NORTH CAROLINA
Department of Environmental Quality

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Subtask 2.11: Identification and Evaluation of Online Flood Mitigation Decision-Making Support Tools

North Carolina Flood Resiliency Blueprint

Prepared for the North Carolina Department of Environmental Quality by AECOM and ESP Associates

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Definitions

A comprehensive list of definitions applicable to multiple North Carolina Flood Resiliency Blueprint documents is provided in a separate document.

Acronyms

FEMA – Federal Emergency Management Agency

FFE – First Floor Elevation

FIRM – Flood Insurance Rate Map

FIS – Flood Insurance Study Report

FRIS – (North Carolina) Flood Risk Information System

LiDAR – Light Detection and Ranging

NCDIT – North Carolina Department of Information Technology

NCEM – North Carolina Emergency Management

RARR – Risk Assessment/Risk Reduction Tool (Mecklenburg County)

RMAT – Resilient Massachusetts Action Team

1 Introduction

2.11 Purpose: A primary, overarching goal of the North Carolina Flood Resiliency Blueprint ("the Blueprint") is to form the backbone of a statewide flood planning process that increases community resiliency to flooding which ultimately leads to a prioritized set of projects and funding strategies that can be implemented by State agencies, local governments, and regional resource managers. The Blueprint will guide these stakeholders in identifying and selecting potential flood mitigation strategies. Phase One of the Blueprint process included stakeholder engagement, a data gap analysis, recommendations, and the development of the Draft Blueprint guidance document. The next phase (Phase Two) of the Blueprint will include the development of a Decision Support Tool. The Blueprint Decision Support Tool will be a critical component of the Blueprint process allowing stakeholders to leverage previously developed data and analysis to make informed decisions for risk evaluation and assessment, mitigation alternative evaluation and tracking the Blueprint's progress using objective metrics. The datasets serving as inputs to the decision support tool and the associated outputs should be updated periodically (recommended annually).

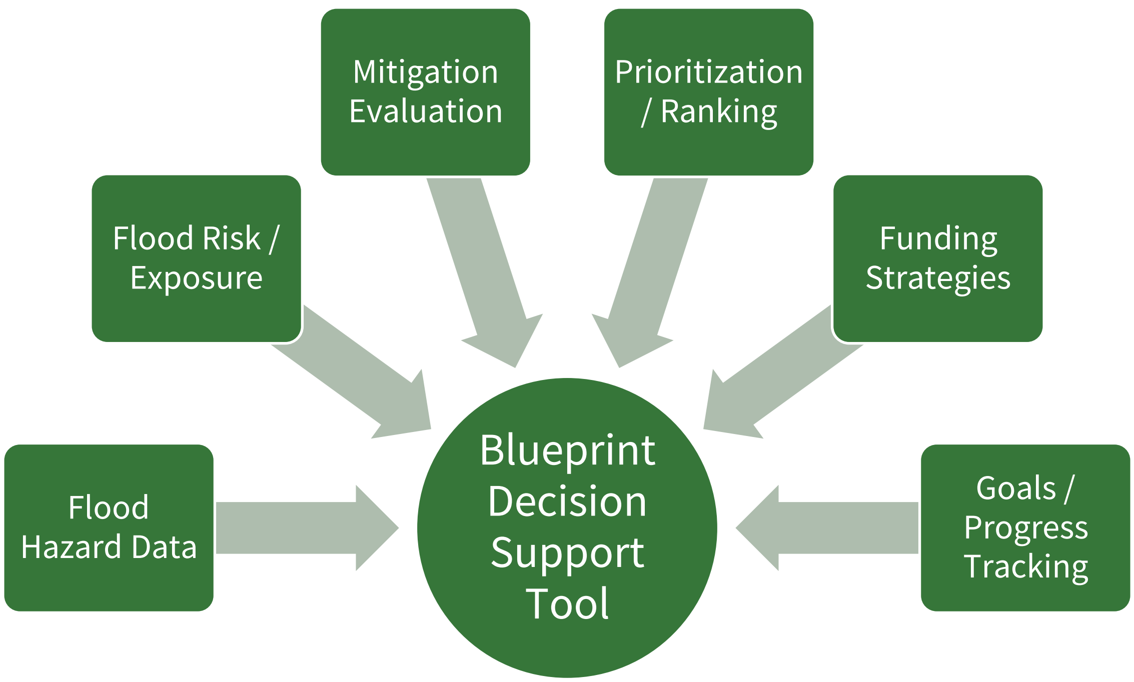

Figure 1-1: The Blueprint Decision Support Tool will leverage various datasets and analyses.

This document identifies and evaluate three existing online flood mitigation decision-making support tools. This report also includes the pros, cons, and any changes recommended for incorporation to meet the Blueprint requirements. This report discusses how databases supporting those tools are administered and requirements of those tools including the feasibility of their deployment on North Carolina Department of Information Technology (NCDIT) infrastructure.

Recommendations for decision-making support tools necessary as they relate to the Blueprint goals are covered in Task 3 and Task 4 of this phase of the Blueprint.

2 Background

Residential and commercial development along riverine and coastal waterways has always existed and continues to increase, resulting in more risk to both people and property within urban and rural areas. North Carolina faces many of the same problems as other coastal and riverine areas across the country, as many find it desirable to be located near large waterbodies. 2023 research by the University of North Carolina at Chapel Hill (Full article: Growing Safely or Building Risk? (tandfonline.com) states for every property removed through buyouts from 1996 to 2017, more than ten new residences were built in floodplains. This, along with an increase in severe flooding events, is driving the need to support risk reduction, increase resilience and implement mitigation projects.

Hydrologic and hydraulic modeling accuracy and resolution, geospatial technology (GIS), building and demographic data, and web development platforms have enabled the development of decision support tools over the past decade. These decision support tools continue to be enhanced with additional mapping technology and data aggregation tools to improve the evaluation of flood risk, consequences, and mitigation alternatives in a user-friendly, mobile interface. Since 2000, the State of North Carolina has been at the forefront of the development of these data and technologies for flood risk communication, management and flood warning.

There are several existing decision support tools that are being used to inform decisions for flood risk awareness and mitigation purposes. Three of these tools are evaluated herein to review pros, cons, and changes which could be implemented to better fit with the mission of the Blueprint efforts. The three decision support tools discussed on the following pages are:

- Mecklenburg County's Risk Assessment/Risk Reduction Tool (RARR)
- North Carolina's Flood Risk Information System Tool (FRIS) and Flood.NC.Gov
- Resilient Massachusetts Action Team Tool (RMAT)

Various stakeholders will use the Blueprint tool including NC DEQ Division of Mitigation Services, NC Emergency Management, NC Department of Transportation, other State and Federal agencies, grant applicants, local planners, COG staff, local floodplain managers, local emergency managers, conservation NGOs, property owners, private investors and academics. Various combinations of stakeholders may ultimately gain value from using the tool (or tool extensions) for applications such as:

- Relative and absolute risk assessment (watershed scale, jurisdictional scale, site scale)
- Mitigation planning (watershed scale, jurisdictional scale)
- Project analysis
- Policy analysis
- Project prioritization
- Analysis of cumulative future hazards
- Disaster response planning
- Comp plan development
- Zoning map development

3 Evaluation of Example Decision Support Tools

3.1 Mecklenburg County Risk Assessment/Risk Reduction Tool (RARR)

3.1.1 Tool Overview

A general overview of the tool's purpose, functionality, and general inputs are summarized below.

Please visit the following link for additional information: https://www.charlottenc.gov/Services/Stormwater/Flood-Preparedness-and-Mitigation.

Mecklenburg County maintains a proactive flood mitigation program which works to reduce flood losses through a combination of mitigation outreach, planning, and project implementation. Over the last 15+ years, the County has invested in the preparation of updated floodplain maps and flood mitigation plans, collection of high-resolution base mapping and building inventory data, and development of a dense gage network and flood warning system. The County has implemented numerous multifaceted mitigation projects which have resulted in the acquisition of over 400 flood-prone structures, restoration of stream corridors, and development of a unique community flood mitigation grant program ("retroFIT"). As part of a multi-year collaborative effort with the Department of Homeland Security (DHS), Mecklenburg County developed a technology framework and sophisticated flood risk analysis tools to aid the County and all municipalities within it in addressing flood risk. The effort includes updating and enhancing the County's Risk Assessment/Risk Reduction (RARR) system.

The RARR initiative is a data-driven framework with associated tools that evaluates properties in the floodplain and prioritizes potential mitigation projects based on a multi-tier, relative scoring system. The RARR system integrates local datasets with a geospatial toolset logic to calculate a "Flood Risk Score" and evaluate/prioritize potential mitigation options at the building/property level. The result of these tools and enterprise database is the RARR flood mitigation planning decision support tool.

The RARR tool integrates numerous datasets/inputs, as well as the Federal Emergency Management Agency (FEMA) hazard datasets shown below:

- Topographic Data
- Hydrographic Data
- Flood Hazard Mapping
- Community Non-Encroachment Areas
- Hydrologic & Hydraulic Modeling
- Enhanced Risk Datasets
- Historic Storm Hazard Mapping
- Buildings Footprints & Database
- Stormwater Infrastructure
- NFIP Policy Data
- Completed Flood Mitigation Projects
- Critical Facilities
- Capital Improvement Projects
- Tax Parcels
- FEMA Elevation Certificates
- Building Permit Information
- Demographic/Social Vulnerability
- Regulatory/Water Quality Buffers
- Environmental Focus Areas

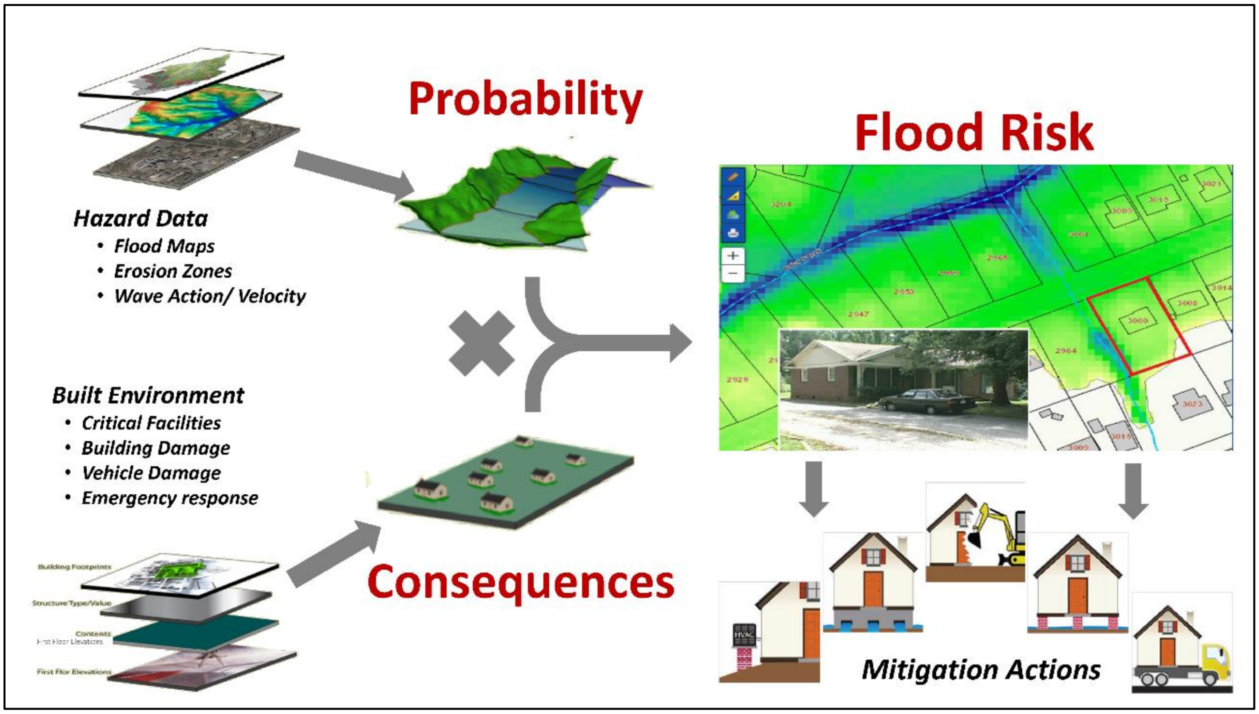

Figure 3-1: RARR Flood Risk and Mitigation Concept

Figure 2**Error! Reference source not found.** illustrates how the RARR tool moves from multiple inputs to structure-level risk assessment/score. The tool applies a unique and sophisticated logic created specifically for Charlotte Mecklenburg Storm Water Services. Flood risk scores are developed on a property-by-property basis through recognition of potential impact categories (e.g., finished floor/living space) of the site, applying probabilities of a flood event, and including any additional risk factors associated with the location.

Table 1: The Mecklenburg County RARR Flood Risk Score Components

Risk Score Component	Risk Score "Base"	Component Description	Flood Risk Score Component Computation Method Details	Example Scoring *(Triggering Component Probability x Base Score)*
A	**2,800**	Flooding above the lowest finished floor (FFE) of a building	Compare flood elevations of seven flood events with the floor elevation (FFE) from the Elevation Certificate (EC); apply the weight of the flood event for the flood elevations exceeding FFE to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
B	**1,200**	Flooding of electrical and/or mechanical equipment	Compare flood elevations of seven flood events with the Lowest Mechanical Elevation (LME) from the EC; apply the weight of the flood event for the flood elevation exceeding LME to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)

Risk Score Component	Risk Score "Base"	Component Description	Flood Risk Score Component Computation Method Details	Example Scoring *(Triggering Component Probability x Base Score)*
C	**1,000**	Flood water is touching a portion of the building (accessibility is limited during flooding)	Compare flood elevations of seven flood events with the Lowest Adjacent Grade (LAG) from the elevation certificates. Apply the weight of the flood event for the flood elevations exceeding LME to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
D	**1,100**	Property is completely surrounded by flood water (may be inaccessible during flooding)	Compare parcels with each floodplain mapping layer to determine which events surround the parcels and apply the weight for the event to the base score. Use the larger flood event returned by Component D and E.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
E	**500**	Structure is completely surrounded by flood water (may be inaccessible during flooding)	Using the primary building location; spatially intersect with each floodplain mapping layer to find the event that surrounds the building; apply the weight for the event to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
F	**2,700**	Structure is completely surrounded by flood water and is a critical facility (may be inaccessible during flooding)	If structure is completely surrounded by water, spatially intersect point feature class of critical facilities (CF) with parcel shape, and test if CF point lies within the building; apply the weight for the triggering event to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
G	**N/A**	Structure is completely surrounded by flood water and is multi-family residential	If structure is completely surrounded by water, check for multi-family residential types; apply the weight for the event to the base score.	0.5 * Component B Score + Component E Score
H	**N/A**	Number of units in multi-family residential building completely surrounded by flood water	If multi-family residential is completely surrounded by water, check for number of units in parcel database. Category H score = G Score * (units – 1). Parcel contains number of units for apartments.	Component G Score * [Parcel Units] – 1
I	**2,000**	Flood water touching building with structural	Compare flood elevations of 7 flood events with the LAG from the EC; apply the weight of the	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*)

Risk Score Component	Risk Score "Base"	Component Description	Flood Risk Score Component Computation Method Details	Example Scoring *(Triggering Component Probability x Base Score)*
		damage as a result of hydrostatic pressure of water with depth of 3ft+	flood event for the flood elevation exceeding LAG + 3ft to the base score.	25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
J	**600**	Flooding of SIGNIFICANT exterior property improvements on single- family residential properties	Check if parcel shape spatially contains any points for significant property improvements; for each significant point found, check if it is contained within each floodplain mapping layer; apply the weight for the event to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
K	**300**	Flooding of MODERATE exterior property improvements on single- family residential properties	Check if parcel shape spatially contains one or more moderate improvements; for each moderate point found, check if contained within each floodplain mapping layer; apply the weight for the event to the base score. If multiple points are found, use the flood of greatest magnitude.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
L	**600**	Flooding around area where single-family residential vehicles are typically parked	Check if parcel shape spatially contains any points for parking locations. For each point found, check if contained within each floodplain mapping layer; apply the weight for the event to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
M	**30**	Flooding impacting any portion of the parcel/yard	Spatially intersect the parcel with each floodplain mapping layer; apply the weight for the event to the base score.	2-yr: 0.5 *(*base score*) 5-yr: 0.2 *(*base score*) 10-yr: 0.1 *(*base score*) 25-yr: 0.04 *(*base score*) 50-yr: 0.02 *(*base score*) 100-yr: 0.01 *(*base score*) 500-yr: .002 *(*base score*)
			Total Risk Score (Numeric Value) ***(Updated Quarterly)***	***Sum of the Applicable Component Calculations Above***

Next, potential mitigation techniques are evaluated at the building and property levels using a particular parcel's risk scores. Based upon the criteria encoded in the tool logic, each of the mitigation techniques are assessed for viability, estimated project cost, benefit-cost ratio, property location, and social vulnerability (if data is available). Final mitigation recommendations are sorted and prioritized taking into account community values (expanding the greenway system, improving water quality, etc.) to create a clear course of action for Mecklenburg County and the property owners to potentially pursue for flood risk reduction. A series of 19 mitigation techniques are evaluated for each property include the following:

1. Property Acquisition
2. Structure Demolition and Rebuild
3. Property Acquisition/Structure Relocation
4. Property Acquisition, Demolition, or Relocation, and Re-sale
5. Structure Elevation
6. Abandon Basement and Fill
7. Dry Floodproofing of Structures
8. Wet Floodproofing of Structures
9. Audible Flood Warning System for Individual Property
10. Storm Water Detention Facilities
11. Storm Water System Control
12. Automated Flood Notifications
13. Public Education
14. Flood Insurance
15. Levee/Floodwall Protection for Multiple Structures
16. Protecting Service Equipment
17. Partial Dry Floodproofing
18. Partial Wet Floodproofing
19. Levee/Wall/Berm for a Single Structure

The system also includes a web-based decision tool for viewing and filtering the flood risk data (scores and mitigation evaluations) in a user-friendly map and dashboard interface. Users can filter the map and dashboard views by watershed, municipality, or a user-specified extent. The tool's dashboards dynamically update for the selected geographic area or what is visible on the current map view.

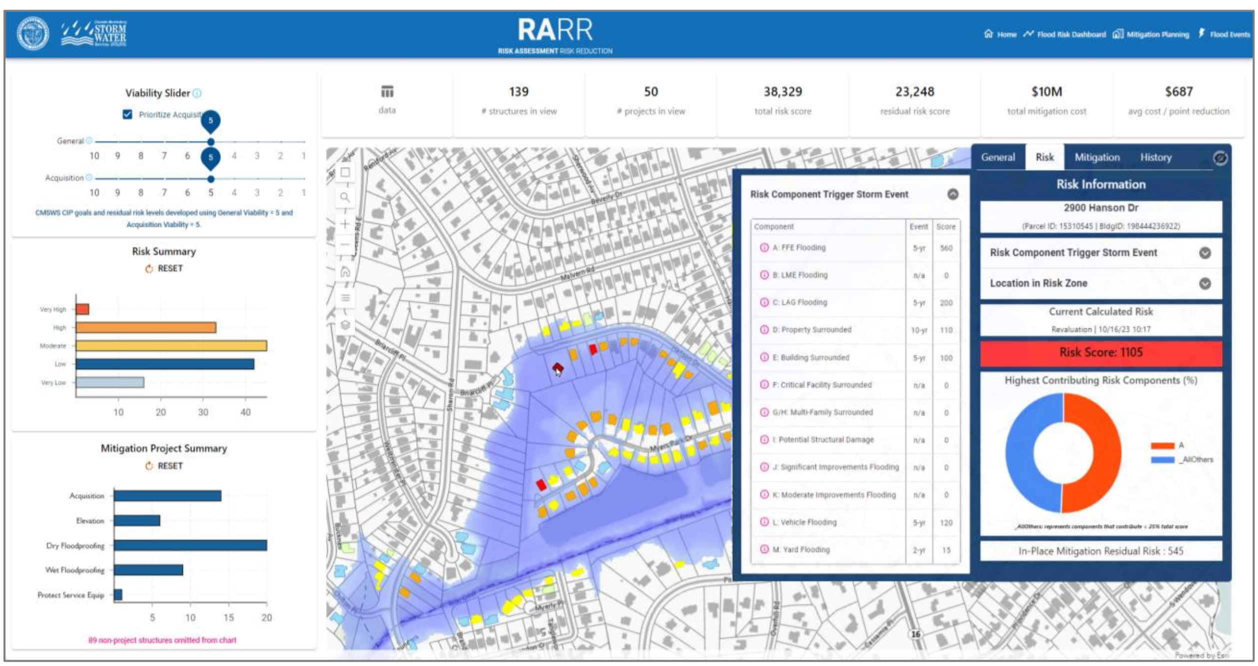

Figure 3-2: The RARR dashboard provides building level flood risk score components.

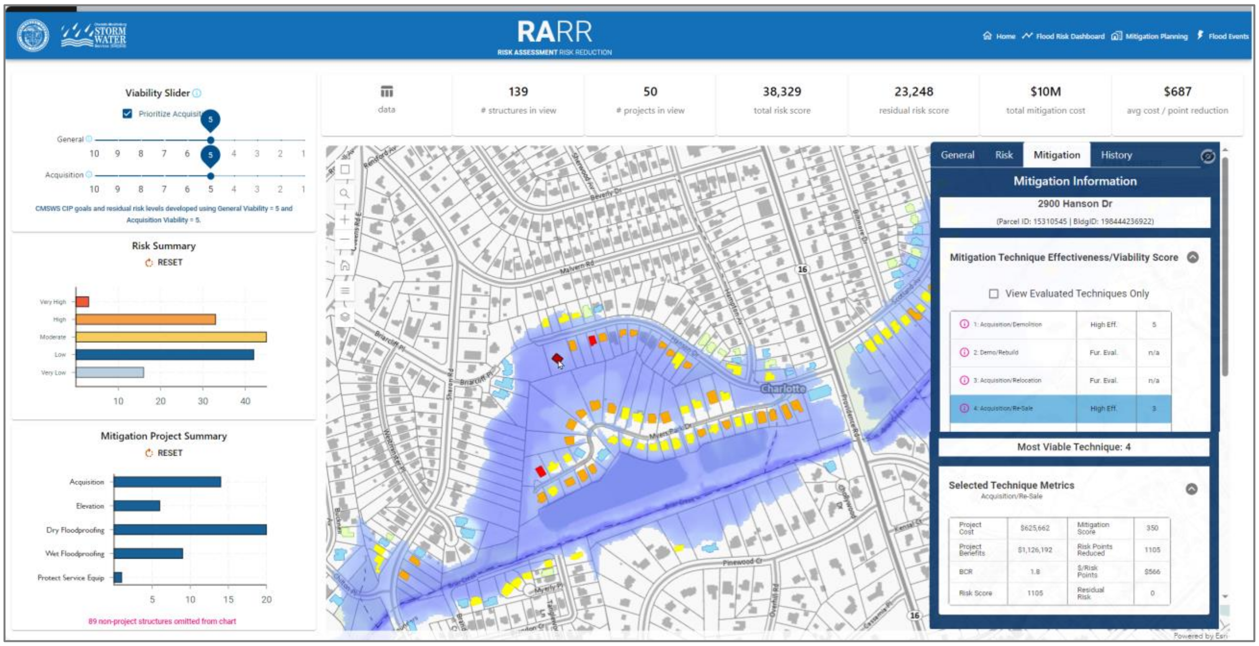

Figure 3-3: The RARR dashboard provides a review and prioritization of up to 19 different building-level flood mitigation alternatives.

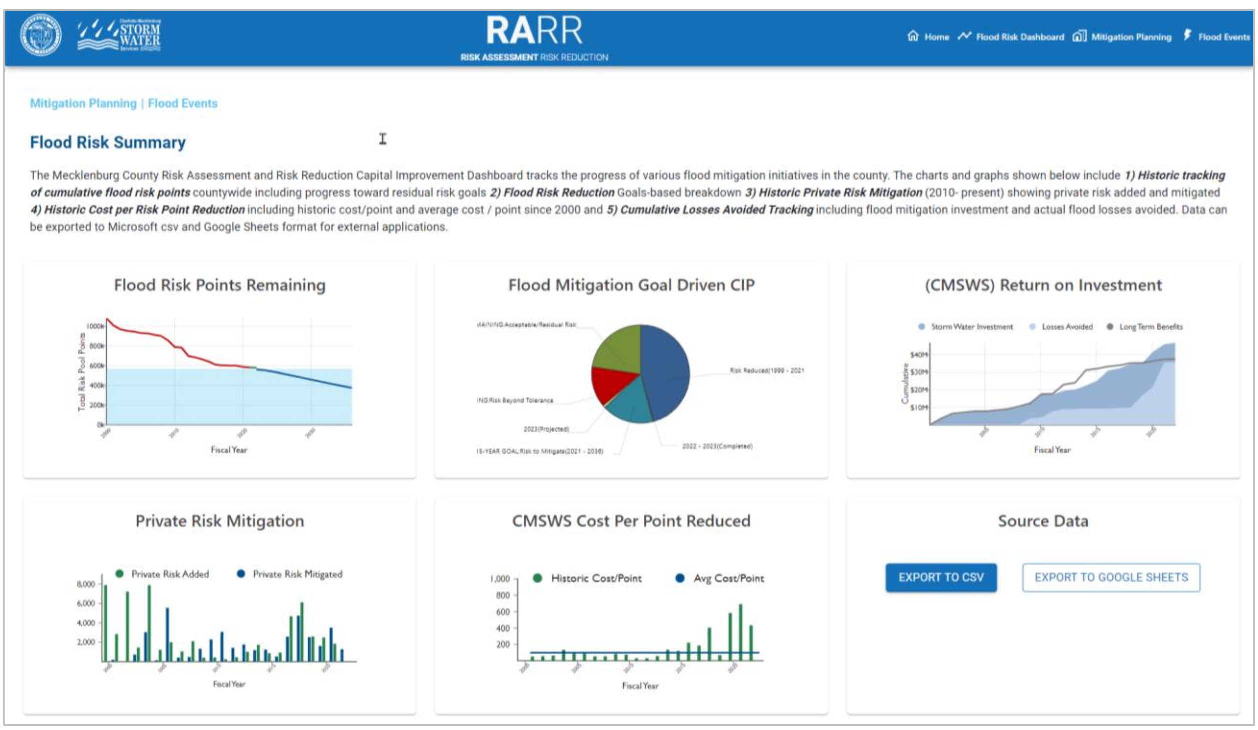

Figure 3-4: The RARR dashboard provides program management performance tracking metrics.

3.1.2 Database Administration

The core infrastructure of the tool's enterprise geodatabase resides securely on Mecklenburg County's on-premises servers, managed by the Information Technology Services team. Administration is performed through ArcGIS Server and Microsoft SQL Server 2016, which also provide the data access layer for the web interface to query and retrieve spatial data. Data updates to calculations of losses avoided, damage estimates, and current conditions are accomplished by a collection of geoprocessing scripts, scheduled to run by the Windows Task Scheduler. Updates to static data such as FEMA maps, county risk assessments, mitigation, building footprints, and insurance certificates are performed ad-hoc with ArcToolbox scripts.

3.1.3 Pros, Cons, and Blueprint Recommendations

Table 2 describes the pros and cons of the RARR toolset relative to the Blueprint effort.

Table 2: Pros and Cons: RARR Toolset Pros and Cons

Pros	• Evaluates and assigns a risk score to all flood-prone buildings within the County. • Evaluates 19 potential mitigation techniques at each flood-prone building. • Determines the most viable mitigation action at each flood-prone building. • Geoprocessing toolsets allow for easy data maintenance.
Cons	• Only available for Mecklenburg County. • The tool only considers building level flood mitigation alternatives. • Flood-prone as defined by the tool includes buildings identified through FEMA regulatory study results. • Not publicly available. Cannot be leveraged directly. • Does not include coastal factors in risk scoring or mitigation evaluations (currently specific to piedmont region). • Relies on data/datasets (foundation type, first floor elevation, parking points) that do not exist statewide. • Would require ongoing maintenance/updates for supporting datasets. This may be difficult to keep up with at the statewide building level. • Does not consider future climate.
Recommended Blueprint Features	• The Blueprint Decision Support Tool should expand on the RARR concepts to include regional detention and nature-based mitigation actions and the associated aggregated benefits. • As this tool is not available publicly, it can only serve as a model for the Blueprint. Care should be taken to ensure the Blueprint Decision Support Tool can be used equally well in data-rich and data-poor areas. • Develop standardized methods for quantifying flood risk/impact category scores across NC basins, with supplemental factors added for different regions. • Incorporate a wide range of accepted mitigation options to fit many contexts. • Recommendations of mitigation techniques to deploy take into account locally defined community values, such as expanding the greenway system, improving water quality, etc.

3.2 North Carolina Flood Risk Information System (FRIS) and Flood.NC.Gov

3.2.1 Tools Overview

A general overview of the tool's purpose, functionality, and general inputs are summarized below.

Please visit the following links for additional information:

- FRIS: Flood Risk Information System
- Flood.NC.Gov: Flood.nc.gov – North Carolina's Flood Information Dashboard

FRIS: The State of North Carolina Floodplain Mapping Program provides the FRIS website for citizens of North Carolina as a public service. FRIS contains risk assessments that are database-driven, as well as digitally accessible flood hazard data, maps, and reports. Along with providing geospatial base map data, imagery, and light detection and ranging (LiDAR) data, the site also provides hydrologic and hydraulic models that are available for download, as well as FEMA Flood Insurance Study (FIS) reports. Users can quickly plug in an address, city, ZIP code, or county into the system to (1) view general flood zone and property information, (2) evaluate property-specific flood risk, (3) explore risk reduction strategies and (4) access FIS reports, stream engineering models, and export relevant map data. FRIS inputs can be found in Table 3, and an example of FRIS Flood Risk Information is shown in Figure 3-5. While values are automatically populated within the Flood Risk Information dropdown, the site also allows for users to revise certain information, either to reflect more accurately known conditions or perform sensitivity tests. The Flood Risk Information tab also provides users with various risk reduction (mitigation) options and estimated costs for those options.

Table 3: FRIS and Flood.NC.Gov Inputs and Downloadable Information

Inputs	Downloadable Information
• Buildings (polygon) attributed with elevation information, occupancy type, foundation type, etc. • FEMA Flood Insurance Rate Map (FIRM) database (floodplains, streams, FIRM panels, etc.) • FEMA Depth Damage Curves (table) • Addresses (points) • Multi-Return water surface elevation**s (**raster) • **Flood probability** datasets (raster) • Stream/Flood Warning Gages • Parcels (polygon) • Mitigation Alternatives Database	• Effective Hydraulic Models • Supporting GIS Datasets • LIDAR topographic datasets • Regulatory Flood Insurance Reports • Site Specific FEMA Digital Flood Insurance Rate Maps

Figure 3-5: FRIS displays regulatory flood hazards and probability/damage estimates.

Flood.NC.Gov: As a companion Decision Support Tool to the FRIS application, the State of North Carolina developed the Flood.NC.Gov flood risk communication portal for non-regulatory and mitigation purposes. The Flood.NC.Gov portal includes a more user-friendly interface to display flood risk information to the public and stakeholders. The information can be accessed via a home page by property address or navigating and exploring a statewide map.

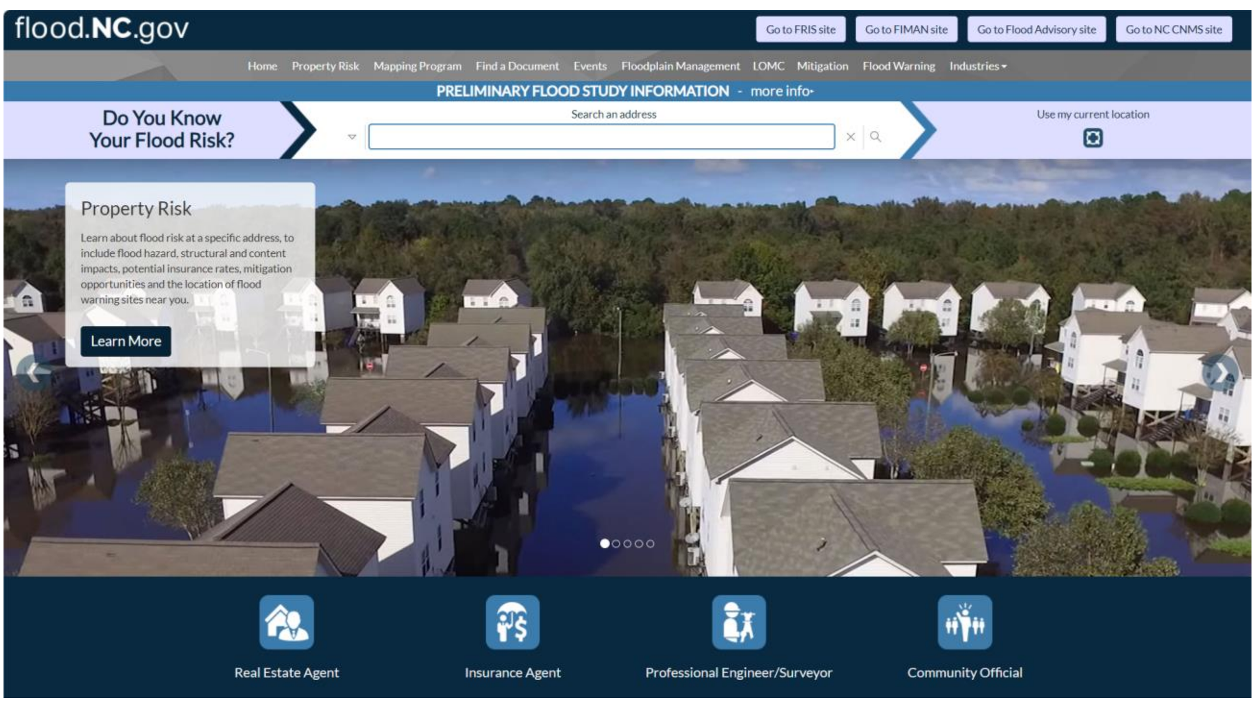

Figure 3-6: The Flood.NC.Gov homepage can be used in desktop or mobile platforms to guide users to building level flood risk, impacts and pre-evaluated mitigation alternatives.

An example of the decision support tool functionality of the Flood.NC.gov tool is the building level dashboard developed for each at risk building. This dashboard leverages the State's enterprise flood hazard and risk geodatabases to display this data in a responsive easy to understand format.

Figure 3-7: Example of the Flood.NC.Gov Building Level Dashboard with interactive widgets.

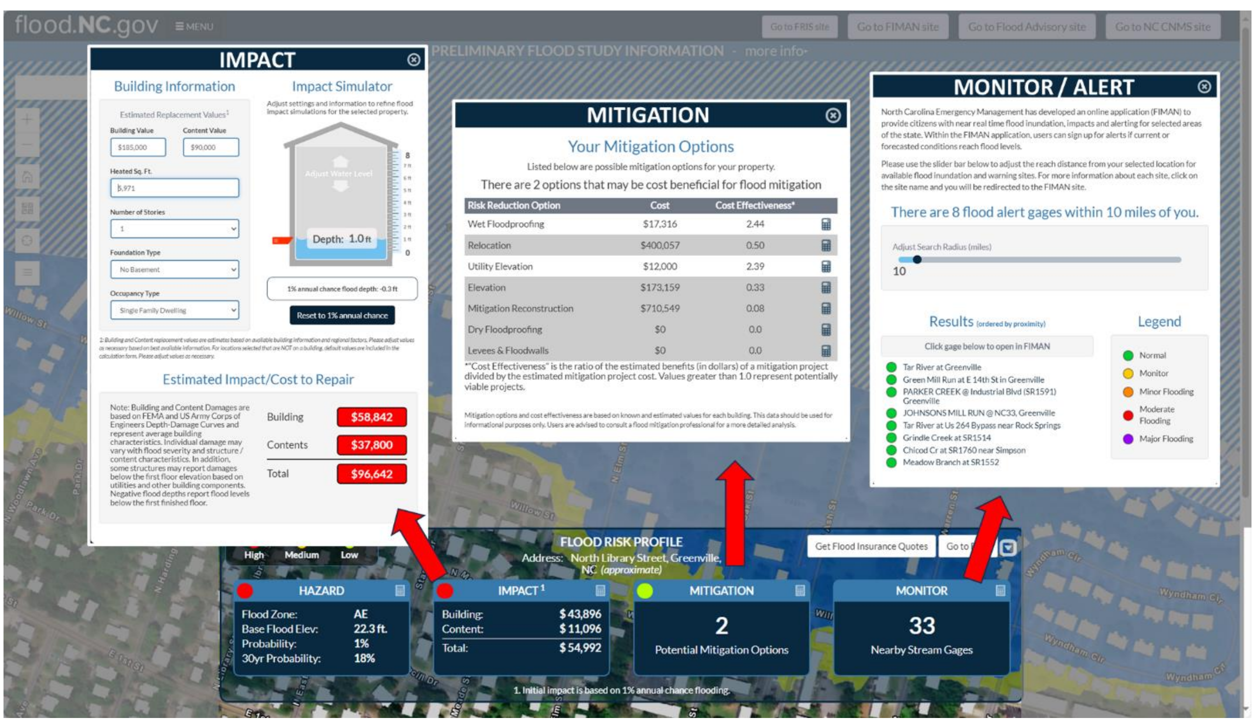

Figure 3-8: Flood.NC.Gov includes building level "dashboards" for each at-risk building including interactive widgets for impacts, mitigation and nearby gages.

The NC.Flood.Gov decision support tool offers a dashboard for at-risk properties in the state. For each selected property, the dashboard displays four (4) informational widgets that offer interactive data windows. These widgets are summarized below:

- **HAZARD:** The Hazard widget shows the current FEMA flood zone that the property is inside and includes information about the regulatory (1% annual chance) base flood elevation, the annual exceedance probability, and the likelihood of flooding over the next 30 years. This widget also allows interactive download of the official FEMA flood insurance rate map (DFIRM) from the enterprise database.
- **IMPACT:** The Flood Impact widget displays an interactive graphic showing the current flood depth above the finished flood elevation of the building. This interactive graphic can be adjusted to show how structural and contents damage vary based on flood depth and building properties (e.g., foundation, number of stories, replacement values, etc.)
- **MITIGATION:** The Flood Mitigation widget displays up to seven building-specific flood mitigation measures. These mitigation measures have been pre-analyzed for cost effectiveness based on building characteristics and flood hazards.
- **MONITOR:** The Monitor Widget leverages the State of North Carolina Flood Inundation Mapping and Alert (FIMAN) System databases to search within a variable radius of the selected building and will redirect the user to the FIMAN website where users can register to receive alerts when existing or forecasted conditions indicate flooding conditions.

3.2.2 Database Administration

The enterprise geodatabases for FRIS and Flood.NC.Gov are hosted on-premises by North Carolina Emergency Management (NCEM). The underlying map services are hosted by NCEM and then utilized by both tools to query and display data. ArcGIS Server plays a pivotal role in managing and optimizing this geospatial ecosystem, ensuring a seamless, real-time data querying and visualization experience for users. An ASP.NET API provides the interactive web pages used to connect and interact with the database. A data repository is available to retrieve various datasets such as LiDAR, FEMA maps, LiDAR topographic data, and engineering models from the database.

3.2.3 Pros, Cons, and Blueprint Recommendations

Table 4 summarizes the pros and cons of the Flood Risk Information System and Flood.NC.Gov relative to the Blueprint effort.

Table 4: Pros and Cons: Flood Risk Information System and Flood.NC.Gov

Pros	• Mobile friendly environment (Flood.NC.Gov). • Datasets access federated, enterprise databases that are continually updated for consistency. • Evaluates risk at the building level. • Communicates Flood Probability with not only the annual exceedance probability but the probability of flood impacts occurring over the next 15 and 30 years. • Allows users to override defaults with better/different information (e.g., building value, stories, square feet, foundation, occupancy). • Provides estimated damages (structural and contents). • Provides risk reduction options and estimated costs and cost effectiveness. • Communicates up to seven building level mitigation alternatives (elevation, flood proofing, acquisition, etc.) with pre-analyzed cost effectiveness. • Provides links to nearby flood monitoring, warning and alert sensors (gages) leveraging the State's Flood Inundation Mapping and Alert Network (FIMAN).
Cons	• The systems do not fully consider the full spectrum of quantifying flood risks including social vulnerability, pluvial flooding, flood velocity, vehicle damage, ingress and egress issues, emergency response, or environmental impacts. • The system does not allow for "batch" evaluation of buildings and results can only be assessed one building at a time. • The system only considers building asset impacts and does not consider other infrastructure and environmental aspects. • The system does not include social vulnerability datasets or considerations. • Unable to revise first floor elevation (FFE) (can calculate assumed FFE based on Depth Above Finished Floor in Flood Risk Information tab and Flood Elevations in Flood Information tab). • The sites do not evaluate nature-based mitigation alternatives. • The sites do not evaluate regional/detention flood mitigation alternatives. • The building stock datasets and replacement value attributed need update and maintenance. • Static models contain fixed results. • The modeling only considers future conditions for a small subset of the State and does not consider climate change or sea level rise.
Recommended Blueprint Features	• The Blueprint Decision Support Tool should allow for user overrides of certain default values in the Blueprint database when evaluating mitigation alternatives or as part of the prioritization modules (similarly to FRIS and Flood.NC.Gov). • The Blueprint should continue to build from the foundational data included in these decision support tools leveraging databases and maintenance as much as possible. • The Blueprint should explore the concept of a multi-variable flood risk "score" tied to flood probability, impacts, social vulnerability and other factors. • The Blueprint Decision Support Tool should evaluate nature-based and regional detention mitigation alternatives and the aggregated costs and associated benefits (e.g., losses avoided, cumulative flood risk score reduction, etc.). • The Blueprint should leverage updated 2-dimensional hydrologic and hydraulic modeling including fluvial, pluvial and future conditions modeling statewide for use in the tool. • Built-in flexibility for tool inputs in case values change over time.

3.3 Massachusetts Climate Resilience Design Standards Tool

3.3.1 Massachusetts Climate Resilience Design Standards Overview

In 2019, the Resilient Massachusetts Action Team (RMAT) was officially launched. This group is responsible for implementation, monitoring, and maintenance of the Massachusetts Climate Resilience Design Standards Tool. The RMAT is tasked with monitoring and tracking the 2018 State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) implementation process; making recommendations; and supporting agencies on plan updates, and facilitating coordination across State government and with stakeholders, including businesses, cities, and towns.

The focus of the Climate Resilience Design Standards Guidance project is to integrate best available statewide climate change projections and hazards data to inform early/conceptual planning and design of infrastructure, buildings, and natural resource assets in Massachusetts in conjunction with traditional engineering assessments, feasibility analyses, and cost-benefit analyses.

More information on the standards and guidance for the creation of the tool can be found at the following locations:

- Introduction: https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/V1.2_SECTION_1.pdf,
- Project Inputs: https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/V1.2_SECTION_2.pdf,
- Preliminary Climate Risk Screening: https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/V1.2_SECTION_3.pdf,
- Climate Resilience Design Standards: https://eea-nescaum-dataservices-assets-prd.s3.amazonaws.com/cms/GUIDELINES/V1.2_SECTION_4.pdf

3.3.2 Tool Overview

A general overview of the tool's purpose, functionality, and general inputs are summarized below.

Please visit the following link for additional information: https://resilient.mass.gov/rmat_home/designstandards/.

In July 2022, the RMAT introduced the Climate Resilience Design Guidance, a downloadable document outlining best practices, forms, and recommended climate resilience design standards for state agencies' capital planning process and grant applications. In addition, the team developed a Climate Resilience Design Standards Tool ("the Tool"), which is an interactive web-tool that provides a preliminary climate risk screening and recommended climate resilience design standards for projects with physical assets. It is also a dynamic resource in which new iterations are released as updated datasets or climate models become available.

The Tool uses the best available data available at the time of the latest update and is subject to revision as more detailed data, new science or new climate models become available. Although the Tool does not specify the projects that can be evaluated, it is not recommended for the following project types: projects with no physical assets or location, projects without discrete locations (e.g., Statewide or regional), projects outside of Massachusetts, or demolition projects.

The Tool is available to the public, and anyone with a valid email address can create an account. The overall tool workflow progresses as follows: (1) Start Here page, (2) Locate Project page, (3) Project

Inputs page (4), Project Output page, (5) View Report page, and (6) Submit Project page. The Start Here page provides a comprehensive overview of the Tool and its associated resources. The Locate Project page leverages GIS applications to mark the appropriate position of a project. Completing a series of questions found on the Project Inputs page then feeds into the Project Outputs page, where relevant scores and ratings are connected to different climate resilience indicators as described in the paragraph below. The View Report page summarizes the information collected up to this point for any downloading needs. Finally, the Submit Report page solidifies the project details within the system for administrators to see and becomes part of the official public record.

Based on user-provided information, the Tool will provide Project Outputs including evaluation of whether the project is within a mapped Environmental Justice population; Ecosystem Service Benefits and Preliminary Climate Exposure Scores; Preliminary Climate Risk Ratings; and recommended Climate Resilience Design Standards. The Tool is considered supplementary to the Climate Resilience Standards & Guidance document, and it is intended that the users of the Tool will apply the Project Outputs to inform, develop, support, and consult on project planning and early design. The Project Outputs are summarized in a downloadable report through the Tool that can be attached to Requests for Proposals, basis of design reports, and/or grant or permitting applications. It is assumed that much of the needed information will be provided by the user. The level of needed data is specific to the area chosen and characteristics of the geographic area. A graphic of the typical design process using The Tool is seen in Figure 3-9.

RMAT Tool User inputs include:

- Project Name
- Project location and extents (drawn as a polygon within The Tool with option to supplement with GIS Parcel boundaries)
- Core Project Information (estimated capital costs, contact info, grant related application, etc.)
- Project Ecosystem Benefits (questions about storm damage reduction, green infrastructure, water quality, etc.)
- Project Exposure (questions about flooding history, impervious area, etc.)
- Project Assets (type/number of assets, construction start, useful life, etc.)
- Project Asset Criticality (time asset can be inaccessible, scope, severity, etc.)

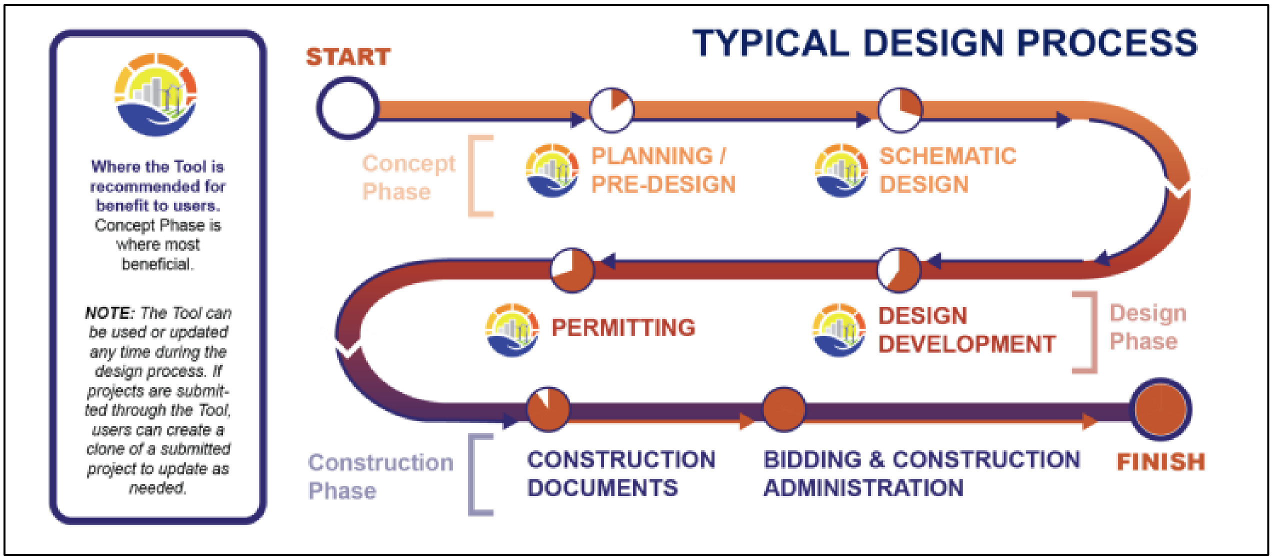

Figure 3-9: Typical Design Process using The Climate Resilience Design Standards Tool.

3.3.3 Database Administration

The enterprise geodatabase for the RMAT tool is administered through Esri's ArcGIS software suite and Microsoft's SQL Server. Through ArcGIS server, a REST application programming interface (API) is configured to allow the web interface to query, filter, and view the spatial and geographic data stored within the geodatabase. Any non-spatial data that is saved and retrieved through the web interface is accessed via a secure ASP.NET API using an Open Database Connectivity (ODBC) driver to execute stored procedures and query records. Maps and data for this viewer is held in "ResilientMass". This tool is created by the Massachusetts Executive Office of Energy and Environmental Affairs to support the Commonwealth with climate change science and tools.

3.3.4 Pros, Cons, and Blueprint Recommendations

Table 5 describe potential pros and cons of the identified toolsets relative to the Blueprint effort.

Table 5: Pros and Cons: MA Climate Resilience Design Standards Tool

Pros	• Provides preliminary climate resilience analysis, including flexible adaptive pathways. • Provides recommendations based on current climate data. • Informs climate-resistant capital planning. • Provides uniform and automated support for evaluation and grant applications. • Supported by robust guidance, methodology documents, best practices, and training resources including videos. • Considers environmental justice (EJ) and ecosystem benefits within the Overall Project Scores Output. This is demonstrated by whether or not the project polygon is located within a mapped EJ population and by generating ecosystem benefits score for the project. • Significant feedback effort completed for the launch of the beta tool, including 13 focus groups, a public feedback survey, and agency feedback. Feedback was synthesized and organized by priority. Incorporated changes

	informed by stakeholder feedback are identified in the Climate Resilience Design Standards and Guidance – Overview. • Free and publicly available.
Cons	• Not recommended for projects with no physical assets or location. • Not recommended for demolition projects. • Specific to Massachusetts coast and not recommended for projects outside of state/region. • Tool would need to be re-created/made compatible with North Carolina design standards. • Support datasets specific to North Carolina would need to be created/used (water surface elevation, wave action, sea level rise, storm surge, etc.). • Designed with the goal of "implementing priority actions" from Massachusetts' State Hazard Mitigation and Climate Adaptation Plan (2018); state agency, local government, and other stakeholder use of the tool is noted but secondary.
Recommended Blueprint Features	• Develop best practices, guidance, and training videos to accompany the launch of the Blueprint Decision Support Tool to aid stakeholder use and implementation of the Blueprint. • Incorporate EJ and ecosystem benefits considerations within the Blueprint Decision Support Tool. • The Blueprint will be designed to input existing state, regional, and local actions in addition to new actions formed by local governments and basin-wide groups and for use by wider stakeholder group (not just state hazard mitigation plan implementation). • Conduct a similarly robust engagement and feedback effort for the beta launch of the Blueprint Decision Support Tool among state agencies, TAGs, and the public to promote transparency and continuous improvement of the Tool.

4 Administration of Tools

Apart from the basic tools, most of these tools have complex systems supporting the data being generated. To support the rapid dissemination and distribution of data required to make the Blueprint project accessible across the state, an evaluation of software and hardware requirements will be needed. To ensure the accuracy and currency of the data that powers these tools, updates are typically managed through a combination of manual interventions and the deployment of automated scripts. An important aspect of this is adequate staffing to support data maintenance/updates and regular funding to support data collection.

Best practices include:

- Updating the ArcGIS Server and SQL Server regularly to enhance security, performance, and ensure combability with newer technologies.
- Logging on any infrastructure hosted on Microsoft Azure to collect and organize performance data to assist in the monitoring of the performance and availability of the tools, their databases, and their supporting components.
- Scheduling a regular database backup to maintain data continuity and prevent disruption of services.
- Optimizing and streamlining the update process to establish a well-defined framework for data management and implement best practices.

5 Summary

The table below summarizes the key features of the example decision support tools reviewed.

Table 6: Example Decision Support Tool Summary Evaluation.

	Mecklenburg County RARR	NC FRIS and Flood.NC.Gov	Massachusetts Climate Resilience Design Standards Tool
Pros	• Provides a multi-component flood risk score to all flood prone buildings. • Evaluates and prioritizes 19 potential mitigation building specific techniques. • Geoprocessing tools allow for easy data maintenance. • Dashboard for program performance metrics.	• Mobile friendly environment. • Federated datasets. • Risk at the building level. • Communicates current Flood Probability and over the next 15 and 30 years. • User specific data overrides. • Provides estimated damages. • Provides risk reduction options, estimated costs and benefits. • Communicates up to seven building level mitigation alternatives. • Provides links to nearby flood warning sites.	• incorporates latest climate data to generate climate resilience analyses and flexible adaptive pathways. • Incorporates environmental justice and ecosystem benefit considerations. • Robust training and guidance materials accompany the Tool. • Free and publicly available.
Cons	• Only considers building level alternatives for buildings within the FEMA SFHA. • Not available to the public. • Relies on robust local datasets that do not exist statewide. • Extensive data maintenance required. • No future conditions.	• Social vulnerability, pluvial flooding, emergency response, environmental impacts and other factors not considered. • The system does not allow for "batch" evaluations. • The system only considers building asset impacts. • The sites do not evaluate nature-based mitigation alternatives. • The sites do not evaluate regional/detention flood mitigation alternatives. • The building stock datasets require significant	• Not recommended for projects with no physical assets or location. • Not recommended for projects without discrete locations (e.g., statewide/regionwide) • MA specific design. Support datasets for NC would need to be created/used.

		maintenance (spatial and tabular). • Models are static. • No statewide future conditions or climate change considerations.	
Blueprint Considerations	• Expand on the RARR concepts to include regional detention and nature-based mitigation actions. • Scale the RARR concepts for incorporation in underserved communities. • Standardize methods for quantifying flood risk/impact category scores statewide. • Incorporate a wide range of accepted mitigation options to fit many contexts. • Incorporate locally defined community values in the prioritization.	• Build on system to allow for user overrides of certain default values in the blueprint database when evaluating mitigation alternatives. • Build from the foundational data and scale down for statewide implementation. • Explore the concept of a multi-variable flood risk "score" including flood probability, impacts, social vulnerability, etc. • Evaluate nature-based and regional detention mitigation alternatives and the aggregated costs and associated benefits. • Leverage updated 2-dimensional modeling including fluvial, pluvial and future conditions.	• Develop best practices, guidance, and training videos to accompany the launch of the Blueprint Decision Support Tool to aid stakeholder use and implementation of the Blueprint. • Incorporate EJ and ecosystem benefits considerations. • The Blueprint will be designed to input existing state, regional, and local actions in addition to new actions formed by local governments and basin-wide groups and for use by wider stakeholder group (not just state hazard mitigation plan implementation.) • Conduct a similarly robust engagement and feedback effort for the beta launch of the Blueprint Decision Support Tool among state agencies, TAGs, and the public to promote transparency and continuous improvement of the Tool.