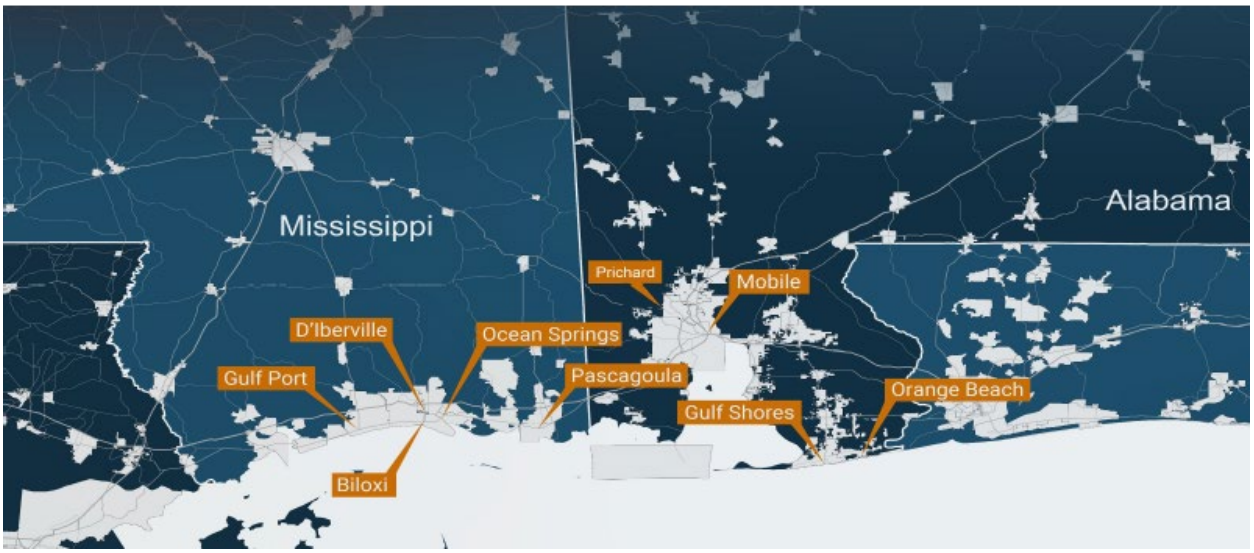

Mediating the Impacts of Local Flooding in the Mississippi-Alabama Coastal Region through Green Infrastructure Plan Evaluation

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PROJECT OVERVIEW

INTRODUCTION

Growth and development of urban environments can threaten the ecosystems of a city and its surrounding areas as undeveloped land is converted into impervious surfaces. This growth and land development, in turn, can lead to degraded ecosystem services, landscape fragmentation, and increased flooding and potential damage.[1] This is particularly an issue for coastal cities as their coastal location makes them susceptible to natural disasters, such as flooding and hurricanes. When coastal cities' locational vulnerability is coupled with land development and the expansion of its urban area, their vulnerability and risk of damages increases, as well as makes them less resilient to natural disasters.[2]

The concept and practice of 'green infrastructure' has emerged as a tool for minimizing the negative impacts of growth and development on a city and its ecosystems. Green infrastructure broadly refers to multifunctional networks of open space and nature-based multi-scalar stormwater management projects that are planned, created, and preserved with the goal of creating more resilient communities that can respond quickly and effectively to flooding events.[3] Green infrastructure practices range from connecting greenways and protecting wetlands to creating bio-retention ponds, green roofs, and rain gardens. The overall goals of green infrastructure planning are to create the conditions for cities to plan for and to respond to flooding events quickly and effectively and, when a natural disaster occurs, to temper the physical impacts and damages from flooding events and stormwater hazards.[4] The US Environmental Protection Agency (EPA) and National Oceanic and Atmospheric Administration (NOAA) both promote green infrastructure as a best practice, offer resources for its implementation, and provide funding for green infrastructure projects.[5]

While green infrastructure is gaining traction in planning practice and research continues to document its effectiveness, the questions remains if coastal cities are incorporating green infrastructure planning and practices into their comprehensive plan's goals and policies, and if there are strategic action steps for implementing them based on best practices. It is at this juncture that this project intervenes. Specifically, the goals of this research project are to help communities become more resilient to the impacts of climate change by mediating flood damages and to identify the roles that plans, planning activities and capacity, and plan implementation play in this process.

[1] Arnold and Gibbons, 1996; Kim and Park, 2016; Shuster et al., 2005.
[2] Kim, Woosnam, and Aleshinloye, 2014; Gill, et al, 2007; Liu, Chen, and Peng; 2014; Reguero, Beck, Bresch, Calil, and Meliane, 2018.
[3] Alabama Department of Environmental Management, 2013; Benedict and McMahon, 2012; Cameron and Blanuša, 2016; Eaton, 2018; Lee, 2018; Lynch, 2016; McDonald et al., 2005; Rouse and Bunster-Ossa, 2013.
[4] Kim and Park, 2016; Lee, 2018; Lynch, 2016.
[5] EPA and NOAA websites, 2019.

PROJECT COMPONENTS

This project is a collaboration between faculty from Auburn University's Masters of Community Planning, Landscape Architecture, and Geosciences programs, and local and regional partners in the Mississippi-Alabama coastal region, including the cities of Biloxi, Gulfport, Oceans Springs, D'Iberville, and Pascagoula in Mississippi, and Mobile, Gulf Shores, Orange Beach, and Prichard in Alabama, as well as several regional and state level planning entities. The aim of the project is to identify best practices related to green infrastructure planning and stormwater management, and to share this knowledge among the partners and with other coastal cities.

To do this, an advisory committee comprised of local and regional planning partners was established as a means to facilitate conversations and information sharing among project partners, to identify best practices in green infrastructure implementation, and to assess the degree to which these practices are incorporated in each city's comprehensive plan. A survey and interviews with planning leaders in the nine Mississippi and Alabama coastal cities were conducted in order to collect detailed information on planning practices and capacity, experiences, opportunities, and constraints. The goal then is to share this information and knowledge on best practices with the regional and local partners. The partner cities' comprehensive plans were also examined in order to understand the degree to which green infrastructure is planned for and supported via this city council adopted document.[6] Using existing scholarship, a rubric was created to evaluate each cities' comprehensive plans and to generate a 'plan quality score.' The results from the scoring help identify strong areas with the plans, as well as areas that could be strengthened. This also provides another opportunity to identify best practices among the partner cities in which others can learn from.

This project also identified landscape patterns that should be protected with the goal of transferring this knowledge to other Mississippi-Alabama coastal communities. To do this, we undertook extensive landscape pattern analysis for green infrastructure. During our analysis, we considered vegetation, wetlands, and barren lands as green infrastructure. The study region was determined based on the availability of USGS gauge stations and is subcategorized into 8 subsections, comprising of 1290 sub-basins delineated within them. Data was collected on regional and local landscape patterns and analyzed using GIS tools ArcPro, ArcSWAT and FRAGSTATS. The distinct steps in the methodology include: delineation of the sub-basins and environmental characteristics within each; calculation of stormwater runoff values within each sub-basin, landscape pattern analysis, and analysis of correlations between runoff and landscape patterns. The purpose of these analyses is to identify open spaces, greenspaces, floodplains, and landscape patterns at the regional scale that should be protected to mediating the impacts of flooding.

[6] Gulf Shores, AL, one of the partner cities, does not have a comprehensive plan, and was therefore not included in this specific analysis activity.

WORKS CITED

Alabama Department of Environmental Management, in cooperation with Alabama Cooperative Extension System and Auburn University. Low Impact Development Handbook for the State of Alabama, 2013.

Arnold Jr, Chester L., and C. James Gibbons. "Impervious Surface Coverage: the Emergence of a Key Environmental Indicator." Journal of the American planning Association 62, no. 2 (1996): 243-258.

Benedict, Mark A., and Edward T. McMahon. Green Infrastructure: Linking Landscapes and Communities. Island Press, 2012.

Cameron, Ross WF, and Tijana Blanuša. "Green Infrastructure and Ecosystem Services–Is the Devil in the Detail?." Annals of Botany 118, no. 3 (2016): 377-391.

Eaton, Timothy T. "Approach and Case-Study of Green Infrastructure Screening Analysis for Urban Stormwater Control." Journal of Environmental Management 209 (2018): 495-504.

Gill, Susannah E., John F. Handley, A. Roland Ennos, and Stephan Pauleit. "Adapting Cities for Climate Change: the Role of the Green Infrastructure." Built Environment 33, no. 1 (2007): 115-133.

Kim, Hyun, Kyle M. Woosnam, and Kayode D. Aleshinloye. "Evaluating Coastal Resilience and Disaster Response: the Case of Galveston and Texas Gulf Counties following Hurricane Ike." Coastal Management 42, no. 3 (2014): 227-245.

Kim, Hyun Woo, and Yunmi Park. "Urban Green Infrastructure and Local Flooding: The Impact of Landscape Patterns on Peak Runoff in Four Texas MSAs." Applied geography 77 (2016): 72-81.

Lee, Hye Kyung. "The Potential Implementation of Green Infrastructure Assessment using High-Resolution National Agriculture Imagery Program Data for Sustainable Hazard Mitigation." International Journal of Sustainable Development & World Ecology 25, no. 4 (2018): 371-381.

Liu, Wen, Weiping Chen, and Chi Peng. "Assessing the Effectiveness of Green Infrastructures on Urban Flooding Reduction: A Community Scale Study." Ecological Modelling 291 (2014): 6-14.

Lynch, Amy J. "Is it Good to be Green? Assessing the Ecological Results of County Green Infrastructure Planning." Journal of Planning Education and Research 36, no. 1 (2016): 90-104.

McDonald, L., W. Allen, M. Benedict, and K. O'Connor. "Green Infrastructure Plan Evaluation Frameworks." Journal of Conservation Planning 1, no. 1 (2005): 12-43.

National Oceanic and Atmospheric Administration. Office of Coastal Management. 'Natural Infrastructure.' Available at: https://coast.noaa.gov/digitalcoast/topics/green-infrastructure.html. Accessed July 11, 2019.

Reguero, Borja G., Michael W. Beck, David N. Bresch, Juliano Calil, and Imen Meliane. "Comparing the Cost Effectiveness of Nature-Based and Coastal Adaptation: A Case Study from the Gulf Coast of the United States." PloS ONE 13, no. 4 (2018): e0192132.

Rouse, David C. and Ignacio F. Bunster-Ossa. "Cleveland and Northeast Ohio: Green Infrastructure for a City in Transition." In Rouse, David C. and Ignacio F. Bunster-Ossa (Eds.). Green Infrastructure: A Landscape Approach. Chicago, IL: American Planning Association, 2013.

Shuster, William D., James Bonta, Hale Thurston, Elizabeth Warnemuende, and D. R. Smith. "Impacts of Impervious Surface on Watershed Hydrology: A Review." Urban Water Journal 2, no. 4 (2005): 263-275.

United States Environmental Protection Agency. 'Green Infrastructure.' Available at: https://www.epa.gov/green-infrastructure. Accessed July 11, 2019.

PART I: PLAN EVALUATION CRITERIA

1. FACT BASE

The fact base provides a description, supported by data, of the current conditions of the community, as well as projections for the future in the absence of planning interventions. This information is essential in order to understand where current development is, where development will likely happen in the future, and to inform decisions about where development should take place going forward. The purpose of the fact base is to provide a foundation, or a rationale, for the goals and strategies that follow in the plan.

Indicators
Current population
Population growth projection
Current economic conditions
Anticipated future economic conditions
Map or inventory of current housing
Map or inventory of future demand/needs for housing
Map or inventory of current land use
Map or inventory of future land use
Existing capacity of public infrastructure (including transportation)
Future demand for public infrastructure (including transportation)
Current stormwater infrastructure and services*
Future needs of stormwater infrastructure and services*
Map or inventory of existing natural resources (e.g., greenways and spaces, forests, parks, wetlands, woodlands, and open spaces)*
Map or inventory of future demand/needs for natural resources (e.g., parks, open spaces)*
Map or inventory of existing green infrastructure projects*
Map or inventory of future demand/needs for green infrastructure*
Classification/description of vegetation and forests*
Classification/description of soils*
Impervious surface area density*
Map or inventory of areas subject to flood hazards or stormwater runoff*

** Green infrastructure specific indicator*

2. GOALS AND OBJECTIVES

The goals and objectives component details the overarching intention and priorities of the plan and the specific actions, with measurable outcomes, that need to be taken to actualize them.

Indicators
Clearly specified goals that seek to promote resiliency and reduce flooding (e.g., protect natural functions and processes; encourage open spaces/recreation actions; maintain stormwater management facilities; control/reduce stormwater runoff and/or flooding; minimize impervious surfaces from development; promote green infrastructure and low impact development; and overall placement strategy for green infrastructure sites)*
Measurable objectives

** Green infrastructure specific indicator*

3. POLICIES, TOOLS, AND STRATEGIES

Policies, tools, and strategies allow a community to operationalize their goals and objectives, and to guide public decision making. Policies, tools, and strategies related to green infrastructure can be categorized into four broad categories – regulatory, incentive-based, public acquisition, and capital improvement strategies.

Indicators

Regulatory policies, tools, and strategies that seek to promote resiliency and reduce flooding (e.g., development regulations aimed at protecting coastal and hazard prone areas by improving existing ordinances, such as the erosion and sediment control ordinances, zoning ordinances, subdivision ordinances, flood plain regulations and other development regulations; urban service/growth boundaries; restrictions on local vegetation and forest removal; stormwater impact fees; limits on impervious surface densities; and land use guidelines aimed at reducing vulnerability for new development and redevelopment in coastal and hazard prone areas)*

Incentive-based policies, tools, and strategies that seek to promote resiliency and reduce flooding (e.g., density bonuses; transfer of development rights; clustered development; stormwater fee discounts; and incentives for innovative practices, such as using water efficient landscaping, low impact design interventions, green infrastructure, and LEED certifications)*

Public land preservation and/or land acquisition policies, tools, and strategies that seek to promote resiliency and reduce flooding (e.g., open space preservation; conservation easements; constructed wetlands; setbacks and buffer zones; and ensuring that publicly owned lands will be used at their highest and best use, except for those public lands that are in environmentally sensitive locations, where conservation should be the objective)*

Capital improvements and funding policies, tools, and strategies that seek to promote resiliency and reduce flooding (e.g., directing funding to projects that support these goals; and adequately funding stormwater management)*

** Green infrastructure specific indicator*

4. IMPLEMENTATION, MONITORING, AND EVALUATION

Implementation, monitoring, and evaluation refers to a plan's description of how it is going to carry out its work, monitor its progress, and evaluate if it is achieving its goals. Implementation details should include specific actions, a designation of responsibilities for the actions, the financial and technical resources needed to carry out the actions, and a timeline for completing the actions. Implementation, then, needs to be monitored in order to track progress. A process and timetable for evaluation allows communities to monitor changing conditions and update their plans accordingly.

Indicators

- Plan for implementation, including actions, designation of responsibilities for actions, financial and technical resources needed, and a timeline for implementation
- Plan for monitoring progress on implementation, including mechanisms for measuring objectives, designation of responsibility for measuring and reporting on implementation, and timetable for measuring and reporting
- Implementation includes the monitoring of ecological health and human impacts, including stormwater runoff impacts*
- Process and timetable for updating plan based on monitoring of changing conditions

** Green infrastructure specific indicator*

5. INTER/INTRA ORGANIZATION COORDINATION AND CAPACITY

The inter/intra organizational coordination and capacity component addresses the fact that successful planning requires coordinating with other organizations and departments within a given municipality, with higher level organizations that may set guidelines or provide funding, and with neighboring municipalities that share ecological features.

Indicators

- Identification of coordination efforts within the jurisdiction specified
- Identification of coordination needs within the jurisdiction specified
- Identification of coordination efforts with other jurisdictions/organizations/ stakeholders
- Identification of coordination needs with other jurisdictions/organizations/ stakeholders
- Identification of coordination efforts with higher levels of governments (state/federal)
- Identification of coordination needs with higher levels of governments (state/federal)
- Identification of coordination efforts with private sectors
- Identification of coordination needs with private sectors
- Integration with other environmental plans/programs in the region*

** Green infrastructure specific indicator*

6. PUBLIC PARTICIPATION

Meaningful public participation in the planning process is a widely accepted best practice within the planning field. It can also increase community support for a plan. Participation extends beyond just the plan development phase and includes involving the public in ongoing monitoring, evaluation, and planning decisions. The participation process also facilitates the sharing of experiences, developing a common understanding of the issues facing a community, and promoting of awareness of how decisions and their impacts are interrelated.

Indicators

- Public participated in the plan creation
- Identification of organizations and individuals involved in plan creation
- Description of the role of public participation during plan creation
- Description of the process in which the public was involved and which techniques were used
- Description of how the public will be involved in implementation, monitoring, and evaluation of the plan
- Description of ongoing efforts to involve the public in planning decisions

** Green infrastructure specific indicator*

PART II: RESULTS

PLAN QUALITY SCORES

Cities	Indicators: Fact base	Goals and objectives	Policies, tools, and strategies	Implementation, monitoring, and evaluation	Inter/intra organizational coordination and capacity	Public participation	Total	GI breadth score	GI depth score
Biloxi, MS	8.75	10	10	8.75	10	8.33	55.83	88%	88%
D'Iberville, MS	8	10	10	5	8.89	2.50	44.39	82%	68%
Gulfport, MS	7.75	10	8.75	3.75	6.67	3.33	40.25	82%	65%
Mobile, AL	5.5	7.5	7.5	8.75	8.89	8.33	46.47	71%	59%
Ocean Springs, MS	9.5	10	6.25	7.5	7.78	5.83	46.86	76%	74%
Orange Beach, AL	7.5	7.5	6.25	2.5	6.67	2.5	32.92	76%	56%
Pascagoula, MS	8.5	10	8.75	5	8.33	2.5	43.08	88%	79%
Prichard, AL	7	10	7.5	3.75	5.56	8.33	42.14	65%	53%
Average	7.81	9.38	8.13	5.63	7.85	5.21	43.99	79%	68%

Notes:

Gulf Shores, AL does not have a comprehensive plan, so while a project partner, the city is excluded from this analysis.

Scores have been standardized. Individual indicator scores for each city range from 0 to 10, with 10 representing the highest possible score and 0 representing the lowest possible score. Total scores for each individual city range from 0 to 60, with 60 representing the highest possible score and 0 representing the lowest possible score.

Breadth and depth scores were calculated for just the green infrastructure specific indicators. Breadth scores refer to the numerical range of different green infrastructure approaches noted in each cities' comprehensive plans. Depth scores refer to the level of description given to them.

PLAN QUALITY SCORES INTERPRETATION

Overall, the eight cities' comprehensive plans have an average score of 43.99, out of a possible score of 60, indicating that the plans collectively represent a high level of quality and green infrastructure engagement. However, the scores have a wide spread with scores ranging from 32.92 on the low end to 55.83 on the high end.

The 'implementation, monitoring, and evaluation' and 'public participation' components are the lowest scoring components across all plans. The 'goals and objectives' and 'policies, tools, and strategies' components are the highest scoring components, with' fact base' and 'inter/intra organizational coordination and capacity' falling in the middle, overall. This suggests that, while goals and policies are well supported with data and clearly articulated, there are limited processes for ensuring that the plan actions will actually be executed in practice and that there are systems of accountability in place. The low overall score in 'public participation' raises concerns about the role the community played in the creation of these plans and their ongoing engagement in planning processes and decisions.

On average, the green infrastructure breadth score (79%) is higher than the green infrastructure depth score (68%), indicating that plans are more likely to mention an aspect of green infrastructure in their plans but not provide great detail about it or its implementation.

PART I: COMMUNITY INVOLVEMENT

In addition to participating in the advisory committee, project partners were asked to participate in a web-based survey and an interview in order to gather detailed information from them, as the planning leaders in these nine Mississippi and Alabama coastal cities and the surrounding region, on their planning practices and processes; organizational planning capacity, including leadership and collaboration; planning responsibility and oversight; and resources, as well as experiences, opportunities, and constraints related to green infrastructure planning in the coastal areas of Mississippi and Alabama. The following is a summary of the themes that emerged.

PART II: COMMUNITY INPUT

1. ORGANIZATION INFORMATION

Participants/respondents: A total of seven, out of the nine, partner cities, as well as two regional or state level planning entities, completed the survey and/or an interview.

Green infrastructure engagement: All organizations have implemented and/or use some form of green infrastructure. Two respondents (22%) noted the presence of local mandates in their cities that require some use of green infrastructure or a focus on sustainability/environmental issues as it relates to planning.

Level of political support within organization for using green infrastructure: The average ranking of political support within one's organization for implementing green infrastructure projects was 5.67, on a scale of 0 to 10 with 0 representing very weak, 5 neutral, and 10 very strong. Responses ranged from 3 to 8.

2. LEADERSHIP AND COLLABORATION

Growth and development versus environmental protections: There is a tension between growth and development on one hand, and environmental protections on the other hand, when it comes to planning coastal cities. Growth and development tends to be prioritized, in particular when there is a quick financial return on a given development, which is often contradictory to adopted plans, ordinances, and general planning expertise.

Level of political support within the larger community for using green infrastructure: The average ranking of political support within one's larger community for implementing green infrastructure projects was 4.89, on a scale of 0 to 10 with 0 representing very weak, 5 neutral, and 10 very strong. Responses ranged from 2 to 7.

Political leadership: There is limited political leadership and will to enforce environmental protections and create new green infrastructure projects. Preservation ordinances and permitting processes are not uniformly or evenly enforced or applied within cities. Changing political leaders and administrations result in changing priorities, including not supporting or undoing past environmental planning efforts.

Collaboration and coordination: Environmental issues do not respect political boundaries or jurisdictions, nor do they align perfectly with the various departments of an organization. However, growth and development, as well as environmental protection, decisions affect all aspects of a city and region.

- On the local level, collaboration, communication, and accountability among city departments is extremely important since all city departments are interrelated and the decisions they each make impact all the others.
- On a regional level, developers tend to choose locations where their development can take place as quickly, easily, and cheaply as possible. If one city is more restrictive, they will likely gravitate to a different one that is less restrictive to develop in. However, the net environmental affect for the region is roughly the same. The collective goal needs to be focused on helping developers develop properties properly and responsibility, with the entire region benefiting as a result.
- All but one respondent (89%) noted an array of different groups and organizations that they collaborate and coordinate with, ranging from other departments within their organization to state and federal level entities. The average ranking of adequacy and effectiveness of these collaborations was 5.22, on a scale of 0 to 10 with 0 representing very ineffective, 5 neutral, and 10 very effective. Responses ranged from 1 to 7.

3. COMPREHENSIVE PLAN RESPONSIBILITY AND OVERSIGHT

Sustainability and green infrastructure commitment: Five respondents (56%) reported that their city/region's comprehensive plan has sustainability as an overarching goal. Six (67%) respondents reported that their city/region's comprehensive plan proposes the use of green infrastructure.

Little accountability in comprehensive planning: There is very limited accountability and oversight for ensuring that what is in a city's comprehensive plan, and its other related plans, actually gets implemented.

Development ordinances: There are a number of important green infrastructure projects currently underway, as well as many noteworthy best practices being utilized (e.g., prioritizing tree plantings and permeable surfaces in design review evaluations, tree preservation ordinances). However, the impact of these projects is weakened by developers' actions because there is no requirements in place in terms of how they must mitigate the impacts of their development, they are too vague in terms of how the requirements are to be met, or the requirements are not enforced; or developers avoid the recommendations that carry no penalty or incentive.

Public input: All but one respondent (89%) affirmed that there are opportunities for public participation as it relates to planning decisions coming out of their department. All respondents (100%) reported that plans, maps, etc. related to their department's planning work is publicly available on a website or other forum.

4. RESOURCES

The reactive nature of planning for natural disasters: Planning for and responding to natural disasters tends to be reactive. For example, when a natural disaster occurs, like a hurricane, the federal relief money that cities receive needs to be used to replace the damaged infrastructure like it was before instead of improving it so it can withstand the next storm. In other words, the funding to support this work tends to be used for mitigation only, and not for changing development patterns or standards.

External funding: Cities are applying for grants to make green infrastructure projects happen – often competing with one another for the same resources and with no guarantee they will get the funding for their projects. A reliable and adequate funding source is needed to order to implement and maintain the green infrastructure projects that planners and public works staff want to create; projects that are often promoted by the comprehensive plan.

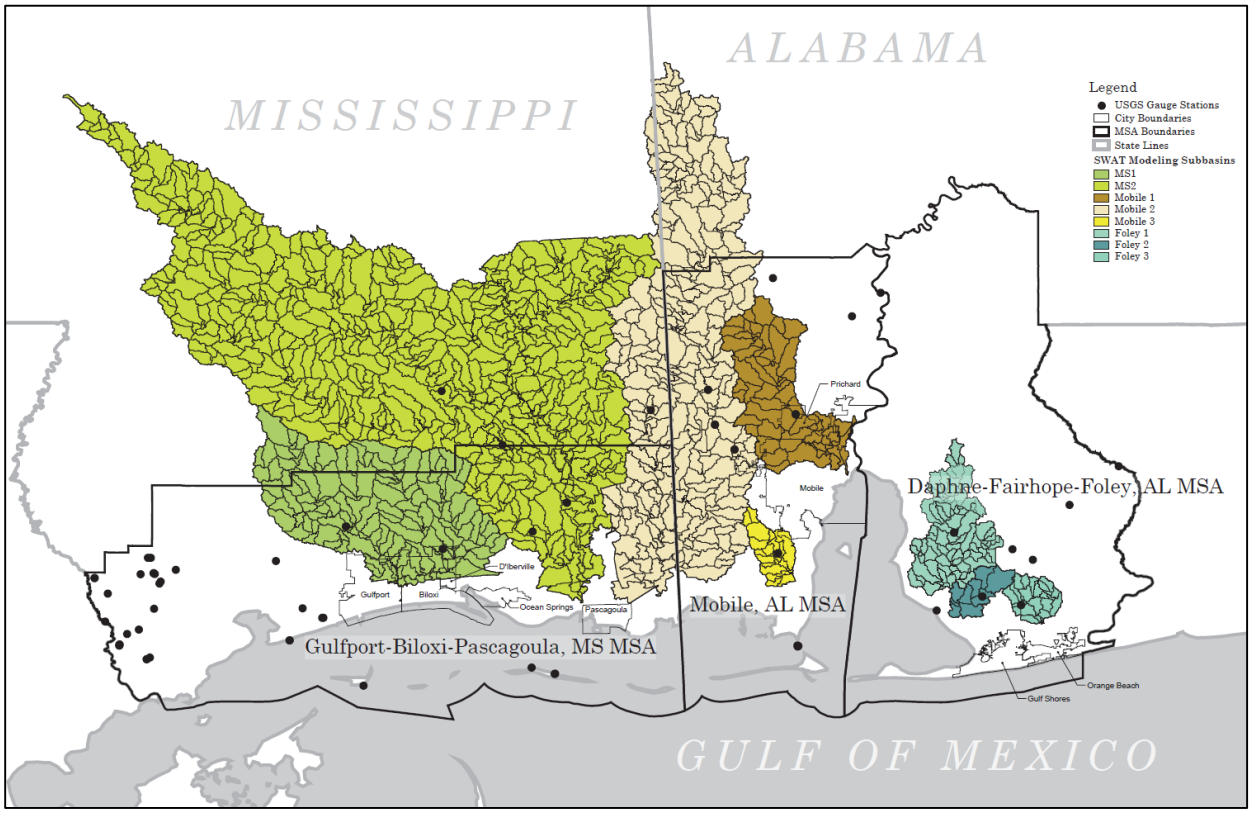
Organizational resources: Respondents were evenly divided in terms of if the resources that are committed to their city's/region's comprehensive plan preparation, implementation, and monitoring are adequate or not.

Staffing resources: Six respondents (67%) reported that staff in their department receives training in green infrastructure or environmental planning. Five respondents (56%) reported that staff in their department receive ongoing training and professional development in GIS applications and skills.

PART I: REGIONAL LANDSCAPE PATTERN ANALYSIS

This project identified landscape patterns that should be protected with the goal of transferring this knowledge to other Mississippi-Alabama coastal communities. To do this, we undertook extensive landscape pattern analysis for green infrastructure. During our analysis, we considered vegetation, wetlands, and barren lands as green infrastructure. The purpose of these analyses is to identify open spaces, greenspaces, floodplains, and landscape patterns at the regional scale that should be protected to mediating the impacts of flooding.

Our study areas were determined based on the availability of USGS gauge stations (shown as black dots on the map below). The goal was to delineate watersheds draining into the major communities on the Mississippi – Alabama coastline to determine their runoff characteristics and understand how green infrastructure effects stormwater runoff. We subcategorized the region into 8 subsections – two in Mississippi, represented in green; three in the Mobile, Alabama area, represented in beige, brown, and yellow; and three in the Daphne, Fairhope, Foley, Alabama area, represented as blues. All of the 1290 sub-basins delineated within these larger areas can be seen on the map below.



We collected comprehensive data on regional and local landscape patterns and analyzed them for each of the 1290 sub-basins using GIS tools ArcPro, ArcSWAT and FRAGSTATS. Part of this methodology has been elaborated from Kim and Park (2016)[1]. The methodology can be divided into four distinct steps:

1. Delineate sub-basins and environmental characteristics within each (ArcGIS Pro).
2. Calculate stormwater runoff values within each sub-basin (ArcHydro and SWAT).
3. Conduct landscape pattern analysis (Fragstats).
4. Calculate correlations between runoff and landscape patterns (OLS).

First, the general characteristics of the peak runoff during the three-year period of 2014 to 2016 in the eight watersheds were estimated. Then, the impacts of landscape patterns on the variations in the mean annual peak runoff depth was analyzed using ordinary least squares (OLS) regression.

1. DATA COLLECTION

Several datasets were collected including mean annual peak runoff depth, mean annual precipitation, average watershed slope, average watershed soil permeability, floodplain area, natural drainage density, wetlands, and impervious rate. The data sources and specific tools used to estimate each of these are listed in the table below.

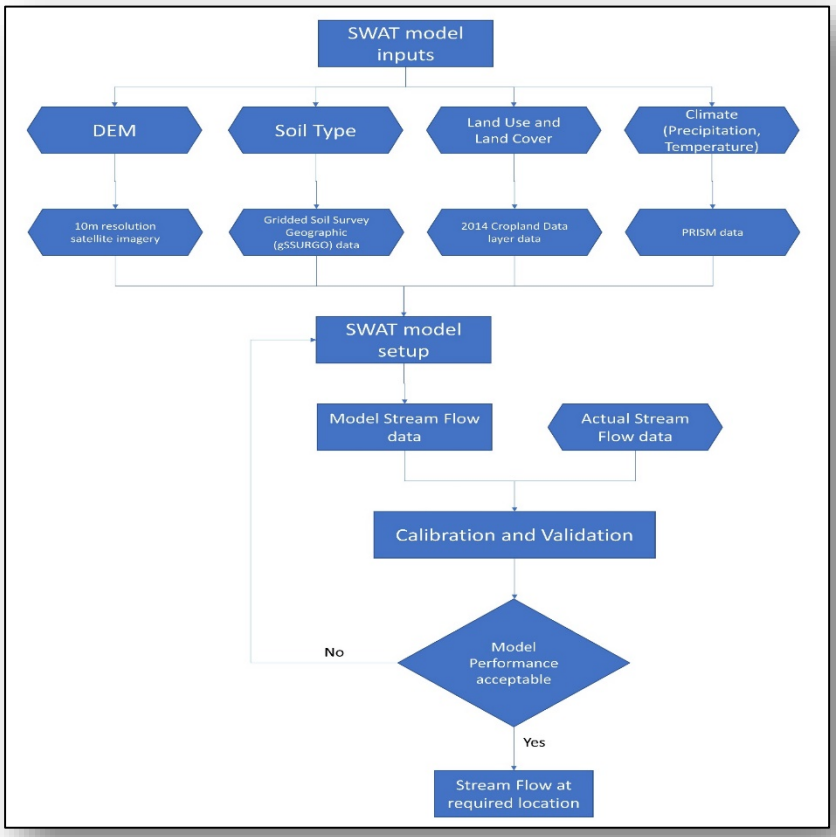
Variable and source	**Measurement**
Slope (NHDPlusV2, NED)	Average watershed slope; units in percentages
Soil Permeability (NRCS)	Average watershed soil permeability; units in inches per hour
Floodplain Area (FEMA)	Area within the FEMA-defined 100-year floodplain; units in percentages
Natural Drainage Density (NHD)	Ratio of total stream length to basin area
Wetland (NLCD)	Proportion of wetland; units in percentages
Impervious Rate (NLCD)	Proportion of developed surfaces; units in percentages

For the ordinary least squares (OLS) regression, mean annual runoff is taken as the dependent variable, and the rest of the variables are control variables. Again, the purpose of this analysis is to determine the variables impact on stormwater runoff.

[1] Kim and Park (2016). Urban Green Infrastructure and Local Flooding: The Impact of Landscape Patterns on Peak Runoff in Four Texas MSAs. *Applied Geography.* Vol. 77, p. 72-81.

2. STORMWATER RUNOFF ESTIMATE

There are many methods for estimating stream flow through an ungauged basin in a watershed. Soil and Water Assessment Tool - known as SWAT - is widely used for discharge modelling. We applied the SWAT tool to estimate the amount of stormwater runoff. Each watershed was modelled separately using ArcSWAT tool in ArcGIS v10.5. The watershed and USGS gauge list was prepared for the eight watersheds as defined in the study region. The inputs needed for the SWAT model are: Digital Elevation Modelling, land use, soil type, weather, and observed discharge data at one of the sub-watershed's outlet. While the first four are used for simulating discharge data, the observed discharge data is used for calibrating and validating the model.



Peak annual runoff along with the area of the watershed was used to calculate the peak annual runoff depth for each sub-basin. To predict the stream flow in ungauged basins, stream flow records must be available for one of the locations in the watershed. The actual stream flow values are statistically compared with model values for that location. The model is calibrated and validated by changing the sensitive parameters until the model performance is acceptable. Once the model is acceptable, the discharge values at the required location can then be used for studies.

Variable and Source	Measurement
Mean Annual Peak Runoff Depth (USGS)	Average maximum daily runoff (mm) at each USGS gauge stations (2014-2016), by water year (natural log-transformed
	Average maximum daily runoff (mm) at each USGS gauge stations (2014-2016), by water year (log-transformed)
Precipitation (PRISM)	Mean annual precipitation; units in mm

3. LANDSCAPE PATTERN ANALYSIS USING ARCGIS AND FRAGSTATS

Landscape metrics are measured at the landscape level, class level, and/or patch level. These were measured for each sub-basin using Fragstats and ArcPro. These landscape metrics describe the spatial structure of patches, classes of patches, or entire landscapes. Landscape pattern analysis provides us useful information about the *composition* and *configuration* of a landscape – what is the proportion of each land cover type present, or the size or shape of different landscape elements. Using GIS tools ArcPro and Fragstats, we analyzed landscape patterns for the 1290 sub-basins and measured them using the following metrics:

Size and Edges were observed by a Percentage of Landscape (PLAND) and Edge Density (ED). PLAND calculates the percentage of a particular patch type. It provides the most important information for showing the richness of some types of patches (such as proportion of vegetation, wetlands, etc.). However, it is less useful in showing the spatial distribution. ED measures the ratio of the total perimeter of patches to a unit area and takes into account the shape and size of patches. The high value of PLAND and ED indicate a landscape with larger and complex shapes.

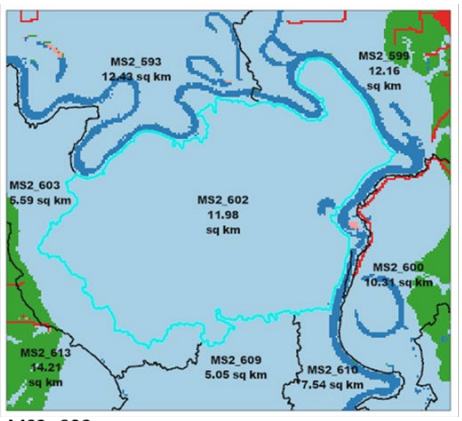
Shape metrics describes whether patches have convoluted shapes. The Shape Index (SHAPE) and Congruity Index (CONTIG) were used to make the shape measurements. SHAPE calculates the patch perimeter and area simultaneously, while CONTIG assesses patch shape based on the spatial connectedness or contiguity of cells within a patch. If a patch is more convoluted in shape, its SHAPE and CONTIG would increase in value.

Isolation metrics help identify the tendency for patches to be isolated in space from other patches. Proximity (PROX) and mean Euclidean Nearest-Neighbor Distance (ENN) were used to identify the level of isolation or nearness of landscapes. PROX measures the distance between the focal patch and neighboring patches of the same type and size within the search radius. PROX increases when a specific patch type is near the same type of patches. Mean ENN factors the average of the straight-line distance between nearest neighbor patches of the same type. When the value of ENN approaches zero, the distance to the nearest neighboring patch decreases.

Connectivity refers to the functional and spatial connectivity among patches. Connectivity of patches was measured by cohesion (COHESION) and connectedness (CONNECT). COHESION calculates the

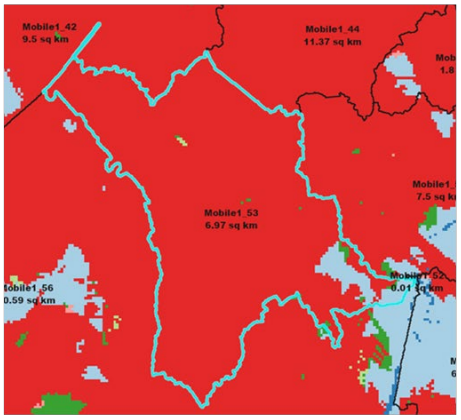
physical connectedness of the corresponding patch types in an area. CONNECT measures each pair of patches that are either connected or not within a certain search radius.

A few other metrics were also measured such as the Shannon's Diversity Index, which measures landscape composition or diversity of land cover types. The images below illustrate outputs of Edge Density, which is one of the landscape metrics measured.

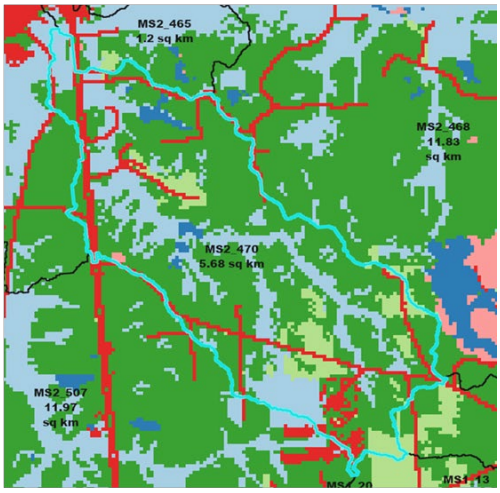


MS2_602

MS2_508



Mobile1_53

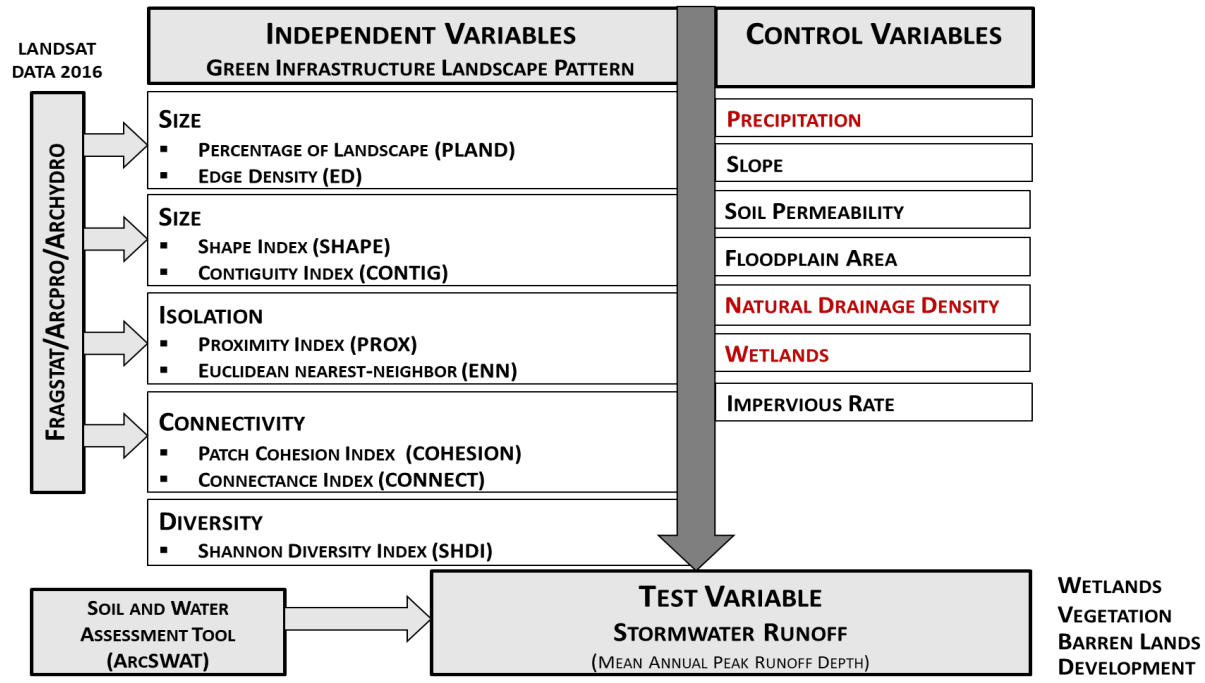


MS2_470

Low values of Edge Density are illustrated on the top and high values of Edge Density are illustrated at the bottom. A large value of Edge Density for a green infrastructure land cover class would be expected to reduce mean and peak runoff, because of the increased complexity and convolution.

PART II: OLS REGRESSION

The variables used in the OLS Regression Models are listed in the chart below:



Extensive data was collected for carrying out regional and local landscape patterns analysis for the 1290 sub-basins using GIS tools of ArcPro, ArcSWAT, and Fragstats. Next, the general characteristics of the peak runoff was estimated for the three-year period from 2014 to 2016 for each of these sub-basins. Then, the impacts of landscape patterns on the variations in the mean annual peak runoff depth was analyzed using OLS regression. The expectation is that desirable landscape patterns consist of larger patches, more connected and unfragmented patches and corridors, wide corridors, and heterogeneous areas of nature throughout human-developed areas.

We developed four separate models, one each for barren lands, vegetation, wetlands, and development. The preliminary results obtained of the OLS regression explain some of the impacts of different green infrastructure land uses in terms of their size, shape, isolation or cluster, and connectivity on local flooding, while controlling for several environmental conditions.

PART III: RESULTS

As expected, in all preliminary models, average precipitation and natural drainage density are very significant and strong predictors of runoff. Meaning, that higher the rainfall and higher the natural drainage density, higher the runoff. In three out of the four models, percentage of wetlands also has a significant, negative association with runoff. The higher the percentage of wetlands in the sub-basin, the lower the runoff. Specifically for the landscape metrics that are measured, the results indicate the following:

- Increased proportion of wetlands, and more connected wetlands, are significantly associated with a reduction in runoff.
  - Percentage of landscape (wet_PLAND) for wetlands has a significant impact on runoff, meaning that a greater proportion of wetlands is associated with reduced runoff.
  - More connected wetlands (wet_CONNECT) are also associated with a reduction in runoff.
- Increased proportion of vegetation, and more connected vegetation, are highly significant and associated with reduced runoff. Proximity Index Mean for vegetation is also significant and associated with reduced runoff.
  - Percentage of landscape for vegetation is highly significant and reduces runoff.
  - Proximity Index mean and connected vegetation (veg_CONNECT) is significant and associated with reduced runoff.
- For barren lands, only Euclidian Nearest Neighbor seems to have an association with runoff, but the effect is negligible.
  - Only Euclidian Nearest Neighbor (Brn_ENN) seems to have a significant association with runoff, but the effect is marginal.
  - No other landscape measure for barren lands was found to have a significant effect on runoff.
- For developed lands, proximity of development does have a significant positive association with runoff.
  - Proximity of development (Dev_PROX_MN) has a significant positive association with runoff.
  - Connectivity (Dev_CONNECT) has a significant association with runoff, implying that more connected development is associated with reduced runoff.

There were other expected associations in the expected directions, even though they were not statistically significant.

To summarize, the results show that: 1) a larger proportion (percentage) of landscape, specifically wetlands and vegetation, reduces peak runoff; 2) less fragmented and clustered landscape patterns decrease peak runoff; 3) highly connected landscapes reduce peak runoff; and 4) proximity to developed lands increases runoff.

Generally, the findings suggest that the proportion and size, fragmentation, and connectivity of vegetation and wetlands at the regional scale affect peak runoff. Therefore, green infrastructure planning should extend beyond local scale and local plans, to consider overall networking and clustering at the regional scale.

LEADERSHIP AND COLLABORATION

There is a low level of perceived political support within the larger community for green infrastructure planning, and a low level of perceived political leadership and will to enforce environmental protections and create new green infrastructure projects. This is couple with a tension between growth and development on one hand, and environmental protections on the other hand, when it comes to planning in coastal cities, and where growth and development is prioritized.

1. Adapt a local mandate(s) that requires some use of green infrastructure or a focus on sustainability/environmental issues as it relates to planning, and that will withstanding changes in political leadership.
2. Uniformly and evenly enforce and apply ordinances and permitting processes that already exist, clarifying them as required to eliminate ambiguities and expanding them as required to ensure requirements and penalties/incentives are explicitly stated.
3. Use the comprehensive plan as a guiding document to inform land use and planning decisions.

Environmental issues do not respect political boundaries or jurisdictions, nor do they align perfectly with the various departments of an organization. Yet, growth and development, as well as environmental protection, decisions affect all aspects of a city and region. To address this, collaboration is needed. However, there is a low level of perceived adequacy and effectiveness when it comes to current collaborations.

1. Designate a staff member, or a team of staff members, to perform 'systems integration' work:
    a. Establish mechanisms for internal and external communication and coordination;
    b. Develop region-wide policies and solutions to planning issues that coalition members implement locally, but have the collective goal of benefiting the entire region;
    c. Explore joint grant applications with regional partners in order to secure additional financial resources for the region's benefit;
    d. Facilitate co-trainings within and across organizations as to promote ongoing professional development opportunities and the promotion of best practices; and
    e. Ensure that collaborative work is action-oriented and results-based.

COMPREHENSIVE PLANNING AND PUBLIC PARTICIPATION

The majority of project partners reported that their city/region's comprehensive plan has sustainability as an overarching goal and proposes the use of green infrastructure. However, there is very limited accountability and oversight for ensuring that what is in a city's comprehensive plan, and it's other related plans, actually gets implemented. The comprehensive plans from the partner cities, collectively, do not clearly or robustly detail how the plan will be implemented, who is going to monitor its progress, and how its success will be evaluated – in other words, how are cities ensuring that the plan actions will actually be executed in practice and that there are systems of accountability in place.

1. Establish a committee or task force responsible for implementing, monitoring, and evaluating the goals and progress of the comprehensive plan. Membership should include representatives from each organization and department mentioned in the plan, as well as at large members from the community. Systems of accountability must be built into this structure.

2. Continue to make the city's/region's plans, maps, and other data available for the public and continue existing opportunities for public participation in the planning and decision making processes, while looking for ways to expand and deepen participation.
    a. Comprehensive plans need to fully describe how the public was involved in the creation or revision of the plan, as well as its ongoing monitoring and evaluation, and future planning decisions.
    b. This is also an education opportunity as not all residents and organization staff understand the issues holistically and the impact of their individual/departmental decisions on the city and the region as a whole.

RESOURCES

Financial and human resources are limited among the project partners, but adequate funding and support are essential for making planning successful. Some funding is reactive in nature, becoming available only after a natural disaster has happened and funds only activities that restore the existing infrastructure. Other funding can be used to proactively address environmental issues and be a catalyst for changing development patterns and standards. Cities and regions need to pursue a diverse portfolio of funding options, as well as invest in their human resources to carry this work out.

1. Designate a staff member, or a team of staff members, to perform grant writing activities.
2. Explore joint grant applications with regional partners.
3. Advocate for a reliable and adequate funding source, at the local or regional level, in order to implement and maintain green infrastructure projects.
4. Facilitate co-trainings within and across organizations as to promote ongoing professional development opportunities and the promotion of best practices, while leveraging limited financial resources and strengthening collaborations.

DESIRABLE LANDSCAPE PATTERNS

A larger and connected landscape is likely to reduce peak runoff. Covering more land areas with trees, shrubs, and wetlands, will increase the infiltration and storage of rainwater locally in an area, reducing runoff and flooding. Regional landscapes that are more connected and less fragmented, specifically consisting of vegetation and wetlands, are likely to reduce runoff. Scattered and fragmented landscapes will have less capacity to store rainwater.

Planning for green infrastructure should extend beyond local jurisdictions and local plans to consider overall networking and clustering at the regional/macro scale. Regional planning agencies should collaborate with local agencies so that attention can be given to the landscape size, connectivity, configuration, and composition. Regional/state-level policies will improve effectiveness of green infrastructure. The regional planning agencies can take the lead and coordinate with local governments to develop and implement an overall networking and clustering plan for green infrastructure. A regional approach is needed to address and map targeted areas where green infrastructure should be strategically preserved and connected with particular emphasis on larger and connected wetlands and vegetation. These plans can then be dovetailed into local comprehensive and land use plans for implementation.

– RESOURCES –

GENERAL RESOURCES

Low Impact Development Handbook for the State of Alabama (262 pages)
http://adem.alabama.gov/programs/water/waterforms/LIDHandbook.pdf
This handbook includes specific information on stormwater control measures (SCMs), including bioretention, permeable pavement, riparian buffers and more. Information includes SCM pollutant removal, site selection, design, construction calculation examples, suggested vegetation, maintenance and additional references. This resource was developed by the Alabama Department of Environmental Management (ADEM) in cooperation with the Alabama Cooperative Extension System and Auburn University. Contributing authors include Katie Dylewski, Jessica Brown, Charlene M. LeBleu and Dr. Eve Brantley. Auburn University landscape architecture graduate students provided graphic design assistance.

Green Infrastructure Tool Box (54 pages)
https://dmr.ms.gov/wp-content/uploads/2019/07/Updated_Green-Infrastructure-Chapter.pdf
Prepared by the Mississippi Department of Marine Resources and Allen Engineering and Science, this document provides a comprehensive overview of green infrastructure, including **Municipal Policy Case Studies** on the national level (Sec. 1.14, page 43).

Mississippi Department of Environmental Quality (MDEQ) Stormwater Runoff Manual (199 pages)
https://www.mdeq.ms.gov/wp-content/uploads/2017/05/Volume_2.pdf
The Erosion and Sediment Control and Stormwater Runoff Management Manuals were made possible via a U.S. Environmental Protection Agency grant and are products of a partnership project among the Mississippi Department of Environmental Quality, the Mississippi Department of Transportation, and the U.S. Department of Agriculture–Natural Resources Conservation Service (NRCS). This manual includes best practices for stormwater control measure planning, site design, infiltration, filtration and retention/detention.

Plants for Green Infrastructure (GI) (5 pages)
https://hoffmannursery.com/assets/files/files/Hoffman_Nursery_Green_Infrastructure_Chart.pdf
This document is an overview of common GI features, including native plant suggestions and well-adapted, introduced plants can also be good choices, and they are marked by an asterisk (*). Quick facts include USDA Zone, Height, Exposure and amount of water needed.

Nature-Based Stormwater Strategies, North Carolina Coastal Federation
https://www.nccoast.org/
Webpage link to the *North Carolina Coastal Federation*. Includes a Resources tab (at top) that is packed with strategies and special publications.

United States Environmental Protection Agency (EPA) Listserv
Sign up to receive information about EPA opportunities you are interested in (i.e., Region 4 EPA).
https://www.epa.gov/newsroom/email-subscriptions-epa-news-releases

MODEL POLICY

Mobile, AL

Mobile (Alabama) Unified Development Code (April 1, 2021Planning Commission Version) Chapter 64, Article 12, Peninsula Overlay, Sec. 64-12-1, page 323 – 329
https://mapformobile.org/wp/wp-content/uploads/2021/04/12-Peninsula-Overlay_Commission.pdf

The Mobile Peninsula Corridor Master Plan **(51 pages)**
https://thepeninsulaofmobile.org/wp-content/uploads/2017/01/Peninsula-of-Mobile-Corridor-Plan_FINAL_Reduced.pdf

You may also be interested in ***The Mobile Peninsula*** website (a 501 (c) (3) non-profit organization):
https://thepeninsulaofmobile.org/#

Examples of Model Green Infrastructure Master Plans

The City of Auburn, AL Green Infrastructure Master Plan (2018)
https://www.auburnalabama.org/water-resource-management/watershed/green-infrastructure-master-plan/
This document provides a framework document to guide the City of Auburn, AL, toward implementing Green Infrastructure practices and creating a more sustainable stormwater management program.

Northside Neighborhood Green Infrastructure Master Plan (US EPA)
https://www.epa.gov/sites/production/files/2015-10/documents/spartanburg_tech_assistance1.pdf
This report was developed under EPA Contract No. EP-C- 11- 009 as part of the 2013 EPA Green Infrastructure Technical Assistance Program for the Northside Community near downtown Spartanburg, South Carolina.

Metropolitan Government of Nashville and Davidson County Green Infrastructure Master Plan (Tennessee)
https://www.nashville.gov/Portals/0/SiteContent/WaterServices/Stormwater/docs/reports/GreenInfrastructureRpt101120.pdf
This joint initiative to develop a "plan for the installation of Green Infrastructure. The plan includes general location and type of SCM installation and its estimated impact on the CSS," and a list of future infrastructure projects for the capital improvement plan, including maintenance costs and estimated impact on the CSS.

Regional Green Infrastructure Plan (for the Milwaukee Metropolitan Sewerage District, Wisconsin)
https://www.mmsd.com/what-we-do/green-infrastructure/resources/regional-green-infrastructure-plan
This document is a systematic plan to implement regional green infrastructure. The District has a 10-year history of partnering on green infrastructure projects, authored "Fresh Coast Green Solutions" to provide a foundation for a plan, and set 2035 goals for significantly more green infrastructure.

– MAPS –

LAND COVER MAP AND TUTORIAL

Below are links to an ArcGIS interactive map of the study area. The map layers include USA Census and Populated Places and USA NLCD Land Cover, along with a gallery of Base Maps. A tutorial video is included. The map can be found here: https://aub.ie/landcover_map
and the video can be found here: https://aub.ie/landcover_map_tutorial