THE UNIVERSITY OF IOWA
IOWA INITIATIVE
FOR SUSTAINABLE COMMUNITIES

# FINAL DELIVERABLE

| | |
|---|---|
| **Title** | Manchester Site Development and Stormwater Management |
| **Completed By** | Chantal DeGroote, Rebecca Ewing, Charlton Rodriguez, and Alex Merten |
| **Date Completed** | May 2020 |
| **UI Department** | Civil & Environmental Engineering |
| **Course Name** | Senior Design - CEE:3084:0001 |
| **Instructor** | Richard Fosse |
| **Community Partners** | City of Manchester |

This project was supported by the Iowa Initiative for Sustainable Communities (IISC), a community engagement program at the University of Iowa. IISC partners with rural and urban communities across the state to develop projects that university students and IISC pursues a dual mission of enhancing quality of life in Iowa while transforming teaching and learning at the University of Iowa.

Research conducted by faculty, staff, and students of The University of Iowa exists in the public domain. When referencing, implementing, or otherwise making use of the contents in this report, the following citation style is recommended:

> [Student names], led by [Professor's name]. [Year]. [Title of report]. Research report produced through the Iowa Initiative for Sustainable Communities at the University of Iowa.

This publication may be available in alternative formats upon request.

Iowa Initiative for Sustainable Communities
The University of Iowa
347 Jessup Hall
Iowa City, IA, 52241
Phone: 319.335.0032
Email: iisc@uiowa.edu
Website: http://iisc.uiowa.edu/

# Stormwater Mitigation & Subdivision Manchester, IA

Report Prepared by:
Chantal DeGroote, Rebecca Ewing, Charlton Rodriguez,
and Alex Merten
Small Town, Big Solutions Inc.
May 8th, 2020

Report Submitted to:
Timothy Vick
Manchester City Manager

## Table of Contents

**Section I - Executive Summary**

The figure below shows the site plan for this project, including; roadway extensions, storm water channels, permanent pool, and subdivision design.

Figure 1: Site plan for Stormwater Mitigation and Subdivision project.

This report presents a blueprint for growth in the northeast corner of Manchester, Iowa that addresses the expansion of city infrastructure and related stormwater issues. It includes the extension of Grand Avenue north to 195th Street and extension of Deann Drive and Fairview Drive to intersect with the proposed Grand Ave. extension. There were plans to develop the land on the east side of Grand Avenue into residential area. The area was zoned for single-family residential lots. The subdivision was planned to feature a road with lots on the north and south side and a cul-de-sac on the end. Furthermore, portions of Manchester were prone to flooding during high rain events. The City requested consideration of flooding impacts as part of the project scope and design of the road extension to better manage stormwater and improve upon the current floodwater mitigation practices. There were multiple retention basins around the Fairview subdivision to control water during times of high rainfall before our project began. However, the flat topography of the project site was a challenge for managing the flood area. A wetland was in the northeastern corner of the project area. A retention basin was north of the Fairview subdivision. It filled completely during high rainfall and put surrounding homes at substantial flood risk. A smaller retention basin existed to the east of the Delaware County Fairgrounds. A third retention basin was south of the Fairview Drive subdivision. The City requested Small Town, Big Solutions Inc. to consider how to manage the new improvements and development to best control flooding. However, it was imperative that existing wetlands remained undisturbed.

Small Town, Big Solutions Inc. was a team of four senior civil and environmental engineering students at the University of Iowa. This project was conducted as part of the capstone design course. Small Town, Big Solutions Inc. consisted of; project manager, Rebecca Ewing, Chantal DeGroote, Alex Merten, and Charlton Rodriguez. The team had acquired quality educational and professional experience that qualified them for the roadway extension and stormwater retention project.

The design process required multiple methods of analysis, using both software and analytical techniques. Hydrological modeling was accomplished using software programs. These programs included HEC-RAS, TR-55, TR-20, ArcMaps, and Civil 3D. They were used to analyze channel flow rates, volumes and tributary runoff. EPAnet and Civil 3D were used for pipe sizing of utilities. This project had environmental impacts and followed local, state and federal guidelines and regulations. Small Town, Big Solutions Inc. followed guidelines outlined by the Iowa Department of Natural Resources (DNR), Army Corps of Engineers, Manchester City Ordinance, Statewide Urban Design and Specifications (SUDAS), and the Department of Transportation (DOT). Final designs were completed in AutoCAD Civil 3D.

Constraints for this project included environmental regulations, construction boundaries, wetland sizing and time. The existing wetlands could not be disturbed. The flat slope of the area proposed a constraint as well. The challenges of this project included the flat terrain on the project site and the configuration of the proposed development. Societal impacts were mostly positive. Negative impacts were minimal and included noise during construction and wildlife disturbance. Due to the unexpected circumstances, lack of resources, and time constraints of COVID-19, the sanitary sewer could not be completely designed. However, a plan view of the sanitary sewer including the PVC pipe network and manholes was done.

Five alternatives were evaluated for the roadway extension and the stormwater retention basin. The recommended design alternative included the extension of Grand Ave. north as well as extension of Fairview Dr. and Deann Dr. east. There was an overland flow route to protect nearby developments in extreme flooding conditions. Storm sewer and water main systems were designed for these extensions using SUDAS standards. A subdivision layout was designed for future single-family residential development. This subdivision was a single road, cul-de-sac design to accommodate ranch-style homes. For flood mitigation, a channel system was designed to divert water from the existing residential area, with the main channel having the capacity to transport a 100-year storm event. The channel system then drained into a permanent pool south of the proposed cul-de-sac.

The new design would be beneficial to the town of Manchester for several reasons. The new road extensions would allow for better access to and from the east side of Manchester. Additionally, Grand Avenue was a suitable candidate to serve as a detour route when Highway 13, the main road through town, was under maintenance. The construction of the roads would provide an overland flow route ensuring major flows during extreme rainfall conditions remained along Grand Avenue and did not travel westward toward nearby residential lots. The storm sewer system would provide capacity to capture 5-year flows from the three roadway extensions, and runoff entering the road from the surrounding area that was not already captured in the proposed stormwater channel system. The storm system would convey these flows into the proposed channel system at one of three locations where the proposed channel crosses underneath the Grand Avenue extension through culverts. Furthermore, the subdivision was designed to prevent water flowing from east to west. Runoff from the front yards would be collected in the storm sewer system which would eventually drain into the permanent pool. The open channels would help guide the water during heavy rainfall events into the permanent pool and limit the impacts of flooding. Figure 2 below shows the current flow of water in the project area with our new design overlaid to portray the importance of the location of our stormwater management techniques.

Figure 2: Small Town, Big Solutions Inc. complete design overlaid on top of the current water flow of Manchester.

The total project cost was estimated to be $3,617,981. The total cost was then broken down into private and public costs. The private cost included the stormwater management basin and subdivision's infrastructure, which was estimated to be $985,456. The total public cost including the roadway extension, stormwater sewer, water main, preliminary sanitary sewer, and channel and culvert, was estimated to be $2,632,525. Both private and public included the respective design elements as well as mobilization, contingencies, and engineering and administration. Section VII provides the overall cost table and Appendix J provides tables breaking down each individual design element cost.

## Section II - Organization Qualifications and Experience

1. **Name of Organization**
   Small Town Big Solutions Inc.

2. **Organization Location and Contact Information**
   Small Town, Big Solutions Inc. was located in the Seamans Center on The University of Iowa Campus in Iowa City, Iowa. The main point of contact was the project manager, Rebecca Ewing. She could be reached by email at rebecca-ewing@uiowa.edu.

3. **Organization and Design Team Description**
   Small Town, Big Solutions Inc. was comprised of a team of senior University of Iowa Students in the Project Design and Management course. Rebecca Ewing was the project manager of this group. She was majoring in environmental engineering. Rebecca had knowledge in wetland design and water resource design. She also had expertise in water quality and pollution control. Chantal DeGroote was the editor and majored in civil engineering with an environmental focus. She specialized in water and wastewater treatment and quality. She assisted researching best practices for wetland mitigation. Alex Merten was majoring in civil engineering with a focus in transportation. Alex had experience with AutoCAD software and facilitated the production of the design plans. Alex was instrumental in the road extension design. Charlton Rodriguez was majoring in civil engineering with a focus in water resources. Charlton had an extensive background in hydrological modeling. Charlton researched area flooding and constructing models that were imperative for the project design.

## Section III – Design Services

1. **Project Scope**

The scope of the project consisted of residential expansion to the northeast with an emphasis on storm water mitigation. The project required design of accurate stormwater mitigation techniques including channels and a permanent pool, roadway extensions, and subdivision design. The objective was to slow down the stormwater to reduce the impacts of flooding in the community of Manchester. To accomplish this, an additional permanent pool and drainage channels were designed. The project scope also included a road extension of Grand Avenue north to 195th Street. The Grand Avenue road extension met with Fairview Drive and Deann Drive. Stormwater sewers and water main systems were designed for these new road extensions. Potential residential expansion and future development were taken into consideration. Lots were designed on the east side of the Grand Avenue extension. A cul-de-sac was also extended south of the existing wetland basin and to the east of the Grand Ave. extension.

Small Town, Big Solutions Inc. provided services for conducting a thorough evaluation of the possible solutions for stormwater mitigation and optimal road extension placement. The site design and road construction were completed in Civil 3D.  All drawings are a uniform standard size, as designated by the American National Standards Institute (ANSI). The site design includes site location, construction boundaries, existing and future utilities location, and existing and final grading. The stormwater drainage and pool design were completed in AutoCAD utilizing the Hydrographs and Express extensions. The design includes hydrologic analysis, pool volume, drawdown time, and inlet and outlet structure(s). The subdivision design was completed in Civil 3D.

The project client was Timothy Vick, Manchester City Manager. Engineer Jason Wenger, Manchester Water Superintendent, Chad Wulfkuhle, and landowner of the proposed project site, Mike Beck were also in contact.

## 2. Work Plan

Alex was responsible for the road design, which included extending Grand Ave. north to meet 195th Street and extension of Deann Drive and Fairview Drive. Chantal was responsible for the subdivision design which included incorporating lots along the Grand Ave. extension and a new residential development featuring a cul-de-sac. Rebecca was responsible for designing the water main and preliminary sanitary sewer. Alex was responsible for storm sewer design. Charlton was responsible for designing the permanent pool and channel system for the stormwater. All team members worked together in completing and designing each aspect of the design. All tasks were to be completed by May 8th. Figure 3 below is the project work plan.

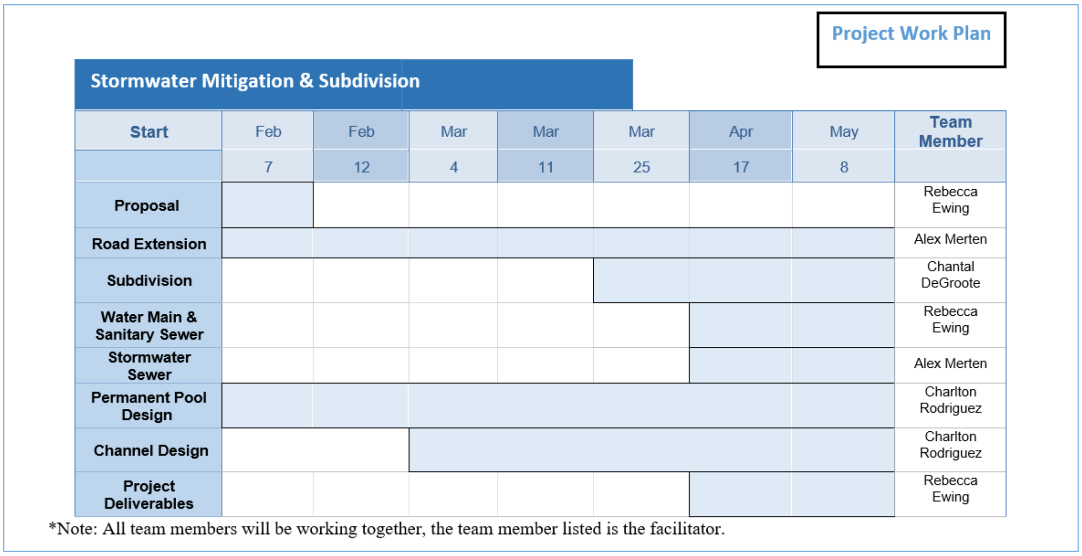



Figure 3: Work plan depicting the schedule of the project, the key dates in which they were accomplished, and the team member responsible.

## Section IV - Constraints, Challenges, and Impacts

### 1. Constraints

The first constraint involved environmental regulations. The City of Manchester specified that the existing wetland areas on the project site must not be disturbed. Wetlands could be extended but not reduced or moved. Disrupting wetlands required 1.5 times the amount of wetland disturbed to be replaced. The Army Corps of Engineers and the Iowa DNR must approve any wetland alterations. Furthermore, construction boundaries were considered. The road extension and stormwater mitigation of the project could not interfere with existing structures. Construction easements needed to be considered before design. The residential area on Fairview Drive could not be altered. The proposed subdivision could only be designed within the property limits of Mike Beck's property. No land elsewhere could be used for permanent pool placement. The roadway design needed to adhere to DOT regulations, SUDAS standards and the local ordinances. Time was another constraint as the final project needed be completed and submitted by May 8$^{th}$, 2020. The final constraint was the capacity of the wetlands. An upstream development plan needed to be designed considering the finite capacity.

### 2. Challenges

One challenge in this project was the flat terrain and slope. This presented great difficulty for managing water flow. Another challenge was designing the road extension and stormwater improvement with the new planned development. An unexpected design challenge was the impact of the COVID-19 outbreak. Our team was no longer able to meet in person. All remaining site visits were cancelled, and any further contact was to be made through Zoom meetings. Furthermore, access to the appropriate design software was only available through the use of VM software. The final design challenge for this project was managing the existing stormwater management areas without disrupting wetlands.

3. **Societal Impact within the Community and/or State of Iowa**
Like many rural communities in Iowa, Manchester was susceptible to extensive flooding. The existing developments in the floodplain experienced structural damage during heavy rain events in the past. Designing a roadway extension with a focus on storm water management would help mitigate impacts of flooding. This would greatly improve property value and quality of life for residents. The City of Manchester was also planning on development in the northeast land area. Designing a subdivision similar to those in the area would provide more housing for a growing population and would be a welcome feature for the expanding town. Residents could also enjoy the aesthetics of two water reclamation areas to experience wildlife and natural areas. Furthermore, significant flood events damaged Delaware County Fairgrounds and disrupted annual fairground festivities in the past. Limiting flooding in this area would ensure the safety of fair attendees. It would also prevent damage to livestock, structures, and fairground property. Improving the wetland area would offer an aesthetic improvement for the community as well. Wetlands serve as an area of recreation and wildlife habitat. Having this near a new development would increase property values in the nearby area. Also, better storm water mitigation and wetlands would improve water quality. Water quality improvement would decrease costs for the City's water treatment facilities. Finally, managing flooding would allow the City of Manchester to make more informed decisions when considering future development.

   Negative impacts were minimal. Noise from construction could impact the residences on Fairview Drive. There would be no traffic delays as this road was not used currently by the residential area. It was possible that the bus depot may have to be used as an alternative entrance at the beginning of the construction process. Local wildlife could be temporarily disrupted during construction; however, no existing wetlands were disturbed.

## Section V - Alternative Design Solutions

Small Town, Big Solutions, Inc. looked for possibilities to mitigate the flooding that impacted the City of Manchester. All alternatives featured a design for an urban roadway extension of Grand Avenue. This road provided a method to relieve traffic during the county fair, promote residential development and redirect runoff. Based on water flow analysis, most of the runoff flowed toward the nearby neighborhood. By constructing this road, there was no concern that runoff would increase flooding for residents on Fairview Drive. Culverts were designed along the projected roadway to manage stormwater. Culverts, a channel system, and elevation manipulation allowed the water to be diverted from the west side of the vacant field to the east side. This was important because the water draining from the western neighborhoods, new subdivision, and roadway extension could be diverted to the new permanent pool.

The first alternative involved manipulations of the Grand Avenue extension. No part of the road right of way width could touch the boundary of the wetland. Pros of this design were that it could be more scenic to drive, however cons were that existing property boundaries could be altered.

Another alternative was redirecting the creek that flowed to the east of the bus barn. This fully incorporated the retention basin to hold excess runoff. The creek was connected to the northern part of the existing detention basin. Pros were no disturbance of the existing basin while cons were an additional retention basin could be required.

The next alternative connected the minor detention basin behind the houses on Fairview Drive to the stormwater drains. This would be done by an outlet control structure. For extreme storm events, an emergency spillway could be directed towards the marsh. A pro of this design was the mitigation of stormwater from the existing subdivisions, while a con was that the existing wetland may require excavation to meet expected elevations.

The fourth alternative was redesigning the channel between the soccer fields and baseball fields to be more sinuous and wider, slowing down the water and allowing for a longer travel time. Pros were this approach would provide mitigation for minor storm events that would protect against recurring damage and protect urban residents. Cons were that this approach would require relocation of the soccer fields.

The final alternative and recommended design included aspects of each alternative mentioned above. This included extension of Grand Ave. north as well as extension of Fairview Dr. and Deann Dr. east. There was an overland flow route to protect nearby developments in extreme conditions. Storm sewer and water main systems were designed for these extensions using SUDAS standards. A subdivision layout was designed for future single-family residential development. This subdivision was a single road, cul-de-sac design, to accommodate ranch-style homes. For flood mitigation, a channel system was designed to divert water from the existing residential area, with the main channel having the capacity to transport a 100-year storm event. The stormwater from the new subdivision drained to the new permanent pool. This was selected as the best design alternative because it would provide adequate stormwater management, without disrupting the existing wetlands or residential areas.

## Section VI – Final Design Details

### Roadway Extension Design

Extensions were designed to continue from three existing roads in the area. Grand Avenue ran north to connect to Honey Creek Road (195th Street) and deflected to the west in order to avoid disturbing the wetland located in the middle of the project area. Deann and Fairview were extended east until intersecting with Grand Avenue.

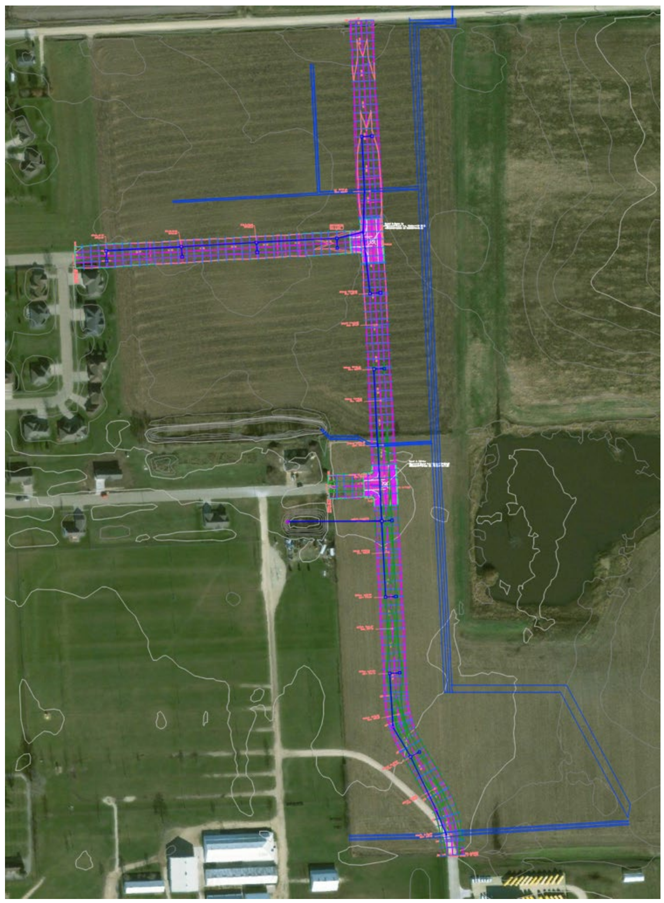


Figure 4: Road extension layout from Civil 3D.

All three streets were designed according to SUDAS with a 30-mph design speed as requested by the client. Grand Avenue was designed as a minor collector, while Deann and Fairview were designed as local roads. All three streets were designed to meet the local standard 34-foot back of curb to back of curb width, with 15-foot lane width and 2-foot curbs on both sides according to Table A1 in Appendix A. Street width allowed for on street parking on both sides of Deann Drive and Fairview Drive, and parking on one side of Grand Avenue.  Each street vertical profile consisted of mainly 0.5% longitudinal slopes, and each high point in the street was slightly higher than the last to create a stair-step effect. This allowed for water to flow toward the beginning of the extensions and created an overland flow route for storm runoff in the event of extreme rainfall. The stair step design also kept ponding depth below the SUDAS required 6-inch depth shown in Table A2 in Appendix A. Locations where the change in longitudinal slope exceeded 1.0% required vertical curves to be designed, each adhering to SUDAS required curve length and K value outlined in Table A3 in Appendix A.

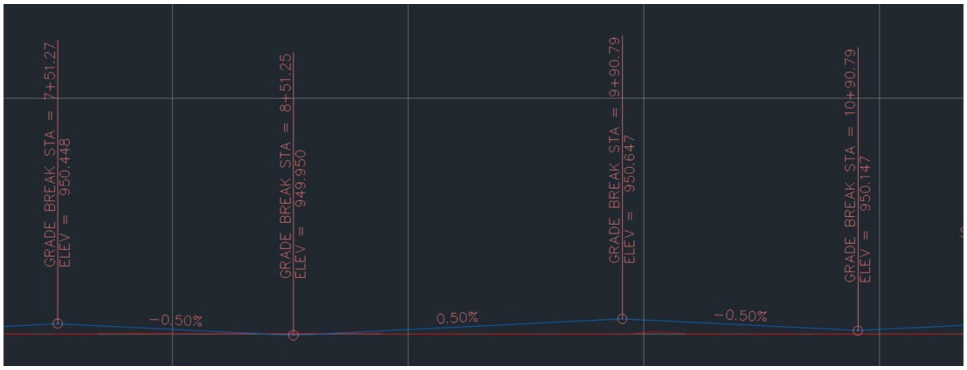


Figure 5: Stair step design on Grand Avenue from Civil 3D.

The cross section for each road consisted of a 3.0% cross slope from crown and a curb and gutter assembly along the edge of traveled way. The pavement was designed to be 8 inches thick on Grand Avenue and 7 inches thick on Deann Drive and Fairview Drive, with a foot of subbase underneath which extended out 2 feet past the curbs per client request. Outside of the roadway was a 16-foot border which allowed for the SUDAS mandated clear zone and room for sidewalks (shown in cross section below) and utility structures. The border width was determined by subtracting local standard right of way by the roadway width and dividing that in half. Please note that while it was accounted for visually in the figure below, the sidewalk was not modeled into the right of way corridor nor was it considered in cost estimations for this project. Outside of the border, the cross-section daylighted to existing ground.

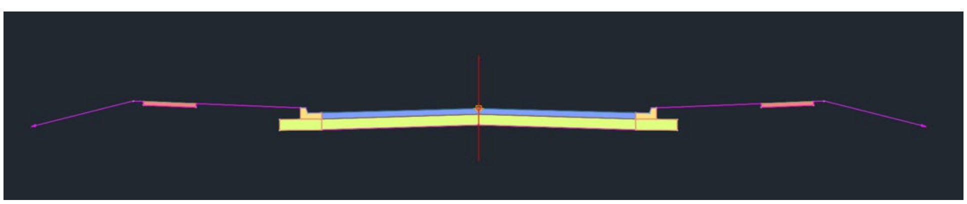


Figure 6: Right of way cross section.

Intersections were designed at the connections between Grand Avenue and Deann Dr., and Grand Avenue and Fairview Drive. Turning radii were set to 30 feet to meet SUDAS criteria in Table A3 in Appendix A and the crown of Grand Avenue was maintained. This allowed for storm runoff to continue along the gutter line of Grand Avenue and prevent the runoff from spilling down the local side streets and entering the residential area.

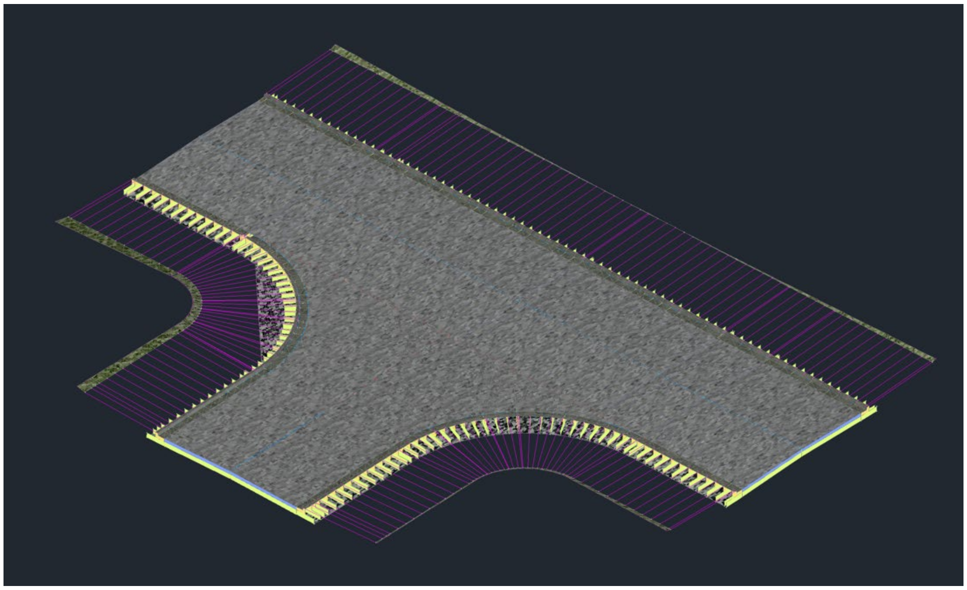


Figure 7: Deann Dr. and Grand Avenue intersection rendering from Civil 3D.

**Stormwater Sewer Design**

AutoCAD Civil 3D was used in accordance with existing ground elevation to determine flow paths and drainage areas. The catchment tool in Civil 3D was utilized to determine catchment areas and time of concentration. Using the time of concentration, rainfall intensities were determined using SUDAS standards located in Appendix B. To determine soil group, a USGS Soil Survey map was generated for the project location shown in Appendix B, along with soil types shown in Table B2 displaying soils in the area. Using the City of Manchester Comprehensive Plan in Appendix B, future land usage was determined in order to select C values from in Appendix B. The rational method alongside SUDAS was used to calculate runoff quantities entering the roadway in an excel spreadsheet for a 5-year storm.

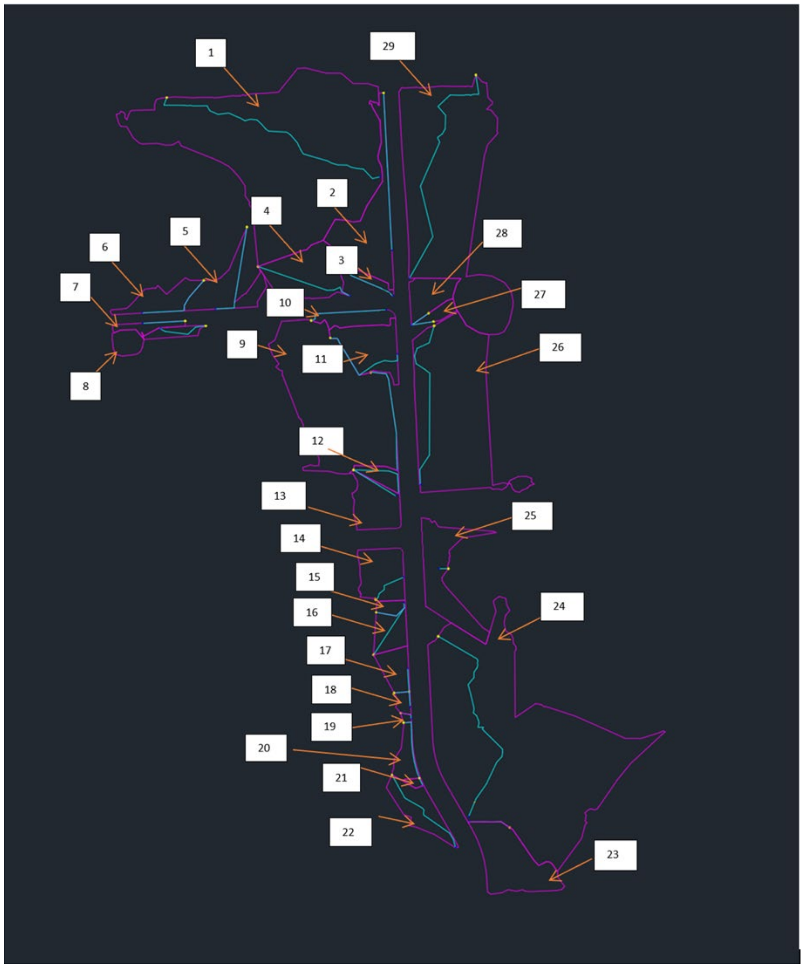



Figure 8: Screenshot of Civil 3D generated Catchments along the new roadway extensions, including flow paths from which time of concentration was determined.

Not all the drainage areas were entering the roadway due to the channel design provided in this project. For locations where the recommended channel was cutting off most of the determined catchments, runoff calculations were based on expected future development. Assuming single family residential lots as outlined in the city comprehensive plan, all off road runoff was estimated to come from front yards of residential lots and the roadway buffer zone. Therefore, the calculations in these locations included the city mandated 25-foot front yard and the designed 16-foot buffer zone outside the back of curb. C values were consistent with ¼ acre R1 lots and the SUDAS minimum time of concentration of 15 minutes was used.

Runoff calculations for the roadway itself used minimum time of concentration of 15 minutes, C values of 0.95 for paved surfaces, and area was calculated using inside curb to crown widths.

Manholes accompanied by SW-501 grate intakes were placed according to SUDAS requirements, meaning one placed within 500 feet of the road high point and successive intakes placed no farther than 400 feet apart outlined. Intakes were placed in low points in the road, except where necessary to maintain SUDAS spacing requirement. Using the Storm Sewer application in Civil 3D, a pipe network was built consisting of minimum 15-inch diameter pipes and up to 24-inch diameter pipes for the largest flows. This design was constrained by minimum pipe cover and minimum water velocity in pipes, both outlined in Appendix B. Channel elevations were not available by the time the sewer system was designed, so the current system sits as high as possible and could be lowered to match culvert elevations.

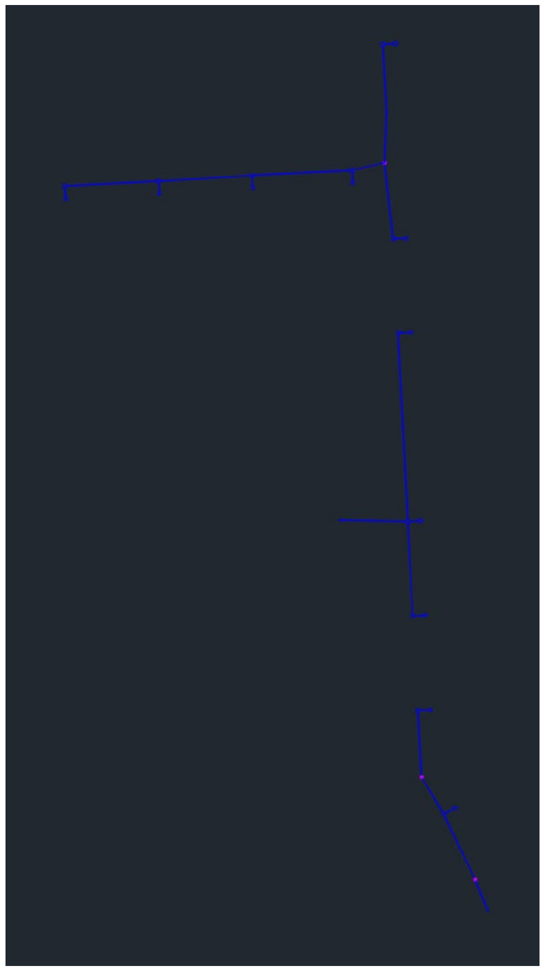


Figure 9: Screenshot of storm sewer layout, including manhole and intake spacing.

The storm sewer system was comprised of five separate systems that capture and convey all water flow from the road itself and nearby land. These systems were designed to tie into the proposed open channel at points where it crossed the Grand Avenue extension. This allowed for minimum pipe sizes and minimal number of required intakes, manholes, and length of pipe. Intakes were placed above culvert conveying open channel flow allowing gutter flow to fall directly into the open channel passing below. The intakes directly over the channels were factored into the cost estimation. It was also recommended that a total of two intakes be placed on both sides of Grand Avenue middle and southern box culvert location along Grand Avenue to help increase overland flow capacity in extreme 100-year rain events.

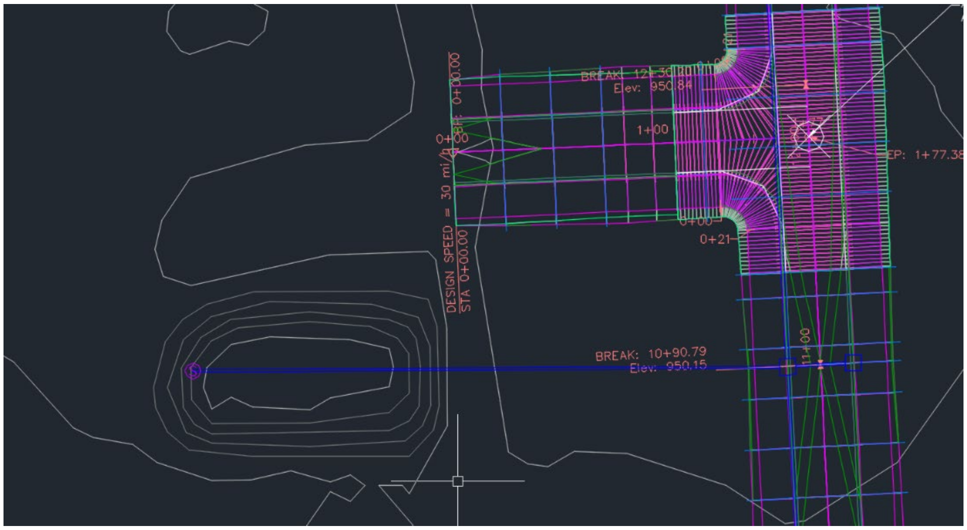



Figure 10: Civil 3D screenshot showing storm sewer tie in allowing basin to be filled in.

Additionally, a storm sewer pipe was to be tied into the pipe dumping into the catch basin on the south side of Fairview Dr, allowing for the basin to be filled in. The design did not include runoff conveyed currently into the basin, so future design should consider this additional flow when sizing the stormwater pipe bringing the flow into the Grand Avenue system.

Because the road design minimized cut and fill cost and the lack of elevation change in the area, storm sewer pipes were not able to meet SUDAS required pipe cover of 4 feet because they had to match culvert elevations. These complications could be avoided by building the road profile up several feet.

**Water Main Design**

The water main was a pressurized pipe system and designed to standards from SUDAS and Iowa DNR AWWA standards. The water mains were extended to the property lines or next street, directed by the jurisdiction. The systems were located at least 4 feet off the back-of-curb of each road. The water main was placed on the south and east side of Grand Ave. and south side of Fairview Dr. and Deann Dr. Water mains were adequately protected from corrosive soil environments and complied with AWWA C105. Soil testing was completed or checked with the Jurisdictional Engineer to determine if corrosive soils were present within the project area. The water main pipe was PVC DR-18 (C900). The Grand Ave system was an 8-inch PVC pipe and the Fairview Dr. and Deann Dr. systems were 6-inch PVC pipes. The pipes were designed with a 5-foot depth of cover according to SUDAS standards to prevent freezing, see Appendix C. The pressurized pipe would need to be adjusted accordingly for crossing between channel and culverts to meet the standard vertical clearance. A tracer wire was required for the PVC piping.

Valves were located at intersections and no more than 400 feet apart. All valves were installed with valve boxes. Slide type valve boxes were used in paved areas and screw type in all other areas. Valves were placed between the existing main and new main. A tapping sleeve was used when making a perpendicular connection to an existing main, at the intersection of Grand Ave. extension and 195th St. If the water pressure exceeded 100 psi, a pressure relief valve system could be installed as opposed to individual building controls. A valve image from Civil3D can be seen below.

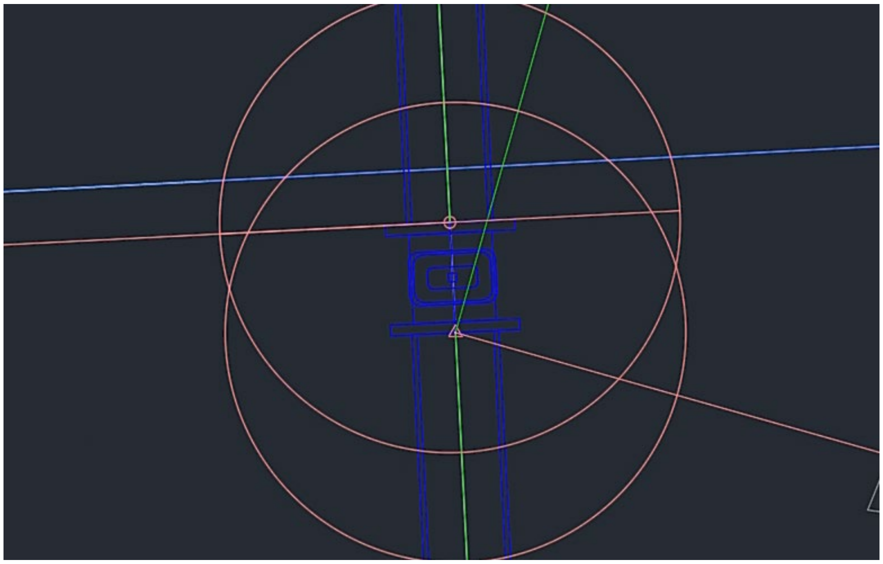


Figure 11: Civil 3D image of a valve joining two pressurized pipes.

Fire hydrants were designed to comply with AWWA C502. The hydrants were 72 inches bury. Hydrants were not connected to or located within 10 feet of sanitary sewers. The connecting pipe between the supply main and hydrant was 6 inches in diameter and independently valved. The hydrant was around 10 feet off the back of the curb to ensure no interaction with the clear zone. Hydrants were located within 25 feet of each intersection. Hydrants were spaced no more than 450 feet apart and within the fairgrounds, no more than 300 feet apart. The hydrants were varied in spacing. A Civil 3D image can be seen below for a hydrant system, including a tee connection, an independent valve, and the hydrant.

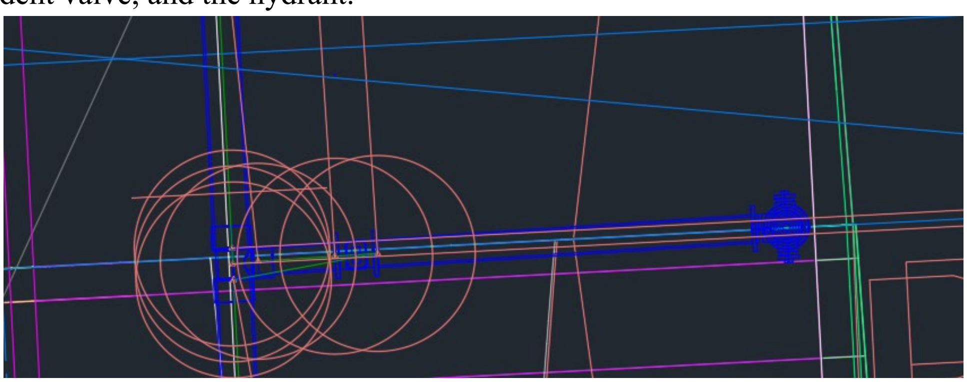


Figure 12: Hydrant system in Civil 3D.

**Preliminary Sanitary Sewer Design**

Although a complete design could not be done, a sanitary sewer system is required for public health and welfare in areas of concentrated population and development. Every community produces water-borne wastes of domestic, commercial, and industrial origin. The sanitary sewer collects water-borne wastes of domestic, commercial, and industrial types and brings them to points of approved discharge or disposal.

The design was done in accordance with SUDAS Chapter 3. The extent of our design included a 12 inch-PVC gravity flow sanitary pipe and 48 diameter-18 frame-24 cone sanitary sewer manhole. The manholes were placed no more than 400 feet apart. The sanitary sewer pipe was placed on the east side of each road extension at least 10 feet away from the water main.

Appendix D provides a table with supporting material for the sanitary sewer design.

**Channel and Culvert Design**

The channel system was designed to accommodate the storm water runoff from all tributaries for no greater than a 100-year flood. The rational method was used to determine the flowrates that enter each channel. All the channels were designed to have a side slope of 5:1 which would allow the homeowner to safely mow the grass channel. The rise of the culverts and the side slope of the channels dictated the channel size. The dimensions were then analyzed using manning's equation and the standard step method. Then, it was doubled check using the HEC-RAS Program.

The property was extremely flat and none of the channels were capable of following SUDAS longitudinal slope standards of a minimal 1.0% slope. The main channel, running parallel to Grand Avenue, was connected to the agricultural lots north of East Honey Creek Drive. The total area excessed 40 acres; therefore, the Rational Method could not be used. For areas larger than 40 acres, the runoff was evaluated using the NRCS-TR55 Method. It was then determined that the max flow rate being received from this agricultural land was 110 cfs. In total, the channel had the capacity to convey 332 cfs of runoff for a 100-year storm event from all the surrounding tributaries. Figure 13 is an example of one of the few channel sections that had a slope greater than 1.0%. This figure also shows how the channel tied into the northern basin.

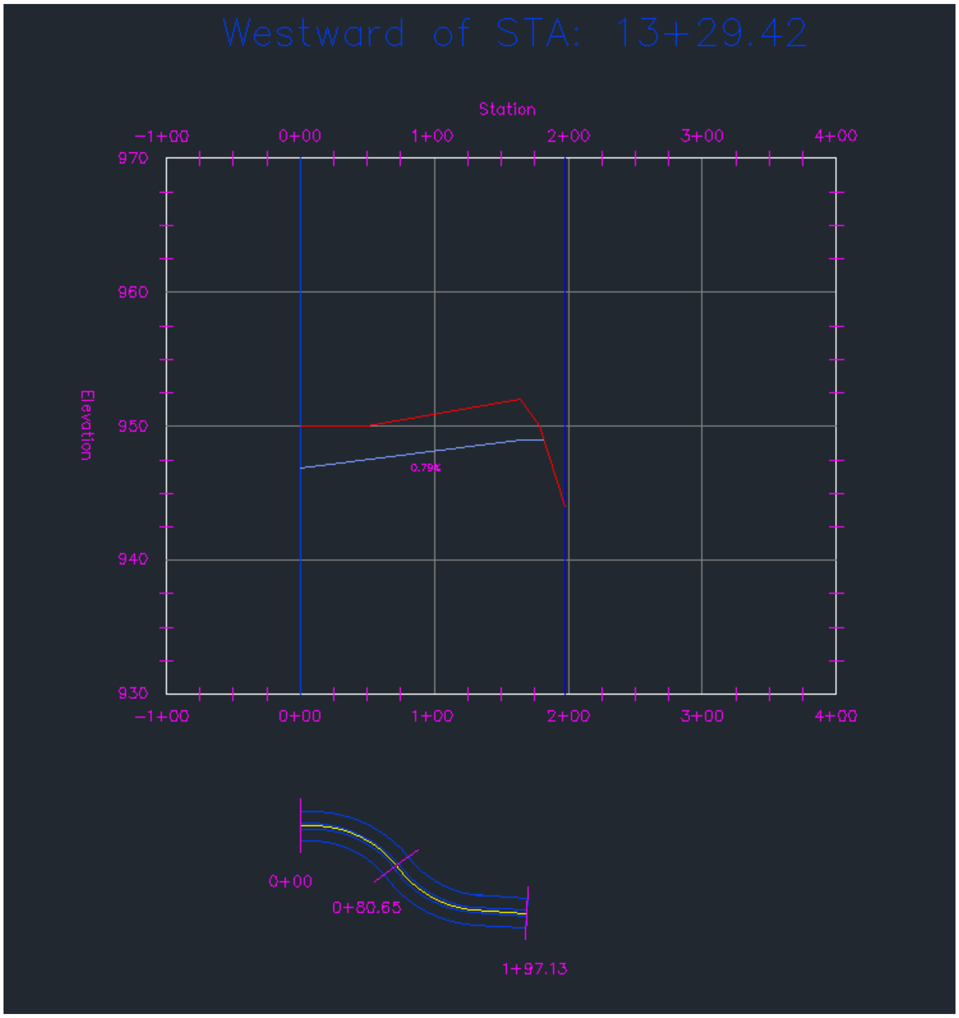



Figure 13: Snapshot of the profile for the channel connected to the northern basin.

The basin just north of Fairview Drive was connected to the new channel system. For this basin the channel would act like an emergency spillway, where the invert of the spillway was 1 foot below the lowest point along the crest of the basin. This invert was located at an elevation of 949 feet. It was suggested that a primary spillway be included into the design. The bed of the basin should be raised from 944 feet to 947 feet and the drainage pipe should discharge into the culvert on Grand Avenue.

Due to the proximity of the channel to the marsh, it was recommended to line the eastern side of the channel with bentonite clay or similar material to prevent disturbing the water level of the marsh.

There were three culvert crossings Grand Avenue and one culvert in the Kramer subdivision. Each culvert was constructed from a reinforced concrete box. All culverts would have a headwall with angle wings of 45 degrees and rounded edges inlets to provide more flow capacity. The crossing just north of Deann Drive included a box culvert that had dimensions of 2 feet by 3 feet. The flowrate at this cross section was 8.31 cfs for a 100-year storm event. The crossing north of Fairview Drive had one 2 feet by 3 feet box culvert. The flowrate at this cross section reached a flowrate of 12.53 cfs. The crossing for the county fairground had 2 feet by 6 feet box culvert. This cross section provided flow transportation for the land purchased by the county fair. The flow rate for this cross section could reach 42.51 cfs for a 100-year storm event. In the Kramer Subdivision, there was a 5 feet by 8 feet box culvert that would transport 282 cfs of runoff during a 100-year storm event. Due to the limited space provided by the topography, there would not be any subgrade between any of the box culverts and the roadway. Bond breaker would be applied to the concrete surfaces to guarantee the permanent bonding of the two concrete surfaces. Figure 14 is an example how HEC-RAS was used to analyze the channels and culvert through the system. This profile is for the channel and culvert in the southern section of Grand Avenue.

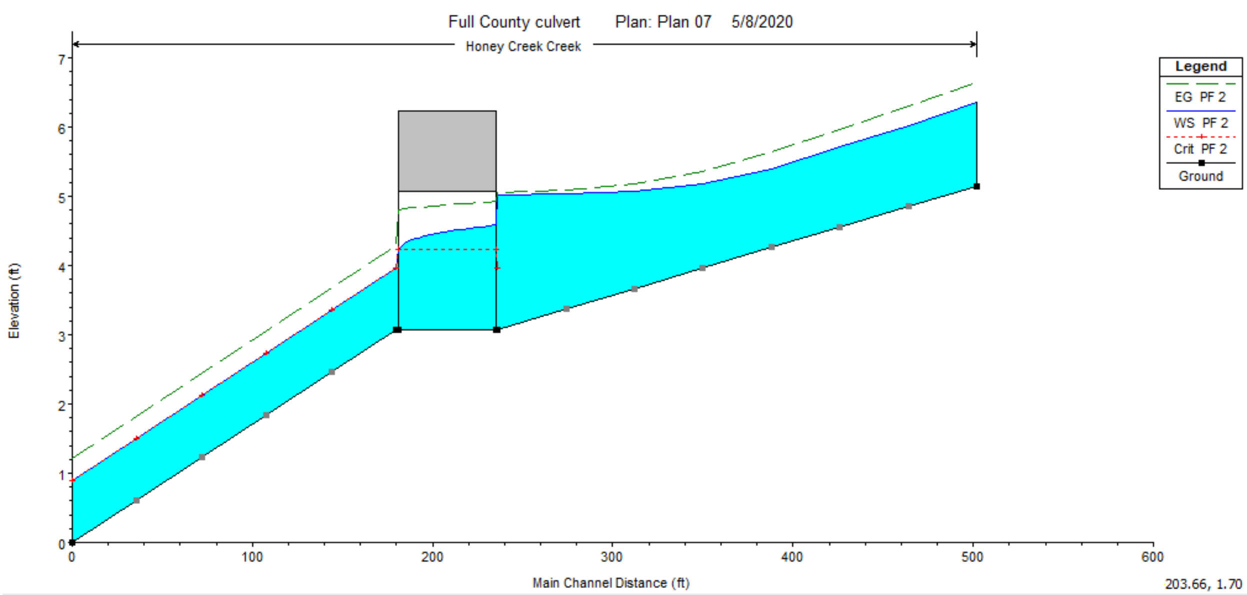


Figure 14: Snapshot of the Profile for the Culvert and Channel using HEC-RAS.

**Stormwater Management Basin Design**

The detention basin was designed to hold the capacity of the storm water runoff of the property owned by Mike Beck. The method that was used to determine this volume of the basin found the ratio of the 5-year preconstruction flowrate to the 100-year postconstruction flow rate. This method determined the volume for a 100-year storm event. A water quality volume analysis was also performed to determine the volume required for a 1-year storm event. The water quality volume was defined in this way for additional environmental benefits. The wetted perimeter by water quality volume had a higher roughness coefficient due to the natural biome. These lower velocities allowed the biome to remove pollutants from the stormwater and improve water quality by letting silt and sand settle.

The volume of the basin was typically found using the channel protection method. While using this method, the 5-year existing curve number was defined to be straight row crops. This provided a curve number of 70. The 100-year proposed was defined as ¼ acres homes that provided a curve number of 69. The time of concentration for both situations was 0.114 hours and 1.434 hour, respectively. When the curve numbers and time of concentration were inputted into the Win TR-55 program, the volume was 0.87 acre-feet. The water quality volume for the same site was found to be 1.30 acre-feet. Due to the similarity of the two situations, there would not be a sufficient increase of runoff due to the new construction. The water quality volume was used to size the pool since it was the larger of the two. Figure 15 shows the size relation of the basin and the amount of extra volume for runoff. The brown section on the left is the main channel and the brown sections on the right are the spillways.

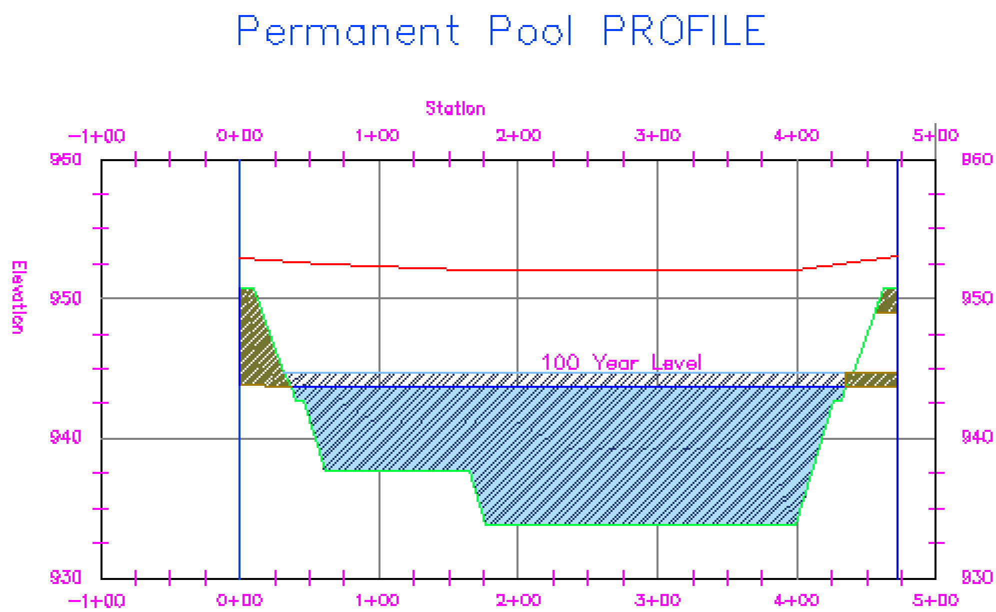



Figure 15: Profile of the permanent pool at a 1:10 scale.

The design of the basin encompassed an area of 1.3 acre-feet and had a depth of 1 foot for a 100-year storm event. This permanent pool was in the shape of a rectangle and had the dimensions of 398 feet by 132 feet. The dimensions of the permeant pool can be seen below in Figure 16.

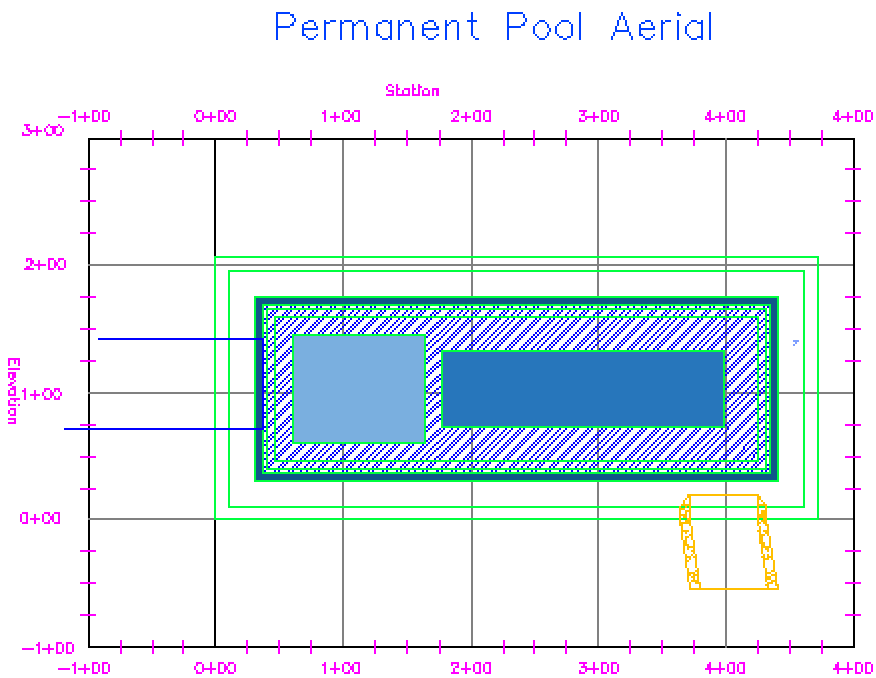



Figure 16: Aerial view of the permanent pool.

The striped area is the permanent pool area. The dark area is the 10-foot-deep area and the light blue area is the 6-foot shallow area. Along the southern end of the basin is the dam, and the dam's elevation of 950.75 feet reaches around the pool.

The permanent pool was located more than 10 feet away from any property line and was advised that no structure be within 25 feet of the permanent pool and maintain an elevation less than 945 feet. Given the circumstances of COVID-19, it was unknown how infiltration would affect the pool or the surrounding features. It was advised that a detailed evaluation on the soil's transmissivity be done. This would determine if the pool would require a liner of bentonite clay or similar.

The velocities into the basin reached 1.102 fps for minor 5-year storm events. Sediment would not be suspended in the flow and would be quickly deposited in the channel and the pool during minor storm events. Therefore, a forebay would not be required for the design of the permanent pool. Also, The City of Manchester had requested methods to avoid a forebay due to their minimal maintenance crew. The size of the permanent pool would still be increased by 25% to compensate for the lack of forebay. An access road along the channel would provide maintenance for the permanent pool. A pump would be required for dewatering and maintenance of the pool.

The permanent storage was twice that of the water quality volume and included a forebay compensation of 25%. The deep section of the pool had a surface area equal to 25% of the surface area of the permanent pool.

The floodplain between the permanent pool level and the 100-year water level had a slope of 6:1 provide a secure footing for recreational activities such as frisbee and fishing.
Safety benches were along the entire perimeter of the permanent pool. These benches were 1 foot below the pool level with a 3:1 slope. Then, the benches flattened out over 6 feet.

Dam construction closely followed SUDAS and Iowa Stormwater Management Manual. The crest of the dam was at an elevation of 950.75 ft with a minimal width of10 feet. There was 0.1-inch riser 5 feet from the edge of the dam. The sides of the dam facing the pool were 4:1 and the outer sides followed the topography. The crest excessed the minimal requirements for a freeboard of 1 foot from the 100-year water level.

The primary spillway was a single staged outlet that would deposit near the Acres Street culvert. The inlet for the primary spillway was at an elevation of 943.75 feet and the outlet will be at an elevation of 943 feet. The primary spillway had a 12-inch reinforced concrete pipe. This would be able to drain the pool from a 100-year water level to the permanent pool level with in 12 hours and allow for debris to pass without clogging the system. Figure 17 and 18 show the primary spillway's inlet and outlet.

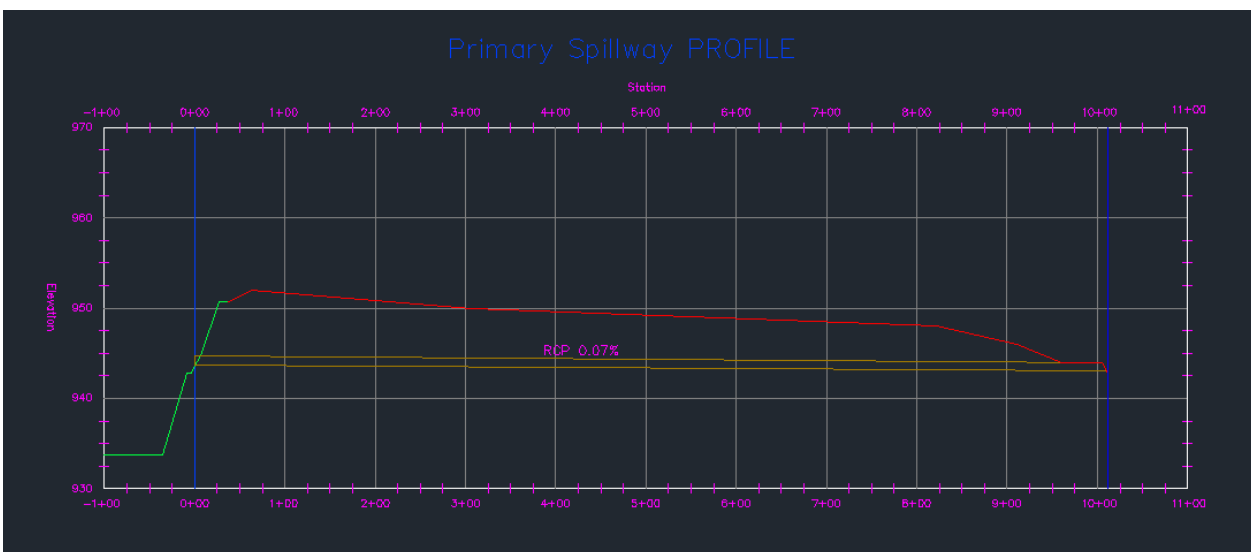



Figure 17: Profile of the Primary Spillway.

Figure 18: Aerial View of the Primary Spillway.

The emergency spillway was located at 949 feet elevation, where the elevation of the crest was 950.75 feet. The distance between the spillway and the crest was 1.75 feet, surpassing the requirements of 1.5 feet. The bed of the emergency spillway was armored in gravel while the sides of the emergency spillway had riprap. The bed width was 53 feet with side slopes of 3:1. This emergency spillway would discharge into the southern detention basin. The basin had additional storage for large events or providing storage for flood areas upstream. There was an additional 3.25 feet between the emergency spillway and the 100-year water level.

**Subdivision's Infrastructure Design**

The project scope required a design for development within the property boundaries of landowner Mike Beck's property. Boundaries for this property can be seen below in Appendix G. Furthermore, lots were designed on the east side of the proposed Grand Avenue extension, running north to south. Drainage constraints limited the property to one cul-de-sac, but it allowed for the potential of larger lot sizes, which could give the area a more up-scale feel. Figure 19 below displays the proposed layout for the subdivision.


Figure 19: Site plan for proposed subdivision.

The lot sizes were designed to the specifications of the City of Manchester. The depth of the lots was 120 feet. The width of the lots was 100 feet. All lot lines were at right angles to the straight street lines and radial at the cul-de-sac. In areas around curves and the end of the cul-de-sac, lots sizes were varied to comply with the requirements of the Zoning Ordinance. Typical lot sizes were 0.28 acres. The lot size was designed for a typical ranch-style home, per the request of the client. Lots had enough space for a 3-car garage. Furthermore, sufficient spacing was allotted between properties for an overland flow route. This property would be owned by the City of Manchester or the Homeowner's Association and would allow for more effective stormwater conveyance. The overland flow route was designed to go between two homes through designated property should rainfall exceed channel capacity. However, the overland flow route could also be designed to run along property lines between two homes. A 20-foot easement was necessary on each side of the property limit.

Along the Grand Avenue extension, 19 lots were designed from north to south. Property was allotted for the channel overland flow route. Open space was also left for possible extension of Deann Drive east.

Design of the subdivision followed specifications in the SUDAS manual and specifications of the City of Manchester. The road for the cul-de-sac maintained a 66-foot right of way, which was used for the Grand Avenue Extension. The cul-de-sac radius right of way was 88 feet, per Manchester design specifications. The border area around the cul-de-sac was the same as the approach street. The transition radius with the approach street was 50 feet for residential streets. The homes were on the north and south side of the roadway. There were 4 lots on the north side and 5 lots on the south side. Around the cul-de-sac there were 6 lots. The cul-de-sac layout can be seen below in Figure 20.

Figure 20: Proposed subdivision layout design.

The front of the yards was maintained on 0.5% slope. The back of the yards was maintained on a –0.5% slope. This allowed for stormwater to run into the street intakes and prevent standing water. Property limits were set 1 foot from the back of the sidewalk. Per the Manchester Zoning Ordinance, front yards would extend 30 feet from the front of the property limit. Therefore, the house was set back 31 feet from the back of the sidewalk. Back yards would be 40 feet from the back of house to rear property limit.

The road into the cul-de-sac was designed like Deann and Fairview as a local road. The pavement was designed to be 7 inches thick, with a foot of subbase underneath which extended out 2 feet past the curbs. Outside of the roadway was a 16-foot right of way which allowed for the SUDAS mandated clear zone and room for sidewalks and utility structures.

Development of a natural area significantly alters the hydrology due to the increase of impervious area. Post-developed peak runoff will be higher than pre-development. The common effects of development are reduced infiltration and decreased travel time.

Intakes were designed with a minimum capacity to convey the 5-year design storm underdeveloped conditions. Storm sewers had the capacity to convey a 5-year storm underdeveloped conditions. Surface water easements were provided in the subdivision design to account for an overland flow route. To design footing drains, SUDAS recommended a discharge (Q) value of 5.0 gpm be used, as the subdivision was less than 50 homes. Culverts had the capacity to convey; 10 year storms without the headwater depth exceeding diameter of the culvert; 50 year storms without the headwater depth exceeding 1 foot over the top of the culvert; and 100 year storms should be conveyed so that the headwater depth does not exceed 1 foot below the low point of the road. There was no curb overtopping for minor design storms. Flow may spread to the crown of the street. SUDAS Table 2A-3.01 can be seen below in Appendix G. For major storms, the ponded area did not exceed the street right-of-way of 66 feet and the depth of the water above the street crown did not exceed 6 inches. Table 2A-3.02 can be seen below in Appendix G. For the design storm of 5 years, the allowable cross street flow did not exceed a 6-inch depth at the crown. For the 100-year design storm, no greater than 9 inches ponding depth can be on the crown of the road. Table 2A-3.03 in Appendix G conveys this information.

Front yards were sloped at no less than 0.5% from front of property line to the front of the home. The back yards were sloped at a negative 0.5% slope from the back of the house to the rear of the property line.

For the stormwater system, storm sewers parallel to the road were placed behind the back of curb. Intakes were spaced no greater than 400 feet apart, per the Iowa Stormwater Management Manual.

The watermain system for the new subdivision was 6-inch PVC pipes. Valves were placed no more than 800 feet apart. One valve was placed at the intersection of the new subdivision and the Grand Avenue extension, one was in the middle of the subdivision road and one was on the end of the cul-de-sac. The pipes were designed with a 5-foot depth of cover according to SUDAS, see Appendix G. A tracer wire was required for the PVC piping. Four fire hydrants were sufficient for the subdivision as hydrants were not to be spaced more than 450 feet apart. For cul-de-sacs greater than 500 feet in length, hydrants were placed at near equal spacings and did not exceed 450 feet. The hydrants were 10 feet from back of the curb to ensure no interaction with the clear zone.

The sanitary sewer design was done in accordance with SUDAS Chapter 3. Per SUDAS recommendations a 12 inch-PVC gravity flow sanitary pipe and 48 diameter-18 frame-24 cone sanitary sewer manhole was used. The manholes were placed no more than 400 feet apart. The sanitary sewer pipe was placed on the north side of the cul-de-sac street and at least 10 feet away from the water main.

During construction and site development, measures were taken to limit environmental impact. Erosion control measures were selected using SUDAS. Sodding is selected due to its high rating for erosion control, and medium rating for flow control, sediment control, and runoff reduction. For sediment control, silt fences and straw wattles were selected. The table used for selection can be seen in Appendix G.

**Overall Strategy for Manchester Stormwater Concerns**

Historically, Manchester experienced stormwater flooding that was devastating to their community. The current flow of water can be seen in Appendix H. With this design, the impacts of flooding should decrease dramatically. Before our project design, there were multiple retention basins around the Fairview subdivision to control water during times of high rainfall. However, the flat topography of the project site was a challenge for managing the flood area. A wetland existed in the northeastern corner of the project area. A retention basin was north of the Fairview subdivision. It filled completely during high rainfall and put surrounding homes at substantial flood risk. A smaller retention basin existed to the east of the Delaware County Fairgrounds. A third retention basin was south of the Fairview Drive subdivision. With the new design, the roadway extensions and utilities provided capture and conveyance capabilities for the 5-year rainfall event on the road and area surrounding the roadway. The geometry of the roadway provided an overland flow route for the 100-year rainfall event and provided locations to allow the excess flow to enter the proposed channel system. The basin south of Fairview would tie into the new stormwater sewer design. The channels would hold and transport stormwater from areas of high rainfall. The northern existing basin would tie into the channel system much like an emergency spillway, a primary spillway was suggested to lower the water level in the basin. The new permanent pool would provide more than adequate space for the difference in runoff due to the new subdivision construction within Mick Beck's property. In addition, the permanent pool would provide 6.5 acre-feet of volume for runoff upstream of this site.

**Water Quality**

Historically, Manchester had nitrate and nutrient problems in their water. There are health concerns that come along with nitrate exposure. With that, water quality needed to be considered in our design. The permanent pool was designed for the Water Quality Volume, providing some water quality assistance. A proper soils test was recommended to see how much of the water would infiltrate the aquifer.

Upon coordination with Daniel Murphy, project manager of Trident Environmental Solutions for the Manchester Wellhead Protection project and his team, they designed a riparian buffer zone along the north and east side of the existing wetland. This helped nutrient removal entering the existing wetland. The design can be seen in Appendix I.

Trident Environmental Solutions also suggested the use of contour buffer strips which could provide up to 85% nitrate removal. These strips were east of our project area. An image of contour buffer strips can be seen in Appendix I.

An Urban Nitrate Strategy was also established by Trident Environmental Solutions. A brochure was designed to inform the people of Manchester about the effects of using fertilizers and other lawn chemicals. Lawncare resources were also provided in the brochure. This brochure can be found in Appendix I. Small Town, Big Solutions Inc. and Trident Environmental Solutions found these nitrate removal designs and strategies vital for the town of Manchester in order to protect the water quality and health of the community.

**Section VII – Engineer's Cost Estimate**

The public cost consisted of roadway extension construction cost, stormwater sewer, water main, and preliminary sanitary sewer construction cost, and channel and culvert construction cost. The private cost consisted of the permanent pool and subdivision. Both public and private costs consisted of 2% mobilization, 5% contingencies, and 10% engineering and administration. We have assumed all necessary ROW and easements would be dedicated for this project. The breakdown of each design element's cost can be seen in Appendix J.

Table 1: Estimate of total project cost.

| **Budget Summary** | |
|---|---|
| **Design Element** | **Cost** |
| **Public** | |
| Roadway Extension | $1,267,656 |
| Stormwater Sewer | $236,286 |
| Water Main | $295,057 |
| Preliminary Sanitary Sewer | $318,328 |
| Channel and Culvert | $132,695 |
| Mobilization | $45,000 |
| 5% Contingencies | $112,501 |
| 10% Engineering and Administration | $225,002 |
| **Total:** | **$2,632,525** |
| **Private** | |
| Stormwater Management Basin | $165,552 |
| Subdivision's Infrastructure | $676,718 |
| Mobilization | $16,845 |
| 5% Contingencies | $42,114 |
| 10% Engineering & Administration | $84,227 |
| **Total:** | **$985,456** |
| **Combined Total:** | **$3,617,981** |

# Appendices

## Appendix A – Roadway Design

Table A1: Roadway design elements based on road classification, SUDAS Ch 5C-1.

| Design Element | Local | | Collector | | Arterial | |
|---|---|---|---|---|---|---|
| | *Res.* | *C/I* | *Res.* | *C/I* | *Res.* | *C/I* |
| **General** | | | | | | |
| Design level of service[1] | D | D | C/D | C/D | C/D | C/D |
| Lane width (single lane) (ft)[2] | 10.5 | 12 | 12 | 12 | 12 | 12 |
| Two-way left-turn lanes (TWLTL) (ft) | N/A | N/A | 14 | 14 | 14 | 14 |
| Width of new bridges (ft)[3] | See Footnote 3 | | | | | |
| Width of bridges to remain in place (ft)[4] | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |
| Vertical clearance (ft)[5] | 14.5 | 14.5 | 14.5 | 14.5 | 16.5 | 16.5 |
| Object setback (ft)[6] | 3 | 3 | 3 | 3 | 3 | 3 |
| Clear zone (ft) | Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1 | | | | | |
| **Urban** | | | | | | |
| Curb offset (ft)[7] | 2 | 2 | 2 | 3 | 3 | 3 |
| Parking lane width (ft) | 8 | 8 | 8 | 10 | N/A | N/A |
| Roadway width with parking on one side[8] | 26/31[9] | 34 | 34 | 37 | N/A | N/A |
| Roadway width without parking[10] | 26 | 31 | 31 | 31 | 31 | 31 |
| Raised median with left-turn lane (ft)[11] | N/A | N/A | 19.5 | 20.5 | 20.5 | 20.5 |
| Cul-de-sac radius (ft) | 45 | 45 | N/A | N/A | N/A | N/A |
| **Rural Sections in Urban Areas** | | | | | | |
| Shoulder width (ft) | | | | | | |
| ADT: under 400 | 4 | 4 | 6 | 6 | 10 | 10 |
| ADT: 400 to 1,500 | 6 | 6 | 6 | 6 | 10 | 10 |
| ADT: 1,500 to 2000 | 8 | 8 | 8 | 8 | 10 | 10 |
| ADT: above 2,000 | 8 | 8 | 8 | 8 | 10 | 10 |
| Foreslope (H:V) | 4:1 | 4:1 | 4:1 | 4:1 | 6:1 | 6:1 |
| Backslope (H:V) | 4:1 | 4:1 | 4:1 | 4:1 | 4:1 | 4:1 |

Table A2: Allowable ponding depth based on road classification, SUDAS Ch 2A-3.

**Table 2A-3.02:** Allowable Pavement Encroachment and Depth of Flow for Major (100 Year) Storm Runoff

| Street Classification | Allowable Depth and Ponded Area |
|---|---|
| Local and Collector | The ponded area should not exceed the street right-of-way and the depth of water above the street crown should not exceed 6 inches. There may be situations where other restrictions are necessary. |
| Major and Minor Arterial | A 12 foot lane is the minimum travel lane to be passable in the center of the street. |

Table A3: Vertical curve design criteria based on design speed, SUDAS Ch 5C-1.

Elements Related to Design Speed

| Design Element | Design Speed, mph[12] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *25* | *30* | *35* | *40* | *45* | *50* | *55* | *60* |
| Stopping sight distance (ft) | 155 | 200 | 250 | 305 | 360 | 425 | 495 | 570 |
| Passing sight distance (ft) | 900 | 1090 | 1,280 | 1,470 | 1,625 | 1,835 | 1,985 | 2,135 |
| Min. horizontal curve radius (ft)[13] | 198 | 333 | 510 | 762 | 1,039 | 926 | 1,190 | 1,500 |
| Min. vertical curve length (ft) | 50 | 75 | 105 | 120 | 135 | 150 | 165 | 180 |
| Min. rate of vertical curvature, Crest (K)[14] | 18 | 30 | 47 | 71 | 98 | 136 | 185 | 245 |
| Min. rate of vertical curvature, Sag (K) | 26 | 37 | 49 | 64 | 79 | 96 | 115 | 136 |
| Minimum gradient (percent) | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Maximum gradient (percent) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

Elements Related to Design Speed

| Design Element | Design Speed, mph[12] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | *25* | *30* | *35* | *40* | *45* | *50* | *55* | *60* |
| Stopping sight distance (ft) | 155 | 200 | 250 | 305 | 360 | 425 | 495 | 570 |
| Passing sight distance (ft) | 900 | 1090 | 1,280 | 1,470 | 1,625 | 1,835 | 1,985 | 2,135 |
| Min. horizontal curve radius (ft)[13] | 198 | 333 | 510 | 762 | 1,039 | 926 | 1,190 | 1,500 |
| Min. vertical curve length (ft) | 50 | 75 | 105 | 120 | 135 | 150 | 165 | 180 |
| Min. rate of vertical curvature, Crest (K)[14] | 18 | 30 | 47 | 71 | 98 | 136 | 185 | 245 |
| Min. rate of vertical curvature, Sag (K) | 26 | 37 | 49 | 64 | 79 | 96 | 115 | 136 |
| Minimum gradient (percent) | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Maximum gradient (percent) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

Table A4: Turning Radii based on road classifications, SUDAS Ch 5C-2.

## Q. Intersection Radii

Minimum curb return radii are shown in Table 5C-2.09 below. Where truck traffic is significant, curb return radii should be provided according to the current AASHTO "Green Book;" turning templates are used in this design. The Iowa DOT has an Iowa truck vehicle that can be used to check the proposed radii for truck routes.

**Table 5C-2.09:** Curb Return Radii Based Upon Roadway Classification

| Roadway Classification | Arterial | Collector | Local - Commercial/ Industrial | Local - Residential |
|---|---|---|---|---|
| Arterial | Special* | Special* | 30' | 30' |
| Collector | Special* | 30' | 30' | 25' |
| Local - Commercial/Industrial | 30' | 30' | 25' | 25' |
| Local - Residential | 30' | 30' | 25' | 25' |

*Special design required. Use turning templates.

## Appendix B – Stormwater Sewer Design

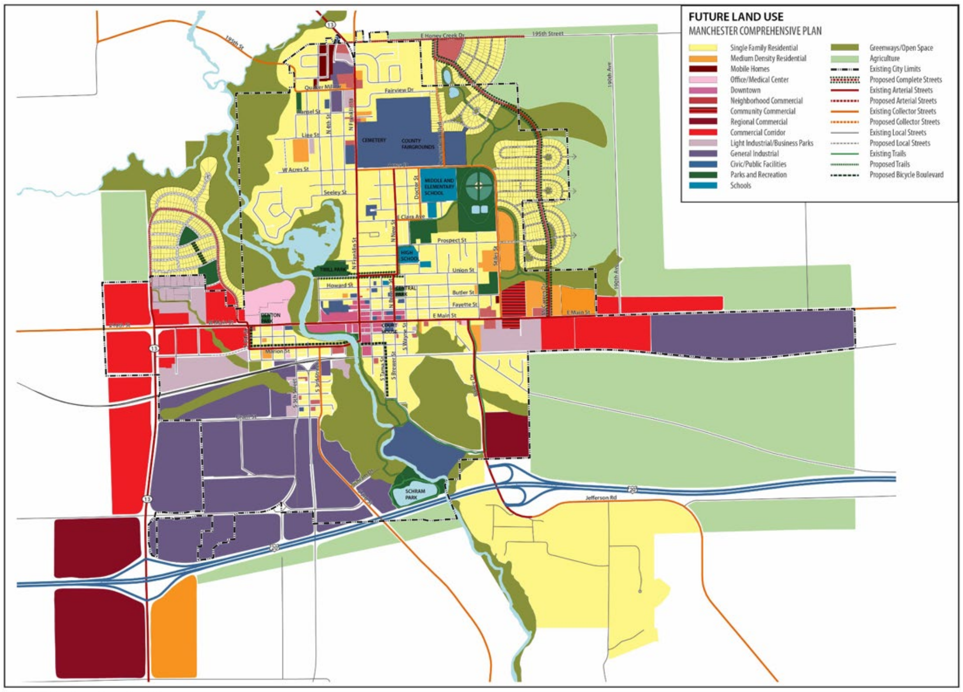



Figure 9.6- Manchester Future Land Use

Figure B1: Manchester comprehensive plan future land use from the city's website.

Table B1: Runoff Coefficients based on soil type, design year, and land use, SUDAS Ch 2B-4.

| **Cover Type and Hydrologic Condition** | | **Runoff Coefficients for Hydrologic Soil Group** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***A*** | | | ***B*** | | | ***C*** | | | ***D*** | | |
| | ***Recurrence Interval*** | ***5*** | ***10*** | ***100*** | ***5*** | ***10*** | ***100*** | ***5*** | ***10*** | ***100*** | ***5*** | ***10*** | ***100*** |
| **Open Space (lawns, parks, golf courses, cemeteries, etc.)** | | | | | | | | | | | | | |
| Poor condition (grass cover < 50%) | | .25 | .30 | .50 | .45 | .55 | .65 | .65 | .70 | .80 | .70 | .75 | .85 |
| Fair condition (grass cover 50% to 75%) | | .10 | .10 | .15 | .25 | .30 | .50 | .45 | .55 | .65 | .60 | .65 | .75 |
| Good condition (grass cover >75%) | | .05 | .05 | .10 | .15 | .20 | .35 | .35 | .40 | .55 | .50 | .55 | .65 |
| **Impervious Areas** | | | | | | | | | | | | | |
| Parking lots, roofs, driveways, etc. (excluding ROW) | | .95 | .95 | .98 | .95 | .95 | .98 | .95 | .95 | .98 | .95 | .95 | .98 |
| Streets and roads: | | | | | | | | | | | | | |
| Paved; curbs & storm sewers (excluding ROW) | | .95 | .95 | .98 | .95 | .95 | .98 | .95 | .95 | .98 | .95 | .95 | .98 |
| Paved; open ditches (including ROW) | | --- | --- | --- | .70 | .75 | .85 | .80 | .85 | .90 | .80 | .85 | .90 |
| Gravel (including ROW) | | --- | --- | --- | .60 | .65 | .75 | .70 | .75 | .85 | .75 | .80 | .85 |
| Dirt (including ROW) | | --- | --- | --- | .55 | .60 | .70 | .65 | .70 | .80 | .70 | .75 | .85 |
| **Urban Districts (excluding ROW)** | | | | | | | | | | | | | |
| Commercial and business (85% impervious) | | --- | --- | --- | --- | --- | --- | .85 | .85 | .90 | .90 | .90 | .95 |
| Industrial (72% impervious) | | --- | --- | --- | --- | --- | --- | .80 | .80 | .85 | .80 | .85 | .90 |
| **Residential Districts by Average Lot Size (excluding ROW)**[1] | | | | | | | | | | | | | |
| 1/8 acre (36% impervious) | | --- | --- | --- | --- | --- | --- | .55 | .60 | .70 | .65 | .70 | .75 |
| 1/4 acre (36% impervious) | | --- | --- | --- | --- | --- | --- | .55 | .60 | .70 | .65 | .70 | .75 |
| 1/3 acre (33% impervious) | | --- | --- | --- | --- | --- | --- | .55 | .60 | .70 | .65 | .70 | .75 |
| 1/2 acre (20% impervious) | | --- | --- | --- | --- | --- | --- | .45 | .50 | .65 | .60 | .65 | .70 |
| 1 acre (11% impervious) | | --- | --- | --- | --- | --- | --- | .40 | .45 | .60 | .55 | .60 | .65 |
| 2 acres (11% impervious) | | --- | --- | --- | --- | --- | --- | .40 | .45 | .60 | .55 | .60 | .65 |
| **Newly Graded Areas (pervious areas only, no vegetation)** | | | | | | | | | | | | | |
| **Agricultural and Undeveloped** | | | | | | | | | | | | | |
| Meadow - protected from grazing (pre-settlement) ............ | | .10 | .10 | .25 | .10 | .15 | .30 | .30 | .35 | .55 | .45 | .50 | .65 |
| Straight Row Crops | | | | | | | | | | | | | |
| Straight Row (SR) ...................... | *Poor Condition* | .33 | .39 | .55 | .52 | .58 | .71 | .70 | .74 | .84 | .78 | .81 | .89 |
| | *Good Condition* | .24 | .30 | .46 | .45 | .51 | .66 | .62 | .67 | .78 | .73 | .76 | .86 |
| SR + Crop Residue (CR) ............ | *Poor Condition* | .31 | .37 | .54 | .50 | .56 | .70 | .67 | .72 | .82 | .75 | .79 | .87 |
| | *Good Condition* | .19 | .25 | .41 | .38 | .45 | .61 | .55 | .60 | .73 | .62 | .67 | .78 |
| Contoured (C) .............................. | *Poor Condition* | .29 | .35 | .52 | .47 | .53 | .70 | .60 | .65 | .77 | .70 | .74 | .84 |
| | *Good Condition* | .21 | .26 | .43 | .38 | .45 | .61 | .55 | .60 | .73 | .65 | .69 | .80 |
| C+CR.............................................. | *Poor Condition* | .27 | .33 | .50 | .45 | .51 | .66 | .57 | .63 | .75 | .67 | .72 | .82 |
| | *Good Condition* | .19 | .25 | .41 | .36 | .43 | .59 | .52 | .58 | .71 | .62 | .67 | .78 |
| Contoured & Terraced (C&T) ..... | *Poor Condition* | .22 | .28 | .45 | .36 | .43 | .59 | .50 | .56 | .70 | .55 | .60 | .73 |
| | *Good Condition* | .16 | .22 | .38 | .31 | .37 | .54 | .45 | .51 | .66 | .52 | .58 | .71 |
| C&T + CR ..................................... | *Poor Condition* | .13 | .19 | .35 | .31 | .37 | .54 | .45 | .51 | .66 | .52 | .58 | .71 |
| | *Good Condition* | .10 | .16 | .32 | .27 | .33 | .50 | .43 | .49 | .65 | .50 | .56 | .70 |

[1] The average percent impervious area shown was used to develop composite coefficients.

Note: Rational coefficients were derived from SCS CN method

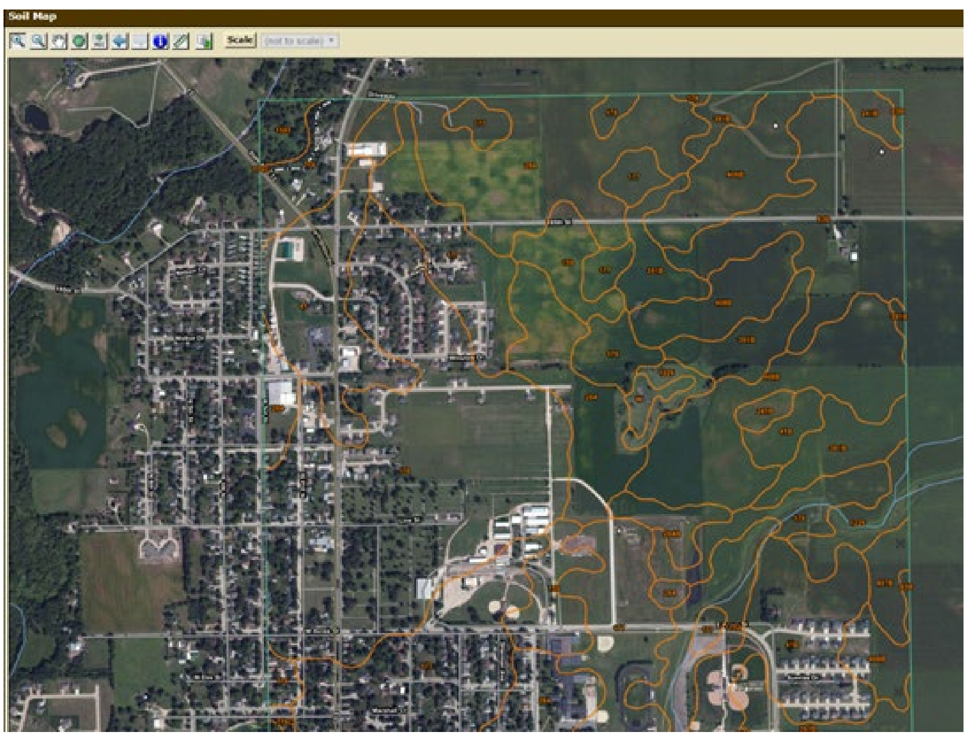



Figure B2: USGS Soil Survey Map.

Table B2: Key for USGS soil survey map containing main soils in the project area.

| | | | |
|---|---|---|---|
| 159 | Finchford loamy sand, 0 to 2 percent slopes | 23.9 | 3.1% |
| 177 | Saude loam, 0 to 2 percent slopes | 119.4 | 15.6% |
| 178 | Waukee loam, 0 to 2 percent slopes | 166.7 | 21.8% |
| 241B | Burkhardt-Saude complex, 2 to 5 percent slopes | 6.7 | 0.9% |
| 284 | Flagler fine sandy loam, 0 to 2 percent slopes | 104.6 | 13.7% |

Table B3: Soil designation, SUDAS Ch 2B-4.

**Table 2B-4.02:** Hydrologic Soil Group for Disturbed Soils

| HSG | Soil Texture |
|---|---|
| A | Sand, loamy sand, or sandy loam |
| B | Silt loam or loam |
| C | Sandy clay loam |
| D | Clay loam, silty clay loam, sandy clay, silty clay, or clay |

Source: NRCS TR-55

**Figure 2B-2.01:** Climatic Sectional Codes for Iowa

| | | |
|---|---|---|
| 1 - Northwest | 4 - West Central | 7 - Southwest |
| 2 - North Central | 5 - Central | 8 - South Central |
| 3 - Northeast | 6 - East Central | 9 - Southeast |

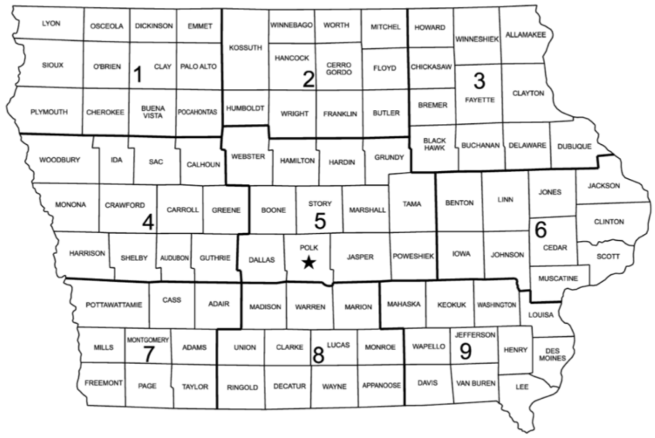
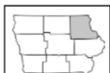



Figure B3: Figure used in determining design rainfall intensity based on geographic location, SUDAS Ch 2B-2.

Table B4: Table used to determine rainfall intensity using time of concentration and design storm, SUDAS Ch 2B-2.

**Table 2B-2.04:** Section 3 - Northeast Iowa
*Rainfall Depth and Intensity for Various Return Periods*



| | **Return Period** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ***1 year*** | | ***2 year*** | | ***5 year*** | | ***10 year*** | | ***25 year*** | | ***50 year*** | | ***100 year*** | | ***500 year*** | |
| **Duration** | ***D*** | ***I*** | ***D*** | ***I*** | ***D*** | ***I*** | ***D*** | ***I*** | ***D*** | ***I*** | ***D*** | ***I*** | ***D*** | ***I*** | ***D*** | ***I*** |
| 5 min | 0.38 | 4.66 | 0.45 | 5.47 | 0.56 | 6.76 | 0.65 | 7.86 | 0.78 | 9.42 | 0.88 | 10.5 | 0.98 | 11.8 | 1.22 | 14.7 |
| 10 min | 0.56 | 3.40 | 0.66 | 4.00 | 0.82 | 4.94 | 0.96 | 5.76 | 1.14 | 6.89 | 1.29 | 7.75 | 1.44 | 8.64 | 1.79 | 10.7 |
| 15 min | 0.69 | 2.77 | 0.81 | 3.24 | 1.00 | 4.02 | 1.17 | 4.68 | 1.40 | 5.60 | 1.57 | 6.31 | 1.75 | 7.03 | 2.19 | 8.77 |
| 30 min | 0.96 | 1.93 | 1.14 | 2.28 | 1.41 | 2.83 | 1.65 | 3.31 | 1.98 | 3.96 | 2.23 | 4.47 | 2.49 | 4.98 | 3.10 | 6.20 |
| 1 hr | 1.25 | 1.25 | 1.47 | 1.47 | 1.85 | 1.85 | 2.17 | 2.17 | 2.64 | 2.64 | 3.01 | 3.01 | 3.39 | 3.39 | 4.34 | 4.34 |
| 2 hr | 1.53 | 0.76 | 1.81 | 0.90 | 2.28 | 1.14 | 2.70 | 1.35 | 3.30 | 1.65 | 3.79 | 1.89 | 4.30 | 2.15 | 5.58 | 2.79 |
| 3 hr | 1.71 | 0.57 | 2.01 | 0.67 | 2.55 | 0.85 | 3.03 | 1.01 | 3.74 | 1.24 | 4.32 | 1.44 | 4.94 | 1.64 | 6.55 | 2.18 |
| 6 hr | 2.01 | 0.33 | 2.36 | 0.39 | 2.98 | 0.49 | 3.56 | 0.59 | 4.43 | 0.73 | 5.17 | 0.86 | 5.97 | 0.99 | 8.07 | 1.34 |
| 12 hr | 2.32 | 0.19 | 2.69 | 0.22 | 3.38 | 0.28 | 4.02 | 0.33 | 5.02 | 0.41 | 5.86 | 0.48 | 6.79 | 0.56 | 9.25 | 0.77 |
| 24 hr | 2.63 | 0.10 | 3.04 | 0.12 | 3.78 | 0.15 | 4.48 | 0.18 | 5.56 | 0.23 | 6.48 | 0.27 | 7.48 | 0.31 | 10.1 | 0.42 |
| 48 hr | 3.00 | 0.06 | 3.44 | 0.07 | 4.23 | 0.08 | 4.98 | 0.10 | 6.12 | 0.12 | 7.10 | 0.14 | 8.15 | 0.16 | 10.9 | 0.22 |
| 3 day | 3.28 | 0.04 | 3.73 | 0.05 | 4.56 | 0.06 | 5.32 | 0.07 | 6.49 | 0.09 | 7.48 | 0.10 | 8.56 | 0.11 | 11.4 | 0.15 |
| 4 day | 3.53 | 0.03 | 4.00 | 0.04 | 4.85 | 0.05 | 5.64 | 0.05 | 6.84 | 0.07 | 7.86 | 0.08 | 8.95 | 0.09 | 11.8 | 0.12 |
| 7 day | 4.17 | 0.02 | 4.72 | 0.02 | 5.70 | 0.03 | 6.58 | 0.03 | 7.87 | 0.04 | 8.95 | 0.05 | 10.1 | 0.06 | 13.0 | 0.07 |
| 10 day | 4.76 | 0.01 | 5.38 | 0.02 | 6.45 | 0.02 | 7.39 | 0.03 | 8.77 | 0.03 | 9.90 | 0.04 | 11.0 | 0.04 | 14.0 | 0.05 |

D = Total depth of rainfall for given storm duration (inches)
I = Rainfall intensity for given storm duration (inches/hour)

**a. Manhole Spacing:** Manholes are to be spaced at intervals not exceeding 400 feet or at intervals not exceeding 500 feet when adequate cleaning equipment is available.

**b. Intake Spacing:** Locate street intakes upgrade from intersections, sidewalk ramps, and outside of intersection radii. At least one intake is to be installed at the low point of the street grade.

**1) First Intake:** An intake should be located no further than 500 feet from the street high point.

**2) Remaining Intakes:** To be spaced at a distance no greater than 400 feet, regardless of gutter flow capacity, in order to meet maintenance needs.

Figure B4: Manhole and Intake spacing recommended by SUDAS Ch. 2C-3.

**D. Physical Requirements**

1. **Minimum Cover over Storm Sewer Pipes:** The recommended minimum cover over storm sewer pipes should be 1 foot or as specified by the type of pipe as described in Chapter 9 - Utilities, whichever is greater. Where the clearance is less than 1 foot below the pavement, the Project Engineer will provide a design method to maintain the integrity of the pipe and pavement. For storm sewer pipe outside of the pavement, the minimum cover should be 1 foot or as specified by the type of pipe (described in Chapter 9 - Utilities), whichever is greater.

2. **Minimum Flow Line Depth for Footing Drain Sewers:** 3 feet 6 inches.

3. **Minimum Pipe Size:**

   a. **Storm Sewers:** 15 inches in diameter.

   b. **Subdrains:** 6 inches in diameter.

   c. **Footing Drain Collector Sewers in Public Right-of-way:** 8 inches in diameter.

   d. **Building Storm Sewer Stubs:** 4 inches in diameter

4. **Velocity within Storm Sewer Pipe:**

   a. Minimum flow (1/2 full pipe) = 3 fps cleaning velocity

   b. Maximum flow (1/2 full pipe) = 15 fps

5. **Velocity at Outlet of Pipe:** Energy dissipation is required when discharge velocities exceed those allowed for downstream channel. (See Tables 2F-2.03 and 2F-2.04).

   a. With flared end section, maximum of 5 fps.

   b. Maximum with flared end section, footing, and rip rap = 10 fps

   c. Maximum with energy dissipation device = 15 fps

6. **Partially Full Pipe Flow:** For convenience, charts for various pipe shapes have been developed for calculating the hydraulic properties (Table 2D-2.01 in Section 2D-2). The data presented assumes that the friction coefficient, Manning's "n" value, does not vary throughout the depth.

2 Revised: 2017 Edition

Chapter 2 - Stormwater Section 2D-1 - General Information for Storm Sewer Design

7. **Minimum Storm Sewer and Footing Drain Grades:**

   a. **Storm Sewer Mains:** Minimum grade is set by the required minimum velocity for storm sewers and footing drain sewers - 3 fps for design storm.

   b. **Cross Runs:** Minimum grade of 1%. Desired minimum velocity of 3 fps for design storm.

   c. **Building Storm Sewer Stubs:** Minimum grade of 1%.

   d. **Subdrains:** Minimum grade of 0.5%.

Figure B5: Design Criteria governing pipe size, slope, and location, SUDAS Ch 2D-1.

## Appendix C – Water Main Design

**Figure 4C-1.01:** Minimum Depth of Cover for Water Main Installation

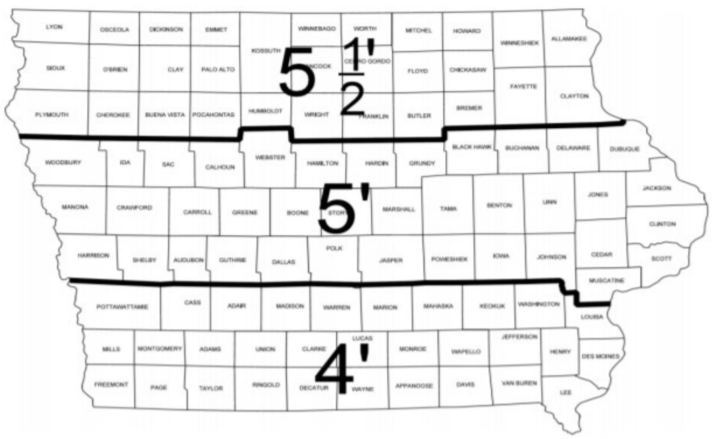



Figure C1: Depth of cover for pressurized pipe systems in Iowa, SUDAS Chpt. 4.

## Appendix D – Preliminary Sanitary Sewer Design

Table D1: Sanitary sewer pipe materials and characteristics in Iowa, SUDAS Chpt. 3.

**Table 3D-1.01:** Sanitary Sewer Pipe Materials

| Typical Application | Pipe Material | Size Range | Standard | Thickness Class (min.) | Pipe Stiffness (min.) | Joints |
|---|---|---|---|---|---|---|
| Gravity Flow | Solid Wall PVC | 8” to 15” | ASTM D 3034 | SDR 26 | 115 psi | Bell and Spigot |
| Gravity Flow | Solid Wall PVC | 8” to 15” | ASTM D 3034 | SDR 35 | 46 psi | Bell and Spigot |
| Gravity Flow | Solid Wall PVC | 18” to 27” | ASTM F 679 | N/A | 46 psi | Bell and Spigot |
| Gravity Flow | Corrugated PVC | 8” to 10” | ASTM F 949 | N/A | 115 psi | Bell and Spigot |
| Gravity Flow | Corrugated PVC | 12” to 36” | ASTM F 949 | N/A | 46 psi | Bell and Spigot |
| Gravity Flow | Closed Profile PVC | 21” to 36” | ASTM F 1803 | N/A | 46 psi | Bell and Spigot |
| Gravity Flow | Truss Type PVC | 8” to 15” | ASTM D 2680 | N/A | 200 psi | Bell and Spigot |
| Gravity Flow | RCP | 18” to 144” | ASTM C 76 | Class IV Wall B | 4,000 psi | Tongue and Groove |
| Gravity Flow | Ductile Iron | 8” to 54” | AWWA C151 | Class 52 | 300 psi | MJ or Push on |
| Gravity Flow | VCP | 8” to 42” | ASTM C 700 | N/A | N/A | Bell and Spigot |
| Gravity Flow | Double Walled Polypropylene | 12” to 30” | ASTM F 2736 | N/A | 46 psi | Bell and Spigot |
| Gravity Flow | Triple Walled Polypropylene | 30” to 36” | ASTM F 2764 | N/A | 46 psi | Bell and Spigot |
| Force Main | Ductile Iron | 4” to 64” | AWWA C151 | Class 52 | 300 psi | MJ or Push on |
| Force Main | PVC | 4” to 30” | AWWA C 900 | DR 18 | 150 psi | Bell and Spigot |

Gravity mains greater than 42 inches in diameter will be lined reinforced concrete pipe or ductile iron.
Force mains greater than 30 inches in diameter will be ductile iron.

## Appendix E – Channel and Culvert Design

Table E1: Limitations of Hydrologic Methods, SUDAS Chpt. 2.

| Method | Size Limitations | Comments |
|---|---|---|
| Rational | 40 acres | Method can be used for drainage areas with similar land uses for estimating peak flows and for the design of small site or subdivision storm sewer systems. *Should not be used for storage design.* |
| NRCS Peak Flow | 0 to 2,000 acres | Method can be used for estimating peak flows for storm sewer or channel design. *Should not be used for storage design.* |
| Modified Rational | 0 to 5 acres | Method can be used for estimating peak flows and developing simple hydrographs from small drainage areas with significantly different runoff coefficients. |
| NRCS TR-55 | 0 to 2,000 acres | Method can be used for estimating peak flows and developing hydrographs for all design applications. Can be used for low-impact development hydrologic analysis. |

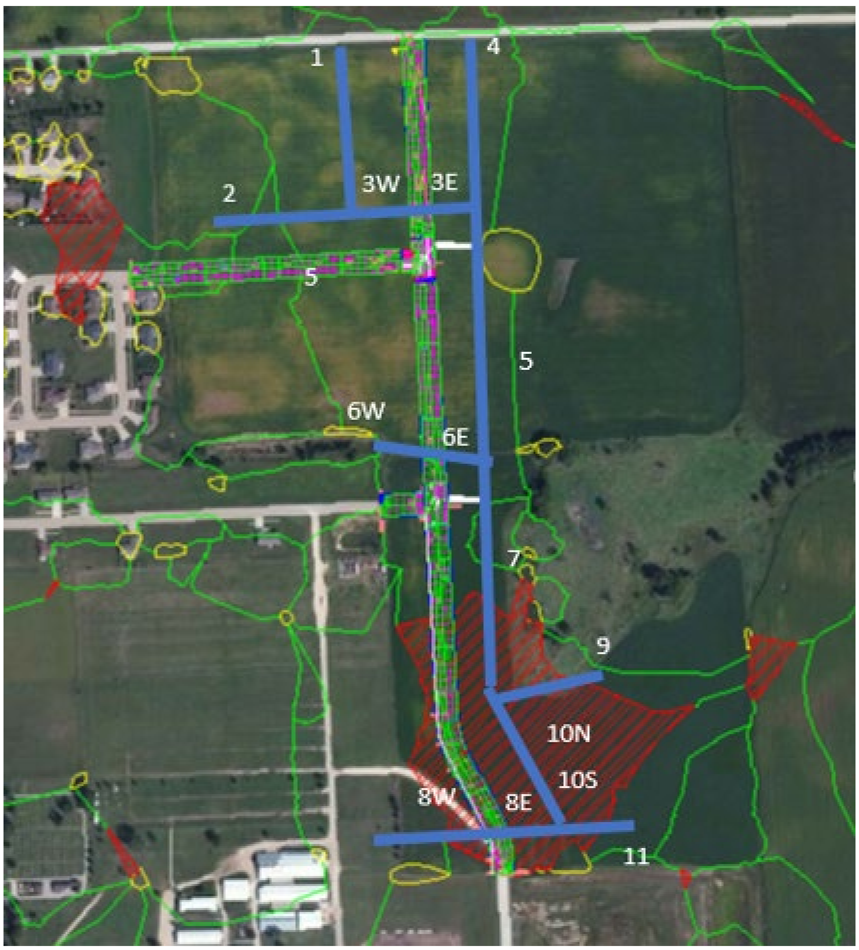



Figure E1: Screen Shot of the Channel Sections

Table E2: Manning's Roughness Coefficient for Sheet Flow, SUDAS Chpt. 2.

| **Surface Description** | ***n*** |
|---|---|
| Smooth Surface (concrete, asphalt, gravel, or bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated Soils: | |
| Residue cover ≤ 20% | 0.06 |
| Residue cover > 20% | 0.17 |
| Grass: | |
| Short grass prairie | 0.15 |
| Dense grasses[1] | 0.24 |
| Bermudagrass | 0.41 |
| Range (natural) | 0.13 |
| Woods:[2] | |
| Light underbrush | 0.40 |
| Dense underbrush | 0.80 |

Table E3: Equations and Assumptions, SUDAS Chpt. 2.

| **Flow Type** | **Depth (feet)** | **Manning's n** | **Velocity Equation (ft/s)** |
|---|---|---|---|
| Pavement and small upland gullies | 0.2 | 0.025 | $V = 20.238(s)^{0.5}$ |
| Grassed waterways (and unpaved urban areas) | 0.4 | 0.050 | $V = 16.135(s)^{0.5}$ |
| Nearly bare and untilled (overland flow); and alluvial fans | 0.2 | 0.051 | $V = 9.965(s)^{0.5}$ |
| Cultivated straight row crops | 0.2 | 0.058 | $V = 8.762(s)^{0.5}$ |
| Short-grass prairie | 0.2 | 0.073 | $V = 6.962(s)^{0.5}$ |
| Minimum tillage cultivation, contour or strip-cropped, and woodlands | 0.2 | 0.101 | $V = 5.032(s)^{0.5}$ |
| Forest with heavy ground litter and hay meadows | 0.2 | 0.202 | $V = 2.516(s)^{0.5}$ |

Table E4: Manning's Roughness Coefficients for Open Channel Flow, SUDAS Chpt. 2.

| Type of Channel and Description | n |
|---|---|
| **A. Closed Conduits Flowing Partly Full** | |
| 1. Steel - Riveted and Spiral | 0.016 |
| 2. Cast Iron - Coated | 0.013 |
| 3. Cast Iron - Uncoated | 0.014 |
| 4. Corrugated Metal - Subdrain | 0.019 |
| 5. Corrugated Metal - Storm Drain | 0.024 |
| 6. Concrete Culvert, straight and fee of debris | 0.011 |
| 7. Concrete Culvert, with bends, connections, and some debris | 0.013 |
| 8. Concrete Sewer with manholes, inlet, etc., straight | 0.015 |
| 9. Concrete, Unfinished, steel form | 0.013 |
| 10. Concrete, Unfinished, smooth wood form | 0.014 |
| 11. Wood - Stave | 0.012 |
| 12. Clay - Vitrified sewer | 0.014 |
| 13. Clay - Vitrified sewer with manholes, inlet, etc. | 0.015 |
| 14. Clay - Vitrified subdrain with open joints | 0.016 |
| 15. Brick - Glazed | 0.013 |
| 16. Brick - Lined with cement mortar | 0.015 |
| **B. Lined or Built-Up Channels** | |
| 1. Corrugated Metal | 0.025 |
| 2. Wood - Planed | 0.012 |
| 3. Wood - Unplaned | 0.013 |
| 5. Concrete - Trowel finish | 0.013 |
| 6. Concrete - Float finish | 0.015 |
| 7. Concrete - Finished, with gravel on bottom | 0.017 |
| 8. Concrete - Unfinished | 0.017 |
| 9. Concrete Bottom Float Finished with sides of: | |
| a. Random stone in mortar | 0.020 |
| b. Cement rubble masonry | 0.025 |
| c. Dry ruble or rip rap | 0.030 |
| 10. Gravel Bottom with sides of: | |
| a. Formed concrete | 0.020 |
| b. Dry rubble or rip rap | 0.033 |
| 11. Brick - Glazed | 0.013 |
| 12. Brick - In cement mortar | 0.015 |
| 13. Masonry Cemented Rubble | 0.025 |
| 14. Dry Rubble | 0.032 |
| 15. Smooth Asphalt | 0.013 |
| 16. Rough Asphalt | 0.016 |
| **C. Excavated or Dredged Channel** | |
| 1. Earth, straight and uniform | |
| a. Clean, after weather | 0.022 |
| b. Gravel, uniform section, clean | 0.025 |
| c. With short grass, few weeds | 0.027 |
| 2. Earth, winding and sluggish | |
| a. No vegetation | 0.025 |
| b. Grass, some weeds | 0.030 |
| c. Dense weeds or aquatic plants in deep channels | 0.035 |
| d. Earth bottom and rubble sides | 0.030 |
| e. Stony bottom and weedy banks | 0.040 |
| 3. Channels not maintained, weeds and brush uncut | |
| a. Dense weeds, high as flow depth | 0.080 |
| b. Clean bottom, brush on sides | 0.050 |
| **D. Natural Streams** | |
| 1. Clean, straight bank, full stage, no rifts or deep pools | 0.030 |
| 2. As D.1 above, but some weeds and stones | 0.035 |
| 3. Winding, some pools and shoals, clean | 0.040 |
| 4. As D.3 above, but lower stages, more ineffective slope and sections | 0.045 |
| 5. As D.3 above, but some weeds and stones | 0.048 |
| 6. As D.4 above, but with stony sections | 0.050 |
| 7. Sluggish river reaches, rather weedy or with very deep pools | 0.070 |
| 8. Very weedy reaches | 0.100 |

Table E5: Runoff Curve Numbers for Urban Areas, SUDAS Chpt. 2.

| Cover Type and Hydrologic Condition | Average Percent Impervious Area[2] | CN's for Hydrologic Soil Group | | | |
|---|---|---|---|---|---|
| | | *A* | *B* | *C* | *D* |
| **Fully Developed Urban Areas (vegetation established)** | | | | | |
| Open space (lawns, parks, golf courses, cemeteries, etc.):[3] | | | | | |
| Poor condition (grass cover < 50%) | -------------- | 68 | 79 | 86 | 89 |
| Fair condition (grass cover 50% to 75%) | -------------- | 49 | 69 | 79 | 84 |
| Good condition (grass cover >75%) | -------------- | 39 | 61 | 74 | 80 |
| Impervious areas: | | | | | |
| Paved parking lots, roofs, driveways, etc. (excluding right-of-way) | -------------- | 98 | 98 | 98 | 98 |
| Streets and roads: | | | | | |
| Paved; curbs and storm sewers (excluding right-of-way) | -------------- | 98 | 98 | 98 | 98 |
| Paved; open ditches (including right-of-way) | -------------- | 83 | 89 | 92 | 93 |
| Gravel (including right-of-way) | -------------- | 76 | 85 | 89 | 91 |
| Dirt (including right-of-way) | -------------- | 72 | 82 | 87 | 89 |
| Urban districts: | | | | | |
| Commercial and business | 85 | 89 | 92 | 94 | 95 |
| Industrial | 72 | 81 | 88 | 91 | 93 |
| Residential districts by average lot size: | | | | | |
| 1/8 acre or less (town homes) | 65 | 77 | 85 | 90 | 92 |
| 1/4 acre | 38 | 61 | 75 | 83 | 87 |
| 1/3 acre | 30 | 57 | 72 | 81 | 86 |
| 1/2 acre | 25 | 54 | 70 | 80 | 85 |
| 1 acre | 20 | 51 | 68 | 79 | 84 |
| 2 acres | 12 | 46 | 65 | 77 | 82 |
| **Developing Urban Areas** | | | | | |
| Newly graded areas (pervious areas only, no vegetation)[4] | -------------- | 77 | 86 | 91 | 94 |
| Idle lands (CN's are determined using cover types similar to those in Table 2B-4.01) | | | | | |

Table E6: Runoff Curve Numbers for Cultivated Agricultural Lands, SUDAS Chpt. 2.

| **Cover Description** | | | **CN's for Hydrologic Soil Group** | | | |
|---|---|---|---|---|---|---|
| ***Cover Type*** | ***Treatment[2]*** | ***Hydrologic Condition[3]*** | ***A*** | ***B*** | ***C*** | ***D*** |
| Fallow | Bare Soil | --- | 77 | 86 | 91 | 94 |
| | Crop residue cover (CR) | Poor | 76 | 85 | 90 | 93 |
| | | Good | 74 | 83 | 88 | 90 |
| Row Crops | Straight Row (SR) | Poor | 72 | 81 | 88 | 91 |
| | | Good | 67 | 78 | 85 | 89 |
| | SR + CR | Poor | 71 | 80 | 87 | 90 |
| | | Good | 64 | 75 | 82 | 85 |
| | Contoured (C) | Poor | 70 | 79 | 84 | 88 |
| | | Good | 65 | 75 | 82 | 86 |
| | C + CR | Poor | 69 | 78 | 83 | 87 |
| | | Good | 64 | 74 | 81 | 85 |
| | Contoured & terraced (C&T) | Poor | 66 | 74 | 80 | 82 |
| | | Good | 62 | 71 | 78 | 81 |
| | C&T + CR | Poor | 65 | 73 | 79 | 81 |
| | | Good | 61 | 70 | 77 | 80 |
| Small Grain | Straight Row (SR) | Poor | 65 | 76 | 84 | 88 |
| | | Good | 63 | 75 | 83 | 87 |
| | SR + CR | Poor | 64 | 75 | 83 | 86 |
| | | Good | 60 | 72 | 80 | 84 |
| | Contoured (C) | Poor | 63 | 74 | 82 | 85 |
| | | Good | 61 | 73 | 81 | 84 |
| | C + CR | Poor | 62 | 73 | 81 | 84 |
| | | Good | 60 | 72 | 80 | 83 |
| | Contoured & terraced (C&T) | Poor | 61 | 72 | 79 | 82 |
| | | Good | 59 | 70 | 78 | 81 |
| | C&T + CR | Poor | 60 | 71 | 78 | 81 |
| | | Good | 58 | 69 | 77 | 80 |
| Close Seeded or Broadcast Legumes or Rotation Meadow | SR | Poor | 66 | 77 | 85 | 89 |
| | | Good | 58 | 72 | 81 | 85 |
| | C | Poor | 64 | 75 | 83 | 85 |
| | | Good | 55 | 69 | 78 | 83 |
| | C&T | Poor | 63 | 73 | 80 | 83 |
| | | Good | 51 | 67 | 76 | 80 |

Table E7: Coefficients for SCS Peak Discharge Method, SUDAS Chpt. 2.

| $I_a/P$ | $C_0$ | $C_1$ | $C_2$ |
|---|---|---|---|
| 0.10 | 2.55323 | -0.61512 | -0.16403 |
| 0.30 | 2.46532 | -0.62257 | -0.11657 |
| 0.35 | 2.41896 | -0.61594 | -0.08820 |
| 0.40 | 2.36409 | -0.59857 | -0.05621 |
| 0.45 | 2.29238 | -0.57005 | -0.02281 |
| 0.50 | 2.20282 | -0.51599 | -0.01259 |

Table E8: Adjustment Factor for Pond and Swamp Areas that are Spread Throughout the Watershed, SUDAS Chpt. 2.

| Percentage of pond and swamp area | $F_p$ |
|---|---|
| 0 | 1.00 |
| 0.2 | 0.97 |
| 1.0 | 0.87 |
| 3.0 | 0.75 |
| 5.0 | 0.72 |

4. **Culverts:** Culverts should have capacity to convey the following.
   a. 10 year storm without the headwater depth exceeding the diameter of the culvert.
   b. 50 year storm without the headwater depth exceeding 1 foot over the top of the culvert.
   c. 100 year storms should be conveyed through the culvert without the headwater depth exceeding 1 foot below the low point of the roadway/embankment, unless there are other, more restrictive elevations.
   d. For culverts that drain areas over 2 square miles, the Iowa DNR rules and regulations will apply.

Figure E2: Culvert Design Capacity recommended by SUDAS Chpt. 2.

Table E9: Manning Coefficients for Common Strom Sewer Material, SUDAS Chpt. 2.

| Type of Pipe | Manning's n |
|---|---|
| Concrete pipe | 0.013 |
| PVC pipe (smooth wall) | 0.010 |
| HDPE or Polypropylene (corrugated exterior, smooth interior - dual or triple wall) | 0.012 |
| HDPE or Polypropylene (corrugated exterior and interior - single wall) | 0.020 |
| CMP (2-2/3" x 1/2" corrugations) | 0.024 |
| CMP (3" x 1" corrugations) | 0.027 |
| CMP (5"x1" corrugations) | 0.025 |
| Structural Plate | 0.032 |

Table E10: Inlet Coefficients for Box Culverts, SUDAS Chpt. 2.

| Box, Reinforced Concrete | |
|---|---|
| Headwall parallel to embankment (no wingwalls): | |
| Square-edged on three edges | 0.5 |
| Rounded on three edges to radius of 1/12 depth or beveled edges on three sides | 0.2 |
| Wingwalls at 30º to 75º to barrel: | |
| Square-edged at crown | 0.4 |
| Crown edge rounded to radius of 1/12 depth or beveled top edge | 0.2 |
| Wingwalls at 10º or 25º to barrel: | |
| Square-edged at crown | 0.5 |
| Wingwalls parallel (extension of sides) | |
| Square-edged at crown | 0.7 |
| Side- or slope-tapered inlet | 0.2 |

**Appendix F – Stormwater Management Basin Design**

$$\left(\frac{Vs}{Vr}\right) = 0.683 - 1.43\left(\frac{qo}{qi}\right) + 1.64\left(\frac{qo}{qi}\right)^2 - 0.804\left(\frac{qo}{qi}\right)^3$$

Figure F1: Storage Volume/Runoff Volume Relationship, Based on Outflow/Inflow Ratio, Iowa Storm Water Management Manual

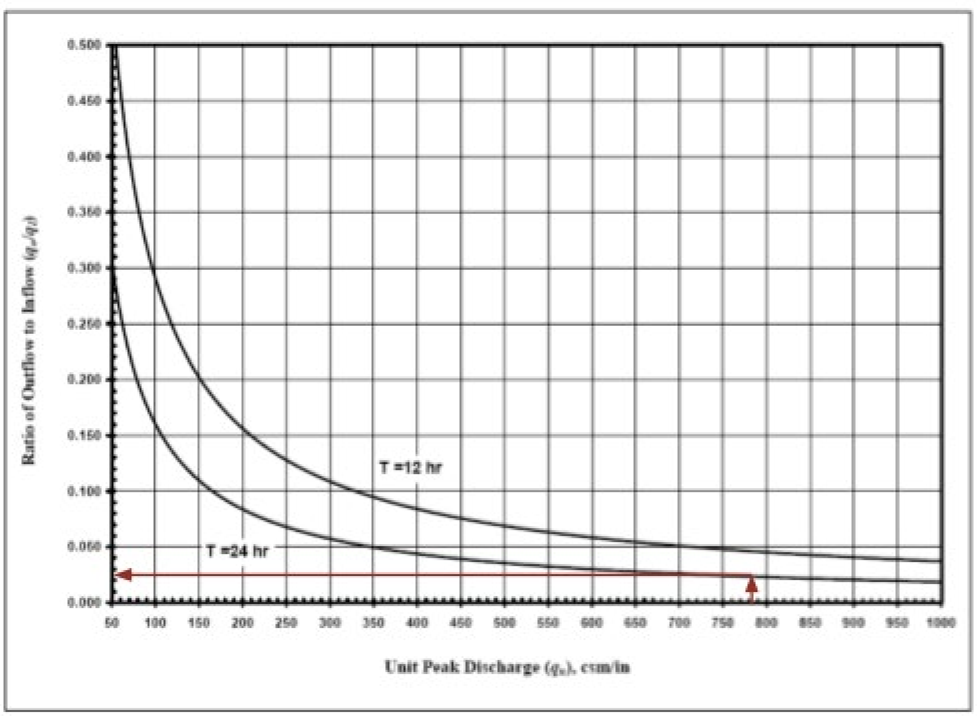



Figure F4: Unit peak Discharge to Inflow Outflow Ratior, Iowa Storm Water Management Manual

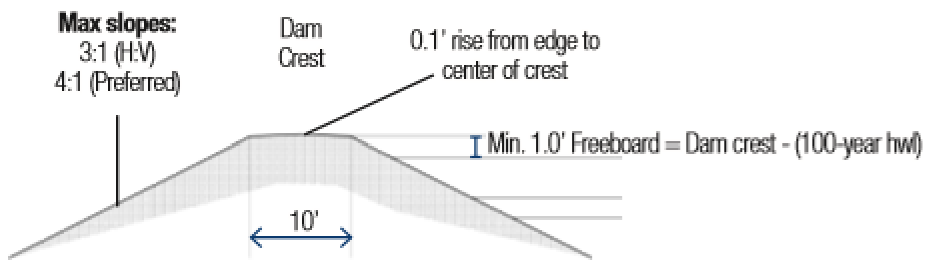



Figure F5: Dam Crest Parameter, Iowa Storm Water Management Manual


Figure F6: Spillway Parameter, Iowa Storm Water Management Manual

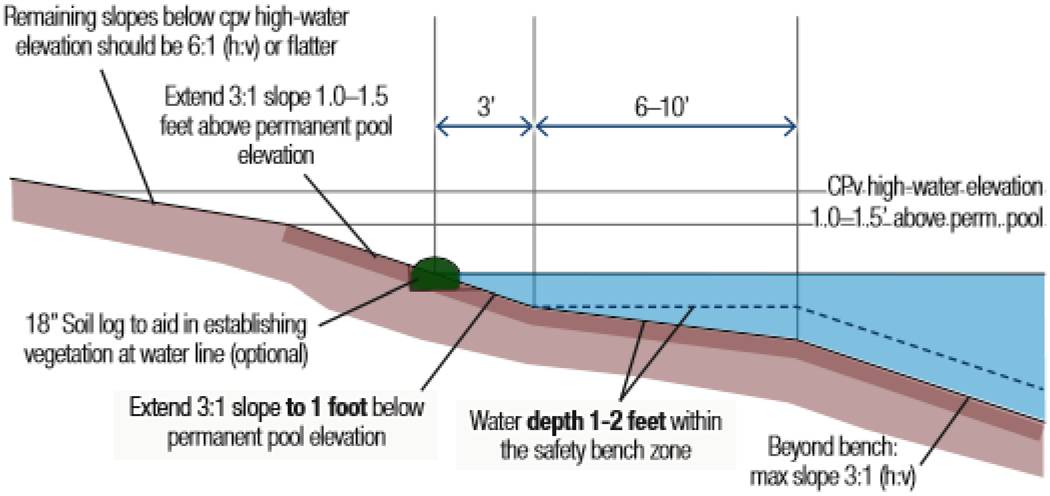



Figure F7: Wide Bench Cross Section, Iowa Storm Water Management Manual

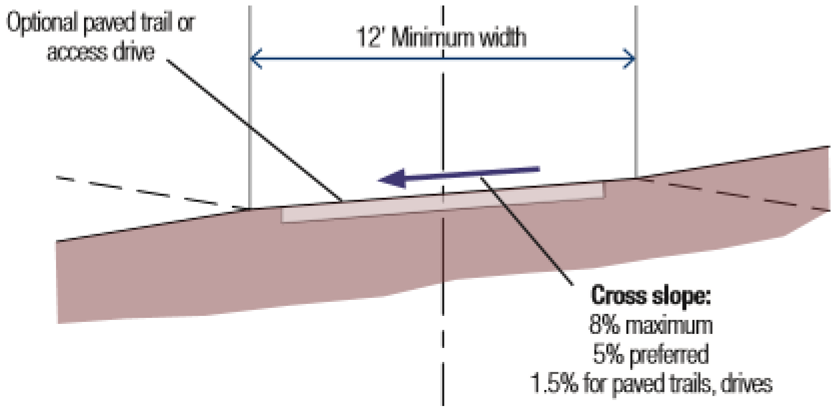



Figure F8: Maintenance Cross Section, Iowa Storm Water Management Manual

**Appendix G – Subdivision's Infrastructure Design**

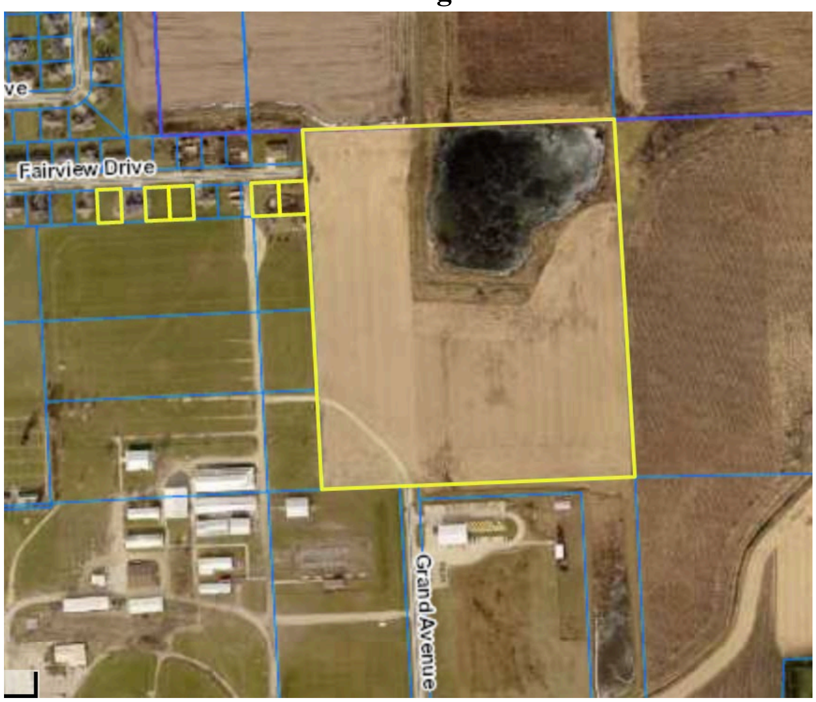



Figure G1: Property limits for subdivision design.

Table G1: Rating for sedimentation and erosion control measures, SUDAS Ch. 7, Section E.

| Section | Control Measure | Benefits | | | | |
|---|---|---|---|---|---|---|
| | | Flow Control (Velocity) | Erosion Control (Stabilization) | Sediment Control (Removal) | Runoff Reduction (Volume) | Flow Diversion |
| *Vegetative and Soil Stabilization Erosion Control Measures* | | | | | | |
| 7E-2 | Compost Blanket | M | M | L | M | |
| 7E-5 | Temporary Rolled Erosion Control Products | L | H | | | |
| 7E-16 | Dust Control | | M | | | |
| 7E-17 | Erosion Control Mulching | L | M | L | L | |
| 7E-18 | Turf Reinforcement Mats | L | H | | | |
| 7E-19 | Surface Roughening | L | L | | L | |
| 7E-22 | Temporary Erosion Control Seeding | M | H | M | L | |
| 7E-23 | Grass Channel | L | H | L | L | |
| 7E-24 | Permanent Seeding | M | H | M | M | |
| 7E-25 | Sodding | M | H | M | M | |
| 7E-26 | Vegetative Filter Strip | L | L | M | L | |
| *Structural Erosion Control Measures* | | | | | | |
| 7E-7 | Check Dams | H | | L | | |
| 7E-8 | Temporary Earth Diversion Structures | | | | | H |
| 7E-9 | Level Spreaders | H | | | | M |
| 7E-10 | Rip Rap | H | H | | | |
| 7E-11 | Temporary Pipe Slope Drains | | | | | H |
| 7E-21 | Flow Transition Mats | L | H | | | |
| 7E-27 | Rock Chutes and Flumes | M | H | | | |
| *Sediment Control Measures* | | | | | | |
| 7E-3 | Filter Berms | L | | L | | L |
| 7E-4 | Filter Socks | L | | L | | L |
| 7E-6 | Wattles | L | | L | | |
| 7E-12 | Sediment Basin | H | | H | L | |
| 7E-13 | Sediment Traps | H | | H | L | |
| 7E-14 | Silt Fences | L | | M | | M |
| 7E-15 | Stabilized Construction Entrance | | | L | | |
| 7E-20 | Inlet Protection | | | L | | |
| 7E-28 | Flocculents | | | H | | |
| 7E-29 | Flotation Silt Curtain | | | M | | |

Table G2: Manchester lot sizing for single-family residential development.

**6.2 Site Development Regulations**

| Regulator | 1-Family Detached | | | | Other Permitted Non-Residential Uses |
|---|---|---|---|---|---|
| | R1-80 | R1-70 | R1-60 | R1-50 | |
| **Site Area per Housing Unit** | N/A | N/A | N/A | N/A | |
| **Minimum Lot Area (square feet)** | 9,000 | 7,500 | 7,000 | 5,000 | 15,000 |
| **Minimum Lot Width (feet)** | 80 | 70 | 60 | 50 | 100 |
| **Minimum Yards (feet)** | | | | | |
| Front Yard | 25 | 25 | 25 | 25 | 30 |
| Side Yard (Note 1) | 6.5 | 6.5 | 6.5 | 5 | 10 |
| Street Side Yard, Corner Lot (Note 2) | 15 | 15 | 15 | 15 | |
| Rear Yard | 30 | 30 | 30 | 30 | |
| **Maximum Height (feet)** (Note 3) | 35 | 35 | 35 | 35 | 35 |
| **Maximum Amount of Total Parking Located in Street Yard** | 0 | 0 | 0 | 0 | 0 |

Table G3: Allowable pavement encroachment and depth of flow for minor storm event.

**Table 2A-3.01:** Allowable Pavement Encroachment and Depth of Flow for Minor Storm Runoff

| Street Classification | Maximum Encroachment[1] |
|---|---|
| Local | No curb overtopping. Flow may spread to crown of street. |
| Collector/Minor Arterial | No curb overtopping. Flow spread must not encroach to within 8 feet of the centerline of a two-lane street. The flow spread for more than two-lane streets must leave the equivalent of two 12 foot driving lanes clear of water; one lane in each direction. For one-way streets, a single 12 foot lane is allowed. |
| Major Arterials (4 lanes or greater) | No curb overtopping. Flow spread must not exceed 10 feet from the face of the curb of the outside lane. The flow spread for streets with more than two-lanes must leave the equivalent of two 12 foot driving lanes clear of water; one lane in each direction. For one-way streets, two 12 foot lanes are required. For special conditions, when an intake is necessary in a raised median, the flow spread should not exceed 4 feet from the face of the median curb for an inside lane. |

Table G4: Allowable pavement encroachment for major storm event.

**Table 2A-3.02:** Allowable Pavement Encroachment and Depth of Flow for Major (100 Year) Storm Runoff

| Street Classification | Allowable Depth and Ponded Area |
|---|---|
| Local and Collector | The ponded area should not exceed the street right-of-way and the depth of water above the street crown should not exceed 6 inches. There may be situations where other restrictions are necessary. |
| Major and Minor Arterial | A 12 foot lane is the minimum travel lane to be passable in the center of the street. |

**Table 2A-3.03:** Allowable Cross-street Flow

| Street Classification | Initial Design Storm Runoff | 100 Year Design Storm Runoff |
|---|---|---|
| Local | 6 inch depth at crown or in cross-pan | 9 inch depth at crown or in cross-pan |
| Collector | Where cross-pans are allowed, depth of flow or in cross-pan should not exceed 3 inches | 6 inch depth at crown |
| Arterial | None | 3 inch or less over crown |

## Appendix H – Overall Strategy for Manchester Stormwater Concerns

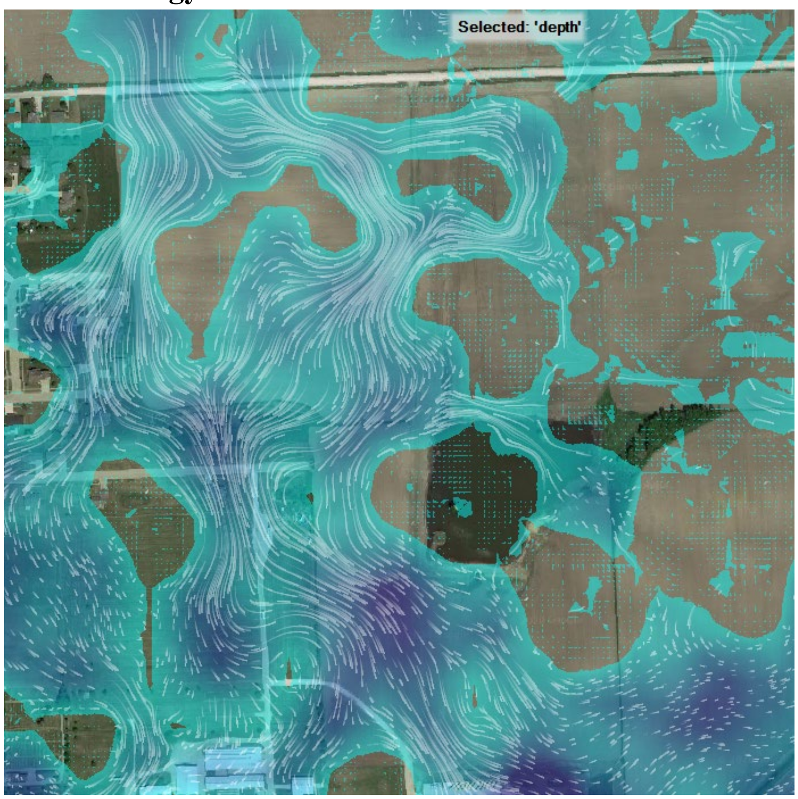



Figure H1: Current flow of water in project area.

**Appendix I – Water Quality**

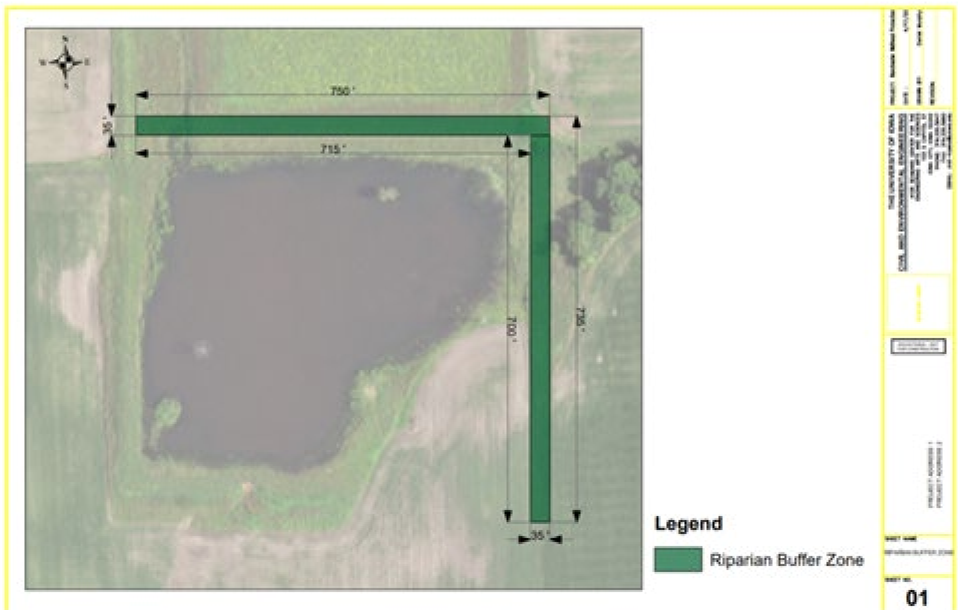



Figure I1: Manchester Wellhead Protection riparian buffer zone design.

Figure I2: Contour buffer strips.

Did you know...

...that chemicals and fertilizers that you apply to your lawn are increasing your *water utility bill*?

Lawn chemicals and fertilizers contain nitrates that pollute your water and make it expensive to clean.

When too much fertilizer is applied, soil can't retain all the nitrate. The excess nitrate will runoff and seep into the ground. The City of Manchester gets its drinking water from an aquifer in the ground, directly below neighborhoods in Manchester.

Nitrate prevalence in our water has been continuing to rise causing water utility bills to increase. Small changes in how you care for you lawn can make a difference in your utility cost and decrease nitrate levels to keep water safe for *everyone*.

Lawn chemicals and fertilizers, when they are used properly, they are a great tool for making your lawn look great. Testing your lawn for what type of care and fertilizers it needs is a first great step. Slow release fertilizers, compost, and aeration are also effective ways to keep your lawn healthy. Small changes in lawncare can substantially improve your lawn and your water utility bill. There are many online resources to facilitate in caring for your lawn. Here are a few:

**Lawncare Resources**

https://www.iowadnr.gov/About-DNR/DNR-News-Releases/ArticleID/168/Greening-Up-Your-Yard-What-You-Can-Do

https://www.iowaagriculture.gov/FieldServices/pdf/SoilQualityBrochure.pdf

https://www.extension.purdue.edu/extmedia/HO/HO-236-W.pdf

Figure I3: Urban Nitrate Strategy brochure.

## Appendix J – Breakdown Cost of Each Design Element

Table J1: Roadway extension construction cost. Cost estimates from Iowa DOT bid tab contracts.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | EXCAVATION, CLASS 10, WASTE | 5,676.44 | CY | $3 | $17,029.32 |
| 2 | SPECIAL BACKFILL | 1,226.24 | CY | $15 | $18,393.60 |
| 2 | MODIFIED SUBBASE | 4,725.71 | CY | $27 | $127,594.17 |
| 3 | STANDARD OR SLIP FORM PORTLAND CEMENT CONCRETE PAVEMENT, CLASS C, CLASS 3 DURABILITY, 7 IN. | 3712 | SY | $60 | $222,720.00 |
| 4 | STANDARD OR SLIP FORM PORTLAND CEMENT CONCRETE PAVEMENT, CLASS C, CLASS 3 DURABILITY, 8 IN. | 8882.9 | SY | $79 | $701,749.10 |
| 5 | CURB AND GUTTER, P.C. CONCRETE, 2.0 FT. | 3778.47 | LF | $40 | $151,138.80 |
| 6 | SEEDING AND FERTILIZING (URBAN) | 12.76078099 | ACRE | $2,275 | $29,030.78 |
| | | | | **TOTAL:** | **$1,267,655.77** |

Table J2: Stormwater Sewer construction cost. Cost estimates from Iowa DOT bid tab contracts.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | STORM SEWER GRAVITY MAIN, TRENCHED, REINFORCED CONCRETE PIPE (RCP), 2000D (CLASS III), 15 IN. | 2277.1 | LF | $34 | $77,421 |
| 2 | STORM SEWER GRAVITY MAIN, TRENCHED, REINFORCED CONCRETE PIPE (RCP), 2000D (CLASS III), 18 IN. | 813.24 | LF | $40 | $32,530 |
| 3 | STORM SEWER GRAVITY MAIN, TRENCHED, REINFORCED CONCRETE PIPE (RCP), 2000D (CLASS III), 24 IN. | 125.21 | LF | $49 | $6,135 |
| 4 | INTAKE, SW-501 | 32 | EACH | $3,300 | $105,600 |
| 5 | MANHOLE, STORM SEWER, SW-402 6 FT. X 6 FT. | 4 | EACH | 3,650 | $14,600 |
| | | | | **TOTAL:** | **$236,286** |

Table J3: Water main construction cost. Cost estimates from Iowa DNR.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | 8" PVC MAIN | 2638.6 | LF | $39.00 | $102,905.40 |
| 2 | 6" PVC MAIN | 1306.41 | LF | $29.25 | $38,212.49 |
| 3 | TEE FITTING | 19 | EACH | $450.00 | $8,550.00 |
| 4 | VALVE | 43 | EACH | $2,200.00 | $94,600.00 |
| 5 | HYDRANT | 17 | EACH | $2,500.00 | $42,500.00 |
| 7 | CUT EXISTING PIPE ANDCONNECT NEW PVC PIPE | 1 | LS | $7,500.00 | $7,500.00 |
| 8 | TRACER WIRE | 3945.01 | LF | $0.20 | $789.00 |
| | | | | **TOTAL:** | **$295,056.89** |

Table J4: Preliminary sanitary sewer construction cost. Cost estimates from the Iowa DNR.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | 48-INCH MANHOLE | 12 | EACH | $3,500 | $42,000 |
| 2 | 12-INCH PVC GRAVITY MAIN | 3837.89 | LF | $72.00 | $276,328 |
| | | | | **TOTAL:** | **$318,328** |

Table J5: Channel and culvert system construction cost. Cost estimates from Iowa DOT bid tab contracts.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | EXCAVATION, CLASS 10, WASTE | 9,081.00 | CY | $3 | $27,243 |
| 2 | REMOVAL OF SILT FENCE | 1322 | LF | $0.25 | $331 |
| 3 | MAINTENANCE OF SILT FENCE | 132 | LF | $0.25 | $33 |
| 4 | SILT FENCE | 1322 | LF | $2.00 | $2,644 |
| 5 | SEEDING AND FERTILIZING (URBAN) | 2.4 | ACRE | $2,275 | $5,460 |
| 7 | PRECAST CONCRETE BOX CULVERT, 2 FT. X 3 FT | 108 | LF | $323 | $34,884 |
| | PRECAST CONCRETE BOX CULVERT, 2 FT. X 6 FT | 54 | LF | $450 | $24,300 |
| 8 | PRECAST CONCRETE BOX CULVERT, 8 FT. X 5 FT | 54 | LF | $700 | $37,800 |
| | | | | **TOTAL:** | **$132,695** |

Table J6: Stormwater management basin construction cost. Cost estimates from Iowa DOT bid tab contracts.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | EXCAVATION, CLASS 10, WASTE | 26642 | CY | $3 | $79,926 |
| 2 | INTAKE, SW-512, 24 IN | 1 | EACH | 3000 | $3,000 |
| 3 | SEEDING AND FERTILIZING (URBAN) | 1.05 | ACRE | $2,275 | $2,389 |
| 4 | REMOVAL OF SILT FENCE | 456 | LF | $0.25 | $114 |
| 5 | MAINTENANCE OF SILT FENCE | 45 | LF | $0.25 | $11 |
| 6 | SILT FENCE | 456 | LF | $2 | $912 |
| 7 | STORMSEWER GRAVITY MAIN, REINFORCEDCONCRET E PIPE, 12 IN. | 990 | LF | 80 | $79,200 |
| | | | | **TOTAL:** | **$165,552** |

Table J7: Subdivision's infrastructure construction cost. Cost estimates from the Iowa DOT bid tabs and Iowa DNR.

| No. | Item | Quantity | Unit | Unit Price | Amount |
|---|---|---|---|---|---|
| 1 | EXCAVATION, CLASS 10, WASTE | 712.96 | CY | $3 | $2,138.88 |
| 2 | SPECIAL BACKFILL | 570.37 | CY | $15 | $8,555.55 |
| 3 | MODIFIED SUBBASE | 600.00 | CY | $27 | $16,200.00 |
| 4 | STANDARD OR SLIP FORM PORTLAND CEMENT CONCRETE PAVEMENT, CLASS C, CLASS 3 DURABILITY, 7 IN. | 6600 | SY | $60 | $396,000.00 |
| 5 | CURB AND GUTTER, P.C. CONCRETE, 2.0 FT. | 2114.16 | LF | $40 | $84,566.40 |
| 6 | STORM SEWER GRAVITY MAIN, TRENCHED, REINFORCED CONCRETE PIPE (RCP),2000D (CLASS III), 24 IN. | 620 | LF | $49 | $30,380 |
| 7 | 44x6x44 CONCRETE RECTANGULARFRAME HEADWALL | 2 | EACH | $3,650 | $7,300 |
| 8 | INTAKE, SW-501 | 4 | EACH | $3,300 | $13,200 |
| 9 | 6" PVC MAIN | 900 | LF | $29.25 | $26,325.00 |
| 10 | TEE FITTING | 4 | EACH | $450.00 | $1,800.00 |
| 11 | VALVE | 2 | EACH | $2,200.00 | $4,400.00 |
| 12 | HYDRANT | 4 | EACH | $2,500.00 | $10,000.00 |
| 13 | TRACER WIRE | 900 | LF | $0.20 | $180.00 |
| 14 | 48 INCH MANHOLE | 4 | EACH | $3,500.00 | $14,000.00 |
| 15 | 12" PVC PIPE | 709 | LF | $72.00 | $51,048.00 |
| 16 | SEEDING AND FERTILIZING (URBAN) | 4.67 | ACRE | $2,275 | $10,624.25 |
| | | | | **TOTAL:** | **$676,718.08** |

**Appendix K – References**

Iowa Sudas, 2020, https://iowasudas.org/manuals/design-manual/

Manchester City Code of Ordinances, Feb. 27, 2017, https://codelibrary.amlegal.com/codes/manchesteria/latest/manchester_ia/0-0-0-13439

USGS Web Soil Survey, Retrieved March 2020, https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx