Three Decades of Coastal GIS at Wisconsin Sea Grant
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About Sea Grant
The National Sea Grant College Program (https://seagrant.noaa.gov/) is administered by the National Oceanic and Atmospheric Administration (NOAA) within the U.S. Department of Commerce. It is a national network of 34 university-based programs involved in scientific research, outreach and education with a mission to enhance the use and conservation of coastal, marine and Great Lakes resources to create a strong and sustainable economy, a healthy environment and resilient and inclusive communities.

Wisconsin Sea Grant (http://seagrant.wisc.edu/) was formed in 1968. It achieved Sea Grant College status in 1972 and was the first program established in the Great Lakes region. In 1978, the UW System transferred responsibility for the management of the system-wide and state-wide program to UW-Madison. It now falls under the administration of the Vice Chancellor for Research and housed in the UW Aquatic Sciences Center. The main office is in Goodnight Hall on the UW-Madison campus and there are field offices in Superior, Green Bay, Manitowoc and Milwaukee.

In its 53 years, Wisconsin Sea Grant has funded hundreds of research projects through a biennial competition. Research topics range from freshwater fisheries and aquaculture, toxic contaminants and water quality to ecological and coastal processes. In that time, Wisconsin Sea Grant has also provided financial support for nearly a thousand graduate students at public and private universities and colleges across Wisconsin. Since 1995, Sea Grant and external agency funds have helped support 125 students in applying geospatial technologies and planning methods to address issues facing the Great Lakes.

GIS Research, Outreach and Education at Wisconsin Sea Grant
In the early 1990s at the outset of the Wisconsin Land Information Program, Allen Miller, then extension program leader at Wisconsin Sea Grant, had a vision that modernized land records in the 15 counties bordering the Great Lakes be utilized to support sustainable and integrated coastal management. In 1995, Wisconsin Sea Grant established a Geographic Information Systems (GIS) Outreach Specialist position in collaboration with the Land Information and Computer Graphics Facility at the University of Wisconsin-Madison.

Over the past three decades, Wisconsin Sea Grant has collaborated with many partners to apply geospatial technologies to better understand coastal management issues facing the Great Lakes. This effort evolved through several phases in that time: 1) providing GIS training for specific coastal issues; 2) discovering, acquiring, and integrating local data to study regional coastal issues; 3) implementing interoperable web mapping services to build a dynamic and

distributed coastal GIS; 4) utilizing visualization and animation to promote a more intuitive understanding of complex coastal issues; and 5) promoting a coastal spatial data infrastructure through development of a coastal web atlas.

Current projects include: 1) enhancing the Wisconsin Coastal Atlas; 2) interactive maps to promote cultural and natural heritage tourism along the Great Lakes; 3) geodesign to guide scenarios for green stormwater infrastructure; 4) geospatial tools to build resilience to coastal hazards; and 5) place-based learning that encourages stewardship of coastal resources.

Figure 1. Coastal GIS at Wisconsin Sea Grant was conceived by Allen Miller, who was also influential in formation of the Wisconsin Land Information Program.

Coastal GIS---Land and water do mix

*For this issue, we chatted with Allen H. Miller, Assistant Director of the University of Wisconsin's Sea Grant Institute about the recent development of a coastal GIS program for Wisconsin.

What is special about the coast, from a GIS perspective?

Al—

GIS is a good tool for integrating a wide variety of information, and it excels when we put it to work in a complex environment such as a coast. Most of us spend virtually

GIS can help us understand the affects of all of our decisions on all coastal resources.

our entire lives on land, so it easy for us to forget that land and water affect each other, and ultimately all of us. Historically, we have known much more about the land—both physically and culturally—than the water. In addition to helping link what we do know about the water, GIS can help us understand the affects of all of our decisions on all coastal resources.

How did the new Wisconsin coastal GIS program begin?

Al—

I had been trying to get something like this going for several years, and finally was successful in convincing the National Sea Grant Program, which funds the other activities of our office, to move in this new direction. As a result, we have developed a joint agreement with Madison campus Land Information and Computer Graphics Facility (LICGF)

That sounds quite ambitious. What will be your priorities?

Al—

Yes, it is a challenge. However, we are focusing first on helping people in Wisconsin's fourteen coastal counties learn how GIS can benefit them. Forty percent of Wisconsin's population is in those counties. We are particularly interested in fostering the interaction between technical staff and elected officials. Since coastal issues involve trade-offs between various choices, GIS needs to work for all these people.

How will you handle the heavier technical tasks?

Al—

Dave Hart is housed at LICGF, where he has access to a high level of GIS expertise. In addition, our Sea Grant staff includes experts in water quality, coastal engineering, and the like. These people are committed to helping our GIS efforts succeed.

Are you working primarily through the county land information offices?

Al—

That is our first point of contact, and we encourage the LIO's to involve the other local governments, regional planning commissions, utilities, and state and federal agencies. It's important for the LIO's to adopt as broad a view of spatial information and GIS as possible, because the ultimate value of the investment in data and tools will arise from sharing data and decisions.

Is the focus largely on natural or

ize useful information for responding. Enhancement of tourism based on diving around shipwrecks, yet

Of the hundreds of relevant studies, only ten came out of a local government context.

protecting them, could be planned with GIS. Even one of the more obvious environmental applications, modelling long term coastal erosion and its effects on lakeshore properties, includes factors of assessment and zoning that are of critical importance to local citizens.

This sounds like a long term process.

Al—

It is, but most GIS development is like that. We expect to make progress in steps, and our new bibliography (see facing page) is one of the first tangible results. We found it particularly interesting that of the hundreds of relevant studies, only ten came out of a local government context, and four of those were from Florida. There is a significant opportunity here for a large group of interested people to make progress in using GIS to help manage the coastal areas of Wisconsin. I believe that, through creative leveraging of modest amount of effort that the Sea Grant Program has allocated here, we can be of great service.

Al, you deserve kudos for getting this program started. It's just the latest chapter in your list of efforts to move Wisconsin land information and GIS forward. Now...let's get back to what you were saying, off mike, about that

Figure 2. This article from 1995 in the Wisconsin Mapping Bulletin describes the formation of the Coastal GIS Applications project at Wisconsin Sea Grant.
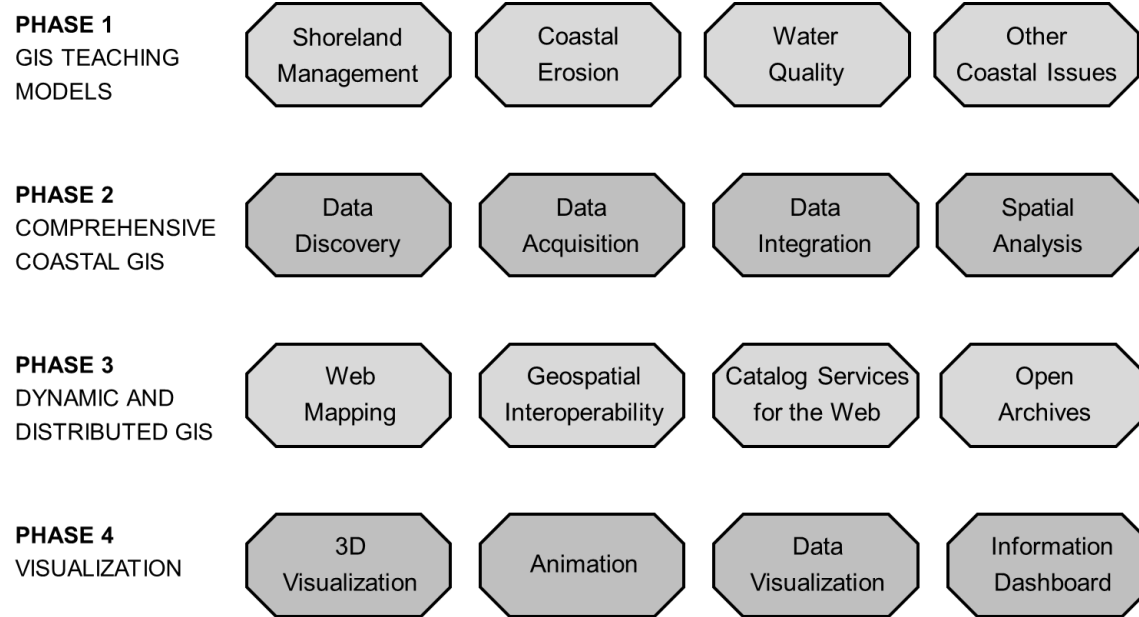
PHASE 1
GIS TEACHING
MODELS

| Shoreland Management | Coastal Erosion | Water Quality | Other Coastal Issues |

PHASE 2
COMPREHENSIVE
COASTAL GIS

| Data Discovery | Data Acquisition | Data Integration | Spatial Analysis |

PHASE 3
DYNAMIC AND
DISTRIBUTED GIS

| Web Mapping | Geospatial Interoperability | Catalog Services for the Web | Open Archives |

PHASE 4
VISUALIZATION

| 3D Visualization | Animation | Data Visualization | Information Dashboard |

Figure 3. This graphic provides an overview of the first four phases of the Wisconsin Coastal GIS Applications project.

Coastal GIS Applications Training (Past Work)

Meetings with land information officers in coastal counties at the start of the coastal GIS outreach project in 1995 uncovered a strong interest and need for GIS training. Although staff indicated that adequate resources existed to support GIS hardware/software acquisition and database development, training funds were scarce in most county budgets. Specific training interests included getting started with a new GIS software package and, in cases where spatial database development was more advanced, applying GIS to specific coastal issues. As a result, dozens of GIS training sessions were held in Madison and coastal counties including Bayfield, Ashland, Door, Kewaunee, Manitowoc and Racine. The training sessions featured local land information used for GIS applications such as shoreland management, coastal erosion and urban nonpoint pollution. Participants found GIS training that leveraged familiar local data for relevant local issues was highly effective.

Figure 4. Coastal GIS Training in Door County in 1999.

<u>Integrating Local Land Information to Address Regional Coastal Issues (Past Work)</u>
As part of a U.S. Army Corps of Engineers' project to assess potential damage along Lake Michigan arising from varying lake levels in the late 1990s, seven geospatial data sets including parcels, structures, elevation and land use were acquired and integrated across 11 coastal counties. Spatial queries related to coastal erosion hazards were conducted, including identification of parcels and structures and the value of property subject to development setbacks.

An important accomplishment of the project was the development of methods for inventory, acquisition, and integration of existing local government spatial data for use in decision-making about regional-scale issues. Significant barriers to the development of an integrated coastal management GIS application utilizing local government spatial data were exposed, including the cost of data acquisition, the time required to receive data after the request is made, and restrictions placed on the use and dissemination of digital data. Nine technical issues were identified that affected the ability to integrate digital spatial data for use in analysis and decision-making related to regional-scale issues. The five spatial analyses using integrated data could only be completed in a partial manner due to incomplete data availability. While the findings painted a mixed picture of whether local government spatial data could be effectively inventoried, acquired and integrated to support analysis and decision-making about coastal issues at a regional scale, the research did provide an early test of land information integration in Wisconsin. Upon completion, the project served as a spark for creation of the local geospatial data collection at the Robinson Map Library.
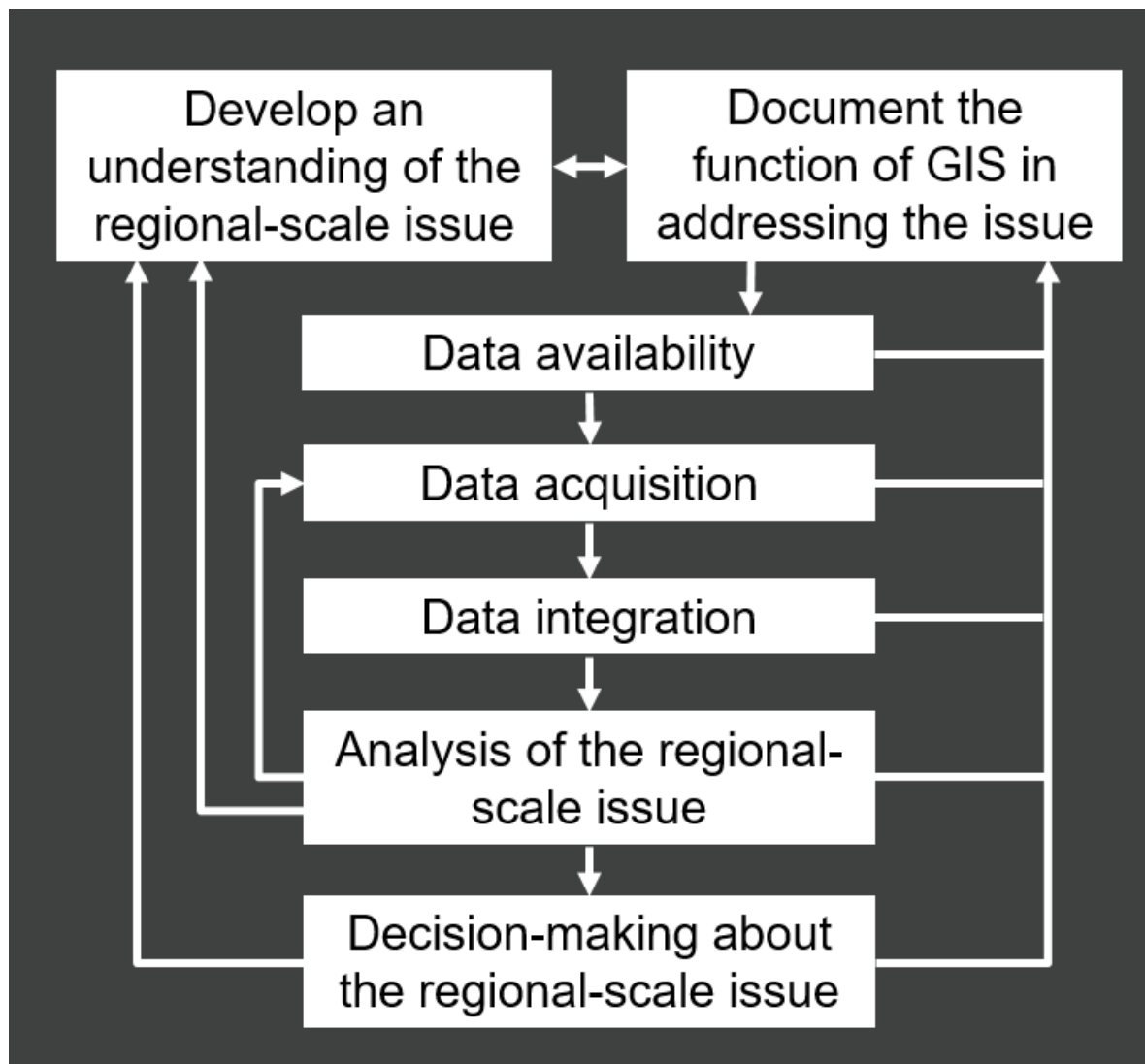
Figure 5. The framework for integrating local land information to guide decision-making about regional coastal issues.

Dynamic and Distributed Coastal GIS (Past Work)

With funding from the NOAA Coastal Services Center from 2003 to 2005, Wisconsin promoted the development of a "dynamic and distributed GIS" to support integrated coastal management along the Lake Superior coast of Wisconsin. A dynamic and distributed GIS is one where custodians, whether they be local, regional, state, federal, academic, or non-profit, maintain and provide access to the most current spatial data and multiple remote users can access and integrate data in real-time from multiple sources.

The project involved the development of web mapping interfaces and tools to support public access to local government GIS data, implementation of interoperable web mapping services, and integration of these services to address regional coastal management issues, including coastal hazards and comprehensive planning.

The project had many beneficial impacts. Public access to GIS data improved in northern Wisconsin and the Lake Superior Coastal Mapping Portal provided a single point of departure for viewing pre-configured maps on a variety of coastal issues of regional interest. The project also advanced searching for and viewing specific web mapping data, understanding how GIS interoperability works and shared examples of how web mapping could be applied to decision-making in the region.
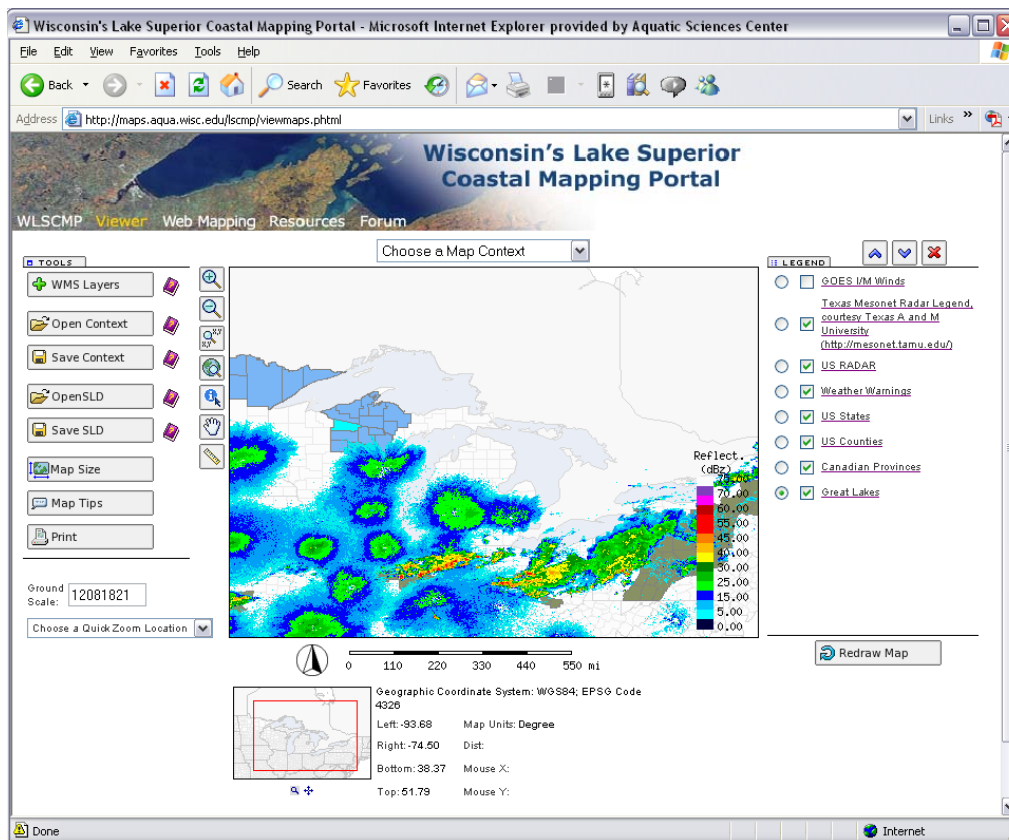

Figure 6. The Lake Superior Coastal Mapping Portal provided an early example of integrating interoperable web mapping services to guide local coastal management.

Visualizing Coastal Processes (Past Work)

Wisconsin Sea Grant began experimenting with 3D visualization software in 1999 as a way to effectively communicate the risks and hazards associated with coastal development and the long-term implications of planning decisions. In 2003, UW Sea Grant collaborated with the Geography Department at UW-Madison as part of a NASA-funded program to apply remote sensing to local government problems. The result was a successful educational web site that helped to bridge the gap between scientific understanding and public perception of coastal hazards. It is very difficult to convey to the public all the complex changes that happen as coastal bluffs erode. When coastal landowners see 3D animations of bluff erosion, they comprehend coastal processes in a way that scientists can't describe solely through formulas and charts. Conversely, the 3D animations help scientists by allowing them to revise their theories. This knowledge representation process can help scientists build better and more useful representations of coastal change. This work has helped make sense of a large volume of scientific and spatial data and has helped identify the most suitable software tools for representing dynamic coastal processes.
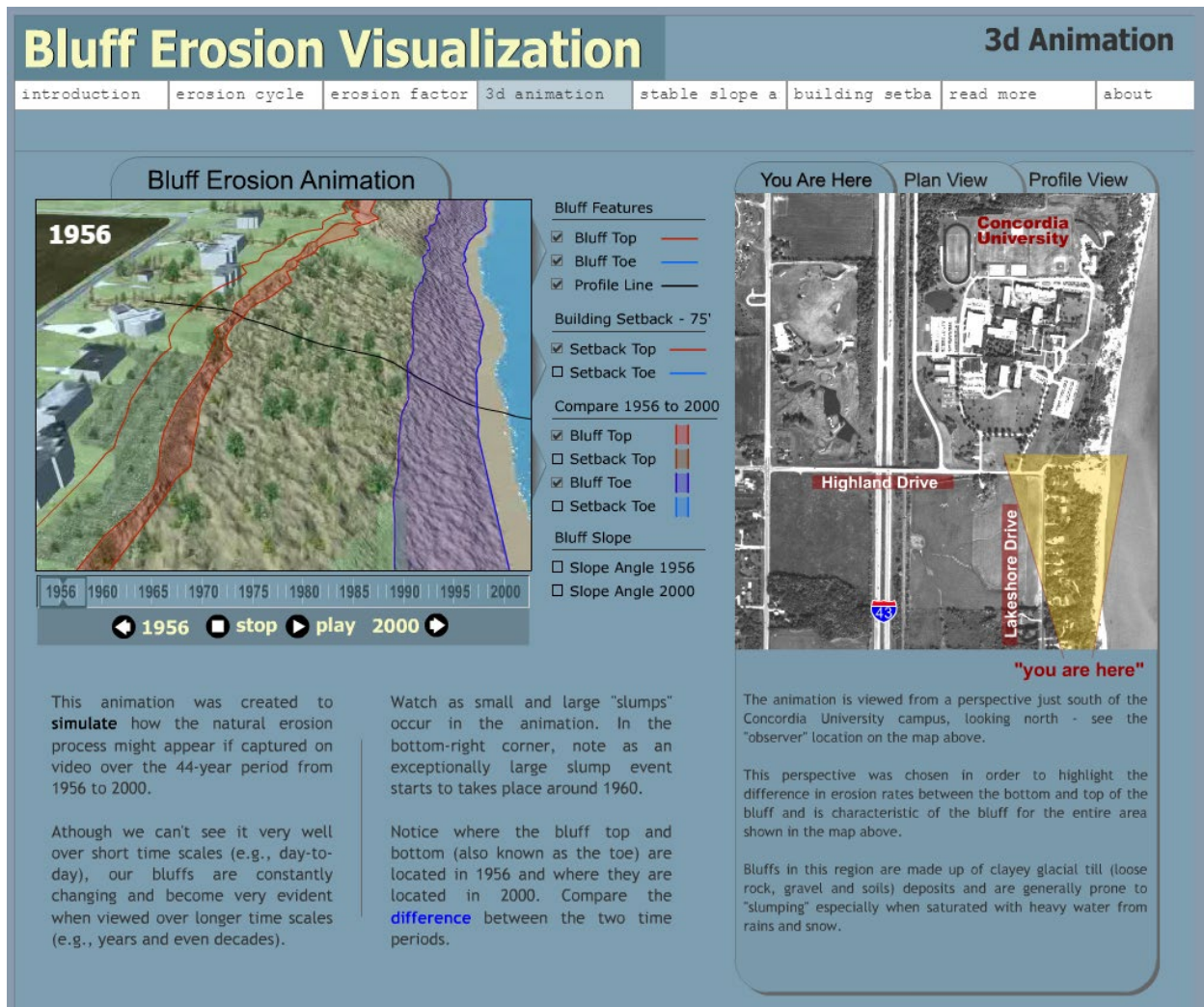

Figure 7. 3D Visualization of Coastal Bluff Erosion Processes in Ozaukee County.

Wisconsin Coastal Atlas (Ongoing Project)

The Wisconsin Coastal Atlas (https://www.wicoastalatlas.net/) is a coastal web atlas or coastal knowledge hub that provides a gateway to maps that encourage exploration of coastal patterns and issues, tools that enable analyses to guide decisions about coastal management, catalogs that enable discovery and access of coastal geospatial data and learning resources to expand awareness of Great Lakes places and issues. It is intended for use by coastal resource managers, planners, researchers, educators and coastal residents.

The atlas includes eight elements: maps, tools, catalog, learn, topics, places, knowledge hubs and about. These elements work together to provide access to resources that can help address specific coastal management issues on the Great Lakes, such as building community resilience to coastal hazards. The **Maps** element of the atlas provides a gallery of interactive maps with customized perspectives allowing users to explore specific coastal issues in Wisconsin. The **Tools** element of the atlas serves as a gateway to spatial decision-support tools relevant to coastal management on the Great Lakes. The **Catalog** element provides several paths to discover, assess, and download geospatial data for the Great Lakes coasts of Wisconsin. The most robust catalog resource is GeoData@Wisconsin (https://geodata.wisc.edu/), which integrates map-based spatial searches with keywords and faceted browsing. The **Learn** element serves as a repository for place-based learning resources, promotes a stronger understanding of Great Lakes Literacy Principles and provides links to information about Great Lakes coastal issues. The **Topics** element of the atlas provides quick access to maps, tools, data and learning resources relevant to specific coastal management issues and the **Places** element does the same for specific geographic locations along the Great Lakes. The **Knowledge Hubs** element helps people discover collections of decision tools relevant and useful to Great Lakes issues. The **About** element provides guidance about how to use the atlas, information about the atlas team and partners and access to publications that derive from research support by development of the atlas.

The Wisconsin Coastal Atlas also functions as a research project that helps build a coastal spatial data infrastructure for Wisconsin. Recent research includes collaboration with the UW Cartography Lab to conduct a competitive analysis of 10 coastal web atlases in the United States and a user survey with stakeholders from those states about their experiences with and opinions on atlas design (Hart et al. 2022). This research is helping guide enhancement the Wisconsin Coastal Atlas to better support adaptive coastal management. Finally, Wisconsin Sea Grant collaborates with the International Coastal Atlas Network (https://ican.iode.org/) to encourage development of coastal web atlases around the world based on the "FAIR" data principles of findability, accessibility, interoperability and reuse (Wilkinson et al. 2016).

Figure 8. Elements of the Wisconsin Coastal Atlas.

Wisconsin Coastal Guide (Ongoing Project)

The Lake Superior and Lake Michigan coasts in Wisconsin contain many sites of great scenic beauty. With support from the Wisconsin Coastal Management Program, Wisconsin Sea Grant developed a story map that promotes natural and cultural heritage tourism. The Wisconsin Coastal Guide (https://wisconsincoastalguide.org/) encourages the type of "deep travel" that strengthens local economies and increases the perception of the Wisconsin Great Lakes coasts as a special scenic resource worthy of sound stewardship.

The structure of the guide features interactive maps based on nine different themes. Clicking on the features represented by icons on the maps bring up popups that provide a path to deeper exploration. Users of the Wisconsin Coastal Guide can view **photos** of the Great Lakes in Wisconsin's 15 coastal counties; take time to **learn** about coastal issues and places through educational activities; examine the rich **maritime heritage** of Wisconsin; listen to **stories** about Great Lakes science and meet people who shape the coast; find **recreation** sites and experience **nature** along the coast; uncover the fascinating **history** of the Great Lakes; find where they can go **boating**; and discover scenic **driving routes** along the Great Lakes in Wisconsin, including the Lake Superior and Lake Michigan Circle Tours, Scenic Byways and Rustic Roads.
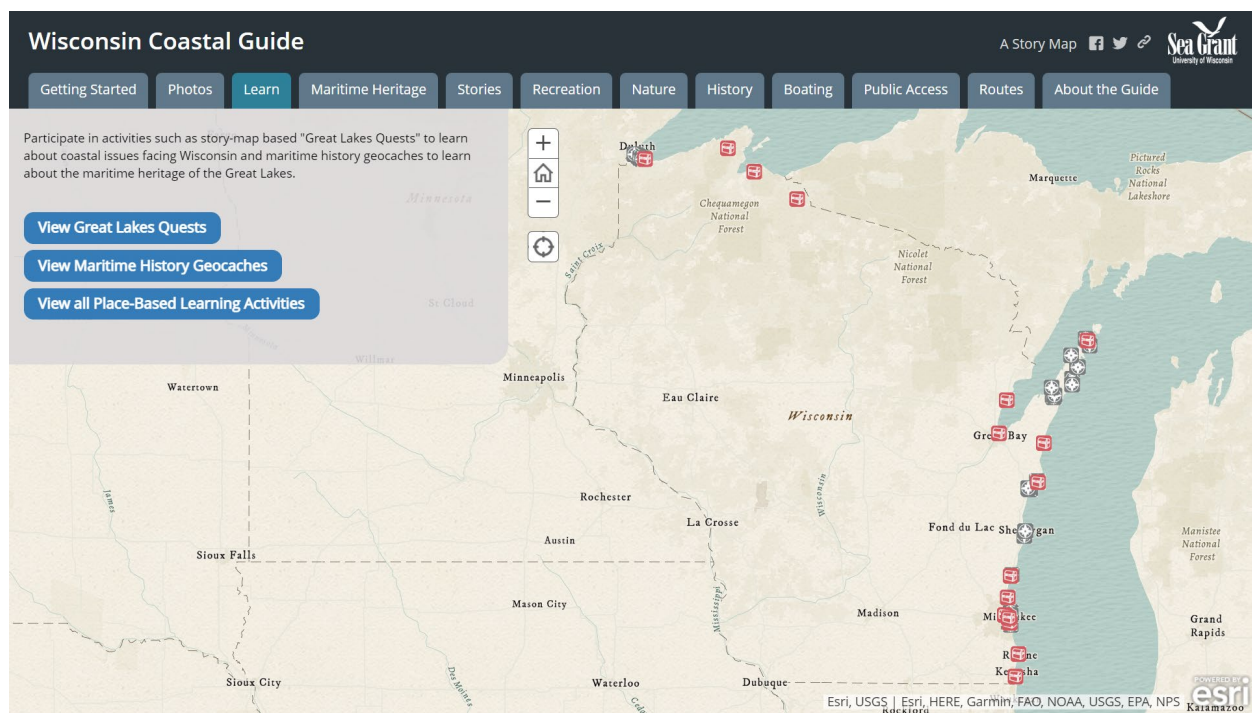

Figure 9. The Wisconsin Coastal Guide as a Esri Story Map Series.

Geodesign for Green Stormwater Infrastructure (Current Project)

It is challenging to communicate the benefits and costs of green stormwater infrastructure, especially in comparison to conventional "gray" infrastructure. The coastal management community needs easy-to-use tools to measure and visualize the incremental contributions that different green stormwater infrastructure practices can make to meet community stormwater capture and infiltration goals, combined with a way to locate these practices through collaborative scenario design processes.

Geodesign is a collaborative design process that uses geospatial technology to consider the current features of a landscape and to create, analyze, and compare planning scenarios. Wisconsin Sea Grant and collaborators are developing and applying geodesign methods and tools that allows users to visualize and draw different green stormwater infrastructure scenarios. The applications allow users to collaboratively design green infrastructure scenarios and measure the cumulative impact that green stormwater infrastructure practices have on capturing and infiltrating urban stormwater runoff across different scales ranging from a development site, a block, a neighborhood, an urban drainage catchment area, a municipality, to a watershed. While green infrastructure cannot solve all urban stormwater issues, the cumulative benefit of many practices in sufficient density can help take the burden off gray infrastructure.
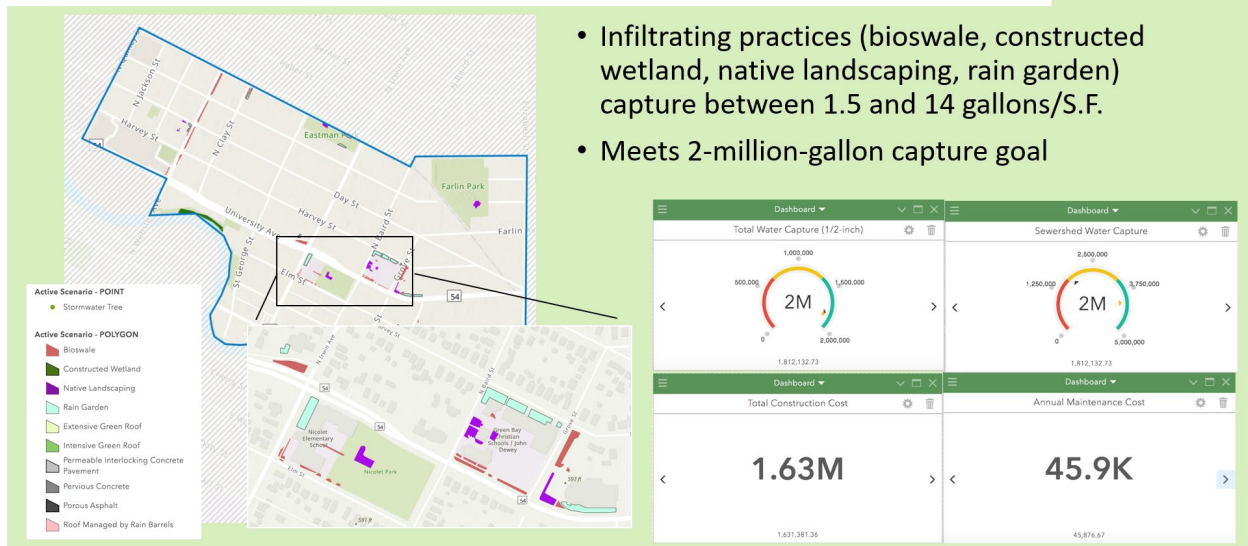

Figure 10. Using ArcGIS GeoPlanner to develop green stormwater infrastructure scenarios.

Coastal Resilience Planning Tools (Current Project)

Most local governments along the Lake Superior and Michigan coasts in Wisconsin have plans in place to guide growth and mitigate natural hazards. While adoption of plans is relatively straightforward, implementation and coordination among plans are more challenging. Wisconsin Sea Grant is collaborating with the Department of Planning and Landscape Architecture at UW-Madison to develop, assess and apply geospatial tools that lead to more effective plan implementation and coordination to build resilience to coastal hazards such as flooding and erosion.

The Wisconsin Coastal Communities Overview map (https://maps.aqua.wisc.edu/wi-overview/) provides information about the counties, cities, villages and towns that border Lake Michigan and Lake Superior. Click on a community to view population statistics and links to their government website, interactive map, community plans and development codes and ordinances.

The "Assessing Coastal Hazards in Wisconsin Through Planning" story map (https://arcg.is/1ajyvO) reviews how coastal hazards are addressed in comprehensive and hazard mitigation plans developed by coastal communities along the Great Lakes in Wisconsin.
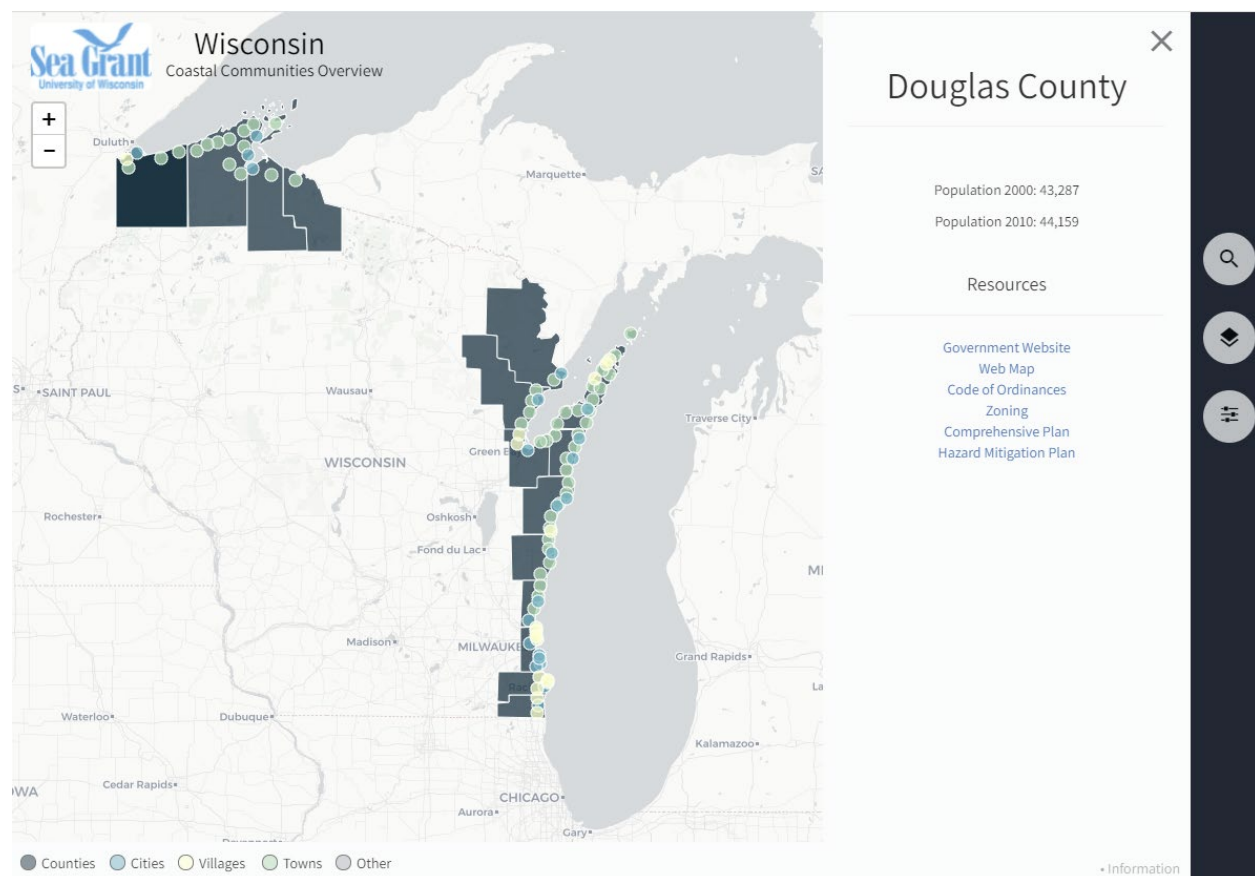

Figure 11. The Wisconsin Coastal Communities Overview map provides information about local governments that border the Great Lakes.
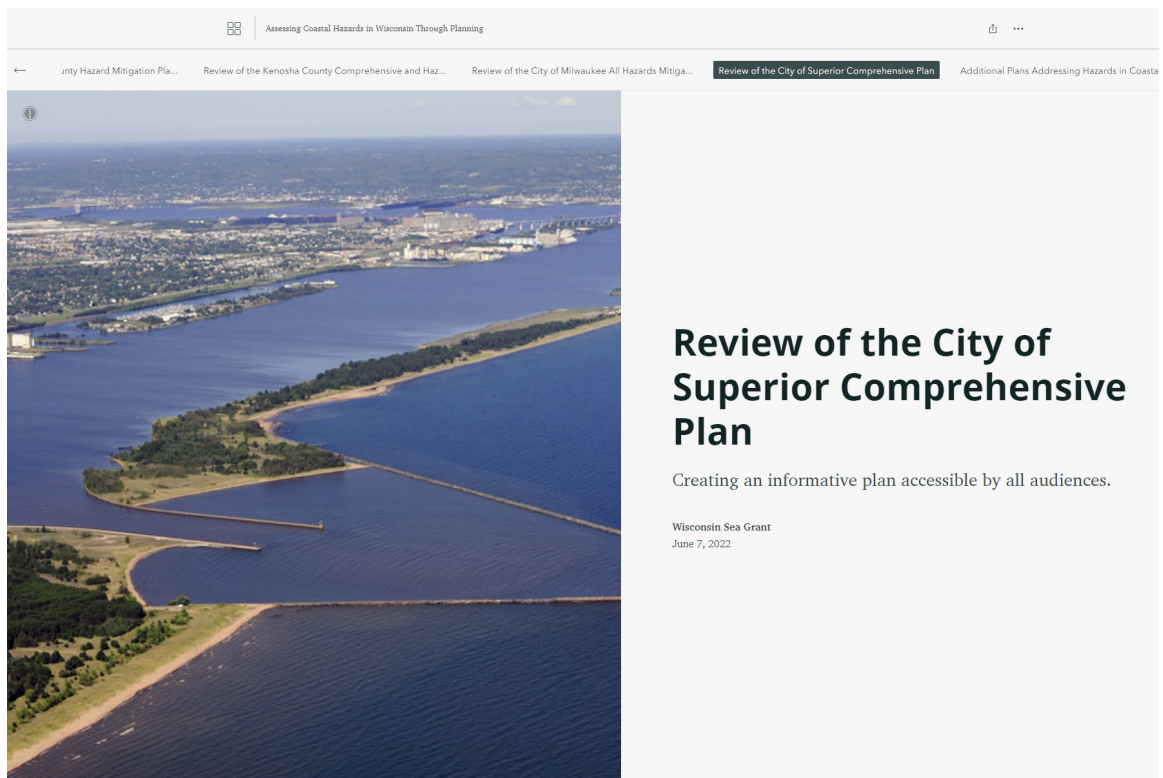
Figure 12. This story map reviews how coastal hazards are addressed in comprehensive and hazard mitigation plans developed by coastal communities.

Great Lakes Quests (Current Project)

Great Lakes Quests are virtual learning activities about coastal topics and places in Wisconsin using ArcGIS Story Map Guided Tours and Qualtrics surveys. They are inspired by the century-old British tradition of letterboxing, in which clue-driven activities encourage people to get out in nature to find a hidden container that holds a notebook and a stamp. Each Quest contains interactive educational components including links to external content, inquiry-based questions and quizzes. Each correct quiz answer reveals a clue that spells a word or phrase that is significant to the coastal topic and area. Quests enhance accessibility through virtual tours and bridge virtual and in-person experiences to support understanding of coastal and environmental issues.

There are two different types of Quests. The first type address coastal issues, such as building resilience to coastal hazards or ecological restoration (https://arcg.is/HurbW). The second type profile Wisconsin coastal counties (https://arcg.is/0vaWmP0). Great Lakes Quests were developed through a collaboration between Wisconsin Sea Grant and the Division of Extension at UW-Madison.
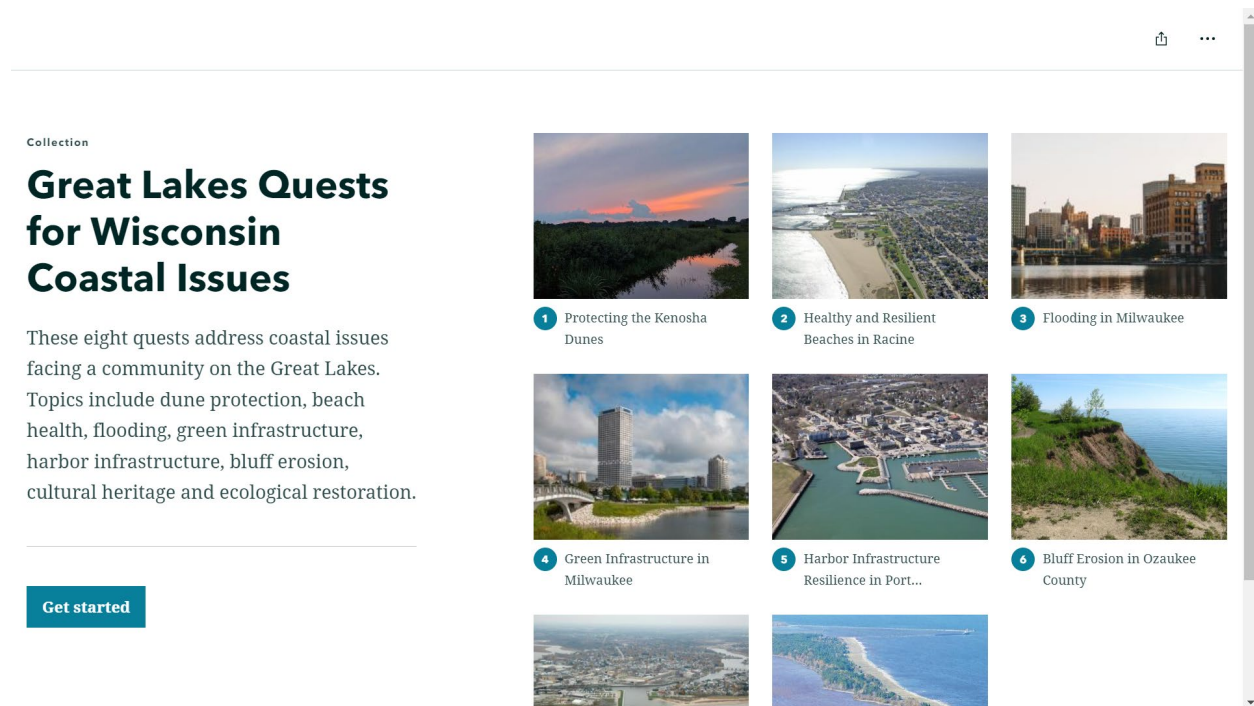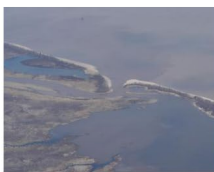

Figure 13. There are eight Great Lakes Quests for Wisconsin Coastal Issues.

Figure 14. There are nine Great Lakes Quests profiling Wisconsin Coastal Counties.