REPORT

TO:	Charles River Watershed Association
FROM:	Weston & Sampson
DATE:	April 12, 2023
SUBJECT:	Eagle Dam Removal Phase II
	Sub-task 3.2: Updated Charles River Flood Model for Eagle Brook
	Sub-task 3.3: Hydraulic Analysis

This report documents the hydraulic and hydrologic (H&H) modeling completed to support the Fiscal Year 2023 MVP Action Grant for the Town of Wrentham related to the Phase II Feasibility Assessment and Community Outreach for Eagle Dam.

The Charles River Flood Model (CRFM) is a computer flood model of the upper and middle Charles River watershed that identifies where and when flooding will occur under various present day (baseline) and future rainfall scenarios. The CRFM uses a software called PCSWMM to simulate flooding across the study area. The cities of Boston and Cambridge, which border the Lower Charles River Basin, already had detailed models demonstrating the impacts of both freshwater and coastal flooding in their communities prior to the launch of this initiative. The CRFM geographic extent covers whole or part of 33 municipalities and a total area of 273 square miles. The technical details of developing, calibrating and validating the CRFM are available in the Charles River Flood Model report found on the CRWA website[1].

Model Updates for Eagle Dam

On February 24, 2023, Weston & Sampson observed existing conditions and used a GPS unit[2] to collect relevant elevations at hydraulic features between Lake Archer in Wrentham, MA and Main Street in Norfolk, MA. The goal of this work was to verify discrepancies identified in Phase I, update information accordingly, and collect additional information necessary to update the H&H model. The April 12, 2023, memorandum titled *Eagle Dam Removal Phase II Sub-task 3.1 Field "Survey" and "Investigations"* documents the field effort.

[1] https://www.crwa.org/watershed-model
[2] Trimble TDC600 Handheld Data Collector

Data collected in the field during February 2023 were used to update the CRFM:

- Dam and roadway heights were modified in the CRFM based on the information collected.
- Dimensions measured were used to represent dam outlets and culverts more accurately along Eagle Brook in the CRFM.
- Lake Archer's outlet was previously modeled assuming the outlet was flowing west from Lake Archer through the Rowell Road, Creek Street, and Gilmore Road neighborhoods. Field work verified the outlet flows southwest between Rowell Road and Welcome Lane before entering the Creek Street culvert. This observation was reflected in updates to the CRFM.
- Previously, the CRFM did not explicitly model the unnamed dam at Mill Pond and the stream crossing immediately downstream. Based on field measurements, this area was incorporated into the updated model.
- Since the CRFM was developed at a watershed scale, the reach from Lake Archer to Main Street was modeled with moderate detail. The two dimensional (2D) mesh in this area had a very coarse resolution. This section of the CRFM was updated to include a 2D mesh with a much finer resolution to provide more detailed estimates of flooding extents and elevations in Eagle Brook. See Figure 1 below for a comparison of the old and new 2D mesh resolutions.

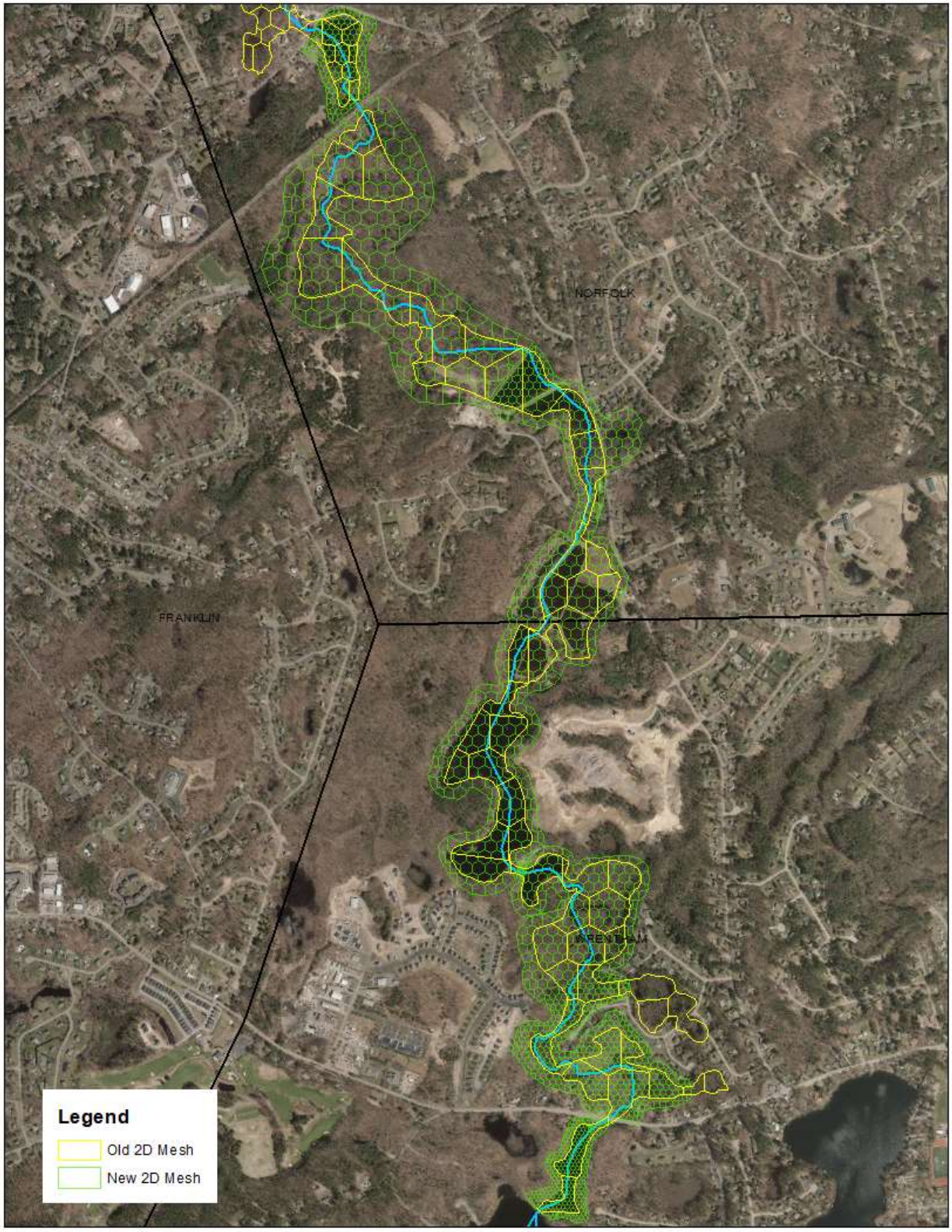
Design rainfall depths and distributions in the CRFM were also updated to reflect the latest guidance on present day climate (i.e., National Oceanic and Atmospheric Administration (NOAA) Atlas 14[3]) and future climate scenarios using the Resilient Massachusetts Action Team (RMAT) Climate Resilience Design Standards Tool[4]. Updated total precipitation depths for 24-hour design storms were made available in the latest version of the RMAT Tool released in April 2022. These are considered the best available climate science data for the project area, and therefore the CRFM was updated to reflect these rainfall projections. The rainfall distribution was also updated to the NOAA Atlas14 temporal rainfall distribution. Table 1 lists the recurrence internals and associated 24-hour design storms under baseline (present day) conditions and future conditions (year 2070).

Table 1: 24-Hour Storm Event Recurrence Intervals and Precipitation Amounts

Recurrence Interval	Baseline Conditions (inches of precipitation in 24 hours, NOAA Atlas 14)	2070 Conditions (inches of precipitation in 24 hours, RMAT Tool)
2-year	3.4	4.6
10-year	5.2	7.1
50-year	7.2	9.8
100-year	8.2	11.1
500-year	11.0	14.9

[3] https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html
[4] https://resilientma.mass.gov/rmat_home/designstandards/

Figure 1: Comparison of 2D Mesh Resolutions



Dam Removal Model Results

The updated CRFM model was used to perform a preliminary evaluation of the potential changes to the expected peak flood level and velocities downstream of the dam during a range of design storm conditions, as a result of dam removal. The ultimate goal of these analyses is to understand the dam removal's potential impact on the hydraulic performance of the Rte. 140 crossing immediately downstream and any impacts to flood risk at several homes in and near the floodplain between the Rte. 140 crossing and Main Street in Norfolk.

Dam removal was evaluated by creating a "dam-out" version of the PCSWMM-based model and comparing its output to the corresponding results of the existing conditions model. To create the dam-out geometry, the dam's existing 15-foot-wide spillway was replaced by a deeper and wider channel. The width of the dam-out channel geometry was estimated from field observations of approximate bankfull width, and the bottom elevation of the new channel was assumed to match that of the upstream and downstream reaches of Eagle Brook, representing a free flowing state. The roughness of the channel was also increased to a value typical of the channel conditions immediately downstream as opposed to that of a concrete spillway.

Ten simulations were conducted of the dam-out model, representing the 2-, 10-, 50-, 100-, and 500-year, 24-hour design storms under both present day and 2070 climate scenarios. The dam-out peak water levels were compared to their existing condition, dam-in counterparts at five locations, including Lake Pearl, the current Eagle Dam location, the upstream face of Rte. 140, the downstream face of Rte. 140, and at an unnamed dam behind 160 Mill Street in Wrentham. Those comparisons are summarized in Tables 2 through 6, respectively, below. These locations are shown on Figure 2.

Table 2: Impacts of Eagle Dam Removal on Maximum Water Levels in Lake Pearl

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft.)
		Dam In	Dam Out	
Present	2	197.55	197.55	0.00
	10	198.07	198.07	0.00
	50	198.78	198.78	0.00
	100	199.14	199.14	0.00
	500	200.10	200.10	0.00
2070	2	197.86	197.86	0.00
	10	198.75	198.75	0.00

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft.)
		Dam In	Dam Out	
	50	199.70	199.70	0.00
	100	200.14	200.14	0.00
	500	201.34	201.34	0.00

**Note: positive change values are increases in water level while negative values are decreases in water level.*

Maximum water levels in Lake Pearl are not expected to be impacted by the removal of Eagle Dam, as shown in Table 2.

Table 3: Impacts of Eagle Dam Removal on Maximum Water Levels in Old Mill Pond

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft)
		Dam In	Dam Out	
Present	2	196.77	196.65	-0.12
	10	197.17	196.86	-0.31
	50	197.73	197.43	-0.29
	100	198.05	197.70	-0.34
	500	198.90	198.45	-0.46
2070	2	196.95	196.74	-0.21
	10	197.69	197.41	-0.29
	50	198.55	198.14	-0.41
	100	198.93	198.47	-0.46
	500	199.95	199.36	-0.58

**Note: positive change values are increases in water level while negative values are decreases in water level.*

Naturally, the removal of Eagle Dam is expected to lower the maximum water level in Old Mill Pond under all design storms and climate scenarios, as shown in Table 3. Those reductions generally increase with the size of the design storm, ranging from a 0.12-foot reduction during the Present Day 2-year event to a 0.58-foot reduction during a 2070 500-year storm.

Table 4: Impacts of Eagle Dam Removal on Maximum Water Levels Upstream of Rte. 140

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft.)
		Dam In	Dam Out	
Present	2	188.70	188.69	0.00
	10	188.94	188.94	0.00
	50	190.26	190.26	0.00
	100	190.61	190.61	0.00
	500	191.56	191.56	0.00
2070	2	188.77	188.77	0.00
	10	190.22	190.22	0.00
	50	191.15	191.15	0.00
	100	191.60	191.60	0.00
	500	192.87	192.88	0.02

**Note: positive change values are increases in water level while negative values are decreases in water level.*

As shown in Table 4, model simulations indicate no change in the maximum water level at the upstream face of Rte. 140, with the exception of the 500-year event under a 2070 climate scenario, which indicates an increase of between 0.01 and 0.02 feet. Normally, such an increase could represent an obstacle to obtaining a "No Rise" certification to remain in compliance with the Federal Emergency Management Agency (FEMA) and Massachusetts Department of Transportation (MassDOT) standards. However, because the design storm represents a future climate scenario, it is not applicable.

Table 5: Impacts of Eagle Dam Removal on Maximum Water Levels Downstream of Rte. 140

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft.)
		Dam In	Dam Out	
Present	2	188.46	188.46	0.00
	10	188.91	188.91	0.00
	50	190.23	190.23	0.00
	100	190.54	190.54	0.00

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft.)
		Dam In	Dam Out	
	500	191.38	191.38	0.00
2070	2	188.55	188.55	0.00
	10	190.18	190.18	0.00
	50	191.01	191.01	0.00
	100	191.41	191.41	0.00
	500	192.58	192.58	0.00

**Note: positive change values are increases in water level while negative values are decreases in water level.*

Maximum water levels at the downstream face of the Rte. 140 crossing are not expected to be impacted by the removal of Eagle Dam, as shown in Table 5.

Table 6: Impacts of Eagle Dam Removal on Maximum Water Levels at the Unnamed Dam Behind 160 Mill Street, Wrentham

Climate Scenario	Recurrence Interval (yrs)	Max Water Level (ft. NAVD88)		Change* (ft.)
		Dam In	Dam Out	
Present	2	186.63	186.63	0.00
	10	186.66	186.66	0.00
	50	186.79	186.79	0.00
	100	186.83	186.83	0.00
	500	187.09	187.09	0.00
2070	2	186.64	186.64	0.00
	10	186.78	186.78	0.00
	50	186.99	186.99	0.00
	100	187.09	187.09	0.00
	500	188.22	188.22	0.00

**Note: positive change values are increases in water level while negative values are decreases in water level.*

Maximum water levels at the unnamed dam behind 160 Mill Street in Wrentham are not expected to be impacted by the removal of Eagle Dam, as shown in Table 6. Given the findings presented in Tables 5 and 6, and our observations of the hydraulics of the reach of Eagle Brook between those two locations, no increases in flood level or additional impacts are expected to any residences near the brook as a result of the Eagle Dam removal.

Velocities at the Rte. 140 crossing were also compared to existing conditions to provide an understanding of how velocities, which are a critical component of estimating bridge scour potential, might change at the crossing. A comparison of peak velocities is provided in Table 7.

Table 7: Impacts of Eagle Dam Removal on Peak Velocities Beneath the Rte. 140 Bridge Crossing

Climate Scenario	Recurrence Interval (yrs)	Velocity (ft./sec.)		Change* (ft./sec.)	Change (%)
		Dam In	Dam Out		
Present	2	0.6	0.8	0.2	27%
	10	1.7	2.0	0.3	17%
	50	3.7	3.7	0.0	0%
	100	5.4	5.4	0.0	0%
	500	9.9	9.9	0.0	0%
2070	2	1.2	1.4	0.2	17%
	10	3.5	3.5	0.0	0%
	50	8.1	8.1	0.0	0%
	100	10.0	10.0	0.0	0%
	500	14.8	14.8	0.0	0%

**Note: positive change values are increases in velocity while negative values are decreases in velocity.*

As shown in Table 7, maximum velocities are shown to increase modestly during three of the ten simulated design storms, specifically the Present Day 2- and 10-year events and the 2070 climate 2-year events. While the relative size of those increases ranges from 17 to 27%, the absolute magnitude of the increases is quite modest, ranging from 0.2 to 0.3 feet per second. In addition, these increases are short-lived, lasting for up to approximately one hour over the course of the 24-hour event.

MassDOT Requirements

While removal of Eagle Dam is not a bridge design project, its impact on the hydraulic performance of the Rte. 140 bridge immediately downstream is a key finding of this study. As discussed above, model

results indicate that the removal of Eagle Dam will have no significant impact on the peak water surface upstream and only a minor impact on maximum velocities at the Rte. 140 bridge. These findings were reviewed in light of the relevant MassDOT and FEMA requirements.

The MassDOT LRFD Bridge Manual, Section 1.3, provides Hydraulic Design Criteria for MassDOT bridge design. For example, the analysis evaluated the 10%, 2%, 1%, and 0.2% (i.e., 10-year, 50-year, 100-year, and 500-year) storm events consistent with Section 1.3.3.3.C of the manual. Those design storms were modeled specifically, along with the 2-year storm, and summarized in previous sections of this report. Rte. 140 or Franklin Street as it is called locally, is classified as a rural minor arterial. The impacts of dam removal were assessed at the 50-year return period among others.

According to Section 1.3.2 Hydraulic Design Criteria of the Bridge Manual, the Rte. 140 crossing should have a minimum clearance of two feet between the design approach water surface and the low chord of the bridge. GPS elevations collected in the field show the low chord of the bridge to be at approximately El. 193.1 NAVD88. According to model results presented in Table 4, during the present day 50-year design storm, the water surface immediately upstream of the bridge reaches a peak level of El. 190.3, representing approximately 2.8 feet of clearance. If Eagle Dam were removed, that minimum clearance would remain the same as no increase is anticipated to the maximum water level.

Section 1.3.5 of the Bridge Manual provides guidelines for “No Rise” Encroachment reviews for MassDOT bridges in regulatory floodways. Eagle Brook is classified as Zone A and is not a Regulatory Floodway. According to the effective FEMA Flood Insurance Study, flood risk in Eagle Brook has only been evaluated with “approximate methods” as there is no effective model for Eagle Brook. However, the results presented above are consistent with the results that would be expected by a formal “no rise” analysis using HEC-RAS or similar software. As described, anticipated increases in peak flood level are not expected to increase under present day climate conditions for any of the five design storms evaluated.

FIGURE 2
TOWN OF WRENTHAM MASSACHUSETTS

H&H ANALYSIS POINTS

Weston & Sampson

In Feet