M E M O R A N D U M

TO:	James Weber (NHDES Dam Bureau)
CC:	Steve Doyon (NHDES Dam Bureau); April Talon (Durham, Town Engineer); Peter Walker & Dave Cloutier (VHB); Allen Orsi (Pare Corporation)
FROM:	Andrew Walker, PH-SW, CFM (Weston & Sampson)
DATE:	March 2, 2020
SUBJECT:	DRAFT Mill Pond Dam (D71.03) Hazard Reclassification Analysis

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The Town of Durham has contracted a consulting team, led by Vanasse Hangen Brustlin (VHB) and including Weston & Sampson, Pare Corporation, and others, to evaluate the feasibility of several alternatives for reconstructing/rehabilitating/repairing/removing Mill Pond Dam, which is currently in Poor condition[1] and incapable of safely passing its design flood[2] in accordance with NHDES dam safety regulations (Env-Wr 303.11). As part of this current project, the project team has evaluated the previously proposed possibility[3] of reducing the dam's hazard classification and therefore reducing its discharge capacity requirements. This technical memorandum summarizes those analyses.

Mill Pond Dam is currently registered as a Class A or Low Hazard structure with a corresponding requirement that it must pass the 50-year design event while maintaining 1.0 ft. of freeboard below the lowest top of dam elevation (gated outlet / right abutment). On August 6, 2018, the Town and Dam Bureau staff met to discuss the possibility of reducing the dam's hazard classification to Class AA or Non-Menace. The Dam Bureau summarized their response to that meeting in a letter[3] to the Town Engineer on September 20, 2018. Based on that letter and on personnel communication[4] between Weston & Sampson and Steve Doyon and James Weber of the Dam Bureau, we understand that while Mill Pond Dam shall remain a Class A or Low Hazard structure given its structural height and the size of its impoundment, if certain conditions are met, the Town may apply for and receive a waiver such that the dam would be regulated as a non-menace structure. Under this waiver, future dam rehabilitation

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[1] Feb. 2020; Pare Corporation; "Mill Pond Dam Visual Inspection Report"
[2] Mar. 2018; Weston & Sampson; "Mill Pond Study Report"
[3] Sep. 2018; NHDES Dam Bureau (Steve Doyon); "Mill Pond Dam – D071003, Hazard Classification Assessment
[4] Jan. 21-22, 2020; Email correspondence between Andrew Walker (Weston & Sampson), Steve Doyon (Dam Bureau) and James Weber (Dam Bureau)

applications would only require the dam's discharge capacity requirement to meet its current discharge capacity, which is identified below in this memo.

The conditions required to obtain such a waiver are laid out in the Dam Bureau's September 2018 "Hazard Classification Assessment" letter. The Dam Bureau expects that any failure of the dam would likely damage the right abutment as indicated by observations from historical floods such as the May 2006 event, during which the abutment and right training wall were damaged when the dam was overtopped. As a result of that event, damage was also sustained to the side yard of the residence at 20 Newmarket Road, adjacent to the dam's right abutment (looking downstream). The Dam Bureau is concerned that if Mill Pond Dam were to fail, the restriction caused by the Rte. 108 bridge immediately downstream might cause additional backwatering that would cause the 20 Newmarket Road residence to become inundated when it would not otherwise have been or, if it was already inundated, to experience more than 1.0 foot of additional inundation as a direct result of the dam's failure. The Dam Bureau's "Hazard Classification Assessment" letter requires that this concern be assessed through the evaluation of flood levels under four different flow conditions:

1. The 50-year flood;
2. The 100-year flood;
3. (Maximum Pool) The flood which causes the water level in Mill Pond/Oyster River to just reach the top of the dam (right abutment, El. 12.88); and
4. The Threshold Flood, which would cause the water level in Mill Pond/Oyster River to just reach the sill elevation of the walk-out basement of the 20 Newmarket Road residence (El. 14.30).

To assess the potential impacts of a dam failure on the 20 Newmarket Road residence, Weston & Sampson has developed a detailed hydraulic model and conducted steady-state simulations of each of these four flow conditions with the dam in its existing state, with various breach geometries near the right abutment, and with the dam removed. The detailed hydraulic model was developed using the Army Corps' of Engineers HEC-RAS software, v.5.0.3. This model was based on an earlier hydraulic model developed in support of Weston & Sampson's 2018 study of Mill Pond sediment and nutrient management options[2], which the Dam Bureau has previously reviewed and approved. Revisions made to the model in support of this project primarily include:

- Extending the model geometry's downstream limit approximately 1.2 miles downstream, from the wooden footbridge downstream of the Rte. 108 bridge to Johnson's Creek near the Town's Wastewater Treatment Facility;
- Incorporating the wooden footbridge;
- Adding three additional cross-sections between Mill Pond Dam and the wooden footbridge;
- Revising the geometry of Mill Pond Dam and the Rte. 108 bridge based on survey gathered in 2019-2020 in support of the current project;
- Adding additional resolution to the underwater portion of several cross-sections representative of the Mill Pond Dam impoundment based on bathymetric survey data gathered by a VHB-led team in 2009; and
- Adding an additional river reach to represent approximately 1.2 miles of Hamel Brook, which converges with the Oyster River within the Mill Pond Dam impoundment.

The HEC-RAS hydraulic model was also updated to include the four design flow conditions described above. Peak inflow rates to the Mill Pond Dam impoundment during 50- and 100-year design flood were estimated from a series of three hydrologic and hydraulic models described in detail in a February 2020 technical memorandum[5] from the project team to the Dam Bureau. Those models were used to define flow conditions at five locations within the modeled Oyster River-Hamel Brook system:

1. Oyster River at the Oyster Reservoir Dam (071.007);
2. Oyster River at the upstream limit of the Mill Pond Dam impoundment;
3. Hamel Brook headwaters, including overflows from the Lamprey River;
4. Mill Pond Dam impoundment at the confluence of the Oyster River and Hamel Brook; and
5. Mill Pond Dam impoundment at the confluence of the Oyster River and College Brook (represents peak flow at the dam).

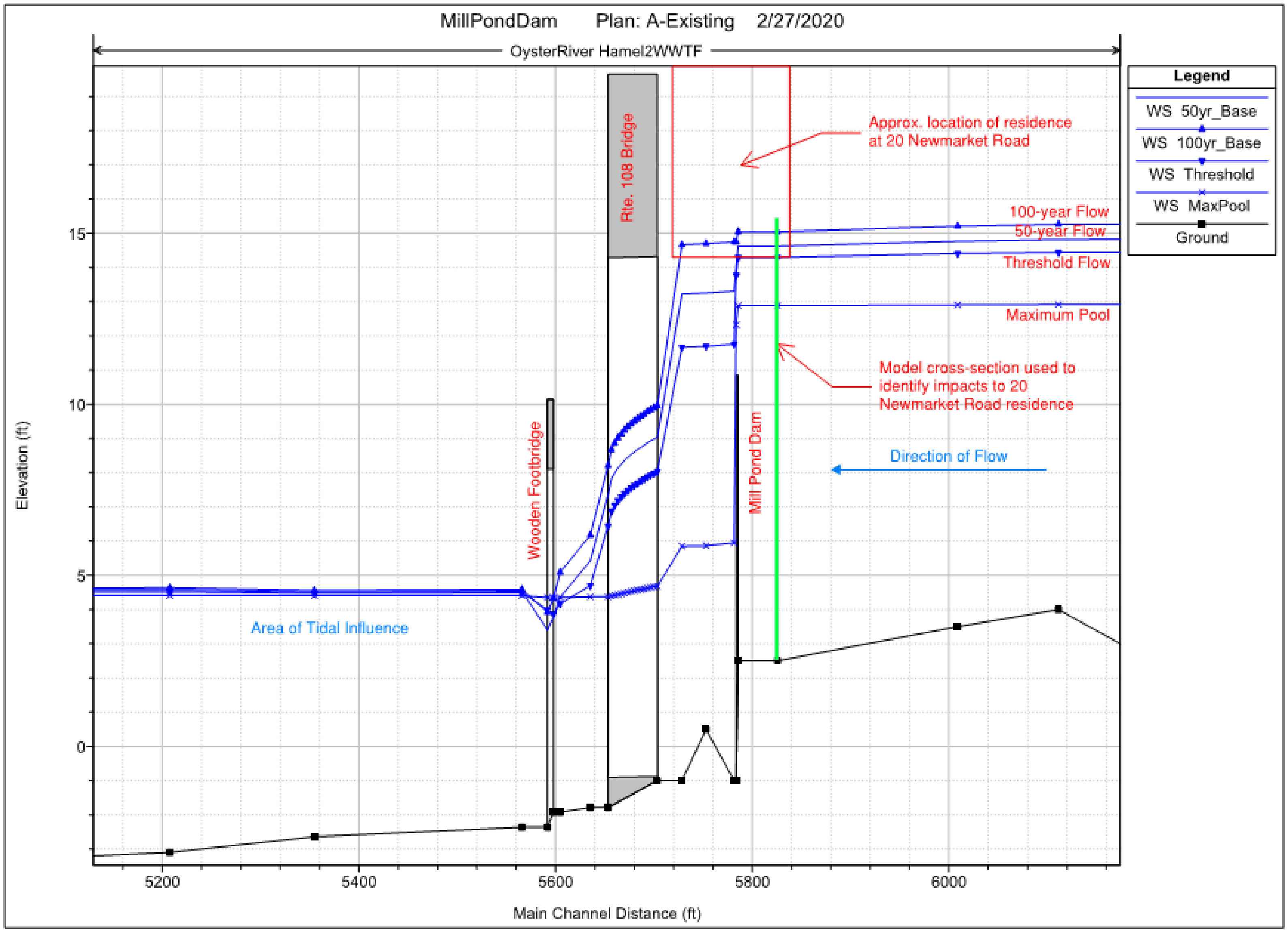
The peak inflows to the Mill Pond Dam impoundment (Location 5) during the 50- and 100-year design events are 3,352 and 3,877, respectively. Peak inflows at Mill Pond Dam for the Maximum Pool and Threshold Flow conditions were estimated by iteratively increasing the flow assigned to the Mill Pond impoundment (Location 5) until simulated peak water levels reached El. 12.88 (right abutment) and El. 14.30 (walk-out basement sill elevation), respectively. Maximum Pool and Threshold Flow inflows at Locations 1-4 were estimated based on the relative proportion of flows under the 50-year event conditions. Ultimately, the peak inflows to the Mill Pond impoundment (Location 5) during the Maximum Pool and Threshold Flow conditions were determined to be 1,015 and 2,810 cfs, respectively. The downstream boundary condition, which is important in this case as the dam is a head-of-tide-structure, was assumed to be Mean Higher High Water (MHHW). As no tidal gage data is publicly available for the Oyster River, MHHW was determined from long-term observations at the Fort Point NOAA gage in Portsmouth Harbor (ID 8423898).

Based on these input parameters, river and pond levels for all four flow conditions with the dam in its existing state, with various breach geometries near the right abutment, and with the dam removed. The simulated water levels for all four flow conditions, with the dam in its existing state, are shown in Figure 1 on the following page.

Based on survey data gathered in late 2019/early 2020, the upstream face of the residence is very nearly even with the dam, and it is clear that the residence could be inundated both by flows that overtop the dam and run along native ground in the right floodplain as well as, potentially, backwatering caused by the restriction of the Rte. 108 crossing downstream. To ensure that impacts to the house were adequately modeled, the residence straddles four model cross-sections, one upstream of the dam and three between the dam and Rte. 108. Because water elevations at the upstream face of the dam/residence will always be higher or equal to water levels in the area between the dam and Rte. 108, the water levels and impacts to the 20 Newmarket Road residence, described below, reference model simulation results for the cross-section immediately upstream of the dam/residence.

[5] February 20, 2020; Weston & Sampson; "Durham Mill Pond Dam – Design Flow Analysis Methodology"

Figure 1. Simulated Peak Water Levels under Existing Conditions



The most significant takeaway from Figure 1 is that under 50- and 100-year flood conditions, the residence at 20 Newmarket Road is impacted with or without a failure of Mill Pond Dam. In contrast, under the Threshold Flow and Maximum Pool conditions, floodwaters are expected to remain at or below the sill elevation of the residence's walk-out basement (El. 14.3). The key question regarding the hazard classification issue, therefore, is whether a failure of Mill Pond Dam would cause the 20 Newmarket Road residence to become inundated during the Threshold Flow and Maximum Pool conditions or whether a dam failure would worsen the inundation of the residence by 1.0 feet or more under the 50- and 100-year flood conditions.

Weston & Sampson also evaluated predicted peak water levels under several potential breach geometries and a dam removal scenario. Since the dam's right abutment has already been shown to represent a point of weakness, it was assumed to fail under all failure scenarios. The right abutment has a maximum width of 26 feet or approximately 19% of the dam's length. New Hampshire's dam safety regulations regarding dam breach parameters (Env-Wr 502.06) for concrete dams, such as Mill Pond Dam, indicate that typical breach geometries range between the width of one monolith and half the dam's length. The Mill Pond Dam spillway consists of nine cells (defined as the void space between adjacent ribs)[1]. We evaluated the failure of the right abutment as well as three additional scenarios that represent increasingly worse failures, where Cells 1, 1&2, and 1-3 also failed. These four failure scenarios comprise breach geometries of approximately 26, 34, and 42% of the dam's total length, consistent with the State's dam safety regulations. Note that because model simulations were conducting in "steady state," the failure scenario results approximate a post-failure condition where inflows/outflows at the dam are still at peak values. During a dam breach, water levels would begin at the Existing Condition values before dropping to the post-failure values reported in the tables below.

A dam removal scenario was also evaluated for each of the four flow conditions. Dam removal was represented by simply removing the Mill Pond Dam inline structure from the HEC-RAS model. Note that no modifications to the channel or riverbanks were represented as would likely occur as part of an actual removal. Simulated water levels at the Rte. 108 Bridge and 20 Newmarket Road residence are summarized in Tables 1A and 1B and Figures 2A through 2D.

Table 1A: Predicted Peak Water Levels at 20 Newmarket Road Residence

Dam Scenario	Peak Water Level (ft. NAVD88) by Flow Condition*			
	50-year Flood	100-year Flood	Threshold Flow	Maximum Pool
Existing	14.62	15.04	14.30	12.88
Dam Failure** Right Abutment	14.29	14.90	13.96	12.52
Dam Failure** Right Abutment and 1 Cell	13.86	14.81	13.44	11.72
Dam Failure** Right Abutment and 2 Cells	13.51	14.76	12.66	9.86
Dam Failure** Right Abutment and 3 Cells	13.35	14.73	12.05	8.14
Dam Removed	13.24	14.69	11.67	5.55

*Peak water levels are reported for the cross-section immediately upstream of the dam/residence.

**Dam failure values approximate post-failure conditions. Peak water levels during dam failure would begin equal to Existing Conditions before dropping to the post-failure values presented in the table.

Table 1B: Predicted Impacts to 20 Newmarket Road Residence

Dam Scenario	Freeboard*				Change from Existing**			
	50-yr	100-yr	Threshold	Max Pool	50-yr	100-yr	Threshold	Max Pool
Existing	-0.32	-0.74	0.00	1.42	---	---	---	---
Dam Failure Right Abutment	0.01	-0.60	0.34	1.78	0.33	0.14	0.34	0.36
Dam Failure Right Abutment and 1 Cell	0.44	-0.51	0.86	2.58	0.76	0.23	0.86	1.16
Dam Failure Right Abutment and 2 Cells	0.79	-0.46	1.64	4.44	1.11	0.28	1.64	3.02
Dam Failure Right Abutment and 3 Cells	0.95	-0.43	2.25	6.16	1.27	0.31	2.25	4.74
Dam Removed	1.06	-0.39	2.63	8.75	1.38	0.35	2.63	7.33

*Freeboard is measured down from the sill of the residence's walk-out basement (El. 14.30). Positive values indicate no inundation occurs.

** Positive values indicate reduced flooding.

The results summarized in Tables 1A and 1B are consistent: regardless of flow condition or dam breach geometry, a failure of Mill Pond Dam is not expected to increase flooding impacts at the location of the 20 Newmarket Road residence. Under no breach scenario or design flood event is the walk-out basement expected to flood when it would not have or experience an additional 1.0 feet or more of flooding due to a failure of the dam. Removal of the dam is expected to reduce flooding impacts at 20 Newmarket Road. Based on the Dam Bureau's "Hazard Classification Assessment" letter of September 2018, the results presented above are consistent with the criteria necessary for the discharge capacity requirement of Mill Pond Dam to be lowered from the 50-year design flow, 3,352 cfs, to its existing discharge capacity. At maximum pool, the dam's spillway currently discharges 1,015 cfs. However, based on the State's dam safety regulations, the dam can safely pass 352 cfs while maintaining 1.0 feet of freeboard.

Figure 2A. Simulated Peak Water Levels During the 50-year Design Flood

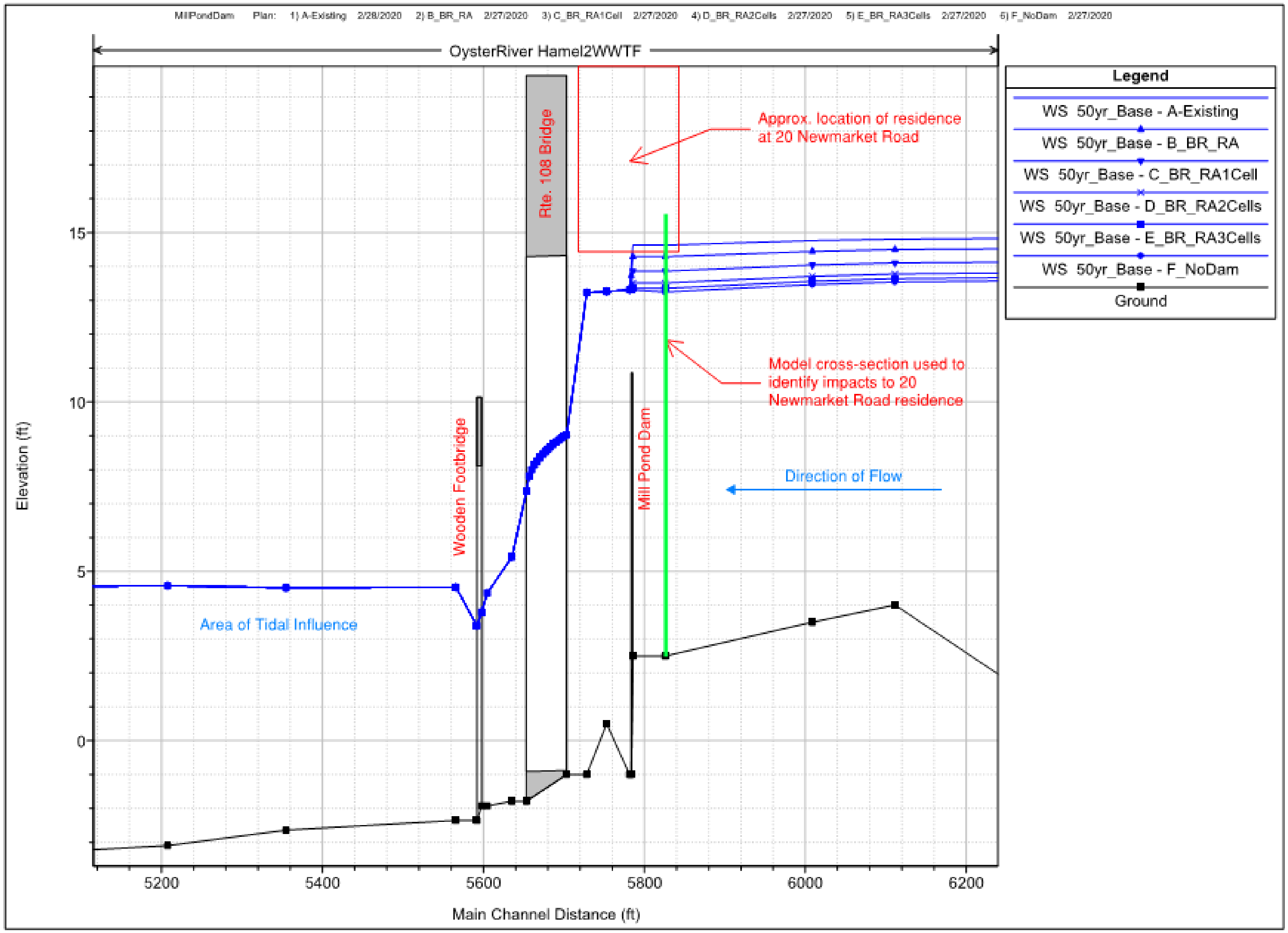


Figure 2B. Simulated Peak Water Levels During the 100-year Design Flood

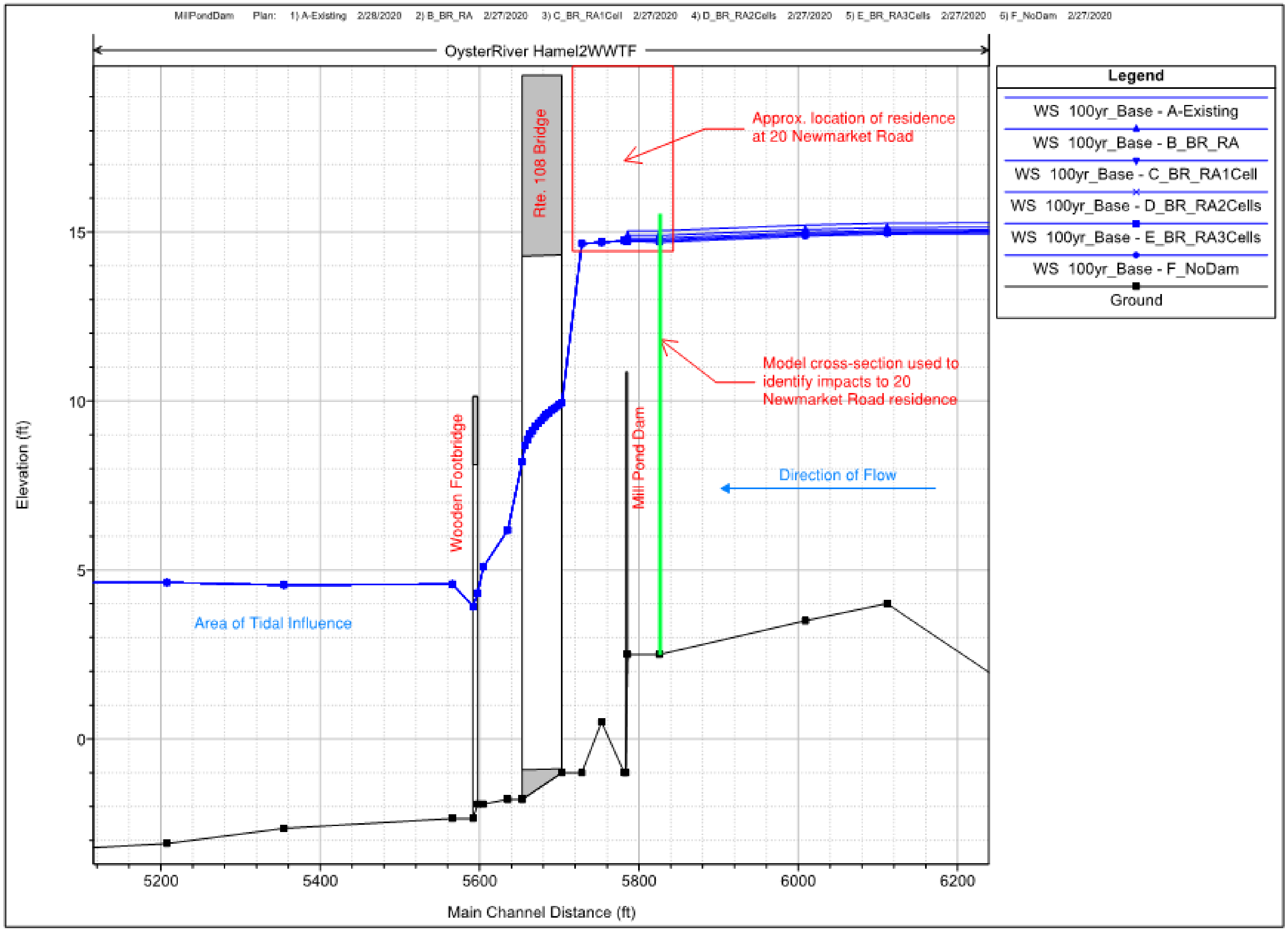


Figure 2C. Simulated Peak Water Levels Under the Threshold Flow Condition

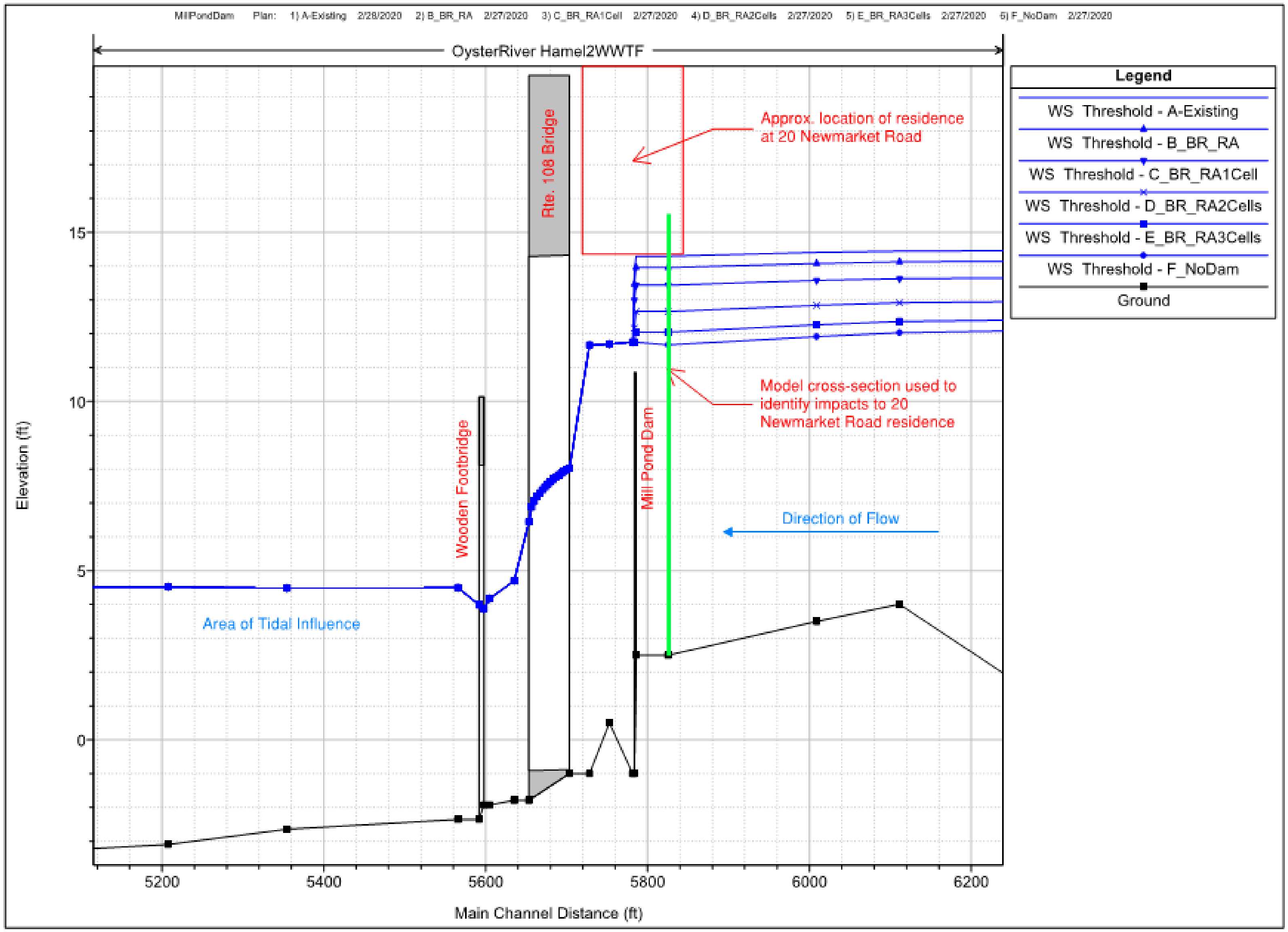


Figure 2D. Simulated Peak Water Levels Under the Maximum Pool Condition