UNIVERSITY OF Nebraska Omaha

What is Your Hydro-Reality?

AIRPORT STORMWATER DATA OBSERVATION & COLLECTION SYSTEM

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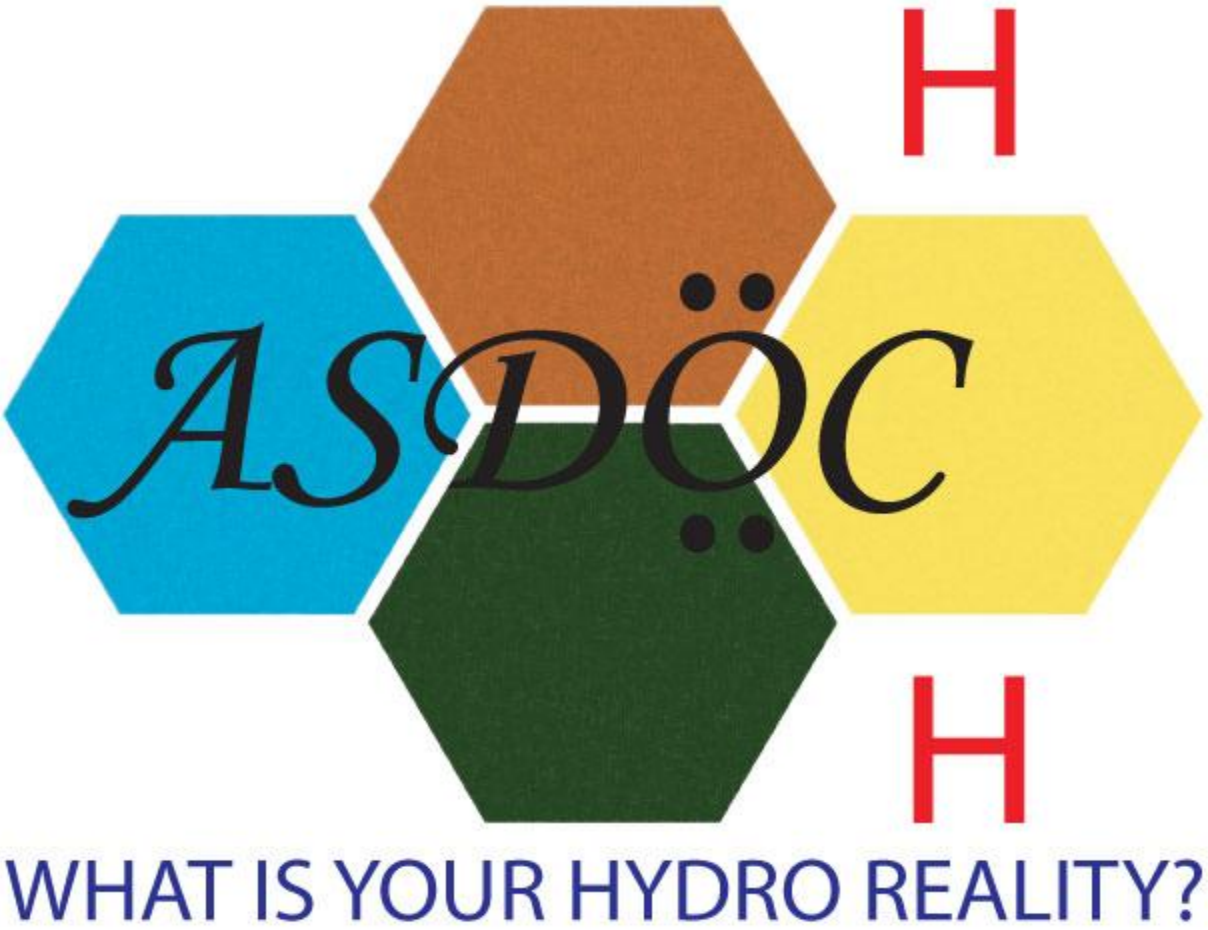
prepared by:

Matthew Hunt
Craig Murphy
Zane Smith
Arlene Steier
Derek Warneke

Faculty Advisor

Dr. David A. Byers, AICP, CM



by
Arlene Steier, Zane Smith, Matt Hunt, Craig Murphey, Derek Warneke

Executive Summary

Understanding the "hydro-reality" of an airport is the subject of this group study. Some, but not all major airports may be aware of their hydrologic situations leaving the rest and general aviation (GA) airports ill prepared for a significant hydrologic event.

The Federal Aviation Administration (FAA) recommends using five years of flood data for original design but does not address the issue of groundwater and runoff monitoring after construction and installation of on-airport drainage systems. This puts airports in the position of being unaware of immediate problems caused by broken drainage lines and pipes from on-field construction, freezing conditions and blockage from silt, organic matter or wildlife. Hazards can result from water on the runway causing braking issues, hydroplaning or erosion and weakening of airfield surfaces threatening collapse and the safety of aircraft operations in the affected area. Steep costs can be incurred in capital expenditures for repairs and for lost operations affecting all airport stakeholders.

As a group, the decision was made to address reduction of damage to airport property from a safety and cost standpoint as the basis the project hypothesis: the ultimate mitigation and solution to the problem of groundwater and runoff damage through monitoring. The approach will involve a system that provides monitoring of the groundwater and drainage for flow and volume both historically and in real time. The system will include an alert that can be delivered by text or email and can be customized as to when the alert is signaled; the system will be easily installed and used.

The Airport Stormwater Data Observation and Collection System (ASDOC System) program will focus on the cost, ease of acquisition of current market "turnkey" equipment and all have been taken into account allowing for use on any airfield stormwater drainage system.

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Problem Statement and Background

Water is one of the most insidious and destructive natural forces that exist. Whether the water is flowing or standing, it has the potential to damage surface and supportive materials. For many of the paved surfaces used for runways, taxiways and ramp areas, uncontrolled water hazards can present interruptions to aircraft operations. Specific to airports throughout the United States, pavement maintenance and repair is one of the largest operational and capital expenses.

The U.S. Department of Transportation (USDOT), through the Federal Aviation Administration, (FAA), issued Advisory Circular (AC) 150/5320-5D on August 15, 2013, addressing the subject of *"Airport Drainage Design,"* totaling 321 pages. Detailed within AC 150/5320-5D, are the subjects of regulatory and environmental considerations, design objectives, maintenance, drainage inlet design, swale sections and size, and material of pipes and culverts. Mathematical equations are given to approximate hourly flow across various surfaces both man-made and natural. Equations for inlet location and capacity of flow on grades, medians and embankments are included (Federal Aviation Administration, 2013a). This document embodies the foundation involved in the creation of stormwater drainage systems at airports. However, the Advisory Circular (AC) does not address guidelines for preemptive monitoring and warning of a potential event.

The AC goes on to state, "The guidelines and recommendations contained in this AC are recommended by the Federal Aviation Administration (FAA) for the design and construction of airport surface and subsurface drainage systems" (Federal Aviation Administration, 2013a).

Nowhere within AC 150/5320-5D is there anything about monitoring the efficiency or the proper working order of the airport stormwater drainage system once installed and operational. Usually, stormwater drainage systems that severely impact operations are given a priority. The Airport's Capital Improvement Plan (ACIP) states that an airport must "preserve and upgrade the existing airport system in order to allow for increased capacity as well as to ensure reliable and efficient use of existing capacity" (Federal Aviation Administration, 2000). Although there may not be statistical data on the exact number of airport stormwater system failures, it has been known to happen on a regular basis throughout the industry.

The design challenge undertaken by the University of Nebraska at Omaha (UNO), Aviation Institute (AI), is to identify the need and investigate the potential for a system that provides the ability for an airport to monitor stormwater runoff and groundwater levels. Once the airport stormwater monitoring system is installed, failure of the system due to debris accumulation in pipes and drains from obstructions created by wildlife, vegetation, ice jams or pipe failures will be detectable before any surface area on the airfield can be compromised and aircraft operations put at risk.

The goal of the University's five-person team was to conceptualize the development of an efficient monitoring system using monitoring equipment that currently exists on the market. This equipment will then be adapted to an on airfield use. Monitors would allow for data collection for historical, trending, and current real-time data for effective management. Any system failure detected in the airport drainage system at critical flow points could be immediately be noted and broadcasted.

The system, once installed, would report back using a wireless signal powered by a solar array to a data collection point with the ability to send a message to the designated individual in the case of a system failure or emergency.

It was the decision of the UNO AI team to research the feasibility of developing a reasonable, cost-effective solution to monitoring an on-airport stormwater drainage system. Keeping water off of and from under runways, taxiways and ramp areas is essential for safe and efficient aircraft operations on the airfield. A stormwater drainage monitoring system would be an effective tool for enhancing the safe use of the airport.

Literature Review and Problem-Solving Approach

There are many different issues that each individual airport (including NPIAS and other airports) face when developing effective drainage systems. Water is the enemy to almost every surface and material currently used for construction at airports. Additionally, at these locations throughout the country, water is unpredictable at times and in specific sites that may not have had a problem in the past, there is always potential for hazard. There are multiple complications associated with water that can affect operations that may frequently go unnoticed or not be foreseen. Key areas include the runway, safety zones, taxiways and other (less essential structures) like hangars, terminals, and Fixed Based Operators (FBO). This puts into perspective the importance of monitoring the quantity of water received at specific points throughout airport property, whether above or underground. Frequent hazards associated with draining failures for many regions across the country include periods of frozen subsoil with the potential of freezing low-level piping, blockages, erosion and sinking, flooding (which occurred locally at Omaha Eppley Airfield [KOMA] in 2011), and excessive runoff contamination. Every airport is very diverse in terms of its locational geography, climate and water table level. However, much of the data for these airports is non-existent and inflows or outflows are not tracked on a daily, monthly or even yearly basis. This difference and lack of evidence between each of these airports substantiates the importance of our design's feasibility. This is why data collection is very important to accurately meet the future and present needs an airport may have.

In summary of our project statement; the overall design intends to satisfy the needs of smaller general aviation airports and the importance of a stormwater failure detection system to find the input and output of water flowage at a specific point within airport property. To determine which equipment would qualify for our design, to accomplish this goal, involved extensive review of various literatures in hydrology and monitoring systems.

Foundational Resources

The largest complication with this project is our team's inexperience in engineering (specifically hydrology). Therefore, the project of creating an initial design was difficult. As an example to alleviate this burden, one of the initial concepts, in attempts to scale the design to an airport, was the examination of water monitoring systems in city planning. Drainage systems for cities are on much larger scale, but airports have been classified as "an independent city" and it was essential to find a basis for a foundational overview of our design.

Unfortunately, in terms of monitoring, many systems that cities utilize can be viewed as archaic, because of the lack of sophistication involved in their designs, and in certain communities, such a system may be nonexistent. Usually, in these circumstances, water blockage and other extreme events are reported after they happen. In existing systems, monitoring at pump or filtration stations, or individual home water-testing occurs, but in other areas outside of these instances there is little information to track water quantity. Another scaling issue involves the numerous miles of piping that is associated with even small or medium size cities, this generally is not the case with general or commercial aviation airports. This can lead to less costly and more effective monitoring of water. Most importantly, because of the limited systems in place within cities, both quantity and quality of water have the potential to be affected anywhere along the interconnecting water system without proper real-time notification. This is essentially the same thing that occurs at a majority of general aviation airports (Federal Emergency Management Agency, 2008).

From our research, we found that there are five main components in an effective water monitoring system. In relation to an airport, the top priorities include the actual monitoring system in use, the locations and existing design of the network, the technology's accuracy and cost, proper installation and training of employees (if required) and how the data is gathered and managed by the airport (Hamilton, 2012). Each of these variables is important to the success of our project.

Aviation Resources

The primary source to guide our design was AC 150/5320-5D. This report provides insight into what is expected from the airports in conducting improvements to stormwater drainage system design. This report detailed many specifics on the construction of culverts, or any structure (usually a pipe) that allows water to flow underneath a runway, taxiway or other pavement, and the importance of capacity of the culvert for stormwater control. Additionally, an important consideration is that drainage design must be able to withstand at least a two-year storm event in compliance to the AC but a five-year storm event capacity is the recommended procedure according to the FAA. Finally, standing water collected over periods of time is also an attractant to wildlife and may go unnoticed depending on the separation of the area in the vicinity of the airport and its encompassing operations. An important aspect of our design is to not create an attractant for local wildlife to maintain compliance with FAA's Wildlife Hazard Mitigation Program. Besides these three admissions, many additional recommended practices dictated in the AC helped in design control for our project (Federal Aviation Administration, 2013a).

Additionally, since multiple government agencies are involved in the outcome of construction projects and their effects on the environment (primarily, the EPA but also the Army Corps of Engineers, U.S Geological Survey [USGS], etc.) our project had many regulations and rules to adhere by. Directly relating to all forms of stormwater drainage systems, it is important to consider the Clean Water Act of 1972 (CWA) when analyzing this project. Essentially, the CWA codifies multiple facets of how federal agencies and businesses operating in the United States must conduct diligence to maintain accordance to the law. Relating to our project, the CWA applies to state regulatory control on water quality in terms of emission control, pollutant and associated mitigation, and information on unlawful discharge (Federal Water Pollution Control Act of 1972, 2002). Fortunately, this act states relatively little about the qualifications and guidelines of implementing a monitoring system. For past and present monitoring systems, this has left a majority of project development and implementation strategies to the contracting entity to plan for an appropriate and effective drainage.

Even if the stormwater monitoring system at a particular airport has the unlikely chance of violating parts of the CWA (because it is a law, it remains vague for interpretation), there is an exception to the rule. Many of the airports bound by this act are able to discharge an amount of particulates in the watershed as long as they hold a National Pollutant Discharge Elimination System (NPDES) permit; this is commonplace at many commercial aviation airports. This need to repeatedly qualify for the permit every five years stresses the importance of an effective method to measure quantity flow in order to lessen the burden on airports and their employees (Transportation Research Board, 2013). Although this may not pertain to the exact methodology of our design, it is important to note how airports operate in terms of water quality in order to identify a relative quantity measure for stormwater drainage.

For the ultimate design of the project, our team began to research the United States Geological Survey (USGS) approach in the National Streamflow Information Program. This program has the capability of sending real-time data through satellite or radio telemetry utilizing strategically placed streamgauges. The USGS (2005) defines a streamgauge as an "active continuously functioning measuring device in the field for which a mean daily streamflow is computed or estimated and quality assured" for a specific period of time. Ultimately, there are two devices that are primarily used by the organization in operations as a streamgauge, a pressure transducer (or pressure sensor) and a float inside a small well. (Olson & Norris, 2005). These devices are used to measure the elevations of water and relate it to discharge as the primary component of water monitoring systems. The two measurements include stream-flow (discharge) and the volume of water that moves over a designated point over a fixed period of time, both relate to the speed of the water and quantity of the water. These measurements provide information on how periods of rain or drought effect flowage and essentially predict possible complications with stormwater flow (Environmental Protection Agency, 2012).

Many of the technical reports detail the importance of stormwater runoff monitoring and tracking in order to improve quality and oversight of stormwater projects as a minor detail. However, they do not specifically dictate the process or equipment needed to successfully implement a monitoring system. The USGS is an exception and currently utilizes technology at small stations around many high-activity waterways throughout the United States in order to collect data on quantity and flows. The ASDOC System was intended to use existing technology that other sources, outside of aviation, use and essentially, retrofit the specific technology into a cost-effective system that could be used for aviation purposes. This system is vital for both large and small airports where stormwater drainage system performance is necessary.

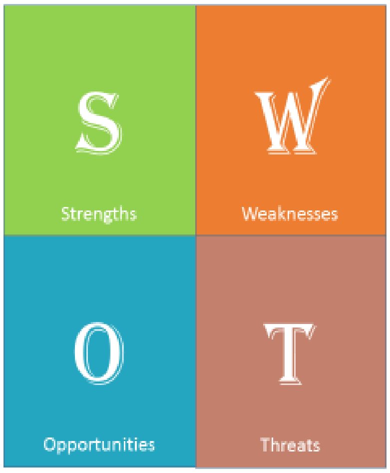
Design Approach

Our team was comprised of individuals based on personal academic selection to assist with research for the project on their own accord instead of drafting individuals with specific knowledge on a certain subjects. To our benefit, many of the individuals on our team are networked with key figures who have expertise and backgrounds in engineering. This aided our team in seeking out knowledge that many of us lacked (as being strictly all within the same aviation administration program). Division of the tasks were based on academic strengths with cooperation throughout the ordeal at least once in a weekly meeting. Additional meetings with various industry experts were frequent and scheduled separately.

After the initial groundwork was constructed, the team identified problems that may occur during our research. One of the foundational models that we applied to our effort was the SWOT Analysis, commonly used in marketing strategies.

Our progress was broken down into four different aspects to fit the SWOT model (see *Figure A)*. This simple but effective method utilizes four fundamental components; strengths, weaknesses, opportunities and threats. These aspects are then related to the external and internal benefits of the system. In our analysis, we evaluated the strengths and weaknesses of how our project design and individual skills interact with the project. Furthermore, we related threats and opportunities based on time, accessibility of professionals and airport regulatory environment to the potentially uncontrollable aspects of this project. This small sample of listed topics actually included a much greater series of problems than we could summarize.

Figure A: SWOT Analysis Framework



1) Strengths
    a. Simple
    b. Inexpensive
2) Weaknesses
    a. Knowledge of hydrology
    b. Commuter college
3) Opportunities
    a. Real world application of design
    b. Potential for increased safety
4) Threats
    a. Pre-existing application
    b. Cost vs. benefit

Throughout our academic career at the Aviation Institute, we have been taught the importance of this business model in uncovering the potential aspects of a certain situation or decision. This SWOT foundational guideline assisted our team in all stages of development.

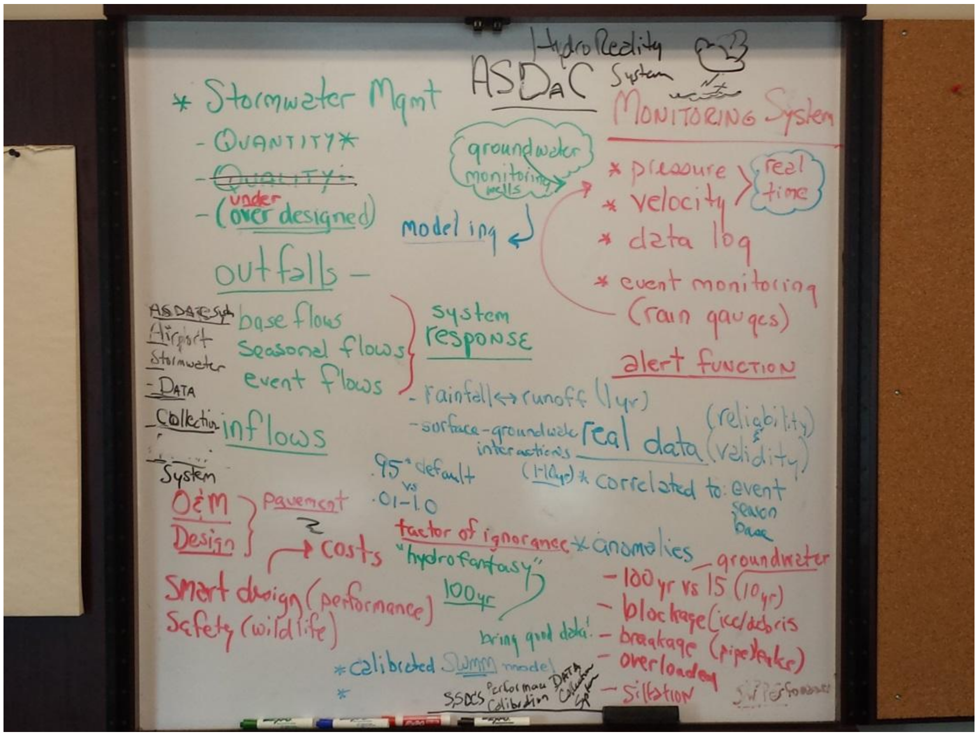
Design Development

Our team's advisor, Dr. Byers, introduced the team to Scott T. Brady, P.E, an expert in hydrology (see Appendix G) from the EG Solutions Group Inc. of Lakewood Ranch, Florida. He provided information on how our approach could benefit airports by adapting a stormwater drainage monitoring system. It was from this guest speaker that our goal shifted from assessing quality, which seemed more concerning, strictly to the quantity of stormwater flowage. Previous to this shift, our primary focus was evaluating how we could reduce the parts per million of pollutants within stormwater and runway runoff areas to a system that would effectively and efficiently monitor the channels of water within the stormwater system. On advice from the expert, we based our ASDOC System project centrally around monitoring stormwater volume and flow (quantity).

Potential Benefactors

In order to produce results that would benefit various airports of all sizes, it was important to have an understanding of what an airport could gain from our research. Many airports were originally constructed on otherwise undesirable land where drainage issues are a problem.

Figure B: Initial Brainstorming Session



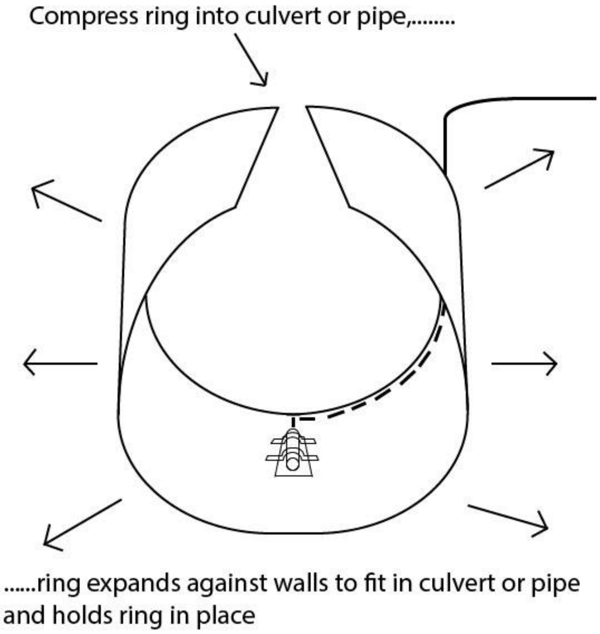
Within our local setting in Omaha, Nebraska, there is one medium hub commercial airport (KOMA), nine other airports that receive commercial service and multiple general aviation airports throughout the state. After speaking with many of the airports close to our university, it was our team's understanding that there are no other quantity monitoring systems installed at any of the airports besides KOMA. With this fact, our team decided that the prime beneficiary of our system would be smaller commercial service and general aviation airports. Since many of these airports may have trouble receiving substantial funding for stormwater system development, it was of our primary concern to keep costs at a reasonable level to possibly fund through state funds and local development to minimize impacts on airport revenue.

Many smaller airports are minimally staffed and the employees tend to serve multiple positions. Therefore, we wanted the ASDOC System to be time-efficient for the individuals responsible for maintaining the system. This is where the real-time data monitoring and communication method become a high priority. Additionally, keeping the maintenance low on these devices will be important in reducing workloads.

Design Details

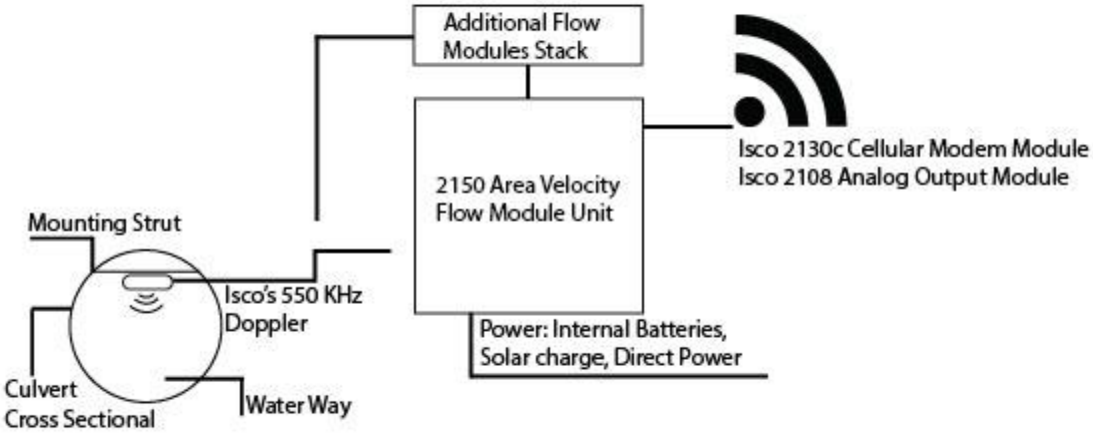
Information from industry experts and research culminated our actual design of the ASDOC System. From the diagram, the sensor is attached to the culvert through a mounting plate with standard stainless steel or chrome plated bolts at a point alongside the passage of the culvert. The mounting plate conforms to the shape of the culvert and uses pressure to stay in place. The location is usually selected based on accessibility, therefore along the start or end of the drainage pipe is common.

Figure C: Schematic Design of Mounting Kit



After attachment of the mounting plate, the installed sensor collects data by measuring the distance from the sensor to the water level and then sends that data back to a central Flow Module Unit through a connection with a barrier cable. The unit then takes the data and calculates the water level and flow rate. Expansion slots on the Flow Module Unit allow for additional sensors to be hooked up, allowing for multiple sites to record data. Collected data is stored on flash memory inside the Flow Module. The data is then either broadcasted to the end user on a defined time table wirelessly or stored onboard until a site visit by someone with appropriate software downloaded onto a computer. Power comes from an onboard battery but can be powered from a direct line in or a nearby solar panel.

Figure D: Schematic Design of Sensor Kit



System Design

When considering water monitoring systems, the ASDOC design would satisfy the five main components involved in an effective process listed below:

1) Monitoring System:

When there is any consideration about construction on an airport, the Federal Aviation Administration (FAA) must be included and must approve of the proposed project. The ASDOC System will require only minimal effort from airport staff to setup. The ASDOC System's sensor is called an Area Velocity Sensor (AVS), essentially a pressure transducer (or sensor), and can be installed inside a drainage pipe or culvert. The Sensor is small enough to fit through a manhole and will be installed at the bottom of the drainage pipe or culvert. As the water starts to build and flow over the device, the AVS will be able to read how much water is in the pipe and how fast it is flowing. The Sensor uses a Doppler-like signal, similar to radar, to detect how much water is flowing and at what velocity.

The AVS can be powered by one of two ways. The first way to power the Sensor is by battery. The battery is encased in the Sensor itself and it can be easily replaced when the battery is low on energy. The second way to power the AVS is with a waterproof electrical wire that is connected to an outside power source like a circuit or solar panel. The Sensor has the potential to be configured (by the manufacturer) to activate when it detects water, thus saving energy and money.

The AVS that will be installed can be also be wireless. In this method, the AVS sends data to a power source data collector (small monitor system capable of processing information) that will be stationed inside the main airport facility. Another wireless way that the system can send data can be sent to an app or program installed on a mobile device like a phone or tablet. The user/users will receive instant notifications of the potential risks that the ASDOC's AVS detects. By having the instant and wireless data collection, the airport operators will be able to immediately assess the situation and deploy the necessary means to address the issue.

To provide alternatives to the airport, the ASDOC system can use three different models of AVSs. All of the sensors and modules our team evaluated are from Isco Industries. The first one is the 2151 Intrinsically Safe Area Velocity Flow Meter. The 2151 Meter has an eight month battery life with an indicator that lets the operator know when to change batteries. It is fully submersible and measures water flows as low as one inch. It has a storage unit for the data the 2151 collects. It has a pressure transducer venting system (small vent tube that allows the barometric pressure from the device to be cancelled out, discounting the pressure from the actual transducer) that automatically compensates for pressure changes. It also comes with 38.4k baud (measurement for number of pulses per second) communication for a quick and easy setup and data retrieval. The options that come with this module include a 25 foot long barrier cable for connecting to a computer and a sensor carrier for attaching a Low Profile Area Velocity Sensor to Isco Standard Mounting Rings. (2150, 2014)

The second device is the 2150 Area Velocity Module. This module uses Doppler technology to measure the velocity. The sensor transmits an ultrasonic wave that measures the shift in the flow of the water. The 2150 is powered by two rechargeable batteries. It comes with a highly efficient power management system that can extend the battery's life up to 15 months. There is an option to use solar power for this Module. This module is easy to upgrade and the data is continuously stored in flash memory so that the data cannot be lost. Some options include wireless modules such as the 2102 module. With the 2102 Module there is no need to go to the Meter itself to retrieve the data (2151, 2014).

The third device is the LaserFlow™ Non-contact Velocity Sensor. This Sensor remotely measures flow in open channels with non-contact Laser Doppler Velocity technology and non-contact Ultrasonic Level technology. This Sensor is installed, via mounting bracket, above the water but in case it does become submerged it will continue to operator and retrieve data. Options that are included with this Sensor are mounting kits and surface-level retrieval tools (LaserFlow™, 2014).

Essentially, each of these devices are pre-programed to tract the quantity flows of water utilizing the Doppler velocity system. These three systems, after installation, transmit continuous ultrasonic frequency waves through electronic pulses that measure the frequency of returning echoes in order to get a reading of the water level. This is a very complex concept and our team had the luxury of the manufacturer already having this type of recording system in place. Showcasing three different products on the market allows the airport in question to consider the cost-benefit analysis for their particular situation.

Figure E: Sample Area Velocity Sensor (on left)/ Area Velocity Flow Module (on right) ©

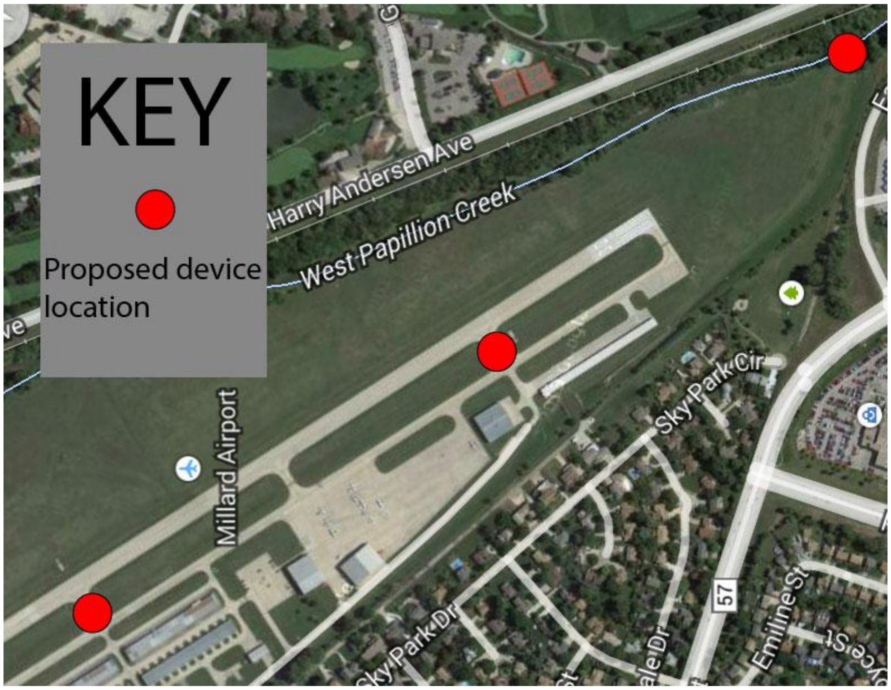
Source: Teledyne Isco, 2100 Series Flow Modules (201)3

2) Existing Design/Location of the Network:

One of our major concerns for utilizing these systems is the ability to implement the exact same design for a different purpose, into use for airports. The fact about these devices is that they are already used in construction projects for both cities and businesses who are interested in evaluating their environmental impact. These units are currently used as testing kits within UNO's Engineering Department.

The ASDOC System would be implemented throughout opening in culverts, stormwater drainage areas and has the capability of entering remote areas involved in stormwater drainage. The sensor size is compatible for pipes of 0.75 x 1.3 x 6.0 in (Height x Width x Depth) or larger (reference Appendix H for additional dimensions). As an example, when considering how to implement our system at an airport such as KMLE, it is important to determine priority areas on the airfield (see *Figure F).* Culverts exist at multiple points parallel to Runway 12/30 on airport property. These essential parts of KMLE's stormwater drainage system need to correctly operate in order for safe operations on the adjacent taxiway and primary runway. Furthermore, flowing parallel to the runway in close proximity is the West Papillion Creek. This waterway has created problems in the past and is known to periodically flood. Positioning of sensors at the points indicated (*Figure F)* would provide preemptive warning for potential problem areas at the Airport.

Figure F: Millard Airport Example Design



Source: Image from Google Earth

Another important aspect of the location is considering where the units can be mounted. It is recommended for mounting purposes that the pipe be between 6-80 inches wide (Teledyne Isco, 2013). This would leave any problem areas potentially covered. Multiple areas could be setup to link to a single computer alleviating the burden of additional monitoring stations. The actual computer system could be set at a centralized location, or at any site. As stated previously, there is the option of utilizing data-based messaging or storing the information on a wired computer.

3) Cost and Accuracy:

The accuracy of the device depends on the system purchased. The accuracy of these devices is based on the premise of pressure transducers. Pressure transducers have been used for many decades, since the 1960's, to collect information on groundwater. Therefore, the accuracy of these devices, including the AVS alongside electronic data-loggers (data recorders), are used so often within civil and military operations that the data is reliable for an airport system (United States Geological Survey, 2004).

The total cost associated with this project, just like any business, would be a primary concern for any airport. The ACIP would be a foundational document and ultimately would be a key process in determining if federal funding would be available for this environmental project. Projects impacting the safe operations of an airport are given the highest priority while protecting the environment is also high on the spectrum of receiving federal funding (Federal Aviation Administration, 2000). The ASDOC System may qualify for both of these instances, especially if stormwater systems create a reoccurring problem for operations. Like with many other revolutionary ideas, it may take a few years for the entire process of approving the ASDOC System. After fielding testing, evaluation and acceptance, the ASDOC System has the potential to be an AIP eligible project. Therefore, airports may have the option of using local funds to cover the cost of implementing the system.

4) Proper Installation/Training of Employees:

In many cases, the devices from Isco are used by engineering practices. There is an operation manual for the products and self-installation is an option. A luxury with these systems is that they are easy to install without an engineering background.

The mounting system is an additional charge and is recommended for installation which would require manpower. To mount the sensor, it is required to bolt the sensor to the mounting plate and then place inside the culvert. This could be a potential problem depending on the diameter, material or accessibility of the culvert and may require a contracted technician or available maintenance professional. Mounting this would be a recommendation for the ASDOC System to secure positioning of the sensor.

The most complex step would the evaluation of the real-time data. The whole concept of our system would use Isco developed software that would compute the quantity from the data sent from the sensor to the information site (computer, phone, Secure Digital (SD) card). This information provides insight into what is being monitored and a majority of engineering companies (if needed for future projects) would understand the implications of the data. The actual tracking of problems and alert system would require additional training in response tactics but the actual data monitoring system operations in its entirety would not.

5) Data Management and Gathering Techniques:

The storage of data, where it is sent and amount of data is dependent on the particular design. However, the actual use of the data is very important in determining the success of the ASDOC System. Effective data management interconnects with the proper training of employees. In certain cases, it may be the airport personnel’s task to keep record and storage of the data for future engineering projects (especially with use of SD cards). This is why our team would suggest using a computer system that is directly linked to the transducer to record continuous data with minimal human oversight. This would allow access to quantity flows at specific periods of time to easily be recollected through a computer database.

Ultimately, many of the choices for the system is up to each individual airport to decide. To fully implement the proper monitoring system it is very important to consider all five of these aspects. There are multiple agencies including the FAA, EPA, local airport authority or county board, and state regulations that must be taken into account before implementing a water monitoring program. There are also multiple variables outside of all the possible ones we have covered. However, the true “essence” for the ASDOC System is to strive for efficiency in all five of these stations.

Safety and Risk Management

As with any facet of the aviation industry, safety is of the utmost importance. The FAA states in the Safety Management Systems Manual that a safety system is a "business-like approach" to the issue. This is accomplished by providing "goal setting, planning, and measuring performance," all of which are an integral part of this proposal (Federal Aviation Administration, 2008).

The ASDOC project is not inherently a high risk proposal. Each potential airport, however, will require a unique safety risk assessment adhering to the local environment. In general, installing the ASDOC system involves minimal impact to the existing infrastructure of the airport, none of which should be particularly hazardous. Furthermore, it will require few extraordinary hazards during implementation and usage due to short installation times and experienced airport personnel being the primary users.

In this preliminary safety risk assessment, we will imagine a potential risk that may be applicable to any airports implementing the ASDOC system. Beyond identifying the risk, we will further address the issue to disclose the methodology. This approach is described in FAA AC 150/5200-37 which includes respectively: describing the system, identifying the hazards, determining the risk, assessing/analyzing the risk, and finally, treating the risk (Federal Aviation Administration, 2007).

1) Describe the System
   - Equipment used for digging a well must cross an active runway to reach the site.
2) Identify the Hazard
   - The time the machinery is crossing the runway and impeding takeoff and landing operations.

- The hired operators may not have experience in an airport environment.

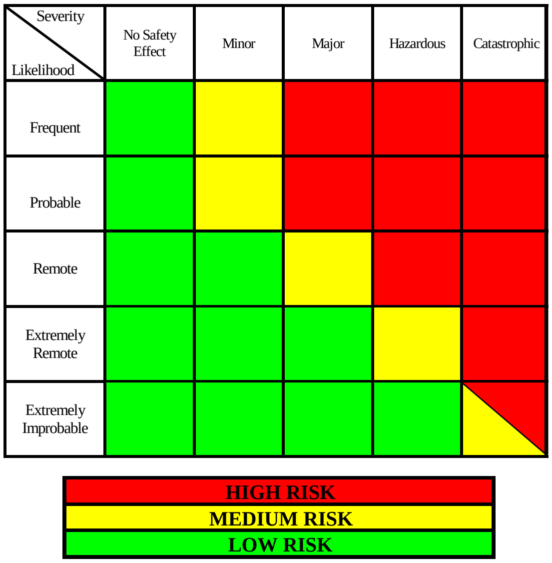
3) Determine the Risk

- The machinery operator may deviate from the planned route causing an incident or accident.
- The machinery operator may enter the runway environment at an improper time causing an incident or accident.
- Said machinery may break-down during the movement impeding the ideal function of the airport.

4) Assess the Risk

- This risk is considerably unlikely; however the result of such a disaster would likely be catastrophic. By using the FAA risk matrix in Figure 1 below, it is determined that this is an acceptable risk provided mitigation strategies are also used (Federal Aviation Administration, 2007)

Figure G: Risk Matrix



Severity / Likelihood	No Safety Effect	Minor	Major	Hazardous	Catastrophic
Frequent	🟩	🟨	🟥	🟥	🟥
Probable	🟩	🟨	🟥	🟥	🟥
Remote	🟩	🟩	🟨	🟥	🟥
Extremely Remote	🟩	🟩	🟩	🟨	🟥
Extremely Improbable	🟩	🟩	🟩	🟩	🟥🟨

🟥 HIGH RISK
🟨 MEDIUM RISK
🟩 LOW RISK

Source: Federal Aviation Administration, AC 150/5200-37: Introduction to safety management systems (SMS) for airport operators (2007)

5) Treat the Risk

- The risk can be mitigated by an experienced airport staff escort. This will prevent straying from an approved route and ensure safe and supervised movement on airport property.
- A potential breakdown during the relocation of equipment may be mitigated by pre-checking all applicable components and examining all available service records and history.
- Any confusion or communication issues may be mitigated by the use of radios and/or other communication equipment by all involved, and notifying all impacted individuals and staff of the planned movement.

While risk assessment is a vital part of any planning and proposal, the ASDOC System project will also serve a positive function in a safety management system (SMS). As a part of an airport's SMS, ASDOC System can be an important and valuable mitigation tool for several risks.

An example of this would be an early warning to a potential flood due to system blockage. While unlikely, such a scenario could potentially shut down an entire airport. The economic loss and cost of any material damages would likely far outweigh the estimated cost of implementing the ASDOC System.

A related, yet distinctly different risk, is the long-term damage done by a poorly managed stormwater drainage system. Erosion of soil or damage to infrastructure by even irregular system failures can be costly and dangerous to airport users. ASDOC System can provide additional assistance in mitigating such a risk.

Another important benefit to any airport is the regular information this system will provide. Should any issue arise in the future, this data may prove invaluable. Some examples being future changes to the airfield, or even complaints by citizens near and around the airport. While this is not a complete list of uses or benefits, it can illustrate the potential positive impact of this system.

To bring this product to the implementation stage, it would have to be approved by the FAA for use within stormwater systems to maintain Part 139 compliance. We believe that this device would not violate any potential operations or safety within the airfield if correct practices are used in the installation of the device. Standardization within a manual or advisory statement on the proper installment of the device would be recommended to reduce the chances of risk.

Interactions with Project Experts/Clarification of Design

After understanding what type of airports would primarily benefit from our research, it was important to prepare a design that could be implemented in currently installed airport stormwater drainage systems. During the project, the progression of our interactions went in an order in which we started dialogue between expert hydrologists and the USGS. It was important to follow this method because these experts work with stormwater systems on a substantial basis. In between response times, we contacted current airport staff to get a perspective on how we could implement this design effectively at an airport. Finally, to implement the design we spoke with manufacturing companies and senior faculty within the Engineering Department at UNO.

Our initial contact was with Mr. Scott T. Brady P.E, a leading hydrologist in the United States. We had planned on measuring the quality of water being pumped out by the airport into the public stormwater system. Mr. Brady informed us that we could measure both water quality and quantity but doing so, is very expensive.

Mr. Brady gave us an introduction to the very basics of stormwater drainage systems and how outflow is measured. He discussed the differences of average flow and event flow. The average flow is how much water we would expect to move through the system on a normal day and event flow, like rain (or other natural and unnatural occurrence) happens. We needed our system to be able to measure water levels around the airport during a significant storm to predict how an event impacts the airport from a standard day. He suggested we would need data for rainfall runoff and periods of drought anywhere from one year to ten years to get usable data. It was essential for our project to measure and collect multiple periods of data from the time a rain event began and ended to the amount of water collected. Afterwards, the data could be compared to pre-event numbers. Doing this would allow the ability to measure the quantity. Information from quantity limits would also help determine the stormwater system drainage performance by monitoring inflows and outflows and tracking anomalies using historical data.

Another major discussion was how engineers design stormwater collection systems for large airports. In general, the plans are designed to handle small average events but may not be engineered to handle a potential 100-year, 10-year or even 5-year precipitation. Systems at current airports may also be overdesigned for the particular region the airport occupies; this is because of lack of accurate data. Monitoring the flow rate through the pipes is important in this situation because identifying a problem area such as culverts being crushed or clogged by debris, etc. would be helpful in determining the impact threat of the area. Data that is already available for a certain region includes information on different climate changes and local geography. This information is consistently tracked, readily available and is part of the standard when deciding how and where to engineer structures.

From our meeting with Mr. Brady, it was evident that obtaining any sort of real-time data has always been a problem for water monitoring. Finding the location and average height of groundwater levels is mostly an educated guess for engineers because tracking the quantity of water flowage is not an industry standard. If we could provide the industry with numbers for where the groundwater table is and how the seasonal changes interact with the surface water, we could ensure stormwater management plans are being designed properly for the specific airport. Mr. Brady reaffirmed that this type of data could help with pavement management and potentially reduce costs on construction, new stormwater systems, and various other projects. By the end of our discussion, Mr. Brady let us know airports need to lessen their emphasis on the quality of water and need to focus on the basics of measuring streamflow (personal communication, February 12, 2014).

As the emphasis of what our project began to evolve, our next expert, Ms. Amanda Flynn, a Physical Scientist in the USGS, was contacted to discuss measuring devices. She informed us that U.S. Geological Survey teams are already measuring water flows at rivers, streams and creeks throughout the United States including several points locally.

Ms. Flynn provided a typical model for a water flow monitoring system (streamgauges). Additionally, she showed us reports on how the gauges remotely update to servers at predetermined times. The reporting time could be determined by the end user and could be set up to report by the minute, hourly, or weekly. She described the difference between surface water and groundwater in terms of monitoring. Both are interconnected and fluctuate depending on the season. This fluctuation is a variable that can cause stability issues in the ground resulting in sink holes and sediment building up, potentially, clogging pipes or creating unstable land.

It was determined, by her input, that both the height and depth of groundwater levels and accumulated surface water are important factors to monitor. Additionally, our research should employ the use of surface water gauges (similar to rain gauges) with the ability to transmit data on any time interval for an effective system. Groundwater monitoring would require separate wells to measure the water-table level and would need to drill test holes 100 to 150 feet deep to get samples. Both devices can be powered by a direct line into the device or by solar power (A. Flynn, personal communication, March 5, 2014). Our team understood this approach would be very costly and may disrupt normal operations during construction. Therefore, the team elected to restrict the project to monitoring specific culverts instead of the water table.

From our next expert, Mr. David L. Roth, Director of Strategic Planning & Engineering for the Omaha Airport Authority, we were able to get an idea of how to apply our current understanding to what an airport would be looking for. Mr. Roth worked at the Omaha Eppley Airport during a massive flood event on the Missouri river in 2011. Omaha had to reinforce levees around the entire field and introduce water pumping stations to keep the field dry and operating.

Mr. Roth reinforced the standards described in AC 150/5320-5D, that airports are recommended (by the FAA) to design for five-year precipitation events, any further and there is potential for the Airport Improvement Plan (AIP) not to cover any additional fees for construction. An important consideration was the type of materials, porous (grass) and impervious (pavements), and how the elevated groundwater will seep through it to try and equalize differentials in pressure. The potential for airports to receive funding for a project such as this was taken into consideration. This is one of the main turning points in which we decided to focus on non-primary and general aviation airports. Millard Airport (KMLE) in Omaha, Nebraska was our target airport and because Mr. Roth represented the Omaha Airport Authority, we were able to discuss the drainage system in place. Millard Airport uses gravity surface drainage channels and unlike many airports, accepts the nearby neighborhood’s rainwater into their drainage system. The system was designed to handle up to one inch of rain per hour (D. L. Roth, personal communication, March 19, 2004).

Figure H: Millard Airport Culvert

A key complication in implementing this system, after the stormwater system is already in place, is that there are an abundance of mathematical algorithms to calculate pressure in relations to flowage in order to implement the correct engineering scale and placement of the system. Upon Mr. Roth's suggestion, it would be most important to implement the ASDOC System at culverts and drainage areas close to suspected primary structures (runways, taxiways, close to riverbanks, etc.).

One of the current methods that KOMA uses to monitor water systems is strategically placed wells throughout the property. These wells use the principle of gravity and maintain equilibrium for the height of water across the entire drainage system. So if the system is overwhelmed, all wells would be filled with water. At a certain level in the well (30 feet below the surface at KOMA), a pressure transducer would essentially be tripped and send an electrical signal to a generator to turn on a motorized pump. If the water continued to rise, additional transducers would signal, resulting in additional pumps starting. This is an expensive program and is simply not feasible for many airports. A simpler alternative that was suggested was to put a PVC pipe with a balloon float (much like those that are used in toilet bowls) down into storm drains on the field to measure capacity. After installation, transducers would trigger, when it passed a certain point, alerting the field attendant to an issue. Mr. Roth provided information on how to scale down what KOMA uses to a more practical, fairly inexpensive system that would be suitable for the needs of smaller airports.

Mr. Jason Terreri, the Aviation Contract Administrator for Hartsfield-Jackson Atlanta International Airport (KATL), was presented with our project idea. He demonstrated for us problems that have occurred with the stormwater system at KATL. He brought into perspective the impact that our project would have on even larger airports.

He discussed similar issues on Dulles International Airport (KIAD) and their situation (the Potomac River running in close proximity with small inlets that run under a taxiway and two runways). In a previous event, overflows severely disrupted the use of one of the runways. This is an extreme case, however decommissioning a runway is serious concern when water monitoring systems are not in place. The expense is not simply for runway repairs but also for the delays and cancellations of multiple flights. For example, at KATL, the Flint River has flooded roadways and taxiways and during a separate incident, drainage pipes were clogged causing a complication with their FAR Part 139 certificate on inspection. (J. Terreri, personal communication, April 3, 2014). Both are real world examples of water causing serious issues at large airports. These examples encouraged us to show our low cost proposal could potentially save thousands if not millions of dollars.

Within our University's Engineering Department, Dr. John Stansbury, a water resource management expert, was briefed on our proposal on implementing the ASDOC System. He assisted us on how to measure pipe capacity. We used examples of KMLE's Runway 30 as our basis. The Runway is considered vulnerable because it is within a known flood plain. Like many airports, if an event were to happen the possibility of losing the complete use of a runway would cripple the airport.

Going back to our initial thoughts on potentially using a float (similar to one used in septic systems), it was brought to our attention that this method would be too simple and had a high potential for failure or inaccuracy. He suggested using a pressure transducer as another alternative for our project. The device would sit on the bottom of pipe and measures pressure of moving or standing water on the top portion of the device in order to determine water levels. To prevent being washed way, the device would be anchored to the culvert.

The final device Dr. Stansbury introduced to us was an Ultra-Sonic transducer. This device is attached to the ceiling of drain pipes and sends ultra-sonic waves to reflect off the surface of the water flowing by to distinguish the water levels. These devices also have the potential to measure velocity.

In relative terms, both of these device are inexpensive and have virtually no maintenance. The device doesn’t have to always be on, saving on battery life, it can be in a standby mode where it senses when water is present and turns on. Power can be supplied by a direct line in or solar power. We also determined the entire system should be coupled to rain gauges around the airport to provide additional information about rain patterns. The rain gauges that would be necessary are inexpensive and would require additional effort form airport staff.

The device is built by a local company called Isco Industries, a Teledyne Corporation, based in Lincoln, Nebraska. Dr. Stansbury has first-hand knowledge of using these devices in civil engineering and indicated he has never had a problem with placing the devices in culverts. The only caveat he offered was that shallow water and steep angles could result in spotty or incorrect readings if the device was placed improperly (J. Stansbury, personal communication, April 8, 2014).

Design Practicality and Feasibility

Design vs. FAA Goals

The ASDOC System is consistent with FAA’s emphasis on safety and environment controls. This system meets requirements to enhance safety by ensuring that stormwater is absent from runways and other components affecting operations at an airport. There is no part of installation or implementation of the system that would increase the risk of potential hazard at the airport.

Additionally, the system has the potential to produce cost-saving benefits by reporting areas of overflows and breakages within stormwater drainage systems before serious events can occur. Mitigation of wildlife attractants (pooling of water) is important to reduce the threat of bird strikes and other interferences animals may cause to aircraft and other structures.

Financial Analysis

Another cost-saving benefit of the ASDOC system is showcased from Isco Flow Meters being the only major cost to the operation. The Submerged Meters (such as the 2150 Meter) have multiple parts that compose the less sophisticated system while the Non-Contact Meter (the LaserFlow™) is the more expensive option with fewer components involved in the functionality of the unit. The Cell Modem is the wireless device that can receive and display data to the operator. Both the Cell Modem and 2015iCDMA are required for real-time monitoring and data storage.

The cost for the systems and the parts are show in the table below *(Figure I)*:

Figure I: Breakdown of Costs

Modules and Accessories

Submerged		Non-Contact Installation	
2150 Module	$ 4,250	2160 LaserFlow™ System	$ 10,530
Scissor Rings	445	Mount for LaserFlow™	570
10 ft USB Cable	245	10 ft USB Cable	245
Flowlink Software	2,055	Flowlink Software	2,055
Solar Panel	900	Solar Panel	900
Battery	125	Battery	125
Total	8,020	Total	14,425
Total for Three Units	**$ 24,060**	Total for Three Units	**$ 43,275**

Submerged Cost Estimates	Percentage	Amount
Installation	25%	$ 2,005
Contingecy	15%	1,203
Maintenance (First Year)	0	-
Maintenance (After First Year Per Year)	10%	802
Total		**$ 4,010**

Non-Contact Cost Estimates	Percentage	Amount
Installation	25%	$ 3,606
Contigency	15%	2,164
Maintenance (First Year)	0	-
Maintenance (After First Year Per Year)	10%	1,443
Total		**$ 7,213**

Cell Modems	
2105i CDMA	$ 3,070
Flowlink Pro Software	3,085
Total	**$ 6,155**

Source: Isco Industries™

The construction cost will be minimal (and may not be applicable) as the Meters can be installed by entering the drainage system through a manhole or culvert ends. The Non-Contact (LaserFlow™) Meter comes with a mount and installation will require the mount to be installed in the pipe or base of the manhole. The overall cost of the Meters and installation process can be approximated at $14,000.00, depending on which Meter is used for monitoring the water. Initial costs may include hiring a contracted service to install the devices and various contingency fees.

To maintain functionality, a reasonable estimate of 10 percent, after the first operational year, of total start-up costs have been considered in the breakdown of prices.

Cost vs. Benefit

As a hypothetical example, a culvert rupturing from a beaver dam blocking the outflow port causes a hydroplaning event on a general aviation aircraft while landing. As a result, an accident with two injuries could occur, causing overwhelming costs. One passenger has suffered a major injury and has medical costs of $955,500. The second passenger has suffered minor injuries and has medical costs of $27,300 (Federal Aviation Administration, 2013b). The damage that the aircraft has suffered is approximately $168,000. With two passengers being injured and the aircraft sustaining damage, the cost could amount to $1.16 million. In this scenario there were no fatalities but it had the possibility of happening and the value of life has been approximated at $9.1 million (Federal Aviation Administration, 2013). The estimated cost of the ASDOC System amounts to approximately $57,000 over a five-year period. In this likely situation, the savings were estimated at $1.1 million. From this example, the benefits of the ASDOC System can potentially save costs for an airport, especially in areas of likely flooding or disturbances in stormwater flow.

Innovation

The potential real-world impact would enable the monitoring advisory board (MAB, staff in charge of response) to monitor and detect any potential hazards that could hinder the operations of the airport due to water damage and failed drainage systems. By having all components of the ASDOC, the MAB will be able to take action and prevent any damage caused by the water underneath the earth by detecting the problems before the cost associated with the event is incurred. Ideally, having our system will save the airport money, create an effective quantity monitoring system and prevent the hassle of correcting a major predicament.

The commercial potential for our proposed system does not have to be isolated to just airports. The foundation of our project has the potential to be used for an entire city's road and water drainage systems. An example of this would be for roads and highways, the ASDOC System can detect where the water is gathering by monitoring inflow and outflow and, in turn, be corrected. A common problem in the Midwest is during the natural freezing and thawing cycle, water may become hazardous if not monitored correctly creating areas of uneven pavement. For the city's drainage and sewer system, the ASDOC System will be able to detect any blockage that could disrupt or even halt the operations of the sewers resulting in extreme headaches for city planners and residential/industrial sites. Overall, if the ASDOC System was everywhere, water may be less insidious to the pavements of the world.

Conclusion

The ASDOCS System allows for the monitoring of airport groundwater and stormwater drainage systems. The ASDOC System is designed to collect historical and real time data providing warning in the event of failure in the drainage system. Equipment suggested for use is easy to install, inexpensive and easy to use. The ASDOC System will mitigate damage from hydrologic events and provide the airport with their "hydro-reality".

Appendix A: List of Students and Staff Contacts

Team Leader
Matthew Hunt
mehunt@unomaha.edu

Team Member
Zane Smith
zanesmith@unomaha.edu

Team Member
Craig Murphey
cmurphey@unomaha.edu

Team Member
Arlene Steier
asteier@unomaha.edu

Team Member
Derek Warneke
dwarneke@unomaha.edu

Note: All team members are upper division undergraduate students in the Aviation Institute's Bachelor of Science in Aviation: Air Transportation Administration degree program

Faculty Advisor
Dr. David A. Byers, Associate Professor
University of Nebraska (Omaha)
Aviation Institute
dbyers@unomaha.edu

Appendix B: Description of the University

The University of Nebraska at Omaha (UNO), founded in 1907, is a fundamental component of the University of Nebraska's collegiate education system. UNO is situated in Nebraska's largest metropolitan area and serves to provide exceptional educational opportunities, discovering and disseminating knowledge through advanced research and teaching, and offering public service to the community, state and the nation.

The Aviation Institute at UNO was established in 1990 as part of UNO's School of Public Administration, and is charged with providing a comprehensive program of aviation studies for both flight and non-flight disciplines. The Aviation Institute offers a Bachelor of Science in Aviation with concentrations in Air Transport Administration and Professional Flight. It also provides Aviation and Transportation concentrations as part of the School of Public Administration's nationally recognized Masters in Public Administration (MPA) resident and on-line programs and the doctoral Public Administration (PhD) degree. The Aviation Institute is a founding member of the Aviation Accreditation Board International (AABI) and the School is accredited by the National Association of Schools of Public Affairs and Administration (NASPAA).

This project was conducted as an upper division 3 credit-hour elective course, AVN 4900, "Special Topics in Aviation". It is anticipated that this course will be offered again as part of the academic program to provide students with opportunities to conduct independent research on contemporary aviation issues.

Appendix C: Non-University Partners

None

Appendix E: Team Evaluations

Matt Hunt

The FAA Design Competition gave me an excellent experience leading different type of people who don't all operate the same way. We also researched a topic that none of us had any experience with, stormwater drainage systems. The best part was being able to apply knowledge we gained from previous classes with our academic advisor to help us solve issues we were facing and find information that applied toward the project and was useful.

Our deadline was the biggest issue, compounded by the students having a full time academic work load and work schedules. Meeting times and deadlines came and went with frustratingly little progress. Also our lack of experience with this type of research and topic gave us a difficult time just finding a starting place. Eventually it was brought to the attention of our academic advisor and he guided us to use our resources from previous classes and focus on getting something on paper.

Coming up with a topic and hypothesis took some time but in our second meeting we came up with the idea of measuring water quality coming in and out of airports. The idea involved knowing the water quality the airport could then prove that they were being a good neighbor and not polluting the water downstream. After contact with airport professionals and discussions with water management individuals we changed the topic to measuring water runoff. This new topic could still prove the airport was being responsible with its water and not flooding the area with its runoff. Again, after some additional discussions with our local airport we decided a better measure was how full the water runoff pipes and drainage ditches were during water events. Now, our plan could alert the airport to an issue with their drainage system preventing erosion and potential collapse of surfaces resulting in closure of the airport and expensive reconstruction costs.

Thanks to the industry professionals, airport operations officers, U.S. Geological Survey members and Hydrologists, we were able to conceptualize an issue airports face and how to potentially solve this issue. Without them we would have no idea drainage was a real issue some airports face or how to go about measuring water levels. They were able to easily explain in minutes what would have took us hours to read and make it understandable to people who are not in the industry or have any experience with the issues.

I took away a useful lesson from leading this group. In previous group work, I have experienced leaders dealt out assignments and expected them to be completed by a deadline. I tried the same hands off approach and found that doesn't always work. People do not always ask for assistance when they need it. If I would have asked for weekly updates and actual evidence of work we could have prevented some headaches later in the school year when other assignments were due. This is why we do group work, to help each other out when the going gets tough. Perhaps my style of leadership was a one of a boss and not a leader. The boss points in a direction and says go! A leader is in front with his subordinates and yells this way. I could have been more involved with each member and their work, knowing this weakness will help me become a more effective leader for the future in the business world.

Zane Smith

The FAA design competition was a great opportunity to learn about a subject that is important to airport operations that I would have not necessarily been able to explore within my everyday curriculum. Some of the important skills that this project helped develop included various degrees of interpersonal skills, teamwork and cooperation, meeting deadlines, and fact finding. This competition actively engaged each of our members into in-depth research that some of our undergraduate classes only barely touched on.

One of the main complications, that our group faced, was the limited experience within engineering of any kind. However, we had the luxury of having an experienced advisor and members that knew experts within the field of hydrology. Probably the most difficult aspect of the project was completion within the three month time-frame. The majority of our team members were taking multiple classes, working and had other situational schedule conflicts. Altogether, we struggled to make a conscience effort to complete this project by the deadline.

None of group had imagined exactly what our topic would cover until our initial meeting. Stormwater drainage systems became one of our strongest brainstormed ideas, therefore, we decided to go outside our comfort zones and choose this topic. The exact focus point of our project was not realized until a few weeks later after speaking with hydrologists and other experts. After gaining knowledge, we realized that quantity of water flow is a less “glamorous” but more important aspect. After finishing this project, I realize that this type of research was severally lacking in the industry.

One of the most critical aspects of our project was the selection and conversation with industry experts. Without this key part, I do not believe we would have grasped any sort of substantial information regarding stormwater systems. Many of the experts we spoke to were straight to the point and offered additional contacts in case we needed some additional insight. Overall, they helped us every step of the way.

The whole outcome of this project was to learn how future aviation professionals can create new ideas to benefit the industry without having the complete knowledge of all the rules and regulations. I believe this project has allowed me to be a bit more creative when it comes to benefiting the current system. I think research projects like this help individuals be more open to cross-training within a career, ultimately, becoming more beneficial to the company or entity they will work for.

Derek Warneke

The FAA Design Competition did provide a meaningful learning experience for me. The experience has showed me the importance of how airports consider environmental impacts and the degree of frustration it must bring. Additionally, this project provided me experience on how to collaborate with various individuals and others. Time management was one of the most important skills I have learned from this because this project required a lot of time and research.

The challenges that we faced were finding the resources, finding the time and understanding what we were looking for. This project was one of the most difficult that any of us have had to do in our entire academic career. There was a lot of research and the more research we did the more we had to figure out how to use it. We overcame the challenges by working together and by frequently meeting with each other. This project required a lot of time and effort along with the other responsibilities. Specifically for me, I had a lot to accomplish.

The process we used for our hypothesis was to see what the industry needed and how the industry would use our system. It would be interesting if our envisioned project can become a reality. Before we could come to this hypothesis, we had to understand what we were going to do. None of us had any prior experience for this project and we all had to learn along the way. However, as we gathered more information, speaking with hydrologists and other professionals, we have determined that what we're looking for was absent within the aviation industry.

Participation by the industry was appropriate, meaningful, and useful because the professionals gave us the necessary insight to complete the competition. We had spoken to a hydrologist, an airport executive, and a civil engineering professor who specialized in this area. Their knowledge was greatly helpful and they provided us with a better understanding of what we were researching.

I learned that time is very limited for a project such as this. I also learned that collaborating with various individuals is not a simple task. The University of Nebraska at Omaha is a commuter university, meaning that most students did not live on campus and had other priorities such as jobs and other activities. This project was important to me because it helped influence my study skills and time management. These skills will help me advance in my professional career when I graduate. In an industry such as aviation, time and professional skills are a must.

Craig Murphey

This FAA design competition has been a very worthwhile and valuable experience. Joining the design competition team helped me get closer with several of my fellow aviation management students. Additionally, it also reinforced the importance of group communication and teamwork. The skills I have used and learned in this endeavor will help me in any career choice I may undertake.

Although this was an overall excellent experience, there were challenges for several reasons. First of these was simply coordination. Finding time for everyone to meet and be able to accomplish the individual and group goals presents its own challenges in a situation such as this. Many of the members, including myself, had outside commitments to balance during the few short months of completing this project.

Furthermore, our group consisted of many different backgrounds, but limited experience or knowledge in many of the potential topics we considered. Due to this reality, we realized we must seek outside advice to bring our proposal to fruition. This, in itself, created further difficulty in locating knowledgeable sources and working around their needs as well as our own.

Through the priceless information we received from experts throughout the country, we found that many of our assumptions were actually on-par with the real world situation. This gave us a drive to pursue a topic we felt was not adequately addressed, yet beckoned our attention.

The FAA design competition clearly contains an aviation industry focus. What was very interesting, however, was that we were forced to adapt ideas and techniques inherently outside of our expertise. I feel this, whether by design or by accident, was as rewarding as any other aspect of the experience. By leaving our comfort zone, we had to adapt and innovate for real-world applications to accomplish our goals. While I feel our team was a group of very intelligent people, I think it’s important to admit when you can’t do it alone. That, and considering the work is worth more than simply a letter grade, was a remarkable feeling for a student nearing the end of their collegiate experience.

Arlene Steier

The learning experience I received was valuable as a student pursuing a B.S. in Air Transport Administration (B.S. ATA) at UNO as well as a stakeholder at the Council Bluffs Municipal Airport (KCBF) in Council Bluffs, IA, where I keep my personal aircraft. While my education to date has focused on the landside as well as the airside of the airport, the focus has been on ramps, taxiways and runways, wind coverage, capacity, navaids, etc. and above all else safety in the airfield environment.

Finding out that most airports do not monitor on airport drainage and groundwater, after the system is installed, until a major event took me by surprise. The cost of repair and replacement can be a staggering sum of capital expense in both repair or replacement and disrupted airport and flight operations that brings sense to the project undertaken by the this group.

There was a lack of knowledge of the subject, although, we recognized there was a problem present. Our team of five includes three senior and two junior students, all B.S. ATA majors all carrying a full time class schedule. There are two private pilots, one flight student and two with no flight training. As a group, we did not have the experience or expertise and this class, for us, was only one semester long and time was against us. We have been working for three months. The group broke the project into sections and met at least bi-weekly to meet with industry professionals and monitor our progress.

We simply set our sights on working to find the information and individuals needed to fully develop our hypothesis completely, verify the hypothesis and determine a solution.

The group started with research. We had to first determine that the problem presented did exist and airports across the country had a need for a system of measurement and reporting. We then sought industry professionals that came from federal government, hydrologists, airport management and operations and the private sector. After determining a path to take, we sought out engineering help from the UNO Civil Engineering program for guidance on equipment that was available on the open market for east of acquisition and reasonable cost.

This project we are presenting could not have been put in front of this panel if we did not have input from national and local industry professionals.

This group started behind the curve and very quickly caught up and formed the final problem statement after speaking to hydrologist Mr. Scott Brady. Mr. Brady focused us as to what needed to be measured. Ms. Amanda Flynn from the United States Geological Survey (USGS,) schooled us in recording and storing data and how it can relate to airport use as well as confirming that there were devices on the market we could use. David Roth from the Omaha Airport Authority (KOMA,) brought experience dealing with groundwater and drainage problems. Mr. Jason Terreri, from Hartsfield-Jackson Atlanta International Airport (KATL) spoke to what KATL and other local airports in other parts of the country were dealing with in regards to groundwater and runoff issues confirming our hypothesis that this is a nationwide problem.

This project allowed me to personally delve below what is seen from the airside of an airport, literally. After touring KOMA and their groundwater system and comparing it to KMLE and other airports in the area, an understanding of the need to monitor a destructive force to one of an airport's major capital investments.

Of added benefit was a networking component for all members of the team for future professional development.

Appendix E-6 - Faculty Advisor Evaluation

Describe the value of the educational experience for your student(s) participating in this Competition submission.

The University of Nebraska Aviation Institute's 2013-2014 FAA University Design Competition Project was extremely valuable for my students. By identifying and investigating a contemporary problem associated with airport stormwater systems, the students were required to step outside their typical field of study to address an area that, for most airport users, is not readily apparent yet vital to their safety.

Initial brainstorming and preliminary exploration of the stormwater topic did not immediately result in an immediate, strong, and enthusiastic response. However, the interaction with industry, government, and airport subject matter experts over the course of their research allowed each student began to see the value of the issue and to learn more (some said more than they bargained for) about hydrology and practical applications for how stormwater is handled at airports of all sizes and evaluating the potential for measuring system performance.

Given that several members of the project team are seniors and were working on other end-of-semester projects, participating in the Design Competition was a definite challenge but served as a capstone for their aviation academic program. It also helped them overcome their reluctance about cold calling and seeking information from experts in the real world.

Their research approach required thinking through the problem statement, investigating foundational engineering principals and accepted practices, and implementing an interdisciplinary action plan to conceptualize a realistic approach toward monitoring real-time stormwater system performance that is scalable to most all airports. While in-depth exposure to airport planners, engineers, and hydrologists addressing the topic of stormwater design and performance metrics was not a normal component of their formal education program , the project forced them to see the important role each discipline plays in airport operations and development. The end result of the project effort is that each member of the project team found a deeper appreciation for the important role stormwater design and management contributes for ensuring the safety of airport users.

Was the learning experience appropriate to the course level or context in which the competition was undertaken?

The University Design Competition Project serves as an extension of the Aviation Institute's curriculum. The Institute's undergraduate academic course work involves airport planning and design but unfortunately does not provide many opportunities for applied research. By having the chance to participate in the Design Competition, it served to motivate students toward a real payoff as opposed to just doing a semester project for a grade. By examining in detail a "real world" issue such as measuring stormwater system performance at airports, the students were able to apply much of what they learned outside the classroom toward providing approaches for a solution to a real problem. The feedback they received from their industry contacts supported what they were proposing, served to reinforce each student’s confidence in their creative talents and practical abilities and ultimately, the validity of their education.

What challenges did the students face and overcome?

While, initial enthusiasm for the project was not apparent, as students were able to discuss their ideas with the industry experts, interest grew rapidly. The Project Team distributed the workload among the members and regular meetings were held to review progress. As with almost all undergraduate student team projects, the interaction among the students was strained at times, including frustrations regarding missed deadlines, quality of deliverables, strong personalities, and project leadership were all challenges. These issues were overcome as the submittal deadline approached and the team ultimately found a level of synergy that resonated among the members.

From a technical perspective, the project was designed to only be conceptual in nature. Because the topic delved into the area of hydrologic engineering design theory and practice which none of the members had any real exposure to, I observed that team was very uncomfortable with their ability to conduct meaningful research and offer a competitive submittal. However, after a quick-study approach of related literature and the opportunity to learn about and discuss their concepts and ideas with the SMEs, their confidence that they were on the right track and working on a realistic project increased significantly.

Would you use the Competition as an education vehicle in the future? Why or why not?

This is the fourth year I've been involved with the FAA University Design Competition at the University of Nebraska and the eighth year as a panel judge. I am very pleased with the broad level of support within UNO for the program and the effort well respected.

I found this to be an excellent method for engaging students interested in airport issues into participating in a meaningful research/practice project. By making contact with industry experts (airport management, consulting firms, and equipment vendors), the students were able to appreciate the practical experience of seasoned professionals and to reduce the intimidation toward contacting experts for advice.

I also have encouraged students to participate not only for the academic experience but also to help build their resumes as they prepare to start their careers in the aviation industry. I intend to continue to serve as an academic advisor for future teams and as a panel judge

Are there changes to the Competition that you would suggest for the future years?

I continue to believe that searching for opportunities to expand and enhance the topics is appropriate.

Another idea I continue to propose is to create a phased approach for narrowing the field with better quality proposals. For example, Phase I could run during the Fall semester with the development of a refined problem statement, literature review, research approach, and a preliminary SMS review along with a Phase II proposal that would include a detailed research plan, budget, and schedule. After screening the proposals, the best three or four for each category would be selected for Phase II to be conducted during the spring semester. Perhaps Phase II selectees could be awarded a modest research stipend for travel and other expenses associated with their project.

Another idea is to perhaps create a Design Competition “Hall of Fame”. Inductees would represent outstanding proposals that reached industry acceptance and at least a limited level of commercial success. Nothing jumps out at me right now but perhaps there are a few that made it this far.

Overall, I think the FAA’s University Design Competition is an excellent program for engaging students in the airport research and bringing innovative ideas to the industry.

Appendix F: References

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Appendix G: Subject Matter Experts

Subject Matter Experts (SME)	Affiliation	Position	Contact Information
Scott T. Brady P.E.	EG Solution	Senior Consultant	sbrady@eg-solutionsinc.com
Amanda T. Flynn	U.S. Geological Survey	Physical Scientist	aflynn@usgs.gov
David L. Roth, P.E.	Omaha Airport Authority	Director of Strategic Planning & Engineering	dave.roth@flyomaha.com
Jason Terreri	Hartsfield-Jackson Atlanta Int'l Airport	Aviation Contract Administrator	404.382.2334
Dr. John Stansbury	Peter Kiewit Institute	Associate Department Chair	jstansbury2@unl.edu

Appendix H: Equipment Specifications

Specifications for ISCO Products©

2150 Flow Module	
Size (HxWxD):	2.9 x 11.3 x 7.5 in (74 x 287 x 191 mm)
Weight:	2.0 lb (0.9 kg)
Materials of construction:	High-impact polystyrene, stainless steel
Enclosure (self-certified):	NEMA 4X, 6P (IP68)
Temperature Range:	-40° to 140° F (-40° to 60° C) operating and storage
Power Required:	12 VDC nominal (7.0 to 16.6 VDC), 100 mA typical, 1 mA standby
Power Source:	Typically, an Isco 2191 Battery Module, containing 2 alkaline or 2 rechargeable lead-acid batteries. (Other power options are available; ask for details.)
Typical Battery Life:	(using 15-minute data storage interval) Energizer® Model 529 alkaline - 15 months; Isco rechargeable lead-acid - 2.5 months
Program Memory:	Non-volatile programmable flash; can be updated using PC without opening enclosure; retains user program after updating.
Built-in Conversions	
Flow Rate Conversions:	Up to 2 independent level-to-area conversions and/or level-to-flow rate conversions.
Level-to-Area Conversions:	Channel Shapes - round, U-shaped, rectangular, trapezoidal, elliptical, with silt correction; Data Points - Up to 50 level-area points.
Level-to-Flow Conversions:	Most common weirs and flumes; Manning Formula; Data Points (up to 50 level-flow points); 2-term polynomial equation
Total Flow Calculations:	Up to 2 independent, net, positive or negative, based on either flow rate conversion
Data Handling and Communications	
Data Storage:	Non-volatile flash; retains stored data during program updates. Capacity 395,000 bytes (up to 79,000 readings, equal to over 270 days of level and velocity readings at 15-minute intervals, plus total flow and input voltage readings at 24-hour intervals)
Data Types:	Level, velocity, flow rate 1, flow rate 2, total flow 1, total flow 2, input voltage, temperature
Storage Mode:	Rollover; 5 bytes per reading.
Storage Interval:	15 or 30 seconds; 1, 2, 5, 15, or 30 minutes; or 1, 2, 4, 12, or 24 hours; Storage rate variable based on level, velocity, flow rate, total flow, or input voltage
Data Retrieval:	Serial connection to PC or optional 2101 Field Wizard module; optional modules for spread spectrum radio; land-line or cellular modem; 1xRTT. Modbus and 4-20 mA analog available.
Software:	Isco Flowlink for setup, data retrieval, editing, analysis, and reporting

Multi-module networking:	Up to four 2100 Series Flow Modules, stacked and/or remotely connected. Max distance between modules 3300 ft (1000 m).
Serial Communication Speed:	38,400 bps
2150 Area Velocity Sensor	
Size (HxWxD):	0.75 x 1.3 x 6.0 in (19 x 33 x 152 mm)
Cable (Length x Diameter):	33 ft x 0.37 in (10 m x 9 mm) standard. Custom lengths available on request.
Weight (including cable):	2.2 lbs (1 kg)
Materials of construction:	Sensor - Epoxy, chlorinated polyvinyl chloride (CPVC), stainless steel; Cable - Polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC)
Operating Temperature:	32° to 140° F (0° to 60° C)
Level Measurement	
Method:	Submerged pressure transducer mounted in the flow stream
Transducer Type:	Differential linear integrated circuit pressure transducer
Range:	(standard) 0.033 to 10 ft (0.010 to 3.05 m); (optional) up to 30 ft (9.15 m).
Maximum Allowable Level:	34 ft (10.5 m)
Accuracy:	±0.01 ft from 0.033 to 10 ft, (±0.003 m from 0.01 to 3.05 m)
Long-Term Stability:	±0.023 ft/yr (±0.007 m/yr)
Compensated Range:	32° to 122°F (0° to 50°C)
Velocity Measurement	
Method:	Doppler ultrasonic, frequency 500 kHz
Typical Minimum Depth:	0.08 ft (25 mm)
Range:	-5 to +20 ft/s (-1.5 to +6.1 m/s)
Accuracy:	(in water with uniform velocity profile, speed of sound = 4850 ft/s, for indicated velocity range); ±0.1 ft/s from -5 to 5 ft/s (±0.03 m/s from -1.5 to +1.5 m/s); ±2% of reading from 5 to 20 ft/s (1.5 to 6.1 m/s)
Temperature Measurement	
Accuracy:	±3.6° F (±2° C)
2191 Battery Module	
Size (HxWxD):	6.0 x 9.6 x 7.6 in (152 x 244 x 193 mm)
Weight (without batteries):	3.2 lb (1.4 kg)
Materials of construction:	High-impact polystyrene, stainless steel
Enclosure (self certified):	NEMA 4X, 6P, (IP68)
Batteries:	Two 6-volt Energizer Model 529* alkaline (25 Ahrs capacity) or Isco Rechargeable Lead-acid (5 Ahrs capacity) recommended. *Note - Energizer 529 ER does not give specified life.

Isco 2151 Intrinsically Safe Flowmeter	
Size (H x W x D):	8.4 x 11.3 x 7.6 in. (21.3 x 28.7 x 19.3 cm) including battery compartment.
Weight:	8.2 lbs. (2.4 kg)
Material:	High-impact molded polystyrene
Enclosure:	NEMA 4X, 6P IP68 (self-certified)
Power:	6.6 to 16.6V DC, 100 mA typical at 12V DC, 1 mA standby
Typical battery life, vs. data storage interval (using two 6-volt akaline batteries, Eveready Energizer 529 or EN529)	
15 minute interval:	8 months
5 minute interval:	4.5 months
Program Memory:	Non-volatile, programmable flash; can be updated using PC without opening enclosure; retains user program after updating
Flow Rate Conversions:	Up to 2 independent level-to-area conversions and/or level-to-flow rate conversions
Level-to-Area Conversions	
Channel Shapes:	Round, U-shaped, rectangular, trapezoidal, elliptical, with silt correction
Data Points:	Up to 50 level-area points
Level-to-Flow Rate Conversions	
Weirs:	V-notch, rectangular, Cipolletti, Isco Flow Metering Inserts, Thel-Mar;
Flumes:	Parshall, Palmer-Bowlus, Leopold-Lagco, trapezoidal, H, HS, HL
Manning Formula:	Round, U-shaped, rectangular, trapezoidal
Data Points:	Up to 50 level-flow rate points
Equation:	2-term polynominal
Total Flow Calculations:	Up to 2 independent, net, positive or negative, based on either flow rate conversion
Data Storage Memory:	Non-volatile flash; retains stored data during program updates. Capacity 395,000 bytes (up to 79,000 readings, equal to over 270 days of level and velocity readings at 15 minute intervals, plus total flow and input voltage readings at 24 hour intervals)
Data Types:	Level, velocity, flow rate 1, flow rate 2, total flow 1, total flow 2, input voltage

Storage Mode:	Rollover with variable rate data storage based on level, velocity, flow rate 1, flow rate 2, total flow 1, total flow 2, or input voltage
Storage Interval:	15 or 30 seconds; 1, 5, 15, or 30 minutes; or 1, 2, 4, 12, or 24 hours. 5 Bytes per reading.
Setup and Data Retrieval:	Serial connection to IBM PC or compatible computer with Isco Flowlink Software.
Baud Rate:	38,400
Operating temperature:	0° to 140°F (-18° to 60°C)
Storage temperature:	-40° to 140°F (-40° to 60°C)
Area Velocity Sensor	
Size (H x W x L):	0.75 x 1.31 x 6.00 in. (1.9 x 3.3 x 15.2 cm)
Cable Length:	25 ft. (7.6 m)
Cable Diameter:	0.37 in. (0.9 cm)
Weight (including cable):	2.1 lbs. (0.95 kg)
Materials:	Sensor - Epoxy, chlorinated polyvinyl chloride (CPVC), stainless steel; Cable - Polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC).
Level Measurement	
Method:	Submerged pressure transducer mounted in the flow stream.
Transducer Type:	Differential linear integrated circuit pressure transducer
Range:	0.033 to 10 ft (0.010 to 3.05 m)
Maximum Allowable Level:	20 ft. (6.1 m)
Accuracy **Non-linearity and hysteresis at 77°F (25°C) per foot of change from calibration depth, for indicated level range**	
0.033 to 5.0 ft (0.03 to 1.52 m):	±0.008 ft/ft (±0.008 m/m)
Greater than 5.0 ft (1.52 m):	±0.012 ft/ft (±0.012 m/m)
Maximum Long-Term Drift:	0.033 ft. (0.010 m)
Temperature Coefficient:	±0.0035 ft/°F (±0.0019 m/°C) (Max error within compensated range, per degree of change from calibration temperature.)
Velocity Measurement	
Method:	Doppler ultrasonic, Frequency 500 kHz, Transmission Angle 20° from horizontal
Typical Minimum Depth:	1 inch (25 mm)
Range:	-5 to +20 ft/s (-1.5 to +6.1 m/s)
Accuracy **In water, uniform velocity, speed of sound = 1480 m/s, for indicated velocity range**	

-5 to +5 ft/s (-1.5 to +1.5 m/s):	±0.1 ft./s (±0.03 m/s)
5 to 20 ft/s (1.5 to 6.1 m/s):	±2% of reading
Operating Temperature:	32° to 160°F (0° to 71°C)
Compensated Range:	32° to 122°F (0° to 50°C)

Appendix I: Organizational Chart

Organizational Chart