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2901 S. Lynnhaven Rd.
Suite 200
Virginia Beach, VA 23452

P 757.213.6679
F 757.340.1415
www.timmons.com

MEMORANDUM

TO: City of Harrisonburg Public Works

FROM: Sydney Plackett, PE

DATE: February 24, 2025

RE: Stormwater Management Study of the Chicago Avenue & Waterman Drive Corridor; Final Recommendations

Methodology

A PCSWMM model was developed to assess the storm sewer system as scoped in the Chicago Avenue & Waterman Drive study (Chicago/Waterman). Refer to Figure 1 for context. The system extends from the Parkview (city-owned) property southward to the outfall east of South Dogwood Drive, ultimately discharging into Blacks Run. The existing conveyance system, which consists of pipes and ditches, was modeled using field data obtained from City GIS, LiDAR, and supplemental site data provided by the City.

Figure 1: Limits of Conveyance System Assessed

Subwatershed hydrology applied to the model was derived using the TR-55 method to determine areas, curve numbers, and times of concentration. Generally, each junction at the upstream-most points of ditches, culverts, and pipes is represented by a subwatershed.

The primary conveyance system was modeled in PCSWMM, along with an overflow system that reflects the cross-section of topographic low points (flood flow lines). This overland system is primarily situated in the front of commercial properties on the eastern side of Waterman Drive. When stormwater in the primary system crests at a junction due to undersized downstream conduits, excess flow is routed to this overflow system.

In evaluating the existing condition for a typical 24-hour storm event, only storms as large as 1 inch could be conveyed by the storm sewer system. This is largely due to bottlenecks in the primary conveyance system caused by undersized pipes (18-20" culverts serving commercial entrances), which result in overland flooding. This is illustrated in Figure 2, where the hydraulic grade line (HGL) crests over the top of the conduits.

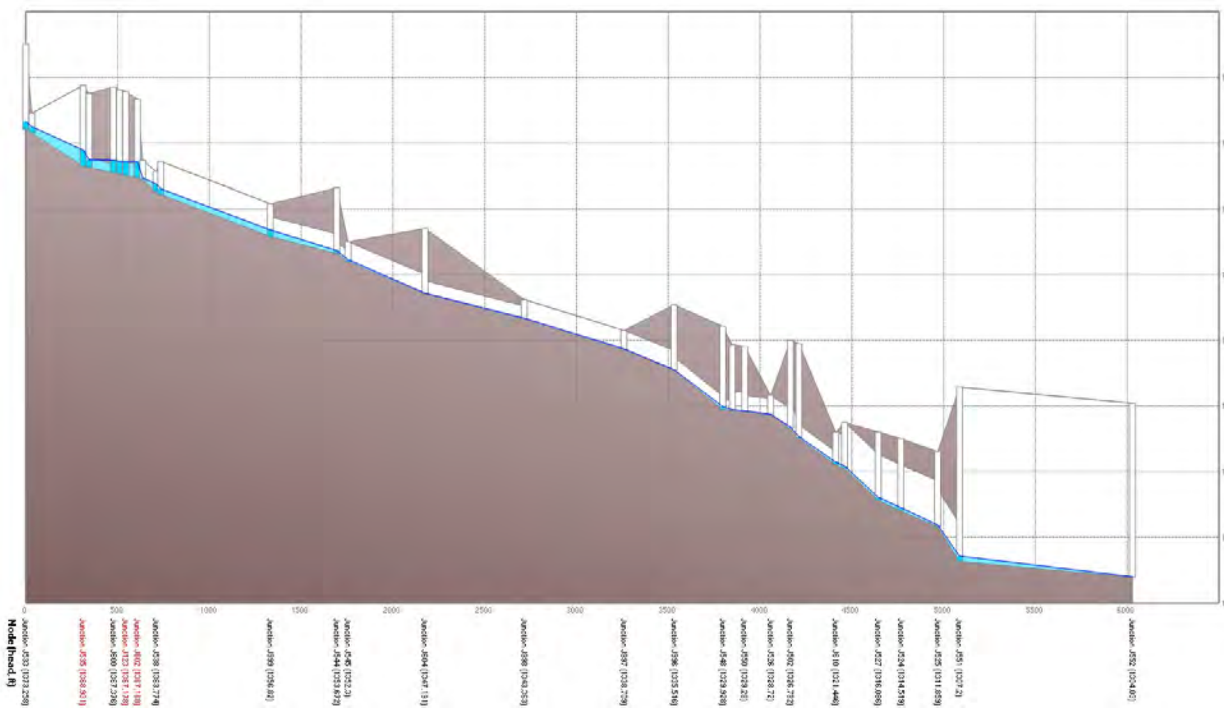


Figure 2: Profile of Chicago/Waterman Western System, Flooded Nodes in Red

<u>Existing System Level of Service and Flooding</u>

To further evaluate system capacity, historic rainfall data was considered. The National Centers for Environmental Information (NCEI) offers monthly summaries of daily rainfall[1] (gauge ID US1VARH001). In assessing each month in 2024, May 2024 had a higher-than-average amount of rainfall, totaling 8.11 inches, with significant events on May 4 (1.95 inches), May 6 (2.20 inches), and May 18 (1.44 inches). Using these dates, hourly precipitation was derived from Weather Underground; the available station closest to the project area was the Shenandoah Valley Regional Airport Station[2]. Cumulative precipitation data every 20 minutes was available for May 4 (1.33 inches total rainfall) and May 18 (2.64 inches total

[1] "Past Weather | National Centers for Environmental Information (NCEI)." National Oceanic and Atmospheric Administration (NOAA), www.ncei.noaa.gov/access/past-weather/22802.

[2] "Weyers Cave, Va Weather History." *Weather Underground*, www.wunderground.com/history/daily/KSHD/date/2024-5-18

rainfall). Since PCSWMM requires time series data like that provided by Weather Underground to accurately simulate storm behavior, only these events were assessed.

For the May 4 event, flooding began after 90 minutes from the start of rainfall; for May 18, flooding began after 5 hours. This is due in-part to storm intensity increasing several hours after initial rainfall. In the case of the May 18 event, flooding did not occur until an intensity of 0.45 inches of rainfall occurred within 20 minutes. Note that the 5 AM – 6 AM intensity of the storm averages to 0.30 inches/hour (see Figure 3, below).

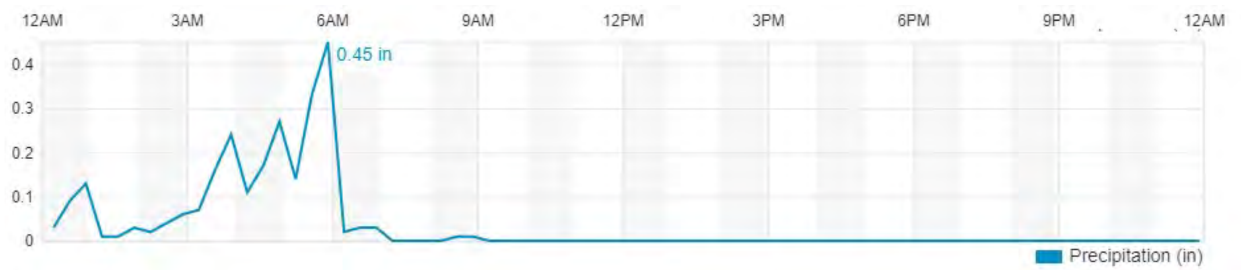


Figure 3: Shenandoah Valley Regional Airport Recorded Rainfall on May 18, 2024

To better understand intensity's effect on the system, a visual comparison was found using rainfalls recorded by the National Weather Service Los Angeles office (NWSLosAngeles). The PCSWMM model was rerun with constant intensities to observe how long it would take to flood. In the May 18 example, the rainfall intensity would cause flooding within 2 hours. Refer to the table for links to selected storm intensities.

Table 1: Intensity (inches/hour) of Storm Needed to Generate Flooding

Intensity (in/hr)	Time to Flood (hr)
0.05	*-
0.10	*8.0
0.15	4.0
0.20	2.5
0.25	*2.25
0.30	2.0
0.35	1.75
0.40	1.50
0.45	1.25
0.50	*1.125

**Denotes rainfall intensity has been recorded by NWSLosAngeles. This was used as a touchstone to communicate intensity to the public.*

It is critical to note that even light rainfall can create flood conditions due to the size of the upstream watershed, approximately 132 acres as shown in Figure 4. Though storm sewers and ditches exist within this area, all runoff is directed to the city-owned Parkview property. This area generates around 280 cubic feet per second (CFS) of flow during a 10-year, 24-hour storm (the design standard for conveyance systems per state guidelines).

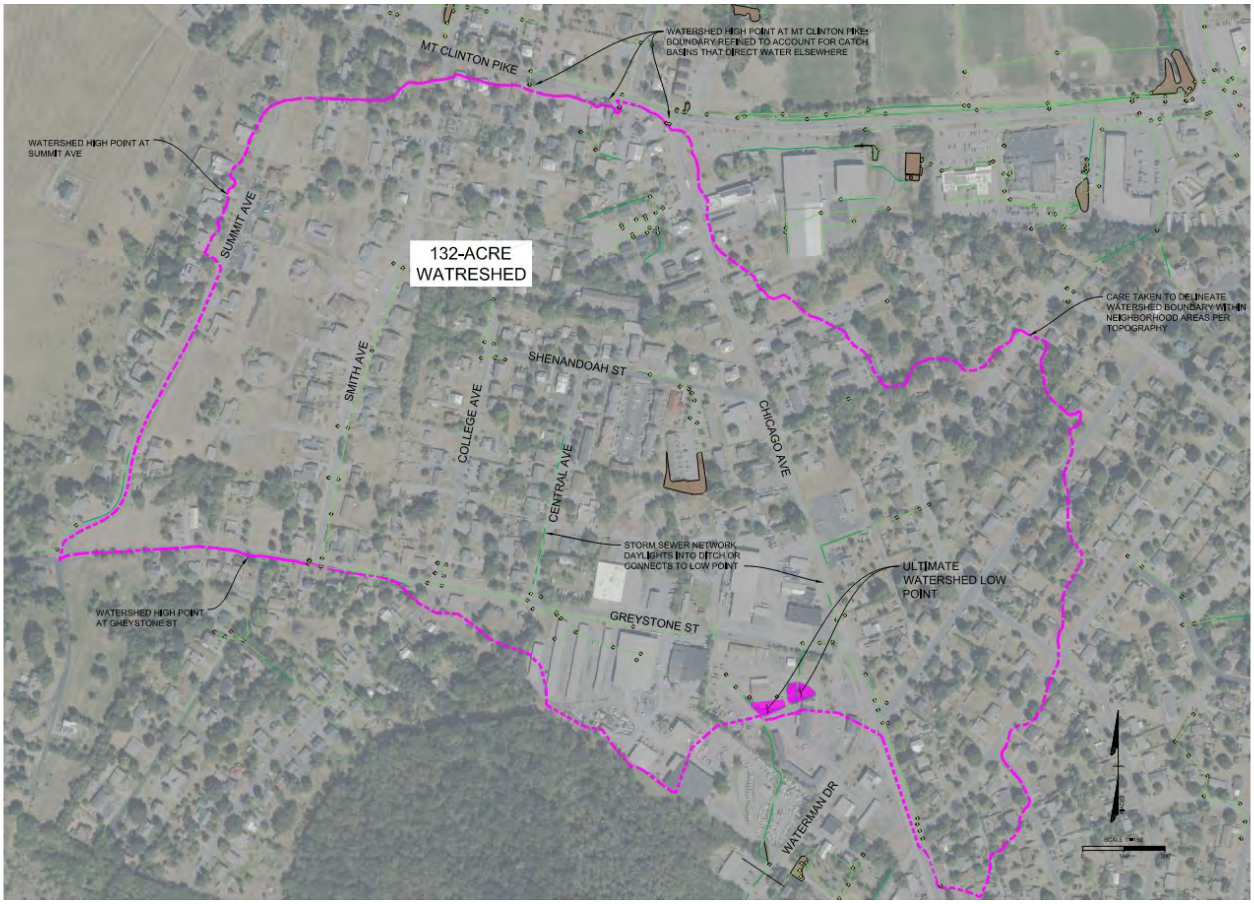


Figure 4: Upper-Most Watershed Directed to Project Area

Conveyance System Assessment and Approach

The goal of this study is to design adequately sized and safely traversable ditches and pipes that prevent flooding during the 10-year, 24-hour storm event. The design extends from the Parkview property to the natural ditch east of Waterman Drive (north of 78 Waterman Drive).

Culverts will be required to accommodate commercial entrances on Waterman Drive's west side. These culverts are a major bottleneck in the current system, so significant upsizing is needed. Based on engineering analysis, three barrels of 48" pipes will provide the necessary conveyance. While this is large, it is justified by the fact that this is the primary conveyance system upstream of a large natural channel.

Special consideration is needed for ground elevation around the (3) 48" pipes, to ensure adequate cover without creating significant mounds, which could be hazardous on a 35 MPH road. Currently, 18"-24" corrugated metal pipes serve commercial entrances with minimal cover (see Figure 5). To install 48" pipes, the conveyance system's flowline must be deeper, requiring a flatter slope. A slope of 0.95% from 515 Waterman Drive southward, and 1.51% northward, was determined to provide adequate cover. This will require an average excavation depth of 3.6 feet along the system.

Figure 5: Existing Culvert Serving Waterman Drive

With this minimum excavation depth, triangular and trapezoidal cross-sections were assessed in PCSWMM for the ditches west of Waterman Drive. A significant observation made was that, given the amount of flow directed through this system, a material with a low “roughness coefficient” is recommended; this means that a concrete lined channel (n = 0.013) is recommended over a channel with rocky bedding (n = 0.030). Using Manning’s equation, this is this difference between a triangular cross section (n = 0.013) with a 14’ wide footprint and a trapezoidal cross section (n = 0.030) with a 21’ wide footprint.

Proposed Recommendations

The findings of a proposed PCSWMM model yield a recommendation for 4-foot-deep concrete-lined triangular channel with a 2:1 side slope. This, combined with the (3) 48” culverts, will provide adequate conveyance to the natural channel east of 78 Waterman Drive (see Figure 6). The system will serve as the primary conveyance along Waterman Drive, with selected pipe crossings to receive flow from the eastern storm sewer piping east of the roadway. A preliminary engineer’s estimate has been prepared for this recommendation, using a contingency and equitable material costs for FY25 within the Harrisonburg, Virginia area. The estimated cost is **$6.1 million**; with approximately 4,000 LF (3/4 mile) of improvements. The project can be broken into multiple phases to spread costs out over multiple fiscal years. Refer to Attachment 1 for additional information.

Figure 6: Proposed Connection to Existing Ditch

With the redirection of runoff into an adequate channel to the east, the remainder of the storm sewer system south of Waterman Drive, adjacent to the Food Maxx property, has adequate capacity.

Public Information Meeting

This preliminary recommendation was presented to the public on October 15, 2024, accompanied by exhibits provided in Attachment 2. During the meeting, business owners along Waterman Drive shared photos and timestamps of flooding incidents, emphasizing that extreme flooding occurs during brief but high-intensity storm events. While not all affected buildings are situated in the low point east of Waterman Drive, water heaving and rising out of the ditch has reached the finished floors of certain buildings. The most severe flooding was reported at 44 Waterman Drive.

Feedback was gathered through conversations with attendees and responses to distributed surveys. Overall, reception to the proposed ditch and pipe improvements was generally positive, but several concerns were identified. Below is a summary of these concerns along with the engineering responses based on current findings:

Faster Flooding from the Large Concrete Flume

Concern: The flume will accelerate water flow, causing faster flooding at the end of Waterman Drive.

Response: The flume is designed to handle 10-year flow rates with moderately high velocities (8 feet per second). The three 48-inch pipes provide sufficient capacity to convey water downstream without increasing flooding risk over Waterman Drive.

Impact on Flooding Upstream of the 72” Grated Culvert

Concern: Improvements may not reduce or may worsen flooding upstream of the 72-inch grated culvert.

Response: The project does not change the outfall or volume of water reaching this culvert. There will be no negative impact from upstream flooding.

Flooding from Overland Flow, Not Blockages

Concern: Significant water flow on Waterman Drive is unrelated to storm sewer blockages, suggesting roadway redesign is necessary.

Response: Overland flow at the intersection of Chicago Avenue and Waterman Drive, upland of the main project area, contributes to roadway flooding. The project incorporates conveyance improvements upstream to manage watershed flow impacting this intersection and ultimately flowing down the roadway.

Exclusion of Proposed Quarry Development

Concern: The quarry development was not considered, potentially increasing runoff and worsening flooding.

Response: The quarry development was excluded due to this study starting before the development was approved by Harrisonburg's City Council. Future development will be required to mitigate increased runoff to meet channel and flood protection standards. Any outfall directed to Waterman Drive must ensure no adverse impact on system capacity.

Adequacy of Design for Storm Events

Concern: The 10-year storm design standard is inadequate due to observed frequency and likelihood of larger events.

Response: The design follows city and state standards, using NOAA Atlas 14 data for precipitation depths.

Clogging of the 72” Grated Culvert

Concern: Frequent clogging of the downstream culvert grate leads to localized ponding, despite adequate conveyance when the grate is cleared.

Response: Business owners regularly clear debris and floatables from the grate to prevent ponding. While this maintenance resolves most issues, it requires consistent effort.

The proposed ditch and pipe improvements are designed to address existing flooding concerns while adhering to city and state design standards. While the system provides adequate conveyance under modeled conditions, operational challenges, such as debris accumulation at the downstream culvert, remain a critical factor. Addressing these challenges may require additional measures, such as enhanced maintenance protocols or physical modifications to the culvert grate.

The input gathered from the meeting and surveys reflects overall support for the project, with specific concerns offering valuable insight for future considerations. Moving forward, collaboration with stakeholders and ongoing monitoring will be essential to ensure the long-term effectiveness of the proposed solutions and to address any emerging issues related to new developments or changing storm patterns.

Alternatives and Other General Considerations

A minor modification to elliptical pipes could reduce excavation depth. A 38"x60" elliptical pipe provides the same capacity as a 48" RCP, reducing depth by 10 inches but increasing width by 3.5 feet. With limited right-of-way, the trade-off between excavation depth and width must be carefully evaluated. While elliptical pipes are 15-30% more expensive, the reduced excavation costs may offset the higher material costs.

The recommended upgrade to the primary stormwater conveyance system is located within the public right-of-way west of the roadway. This design ensures containment for up to a 10-year storm event, largely due to the deeper proposed flowline. However, the natural flowline along Waterman Drive is east of the roadway on private property, where overland flow will continue to accumulate during larger storms. Acquiring easements to develop a cross-section east of the roadway could improve capacity for larger storm events.

Water quality considerations were also evaluated. Due to size of the watershed upland of the project area (132 acres), implementing a linear water quality practice, such as a regenerative stormwater conveyance (RSC) channel, is not feasible; a basin-type best management practice (BMP) would be required.

Preliminary Basin BMP Overview

The overall low-lying area within the vicinity of Waterman Drive is located to the east of the roadway, within privately owned parcels. The basin would need to be sited on this side of the roadway, at the expense of property acquisition, and needs to be sized to accommodate the minimum treatment volume (Tv), the 10-year maximum outgoing flow rate, and safe conveyance of a 100-year storm event.

Basin types include constructed wetlands, wet ponds, and extended detention (ED) ponds. While ED ponds generate the least amount of total phosphorus treatment (15% for level 1), it provides the best touchstone of a minimum basin size. An ED basis comprises of a dry basin storage area as well as select permanent pools and forebays to conform to design criteria.

The most effective way to minimize the basin size is by treating the basin as an offline BMP. This means pipe(s) should be sized to convey the 1" water quality volume storm to connect the western conveyance channel to a basin located to the east. This preliminary volume and associated pipe sizing was found using two considerations: (1) the required Tv of the uppermost watershed as required per the Virginia Stormwater Management Handbook (VSMH) (±205,000 CF) and (2) the volume of a 1", 24-hour storm approximated by PCSWMM of the redirected watershed (±195,000 CF), which associates with ±30 CFS flow rate. With a ±5% difference, this preliminary pipe sizing methodology is recommended to convey the 1" storm to the point of rerouting the flow to the offline BMP. To ensure this first flush is directed to the basin, a weir set to the height of the pipes must be located within the proposed conveyance channel.

Because ED basins permit up to 5' of Tv in a level 1 configuration, a preliminary basin bottom was sized to accommodate 4' of depth for only the rerouted flow, yielding approximately 50,000 SF contours. The remainder of the basin was sized to accept the incoming sheet flow intercepted by the location of this new basin, which includes Tv capture from +4'-5' from the basin bottom. These upper elevations of the contours were sized to accommodate the 10-year and 100-years of the incoming sheet flow watershed. The below figure identifies a preliminary basin size needed to accommodate these two inflows. Cyan linework identifies the offline Tv volume, and green linework indicates the remainder of the basin size and associated grade tie-in.

Figure 7: Preliminary Extended Detention Basin Size

The location chosen is preliminary but does have its own set of unique challenges. It minimizes the quantity of incoming sheet flow from the northeast but is sited on a parcel that comprises of a 5% cross slope along the parcel, which requires a slightly larger footprint to tie into existing grade. This basin size affiliated with a 4:1 slope within the pond itself with a 2:1 tie into existing grade above the basin top. An average 13' excavation depth is needed in this basin

Shifting the pond southward along Waterman Drive allows for a pond to be sited in a parcel that has a locally mounded grade and reduces the overall excavation depth to 10'; however, a larger footprint is needed to accommodate the larger area of watershed captured. Overall, approximately 20,000 CF of excavation in rocky subgrade in addition to the cost of property acquisition is required to provide nearly 18 lbs/year of treatment of this minimally sized basin. Other BMP options are available with better efficiency, but design criteria require additional depth for wet storage (e.g., level 2 wet pond), or a larger footprint to accommodate a smaller maximum Tv depth (e.g., level 2 construction wetland, 1' maximum Tv depth).

A point of note is the rerouting of select volume to a basin does allow for a reduction of a concrete conveyance channel by approximately 1 foot based on preliminary PCSWMM routing. This yields an 18 SF concrete cross section versus 32 SF of a 4' deep ditch, which allows a reduction in excavation along the conveyance channel by 45% (~2,100 CF), which does not provide a beneficial offset given the scale of excavation needed for a basin.

Additionally, due to the basin being adjacent to a known sinkhole within the quarry, a survey for karst features must be completed per criteria in Chesapeake Bay Stormwater Network Technical Bulletin No 1, Ver. 2 and guidelines in Appendix E of the Virginia Stormwater Management Handbook. There may be topographic limitations to this option given the anticipated excavation depth.

Attachments

1 Chicago Ave and Waterman Drive Stormwater Improvement Study Opinion of Probable Construction Cost

2 Waterman Drive Stormwater Management Project Data

3 Waterman Drive Stormwater Conveyance Improvements

4 Additional Project Maps

Chicago Ave and Waterman Dr Stormwater Improvement Study
OPINION OF PROBABLE CONSTRUCTION COST

DATE: FEBRUARY 24, 2025

For Preliminary Use Only- South Phase

Item No.	Description	Unit Price	Unit	Quntity	Total Price
1	Mobilization / Demobilization	$ 96,882.50	LS	1	$ 96,882.50
2	Erosion and Sediment Control Measures	$ 10,000.00	LS	1	$ 10,000.00
3	Asphalt Pavement Removal	$ 25.00	SY	290	$ 7,250.00
4	Rock Excavation	$ 300.00	CY	680	$ 204,000.00
5	Trench Pavement Restoration (SM-9.5A Asphalt)	$ 160.00	TON	65	$ 10,400.00
6	Trench Pavement Restoration (BM-25 Asphalt)	$ 150.00	TON	150	$ 22,500.00
7	48" RCP	$ 500.00	LF	525	$ 262,500.00
8	48" VDOT ES-1	$ 5,000.00	EA	2	$ 10,000.00
9	Right of Way Acquisition	$ 20,000.00	LS	1	$ 20,000.00
10	Construction Survey Layout	$ 750.00	LS	1	$ 750.00
11	Maintenance of Traffic Control	$ 10,000.00	LS	1	$ 10,000.00
12	Design/Engineering	$ 50,000.00	LS	1	$ 50,000.00
13	Construction Management and Inspection	$ 2,000.00	LS	1	$ 2,000.00
				Total	$ 706,282.50
			Contingency	50%	$ 353,141.25
				Grand Total	**$ 1,059,423.75**

Chicago Ave and Waterman Dr Stormwater Improvement Study
OPINION OF PROBABLE CONSTRUCTION COST

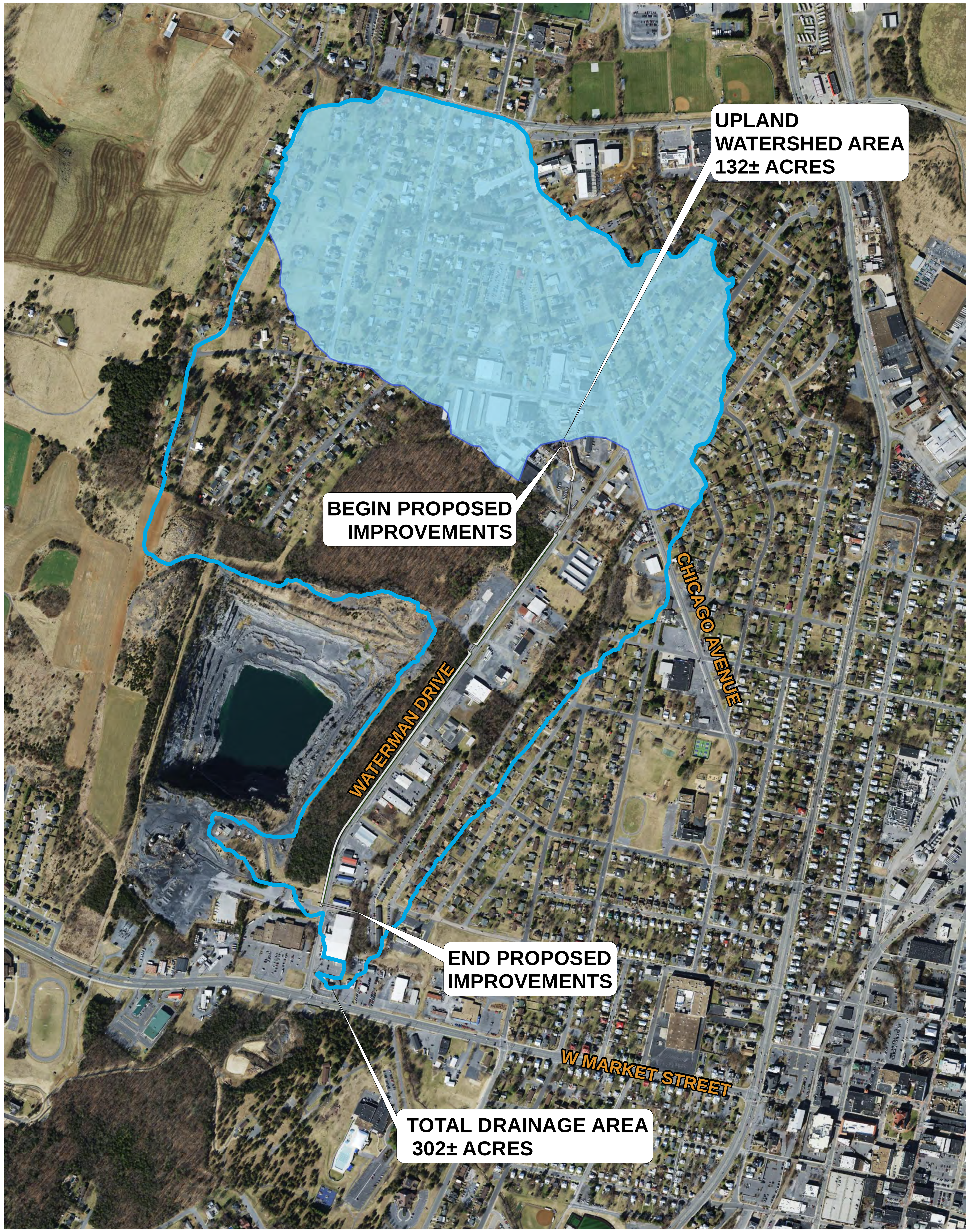
DATE: FEBRUARY 24, 2025

For Preliminary Use Only- Full Project

Item No.	Description	Unit Price	Unit	Quntity	Total Price
1	Mobilization / Demobilization	$ 475,278.75	LS	1	$ 475,278.75
2	Erosion and Sediment Control Measures	$ 80,000.00	LS	1	$ 80,000.00
3	Asphalt Pavement Removal	$ 25.00	SY	1025	$ 25,625.00
4	Rock Excavation	$ 300.00	CY	4610	$ 1,383,000.00
5	Borrow Excavation	$ 100.00	CY	250	$ 25,000.00
6	Trench Pavement Restoration (SM-9.5A Asphalt)	$ 160.00	TON	165	$ 26,400.00
7	Trench Pavement Restoration (BM-25 Asphalt)	$ 150.00	TON	370	$ 55,500.00
8	4" Class A3 Concrete	$ 600.00	CY	770	$ 462,000.00
9	48" RCP	$ 500.00	LF	1610	$ 805,000.00
10	48" VDOT ES-1	$ 5,000.00	EA	10	$ 50,000.00
11	48" VDOT EW-2	$ 3,000.00	EA	2	$ 6,000.00
12	VDOT JB-1	$ 5,000.00	EA	1	$ 5,000.00
13	Right of Way Acquisition	$ 75,000.00	LS	1	$ 75,000.00
14	Construction Survey Layout	$ 40,000.00	LS	1	$ 40,000.00
15	Maintenance of Traffic Control	$ 100,000.00	LS	1	$ 100,000.00
16	Design/Engineering	$ 426,528.75	LS	1	$ 426,528.75
17	Construction Management and Inspection	$ 30,000.00	LS	1	$ 30,000.00
				Total	$ 4,070,332.50
			Contingency	50%	$ 2,035,166.25
				Grand Total	**$ 6,105,498.75**

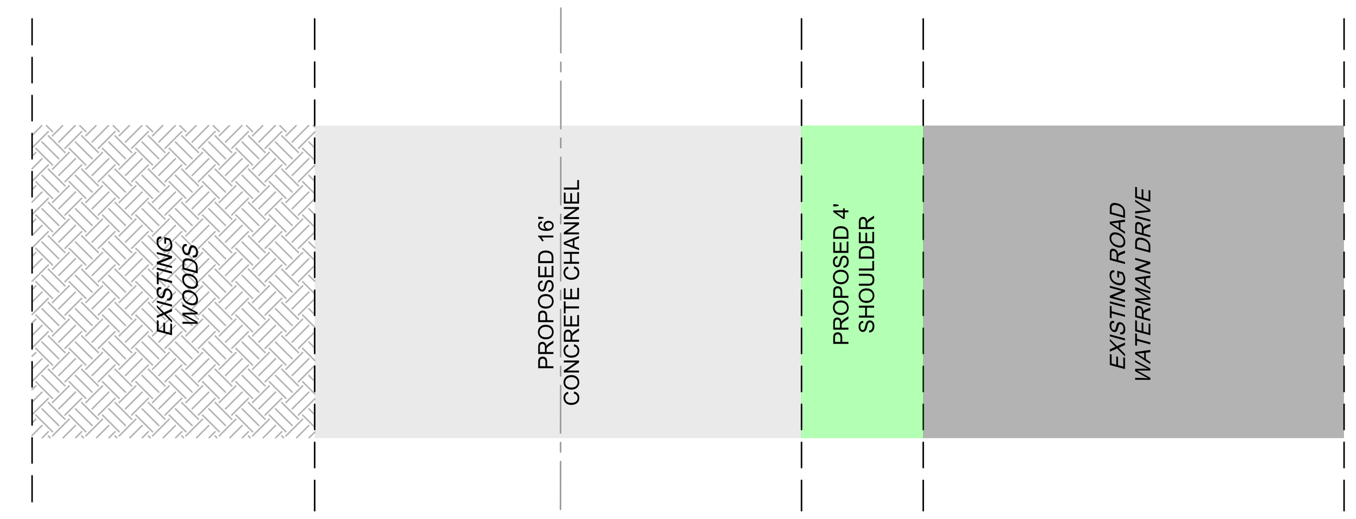
CHICAGO AVENUE + WATERMAN DRIVE

WATERMAN DRIVE STORMWATER MANAGEMENT PROJECT DATA

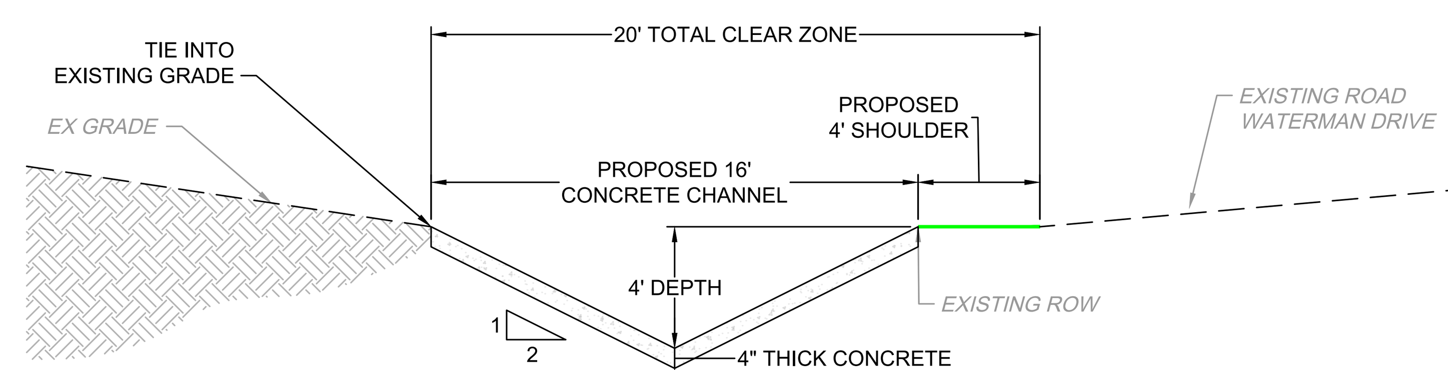


SCAN TO WATCH!

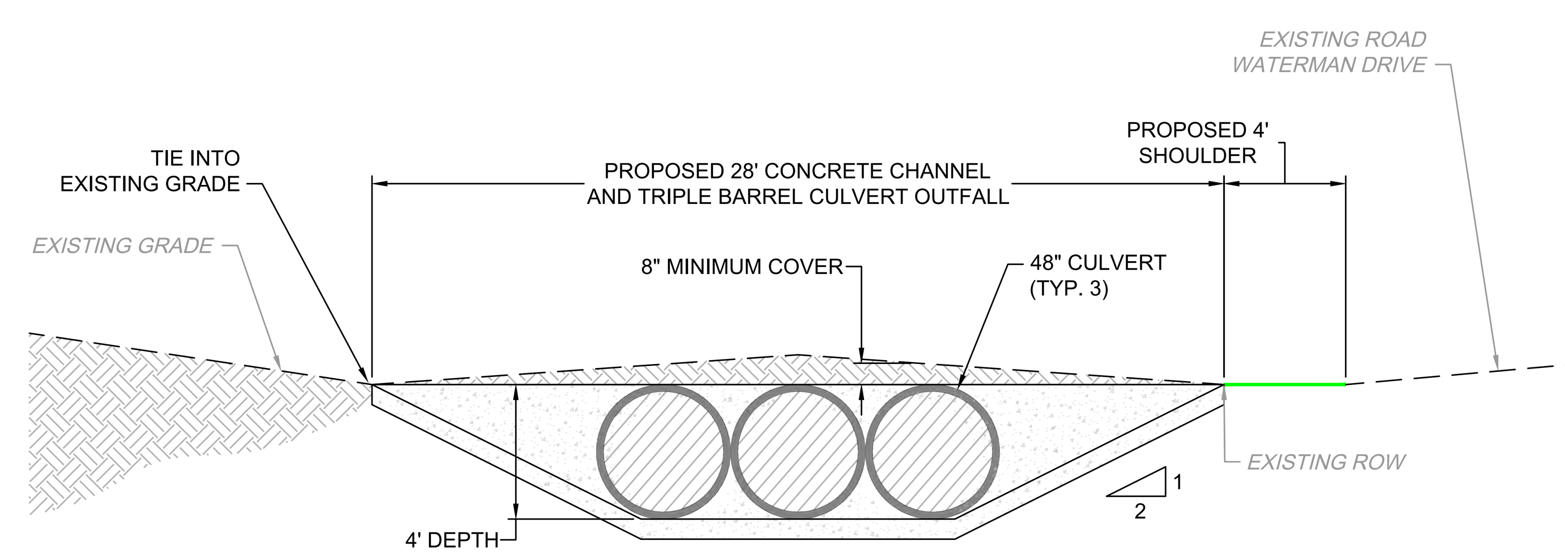
IT ONLY TAKES 0.25 INCHES OF RAINFALL PER HOUR FOR WATERMAN DRIVE TO FLOOD WITHIN 2 HOURS!



PLAN VIEW
N.T.S



CHANNEL SECTION VIEW
N.T.S



CULVERT SECTION VIEW
N.T.S

PROJECT OVERVIEW

- The lowest point of land in the study watershed is in front of commercial properties to the east of Waterman Drive.
- A channel to the west of Waterman Drive cannot handle water flow properly, causing the road to flood even during light rainstorms.
- The main priority is to ensure the roadway ditch safely convey stormwater drainage in public areas.
- The design is based on a 10-year 24-hour storm, meaning the system is built to handle about 1.2 inches of rainfall in 12 minutes at the storm's peak.
- This requires excavation of the existing ditch to a 4-foot total depth and inclusion of (3) 48-inch pipes at driveways along the roadway ditch.

EXISTING DITCH

CITY OF HARRISONBURG PUBLIC WORKS

Chicago Avenue + Waterman Drive

Waterman Drive Stormwater Conveyance Improvements

Chicago Avenue + Waterman Drive

Waterman Drive Stormwater Management
Project Data

Watershed Area

- Catchment Area 1
- Catchment Area 2

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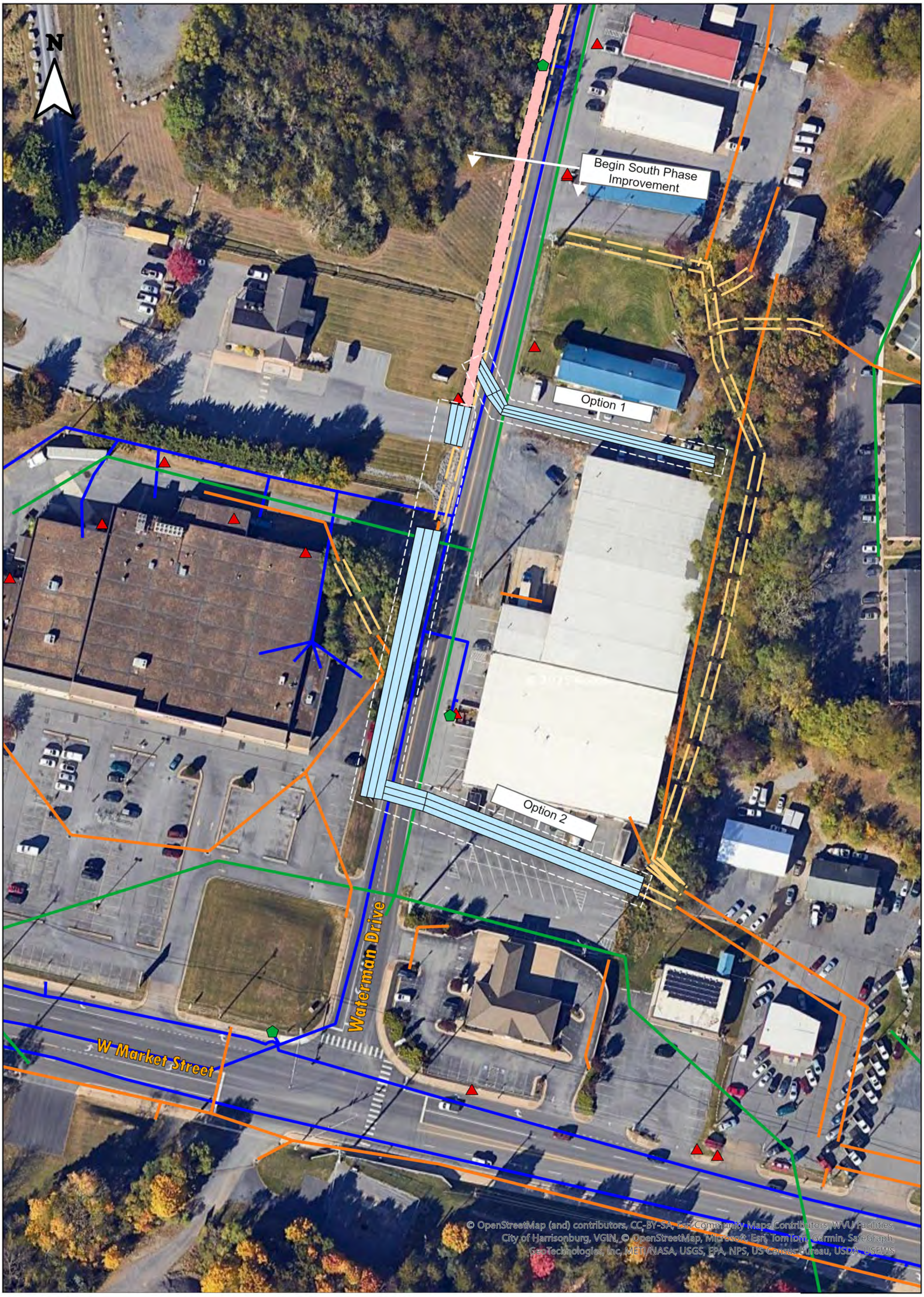
Waterman Drive & Market Street Proposed Ditch Connection

110 Waterman Dr - 800 W Market St

- Proposed barrel 48" culvert
- Proposed concrete channel
- Proposed barrel 48" culvert update
- Storm sewer
- BMP
- Manhole
- Drop inlet
- Pipe structure



Waterman Drive & Market Street South Phase Project Area

110 Waterman Dr - 800 W Market St

Existing Utilities

- Fire hydrant
- Water meter
- Ditches
- Water line
- Storm sewer
- Sanitary sewer

Proposed Utilities

- Proposed concrete channel
- Proposed barrel 48" culvert