



NORTH CAROLINA
Department of Transportation

Hydraulic Tools Overview

Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina

OUR MISSION

Connecting people, products and places safely and efficiently with customer focus, accountability and environmental sensitivity to enhance the economy and vitality of North Carolina



Hydraulic Tool Categories

- Flood Warning/ Planning Tools
- Hydraulics Data
- Stormwater
- Hydraulic Calculators

Flood Warning/ Planning Tools

FIMAN-T: Flood Inundation Mapping Alert Network for Transportation

- Gauge-based tool providing near real time awareness of flood impacts to roads and bridges within limited areas around riverine and coastal gages

T-SAPP: Transportation Surge Analysis Prediction Program

- Predictive tool based on ADCIRC modeling provided by UNC-RENCI Center capable of providing advance awareness of potential coastal roadway flood impacts for entire NC coast specific to individual storms

BridgeWatch

- Bridgwatch is a real-time bridge flooding warning system that relies on stream gauges and weather radar to indicate when bridges and culverts are near flooding, actively flooding, or weather conditions are favorable for flooding

RIT: Roadway Inundation Tool

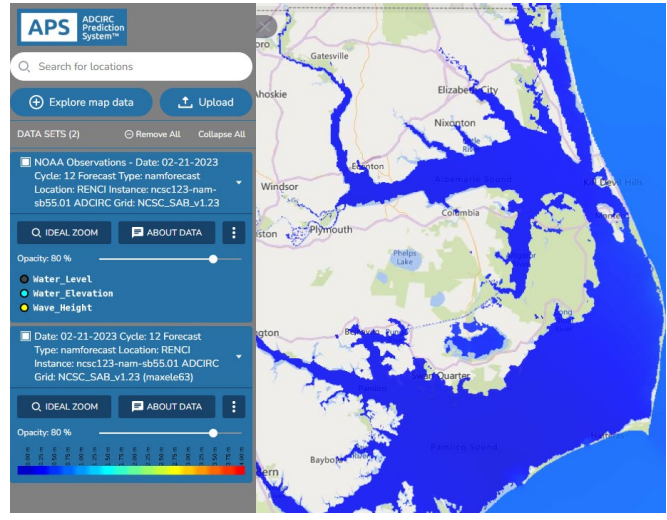
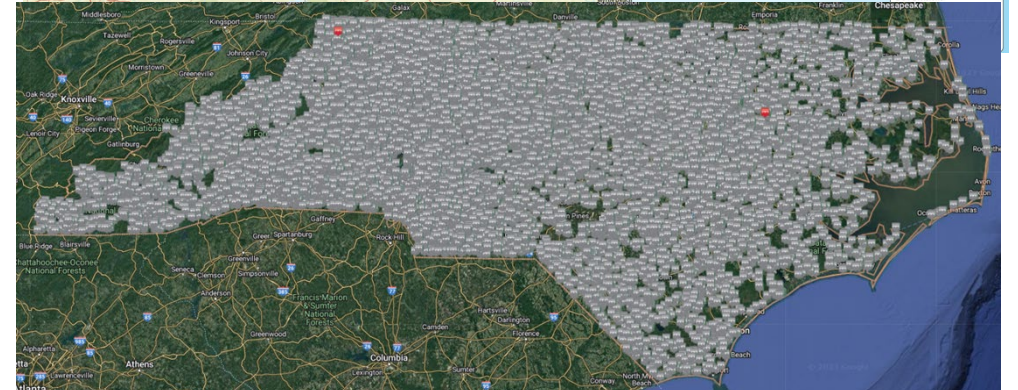
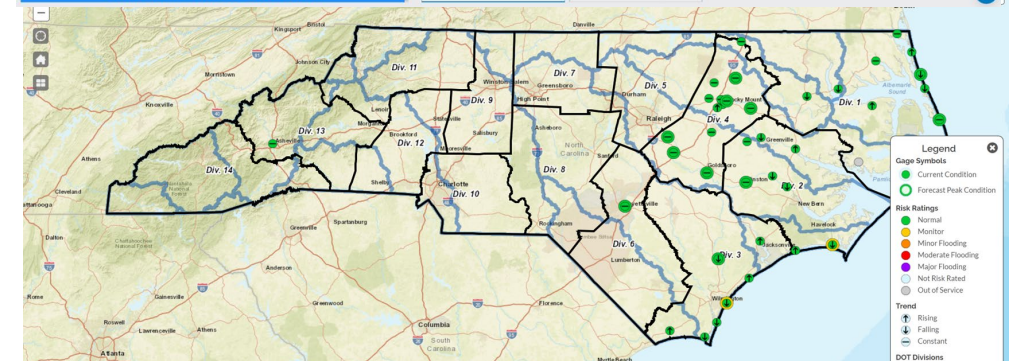
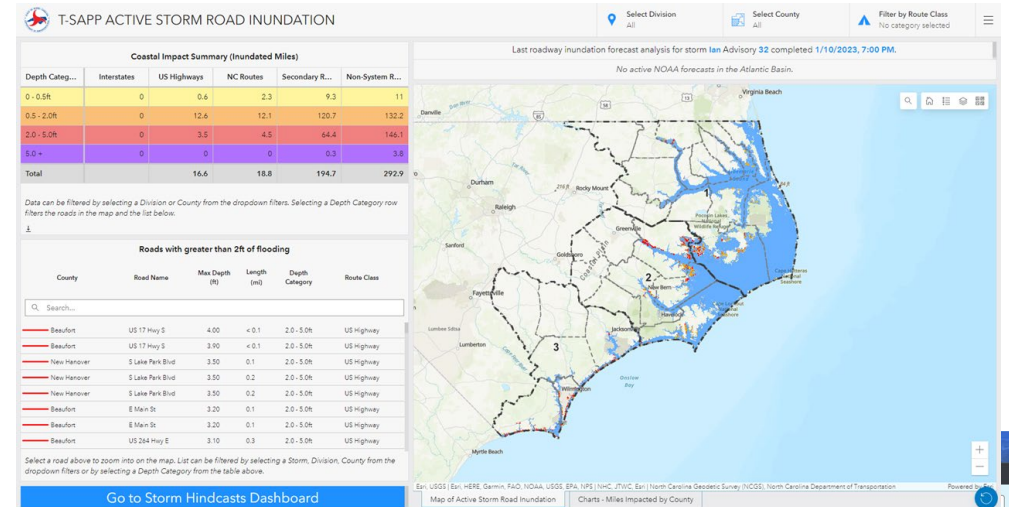
- Planning tool with estimated roadway inundation based on static flood recurrence intervals from FEMA studies

CRIS: Coastal Roadway Inundation System

- Planning tool for coastal road inundation based on intervals of static, level pool flooding along the NC coast

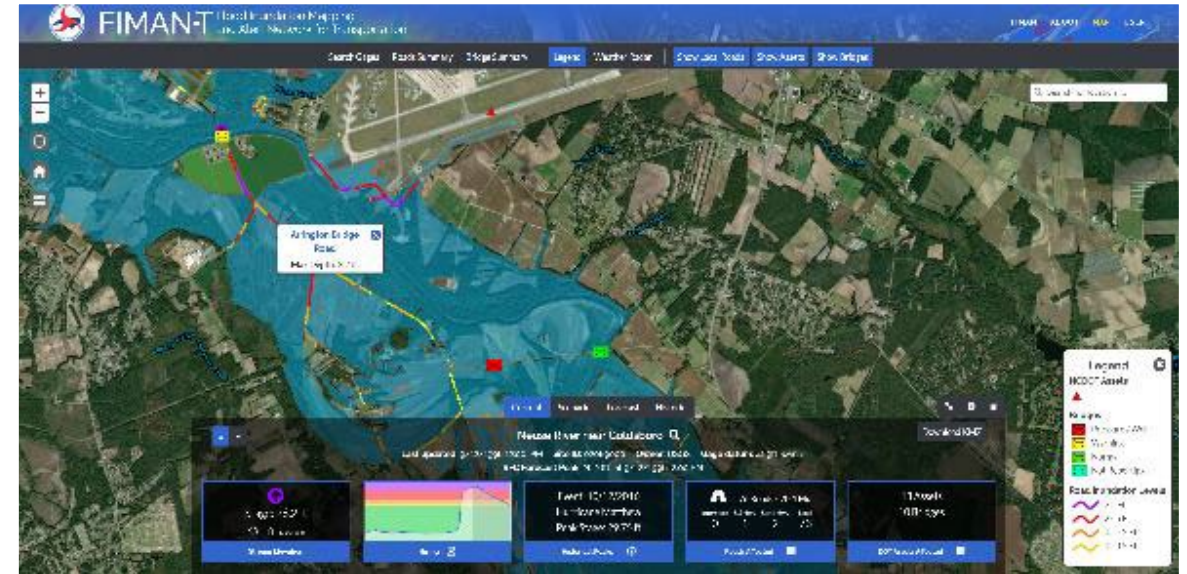
Flood Warning Tools-Storm Prep

- FIMAN-T
- T-SAPP (Transportation Surge Analysis Predictive Program)
- BridgeWatch

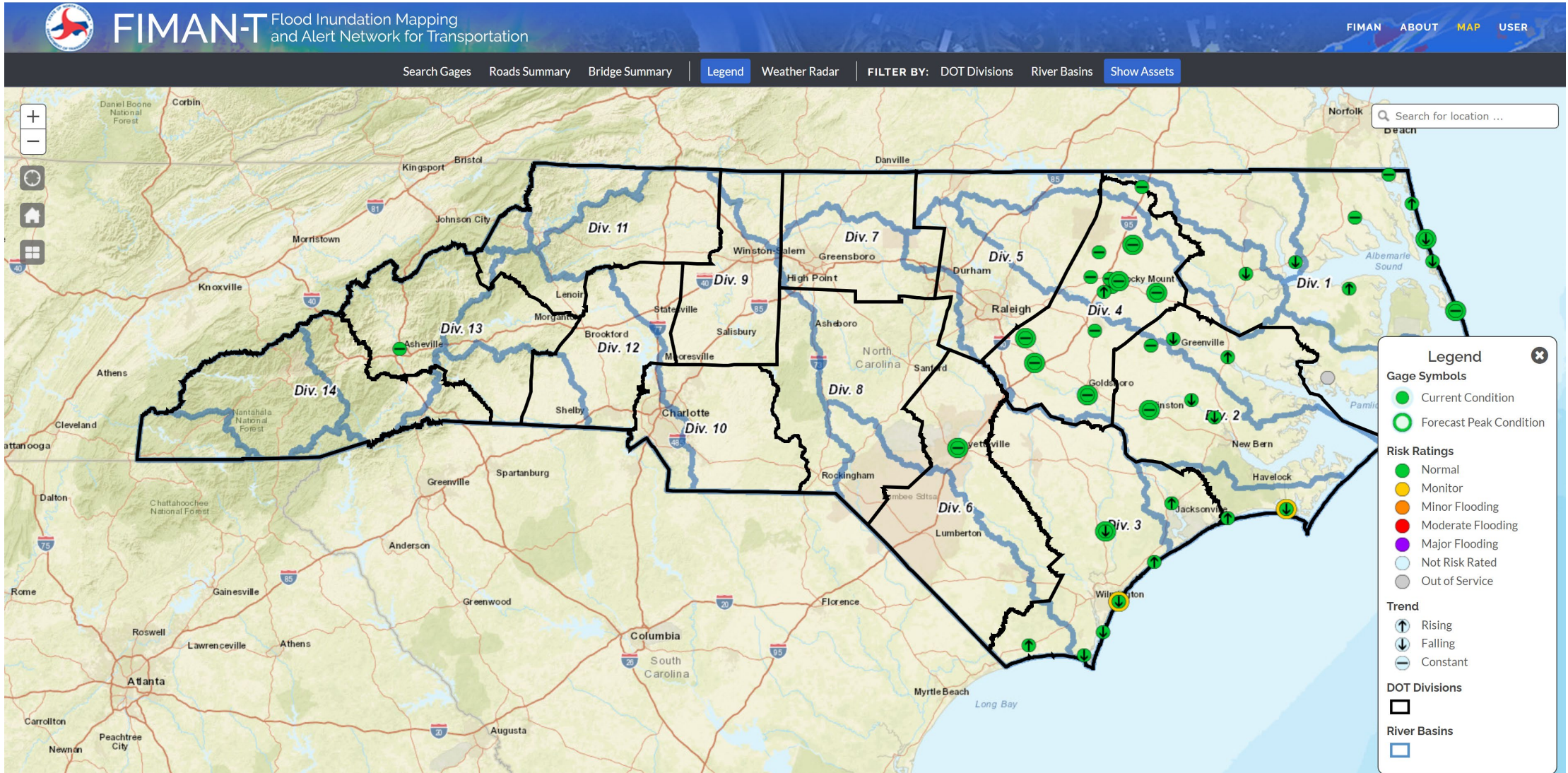


FIMAN-T

- Leverages North Carolina's 15-year investment in flood warning gauges and geospatial data.
- Provides real time and forecasted roadway inundation depths for high-risk locations.
- Visualized current and forecasted road flooding both upstream and downstream of gauged sites (Riverine and Coastal)
- Visualize NCDOT asset impacts.
- Provides bridge hydraulic performance (freeboard and overtopping) for over 100 bridges.
- Advanced reporting tools.
- Export tools to Google Earth.



FIMAN-T: Home Screen



FIMAN-T Display “Tabs”

The screenshot shows the FIMAN-T web application interface. At the top left is the FIMAN-T logo with the text "Flood Inundation Mapping and Alert Network for Transportation". To the right are navigation links for "FIMAN", "ABOUT", "MAP", and "USER". Below the header is a search bar and several menu items: "Search Cases", "Roads Summary", "Bridges Summary", "Legend", "Weather Radar", "Show Local Roads", "Show Assets", and "Show Bridges". The main content area features a map of the Neuse River at Kinston. A dark overlay on the map contains a tabbed interface with four tabs: "Current" (highlighted in blue), "Scenario", "Forecast", and "Historic". Below the tabs, the text reads "Neuse River at Kinston" with a search icon. Further down, it provides site details: "Last updated: 9/12/1996 12:00, PM", "Site ID: 02089500", "Owner: USGS", and "Gage datum: 9.8ft NAVD88". A forecast is also shown: "RFC Forecast Peak: 23.3 (ft) at 9/17/1996 2:00 PM". A yellow text box at the bottom of the screenshot explains the four tabs: "Current", "Scenario", "Forecast", and "Historic".

Current: Current hydrograph, inundation, road/bridge/asset impacts, forecasted peak.

Scenario: Planning tools for various stream gage levels and impacts.

Forecast: Time-based forecast inundation, road/bridge/asset impacts etc.

Historic: Historic flood peaks, inundation, road/bridge/asset impacts for comparative purposes.

FIMAN-T: Current Conditions: Bridge Hydraulic Performance

FIMAN-T Flood Inundation Mapping
and Alert Network for Transportation

FIMAN ABOUT MAP USER

Search Gages Roads Summary Bridge Summary Legend Weather Radar Show Local Roads Show Assets Show Bridges

Neuse River near Goldsboro

Current Stage: 26.2 Ft
Elevation: 0.0 (NAVD 88)

Bridges Assets

Export to Excel

Road Name	Bridge Number	Flood Source	Road Elevation (ft)	Low Chord Elevation (ft)	Current / Scenario WSEL	Freeboard (ft)
NC581	950314	NEUSE RIVER OVERFLOW	65.2	60.7	64.5	-3.8
NC111	950042	NEUSE RIVER OVERFLOW	63.0	59.8	60.5	-0.7
NC111	950054	POND OFF NEUSE RIVER	63.9	60.7	60.5	0.2
NC 581 (Arrington Bridge Rd)	950018	NEUSE RIVER	72.5	69.1	68.7	0.4
US13/US117	950052	NEUSE RIVER OVERFLOW	74.4	72.2	71.2	1.0

1 - 5 of 10 items

Neuse River near Goldsboro

Last updated: 9/12/1996 12:00 PM Site ID: 02089000 Owner: USGS Gage datum: 41.9ft NAVD88
RFC Forecast Peak: 26.2 (ft) at 9/12/1996 2:00 PM

Download KMZ

Stage: 26.2 ft
68.1 ft NAVD 88

Stream Elevation

Rising

Event: 10/12/2016
Hurricane Matthew
Peak Stage: 29.75 ft

Historical Peaks

76 Roads - 20.4 Mi.

Interstate US Hwy State Hwy Local
0 1 2 73

Roads Affected

18 Assets
10 Bridges

DOT Assets Affected

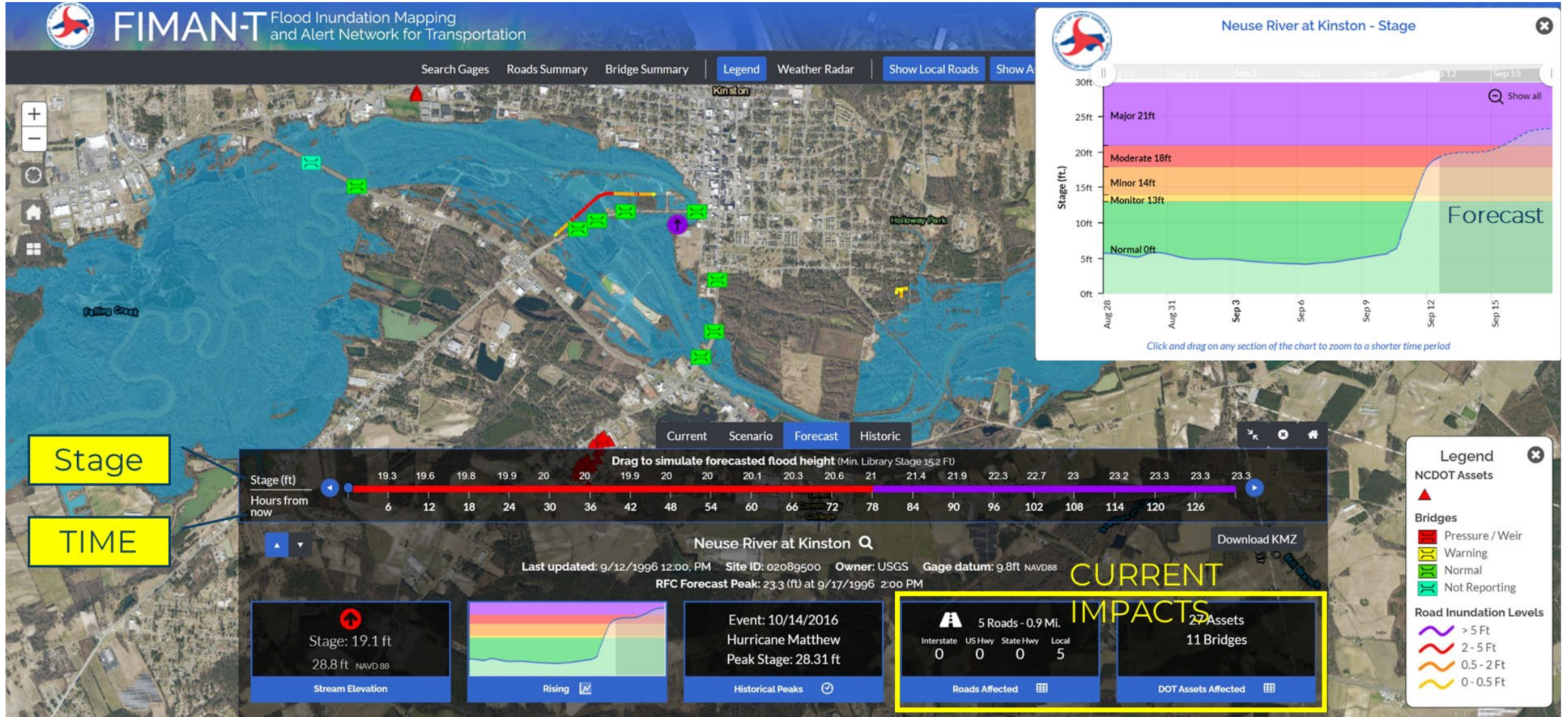
Bridges

- Pressure / Weir
- Warning
- Normal
- Not Reporting

Road Inundation Levels

- ~ > 5 Ft
- ~ 2 - 5 Ft
- ~ 0.5 - 2 Ft
- ~ 0 - 0.5 Ft

FIMAN-T: Forecast Tab



FIMAN-T: Forecast Tab

FIMAN-T Flood Inundation Mapping and Alert Network for Transportation

Search Gages Roads Summary Bridge Summary Legend Weather Radar Show Local Roads Show Assets Show Bridges

Search for location ...

Stage

TIME

Peak

Drag to simulate forecasted flood height (Min. Library Stage 15.2 Ft)

Stage (ft) 19.3 19.6 19.8 19.9 20 20.1 20.3 20.6 21 21.4 21.9 22.3 22.7 23 23.2 23.3 23.3

Hours from now 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120 126

Neuse River at Kinston

Last updated: 9/12/1996 12:00 PM Site ID: 02089500 Owner: USGS Gage datum: 9.8ft NAVD88

RFC Forecast Peak: 23.3 (ft) at 9/17/1996 2:00 PM

PEAK IMPACTS

Event: 10/14/2016 Hurricane Matthew Peak Stage: 28.31 ft

Historical Peaks

60 Roads - 10.0 Mi.

Interstate	US Hwy	State Hwy	Local
0	0	1	59

Roads Affected

27 Assets
11 Bridges

DOT Assets Affected

Legend

NCDOT Assets

- Pressure / Weir
- Warning
- Normal
- Not Reporting

Road Inundation Levels

- > 5 Ft
- 2 - 5 Ft
- 0.5 - 2 Ft
- 0 - 0.5 Ft

FIMAN-T: Historic Tab / Event Viewer

FIMAN-T Flood Inundation Mapping and Alert Network for Transportation

Search Gages Roads Summary Bridge Summary Legend Weather Radar Show Local Roads Show Assets Show Bridges

Historic Event Inundation

Historic Flood Summary
(Select an event in the table below to view flood inundation and impacts on the map)

Historic Event Name	Date	Peak Stage (ft)
Hurricane Matthew	10/14/2016	28.31
Hurricane Floyd	09/23/1999	27.71
Hurricane Florence	09/21/2018	25.78
July 1919 Flood	07/24/1919	25
Hurricane Fran	09/17/1996	23.3

1 - 5 of 5 items

- Historic flood elevations obtained from USGS, NWS, NCEM, and other sources.
- Historic floodplain mapping shown may be rounded to the nearest FIMAN map inundation mapping available.
- Road and Bridge impacts are based on current road elevations and bridge data and may not reflect transportation assets at the time of the event.

Legend
NCDOT Assets

- Bridges
 - Pressure / Weir
 - Warning
 - Normal
 - Not Reporting
- Road Inundation Levels
 - > 5 Ft
 - 2 - 5 Ft
 - 0.5 - 2 Ft
 - 0 - 0.5 Ft

Neuse River at Kinston

Last updated: 9/12/1996 12:00 PM Site ID: 02089500 Owner: USGS Gage datum: 9.8ft NAVD88

RFC Forecast Peak: 23.3 (ft) at 9/17/1996 2:00 PM

Stage: 19.1 ft
28.8 ft NAVD88

Rising

Event: 09/21/2018
Hurricane Florence
Peak Stage: 25.78 ft

Roads Affected: 87 Roads - 17.6 Mi.
Interstate: 0 US Hwy: 0 State Hwy: 2 Local: 85

DOT Assets Affected: 27 Assets
11 Bridges

Historic Event Impact

Peachtree St
Max Depth: 5.0 ft.

FIMAN-T: Validation

FIMAN-T Flood Inundation Mapping and Alert Network for Transportation

Search Gages Roads Summary Bridge Summary Legend Weather Radar Show Local

Slick Rock Road downstream of Goldsboro
FIMAN-T Inundation and Road Flooding Depth Ground Truth

Photo taken here

Neuse River near Goldsboro
Last updated: Feb 12, 2020 at 9:15 AM Gage datum: 41.9ft NAVD88 Site ID: 0206

Stage: 22.4 ft
64.3 ft NAVD88
Stream Elevation

Constant

Peak Stage: 22.5 ft
2/12 1:00 PM
No Data Available
Forecasted Peak

Roads Affected DOT Assets Affected

0-0.5 Ft

Inundation Match

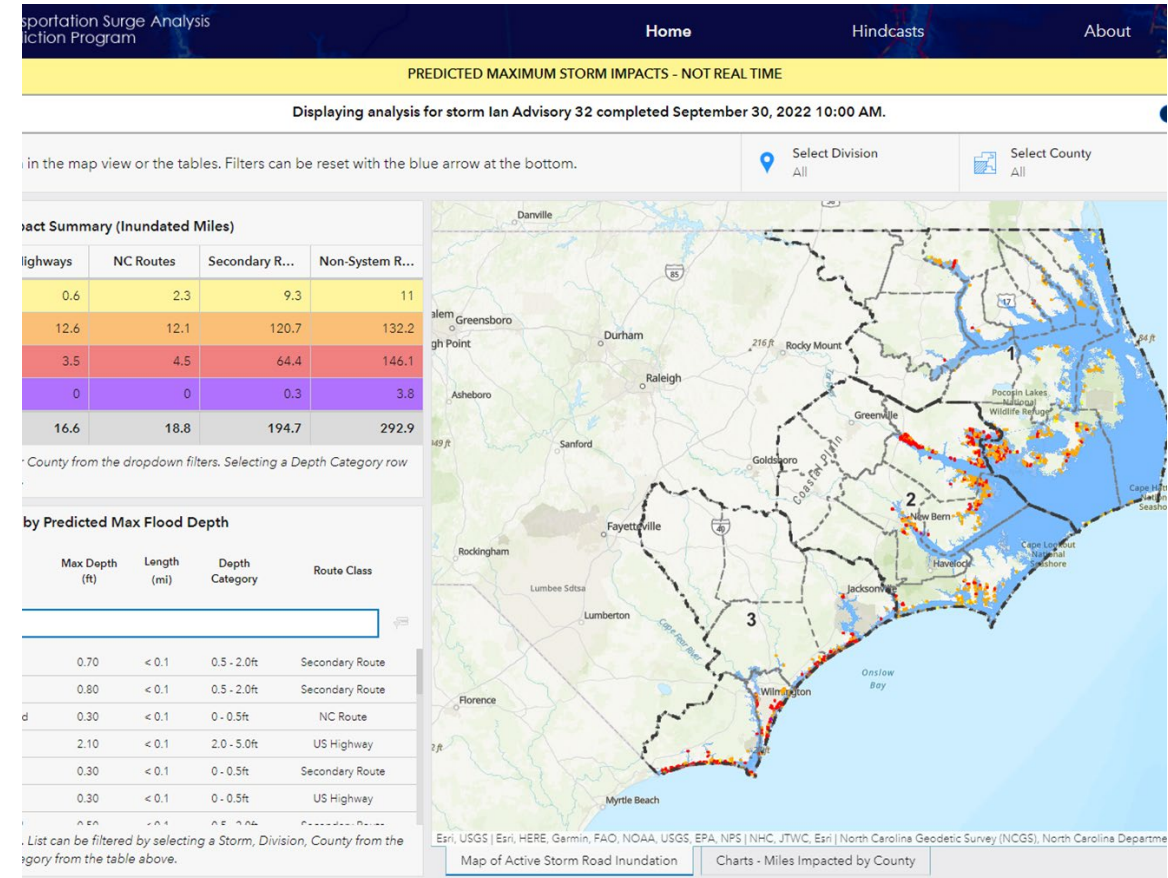
Slick Rock Road
Photo Taken: 2/12/20 at 9:50am

FIMAN-T Shows 1.5 feet of water over road.

T-SAPP: Transportation Surge Analysis Prediction Program

What is T-SAPP?

- Storm Surge forecast values (Statewide) are downloaded from APS THREDDS Server Every 6 hours during events.
- Geoprocessing tools to process, develop inundation mapping, inundation depths, roadway depths, bridge overtopping, etc.
- Interactive web mapping application
- Comparison to past storm events (Fran, Floyd, Matthew, Florence, Dorian, Isaias, Ian)




T-SAPP: Current Metrics

Item	Metric
Active Sites	N/A (Entire Coastline)
Monitored Roadway Miles	10,990 miles
Coastal Bridges Monitored	199
Historic Flood Events Included	7 Fran (1996), Floyd (1999), Matthew (2016), Florence (2018), Dorian (2019), Isaias (2020), Ian (2022)
Historic Impacted Roadway Miles Mapped	6,637 miles
Historic Flood Inundation Area Mapped (7 events)	46,459 sq. miles



T-SAPP: Home Screen

 **T-SAPP** Transportation Surge Analysis Prediction Program

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PREDICTED MAXIMUM STORM IMPACTS - NOT REAL TIME

Displaying analysis for storm Ian Advisory 32 completed September 30, 2022 10:00 AM.
 Download Roadways Table

Use the filters to control what is shown in the map view or the tables. Filters can be reset with the blue arrow at the bottom.

📍 Select Division
All

🗺️ Select County
All

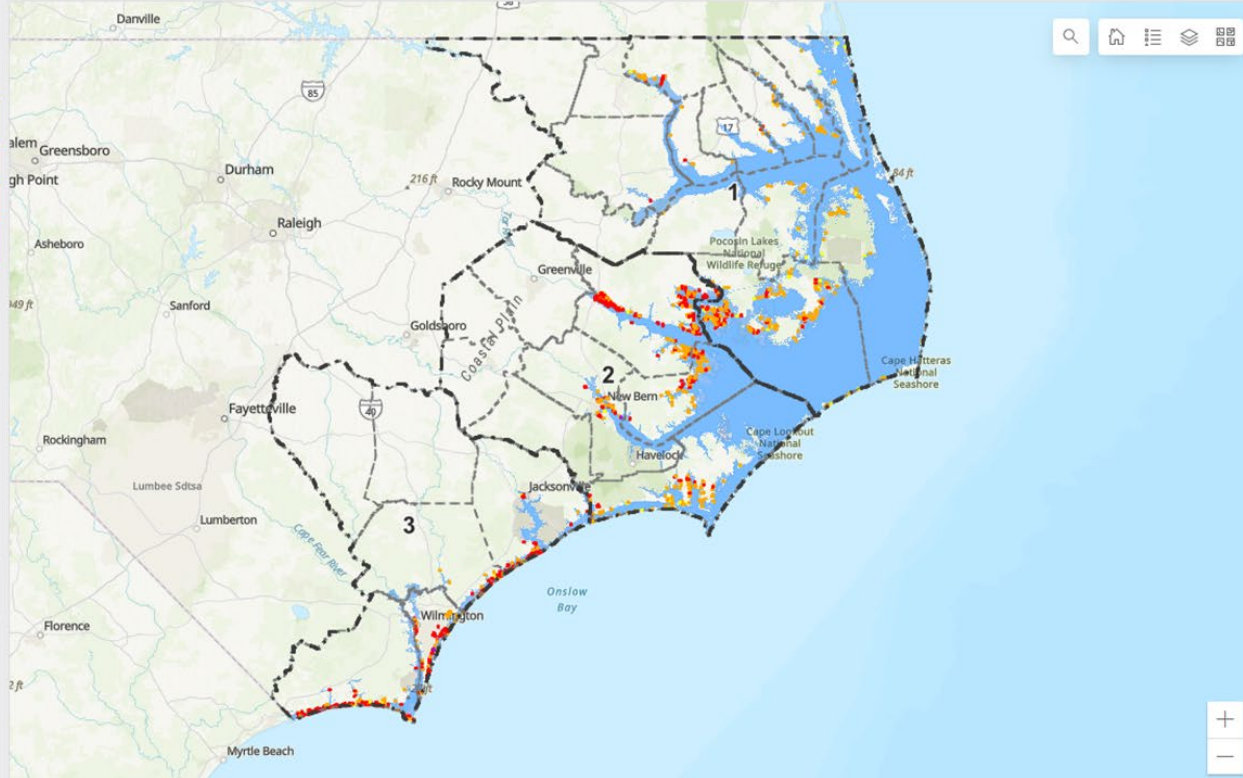
⬆️ Filter by Route Class
No category selected

☰

Coastal Impact Summary (Inundated Miles)

Depth Categ...	Interstates	US Highways	NC Routes	Secondary R...	Non-System R...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
5.0 +	0	0	0	0.3	3.8
Total		16.6	18.8	194.7	292.9

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.



Roadways by Predicted Max Flood Depth

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
<input style="width: 100%; border: 1px solid #ccc;" type="text" value="Search..."/>					
Camden	SA-99825	0.70	< 0.1	0.5 - 2.0ft	Secondary Route
Hyde	Nebraska Rd	0.80	< 0.1	0.5 - 2.0ft	Secondary Route
Pasquotank	Salem Church Rd	0.30	< 0.1	0 - 0.5ft	NC Route
Perquimans	N Church St	2.10	< 0.1	2.0 - 5.0ft	US Highway
Camden	Texas Rd	0.30	< 0.1	0 - 0.5ft	Secondary Route
Hyde	US 264 Hwy	0.30	< 0.1	0 - 0.5ft	US Highway

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Esri, USGS | Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS | NHC, JTWC, Esri | North Carolina Geodetic Survey (NCGS), North Carolina Department of Transportation Powered by Esri

Map of Active Storm Road Inundation
Charts - Miles Impacted by County

T_SAPP: Event Viewer

T-SAPP Transportation Surge Analysis Prediction Program

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PREDICTED MAXIMUM STORM IMPACTS - NOT REAL TIME

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Use the filters to control what is shown in the map view or the tables. Filters can be reset with the blue arrow at the bottom.

Select Division: All

Select County: All

Filter by Route Class: No category selected

Coastal Impact Summary (Inundated Miles)

Depth Categ...	Interstates	US Highways	NC Routes	Secondary R...	Non-System R...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
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Total		16.6	18.8	194.7	292.9

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Roadways by Predicted Max Flood Depth

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Pamlico	Orchard Creek Rd	1.00	0.1	0.5 - 2.0ft	Secondary Route
Pamlico	Orchard Creek Rd	1.70	0.1	0.5 - 2.0ft	Secondary Route
Pamlico	Orchard Creek Rd	5.20	0.1	5.0 +	Secondary Route

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Zoom to Pan

Orchard Creek Rd

Max Depth (ft): **5.20**

[Open in Google Maps](#)

Basemaps

- Imagery
- Imagery Hybrid
- Streets
- Topographic
- Navigation
- Streets (Night)
- Terrain with Labels

NC CGIA, Maxar, Microsoft | NHC, JTWC, Esri | North Carolina Geodetic Survey (NCGS), North Carolina Department of Transportation
Powered by Esri

[Map of Active Storm Road Inundation](#)
[Charts - Miles Impacted by County](#)

T-SAPP: Dashboard

T-SAPP Transportation Surge Analysis Prediction Program

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PREDICTED MAXIMUM STORM IMPACTS - NOT REAL TIME

Displaying analysis for storm Ian Advisory 32 completed September 30, 2022 10:00 AM.
 Download Roadways Table

Use the filters to control what is shown in the map view or the tables. Filters can be reset with the blue arrow at the bottom.

📍 Select Division
All

🗺️ Select County
All

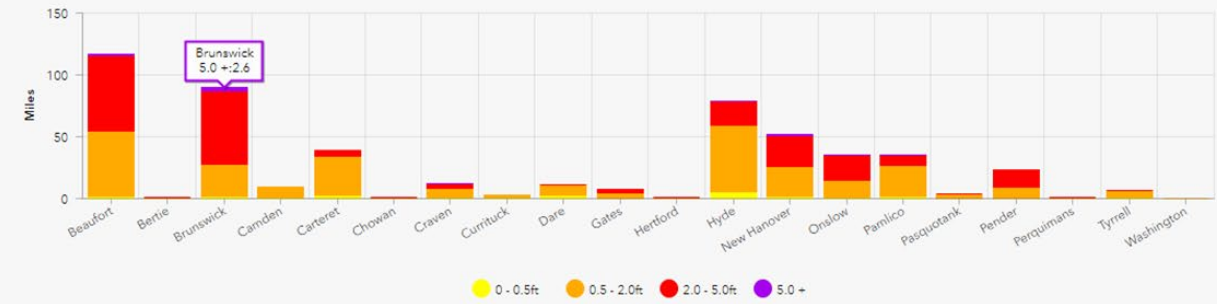
⬆️ Filter by Route Class
No category selected

Coastal Impact Summary (Inundated Miles)

Depth Categ...	Interstates	US Highways	NC Routes	Secondary R...	Non-System R...
0 - 0.5ft	0	0.6	2.3	9.3	11
0.5 - 2.0ft	0	12.6	12.1	120.7	132.2
2.0 - 5.0ft	0	3.5	4.5	64.4	146.1
5.0 +	0	0	0	0.3	3.8
Total		16.6	18.8	194.7	292.9

Data can be filtered by selecting a Division or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Miles Impacted by County & Depth Category

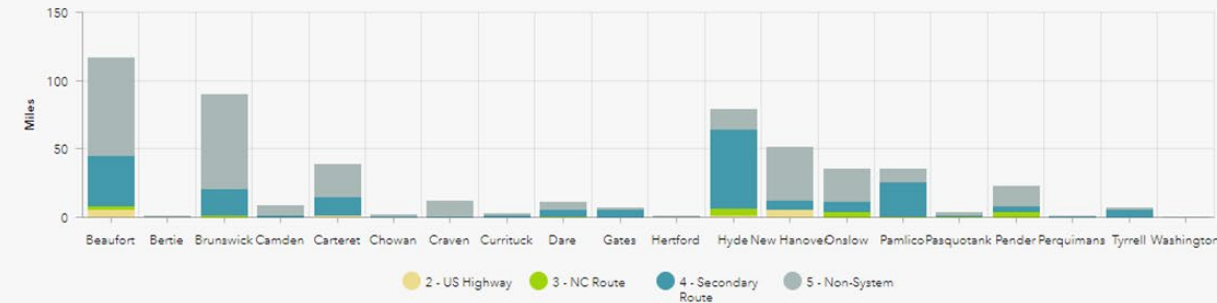


Roadways by Predicted Max Flood Depth

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
Camden	SA-99825	0.70	< 0.1	0.5 - 2.0ft	Secondary Route
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Pasquotank	Salem Church Rd	0.30	< 0.1	0 - 0.5ft	NC Route
Perquimans	N Church St	2.10	< 0.1	2.0 - 5.0ft	US Highway
Camden	Texas Rd	0.30	< 0.1	0 - 0.5ft	Secondary Route
Hyde	US 264 Hwy	0.30	< 0.1	0 - 0.5ft	US Highway


Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.

Miles Impacted by County & Route Class



Map of Active Storm Road Inundation
Charts - Miles Impacted by County

T-SAPP: Historic Event Viewer


T-SAPP Transportation Surge Analysis Prediction Program

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HINDCAST STORM INUNDATION IS SHOWN AT THE MAXIMUM IMPACT.

[Download Roadways Table](#)

Use the filters to control what is shown in the map view or tables. Filters can be reset with the blue arrow at the bottom.

6
Select Storm Hindcast
MATTHEW (2016)

📍
Select Division
All

🗺️
Select County
All

⬆️
Filter by Route Class
No category selected

☰

Coastal Impact Summary (Inundated Miles)

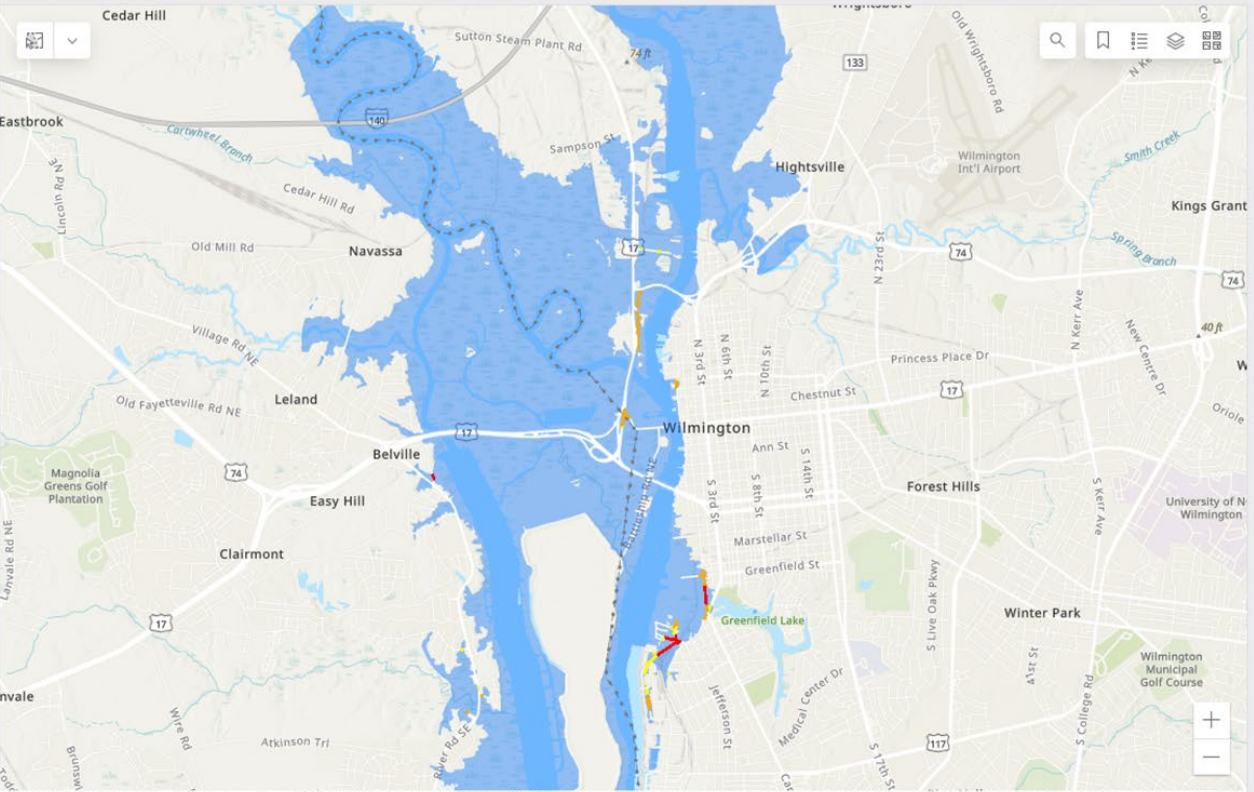
Depth Categ...	Interstate	US Highway	NC Route	Secondary R...	Non-System R...
0 - 0.5ft	0	2.7	9.5	59.1	66.1
0.5 - 2.0ft	0	2.5	15.1	105.5	113
2.0 - 5.0ft	0	0.3	5.2	19	21.6
5.0 +	0	0	0	0	0.1
Total		5.4	29.8	183.7	200.9

Data can be filtered by selecting a Storm, Division, or County from the dropdown filters. Selecting a Depth Category row filters the roads in the map and the list below.

Roadways by Predicted Max Flood Depth

County	Road Name	Max Depth (ft)	Length (mi)	Depth Category	Route Class
<input style="width: 100%;" type="text" value="Search..."/>					
New Hanover	S Front St	2.20	0.2	2.0 - 5.0ft	US Highway
Brunswick	Old River Rd	2.10	0.1	2.0 - 5.0ft	Secondary Route
New Hanover	Private	3.40	0.2	2.0 - 5.0ft	NC Route
New Hanover	Woodbine St	3.10	0.1	2.0 - 5.0ft	NC Route
New Hanover	Private	3.00	0.1	2.0 - 5.0ft	NC Route
New Hanover	Myers Blvd	2.80	0.1	2.0 - 5.0ft	NC Route

Select a road above to zoom into on the map. List can be filtered by selecting a Storm, Division, County from the dropdown filters or by selecting a Depth Category from the table above.



Map of Hindcast Road Inundation
Charts - Miles Impacted by County

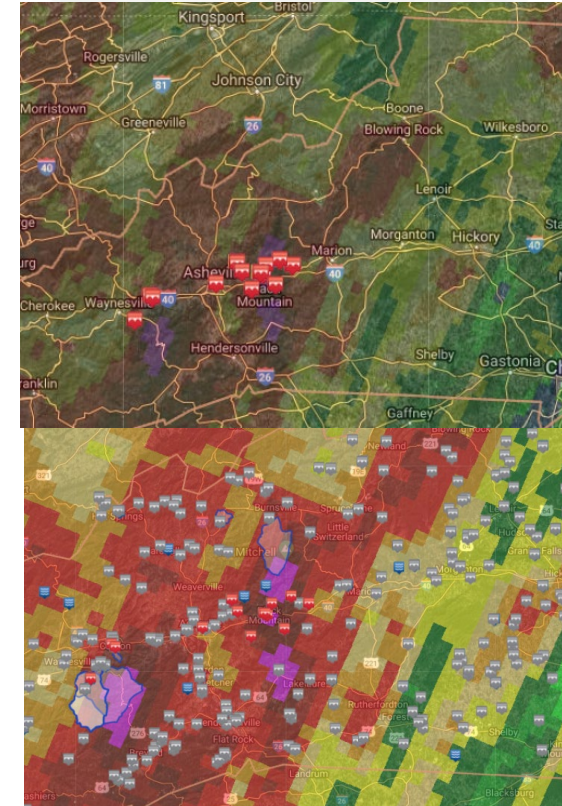
Esri, NASA, NGA, USGS, FEMA | State of North Carolina DOT, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA | North Carolina Geodetic S... Powered by Esri

NCDOT BridgeWatch

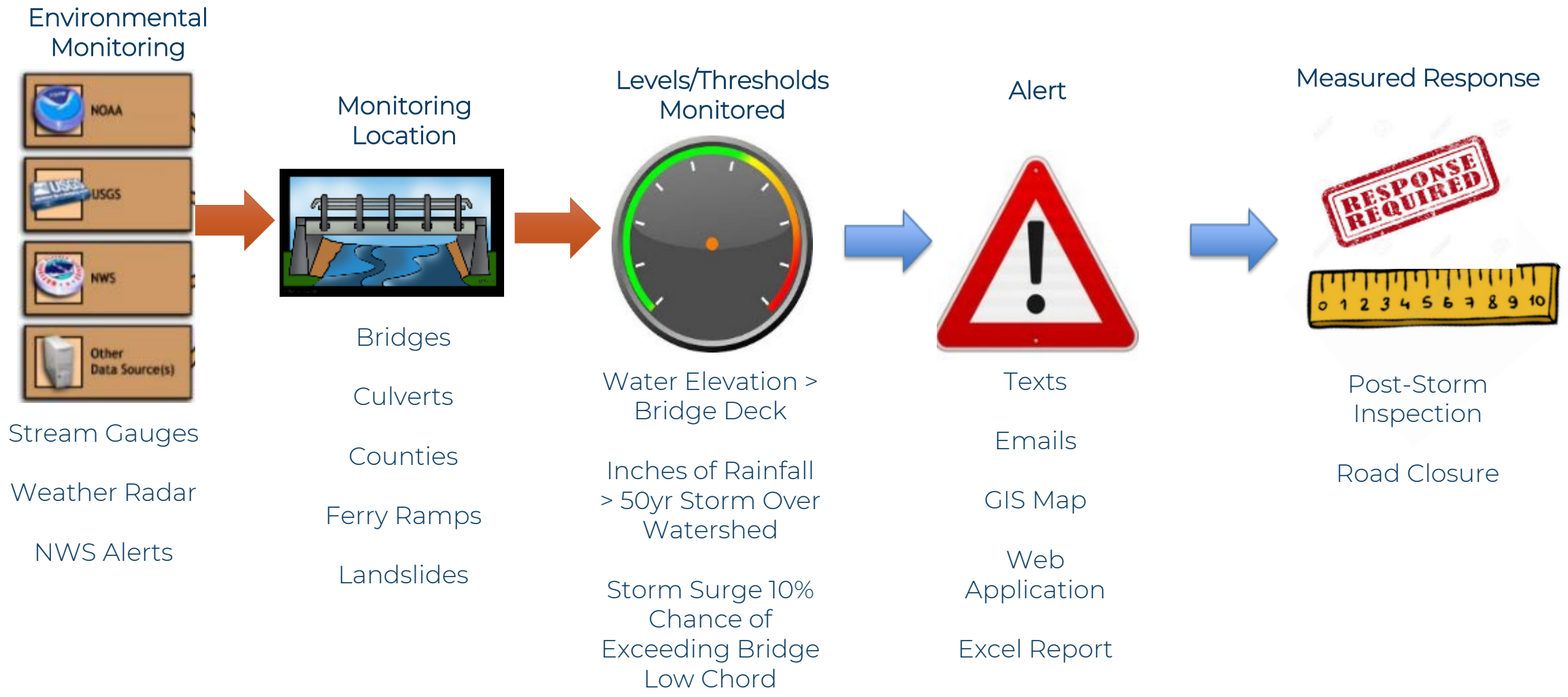


What is BridgeWatch?

- Real-time monitoring for structures over water.
- Alerted immediately when levels exceed set threshold
- Alerts help identify flooded roadways and scour critical structures impacted by heavy rainfall



Bridge Watch: How it works



Bridge Watch: Flood Warning and Asset Management

BridgeWatch

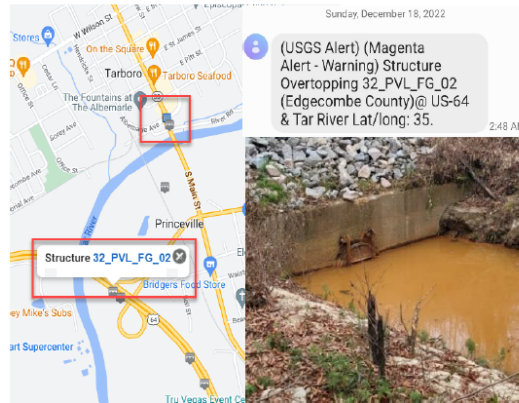
Public Safety Through Real-time Structure Monitoring



Overview: BridgeWatch is an online asset-management service that collects and process data from stream gauges, weather radar, National Weather service, and National Hurricane Center and compares these external datasets to user defined limits. The program sends alert notifications via email or cell phone when user defined thresholds are exceeded.

Statistics: Monitoring locations represent NCDOT assets at which parameters are compared to external data sources. Currently, BridgeWatch monitors over 15,000 bridges, approaches, and culverts. Additionally, 25 ferry ramps, 14 levee and flap gate locations near Princeville, and 21 Western Division landslide locations are monitored.

Critical Conditions: The severity and indication of real-world conditions at a monitoring location depends on the alert type and level. There are three alert categories: gauge, rainfall, or storm surge. Color coding of alert levels, that follows the National Weather Service flood risk colors, indicates alert priority. Gauge alerts, based on real-time water levels, are considered the most reliable and highest priority during a storm event. Alert notifications sent via SMS text or email include key details such as severity, type, location of asset, and values exceeded.



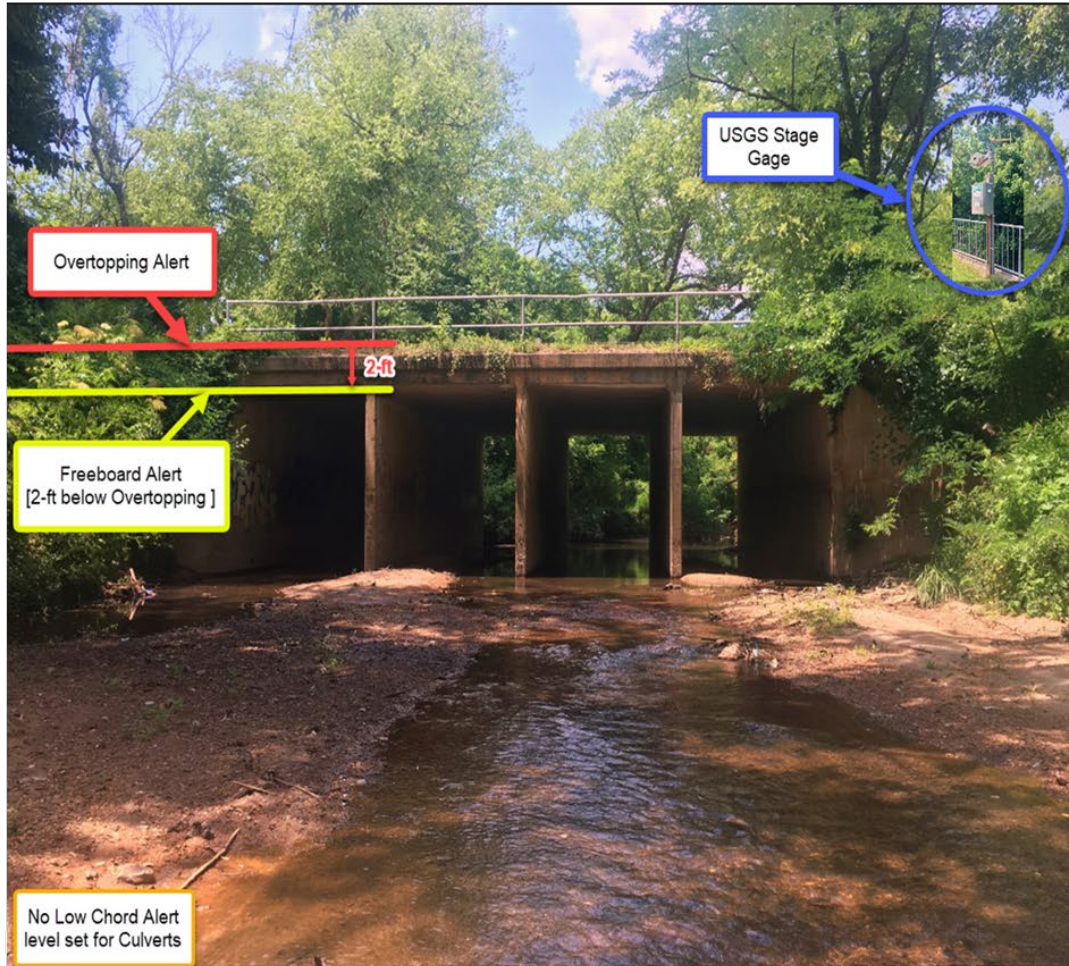
Example of flap gate structure in BridgeWatch with thresholds linked to upstream USGS gage (left), the text alert format for the flap gate (upper right) and field verification of alert (lower right).

Alert Types

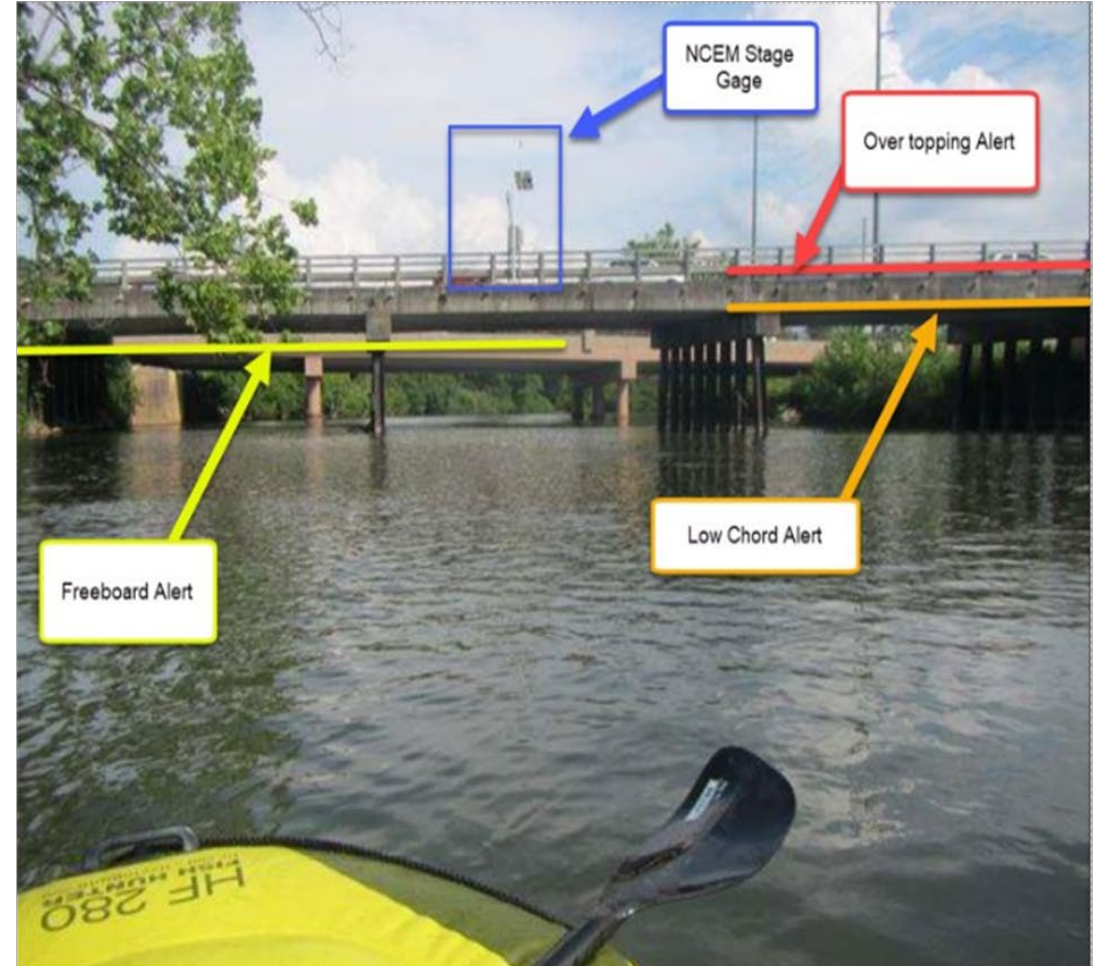
- Gauge Alert, Overtopping, (Warning-Magenta):** Issued when on-site water surface elevation gauge indicates water is overtopping the bridge, bridge approach, or the roadway over a culvert.
- Gauge Alert, Low Chord, (Warning-Red):** The low chord is typically the lowest structure member (beam) above the stream or river. Officials are notified when flood waters reach this level. Low chord alerts are not issued for culverts.
- Gauge Alert, Freeboard, (Watch-Orange):** Officials are notified when stream levels rise close to a critical level at a structure, which indicates that flooding is approaching the bridge structure or road overtopping for culverts. Generally these alerts are triggered when stream levels are within 2-ft of low chord for bridges or within 2-ft of overtopping roadway for culverts. Some coastal bridges use 1-ft below low chord.
- Rainfall Alert, NEXRAD or QPF, (Watch-Yellow):** The system actively monitors NEXRAD for over 15,000 of structure drainage areas statewide. Officials are notified if rainfalls (actual or forecasted) trigger predetermined rainfall intensity thresholds.
- Storm Surge Alerts:** National Hurricane Center advisories are monitored and forecasted storm surge levels are compared to bridge elevations. Custom alerts are available for when forecasted storm surge may impact bridges.

BridgeWatch: Stage Threshold Examples

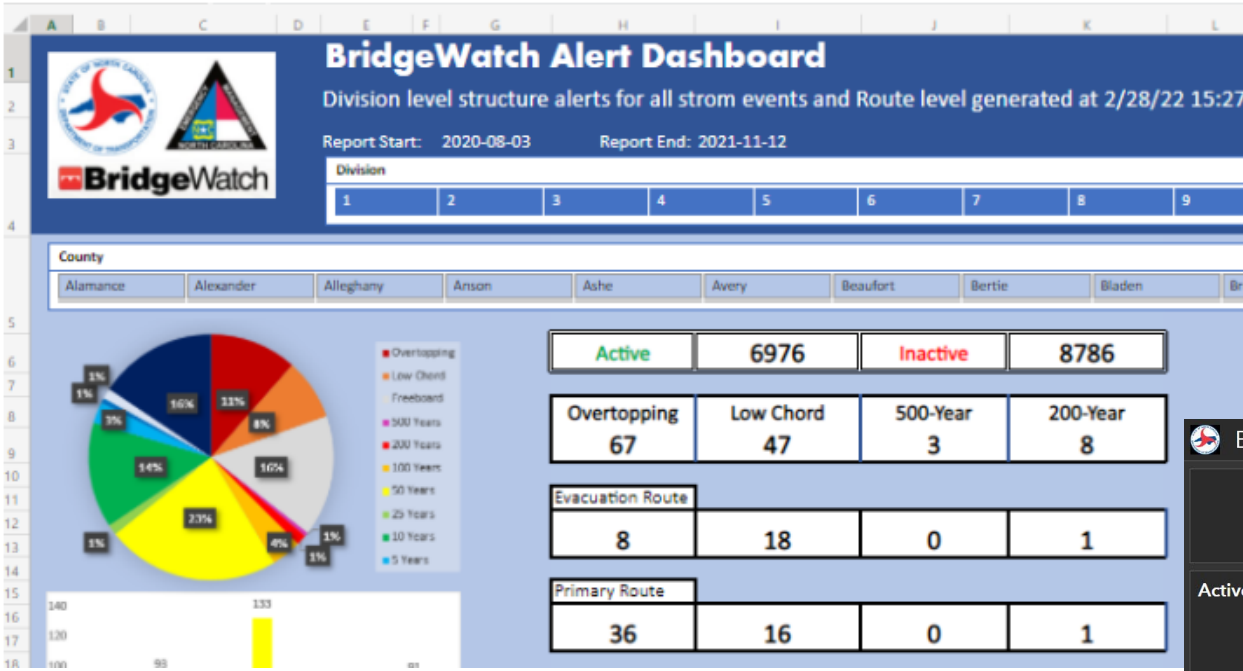
Culvert



Bridge



Bridge Watch: Flood Warning and Asset Management



CAUTION: External email. Do not click links or open attachments unless you verify. Send all suspicious email as an attachment to [Report Spam](#).

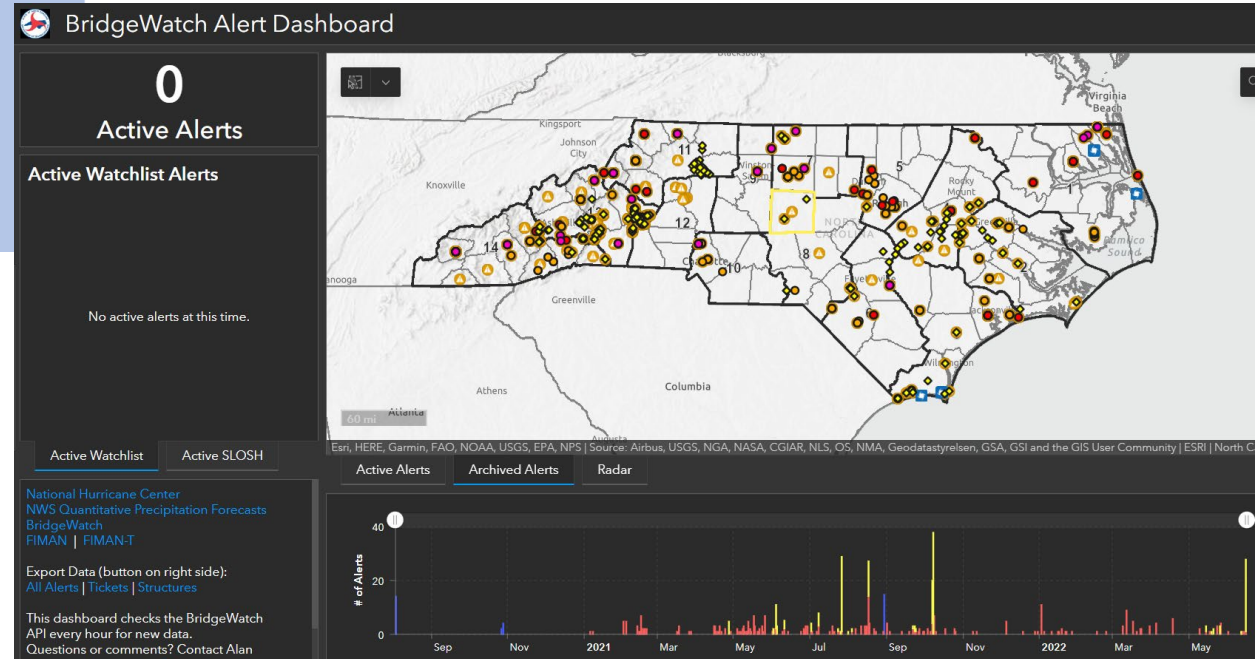
Gauge malfunctions and the possibility of system miscalibration are sources of error that make field verification of BridgeWatch alerts a necessary part of using the system. Do not rely solely on alerts for critical decision making.
Low Chord bridges: 730431 (In Pitt County)

_Red_Alert - Warning
[NCEM Low Chord](#)
 Structure: [730431](#)
 County: Pitt County
 Road: SR1591
 Stream: PARKER CREEK
 Lat/Long: 35.644,-77.346
 Gauge: 30119
 Time: 2023-01-26 02:55:00 EST
 Event Value: 11.02
 Threshold Exceeded: 11.01
 Scour Critical (Item 113): 8
 Drift: G
 Substructure Condition (60): 8
 Channel Condition (61): 8

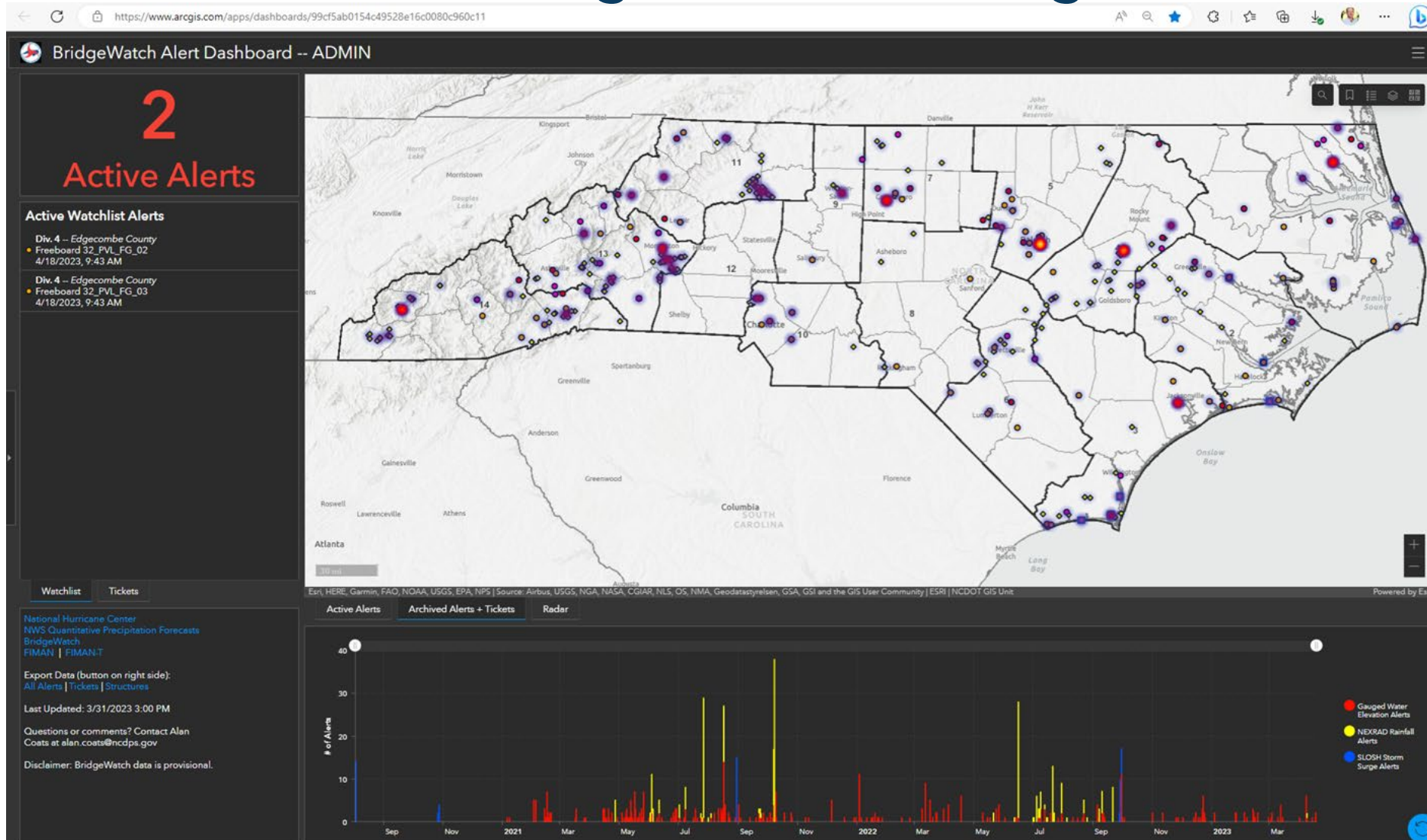
(Device Alert) (Orange Alert - Watch) Freeboard Br 730431 (Pitt County)@ SR1591 & PARKER CREEK Lat/long: 35.644,-77.346 Time: 11:35 PM

Thursday, January 26, 2023

(Device Alert) (Red Alert - Warning) Low Chord Br 730431 (Pitt County)@ SR1591 & PARKER CREEK Lat/long: 35.644,-77.346 Time: 2:10 AM



Bridge Watch: Flood Warning and Asset Management



Flood Planning Tools-Storm Prep

RAFT: Resilience Analysis Framework for Transportation

- CRIS: Coastal Roadway Inundation Simulator
- RIT: Roadway Inundation Tool

RAFT Resilience Analysis Framework for Transportation

MY CONTENT

APPLICATIONS

CRIS Coastal Roadway Inundation Simulator

RIT Roadway Inundation Tool

COASTAL ROADWAY INUNDATION SIMULATOR (CRIS)

Users can simulate coastal flooding on both primary and secondary roads and export results to a KML for further visualization. Simulations are limited to coastal counties only.

ROADWAY INUNDATION TOOL

This tool allows the user to see potential overtopping depths and flood effects at each primary road river crossing and quantify potential effects based on standard FEMA recurrence intervals (10, 25, 50, 100 & 500yr flood).

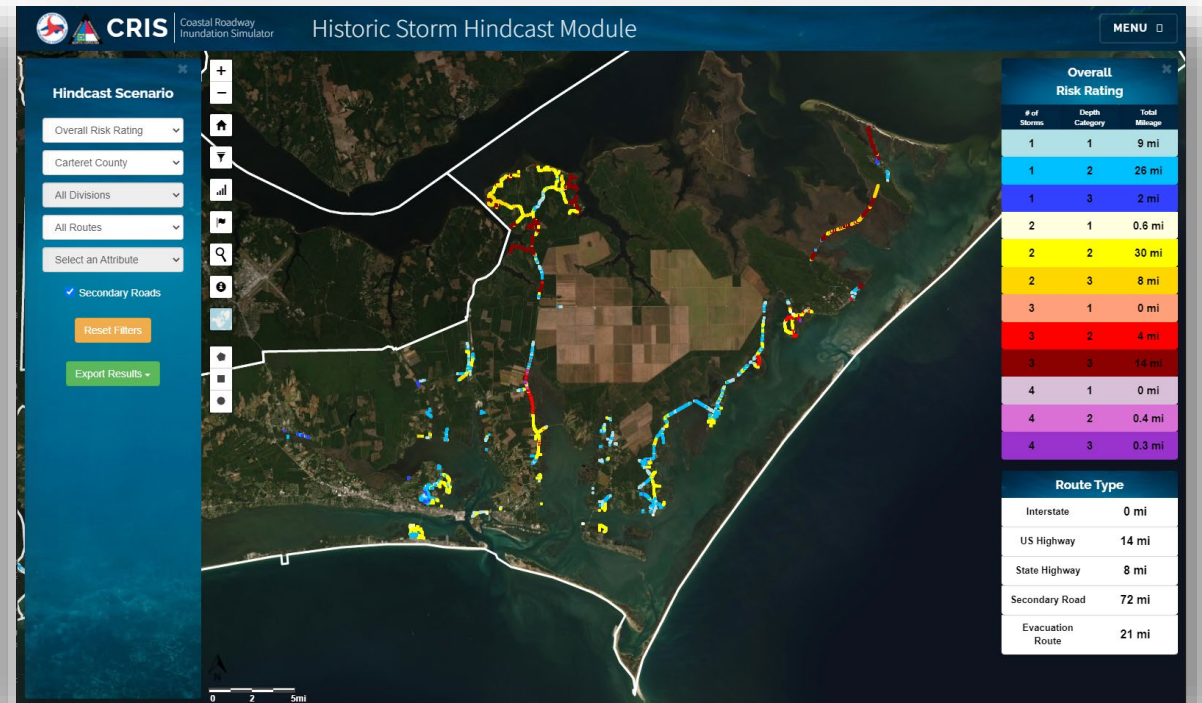
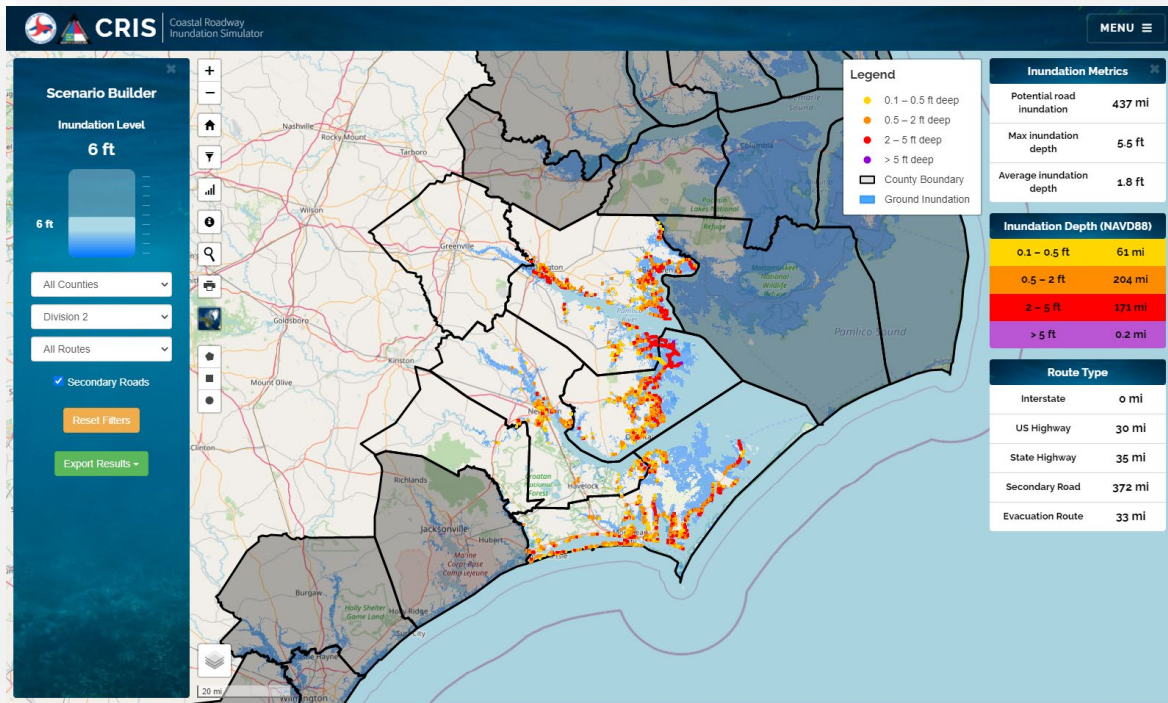
Inundation Metrics	
Potential road inundation	23 mi
Max inundation depth	9.8 ft
Average inundation depth	3.8 ft

Inundation Depth (ft/1000ft)	
0.1 - 0.5 ft	1.7 mi
0.5 - 1 ft	6 mi
1 - 1.5 ft	11 mi
1.5 - 2 ft	4 mi

Roadway Type	
Interstate	0 mi
US Highway	12 mi
State Highway	10 mi
Secondary Road	0 mi
Evacuation Route	17 mi

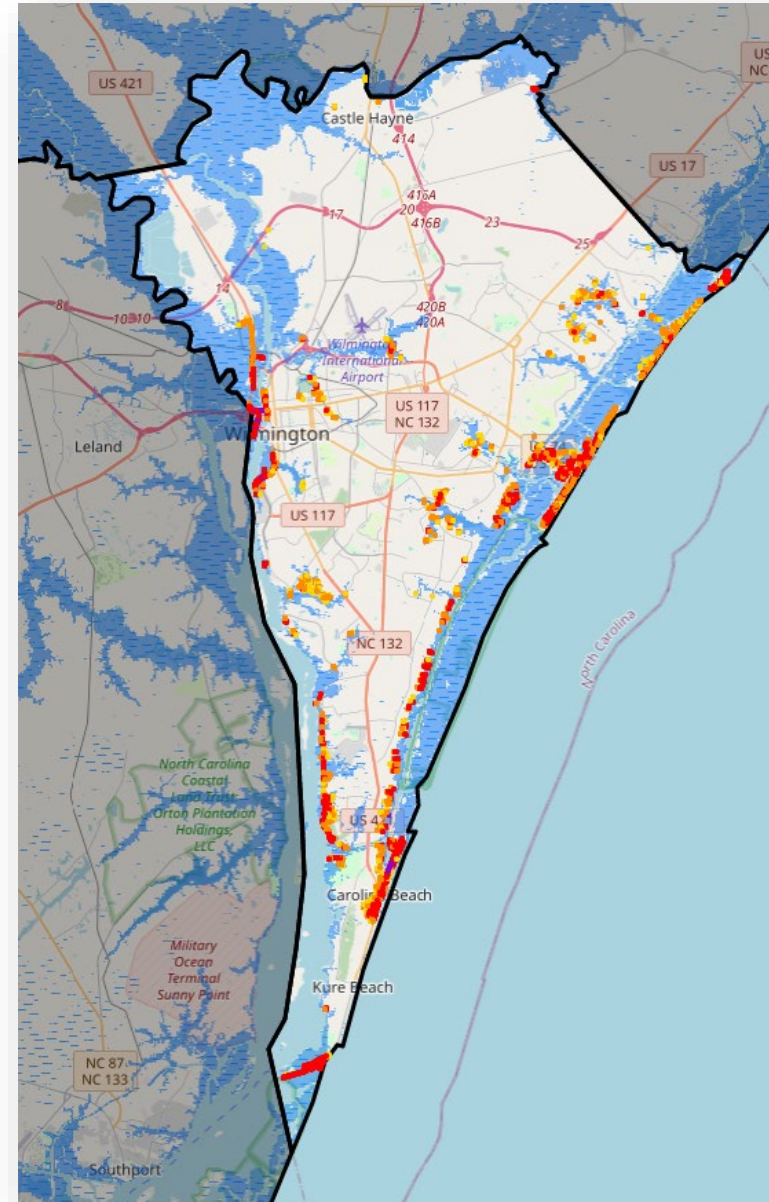
Coastal Roadway Inundation Simulator (CRIS)

- Predicts impacts of roadway inundation for 23 coastal counties
- Inundation levels range from 1 to 17 feet
- Historic Storm Hindcast Module displays impacts from six past hurricanes



CRIS: Goals

- Quantify and simulate inundation impacts
- Plan for:
 - Emergency response
 - Evacuation
 - Road closure
 - Future resiliency
- Assist with maintenance of roadway infrastructure



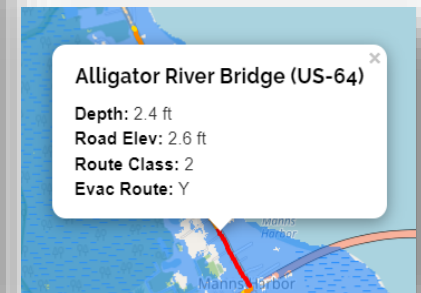
CRIS: Metrics and Process

- NC QL2 LiDAR (2014-2015) used to assign roadway centerline elevations (NAVD88 FT)
- LiDAR-based modeling used to produce inundation boundaries
- Points were generated every 50 feet along road centerlines
- At each point, roadway elevations were compared to the selected inundation profile to calculate inundation depth
- Mileage statistics determined by multiplying the number of impacted points by 50

Inundation Metrics	
Potential road inundation	71 mi
Max inundation depth	5.9 ft
Average inundation depth	2.1 ft

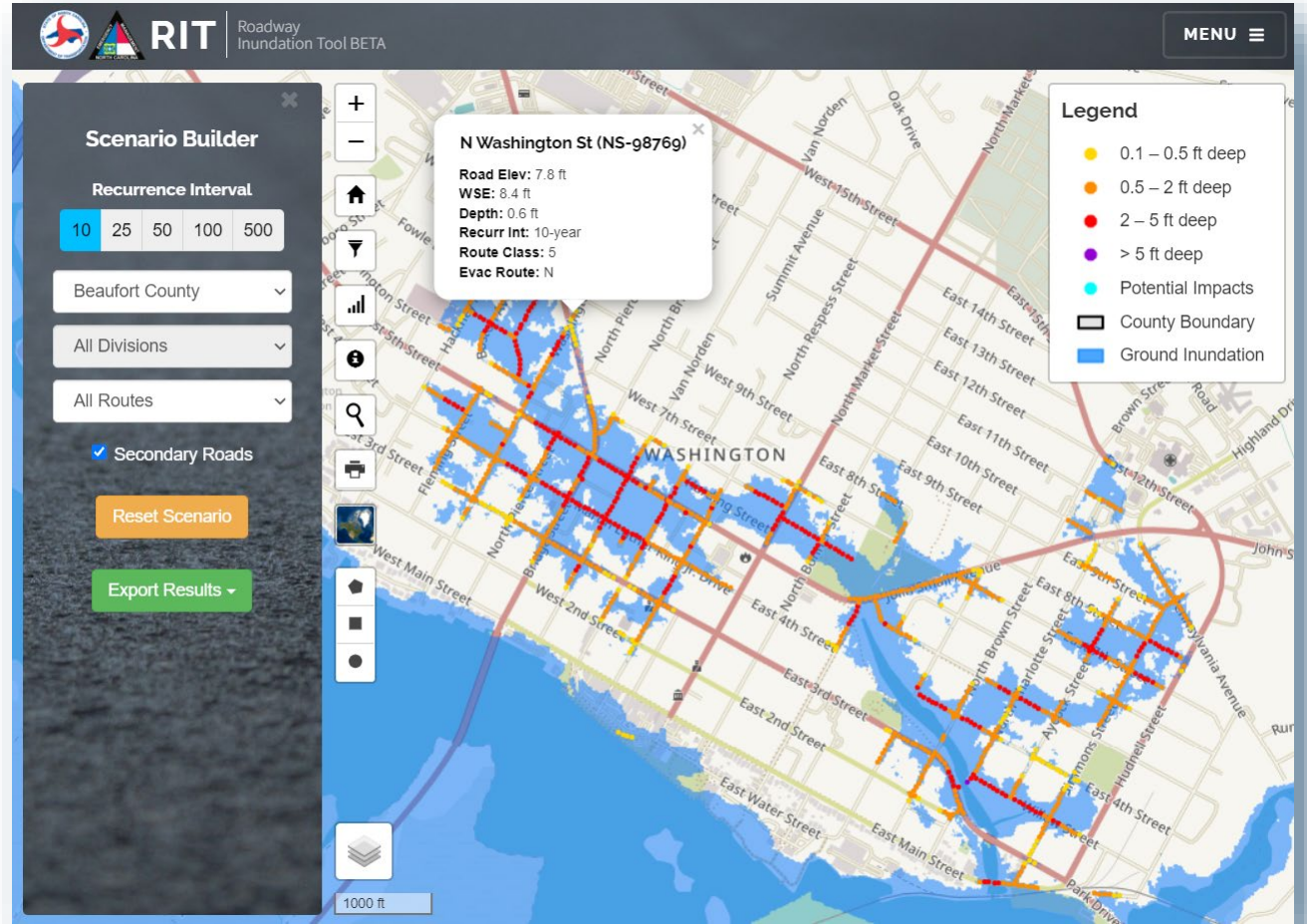
Inundation Depth (NAVD88)	
0.1 – 0.5 ft	7 mi
0.5 – 2 ft	29 mi
2 – 5 ft	34 mi
> 5 ft	0.5 mi

Route Type	
Interstate	0 mi
US Highway	10 mi
State Highway	0 mi
Secondary Road	61 mi
Evacuation Route	10 mi



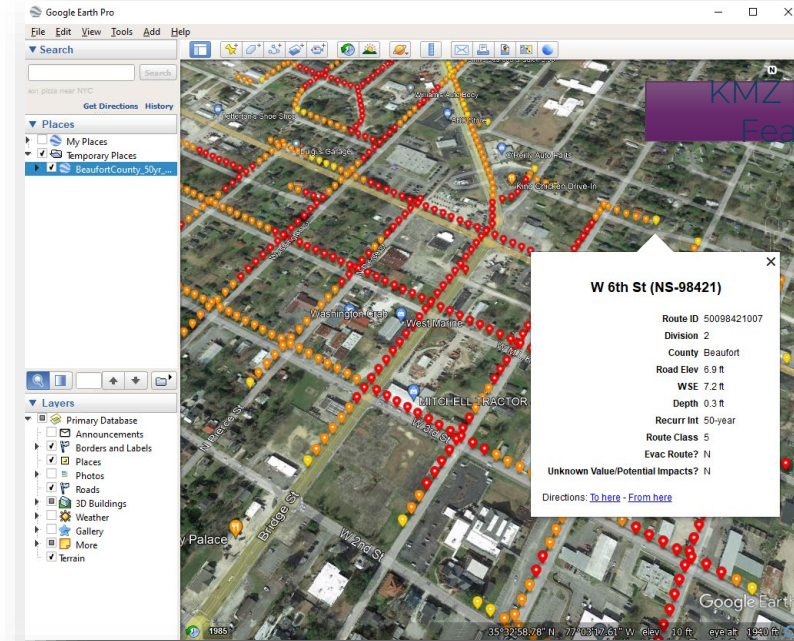
Roadway Inundation Tool (RIT)

- Based on multi-frequency riverine flood studies
 - 10-, 25-, 50-, 100- and 500-year recurrence intervals
- Statewide coverage
- Primary and secondary roads
- Originally an ArcGIS Online dashboard
- Built using open-source, scalable technologies

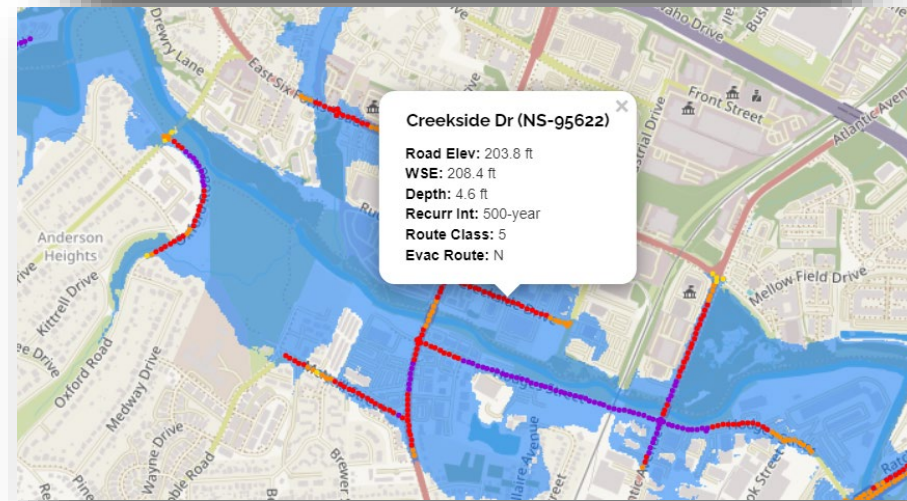


RIT: Goals

- Visualize and quantify road inundation
- Help NCDOT plan for:
 - Emergency response
 - Evacuation
 - Road closure
 - Climate change resiliency
- Provide quick, flexible access to data without reliance on GIS software
- Identify roads that may require higher maintenance or eventual replacement



KMZ Export Feature



Hydraulics Data

- Hydraulics Data Reservoir
 - This Repository is the final gathering place for records and documents utilized by the NCDOT as they relate to the Hydraulic aspects of design & maintenance.
- Drainage Investigation Dataset
 - Available on ATLAS
 - The NCDOT Drainage Investigations dataset is a statewide point layer containing locations of Drainage Investigations for tracking and review.
- MPE – Multi- Sensor Precipitation Estimates (MPE) –
 - This simple mapping application enables you to visually see precipitation estimates over time for project sites.

Hydraulics Data Reservoir

Available on Site

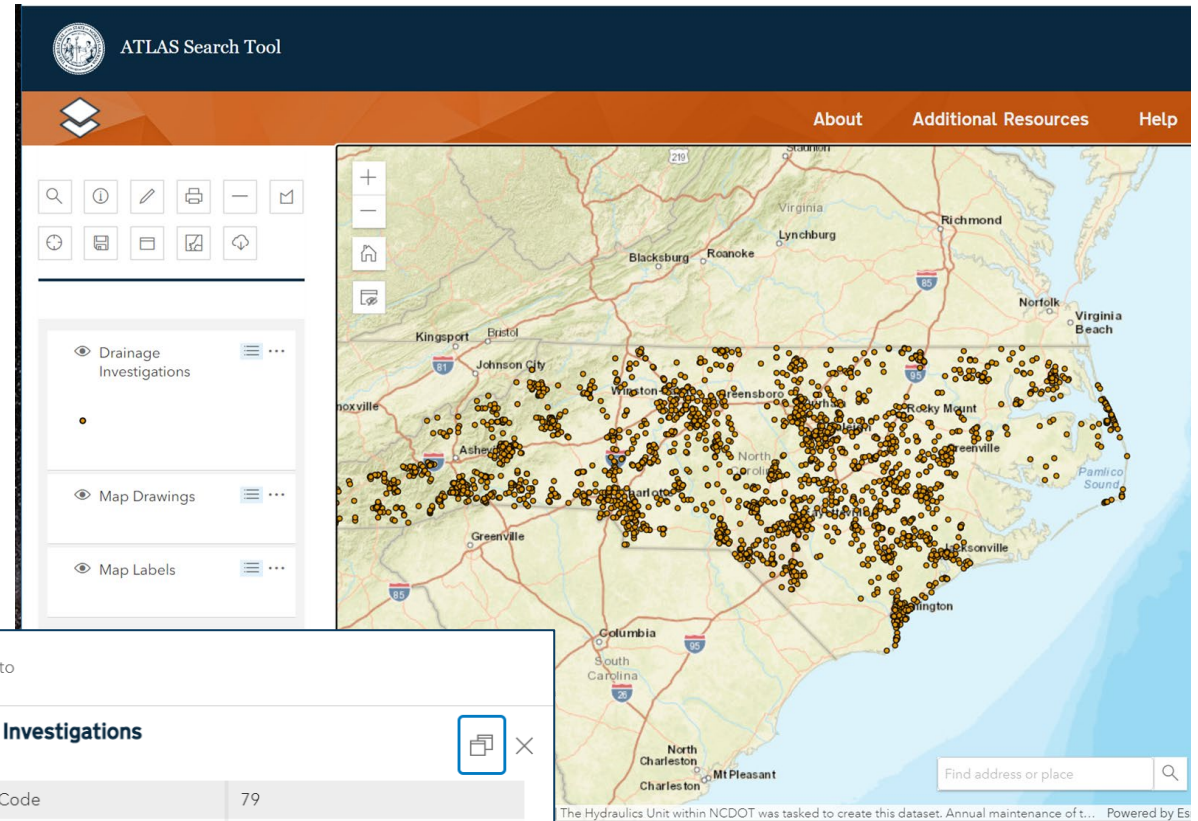
- Archived BSR/CSR
- Scour Assessments
- Archived Redline Drainage plans will be added soon.

The screenshot shows the 'Hydraulics Data Reservoir' website. At the top, there is a navigation bar with 'Connect NCDOT BUSINESS PARTNER RESOURCES', 'Home', 'Help', and 'Team Sites'. Below this is a 'Hydraulics Personnel Only' section with a search bar. The main content area features a 'Hydraulics Unit' logo and a descriptive text: 'This Repository is the final gathering place for records and documents utilized by the NCDOT as they relate to the Hydraulic aspects of design & maintenance.' On the left, there are navigation buttons for 'Hydraulic Design Reports (BSRs/CSRs)', 'Hydraulic Drainage Plans (redlines)', and 'Scour Reports', along with a 'Recent' list. The main content area is divided into 'Reports' and 'Plans' sections. The 'Reports' section includes a search bar and a list of report categories. The 'Plans' section includes a search bar and a list of plan categories. On the right, there is a detailed view of 'Hydraulic Design Reports (BSR/CSR)' for 'County Alameda to Jackson', showing a table of reports with columns for Structure Number, Name, Latitude, Longitude, Report Year, County, and Division.

Structure Number	Name	Latitude	Longitude	Report Year	County	Division
000000	00 0000 1951 NO TIP BASON CK (2 MI E OF OSSIPEE) UK	36.17505	-79.48273	1951	Alameda	7
000000	00 0000 1951 NO TIP STA_4120 MICHAEL BR WO_5-9-42-205 UK			1951	Alameda	7
000000	00 0000 1950 NO TIP STA_8930 SOUTHERN RR US 54 B WO_5-9-42-205 UK			1950	Alameda	7
000000	00 0000 1939 NO TIP STA_435 DRY CR NC 87 WO_5102 [-79.489809,36.127123] UK	36.12712	-79.48981	1939	Alameda	7
000000	00 0000 1957 NO TIP STA_223451 BACK CR US 70 WO_815014 UK	36.09350	-79.33573	1957	Alameda	7
000000	00 0000 1988 r0611 stream us70 byp WO_81470201 UK			1988	Alameda	7
000000	00 0000 1995 B2501 trib to big alameda cr sr1146 WO_81470701 UK	36.04217	-79.48735	1995	Alameda	7
000000	00 0000 1999 U2406 DRY CR NC 100 BYP UK	36.11051	-79.49019	1999	Alameda	7
000000	00 0000 2000 U2905 STA_3665 STREAM NEW RTE UK			2000	Alameda	7

Drainage Investigation Dataset

- A statewide point layer containing locations of Drainage Investigations for tracking and review.
- Locations contain information related to the location, division involved and related documents.
- Data is used to help facilitate understanding of past investigations and correlation between requests receive to help understand if they are potentially related to past incidents or a larger drainage problem.
- While the layer itself is not restricted, the documents linked to this layer are restricted, and must be requested from the Hydraulics Unit using the provided form.
- Use of this dataset for project scoping or screening is merely pre-decisional.



Drainage Investigations	
CountyCode	79
Division	9
DocumentDate	2/20/2005, 7:00 PM
Latitude	35.64555
Longitude	-80.48408
ViewDocumentation	View
DocumentName	DI_79_SR2541_20050221.pdf
County	Rowan
Route	SR2541
DocumentationRequest	To request this document, please contact the Hydraulics Unit by filling this form https://forms.office.com/g/ANUC2xbEbK

Multi-Sensor Precipitation Estimates



Welcome, Matthew Lauffer. Not you? [Click here to logout.](#)

Use the links above or below to navigate this website. [View a tutorial](#) on the usage of this website.

The precipitation estimates provided herein are derived from the NWS WSR-88D Doppler Radar. Radar precipitation estimates can be grossly inaccurate, so radar-based precipitation values are calibrated with the routinely available hourly surface gages. The combined product provides the spatial resolution of radar with the increased accuracy of surface gage networks. These gage-calibrated radar estimates are known as Multi-sensor Precipitation Estimates, or MPE.

There are still errors in MPE. A study by the State Climate Office of North Carolina suggests that MPE compares well with an independent daily precipitation gage network over the Carolinas. Details of this study are available [online](#).

The MPE grids used in this tool are routinely produced by the National Weather Service and National Centers for Environmental Prediction.

MAP

This simple mapping application enables you to visually see accumulated MPE estimates over time. When zoomed in, roads, water features, and town names can be overlaid for reference. Additionally, your project sites can be noted on the map for additional reference. The past 0, 12, 24, 48, and 72 hours are available to view spatially. 1-week, 30- and 60-day options are also available.

MY PROJECTS

This page shows a list of all projects that you are subscribed to receive precipitation alerts from. Each project has a list of associated sites. Accumulated MPE values are listed for all sites in text format. You can also view all projects.

MY ALERTS

This is the alert management system. This is where to go to manage your e-mail alert subscriptions.

GET MORE MPE DATA

Quickly get the MPE values for any latitude/longitude in and around North Carolina.

Cardinal Data Request System

Cardinal is a high-powered, user-oriented, one-stop-shop for North Carolina weather and climate data housed at the North Carolina State Climate Office. Cardinal makes weather and climate data more accessible to users, with features and prompts that take the guesswork out of station and parameter identification and selection. The system includes a step-by-step interface to request data, as well as a My Requests page for users to access their requested data and to view their current, in-progress, recently completed, and past data requests.

Select Layers:

- MPE
- Precip Estimate
- My Project Sites
- Geographic**
 - County Lines
 - Cities
 - Rivers & Streams
 - HUC-6
 - HUC-8
- Transportation**
 - Interstates
 - Primary Roads
 - Secondary Roads

[Make PDF](#)

Time Period:
Last 90 days

Period: 2160 hour
Using 24 hour files

Start: 7AM EST Tue, Feb 14, 2023
End: 7AM EST Mon, May 15, 2023

Legend:

- County Lines
- <= 2 in.
- 2 - 4 in.
- 4 - 6 in.
- 6 - 8 in.
- 8 - 10 in.
- 10 - 12 in.
- 12 - 14 in.
- 14 - 16 in.
- 16 - 16.75 in.
- 16.75 - 17.5 in.
- 17.5 - 18.25 in.
- 18.25 - 19 in.
- 19 - 19.75 in.
- 19.75 - 23.75 in.

Mouse Coordinates (lon °W, lat °N): -78.70578, 36.43683

Stormwater

- NC-SELDM Catalog Tool
- BMP Decision Support Matrix
- Stormwater Control Measure Summary Sheets

NC-SELDM Catalog Tool

The screenshot shows an Excel spreadsheet with the following sections:

- Input Fields:**
 - Project Number: [Yellow cell]
 - Name & Firm: [Yellow cell]
- Upstream basin characteristics (from StreamStats - see the 'Detailed Instructions' worksheet).**

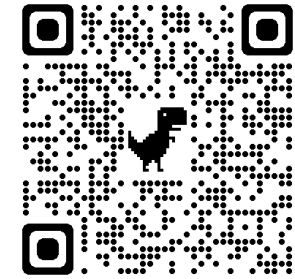
Parameter Code	Parameter Description	Value	Unit
CSL10_85fm	Change in elevation between points 10 and 85 percent of length along main channel to basin divide divided by length between points.	[Yellow cell]	feet per mile
DRNAREA	Area that drains to a point on a stream.	[Yellow cell]	square miles
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset.	[Yellow cell]	percent
PCTREG1	Percentage of drainage area located in Region 1 - Piedmont / Ridge and Valley.	[Yellow cell]	percent
PCTREG2	Percentage of drainage area located in Region 2 - Blue Ridge.	[Yellow cell]	percent
PCTREG3	Percentage of drainage area located in Region 3 - Sandhills.	[Yellow cell]	percent
PCTREG4	Percentage of drainage area located in Region 4 - Coastal Plains.	[Yellow cell]	percent
- Highway drainage area characteristics (from preliminary design plans - see the 'Detailed Instructions' worksheet).**

Parameter Name	Parameter Description	Value	Unit
Drainage area size	Highway and bridge deck area that drains to the highway-stream crossing of interest.	[Yellow cell]	acres
Avg. highway slope	Average highway slope draining to the stream (elevation change btw. highest and lowest points divided by the length of the flow-path).	[Yellow cell]	percent
Avg. drainage length	Average length of the flow-paths between the highest and lowest elevations on the highway that drain to the stream.	[Yellow cell]	feet
- Output (raw output below, details in the 'Report' worksheet).**

Output	Output Explanation
#N/A	Error - check input parameters
[Red cell]	No result returned - check for errors in the input parameter cells.
[Green cell]	Valid result returned based on input parameters.

BMP Decision Support Matrix

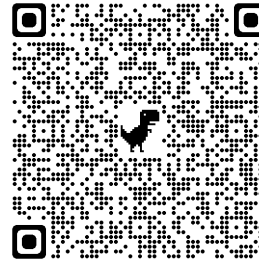
BMP Selection Criteria	Bio-embankment ^{1a}		Biofiltration Conveyance ^{1a}		Bioretention ^{1a,2}		Bioswale ^{1a}		Dry Detention Basin ^{1a}	Filter Strip w/ Level Spreader ^{1a}	Filtration Basin ^{1a,2}		Green Roof ^{1a}	Infiltration Basin ^{1b}	Open Graded Friction Course ^{1a}	Permeable Pavement		Preformed Scour Hole ^{1a}	Rainwater Harvesting ^{1a,3}	Sand Filter ^{1a,4}	Soil Improvement ^{1a}	Storm-water Wetland ^{1a}	Swale ^{1a}		Tree Box ^{1a}	Wet Detention Basin ^{1a}
	w/o IWS	w/IWS	w/o IWS	w/IWS	w/o IWS	w/IWS	w/o IWS	w/IWS			Detention ^{1a}	Infiltrating ^{1a}				Dry	Wet									
Removal Efficiency for Parameters of Concern (POCs)¹																										
Bacteria	Med	Med	High	Med	Low	Low	High	Low ¹²	High	Low	Med	High	Low	High	Low	Med	High	Low	Varies	Med	Low	High	Low	Med	High	
Metals																										
Dissolved Metals	Low	Low	Med	Med	Low	Low	Med	Low	High	Low	Low	High	Low	High	Low	Med	High	Low	Varies	Low	Low	Med	Low	Med	Low	
Total Recoverable Metals	Low	Low	High	Med	Med	Med	High	Low	High	Low	Med	High	Low	High	Low	Med	High	Low	Varies	Low	Low	High	Low	Med	Med	
Nutrients																										
Dissolved Nitrogen ⁵	Low	Low	Med	Med	High	Low	Med	Low	Low	Med	High	Low	High	Low	Low	High	Low	Varies	Low	Low	Med	Low	Low	Low	Low	
Total Nitrogen ⁵	Low	Low	Med	Med	High	Low	Med	Low	Low	Med	High	Low	High	Low	Low	High	Low	Varies	Low	Low	High	Low	Med	Med	Low	
Dissolved Phosphorus	Med ¹¹	Med ¹¹	Med ¹¹	Med ¹¹	Low	Low	Med ¹¹	Low	High	Low	High	Low	High	Low	Med	High	Low	Varies	Med ¹¹	Low	Med	Low	Low	Med ¹¹	Low	
Total Phosphorus	Med	Med	High	Med	Med	Low	High	Med	High	Low	High	Low	High	Low	Med	High	Low	Varies	Med	Low	High	Low	Med	Med	Med	
Oil and Grease	High	High	High	High	Med	Med	High	N/A	High	Med	High	High	High	Med	Med	High	Med	Varies	Med	Med	High	Med	High	High	Low	
Organics	High	High	High	High	Med	Med	High	Med	High	Low	High	High	High	Low	Med	High	Med	Varies	Med	Med	High	Med	High	High	Low	
Temperature	Med	Med	High	Med	Low	Med	High	High	High	Low	High	High	High	Low	Med	High	Med	Low	Med	High	Low	Low	High	High	Low	
Total Suspended Solids	High	High	High	High	Med	Med	High	High	High	Med	High	High	High	Med	Med	High	Med	High	High	High	Med	High	High	High	High	High
Trash	Med	High	High	High	High	High	High	High	N/A	High	High	High	High	Med	High	High	High	High	High	Med	High	High	High	High	High	
Water Quantity																										
Runoff Volume Reduction	Med	Low	Med	Med	High	Med	High	Med	Low	Med	High	Med	High	Low	Low	High	Low	Varies	Low	Med	Low	Low	Med	Low	Low	
Peak Flow Control	Low	Low	Med	Med	High	Med	High	Med	Med	Med	High	Med	High	Low	Med	High	Low	Varies	Med	Low	High	Low	Low	Low	High	
Siting Constraints and Other Implementation Considerations																										
Space Requirement	Low	Low	Med	Med	Med	Med	Low	Med	Low	Med	Low	Med	Low	Med	Low	Med	Low	Low	Med	Low	High	Low	Low	Low	High	
Environmental Issues⁶																										
Contaminated Soils ⁷	Use liner	Use liner	Use liner	Use liner	Use liner	Use liner	Use liner	Use liner	Yes	No	Yes	Use liner	No	No	Yes	Use liner	No	Use liner	No	Use liner	Use liner	Use liner	Use liner	Use liner	Use liner	
Physical Site Limitations⁸																										
Karst Topography	Use liner	Use liner	Use liner	Use liner	Use liner	Yes	Use liner	Yes	No	Yes	Use liner	No	Yes	Yes	Use liner	No	Yes	Yes	Use liner	Yes	Use liner	Yes	Use liner	Use liner	Use liner	
Shallow Bedrock ⁹	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Shallow Water Table ⁹	No	Yes	No	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No	
Steep Slopes (>5%) ¹⁰	No	Yes	No	No	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	No	No	No	No	
Cost Considerations																										
Construction Cost	\$-\$\$	\$\$-\$\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	
O&M Cost	\$-\$\$	\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$	\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	\$-\$\$	



¹ "High", "Med", "Low", or "N/A". ^{1a} EMC-based pollutant reduction. ^{1b} Load-based pollutant reduction.
² All NCDOT Bioretention and Filtration Basin facilities include underdrain; if no underdrain, see Infiltration Basin.
³ Water quality and quantity performance varies based on size of system and use of captured water.
⁴ For Sand Filter, an enclosed chamber type system (e.g., Austin/Delaware) is assumed.
⁵ Note that nitrogen concentrations in roadway runoff are generally low; this reduces the removal efficiency of many BMPs.
⁶ "Yes" indicates BMP is suitable for locations with a particular siting constraint. "No" indicates that the BMP is not suitable.
⁷ When contaminated soils are present, consultation with the Geotech Unit and Hydraulics Unit is highly recommended.
⁸ For suitable BMPs, it may be necessary to increase practice footprint and/or install an impermeable liner to achieve desired performance.
⁹ For suitable BMPs, an impermeable liner may be required. Additional investigation and consultation with Geotech and Hydraulics Units recommended.
¹⁰ For green roof, slope refers to roof pitch. Note that design modifications are required for roof pitch >8% (per NCDEQ).
¹¹ With media amended or enhanced to increase dissolved P removal.
¹² Green roofs are not typically a significant source of bacteria.

Stormwater Control Measure Summary Sheets

- To be a part of the 3D series (Drainage Summary) sheets in plan sets
- Auto-populated from entries in the stormwater management plan



COMPUTED BY: _____ DATE: _____		(08-05-21)		TIP/PROJECT NO: _____ SHEET NO: _____		
DRAWN BY: _____ DATE: _____				T-124 3D-3		
STATE OF NORTH CAROLINA DIVISION OF HIGHWAYS						
SUMMARY OF STORMWATER CONTROL MEASURES						
CONTR SHEET NO.	SCH TYPE	LINE	STATION	Location (EASTING)	Latitude	Longitude
1	Retention Basin	L	10+25	LT	33 1265	-78 1265
2	Basin	L	10+50	RT	33 1234	-78 2571
3	Basin	L	10+75	LT	33 1255	-78 1643
4	Dry Detention Basin	L	10+42	RT	1 2854	-78 3624
5	Basin	Y1	25+00	RT	31 2854	-78 3264

Completing 3D Series Hydraulic Summary Plan Sheets, Including Drainage Summary Sheets and Stormwater Control Measure Summary Sheets

August 5, 2021

Construction plan sheets include 3D Series drainage summary sheets. Traditionally these sheets have included the summary of pipe and drainage structure types. With the implementation of Project Delivery Network version 2.0 the 3D series sheets will now also include stormwater control measure summaries for projects where stormwater controls are included. Not all projects will include stormwater control measures, thus these sheets should be the last sheets within the 3D series.

Drainage Summary Sheets:

Drainage summary sheets should be filled out per guidance in the "Drainage Summary Sheet – Steps for Hydraulic Users" located on the Connect site here: <https://connect.ncdot.gov/resources/hydro/Geopak%20Applications%20Documents/Drainage%20Summary%20Sheet%20-%20Hydro%20Steps.pdf>

Once the traditional drainage summary sheets have been filled out the user should add the stormwater control summary sheets starting with the next available consecutive page number.

Stormwater Control Measure Summary Sheets:

The Highway Stormwater Program (HSP) has amended the Stormwater Management Plan (SMP) template to automate the creation of the stormwater control measure summary sheet. Hydraulic design engineers are required to complete a Stormwater Management Plan (SMP) for all projects and should always use the latest SMP template version found on the Connect Site here: <https://connect.ncdot.gov/resources/hydro/Pages/HSPProductPages.aspx?PRQD=SMP>

Users should complete the SMP per the instruction included in that document. As a general summary, users should fill out the 'General Project Information' and 'Waterbody Information' tabs along with any applicable stormwater control measure tabs (Swales, Filter Strip, PSHs & Energy Dissipators, Level Spreader & HSB, Other Toolbox BMPs, Other Non-Toolbox BMPs). These tabs are illustrated in Figure 1.


Hydraulic Calculators

- Hydroplaning Assessment Tool
 - This tool will assist in completing hydroplaning assessments, when required, on the projects
- Outlet Analysis
 - Coming Soon



Hydroplaning Assessment Tool

<https://connect.ncdot.gov/resources/hydro/DrainageStudiesGuidelines/NCDOTHydroplaningAssessmentTool.xlsm>



Hydroplaning Analysis Tool

General Inputs Date

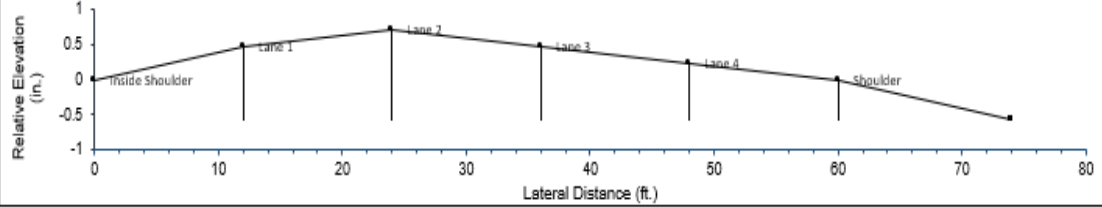
TIP	<input type="text" value="Example"/>	Designer	<input type="text" value="Designer's Name"/>
County	<input type="text" value="Johnston"/>	NCDOT Division No.	<input type="text" value="Division 4"/>
Project Description	<input type="text" value="Short Description of the Project"/>		
Typical Section/Area of Concern	<input type="text" value="Typical Section 1 - Assumed 5% Long. Grade (tangent section) [Ex: 1.0]"/>	Alignment	<input type="text" value="L"/>
Assessment Type	<input type="text" value="Preliminary"/>	Station/Milepost Range	<input type="text" value="Sta. or Mile Marker"/>
Analysis Description	<input type="text" value="Greater than 36 ft. of Impervious Pavement"/>	Direction	<input type="text" value="Northbound"/>
Analysis Notes	<input type="text" value="Dense graded asphalt and a 0.02 ft/ft cross slope over 3 lanes fails"/>		

Pavement Inputs

Longitudinal Grade (%) **Mean Profile Depth (in.)**

Surface Type

	1	2	3	4	5	6	7	8	9	10	11	12
Description	Inside Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
Design Speed (mph)	45	70	70	70	70	45						
Cross Slope (ft/ft)	-0.04	-0.02	0.02	0.02	0.02	0.04						
Width (ft.)	12	12	12	12	12	14						



Relative Elevation (in.) vs Lateral Distance (ft.)

Scenario Roadway Typical

Risk Analysis Results
Based on AVERAGE WFT, PAYDRN HPS Model, and a worst-case scenario rainfall intensity (in/hr)

Description	Side Should	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder					
Rainfall Intensity (in/hr)	4.0	2.0	2.0	2.0	2.0	4.0					
Water Film Thickness (in)	0.081	0.036	0.036	0.061	0.080	0.136					
Driver Speed (mph)	45.0	58.0	58.0	58.0	58.0	45.0					
Hydroplaning Speed* (mph)	54.9	66.7	66.7	58.7	55.0	52.1					

* The speed has been adjusted up +5 mph to account for Modern Tires.

General Inputs Date: 7/26/2022

TIP	Example	Designer	Designer's Name
County	Johnston	NCDOT Division No.	Division 4
Project Description	Short Description of the Project		
Typical Section/Area of Concern	Typical Section 1 - Assumed 5% Long. Grade (tangent section) [Ex 1.0]	Alignment	L
Assessment Type	Preliminary	Station/Milepost Range	Sta. or Mile Marker
Analysis Description	Greater than 36 ft. of Impervious	Direction	Northbound

Pavement Inputs

Longitudinal Grade (%) Mean Profile Depth (in.)

Surface Type

	5				
Description	Dense Graded Asphalt (DGAC)				
Design Speed					
Cross Slope (ft.)					
Width (ft.)					

Relative Elevation (in.)

- Dense Graded Asphalt (DGAC)
- Open Graded Friction Course (OGFC)
- Concrete Pavement (PCC)
- Ultra-Thin Bonded Wearing Course
- User-Defined

	Shoulder						
	45	70	70	70	70	70	80

Inputs

- General
- Pavement
- Roadway

Scenario Results

Risk Analysis Results
(Based on AVERAGE WFT and PAVDRN HPS Models)

Risk Analysis Results
Based on AVERAGE WFT, PAVDRN HPS Models

Description	Site
Rainfall Intensity (in/hr)	
Water Film Thickness (in)	
Driver Speed (mph)	
Hydroplaning Speed* (mph)	

* The speed has been adjusted up +5 mph

Possible Hydroplane Conditions
High



High: HPS is ≥ 4 mph Below the Predicted
Low: HPS is ≥ 2 mph Below The Predicted
 Mitigation methods needed and provide driver responsibility.
None: HPS is greater than Predicted

Predicted Water Film Thickness (in.)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Side Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
0.1	-0.012	-0.014	-0.014	-0.009	-0.005	-0.004						
0.25	-0.002	-0.006	-0.006	0.002	0.009	0.010						
0.5	0.009	0.003	0.003	0.015	0.024	0.027						
1	0.025	0.016	0.016	0.034	0.047	0.051						
2	0.048	0.036	0.036	0.061	0.080	0.086						
3	0.066	0.051	0.051	0.082	0.106	0.113						
4	0.081	0.064	0.064	0.100	0.128	0.136						

Predicted Driver Speed (mph)

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Side Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
0.1	45.0	70.0	70.0	70.0	70.0	45.0						
0.25	45.0	70.0	70.0	70.0	70.0	45.0						
0.5	45.0	64.0	64.0	64.0	64.0	45.0						
1	45.0	62.0	62.0	62.0	62.0	45.0						
2	45.0	58.0	58.0	58.0	58.0	45.0						
3	45.0	45.0	45.0	45.0	45.0	45.0						
4	45.0	45.0	45.0	45.0	45.0	45.0						

Predicted Hydroplaning Speed (mph)

"These speeds are increased by 5MPH to account for Gunaratne research."

Plane Number	1	2	3	4	5	6	7	8	9	10	11	12
Intensity (in/hr)	Side Shoulder	Lane 1	Lane 2	Lane 3	Lane 4	Shoulder						
0.1	999.0	999.0	999.0	999.0	999.0	999.0						
0.25	999.0	999.0	999.0	132.5	94.2	89.9						
0.5	93.9	122.5	122.5	82.1	73.1	71.3						
1	72.9	80.6	80.6	67.6	62.4	61.3						
2	62.3	66.7	66.7	58.7	55.0	54.2						
3	57.7	61.3	61.3	54.7	52.6	52.5						
4	54.9	58.1	58.1	52.8	52.2	52.1						

Typical Section/Area of Concern	Rollover Transition [Ex 3.0]		
Assessment Type	Final		
Analysis Description	Superelevation Transition		
Superelevation Transition	# of lanes	3	Factor
			1.5
	Fails with Dense Graded Asphalt		

Superelevation Transitions

Risk Analysis Results

Based on AVERAGE WFT, PAVDRN HPS Model, and a worst-case scenario rainfall intensity (in/hr)

Pavement

Longitude

Surface

Max WFT Condition within the SE Rollover	
Rainfall Intensity (in/hr)	2.0
Water Film Thickness (in)	0.106
Driver Speed (mph)	58.0
Hydroplaning Speed* (mph)	52.6

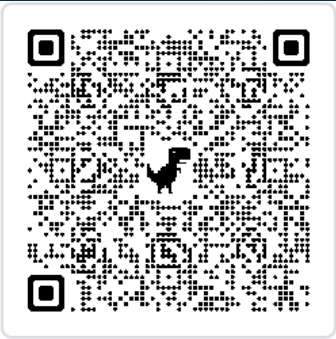
Description

* The speed has been adjusted up +5 mph to account for Modern Tires.

Design Speed (mph)	45	70	70	70	70	45						
Cross Slope (ft/ft)	-0.04	-0.02	0.02	0.02	0.02	0.04						
Width (ft.)	12	12	12	12	12	14						

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The Hydraulics Unit provides technical expertise, guidance, design and quality assurance to manage stormwater, riverine and coastal impacts in and around roadways for the protection of the public, the environment and NCDOT assets.

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