Village Stormwater Mitigation

2021 NCEES Award Submission

Project Description

Figure 1: Downtown in the Village

This project takes place in a small Midwest village known for its scenic views and Swedish heritage. The community lies on the Mississippi River, surrounded by 400-foot-tall bluffs with steep topography, like other towns along the Mighty Mississippi. The watershed reaches upland in the surrounding township and flows into the Village and river. A concrete channel (indicated by the blue line in Figure 2) was built in the 1950s by the railroad to help prevent runoff from washing out the railroad tracks. This channel has become the main drainageway through the community and many businesses and homes are located close by.

The concrete channel now has areas of disrepair, and it contains substantial sediment deposits that have resulted in vegetation impeding the flow of water through the channel. To successfully mitigate flooding risk, the channel may need to be refurbished, or upstream detention/retention methods may need to be implemented to lower the peak flood rates.

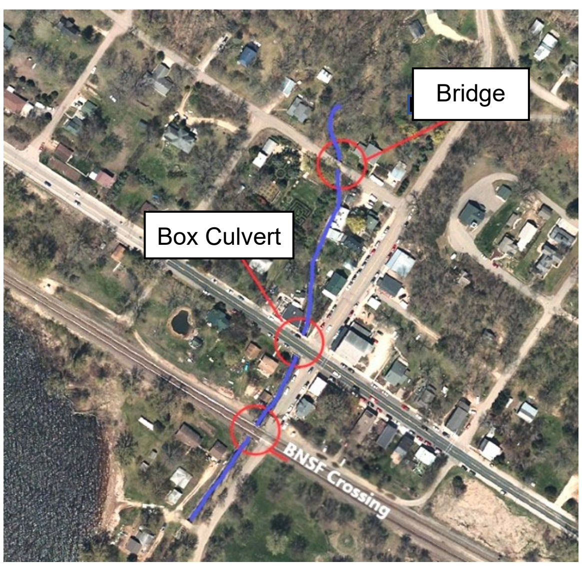


Figure 2: Aerial view of the project site.

In addition to deterioration of the concrete channel, runoff intensity and frequency are increasing due to climate change and the community is concerned about heavy rainfall events that may exacerbate flooding and erosion. In response to this concern, the Village wants to implement a stormwater mitigation system to reduce upland runoff and safely convey the flows through the main drainageway in the Village.

Currently, the village does not own the land that the concrete channel was constructed on; there are numerous privately-owned segments. The Village's project manager believes the rights are acquirable via easements, but this is a very real constraint on the path to construction. Land acquisition is also complicated by the need to acquire roughly 32 acres of privately held land in upland portions of the watershed north of the Village and near a cemetery. This land (or an easement) is being sought to provide areas where upland stormwater mitigation can occur.

The Village challenged a team of undergraduate engineering students (the student team) to design a solution to the problem that accomplishes four goals:

- Reduces flood volumes and soil erosion during heavy rainfall events
- Utilizes upstream detention or retention basins
- Considers repairs to the existing concrete channel for safe and enhanced conveyance
- Selects a feasible and safe location(s) at which the community can manage the new features, while enjoying the natural environment

With this guidance in mind, the student team collaborated with faculty members, professional engineers, mentors, the public, and the Village engineer to create their solution. The final design applies principles from geotechnical, structural, hydrologic, hydraulic, and construction engineering. As part of the project, the student team prepared and submitted the following:

- Full proposal in response to a request for proposals, as though they were competing for the project
- Formal preliminary design report describing three concept designs
- List of pertinent regulatory standards and professional codes
- Geotechnical report
- Final design of the selected alternative
- Contract documents (construction contract, technical specification, construction plans)
- Regular project management reports and peer evaluation reports
- Cost opinions and project schedules
- Three formal presentations

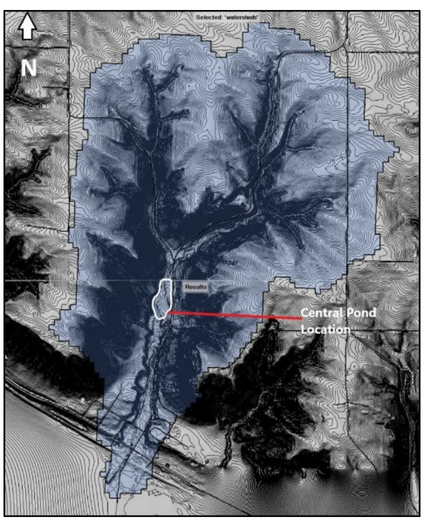


Figure 3: Central Pond Location

The three concept designs submitted by the student team are as follows: Central Pond Location; Multiple Pond Locations; and Concrete Channel Rehabilitation.

The Central Pond Location (Figure 3) is a large retention pond built directly upstream from the channel with a water storage capacity of nearly 120 acre-feet and potential space for a park or walking path. This option achieves the greatest reduction in peak flows and provides space for the community to enjoy nature.

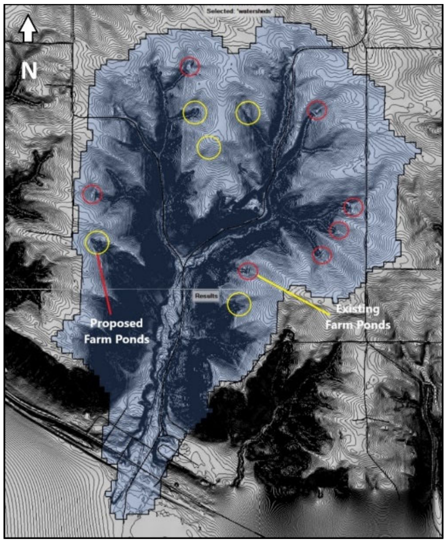


Figure 4: Multiple Pond Locations

The Multiple Pond Locations (Figure 4) option involves building five strategically placed ponds upstream on forested area and farmland to flatten peak runoff.

The third concept focuses on how changes to the existing channel can help mitigate flood risk in the Village. This option involves refurbishing the concrete channel to increase the flow capacity and building a new channel where the existing channel may not be wide enough to accommodate the anticipated flow from a large storm event. The area would be more aesthetically appealing, after removing debris and repairing cracks (Figures 5 and 6).

Figure 5: Existing conditions of vegetation overgrowth in the channel

Figure 6: Existing conditions and deterioration in the channel

The Central Pond Location was ultimately recommended by the student team, and the recommendation was accepted by the Village. This option meets the Village's criteria and presents the most successful stormwater management results out of all three concepts. The combination of conservation easements and a centrally located retention pond brings large-scale conventional stormwater management and sustainability-minded conservation together to protect the Village. The design also provides a substantial area downstream from the pond where walking paths and historical/cultural markers for the Village can be created. To successfully implement this design, further steps are needed to acquire the necessary conservation easements.

Collaboration of Faculty, Students and Licensed Professional Engineers

Were licensed professional engineers (P.E.s) involved?

Two P.E.s from the local community served as mentors throughout the semester, meeting weekly with the student team. They provided design supervision, guidance from professional experiences, critique and oversight for presentations and reports, and advice for client relationships and public meetings. In addition, overall instruction for the course was provided weekly by two P.E.s and a licensed architect. Two student team presentations (at the preliminary and final design stages) were made to a panel of experts from the local P.E. community, thereby widening the students' exposure to other professionals and affording opportunities for additional critique of their work. This panel of experts also included two P.E.s, bringing the total number of P.E.s involved on the project to six.

How did the students, faculty, and P.E.s interact?

The student team was responsible for meeting pre-established goals for time management, presentations, design components, deliverables, and schedules. Weekly contact between mentors and students allowed the students to gain insights and advice grounded in the P.E.s' many years of experience, which helped guide project success. At the same time, mentors and faculty made themselves available for phone or email discussions as necessary and provided review of the student team's deliverables.

What did the students learn through the collaboration that would not have been learned in the classroom?

Communication and Collaboration as Components of Design: Collaboration between engineers, stakeholders, regulatory agencies, and the public is difficult, if not impossible, to teach in the classroom. In this project, the student team spoke directly to the Village's project engineer and the public, learning to listen and balance the needs and requirements of various entities. The project constraints and needs then became critical elements of three concept designs.

Multiple Right Answers: Most classroom activities and problems are designed to promote an understanding of the theory by having a single "correct" answer. In this project, having achieved an understanding of the engineering, environmental, and public constraints, the students prepared an evaluation matrix in which

Criteria	Weight	Alternative I – Large Pond	Alternative II – Farm Ponds	Alternative III – Channel
Reduction in Peak Flows	**25%**	3.0	1.0	1.0
Economic Sustainability	**25%**			
Initial Cost	15%	1.0	1.0	3.0
Maintenance Cost	10%	2.0	2.0	3.0
Environmental Sustainability	**20%**			
Water Quality Treatment	15%	3.0	3.0	0.0
Limited Impact On Land	5%	2.0	2.5	3.0
Social Sustainability	**20%**			
Walking Area	10%	3.0	0.0	0.0
Safety	10%	2.0	2.5	3.0
Constructability	**10%**	2.0	2.0	3.0
Totals	**100%**	**1.65**	**1.18**	**1.15**

Figure 7: Evaluation matrix developed by the students to weigh all three concept designs

weighted decision criteria were applied to the three concept designs. The team recommended the Central Pond Location design, which utilizes a new stormwater management pond to increase upstream control of flood waters and allow for cleaning and repair of the existing concrete channel.

Application/Integration of Multiple Disciplines: To achieve success, this project required students to combine their individual skills and complete tasks in several disciplines of civil and environmental engineering (geotechnical, structural, hydraulic, construction, and hydrologic). The design also required an understanding of applicable codes. This was achieved by identifying the skill sets of each team member, assigning tasks appropriate for each person's skill set, and seeking advice from mentors, faculty, and other students in areas where needs remained.

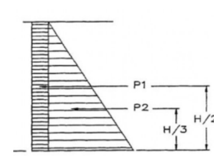
How to Identify Uncertainties: Engineering projects have uncertainties, and an awareness of the uncertainties informs the designers and users of related risks. In this project, students were challenged to identify areas where they did not have or could not find pertinent information, or where certain information was not knowable prior to analyses. They correctly identified several items (numerous hydraulic structures in the watershed for which detailed geometric data was unavailable, roads and bridges for which elevations were not accurately known, geotechnical conditions, current-day structural integrity of the existing channel, etc.) as items that should be noted and considered.

Protection of Health, Safety, and/or Welfare of the Public

The student team was challenged to design a stormwater mitigation system that protects the Village from flooding during increasingly frequent and intense storms. The engineering and construction decisions made in the 1950s by the railroad to protect its rail line did not serve the Village long-term. The existing system is old, undersized, unsafe, and generally lacking in its ability to protect the Village. Due to these inadequacies, both the population and the ecology of the area are at risk from flood water, soil erosion, and the transport of upstream sediment and pollutants to the Mississippi River. The design submitted by the student team implements measures to reduce runoff, treat the stormwater, and infiltrate it downstream at a slower rate. The design also keeps excess sediment from going downstream into the Mississippi River, thereby benefitting the environment and public collectively.

Channel Wall Calculations

The precast section of the channel was modeled as a retaining wall for these calculations. The Load of the earth acting on the wall can be modeled as seen below:



The required moment resistance about the rebar dowel section can then be determined.

$Pa = .5k_a\gamma H\hat{}2$

H = Retaining Wall Height = 5 ft.

Pa = P2 = Point Load of Earth Pressure on Wall

$k_a = \frac{1-\sin(\emptyset)}{1+\sin(\emptyset)}$

Ø = Friction angle of soil = 30 degrees

Figure 8: Calculations prepared by the student team

Multidiscipline and/or Allied Profession Participation

The student team performed work including structural, geotechnical, hydraulic, hydrological and construction engineering, drafting, estimating, scheduling, client and community interaction, review of regulatory requirements and professional standards, research on grant sources, and the preparation of written reports and construction documents. The four undergraduate engineering students on the team logged approximately 800 hours of design work, including meetings with mentors and faculty and as a team.

Two volunteer P.E.s served as the team's mentors, while two P.E.s and a licensed architect served as the course instructors. These licensed professionals met at least once per week, and often twice per week with the students, and were available by telephone or email to answer questions and provide advice. Other faculty members served as advisors, and members of the local engineering community (including two P.E.s) served as judges for two formal presentations by the student team.

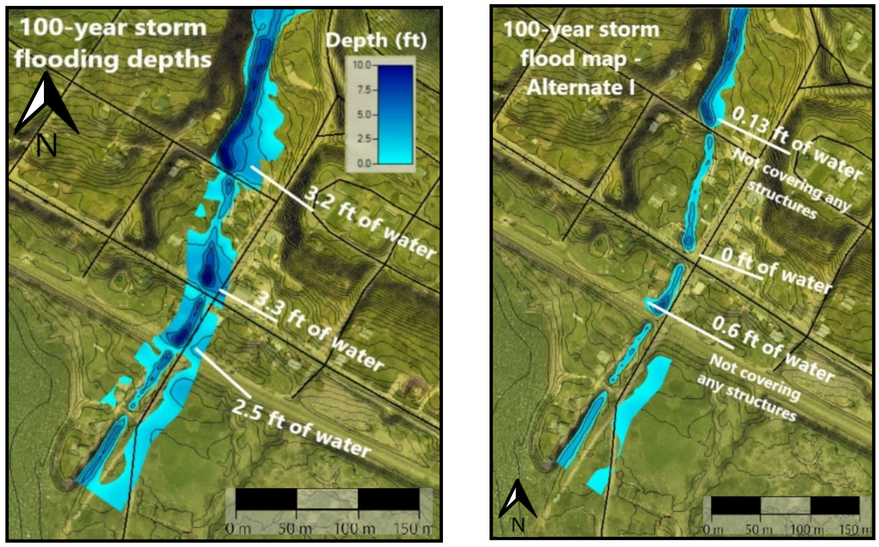


Figure 9: Comparison of existing conditions and the Central Pond Location alternative for a 100-year storm event

Knowledge and Skills Gained

Students applied their engineering curriculum to a real-world problem, a task considerably beyond the requirements of any specific class. They used their knowledge of civil engineering to evaluate alternatives, considered risks and benefits, and created a viable final design, while managing themselves to meet the time and budget constraints of their client and internal organization. The internal teamwork and integration with outside entities (mentors, instructors, village engineer, public, regulatory agencies, etc.) provided valuable lessons for applying engineering principles and theory while acting with regard for public and client needs.

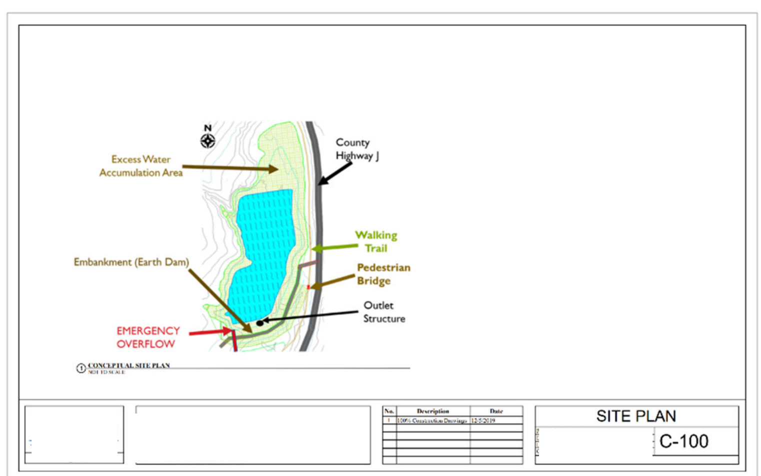


Figure 10: Conceptual Site Plan for the Central Pond Location prepared by the students

Their interaction with mentors and other members of the engineering community taught them valuable communication skills, and gave them insights into questions about ethics, professional responsibilities, and the logistics of taking a design project to completion. Constructability and practicality are demonstrated in the construction drawings the students prepared (Figure 10 and Figure 11).

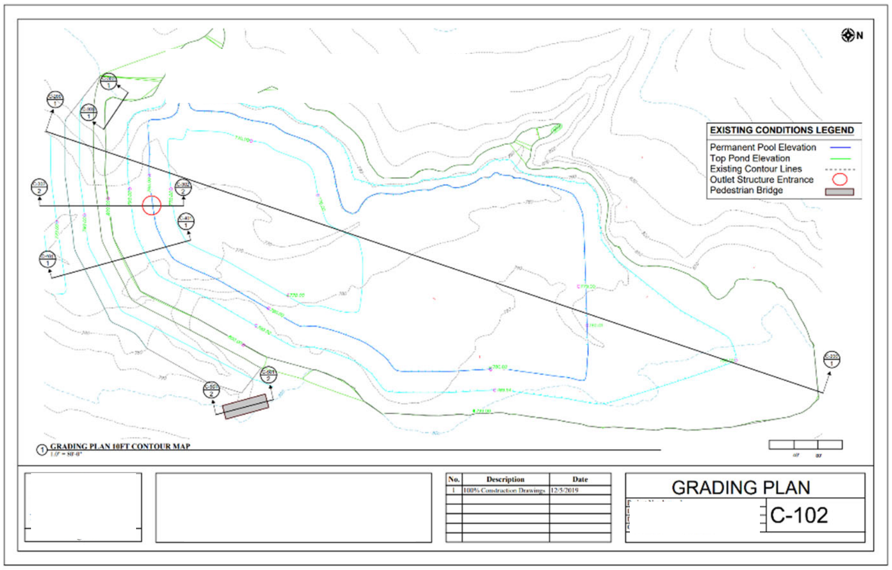


Figure 11: Grading plan prepared by the students for the Central Pond Location

This unique project incorporated the requirements of several stakeholders, including the Village's project engineer, the public, State and County Transportation Departments, and regulatory agencies. The students identified applicable codes and standards, prepared contract documents (contract, technical specification, plans), and responded to requests for information. The project also reinforced how to communicate and work effectively as a team and with project stakeholders. Lastly, the student team presented their final design to the Village board, providing them with a unique opportunity to gain experience in a public setting and respond to questions.