ENGINEERING

McMaster University

Source Water Monitoring:

Final Project Report

ENGINEER 2PX3 – Integrated Engineering Design Project II

Tutorial 3 (Design Studio Section)

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Executive Summary

Ensuring source water quality is crucial to safeguard ecosystems and human health. In recent years, we have seen an upsurge of toxin-emitting cyanobacteria in fresh bodies of water, which, if left unchecked, could poison crucial water sources for many rural communities. Existing satellite-based systems are currently in place to monitor these blooms and alert local water processing facilities, but these lack the accuracy to detect emerging blooms and survey smaller bodies of water. We have designed a drone-based algal bloom detection system for the Rainy Lake-of-the-Woods Basin that will obtain higher quality images and employ state-of-the-art image processing to detect these blooms as early as possible while minimizing our impact on the environment. This system will consist of long range fixed-wing drones that will fly in between control stations integrated into several of the region's water processing plants. The image map obtained from these flights will then be processed to look for new algal blooms, and potential areas of concern will have their water sampled by our drones for further confirmation, with the relevant water processing plants being notified of all positive results. This system is illustrated visually in Figure 1:

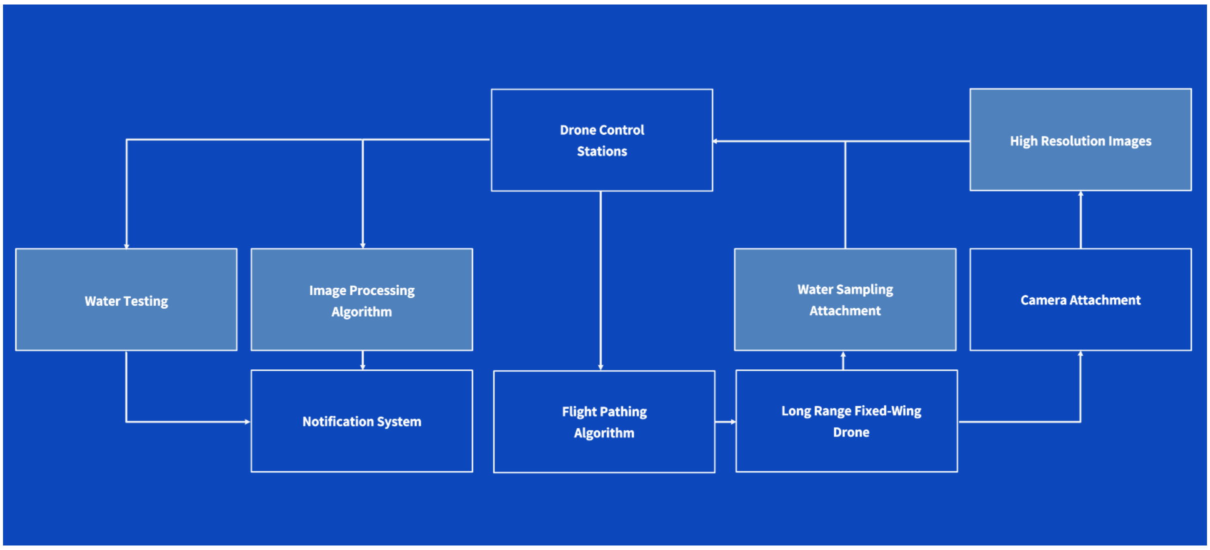

Figure I. System Process Flowchart

Although the operation of this system will be smooth, there are a number of preliminary actions still to be taken, including the purchase and modification of the drones, the construction of the control stations, the development of the image processing algorithms, and the procurement of the relevant certifications.

Introduction

The impacts of climate change are becoming increasingly apparent and are continuing to rise in severity as time passes. Algal blooms are on the rise in Canada because of factors like climate change, which creates nutrient-rich, warm bodies of water that promote their growth. Communities rely on freshwater resources, but harmful toxins from Cyanobacteria can cause various health issues in humans and the environment. Existing water monitoring systems rely on satellite imagery which can be unreliable for smaller more remote settings like the Rainy Lakes. Stakeholder analysis is crucial to the integrity of the project, as all decisions must consider the needs of our various stakeholders. Our client is the most impactful stakeholder in the project, as the source water monitoring system is directly based on their direction. In the given opportunities, we discussed with our client the necessary information to further improve our project, like the region specifics and budget ideas. We also deduced through discussion with our client that around a 95% accuracy rate is feasible with today's technology. There were further client considerations to be made, as the client made requests on a rolling basis, and required discussion as the project moved forward. Aside from our direct client, we have several other stakeholders who are affected by our project. Water companies require information regarding the monitoring system and how it will be implemented as they will also be working in the monitored regions. They will need to know how often the monitoring is done and how invasive it will be. The government is a major stakeholder, as they impose many constraints onto the project, such as altitude constraints. They will be concerned with keeping the airspace clear, as well as building regulations for drone recharging bases. Constraints are avoidable with strong planning. The amount of local population may be low; however, they are still a stakeholder in this project. So too is the local wildlife in this region. Locals will not appreciate feeling their privacy is breached, and both stakeholders will be affected by noise pollution and potential drone failure. Again, many stakeholder problems are addressable with simple operational planning (scheduling, routing).

The project goal is to create an effective drone-based monitoring system to survey the Rain-Lake of the Woods Basin for algal blooms and report its findings to local water agencies. The objective of the system is to detect algal blooms at a higher degree of accuracy than pre-existing methods. This will be through drone imaging and machine learning technology. The system will be unobtrusive to local environment and residents. Using convolution neural networks and machine learning, the drone will follow a maximally efficient path, while following a frequent schedule during the time-periods where algal blooms occur most. Multiple drones will be featured as well as multiple bases/stations throughout the basin, located alongside water plants. Drones can dock, charge and perform complex image processing here. An encrypted communication system is also to be in place for communication of information to the relevant parties for detection. An area outside of the scope of our project is physically building this system. Although have conducted all necessary research and gathered ideas and information, the physical system will not be made. Therefore, no hands-on experience will be achieved, as we are responsible for the blueprints only. The constraint to this system revolves around the legality of our processes. So, we will constrain to exclusively ensuring we image only the bodies of water needed. The system must also abide by all regulations set in place. This includes Municipal, Provincial, Airspace, and more. The monitoring system must be within a reasonable budget and utilize currently available technology. The monitoring system must survey accurately and must detect algal blooms if they exist. We are operating under the assumption that all technology needed will be available. We also assume all technologies needed will integrate without error. More assumptions are that the government will grant permissions when needed, and that algal bloom properties (size, colour, cause, etc.) will not change.

Decision Process

Throughout the project, many decisions had to be made regarding the various aspects of the water monitoring system. The initial recommendation was to have a fixed-wing drone, with multiple bases littered along a circular flight path. The drone would follow this path and when above a specified body of water would take a picture. This initial design heavily improves upon current water monitoring methods, which use satellite imaging. We decided upon a camera which has far greater specs, netting a 30000% improvement [cite this]. Once the drone would arrive back at the next base, it would then employ a convolution-based algorithm for algae detection. The information would then be communicated to the necessary agencies.

This initial recommendation is very vague and did not initially specify in enough detail some aspects of the design. However, with certain alterations, considerations, and decisions this design can be significantly improved. The first area of improvement was the model of the drone. It was recognized that a fixed-wing drone would be capable of fulfilling the need to have long flights, and low power consumption while being very quiet. However, it would require a trade-off in the ease of construction and base footprint as a runway would be needed. This would not be feasible with the current base setup. The decision matrix in *Table I.* was used to finalize the drone model. Range, noise, and energy were the most important characteristics of the drone that was to be used. This is mainly a consideration due to the socio-cultural and environmental layers of PERSEID. A lower noise index will create less interference with the local population as well as local wildlife. The higher range is positive for the regulatory because the drone must be able to fly longer ranges if certain airspace is ruled out. The ruled-out airspace can be seen in *Figure II.* as the flight-path will likely change very often due to the nature of these restrictions. Energy consumption was a good consideration for the environmental layer because lower energy consumption is generally eco-friendly. Reliability and overall ease covered things like drone reliability, construction, and other changing requirements. *Table I.* was used to decide upon a fixed-wing hybrid VTOL model drone. This would allow for vertical take-off and landing, meaning there is no requirement for a runway. It also means the drone has more overall reliability as there are propellors always available for use. It has the benefits of a fixed-wing drone combined with the maneuverability capabilities of a quadcopter.

	(A) Decision to evaluate:	Drone Model			
	Score (auto-calculated):	27	77	32	81
	(D) Options:	Multi-Rotor	Fixed-Wing	Single-Rotor	Fixed-Wing Hybrid VTOL
(B) Factors of this decision	(C) Rank of Factors (0-3)	(E) Meets need? (0 - 3)	(E) Meets need? (0 - 3)	(E) Meets need? (0 - 3)	(E) Meets need? (0 - 3)
Range Capability	5	2	5	2	5
Noise Pollution	4	0	5	2	5
Energy Consumption	4	1	5	2	5
Size/Weight	1	4	3	3	4
Reliability, Overall Ease	3	3	3	1	4

Table I. Decision Matrix for Drone Model

Figure II. Areas of Concern for Flight – Orange: Need Permission, Yellow: Caution

Another change to the initial recommendation is the layout and specifics of the drone bases. After considering the socio-cultural layer of PERSEID it became apparent that numerous random base locations in the area would not be perceived well. This would also be very taxing environmentally, as the construction would have a major footprint. There would then be a struggle to staff the locations, as there is a legal requirement to do so. Considering the socio-cultural, environmental, and regulatory layers of PERSEID aided the decision to entirely change the base layout. It was decided that integration with the various water plants would be ideal for our monitoring system. If the system can be integrated alongside pre-existing water plants in major areas as seen in *Figure III.*, the construction footprint reduces significantly. This optimizes our system is accordance with the environmental layer. Next, the staffing issue is solved by this potential partnership due to the more accessible location as well as more employees available. This is beneficial to avoid legal troubles in accordance with the regulatory layer. Finally, the bases will be out of the way from any locals, making a positive difference socio-culturally. The specifics of the drone bases were also finalized. The bases will have a platform for the drone to land on, which will wirelessly charge the drone through pin contact with the platform. This decision was made to reduce the need for manual interaction and ensures that the drone will always be prepared to fly.

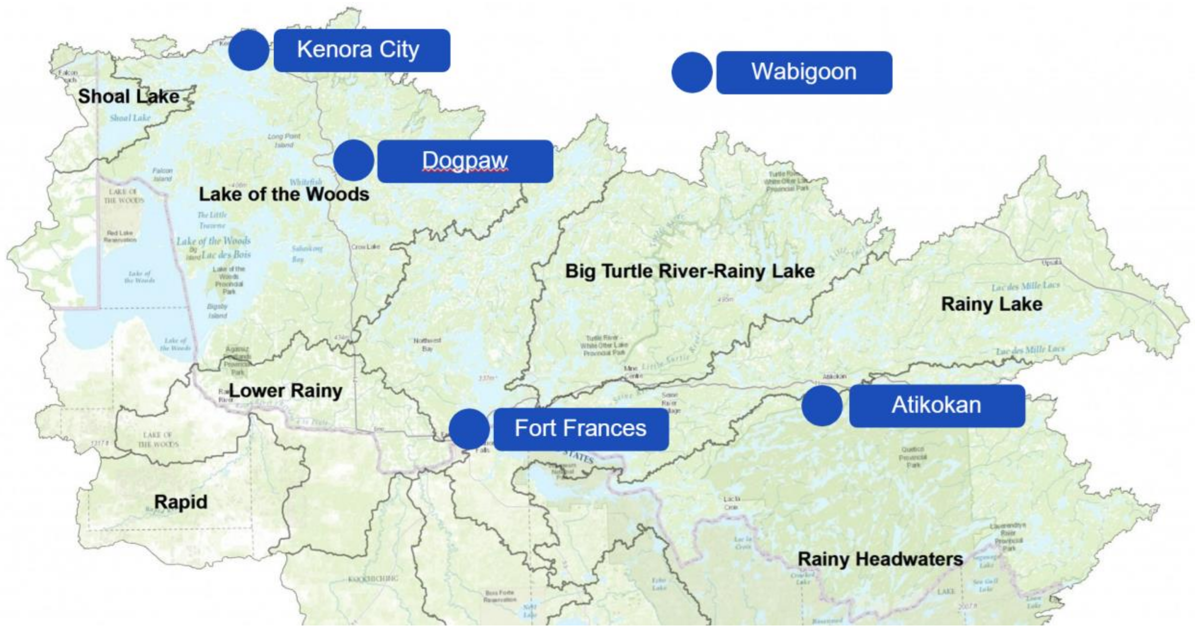

Figure III. Drone Base Layout According to Major Areas

When exploring solutions to and ideas for the design, it was important to specify how the system would detect algal bloom in the first place. Image processing by way of a convolution neural network would allow for identifying different spectrums of light that are present in an image. Cyanobacterial blooms are currently detected with similar deep learning technology on satellites with camera quality worse than this system. With an emphasis on the performance layer of PERSEID, it was important to identify the priorities of an image processing system. For this system it is crucial that the occurrence of any false negative is decreased. This is because although a false positive may be bothersome due to the need to physically travel and test, it does not have further complications. A false negative, however, has severe implications for the local wildlife, and safety of the water for consumption or use. When exploring the following empirical model of false positives and false negatives:

$$FP = \frac{1 - 2 * FN}{4 * FN + 2}$$

It was deduced that there is a trade-off in wanting to reduce false negatives. Ideally, it is preferred that both false positives and false negatives are completely minimized, however in real world applications this is not possible. With current technology the accuracy is in the 90% range leaning towards 100%. Therefore, our implementation should be within this same 90% range in terms of overall accuracy. This means FP and FN rates combined should be 10% or less. Furthermore, since we need FP to be greater than FN, our FN rates should be less than 5%, leaving our FP rate to fill in the gap to be slightly over FN. One more consideration to make is the use of multiple algorithms in conjunction. To do this, two or three algorithms which all comparatively minimize false negative rates in a low noise setting will be needed. Low noise is due to the high quality images that this system uses. After combining three algorithms, the final recommendation is to use a voting system. For example, if there are 2 out of 3 reports of an algal bloom, the decision will be that there is an algal bloom. Otherwise, the decision is no algal bloom. This could improve the FP and FN rates, as it takes into account the pros and cons of all the algorithms at once. By requiring at minimum 2 functions to agree on a positive report, the FP rate is reduced because the odds that both functions are reporting a FP is low. FN rate is also reduced because of the same reason. The odds that at least 2 functions make a false negative report is low. With this layered, voting, convolution system in place, the system is highly efficient and accurate and detecting algal bloom.

The overall system itself must also require some changes. Initially, an operational schedule seemed trivial as the drone could simply fly on a day-by-day basis around the base layout. However, with the new layout and the client request, the operational schedule may need to change. The client requested for one day per week where thorough maintenance could be performed on the drone. Incorporating this is a simple change to our design. When considering the regulatory layer, it was found that the drone would require some level of maintenance every flight according to the Canadian Aviation Regulations [1]. Due to the bases now being in more accessible areas with a proper staffing solution, the maintenance can be done every flight instead of just once per week. Therefore, the operational schedule does not need to change, and the drone can continue to fly every day during warmer climates when algal bloom is more common. During colder weather, we will have less frequent flying, only when the weather permits.

Another client consideration was to incorporate a water sampling system. This required far more research and changed a few aspects of the design. This water sampling system would significantly decrease the need for human interaction for testing. The challenge with collecting water samples is water damage and mechanical failure. However, finding a consistent and effective enough way to collect water non-mechanically is also a major challenge. Mechanical solutions are much easier to find. First, the possibility of use a hatch-like mechanical feature to collect water was explored. This was quickly scrapped due to the complexity of parts and the mechanical failure factor. The next possible idea was to use a scooping system in order to open a container and simply scoop the water during flight. This solution works in theory, however if put into use, there are far too many factors to consider, including mechanical failure, speed, altitude. To combat this mechanical failure, our team researched and developed testing compartments made of porous PVDF and cellulose compounds that absorb water samples and guide them through a μPAD. This binds with cyanobacteria, indicating a potential algal bloom. This non-mechanical system reduces the risk of water damage and has an efficacy of 87-91% in detecting cyanobacteria [2]. This decision was made over a mechanical system due the increased possibility of failure in the latter. This falls under the reliability decision factor for the drone. The drone could easily descend and collect the required water sample for testing. Using the VTOL technology, the drone could then ascend again as well as regain speed. The μPAD compartment is notably removable and will be changed by trained personnel once the drone has returned to the home station.

The client also requested to ensure the system has protection from data leaks and some sort of privacy protection. This was a new angle that we had not considered prior to the client's request. This also falls under the socio-cultural layer of PERSEID. To cover this request, the system was altered to have a level of encryption when transmitting data. This encryption can be done with a process called private key encryption, which uses an algorithm to encrypt or decrypt data. Therefore, only those who have access to these algorithms will be able to access the information. The data transmission will also only take place once the drone is safe and secure within a base. Furthermore, the physical bases themselves will be secure from any interference due to their integration with water plants. All the standard security will be available for use. The system will incorporate a record of access of the information, which is a simple but effective way to see who has accessed the data.

In the final weeks of the project, there was one final client request to consider. This involved two possible scenarios in which data collection could be outsourced to local residents. The options were to either only use the local residents, or to use them as a supplement to the current system. The latter was chosen. First, it was important to identify a list of relevant considerations. Quality control was the most major concern, as local residents cannot always be trusted if they are not given the correct training or information in the first place. It was also determined that this solution would be relatively cost effective because of the lack of drone usage or construction need. The main idea to incorporate this client request was to develop a database where local residents in unserviceable areas can submit data in the form of images. These images could be filtered to only use ones that are clear enough to run machine learning algorithms on. Another solution that can be incorporated alongside the photo database is the a water sampling system. If certain local residents are provided with the necessary training and information, they can also be provided with the μPAD filter kits to test water themselves. Information from this physical testing can be forwarded to the system database where the necessary agencies can make further testing decisions.

Final Proposed Design

Upon completion of the design process, our team was able to present a highly sophisticated yet comprehensive design that aptly caters to all the elements within the allocated project scope. We will be setting up stations across of the Rainy Lake of the Woods region wherein the drone will take fly over and detect possible zones of algal blooms. Upon the drone's return flight, it will pause at flagged zones, testing the area for Cyanobacteria. Our proposed model—featuring not only physical additions but systematic enhancements—seamlessly integrates all necessary components while ensuring that each element aligns with our PERSEID considerations whilst maintaining a fundamental level of efficiency.

Performance and Environment - External additions

In concordance with our project objectives, we are not looking to build a UAV from scratch but rather improve upon an existing drone model. As a team we have decided to use the Delta Quad Pro, a commercial Fixed-wing drone model with built in vertical take-off and landing (VTOL) and imaging technology, as our base model. Our performance and environmental objectives require the drone and its subsequent assets to be lightweight, durable and constrained by a flight range of around 115km, the latter of which is the largest estimated flightpath necessary as displayed below.

$$FOS = \frac{Largest\ Allowable\ Flight\ Range}{Largest\ Flight\ Range}$$

$$1.3 = \frac{\mathbf{110.5\ km}}{85\ km}$$

Note: the largest distance between bases Wabigoon and Atikokane is approximately 85km

Base Delta Quad Pro Specifications			
Wingspan	240cm	*Battery Type*	LiPo
Standard Box Dimensions	118 x 49 x 40 cm	*Battery Capacity*	23Ah
Maximum Altitude	4000m	*Weight Including Battery*	5 Kg
Flight Range	100km	*Operating Temperature*	Between -20 and +45 Celsius
Material composition	carbon fibre composite + polymer composite		

Table II – base drone specifications prior to our additions [3]

Built from carbon fibre and reinforced polymer composites, the Delta Quad Pro houses a 2.4-meter wingspan and can fly up to 100km, *Table II*. However, in order to accommodate for the required factor of safety—a measure in place to account for flight pathing changes and meteorological discrepancies—a flight range of approximately 115km is required. In order to achieve this figure, the development of in-flight recharging techniques is necessary. We estimate that we can achieve this figure via the addition of flexible solar cells and PZT technology displayed in *figure IV*. The flexible design of the solar cells enables the panels to maintain a lightweight structure while still producing a high output. The upper shell of the model is convex in nature which is ideal for solar technology as that is where sunlight can be absorbed from maximum efficacy. Solar panels may face challenges in meeting optimal weather conditions. However, current technology demonstrates 70% efficiency even in shaded environments [3]. A drawback may be a decrease in output and efficiency of up to 8% with increased surface temperature [4]. Nonetheless, we estimate that the addition of these panels will increase our range by 10-15%; an advantageous trade-off adhering to our efficiency and lightweight objectives. In addition, in order to take advantage of the natural vibrations and bending that occurs during fight, we decided to employ stress-flexing piezoelectric devices to the cantilevers of our model as outlined in *figure III*. Stress flexing piezoelectric devices are added to the end of a fixed wing drone in order to generate electricity from the deformation caused by wing vibrations during flight. These devices would be placed at the trailing edge of the cantilever wings where they can capture the maximum amount of deformation energy [5]. This additional electricity can then be used to power the drone's systems or to recharge its batteries, thus increasing the flight range without adding extra weight or decreasing aerodynamic efficiency.

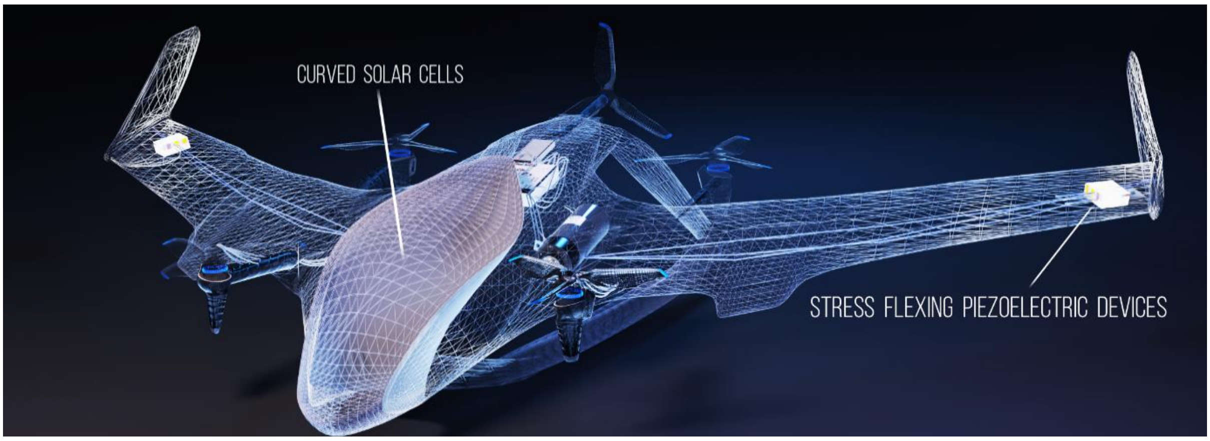

Figure IV - Grid View Drone Model

As per our client request, we have implemented water sampling and testing into our design. Our objective was to develop a system that allows for the absorption of the sample into the testing compartments immediately upon landing on the water, and subsequent analysis during the rest of the flight. This system is highly advantageous due to its efficiency and minimal reliance on mechanical components, we which considered as the greatest limiting factor. The external structure of the floats will focus on being aerodynamic, lightweight and more importantly, capable of absorption. Although a detriment to the aerodynamics of the model, we decided to have the floats located below the fuselage, separate from the drone as a preventative measure in order to avoid water damage and decrease the effects of backwash from the VTOL propellors. The drone will house two floats, located under the fuselage and will be cylindrically shaped with snouts on either end as shown in *figure IV*. This design is advantageous as the streamlined shape reduces drag, maximizes volume and stress distribution whilst minimizing corner loads which may propagate stress build-up and crack growth [6], which is ideal given our endurance object. As a result, this design allows for extensive repeatability which is critical due to the frequency of use necessary. The floats will contain the water sampling system described in the design process and have been designed such that the used μPAD filters can be removed and replaced by trained personnel upon re-entry to home base.

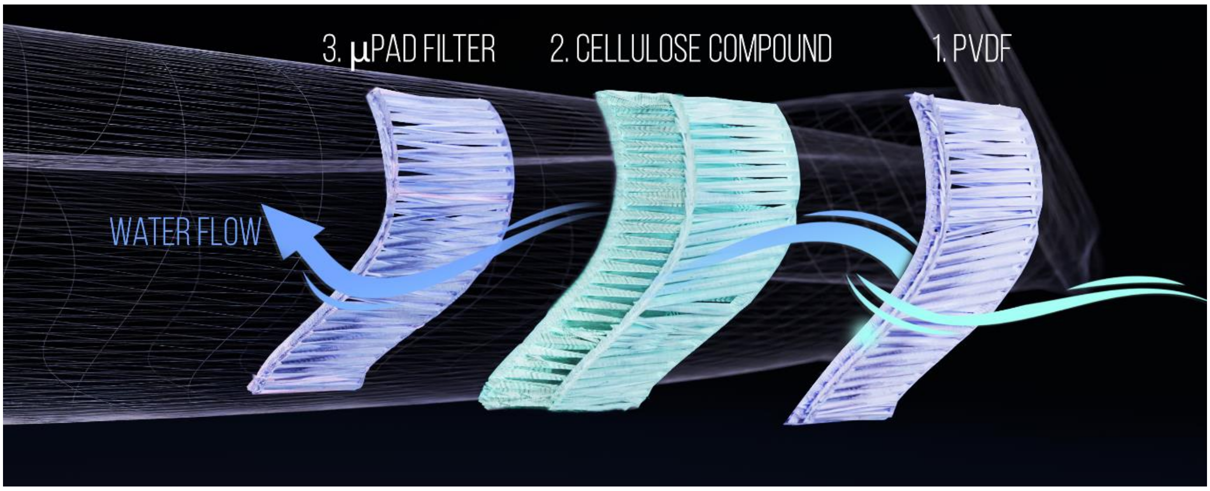

Figure V - Grid View Water Flow System

Performance and Environment - internal and systematic implementation

Internally, our final design will incorporate AI for enhancement of imaging technology and flight pathing. As the camera model, we have decided to use the Micasense RedEdge-MX, a multispectral camera system that captures images in five discrete spectral bands, including the visible, near-infrared, and red edge regions of the electromagnetic spectrum. This spectral resolution allows for the detection of specific reflectance signatures of different types of vegetation and other materials, including cyanobacteria in bodies of water. The camera will take photos as the drone passes over and will use convolutional neural networks to piece together a map of the region in question and will geotag areas where it considers contaminated. The decision making for what it considers contaminated is brought upon via the algorithm combination system mentioned during the design process. Convolutional neural networks will also be used to optimize flight pathing.

Regulatory and sociocultural considerations

Although performance and environmental considerations are crucial for a functioning system, the system can only be viable if regulatory and socio-cultural constraints are considered. In terms of regulation, we must consider governance for flight operations and flight pathing. Although we originally planned on having a fully autonomous system, Canadian Aviation Regulation requires at least one remote pilot per aircraft. As such we will request an SFOC-RPAS certification—which allows for increased flight heights and allows singular personnel to pilot up to 5 drones at a time [1]. In addition, we must also adhere to zoning laws during flight, as outlined in *Figure 1*. As per the nature of surveillance, we have requested special permission in case high risk locations are within the flight path or imaging. If this is not granted, we will use our AI operating system to blur out any areas in which we do not have permission to view. The progression of this system is dependent on the regulatory grants received and we will update it accordingly. In terms of privacy, we have also decided to obscure any local private property or residents. Finally, during the penultimate weeks of this project, we received one final client request regarding community involvement in the system. This request will not cause any changes to the system but rather be an additional accommodation. Residents in unserviceable areas will be given a drop-box wherein they can submit clear images of potential algal bloom—which will be filtered as a means of quality control by our algorithms. Additionally, if the area is determined as contaminated, we plan on developing simple μPAD filter kits wherein residents can check for algal blooms. The collected data will then be added to our system and forwarded to the relevant agencies.

Conclusions

Throughout the development of our source water monitoring system, much thought had to be put towards ensuring that the end product was feasible and able to be realistically implemented. This entailed thorough consideration of all the project's areas of impact. To do this, we used the PERSEID method, which stands for Performance, Environmental, Regulatory and Socio-Cultural considerations in Engineering Integrated Design. Within each of these broader areas, we focused on specific considerations that applied to our project and developed solutions for each consideration. The feasibility of the project can then be analysed based on how realistically each of those smaller solutions can be implemented.

The pressing technical concerns, beyond basic functionality, regard how our system will improve over existing satellite-based systems. To be feasible, our system needs to be more accurate and faster to detect algal blooms, in addition to reducing the need for onsite personnel required for water testing. Consistency is another major factor, as any system replacing satellite imagery will need to operate with at least the same frequency and predictability. System accuracy is an easily resolved concern, as the satellite currently used for algal bloom monitoring in Rainy Lake uploads images with a spatial resolution of 300m, meaning that each pixel represents 300 square meters. Even with the lowest resolution camera attachment for the drone we are using, our spatial resolution would be 1.31cm, which represents a 30000% improvement in accuracy and will facilitate the discovery of much smaller blooms before they increase in scale and pose a greater threat. Personnel requirement is one of our largest areas of concern with regards to feasibility, as the maintenance and piloting of drones will unquestionably require more operating staff than before. This increase in staffing, however, is mitigated through the integration of our control stations with local water processing plants. This allows us to source and train maintenance staff from existing water treatment plant employees, reducing the scope of our new hires to just drone pilots. Because of the increased accuracy and water testing capabilities of our system we will still be eliminating the need for inconvenient in-person testing, providing a convenient compromise to our initial problem. Consistency, the last major performance-based concern, also helps to address a client request, which necessitated that drone maintenance was performed at least once weekly. The integrated fault monitoring within the drone, frequent flight readiness checks, and the requested once-weekly thorough maintenance check by the water treatment plant workers will ensure that our drones will always be flight ready, and that the limitations on flight schedule will be dictated by weather alone.

Another large area of focus was the environmental impact of our system. It would be unreasonable for us to propose solutions that contribute to cleaner drinking water but detrimentally affect local wildlife and the general basin ecosystem. It is fortunate then that most of our large environmental areas of concern are addressed at least in part by other aspects of the system. Drones already have a low environmental impact, due to them being powered by electricity, and although their noise could affect local wildlife, the drone chosen for surveying and sampling features a fixed wing design, which is much quieter than its quadcopter alternatives. Drone collisions with local birds is also an important factor, but built-in lights, such as those featured on the delta quad, have been proven to greatly reduce harm to bird populations [7]. The construction, infrastructure, and operating power draw of the control stations was another source of concern, but integrating the stations into existing water processing plants reduces their impact by building on predeveloped land that already has the necessary power grid connections to properly support our system.

To properly ensure feasibility we must also account for the laws and regulations necessary for a drone system like this to operate, which in this case are dictated by the Canadian Aviation Regulations. Section IX, which covers unmanned aerial vehicles, gives standard guidelines for registering both pilots and drones, as well as requiring safety protocols in case of failure and land surveys of the drone take-off and landing areas before construction [1]. They also state that a pilot must be on hand who can take control of the drone at any given moment, meaning our system will not be fully autonomous. Most critical to the system is the Special Flight Operations Certification for Remotely Piloted Aircraft Systems (SFOC-RPAS), which will be required due to the long-range flights that send the drones beyond the line of sight of the pilot. These certifications also grant lenient permissions with regards to flight height, number of drones piloted by a single pilot, and restricted airspace. Our flight pathing will be regulatorily feasible as well, as our certifications allow us to fly in controlled airspace if permitted by local flight authorities.

For the system to be fully implemented, we also made sure to consider socio-cultural impact. Long range drone flights are not a common sight for most in Canada, particularly in such a rural region, and public reception to frequent flyovers might not be positive. The images taken by the drones will also likely raise concerns related to privacy and security, which will need to be mitigated. Our solution will be to implement a public information program, through which residents and users of the area will be fully informed of the purpose of the drones, the image filtering and analysis process, the encryption being done to all data transmitted, and the flight schedule. It has been shown that being informed of drone flyovers reduced negative reception considerably, further cementing this information program as necessary [8].

With the project deemed feasible and ready to implement, there are several important steps still to be taken, broken down in Table 3:

Relevant Area	Action Item
Control Stations	Contact water treatment plants to discuss control station integration
	Obtain contractors, develop plans for each control station
Regulatory	Obtain SFOC-RPAS certification from Minister of Aviation
	Contact airports, heliports in region to discuss flight coordination, permission
Staffing	Contact water treatment plants to train employees for drone maintenance
	Hire drone pilots, begin training / certification if not already obtained
Drone	Request quote from drone manufacturer
	Discuss drone modifications with drone manufacturer
Public Information Program	Hire third party PR firm to develop information program
	Contact provincial / national parks, news agencies, community centres, school boards, to discuss information program distribution
Software	Hire third party contractors to begin development of flight pathing, image processing algorithms

Table III. Relevant Areas and Corresponding Action Items

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Appendices

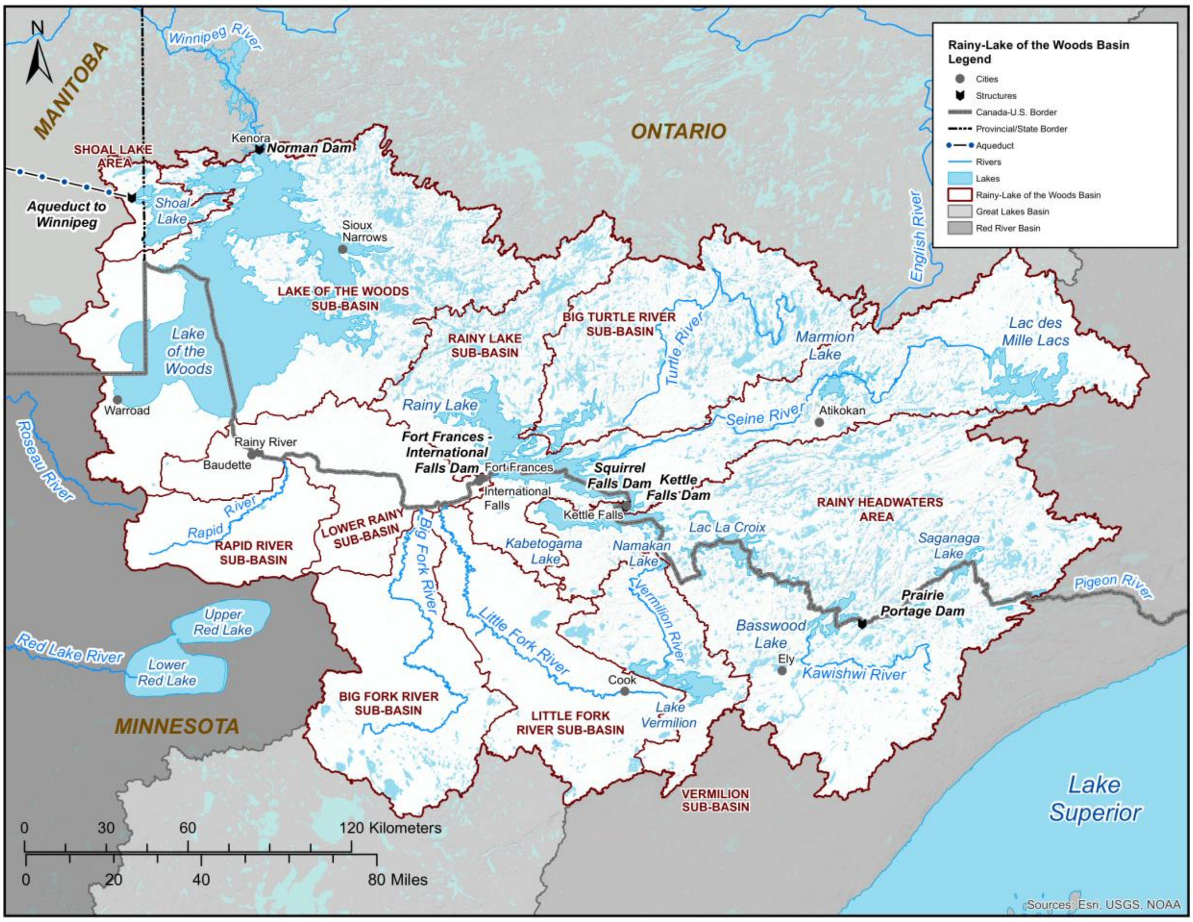

Figure VI. General Map of Rainy-Lakes Basin