Attachment 11:

HEC-RAS Model Update for the Maple Swamp Bridge, October 28, 2019

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MEMORANDUM

To:	Roy Bruce, P.E. – H.W. Lochner, Inc.
From:	Moffatt & Nichol
Date:	October 28, 2019 (revised - June 22, 2020)
Subject:	Mid-Currituck Bridge – Maple Swamp Bridge HEC-RAS Model Update
M&N Job No.:	10555

In a 2009 memorandum titled "Mid-Currituck Bridge Detailed Study Alternatives Assessment of Hydraulic Impacts to Flood Elevations, Existing Drainage Patterns, and Groundwater," a one-dimensional, unsteady flow model was developed using HEC-RAS (Hydraulic Engineering Center-River Analysis System) to compare the impact of a proposed bridge over the Maple Swamp in Currituck County, NC. The Maple Swamp bridge is a portion of the proposed Mid-Currituck Bridge, which will span the Currituck Sound, connecting NC 158 on the Currituck Peninsula with NC 12 on the Outer Banks. The 2009 model was later updated in 2010 by reducing roughness values to reflect logging that had occurred. The 2010 HEC-RAS model included a comparison of the maximum water surface elevations for a 100-yr and 10-yr storm surge on both the existing geometry and the proposed fill scenario. The 100-yr and 10-yr storm surges for that analysis were developed using data from the Flood Insurance Rate Map (FIRM) panel (Map Number: 3720990600J; Effective Date: December 16, 2005) and the Flood Insurance Study (FIS) for Currituck County (FIS number: 37053CV000A; Effective Date: December 16, 2005) developed by the Federal Emergency Management Agency (FEMA).

The Mid-Currituck Bridge design was changed in 2019 to a 79-span structure. The HEC-RAS model for the Maple Swamp Bridge was updated to reflect the new bridge design. Additionally, the FEMA FIRM panels and the FIS used for the original hydraulic analysis on the Maple Swamp Bridge have been revised since 2018. Thus, similar analysis was performed with the new proposed Maple Swamp Bridge using the more recent data from the FEMA documentation.

The Maple Swamp Bridge proposed bridge structure has been updated since October 2019 from a 79-span structure to an 80-span structure with minor changes to the span lengths for the last 3-4 spans on each end. Thus, the modeling effort was updated from the previous 2019 model to incorporate these design changes. Additionally, a scour analysis was performed for the 80-span bridge design. The design changes and the results of the scour analysis are described below.

Updated Bridge Geometry

The original files from the 2010 model were copied over to a new file folder, and a new geometry file was created by copying the original proposed fill geometry and updating the bridge structure. Information for the design of the Maple Swamp Bridge for the 2019 HEC-RAS model came from an email dated 7/17/2019 from Roy Bruce of Lochner. For a description of the 2019 Maple Swamp Bridge 79-span design, please refer to the previous memo dated October 28, 2019. The current proposed bridge design was updated on 3/30/2020 to an 80-span bridge. Span 1 has a length of 88 ft, spans 2 through 4 have a length of 89 ft, spans 5 through 76 have a length of 100 ft, spans 77 through 79 have a length of 73 ft, and span 80 has a length of 70 ft. The western side of the bridge has a 118 ft width for 354 ft of the bridge length, and tapers to a 36 ft width after 700 ft of the bridge length. The greater width and subsequent tapering represent approximately 13% of the total bridge length, and thus a bridge width of 36 ft was used in HEC-RAS. The bridge was assumed to be at the same centerline as the previous proposed bridge in the HEC-RAS model. The cross sections, the inline structure representing an old logging road within both the existing and proposed geometry files, and the bridge structure representing Aydlett Road within the existing and proposed geometry file were left unchanged.

The 2010 HEC-RAS model only used the energy equation for the bridge modeling approach of the proposed Maple Swamp bridge. Upon review of the momentum equation and the Yarnell equation for the bridge modeling approach, the momentum equation was found to give the highest energy answer and resulted in deeper scour results. Thus, the momentum equation was used instead of the energy equation for the bridge modeling approach in the 2020 HEC-RAS model.

Updated Unsteady Flow Models

The 2010 HEC-RAS model used two unsteady flow data corresponding to the 100-yr and the 10-yr storm surge, including a flow hydrograph for the upstream boundary and a stage hydrograph for the downstream boundary. The flow hydrograph for both the 10-yr and the 100-yr storm surge conditions was a uniform hydrograph of 35.5 cfs and was left unchanged for the updated analysis. The stage hydrographs for the 10-yr and 100-yr were created using a peak stillwater elevation of 3.5 ft NAVD88 and 6.0 ft NAVD88 respectively. A review of the revised FEMA FIRM panels for the Maple Swamp (Map Numbers: 3720990600K and 3720990400K; Effective Date: December 21, 2018) showed that the Maple Swamp is located within Zone AE, and the Base Flood Elevation for a 100-yr storm event is now 4.0 ft NAVD88 at the downstream boundary of the Maple Swamp. The 100-yr storm surge event was thus updated in the 2019 HEC-RAS model to reflect the 4.0 ft NAVD88 peak stillwater elevation. Additionally, the revised FEMA FIS for Currituck County (FIS Number: 37053CV000B; Effective Date: December 21, 2018) does not have 10-yr stillwater elevations for the Maple Swamp, but it is assumed there is a minimal increase in tidal elevations during a 10-yr storm event and therefore a minimal impact on the Maple Swamp. Thus, the 10-yr storm surge was not analyzed in the 2019 HEC-RAS model.

The FEMA data used for the 2019 HEC-RAS model is currently still effective, so the 100-yr storm surge flow hydrograph used for the 2019 HEC-RAS model was left unchanged for the 2020 HEC-RAS model. A 500-yr storm surge was required for the scour analysis. The Currituck County FIS indicates a maximum 500-yr stillwater elevation of 5.0 ft NAVD88 from coastal transects taken around the downstream boundary of the Maple Swamp, and thus a 500-yr storm surge event was created for the 2020 HEC-RAS model using a 5.0 ft NAVD88 peak stillwater elevation.

The 2010 HEC-RAS model also included restart files (hotstart files) for initializing the model, which were incompatible with version 3 of HEC-RAS. New hotstart files were created for the 100-yr and the 500-yr storm surge conditions to stabilize the model during initialization at a constant flow rate of 35.5 at the upstream boundary.

2020 HEC-RAS Model Results

The existing geometry and the proposed 80-span bridge geometry were both run in the 2020 HEC-RAS model using the 100-yr storm surge event, and the maximum water surface elevations from each run were compared. The modeling results show the addition of the proposed bridge corresponds to a 0.02 ft decrease in maximum water surface elevation approximately 3,000 ft downstream (North) of the proposed bridge at River Station 1.9, and a 0.06 ft decrease approximately 2,000 ft upstream (South) at River Station 8. These results suggest that the proposed Maple Swamp bridge will have a negligible impact on the flood elevations within the Maple Swamp.

Scour Analysis

A scour analysis was performed for the proposed Maple Swamp Bridge using methods from HEC-18 (*Evaluating Scour at Bridges*). The live-bed contraction scour equation from HEC-18 was used to calculate contraction scour for the 100-yr and 500-yr conditions. The data used for the contraction scour calculations included the hydraulic depth (ft), the top width of the channel (ft), and the flowrate (cfs). These values were taken from the upstream bridge cross section of the Maple Swamp Bridge (RS: 5.5U) and the approach cross section of the Maple Swamp Bridge (RS: 8) from the proposed bridge model in HEC-RAS. A summary of these values is shown in Table 1. The HEC-18 pier scour equation was used to calculate pier scour for the 100-yr and 500-yr conditions. Data for the pier scour calculations included the hydraulic depth at each pier location (ft), and the Froude Number, which is a function of the velocity in the channel (ft/s). These values were taken from the upstream bridge cross section (5.5U).

The contraction scour was found to be negligible for the 100-yr condition and 0.54 ft for the 500-yr condition. The total scour for each applicable bent is shown in Table 2. The maximum total scour found for the Maple Swamp Bridge was 0.25 ft from bents 54 to 69 for the 100-yr condition, and 0.97 ft from bents 54 to 69 for the 500-yr condition. Bents 1 through 8 and bents 73 through 80 were not inundated during peak storm surge conditions, and thus no scour is expected at those piers.

Table 1: Summary of data from the 2020 HEC-RAS model used to calculate contraction scour using the live-bed equation from HEC-18. Negative flowrates suggest flow moving upstream, indicative of the downstream storm surge pushing the flow upstream at the measured river stations. The resulting contraction scour was found to be 0 ft for the 100-yr condition, and 0.60 ft for the 500-yr condition.

	Upstream Bridge Cross Section (RS: 5.5U)		**Approach Cross Section (RS: 8)**	
	100-yr	**500-yr**	**100-yr**	**500-yr**
Hydraulic Depth (ft)	0.81	1.72	0.47	1.42
Flowrate (cfs)	34.04	-139.44	36.24	-75.76
Top Width (ft)	6031.76	6256.58	5226.65	5970.26

Table 2: Table of calculated total scour (contraction scour + pier scour) for the 100-yr and 500-yr flow conditions at each bent of the proposed Maple Swamp Bridge based on methods from HEC-18. Bents 1-8 and 73-80 were not included as the maximum water surface elevation did not reach those bents and thus experience no scouring. Stations are based on the -L- chain from the roadway design plans.

Bent Number	**Station**	**Scour Depth (ft)**		**Bent Number**	**Station**	**Scour Depth (ft)**	
		100-yr	**500-yr**			**100-yr**	**500-yr**
9	31+00.	0.00	0.89	41	63+00.	0.23	0.96
10	32+00.	0.00	0.93	42	64+00.	0.23	0.96
11	33+00.	0.15	0.94	43	65+00.	0.23	0.96
12	34+00.	0.19	0.94	44	66+00.	0.23	0.96
13	35+00.	0.20	0.94	45	67+00.	0.23	0.96
14	36+00.	0.20	0.94	46	68+00.	0.24	0.96
15	37+00.	0.21	0.95	47	69+00.	0.24	0.96
16	38+00.	0.21	0.95	48	70+00.	0.24	0.96
17	39+00.	0.21	0.95	49	71+00.	0.24	0.96
18	40+00.	0.22	0.95	50	72+00.	0.24	0.96
19	41+00.	0.22	0.95	51	73+00.	0.24	0.96
20	42+00.	0.22	0.95	52	74+00.	0.24	0.96
21	43+00.	0.22	0.95	53	75+00.	0.24	0.96
22	44+00.	0.22	0.95	54	76+00.	0.25	0.97
23	45+00.	0.22	0.95	55	77+00.	0.25	0.97
24	46+00.	0.22	0.95	56	78+00.	0.25	0.97
25	47+00.	0.22	0.95	57	79+00.	0.25	0.97
26	48+00.	0.22	0.95	58	80+00.	0.25	0.97
27	49+00.	0.22	0.95	59	81+00.	0.25	0.97
28	50+00.	0.22	0.95	60	82+00.	0.25	0.97
29	51+00.	0.22	0.95	61	83+00.	0.25	0.97
30	52+00.	0.22	0.95	62	84+00.	0.25	0.97
31	53+00.	0.22	0.95	63	85+00.	0.25	0.97
32	54+00.	0.22	0.95	64	86+00.	0.25	0.97
33	55+00.	0.23	0.95	65	87+00.	0.25	0.97
34	56+00.	0.23	0.95	66	88+00.	0.25	0.97
35	57+00.	0.23	0.95	67	89+00.	0.25	0.97
36	58+00.	0.23	0.95	68	90+00.	0.25	0.97
37	59+00.	0.23	0.96	69	91+00.	0.25	0.97
38	60+00.	0.23	0.96	70	92+00.	0.24	0.96
39	61+00.	0.23	0.96	71	93+00.	0.23	0.95
40	62+00.	0.23	0.96	72	94+00.	0.00	0.93

Conclusion

In summary, the 2010 HEC-RAS model for the Maple Swamp Bridge was updated in 2019 with a 79-span bridge structure and more recent estimates of storm surge and Base Flood Elevations from FEMA FIRM panels and FIS. The 2019 HEC-RAS model has now been updated to the 2020 HEC-RAS model with an 80-span bridge structure. The model results indicate that for a 100-yr storm surge, the addition of the proposed bridge has a negligible impact on flood elevations on both the upstream and downstream sides of the proposed bridge. The maximum expected scour at the proposed bridge is 0.25 ft for the 100-yr storm surge condition and 0.97 ft for the 500-yr storm surge condition. Table 3 shows the 100-yr existing and proposed water surface elevation based on the inputs described in this memorandum.

Table 3: 100-yr existing and proposed water surface elevations from the 2020 HEC-RAS model.

River Station	Existing Conditions Water Surface Elevation (ft)	Proposed Conditions (with Bridge) Water Surface Elevation (ft)
13	6.15	6.15
12	4.23	4.23
11	3.64	3.64
10	3.46	3.46
9.5	Aydlett Road	
9	2.69	2.63
8	2.68	2.63
6	2.68	2.63
5.5	New Maple Swamp Bridge	
5	2.68	2.66
4	2.68	2.68
3	2.70	2.69
2	2.87	2.85
1.95	Old Logging Road	
1.9	2.87	2.85
1	3.46	3.46
0	3.86	3.86
-1	4.00	4.00