Meadow Creek Golf Course Flooding Mitigation

How Emerging Technologies such as BIM, Drones or 3D Printing Impacts Sustainable Practices, as well as Waste Reduction.

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By

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In relation to the capstone project, the Meadow Creek Golf Course, located in Charlottesville, Virginia, is facing ongoing stormwater management drainage, erosion, and sediment control issues. Specifically, this is affecting the 17th hole the greatest, creating an ongoing enlargement of a headcut that is expanding onto the hole's playing area. The current drainage infrastructure such as upstream ponds and channels is inadequate, leading to sedimentation, water quantity, and water quality issues. The ponds, basins, and streams that are present in this area cannot effectively treat or handle stormwater runoff. This is causing the golf course to get flooded, and therefore runoff into the Rivanna River, bringing vast amounts of unnecessary nutrients and debris to the local waterway. This is causing algae to form exponentially, reducing the amount of dissolved oxygen available for the present aquatic life and vegetation in this area. Additionally, the existing stormwater infrastructure is not designed to manage these issues effectively, leading to overland bypass flows from a current pipe who's condition and outlet are known to worsen the erosion and sediment problems.

Now for the technical project, I am writing about the topic of technology within the construction industry. The goal is to analyze how emerging technologies such as BIM, drones or 3D printing impacts sustainable practices, as well as waste reduction. This is important because as technology continues to develop, monitoring how the technology affects environmental impacts is just as valuable as the purpose of the technology itself. In a world where technology is advancing at an exceptional rate, utilizing the technologies to improve surrounding communities in terms of sustainability and environmental health is critical. Simply developing these technologies will not accomplish their fulfilling intent unless used to impact the environment in such a positive way.

Both projects, though distinct in focus, share a common thread in their emphasis on sustainability and environmental health. The Meadow Creek Golf Course's stormwater management issues highlight the urgent need for more effective infrastructure solutions that address water quality, sedimentation, and erosion problems. This challenge ties directly into the second project's exploration of emerging technologies within the construction industry, which include tools like BIM, drones, and 3D printing. These technologies have the potential to revolutionize how we approach environmental management and infrastructure design, offering new methods to address the kind of water management issues at the golf course. For example, BIM can help in designing more efficient stormwater systems, drones can aid in monitoring erosion, and 3D printing can create sustainable, customized solutions for water management infrastructure. Both projects underscore the importance of technological innovation not only for improving human systems but also for safeguarding natural resources and promoting environmental health. By integrating these emerging technologies into the design and construction processes, we can reduce waste, improve resource management, and help restore ecosystems impacted by issues like those seen at the golf course.

Meadow Creek Golf Course Flooding Mitigation

First and foremost, in order to combat the issues that the Meadow Creek Golf Course is facing, a general scope is needed to fully outline various responsibilities and tasks that must take place for the success of the project. The core pieces of the scope includes: Conducting preliminary desktop and field investigations to confirm drainage pathways and site conditions, perform a watershed assessment and hydrologic/hydraulic (H&H) modeling, analyze alternatives for cost-effective practices, create a feasibility report, develop schematic design drawings and accompanying

technical specifications, create an updated cost estimate with a Basis of Design report, address permitting concerns and finalize schematic design packages for client review. Currently, the team is completing data collection and continuing to monitor the expansion of the head cut at hole 17. In the little time that our capstone team has been involved, there has been major expansion, the most significant being following Hurricane Helene. During the immense rainfall of Hurricane Helene, the Rivanna River had flooded to the point that the entire tee box and fairway was underwater. The only visible portion of the hole was the upper part of the green and the flag that marks the hole. Once the water receded, the expansion of the head cut was quite visible. As the site visits and data collection begins to wrap up, feasibility reports will be created to ensure the economic viability of this project. With this, the preliminary design phase can be initiated. During this phase, initial designs will be discussed and decided on to determine the best possible solution before moving forward to the final design package.

Early on, the capstone team has used multiple technologies to better understand the flooding of Meadow Creek. The first being a remote controlled device, which was deployed to roll into the concrete pipe at the base of the green on hole 17, to observe its structural integrity. This specific pipe is designed to be an outlet for water flow from Meadow Creek into the Rivanna River. Ultimately, the evidence provided by the footage suggests that there is a major structural collapse about 135 feet into the pipe. This major collapse certainly could be a driving force for the flooding taking place. In addition to the exploration robot, drones have been used to monitor the conditions at the project site. Aerial photos are taken weekly so that expansion rates can be tracked, as the head cut steadily encroaches on the golf course. Dimensions of the head cut and the distance from various points on the golf course can be easily detailed using the high quality

imagery of the drone. Having detailed imagery significantly improves preliminary designs by improving the overall perception of the problem for all parties involved.

Emerging Technologies' Impact on Sustainable Practices

The STS research is to learn how emerging technologies are transforming the construction industry by driving improvements in sustainability and waste reduction. With the construction sector being a major contributor to environmental degradation through resource consumption, energy use, and waste generation, innovative tools such as Building Information Modeling (BIM), drones, and 3D printing are offering promising solutions.

One of the most impactful areas of these technologies is in waste management. According to the U.S. Environmental Protection Agency (EPA), reducing construction and demolition (C&D) waste not only conserves landfill space but also lowers environmental pollution and promotes economic growth by creating jobs in the recycling industry (Sustainable Management of Construction and Demolition Materials, 2024). BIM plays a critical role here by enabling precise material planning and tracking. BIM's ability to simulate construction processes digitally allows for more accurate predictions of material needs, reducing the risk of over-ordering and minimizing waste. This technology also optimizes scheduling and project coordination, which reduces errors and the need for rework—both significant sources of waste (Reducing Construction Waste through BIM Prediction Modelling, 2024).

Furthermore, 3D printing also contributes significantly to waste reduction. This technology allows for the creation of structures using recycled materials, such as demolition waste. A study on geopolymer-based 3D printing showed that it offers lower carbon emissions compared to

traditional materials like Portland cement, while also minimizing waste by printing only the necessary amount of material (Alim Khan, 2023). Although energy use remains a concern in some aspects of 3D printing, the technology presents long-term sustainability benefits, especially as it becomes more energy-efficient and the materials used become increasingly eco-friendly. Additionally, 3D printing supports a more sustainable approach by allowing for precision in material use, reducing excess and waste.

The integration of drones in construction further promotes sustainability and waste reduction. Drones equipped with high-resolution cameras and GPS technology enable real-time site monitoring, topographical mapping, and progress tracking. By capturing precise aerial data, drones help identify inefficiencies, assess environmental conditions, and ensure compliance with sustainability guidelines. Continuous monitoring allows project managers to make informed decisions and avoid costly mistakes that could result in material waste or delays. Drones also support energy-efficient construction practices by optimizing site layouts and assessing factors such as solar exposure for future energy needs (Koetsier, 2022).

In addition to reducing waste, these technologies foster economic and societal benefits. The widespread adoption of sustainable construction technologies drives the growth of new industries, creating jobs and fueling local economies. Deloitte argues that the rise of manufacturers focused on green technologies could significantly boost the economy, particularly as more companies embrace sustainability in construction (Sustainable Construction and Buildings, n.d.). Technologies like BIM and drones improve project efficiency, which reduces overall costs and construction timelines. While the initial investment in these technologies can be high, the long-term benefits—such as lower material costs and enhanced efficiency—ultimately justify the upfront expense.

Technologies like BIM and drones also help optimize resource use throughout the construction lifecycle. BIM, for example, supports a circular approach to construction by enabling the reuse and recycling of materials. The detailed models created by BIM can track materials throughout a building's life, ensuring that they are used efficiently and repurposed when possible (The Role of Building Information Modeling (BIM) in Reducing Construction Waste, 2023). Similarly, drones aid in real-time tracking of project status that allow for improved aerial perspectives that would not be possible without their services. This combination of digital modeling and on-site monitoring enhances sustainability efforts by streamlining workflows and reducing inefficiencies.

To analyze these emerging technologies, the study will begin with a review of existing literature and case studies, comparing projects that adopted these technologies with those that did not, to assess their effectiveness in reducing waste, improving efficiency, and lowering environmental impact. Evidence will be collected through quantitative data—such as reductions in material waste, energy consumption, and project costs—and qualitative insights from industry partners. This will include feedback on the challenges and benefits of using these technologies in real-world settings. Key data points will involve waste reduction metrics, cost savings, and the reuse of materials enabled by the technologies. Environmental impact data will be interpreted through a Life Cycle Assessment (LCA), comparing the overall sustainability of traditional methods with technology-driven approaches.

Conclusion

In conclusion, both the Meadow Creek Golf Course project and the STS project underscore the importance of sustainable practices in mitigating environmental challenges. The stormwater

management issues at the golf course highlight the critical need for improved infrastructure to address water quality, erosion, and sedimentation. Technologies such as BIM, drones, and 3D printing present promising solutions not only for designing more efficient stormwater systems but also for advancing sustainability in the construction industry. These technologies offer precise, data-driven tools for reducing waste, improving resource management, and optimizing project efficiency. By leveraging tools like BIM for material planning, drones for real-time monitoring, and 3D printing for sustainable construction, significant strides can be made in addressing both local environmental issues, like those at Meadow Creek, and broader challenges within the construction sector. Integrating these technologies into future infrastructure projects can lead to long-term environmental, economic, and societal benefits, promoting healthier ecosystems, reduced carbon emissions, and more sustainable construction practices.

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