SANBORN HEAD

1 Technology Park Drive
Westford, Massachusetts 01886

Paul Caggiano Development, LLC
2 Heritage Lane
Lynnfield, Massachusetts 01940

October 24, 2022
File No. 5481.00

Re: Summary of Mounding Analysis and Opinion Summary Letter
Proposed Vallis Way Residential Development
109 Lowell Street, Lynnfield, Massachusetts

Dear Paul:

On behalf of Paul Caggiano Development, LLC (Client), Sanborn, Head & Associates, Inc. (Sanborn Head) has prepared this memorandum to summarize the groundwater mounding analysis completed in support of the proposed Vallis Way residential development in Lynnfield, Massachusetts. The Site is located on the northern, undeveloped portion of the lot currently identified as 109 Lowell Street property (the Site).

BACKGROUND

We understand you are proposing to develop a 4-lot single family residential development at the above referenced location as shown on plans provided by Hayes Engineering, Inc. (Hayes) of Wakefield, Massachusetts. The stormwater basin is proposed in the northwesternmost portion of the Site with a proposed basin bottom elevation of 140.5' and top of basin elevation of 147.0'.

We understand that Mr. Bill Jones of Linden Engineering, who has reviewed the proposed project on behalf of the Town of Lynnfield Planning Board including the initial groundwater mounding calculations prepared by Hayes Engineering, Inc.[1], asked for an independent mounding analysis by a firm specializing in hydrogeologic engineering. In particular, Mr. Jones has requested that the analysis evaluate the potential for groundwater breakout in the basin itself and downgradient from the basin while assuming conservative, consecutive 24-hour storm events (a 25-year NOAA Atlas 14 storm immediately followed by a 100-year NOAA Atlas 14 storm).

Existing subsurface information provided to Sanborn Head includes a Geotechnical Report prepared by Lahlaf Geotechnical Consulting, Inc. (LGCI), dated November 22, 2021, and three (3) test pit logs completed by Hayes at the Site on April 13, 2021. In addition, the HydroCAD data generated by Hayes for these storms and for use in the mounding analysis has also been provided to Sanborn Head.

[1] Memorandum titled Groundwater Mounding Calculations, dated March 11, 2022, prepared by Hayes Engineering, Inc. for the Town of Lynnfield Planning Board

LIMITED SUBSURFACE INVESTIGATION

Based on our review of the background information as well as the readily available hydrogeologic information in the vicinity of the Site, Sanborn Head recommended completion of a limited subsurface investigation to confirm the key Site-specific aquifer parameters (saturated thickness and hydraulic conductivity) required to support a mounding analysis. The saturated thickness represents the vertical thickness between the top of the estimated seasonal high groundwater (ESHW) elevation and the top of either the underlying effective impermeable soil layer (if present) or bedrock, whichever is shallower. This saturated aquifer soil profile transports the applied stormwater away from the basin via lateral groundwater flow. The hydraulic conductivity (K) value represents the Site-specific aquifer's ability to transport groundwater (i.e., the ratio of groundwater velocity to driving energy head).

Sanborn Head subsequently observed the advancement of two soil borings which were completed as 2-inch diameter PVC monitoring wells at the Site between September 1 and 2, 2022. SH-1 was installed within the proposed stormwater basin area and SH-2 was installed approximately 240 feet to the east. The borings were advanced by G&M Drilling using a drive and wash drilling technique. Copies of the boring logs are provided as an attachment.

Soil samples were collected at approximately 5-foot intervals using a 2" outer diameter split spoon sampler. In general, the subsurface geologic conditions were consistent with those noted by Hayes and LCGI. In the location of the proposed basin (SH-1), the proposed receiving layer soils (i.e., soils representative of the bottom of the proposed basin [approximate elevation 140.5'], or approximately 9 feet below the current ground surface) were confirmed to be extremely favorable sand and gravel down to the approximate top of weathered bedrock at approximate elevation 127'. Groundwater was also observed in SH-1 at an approximate elevation of 128' (approximately 22 feet below the current ground surface).

Boring SH-2 displayed a similar sand and gravel profile with an approximate 5-foot layer of sand encountered between 19 and 24 feet below the ground surface (between approximate elevation 124 and 129. Weathered bedrock was encountered at an approximate elevation of 119' (approximately 29 feet below the current ground surface). Groundwater was observed in SH-2 at an approximate elevation of 130.5' (approximately 17.5 feet below the current ground surface) confirming SH-2 to be located upgradient from the proposed stormwater basin (SH-1).

Saturated Thickness

The saturated thickness represents the vertical thickness between the ESHW elevation and the top of the underlying effectively impermeable soil layer.

No soil redoximorphic (mottling) features (potentially indicative of ESHW) were observed at the Site by Hayes or LGCI, nor in Sanborn Head's soil borings. However, LGCI's October 2021 geotechnical test pits observed groundwater at an approximate elevation of 133.4' (approximately 13.5 and 13 feet below the ground surface) within the proposed stormwater basin location. The previous Hayes test pits (SWMA-1 to 3) did not observe groundwater or mottling to their bottom depths of approximately 11 and 12 feet below the ground surface in

April 2022. Given that groundwater was observed by Sanborn Head at an approximate elevation of 128' (during September 2021 drought conditions) within the proposed basin area and given the lack of observed mottling, it is our opinion that the groundwater level measured by EGCI may be conservatively assumed as the ESHW elevation at 133.4'. It is also our opinion that the Frimpter method for ESHW is not appropriate for this Site as it would represent an overly conservative and unrealistic estimate especially given the extremely permeable Site soils.

Although the top of the bedrock surface was identified as weathered by the drilling program and therefore would have some degree of additional permeability, we assumed that this elevation represents an impermeable surface as a conservative mounding analysis assumption. Therefore, for the purpose of the mounding analysis, the ambient saturated thickness was estimated as the ESHW elevation (133.4') minus the top of weathered bedrock (127'), or approximately 6.4 feet.

Hydraulic Conductivity (K)

Unfortunately, the insufficient water thickness within SH-1 (only approximately 1 foot due to the drought) precluded slug testing within SH-1. Further, we were unable to displace enough water volume in SH-2 to create a response sufficient for hydraulic conductivity estimation. However, lack of measurable response in the slug test in-situ transducer supports a relatively high hydraulic conductivity.

A soil sample representative of the receiving layer soils (SH-1/S-3(9-11')) was collected and analyzed for soil grain size distribution. The soil was identified as an extremely permeable moist, brown gravel with sand. The laboratory grain size distribution report is included as an attachment.

A commonly used grain size correlation to hydraulic conductivity (the Hazen Equation using a D_{10} of 0.21 mm) would result in a K value of approximately 12,500 ft/day. Published K values for gravel range from approximately 0.1 to 100 cm/sec (280 to 280,000 ft/day)[2]. While a case can be made for a higher K value assumption, we have assumed a K value of 300 ft/day for the purpose of the mounding analysis, which is considered conservative as it falls on the low end of the published gravel values.

MOUNDING ANALYSIS

Upon collection of the data, Sanborn Head engaged McLane Environmental, LLC (McLane) of Princeton, New Jersey to complete the mounding analysis. McLane completed both an updated Hantush mounding analysis using the newly generated Site-specific information identified above and a bedrock elevation contour plan using additional bedrock data collected from the vicinity of the Site to gain an additional understanding as to how the bedrock surface may influence groundwater flow in the Site area.

Using the assumed loading rates provided by Hayes as generated from their HydroCAD model, the peak mound thickness below the bottom of the basin was estimated as 5 feet after 48

[2] Groundwater, Freeze and Cherry, 1979.

hours (back-to-back 25 and 100 year assumed storm events). This translates to a peak groundwater mound elevation of 138.4' when applied to the ESHW elevation, which remains approximately 2 feet below the bottom of the proposed basin elevation. McLane's summary report, titled Updated Stormwater Basin Mounding Analysis for Proposed Vallis Way Residential Development Site, dated October 20, 2022, is provided as an attachment.

It was also noted that the model assumes a flat impermeable bedrock surface below the receiving layer soils, whereas the actual downgradient bedrock surface drops steeply to the west. This indicates that the actual mound is likely to be even lower than that estimated by the mounding analysis.

Similarly, the downgradient overburden groundwater elevations also drop steeply to the west as can be estimated by the topography, surface water features, and publicly available water supply well logs; the hydraulic gradient may be estimated as roughly 0.02[3]. Based on this estimated gradient, as well as the decreasing mound height with distance from the proposed basin (e.g., at approximately 180 feet from the basin, the peak mound drops to only 1'), it is our opinion that surficial groundwater breakout is unlikely within either the downgradient golf course or the closest downgradient residential buildings (e.g., 19 Smith Farm Trail).

CONCLUSIONS

Based on the mounding analysis completed as detailed herein, it is our opinion that groundwater breakout will not occur either within the proposed basin (i.e., the estimated peak groundwater mound elevation [138.4'] does not reach up to the bottom of the proposed basin elevation) or downgradient from the proposed basin (i.e., within the golf course or adjacent residential building at 19 Smith Farm Trail) as a result of the proposed back to back specified design storms.

We appreciate the opportunity to provide our services to you. Should you have any questions, please do not hesitate to call me.

Very truly yours,
SANBORN, HEAD & ASSOCIATES, INC.

Matthew P. Heil, P.E., LSP
Vice President

Attachments: Monitoring Well Logs SH-1 and SH-2
Laboratory Soil Grain Size Distribution for SH-1/S-3(9-11')
Updated Stormwater Basin Mounding Analysis for Proposed Vallis Way Residential Development Site, 109 Lowell Street, Lynnfield, MA, prepared by McLane Environmental, LLC, dated October 20, 2022

[3] Hydraulic Gradient Estimate: ((133.4' ESHW) – (118' Pond Elevation) / (700 feet distance)) = 0.02

SANBORN HEAD

Sanborn, Head & Associates, Inc.

Project: 109 Lowell Street
Location: Lynnfield, MA
Project No.: 5481.00

Log of Monitoring Well SH-1

Ground Elevation: 149.5 ± feet
PVC Elevation: 152.63 ± feet
Datum:

Drilling Method: Drive and Wash

Sampling Method: 2" O.D. Split Spoon

Drilling Company: G&M
Foreman: S. Canning
Date Started: 09/01/22 **Date Finished: 09/01/22**
Logged By: M. Morrisey **Checked By: M. Heil**

Groundwater Readings

Date	Time	Depth to Water	Ref. Pt.	Depth of Casing	Depth of Hole	Stab. Time
09/01/22	12:10	22'	Ground Surface		Well Installed	~1 hr
09/08/22	09:00	22.2'	Ground Surface		Well Installed	7 days

Depth (ft)	Sample Information: Sample No.	Depth (ft)	Spoon Blows per 6 in	Pen/ Rec (in)	Field Testing Data	Stratum: Log	Description	Geologic Description	Well Diagram	Well Description
0	S-1	0 - 2	1 WOH 1 WOH	24/10			-----0'----- TOPSOIL -----0.5'-----	S-1A (0 to 0.5'): TOPSOIL. S-1B (0.5 to 2'): Loose, brown, fine to medium SAND, some Silt, trace Gravel. Dry.		
2							SUBSOIL			Bentonite Chips (2 to 3')
4	S-2	4 - 6	3 3 4 6	24/10			-----3'-----	S-2 (4 to 6'): Loose, brown, fine to coarse SAND, some Silt, little Gravel. Moist.		
6							SILTY SAND			Formation Material (3 to 8')
8										
10	S-3	9 - 11	11 19 21 22	24/16			-----9'-----	S-3 (9 to 11'): Dense, brown, fine to coarse GRAVEL and Sand, trace Silt. Moist.		
12										
14	S-4	14 - 16	4 10 11 10	24/17				S-4 (14 to 16'): Medium dense, brown, fine to coarse SAND and Gravel, little Silt. Moist.		
16							SAND & GRAVEL			Filter Sand (8 to 25')
18										2" Dia. Sch. 40 PVC Well Screen (0.010" Slots) (10 to 25')
20	S-5	19 - 19.3	100/4"	4/0				S-5 (19 to 19.3'): No recovery. Boulder likely from approximately 19 to 22 feet based on drilling behavior.		
22										
24	S-6	24 - 24.1	100/1"	1/1			-----23'----- WEATHERED BEDROCK -----25'-----	S-6 (24 to 24.1'): WEATHERED BEDROCK. Wet. Boring terminated at 25 feet bgs.		
26								NOTES: 1. Monitoring well elevations provided by Hayes Engineering, Inc. via email on September 19, 2022.		
28										

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SANBORN HEAD

Sanborn, Head & Associates, Inc.

Project: 109 Lowell Street
Location: Lynnfield, MA
Project No.: 5481.00

Log of Monitoring Well SH-2

Ground Elevation: 148.3 ± feet
PVC Elevation: 151.39 ± feet
Datum:

Drilling Method: Drive and Wash

Sampling Method: 2" O.D. Split Spoon

Drilling Company: G&M
Foreman: S. Canning
Date Started: 09/01/22 **Date Finished: 09/02/22**
Logged By: M. Morrisey **Checked By: M. Heil**

Groundwater Readings

Date	Time	Depth to Water	Ref. Pt.	Depth of Casing	Depth of Hole	Stab. Time
09/02/22	11:20	17.5'	Ground Surface		Well Installed	~1 hr
09/08/22	10:00	17.9'	Ground Surface		Well Installed	6 days

Depth (ft)	Sample Information: Sample No.	Depth (ft)	Spoon Blows per 6 in	Pen/ Rec (in)	Field Testing Data	Stratum: Log	Description	Geologic Description	Well Diagram	Well Description
0							-----0'-----			
2										Bentonite Chips (2 to 3')
4										
6										Formation Material (3 to 10')
8										
10	S-1	9 - 11	7 15 12 10	24/12			SAND & GRAVEL	S-1 (9 to 11'): Medium dense, brown, fine to coarse SAND and Gravel, trace Silt. Moist.		Bentonite Chips (10 to 12')
12										
14	S-2	14 - 16	4 5 5 3	24/10				S-2 (14 to 16'): Loose, brown, fine to coarse GRAVEL and Sand, trace Silt. Moist.		
16										
18										
20	S-3	19 - 21	5 5 5 4	24/11			-----19'-----	S-3 (19 to 21'): Loose, brown, fine to medium SAND, little Silt, trace Gravel. Wet.		
22							SAND			2" Dia. Sch. 40 PVC Well Screen (0.010" Slots) (14 to 29')
24										

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SANBORN HEAD

Sanborn, Head & Associates, Inc.

Project: 109 Lowell Street
Location: Lynnfield, MA
Project No.: 5481.00

Log of Monitoring Well SH-2

Ground Elevation: 148.3 ± feet
PVC Elevation: 151.39 ± feet
Datum:

Drilling Method: Drive and Wash

Sampling Method: 2" O.D. Split Spoon

Drilling Company: G&M
Foreman: S. Canning
Date Started: 09/01/22 **Date Finished: 09/02/22**
Logged By: M. Morrisey **Checked By: M. Heil**

Groundwater Readings

Date	Time	Depth to Water	Ref. Pt.	Depth of Casing	Depth of Hole	Stab. Time
09/02/22	11:20	17.5'	Ground Surface		Well Installed	~1 hr
09/08/22	10:00	17.9'	Ground Surface		Well Installed	6 days

Depth (ft)	Sample Information: Sample No.	Depth (ft)	Spoon Blows per 6 in	Pen/ Rec (in)	Field Testing Data	Stratum: Log	Description	Geologic Description	Well Diagram	Well Description
24	S-4	24 - 26	11 7 9 10	24/11			-----24'-----	S-4 (24 to 26'): Loose, brown, fine to coarse SAND and Gravel, little Silt. Wet.		
26							SAND & GRAVEL			Filter Sand (12 to 29')
28										2" Dia. Sch. 40 PVC Well Screen (0.010" Slots) (14 to 29')
	S-5	29 - 29.9	9 40+	11/11			-----29'-----	S-5 (29 to 29.9'): Dense, brown, fine to coarse GRAVEL and Sand, trace Silt. WEATHERED BEDROCK.		Formation Material (29 to 30')
30							WEATHERED BEDROCK -----30'-----	Boring terminated at 30 feet bgs due to refusal on apparent weathered bedrock.		
32								NOTES: 1. Monitoring well elevations provided by Hayes Engineering, Inc. via email on September 19, 2022.		
34										
36										
38										
40										
42										
44										
46										
48										

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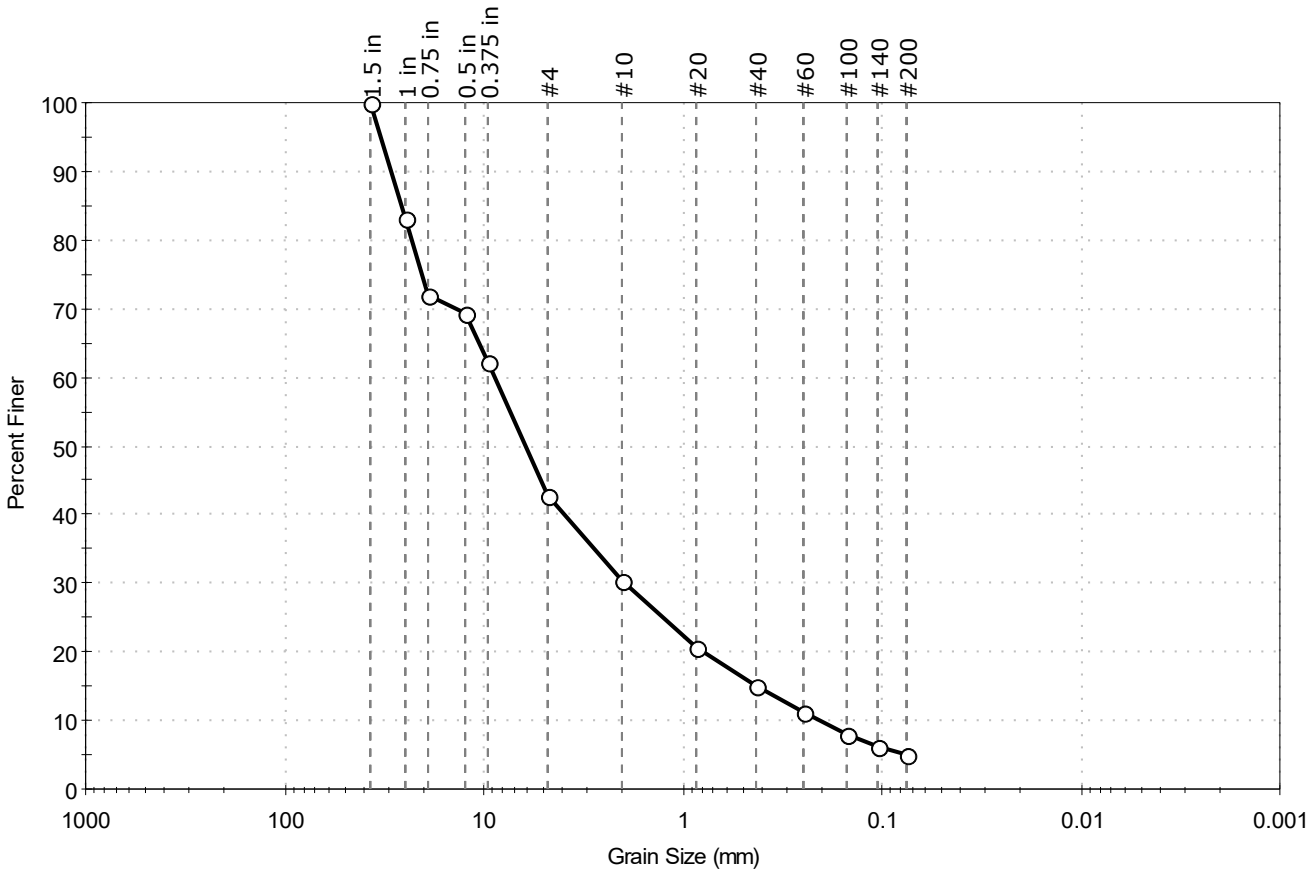
GeoTesting EXPRESS

Client:	Sanborn, Head & Associates, Inc.				
Project:	109 Lowell Street				
Location:	Lynnfield, MA			Project No:	GTX-316073
Boring ID:	SH-1	Sample Type:	jar	Tested By:	ckg
Sample ID:	S-3	Test Date:	09/13/22	Checked By:	bfs
Depth :	9'-11'	Test Id:	685140		
Test Comment:	---				
Visual Description:	Moist, brown gravel with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D6913



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	57.2	37.9	4.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1.5 in	37.50	100		
1 in	25.00	83		
0.75 in	19.00	72		
0.5 in	12.50	69		
0.375 in	9.50	62		
#4	4.75	43		
#10	2.00	30		
#20	0.85	21		
#40	0.42	15		
#60	0.25	11		
#100	0.15	8		
#140	0.11	6		
#200	0.075	4.9		

Coefficients

D_{85} = 26.1268 mm	D_{30} = 1.9174 mm
D_{60} = 8.7799 mm	D_{15} = 0.4196 mm
D_{50} = 6.1427 mm	D_{10} = 0.2089 mm
C_u = 42.029	C_c = 2.004

Classification

ASTM — Well-graded GRAVEL with Sand (GW)

AASHTO — Stone Fragments, Gravel and Sand (A-1-a (1))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

McLane Environmental LLC
Consulting Scientists & Engineers

A Limited Liability Company
707 Alexander Road, Suite 206
Princeton, NJ 08540
609.987.1400 Fax 609.987.8488

October 20, 2022

Matt Heil, P.E., LSP
Sanborn, Head & Associates, Inc.
1 Technology Park Drive
Westford, Massachusetts 01886

Re: Updated Stormwater Basin Mounding Analysis for Proposed Vallis Way Residential Development Site
109 Lowell Street
Lynnfield, MA

Introduction

At the request of Sanborn, Head & Associates, Inc. (SHA), McLane Environmental, LLC (McLane Environmental) performed analyses to estimate the extent of expected groundwater mounding beneath a stormwater basin following back-to-back 25-year and 100-year storm events (each for a duration of 24hours, for a total of 48 hours) at a proposed residential development site located in Lynnfield, Massachusetts. The mounding analyses were performed using a Hantush Mounding calculation tool developed by the United States Geologic Survey (USGS) and compared favorably with analyses previously performed by Hayes Engineering, Inc. (Hayes, on behalf of the proposed developer, Paul Caggiano Development, LLC) for the Town of Lynnfield Planning Board using a different mounding calculator and preliminary estimates of site parameters. The loading rates were based on HydroCAD modeling results provided by Hayes.

The McLane Environmental analyses incorporated site specific data recently collected by SHA (including depth to groundwater immediately beneath the proposed stormwater basin, and an estimated hydraulic conductivity value for the receiving material). Additionally, the new analyses utilized recently collected depth to bedrock data, along with depth to bedrock data obtained from nearby irrigation and supply wells and publicly available surficial geology reports, to develop contours of the underlying bedrock surface beneath (and in the vicinity of) the proposed stormwater basin to gain a better understanding as to how the bedrock surface may influence groundwater flow conditions in this area.

The results of the Hantush mounding analyses indicated that following the back-to-back 25 and 100-year storm events, a maximum mound height of 5 feet would be expected beneath the basin after 48 hours. This corresponds to an elevation of 138.4 feet mean sea level (ft msl), which is 2.1 feet below the elevation of the bottom of the proposed stormwater basin (approximately 140.5 feet msl). As discussed further in the sections below, these results indicate that the entire volume of water associated with the back-to-back storm events could be infiltrated in the subsurface in a 48-hour period without breakout at the land surface in the vicinity of the basin. Further, although analysis of the bedrock surface indicates

that it is relatively flat beneath the proposed stormwater basin, it also indicates that it steeply dips to the west of and downgradient from the proposed stormwater basin, indicating that the Hantush calculated mounding elevations in this direction would likely be lower than those predicted by the Hantush calculation (which assumes a flat aquifer base).

The updated Hantush mounding analyses and bedrock surface contouring analyses performed by McLane Environmental are discussed further in the sections below.

Overview of Analyses

As noted above, McLane Environmental performed a Hantush mounding calculation that updated previous mounding analyses performed by Hayes by incorporating site-specific data that was collected or provided by SHA, or obtained by McLane Environmental. The data was collected over the span of approximately two weeks in September 2022 and included: (1) Updated depth to bedrock data from soil borings observed by SHA (2) a grain-size gradation curve for receiving layer soils collected below the proposed basin for characterizing hydraulic conductivity and (3) estimated seasonal-high groundwater (ESHGW) table elevation for calculation of initial saturated thickness. The updated bedrock depth data included a combination of data obtained from publicly available well logs completed for water supply wells in vicinity of the proposed residential site, lithologic logs for boreholes that were drilled to bedrock at and in the vicinity of the proposed stormwater basin, and surface geologic map layers which showed bedrock outcropping near the Site (MassGIS 2022). SHA also used the grain-size gradation curve data from a soil sample obtained in the proposed location of the stormwater basin to estimate a hydraulic conductivity of approximately 300 ft/day, which was utilized in the Hantush mounding calculation. The ESHGW table elevation (133.4 ft msl) was also obtained from SHA, which represents the higher of two previous groundwater measurements obtained in the field from test pits completed near the proposed stormwater basin on October 12, 2021 by Lahlaf Geotechnical Consulting, Inc.

Hantush Mounding Calculations

For the updated mounding analysis, the USGS Hantush mounding calculator utility (Carleton, 2010) was utilized. This spreadsheet calculator requires several input parameters related to aquifer characteristics and recharge/infiltration to calculate maximum height and extent of groundwater mounding beneath a hypothetical stormwater basin. For this analysis, it is McLane Environmental's understanding that the proposed stormwater basin is required to infiltrate 68,096 cubic feet of water in a 48-hour period, the equivalent of a 100-year NOAA Atlas 14 24-hour precipitation event (46,802 cubic feet), followed immediately by a 25-year NOAA Atlas 14 24-hour precipitation event (21,294 cubic feet) (Hayes, 2022). The input parameter values used in the Hantush mounding analysis (and the source of those input parameters) are included in **Table 1**.

Table 1: Hantush mounding calculator input parameters

Input Parameter (unit)	Value	Source
Recharge/infiltration rate (feet/day)	11.70	SHA
Specific Yield (dimensionless)	0.200	Assumed
Horizontal hydraulic conductivity (feet/day)	300	SHA
Basin length/width (feet)	87.7 / 33.1	Hayes/SHA
Duration of recharge/infiltration event (days)	2.0	SHA
Initial thickness of saturated zone (feet)*	6.4	SHA

* Initial thickness of the saturated zone is calculated by subtracting the ESHGW table elevation from the bedrock elevation below the proposed stormwater basin (133.4 feet – 127 feet). The depth to bedrock below the proposed basin was provided by SHA as documented in their boring/monitoring well log for SH-1.

Bedrock Surface Mapping

Bedrock elevations were mapped for the site area based on data provided to McLane Environmental by SHA or obtained by McLane Environmental from MassGIS. Bedrock elevations were estimated for the area beneath and in the vicinity of the proposed stormwater basin by taking LiDAR topographic elevations at each of the locations where bedrock depths had been recorded, and then subtracting them from measured depths to bedrock. Bedrock outcrop elevations were estimated from the LiDAR elevations at outcrop locations. The resulting bedrock elevation data (**Table 2**) was then used to generate bedrock elevation contours in the *Surfer* program (Golden Software, LCC) using the Kriging algorithm.

Table 2: Bedrock elevations used for surface mapping at the Lynnfield Site

Location ID	Massachusetts State Plane Coordinates Northing (NAD 1983)	Massachusetts State Plane Coordinates Easting (NAD 1983)	Bedrock Elevation (ft. msl)
1219 Main Street	779853.037	3028393.996	48
1215 Main Street	779733.333	3027812.26	62
110 Lowell Street	781611.586	3026506.375	158
28 Durham Drive	780640.219	3026197.387	162
15 Pocahantas Way	779883.563	3027711.833	55
8 Mohawk Lane	781904.328	3027722.8	152
7 Smith Farm Trail	780781.396	3027101.944	83
2 Lil's Way	782194.29	3026406.929	162
3 Lil's Way	781912.082	3026305.546	170
SH-1	781294.115	3027481.858	127
SH-2	781515.729	3027566.15	119
B-1	781653.164	3027149.442	160
Bedrock Outcrop #1	781424.843	3028063.242	164
Bedrock Outcrop #2	781244.028	3027826.46	161
Bedrock Outcrop #3	781859.662	3027886.732	171

Analysis Results

The groundwater mounding analysis showed that the maximum mounding that would occur at the center of the stormwater basin after infiltrating 68,096 cubic feet of water over a 48-hour period is 5 feet (**Figure 1**). When considering the ESHGW table elevation as a starting point (133.4 feet msl), this results in an overall groundwater elevation of 138.4 feet msl. This elevation is 2.1 feet below the elevation of the bottom of the proposed stormwater basin (estimated to be at 140.5 feet msl), which shows that the entire volume of water was able to infiltrate into the proposed basin during the given timeframe, without any breakout.

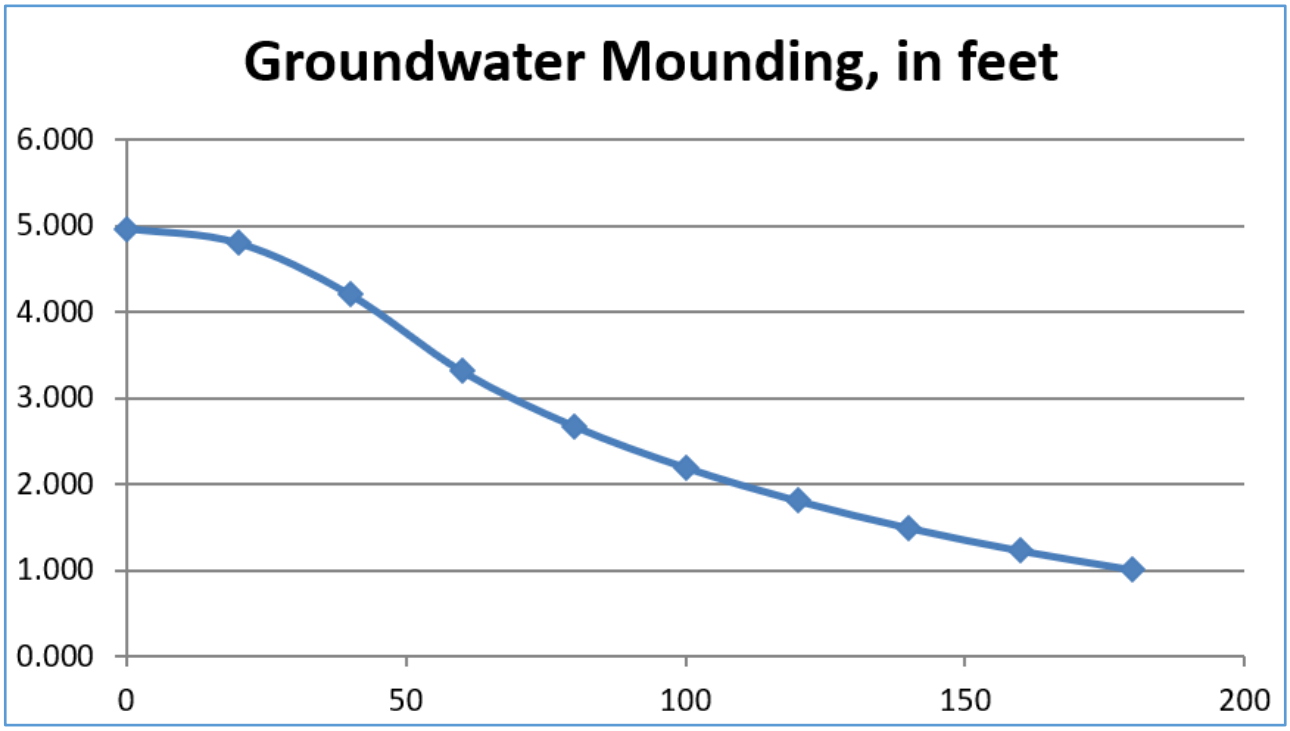


Figure 1: Maximum groundwater mounding at the center of the proposed stormwater basin (x = 0), up to 180 feet away from the center of the proposed stormwater basin.

The maximum height of the calculated groundwater mound up to approximately 180 feet away is 1 foot, which would correspond to a groundwater elevation of approximately 134.4 ft msl when considering the ESHGW table elevation at the proposed basin location. It must be noted however, that one of the primary assumptions of a Hantush mounding analysis is that the aquifer base (in this case the bedrock surface) is assumed to be flat. For the purposes of this analysis, the bedrock surface was assumed to be a uniform elevation of 127 feet. Based on the contoured bedrock surface shown in **Figure 2**, it is apparent that that although the estimated bedrock surface is relatively flat beneath the proposed stormwater basin (blue polygon), it steeply dips to the west and downgradient from of the proposed stormwater basin from approximately 127 feet msl to as low as 50 feet msl at 1219 Main Street to the Northwest (**Figure 2**). Thus, although the bedrock is relatively flat beneath the proposed stormwater basin, it steeply dips to the west of the stormwater basin, indicating that the Hantush calculated mounding elevations in this direction would likely be lower (e.g., in the vicinity of the residential property located at 19 Smith Farm Trail – the yellow polygon in **Figure 2**).

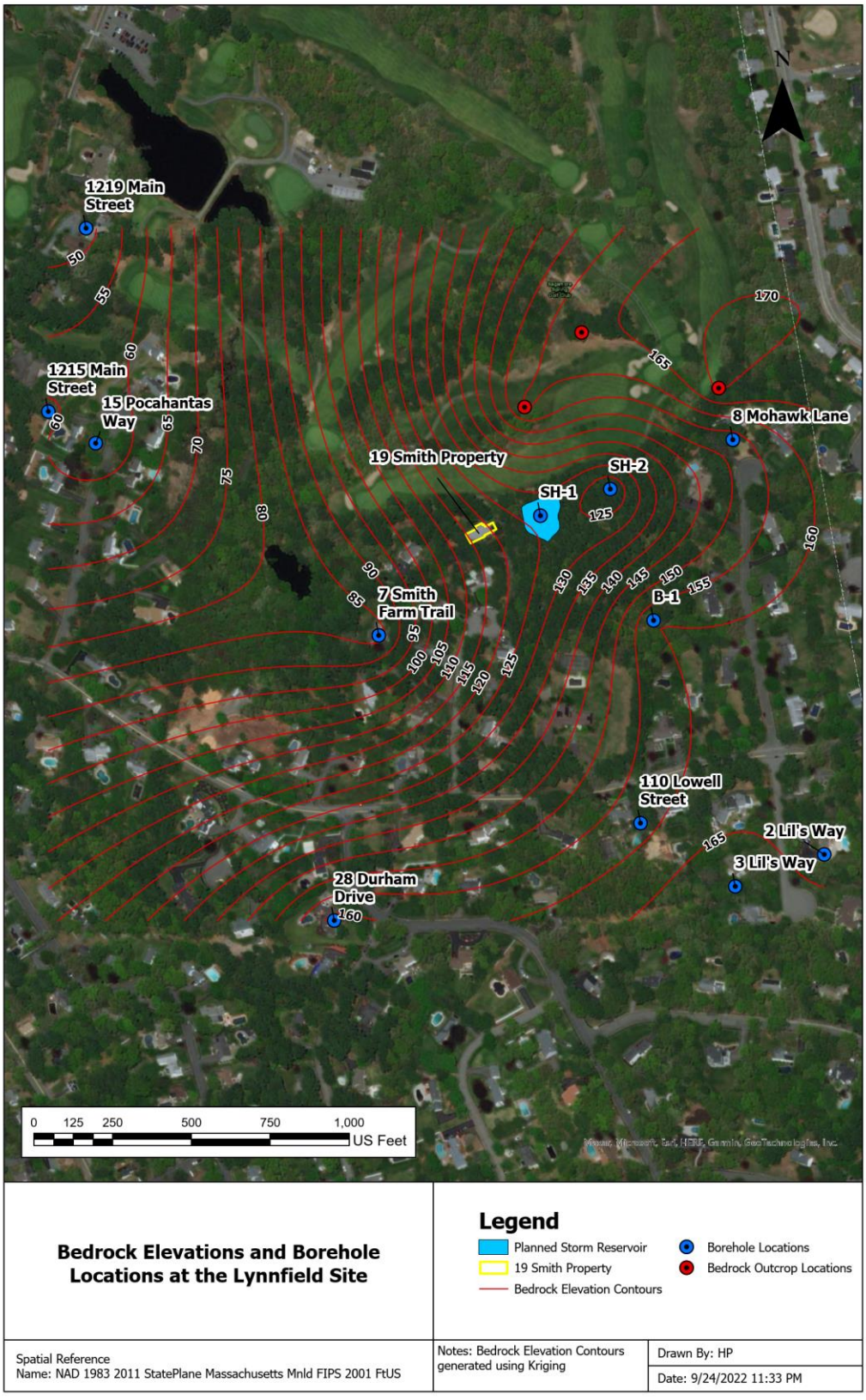


Figure 2: Bedrock elevation contours at the Lynnfield Site area.

Assumptions and Limitations

It should be noted that there a number of simplifying assumptions with regard to the Hantush mounding calculations described herein. For example, the Hantush method assumes that the stormwater basin is perfectly rectangular. The proposed stormwater basin is not rectangular, but the area considered was practically equivalent to the proposed basin area if it was perfectly rectangular. Additionally, the Hantush method assumes that the aquifer base (in this case, the bedrock surface) is completely flat over the entire area (and of infinite extent), that all flow is horizontal, and that the groundwater mound extends radially in all directions. As discussed above, however, bedrock elevation contours show that although the bedrock is relatively flat beneath the proposed stormwater basin, it steeply dips to the west of and downgradient from the stormwater basin, indicating that the Hantush calculated mounding elevations in this direction would likely be lower. In conclusion, the assumptions inherent to the Hantush method, when applied to the prescribed storm conditions and Site-specific environmental conditions at the Vallis Way Site, are adequately conservative for the intended mounding analysis.

Finally, the Hantush mounding analyses and bedrock surface contouring analyses described herein are based on data and information provided by SHA or obtained by McLane Environmental to date. To the extent that additional data is obtained, these analyses can be updated by McLane Environmental if so requested by SHA.

References

Carleton, G.B., 2010, Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins: U.S. Geological Survey Scientific Investigations Report 2010–5102, 64 p.

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