PROJECT INFORMATION

Project Director's Name*	Anderson
Organization*	Auburn University
Project Title*	A coupled natural-human framework for risk assessment of coastal communities from land-use and climate change
Reporting Period*	Final

Note to Grantees: In sections 1 to 5, we ask you to highlight your accomplishments (including outputs and outcomes) through this grant award. <u>These sections of the final grant report will be made available to the public.</u>

1. GOALS AND ACCOMPLISHMENTS

1.1 Please restate the goals and objectives of your project.*

This project sought to understand how various socio-economic and climatic factors may change forest landowner decisions and ultimately reduce forest cover along the northern Gulf of Mexico (GOM). Further, we seek to understand the extent that future forest loss and LULC change will alter drainage patterns and water quality to estuaries and their associated communities along the coast. Our study area comprised of ten HUC-8 watersheds (a policy-relevant watershed unit in line with federal resource management agencies) draining to the northern GOM along coastal Alabama and west-Florida. This area, known as the “Emerald Coast”, is renowned for its clear waters, productive bays, and popular beaches. Assessing the future risk of LULC change while providing meaningful guidance will require an integrated human-natural approach. Therefore, we devised a coastal human-natural (CHN) framework to address important research and management questions facing this region. Our CHN framework consists of a series of surveys, data gathering, and model applications to connect social and environmental factors from watersheds to coastal zones. Specific objectives related to our project included:

1) Determining if recent and continued changes in LULC, climate (especially tropical storm activity) and other socio-economic factors will increase forest conversion and loss in the study area.

2) Using the Perdido Bay and St. Andrew Bay watersheds, determine if there are thresholds in which the conversion of watershed forest cover will result in substantial alterations in flow and water quality that impair downstream coastal ecosystems and associated ecosystem services.

3) Using the Perdido Bay and St. Andrews Bay watersheds, determine if there are important land holdings or local areas where sustaining forest cover is particularly important for coastal waters and ecosystems.

4) Determining how changes in coastal ecosystems feedback to socio-economic considerations for watershed forest management.

1.2 Describe the accomplishments of your project. You should include both the anticipated accomplishments that you outlined in your project proposal as well as any *unanticipated* accomplishments that have since occurred. Describe any activities you have conducted, programmatic progress made, or project benchmarks and milestones met.*

Our study required the coordination of various data gathering and modeling exercises to make important linkages in our CHN Framework. These efforts are essentially components of the framework and individually represent important accomplishments for our project. For instance, Co-PI Morse and PhD student Anna Brown led a series of forest landowner surveys in the study to discern how recent hurricane activity and other socioeconomic changes would affect (or not) their decision to keep forestland in forest cover. Coordinating with Co-PI Hall, the forest landowner survey was administered by mail to over 3,000 forest owners across coastal Alabama and Florida Panhandle. A subpopulation of forest owners was surveyed to investigate potential for conversion to other land uses, along with the underlying market, policy, and environmental factors. Using public county tax appraiser information, they identified all timberland owners of parcels of at least 50 acres, with no maximum parcel size, within the study area and randomly reduced the sample down to 3000 landowners to receive surveys. The survey questions elicited landowner characteristics, current land uses, history with and interest in conservation, perceptions of hurricane risk (including potential increases in frequency, strength, and wind damage) and underlying influences on decision-making (e.g., timber markets, forest policy), and a forest decision-making assessment. The decision-making assessment included three hurricane frequency scenarios.

Indications of forest landowner tendencies and other demographic information were used by Co-PI Dwivedi and his PhD student Asiful Alam to model and map future land use land cover (LULC) in the Perdido Bay and St. Andrew Bay watersheds. They used Google Earth Engine (GEE) for the center of the analysis and pre-processed Landsat imagery available through GEE to assess land use change across Perdido Bay and St. Andrew Bay from 1991 to 2021 at five-year intervals. Using National Land Cover Database (NLCD) 30x30m and National Agricultural Imagery Program (NAIP), major land uses were identified in the Perdido Bay and St. Andrew Bay watersheds and eventually classified into 9 major consolidated land classes to reduce the error generated from spatial heterogeneity. NLCD 2019 and NAIP 2018 data for creating ground control points for the accuracy assessment. Various supervised machine learning classifiers were then used to classify remotely sensed data. Random Forest algorithms in GEE platform were used to train the Landsat data in respect to NLCD and NAIP with 70% data for training and the remaining 30% used in the validation data set. These data points were not used in class identification and labeling, but used for measuring accuracy of our supervised classification. The accuracy of the classification results was used to generate an error matrix and accuracy measures for final classification which tells the scenarios of land use changes from one class to another in a given period. From the outputs of this process, we used the transition maps in a Markov model to predict the future land use in the two watersheds. The model generates a probability distribution over next state is assumed to depend only on the current state, but not on previous ones (non-after effect) (Guan et al., 2011). Future LULC was projected and mapped out to 2050 and compared to 2021 data.

To determine future conditions across the watershed-bay continuum, it was necessary to understand how climate is changing as well. Our CHN Framework included efforts to downscale data from the Community Earth System Model version 2 Large Ensemble (CESM2-LE) project available through the NSF- National Center for Atmospheric Research. Co-PI Kumar and graduate students Chris Whatley and Yanan Duan downscaled these global data to a 25-km resolution and fitted to our study area. In downscaling CEM2-LE data, they employed a Bias-Correction Spatial Disaggregation (BCSD) downscaling approach (Thrasher et al. 2022) following the procedure outlined in Xu and Wang (2019). The CESM2-LE downscaling effort was needed because exiting downscaled data (e.g. Thrasher et al. 2022) are land-only products that does not provide data for the bay region. Co-PI Kumar and his team considered the historical period of 1980–2014 as the reference period, and 2015-2050 as future projection period. They used ECMWF Reanalysis version 5 (ERA5) data as observation in the historical period. Additionally, they used North American Regional Reanalysis (NARR) for correcting for biases in ERA5 precipitation. The BCSD method is a trend-preserving statistical downscaling technique involving data preprocessing, bias correction, and spatial disaggregation. During preprocessing, 9-year running averages are computed and removed to obtain daily anomalies, which are then corrected for biases using quantile mapping. After bias correction, the previously extracted 9-year running averages of observations and projections are added back to the corrected model data for the periods 1981–2014 and 2015–2050, period respectively. Finally, the adjusted data is interpolated to a higher resolution, combining climatology and scale factors to achieve downscaled results. Further, given our project emphasis on hurricane occurrence, historical hurricane and land use analysis were completed for both Perdido and St. Andrew Bays.

To evaluate future watershed contributions to Perdido Bay and St. Andrew Bay, Co-PI Kalin along with PhD student Dongjun Lee developed individual SWAT (Soil & Water Assessment Tool) models for each system. For this effort, watershed models were calibrated for flow, sediment, organic N/P, and water temperature. Model calibration was carried out at multiple sites on each system using USGS and other data available in the watersheds. Historic and current LULC from 2001 NLCD and updated for 2021 NLCD were used to generate flow and constituent loadings to the bay, which were used by the ecosystem model to assess the water quality in the bay over the past 20 years. The LULC and climate projections for the 2025-2050 period were used in the validated SWAT models to generate estimates future flow and loadings to the respective bays and shared with the coastal ecosystem team for their modeling.

Co-PI Lehrter and post-doctoral associate Zhilong Liu used both watershed and climatic data as inputs to a three-dimensional hydrodynamic model that was developed and validated for the Perdido Bay and St. Andrew Bay system. After considerable evaluation the bay model developed for our study was a linked Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) and Coastal General Ecosystem Model (CGEM). This SCHISM-CGEM model presented a needed balance between spatial resolution, accuracy, and computational speed. Using future climate and hydrologic (i.e., SWAT outputs) data, the SCHISM-CGEM model was to predict changes in estuarine water quality driven by changes in watershed discharges and loads of carbon, sediments, and nutrients. The potential outputs of the bay models and how these changes related to other bay environmental issues

considered important by coastal stakeholder groups were examined by Co-PI Dunning and her PhD student Greg Johnson. Coastal-decision maker surveys were administered at two stakeholder meetings and other coastal events. Stakeholder meetings were organized by PI Anderson in coordination with the Pensacola & Perdido & Bay Estuary Program (Oct 13, 2021) and the St. Andrew & St. Joseph Bay Estuary Program (Dec 1, 2021) where over 45 persons combined attended and contributed to data source identification, elucidating priorities, and providing further contacts for the two study sites and other relevant information on the gulf coast. Using these workshops and other events, approximately 50 stakeholder surveys from coastal decision-makers/stakeholders from all levels of government, NGOs, academia, and private business were administered and used to evaluate stakeholder perceptions of important environmental stressors and various watershed-bay water quality issues.
Finally, in addition to completing the individual components, findings are being generated using the complete CHN Framework which considers whole-system bay responses to changes across the watershed-bay continuum. The frameworks developed for both Perdido and St. Andrew Bay have become a tool for planners in these regions that are interested in evaluating future scenarios. For instance, our team is currently completing an analysis which identifies possible thresholds for watershed forest loss that could trigger important changes in bay water quality. Our team continues to communicate with various stakeholder groups interested in long term planning efforts for bay sustainability to explore their own watershed scenarios and how they may affect future scenarios of land use and climate change.

2. Outputs

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2. OUTPUTS

Outputs are tangible or measurable deliverables, products, data, or publications produced during the project period.

2.1. Please indicate the number of students (K-12, undergraduate, or graduate), postdoctoral scholars, citizen scientists, or other trainees involved in the project. *

Please enter 0 if none were involved.

K-12 students	0
Undergraduate students	5
Graduate students	7
Postdoctoral scholars	1
Citizen Scientists	0
Other Trainees	0

2.2. Has your project generated any data and/or information products? *

Generation of data includes transformations of existing data sets and generation of data from existing resources (e.g., maps and images). Information products include publications, models, software, code, curricula, and digital resources.

(Check all that apply.)

Responses Selected:

Data

2.3. Briefly describe how you fulfilled the approved Data Management Plan and, if applicable, any changes from the approved plan. *

To date, our project team continues to develop final scenario products associated with the CHN Framework. Our data management plan (DMP) for this project remains unchanged with all newly generated, collected, or modeled data pertaining to the project components will be considered the primary subject of the DMP. Metadata and readme files will be prepared along with all data.
All generated data will be available to anyone interested, after publication and upon request to the PD. The availability of these data will also be mentioned in all relevant publications. As detailed in the DMP, the project will be producing a large cache of model results, historical data, analyses, and survey data. At the conclusion and/or publication of the project components, data products shall be transferred to NOAA NCEI for long-term archiving and accessibility. Auburn University has a dedicated Research Data Management Librarian who will facilitate the archiving process. To ensure data security, we will store two copies of the research datasets at the Auburn University Repository of Research Assets (AUrora: http://aurora.auburn.edu). We will also have a copy backed up in Auburn's Box storage, which is protected by 2FA. Metadata will be available immediately after data are archived.

If your project has generated data, please download the Excel worksheet entitled GRP Data Management Reporting. Use the "Data Report" tab in the worksheet to create an inventory of data sets that you produced and to verify deposit in a curation facility. Upon completion, please upload the worksheet to your task list. If you need guidance on how to complete the Data Report, please e-mail gulfgrants@nas.edu. A member of GRP's data management staff will reach out to you.

2.4. Aside from data and information products, what other tangible or measurable deliverables or products (e.g., workshops, trainings, and outreach events) were produced during the project period? *

Upon completion of this form, you may upload supplemental material that represent the tangible or measurable deliverables or products to complement this narrative report.

Two stakeholder workshops were conducted in coordination with our estuary program partners. The first workshop was organized and participated with the PPBEP and conducted on 13 October 2021. A total of 35 people attended representing a range of stakeholder organizations. Speaker participants at this workshop included our team, Pensacola & Perdido staff and Mobile Bay NEP staff. The second workshop was organized and participated in with SASJBEP and conducted on 1 December 2021. A total of 17 people attended also representing a range of stakeholder organizations but with a high proportion of technical professionals that were advising SASJBEP.
Two conference sessions were organized by PI Anderson and devoted to the CHN Framework and the various project components. The first was a Coastal Resiliency conference session at the Alabama Water Resources Conference at Orange Beach, AL on Sept. 8, 2022. Three talks devoted to the project were presented to approximately 40 water professionals and other conference attendees.

3. Data Management

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3. DATA MANAGEMENT

In this section, please provide a response to each question to complement the **Data Report** in the GRP Data Reporting Excel worksheet.

3.1 If you listed multiple data sets in the data reporting table, please briefly describe how these data sets relate to one another. *

Data sets will made available in our designated repository upon completion of publications. By design, these data sets were produced and used by others within the CHN modeling framework. For instance, the forest landowner survey data informed modeling associated with future LULC in two watersheds. Downscaled climate data and projected LULC data sets were used to run hydrological modeling runs in SWAT. Climate data and hydrological data were input data sets for the linked SCHISM-GCEM bay modeling runs.

3.2. Please provide a list of additional documentation to describe the data listed in the reporting table (e.g., code books, lab manuals, workflow procedures). Enter none if you did not produce any additional documentation to describe the data. *

None.

3.3. Beyond depositing data and metadata in a repository, what other activities have you undertaken or will undertake to ensure that others (e.g., researchers, decision makers, and the public) can easily discover project data? What other activities have you undertaken to ensure that others can access and re-use these data in the future? *

As more peer-reviewed papers are generated and the results of the CHN Framework are reported in conferences, there will be more opportunities to direct readers and resource managers to our data repository. We will utilize these opportunities to direct and encourage data produced from this study.

3.4. Are any data products you produced sensitive, confidential, and/or proprietary? *

No

5. Project Outcomes

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5. PROJECT OUTCOMES

Outcomes refer to the **impact(s), consequence(s), result(s), or effect(s)** that occur from carrying out the activities or outputs of the project. Outcomes may be environmental, behavioral, health-related, or programmatic. Example outcomes include, but are not limited to: increased learning, knowledge, skills, and motivation; policy changes; actions taken by a group as a result of information generated by your project.

5.1. Please describe the outcomes achieved during your project and how they were assessed. For this question, we are interested in learning about the immediate short-term outcomes that have already occurred during or as a result of your project. Do not include long-term outcomes you foresee your work contributing to beyond the end of the project. *

From our administered forest landowner survey, over 2800 surveys were ultimately delivered and we received an 18% response rate (519 usable surveys). Nearly half of the landowners who responded planned to retain their entire forest in the next decade. Across all respondents, forest landowners indicated that they would retain an average of 64-73% of their forest. While most of the private forest in the sample is likely to be retained through 2031, this implies approximately a quarter is at risk of conversion even with no assumed changes in hurricane patterns. Increased risk of hurricanes had a small effect size on decision-making even though more than half of the counties in our study region had recently experienced damage from Hurricane Michael.

Other demographic factors in landowners indicated tendencies in managing forest lands in the study watersheds. Older landowners and resident landowners were less likely to choose to sell or convert a portion of their woodland than younger or absentee landowners, respectively. Age had the smallest effect on decision-making odds; however, it significantly affected the odds of more decision classes than any variable other than market factors. Older landowners were also less likely to place woodlands in conservation, but age did not impact the odds of respondents deciding to sell land with no other action, so older landowners may just be less likely to make management intensive-LULC changes overall. The population in the study region is older and aging has been identified as a leading factor in forest parcelization and fragmentation (Gobster and Rickenbach 2004; Gruver et al. 2017). Understanding the impact of intergenerational transfer of woodland is urgent for predicting future forest fragmentation.

The information from landowner surveys along with prevailing development trends used to model future land use in the Perdido and St. Andrew Bay watersheds. Results land use modeling predicted that urban growth would continue in both watersheds. In the Perdido Bay watershed, urban expansion associated with the city of Pensacola was the dominant change agent in the watershed and project change in urban developed land is expected to increase by 58% compared to NLCD estimates for 2021. Similarly, urban developed land is expected to increase by 30% in the St. Andrew watershed compared to NLCD estimates for 2021, largely due to expansion of the greater Panama City region.

Results from the downscaled CEM2-LE data for this region indicate an increasing trend in precipitation and temperature is expected. Warming for the study area is expected to 0.41±0.14°C/decade for the region. Projected average annual increases in minimum and maximum temperatures (comparing 1991-2020 and 2021-20250) were 0.89 and 1.60 ◦C, respectively. An increase in precipitation is also projected for the region. However, internal climate variability is expected to dominate the precipitation response in the climate projections: 0.25±3.5%/decade for the region. Other results from high-resolution long-term hurricane data is developed (GRID-HURDAT2). Hurricane associated extreme precipitation has increased (particularly after 2015) despite no significant trend in landfalling hurricanes.

After successfully developing SWAT models for both Perdio Bay and St. Andrew Bay watersheds, both models were used to predict streamflow and fluxes of sediment, nitrogen (N), phosphorous (P), carbon (C) at the watershed outlets and compare historical (1991-2020) and future period (2011-2050) based on modeled land use change (assuming business as usual) and climate projections. Some of the interesting findings from the SWAT modeling are provided below:

1. Both watersheds have relatively low levels of sediment discharging to the bay. The average concentration of sediment discharging to the Perdido and St. Andrew watershed for the 1991-2020 period was 5.6 and 3.9 mg/L respectively. In the future (2021-2050) these numbers are expected changes to increase to 23.9 and 6.4 mg/L, respectively, due to expected change in land use and change in climate. However, these number are still low and likely does not pose much risk, especially at St. Andrew Bay.
2. Total-N levels for the 1991-2020 period at Perdido and St. Andrew watershed were 0.59 and 0.21 mg/L. Total-P levels were 0.11 and 0.007 mg/L. These levels are expected to increase to 1.00 and 0.22 mg/L for TN, and 0.64 and 0.012 mg/L for TP at Perdido and St. Andrew watersheds.
3. Compared with the Perdido watershed, concentrations of sediment and nutrients discharging to the St. Andrew Bay watershed have relatively low levels in historic period and future periods.
4. Future changes in land use and climate are expected to have a much bigger impact on the Perdido Bay watershed. The biggest increase is expected to happen with TP loading.
5. Critical sources occur in both watersheds but are not always the same when we consider sediment, TN and TP. The sub-watersheds expected to see biggest increases in sediment, TN and TP loading in the future also show large variations between constituents.

An estuarine ecosystem model was successfully created consisting of the Semi-implicit Cross-scale Hydroscience Integrated Modeling system (SCHISM) to the biogeochemical model with an embedded bio-optical model called the Coastal Generalized Ecosystem Model (CGEM). The linked SCHISM-CGEM model receives freshwater discharges and loads calculated by SWAT and then advects, mixes, and reacts to the materials over a three-dimensional model grid of the estuary. Using initial projected inputs from the SWAT models, some results indicate potential issues regarding future bay health. For instance, the predicted 20% increase in river discharge is predicted to increase CDOM loading and reduce water clarity by 16% in St. Andrew Bay. CDOM is a particularly important bay water variable because of its potential to absorb light and reduce water column clarity. Ongoing work will explore long term modeling scenarios however, the SCHISM-CGEM outputs show clear variations between the bay systems and within them regarding CDOM, salinity and other measures that will potentially affect bay water quality and ecosystems.

Considering current and future water quality issues along the study area, survey results from local coastal stakeholders were evaluated for their perceptions of the environmental problems facing their estuaries and coastal communities. A primary issue raised was the rate at which previously forested land is being converted to agriculture, residential, or commercial uses. A total of 39% of the respondents reported that this was the biggest environmental stressor facing the region and 33% considered it among the top three issues. The second most commonly mentioned problem was pollution (i.e., sedimentation, stormwater overflow, and wastewater seepage). A total of 37% of the respondents considered this as the most important issue and 30% of the respondents reported it was in the top three issues. The third most commonly mentioned problem was climate change and its associated impacts, such as sea level rise. A total of 7% of the respondents mentioned that it was the most important stressor, and 24% reported it was among the top three environmental stressors. The identified stressors and their ranking were similar between respondents from the various regions and venues sampled for this study (Johnson et al. 2024).

From the compilation of findings discussed above, we can begin to extract findings at a systems-level from the CHN Framework. For instance, initial hypotheses by our team emphasized that the increased prevalence of hurricanes would be an important factor for land use change, however forest landowner surveys indicated this was a marginal factor. Nevertheless, only three-quarters of forest lands may persist in the immediate future based on current landowner plans. This coupled with continued urban expansion in both watersheds show that significant land use change will continue over the next 30 years. The change in watershed land use, coupled with shifts expected in precipitation and temperature will contribute to increased runoff and loading of sediment, nutrients. The increases in watershed loading of nutrients to bays will be significant in relation to present loads, however the absolute rate of pollution loading is still fairly low and may not trigger significant changes. However, there are some early indications that increased future discharge expected at St. Andrew Bay may yield increases in CDOM loading which may reduce water clarity. Additional bay modeling is expected to further elucidate important thresholds related to SWAT model projections.

5.2. We're interested in hearing not just the results of your project but what are their implications for or contributions to:

- **offshore energy system safety,**
- **environmental protection and stewardship, and/or**
- **health and community resilience**

Please describe what you consider to be the most remarkable accomplishment or finding of your project. What can others learn from your accomplishment and finding? How do you see it fitting in with your greater field of study or community of practice? *

Our project team is continuing to analyze various watershed/climate scenarios to investigate a range of possible outcomes for the Perdido Bay and St. Andrew Bay. To this end, it is our goal to use the CHN Framework for improved environmental protection and stewardship along the Gulf coast. We are seeking opportunities to work with various state, county, NGO, agency, or other coastal partners that could utilize the CHN Framework to address specific questions and watershed planning/climate scenarios that are important to them. As a team, we are committed to working with partners and finding opportunities to address important planning questions posed by our partners for better environmental stewardship of our coastal waters.

6. Communication

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Note to Grantees: In Section 6, we seek input from you to help us evaluate the Gulf Research Program's funding strategy. This section will not be made available to the public.

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6. Information to Inform GRP Evaluations

6.1. Sharing the difficulties you encountered helps us learn from your experience. Describe any challenges you encountered in your project and how you addressed or overcame them. Challenges are inherent to conducting any complex project. These may include (but are not limited to): unexpected staffing changes, changes in the community you are working in, appearance of a new technology or dataset in the field you are working in, challenges accessing a field site, policy or regulatory changes that affect the issue you are addressing, low recruitment rates, delays in setting up services, or other problems in implementing and conducting your project. *

As discussed above, the completion of two CHN Frameworks for the Perdido and St. Andrew watershed represents a tremendous accomplishment in terms of watershed-bay planning. This was also a tremendous challenge to develop and, to date, we continue to work on some of the CHN Framework outputs. An inherent challenge with this kind of interdisciplinary modeling project is the level of dependency in various components. The delay in one component often caused delays in development of other components dependent on data outputs. Other project-wide delays were caused by the timing of initial funding which resulted in a protracted recruitment period for many of the graduate students associated with the project. We do not necessarily view these as shortcomings of the project but the reality of working on a highly complex and interdisciplinary project. However, the benefit certainly outweighs the cost and the completion and successful linkage of these various data and modeling components represents a tremendous opportunity for watershed and bay planners.

6.2. We like to hear about what you learned from your work and how you feel it affects future work or the work of others. Think back on your project strategies, methods, and activities, what worked and what did not? Is there anything you would do differently in the future? If so, tell us what and why. *

As mentioned above, there was an inherent challenge of keeping on schedule given the highly dependent nature of certain elements of our project. In hindsight, this project was even more ambitious than we expected during the proposal phase. While many of these delays were unavoidable and we do not think there is much we would have done differently, there may have been opportunities to work around delays associated with a single component so that it didn't affect the timing of work in the other components as much. Completing all of the data/modeling and then coordinating these components to be linked required a high level of coordination among team members which should be recognized by any team that is contemplating an effort such as this. As mentioned, our project team would welcome the opportunity to develop a CHN Framework for other watersheds along the Gulf of Mexico and beyond. Having the experience of developing the two framework for this project, we are in a much better position to produce these efficiently.

6.3. What are the next steps for this work, either for you and your project team or other researchers? Has this project led to other opportunities to work in this area? *

Our project team is continuing to analyze various watershed/climate scenarios to investigate a range of possible outcomes for the Perdido Bay and St. Andrew Bay. Through this project, we have developed several working relationships with the various estuary programs represented on this project and had interactions with other highly relevant organizations (e.g., the Northwest Florida Water Management District). Our goal is to find opportunities to allow these organizations to work with us and utilize the CHN Framework to address specific questions and scenarios that are important to them. While the complexity of this CHN Framework will not allow this to be a self-administered tool, our team is committed to working with our partners and finding opportunities to pursue planning questions posed by our partners.

6.4. Have you developed new collaborations or partnerships (formal or informal) as a result of this work? If yes, please describe the new collaborations or partnerships. *

Yes. Our work has been the product of collaborations with other coastal stakeholders, most notably estuary programs working along the gulf (Mobile Bay NEP, Perdidio & Pensacola Bay Estuary Program and St. Andrew and St. Joseph Bay Estuary Program). These interactions have led to further connections that will allow us to pursue the use of the CHN Framework. A recent letter of intent was submitted to NOAA to expand on the work started here. We have Resources targeted as part of this proposal are several regional watershed-bay systems located in the northeastern Gulf of Mexico (Alabama and west Florida) including: Perdido Bay, Pensacola Bay, Choctawhatchee Bay, St. Andrew Bay and St. Joseph Bay (Fig. 1). Our project will employ an existing data and modeling network (The Coastal Human-Natural [CHN] Framework) to determine the future health of these bays and associated estuarine habitats. Current changes in watershed land use, climate, and sea level rise are increasing the risk of changing regional drainage patterns and changing estuary conditions such as water clarity, salinity, and temperature. Our team will work with regional planners and bay managers to use the CHN Framework to assess current and future (30-yr) risks to these estuaries and identify opportunities to improve resiliency.

6.5. What, if any, positive changes in policy or practice do you foresee as a result of your work? *

As a result of this work, we continue discuss and look for opportunities to allow coastal land planners to utilize the CHN Framework to address their own planning inquiries and scenarios. Possible users may include key representatives from state land acquisition programs, NGOs (e.g., TNC), the Florida Forest Service, the Alabama Forestry Commission, the Northwest Florida Water Management District, state congressional districts, and county commissioners. We will continue to provide demonstrations of the CHN Framework and the need for incentive to maintain forest cover in the region to sustain coastal ecosystems. This framework can support potential institutional strategies that support forest operations/cover in the region and potentially target forest conservation. It is our goal to make this available to guide planning for the Perdido Bay and St. Andrew watersheds but pursue opportunities to develop other watershed-bay frameworks like it.

6.6. If you could make one recommendation to the Gulf Research Program for how best to build on the work you conducted in this project, what would it be? *

Our suggestion would be to support initiatives that further opportunities for long-term collaboration between researchers and the Gulf of Mexico coastal stakeholder community. This project and the CHN Framework that we've developed is a powerful planning tool. Recent federal funding opportunities involving the Gulf coast (e.g., the NOAA RESTORE Science Program FFO-2025: Long-term Trends) have emphasized the need for collaborative and interactive work for addressing important environmental and resilience issues facing the coast. We think these are wise approaches and would recommend the GRP consider supporting a similar priority for advancing ecosystem and community planning along the GOM. Investments in elaborate modeling tools and frameworks, such as the CHN Framework, have been developed and there is now a need to support more collaborations with stakeholders to employ these tools.

Our project clearly emphasizes the role of watersheds and their influence on coastal receiving waters. Emphasis and possible engagement by the GRP about the role of watershed forests and their substantial benefit to coastal waters would certainly build on this project. Many regions have developed established watershed partnerships between water quality stakeholders, forest landowners, and forest associations/agencies. One finding from our work is that we are on the cusp of a tremendous generational exchange of property in the watersheds draining to the northeast GOM (and likely other parts as well). Some of the ramifications of this exchange can be yielded from our survey results, but there are still uncertainties about the future of many lands in these watersheds. Continued GRP support for research, outreach and education to understand the role of forested watersheds and their futures along the Gulf coast are highly recommended.

7. Communication and Dissemination

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Note to Grantees: In Section 7, we ask you to help us communicate the importance, progress, and accomplishments of your work. Information provided in this section will be used by the Gulf Research Program to highlight its funded projects in print and electronic informational and promotional materials. The intended audience for the information provided in this section is different and should be thought of as a general audience. When you return to the dashboard, you may upload images that represent and illustrate the work of your project.

7.1. Please describe the most exciting or surprising thing you have learned while working on this project in a way that is understandable by a general audience. *

Our team of social scientists, hydrologists, ecosystem modelers, and ecologists worked together to determine how urban development and forest landowners may influence future (year 2050) coastal water clarity in the bays along the Florida Panhandle and Alabama. Using Perdido Bay and St. Andrew Bay as a case study, we collected data and developed a series of computational models (a Coastal Human-Natural Framework) to evaluate how changes to the climate and the lands draining to these bays may impact water clarity. We surveyed forest landowners across the region and found that some future forest loss is expected but many of them expect to keep their land in forests, even when faced with increased hurricanes. This is important because of the value they provide to downstream water quality. Watershed urbanization and precipitation are expected to increase in the next 30 years, and this will likely increase river flows and some pollution coming to the bays. While some pollutants may not increase to critical levels, our models show some important changes are possible. For instance, the increased river flows we detected are expected to increase dissolved and particulate matter in bay waters and cause decreased clarity. Our team is working with planners in both states to further investigate how various combinations of future climate and land use change may influence our coastal bay waters.

7.2. Do you have any stories that capture the impact of this project? (optional)

If so, please share one or two. Examples of what we are interested in include stories of people/communities that the project has helped; lives that have changed; work that led to policy change, such as legislation or regulation; and research breakthroughs.

I would say that our project is designed to have a longer-term impact related to more effective planning and hasn't yielded a research breakthrough to date. I would add that the successful connection of models linking climate, land use, hydrology and bay water quality is a noteworthy accomplishment, and we expect the impacts from our project will come in the future when this framework is utilized by various coastal planning entities for better watershed management and protection of the Gulf coast.

7.3. Have any communications, outreach, or dissemination activities occurred in relation to your project?*

Please describe:

- Any press releases issued (other than that issued by the National Academies of Sciences, Engineering, and Medicine) about the project.
- Any media coverage or news stories about the project.
- Any social media accounts, websites, listservs, or other communication vehicles used to communicate information about this project. Please include relevant web addresses if available.

Our project had articles published in two local newspapers:

Opelika-Auburn News, Auburn University: The Newsroom, SFWS News, "Auburn-led team studies land use, forest cover change to protect Gulf Coast waters", 12 Nov 2020

Panama City New Herald, "Auburn University to study land use change in the Panhandle from Hurricane Michael", 17 Nov 2020.

In addition, two press releases from Auburn University Office of Communication and Marketing and the AU College of Forestry, Wildlife and Environment:

"Auburn-led team studies land use, forest cover change to protect Gulf Coast waters." Published: 12 Nov 2020
https://ocm.auburn.edu/newsroom/news_articles/2020/11/120900-nasem-team.php?nlan