Project Title: Implementing an integrated, wireless monitoring network to enhance decision making in communities impacted by environmental and industrial change

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Funding Source: NSF Smart and Connected Communities

Overview:
Texas coastal communities have historically been exposed to environmental threats from natural and industrial sources. In Ingleside on the Bay (IOB), a small, rural community situated along the shoreline of Corpus Christi Bay, tropical storms and high rates of relative sea-level rise cause extreme and nuisance flooding, while industrial expansion is placing stress on the community's way of life and the natural resources upon which it relies. Such communities lack the comprehensive data needed to advocate for and make informed decisions about risk reduction strategies to mitigate the impacts of industrial growth and climate change. This proposal engages with the nonprofit Ingleside on the Bay Coastal Watch Association (IOBCWA), community members, and governmental representatives to assess the role of distributed, real-time sensor technology in improving IOB's capacity to respond to dynamic environmental conditions that affect the quality of its air, water, and land resources. It also examines how emerging community-based nonprofits like IOBCWA engage with diverse organizations in response to new threats and how they can utilize environmental sensing data in planning and advocacy efforts.

This project will leverage interdisciplinary, sociotechnical methods to (1) assess the current structure of communication and information-sharing networks related to environmental threats and mitigation planning in IOB; (2) activate academic-civic partnerships to deploy environmental monitoring sensors to generate a pilot smart grid for comprehensive and timely data collection; (3) develop a preliminary online data visualization dashboard that makes sensor data available in real-time to the community; and (4) assess how the data and dashboard can be utilized by residents and nonprofit organizations to inform sustainable planning and development strategies that address industrial permitting challenges and safeguard community and environmental well-being. To achieve our technical objectives, we will develop and deploy a pilot sensing network for real-time environmental monitoring, design an online dashboard and data analysis framework to display the collected data in real-time, and beta test the dashboard among a diverse group of residents, community leaders, and local stakeholders. To achieve our social science objectives, we will apply grounded theory to characterize the evolving role of community-based nonprofits in networking, civic engagement, and policymaking efforts in IOB and identify data needs that can be addressed by leveraging sensor technology to provide a scientific basis for decision-making. Community workshops will provide opportunities to refine the study needs and objectives, obtain feedback on the sensor network and dashboard, and co-develop a vision for future integrative research efforts.

Approach:
Building on past collaborations between the research team and community, we will conduct a community workshop with residents and local stakeholders from governmental and nonprofit organizations at the start of the project. This workshop will focus on (1) understanding the community's concerns with respect to environmental monitoring, climate change, and industrial development and (2) identifying key data needs (e.g., type, accuracy, frequency, location) that the participants believe are necessary to characterize environmental quality in IOB. We will draw on the experience of the participants to identify critical assets and "hot-spots" of environmental concern via interactive tabletop mapping exercises to inform sensor deployment locations. Participants will also be given mock-ups of potential data dashboard configurations and will be asked to provide feedback on the content and usability. This feedback will guide the initial design of the dashboard to ensure that it is relevant to stakeholder needs and accessible for users.

Based on input from this workshop, we will outline a sensor deployment strategy and perform initial pilot testing of the sensor prototypes to refine the configuration and data collection frequency. The

wireless network will consist of low-cost environmental sensors, such as particle concentration laser sensors, total dissolved solids meters, pH meters, and ultrasonic water level sensors, which will be deployed throughout the community to monitor air/water quality and flood hazards. These sensors have been used with varying levels of success in past studies, so we will subject them to rigorous testing and validation in the lab before deployment and will then conduct ongoing comparisons with co-located research-grade monitoring stations in and around IOB to quantify trade-offs between cost, resolution, and accuracy. As the estimated coverage of the network will be several square miles, we plan to use Long Range Wide Area Network (LoRaWAN) as the underlying network technology to transmit data to a central server for real-time processing and visualization in a low-cost and energy-efficient manner. LoRaWAN can provide a single hop transmission over several miles with ease, so the targeted area will require at most several gateways (depending on line-of-sight from deployed sensor nodes), resulting in a reliable star shaped network topology where each sensor will be directly connected to a gateway and the server. To reduce costs and enable flexibility for the sensors, we will develop our own sensor nodes and gateways using open source solutions (e.g., Raspberry Pi or Arduino) with add-on modules for LoRaWAN. Monitoring and maintenance of the wireless network will be done collaboratively through remote monitoring at UT Arlington and local oversight by trained community members, several of whom have experience with sensor technology.

We will then develop a beta version of the data dashboard, which will display the sensor measurements on a map of the area for real-time visualization. Other relevant data from existing research-grade monitoring stations, including nearby tide gauges, weather stations, and a recently installed air quality monitor, will also be displayed. The dashboard will be made available over multiple platforms, including browsers and mobile apps, to allow stakeholders and the public to monitor current conditions throughout the community. Post-processing of the sensor data will focus on assessing spatial and temporal trends in environmental conditions in IOB. Datasets obtained from the various sensors and monitoring stations are likely to show correlations during events. For example, a period of high ship traffic could lead to higher levels of airborne particulate matter, increased turbidity in nearshore areas, and elevated water levels. We will thus apply multimodal data fusion techniques based on deep learning approaches to explore the embedded correlations in these datasets and to assess the added diversity and insights gained through integration of low-cost sensors. Summary metrics and results from these analyses will be reported via the dashboard and will be used to inform future refinements to the configuration of the sensor network (i.e., optimal number and placement of nodes).

Following initial development and testing of the dashboard, a diverse subset of IOB residents and stakeholders will be recruited to serve as beta testers. These users will be asked to provide feedback on the functionality and accessibility of the online and mobile interface and the usefulness and relevance of the content displayed. The project team will meet with beta users through virtual teleconference at least twice during the testing period for focused feedback and will provide an online form where users can submit specific issues or requests at any time. We will also track and collect information about users' page views and navigation within the dashboard for ongoing analysis of its functionality. User feedback and usage trends will be incorporated to improve the dashboard in an iterative process over the course of the pilot project. At the conclusion of the pilot deployment, we will hold a second workshop with community members and stakeholders to demonstrate how to use the dashboard and discuss trends in environmental conditions observed during the pilot period. We will also facilitate collaborative discussions among participants to identify opportunities to integrate the dashboard data into ongoing efforts that can inform decision-making about sustainable development strategies.