THE UNIVERSITY OF IOWA
IOWA INITIATIVE
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FINAL DELIVERABLE

Title	Manchester Water Source Protection Plan
Completed By	Daniel Murphy, Jade Flansburg, and John Quin
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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.

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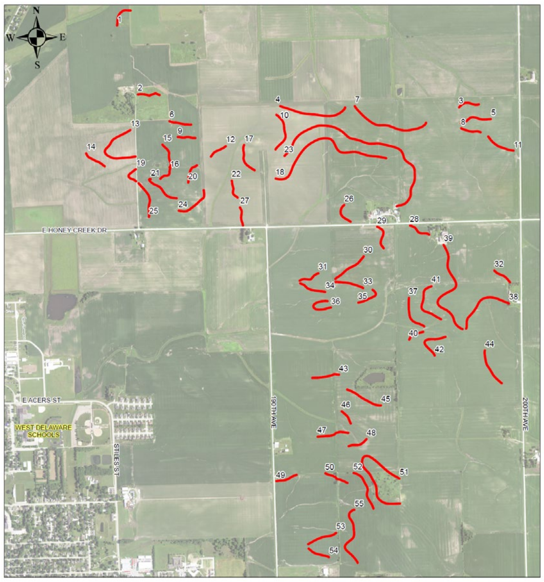

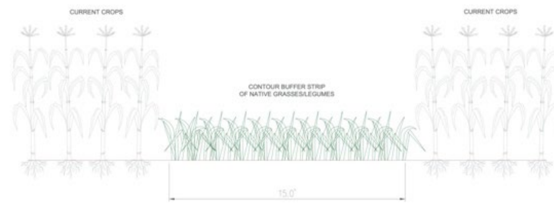

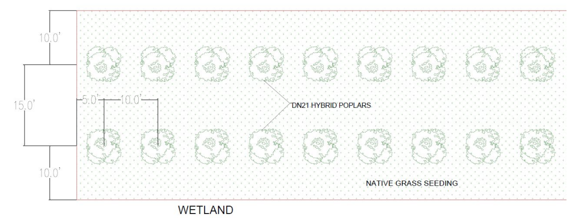

Water Source Protection Plan

City of Manchester
May 8, 2020

Trident Environmental Solutions

Civil and Environmental Engineering
College of Engineering
The University of Iowa

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Section I – Executive Summary

The purpose of this report is to give a comprehensive plan for water source protection in and around the City of Manchester. Manchester currently sources its drinking water from a well system that draws from the Silurian aquifer. The groundwater in recent years has had increasing levels of nitrates, surpassing the U.S. Environmental Protection Agency maximum contaminant level of 10 mg/L. An ion exchange system has been put into place to treat to groundwater, but, because of the increase in nitrate concentration, maintenance of the system has become increasingly expensive for the city. To limit further increase of nitrate concentration in the groundwater system, Trident Environmental Solutions has created a plan to cover various sources of nitrate pollution. This report contains various alternatives to reduce nitrates in the groundwater. Three alternatives were selected and designed so that they may be established within the recharge zone of Manchester's wells. These recommended alternatives are contour buffer strips, riparian buffer zone, and urban nitrates education.

Contour buffer strips were designed using the Agricultural Conservation Planning Framework (ACPF) tool created by the U.S. Department of Agriculture. With data provided from the Iowa Department of Natural Resources (IDNR), effective location and size of the strips to retain and treat nitrate runoff were found. A total of 55 strip locations with widths of a minimum of 15 feet were mapped out and designed. Grasses and legumes recommended for this design include Ladino clover with Timothy for poor drainage areas and Alfalfa with orchard grass for dry areas. It is recommended that grasses and legumes be planted with 50 stems for every square foot. This design requires minimal upkeep with recommended burning or mowing every three years. Shown below is an example of what the contour strips would look like in Figure 1.1.

Figure 1.1. Example of an aerial view of contour buffer strips (NRCS)

An estimated cost of $13,160.00 was found for the contour buffer strip implementation. This estimate does not include the foregone income for the farmers. A ten-year estimate for the foregone income of farmers is $82,250. This could change depending on potential grants given by the NRCS for buffer strips. Once established, these strips have potential to remove 50 percent or more of nutrient runoff. They could also help with crop yield because of their erosion capabilities.

A riparian buffer zone was designed at an existing wetland to enhance nitrate removal and retain excess water during storm events. The riparian buffer zone will consist of a mix of hybrid poplar and Iowa willow trees purchased as 8 to 9-foot poles. These will be planted in a shallow triangular swale surrounding the north and east side of an existing wetland on the east side of Manchester. The swale will consist of porous pea gravel at the bottom and be topped with existing soil. Native grasses such as switchgrass are recommended to be planted to accompany the poplar trees. Native wildflowers or other terrestrial plants could be used for wildlife habitat and aesthetics. An example profile schematic of a riparian buffer zone working in conjunction with a wetland from a study on riparian zones and wetlands is displayed below in Figure 1.2.

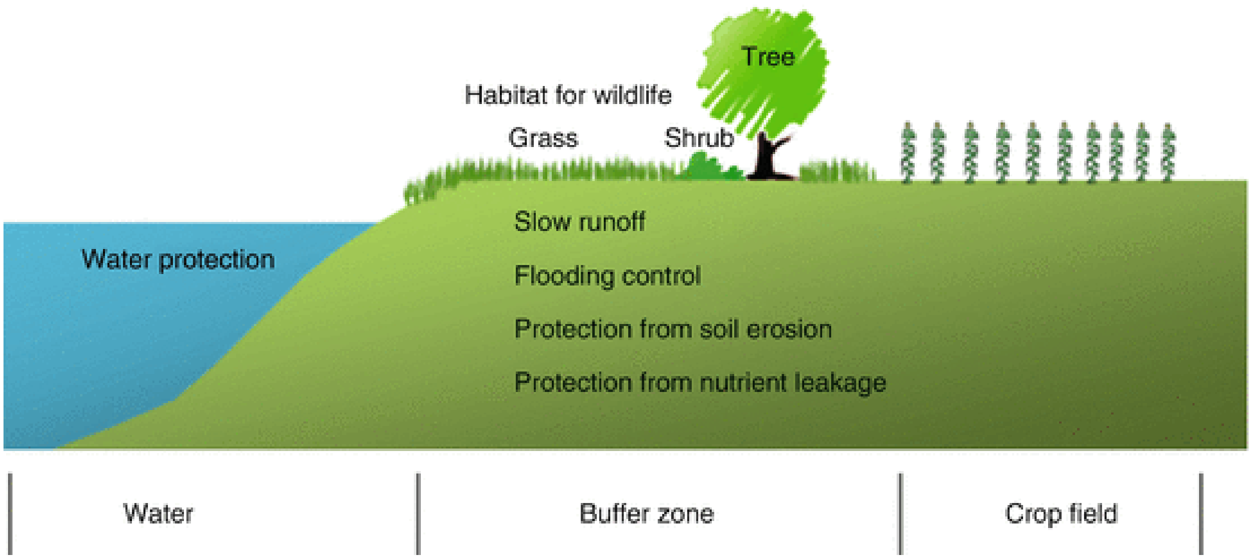

Figure 1.2. Profile view and benefits of riparian buffer zone in conjunction with a wetland (Ma M., 2016)

The aerial footprint for this design is approximately 1.2 acres and has an estimated cost of $303,475.50. This design would require little maintenance once implemented. Once established, the riparian buffer zone could have an 83 percent nitrate removal efficiency.

A brochure for urban education was designed to remediate excess fertilizer techniques in lawncare practices so that less nitrate pollution comes from urban origins. This brochure was created to be easy to understand and short so that main points are conveyed clearly. The goal of the brochure is to make citizens aware that lawn chemicals and fertilizers are polluting the groundwater and making their water utility bill more expensive. If these brochures are created by a graphic designer and are printed and mailed to all homes in Manchester, the estimated cost would be $2,560. This recommendation could cost less if posted on the City of Manchester's website or sent in an electronic newsletter. Effectiveness cannot be measured precisely with this recommendation, but this would be a great start for public education in the City of Manchester.

The total cost for the water source protection plan would be $414,954.15. If implemented, these techniques have potential to remove a significant amount of nitrate from the groundwater and retain excess water during flood events. This plan would be a beneficial investment for the City of Manchester's water to stay under the MCL for nitrate without spending more on ion exchange and maintenance in the well systems.

Section II – Organization Qualification and Experience

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Trident Environmental Solutions, a senior design group at the University of Iowa, is pleased to present the following report to the City of Manchester to improve their groundwater quality. The following paragraphs highlight upon the qualifications of each team member.

Trident Environmental Solutions left to right: Daniel Murphy, Jade Flansburg, and John Quin

Daniel Murphy is the project manager for the design group and studied Civil and Environmental Engineering, along with a GIS minor. Daniel has experience through internships on both the private and public side of engineering. Through those internships, he has documented many types projects in the field through routine inspections, worked with GIS in many different applications, and has researched and began permitting for water-related projects. Along with internship experience, Daniel's coursework includes Environmental Engineering Design, Environmental Chemistry, Hydrology, GIS for Environmental Studies, and many more related courses. He also has been a TA for the courses of Environmental Engineering Design and Sustainable Systems. These past experiences and degree coursework have given Daniel important insight into this design project, especially in dealing with the groundwater quality of Manchester.

Jade Flansburg studies Environmental Engineering. Jade has had experience in working with GIS and researching properties from prior internships. Additionally, in her internship experience, she has done field work with inspections of concrete. She has had multiple classes designing water treatment systems as well as modeling groundwater flow. Jade has completed coursework in Environmental Design, Water Treatment, and Environmental Chemistry where she has explored ways to analyze and treat drinking water. She has also taken Groundwater and Water Design where she has modeled groundwater flow and created design options for water systems. Collectively, her industry and coursework experience has left her well-equipped to analyze groundwater in Manchester and design solutions to remediate the town's groundwater.

John Quin studies Environmental Engineering. John has worked on several projects that required the mapping of watersheds on GIS software and has obtained a basic knowledge in CAD. His education has focused mainly on water resources with training in the treatment and distribution of water. John has spent several years doing water quality research in the University of Iowa Environmental Engineering labs, giving him experience in instrumentation and data analysis. John also has direct experience designing ways to treat contamination from the course Environmental Engineering Design. His position as a TA for Fluid Mechanics and the Principals of Hydraulics and Hydrology has honed his communication skills. John has previously worked for the City of Cedar Falls, performing stormwater inspections. These experiences will allow John to bring key insight to the project.

Section III – Design Services

Project Scope

The City of Manchester has levels of nitrates that exceed the maximum contaminant level in their groundwater which they utilize as drinking water. Manchester has found that after rainfall events a spike in the quantity of nitrate in the drinking water supply is seen. This is likely from the excessive fertilization that has seeped nitrogen into the groundwater system. To deal with this Manchester has been treating a portion of the water with ion exchange and blending that with the contaminated water to bring the quality below the limit set by the Safe Drinking Water Act. This process is expensive and has prompted Manchester to seek other solutions.

The priority of Trident Environmental Solutions is to create a watershed management plan for the prevention of additional nitrates entering the groundwater system. There are several ways to accomplish this and thus multiple alternatives have been proposed as a solution. Alternatives considered include natural system approaches, well house treatment modification, and public education. Trident Environmental Solutions performed research and consulted with experts in the area on Manchester's groundwater system. Research has found that there are multiple groundwater analyzes that have taken place in Manchester. Experts that have been consulted with have been a part of Manchester's groundwater analysis including Mike Gannon of the IGS and research specialist at IIHR and Calvin Wolter, GIS Analyst in hydrologic modeling of the IDNR. With their advice, along with the City of Manchester's input, three alternatives were selected and designed. Alternatives selected are a wetland enhancement with a riparian zone, contour buffer strips, and urban education on nitrates. Wetland enhancement with riparian buffer strips were designed using resources from the EPA and Dr. Lou Licht of Ecolotree. Contour buffer strips were sized and located for most effective remediation using the Agricultural Conservation Planning Framework (ACPF) tool. This tool utilized geospatial data from Manchester and gave the best set up to retain nutrients in crop soil. Remediating nitrates from seeping into the groundwater from urban areas were explored and researched from other cities who have educational tools put into place. Plan sets for the riparian buffer strips and a map for best locations for buffer strips in the cropland were created. An educational brochure was put together for citizen use to learn more about the importance of less fertilizer usage in lawncare.

Work Plan

Major tasks completed are shown below in the following Gantt chart. This chart is organized by the dates that each major task was started and completed and who completed them. Major tasks are their description are shown in the following table.

Table 3.1. Tasks and description for final project work plan

Task	Description
1	RFP Writing and Presentation (group)
2	Groundwater Analysis and Research (group)
3	Selection of Designs (group)
4	Analysis of Riparian Strips and Buffer Strip Design (Jack)
5	Research and Writing Urban Nitrate Education (Jade)
6	Drawings and Maps of Riparian and Buffer Strip Design (Daniel)
7	Final Report Draft (group)
8	Presentation Practice (group)
9	Final Report Edit (group)
10	Final Presentation

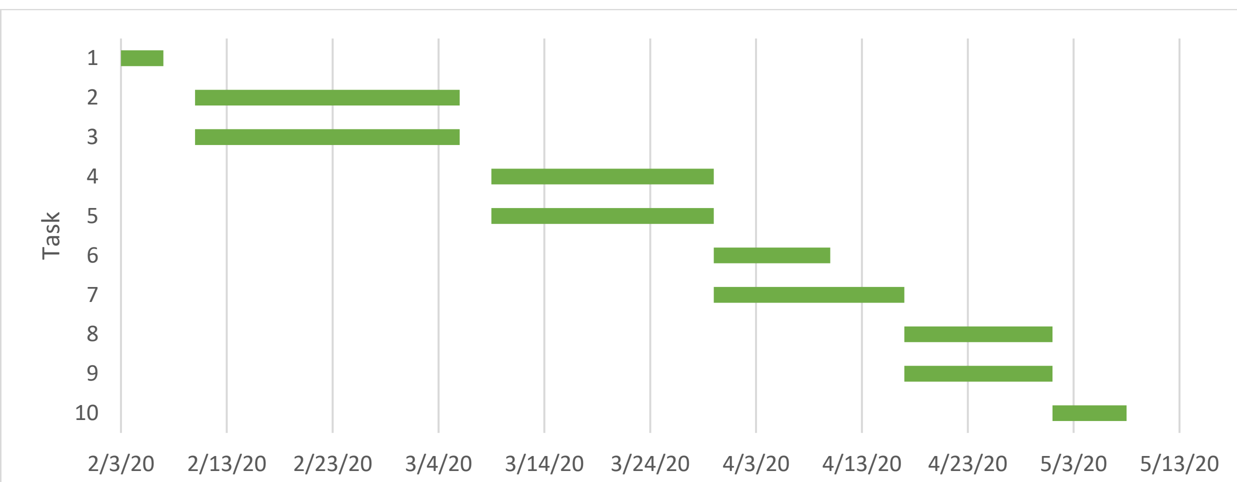


Figure 3.1. Gantt chart for work plan

Section IV – Constraints, Challenges and Impacts

Constraints

Initially, it was thought that a viable solution to the nitrate contamination may be to alter and upgrade the treatment process at the Manchester water treatment plants. When suggested to the clients, it was made clear that the city was not interested in this type of solution. The city of Manchester already uses an ion exchange process that is expensive. Our client wanted us to focus on reducing the nitrate contamination in groundwater before it reaches the municipal wells. This constraint narrowed our design alternatives.

The client expressed to our design group that it was important to them that the final design be something that the city did not need to invest a serious amount of time and resources into maintaining. The city didn't want to have to continuously pay for parts or our design to be repaired or cleaned. It was also crucial that our design could be built or operated without the presence of our design group and trained environmental engineers.

Cost of the project was also an important constraint on our decision-making process. We were informed upon our first meeting with the client that our design would only be constructed if they were to receive funding through a grant.

With these constraints in mind we determined that our design must work with the natural landscape. Treating nitrates from the ground water before they were taken up by the well would mean that our design would have to be constructed outside and to have a significant impact it must intercept a large area. We also came to the conclusion that the best way to reduce the resources and time used in maintaining a design would be to make it self-sufficient. This would mean designing a solution that utilized the natural biological cycles of the landscape, especially the existing wetland. Essentially to construct an ecosystem that can treat nitrate regulate itself. This idea also happens to be much more cost effective than most mechanical designs. Also, designing a solution that involves creating habitats for biodiversity gives the city more potential to utilize grant opportunities.

Challenges

This design project is unique due to two different design groups working on a project in the same vicinity. Since the design of the wetland is directly related to the other design group's road and stormwater design, clear and effective communication was vital to an adequate design. If design changes were not effectively communicated, it would pose problems in the adequacy of our final wetland design. A major challenge of this project was to determine how the other groups design may influence ours. Also, determining which design group was responsible for specific tasks was initially confusing.

Other than communication challenges between our and the other design group, certain characteristics of the land also posed an issue in diverting stormwater. The area surrounding the wetland area is extremely flat; this made it difficult in effectively diverting any stormwater runoff into the wetland and determining new locations for a wetland. If the water does not make it to the wetland Nitrate will be filtered, the aquifer will be recharged with polluted water.

Another challenge was balancing our solution make it appear more attractive to farmers, a major constituent of the city of Manchester. It is no secret that the vast majority of the nitrate is produced by fertilizer used on farms, however no solution we design will be implemented without the support of the farmers. They are the ones that own the land in which our design would ultimately be constructed and are a powerful voice in the community. We determined to include steps that urban residents could take into our final design so as not to push the entire burden of relieving the city's nitrate contamination onto the farming community.

An unforeseen challenge that we contended with was the Coronavirus. Our design group was forced to communicate virtually. This had the effect of completely reworking our schedules and made more difficult to get a hold of experts whose opinions we were seeking. The Coronavirus also prevented our group from conducting an onsite analysis of groundwater flow. Instead, we had to rely on the city engineers at Manchester to provide us with this data.

Societal Impact

An important focus of this design project is to positively affect the residents of Manchester. Through natural Nitrate removal through a wetland design, local water costs will decrease due to less intensive treatment of well water by the city. Also, driving down Nitrate concentration in wells will help the city further meet EPA NPDES requirements if future maximum containment levels are more stringent. Along with water cost and quality improvement, revamping this wetland will provide an aesthetically pleasing area and opportunity for recreation development.

More important than saving money and having a nice aesthetic, reducing the amount of nitrate the people of Manchester are drinking will improve their public health. Drinking water with high levels of nitrate can cause a fatal disease known as Methemoglobinemia. According to the Minnesota department of health Methemoglobinemia reduces the ability of red blood cells to carry oxygen and can cause the afflicted to suffocate. Infants are especially susceptible to Methemoglobinemia ("Nitrate and Methemoglobinemia").

Section V – Alternative Solutions Considered

Various design alternatives have been generated to facilitate the nitrate removal of Manchester's groundwater. Research and consultation with industry experts was performed to ensure a comprehensive list of all possible solutions. Design alternatives are categorized in this section by a natural systems approach, modification at well houses to remove or avoid nitrate, and urban nitrate removal. Each alternative contains a brief description along with advantages and disadvantages unique to each. Alternatives were presented to the City of Manchester who selected three alternatives for the final design. Selected alternatives for the final design are at the end of this section along with the determining factors for their selection.

Natural Systems Approaches

Natural systems alternatives would be implemented at the site to remediate nitrate and slow the infiltration of water into the groundwater system. The following alternatives were considered in the natural systems approach.

Wetland Expansion or Implementation

Iowa's natural landscape before being modified for crops contained many wetlands. This approach would bring back a naturally occurring landscape. Expanding the current wetland in Manchester or implementing various cells of wetlands where flooding is an issue would be favorable for storage and treatment of water. This approach would significantly slow the infiltration of water into the groundwater system and require low maintenance. Building upon wetlands would be favorable for working in conjunction with the stormwater design group because it would help with containing access water to avoid flooding during storm events. This design would require a significant footprint which would need to be negotiated with the landowner. Implementing this design would require costs from a landscaping service to build. Operation and maintenance would need to be explored for this alternative, but it is assumed once this alternative is implemented low maintenance would be required.

Building Upon Conservation Reserve Program

Current practice with the cropland is various rows of CRP grasses. This could be expanded upon and implemented on a greater surface area of the cropland. Native grass options would be explored to find the best combination to have a root system that would effectively absorb and slow water infiltration to naturally treat it before entering the groundwater system. Building upon CRP practices would be simple because of its existing implementation. Maintenance would be reliant on the landowner. This option is contingent on how willing the landowner would be to give up more cropland for CRP grasses. A negotiation to rent or buy some of the land could be made to install more CRP grasses. This could be costly and would require installation by a third-party.

Biofuel Production

A portion of cropland could be utilized to grow native, mixed prairie grasses or hemp to be harvested for processing of biofuels. This practice is something currently implemented by the University of Iowa. The University pays annual rent to cropland owners and hires out a third-party contractor to provide agricultural services for planting and harvesting the crop. The landowner essentially has no risk in this process. These grasses are processed into energy pellets for the University's power plant in conjunction with their sustainability goals to be coal-free by 2025. Various organizations would be explored for this alternative to cultivate grasses for biofuels. This is a low cost and maintenance option because of the other parties involved. This alternative would require a large footprint and would need to be negotiated with the landowner. Biofuel production on the cropland is contingent on the interest of the landowner and parties associated with implementing it. This option could be implemented by Manchester on a smaller scale but would require heavy maintenance and operation if performed independently.

Agricultural Conservation Planning Framework (ACPF)— Contour Buffer Strips

The ACPF was established to find the best alternatives and locations for nutrient retention in cropland. This tool was especially useful for this project. Using hydrogeologic data from the cropland, the ACPF tool generated several solutions for nutrient runoff, but had the most success with the placement of buffer strips in the cropland. The tool found areas of vulnerability to runoff and seepage of excess nutrients from the crops. It then located several locations for the best placement of buffer strips. Buffer strips would consist of strips of prairie grass and perennial vegetation that would exist around cropland to help with runoff and nutrient loss. In addition, buffer strips help with any erosion concerns with the cropland. An aerial view of an example of contour buffer strips in shown below in Figure 5.1.

Figure 5.1. Example of an aerial view of contour buffer strips (NRCS)

They would also be beneficial because they could help with flooding because of their capacity to hold water. Buffer strips have the capacity to remove 50 percent or more of nutrients which includes nitrates. ("Buffer Strips"). An issue with contour buffer strips is taking cropland out of production. Buffer strips could be used in application to the Conservation Reserve Program (CRP) where farmers get incentive for taking their cropland out of production for buffer strips. ("Conservation Reserve Program").

STRIPS Program

Another, similar alternative to contour buffer strips is the Science-based Trails of Row crops Integrated with Prairie Strips (STRIPS) program at Iowa State University. Prairie Strips are another promising method of controlling the amount of nitrate that is leaves the farm and enters the ground water. Prairie strips refer to the layering of monoculture farmland with bands of prairie. These prairies are planted with perineal grasses, forbs, legumes and sedges. These prairie plants have deep roots that are able to slow down subsurface flow and absorb nitrate that would otherwise enter the aquifers of wells. Iowa State researchers have spent many years testing and proving the effectiveness of this technique. This effectiveness is displayed in Figure 5.2.

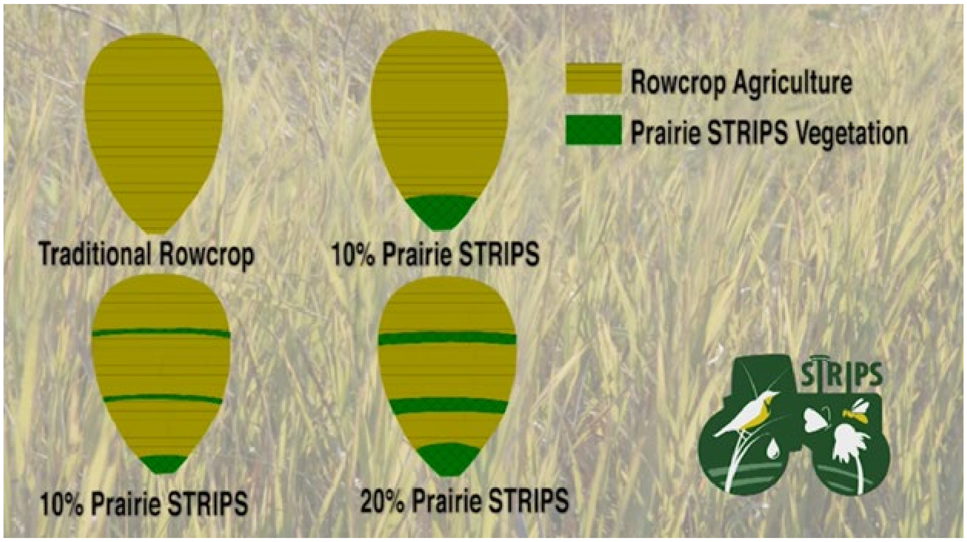


Figure 5.2. Nutrient removal comparison for row crops and with STRIPS vegetation

The STRIPS research team has shown that by converting just ten percent of field into prairie, the nitrogen concentration downstream can be reduced by 85% ("What Are Prairie Strips"). This solution also has several additional benefits along with its ability to treat nitrate. Implementing prairie strips would help farmers prevent loss of topsoil, a pressing issue. Also, this solution would provide an increase in biodiversity in the landscape. Using indigenous Iowan plants and providing habitats to threatened species lends this solution particularly well to grant opportunities. A drawback to this alternative is taking cropland out of production.

Riparian Zone Around Wetland

Wetlands naturally treat and hold on to water and by enhancing this retention of water with riparian buffer strips more natural treatment would occur. The addition of riparian buffer strips surrounding the wetland could be beneficial for further removing nutrient, holding more water to prevent flooding, and having aesthetic appeal. A localized groundwater analysis could be utilized to understand the direction and velocity of groundwater around the wetland on the east side of Manchester. This data would help create an effective design for the riparian strips around the wetland. Landowner, Michael Beck, is willing to work with the City of Manchester which the wetland on his property desirable for enhancement. Wetlands are natural ways to treat water and because of the water being stored there it can be treated further by enhancing the wetland with a riparian zone of water-loving trees. The vegetation would be aesthetically pleasing while retaining more of the groundwater for complete treatment and removal of nutrients. This would be favorable because no land is being taken out of production and there is aesthetic appeal. A profile schematic of a wetland and riparian buffer zone is shown below in Figure 5.3.

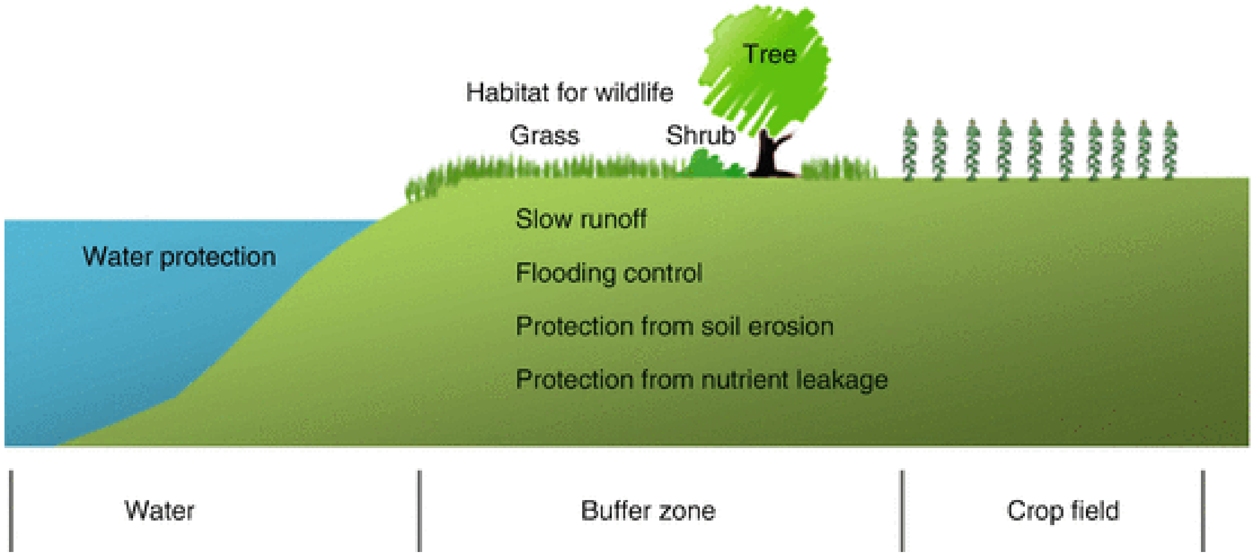


Figure 5.3. Profile view and benefits of riparian buffer zone in conjunction with a wetland (Ma M., 2016)

Once implemented, this alternative would require no intensive upkeep. Drawbacks of this alternative would be the costs for trees themselves and the installation of them. Results may take a few years to be seen as the trees become established.

Drainage Water Management Plan with IWA Hydrologic Network Implementation

After speaking to professor Craig Just at the University of Iowa, our design group was informed of a new strategy being currently being tested in fields around the country. The idea is to install a gate or weir at the end of farm tiles with which the farmer is able to control the water level. Figure 5.4 below displays this strategy.

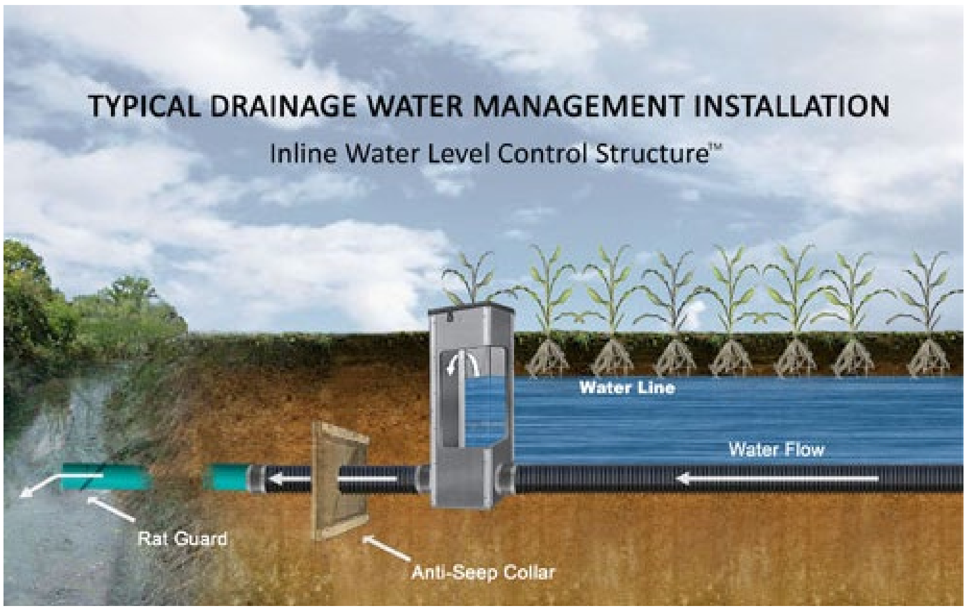


Figure 5.4. Typical drainage water management side profile

During the parts of the year when crops are not growing, farmers could purposely create an anoxic zone by raising the gate to its full extent, significantly reducing the speed at which water leaves their property and raising the water level. This alternative would require the use of a hydrologic monitoring system so that the water level can be accurately predicted and adjusted. The Iowa Flood Center is currently in the process of establishing a hydrologic monitoring system around the state and have yet to place one in the Manchester area. The clients also seemed eager to have monitoring system near them. Also, this alternative would give farmers more control over the amount of water infiltrating the roots of their crops.

Well House Treatment Modifications

Deepen Groundwater Wells

An option to avoid the nitrate in the accessible groundwater is to deepen the wells to access older water that has less nitrate. Once constructed and implemented this option would keep maintenance and operation virtually the same as it is now and require less resin than before to treat the groundwater. This option would require an in-depth analysis of the groundwater and its movement. Analysis would have to conclude with certainty that deepening the wells would significantly avoid nitrates. This alternative could be costly to reconstruct and shut off water supply to Manchester while under construction. More in-depth analysis and reconstruction would take a significant amount of time. Depending on groundwater movement, deepening the wells would delay the nitrate problem to a later date for when the nitrate-rich water continues downwards.

Reverse Osmosis Treatment (RO)

Modifying the water treatment process with RO could be a viable option for treating the groundwater. This would thoroughly treat the groundwater to meet treatment goals. Ion exchange with resin would no longer be necessary in the treatment of the groundwater, which would eliminate the annual costs for resin. RO would be advantageous because of how membranes are compact and stack, leaving a small footprint. Implementation would be significantly costly and require a large amount of inspection and maintenance to avoid fouling the membranes along with a large capital cost. This option would heavily modify the present water treatment system and would require operators to be trained in RO. There may need to be additional step of filtration to avoid scratching the membranes. The addition of a filtration step will require a larger footprint and construction. Other than nitrate contamination, there aren't other issues with the groundwater making this option perhaps more effective than is necessary.

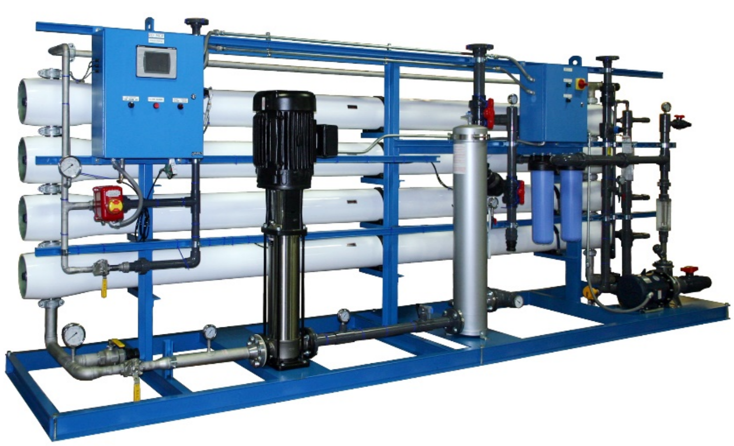


Figure 5.5. Image of the type of reverse osmosis system suggested to be installed as a solution

Urban Nitrate Removal

Public Educational Brochure and Yard Sign

Another source of nitrate is from lawncare methods—namely excessive fertilizer uses from homeowners. Excessive fertilization on lawns causes runoff of nutrients into the groundwater, further contaminating it with nitrate. Citizens aren't aware of the implications of excessive lawncare fertilization and how it affects them. Providing the citizens of Manchester with an educational brochure outlining how they have financial and public health stake when high levels of nitrates are in the groundwater could lead to more mindful lawncare practices. The brochure would have resources for other ways to improve lawns with less fertilization. Yard signs could be used to give community pride in sustainable lawncare. This alternative has low costs and could make readers more aware of how they can help their community.

Selection of Alternatives

After analysis of each alternative and consultation with the City of Manchester, three were selected to work in conjunction with one another to reduce nitrates in Manchester's groundwater. The selected alternatives are implementing a riparian zone around the wetland, contour buffer strips, and urban education. These alternatives have been chosen and designed because of their compatibility with one another to remove nitrates. They all are relatively low-cost solutions with minimal upkeep and are thorough in covering all areas where nutrients infiltrate into the groundwater in Manchester. Another benefit is that both the buffer and riparian strips will retain more water to treat and retain it from flooding the area which is ideal for dovetailing with the stormwater flooding group also working with the City of Manchester.

Section VI – Final Design Details

Riparian Buffer Zone

There has been a significant amount of studies to show that wetland environments are incredibly effective at removing nitrates from groundwater flow. Wetlands accomplish this by creating an anoxic environment that force microorganisms to depend on nitrate and other compounds as their source of oxygen. Wetlands often form these conditions because they contain an abundance of carbon in the water that depletes the dissolved oxygen. After the biome of microbes found in the wetland consume the oxygen component of nitrate the byproduct released is harmless nitrogen gas.

The effectiveness of nitrate removing wetlands is dependent on several factors. The temperature of the water is crucial to the activity of the microorganisms metabolizing the nitrate. Removal rates of nitrate have been found to be much higher during the Summer months. The types of vegetation found in the wetland can determine the success of the nitrate consuming organisms. Leaf and stem material acts as a more readily available carbon source as opposed to hard wood material. The size of the wetland is also very important as it determines the residence time, or how long the water will remain in the wetland.

Using this knowledge and information provided by the EPA, our design team was able to estimate the effectiveness of the existing wetland. The EPA has guidelines for modeling the ability of different types of buffers to treat nitrate and other fertilizers. The guidelines used for calculating removal efficiency are shown below in Table 6.1. With GIS technology we determined that the width of the current wetland is 105 m and would correlate to a removal efficiency of 83 percent based on the EPA model. This value is certainly just an estimate as the EPA themselves state that the model is not completely accurate for predictions involving wetlands but can more precisely predict the removal efficiency of forest and grassland buffers.

Table 6.1. Nitrogen removal of different riparian vegetative cover types

Flow Path or Vegetative cover type	N	Mean nitrogen removal effectiveness (%)	1SE	Relationship to buffer width		Approximate buffer width (m) by predicted effectiveness		
				Model	R^2	50%	75%	90%
All studies	66	74.2	4.0	y = 10.5*ln(x) + 40.5	0.137	3	28	112
Surface flow	18	33.3	7.7	y = 20.2*ln(x) – 21.3	0.292	34	118	247
Subsurface flow	48	89.6	1.8	y = 1.4*ln(x) + 84.9	0.016	np	np	np
Forest	22	90.0	2.5	y = -0.7*ln(x) + 92.5	0.003	np	np	np
Forested Wetland	7	85.0	5.2	y = -7.3*ln(x) + 104.3	0.203	np	np	np
Grass	22	53.3	8.7	y = 23.0*ln(x) – 13.6	0.277	16	47	90
Grass/forest	8	80.5	10.2	y = 18.1*ln(x) + 20.4	0.407	5	20	47
Wetland	7	72.3	11.9	y = 3.0*ln(x) + 68.9	0.005	np	np	np

A method of achieving a higher removal efficiency would be the planting of a barrier of trees intersecting the path of subsurface flow surrounding the wetland. This barrier of trees is called a riparian buffer zone; to determine the appropriate location to plant the trees the path of flow must be known. Our design group intends on using hand augers to measure the hydraulic head at three different locations around the wetland. These measurements can be used to find the gradient of the flow and the best location for the trees.

This riparian buffer zone will contain a row of Iowa Willow trees closest to the wetland and a row of hybrid poplar trees on the outer edge of the zone. These trees will be planted in an excavated trough with 3/8" pea gravel at the bottom and a layer of existing soil covering the gravel. Along with increasing the residence time of water in the wetland, the riparian buffer zone also allows the Nitrate-rich water from the surrounding agricultural land to the roots of the willow and hybrid poplar trees for conversion in an anoxic zone; having a trough with porous gravel will help deliver this water to the root zone faster (Ausland, 2015). Iowa willows and hybrid poplar trees were chosen for use in the riparian buffer zone due to their dense root structure and high effectiveness of converting pollutants, such as nitrate; these trees are able to create a biome of microbes in the root structure that can effectively convert nitrate to nitrogen gas. This zone with then be seeded with native grass to prevent the loss of topsoil due to erosion.

The constructed riparian buffer zone will be 35 feet across and will be 750 feet along the North side and 735 feet long along the East side. This aerial footprint is 50,750 square feet or approximately 1.2 acres. The excavated trough will contain 3/8" pea gravel at the bottom 2.5 feet, existing topsoil the next 1 foot to match the existing ground level. Initially, the approximately 3,300 cubic yards of earth will be removed to create the shape of the triangular swale. The Iowa willows and hybrid poplar trees, purchased as 8-9 foot poles, will be placed at the bottom of the swale. The tree poles are planted in two rows parallel to the riparian buffer zone. These rows will be 15 feet apart and 10 feet from the edge of the riparian buffer zone. Individual trees will be spaced 10 feet apart, starting 5 feet from the edge of the end of each side of the buffer zone. After the poplar poles are secured in the ground, placement of the approximately 4700 cubic yards of 3/8" pea gravel along the bottom 2.5 feet and 1900 cubic yards of the original soil will be layer on top of the pea gravel, flush with the surrounding land. Finally, the bare soil will be seeded with native grass, such as switchgrass. Using the EPA model shown in Figure 6.1 it was determined that this buffer design has the capacity to treat approximately 63 percent of the nitrates that intersect it.

Contour Buffer Strips

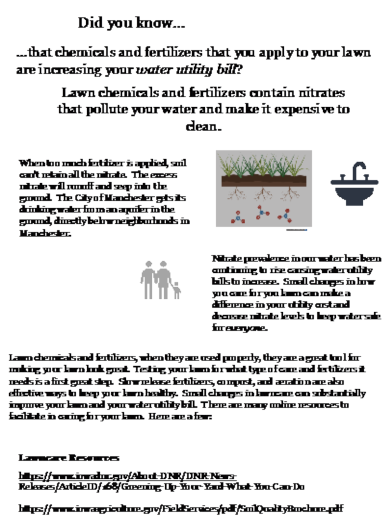
In order to locate effective placement of contour buffer strips, the Agricultural Conservation Planning Framework (ACPF) tool, developed by the USDA, was used. This tool provides many different conservation options, including practices that may influence erosion and water quality (Using Watershed Information to Power Conservation). The ACPF tool utilizes high resolution land data through an ArcGIS toolbox to create the conservation options. Previously, the Iowa DNR compiled the needed data and completed the ACPF tool analysis for the area surrounding Manchester; this data was made available to our design group and was specifically used to locate suitable areas in adjacent agricultural fields for contour buffer strips.

Contour buffer strips are narrow strips of vegetation, often grasses or a mix of grasses and legumes, that run along the contours of agricultural fields (Contour Buffer Strips – Conservation Practice Standard). Implementation of these buffer strips can help in a variety of different ways, but for this instance the main purpose is to reduce nutrient transportation in both the runoff and groundwater. This practice may help further remove and convert the ammonia-based applied nutrients in agricultural field so Nitrates seeping into the groundwater and lowered. The owner of the farmland will also see benefits outside the capture of nutrient-rich runoff. Buffer strips are highly effective at slowing the speed of runoff, helping decrease the erosion of topsoil within the farmland itself (Conservation Choices: Contour Buffer Strips).

The design and implementation of the contour buffer strips is a simple process. Using the ACPF tool to locate suitable areas and sizes for these strips following the contours of the land, 55 individual segments were located. Using the NRCS Iowa Conservation Practice Standards, the proposed contour buffer strips will be the minimum 15 feet wide and corresponding lengths found in the plans found in the Appendix (Contour Buffer Strips – Conservation Practice Standard). The buffer strip vegetation will include a mixture of grasses and legumes; two seed mixture suggestions are Ladino clover with Timothy for poorly drained soils and Alfalfa with Orchardgrass for dryer soils (Seeding Rates for Conservation Species for Montana). The Iowa Seed Directory (found at http://www.iowacrop.org/Seed_Directory.htm) is another great source to find the availability of seed and information of specific types of seed. The density of vegetation required for the grass-legume mixture is 50 stems per square foot. Before the application of this seed, crops will need to be removed from the buffer strip area and the ground will be tilled. The upkeep and maintenance of contour buffer strips is light; it is suggested ever three years to either burn or mow the grass and legume vegetation.

Urban Nitrate Removal Education Brochure

A tool that other communities have used to reduce urban sources of nitrate in the drinking water is public education. An educational brochure has been developed for the use of citizens of the City of Manchester to understand the implications of excess fertilization in lawncare practices. Several sample public education sources were used in reference to create a brochure for the City of Manchester including Soil Quality from the Iowa Department of Agriculture, Nutrient Pollution Fact Sheet from the University of Cornell, and Nutrient Pollution Fact Sheet from the Utah Department of Natural Resources. These examples can be found in Appendix B. Another strong example found was from the City of Coralville Iowa's website page "Your Best Lawn" (https://www.coralville.org/882/Your-Best-Lawn) comprehensive steps are provided for residents to receive compensation for sustainable lawncare. This brochure was developed to effectively capture citizen attention by explaining why excess nitrates are costing them more money and is a public health issue. It is meant to be easily understood by a broad range of backgrounds and is short in length to convey main points. Additional links to resources on alternative lawncare practices are provided on the brochure. The following shows the set-up of the brochure.



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 6.2. City of Manchester urban nitrate removal brochure

A pdf of the brochure is also provided in Appendix B. This brochure could be distributed by mail or electronically on the City of Manchester's website or newsletter.

Section VII – Engineer's Cost Estimate

Table 7.1. Preliminary Cost Estimate

ITEM	QUANTITY	UNIT	UNIT PRICE	TOTAL
Contour Buffer Strips				
Orchardgrass Seed	32.9	ACRE	$150.00	$4,935.00
Alfalfa Seed	32.9	ACRE	$150.00	$4,935.00
Seed Distribution	32.9	ACRE	$50.00	$1,645.00
Field Tilling	32.9	ACRE	$50.00	$1,645.00
Subtotal				$13,160.00
Riparian Buffer Zone				
3/8" Pea Gravel	6600	TON	$25.00	$165,000.00
Iowa Willows/Hybrid Poplars (8-9 ft poles - bag of 50)	6	BAG	$3,300.00	$19,800.00
Native Grass Seeding	1.17	ACRE	$150.00	$175.50
Trough Excavation	8500	CUB YD	$5.00	$42,500.00
Backfilll of Soil and Gravel	1900	CUB YD	$40.00	$76,000.00
Subtotal				$303,475.50
Urban Nitrate Removal Education Brochure				
Printing Brochures	2400	EA	$0.10	$240.00
Stamps	2400	EA	$0.55	$1,320.00
Brochure Design	1	LS	$1,000.00	$1,000.00
Subtotal				$2,560.00
TOTAL				**$319,195.50**

Contour Buffer Strips Cost Estimate

Costs associated with the contour buffer strips include the cost for labor and equipment rental to till the 15' strip lanes, the cost of the Orchardgrass and Alfalfa seed and payments to farmers for foregone income based on the amount of farmland needed. The estimated cost for the materials and construction of the contour buffer strips are $13,160.

Another cost that may be associated with the contour buffer strips is payment to farmers due to foregone income for the portions of the field taken out of production. The foregone income was based on the Delaware County average corn yield of around 200 bushels per acre, a bushel of corn costing $3.50 per acre and each acre costing the farmer around $300 per acre to tend to; the net income lost per acre was calculated at $400 per acre (Iowa Corn and Soybean County Yields, Iowa Cash Corn and Soybean Prices). The cost estimate provided in Table 7.2 below shows a one-year payment and a 10-year lump sum payment costing $8,225 and $82,250, respectively.

Table 7.2. Foregone Income Estimate

Foregone Income (corn) payments				
1-year payment	32.9	ACRE	$250.00	$8,225.00
10-year payment	32.9	ACRE	$250.00	$82,250.00

Riparian Buffer Zone Cost Estimate

Costs associated with the riparian buffer zone construction and implementation are the equipment and labor costs for constructing of the trough, planting the trees, placing the gravel in the swale, covering the gravel with excavated soil and seeding the bare earth around the trees. The estimated cost for the riparian buffer zone is $303,475.50.

Urban Nitrate Removal Education Brochure Cost Estimate

The only costs for the urban nitrate removal education brochure are printing and delivery the brochure for each of the 2400 houses in Manchester; also included is the cost for the design of the brochure that will be sent to residents. The estimated cost for the brochure is $2,560.

Table 7.3. Total Project Cost Estimate

Construction Subtotal	$319,195.50
10% Contingencies	$31,919.55
20% Engineering and Administration	$63,839.10
Total Project Cost	**$414,954.15**

The total project cost estimate seen in Table 7.3 includes the total construction subtotal, a 10% contingency cost and a 20% engineering and administration cost; the total project cost does not include foregone income payments. These percentages were calculated based on the construction subtotal. The total estimated project cost is $414,954.15.

Appendices

Appendix A: References

Buffer Strips: Common Sense Conservation. (n.d.). Retrieved March 2020, from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143_023568

Conservation Choices: Contour Buffer Strips, National Resources Conservation Service. Retrieved April 2020, from https://www.nrcs.usda.gov/wps/portal/nrcs/ia/newsroom/factsheets/NRCSEPRD413956/

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Constructed Wetlands for Nitrate Removal from Tile Drainage Water. University of Illinois, biogeochemistry.nres.illinois.edu/Biogeochem_lab/pdfs/Wetland%20Fact%20sheet%20%20for%20web%208-26.pdf.

Contour Buffer Strips - Conservation Practice Standard, National Resources Conservation Service (2016).

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Using Watershed Information to Power Conservation, Agricultural Conservation Planning Framework, https://acpf4watersheds.org/files/2019/04/acpf-summary-0419-final.pdf

"What Are Prairie Strips?" Science-Based Trials of Rowcrops Integrated with Prairie Strips, www.nrem.iastate.edu/research/STRIPS/content/what-are-prairie-strips.

Your Best Lawn: Coralville, IA. (n.d.). Retrieved March 2020, from https://www.coralville.org/882/Your-Best-Lawn

Your Home and Water Quality Impacts in Rockland County. (n.d.). Retrieved March 2020, from https://s3.amazonaws.com/assets.cce.cornell.edu/attachments/32370/WaterQuality(English).pdf?1533048056

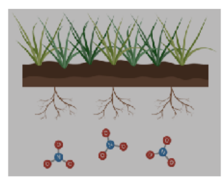
Appendix B: Public Education on Urban Nitrates

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 B.1. Design of Manchester educational brochure

althy lawn that
requires less water and reduced fertilizer
and pesticide applications.

Figure B.2. Soil Quality from the Iowa Department of Agriculture page 1

How to Upgrade Your Lawn

A New Lawn

Compost being spread over the soil prior to seeding or sodding.

- Soil quality restoration is easiest when performed as part of final landscaping with new construction.
- Deep tillage (8-12 inches deep) breaks up compacted soils.
- An addition of compost will increase organic matter levels.
- Recommended levels of 5% or more soil organic matter content can usually be achieved by incorporating 1-3 inches of quality compost into the soil before sodding or seeding.

An Existing Lawn

- If you wish to improve a landscape with existing turf, you can aerate the soil and apply a surface blanket of compost in the spring or fall.

This homeowner was unhappy with his lawn. The compacted soil with low organic matter didn't allow water to soak in and it ran off. This caused dried-out conditions and resulted in dry, stressed grass.

Aerate it!

Aeration helps to improve soil quality by facilitating the movement of organic matter into the soil profile.

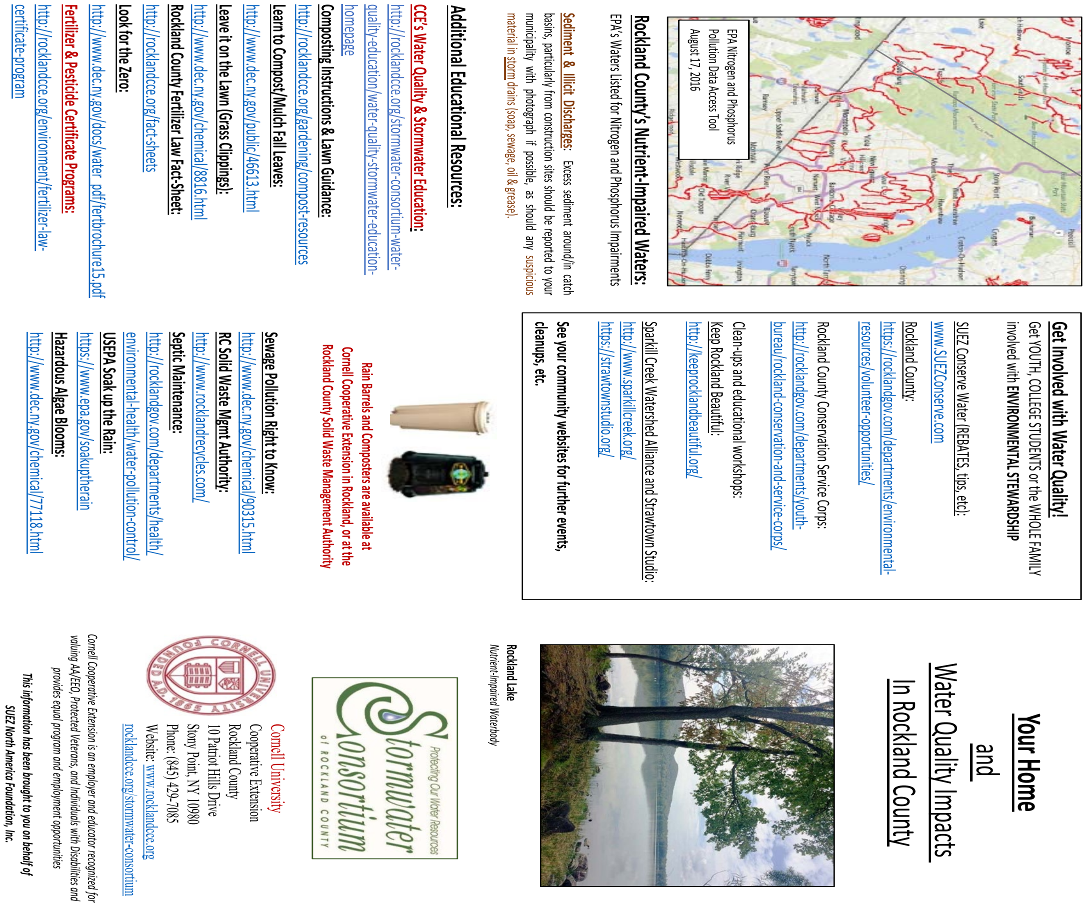
- Aerate your lawn with a plug or deep-tine aerator.
- A common misperception is that aeration itself helps relieve compaction and allows oxygen to permeate down to plant roots.
- An application of ¼ to ¾ inch of compost is recommended after aeration. This will help fill the aeration holes with organic matter to amend the soil.
- Eventually the void created by the soil plug will fill in.
- To have a lasting impact on the health of your lawn, fill the plugs with good quality compost and reseed to get the greatest benefit from core aeration.

Spread That Compost

A thin layer of compost being blown onto a lawn to increase organic matter content.

- Compost may be spread onto bare ground or existing lawns in a number of ways, depending on size of project and *do-it-yourself* ability.
- It can be blown onto the lawn, applied with a skid loader, wheel barrrow and shovel, manure spreader, or lawn fertilizer spreader.
- A fertilizer spreader works well to apply a thin layer of high quality fine-graded compost to an exiting lawn.
- Grass seed is normally added with the compost to help fill in patchy turf or seed an area.

Figure B.3. Soil Quality from the Iowa Department of Agriculture page 2



Rockland County's Nutrient-Impaired Waters:
EPA's Waters Listed for Nitrogen and Phosphorus Impairments

EPA Nitrogen and Phosphorus Pollution Data Access Tool
August 17, 2016

Sediment & Illicit Discharges: Excess sediment around/in catch basins, particularly from construction sites should be reported to your municipality with photograph if possible, as should any suspicious material in storm drains (soap, sewage, oil & grease).

Additional Educational Resources:

CCE's Water Quality & Stormwater Education:
http://rocklandcce.org/stormwater-consortium-water-quality-education/water-quality-stormwater-education-homepage
Composting Instructions & Lawn Guidance:
http://rocklandcce.org/gardening/compost-resources
Learn to Compost/Mulch Fall Leaves:
http://www.dec.ny.gov/public/46613.html
Leave it on the Lawn (Grass Clippings):
http://www.dec.ny.gov/chemical/8816.html
Rockland County Fertilizer Law Fact-Sheet:
http://rocklandcce.org/fact-sheets
Look for the Zero:
http://www.dec.ny.gov/docs/water_pdf/fertbrochure15.pdf
Fertilizer & Pesticide Certificate Programs:
http://rocklandcce.org/environment/fertilizer-law-certificate-program

Get Involved with Water Quality!
Get YOUTH, COLLEGE STUDENTS or the WHOLE FAMILY involved with **ENVIRONMENTAL STEWARDSHIP**

SUEZ Conserve Water (REBATES, tips, etc):
www.SUEZConserve.com
Rockland County:
https://rocklandgov.com/departments/environmental-resources/volunteer-opportunities/

Rockland County Conservation Service Corps:
http://rocklandgov.com/departments/youth-bureau/rockland-conservation-and-service-corps/

Clean-ups and educational workshops:
Keep Rockland Beautiful:
http://keeprocklandbeautiful.org/

Sparkill Creek Watershed Alliance and Strawtown Studio:
http://www.sparkillcreek.org/
https://strawtownstudio.org/

See your community websites for further events, cleanups, etc.

Rain Barrels and Composters are available at Cornell Cooperative Extension in Rockland, or at the Rockland County Solid Waste Management Authority

Sewage Pollution Right to Know:
http://www.dec.ny.gov/chemical/90315.html
RC Solid Waste Mgmt Authority:
http://www.rocklandrecycles.com/
Septic Maintenance:
http://rocklandgov.com/departments/health/environmental-health/water-pollution-control/
USEPA Soak up the Rain:
https://www.epa.gov/soakuptherain
Hazardous Algae Blooms:
http://www.dec.ny.gov/chemical/77118.html

Your Home
and
Water Quality Impacts
In Rockland County

Rockland Lake
Nutrient-Impaired Waterbody

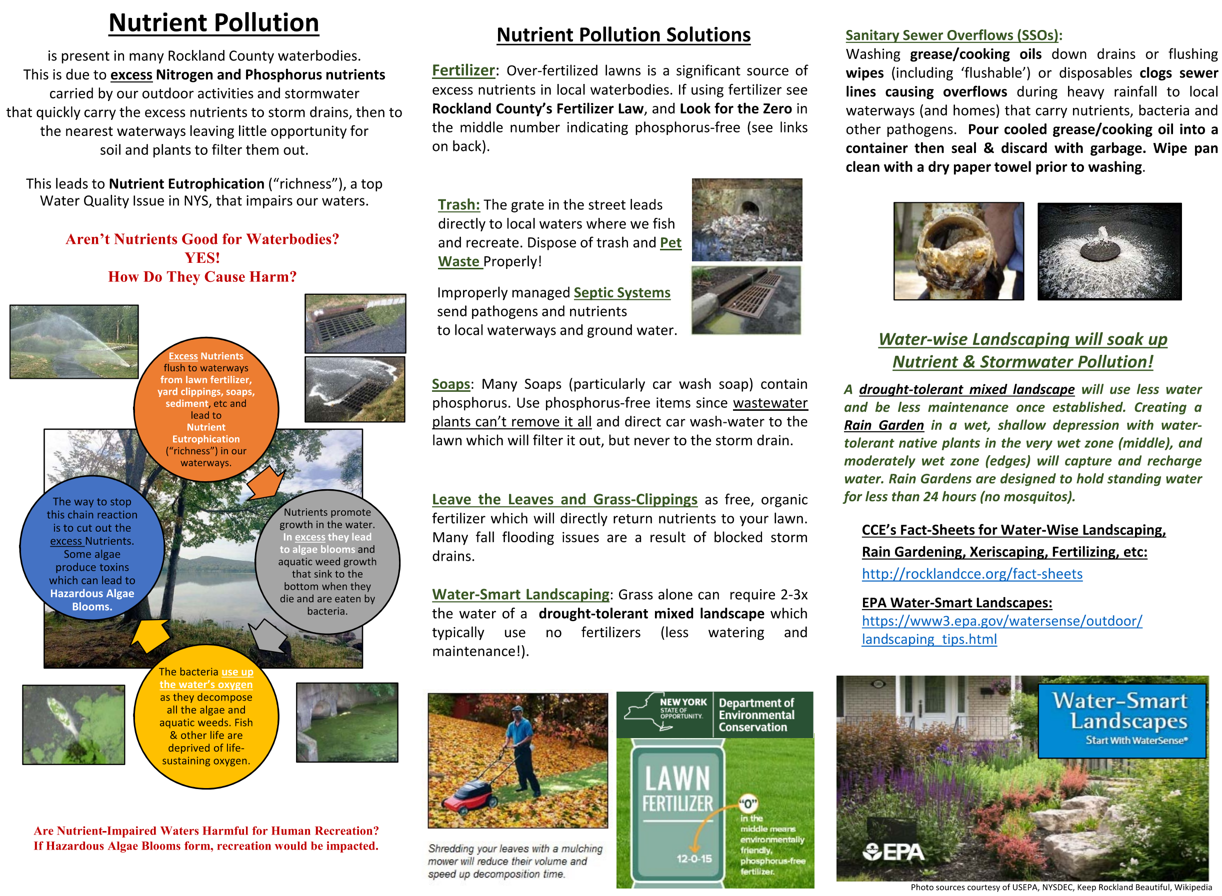
Protecting Our Water Resources
Stormwater Consortium
of Rockland County

Cornell University
Cooperative Extension
Rockland County
10 Patriot Hills Drive
Stony Point, NY 10980
Phone: (845) 429-7085
Website: www.rocklandcce.org
rocklandcce.org/stormwater-consortium

Cornell Cooperative Extension is an employer and educator recognized for valuing AA/EEO, Protected Veterans, and Individuals with Disabilities and provides equal program and employment opportunities

This information has been brought to you on behalf of SUEZ North America Foundation, Inc.

Figure B.4. Nutrient Pollution Fact Sheet from the University of Cornell front side



Nutrient Pollution

is present in many Rockland County waterbodies. This is due to excess **Nitrogen and Phosphorus nutrients** carried by our outdoor activities and stormwater that quickly carry the excess nutrients to storm drains, then to the nearest waterways leaving little opportunity for soil and plants to filter them out.

This leads to **Nutrient Eutrophication** ("richness"), a top Water Quality Issue in NYS, that impairs our waters.

Aren't Nutrients Good for Waterbodies?
YES!
How Do They Cause Harm?

Excess Nutrients flush to waterways from lawn fertilizer, yard clippings, soaps, sediment, etc and lead to **Nutrient Eutrophication** ("richness") in our waterways.

Nutrients promote growth in the water. **In excess they lead to algae blooms** and aquatic weed growth that sink to the bottom when they die and are eaten by bacteria.

The bacteria use up the water's oxygen as they decompose all the algae and aquatic weeds. Fish & other life are deprived of life-sustaining oxygen.

The way to stop this chain reaction is to cut out the excess Nutrients. Some algae produce toxins which can lead to **Hazardous Algae Blooms.**

Are Nutrient-Impaired Waters Harmful for Human Recreation?
If Hazardous Algae Blooms form, recreation would be impacted.

Nutrient Pollution Solutions

Fertilizer: Over-fertilized lawns is a significant source of excess nutrients in local waterbodies. If using fertilizer see **Rockland County's Fertilizer Law**, and **Look for the Zero** in the middle number indicating phosphorus-free (see links on back).

Trash: The grate in the street leads directly to local waters where we fish and recreate. Dispose of trash and **Pet Waste** Properly!

Improperly managed **Septic Systems** send pathogens and nutrients to local waterways and ground water.

Soaps: Many Soaps (particularly car wash soap) contain phosphorus. Use phosphorus-free items since wastewater plants can't remove it all and direct car wash-water to the lawn which will filter it out, but never to the storm drain.

Leave the Leaves and Grass-Clippings as free, organic fertilizer which will directly return nutrients to your lawn. Many fall flooding issues are a result of blocked storm drains.

Water-Smart Landscaping: Grass alone can require 2-3x the water of a **drought-tolerant mixed landscape** which typically use no fertilizers (less watering and maintenance!).

Shredding your leaves with a mulching mower will reduce their volume and speed up decomposition time.

NEW YORK STATE OF OPPORTUNITY. Department of Environmental Conservation
LAWN FERTILIZER
12-0-15
"0" in the middle means environmentally friendly, phosphorus-free fertilizer.

Sanitary Sewer Overflows (SSOs):
Washing **grease/cooking oils** down drains or flushing **wipes** (including 'flushable') or disposables **clogs sewer lines causing overflows** during heavy rainfall to local waterways (and homes) that carry nutrients, bacteria and other pathogens. **Pour cooled grease/cooking oil into a container then seal & discard with garbage. Wipe pan clean with a dry paper towel prior to washing.**

Water-wise Landscaping will soak up Nutrient & Stormwater Pollution!

A drought-tolerant mixed landscape will use less water and be less maintenance once established. Creating a Rain Garden in a wet, shallow depression with water-tolerant native plants in the very wet zone (middle), and moderately wet zone (edges) will capture and recharge water. Rain Gardens are designed to hold standing water for less than 24 hours (no mosquitos).

CCE's Fact-Sheets for Water-Wise Landscaping, Rain Gardening, Xeriscaping, Fertilizing, etc:
http://rocklandcce.org/fact-sheets

EPA Water-Smart Landscapes:
https://www3.epa.gov/watersense/outdoor/landscaping_tips.html

Water-Smart Landscapes
Start With WaterSense®
EPA

Photo sources courtesy of USEPA, NYSDEC, Keep Rockland Beautiful, Wikipedia

Figure B.5. Nutrient Pollution Fact Sheet from the University of Cornell inside of brochure

October 201[illegible]

m/newseq

On Twitter
@deqdonna or @UTDEQ

Figure B.6. Nutrient Pollution Fact Sheet from the Utah Department of Natural Resources