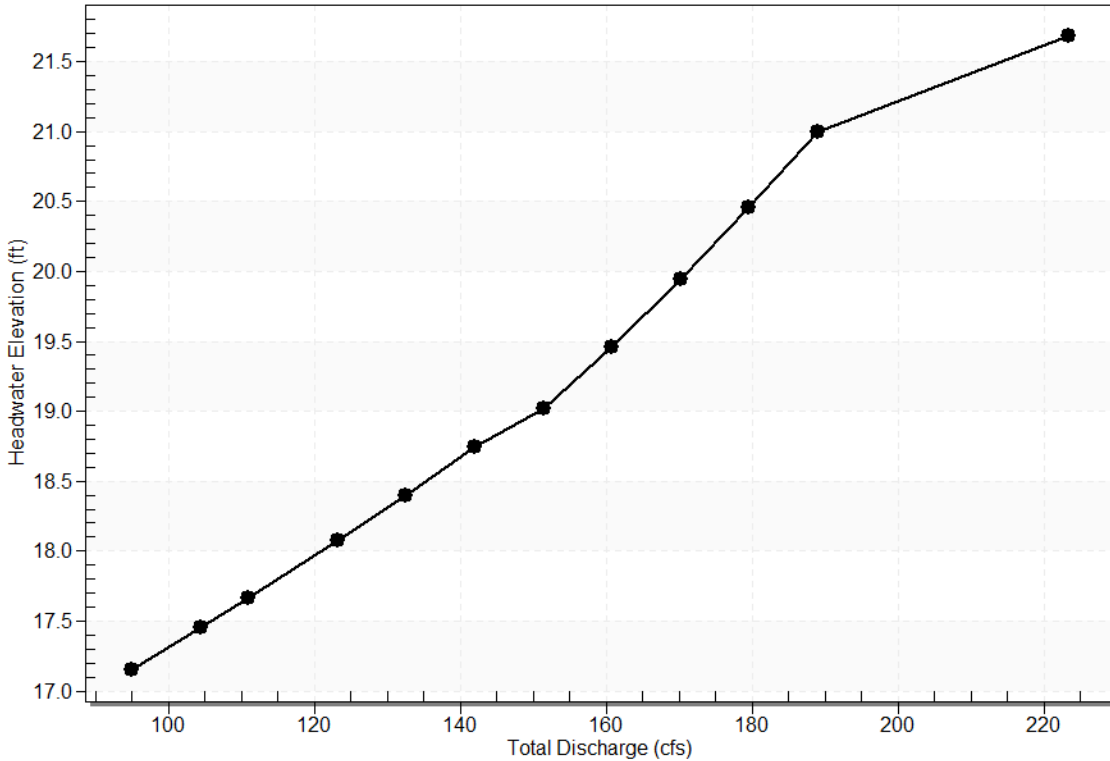
Maximum Flow: 189.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-4**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-4 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
17.15	95.00	95.00	0.00	1
17.45	104.40	104.40	0.00	1
17.67	111.00	111.00	0.00	1
18.07	123.20	123.20	0.00	1
18.40	132.60	132.60	0.00	1
18.75	142.00	142.00	0.00	1
19.02	151.40	151.40	0.00	1
19.46	160.80	160.80	0.00	1
19.94	170.20	170.20	0.00	1
20.45	179.60	179.60	0.00	1
21.00	189.00	189.00	0.00	1
21.50	197.30	197.30	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-4**

**Total Rating Curve**  
Crossing: PR. CD-4



**Culvert Data: PR. CD-4**

**Table 2 - Culvert Summary Table: PR. CD-4**

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)
95.00 cfs	95.00 cfs	17.15	4.45	4.743	7-c	-	2.86	2.86	2.25	8.91	0.00
104.40 cfs	104.40 cfs	17.45	4.75	5.045	7-c	-	3.00	3.00	2.25	9.26	0.00
111.00 cfs	111.00 cfs	17.67	4.98	5.258	7-c	-	3.10	3.10	2.25	9.50	0.00
123.20 cfs	123.20 cfs	18.07	5.42	5.662	7-c	-	3.27	3.27	2.25	9.96	0.00



<b>132.6</b> <b>0 cfs</b>	132.6 0 cfs	18.40	5.79	5.98 8	7- A2 c	- 1.00	3.39	3.3 9	2.25	10.3 2	0.00
<b>142.0</b> <b>0 cfs</b>	142.0 0 cfs	18.75	6.18	6.33 6	7- A2 c	- 1.00	3.50	3.5 0	2.25	10.6 9	0.00
<b>151.4</b> <b>0 cfs</b>	151.4 0 cfs	19.02	6.60	6.61 2	7- A2 c	- 1.00	3.61	3.6 1	2.25	11.0 8	0.00
<b>160.8</b> <b>0 cfs</b>	160.8 0 cfs	19.46	7.05	6.88 3	7- JA 2c	- 1.00	3.71	3.7 1	2.25	11.4 7	0.00
<b>170.2</b> <b>0 cfs</b>	170.2 0 cfs	19.94	7.53	7.17 0	7- JA 2c	- 1.00	3.80	3.8 0	2.25	11.8 8	0.00
<b>179.6</b> <b>0 cfs</b>	179.6 0 cfs	20.45	8.04	7.47 3	7- JA 2c	- 1.00	3.88	3.8 8	2.25	12.3 1	0.00
<b>189.0</b> <b>0 cfs</b>	189.0 0 cfs	21.00	8.59	7.79 2	7- JA 2c	- 1.00	3.96	3.9 6	2.25	12.7 6	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 12.41 ft,

Outlet Elevation (invert): 12.44 ft

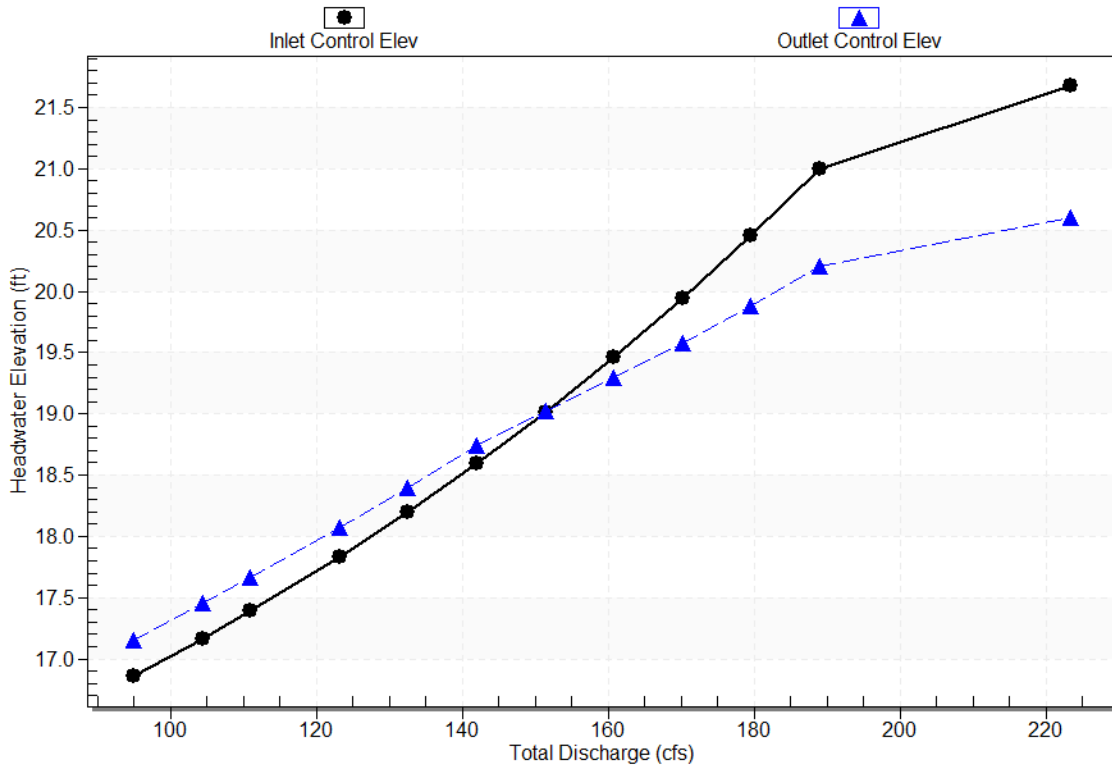
Culvert Length: 102.00 ft,

Culvert Slope: -0.0003

### Culvert Performance Curve Plot: PR. CD-4

#### Performance Curve

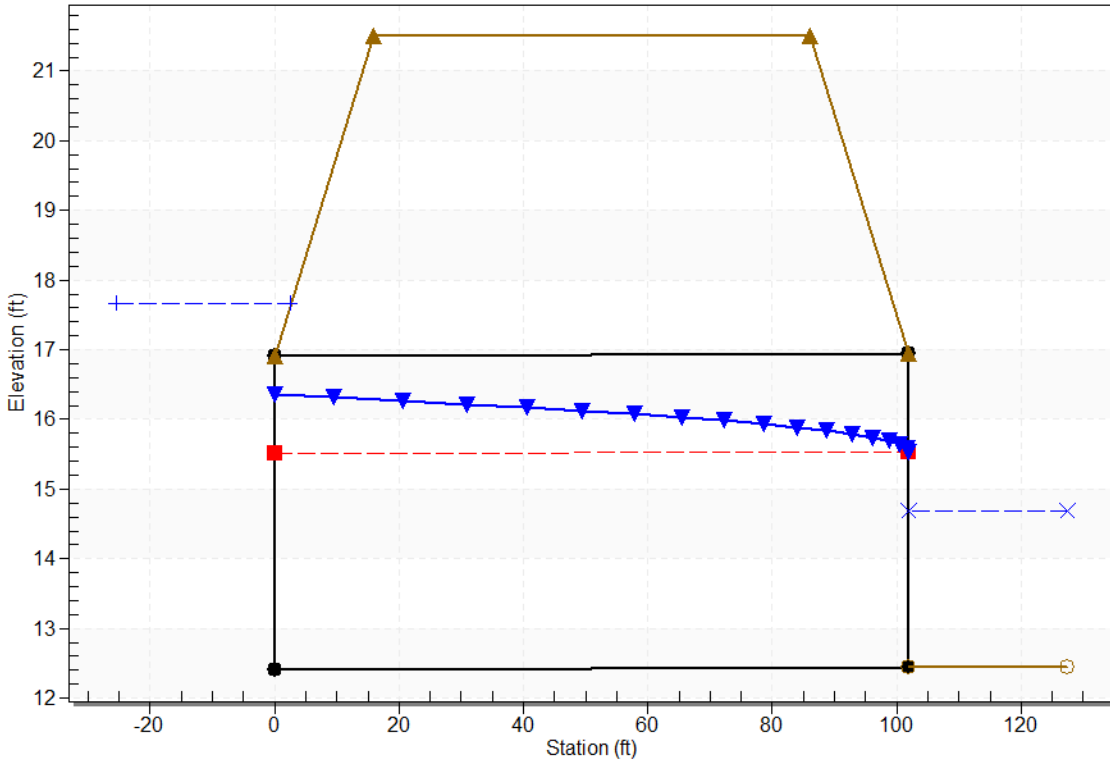
Culvert: PR. CD-4



### Water Surface Profile Plot for Culvert: PR. CD-4

Crossing - PR. CD-4, Design Discharge - 111.0 cfs

Culvert - PR. CD-4, Culvert Discharge - 111.0 cfs



### Site Data - PR. CD-4

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 12.41 ft

Outlet Station: 102.00 ft

Outlet Elevation: 12.44 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-4

Barrel Shape: Circular

Barrel Diameter: 4.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall ( $K_e=0.5$ )

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-4

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-4)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
95.00	14.69	2.25
104.40	14.69	2.25
111.00	14.69	2.25
123.20	14.69	2.25
132.60	14.69	2.25
142.00	14.69	2.25
151.40	14.69	2.25
160.80	14.69	2.25
170.20	14.69	2.25
179.60	14.69	2.25
189.00	14.69	2.25

### Tailwater Channel Data - PR. CD-4

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 14.69 ft

### Roadway Data for Crossing: PR. CD-4

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 21.50 ft

Roadway Surface: Paved

Roadway Top Width: 70.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 9.00 cfs

Design Flow: 10.00 cfs

Maximum Flow: 18.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-5**

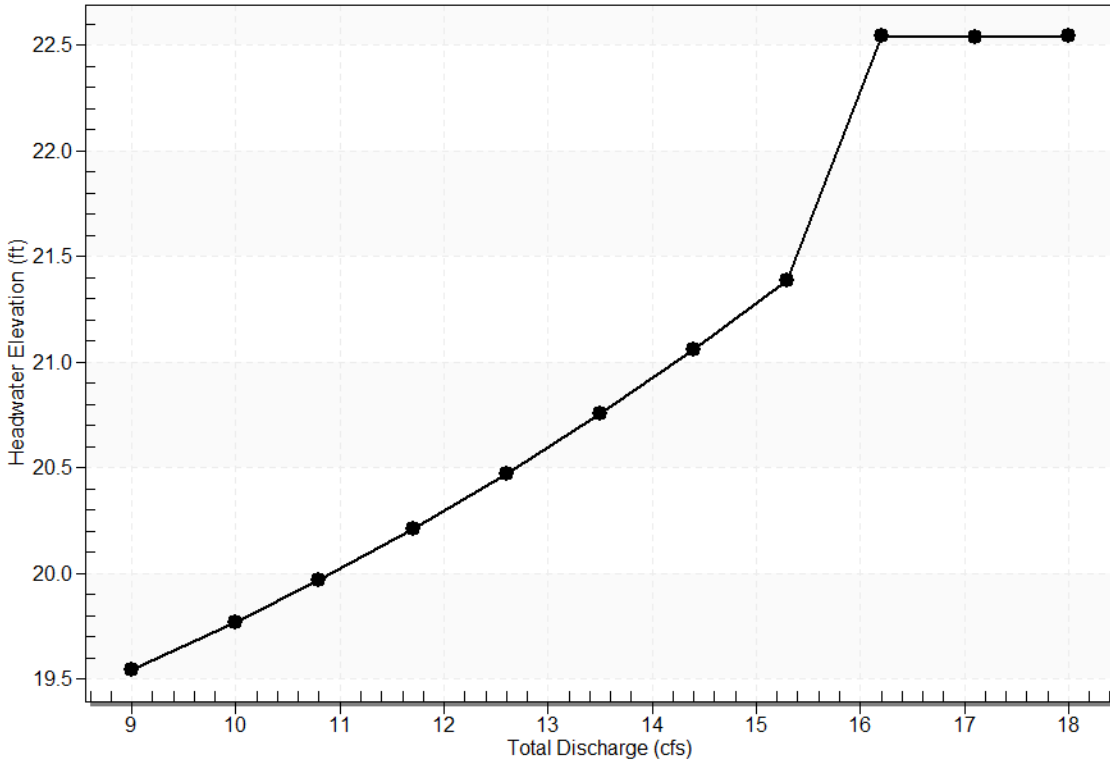
<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-5 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
19.55	9.00	9.00	0.00	1
19.77	10.00	10.00	0.00	1
19.97	10.80	10.80	0.00	1
20.21	11.70	11.70	0.00	1
20.47	12.60	12.60	0.00	1
20.75	13.50	13.50	0.00	1
21.06	14.40	14.40	0.00	1
21.39	15.30	15.30	0.00	1
22.54	16.20	15.62	0.48	23
22.54	17.10	15.62	1.43	5
22.54	18.00	15.62	2.33	4
22.50	15.61	15.61	0.00	Overtopping



**Rating Curve Plot for Crossing: PR. CD-5**

**Total Rating Curve**

Crossing: PR. CD-5



**Culvert Data: PR. CD-5**

**Table 2 - Culvert Summary Table: PR. CD-5**

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
<b>9.00 cfs</b>	9.00 cfs	19.55	1.75	1.046	5- JS1 f	0.67	0.96	1.17	5.90	5.06	0.00
<b>10.00 cfs</b>	10.00 cfs	19.77	1.97	1.477	5- JS1 f	0.71	1.01	1.17	5.90	5.62	0.00
<b>10.80 cfs</b>	10.80 cfs	19.97	2.17	1.854	5- JS1 f	0.75	1.04	1.17	5.90	6.07	0.00
<b>11.70 cfs</b>	11.70 cfs	20.21	2.41	2.314	5- JS1 f	0.79	1.06	1.17	5.90	6.58	0.00

<b>12.60 cfs</b>	12.60 cfs	20.47	2.67	0.0*	5- JS1 f	0.83	1.08	1.1 7	5.90	7.08	0.00
<b>13.50 cfs</b>	13.50 cfs	20.75	2.95	0.0*	5- JS1 f	0.88	1.10	1.1 7	5.90	7.59	0.00
<b>14.40 cfs</b>	14.40 cfs	21.06	3.26	0.0*	5- JS1 f	0.93	1.11	1.1 7	5.90	8.10	0.00
<b>15.30 cfs</b>	15.30 cfs	21.39	3.59	0.0*	5- JS1 f	0.98	1.07	1.1 7	5.90	8.60	0.00
<b>16.20 cfs</b>	15.62 cfs	22.54	3.71	4.74 1	4- FFf	1.17	1.14	1.1 7	5.90	8.78	0.00
<b>17.10 cfs</b>	15.62 cfs	22.54	3.71	4.73 9	4- FFf	1.17	1.14	1.1 7	5.90	8.78	0.00
<b>18.00 cfs</b>	15.62 cfs	22.54	3.71	4.74 1	4- FFf	1.17	1.14	1.1 7	5.90	8.78	0.00

\* Full Flow Headwater elevation is below inlet invert.

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 17.80 ft,

Outlet Elevation (invert): 14.60 ft

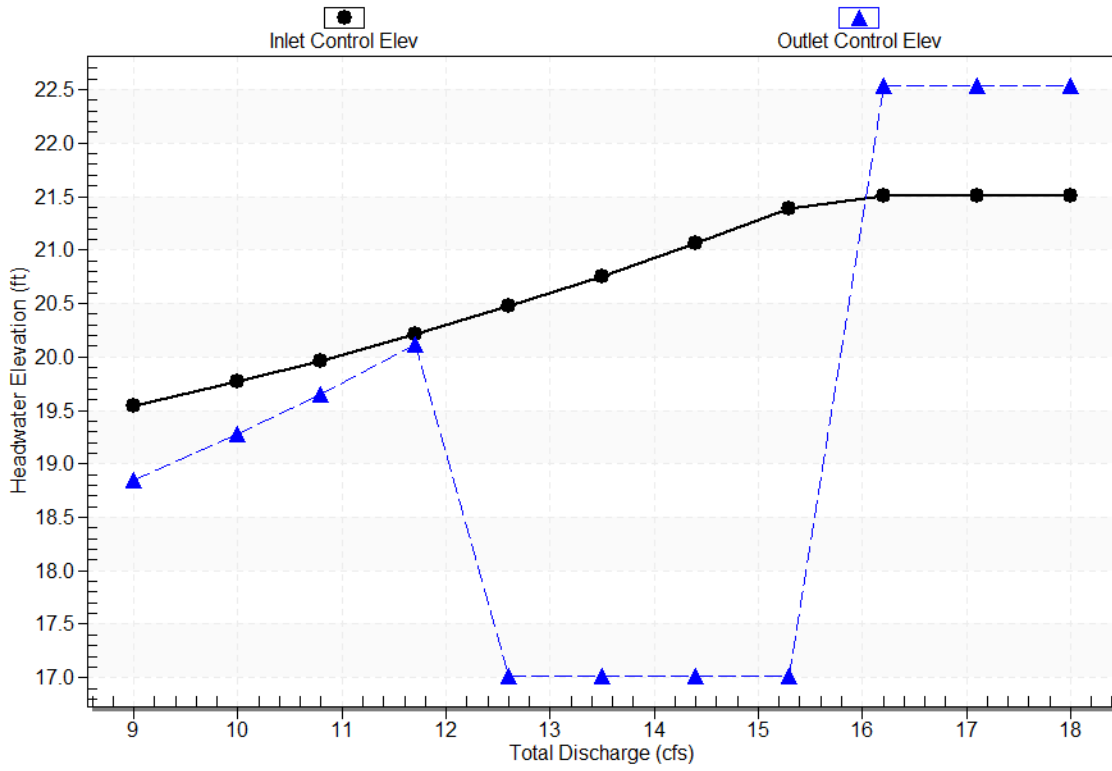
Culvert Length: 190.03 ft,

Culvert Slope: 0.0168

### Culvert Performance Curve Plot: PR. CD-5

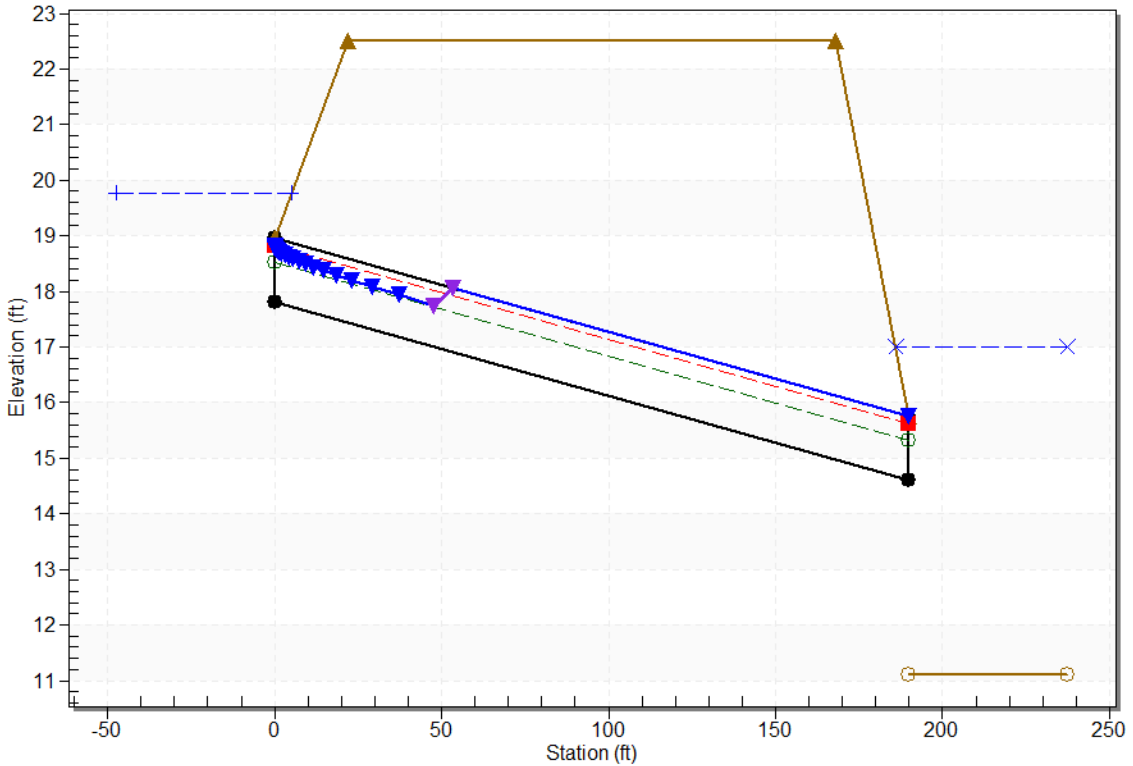
#### Performance Curve

Culvert: PR. CD-5



### Water Surface Profile Plot for Culvert: PR. CD-5

Crossing - PR. CD-5, Design Discharge - 10.0 cfs  
Culvert - PR. CD-5, Culvert Discharge - 10.0 cfs



### Site Data - PR. CD-5

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 17.80 ft

Outlet Station: 190.00 ft

Outlet Elevation: 14.60 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-5

Barrel Shape: Elliptical

Barrel Span: 23.00 in

Barrel Rise: 14.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-5

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-5)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
9.00	17.01	5.90
10.00	17.01	5.90
10.80	17.01	5.90
11.70	17.01	5.90
12.60	17.01	5.90
13.50	17.01	5.90
14.40	17.01	5.90
15.30	17.01	5.90
16.20	17.01	5.90
17.10	17.01	5.90
18.00	17.01	5.90

### Tailwater Channel Data - PR. CD-5

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 17.01 ft

### Roadway Data for Crossing: PR. CD-5

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 22.50 ft

Roadway Surface: Paved

Roadway Top Width: 146.00 ft



# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 10.00 cfs

Design Flow: 12.00 cfs

Maximum Flow: 21.00 cfs

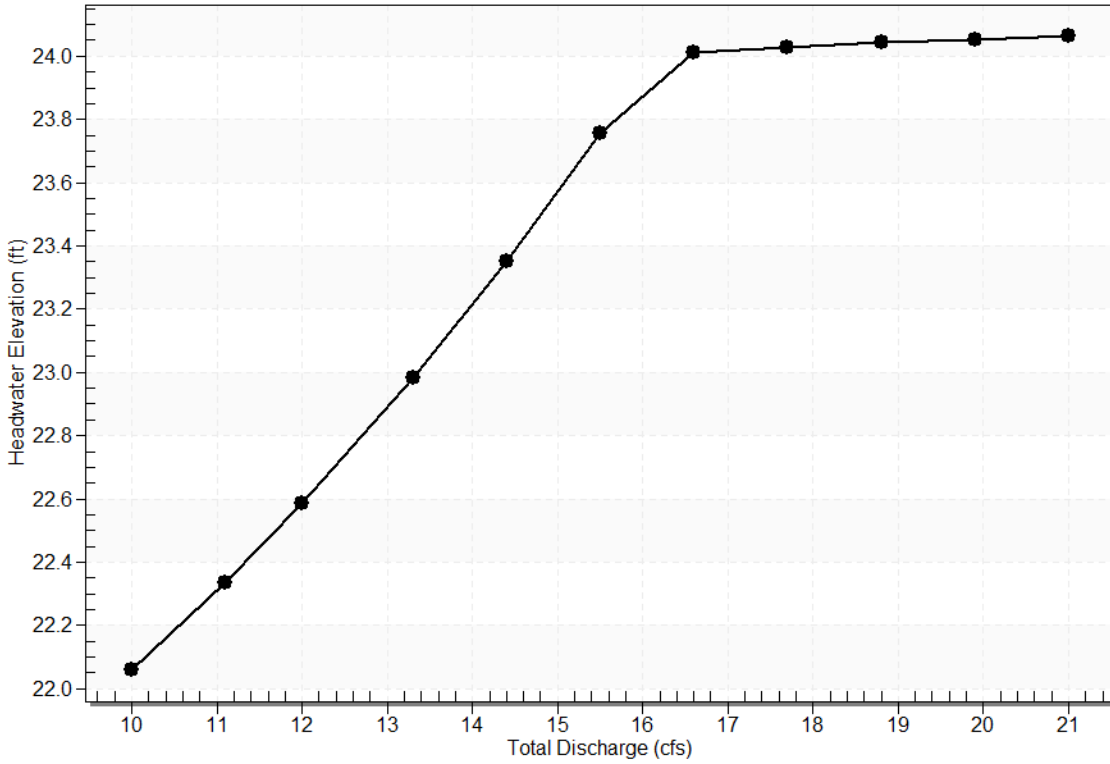
**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-6**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-6 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
22.06	10.00	10.00	0.00	1
22.34	11.10	11.10	0.00	1
22.58	12.00	12.00	0.00	1
22.98	13.30	13.30	0.00	1
23.35	14.40	14.40	0.00	1
23.76	15.50	15.50	0.00	1
24.01	16.60	16.13	0.35	31
24.03	17.70	16.17	1.45	5
24.04	18.80	16.20	2.52	4
24.05	19.90	16.23	3.53	3
24.06	21.00	16.25	4.63	3
24.00	16.10	16.10	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-6**

**Total Rating Curve**

Crossing: PR. CD-6



**Culvert Data: PR. CD-6**

**Table 2 - Culvert Summary Table: PR. CD-6**

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)
10.00 cfs	10.00 cfs	22.06	2.80	2.412	7-M2c	0.00	0.00	0.78	5.86	10.43	0.00
11.10 cfs	11.10 cfs	22.34	3.19	2.652	7-M2c	0.00	0.00	0.82	5.86	10.67	0.00
12.00 cfs	12.00 cfs	22.58	2.49	2.227	7-M2c	0.00	0.42	0.74	5.86	10.22	0.00
13.30 cfs	13.30 cfs	22.98	3.92	3.083	5-M1f	0.00	0.00	0.93	5.86	10.72	0.00

<b>14.40</b> <b>cfs</b>	14.40 cfs	23.35	3.94	3.09 4	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 3	0.00
<b>15.50</b> <b>cfs</b>	15.50 cfs	23.76	3.95	3.10 2	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 4	0.00
<b>16.60</b> <b>cfs</b>	16.13 cfs	24.01	3.97	3.10 9	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 5	0.00
<b>17.70</b> <b>cfs</b>	16.17 cfs	24.03	3.98	3.11 5	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 6	0.00
<b>18.80</b> <b>cfs</b>	16.20 cfs	24.04	3.99	3.12 1	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 7	0.00
<b>19.90</b> <b>cfs</b>	16.23 cfs	24.05	4.00	3.12 6	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 7	0.00
<b>21.00</b> <b>cfs</b>	16.25 cfs	24.06	4.01	3.13 1	5- M1 f	0.00	0.00	0.9 3	5.86	10.7 8	0.00

### Culvert Barrel Data

Culvert Barrel Type Single Broken-back Culvert

Inlet Elevation (invert): 20.09 ft,

Break Elevation (invert): 20.07 ft,

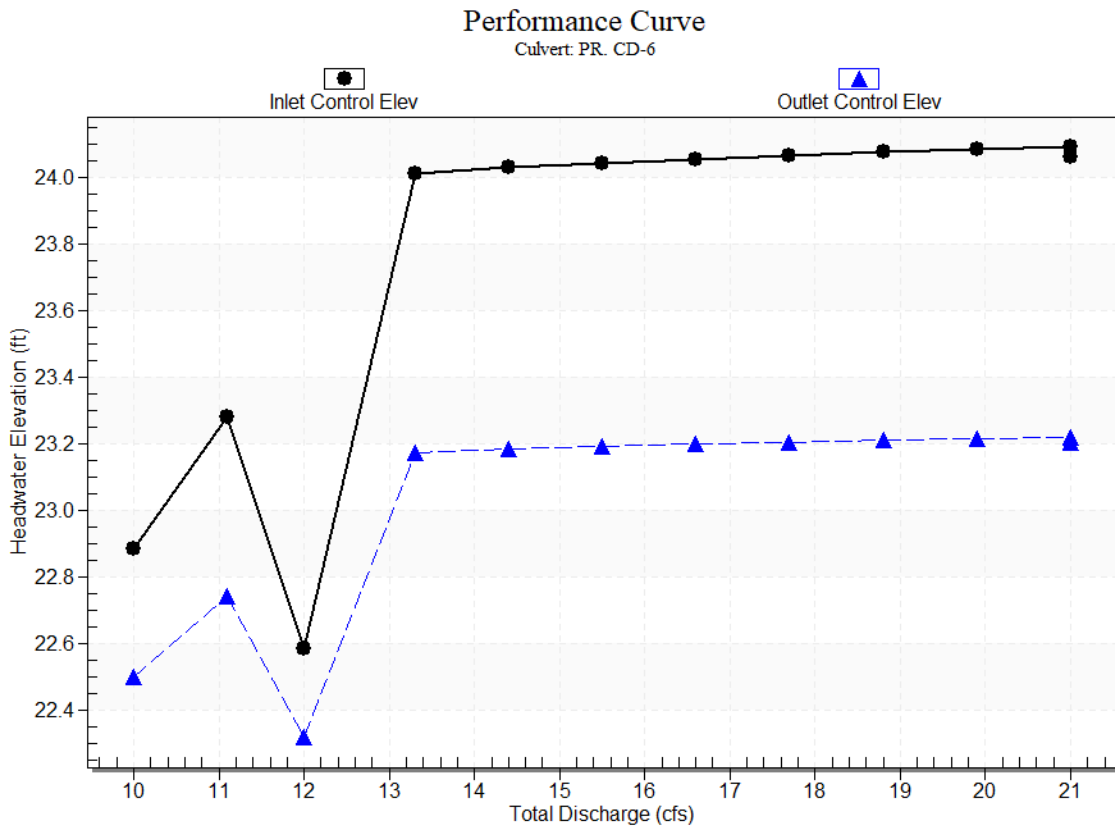
Outlet Elevation (invert): 18.47 ft

Culvert Length: 117.01 ft,

Upper Culvert Section Slope: 0.0004

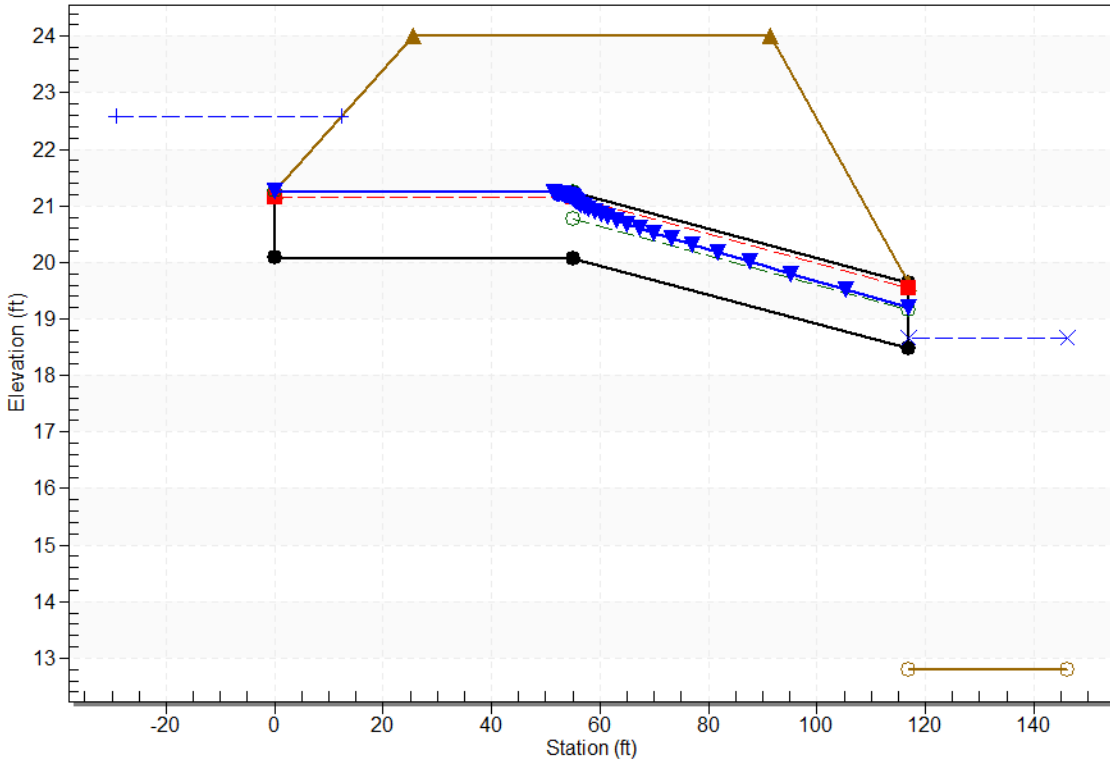
Steep Culvert Section Slope: 0.0258

### Culvert Performance Curve Plot: PR. CD-6



### Water Surface Profile Plot for Culvert: PR. CD-6

Crossing - PR. CD-6, Design Discharge - 12.0 cfs  
Culvert - PR. CD-6, Culvert Discharge - 12.0 cfs



### Site Data - PR. CD-6

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 20.09 ft

Break Station: 55.00 ft

Break Elevation: 20.07 ft

Outlet Station: 117.00 ft

Outlet Elevation: 18.47 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-6

Barrel Shape: Elliptical

Barrel Span: 23.00 in

Barrel Rise: 14.00 in



Upper Section Material: Concrete

Lower Section Material: Concrete

Embedment: 0.00 in

Upper Section Manning's n: 0.0120

Lower Section Manning's n: 0.0120

Culvert Type: Single Broken-back

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-6

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-6)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
10.00	18.66	5.86
11.10	18.66	5.86
12.00	18.66	5.86
13.30	18.66	5.86
14.40	18.66	5.86
15.50	18.66	5.86
16.60	18.66	5.86
17.70	18.66	5.86
18.80	18.66	5.86
19.90	18.66	5.86
21.00	18.66	5.86

### Tailwater Channel Data - PR. CD-6

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 18.66 ft

### Roadway Data for Crossing: PR. CD-6

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 24.00 ft

Roadway Surface: Paved

Roadway Top Width: 66.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 19.00 cfs

Design Flow: 22.00 cfs

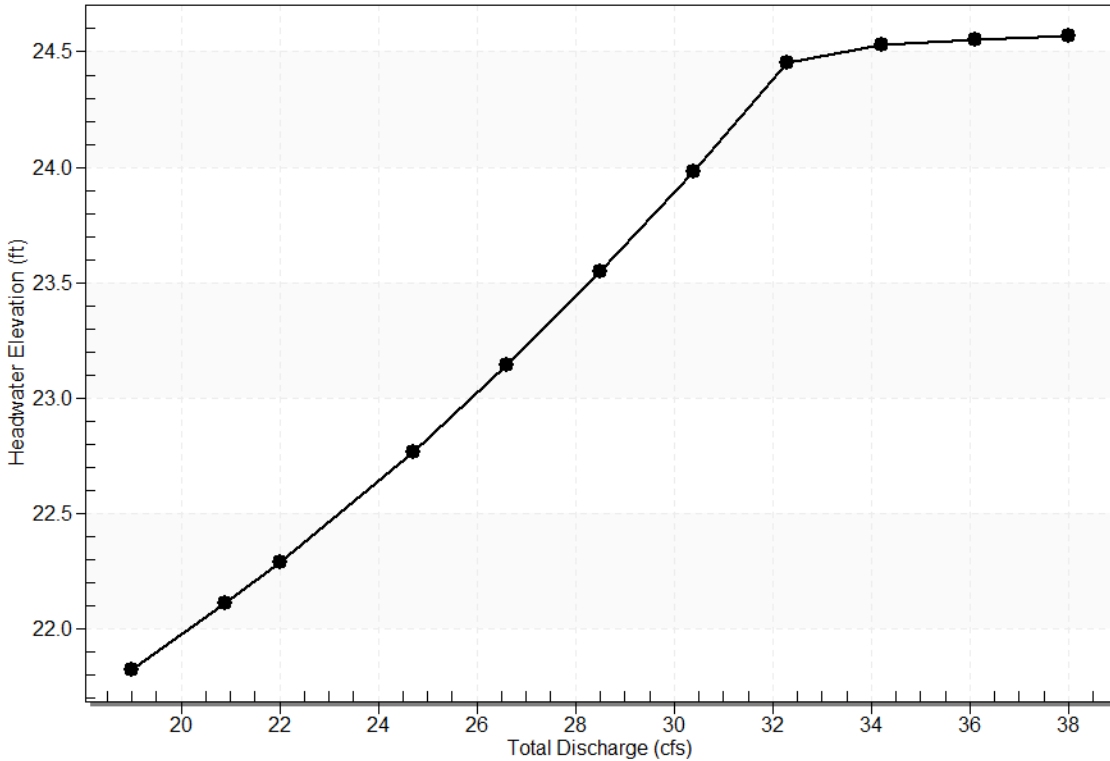
Maximum Flow: 38.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-7**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-7 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
21.82	19.00	19.00	0.00	1
22.11	20.90	20.90	0.00	1
22.29	22.00	22.00	0.00	1
22.77	24.70	24.70	0.00	1
23.14	26.60	26.60	0.00	1
23.55	28.50	28.50	0.00	1
23.98	30.40	30.40	0.00	1
24.45	32.30	32.30	0.00	1
24.53	34.20	32.58	1.52	10
24.55	36.10	32.66	3.36	5
24.57	38.00	32.73	5.18	4
24.50	32.47	32.47	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-7**

**Total Rating Curve**  
Crossing: PR. CD-7



**Culvert Data: PR. CD-7**

**Table 2 - Culvert Summary Table: PR. CD-7**

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)
19.00 cfs	19.00 cfs	21.82	2.42	1.355	5- JS1 f	0.79	1.31	1.58	5.91	5.93	0.00
20.90 cfs	20.90 cfs	22.11	2.71	1.633	5- JS1 f	0.84	1.37	1.58	5.91	6.52	0.00
22.00 cfs	22.00 cfs	22.29	2.89	1.806	5- JS1 f	0.86	1.40	1.58	5.91	6.86	0.00
24.70 cfs	24.70 cfs	22.77	3.37	2.269	5- S2 n	0.93	1.45	0.99	5.91	11.81	0.00

<b>26.60</b> <b>cfs</b>	26.60 cfs	23.14	3.74	2.62 7	5- S2 n	0.97	1.47	1.0 4	5.91	12.0 6	0.00
<b>28.50</b> <b>cfs</b>	28.50 cfs	23.55	4.15	3.01 1	5- S2 n	1.02	1.50	1.0 9	5.91	12.2 6	0.00
<b>30.40</b> <b>cfs</b>	30.40 cfs	23.98	4.58	3.42 2	5- S2 n	1.06	1.48	1.1 3	5.91	12.5 2	0.00
<b>32.30</b> <b>cfs</b>	32.30 cfs	24.45	5.05	3.97 0	5- S1f	1.11	1.38	1.5 8	5.91	10.0 8	0.00
<b>34.20</b> <b>cfs</b>	32.58 cfs	24.53	5.13	3.92 7	5- S2 n	1.11	1.49	1.1 9	5.91	12.7 6	0.00
<b>36.10</b> <b>cfs</b>	32.66 cfs	24.55	5.15	3.94 6	5- S2 n	1.12	1.51	1.1 9	5.91	12.7 6	0.00
<b>38.00</b> <b>cfs</b>	32.73 cfs	24.57	5.17	3.96 1	5- S2 n	1.12	1.44	1.1 9	5.91	12.8 1	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 19.40 ft,

Outlet Elevation (invert): 17.37 ft

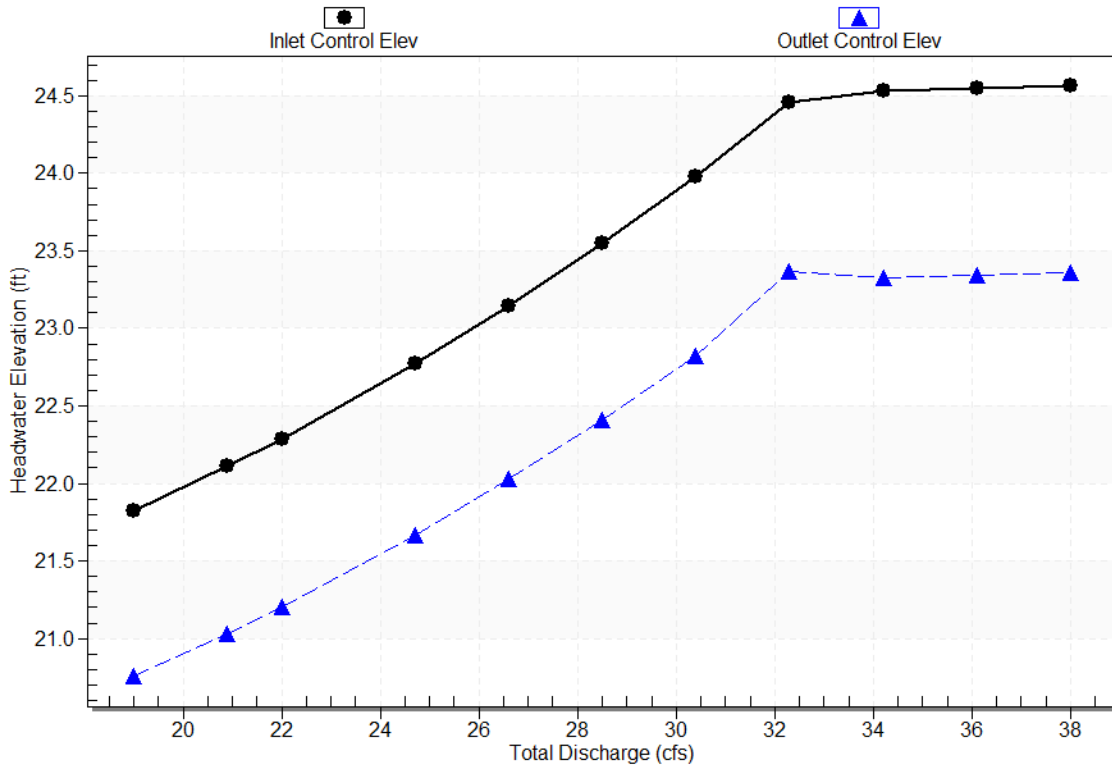
Culvert Length: 85.02 ft,

Culvert Slope: 0.0239

### Culvert Performance Curve Plot: PR. CD-7

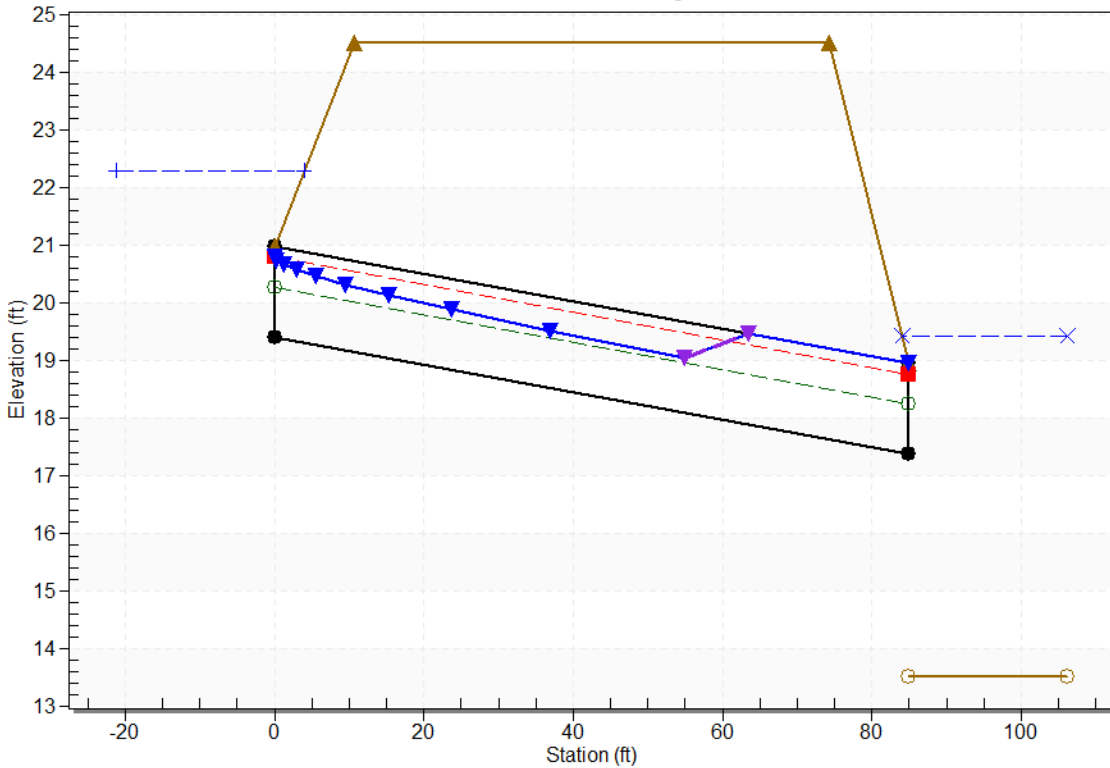
#### Performance Curve

Culvert: PR. CD-7



### Water Surface Profile Plot for Culvert: PR. CD-7

Crossing - PR. CD-7, Design Discharge - 22.0 cfs  
Culvert - PR. CD-7, Culvert Discharge - 22.0 cfs



### Site Data - PR. CD-7

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 19.40 ft

Outlet Station: 85.00 ft

Outlet Elevation: 17.37 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-7

Barrel Shape: Elliptical

Barrel Span: 30.00 in

Barrel Rise: 19.00 in

Barrel Material: Concrete

Embedment: 0.00 in



Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-7

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-7)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
19.00	19.43	5.91
20.90	19.43	5.91
22.00	19.43	5.91
24.70	19.43	5.91
26.60	19.43	5.91
28.50	19.43	5.91
30.40	19.43	5.91
32.30	19.43	5.91
34.20	19.43	5.91
36.10	19.43	5.91
38.00	19.43	5.91

### Tailwater Channel Data - PR. CD-7

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 19.43 ft

### Roadway Data for Crossing: PR. CD-7

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 24.50 ft

Roadway Surface: Paved

Roadway Top Width: 63.50 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 18.00 cfs

Design Flow: 21.00 cfs

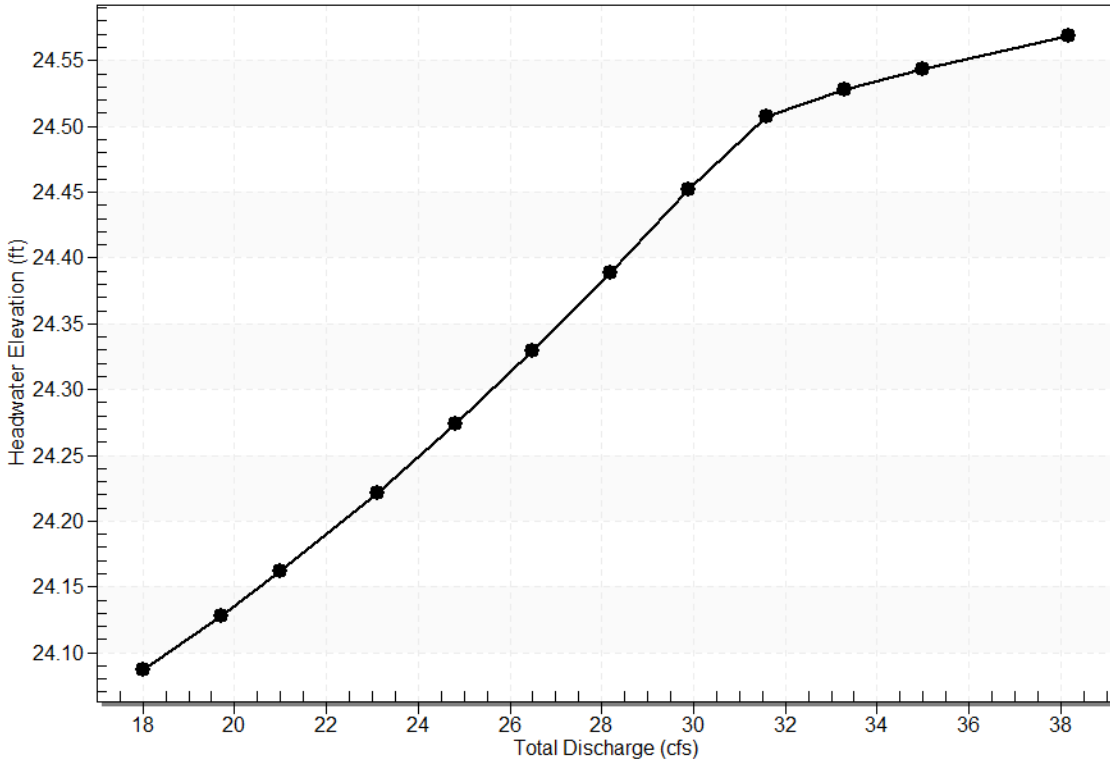
Maximum Flow: 35.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-8**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-8 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
24.09	18.00	18.00	0.00	1
24.13	19.70	19.70	0.00	1
24.16	21.00	21.00	0.00	1
24.22	23.10	23.10	0.00	1
24.27	24.80	24.80	0.00	1
24.33	26.50	26.50	0.00	1
24.39	28.20	28.20	0.00	1
24.45	29.90	29.90	0.00	1
24.51	31.60	31.30	0.18	12
24.53	33.30	31.82	1.36	5
24.54	35.00	32.20	2.67	4
24.50	31.11	31.11	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-8**

**Total Rating Curve**  
Crossing: PR. CD-8



**Culvert Data: PR. CD-8**

**Table 2 - Culvert Summary Table: PR. CD-8**

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)
18.00 cfs	18.00 cfs	24.09	1.59	3.087	4-FFf	0.78	1.13	2.42	8.36	2.43	0.00
19.70 cfs	19.70 cfs	24.13	1.69	3.128	4-FFf	0.81	1.18	2.42	8.36	2.66	0.00
21.00 cfs	21.00 cfs	24.16	1.76	3.162	4-FFf	0.84	1.22	2.42	8.36	2.83	0.00
23.10 cfs	23.10 cfs	24.22	1.87	3.221	4-FFf	0.88	1.28	2.42	8.36	3.11	0.00
24.80 cfs	24.80 cfs	24.27	1.96	3.274	4-FFf	0.92	1.33	2.42	8.36	3.34	0.00
26.50 cfs	26.50 cfs	24.33	2.05	3.329	4-FFf	0.95	1.38	2.42	8.36	3.57	0.00

<b>28.20</b> cfs	28.20 cfs	24.39	2.13	3.38 9	4- FFf	0.98	1.43	2.4 2	8.36	3.80	0.00
<b>29.90</b> cfs	29.90 cfs	24.45	2.22	3.45 2	4- FFf	1.02	1.47	2.4 2	8.36	4.03	0.00
<b>31.60</b> cfs	31.30 cfs	24.51	2.30	3.50 7	4- FFf	1.04	1.51	2.4 2	8.36	4.22	0.00
<b>33.30</b> cfs	31.82 cfs	24.53	2.32	3.52 8	4- FFf	1.05	1.52	2.4 2	8.36	4.29	0.00
<b>35.00</b> cfs	32.20 cfs	24.54	2.35	3.54 3	4- FFf	1.06	1.53	2.4 2	8.36	4.34	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

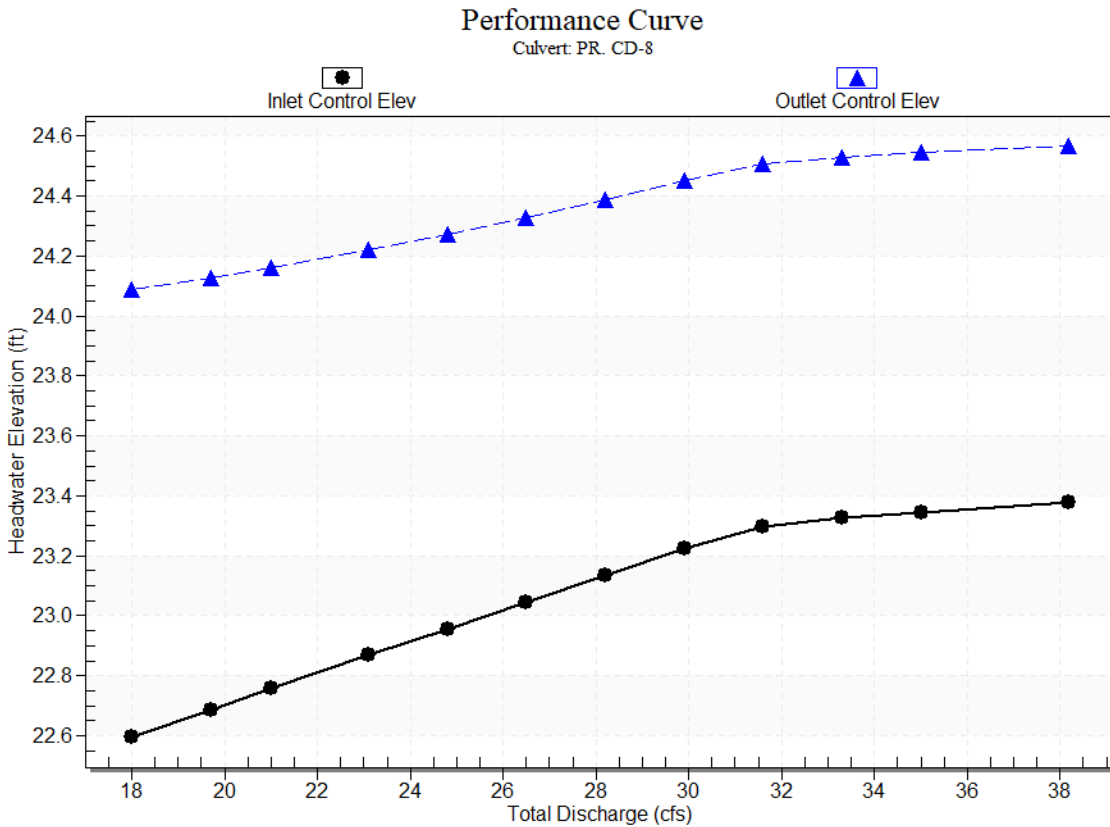
Inlet Elevation (invert): 21.00 ft,

Outlet Elevation (invert): 19.50 ft

Culvert Length: 124.01 ft,

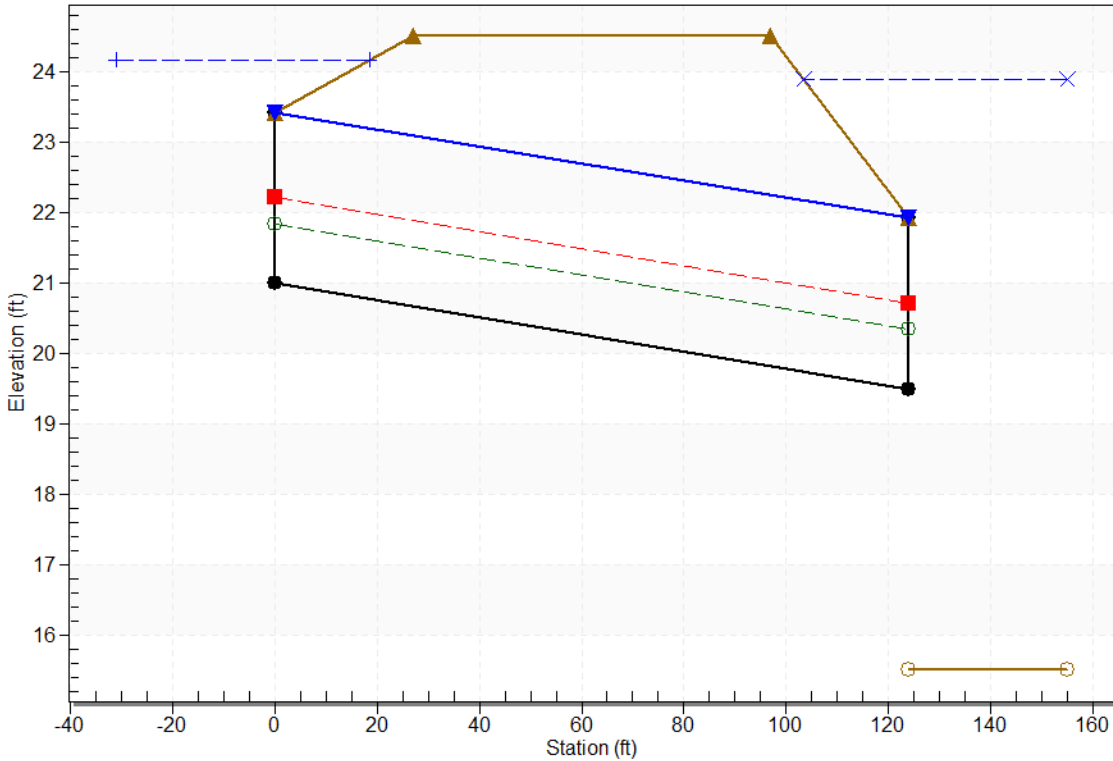
Culvert Slope: 0.0121

### Culvert Performance Curve Plot: PR. CD-8



### Water Surface Profile Plot for Culvert: PR. CD-8

Crossing - PR. CD-8, Design Discharge - 21.0 cfs  
Culvert - PR. CD-8, Culvert Discharge - 21.0 cfs



### Site Data - PR. CD-8

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 21.00 ft

Outlet Station: 124.00 ft

Outlet Elevation: 19.50 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-8

Barrel Shape: Elliptical

Barrel Span: 45.00 in

Barrel Rise: 29.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-8

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-8)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
18.00	23.88	8.36
19.70	23.88	8.36
21.00	23.88	8.36
23.10	23.88	8.36
24.80	23.88	8.36
26.50	23.88	8.36
28.20	23.88	8.36
29.90	23.88	8.36
31.60	23.88	8.36
33.30	23.88	8.36
35.00	23.88	8.36

### Tailwater Channel Data - PR. CD-8

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 23.88 ft

### Roadway Data for Crossing: PR. CD-8

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 24.50 ft

Roadway Surface: Paved

Roadway Top Width: 70.00 ft



# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 19.00 cfs

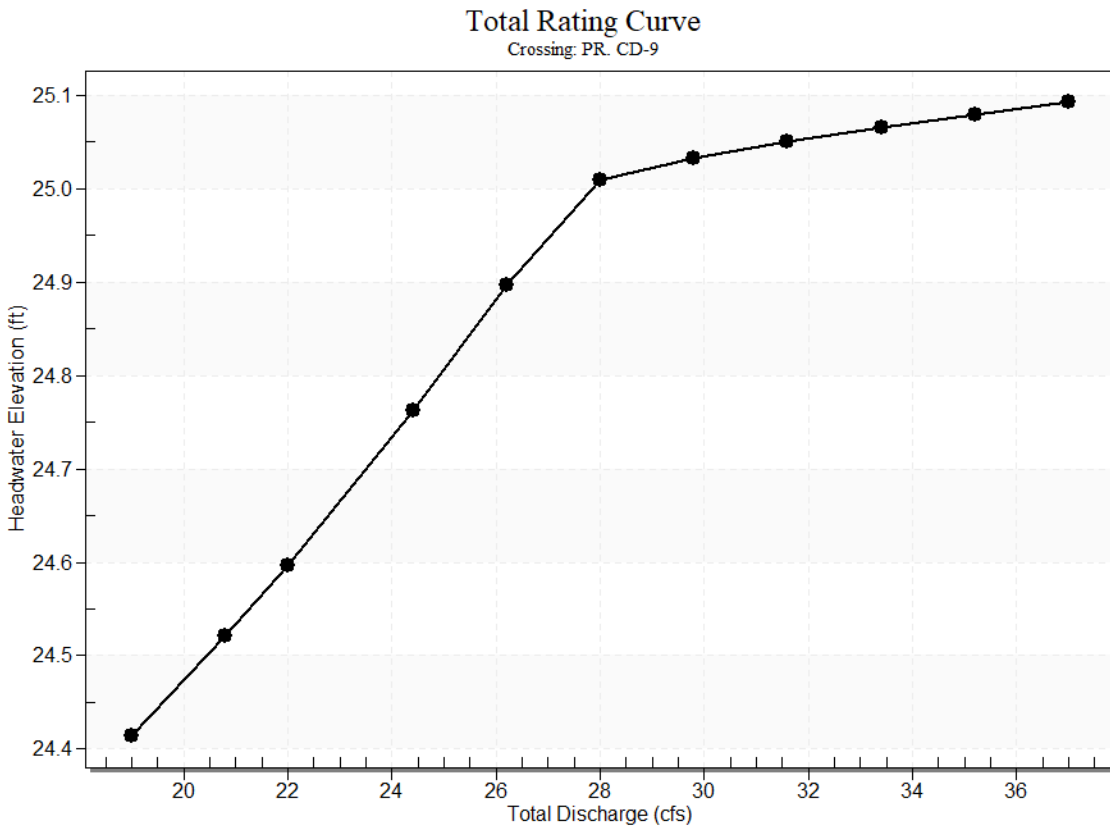
Design Flow: 22.00 cfs

Maximum Flow: 37.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-9**

<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-9 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
24.41	19.00	19.00	0.00	1
24.52	20.80	20.80	0.00	1
24.60	22.00	22.00	0.00	1
24.76	24.40	24.40	0.00	1
24.90	26.20	26.20	0.00	1
25.01	28.00	27.61	0.27	19
25.03	29.80	27.90	1.75	5
25.05	31.60	28.11	3.34	4
25.07	33.40	28.30	5.01	4
25.08	35.20	28.45	6.57	3
25.09	37.00	28.61	8.23	3
25.00	27.49	27.49	0.00	Overtopping

**Rating Curve Plot for Crossing: PR. CD-9**



**Culvert Data: PR. CD-9**

**Table 2 - Culvert Summary Table: PR. CD-9**

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)
19.00 cfs	19.00 cfs	24.41	1.83	4.015	4-FFf	0.78	1.22	2.00	8.41	3.71	0.00
20.80 cfs	20.80 cfs	24.52	1.96	4.121	4-FFf	0.82	1.28	2.00	8.41	4.06	0.00
22.00 cfs	22.00 cfs	24.60	2.04	4.197	4-FFf	0.84	1.32	2.00	8.41	4.29	0.00
24.40 cfs	24.40 cfs	24.76	2.22	4.362	4-FFf	0.89	1.40	2.00	8.41	4.76	0.00
26.20 cfs	26.20 cfs	24.90	2.36	4.497	4-FFf	0.93	1.45	2.00	8.41	5.11	0.00
28.00 cfs	27.61 cfs	25.01	2.47	4.609	4-FFf	0.96	1.49	2.00	8.41	5.39	0.00

<b>29.80</b> cfs	27.90 cfs	25.03	2.50	4.63 3	4- FFf	0.96	1.50	2.0 0	8.41	5.44	0.00
<b>31.60</b> cfs	28.11 cfs	25.05	2.52	4.65 1	4- FFf	0.97	1.51	2.0 0	8.41	5.48	0.00
<b>33.40</b> cfs	28.30 cfs	25.07	2.53	4.66 6	4- FFf	0.97	1.51	2.0 0	8.41	5.52	0.00
<b>35.20</b> cfs	28.45 cfs	25.08	2.54	4.67 9	4- FFf	0.98	1.52	2.0 0	8.41	5.55	0.00
<b>37.00</b> cfs	28.61 cfs	25.09	2.56	4.69 3	4- FFf	0.98	1.52	2.0 0	8.41	5.58	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

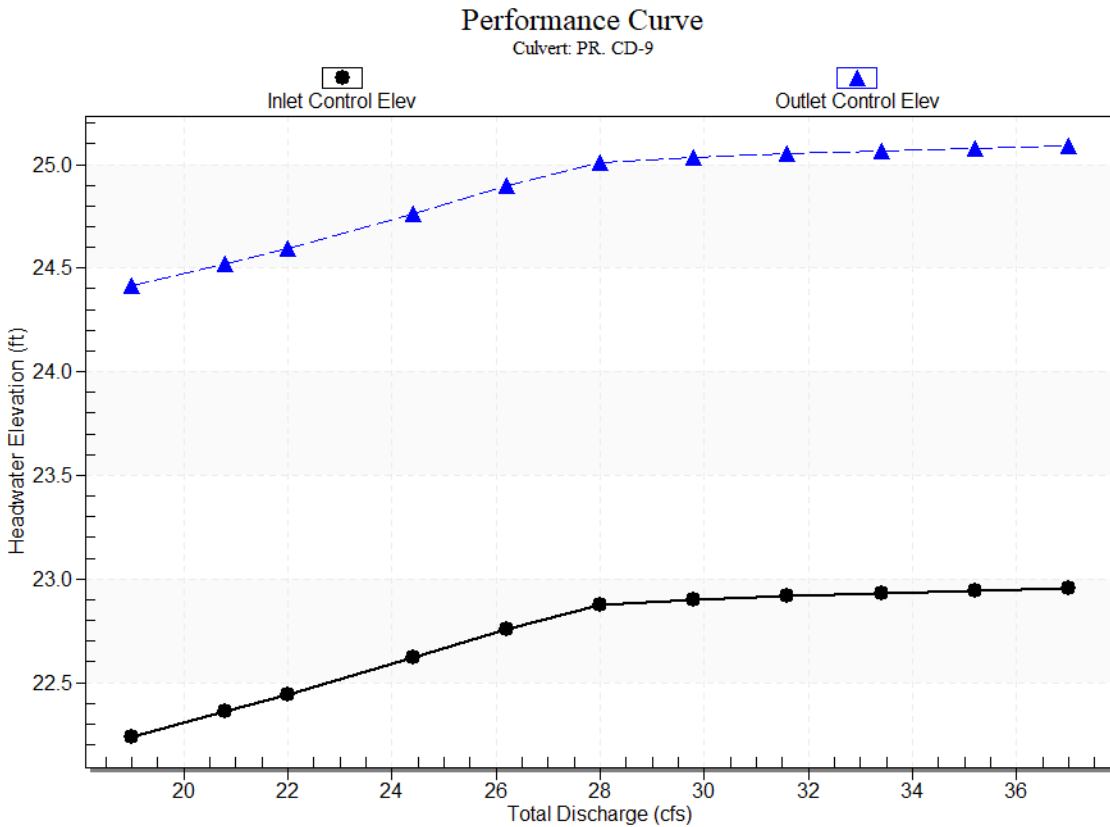
Inlet Elevation (invert): 20.40 ft,

Outlet Elevation (invert): 18.30 ft

Culvert Length: 126.02 ft,

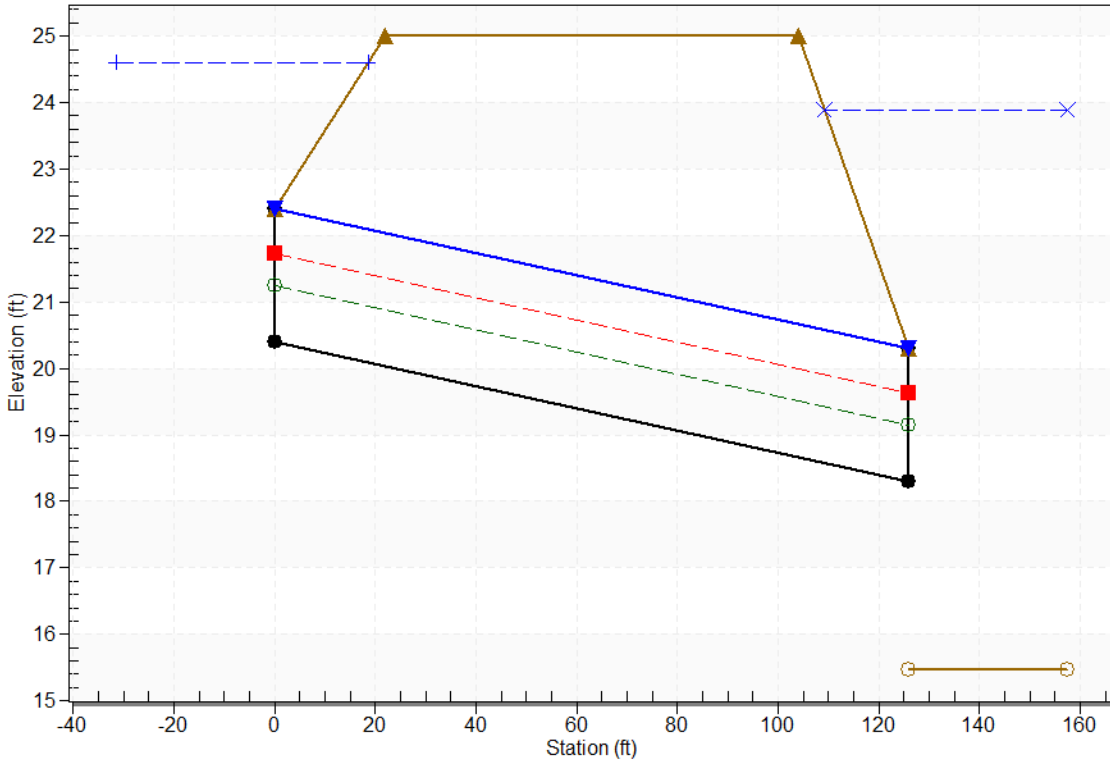
Culvert Slope: 0.0167

### Culvert Performance Curve Plot: PR. CD-9



### Water Surface Profile Plot for Culvert: PR. CD-9

Crossing - PR. CD-9, Design Discharge - 22.0 cfs  
Culvert - PR. CD-9, Culvert Discharge - 22.0 cfs



### Site Data - PR. CD-9

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 20.40 ft

Outlet Station: 126.00 ft

Outlet Elevation: 18.30 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-9

Barrel Shape: Elliptical

Barrel Span: 38.00 in

Barrel Rise: 24.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-9

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-9)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
19.00	23.88	8.41
20.80	23.88	8.41
22.00	23.88	8.41
24.40	23.88	8.41
26.20	23.88	8.41
28.00	23.88	8.41
29.80	23.88	8.41
31.60	23.88	8.41
33.40	23.88	8.41
35.20	23.88	8.41
37.00	23.88	8.41

### Tailwater Channel Data - PR. CD-9

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 23.88 ft

### Roadway Data for Crossing: PR. CD-9

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 25.00 ft

Roadway Surface: Paved

Roadway Top Width: 82.00 ft

# HY-8 Culvert Analysis Report

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## Crossing Discharge Data

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

Minimum Flow: 19.00 cfs

Design Flow: 22.00 cfs

Maximum Flow: 37.00 cfs

**Table 1 - Summary of Culvert Flows at Crossing: PR. CD-10**

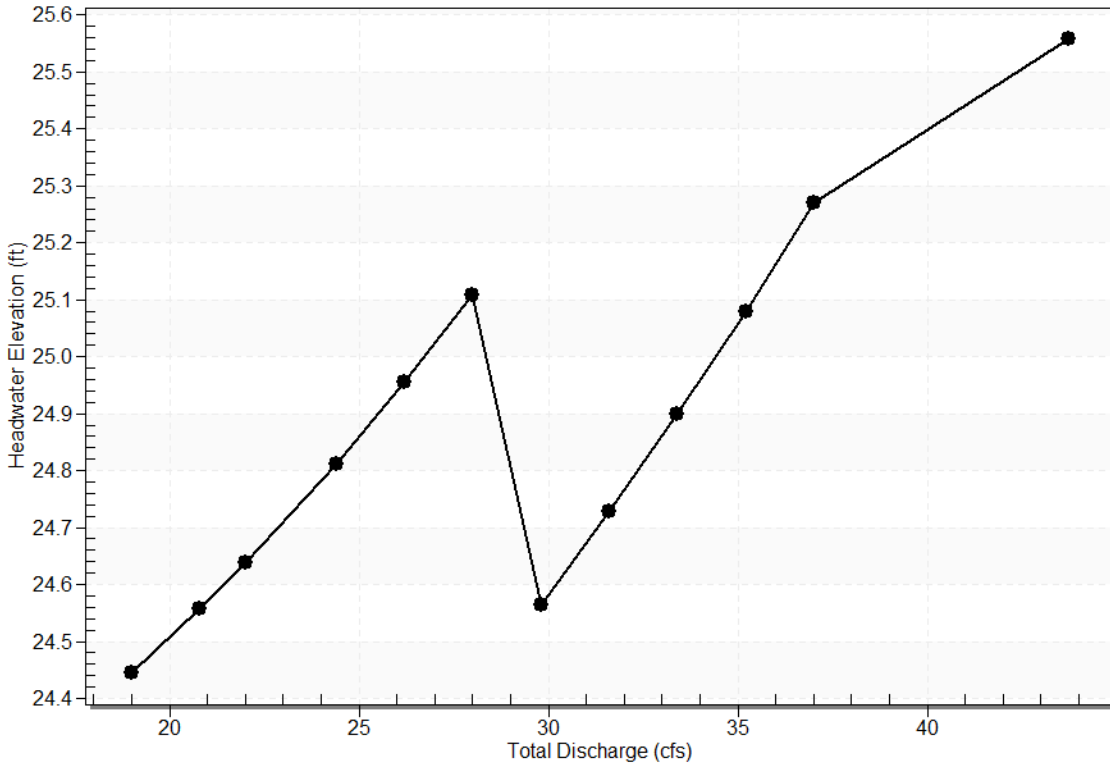
<b>Headwater Elevation (ft)</b>	<b>Total Discharge (cfs)</b>	<b>PR. CD-10 Discharge (cfs)</b>	<b>Roadway Discharge (cfs)</b>	<b>Iterations</b>
24.45	19.00	19.00	0.00	1
24.56	20.80	20.80	0.00	1
24.64	22.00	22.00	0.00	1
24.81	24.40	24.40	0.00	1
24.96	26.20	26.20	0.00	1
25.11	28.00	28.00	0.00	1
24.56	29.80	29.80	0.00	1
24.73	31.60	31.60	0.00	1
24.90	33.40	33.40	0.00	1
25.08	35.20	35.20	0.00	1
25.27	37.00	37.00	0.00	1
25.50	39.03	39.03	0.00	Overtopping



**Rating Curve Plot for Crossing: PR. CD-10**

**Total Rating Curve**

Crossing: PR. CD-10



**Culvert Data: PR. CD-10**

**Table 2 - Culvert Summary Table: PR. CD-10**

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)
19.00 cfs	19.00 cfs	24.45	1.84	2.545	4-FFf	0.86	1.22	2.00	7.89	3.71	0.00
20.80 cfs	20.80 cfs	24.56	1.96	2.658	4-FFf	0.90	1.28	2.00	7.89	4.06	0.00
22.00 cfs	22.00 cfs	24.64	2.05	2.738	4-FFf	0.93	1.32	2.00	7.89	4.29	0.00
24.40 cfs	24.40 cfs	24.81	2.23	2.913	4-FFf	0.99	1.40	2.00	7.89	4.76	0.00
26.20 cfs	26.20 cfs	24.96	2.36	3.055	4-FFf	1.03	1.45	2.00	7.89	5.11	0.00
28.00 cfs	28.00 cfs	25.11	2.51	3.208	4-FFf	1.07	1.50	2.00	7.89	5.46	0.00

<b>29.80</b> <b>cfs</b>	29.80 cfs	24.56	2.66	1.98 0	5- JS1 f	1.11	1.55	2.0 0	7.89	5.81	0.00
<b>31.60</b> <b>cfs</b>	31.60 cfs	24.73	2.83	1.98 0	5- JS1 f	1.15	1.60	2.0 0	7.89	6.16	0.00
<b>33.40</b> <b>cfs</b>	33.40 cfs	24.90	3.00	1.98 0	5- JS1 f	1.19	1.64	2.0 0	7.89	6.52	0.00
<b>35.20</b> <b>cfs</b>	35.20 cfs	25.08	3.18	1.98 0	5- JS1 f	1.23	1.68	2.0 0	7.89	6.87	0.00
<b>37.00</b> <b>cfs</b>	37.00 cfs	25.27	3.37	1.98 0	5- JS1 f	1.27	1.72	2.0 0	7.89	7.22	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 21.90 ft,

Outlet Elevation (invert): 20.20 ft

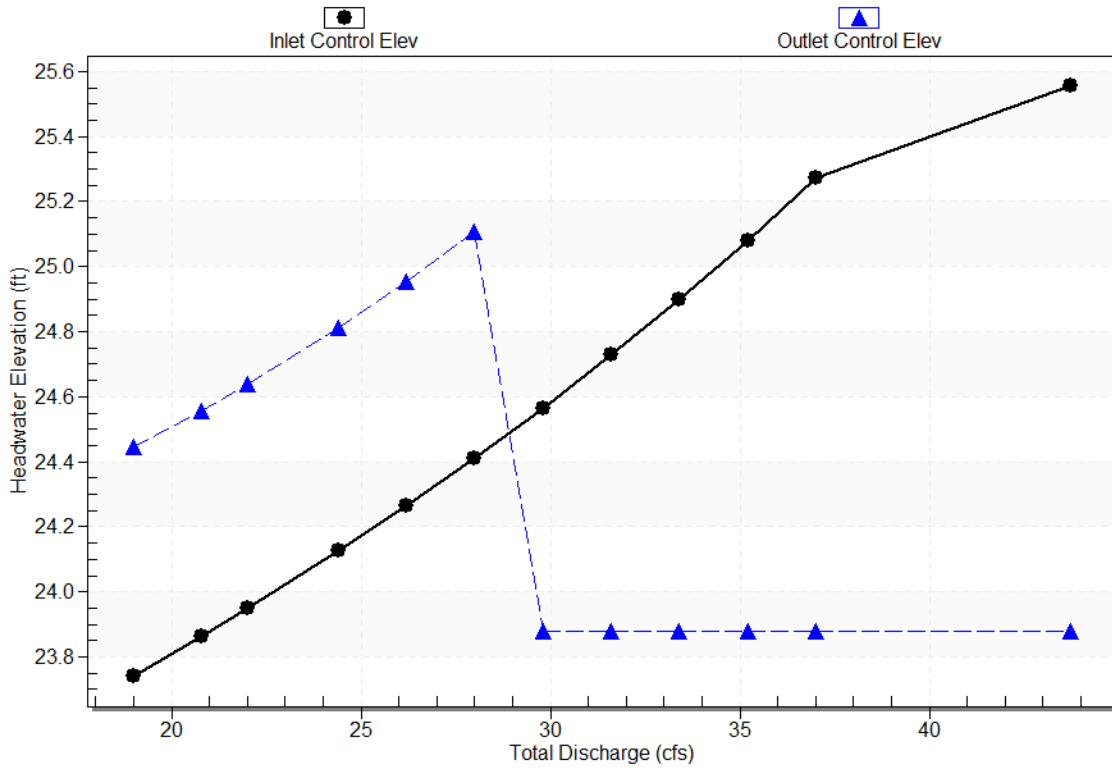
Culvert Length: 144.01 ft,

Culvert Slope: 0.0118

### Culvert Performance Curve Plot: PR. CD-10

#### Performance Curve

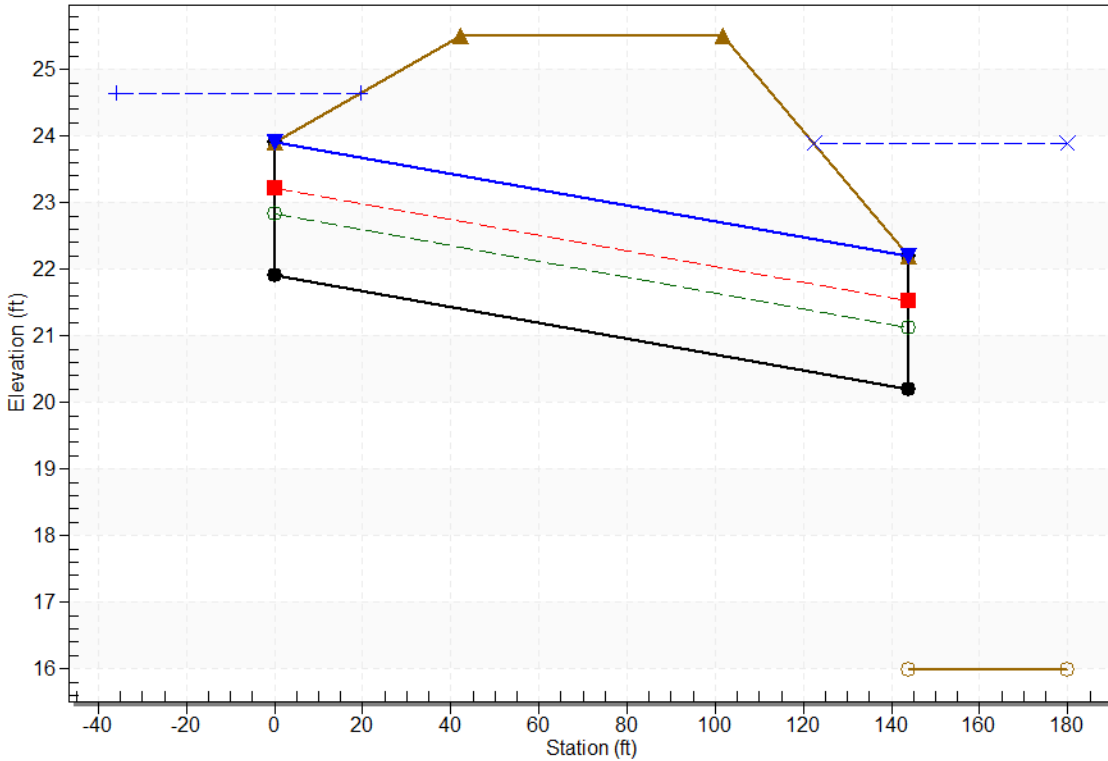
Culvert: PR. CD-10



### Water Surface Profile Plot for Culvert: PR. CD-10

Crossing - PR. CD-10, Design Discharge - 22.0 cfs

Culvert - PR. CD-10, Culvert Discharge - 22.0 cfs



### Site Data - PR. CD-10

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 21.90 ft

Outlet Station: 144.00 ft

Outlet Elevation: 20.20 ft

Number of Barrels: 1

### Culvert Data Summary - PR. CD-10

Barrel Shape: Elliptical

Barrel Span: 38.00 in

Barrel Rise: 24.00 in

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

### Tailwater Data for Crossing: PR. CD-10

Table 3 - Downstream Channel Rating Curve (Crossing: PR. CD-10)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
19.00	23.88	7.89
20.80	23.88	7.89
22.00	23.88	7.89
24.40	23.88	7.89
26.20	23.88	7.89
28.00	23.88	7.89
29.80	23.88	7.89
31.60	23.88	7.89
33.40	23.88	7.89
35.20	23.88	7.89
37.00	23.88	7.89

### Tailwater Channel Data - PR. CD-10

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 23.88 ft

### Roadway Data for Crossing: PR. CD-10

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 100.00 ft

Crest Elevation: 25.50 ft

Roadway Surface: Paved

Roadway Top Width: 59.50 ft

# *C-20 Culverts*

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HY-8 Analysis



# Hoffer Avenue

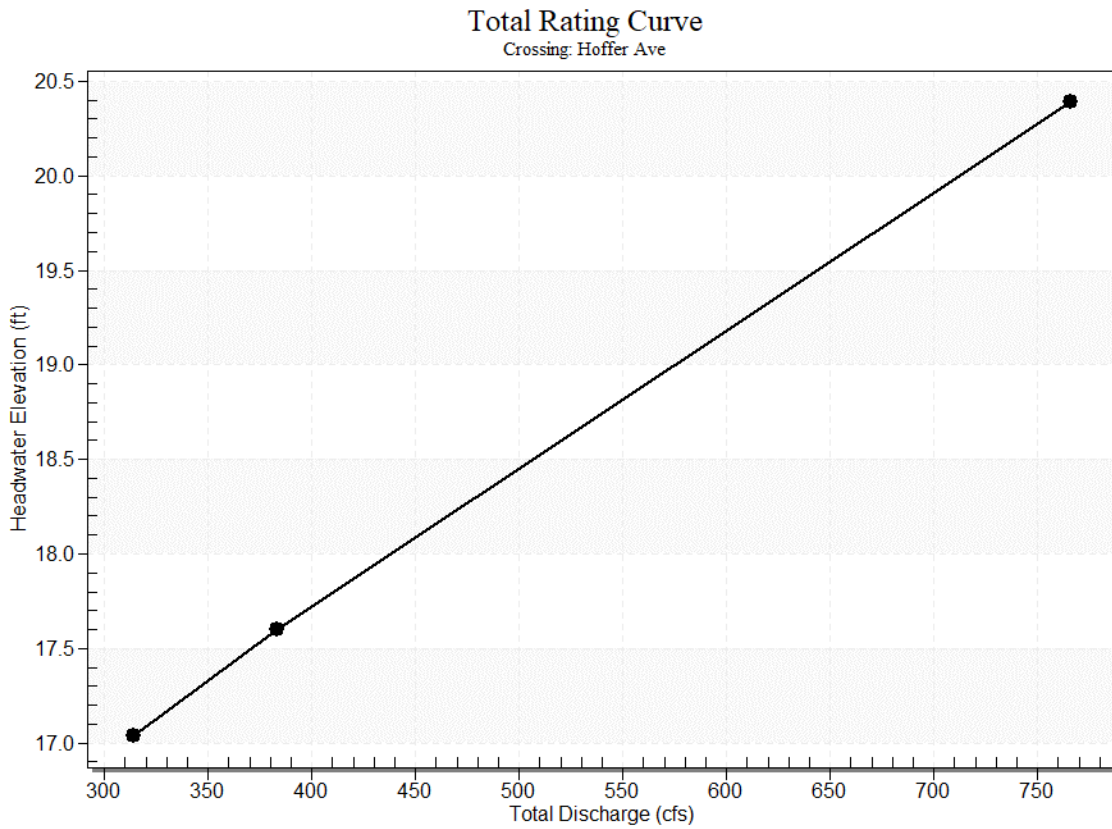
## Crossing Discharge Data

Discharge Selection Method: User Defined

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

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
17.04	10 year	314.14	314.14	0.00	1
17.60	25 year	382.93	382.93	0.00	1
20.00	Overtopping	592.01	592.01	0.00	Overtopping

## Rating Curve Plot for Crossing: Hoffer Ave



## Culvert Data: Culvert 1

Table 2 - Culvert Summary Table: Culvert 1

Discharge Names	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)
10 year	314.14 cfs	314.14 cfs	17.04	6.17	9.640	4-FFf	3.99	3.63	6.00	8.78	6.54	0.00
25 year	382.93 cfs	382.93 cfs	17.60	7.15	10.204	4-FFf	4.64	4.14	6.00	8.78	7.98	0.00

## Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 7.40 ft,

Outlet Elevation (invert): 7.10 ft

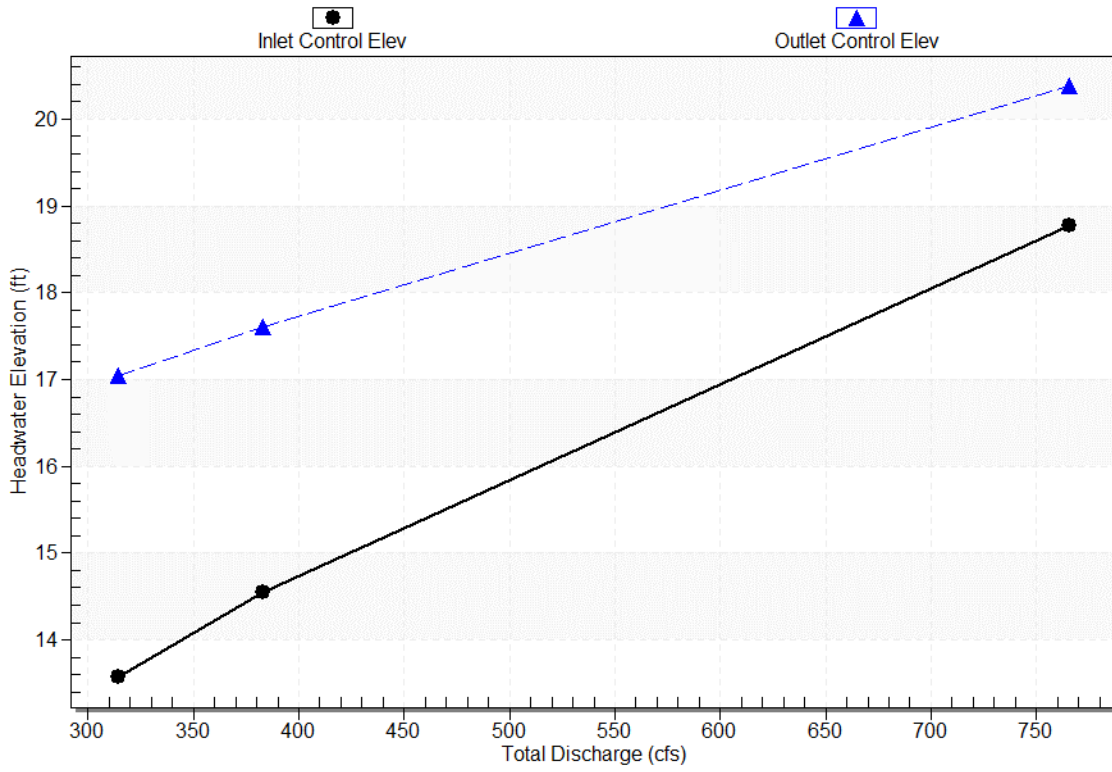
Culvert Length: 120.00 ft,

Culvert Slope: 0.0025

### Culvert Performance Curve Plot: Culvert 1

#### Performance Curve

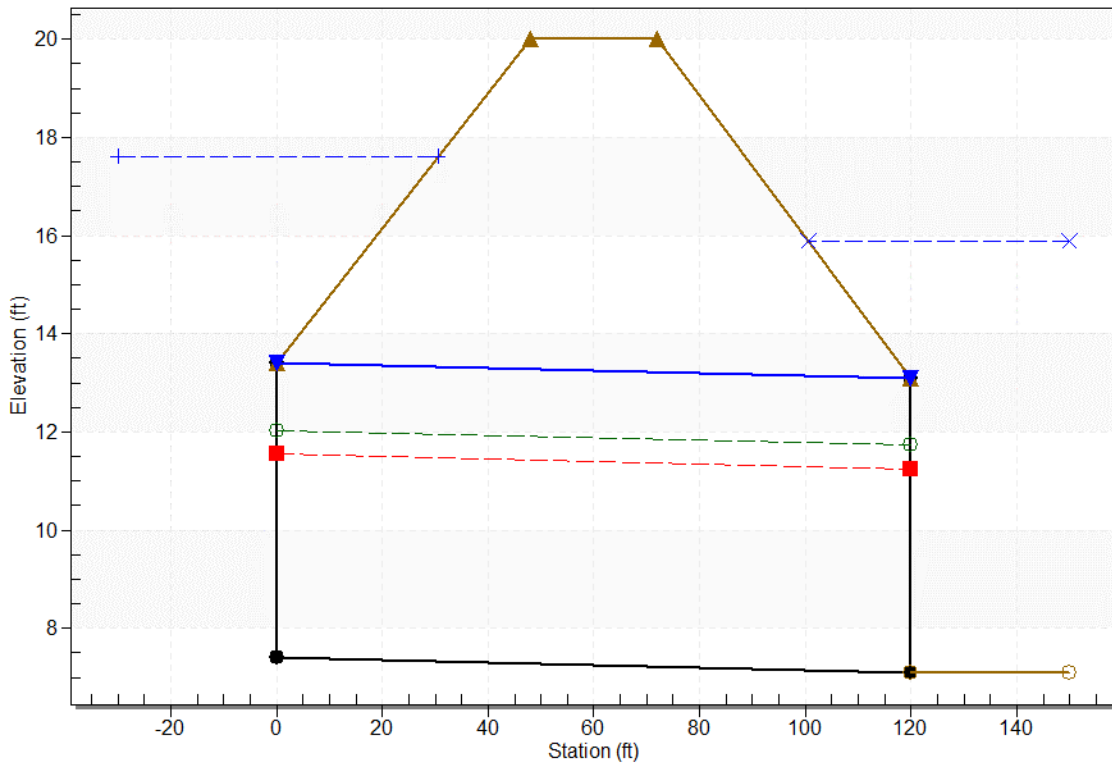
Culvert: Culvert 1



### Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Hoffer Ave, Design Discharge - 382.9 cfs

Culvert - Culvert 1, Culvert Discharge - 382.9 cfs



### Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 7.40 ft

Outlet Station: 120.00 ft

Outlet Elevation: 7.10 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: None

### Tailwater Data for Crossing: Hoffer Ave

Table 3 - Downstream Channel Rating Curve (Crossing: Hoffer Ave)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
314.14	15.88	8.78
382.93	15.88	8.78

### Tailwater Channel Data - Hoffer Ave

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 15.88 ft

### Roadway Data for Crossing: Hoffer Ave

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 20.00 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft

# Hurley Boulevard

## Crossing Discharge Data

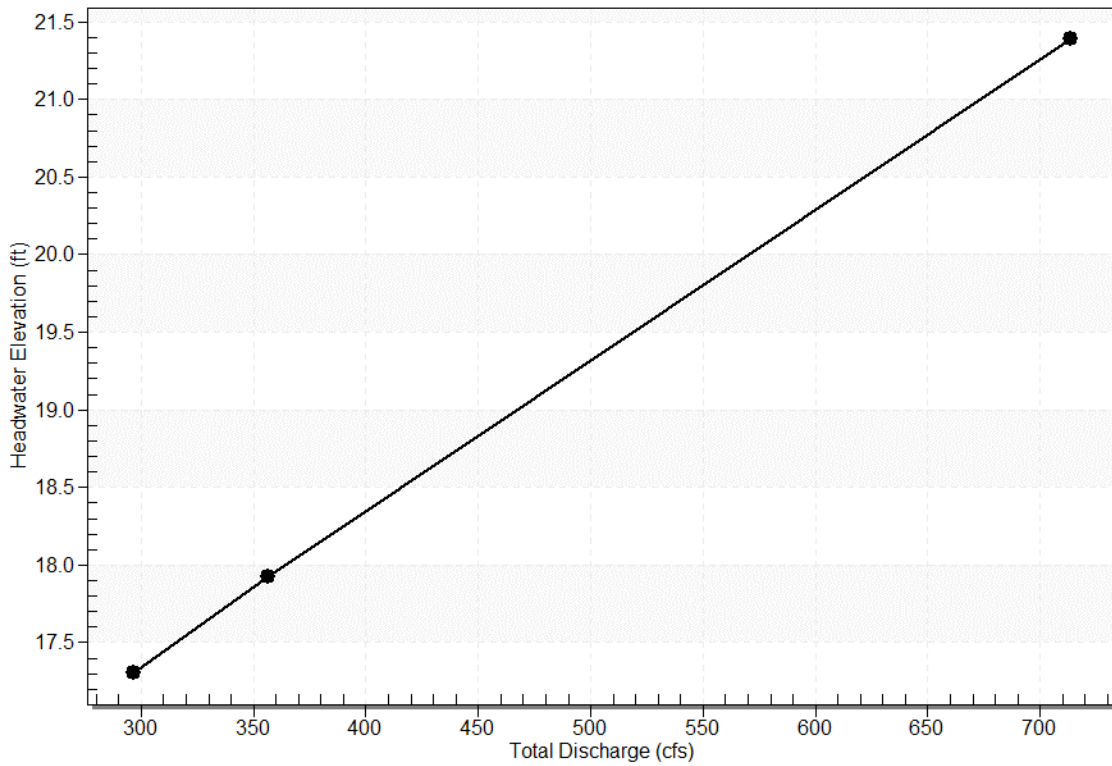
Discharge Selection Method: User Defined

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

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
17.31	10 year	296.71	296.71	0.00	1
17.93	25 year	356.73	356.73	0.00	1
21.00	Overtopping	547.37	547.37	0.00	Overtopping

## Rating Curve Plot for Crossing: Hurley Blvd

Total Rating Curve  
Crossing: Hurley Blvd





## Culvert Data: Culvert 1

Table 2 - Culvert Summary Table: Culvert 1

Discharge Names	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)
10 year	296.71 cfs	296.71 cfs	17.31	5.92	6.208	1-S1f	3.13	3.50	6.00	6.28	6.18	0.00
25 year	356.73 cfs	356.73 cfs	17.93	6.77	6.829	1-S1f	3.59	3.95	6.00	6.28	7.43	0.00

## Culvert Barrel Data

Culvert Barrel Type Straight Culvert

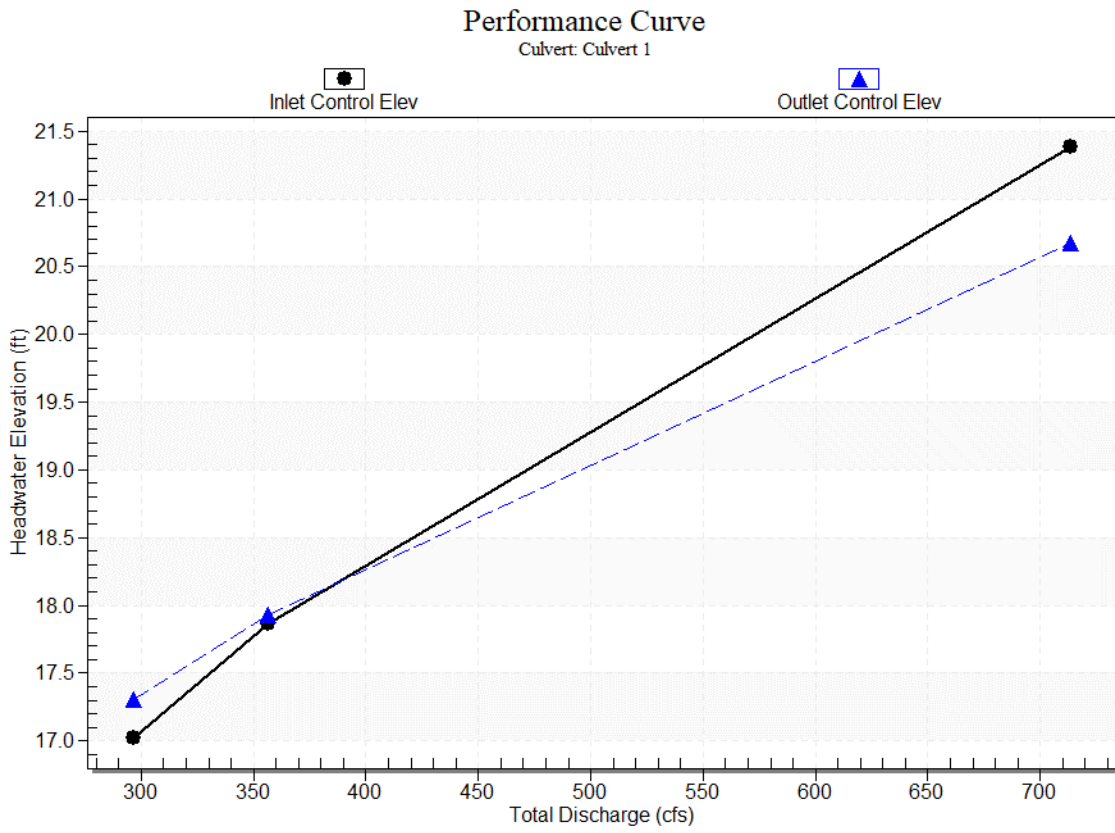
Inlet Elevation (invert): 11.10 ft,

Outlet Elevation (invert): 9.60 ft

Culvert Length: 350.00 ft,

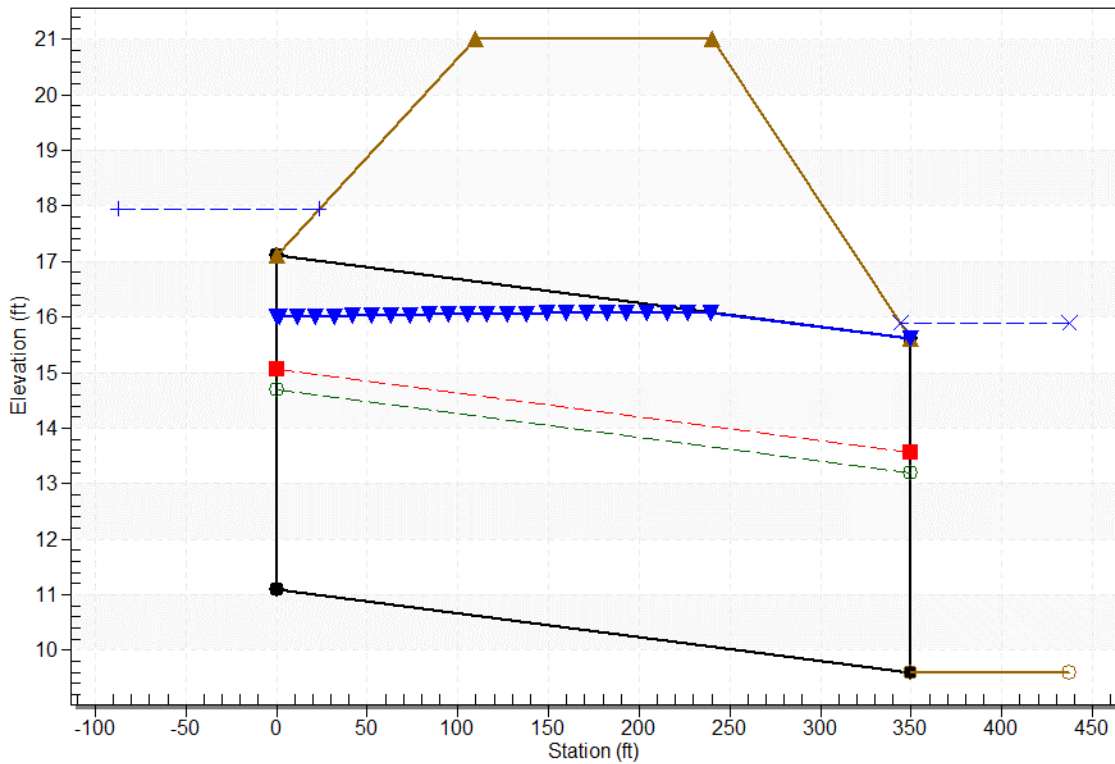
Culvert Slope: 0.0043

### Culvert Performance Curve Plot: Culvert 1



### Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Hurley Blvd, Design Discharge - 356.7 cfs  
Culvert - Culvert 1, Culvert Discharge - 356.7 cfs



### Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 11.10 ft

Outlet Station: 350.00 ft

Outlet Elevation: 9.60 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: None

### Tailwater Data for Crossing: Hurley Blvd

Table 3 - Downstream Channel Rating Curve (Crossing: Hurley Blvd)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
296.71	15.88	6.28
356.73	15.88	6.28

### Tailwater Channel Data - Hurley Blvd

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 15.88 ft

### Roadway Data for Crossing: Hurley Blvd

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 21.00 ft

Roadway Surface: Paved

Roadway Top Width: 130.00 ft

# Hillcrest Avenue

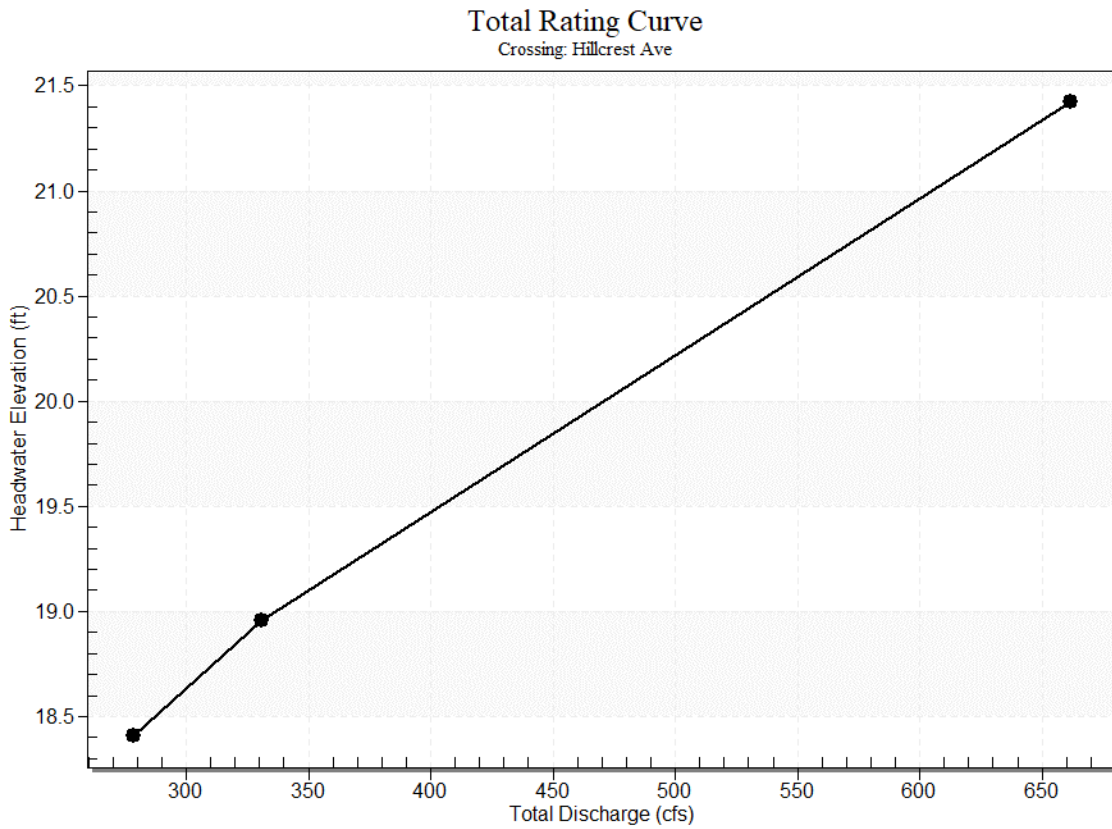
## Crossing Discharge Data

Discharge Selection Method: User Defined

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

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
18.41	10 year	278.56	278.56	0.00	1
18.96	25 year	330.82	330.82	0.00	1
21.00	Overtopping	471.48	471.48	0.00	Overtopping

## Rating Curve Plot for Crossing: Hillcrest Ave



## Culvert Data: Culvert 1

Table 2 - Culvert Summary Table: Culvert 1

Discharge Names	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)
10 year	278.56 cfs	278.56 cfs	18.41	5.67	5.960	3-M2t	5.16	3.35	4.63	4.63	7.52	0.00
25 year	330.82 cfs	330.82 cfs	18.96	6.41	6.509	3-M2t	6.00	3.76	4.63	4.63	8.93	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

Inlet Elevation (invert): 12.45 ft,

Outlet Elevation (invert): 12.40 ft

Culvert Length: 50.00 ft,

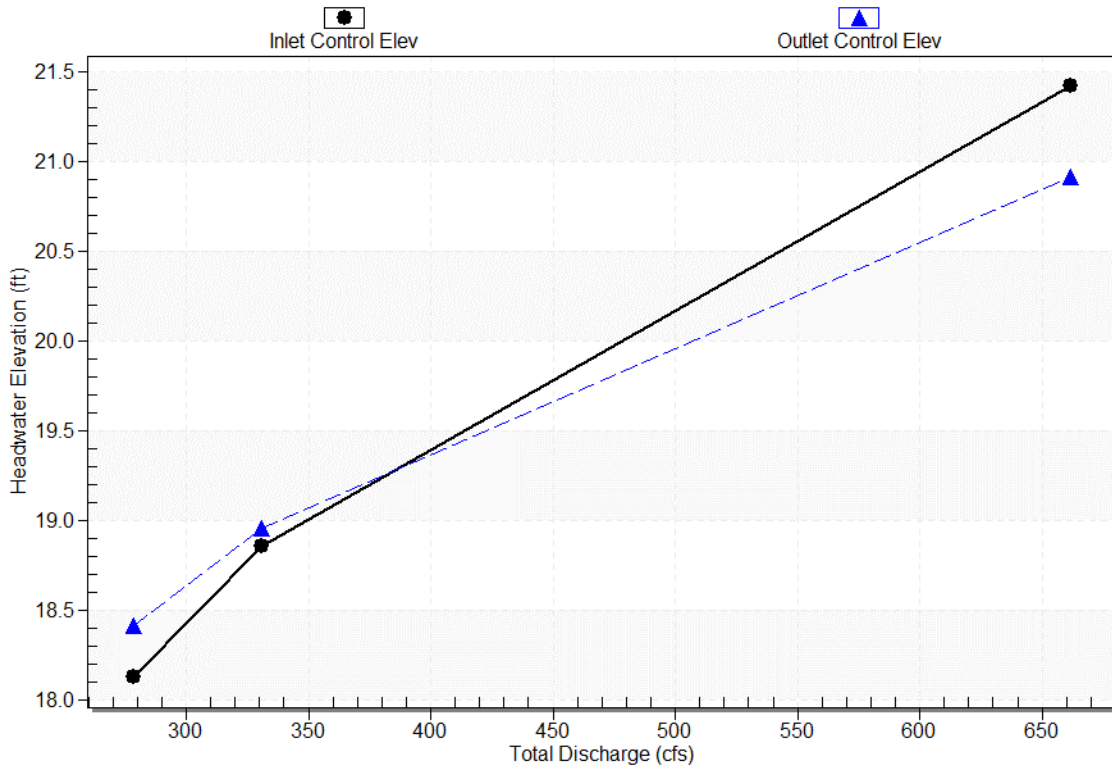
Culvert Slope: 0.0010



### Culvert Performance Curve Plot: Culvert 1

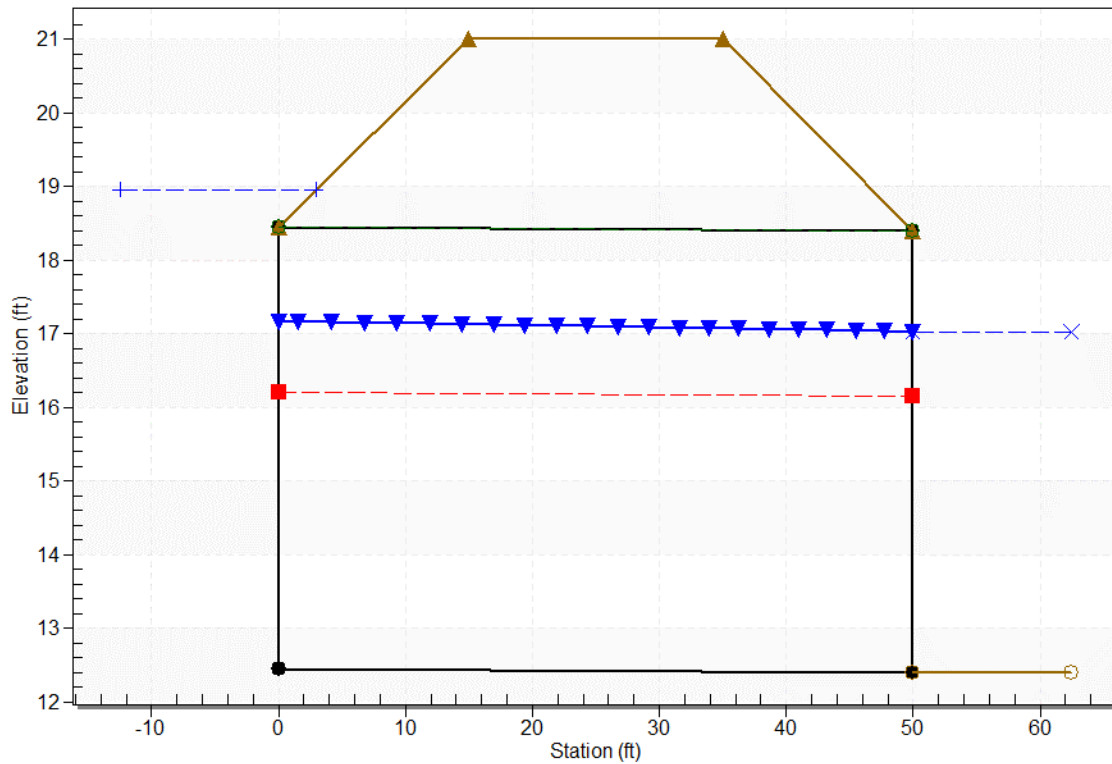
#### Performance Curve

Culvert: Culvert 1



## Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Hillcrest Ave, Design Discharge - 330.8 cfs  
Culvert - Culvert 1, Culvert Discharge - 330.8 cfs



## Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 12.45 ft

Outlet Station: 50.00 ft

Outlet Elevation: 12.40 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: None

### Tailwater Data for Crossing: Hillcrest Ave

Table 3 - Downstream Channel Rating Curve (Crossing: Hillcrest Ave)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
278.56	17.03	4.63
330.82	17.03	4.63

### Tailwater Channel Data - Hillcrest Ave

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 17.03 ft

### Roadway Data for Crossing: Hillcrest Ave

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 21.00 ft

Roadway Surface: Paved

Roadway Top Width: 20.00 ft

# Public Works

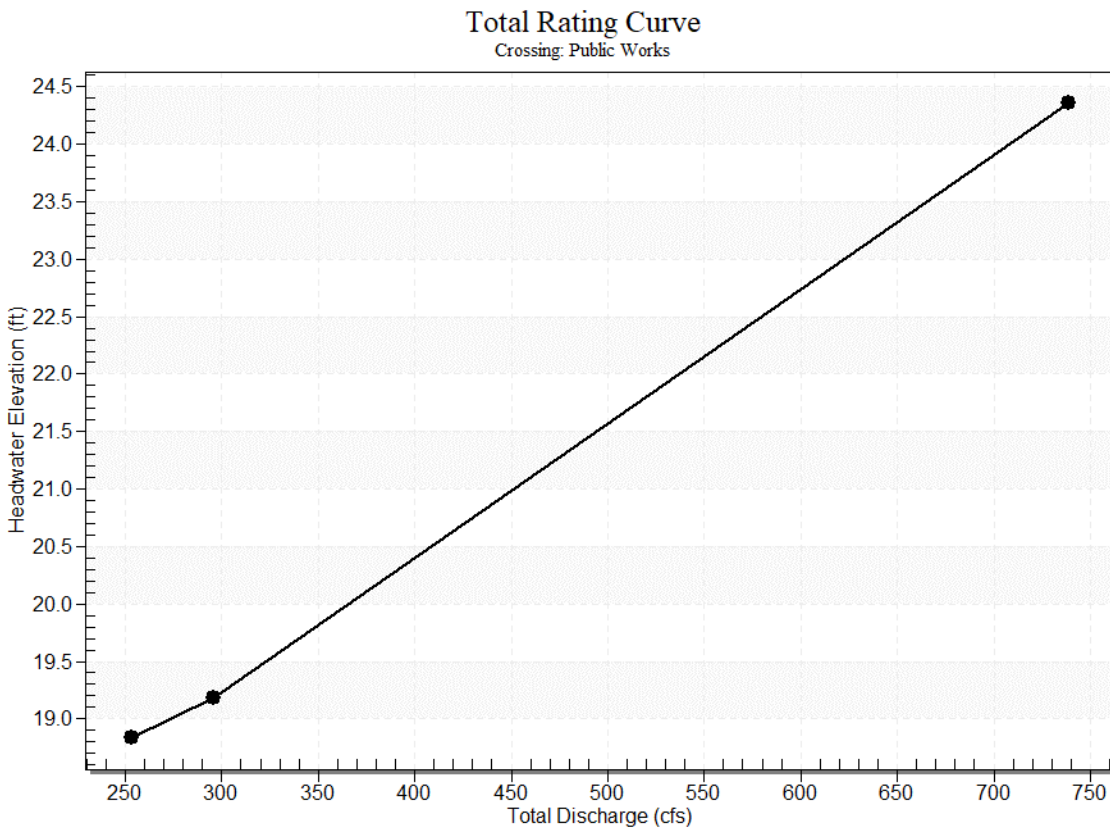
## Crossing Discharge Data

Discharge Selection Method: User Defined

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

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
18.84	10 year	253.41	253.41	0.00	1
19.18	25 year	295.49	295.49	0.00	1
24.00	Overtopping	608.70	608.70	0.00	Overtopping

## Rating Curve Plot for Crossing: Public Works



## Culvert Data: Culvert 1

Table 2 - Culvert Summary Table: Culvert 1

Discharge Names	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)
10 year	253.41 cfs	253.41 cfs	18.84	5.32	5.989	3-M2t	5.47	3.15	5.07	5.07	6.25	0.00
25 year	295.49 cfs	295.49 cfs	19.18	5.91	6.332	3-M2t	6.00	3.49	5.07	5.07	7.29	0.00

## Culvert Barrel Data

Culvert Barrel Type Straight Culvert

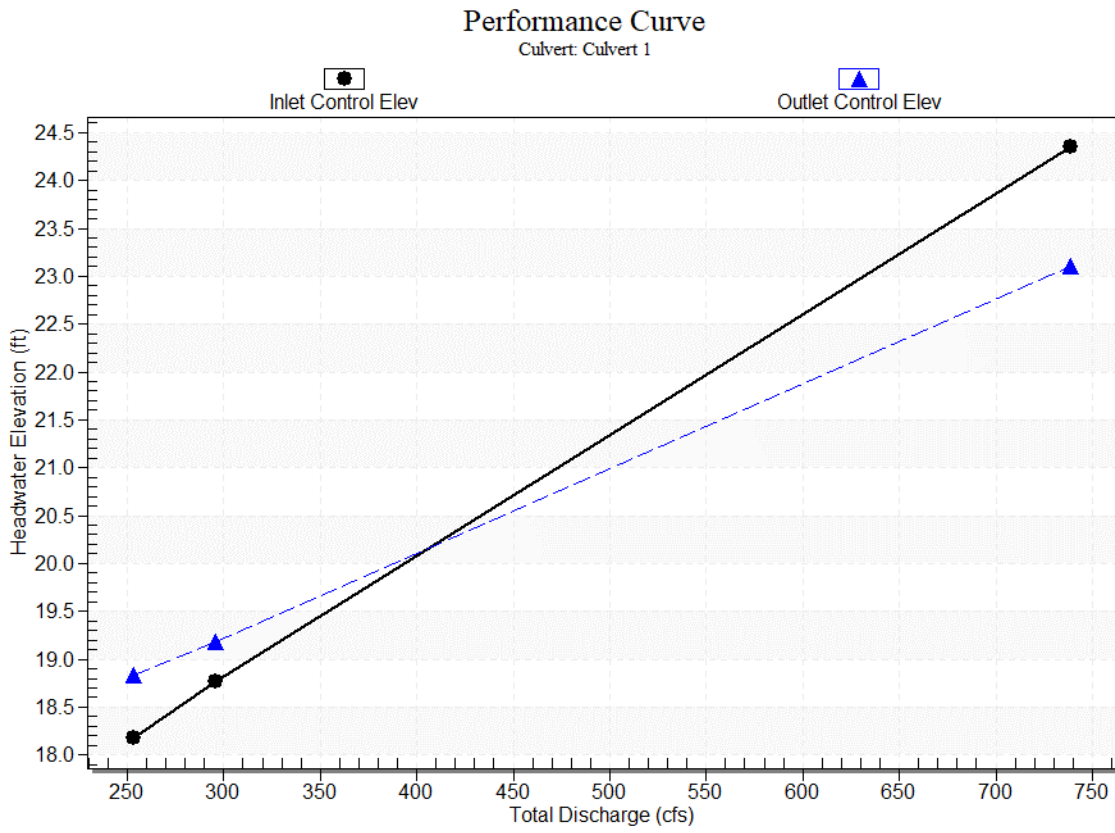
Inlet Elevation (invert): 12.85 ft,

Outlet Elevation (invert): 12.80 ft

Culvert Length: 70.00 ft,

Culvert Slope: 0.0007

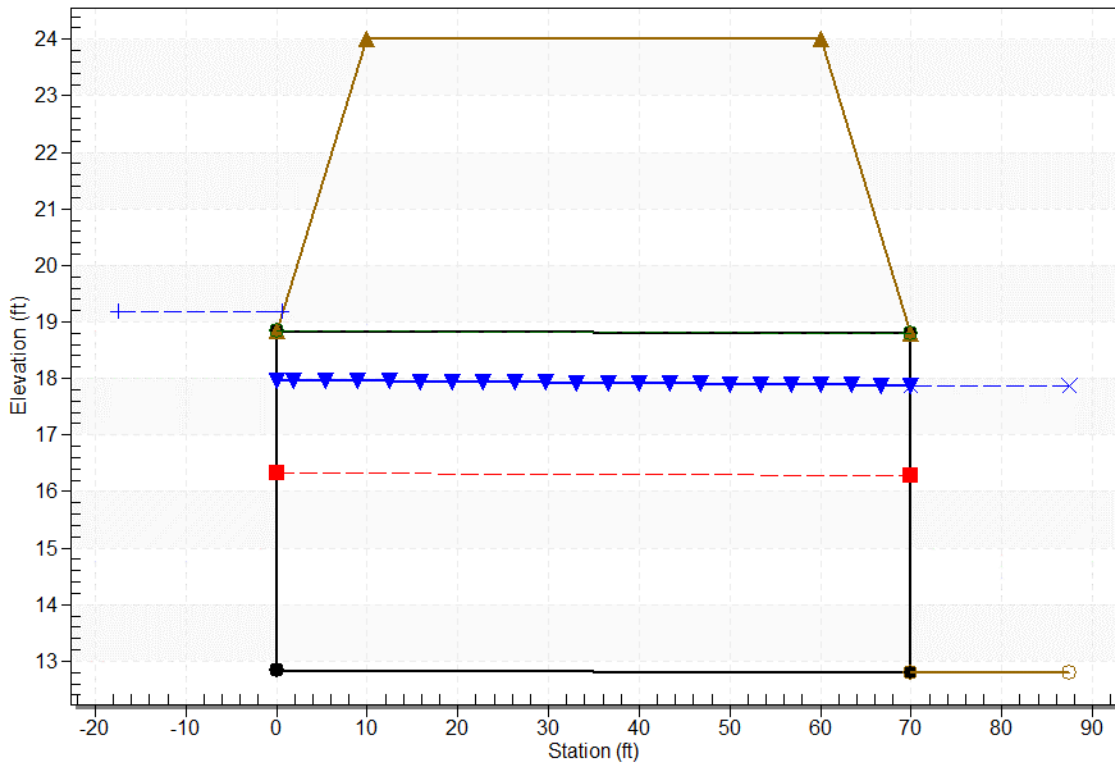
### Culvert Performance Curve Plot: Culvert 1





### Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Public Works, Design Discharge - 295.5 cfs  
Culvert - Culvert 1, Culvert Discharge - 295.5 cfs



### Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 12.85 ft

Outlet Station: 70.00 ft

Outlet Elevation: 12.80 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: None

### Tailwater Data for Crossing: Public Works

Table 3 - Downstream Channel Rating Curve (Crossing: Public Works)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
253.41	17.87	5.07
295.49	17.87	5.07

### Tailwater Channel Data - Public Works

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 17.87 ft

### Roadway Data for Crossing: Public Works

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 24.00 ft

Roadway Surface: Gravel

Roadway Top Width: 50.00 ft

# Methodist Church

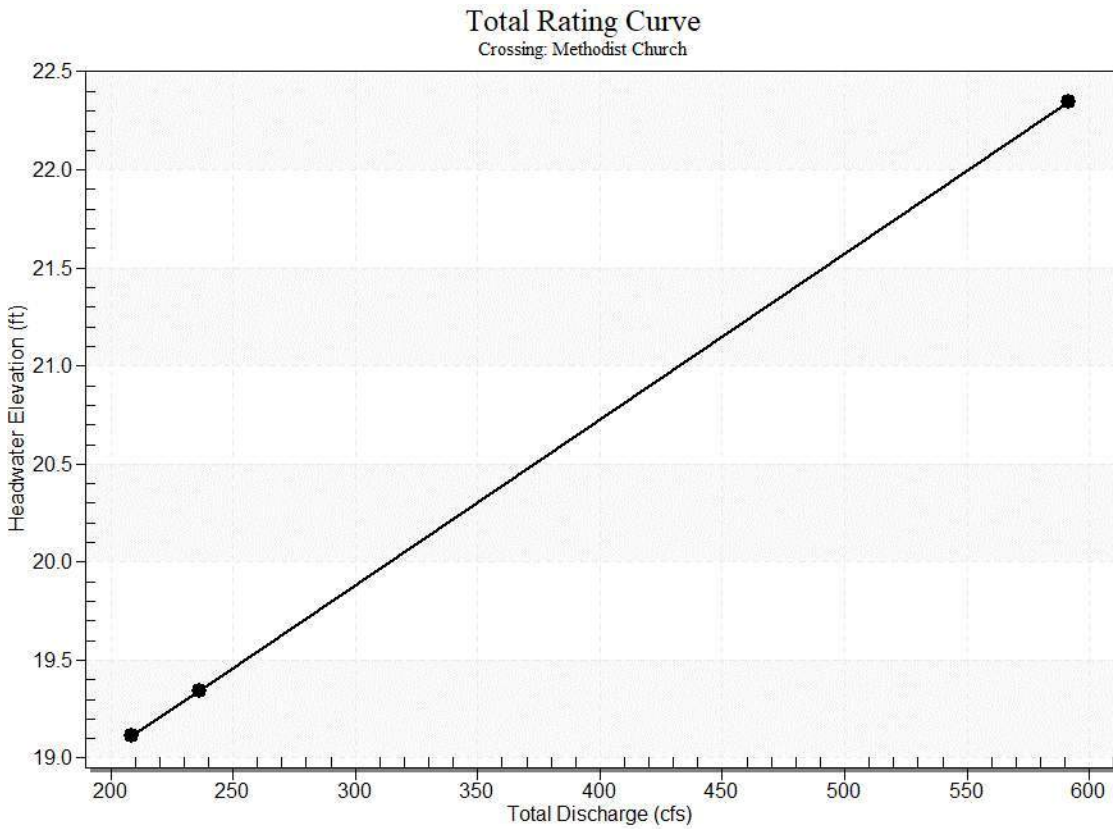
## Crossing Discharge Data

Discharge Selection Method: User Defined

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

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
19.12	10 year	208.66	208.66	0.00	1
19.34	25 year	236.58	236.58	0.00	1
22.00	Overtopping	447.81	447.81	0.00	Overtopping

## Rating Curve Plot for Crossing: Methodist Church



## Culvert Data: Culvert 1

Table 2 - Culvert Summary Table: Culvert 1

Discharge Names	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)
10 year	208.66 cfs	208.66 cfs	19.12	4.67	5.265	1-S1t	2.50	2.76	4.68	4.68	5.57	0.00
25 year	236.58 cfs	236.58 cfs	19.34	5.07	5.490	1-S1t	2.73	3.01	4.68	4.68	6.32	0.00

## Culvert Barrel Data

Culvert Barrel Type Straight Culvert

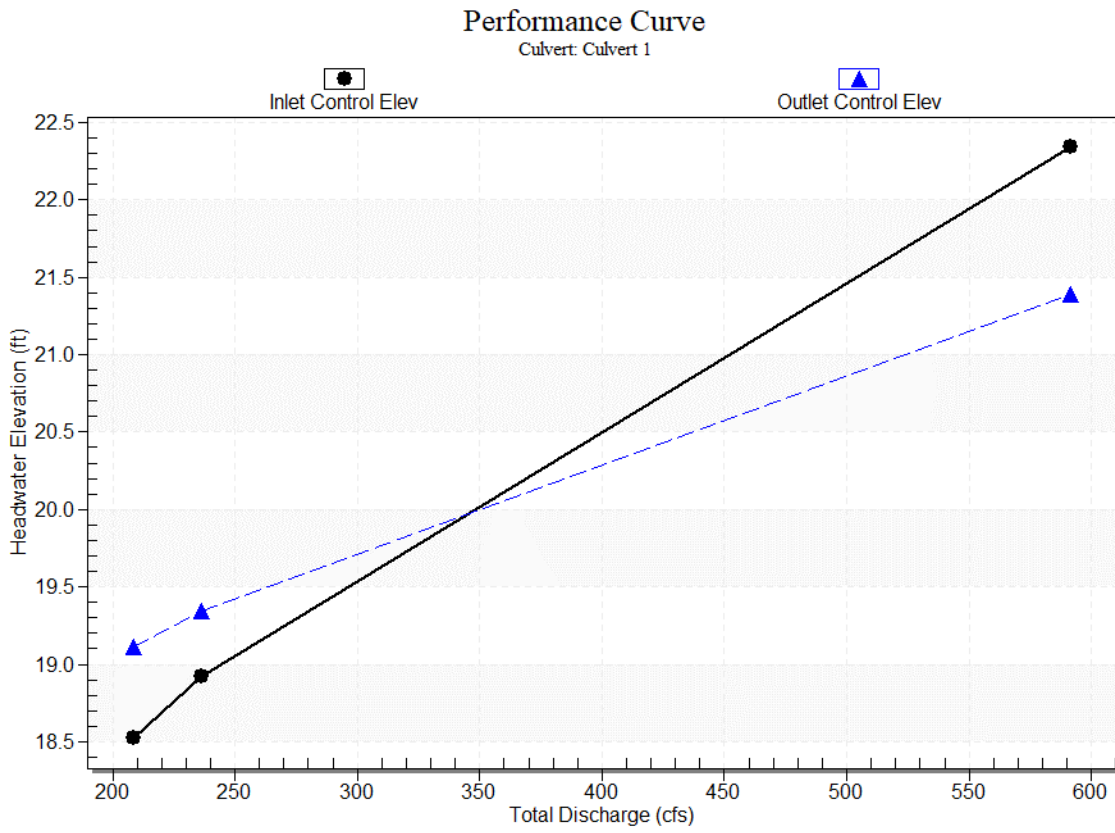
Inlet Elevation (invert): 13.85 ft,

Outlet Elevation (invert): 13.65 ft

Culvert Length: 50.00 ft,

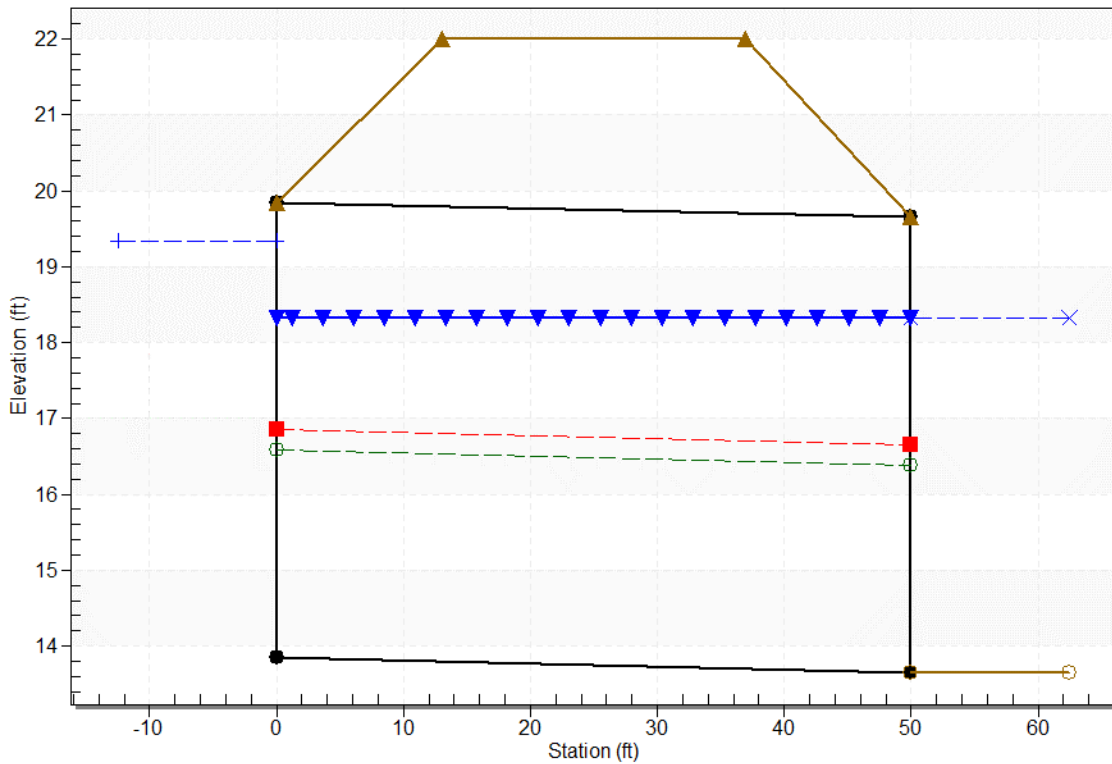
Culvert Slope: 0.0040

### Culvert Performance Curve Plot: Culvert 1



### Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Methodist Church, Design Discharge - 236.6 cfs  
Culvert - Culvert 1, Culvert Discharge - 236.6 cfs



### Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 13.85 ft

Outlet Station: 50.00 ft

Outlet Elevation: 13.65 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: None

### Tailwater Data for Crossing: Methodist Church

Table 3 - Downstream Channel Rating Curve (Crossing: Methodist Church)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
208.66	18.33	4.68
236.58	18.33	4.68

### Tailwater Channel Data - Methodist Church

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 18.33 ft

### Roadway Data for Crossing: Methodist Church

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 22.00 ft

Roadway Surface: Paved

Roadway Top Width: 24.00 ft



# Jupiter Boulevard

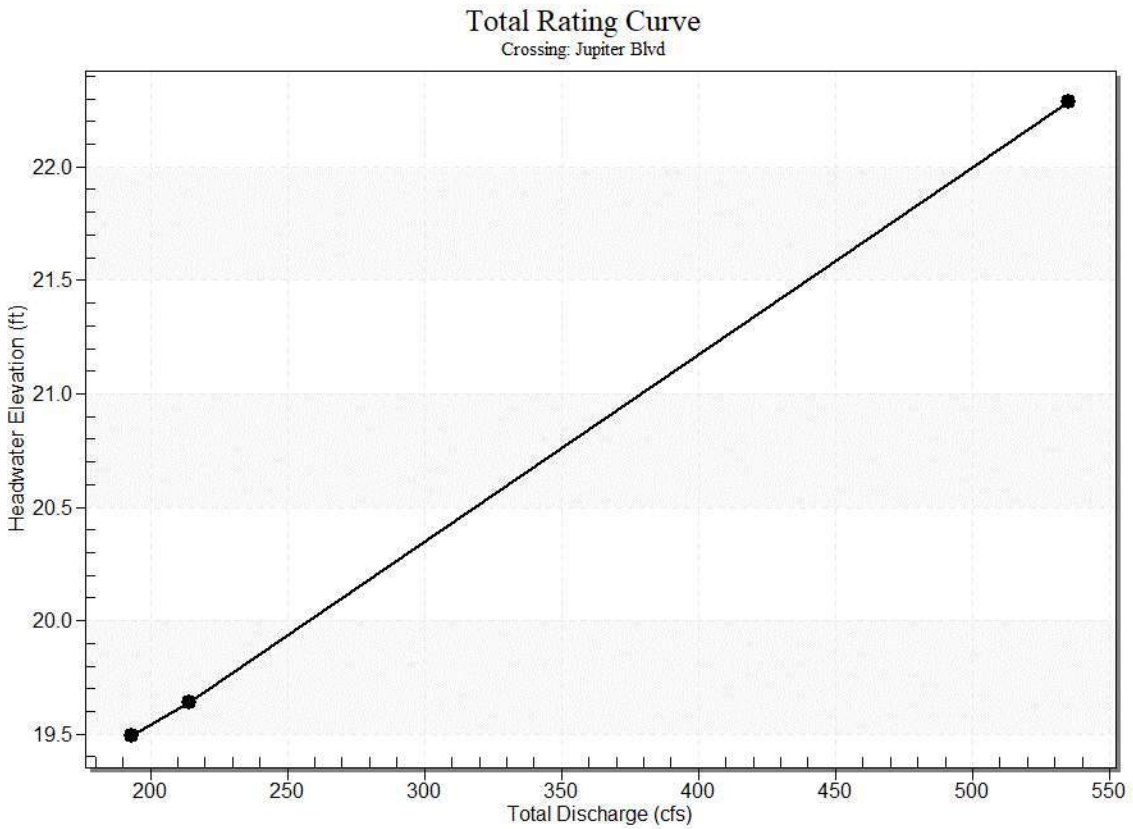
## Crossing Discharge Data

Discharge Selection Method: User Defined

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

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
19.49	10 year	193.23	193.23	0.00	1
19.64	25 year	214.00	214.00	0.00	1
22.00	Overtopping	425.63	425.63	0.00	Overtopping

## Rating Curve Plot for Crossing: Jupiter Blvd



## Culvert Data: Culvert 1

Table 2 - Culvert Summary Table: Culvert 1

Discharge Names	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)
10 year	193.23 cfs	193.23 cfs	19.49	4.44	5.294	1-S1t	2.62	2.63	4.96	4.96	4.87	0.00
25 year	214.00 cfs	214.00 cfs	19.64	4.75	5.438	3-M1t	2.82	2.81	4.96	4.96	5.39	0.00

### Culvert Barrel Data

Culvert Barrel Type Straight Culvert

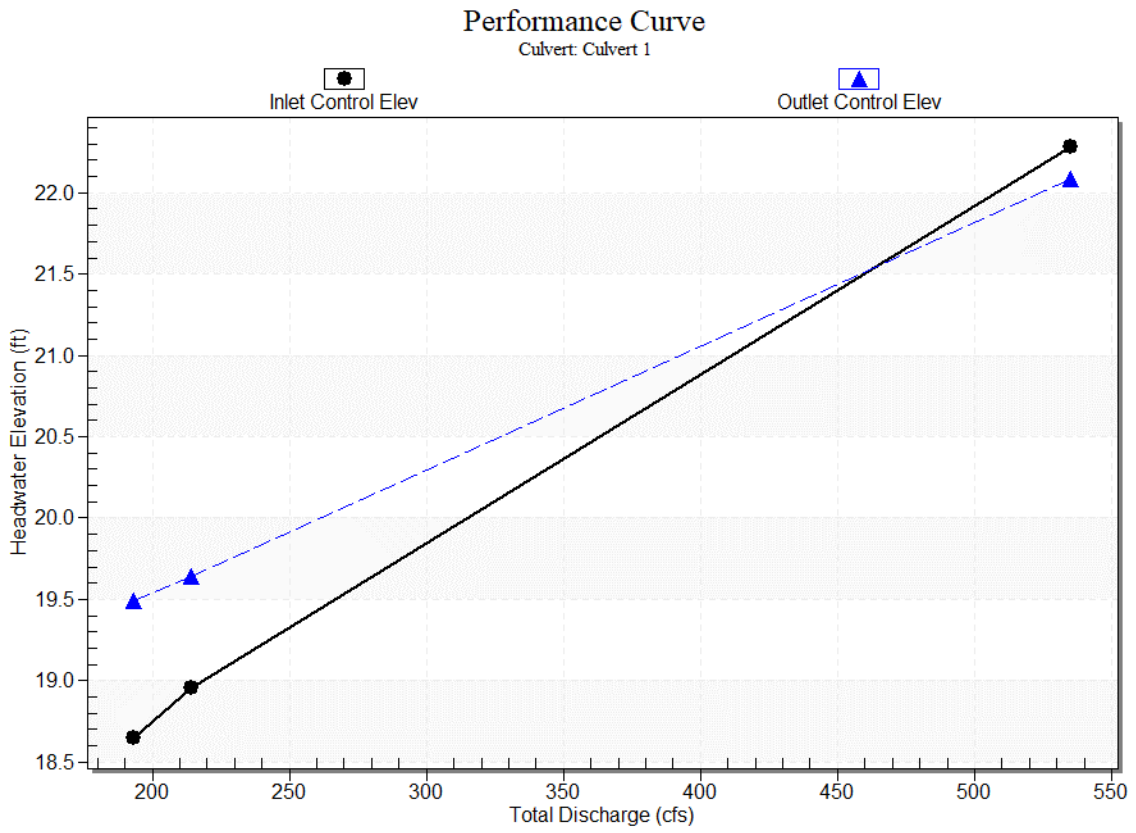
Inlet Elevation (invert): 14.20 ft,

Outlet Elevation (invert): 13.90 ft

Culvert Length: 100.00 ft,

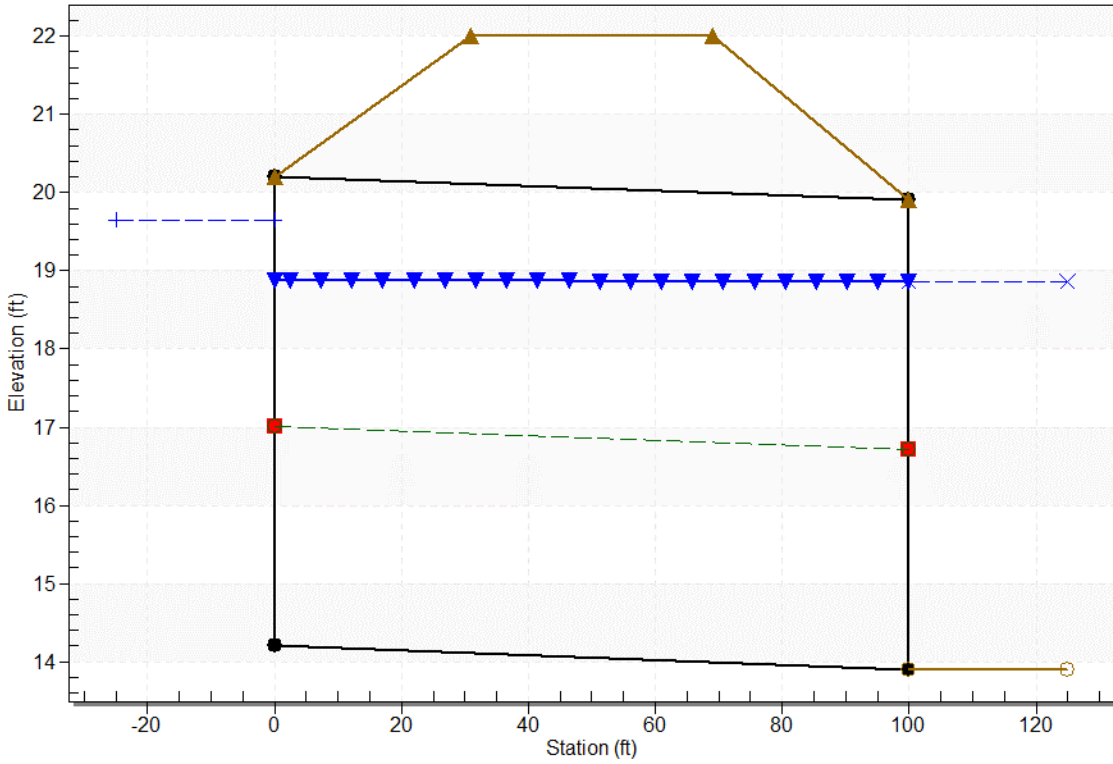
Culvert Slope: 0.0030

### Culvert Performance Curve Plot: Culvert 1



### Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Jupiter Blvd, Design Discharge - 214.0 cfs  
Culvert - Culvert 1, Culvert Discharge - 214.0 cfs



### Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 14.20 ft

Outlet Station: 100.00 ft

Outlet Elevation: 13.90 ft

Number of Barrels: 1

### Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 8.00 ft

Barrel Rise: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Culvert Type: Straight

Inlet Configuration: Square Edge (90°) Headwall

Inlet Depression: None

### Tailwater Data for Crossing: Jupiter Blvd

Table 3 - Downstream Channel Rating Curve (Crossing: Jupiter Blvd)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)
193.23	18.86	4.96
214.00	18.86	4.96

### Tailwater Channel Data - Jupiter Blvd

Tailwater Channel Option: Enter Constant Tailwater Elevation

Constant Tailwater Elevation: 18.86 ft

### Roadway Data for Crossing: Jupiter Blvd

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 200.00 ft

Crest Elevation: 22.00 ft

Roadway Surface: Paved

Roadway Top Width: 38.00 ft

# Malabar Road PD&E Study

FM No. 437210-1-28-01

## ***APPENDIX E***

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### **Cross Drain Pictures and Review Checklist**

# Malabar Road PD&E Study

FM No. 437210-1-28-01

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### Review Checklist

# CD-1

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 62+80 Size/Type 2 - 96" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                      *Basin divide*                      *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                      *Wetlands*

Normal high water marks: Approx. 2' below crown of pipe

Tailwater:      Ditch      *Piped outfall*                      *Overland flow*                      *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



North MES





South MES

### Review Checklist

# CD-2

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 89+18 Size/Type 8' x 6' CBC

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                      *Basin divide*                      *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                      *Wetlands*

Normal high water marks: None

Tailwater:      Ditch      *Piped outfall*                      *Overland flow*                      *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: Please note, images taken depict old round pipe. This culvert is

permitted for replacement with an 8' x 6' CBC which is taken as

the existing condition for the purpose of this study.





North End of Pipe





South End of Pipe

### Review Checklist

# CD-3

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 114+67 Size/Type 18" CMP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                      *Basin divide*                      *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                      *Wetlands*

Normal high water marks: None

Tailwater:      Ditch      *Piped outfall*                      *Overland flow*                      *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: Pipe outlet could not be located

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





South End of Pipe

### Review Checklist

# CD-4

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 115+71 Size/Type 54" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                      *Basin divide*                      *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                      *Wetlands*

Normal high water marks: Approx. 6" above pipe invert

Tailwater:      Ditch      *Piped outfall*                      *Overland flow*                      *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_





North End of Pipe





South End of Pipe  
(top view)

### Review Checklist

# CD-5

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 155+75 Size/Type 13" x 21" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                  *Basin divide*                  *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                  *Wetlands*

Normal high water marks: None

Tailwater:      Ditch      *Piped outfall*                  *Overland flow*                  *Swamp*

Erosion/Sedimentation: Endwall not supported underneath

Misc. Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





North Headwall





South Catch Basin

### Review Checklist

# CD-6

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 176+84 Size/Type 14" x 23" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                      *Basin divide*                      *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                      *Wetlands*

Normal high water marks: None

Tailwater:      Ditch      *Piped outfall*                      *Overland flow*                      *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_





North End of Pipe





South Headwall

### Review Checklist

# CD-7

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 188+40 Size/Type 21" x 28" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping?      *Roadway*                      *Basin divide*                      *In roadway ditch*

Concerns with culvert extension?      *Limited right of way*                      *Wetlands*

Normal high water marks: None

Tailwater:      Ditch      *Piped outfall*                      *Overland flow*                      *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





North End of Pipe





South Manhole

### Review Checklist

# CD-8

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 224+58 Size/Type 18" x 30" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping? Roadway *Basin divide* *In roadway ditch*

Concerns with culvert extension? *Limited right of way* *Wetlands*

Normal high water marks: None

Tailwater: Ditch *Piped outfall* *Overland flow* *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: End of pipe broken with rebar exposed

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





North End of Pipe





South Headwall

### Review Checklist

# CD-9

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage Parkway to Minton Road

Location: 238+72 Size/Type 19" x 30" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping? Roadway Basin divide In roadway ditch

Concerns with culvert extension? Limited right of way Wetlands

Normal high water marks: Approx 6" below crown of pipe

Tailwater: Ditch Piped outfall Overland flow Swamp

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





North End of Pipe





South MES & Manhole



### Review Checklist

# CD-10

Date: 05/03/21  
Project: Malabar Road from St. Johns Heritage  
Parkway to Minton Road

Location: 248+33 Size/Type 19" x 30" RCP

Road surface/Leaking joints? No

Recent development in basin? Yes

Overtopping? Roadway *Basin divide* *In roadway ditch*

Concerns with culvert extension? *Limited right of way* *Wetlands*

Normal high water marks: None

Tailwater: Ditch *Piped outfall* *Overland flow* *Swamp*

Erosion/Sedimentation: \_\_\_\_\_

Misc. Comments: End of pipe broken with rebar exposed

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_





North End of Pipe





South Headwall

# Malabar Road PD&E Study

FM No. 437210-1-28-01

## ***APPENDIX F***

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### **National Bridge Inventory Data**



# Malabar Road PD&E Study

FM No. 437210-1-28-01

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- [Go to:](#)
- [Map](#)
- [Facts](#)
- [Latest Inspection](#)
- [Previous Inspections](#)

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# Malabar Rd over Canal

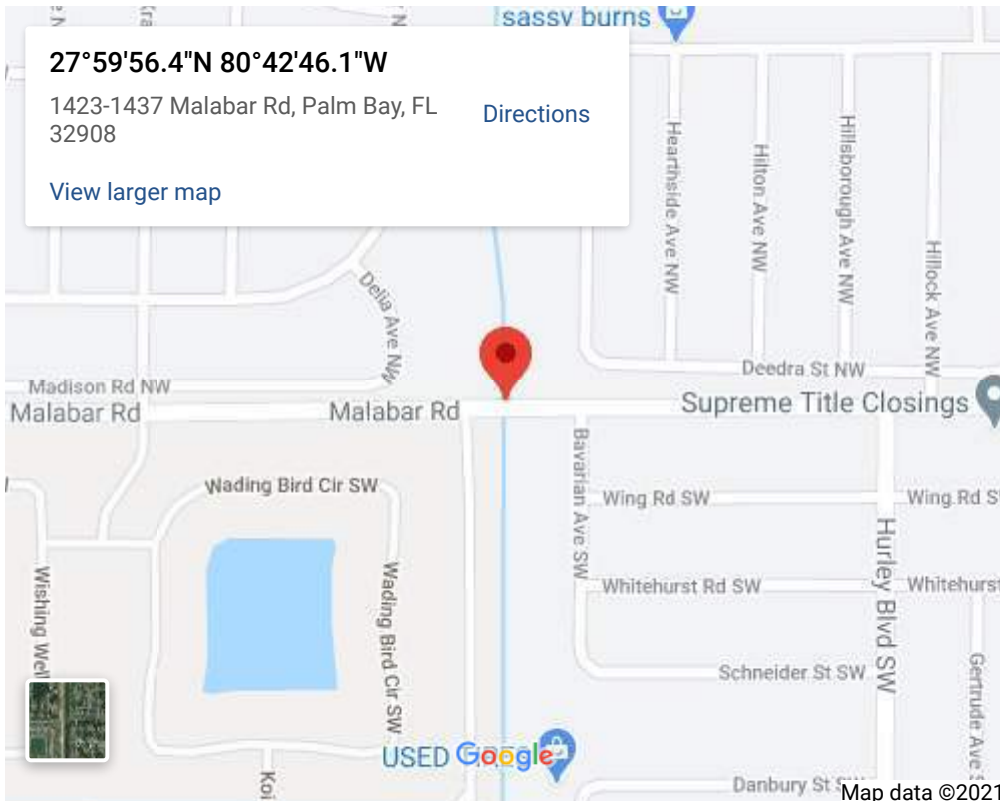
[Brevard County, Florida](#)

## Map

- [Google Maps](#)
- [Bing Maps](#)
- [OpenStreetMap](#)
- [MapQuest.com](#)
- [USGS National Map](#)
- [Geo URI \(Android\)](#)

### Coordinates:

+27.99900, -80.71282  
27°59'56" N, 80°42'46" W



## Facts

Source: National Bridge Inventory. Information not verified; use at your own risk.

Name: Malabar Rd over Canal  
 Structure number: 704004  
 Location: 2.5 Miles West of CR-509  
 Purpose: Carries highway and pedestrian walkway over waterway  
 Route classification: Local (Urban) [19]  
 Length of largest span: 27.9 ft. [8.5 m]  
 Total length: 140.1 ft. [42.7 m]  
 Roadway width between curbs: 28.2 ft. [8.6 m]  
 Deck width edge-to-edge: 36.7 ft. [11.2 m]  
 Owner: County Highway Agency [02]  
 Year built: 1972  
 Historic significance: Bridge is not eligible for the National Register of Historic Places [5]  
 Design load: MS 18 / HS 20 [5]  
 Number of main spans: 5  
 Main spans material: Prestressed concrete [5]  
 Main spans design: Slab [01]  
 Deck type: Concrete Precast Panels [2]  
 Wearing surface: Bituminous [6]

## Latest Available Inspection: February 2018

Good/Fair/Poor  
 Condition: Good  
 Status: Open, no restriction [A]  
 Average daily traffic: 2,871 [as of 2014]  
 Truck traffic: 11% of total traffic  
 Deck condition: Good [7 out of 9]  
 Superstructure condition: Good [7 out of 9]  
 Substructure condition: Good [7 out of 9]  
 Structural appraisal: Better than present minimum criteria [7]  
 Deck geometry appraisal: Meets minimum tolerable limits to be left in place as is [4]  
 Water adequacy appraisal: Equal to present desirable criteria [8]  
 Roadway alignment appraisal: Equal to present desirable criteria [8]  
 Channel protection: Bank protection is in need of minor repairs. River control devices and embankment protection have a little minor damage. Banks and/or channel have minor amounts of drift. [7]  
 Scour condition: Bridge foundations determined to be stable for assessed or calculated scour condition. [5]  
 Sufficiency rating: 77.6

## Previous Inspections

Date	Condition	Deck	Superstructure	Substructure	ADT	Suff. Rating
------	-----------	------	----------------	--------------	-----	--------------

February 2018	Good	Good	Good	Good	2871	77.6
February 2016	Good	Good	Good	Good	2871	77.6
February 2014	Good	Good	Good	Good	2871	77.6
February 2012	Good	Good	Good	Good	2871	77.6
February 2010	Good	Good	Good	Good	2871	77.6
February 2008	Good	Good	Good	Good	2871	77.6
March 2006	Good	Good	Good	Good	2871	77.6
March 2004	Good	Good	Good	Good	2871	78.6
March 2002	Good	Very Good	Very Good	Good	2871	95.1
February 2000	Good	Very Good	Very Good	Good	2834	78.7
February 1998	Good	Very Good	Very Good	Good	2232	86.9
February 1996	Good	Very Good	Very Good	Good	2188	82.1
March 1994	Good	Good	Very Good	Good	900	84.3
January 1992	Good	Good	Very Good	Good	900	84.3

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