A real-time data monitoring prototype protocol to advance environmental management through a citizen science approach– A case study in Nepal

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This professional project tests a theoretical framework strategy that can be used to help start a wireless environmental sensor network though a citizen science approach. Its purpose is to help Nepal gain access to a long-term data collection plan, thus enhancing local communities' abilities to learn and make strong data-driven decisions focused on human and environmental health.

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SUMMARY

The lack of environmental monitoring data has restricted the efficiency of proper environmental management in the developing world. Although monitoring technologies have been touted for their potential to advance environmental understanding and management, there are very few examples of practical applications where this has been accomplished in the developing world. Due to the positive influx of urbanization and tourism in Siddharthanagar, South Nepal, the Nepal Study Center (NSC) from the University of New Mexico (UNM) teamed up with the poly-tech college Pratiman-Neema Health Institute (PNMHI) to address future environmental changes through a citizen science approach, known as the Danda River Monitoring Program (DEMP).

The objective of this professional project is to develop and deploy a prototype protocol for monitoring air, weather, and water in a location in Nepal where environmental data is not available. This professional project identifies and executes a practical framework strategy to initiate a wireless environmental sensor network to gain access to a long-term data collection plan through a citizen science approach. Citizen science is the participation of any citizen who interacts in a data collection and monitoring process. The scientific data gathered from the monitoring sensors, combined with curricular toolkits, will be used in a digital lab setting to educate students and community members to enhance their learning and environmental awareness.

Assisting in the initial implementation process was impactful, for the wireless sensors are currently collecting data, a citizen science survey was successfully administered to understand future improvements, and a robust collaborative relationship between NSC and PNMHI was established. Furthermore, an enhancement of the capabilities of the community to learn and make firm data-driven decisions focused on human and environmental health was implemented.

The value that this project brings to the community is fourfold: water resource management, health management, a platform for enhanced science studies, and an established program to attract eco-tourism that will, in turn, preserve the ecosystem and natural heritage of the community. Ultimately, the study found that the efforts performed to demonstrate a positive impact on the community in Nepal. This program has strong support from various stakeholders and the potential to improve the environment and health of the people in Nepal.

ACKNOWLEDGMENTS

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PROFESSIONAL PROJECT OVERVIEW

Rapid urbanization and human migration from rural to urban cities can cause drastic environmental and ecological impacts. It can affect energy demands, cause climate changes that alter hydrologic cycles and quality, and threaten biodiversity; thus, proper natural resource management is necessary (Seto, 2011). Seto (2011) states that in India, China, Africa, and North America, urban land expansion rates are higher than urban population growth in which the urban growth is considered more expansive then compact, suggesting that as population continues to grow, so does rapid urbanization. The World Bank reports that in Nepal, urban population growth rates are up to 7 percent and, consequently, even though the urban areas tend to drive economic growth, the sustainability of urbanization in Nepal is a concern due to the lack of adequate planning (World Bank, 2013). Specifically, in the municipality of Siddharthanagar, Nepal, urbanization and natural resource management have gained interest in the community for multiple reasons. First, the area has a world heritage site, where thousands of people from all over the world travel to peruse their pilgrimage to the Lumbini temple, also known as the birthplace of Buddha (UNESCO, 2018). Second, a new international airport is currently under development, thus increasing the opportunity for more tourism and incentives to urbanize the area (A. Bohara, personal communication, January 2018) third, Siddharthanagar was recently named the new capital of the metropolitan area. In response to this influx of urbanization and tourism (A. Bohara, personal communication, January 2018), the Nepal Study Center (NSC) from the University of New Mexico (UNM) has teamed up with a poly-tech college, Pratiman-Neema Health Institute (PNMHI), to address future environmental changes through a citizen science approach known as the Danda River Ecological Monitoring Program (DEMP).

Environmental management in the developing world is hamstrung by a lack of environmental monitoring data. This professional project is therefore focused on addressing this challenge by

exploring the potential of emerging technologies, specifically autonomous and wireless environmental sensors. Although such technologies have been touted for their potential to advance environmental understanding and management, there are very few examples of practical applications where this has been accomplished in the developing world. The objective of this professional project is to develop and deploy a prototype protocol for monitoring air, weather, and water in a location in Nepal where there is neither environmental data available in the area to provide the community with a baseline understanding of the environmental parameters, nor are there educational tools to enhance their awareness.

The study was conducted in close collaboration with Dr. Alok Bohara, Full Professor of Economics and Founding Director of the of Nepal Study Center (NSC) at the UNM; Dr. Mark Stone, Associate Professor of the Civil Engineering Department at UNM; and John Fleck, Director of the Water Resource Program at UNM. The environmental sensors were successfully deployed in Nepal during the December 2017 – January 2018 Himalayan study abroad seminar trip, sponsored by the NSC. This project worked in collaboration with the host partner, Pratiman-Neema Health Institute (PNMHI), located in Siddharthanagar, Nepal. The program introduced the monitoring system using a citizen science approach known as the Danda Environmental Monitoring Program (DEMP).

After this introduction and a brief personal statement, this paper will begin with a literature review in order to assimilate the link between biodiversity, smart environment and wireless sensors, and citizen science. Following the literature review, a case study section will discuss the in-the-field research performed in Nepal, including the objective, issues, area of interest, and collaborative partners associated with the project. Then, the methods section will discuss the environmental sensor installation efforts in detail. Next, the results section will present the data collection readings provided from the three environmental sensors (air quality, weather measurements, and water dynamics) and discuss the results from a citizen science survey that was distributed. Finally, the conclusion section will elaborate on the meaning and value of the sensor data, the survey results, and the future options the Nepal Study Center has to enhance

the efforts for prospective students worldwide who express interested in being involved in the DEMP citizen science initiative.

PERSONAL STATEMENT

Growing up in a desert community where water has always been a topic of concern, I found myself fascinated with the value of water at a young age. Throughout childhood, I can remember talking long walks along the Rio Grande Bosque in New Mexico with my family and classmates, learning about environmental systems and wildlife. I enjoyed the river in my community thoroughly. The idea of a community not being able to enjoy their river system due to pollution makes this Danda River Monitoring Program project very meaningful to me. Throughout my studies, I have had the opportunity to travel to various countries around the world. With an open mind, I viewed each country through a different lens and found a familiar pattern, all related to water, especially in the developing world. Adequately managed water is known to enhance the quality of life, and unfortunately, most river systems in the developing world tend to need more affection. This professional project is important to me because it gave me the opportunity to emerge myself into an unfamiliar community and contribute toward helping to make the Danda River in a community in Nepal clean.

LITERATURE REVIEW

Three essential pillars form the foundation for the Danda Environmental Monitoring Program (DEMP). These pillars are biodiversity as it relates to urbanization, smart environments using Wireless Sensor Networks (WSN), and citizen science (CS), all of which involve collaboration and partnerships when working with a host partner in a developing nation. This section will synthesize published work on these three topical areas in order to form the association between urbanization, biodiversity, smart environment monitoring, and citizen science.

RAPID URBANIZATION AND BIODIVERSITY

Duraiappah (2005) defines biodiversity as the variability between living organisms that includes diversity within species, between species, and of the ecosystem. It is said that “biodiversity is the foundation of ecosystem services (services the ecosystem provides to humans) that

critically contribute to human well-being; thus, decisions that influence biodiversity are important to human-managed ecosystems as well as natural ones" ("Biodiversity and Human Well-being," 2018, p. 1.1). Examples of ecosystem services include pollution control by ecosystems, soil formation and retention, resistance against invasive species, pollination of plants, climate regulation, and nutrient and water cycling (Duraiappah, 2005). According to the World Health Organization (WHO), a rapid growth in "unplanned and unstainable" urban development tends to make developing cities vulnerable to emerging environmental health hazards (Orginization W. H., 2018, p. a). According to the WHO, 50% of the world population will be living in urban areas by 2050 (Orginization W. H., 2018, p. b). The report went on to conclude:

> As urban populations grow, the quality of global and local ecosystems, and the urban environment will play an increasingly important role in public health with respect to issues ranging from solid waste disposal, provision of safe water and sanitation and injury prevention to interface between urban poverty, environmental and health. (Orginization W. H., 2018, p. b)

During a rapid increase in urbanization, there is often a devaluation of greenspaces, biodiversity, loss of waterways, and air and water quality (Ruta, 2010). Thus, while ecosystem biodiversity plays an important role in human health around the world, it is currently being threatened by environmental challenges such as pollution. The World Bank Group's *2010 Environment Strategy Report* suggests that if trends continue through 2030, particulate matter emissions will cause deteriorations in urban air quality, decreasing biodiversity and disrupting ecosystem services around wetlands. Additionally, municipal waste generation, improper waste management, and increased water pollution will continue to present great challenges (Ruta, 2010), all of which affect the biodiversity and the natural environment, and in turn, human health. Pruss-Ustun, Wolf, Bos, and Neria (2016) estimate that 12.6 million deaths each year are attributable to air, water, and soil pollution. Therefore, understanding how to properly plan for the rapid growth of communities moving from rural to urban areas is important not only for the environment, but for human health, as well. According to Hui, (2013), biodiversity plays a

critical role in maintaining ecosystem productivity, services, sustainability, stability, and human health and wellbeing, all of which explain why biodiversity issues are becoming more of concern globally. By prioritizing the protection of biodiversity and the natural environment, decisions to protect ecosystem services in turn enhance the wellbeing of human health.

SMART ENVIRONMENT AND WIRELESS SENSOR NETWORKS

The primary reasons for environmental pollution are lack of regulation, education, knowledge, wealth distribution, scientific data, and—especially pertinent to this project—information. Ruta (2010) suggests that "an immediate action commonly requires dependable and accurate information," (p. 5) and stakeholders in the environment—such as local governments, non-profit organizations (NGOs), the private sector, institutions, and communities—look to official statistics for accurate and actionable information. Currently, however, the collection of accurate and real-time environmental data, especially in developing nations, is perceived as expensive and logistically challenging (Ruta, 2010). Consequently, environmental management in the developing world is hamstrung by a lack of environmental monitoring data. Without a mechanism to collect environmental data, the capacity to integrate scientific data and knowledge into decision- and policy-making is limited, thus inhibiting scientists' and governing bodies' ability to make constructive recommendations (Ruta, 2010). Furthermore, lack of data can limit education and the ability to draw scientific conclusions about local environmental changes (Ruta, 2010).

To achieve environmentally sustainable development through data-driven decision-making, the notion of environmental data monitoring through smart technologies is becoming more of a reality. One such technology is a "smart environment," which comes from Wireless Sensor Networks (WSN) that are already used to monitor real-time data, in many cases triggering various warning systems based on information gathered through wireless sensing. When harnessed collectively, wireless sensor data can give a more complete picture of real-time environmental circumstances; can be cost-effective, autonomous, and energy-efficient; and can help mitigate data gaps and the labor costs related to filling those gaps around the world (Pathan, Hong, & Lee, 2006). Typically, sensors can monitor temperature, pressure, humidity,

soil makeup, vehicular movement, noise levels, lighting conditions, and the presence of objects or substances (Estrin, Govindan, Heidemann, & Kumar, 1999), in order to, for example, monitor water levels or water quality or even track movements of animals. Thus, wireless sensors comprising a smart environment increase the ability to collect data and then facilitate educational awareness and data-driven policy-making—capabilities that are especially important for developing countries. Pathan, Hong, and Lee (2006) offer an example in Bangladesh, where wireless sensors were deployed to acquire data related to flooding, tsunami, and road traffic. This technology showed great promise for helping the developing country prepare for and manage the repercussions of frequent environmental challenges and natural disasters it experiences each year.

CITIZEN SCIENCE

Citizen Science (CS) is said to "bridge the gaps by harnessing the power of people who are motivated by curiosity, a desire to advance research or concern about environmental conditions in their communities, then connecting them to projects that benefit from their energy and dedication" (Cavalier, 2018 p.1). What is distinctive about CS is that it enables people who are not formal scientists to participate in the discovery of new scientific knowledge through observation, participation, a sense of ownership, and data collection (Conrad & Hilchey, 2010). CS opens the door for communities and the public to act through incorporating education through citizen science projects.

In a 2010 article, Conrad and Hilchey describe how, on a global scale, decision-makers and NGOs are beginning to involve CS volunteers with environmental monitoring and data collection. This involvement is due to the logistical challenges associated with deploying autonomous environmental sensors and the need to monitor environmental parameters continuously to fill data gaps in the developing world. Since 2007, "there has been an explosion of the interest in using the Web to create, assemble, and disseminate geographic information provided voluntarily by individuals" (Goodchild, 2007, p. 211). For example, platforms such as Project NOAH and SciSpi have free mobile applications that enable CS participants to observe wildlife and nature, and share photos from their schools, backyards, towns, and cities (Cavalier,

2018). This enhances the ability of participants to contribute to CS data collection and monitoring from anywhere in the world.

A perfect example in the United States is the Bosque Environmental Monitoring Program (BEMP), where a group of CS BEMP students use groundwater environmental sensors to gather long-term data related to the overall condition of the New Mexico Bosque forest's ecosystem, along New Mexico's Rio Grand River (BEMP, 2018). The objective of the BEMP program is to involve citizen volunteers to enhance local environmental connections, increase public understanding of the complex ecosystem, and fulfill important environmental research needs. The BEMP model is strong because it requires participants to learn high-level scientific method data collection skills to ensure the integrity of high-quality data results (BEMP, 2018).

Ultimately, Congrad and Hilchey summarize the issue this professional project takes on, and its solution, saying:

> . . . the need to have a comprehensive understanding of ecosystem integrity, including function and structure, is often confounded by the lack of, or inadequate and incomplete, data and monitoring initiatives by professional and scientists and government agencies. To fill the void, nonprofessionals and citizen organization have established a method to track trends and work toward effective and meaningful management planning, management and stewardship. (Conrad & Hilchey, 2010, p. 1)

Wireless environmental sensors now enable data collection that might previously have been unaffordable or inaccessible. CS, meanwhile, facilitates community engagement and involvement with the WSN tools, such as phone applications that display real-time data tracking specific birds in various regions or school programs that involve the student body to collect ecological data in the field. Ideally, implementing wireless environmental sensors using a CS approach calls for active collaboration, partnership, and participation. Not all CS and environmental sensor monitoring initiatives are entirely accepted by every community, but as more and more organizations start to practice CS, these methods will slowly become a norm for these types of data collection projects. Recently, the U.S. Army Corps of Engineers announced during one of their presentations in Albuquerque, New Mexico, that they often look to the

BEMP program for reliable data that inform their decisions. This statement is a good indicator that strong organizations are beginning to put faith in the CS approach for quality and reliable data collection (BEMP, 2018).

CASE STUDY

This case study was performed to explore the complexities associated with deploying wireless environmental sensors as part of a citizen science research project, due the lack of practical examples in this topic area. This case study can be considered a feasibility multimethod research study, consisting of preliminary survey data research, visual and in-the-field observations, and hands-on teaching through a qualitative and quantitate analysis approach.

First, the NSC analyzed survey data from a previous 2016 Nepal study that delivered information related to the urban health of the municipality of Siddharthanagar, Nepal, and surrounding areas. Specifically, the study looked at variables related to the watershed and river system known as the Danda River. Upon further analysis, the NSC researchers found data relations between significant variables such as waterborne disease and hand washing, traffic and quality of life ratings, and education and wiliness to pay for a cleaner river. With this preliminary data, they concluded that there was a need to enhance the awareness of the environmental parameters associated with the health of the Danda River and surrounding areas affected by the river system. For more detailed information on the previous studies, visit the NSC website (nepalstudycenter.unm.edu).

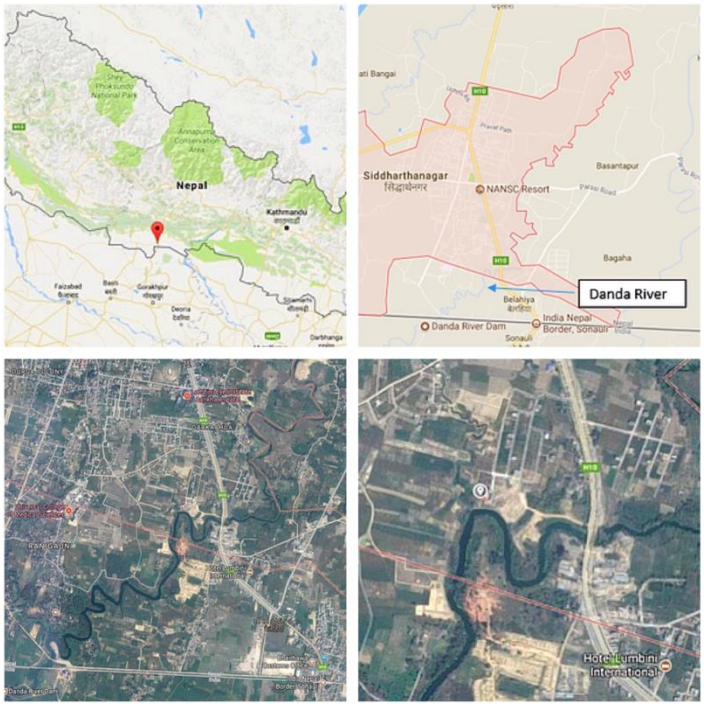
Next, during Winter 2017 (December 19, 2017 – January 6, 2018), a group of undergraduate and graduate students from the University of New Mexico (UNM) embarked on a trip to Nepal called The Himalayan Study Abroad Program. The program was hosted by the Nepal Study Center (NSC) in the UNM Department of Economics. NSC's mission is to work in collaboration with the community of Siddharthanagar, the host institutional college campus collaborators at PNMHI, local schools, and authorities to develop the foundation for long-term data collection and environmental monitoring, in hopes that the information will be used to inform sustainable solutions for a "cleaner environment and healthier living" (NSC, 2018).

Finally, during The Himalayan Study Abroad Program stay in Nepal, the students installed environmental sensors and trained the PNMHI faculty, staff, and eco-club members on how to use the sensors as well as the theory behind why the future data collection will be important to the community and the health of the Danda River. Additionally, the NSC contributed to the environmental awareness education DEMP initiative through hosting a seminar and training day. The specificities of these efforts are explained in the methods section of the paper.

AREA OF INTEREST

This case study takes place in the small and environmentally diverse country of Nepal. Nepal is a landlocked country located in the Himalayan region of South Asia. It borders China in the north and India in the south and is known for its vast and diverse natural beauty. This case study was performed in-the-field at a poly-tech college called Pratiman-Neema Health Institute (PNMHI), which is located in the Siddharthanagar municipality, formerly known as Bhairahawa. Siddharthanagar consists of 13 wards, and the two wards that the NSC worked in were Ward 3 (PNMHI campus) and Ward 5 (the Mayor's office). The reasons this collection area was desirable are as follows:

Siddharthanagar has unique attributes that make it a perfect place for the first citizen science environmental program to be implemented in Nepal. First, for many years, this area was known as the "Gateway of Lumbini," identifying it as a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Site known as the Lumbini Circle where thousands of Hindu pilgrims and Buddhist monks from every corner of Asia travel to make their pilgrimage (UNESCO, 2018). Second, not only does this area possess strong religious attraction, it is also known to be an industrial center that impacts the economy due to significant border trade with India (A. Bohara, personal communication, Dec. 1, 2017). Significant development is imminent and visible based on constant construction, and a soon-to-be-built international airport will facilitate an even greater influx of tourism (A. Bohara, personal communication, Dec. 1, 2017). Finally, the central element is the critical watershed called the Danda River, which flows through Siddharthanagar. This river hosts a variety of wild species and is used for domestic and industrial purposes, yet has little regulatory protection and currently no reported



environmental data. Due to the influx of people migrating from the rural to urban parts of Nepal as well as the fact that Siddharthanagar was recently announced as the capital of the municipality, understanding the ecosystem and finding ways to protect the land and watershed for the health of the people and the environment has become an active mission for the NSC and PNMHI.

FIGURE 1 NEPAL MAP; THE MANUCIPALITY OF SIDDHARTHANAGAR; THE RIVER SYSTEM KNOWN AS THE DANDA RIVER; AND THE PNMHI SCHOOL CAMPUS BUILDING

PNMHI

The Pratiman-Neema Health Institute (PNMHI) is the leading host partner for DEMP. This school is the central hub for the environmental sensors and is the primary host and physical location for anyone who wants to participate in DEMP and the associated eco-club. Currently, there is an environmental coordinator who works for the Center for Sustainability located at the PNMHI and facilitates all the interactions between the visitors from NSC and PNMHI. All of the sensor installations and training took place at PNMHI with one exception: the sensor installation at the Mayor's office. (See the *Methods* section of this paper for specific site locations.)

The Danda River

The Danda River flows through the municipality of Siddharthanagar, Nepal. The river starts in the northeast corners of the Rupandehi and Nawalparasi districts; runs southwest through various rural counties, including the city of Bhairahawa; and ends at the Indian-Nepal border (Nepal Study Center, 2016). The river flows through urban settlements, farmlands, open spaces, and three rural counties (Nepal Study Center, 2016). The Danda River is known to be a groundwater-fed river system and is said to be a natural river (Nepal Study Center, 2016). Some

areas along the river are known to have pristine reaches that provide homes for various species of insects, birds, and reptiles, portraying a healthy riparian ecosystem (Nepal Study Center, 2016). However, there are other reaches of the river that are regularly disrupted due to uncontrolled algae growth (eutrophication) along the river (Nepal Study Center 2016). The pollutants that cause this eutrophication come from upstream agricultural and domestic waste discharges (Nepal Study Center, 2016). Due to urban population growth, increased tourism, farmland runoff, and factories, the impaired riparian areas along the Danda River have become a concern.

According to the facility of PNMHI and Nepal's Department of Hydrology and Meteorology, there is no published data on the Danda River. Among many environmental challenges in the area, particularly pollution due to illegal dumping and industrial inputs, the NSC has made it a priority to monitor water quality. While pollution is discussed as part of this case study because it is a large contributor to the area's environmental challenges, the case study focuses on river dynamics—also known as "river stage"—as the main area of interest.

River stage is important to understand because it involves the patterns of the river flow. Being able to predict the flows of the river could be a great benefit to the PNMHI campus. Due to the heavy monsoon season in the summer months, flooding at the PNMHI is a major safety concern. To protect against major flooding on the school grounds, a gabion wall was built, but even with the wall in place, during heavy rains, the river flow still expands to the bottom floor of the PNMHI building (A. Bohara, personal communication, Dec. 18, 2017). During the visit, it was personally observed that the flow of the river can vary, because upstream there is heavy agriculture use and a dam that controls the flow and is often turned on and off without notice. Understanding the weather conditions in the area, along with the river stage can be a beneficial tool for predicting the Danda River flooding conditions. Additionally, future efforts to restore the unique biodiversity and plant and animal health along the Danda River require an understanding of the river's flow patterns. The natural flow regime of the river is known to keep it healthy. Additionally, understanding flow patterns can help water managers understand how to manage the ecosystem better.

Problem Statement

The problem this case study is attempting to solve is that long-term ecological data does not exist for the Danda River. There is no high quality aerial photography and no hydrology data, yet frequent flooding and health and biodiversity concerns underscore the need for data in this area. Due to the complete lack of data, any form of environmental monitoring initiation—in this case, wireless sensor monitoring of river flow—can add great value to the short and long-term goals of increasing knowledge of the Danda River for the sake of health and environmental improvements. Additionally, strategies developed to overcome various obstacles inherent in any monitoring initiative—such as communication barriers, scheduling and coordination setbacks, and technology difficulties such as reliable Wi-Fi and data downloading accessibility—are expected to add value to the aim of the project.

Objectives

The overall objectives of the case study are threefold. The first objective is the NSC's goal of specifically deploying three environmental sensors to monitor a variety of environmental parameters as part of a long-term data monitoring system. The second objective is to provide a protocol known as a Standard Operation Procedure (SOP) that can be used to further educate participants and enhance the host partners' environmental curriculum. The third objective is determining and communicating the value that the DEMP initiative will bring to the community.

The short-term tasks include initiating DEMP by deploying the first round of environmental sensors, collecting the first few months of environmental data from the sensors, and creating a living document of SOPs as a tool to provide practical guidance for preparing, implementing, and operating sensor deployment. Additionally, a survey was handed out to the participants in order to quantify and qualify the impact of the program.

The long-term vision includes increasing the body of knowledge related to environmental data in Nepal, in order to eventually set the stage to create useful data analysis tools and graphs that can encourage data-driven policy decisions by stakeholders in the community, and also to spark interest in and ownership of similar ecological monitoring initiatives.

The value that this project brings to the community is fourfold: (1) inform to advance water resource management, (2) health management, (3) a platform for science studies, and (4) an established program to attract eco-tourism that will in turn preserve the ecosystem and natural heritage of the community. Meanwhile the value to student participants is the opportunity granted by the host partner, PNMHI, to conduct professional research studies while experiencing international culture and traditions at the same time.

The nature of the case study is to determine what major issues will need to be overcome to further the long-term data collection process and to ultimately justify the impact these efforts will make on the community.

DANDA ECOLOGICAL MONITORING PROGRAM CITIZEN SCIENCE INITIATIVE

DEMP is an international collaborative project between PNMHI, a non-profit organization in Siddharthanagar, Nepal, and the NSC's Sustainable Development Lab team of the University of New Mexico (UNM). The primary aim of the program is to close the knowledge gap on various environmental parameters to help improve the urban ecosystem in Siddharthanagar, Nepal. The secondary aim is to collect quality data in an effort to generate positive impacts on health, well-being, knowledge, attitude, behavior and the quality of life for the community who live in and near the urban city of Siddharthanagar (NSC S. D., 2016). To progress DEMPs long-term goals, this environmental wireless sensor deployment case study was initiated in January 2018 to further the efforts in improving environmental and health management practices in the country of Nepal.

PARTNERSHIPS AND COLLABORATION

Nepal is a very collaborative culture. According to their government mission, they regularly collaborate with various NGOs and private sector companies to make positive improvements in the community (A. Bohara, personal communication, Dec. 1, 2017). The stakeholders in this case study project include the eco-club members, political, intuitions and local government. The reason this project is of interest to the NSC is that it demonstrates firm ties between the participating organizations, whereas too often NGOs come into the country and leave without a sustainability plan.

Working internationally on service projects takes large amounts of communication, persistence, and dedication. Consequently, the efforts made by the NSC would have not been possible without strong partnership and collaboration between the following organizations. (**Table 1)** provides information on all of the partnerships associated with the assurance of DEMPs sustainability and success.

TABLE 1: TABLE OF COLLOBORATING ORGINIZATIONS

Organizations	Description
University of New Mexico Nepal Study Center (UNM-NSC)	The University of New Mexico is a University in Albuquerque, New Mexico. The Nepal Study Center (NSC) is a program at UNM. The NSC was founded by Dr. Alok Bohara. The NSC is an organization dedicated to fostering intellectual collaboration and sharing knowledge with a dedicated focus and wider perspective on the socio-economic development and sustainability, health, technology transfer, and environmental issues of the Himalayan region and the countries in South Asia (NSC, 2018).
UNM Water Resource Program (WRP)	The WRP is a department at UNM dedicated to graduating water resource graduate students that focus on water -related issues, training for environmental professionals, and promoting fair, healthy, and sustainable solutions to the challenges of water use in New Mexico (WRP, 2018).
Pratiman-Neema Memorial Foundation (PNMF)/Pratiman-Neema Health Institute (PNMHI)	PNMF is a nonprofit organization and founding trustee of the Polytechnic Institute of PNMHI. The foundation has three objectives: academics, research and community engagement to bring people and institutions to work on ideas that are creative, long-lasting, and sustainable. The foundation focuses on organically dynamic, forward-looking initiatives and pays close attention to vulnerable and less privileged communities (PNMF, 2018). PNMHI is a polytechnic school located in Bhairahawa, Lumbini, Nepal. As a multidisciplinary college, PNMHI teaches paramedical science; engineering and environmental science; and economics, business, and behavioral science. The school's mission is to acquire knowledge, build skills, and nurture wisdom (PNMHI, 2018).
Bosque Environmental Monitoring Program (BEMP)	BEMP's mission is science, education, and stewardship of the Rio Grande and its watershed through long-term, hands-on student research of ecosystem response and function to inform public policy (BEMP, 2018).
Eco-club	The eco-club consists of PNMHI as the headquarters and two public schools upstream and downstream of the Danda River. The eco-club was created by DEMP to host environmental hands-on CS learning. Beyond the three core schools, PNMHI invites institutions from all over the region to participate in the CS initiative, including the agricultural college and medical colleges located near PNMHI. The local government (including the mayor of Siddharthanagar and other local government officials as well as PNMHI board members and the Minister of Health) are all involved in the eco-club activities.

METHODOLOGY

The methodology section of this professional project paper will discuss in more detail the tools used, the environmental sensor application specifications, the three on-site visits in Nepal, the citizen science approach, and the data collection plan during the winter break visit in Nepal. Additionally, the future data collection plan for the continuation of the DEMP long-term data collection process is included.

Google Maps Tool

To identify the site area prior visiting Nepal, Google Earth was used to create a general map of the study site area. The desired and ideal method to identify and create a map of this area is to use Geographic Information System (GIS) tools, but because so little data about this specific area is available, creating a map using GIS was not an option. Google Earth allowed us to perform a site analysis of the Danda River, identifying buildings, agricultural fields, and important landmark structures such as a brick factory and other buildings located next to the Danda River.

Environmental Sensor Application Specifications

This section will briefly describe each autonomous environmental sensor (Laser Egg, Weather Station, and Pressure Transducer), its function/capabilities, its set-up design, and the current status and location of the sensor data **(Figure 2, 3 and Table 2)**.

FIGURE 2: (WARD 3.) SENSOR LOCATIONS AT PNMHI

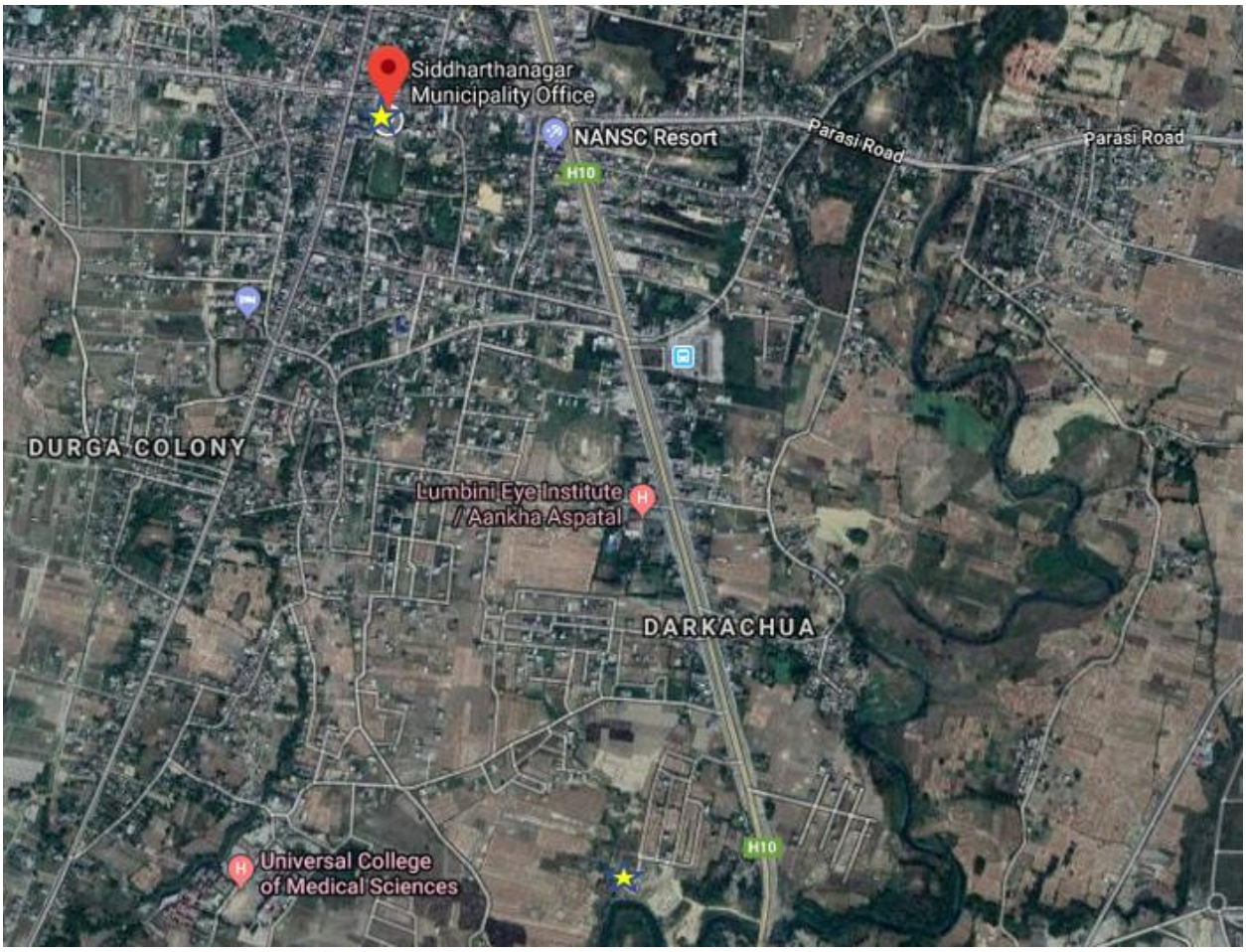


FIGURE 3: (WARD 3. PNMHI AND WARD 5. MAYOR'S OFFICE (MUNICIPALITY OFFICE). THE SECOND LASER EGG IS LOCATED AT WARD 5.

TABLE 2: SENSOR INSTALLATION LOCATIONS

Sensor	Location	Comments
Laser Egg	1. PNMHI campus (Ward 3.) 2. Mayor's (Ward 5.)	Two indoor air quality sensors were set up in two different locations. Ideally, in the future DEMP will have 13 sensors collecting data in various locations.
Weather Station	1. PNMHI campus (Ward 3.)	The Weather Station is set up at the PNMHI campus, and eventually DEMP will have more stations set up to collect data.
Levelogger	1. PNMHI campus (Ward 5.)	There is one Levelogger collecting data. Eventually DEMP would like more sensors collecting data along the Danda River and in a well to collect data for groundwater.

The wireless sensor network described here was developed to address the lack of environmental monitoring data in Nepal. Ideally, such a system should have the following capabilities (Wijesinghe, Siriwardena, & Dias, 2013):

- The system operates with little human labor.
- The sensors are relatively affordable
- The sensors have applications that function from any smart device and can be viewed by community members who have access to the device.
- The system collects data in real-time and can operate over long periods of time.
- Data can be monitored remotely.
- The system can operate in areas with poor connectivity.
- All elements can be installed, maintained, and repaired by trained but non-technical personnel.
- The operation of the system is energy efficient.
- The system can issue alerts when necessary.

Currently, the three different sensors possess a majority of the bulleted qualities except for the desired alert system that is desired for the future.

LASER EGG

Laser Eggs are sensors that monitor air quality based on a measurement called the Air Quality Index (AQI) (Kaiterra, n.d.). AQI is a number used by government agencies to communicate to the public the level of air quality (USEPA, 2016). The higher the number, the more likely a community is to experience negative health effects (USEPA, 2016). The Laser Egg measures the air quality in particulate matter 2.5 ($PM_{2.5}$). It refers to tiny particles or droplets in the air that are two and one-half microns or less in width, the AQI is a scale that makes it easier for the general public to quickly determine and understand the air quality level (Kaiterra, n.d.). The Laser Egg in this project was developed to measure indoor air quality; therefore, in this case study, only indoor air quality was measured.

The Laser Egg by the company Kaiterra was selected for this project because of its affordability, user-friendly interface, and real-time data display on the Laser Egg sensor, as well as a built-in application that can be accessed easily through a download on a smart device.

The sensor is programmed to measure the air quality every 0.1 seconds through a small fan built into the shell which intakes the ambient air through the back of the sensor. A laser beam streams across the air current, and then the refracted light measures the partial size count and diameter of the particles in the air (Kaiterra, n.d.). For more detail about the Standard Operation Procedure (SOP), see (**Appendix A.1**).

SETUP DESIGN

During the preliminary stages, two Laser Eggs were tested in Albuquerque, New Mexico, before deployment in Nepal. The initial testing of the Laser Egg allowed the researchers to address and anticipate potential challenges. Some of the difficulties associated with the Laser Egg included Wi-Fi connectivity, pairing issues with various smartphone devices, and missing equipment that needed to be additionally purchased (for example, a wall power adapter and an adapter to fit Nepal outlets). The advanced testing was crucial for the success of the limited-time deployment in Nepal.

After a site visit, the selected areas for the Laser Eggs were established. One Laser Egg was set up inside the PNMHI Sustainability Action Lab conference room. The Laser Egg was displayed in the Sustainability Lab at PHNMI (Ward 3.) so that the students could see the real-time air quality index (AQI), and PNMHI and NSC used the Kaiterra mobile application (paired to the Laser Egg) to access complete AQI data (**Appendix A.1**).

The second Laser Egg was set up at the Mayor of Siddharthanagar's Office (Ward 5.). The reason this was done was so that the researchers could see whether there were differences in indoor air quality between two different areas. For example, PNMHI air quality might differ from the Mayor's office because of variables such as the nearby brick factory's pollution outputs, traffic, and/or temperature.

CURRENT STATUS SINCE DEPLOYMENT

Currently, two Laser Eggs are collecting indoor air quality data in two separate locations in Siddharthanagar. Plans are moving forward to establish a network of Laser Eggs (approximately 15) and deploy them at various school campuses around Nepal. Eventually, the data will be collected, and a specific app is currently being developed by the NCS to obtain all the air quality

data for a long-term, real-time view of air quality, which will be provided on the internet for everyone to access.

LEVELOGGER PRESSURE TRANSDUCER

Levelogger Pressure transducers are designed to measure the level and temperature of water for various water resource management applications (Solinst, n.d.). These can include: long-term groundwater monitoring; river, lake, and stream gauging; aquifer testing; wetlands and storm water runoff monitoring; and agricultural stormwater runoff monitoring (Solinst, n.d.). A Solinst Levelogger Edge water level and temperature logger was used in this case study to initiate the process of measuring river dynamics (river stage) of the Danda River. It was donated by the UNM Civil Engineering Department GIS Lab. It was selected because of its relative affordability, durability, long-lasting battery life, large data point memory, and potential Bluetooth and smartphone application capabilities. Additionally, this device was used in previous UNM international watershed research studies (M. Stone, personal communication, Nov. 15, 2017).

The Levelogger starts to measure data once it is programmed and deployed into the river. It measures the temperature and the pressure of the water in feet. The logger was programmed to fit the parameters of the project using the Solinst software on a computer. To accurately measure the level of the water, the barometric pressure also needs to be measured. The company Solinst provides a barometric sensor, but for this study, the 1-in-5 Pro Weather Station provided barometric data for this study because the UNM lab did not need to order an additional sensor. The Levelogger Standard Operation Procedure (SOP) can be viewed in (**Appendix A.3**).

SETUP DESIGN

During the preliminary stages of the study, the Levelogger was tested by following the Levelogger Solinst manual directions before implementation in Nepal. A design was created prior to the deployment of the sensor to understand what materials were needed to be purchased and ordered so that they were available for building the well for the sensor to be deployed in during the day of the deployment in Nepal see (**Figure 4**).

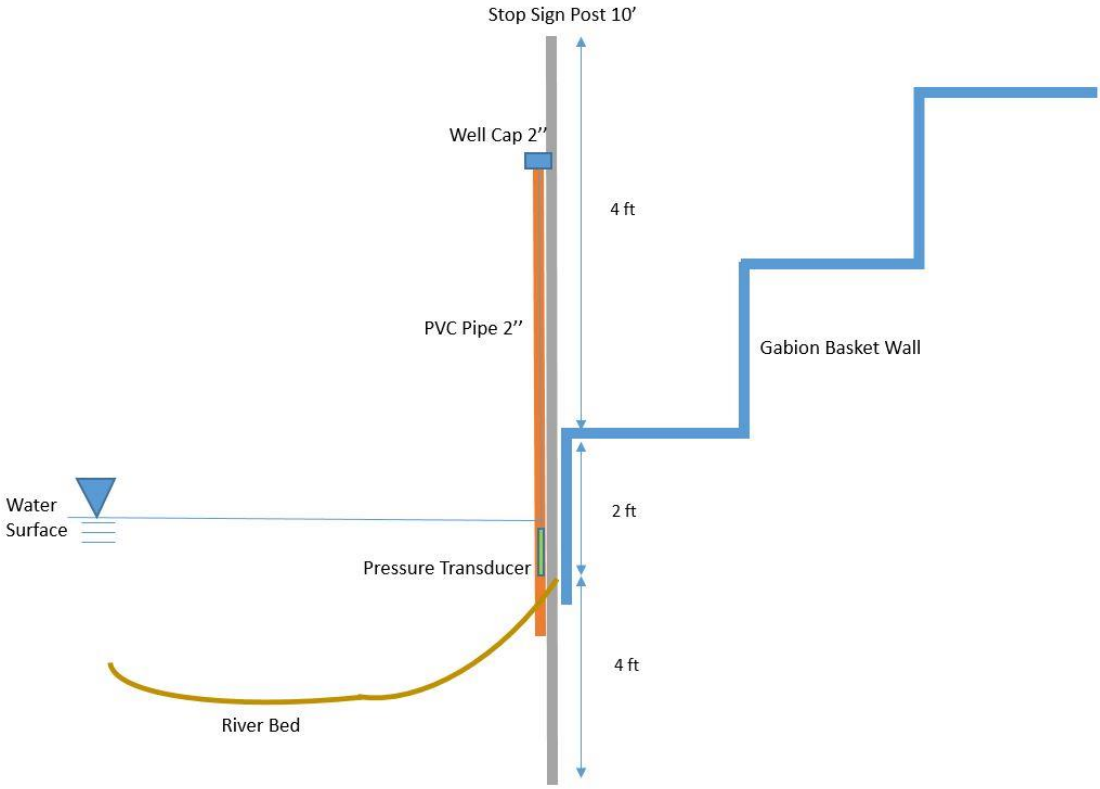


FIGURE 4: THIS SCAMATIC IS THE INITIAL DESIGN. THE GREY STOP SIGN POST WOULD BE INSTALLED AND SECURED TO THE GABION BASKET WALL. THE ORANGE PVC PIPING WAS THE ORIGINAL DESIGN FOR THE PRESSURE TRANSDUCER TO BE DEPLOYED DOWN INTO THE DANDA RIVER TO ACT AS A WELL. THE ACTUAL INSTALLATION OF THE SET UP WAS CHANGED WHEN NSC ARRIVED TO THE SITE AREA

On the day of deployment in Nepal, some of the design parameters had to be changed based on the materials available to build the well and physical safety challenges that arose. The eco-club students and environmental coordinator need to have access to the well to collect the data; therefore, installing it in a safe location was a priority because the river depth would fluctuate and the well had the potential to be underwater during certain times of the year. A steel pipe with holes that allowed water to flow inside was secured along a gabion, and the Levelogger was attached to a rope, lowered down the steel pipe well, and sealed with a locked

cap. Vandalism and theft is a concern in the area; therefore, the PNMHI locked and marked the well with a “danger” sign for protection.

CURRENT STATUS SINCE DEPLOYMENT

Currently, the Levelogger is deployed along the Danda River, secured inside the steel pipe well, measuring six readings a day (00:00, 09:00, 03:00, 06:00, 12:00, 15:00, 18:00, 21:00). Plans to deploy a second Levelogger for more accurate river stage reading have been suggested to the NSC and PNMHI.

FIGURE 5: CURRENT SET UP AFTER INSTALLATION

5 IN 1 PRO WEATHER STATION

Weather stations are used to measure outdoor weather-related variables. The Pro 5-in-1 Weather Station by the company Acurite measures five different outdoor conditions including the temperature, humidity, wind speed, wind direction, and rainfall. The Pro 5-in-1 Weather Station was selected for this project because of its affordability, user-friendliness, durability, wireless network connectivity, and smart device application capabilities. The station has a monitor that displays the weather parameters in real-time, an application that displays the readings, and an online network for communities to access the weather measurements on the web from anywhere. For more information on the specific installation process, see (**Appendix A.2**).

SETUP DESIGN

The Weather Station must be set up in a safe location where the data can be wirelessly transmitted to a monitor that displays the weather data and uses weather prediction algorithms to generate and display an accurate forecast for the station’s exact location (Acurite, 2018). During the pre-testing stages of the project, one Weather Station was set up in Albuquerque, New Mexico. This allowed the researchers to foresee any significant issues that

might need to be resolved before the sensor's deployment in Nepal. During the testing stages, it was found that the primary challenge in Nepal was going to be the Wi-Fi connectivity due to the router location at PNMHI.

After a site visit in Nepal, a desirable location for the Weather station was established. The NSC students installed the station on top of the PNMHI roof and set up the monitor display in the Sustainability Action Lab.

CURRENT STATUS SINCE DEPLOYMENT

Currently, the Weather Station is collecting data, which is being displayed on the Acurite website and the monitor in the PNMHI Sustainability Action Lab. The plan is to deploy the second Weather station in close proximity to the current Weather station for more data readings in the area.

ON-SITE VISIT

During the visit in Nepal, before deploying the environmental sensors, the NSC group went out into the field to visually and qualitatively examine the three local sites in order to better understand why these environmental parameters where being measured in the first place. The first site was the PHNMI campus, where the Danda River flows south of the school building. The second site was a nearby stretch of the Danda River, located next to a medical college where a large brick factory operates about 15 km from to the Danda River bank. The third site was a location at the India and Nepal border, where a local dump site leaches waste and burning material into the air and the Danda River. After viewing the three different site locations, the team was capable of making a solid case for where the environmental sensors needed to be deployed, as well as why the sensors were so crucial in these areas in the first place.

Site	View	Observations
1. Danda River gabion wall		This location is South of the PNMHI building. It has large amounts of plastic and trash along the banks; many cows feed and defecate along the bank; and only 12 km upstream resides a functioning brick factory that releases large amounts of smog into the air every day.
2. Brick factory located along the Danda River		Next to the medical college resides another brick factory that does not comply with the 30 km encroachment policy along the river (A. Bohara, personal communication, January 2018). Visual discharge from the brick factory is released into the river bank and the air each day.
3. Danda River dump site		This site has enormous amounts of waste being delivered and dumped every day. A cloud of smoke continually burns over the site, leaving ash residue to seep into the soil and Dana River, while smoke fills the air for days on end.

TABLE 3. ALL SITE LOCATIONS VISITED IN NEPAL

CITIZEN SCIENCE APPROACH

FIGURE 6: SENINAR DISCUSSION AT PNMHI

The goal behind the citizen science approach is to enable citizens—in this case students—to establish a sense of ownership over the data collection process. DEMP was designed to facilitate an environment in which students could participate in learning about the environment through citizen science data collection processes. The mechanisms through which the data are collected are the environmental sensors, and the impact of the initiative is the knowledge the students gain from learning about the sensors, how they function, why they are measuring the different parameters, and ultimately how the students themselves are capable of being scientists that can collect data themselves. The citizens who are involved are the ones making DEMP sustainable; therefore, a club called the "eco-club" (short for ecology club) was created to host students interested in improving their local environment. The eco-club has its headquarters at PNMHI, and the other participants consist of two public high schools located upstream and downstream of the Danda River. The ultimate objective of the eco-club is to create an environment where students can gather a few times a year to participate in the data collection process.

During the visit in Nepal, the students from UNM helped to teach the eco-club about the newly installed environmental sensors. They facilitated a day of lectures consisting of presentations

oriented toward educating the students about the environment, local health concerns, and the specifications of the environmental sensors. To enrich the learning process, after the presentations, the UNM-NSC students gave hands-on instruction by demonstrating how the sensors work in the field and how the data can be collected by the eco-club students. Specifically, NSC made the decision to create three worksheets that the eco-club could use to manually collect the data. Even though the data is autonomously collected and stored online, NSC felt it was important for the eco-club members to learn how to look at the sensors and write down the data on their personal worksheets. To view the worksheet, please refer to (**Appendix C.**).

The citizen science approach's main objective is for the students to take the initiative in collecting the data and learning from the collection process. Ultimately, the eco-club participants spent seven days learning the installation process, participating in the presentation seminar day, and taking field notes during the hands-on sensor demonstration process.

Data Collection Plan

To ensure that the data collection would be sustainable, an environmental coordinator was hired full-time for on-the-ground work at PNMHI to oversee data collection and delivery to the NSC each month. The environmental coordinator's responsibility is to ensure that the data gets from the Laser Egg, Levelogger, and Weather Station to the NSC.

Currently, the Laser Egg and Weather Station show the data in real-time on both the monitor display and on an app that can be easily downloaded onto a smart device. The Laser Egg data files are exported manually by the environmental coordinator at PNMHI from the Kaiterra application at the end of each month and emailed to the NSC, at which point they are entered into an Excel spreadsheet by the environmental coordinator to be displayed on a graph (**Appendix A.1, A.2**). The Weather Station, meanwhile, continuously displays real-time weather data on a monitor that is in the Office of Sustainability Lab at PNMHI. Each month, the environmental coordinator and eco-club members plug the Weather Station monitor into a computer and export the data to record all the measurements 3. LEVELOGGER Pressure Transducer (SOP)

The Levelogger, on the other hand, has Bluetooth and application capabilities, but due to Wi-Fi connectivity and measurement conversion issues, it requires data to be manually (not automatically) downloaded onto a computer once a month. To collect the Levelogger data, the environmental coordinator and eco-club members choose a specific time when the Danda River flows are safe, and they remove the sensor and export the data to a computer at the Office of Sustainability Labs (PNMHI) using the Solinst Levelogger software program.

The data collection methods are still being developed, but as of now, the environmental data is being collected and stored in the Office of Sustainability Lab (PNMHI) and then electronically sent to the NCS (UNM). In the future, the NCS wants to build an application to automatically collect the data and then display it in real time for the community to see and interact with on the web. The present data collection methods are living documents and currently under development.

TABLE 4: DATA COLLECTION METHODS FOR ALL ENVIRONMENTAL SENSORS

Sensor	Data Collection Method	Timing of Data Collection
Laser Egg	The Laser Egg autonomously collects and stores the data in its application. Each month the data will be manually exported and emailed to the NSC.	Continuously; once at the end of each month.
Levelogger	The Levelogger collects and stores readings on the pressure transducer. Every 2–3 months the environmental coordinator and eco-club will travel to the river to remove the sensor, manually download the data onto a PC in the Office of Sustainability lab (PNMHI), and then send the .csv file to the NSC.	Every 2-3 months at the end of each month.
Weather Station	The Weather Station autonomously collects and stores the data on its monitor and the Acurite website and app. Each month the data will be manually exported and emailed to the NSC.	Continuously; once at the end of each month.

Citizen Science Survey— "Measuring Impact"

During the visit in Nepal, the UNM-NSC students handed out a survey to the eco-club members and the faculty and staff that attended the trainings and field demonstrations. The survey consisted of a series of questions that asked questions on feedback. The NSC wanted to know if their efforts make an impact. During the in-person presentation, there were concerns that needed to be addressed. For example, language barrier issues, terminology familiarity, and style of training. The NSC found it important to gain feedback so that next time a new group of students travel to Nepal, the efforts to enhance the environmental education can be improved. Ultimately the NSC wanted to understand weather or not their efforts made a positive impact toward the DEMP initiative. To view the survey questions please refer to (**Appendix B**).

Results And Discussion

This section provides the environmental sensor readings, presented in graph form, as well as the citizen science survey data results. Ultimately, although the sensor readings might not be exact due to the prototype nature of the study, the data that were collected are enough to confidently infer that the efforts made during the visit to Nepal in 2018 were meaningful.

SENSOR DATA

LASER EGG

AQI	Air Pollution Level	Health Implications	Cautionary Statement (for PM2.5)
0 - 50	Good	Air quality is considered satisfactory, and air pollution poses little or no risk	None
51 -100	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
101-150	Unhealthy for Sensitive Groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should limit prolonged outdoor exertion.
151-200	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects	Active children and adults, and people with respiratory disease, such as asthma, should avoid prolonged outdoor exertion; everyone else, especially children, should limit prolonged outdoor exertion
201-300	Very Unhealthy	Health warnings of emergency conditions. The entire population is more likely to be affected.	Active children and adults, and people with respiratory disease, such as asthma, should avoid all outdoor exertion; everyone else, especially children, should limit outdoor exertion.
300+	Hazardous	Health alert: everyone may experience more serious health effects	Everyone should avoid all outdoor exertion

FIGURE 7 : THIS CHART SHOWS HOW THE AIR QUALITY INDEX (AQI) RANKS POLLUTION LEVELS RELATED TO HUMAN HEALTH (AIR QUALITY INDEX SCALE AND COLOR LEGEND (2018). CHART. LICENSED AQINC.ORG)

The following graphs present Laser Egg data as AQI vs. time readings for the month of February 2018 (Mayor's office only) and the month of January for PNMHI and the Mayor's office, respectively.

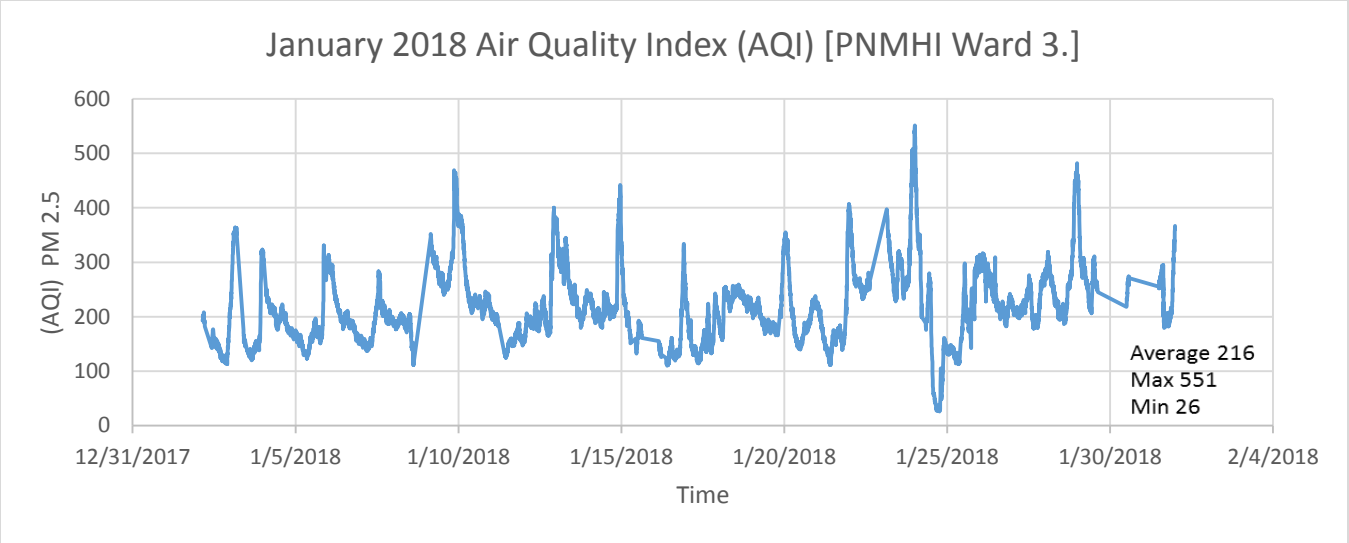


FIGURE 8: JANUARY 2018 LASER EGG DATA, PNMHI WARD 3.

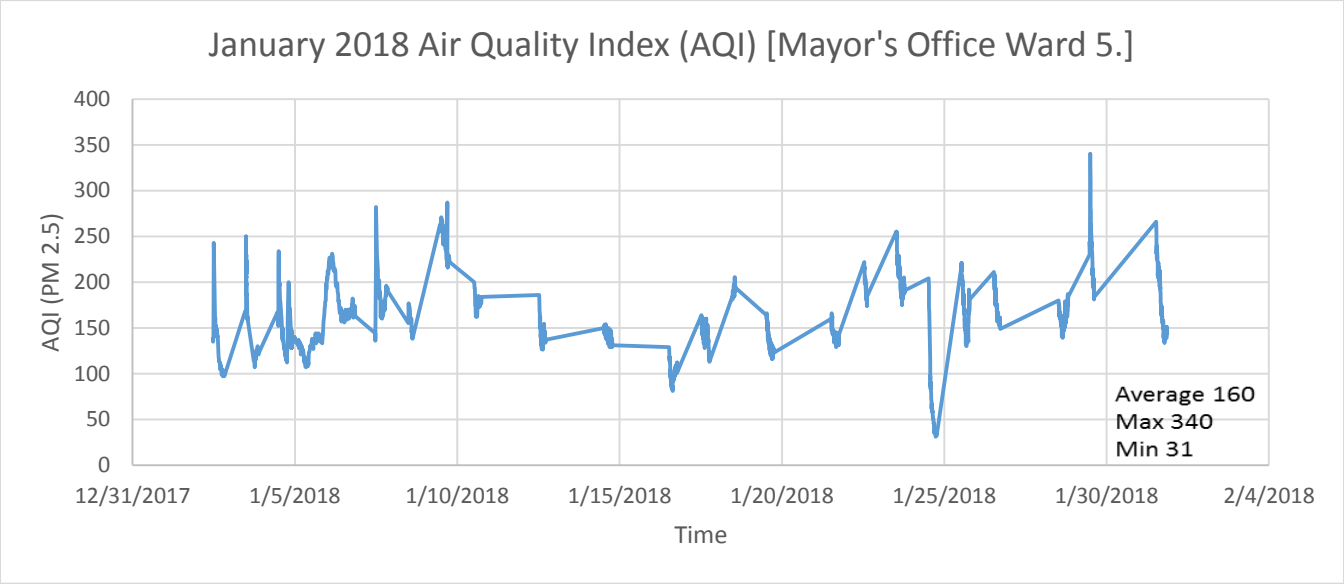


FIGURE 9: JANUARY 2018 LASER EGG DATA, MAYOR'S OFFICE WARD 5.

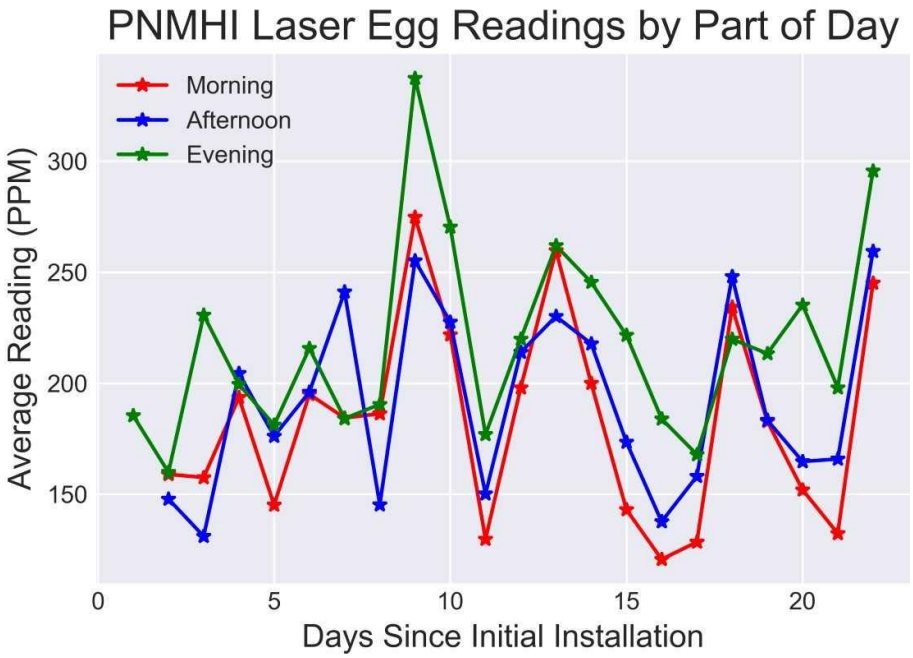


FIGURE 10: THIS GRAPH DEMONSTRATES THE MORNING, AFTERNOON, AND EVENING TRENDS FOR THE PHNMI LOCATION. THIS GRAPH SHOWS THAT EVENINGS TEND TO HAVE HIGHER READINGS THEN THE MORNINGS. ONE CAN INFER THAT THIS MIGHT BE DUE TO THE BRICK FACTORY NEXT TO THE PNMHI BUILDING

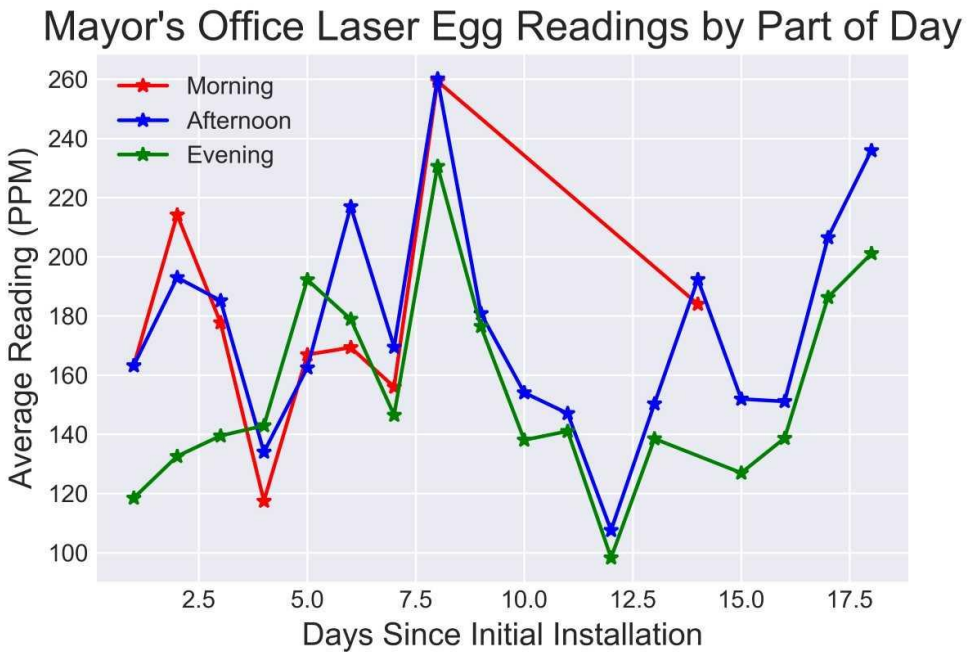


FIGURE 11: THIS GRAPH DEMONSTRATES THE MORNING, AFTERNOON, AND EVENING TRENDS IN AIR QUALITY FOR THE MAYOR'S OFFICE. AS ONE CAN SEE IN THE GRAPH, THE MORNING READINGS ARE THE HIGHEST PM2.5. ONE CAN INFER THAT THIS MIGHT BE DUE TO TRAFFIC IN THE MORNINGS

5 IN 1 PRO WEATHER STATION

The Weather Station graphs demonstrate the five parameters that were measured by the sensor in January 2018.

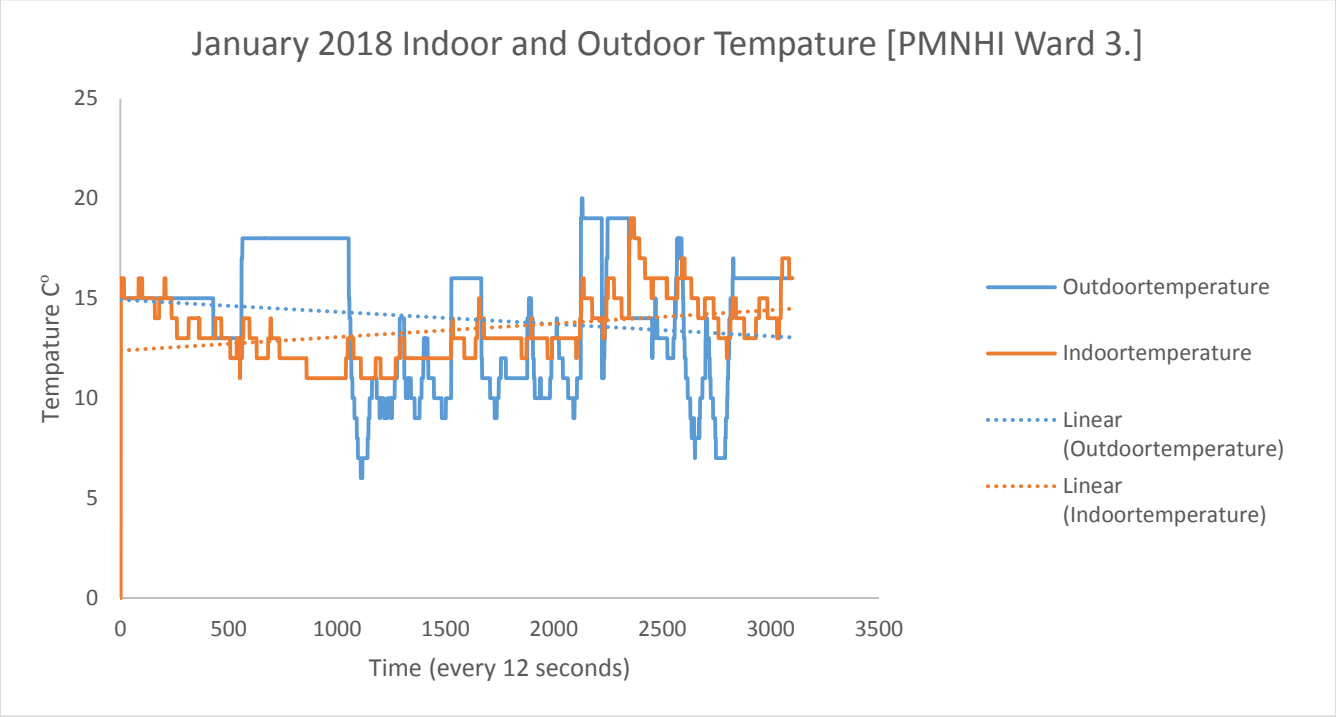


FIGURE 12: INDOOR AND OUTDOOR TEMPERATURE, JANUARY 2018.

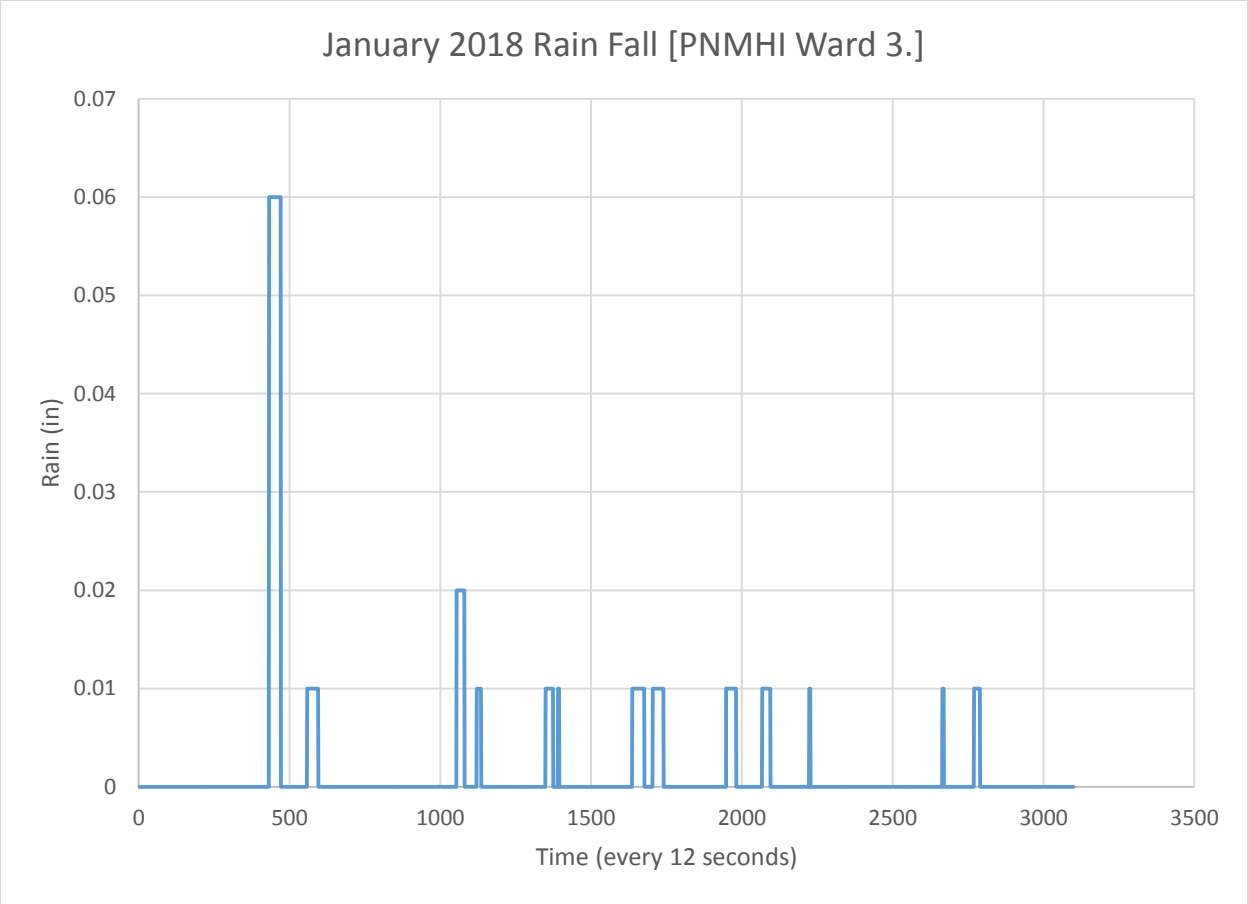


FIGURE 13: RAINFALL, JANUARY 2018.

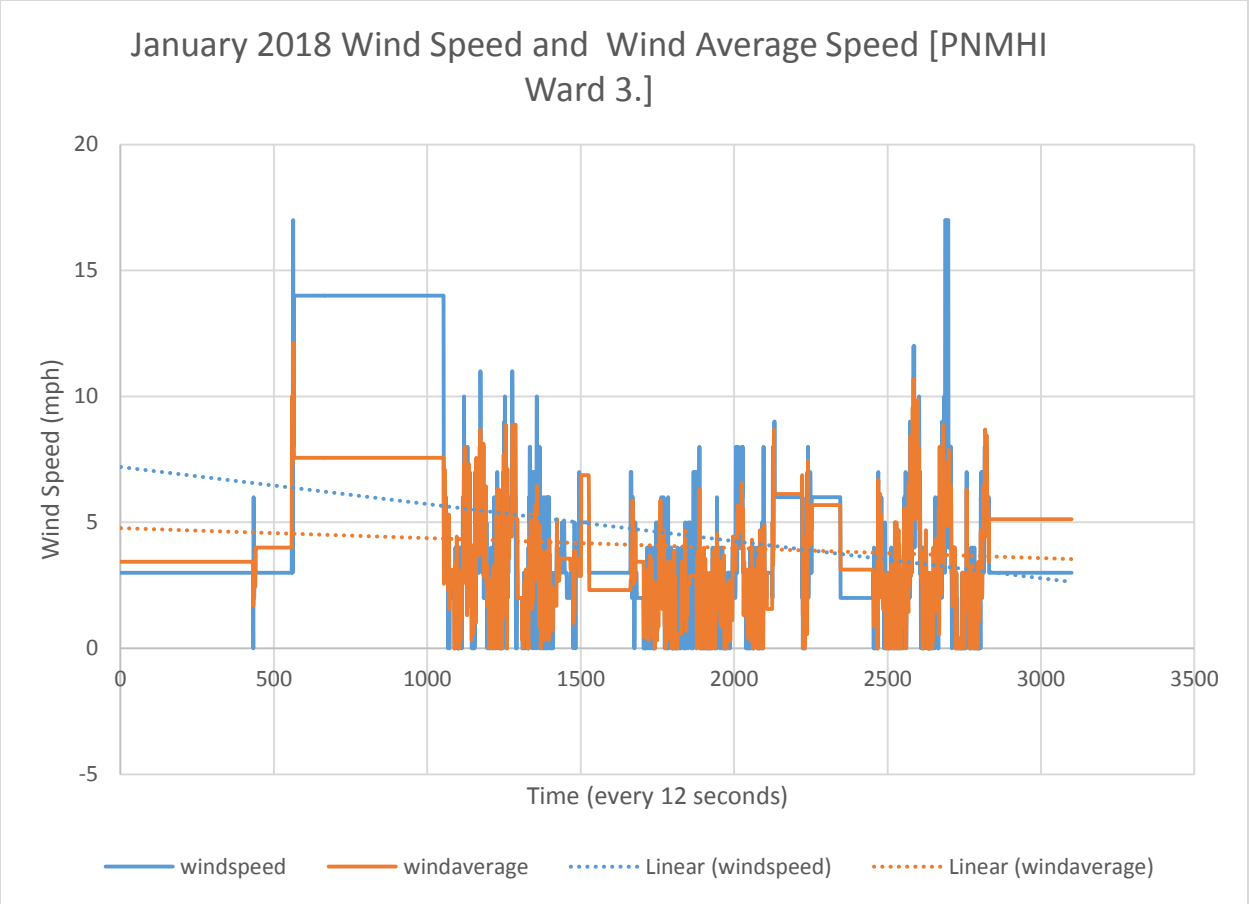


FIGURE 14: WIND SPEED, JANUARY 2018.

Wind Direction and Degrees

Cardinal Direction	Degree Direction
N	348.75 - 11.25
NNE	11.25 - 33.75
NE	33.75 - 56.25
ENE	56.25 - 78.75
E	78.75 - 101.25
ESE	101.25 - 123.75
SE	123.75 - 146.25
SSE	146.25 - 168.75
S	168.75 - 191.25
SSW	191.25 - 213.75
SW	213.75 - 236.25
WSW	236.25 - 258.75
W	258.75 - 281.25
WNW	281.25 - 303.75
NW	303.75 - 326.25
NNW	326.25 - 348.75

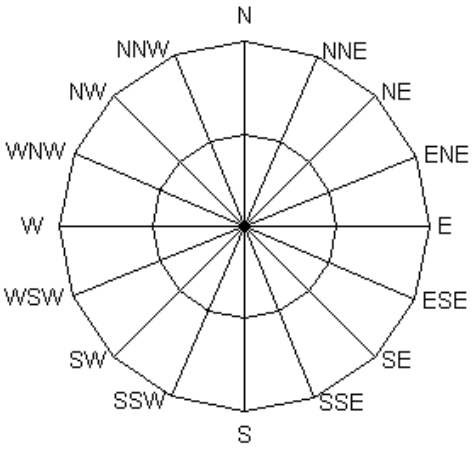


FIGURE 15: WIND DIRECTION AND DEGREES (INSERT CITATION HERE (WIND DIRECTION AND DEGREES (2018). CHART. LICENSED RAYZ.COM/WEBSERVICES).

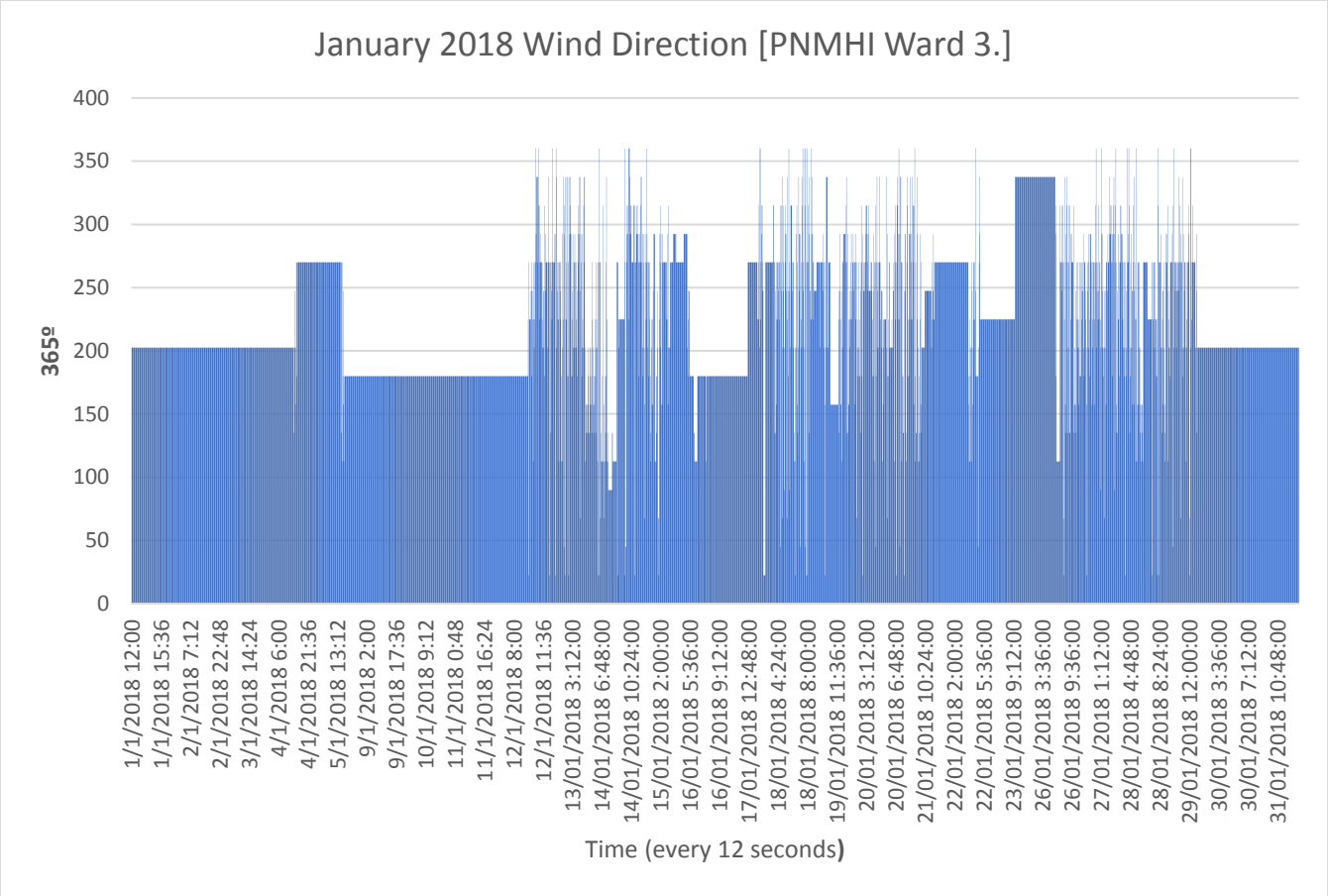


FIGURE 16: WIND DIRECTION, JANUARY 2018.

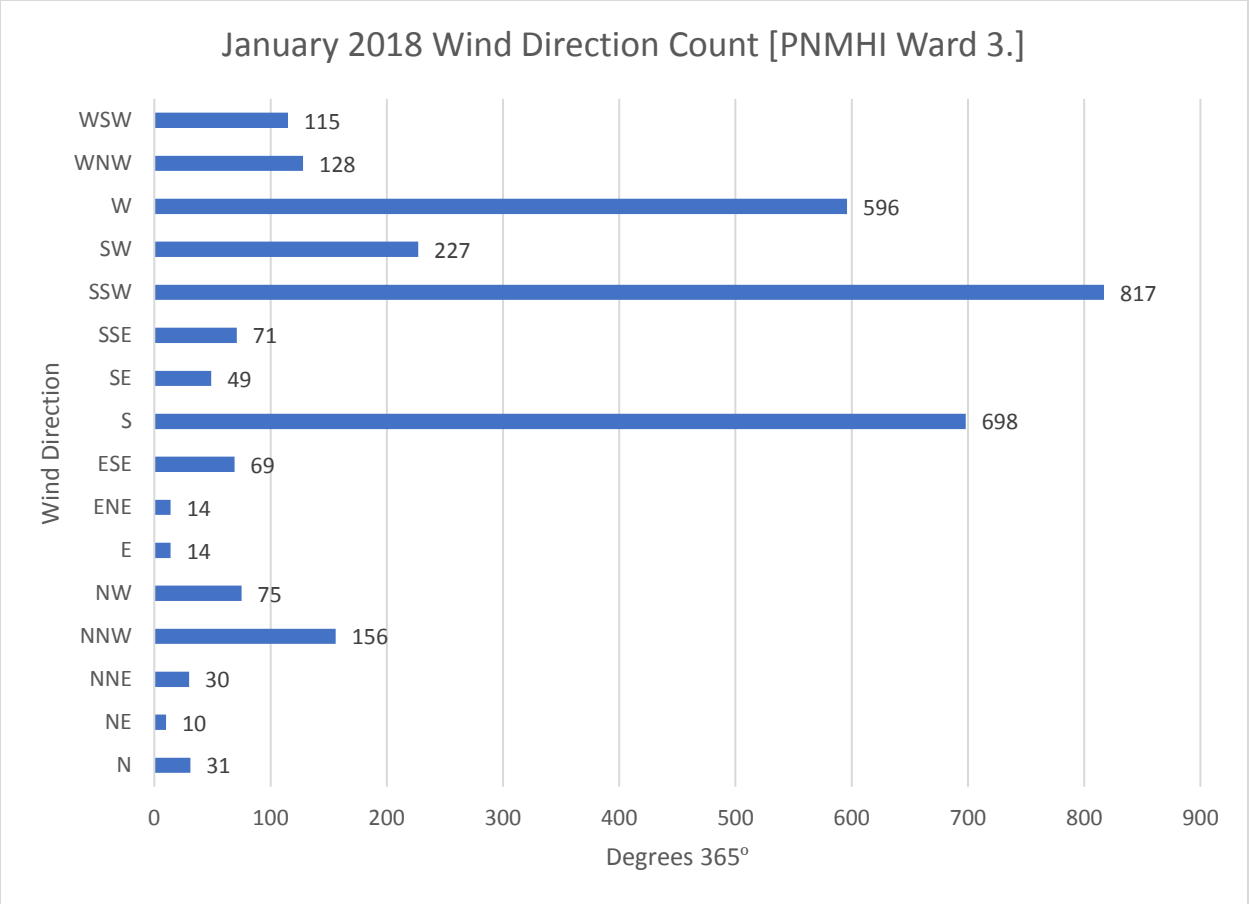


FIGURE 17: WIND DIRECTION COUNT, JANUARY 2018.

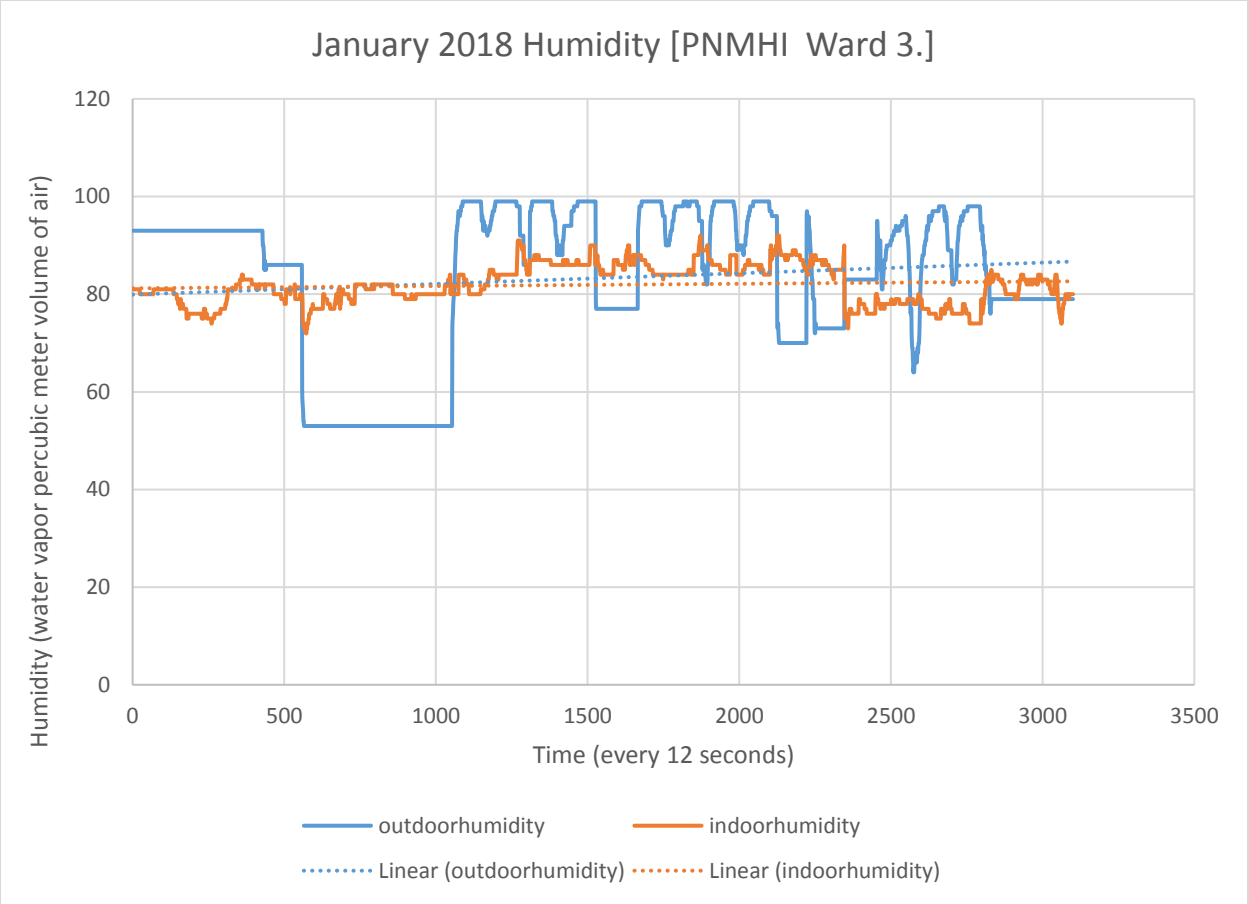


FIGURE 18: INDOOR AND OUTDOOR HUMIDITY, JANUARY 2018.

LEVELOGGER PRESSURE TRANSDUCER

The pressure transducer data demonstrates the depth of the river for the month of January 2018. The Levelogger Solnist manual describes that to accomplish an accurate manual barometric pressure compensation, the atmospheric pressure station should not be greater than 20 miles away and within an elevation change of 1000 feet; therefore, it is okay to use an alternate barometric data collector, for example a local weather station (i.e. 5-in-1 pro weather station). The compensations require the Levelogger data and the barometric data to be in the same units (Solnist, 2018).

The Levelogger (L) measures total (absolute) pressure. When the Levelogger is submerged in the water, it is recording barometric pressure and water pressure; therefore, to accurately measure only water (A) above the sensor, barometric pressure (B) needs to be subtracted from the total pressure (L). (Solnist, 2018)

EQUATION 1: ELEVATION HEAD (FT)

$$A = L - \frac{B * 0.54}{12}$$

$A = Acutal\ water\ column\ height\ (ft)\ (Elevation\ Head)$

$B = Barometric\ Pressure\ (mm\ Hg)$

$L = Levelogger\ total\ pressure\ reading\ (ft)$

$D = Depth\ to\ water\ level, below\ reference\ datum\ (ft)$

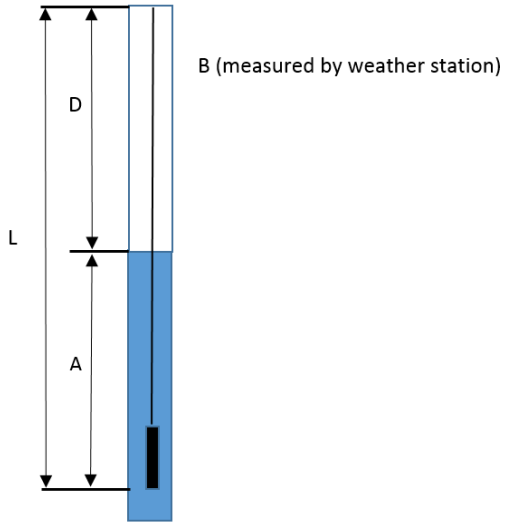


FIGURE 19: SCHEMATIC OF A VISUAL DIAGRAM OF THE MEASURMENTS TO CALCULATE THE DEPTH OF THE WATER IN THE RIVER.

TABLE 5: TABLE USED FOR ELEVATION HEAD CONVERSION EQUATION 1

Multiply by				
Convert from	Convert to			
	pound square feet	*pound square inches (psi)*	*inches Hg*	*inches H_2O*
Pa (N/m^2)	0.021	$1.450326\ 10^{-4}$	$2.96\ 10^{-4}$	$4.02\ 10^{-3}$
bar	2090	14.50	29.61	402
atmosphere	2117.5	14.69	29.92	407
mm Hg	2.79	0.019	0.039	0.54
mm H_2O	0.209	$1.45\ 10^{-3}$	$2.96\ 10^{-3}$	0.04
m H_2O	209	1.45	2.96	40.2
kg/cm^2	2049	14.21	29.03	394
pound square feet (psf)	1	0.0069	0.014	0.19
pound square inches (psi)	144	1	2.04	27.7
inches Hg	70.8	0.49	1	13.57
inches H_2O	5.2	0.036	0.074	1

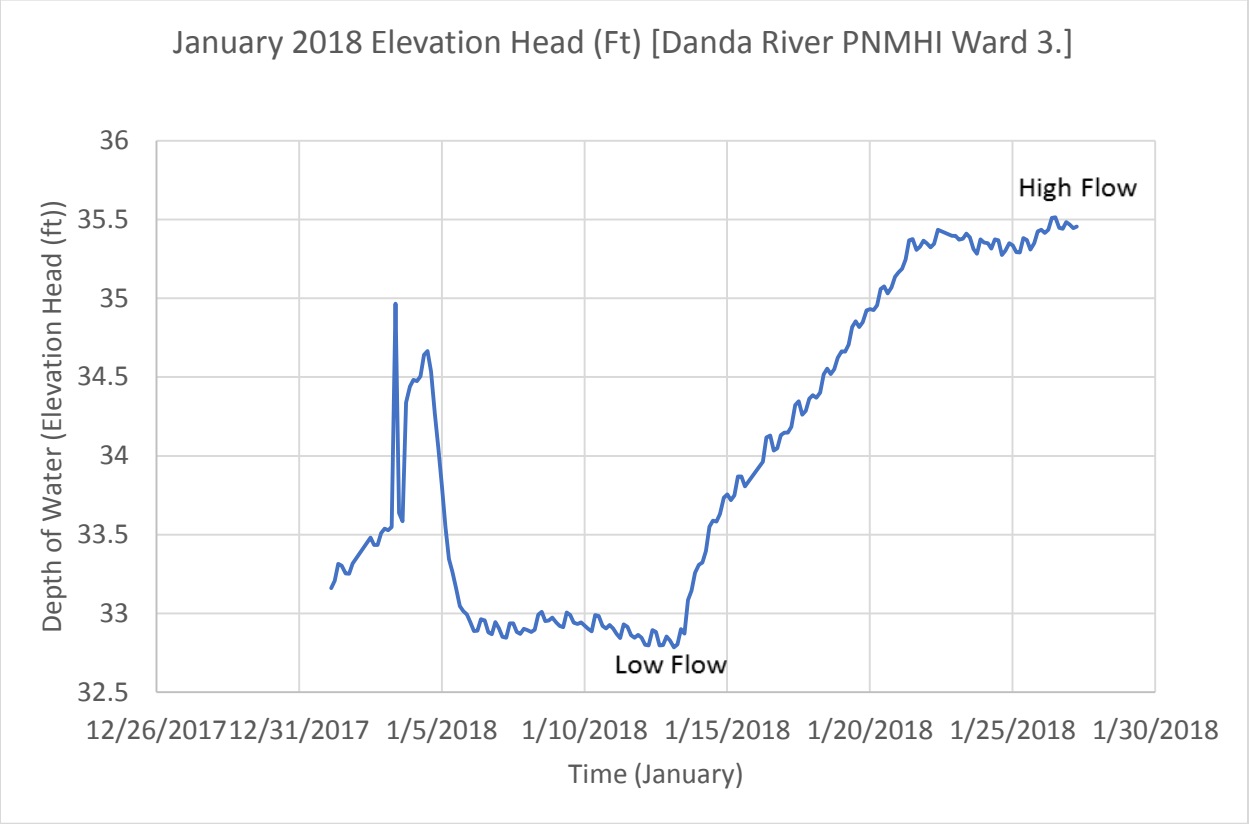


FIGURE 20: RIVER STAGE, DANDA RIVER, JANUARY 2018. THIS GRAPH IS A RELATIVE MEASUREMENT DEMONSTRATING HIGH AND LOW FLOWS. THE GRAPH PLOTS ELEVATION HEAD (FT) AGAINST TIME STEP (ONE READING PER EVER THREE HOURS). THE MONTH OF JANUARY HAD A SPIKE OF HIGH FLOWS AT THE END OF THE MONTH

CITIZEN SCIENCE SURVEY

The citizen science survey was distributed by the NSC, and 26 participants were questioned. The following graphs show the responses of the participants, which NSC used determine whether or not the activities that were performed made an impact on the community, the survey participants that consisted of the eco-club and PNMHI faculty in particular.

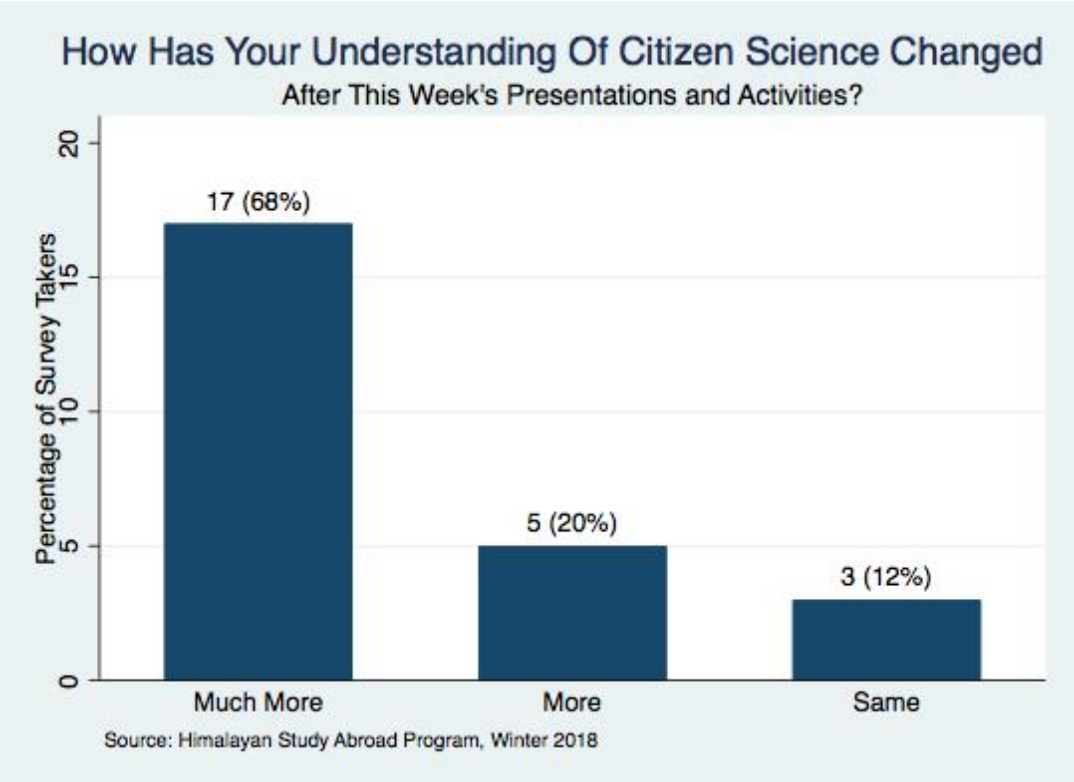


FIGURE 21: THIS GRAPH DEMONSTRATES THAT 68% OF THE SURVEY PARTICIPANTS UNDERSTAND CITIZEN SCIENCE "MUCH MORE" AFTER THE WEEK'S PRESENTATIONS AND ACTIVITIES

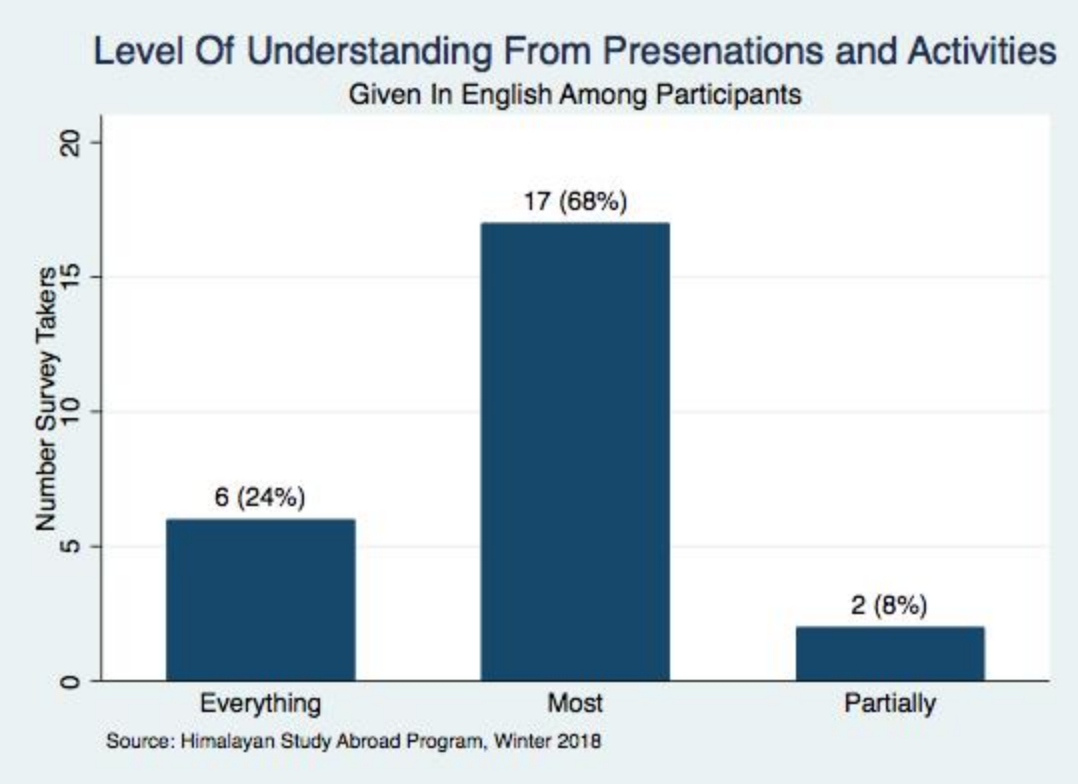


FIGURE 22: THIS GRAPH DEMONSTRATES THAT ABOUT 68% OF THE SURVEY TAKERS UNDERSTOOD MOST OF THE PRESENTATIONS, REGARDLESS OF THE LANGUAGE BARRIER, WHEREAS 24% UNDERSTOOD EVERYTHING AND ONLY 2% UNDERSTOOD PARTIALL.

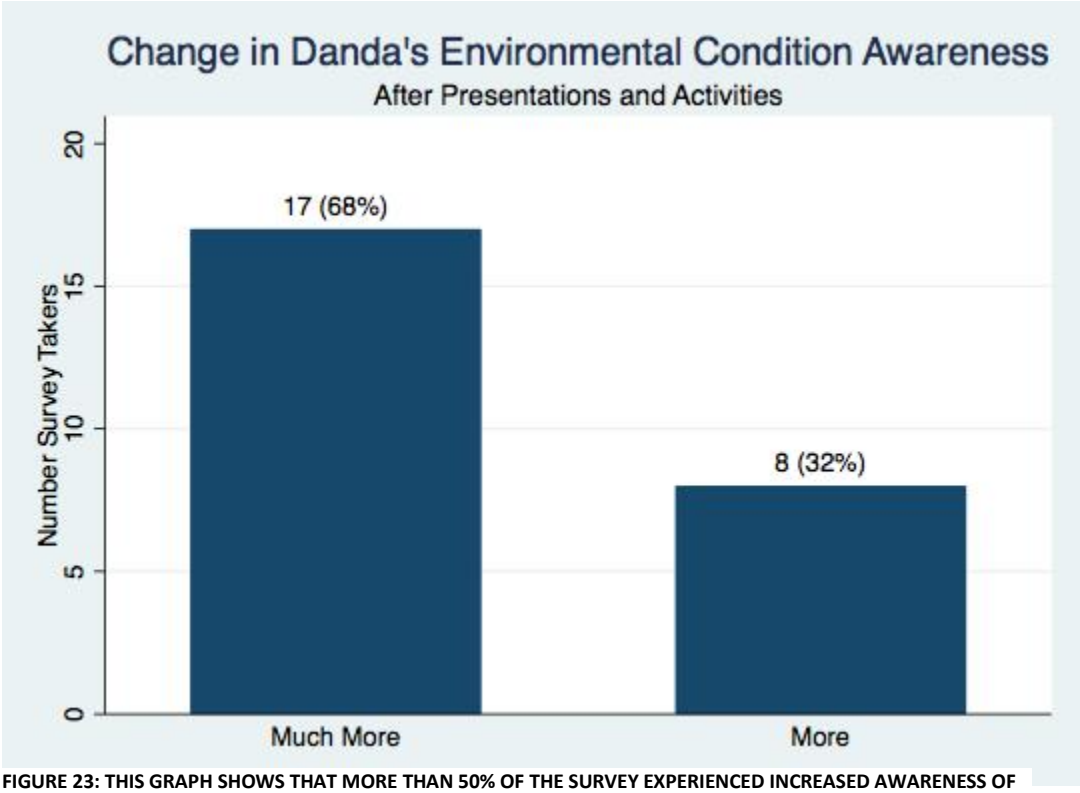


FIGURE 23: THIS GRAPH SHOWS THAT MORE THAN 50% OF THE SURVEY EXPERIENCED INCREASED AWARENESS OF THE DANDA RIVER'S ENVIRONMENTAL CONDITION AFTER THE PRESENTATIONS AND ACTIVITIES

CONCLUSION

Environmental management in the developing world is restricted by a lack of environmental monitoring data. This project focused on addressing this challenge through the emerging technologies of autonomous and wireless environmental sensors. Such techniques have been used to advance environmental understanding and management, but there are very few case study examples of practical applications where this has been accomplished in the developing world.

The sensor results demonstrate that the sensors are successfully collecting and reporting environmental data, while the CS survey data indicates that the December 2017 seminar abroad efforts to inform, educate, and involve the eco-club community were successfully impactful. Thus, the following objectives were achieved:

- Education: Enhancing environmental education tools with a citizen science curriculum that improves community awareness.
- Real-time data: Establishing a system that enables anyone interested (who has an internet connection) to access the data through improved data collection capabilities.
- Cross-university collaboration: Involving a variety of universities with different but mutually beneficial agendas in the research.
- Practical data collection: Identifying and successfully deploying environmental sensors that are affordable, useful, and "accurate enough," and provide an appropriate baseline to understand the environmental issues in the developing world.
- Sustainability: Establishing a program that can survive and grow over time, including a study abroad program that visits the site once a year and an environmental coordinator at PNMHI, as well as assurance and support from influential policymakers in Nepal.

A significant indicator that this pilot project would be successful in the long term was acceptance by the local government. During the NSC stay, the students witnessed the government officials' verbal support of the program and heard the officials acknowledge the importance of the initiative. Furthermore, the DEMP initiative was announced on the Nepali National news and published in the local newspaper. These outcomes demonstrate the willingness of the community to accept and adopt the DEMP environmental sensors initiative.

The long-term value of the project will only be gauged as time passes, but as of now, the sensors are collecting data, a group of eco-club members has affirmed their knowledge of and commitment to the project, and a future visit to engage with the citizen science initiative is planned for January 2019. These types of projects take considerable time and collaboration, and as of now, as demonstrated survey results (**Figure 21, 22, 23**), it is safe to say the project brought great educational value to the community members of PNMHI and the students of UNM. The environmental data might not be very accurate or reliable at this time, but as a prototype, this case study has successfully sparked curiosity and interest and has laid the cornerstone for a long-lasting collaborative commitment from various stakeholders around the world.

FUTURE RESEARCH

The research that may follow from this case study is limitless. The future goal of DEMP is to enhance educational awareness in Nepal through data monitoring. However, there are a lot of different environmental parameters that need to be monitored, not just the Danda River stage. Furthermore, to better understand the data, the project needs more sensors; therefore, future research could include setting up more sensors in all 15 wards in Siddharthanagar. Beyond the Laser Egg, Weather Station, or Levelogger, there are many other types of autonomous sensors that can be researched and deployed in Nepal—for example, a sensor that measures water quality. Furthermore, the groundwater needs to be monitored, for there is no data on its quality or its quantity.

The NSC has plans to create a website for all the data to automatically upload so that anyone who has access to the internet can go to the website and see the data in real time. This project

is well underway, but faces a number of challenges. Long-term data research is a system that takes time to develop; therefore, this restorative research project in Nepal is still in its infancy and has a lot of room for more positive growth.

Nepal Study Center future projects include the following bullet points:

- Watershed Biogallery
- Groundwater monitoring quality and river stage
- Arsenic water quality monitoring in groundwater
- Laser egg and weather station installation in all 15 Wards
- Wetland restoration project on PNMHI campus

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APPENDIX

A. STANDARD OPERATIONAL PROCEDURE (SOP)

1. LASER EGG (SOP)

LASER EGG
NEPAL STUDY CENTER
LUMBINI SUSTAINABILITY CIRCLE

Citizen Science Danda River Monitoring Program (DEMP)

- The Laser egg is an air quality monitor that measures and displays Air Quality Index (AQI) for US EPA and Chinese Conversions.
- The sensor measures particle count for >0.3 µm & 2.5 µm with PM2.5 concentration (µm/m^3)
- The Egg has Wi-Fi internet connection so that all data recorded while connected to the internet is stored in cloud based database.
- The Egg has an IOS and android app called "Breathing Space" that will display and record the data for exportation and collection

PRATIMAN-NEEMA MEMORIAL FOUNDATION

Air Quality Monitoring

—

YOGDAN Study Abroad Program

—

December 2017

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Eco-adventure Hands-on Service-learning Experiential - learning

—

Community Learning Environment

University of New Mexico
bohara@unm.edu

Pratiman-Neema
Swati_thapa@hotmail.com

DECEMBER 2018 ACTION LAB STUDY ABROAD DEPLOYMENT

STANDARD OPERATING PROCEDURE (SOP)

LASER EGG AND KAITERRA APP- SETUP AND DATA EXPORT

By Corinne Fox

CONTENTS

DECEMBER 2018 ACTION LAB SUMMARY:

Figure 1: Nepal Study Center in the Sustainability action lab room at PNMHI installing the Laser Egg

Laser Eggs are sensors that monitor particulate matter in the air in real-time (Kaiterra, n.d.). This particulate matter concentration is measured against the Air Quality Index (AQI). AQI is a number used by government agencies to communicate the level of air quality to the public (USEPA, 2016). The higher the number, the more likely a community is to experience negative health effects. In this project, the Laser Egg was used to monitor indoor air quality.

The Laser Egg by the company Kaiterra was selected for this project because of its affordability, user-friendly interface, and real-time data display on the Laser Egg sensor, and because it has a built-in application that can be accessed easily through a download on a smart device.

The sensor is programmed to take a measurement every 0.1 seconds through a small fan built into the shell which sucks in the ambient air through the back of the sensor. A laser beam streams across the air current and the refracted light measures the partial size count and diameter (Kaiterra, n.d.).

OPERATIONAL CHECK LIST

- First, read the instructions that come with the laser Egg (inside the box or refer to *Additional Resources C* in this Standard Operational Procedure)
- Open the Laser Egg box and make sure all the materials are in the box.
    a. Laser Egg
    b. Charging cord
    c. Instructions

(Charging Cord)

(All material in the box: http://www.kaiterra.com/support/knowledge-base/in-the-box-2/)

- Purchase the following additional materials: an adapter with a USB inlet and a wall converter to plug the Laser Egg into the wall for charging for the item does not come with a converter or adapter.

(Charging converter)

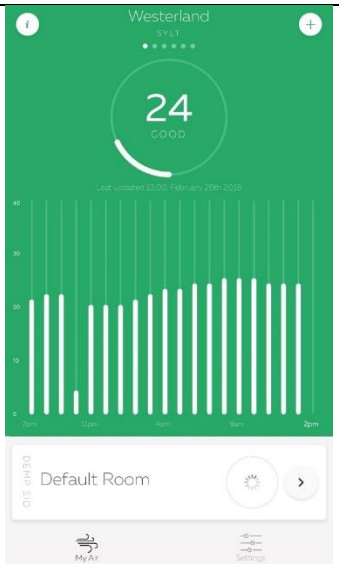
(Charging adapter)

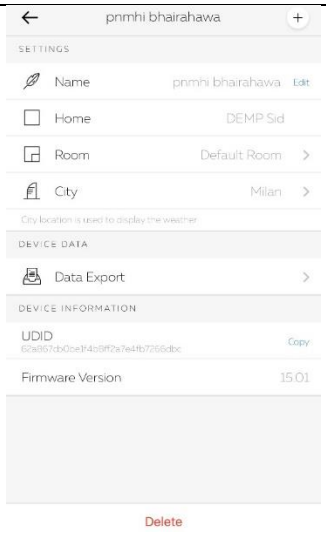
- Download the Kaiterra phone or tablet application (GooglePlay or Apple store) onto a smart device.

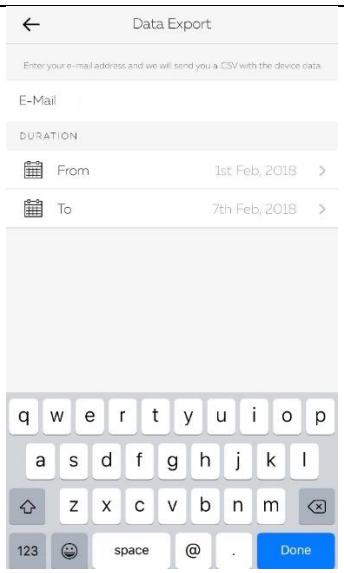
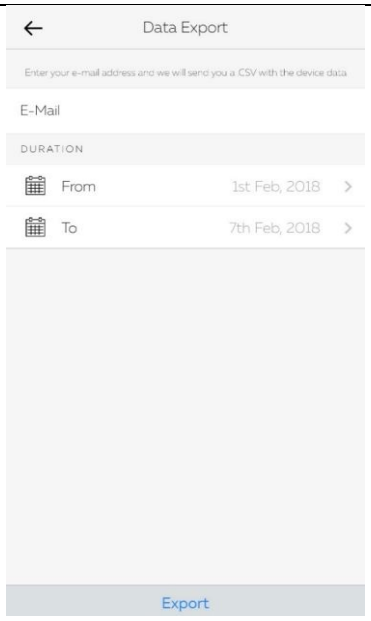
  Important Notes: (1) Before the deployment and application process, it is critical to have access to Wifi and Wifi passwords. (2) If the Laser Egg is not plugged in to power and the battery is not fully charged, it will run out of battery and not collect data. (3) The application needs to be downloaded onto a smartphone or other smart device before the pairing process.

- Follow the Laser Egg and Kaiterra application pairing instructions (located inside box or in *Additional Resources C*.)
- Once the Laser Egg is paired with the Kaiterra application, place the Laser Egg in a desired location and make sure it is plugged in. Although the Laser Egg has a battery, it will only stay charged for short a period of time (less than 8 hours) if it is not connected to an external power source. A desired location would therefore be considered somewhere safe, without external air pollution flow, and a clear and dust-free indoor location, for example of a bookshelf or desk, which has a power outlet nearby.
- Additionally, if one wants to access the Laser Egg data on a different smart device, one must follow the pairing process (located inside Laser Egg box or *Additional Resources C*.)

DOWNLOADING DATA

The picture to the right is the screen when the Kaiterra application first opens. Select “Default Room”: here you will see PNMHI and Mayor because these two Laser Eggs are already set up.	

Select either PNMHI or DEMP Sidd Mayor depending on what data you want to download. Do this by selecting the gear to the right of the Laser Egg name.	
Now select “Data Export” under DEVICE DATA.	

Enter in the email address to which the data should be sent, and under DURATION, select a FROM and TO date (6-day increments) Send email to : bohara@unm.edu	
Select Export at the bottom of the screen. Check the email account that was entered earlier; the data should have arrived as a csv. File and can be opened in Microsoft Excel.	

ADDITIONAL RESOURCES:

A. This website is helpful for questions and troubleshooting: http://www.kaiterra.com/support/
B. For additional technical questions email: SUPPORT@KAITERRA.COM

C. The Document below is the step-by-step process to pair the Laser Egg and the Kaiterra application

MODE BUTTON

By pressing the mode button, you can cycle through the different displays on the Laser Egg, and understand more details about the air quality around you.

AQI CN MODE

The Air Quality Index is a representation of air quality on a 0-500 scale, calculated here using the Chinese conversion method.

AQI US MODE

The Air Quality Index is a representation of air quality on a 0-500 scale, calculated here using the United States EPA method.

CONCENTRATION MODE

The concentration of PM2.5 in micrograms per cubic metre is a standard measure of particulate air pollution, commonly used by governmental institutions. AQI calculations are based on this number.

PARTICLE COUNT MODE

This mode displays the number of particles in 0.1L of air. Both the number of particles larger than 0.3 microns and larger than 2.5 microns in size are displayed. Particles 0.3 microns in size include bacteria and smog, while those 2.5 microns in size include large dust particles.

NIGHT MODE

This mode turns down the brightness of the LCD screen, perfect if you want to get some sleep while the Laser Egg continues to record data. You can still receive alerts of changes in air quality on your phone.

DATA TRANSFER

Data will be uploaded every 30 seconds when the Laser Egg is connected to Wi-Fi (icon). If left untouched for 15 minutes, the icon will appear and data will be uploaded every 5 minutes. This helps extend the lifespan of the Laser Egg.

TECH SPECS

Battery type: Lithium
Battery capacity: 2300mAh
Input voltage: DC5.0V
Input current: 1A
Screen size: 2.6"
Connection: Wi-Fi (2.4GHz)
Supported platforms: Android; iOS
Compliance standard: Q/CYDSH 002-2015
Manufacturer: Origins Technology Limited

Made with in China

CONTACT

www.origins-china.com
400-863-0600

Visit us at the Origins Breathing Space
Beixinqiao Toutiao No. 2, Dongcheng, Beijing

北京市东城区北新桥头条二号

LASEREGG
by origins

TAKE CHARGE
OF YOUR ENVIRONMENT

ACCURACY

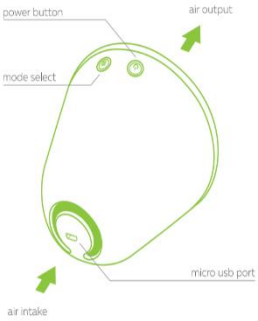
Laser particle counter and cloud calibration provide top-level accuracy.

CONNECTIVITY

Wi-Fi enabled for real-time data and wireless monitoring.

MOBILITY

Small enough to fit in the palm of your hand. Monitor the air in your home, or wherever you choose to go.



STEP 1

Plug in your Laser Egg.

STEP 2

Push the power button.

STEP 3

Download Breathing Space by Origins from the Apple App Store or our website.

Available at:
app.origins-china.com

STEP 4

Download mobile app
Go to Options
Press: Add Laser Egg
Press: Add Through Wifi

Follow the instructions on screen.

STEP 5

Check your air from anywhere!

2. 5 IN 1 PRO WEATHER STATION (SOP)

5-IN-1 WEATHER STATION
NEPAL STUDY CENTER
ENVIRONMENTAL ACTION LAB

Citizen Science Danda River Monitoring Program (DEMP)

- The Weather Station measures:

1. Temperature
2. Humidity
3. rain
4. wind speed
5. wind direction

- The Dual digital display allows one to observe weather data in multiple rooms via monitor and phone application called ACURITE

PRATIMAN-NEEMA
MEMORIAL FOUNDATION

Weather Monitoring

—

YOGDAN Study Abroad Program

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December 2017

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Eco-adventure Hands-on Service-learning Experiential - learning

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DECEMBER 2018 ACTION LAB STUDY ABROAD DEPLOYMENT

STANDARD OPERATING PROCEDURE (SOP)

WEATHER STATION, ACURITE APP SETUP AND DATA EXPORT

By Corinne Fox

CONTENTS

The materials and directions are directly referenced from the Acurite website and manual: https://www.acurite.com/learn/weather-stations/acurite-5-in-1-sensor

DECEMBER 2018 ACTION LAB SUMMARY:

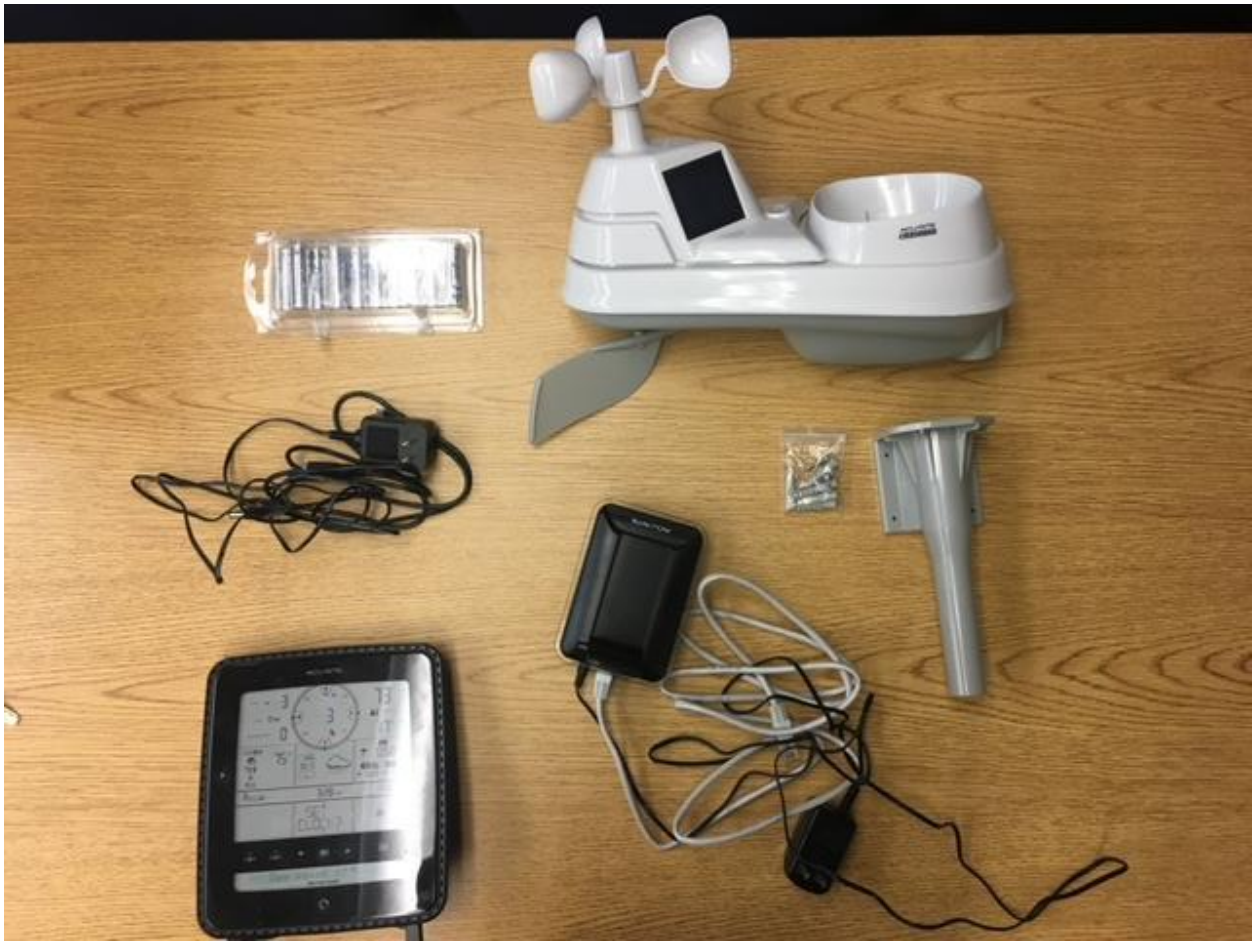
Figure 1: Nepal Study Center participants installing the Weather Station.

Weather stations are used to measure outdoor weather-related variables. The Pro 5-in-1 Weather Station Sensor by the company Acurite measure five different outdoor conditions: temperature, humidity, wind speed, wind direction, and rainfall (Acurite, 2018). The Weather Station was selected because of its affordability, user-friendliness, durability, wireless network abilities, and smart device application capabilities (Acurite, 2018). The sensor has a monitor that displays the weather parameters in real-time, an application that displays the readings, and an online network for communities to access the weather measurements on the web from anywhere.

The Weather Station must be set up in a safe location where the data can be wirelessly transmitted to the monitor that displays the weather data and uses weather prediction algorithms to generate and display a most accurate forecast available for the exact location (Acurite, 2018). For example, the Nepal Study Center installed the station on the roof of the PNMHI building where no one can get to the device and where it cannot be damaged by harsh weather.

TOOLS AND MATERIALS

1. 5-in-1 Pro Weather Station



2. AAA batteries for monitor

3. Additional tools needed to install the station include: drill, drill bit, extension cord, computer with internet access, and a smart device for the application download.

SETTING UP THE WEATHER STATION

For installation, the Acurite website has very helpful resources. Before installation read the manual and watch the videos:

- Manual: https://www.acurite.com/learn/installation/5in1
- Station: https://www.acurite.com/media/manuals/06014RM-instructions.pdf
- Station Monitor: https://www.acurite.com/media/manuals/01036-instructions-PC-Connect.pdf
- Troubleshooting: https://www.acurite.com/media/manuals/01512-01531-instructions.pdf
- Rain Gauge Video: https://www.youtube.com/watch?time_continue=6&v=sB9xFl7HYPg
- Maintenance Video: https://www.youtube.com/watch?time_continue=14&v=IQouEzdPqDw
- Installation Video: https://www.youtube.com/watch?time_continue=4&v=Lx7GP_Vrgqs

  After the weather station is installed, it should be ready to start collecting data. The data is displayed on the Acurite website and the monitor, and can be accessed via phone application.

Downloading Data

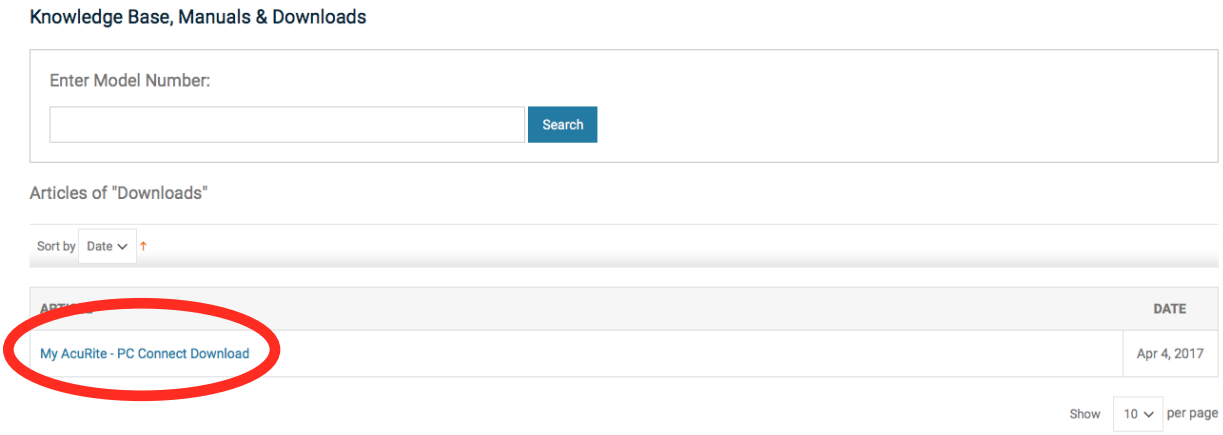
The Nepal Study Center environmental coordinator is in charge of downloading the weather data from the monitor by plugging it into the desktop computer and downloading it into a CSV document. This is the current system for downloading the data.

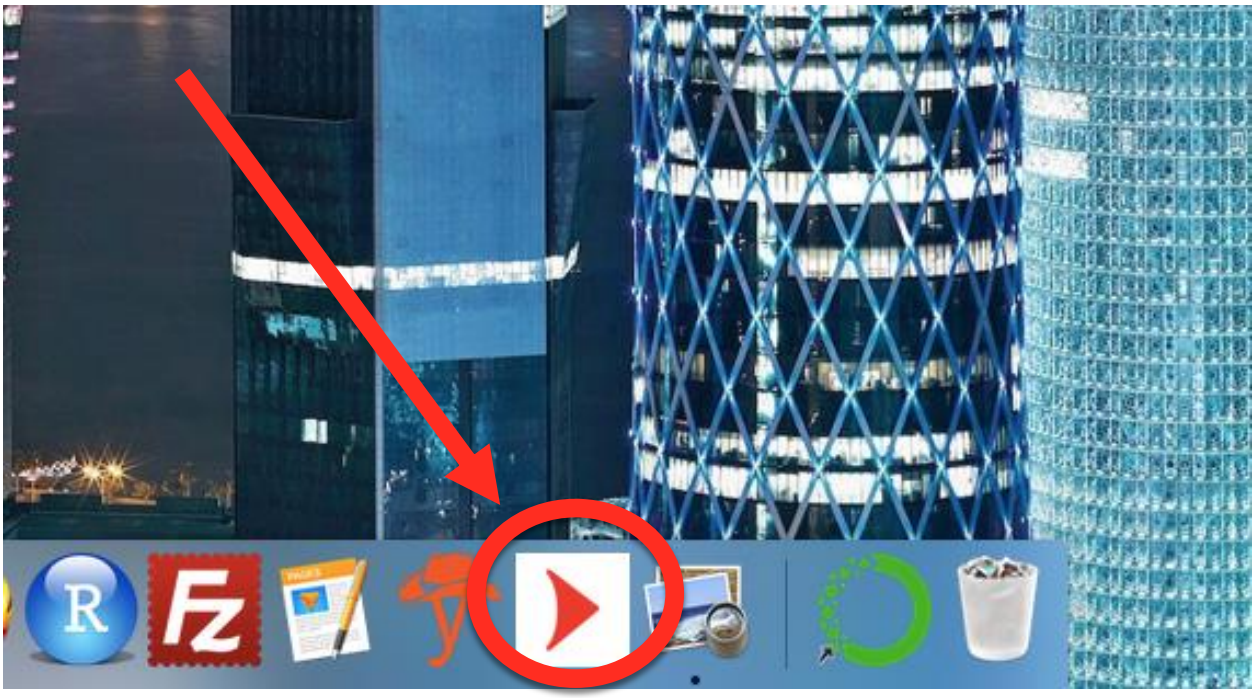
After the data is downloaded, it is emailed to Dr. Bohara (bohara@unm.edu) and then cleaned up for further analysis.

1) Before the equipment is synced with your personal computer, be sure that your Weather Station (both indoor and outdoor components) is functioning and recording real-time weather data. You will know if it is functioning if you see the data on the monitor and on the application.

2) In order to transfer data from the station to your computer, you will need some software that allows the two to connect to each other. Go to:

http://www.acurite.com/kbase/downloads/ and download the version which is suitable for your operating system. The download should be relatively short.



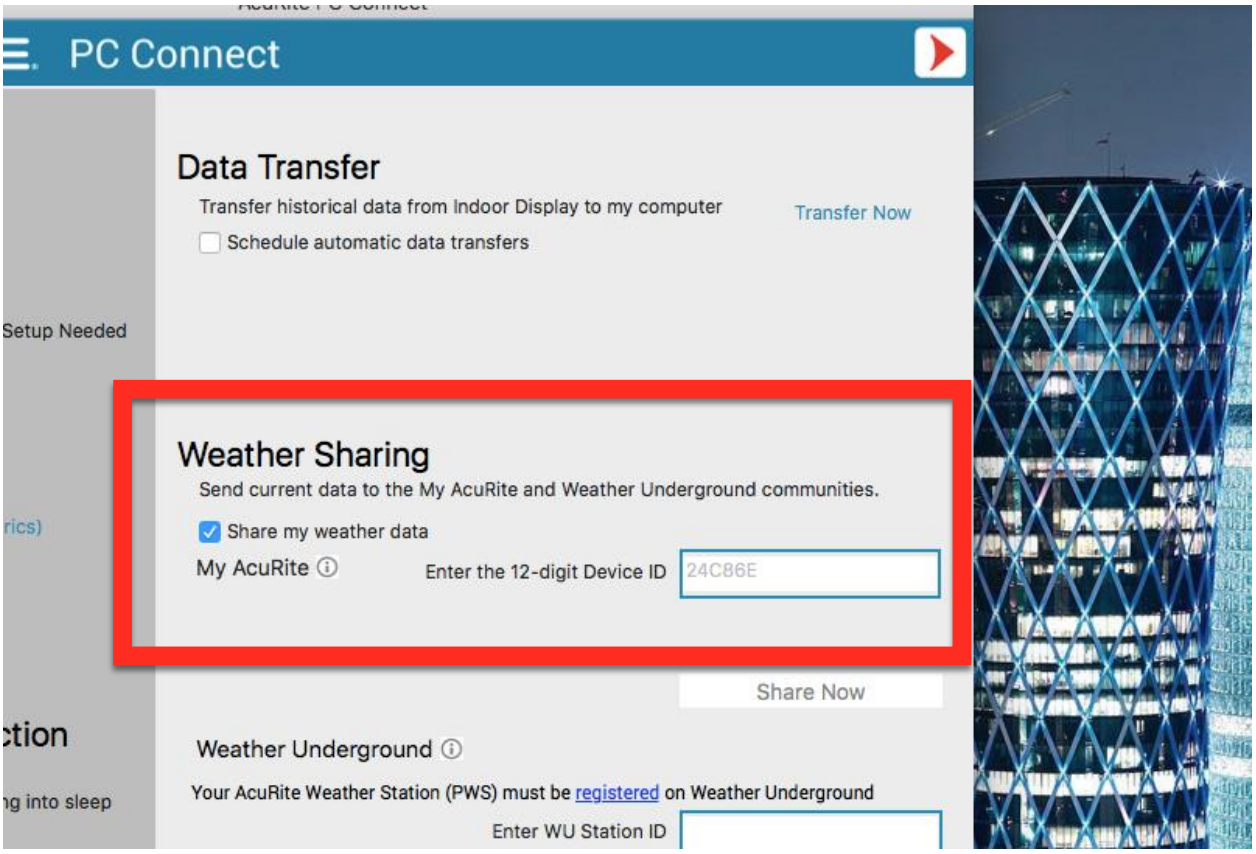


3) Open up the newly-downloaded program. The icon on your computer will be displayed as a white square with a right-pointing red arrow in the center of it.

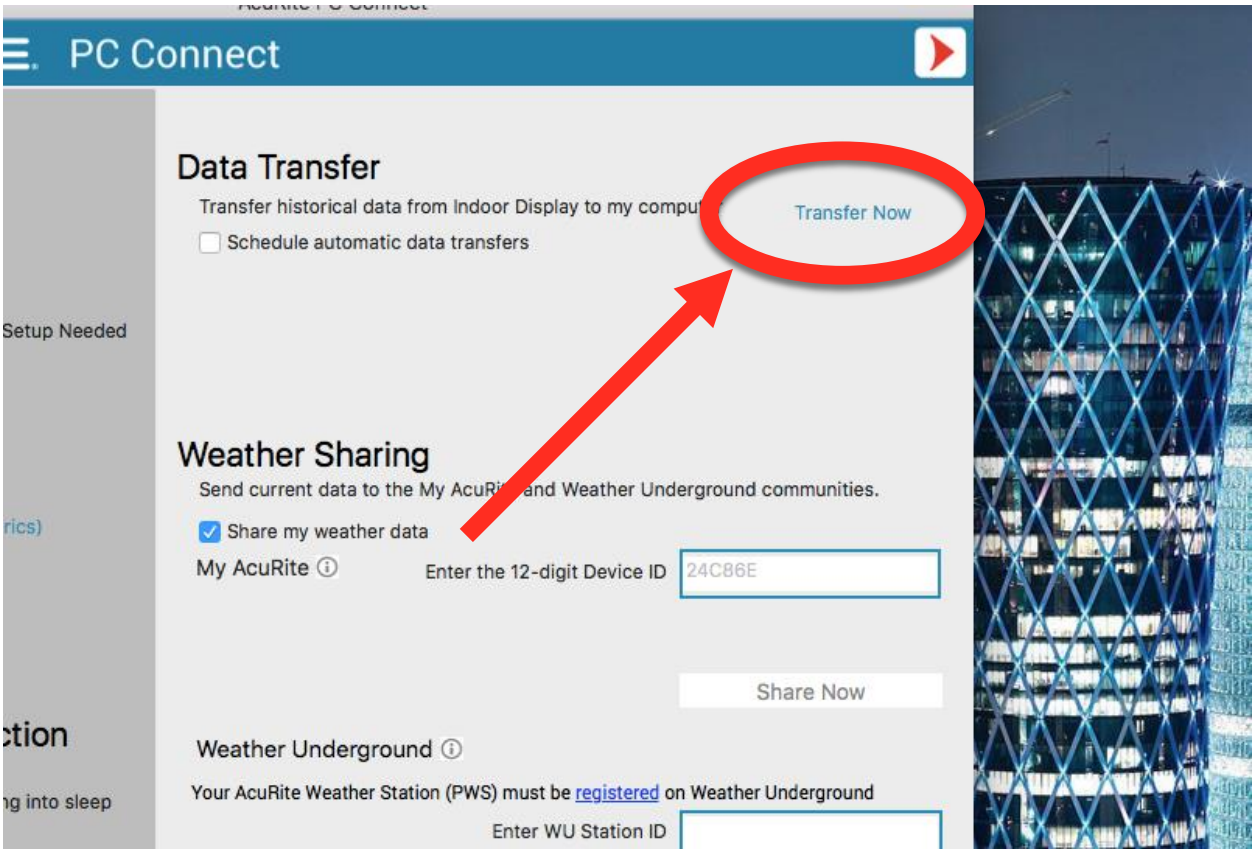
4) If you search within the box that your weather station came with, you will find a small USB cable that connects to your computer and the indoor component of your station. (In our case, this piece of equipment was black in color and displayed the real-time weather reports on a blue screen.) Connect the indoor component of your weather station into a free USB port on your computer.

5) Return to the opened program.

6) On the software window, you will see bolded text at the top that reads *Data Transfer*. This area, along with the drop-down menu slightly below it, is what we are interested in.


PC Connect
Data Transfer
Transfer historical data from Indoor Display to my computer
Transfer Now
Schedule automatic data transfers
Setup Needed
Weather Sharing
Send current data to the My AcuRite and Weather Underground communities.
Share my weather data
My AcuRite
Enter the 12-digit Device ID
24C86E
Share Now
Weather Underground
Your AcuRite Weather Station (PWS) must be registered on Weather Underground
Enter WU Station ID

7) To the right of this area, you will see blue text that reads *Transfer Now*. Click this text. The software will upload the real-time data being displayed on your weather station into a *.csv* file.



8) After you click, a new window will pop up; you will be prompted to input where on your personal computer you want all of your data to be saved. Enter a safe location that you will remember into the text area. You will now have a *.csv* file that contains all of the weather data at that particular point in time.

ADDITIONAL RESOURCES

A. Display for 5-in-1 Weather Sensor

ACU▸RITE **Instruction Manual**

Display for 5-in-1 Weather Sensor

model 06022RM

Package Contents

1. Display unit with tabletop stand
2. Power adapter
3. Instruction Manual

This product requires an AcuRite 5-in-1 Weather Sensor (sold separately) to be operational.

IMPORTANT PRODUCT MUST BE REGISTERED TO RECEIVE WARRANTY SERVICE

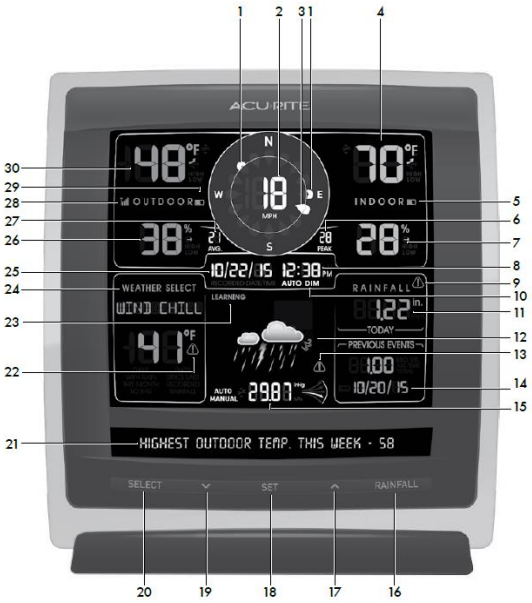
PRODUCT REGISTRATION
Register online to receive 1 year warranty protection
www.**AcuRite**.com

Questions? Contact Customer Support at (877) 221-1252 or visit www.**AcuRite**.com.

SAVE THIS MANUAL FOR FUTURE REFERENCE.

Features & Benefits

Display Unit



2

1. **Previous 2 Wind Directions**
2. **Current Wind Speed**
3. **Current Wind Direction**
4. **Current Indoor Temperature**
   Arrow icon indicates direction temperature is trending.
5. **Display Low Battery Indicator**
6. **Peak Wind Speed**
   Highest speed from the last 60 minutes.
7. **Current Indoor Humidity**
   Arrow icon indicates direction humidity is trending.
8. **Clock**
9. **Rainfall Alert Indicator**
   Indicates rainfall of more than 1" of rain in 2 hours or less.
10. **AUTO DIM Indicator**
11. **Current Rainfall**
    Accumulates data during rainfall.
12. **12 to 24 Hour Weather Forecast**
    Self-Calibrating Forecasting pulls data from your 5-in-1 sensor to generate your personal forecast.
13. **Storm Alert Indicator**
14. **Month/Year/All-Time Rainfall**
15. **Current Barometric Pressure**
    Arrow icon indicates direction pressure is trending.
16. **RAINFALL Button**
    Press to change the RAINFALL data being displayed (Month, Year, All-Time).
17. **^ Button**
    for setup preferences.
18. **SET Button**
    for setup preferences.
19. **v Button**
    for setup preferences.
20. **SELECT Button**
    Press to change the WEATHER SELECT category data being displayed.
21. **Weather Ticker™**
22. **Heat Index/ Wind Chill Alert Indicator**
23. **Learning Mode Icon**
    Disappears after weather forecast self-calibration is complete.
24. **WEATHER SELECT**
    Displays heat index, dew point, wind chill, feels like, days with rain this month, and days since last recorded rainfall.
25. **Date**
26. **Current Outdoor Humidity**
    Arrow icon indicates direction humidity is trending.
27. **Average Wind Speed**
    of all speeds from past 2 minutes.
28. **5-in-1 Sensor Signal Strength**
29. **Sensor Low Battery Indicator**
30. **Current Outdoor Temperature**
    Arrow icon indicates direction temperature is trending.

BACK OF DISPLAY UNIT

1. **Integrated Hang Hole**
   for easy wall mounting.
2. **Backlight Button**
   Dimmer control while using power adapter. Activates momentary backlight while on battery power.
3. **Plug-in for Power Adapter**
4. **Removable Tabletop Stand**
5. **CLEAR ALL/RESET Button**
   Press and HOLD for 10 seconds for full reset to factory defaults.
6. **A-B-C Switch**
   ID code that must match 5-in-1 sensor's A-B-C switch to ensure units synchronize.
7. **Power Adapter**
8. **Battery Compartment Cover** (not shown)

Display Unit Setup

AcuRite recommends high quality alkaline batteries for the best product performance. Heavy duty or rechargeable batteries are not recommended.

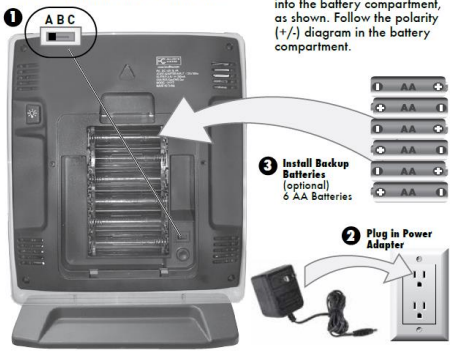
1 Set the A-B-C Switch

The A-B-C switch is located inside the battery compartment. It can be set to A, B or C. However, you must select the same letter choices for both the sensor and the display unit in order for the units to synchronize.

2 Plug Power Adapter into Electrical Outlet

3 Install or Replace Batteries (optional)

Insert 6 x AA alkaline batteries into the battery compartment, as shown. Follow the polarity (+/-) diagram in the battery compartment.



IMPORTANT: Batteries are a backup power source to preserve records in the event of a power outage. Power adapter is the recommended primary power source to enjoy the full Functionality of this product.

PLEASE DISPOSE OF OLD OR DEFECTIVE BATTERIES IN AN ENVIRONMENTALLY SAFE WAY AND IN ACCORDANCE WITH YOUR LOCAL LAWS AND REGULATIONS.

BATTERY SAFETY: Clean the battery contacts and also those of the device prior to battery installation. Remove batteries from equipment which is not to be used for an extended period of time. Follow the polarity (+/-) diagram in the battery compartment. Promptly remove dead batteries from the device. Dispose of used batteries properly. Only batteries of the same or equivalent type as recommended are to be used. DO NOT incinerate used batteries. DO NOT dispose of batteries in fire, as batteries may explode or leak. DO NOT mix old and new batteries or types of batteries (alkaline/standard). DO NOT use rechargeable batteries. DO NOT recharge non-rechargeable batteries. DO NOT short-circuit the supply terminals.

Set the Time, Date & Units

Press the "SET" button, located on the front of the display unit, to enter SET MODE. Once in set mode, the preference you are currently setting will blink on the display.

To adjust the currently selected (flashing) item, press and release the "^" or "v" buttons (press and HOLD to fast adjust).

To save your adjustments, press and release the "SET" button again to adjust the next preference. The preference set order is as follows:

TOP DISPLAY:
CLOCK HOUR
CLOCK MINUTE
CALENDAR MONTH
CALENDAR DATE
CALENDAR YEAR
TEMPERATURE UNITS (°F or °C)
WIND SPEED UNITS (MPH, km/h, Knots)
RAINFALL UNITS (in or mm)
PRESSURE UNITS (inHg or hPa)

TICKER DISPLAY:
LANGUAGE (English, French, Spanish)
WEATHER TICKER SPEED (SLOW, MEDIUM, FAST)

You will automatically exit SET MODE if no buttons are pressed for 20 seconds. Enter SET MODE at any time by pressing the "SET" button.

Display Backlight Settings

This weather station's color display features three different lighting settings: High (100%) brightness, Medium (60%) brightness and Low (30%) brightness

Using battery power alone, the backlight is available momentarily for 10 seconds by pressing the "BACKLIGHT" button.

When display is powered with the power adapter, backlight remains on at 100% brightness. Press "BACKLIGHT" button once to dim to 60% brightness; press again to dim to 30%, press a 3rd time to enter "AUTO DIM" mode. "AUTO DIM" will appear below the time.

AUTO DIM MODE: Automatically adjusts display brightness based on time of day & year.	
MARCH 11- NOVEMBER 4	6:00 a.m. - 9:00 p.m. = 100% brightness
	9:01 p.m. - 5:59 a.m.= 30% brightness
NOVEMBER 5 - MARCH 10	7:30 a.m. - 7:00 p.m.= 100% brightness
	7:01 p.m. - 7:29 a.m. = 30% brightness

OPERATION

Placement for Maximum Accuracy

AcuRite sensors are sensitive to surrounding environmental conditions. Proper placement of both the display unit and the sensor are critical to the accuracy and performance of this product.

Display Unit Placement
Place the display unit in a dry area free of dirt and dust. To ensure accurate temperature measurement, place out of direct sunlight and away from heat sources or vents. Display unit stands upright for tabletop use or is wall-mountable.

Using the Professional Weather Center

Learning Mode

Self-Calibrating Forecasting use a unique algorithm to analyze changes in pressure over a time period (called Learning Mode) to determine your altitude. After 14 days, the Learning Mode icon disappears from the display screen. At this point, the self-calibrated pressure is tuned in to your location and the unit is ready for superior weather prediction.

Weather Forecast

AcuRite's patented Self-Calibrating Forecasting provides your personal forecast of weather conditions for the next 12 to 24 hours by collecting data from the sensor in your backyard. It generates a forecast with pinpoint accuracy - personalized for your exact location.

View the complete list of icons at www.AcuRite.com/acurite-icons

Weather Select

Weather Select displays data including wind chill, dew point, heat index, feels like, days with rain this month, and days since last recorded rainfall. To change the "Weather Select" category shown, press the "SELECT" button on the front of the display.

Barometric Pressure

Subtle variations in barometric pressure greatly affect the weather. This weather center displays the current pressure with an arrow icon to indicate the direction the pressure is trending (FALLING, STEADY, or RISING).

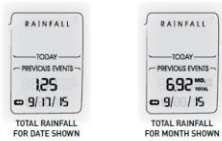
Rainfall Tracking

This weather station features enhanced tracking of historical rainfall data. Rain accumulation data is recorded for today, over all-time, by year, by month, and by rainfall event.

Press the "RAINFALL" button to review rainfall records. The ⇔ icon is shown on the display while historical data is being viewed.

Records are shown in the following order:

PREVIOUS RAINFALL #1*
PREVIOUS RAINFALL #2*
PREVIOUS RAINFALL #3*
CURRENT MONTH TOTAL RAINFALL
PREVIOUS MONTH TOTAL RAINFALL
2 MONTHS AGO TOTAL RAINFALL
CURRENT YEAR TOTAL RAINFALL
PREVIOUS YEAR TOTAL RAINFALL
ALL-TIME TOTAL RAINFALL (date shown is start date of the all-time total; the date the display was powered on)



*Previous rainfall is the amount of rain recorded from 12:00am to 11:59pm on the date shown.

Weather Ticker™

The Weather Ticker automatically flashes your real-time weather information and alerts as text in the lower part of the display unit screen.

The possible WEATHER TICKER messages are as follows:

HEAT INDEX-XX
WINDCHILL-XX
DEW POINT-XX
IT FEELS LIKE XX OUTSIDE
7 DAY HIGH TEMP. XX- MM/DD
7 DAY LOW TEMP. XX- MM/DD
30 DAY HIGH TEMP. XX- MM/DD
30 DAY LOW TEMP. XX- MM/DD
ALL TIME HIGH TEMP. XXX...RECORDED MM/DD/YY
ALL TIME LOW TEMP. XXX...RECORDED MM/DD/YY
24 HOUR TEMP. CHANGE +XX
ALL TIME HIGH WIND XX MPH...RECORDED MM/DD/YY
7 DAY AVERAGE WIND XX MPH
TODAY'S AVERAGE WIND XX MPH
MOON- NEW
MOON- WAXING CRESCENT
MOON- FIRST QUARTER
MOON- WAXING GIBBOUS
MOON- FULL
MOON- WANING GIBBOUS
MOON- LAST QUARTER
MOON- WANING CRESCENT
INDOOR HUMIDITY OK
INDOOR HUMIDITY HIGH
INDOOR HUMIDITY LOW
NEW LOW TEMP. RECORD XX
NEW HIGH TEMP. RECORD XX
NEW WIND RECORD TODAY XX
CURRENT RAINFALL X.XX/HR.
RAIN EVENT STARTED XX HRS. AGO
SENSOR BATTERIES LOW
DISPLAY BATTERIES LOW
SENSOR SIGNAL LOST...CHECK BATTERIES AND PLACEMENT
CAUTION- HEAT INDEX IS XXX
CAUTION- WIND CHILL IS XXX
CALIBRATION

Troubleshooting

Problem	Possible Solution
Inaccurate temperature or humidity	• Make sure both the display unit and 5-in-1 sensor are placed away from any heat sources or vents (see page 7). • Make sure both units are positioned away from moisture sources (see page 7). • Make sure 5-in-1 sensor is mounted at least 5 ft off of the ground. • Calibrate indoor and outdoor temperature and humidity (see page 11).
No rainfall	• Check to ensure the rain gauge stabilizer (plastic tab) has been removed from the bottom of the sensor. • Clear debris, such as leaves, out of the rain collector funnel and debris screen. • Calibrate the Rain Gauge.
Inaccurate wind readings	• What is wind reading being compared to? Pro weather stations are typically mounted at 30 ft high or more. Make sure to compare data using a sensor positioned at the same mounting height. • Check location of the sensor. Ensure it's mounted a minimum of 5 ft in the air with no obstructions around it (within several feet). • Ensure wind cups are spinning freely. If they hesitate or stop try lubricating with graphite powder or spray lubricant.
Display screen not working	• Check that the batteries are installed correctly. Batteries may need to be replaced. • Reset the display by pressing and holding the CLEAR ALL/RESET button for 10 seconds, located in the battery compartment of the display unit. Date and time will need to be entered after a reset.

If your AcuRite product does not operate properly after trying the troubleshooting steps, visit www.AcuRite.com or call (877) 221-1252 for assistance.

Care & Maintenance

Display Unit Care

Clean with a soft, damp cloth. Do not use caustic cleaners or abrasives. Keep away from dust, dirt and moisture. Clean ventilation ports regularly with a gentle puff of air.

Calibration

The indoor / outdoor temperature and humidity readings, and barometric pressure can be calibrated on the display unit to improve accuracy. Calibration can improve accuracy when sensor placement or environmental factors impact the data accuracy.

1. To access calibration mode, press AND HOLD the "^", "SET", and "v" buttons simultaneously for at least 5 seconds.
2. To adjust the currently selected (flashing) item, press and release the "^" or "v" buttons to calibrate the data value higher or lower from the actual reading.
3. To save your adjustments, press and release the "SET" button to adjust the next preference. The " " icon will remain illuminated next to calibrated values.

   The preference set order is as follows:
   OUTDOOR TEMPERATURE
   OUTDOOR HUMIDITY
   INDOOR TEMPERATURE
   INDOOR HUMIDITY
   BAROMETRIC PRESSURE (must be set to MANUAL mode to calibrate)*

   *To change from AUTO to MANUAL pressure mode and vice versa, press AND HOLD the "SET" button for at least 10 seconds. The display indicates the current pressure mode selected,"AUTO" or "MANUAL".

After 10 seconds of inactivity, the display will save the adjustments and exit calibration mode. Note: Calibrations will be erased if the display is reset or if batteries are removed and the power adapter is unplugged.

Specifications

TEMPERATURE RANGE	Outdoor: -40ºF to 158ºF; -40ºC to 70ºC
	Indoor: 32ºF to 122ºF; 0ºC to 50ºC
HUMIDITY RANGE	Outdoor: 1% to 99% RH
	Indoor: 1% to 99% RH
WIND SPEED	0 to 99 mph; 0 to 159 kph
WIND DIRECTION INDICATORS	16 points
RAINFALL	0 to 393 in; 0 to 9999mm
WIRELESS RANGE	330ft / 100m depending on home construction materials
OPERATING FREQUENCY	433 MHz
POWER	Display: 4.5V, 250mA AC adapter 6 x AA alkaline batteries (optional)
	Sensor: 4 x AA alkaline or lithium batteries
DATA REPORTING	Wind Speed: 18 second updates; Direction: 30 seconds Outdoor temperature & humidity: 36 second updates Indoor temperature & humidity: 60 second updates

FCC Information

This device complies with part 15 of FCC rules. Operation is subject to the following two conditions:
1- This device may NOT cause harmful interference, and
2- This device must accept any interference received, including interference that may cause undesired operation.
WARNING: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.
NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
• Reorient or relocate the receiving antenna.
• Increase the separation between the equipment and the receiver.
• Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
• Consult the dealer or an experienced radio/TV technician for help.
NOTE: The manufacturer is not responsible for any radio or TV interference caused by unauthorized modifications to this equipment. Such modifications could void the user authority to operate the equipment.
This device complies with Industry Canada licence-exempt RSS standard(s).
Operation is subject to the following two conditions:
(1) This device may not cause interference, and
(2) This device must accept any interference received, including interference that may cause undesired operation of the device.

Customer Support

AcuRite customer support is committed to providing you with best-in-class service. **For assistance**, please have the model number of this product available and contact us in any of the following ways:

(877) 221-1252 info@chaney-inst.com

24/7 support at www.**AcuRite**.com

- Installation Videos
- Instruction Manuals
- Replacement Parts
- Register your Product
- Support User Forum
- Submit Feedback & Ideas

IMPORTANT PRODUCT MUST BE REGISTERED TO RECEIVE WARRANTY SERVICE

PRODUCT REGISTRATION
Register online to receive 1 year warranty protection
www.**AcuRite**.com

Limited One Year Warranty

At AcuRite, we proudly uphold our commitment to quality technology. Chaney Instrument Co. warrants that all products it manufactures to be of good material and workmanship, and to be free of defects when properly installed and operated for a period of one year from the date of purchase.

We recommend that you visit us at www.AcuRite.com for the fastest way to register your product. However, product registration does not eliminate the need to retain your original proof of purchase in order to obtain warranty benefits.

Chaney Instrument Co. warrants that all products it manufactures to be of good material and workmanship, and to be free of defects when properly installed and operated for a period of one year from the date of purchase. Remedy for breach of this warranty is limited to repair or replacement of the defective item(s). Any product which, under normal use and service, is proven to breach the warranty contained herein within ONE YEAR from date of sale will, upon examination by Chaney, and at its sole option, be repaired or replaced by Chaney. Transportation costs and charges for returned goods shall be paid for by the purchaser. Chaney hereby disclaims all responsibility for such transportation costs and charges. This warranty will not be breached, and Chaney will give no credit for products it manufactures which have received normal wear and tear, been damaged (including by acts of nature), tampered, abused, improperly installed, damaged in shipping, or repaired or altered by others than authorized representatives of Chaney.

The above-described warranty is expressly in lieu of all other warranties, express or implied, and all other warranties are hereby expressly disclaimed, including without limitation the implied warranty of merchantability and the implied warranty of fitness for a particular purpose. Chaney expressly disclaims all liability for special, consequential or incidental damages, whether arising in tort or by contract from any breach of this warranty. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you. Chaney further disclaims all liability from personal injury relating to its products to the extent permitted by law. By acceptance of any of Chaney's products, the purchaser assumes all liability for the consequences arising from their use or misuse. No person, firm or corporation is authorized to assume for Chaney any other liability in connection with the sale of its products. Furthermore, no person, firm or corporation is authorized to modify or waive the terms of this paragraph, and the preceding paragraph, unless done in writing and signed by a duly authorized agent of Chaney. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

For in-warranty claims:
Chaney Instrument Co. | 965 Wells St. | Lake Geneva, WI 53147

3. LEVELOGGER PRESSURE TRANSDUCER (SOP)

SOLINST LEVELOGGER ® EDGE

NEPAL STUDY CENTER

LUMBINI SUSTAINABILITY CIRCLE

Citizen Science Danda River Monitoring Program (DEMP)

- The Levelogger is a self-contained water level datalogger that monitors the depth of the river.
- It has a memory capacity of 40,000 temperature and water level data points
- The Levelogger has a long lasting lithium battery that can last up to 10 years.
- The Levelogger has wireless capabilities and uploads real-time data to an application interface

PRATIMAN-NEEMA MEMORIAL FOUNDATION

River Stage Monitoring

YOGDAN Study Abroad Program

December 2017

Eco-adventure Hands-on Service-learning Experiential - learning

Community Learning Environment

University of New Mexico
bohara@unm.edu

Pratiman-Neema
Swati_thapa@hotmail.com

ACTION LAB STUDY ABROAD DEPLOYMENT

STANDARD OPERATING PROCEDURE

LEVELOGGER PRESSURE TRANSDUCER- RIVER STAGE

By Corinne Fox

CONTENTS

DECEMBER 2018 ACTION LAB SUMMARY:

Figure 1 and 2: Action Lab team teaching the students how to deploy the Levelogger into the pipe well connected to the gabion wall

A pressure transducer can measure the level and temperature of water for various applications such as long-term groundwater monitoring; river, lake, and stream gauging; aquifer testing; wetlands and stormwater runoff monitoring; agricultural stormwater runoff monitoring; and more for water resource management (Solinst, n.d.). A Solinst Levelogger Edge water level and temperature logger was used in this case study to begin to measure the river dynamics (river stage) of the Danda River. River stage is the depth of the river at the time of measurement. Two sensors were donated by the UNM Civil Engineering Department Geographic Information System (GIS) Lab and were specifically selected because of their relative affordability, durability, long-lasting battery life, large data point memory, and potential blue tooth and smartphone application capabilities. This sensor was also used successfully in previous UNM international watershed research studies conducted by the Water Resource Engineering Department, for example in Mexico.

The Levelogger starts to measure data once it is programmed and deployed into the river (Solinst, n.d.). It measures the temperature and the pressure of the water in feet (Solinst, n.d.). The logger can be programmed using the Solinst software on a computer to fit the parameters of the project. To accurately measure the level of the water, the barometric pressure needs to be measured. The company Solinst provides a barometric sensor, but for this study, the 5-in-1 Pro Weather Station provides barometric data for this study.

SETUP DESIGN

During the preliminary stages of the research, the Leveloggers were tested by following the Solinst directions prior to deployment in Nepal. A design was created prior to the deployment to ensure the proper materials were purchased and ready for use on the ground during the day of the deployment in Nepal. The figure below was created to provide a general outline as to

how the well pipe would be installed and then how the levelogger would be disseminated down into the well to collect readings from the river flow.

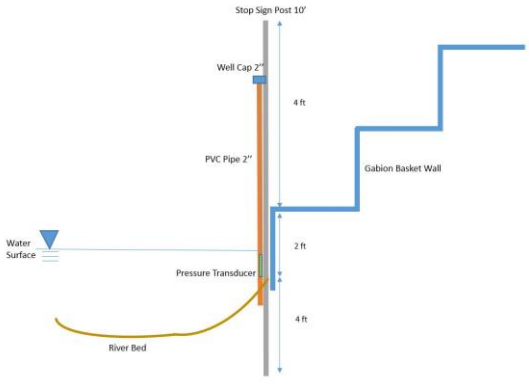


Figure 3 and 4: Initial well design and gabion wall along the PNMHI campus

MATERIALS AND TOOLS

Before starting, make sure to have internet access to access the website links provided in this SOP.

1. Begin by familiarizing yourself with the Solinst material: https://www.solinst.com/products/data/brochure-dataloggers-telemetry.pdf and https://www.solinst.com/products/dataloggers-and-telemetry/precision.php (read all tabs)
   User guide: https://www.solinst.com/products/dataloggers-and-telemetry/3001-levelogger-series/operating-instructions/user-guide/3001-user-guide.pdf
   Quick Start Guide: https://www.solinst.com/products/dataloggers-and-telemetry/3001-levelogger-series/operating-instructions/quick-start-guide/3001-quick-start-guide.pdf
2. Download the Solinst software onto the computer you intend to use by going to this link: https://www.solinst.com/downloads/

Figure 5: Levelogger materials

Resources for Operational and installation Process

Before installation make sure you have all the proper materials listed in this brochure: https://www.solinst.com/products/data/brochure-dataloggers-telemetry.pdf

A. Levelogger

(https://www.solinst.com/products/dataloggers-and-telemetry/software.php)

B. Levelogger cable
C. Solnist Levelogger Software (downloaded onto a desktop computer)

Levelogger

- Familiarize yourself with the material provided on this website: https://www.solinst.com/products/dataloggers-and-telemetry/precision.php

Software

- This resource is what will be needed to understand the Levelogger software: https://www.solinst.com/products/dataloggers-and-telemetry/software.php

Installation and Programing Material

- This website offers guidance for installation and programing: https://www.solinst.com/products/dataloggers-and-telemetry/programming-deployment.php

Additional Resources:

A. This website is helpful for questions and troubleshooting: https://www.solinst.com/products/dataloggers-and-telemetry/3001-levelogger-series/levelogger-edge/
B. This video is helpful for programing the Levelogger: https://youtu.be/1bnFtonvwwA
C. This video is helpful for groundwater basics: https://www.youtube.com/watch?v=CpLpXx1Mkr8

B. CITIZEN SCIENCE SURVEY

Himalayan Study Abroad Program: Urban Health and Environment
Sustainable Development Action Lab (SDAL)
Nepal Study Center, University of New Mexico
Department of Economics

In collaboration with the
Lumbini Center for Sustainability (LCS), PNMF
Siddharthanagar, Nepal

Namaste. Please help the University of New Mexico's SDAL Team understand how we can better collaborate with you in the future by answering the following questions. Please ask questions, if needed.

Name: _____

Gender: _____

Age: _____

Mention your grade level if you are a student: _____

Or mention your occupation and position if a professional: _____

How has your understanding of citizen science changed following this week's presentations and activities? Circle one option.

1—I understand much more about citizen science.
2—I understand a little more about citizen science
3—I have the same understanding about citizen science.

Was English a barrier to your understanding throughout the presentations and activities? Circle one option.

1—I understood everything.
2—I understood most of the information.
3—I partially understood the information.
4—I rarely understood the information.
5—I did not understand anything.

How has your awareness of the current environmental condition of the Danda River changed following this week's presentations and activities? Circle one option.

1—I am much more aware.
2—I am somewhat more aware.
3—I have the same awareness

To which of the following technological devices do you have access? Circle all that apply.

Feature Phone
Smart Phone
Landline
Personal Computer
School Computer
Other: _____

Which social media platforms do you use? Also, please indicate how often you use each one. Circle all that apply.

1—I use daily
2—I use sometimes
3—I rarely use.

Facebook (1 2 3)
Instagram (1 2 3)
Twitter (1 2 3)
Snapchat (1 2 3)
Tumblr (1 2 3)
YouTube (1 2 3)
Pinterest (1 2 3)
Reddit (1 2 3)
Other: _____

What computer programs do you know how to use? Circle all that apply.

Word (or other word processor)
Excel (or other spreadsheet software)
PowerPoint (or other presentation software)
Statistical Software (Such as SPSS or others)
Other: _____

What is the best way for the UNM SDAL to stay connected with you? Circle one option.

Email
Skype/Google Hangouts/FaceTime
Yogdan Website
Facebook
Other: _____

What resources and information could the UNM SDAL provide you to help you stay informed of our activities?

Do you have any suggestions/ideas that UNM SDAL can use in the future? Please explain.

What was your favorite and least favorite part of the activities and presentations? Please explain.

C. Citizen Science Worksheet

1. LASER Egg Worksheet

Air Quality Index (AQI) Assessment Data Sheet

Water quality index is important to know because it tells you how many particles are in the air. When pollution is heavy the air quality is not healthy for humans and animals. In Table 2, fill in the date and the air quality number you see on the Laser Egg. In Figure 1, you will see the different levels of AQI and why they are important to understand.

Table 2. Air quality index from laser egg.

Date	AQI Measurement	AQI Rating (see Figure 1)

Figure 1. Air quality rating based on index.

2. 5 IN 1 PRO WEATHER STATION WORKSHEET

Weather Station Assessment Data Sheet

Understanding weather helps us know different climatic patterns in the region. In this excursive one will look at the weather station screen and fill in the measurements that are being collected by the Pro 1 and 5 Weather Station.

Look at the weather station monitor screen or the Acurite app and write down the corresponding numbers for each measurement in Table 3.

Table 3. Current weather conditions.

Weather Measurement	Weather Data
Temperature (°C)	
Humidity (%)	
Wind Speed (Km/hr)	
Precipitation (in)	
Barometric Pressure (Hg)	

For more information on the projects, visit:

- **Nepal Study Center:** http://nepalstudycenter.unm.edu/SustainableResearchLab/UndergraduaterResearchInitiatives.html
- **Nepal Study Center Blog:** https://foxc01.wixsite.com/yogdan/contact