Howe Island Case Solutions

Team Neptune - Zain Glover, Gawthaman Senthilvelan

Kingston, Ontario

January 27, 2024

Howe Island Water Management

Currently, the changes in precipitation and weather patterns have caused issues regarding agricultural runoff and drought. The proposed solution addresses these issues by preventing the flow of contaminated water to the river and wetlands, by implementing a modernised moat. Through this re-engineering design, a source of perpetual hydration for the farm's crops and house will be provided.

In order to combat agricultural runoff, a leading cause of the degradation of the island's wetlands, the solution seeks to implement a moat surrounding the soil areas of the farm, preventing the water containing pesticides and other chemicals from entering the river (Figure 1, Appendix A). The given topography of the farmland suggests that this area resides on a slope, thus the excess water in higher precipitation months can easily funnel into the moat [1]. To ensure long-term safety of the system, the flooring of the moat will be covered with an HDPE (high density polyethylene) material, affirming the longevity of the solution, while also ensuring scalability [2]. A material fatigue analysis of the HDPE should be conducted to ensure that the "torrential downpours" of rain do not harm the system.

The moat's flooring is made of 2.5° ramps at all 4 sides in order to effectively funnel incoming precipitation to the middle portion of the south-most side (Figure 2, Appendix A). Here, precipitation will be pumped by a drilled water pump and directed to polypropylene cisterns for storage by a rubber hose. Having durable cisterns is pivotal in ensuring long-term effectiveness of this system. Since the collected precipitation will account for over almost all of the crop's water requirements, the pre-existing well and filtration system can be completely allocated to the farm house.

Due to the amount of water needed for plants during lower precipitation months, the island would need approximately two 1000 gallon cisterns. A rubber hose would channel water into one cistern at a time, and once it has reached capacity, a reflective infrared sensor attached to the top of the inner cistern housing would emit a signal to an external monitor to display that the tank is full (Figure 3, Appendix C). This will signal for the farmer to close the handle on the corresponding tank valve and to open the next one. Infrared signals work on the principle of infrared light reflection, such that the sensor tip emits light within the cistern and measures the intensity of the reflected light to ascertain the water level [3]. A reflecting infrared sensor was chosen in comparison to other types due to the ease of installation and fast response times [3].

There are some limitations to this system however, as there is no guarantee that the land is strong enough for building a significant moat around its perimeter. An on-site analysis would need to be done to ensure the safety of both the environment and the family living there. Additionally, with such a significant change in the landscape of the farm, it is crucial that the farmers consent to this new system.

Apart from obscure deterrents, implementing this system would greatly improve the environmental conditions of the land while staying well within the proposed budget for the project. Having the moat around the soil areas will not only prevent agricultural runoff, but also promote healthy plant growth. Surrounded by water year-round, the crops will stay hydrated and nourished throughout the entirety of the harvesting season. In regards to the long term economic consequences, the system will require some maintenance checkups as the farmers will need to ensure the water pump and the sensor are functional. However due to the excess budget, this money can be used to fund this maintenance (Appendix B). However the reinforcement of HDPE, and other durable materials ensures that the system will work in the long term.

Howe Island Ferry Transportation

Currently, the increasing population of Howe Island demands a more efficient method of transportation for its crossings. The current ferry system, which is slow, high-maintenance, and environmentally damaging, is in need of an upgrade [4]. To solve this issue, a cable-stayed bridge will be implemented at the West Crossing to ensure the issue’s permanent solution.

The design of the project is a simple one-lane cable-stayed bridge, with a traffic controlled roundabout on each of the bridge's sides (Figure 5, Appendix C). To account for the large weight forces and bending moments, the bridge will be made of steel to ensure its longevity and safety [5]. Since the bridge is only one lane, traffic control persons will be placed on either side of the bridge to direct traffic and avoid all collisions.

In the short-term the economical impacts may seem severe, as the project would cost approximately 8 million dollars to execute, however the various strengths in this particular solution, that other designs cannot achieve, justify this price (Appendix D). With durable steel beams, this design would undoubtedly last for decades with limited maintenance costs. Cable steel bridges are one of the fastest-to-build and material-effective types of bridges today [6]. With the continuous rise in population, creating a new ferry is not justifiable as it can not be guaranteed that the increase in capacity can be managed. This means that over time, the ferry may once again run into the same issue. With our calculations, the bridge can withstand forces far greater than 65 metric tonnes (Figure 4, Appendix C). This implication suggests that even if the population size continues increasing and the demand for a form of transportation at the West Crossing surges, the bridge, though costly, ensures to account for this matter. Furthermore, the bridge would incur smaller maintenance costs compared to the ageing ferry (approximately 4% vs. 10% respectively) [7] [8].

Additionally, the solution is more environmentally friendly than the current method used by the Howe Islands. With the ageing ferries, the pollution emitted from the ships will inevitably harm the surrounding environment long-term. Contributing to the greenhouse effect and other environmental concerns, ferries typically use diesel fuel which are a source of ground-level ozone and particulates [9]. The implementation of a cable-stayed bridge is superior in regards to societal factors as well, since during colder temperatures, ferries can get trapped in the ice, as illustrated by the 60 cm of ice in winter months. This causes various delays and travel interruptions that would affect the livelihood of the Howe Island civilians [10]. The bridge would not face this consequence, as the icy conditions of the lake would not affect the transportation of its residents.

Appendix A - Schematic

A full view of the projects design can be found from this Autodesk TinkerCAD link below:
https://www.tinkercad.com/things/6w9pygZBcbV-oec-case-1/edit?returnTo=%2Fdashboard&sharecode=NpF8nLKf6f2FCR_5BmXihABX03diiB-vU1A6_s_sCC4

Note all figures below were created using TinkerCAD, and are not to scale. The size of the farmland has been greatly reduced to emphasise the implemented design.

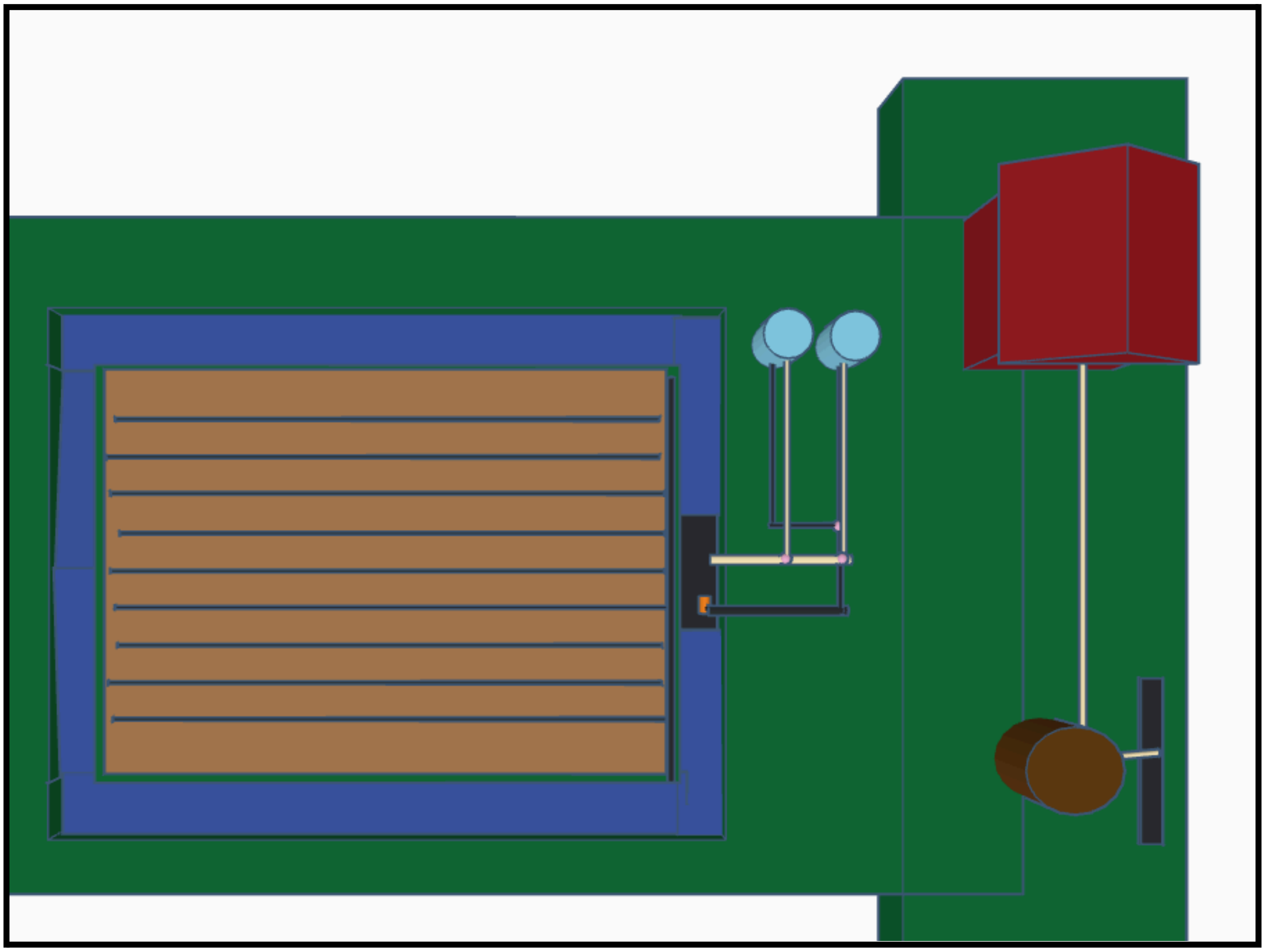

Figure 1. A bird's eye view of the farm and implemented moat. Note the image is not to scale.

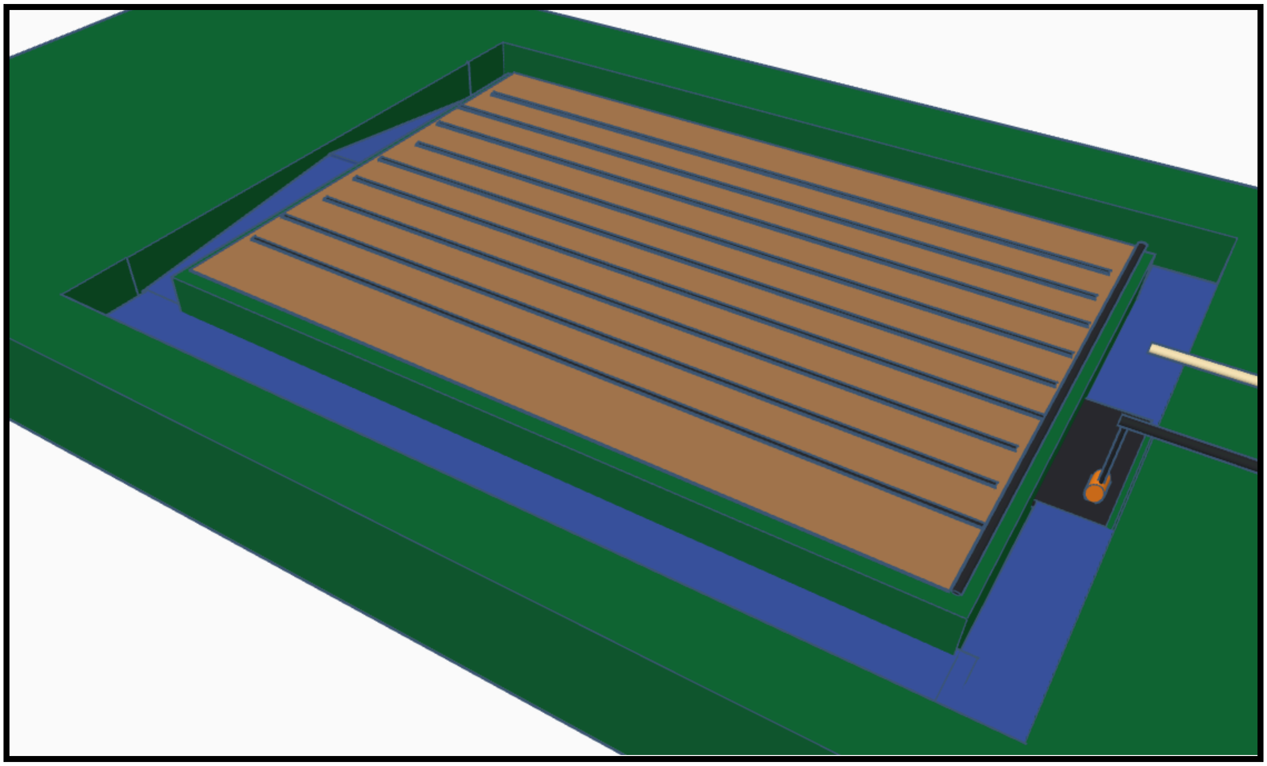

Figure 2. A view of the angled concrete ramped sections inside the moat, highlighted blue.

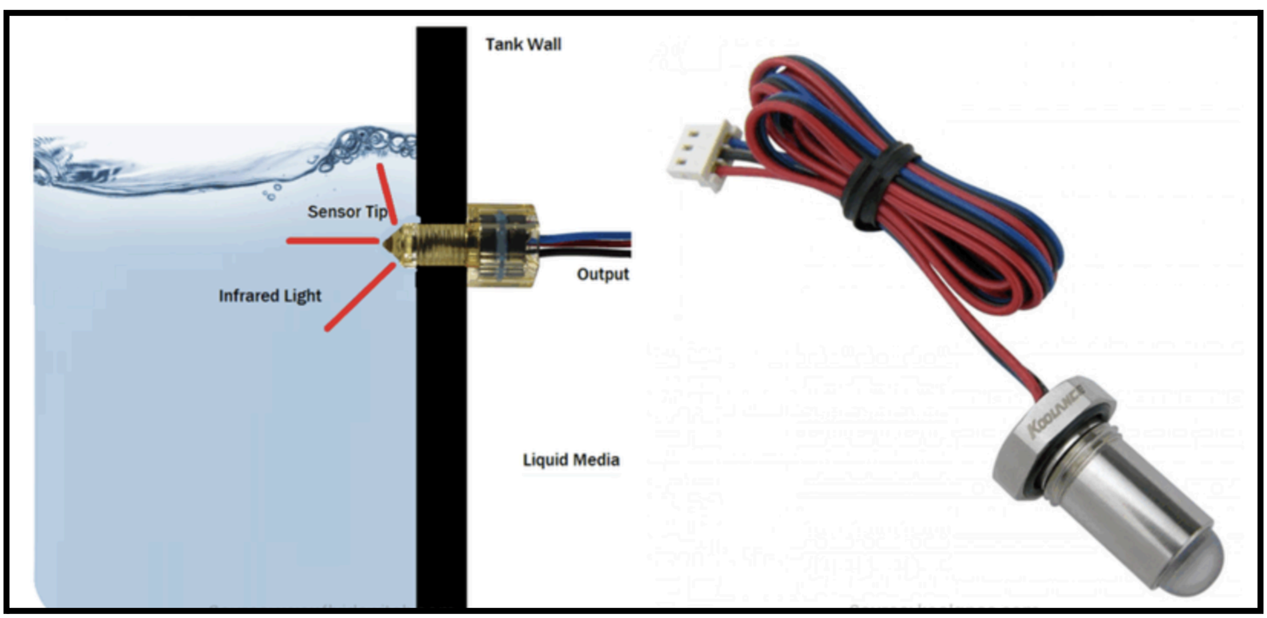

Figure 3. An infrared water sensor. Taken from [3].

Appendix B - Approximate Total Cost of Case 1

Item	Cost (CAD)	Source
Polypropylene Cistern (x2)	5764	Cistern Pricing
Rubber Hose (150 m) (x2)	250	Rubber Hose Pricing
Valves (x2)	14	Valves Pricing
HDPE Moat Liner (571m^2)	1920	HDPE Liner Pricing
Sensor (x2)	110	Infrared Water Sensor Pricing
Pump	75	Standard Water Pump Pricing
Total Cost	8133	N/A

Appendix C - Bridge Diagrams

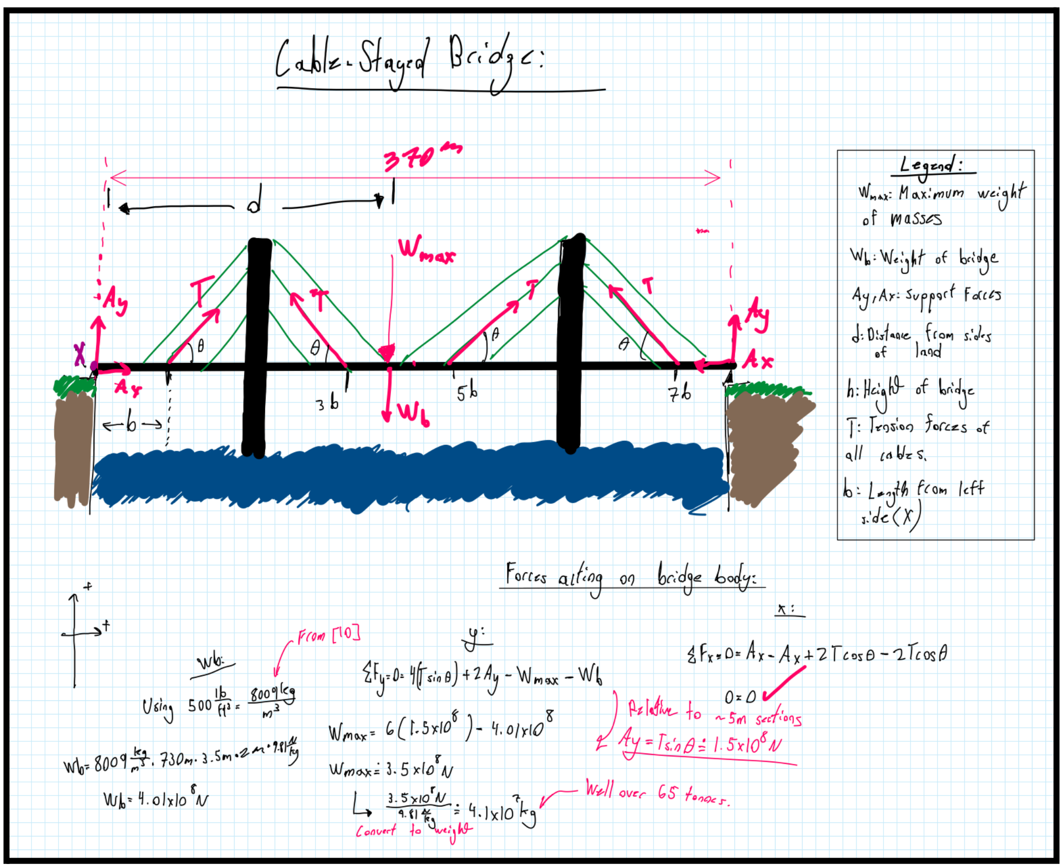

Figure 4. A statics analysis of the cable-stayed bridge. The weight constant for the weight of the bridge is taken from Arete Structures [11].

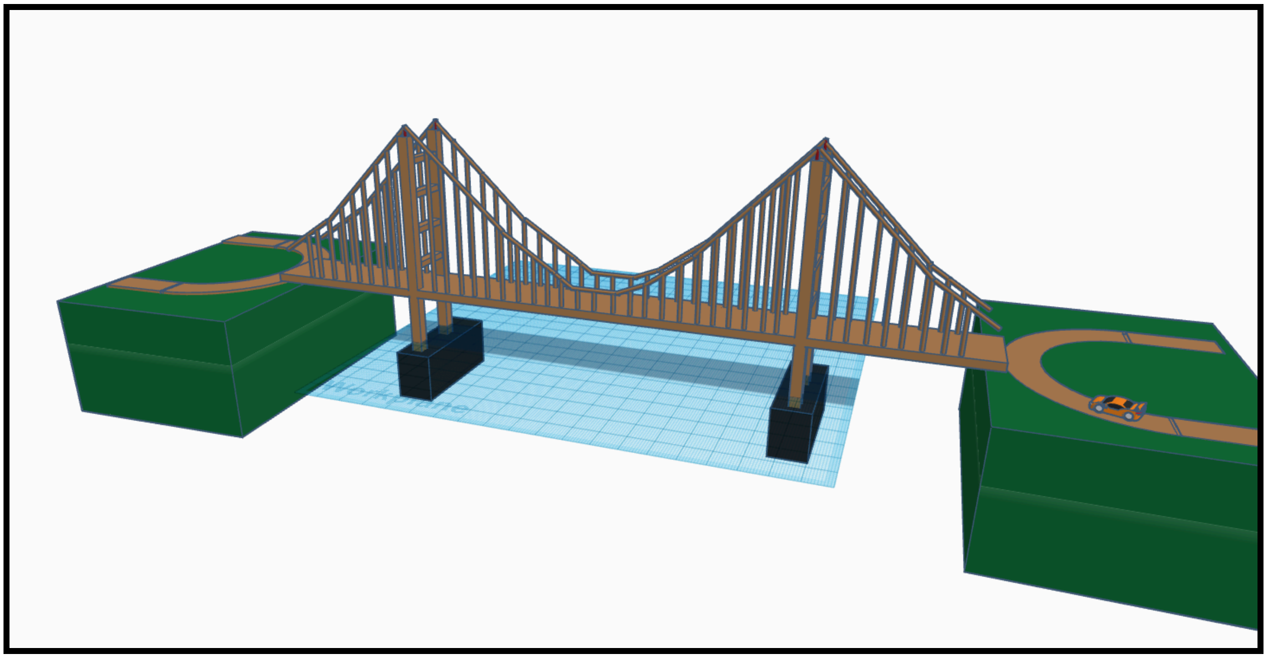

Figure 5. A TinkerCAD schematic of the bridge and surrounding area. Adapted from a community design.

Appendix D - Bridge Cost

According to the Detroit River International Crossing, Cable Stay bridges can cost between $4,500 - $5,000 USD per square metre [12]. If our bridge spans 370m, and is 3.5m in length, our bridge will cost approximately $7,867,125 - $8,741,250 CAD.

References

[1] OEC. “OEC 2024 Re-Engineering Case 1 Official Package”.

[2] “What is HDPE?,” ACME Plastics, Inc., https://www.acmeplastics.com/what-is-hdpe (accessed Jan. 27, 2024).

[3] Matan, “Infrared Level Sensor: How it works, application & advantages,” Electricity, https://www.electricity-magnetism.org/infrared-level-sensor/ (accessed Jan. 26, 2024).

[4] OEC. “OEC 2024 Re-Engineering Case 2 Official Package”.

[5] “Best Material for Bridges: Steel,” US BRIDGE, https://usbridge.com/best-material-bridges-steel/#:~:text=Best%20Material%20for%20Bridges%3A%20Steel,-Steel&text=Its%20strength%20and%20permanence%20are,as%20wood%2C%20concrete%20and%20stone.

[6] “Cable Stayed vs. Suspension Bridges”, Port of Long Beach, https://newgdbridge.com/cable-stayed-vs-suspension-bridges/#:~:text=They%20require%20much%20less%20steel,construction%20materials%20than%20suspension%20bridges.

[7] Marine Depot Direct, “20 boat maintenance statistics – the true cost of boating,” Marine Depot Direct, https://www.marinedepotdirect.com/blog/boat-maintenance-statistics (accessed Jan. 27, 2024).

[8] J. D. Cook, “Maintenance costs,” John D. Cook | Applied Mathematics Consulting, https://www.johndcook.com/blog/2010/03/31/maintenance-costs/ (accessed Jan. 27, 2024).

[9] “U.S. Energy Information Administration - EIA - independent statistics and analysis,” Diesel fuel and the environment - U.S. Energy Information Administration (EIA), https://www.eia.gov/energyexplained/diesel-fuel/diesel-and-the-environment.php#:~:text=Diesel%20fuel%20(refined%20from%20crude,level%20ozone%20and%20particulate%20matter. (accessed Jan. 27, 2024).

[10] “Ferry gets stuck in ice off the coast of nova scotia: Watch news videos online,” Global News, https://globalnews.ca/video/3363808/ferry-gets-stuck-in-ice-off-the-coast-of-nova-scotia#:~:text=Description&text=April%207%2C%202017-,A%20Canadian%20ferry%20carrying%20more%20than%20200%20passengers%20became%20trapped,ice%20for%20the%20stranded%20ship. (accessed Jan. 27, 2024).

[11] Pedestrian Structures, “FRP VS. STEEL PEDESTRIAN BRIDGE COMPARISON,” Arete Structures, https://aretestructures.com/frp-steel-pedestrian-bridge/#:~:text=Steel%20Material,and%20during%20the%20construction%20process.

[12] “Cable Stay Bridge.” Detroit River International Study, https://www.partnershipborderstudy.com/pdf/Cable%20Stay%20Bridge_2.pdf