UNDERWOOD engineers

99 North State Street
Concord, NH 03301
Tel: 603-230-9898 Fax: 603-230-9899

Technical Memorandum

To:	Paulette Malo – Town of Pembroke, NH	File No. 2486.08
Cc:	Keith Pratt, Ross Baker – Underwood Engineers	
From:	David J. Mercier, P.E. – Underwood Engineers	
Date:	May 23, 2022	
Subject:	**SEWER INTERCONNECTION CAPACITY ANALYSIS**	

BACKGROUND:

In March of 2020, the Pembroke and Concord Sewer Interconnection Feasibility Analysis memorandum was issued by Underwood Engineers (UE). The memo explored the feasibility of sending a portion of the Pembroke sewer flow to Concord, identified modifications that will be required to existing sewer infrastructure, and estimated costs that will be associated with establishing a new interconnection. Two (2) zones were identified based on the layout of Pembroke's existing collection system that could most efficiently be conveyed to the Concord system. For each zone, various evaluations were performed including projecting average and peak flows, identifying future infrastructure upgrades, and developing opinions of cost to perform an interconnection.

After issuing the feasibility analysis memo, discussions were held with the City of Concord regarding the possibility of accepting a portion of Pembroke's wastewater. The City expressed they would need to understand the anticipated strength of the wastewater in addition to the quantity in order to arrive at a decision to accept the waste, as well as to determine a cost for treatment. The Town of Pembroke subsequently retained UE to sample at key junction points for Zone 1 and Zone 2 to determine the quality of the wastewater. In October of 2020, the Sewer Interconnection Sampling Analysis memorandum was issued by UE which concluded that both Zones meet typical municipal wastewater quality criteria. Concord acknowledged this and stated the next step for Pembroke would be to evaluate what Concord collection system infrastructure would have to be upgraded to accept the Pembroke flows. This memo presents those evaluations.

UE performed a sewer capacity analysis for the Concord sewer collection system from the point where the interconnection would occur at the Airport Road and Manchester Street intersection, down Manchester Street to Manhole 2581 near Old Turnpike Road. The existing Merrimack River siphon full flow capacity was estimated, however the siphon and the existing sewer up Old Turnpike Road was not included in this analysis as insufficient information was available. The City provided UE with various record drawings, flow reports, and GIS information which were used in the SewerCAD modeling. Models were created to evaluate the Manchester Street sewer with current flows and future peak flows from the proposed expansions in Concord and the Pembroke interconnection.

KNOWNS & ASSUMPTIONS:

The following record materials were provided by the City of Concord:

- "Outskirts Sewer" Manchester Street As-Built Record Drawings, 1971
- Manchester Street Sewer ArcGIS shapefiles
- ArcGIS screenshot of Proposed Terrill Park Force Main
- ArcGIS screenshot of the Old Turnpike Road sewer collection system boundary
- "Manchester Street Roll Plan"
- "Manchester Street Reconstruction" Utilities Plan by HTA, 2011
- "Proposed Sewer Force Main Plan & Profile" Sheet C1.5 by Wilcox & Barton, 2020
- "Garvins Falls Sewer Feasibility Study Report" by VHB, 2004
- "Manchester Street Sewer Flow Report" by VHB, 2006
- "Manchester Street Survey" CAD drawing by RDB, 2008

UE proceeded with the modeling and analysis with the following assumptions:

- The Manchester Street sewer material, size, length, slope, and elevations shown on the 1971 "Outskirts Sewer" drawings are the most accurate representation of the current Manchester Street sewer.
- All manholes were assumed to be 4 feet in diameter.
- For manholes where no elevation data was available (MH-4289), the Rim and Invert elevations were back-calculated based on the upstream and downstream elevations and slope.
- MH-2581 on Old Turnpike Road was assigned to be a free flow outfall for the purposes of the SewerCAD model. During modeling, it was assumed that sewer downstream of MH-2581 and the siphon were not over capacity and surcharging back into MH-2581. This would need to be verified.
- The SewerCAD model did not include the flows contributed from the sewer up Old Turnpike Road to Sheep Davis Road shown in **Figure 5**, which ultimately flows into MH-2581.
- The "Manchester Street Siphon" record plan by Camp Dresser & McKee Inc. dated July 1978 is the most accurate representation of the current siphon and was used in the siphon capacity calculation.
- The "Garvins Falls Sewer Feasibility Study" by VHB Inc. dated March 2004 was used to incorporate future Concord sewer expansion peak flows into the SewerCAD model.
- The full flow sewer capacities presented in the "Manchester Street Sewer Flow Monitoring Report" by VHB Inc. dated December 20, 2006 were used in the Manchester Street SewerCAD Capacities calculation seen in **Appendix B**.

ANALYSIS:

Full Flow Pipe Capacities

UE started by creating the existing Manchester Street SewerCAD model using the 1971 "Outskirts Sewer" drawings and the ArcGIS shapefiles provided by the City since these two sets of records shared the same pipe lengths, diameters, materials, and manhole rim and invert elevations. **Figure 1** and **Figure 2** provide a visual representation of the existing Manchester Street sewer based on the above-mentioned record information.

Once the sewer infrastructure was added to the existing model, UE compared the full flow pipe capacities to the full flow pipe capacities from the 2006 VHB Flow Monitoring Report which is provided in **Appendix B**. As seen in **Table 1** below, there are minimal differences between the full flow capacities calculated by UE and VHB except for instances where record information differed. These differences are described in the "Comments" column of **Table 1**.

Table 1 – Manchester Street Existing Sewer Full Flow Capacity Comparison

VHB Sewer Section	Record Info Sewer Section	SewerCAD ID	VHB Design Flow (gpd)	VHB Full Flow Capacity (gpd)	Existing Full Flow Capacity (gpd)	% Difference	Comments
1	2580 - 2581	CO-29	1,840,000	No data	7,665,320		
2	2578 - 2580	CO-28	1,840,000	2,524,266	2,501,247	-1%	
3	2577 - 2578	CO-27	1,840,000	2,445,069	2,443,078	0%	
4	4289 - 2577	CO-26	1,840,000		2,753,310		MH 4289 in between MH 2576 - MH 2577 has no data. Section 4 is split in two but VHB Report has it as one section.
4*	2576 - 4289	CO-25	1,840,000	2,740,295	2,746,847	0%	
5	2575 - 2576	CO-24	1,840,000	2,814,473	2,785,626	-1%	
6	2574 - 2575	CO-23	1,840,000	3,201,784	3,192,806	0%	
7	2573 - 2574	CO-22	1,840,000	9,224,636	9,197,091	0%	
8	2572 - 2573	CO-21	1,840,000	9,246,845	9,222,944	0%	
9	2571 - 2572	CO-20	1,840,000	10,127,096	9,313,428	-8%	MH 2572 is a dop MH. The slope is 0.05 but VHB had a slope of 0.059 which is causing the discrepency. However, MH 2572 drop inlet is EL 257.44 and drop outlet is EL 254.78. VHB slope assumes no drop and pipe enters MH 2572 at EL 254.78.
10	2570 - 2571	CO-19	1,840,000	9,534,119	9,507,323	0%	
11*	2569 - 2570	CO-18	1,840,000	6,616,423	7,290,456	10%	Record drawings show 240' of 15" VCP between MH 2569 - MH 2570. VHB Flow Report shows 294' in this section.
Section 1 - 11 Sub Total			**22,080,000**	**58,475,006**	**68,619,476**		
12	2564 - 2569	CO-17	1,650,000	9,827,747	7,742,878	-21%	MH 2569 is a dop MH. The slope is 0.034 but VHB had a slope of 0.055 which is causing the discrepency. However, MH 2569 drop inlet is EL 295.66 and drop outlet is EL 289.56. VHB slope assumes no drop and pipe enters MH 2569 at EL 289.56.
13	2563 - 2564	CO-16	1,650,000	4,514,238	4,504,829	0%	
14	2562 - 2563	CO-15	1,650,000	2,811,695	2,817,942	0%	
15	2561 - 2562	CO-14	1,650,000	2,186,079	2,184,551	0%	
16	2560 - 2561	CO-13	1,650,000	2,342,420	2,339,668	0%	
17	2559 - 2560	CO-12	1,650,000	2,343,547	2,339,668	0%	
Section 12 - 17 Sub Total			**9,900,000**	**24,025,726**	**21,929,536**		
18	2558 - 2559	CO-11	1,350,000	1,948,487	1,945,414	0%	
19	2626 - 2558	CO-10	1,350,000	2,034,860	2,035,899	0%	
20	2625 - 2626	CO-9	1,350,000	1,809,627	1,809,688	0%	
21	2620 - 2625	CO-8	1,350,000	1,919,050	1,919,561	0%	
22	2609 - 2620	CO-7	1,350,000	1,933,441	1,919,561	-1%	
23*	2601 - 2609	CO-6	1,350,000	No data	1,945,414		Record drawings show only one 254' section of 15" VCP sewer between MH 2601 - MH 2609. VHB Flow Report has this broken between two (one 52' and one 202') sections.
24*			1,350,000	No data			
25	2590 - 2601	CO-5	1,350,000	2,103,279	2,087,604	-1%	
26	2579 - 2590	CO-4	1,350,000	1,969,996	1,958,341	-1%	
27	2568 - 2611	CO-2	1,350,000	No data	3,470,722		
28	2611 - 2579	CO-3	1,350,000	No data	1,137,518		
29	2557 - 2568	CO-1	1,350,000	1,788,341	1,719,203	-4%	Record drawings show 43' of 12" VCP between MH 2557 - MH 2568. VHB Flow Report has 40' in this section which may cause a slight discrepency.
Section 18 - 29 Sub Total			**16,200,000**	**15,507,081**	**21,948,925**		
Grand Total			**48,180,000**	**98,007,813**	**112,497,937**		

A full flow capacity calculation for the existing Merrimack River siphon was performed separately from the SewerCAD model and is provided in **Appendix A**. Based on the assumptions cited in the calculation, the full flow capacity of the 12" DI siphon barrel is 2,280,407 gpd and the full flow capacity of the 18" DI siphon barrel is 5,525,380 gpd for a combined total of 7,805,787 gpd. UE did not calculate the full flow pipe capacities for the Old Turnpike Road sewer collection basin which connects to the Manchester Street sewer at Terrill Park just before the siphon, and we have no information on flows coming from that area. However, we anticipate the addition of a third siphon barrel will be required when the future Manchester Street sewer expansions are built and further analysis of the Old Turnpike Road sewer collection basin are performed by others, regardless of whether the proposed Pembroke interconnection occurs.

Existing Flow Analysis

Once the full flow pipe capacities were confirmed, UE added the existing Manchester Street flows from the 2004 Garvins Falls Sewer Feasibility Study report into the existing SewerCAD model. **Table 2** summarizes the average day and peak flows from each of the sewer areas and lists which manhole the flow was added into the model. **Figure 1** and **Figure 2** depict this visually. For continuity purposes, UE used the same flow area labels as shown in Figure 3 of the 2004 Garvins Falls Sewer Feasibility Study report which has been provided in **Appendix C**.

Table 2 – Manchester Street Existing Sewer Flows

Sewer Section	Contributing Flow Areas[2]	Average Daily Flow (gpd)[1]	Peak Flow (gpd)	Flow Input Manhole
2557 - 2559	M1	147,124	588,496	2557
	I1	58,634	234,536	2579
	Sub Total	**205,758**	**823,032**	
2559 - 2569	M2	101,845	407,380	2559
	Sub Total	**101,845**	**407,380**	
2569 - 2581	M3	311,705	1,184,479	2569
	Sub Total	**311,705**	**1,184,479**	
	Total	**619,308**	**2,414,891**	

Notes:
1. Average daily flows and their corresponding peaking factors were taken from "Appendix C - Peak Sewer Flows" of the 2004 VHB Garvins Falls Sewer Feasibility Study to calculate the peak flows.
2. Manchester Street contributing flow areas taken from "Figure 3 – Sewer Flow Areas" of the 2004 VHB Garvins Falls Sewer Feasibility Study.

According to the results of the existing Manchester Street SewerCAD model, none of the existing pipes are currently over capacity. However, the following sewer pipes listed in **Table 3** below are over 85% capacity and were already scheduled to be replaced and upsized to 18" when the Garvins Falls sewer expansion occurs.

Table 3 – Manchester Street Sewer Pipes Near Capacity with Existing Flows

Sewer Section	Existing Pipe	Full Flow Capacity (gpd)	Existing Capacity (%)
2575 – 2576	15" VCP	2,785,626	86.5
2576 – 4289	15" VCP	2,746,847	87.7
4289 – 2577	15" VCP	2,753,310	87.6
2577 – 2578	15" VCP	2,443,078	98.7
2578 – 2580	15" VCP	2,501,247	96.3

<u>Future Flow Analysis</u>

After the existing SewerCAD model was created and the existing peak flows were incorporated, UE added the future flows from the 2004 Garvins Falls Sewer Feasibility Study report and the Pembroke interconnection into the existing SewerCAD model. **Table 4** summarizes the average day and peak flows from each of the sewer areas and lists which manhole the flow was added into in the model. **Figure 3** and **Figure 4** depict this visually. For continuity purposes, UE used the same flow area labels as shown in Figure 3 of the 2004 Garvins Falls Sewer Feasibility Study report which has been provided in **Appendix C**.

Table 4 – Manchester Street Sewer Future Flows

Sewer Section	Contributing Flow Areas[2]	Average Daily Flow (gpd)	Peak Flow (gpd)	Flow Input Manhole
	M1	147,124	588,496	2557
	I1	58,634	316,623	2579
	G1-5	32,025	192,150	2611
2557 - 2559	Pembroke Zone 1 & 2	278,000	1,490,000	2557
	Sub Total	**515,783**	**2,587,269**	
	M2	101,845	366,642	2559
2559 - 2569	G1-2	19,784	106,833	2559
	G1-3	62,000	223,200	2559
	G1-4	135,789	733,261	2559
	Sub Total	**319,418**	**1,429,936**	
	M3	311,705	1,090,968	2569
2569 - 2581	G1-1	14,744	77,406	2569
	Sub Total	**326,449**	**1,168,374**	
	Total	**1,161,650**	**5,185,579**	

<u>Notes:</u>
1. Average daily flows and their corresponding peaking factors were taken from "Appendix C – Peak Sewer Flows" of the 2004 VHB Garvins Falls Sewer Feasibility Study to calculate the peak flows.
2. Manchester Street contributing flow areas taken from "Figure 3 – Sewer Flow Areas" of the 2004 VHB Garvins Falls Sewer Feasibility Study.

The future flows in **Table 4** above would cause the majority of the existing Manchester Street sewer pipes to be over capacity. The only sewer pipes that would not be over capacity are those between MH 2563 and MH 2574 which is due to their location on the steep hill between Garvins Falls Road and Old Turnpike Road (see **Figure 4**). Although these pipes are 15" just like the rest of Manchester Street, they have slopes of 1.2 – 5% as compaed to the flatter areas with slopes ranging from 0.2 – 0.4%. The following sewer pipes listed in **Table 5** below will be over 100% capacity and will require upsizing if the Concord sewer expansions and the Pembroke interconnection occur.

Table 5 – Manchester Street Existing Sewer Pipes Over Capacity with Future Flows

Sewer Section	Existing Pipe	Full Flow Capacity (gpd)	Future Capacity (%)
2557 – 2586	12” VCP	1,719,203	121
2568 – 2611	15” VCP	1,971,267	105.6
2611 – 2579	15” VCP	2,003,583	113.4
2579 – 2590	15” VCP	1,958,341	132.4
2590 – 2601	15” VCP	2,087,064	124
2601 – 2609	15” VCP	1,945,414	133.4
2609 – 2620	15” VCP	1,919,561	134.9
2620 – 2625	15” VCP	1,919,561	135.2
2625 – 2626	15” VCP	1,809,688	143.4
2626 – 2558	15” VCP	2,035,899	127.3
2558 – 2559	15” VCP	1,945,414	133.4
2559 – 2560	15” VCP	2,339,668	172
2560 – 2561	15” VCP	2,339,668	172.1
2561 – 2562	15” VCP	2,184,551	184.3
2562 – 2563	15” VCP	2,817,942	142.9
2574 – 2575	15” VCP	3,192,806	162.7
2575 – 2576	15” VCP	2,785,626	186.5
2576 – 4289	15” VCP	2,746,847	189.1
4289 – 2577	15” VCP	2,753,310	188.8
2577 – 2578	15” VCP	2,443,078	212.7
2578 – 2580	15” VCP	2,501,247	207.6

To address the over capacity issue, UE first proceeded with upsizing the pipes based on Figure 5 of the 2004 Garvins Falls Sewer Feasibility Study report which has been provided in **Appendix D**. Unfortunately, once the Pembroke interconnection occurs, all of the upsized pipes shown in **Table 6** will still be over 100% capacity except for sewer reach 2562 – 2563.

Table 6 – Manchester Street Sewer Pipes Over Capacity after Garvins Falls Upgrades

Sewer Section	Proposed Pipe	Full Flow Capacity (gpd)	Future Capacity (%)
2557 – 2586	12” VCP	1,719,203	121
2568 – 2611	15” VCP	1,971,267	105.6
2611 – 2579	15” VCP	2,003,583	113.4
2579 – 2590	15” VCP	1,958,341	132.4
2590 – 2601	15” VCP	2,087,064	124
2601 – 2609	15” VCP	1,945,414	133.4
2609 – 2620	15” VCP	1,919,561	134.9
2620 – 2625	15” VCP	1,919,561	135.2
2625 – 2626	15” VCP	1,809,688	143.4
2626 – 2558	15” VCP	2,035,899	127.3
2558 – 2559	15” VCP	1,945,414	133.4
2559 – 2560	18” VCP	3,806,807	105.7
2560 – 2561	18” VCP	3,806,807	105.8
2561 – 2562	18” VCP	3,554,744	113.4
2562 – 2563	18” VCP	4,582,388	87.9
2574 – 2575	15” VCP	3,192,806	162.7
2575 – 2576	18” VCP	4,530,682	114.7
2576 – 4289	18” VCP	4,466,050	166.3
4289 – 2577	18” VCP	4,472,514	166.1
2577 – 2578	18” VCP	3,974,850	130.8
2578 – 2580	18” VCP	4,071,797	127.7

Notes:
1. Sewer reaches upsized to 18” based on Figure 5 of the 2004 VHB Garvins Falls Sewer Feasibility Study.

UE then proceeded with increasing sewer pipe diameters in the model to obtain full flow capacities below 85% with all future flows from Garvins Falls and Pembroke included. Because larger diameter pipes would need to be installed to accommodate the future flows from **Table 4**, UE modeled these larger diameter pipes as SDR 35 PVC which is the most common new gravity sewer material. As seen in **Table 7**, UE proposed that all sewer pipes on Manchester Street be upsized with the exception of the pipes on the steep hill between Garvins Falls Road and Old Turnpike Road (MH 2564 – MH 2574). As mentioned previously, these pipes on the hill do not need to be replaced due to the available capacity from the steep slopes.

Table 7 – Manchester Street Sewer Pipes Capacity with UE Proposed Upgrades

Sewer Section	Proposed Pipe	Full Flow Capacity (gpd)	Future Capacity (%)
2557 – 2586	15" PVC	4,052,408	51.3
2568 – 2611	18" PVC	4,162,281	50
2611 – 2579	18" PVC	4,239,840	53.7
2579 – 2590	18" PVC	4,136,429	62.6
2590 – 2601	18" PVC	4,420,808	58.6
2601 – 2609	18" PVC	4,104,113	63.1
2609 – 2620	18" PVC	4,065,334	63.8
2620 – 2625	18" PVC	4,052,408	63.9
2625 – 2626	18" PVC	3,819,733	67.8
2626 – 2558	18" PVC	4,304,471	60.2
2558 – 2559	18" PVC	4,110,576	63.1
2559 – 2560	*18" PVC*	*4,950,788*	*81.3*
2560 – 2561	*18" PVC*	*4,944,325*	*81.4*
2561 – 2562	*18" PVC*	*4,614,703*	*87.2*
2562 – 2563	*18" PVC*	*5,952,580*	*67.6*
2563 – 2564	*18" PVC*	*9,520,249*	*42.3*
2574 – 2575	18" PVC	6,747,549	77
2575 – 2576	21" PVC	8,880,396	58.5
2576 – 4289	21" PVC	8,764,059	59.3
4289 – 2577	21" PVC	8,776,985	59.2
2577 – 2578	21" PVC	7,788,120	66.7
2578 – 2580	21" PVC	7,982,015	65.1
2580 – 2581	21" PVC	24,437,246	21.3

As noted in **Table 6**, the sections of sewer between MH 2559 and MH 2564 *(italics)* were scheduled to be upsized to 18" to accommodate the Garvins Falls sewer expansions. These pipe reaches will not need to be upsized further to accommodate Pembroke flows. All (shaded) pipes will require upsizing to accommodate Pembroke flows on top of Garvins Falls flows. It should also be noted that although the section of pipe between MH 2580 and MH 2581 does not need to be upsized to 21" for capacity reasons, UE would not recommend leaving an oddball 15" VCP pipe at this location. Note: MH 2581 also receives flow from the Old Turnpike Road sewer collection basin which is a significant part of the Concord sewer system as seen in **Figure 5**.

Cost Estimation

The following conceptual opinion of cost for the replacement and upsizing of the Manchester Street sewer pipes to accommodate the future Concord sewer expansions and the proposed Pembroke interconnection is shown in **Table 8**. The total estimated cost for the Manchester Street sewer upgrades is approximately $5.3M (MH 2557 – MH 2581). This cost does not include the purchase of treatment capacity for Pembroke which will be negotiated in an Intermunicipal Agreement should the interconnection occur.

Table 8 – Opinion of Cost for Proposed Manchester Street Sewer Upgrades

Sewer Reach	Length (LF)	Existing Pipe	Proposed Pipe	Unit Cost ($/LF)[1]	Cost
2557 - 2568	43	12" VCP	15" PVC	$500	$21,500
2568 - 2611	202	15" VCP	18" PVC	$500	$101,000
2611 - 2579	65	15" VCP	18" PVC	$500	$32,500
2579 - 2590	300	15" VCP	18" PVC	$500	$150,000
2590 - 2601	307	15" VCP	18" PVC	$500	$153,500
2601 - 2609	254	15" VCP	18" PVC	$500	$127,000
2609 - 2620	302	15" VCP	18" PVC	$500	$151,000
2620 - 2625	294	15" VCP	18" PVC	$500	$147,000
2625 - 2626	304	15" VCP	18" PVC	$500	$152,000
2626 - 2558	290	15" VCP	18" PVC	$500	$145,000
2558 - 2559	300	15" VCP	18" PVC	$500	$150,000
2559 - 2560[4]	267	15" VCP	18" PVC	$500	$133,500
2560 - 2561[4]	296	15" VCP	18" PVC	$500	$148,000
2561 - 2562[4]	274	15" VCP	18" PVC	$500	$137,000
2562 - 2563[4]	213	15" VCP	18" PVC	$500	$106,500
2563 - 2564[4]	270	15" VCP	18" PVC	$500	$135,000
2574 - 2575	294	15" VCP	18" PVC	$500	$147,000
2575 - 2576	292	15" VCP	21" PVC	$550	$160,600
2576 - 4289	157	15" VCP	21" PVC	$550	$86,350
4289 - 2577	145	15" VCP	21" PVC	$550	$79,750
2577 - 2578	254	15" VCP	21" PVC	$550	$139,700
2578 - 2580	178	15" VCP	21" PVC	$550	$97,900
2580 - 2581	65	15" VCP	21" PVC	$550	$35,750
3rd Siphon Barrel[2]	510	12" & 18" DI	TBD[3]	$600	$306,000
				Sub Total	$3,043,550
				Contractor OH&P (15%)	$456,533
				Contingency (30%)	$913,065
				Total Construction Cost	$4,413,148
				Engineering (20%)	$882,630
				Total Probable Cost	**$5,295,777**

Notes:
1. Unit costs are based on recent cost opinions for similar sewer replacement projects on highly travelled paved roads in other Towns.
2. New siphon barrel to be directionally drilled 410 feet under the Merrimack River with an allowance of 50 feet either side of siphon structures.
3. New siphon barrel size to be determined based on further evaluation of other Concord collection system expansions and growth.
4. These pipe sections were recommended to be upsized to 18" for the Garvins Falls sewer expansion and will not need to be upsized further to accommodate the Pembroke connection.

Since the peak flow from Zone 1 and Zone 2 of the Pembroke collection system is 1,490,000 gallons/day and the total estimated peak flow after the Concord sewer expansions are built is

5,185,579 gallons/day according to **Table 4**, the Town of Pembroke would constitute 29% of the future Manchester Street sewer flows upstream of MH 2581. Pembroke's percentage of the future needed siphon capacity could not be calculated as the existing and future flows coming from the Old Turnpike Road sewer collection basin (seen in **Figure 5**) are unknown at this time. UE did not evaluate the sewer pipe capacity between Old Turnpike Road and the siphon, or form the siphon to the Hall Street WWTF. For now, it is being assumed these reaches of pipe will not need to be upsized but this should be verified.

The City of Concord and their engineering firm are just beginning evaluations of other areas of the Concord collection system including the Old Turnpike Road sewer collection basin and the multiple siphons the City has crossing the Merrimack River. The City of Concord may upgrade the existing siphon at the end of the Manchester Street sewer whether or not the interconnection with Pembroke occurs. However to be conservative, UE has assumed that Pembroke will be involved in these upgrades and contribute 29% of the upgrade costs.

CONCLUSIONS AND RECOMMENDATIONS:

In the first phase of this sewer interconnection analysis, UE estimated the average day and peak hour flows from both Zone 1 and Zone 2 of the Pembroke sewer collection system. In the first technical memorandum issued in March of 2020, UE estimated the cost to collect and transmit flow from both Zone 1 and Zone 2 to the Concord collection system to be $8.95M. In the second phase of this sewer interconnection analysis, UE performed 24 hour composite sampling at convergence locations of Zone 1 and Zone 2 and sent the results to the City of Concord who confirmed the wastewater quality is typical and acceptable. The outcome from the second technical memorandum issued in October of 2020 was that the existing Manchester Street sewer capacity would need to be evaluated and that Pembroke would have to pay for a portion of the necessary upgrades to accommodate the interconnection. In this third phase of the analysis, UE determined which Manchester Street sewer pipes would need to be upgraded to accommodate both future flows from Concord and Pembroke. The estimated cost for the Manchester Street upgrades is $5.3M. **Table 9** presents the total estimated cost to Pembroke for sending wastewater from both Zone 1 and Zone 2 to the Concord collection system.

Table 9 – Total Project Conceptual Opinion of Cost

Project	Cost[3]
Pembroke Zone 1 and Zone 2 Infrastructure Upgrades	$8,950,000
Manchester Street Infrastructure Upgrades (29%)[1]	$1,520,000
City of Concord Connection Fees[2]	$4,170,000
Total	**$14,640,000**

Notes:
1. This cost assumes the Town of Pembroke will pay 29% of the $5.3M based on their percentage of peak flow in the Manchester Street sewer system.
2. This cost assumes $15/gal connection fee multiplied by the average daily flow from Zone 1 & Zone 2 (278,000 gpd)
3. Costs are in 2020 and 2021 dollars.

The cost per gallon of capacity gained for both Zone 1 and Zone 2 would be $14.64M/278,000 gpd or $52.66/gal. Building a new wastewater treatment facility in the 278,000 GPD size range in today's dollars (2021) would likely cost $40-$50/gal. Based on the analyses and assumptions cited in this memorandum, $52.66/gal is considered reasonable.

If Pembroke agrees and wishes to continue interconnection discussions with the City of Concord, next steps should include agreement on a buy-in fee, confirmation of annual treatment costs based on the quality and quantity of flow, establishment of Manchester Street sewer upgrade fees paid by Pembroke, and establishment of siphon upgrade fees to be paid by Pembroke. It should also be confirmed that sewer upgrades are not needed between Old Turnpike Road and the siphon and from the siphon to the WWTF.

FIGURES

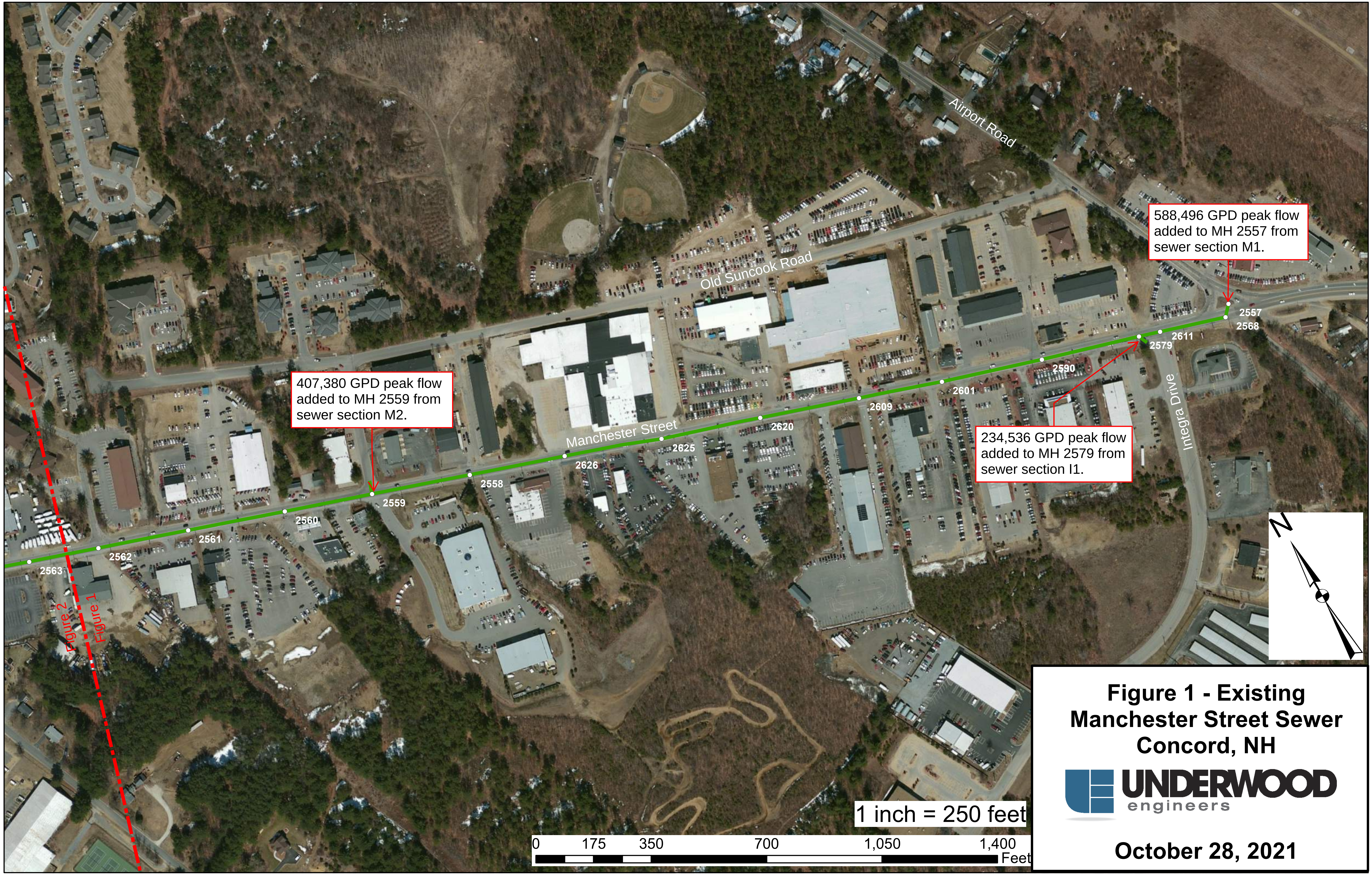

Figure 1 - Existing Manchester Street Sewer Concord, NH

October 28, 2021

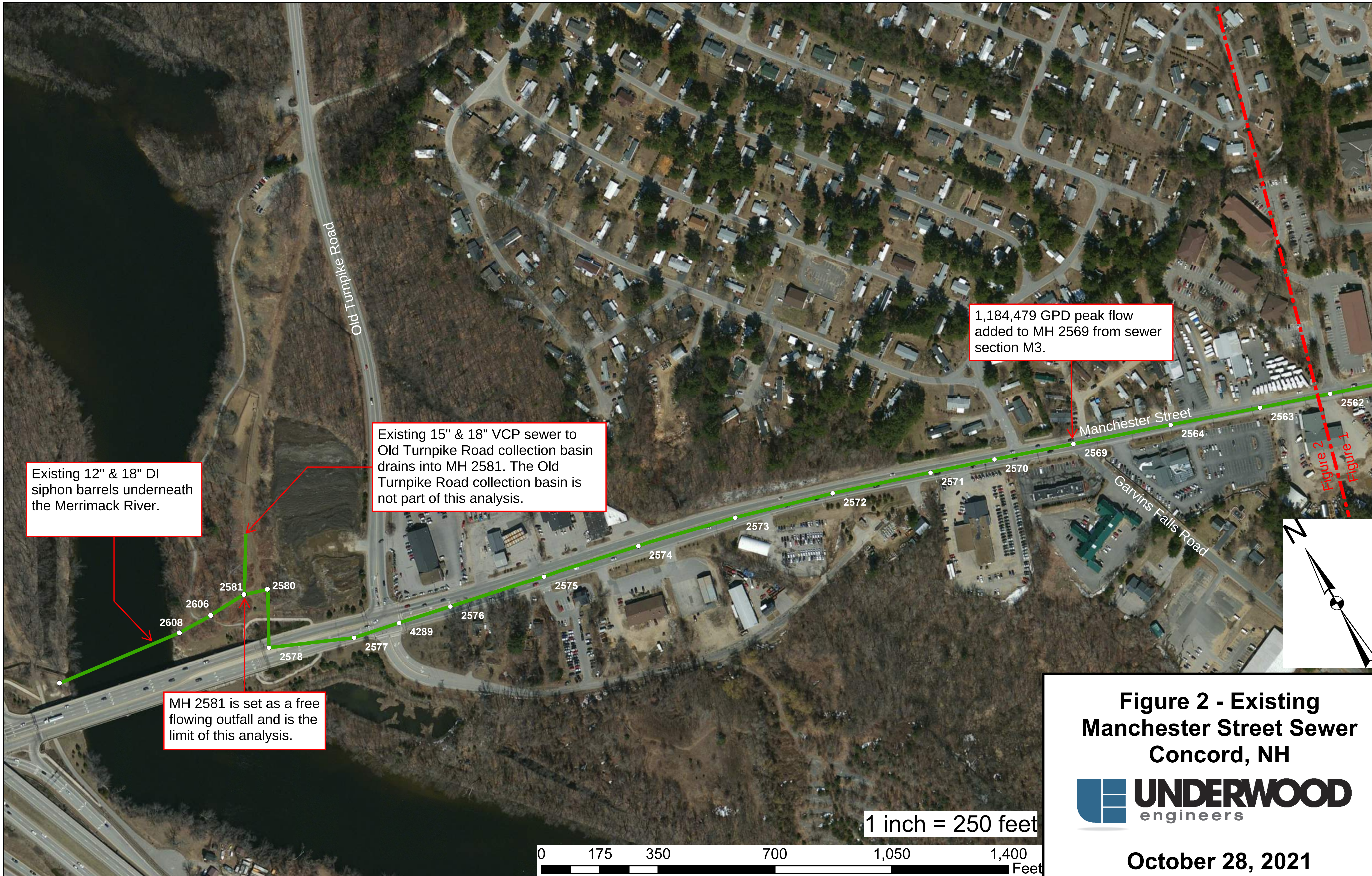

Figure 2 - Existing Manchester Street Sewer Concord, NH

October 28, 2021

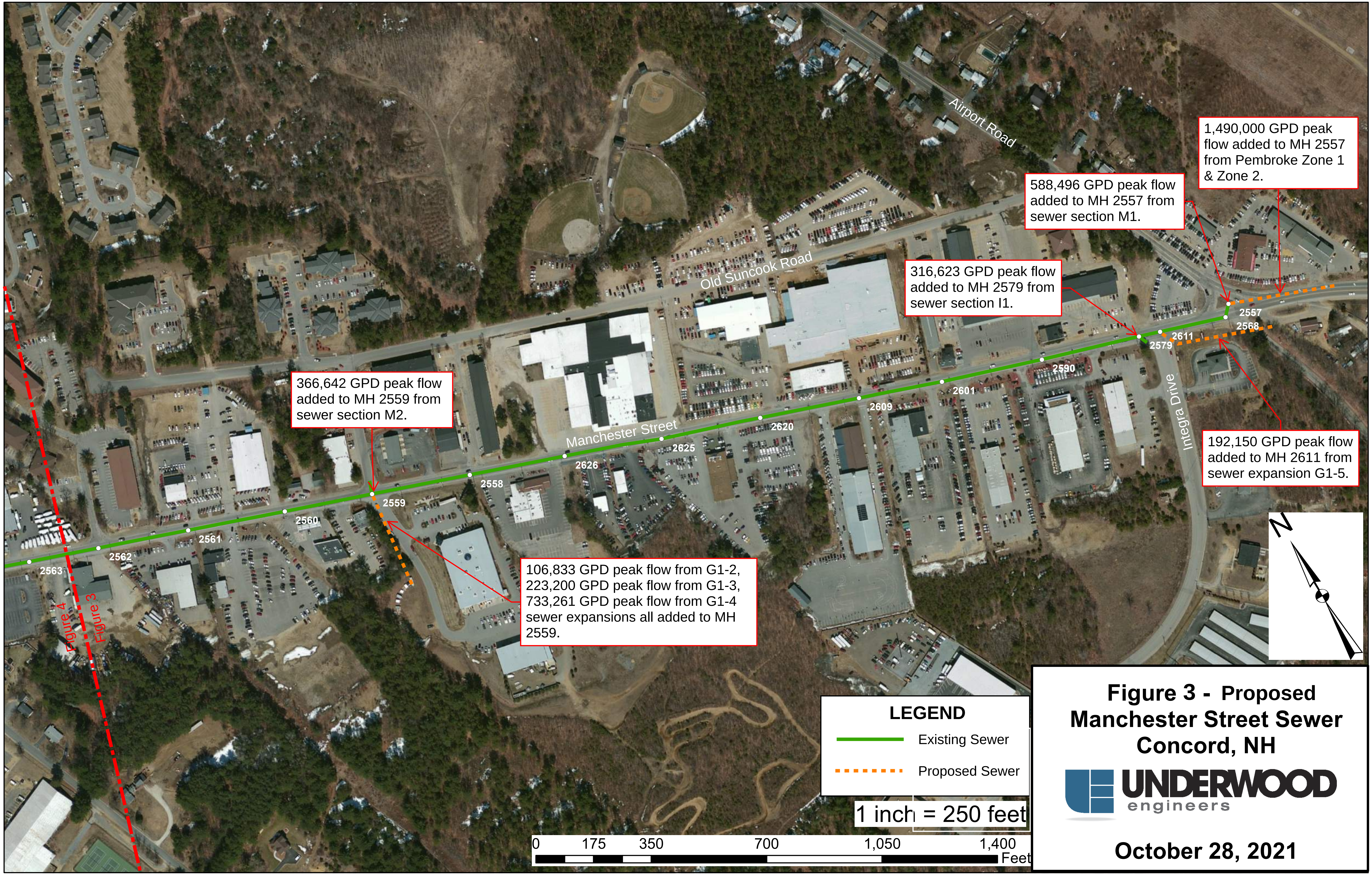

Figure 3 - Proposed Manchester Street Sewer Concord, NH

Old Turnpike Road
Manchester Street
Garvins Falls Road
1,090,968 GPD peak flow added to MH 2569 from sewer section M3.
Existing 15" & 18" VCP sewer to Old Turnpike Road collection basin drains into MH 2581. The Old Turnpike Road collection basin is not part of this analysis.
Existing 12" & 18" DI siphon barrels underneath the Merrimack River. New siphon barrel designed and installed by others.
77,406 GPD peak flow added to MH 2569 from G1-1 sewer expansion.
MH 2581 is set as a free flowing outfall and is the limit of this analysis.
2562
2563
2564
2569
2570
2571
2572
2573
2574
2575
2576
4289
2577
2578
2580
2581
2606
2608
Figure 4
Figure 3
N
LEGEND
Existing Sewer
Proposed Sewer
1 inch = 250 feet
0 175 350 700 1,050 1,400 Feet
Figure 4 - Proposed Manchester Street Sewer Concord, NH
UNDERWOOD engineers
October 28, 2021


FIGURE 5 - OLD TURNPIKE ROAD SEWER COLLECTION BASIN
CONCORD, NH
FIGURE PROVIDED BY CITY OF CONCORD
OCTOBER 29, 2021
OLD TURNPIKE ROAD SEWER COLLECTION BASIN BOUNDARY
OLD TURNPIKE ROAD SEWER FLOWS INTO MH 2581 BEFORE SIPHON
Legend
Sewer Manholes
Sewer Service Lateral
Sewer Mains
0 400 800 1,600 2,400 Feet
1 inch = 400 feet
N S E W

APPENDIX A

Existing Manchester Street Siphon Full Flow Capacity
Calculation

UNDERWOOD engineers

25 Vaughan Mall
Portsmouth, NH 03801
Tel (603) 436-6192
Fax (603) 431-4733

99 North State Street
Concord, NH 03301
Tel 603 230 9898
Fax 603 230 9899

Job No.	:	**2486**	**Calc. No.**	
Project	:	**Concord Sewer Capacity Analysis Pembroke Intercon**	**Drawing Ref.**	
			Calculation by	**RMB**
Description	:	**Merrimack River Siphon Full Flow Capacity Estimation**	**Date**	**14-Sep-21**
			Page	**1**

REF. | CALCULATIONS | NOTES

PURPOSE:

To estimate the full flow capacity of the 12" and 18" DI siphon underneath the Merrimack River by Terrill Park.

ASSUMPTIONS:

1 The elevations and lengths on the 1978 Manchester St Siphon Record Drawings by Camp Dresser & McKee Inc. are accurate.

2 The appropriate formula to estimate the full flow capacity is the Darcy Weisbach equation.

3 The headloss (h_f) over the length of both siphon barrels is the difference between the pipe invert elevations in MH 2608 & MH 2610 shown in profile view on Sheet 51

4 The equivalent sand grain roughness (k_s) in inches for ductile iron pipe is similar to the ks value for "Wrought Iron, Steel"

5 The viscosity of the sewage is similar to the viscosity of water at 70 degrees F

REFERENCES:

1 "Engineering Fluid Mechanics" by Donald F. Elger, et al. 11th edition. Figure 10.14 - Moody Diagram and Table 10.14 - Equivalent Sand Grain Roughness for Various Pipe Materials.

2 "Manchester St Siphon" record drawings dated July 1978 by Camp Dresser & McKee Inc. Sheet 51 plan and profile view.

KNOWNS:

1 Darcy Weisbach Equation:

$$h_f = f * (L/D) * (V^2/2g)$$

where f is the friction factor taken from the Moody Diagram using the relative roughness:

$$k_s/D$$

and the Reynolds Number parameter:

$$D^{3/2} * (2gh_f/L)^{1/2}/v$$

2 List of known values:

12" ductile iron siphon barrel dia = (D_1) =		1	ft	Reference 2
18" ductile iron siphon barrel dia = (D_2) =		1.5	ft	Reference 2
Upstream MH 2608 D_1 invert elevation =		217.63	ft	Reference 2
Upstream MH 2608 D_2 invert elevation =		217.63	ft	Reference 2
Downstream MH 2610 D_1 invert elevation =		215.51	ft	Reference 2
Downstream MH 2610 D_2 invert elevation =		216.14	ft	Reference 2
Headloss D_1 = (h_f) =		2.12	ft	
Headloss D_2 = (h_f) =		1.49	ft	
Acceleration due to gravity = (g) =		32.2	ft/s^2	Reference 1
Length between MH 2608 and MH 2610 = (L) =		410	ft	Reference 2
Kinematic viscosity (v) of water @ 70 F =		0.000016	ft^2/s	Reference 1 Table A5
Equivalent roughness of ductile iron pipe = (ks) =		0.002	in	Reference 1 Table 10.4
	OR	0.0002	ft	

PLEASE INITIAL AS CHECKED | CHKD:

UNDERWOOD engineers

25 Vaughan Mall
Portsmouth, NH 03801
Tel (603) 436-6192
Fax (603) 431-4733

99 North State Street
Concord, NH 03301
Tel 603 230 9898
Fax 603 230 9899

Job No.	:	**2486**	**Calc. No.**	
Project	:	**Concord Sewer Capacity Analysis Pembroke Intercon**	**Drawing Ref.**	
			Calculation by	**RMB**
Description	:	**Merrimack River Siphon Full Flow Capacity Estimation**	**Date**	**14-Sep-21**
			Page	**2**

REF. | CALCULATIONS | OUTPUT

CALCULATE : 12" Siphon Full Flow Estimation

1 Solve for Reynolds Number parameter

$D^{3/2} * (2gh_f/L)^{1/2}/v =$ 36066

OR $3.61*10^4$

2 Solve for relative roughness

$k_s/D =$ 0.00017

3 Use Moody Diagram to determine f value

f = 0.0165

4 Find velocity (V) using Darcy Weisbach equation

$h_f = f * (L/D) * (V^2/2g)$

OR

$V^2 = hf/f * (L/D)/2g =$ 20.18

V = 4.49 ft/s

5 Solve for flow (Q) using Continuity equation

Q = V/A

A = π/4 * D2 = 0.7854 sq ft

Q = 3.53 cfs

OR **2,280,407 gpd**

CALCULATE : 18" Siphon Full Flow Estimation

1 Solve for Reynolds Number parameter

$D^{3/2} * (2gh_f/L)^{1/2}/v =$ 55547

OR $5.56*10^4$

2 Solve for relative roughness

$k_s/D =$ 0.00011

3 Use Moody Diagram to determine f value

f = 0.015

4 Find velocity (V) using Darcy Weisbach equation

$h_f = f * (L/D) * (V^2/2g)$

OR

$V^2 = hf/f * (L/D)/2g =$ 23.40

V = 4.84 ft/s

5 Solve for flow (Q) using Continuity equation

Q = V/A

A = π/4 * D2 = 1.767 sq ft

Q = 8.55 cfs

OR **5,525,380 gpd**

PLEASE INITIAL AS CHECKED | CHKD:

UNDERWOOD engineers

25 Vaughan Mall
Portsmouth, NH 03801
Tel (603) 436-6192
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99 North State Street
Concord, NH 03301
Tel 603 230 9898
Fax 603 230 9899

Job No.	:	**2486**	**Calc. No.**	
Project	:	**Concord Sewer Capacity Analysis Pembroke Intercon**	**Drawing Ref.**	
			Calculation by	**RMB**
Description	:	**Merrimack River Siphon Full Flow Capacity Estimation**	**Date**	**14-Sep-21**
			Page	**3**

REF.	CALCULATIONS	OUTPUT
	RESULTS:	
	Total double barrel siphon full flow capacity = 12.08 cfs	
	OR **7,805,787 gpd**	
	Per TR-16, siphons shall meet the following requirements	
1	No less than two (2) barrels	
2	Minimum pipe size of 6 in	
3	Manholes at either end of the pipes for flushing and maintenance	
4	Pipes shall have minimum velocity of at least 3 ft/s for average flows to keep the pipe free of settleable solids	
5	Inlet and outlet should be arranged so normal flow is diverted to one (1) barrel so that either barrel can be taken out of service for maintenance	

PLEASE INITIAL AS CHECKED	CHKD:

FIGURE 10.14

Friction Factor *f* versus Reynolds number. Data from Moody (3).]

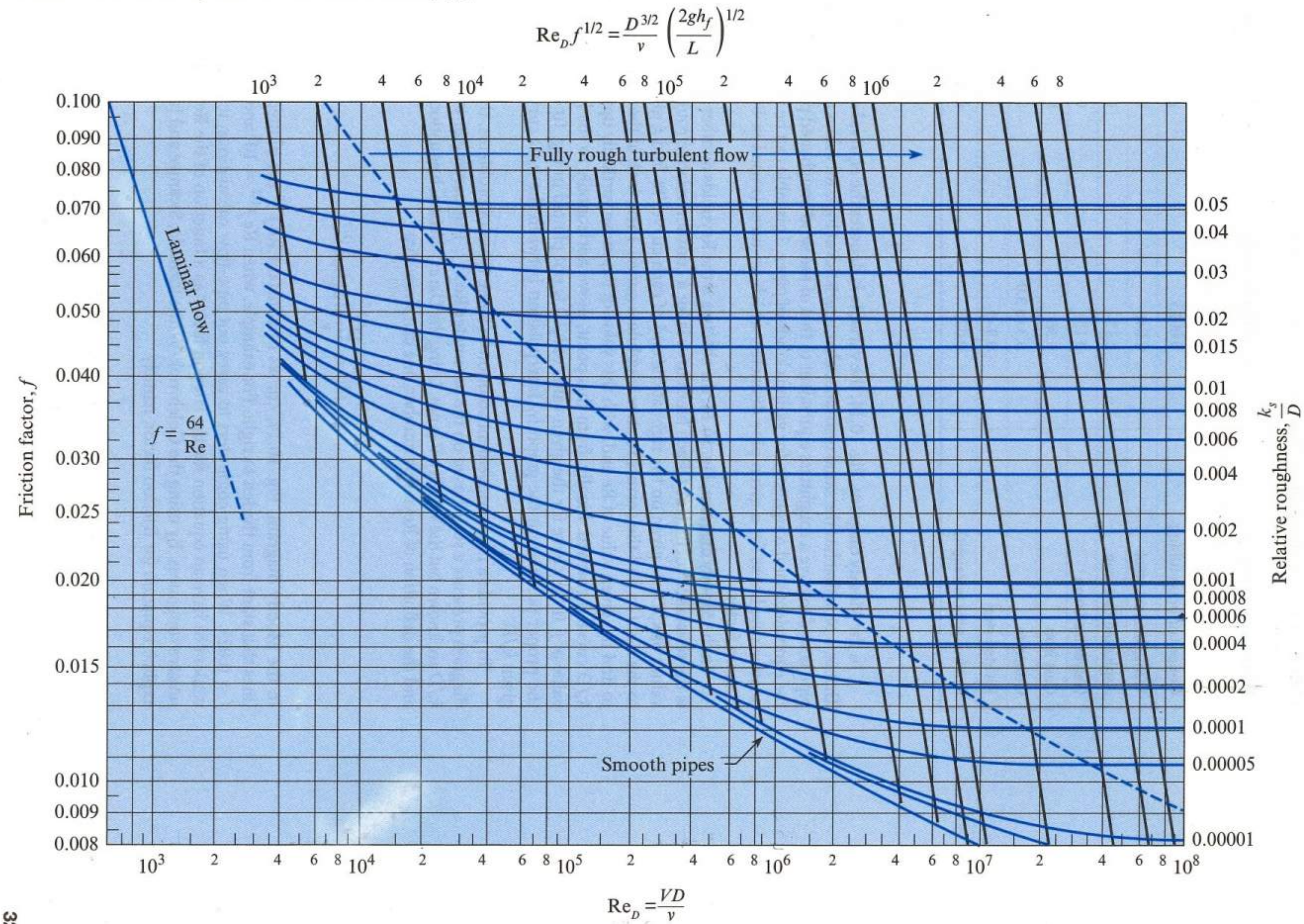


TABLE 10.4 Equivalent Sand-Grain Roughness, (k_s), for Various Pipe Materials

Boundary Material	k_s, Millimeters	k_s, Inches
Glass, plastic	0.00 (smooth)	0.00 (smooth)
Copper or brass tubing	0.0015	6×10^{-5}
Wrought iron, steel	0.046	0.002
Asphalted cast iron	0.12	0.005
Galvanized iron	0.15	0.006
Cast iron	0.26	0.010
Concrete	0.3 to 3.0	0.012–0.12
Riveted steel	0.9–9	0.035–0.35
Rubber pipe (straight)	0.025	0.001

In the Moody diagram, Fig. 10.14, the variable k_s denotes the **equivalent sand roughness**. That is, a pipe that has the same resistance characteristics at high Re values as a sand-roughened pipe is said to have a roughness equivalent to that of the sand-roughened pipe. Table 10.4 gives the equivalent sand roughness for various kinds of pipes. This table can be used to calculate the relative roughness for a given pipe diameter, which, in turn, is used in Fig. 10.14 to find the friction factor.

In the Moody diagram, Fig. 10.14, the abscissa is the Reynolds number Re, and the ordinate is the resistance coefficient f. Each blue curve is for a constant relative roughness k_s/D, and the values of k_s/D are given on the right at the end of each curve. To find f, given Re and k_s/D, go to the right to find the correct relative roughness curve. Then, look at the bottom of the chart to find the given value of Re and, with this value of Re, move vertically upward until the given k_s/D curve is reached. Finally, from this point, move horizontally to the left scale to read the value of f. If the curve for the given value of k_s/D is not plotted in Fig. 10.14, then simply find the proper position on the graph by interpolation between the k_s/D curves that bracket the given k_s/D.

To provide a more convenient solution to some types of problems, the top of the Moody diagram presents a scale based on the parameter $\mathrm{Re}\, f^{1/2}$. This parameter is useful when h_f and k_s/D are known but the velocity V is not. Using the Darcy-Weisbach equation given in Eq. (10.12) and the definition of Reynolds number, one can show that

$$\mathrm{Re}\, f^{1/2} = \frac{D^{3/2}}{\nu}(2gh_f/L)^{1/2} \tag{10.38}$$

In the Moody diagram, Fig. 10.14, curves of constant $\mathrm{Re}\, f^{1/2}$ are plotted using heavy black lines that slant from the left to right. For example, when $\mathrm{Re}\, f^{1/2} = 10^5$ and $k_s/D = 0.004$, then $f = 0.029$. When using computers to carry out pipe-flow calculations, it is much more convenient to have an equation for the friction factor as a function of the Reynolds number and relative roughness. By using the Colebrook-White formula, Swamee and Jain (7) developed an explicit equation for friction factor, namely

$$f = \frac{0.25}{\left[\log_{10}\left(\frac{k_s}{3.7D} + \frac{5.74}{\mathrm{Re}_D^{0.9}}\right)\right]^2} \tag{10.39}$$

TABLE A.5 Approximate Physical Properties of Water* at Atmospheric Pressure

Temperature	Density	Specific Weight	Dynamic Viscosity	Kinematic Viscosity	Vapor Pressure
	kg/m^3	N/m^3	$N \cdot s/m^2$	m^2/s	N/m^2 abs
0°C	1000	9810	1.79×10^{-3}	1.79×10^{-6}	611
5°C	1000	9810	1.51×10^{-3}	1.51×10^{-6}	872
10°C	1000	9810	1.31×10^{-3}	1.31×10^{-6}	1,230
15°C	999	9800	1.14×10^{-3}	1.14×10^{-6}	1,700
20°C	998	9790	1.00×10^{-3}	1.00×10^{-6}	2,340
25°C	997	9781	8.91×10^{-4}	8.94×10^{-7}	3,170
30°C	996	9771	7.97×10^{-4}	8.00×10^{-7}	4,250
35°C	994	9751	7.20×10^{-4}	7.24×10^{-7}	5,630
40°C	992	9732	6.53×10^{-4}	6.58×10^{-7}	7,380
50°C	988	9693	5.47×10^{-4}	5.53×10^{-7}	12,300
60°C	983	9643	4.66×10^{-4}	4.74×10^{-7}	20,000
70°C	978	9594	4.04×10^{-4}	4.13×10^{-7}	31,200
80°C	972	9535	3.54×10^{-4}	3.64×10^{-7}	47,400
90°C	965	9467	3.15×10^{-4}	3.26×10^{-7}	70,100
100°C	958	9398	2.82×10^{-4}	2.94×10^{-7}	101,300
	$slugs/ft^3$	lbf/ft^3	$lbf\text{-}s/ft^2$	ft^2/s	psia
40°F	1.94	62.43	3.23×10^{-5}	1.66×10^{-5}	0.122
50°F	1.94	62.40	2.73×10^{-5}	1.41×10^{-5}	0.178
60°F	1.94	62.37	2.36×10^{-5}	1.22×10^{-5}	0.256
70°F	1.94	62.30	2.05×10^{-5}	1.06×10^{-5}	0.363
80°F	1.93	62.22	1.80×10^{-5}	0.930×10^{-5}	0.506
100°F	1.93	62.00	1.42×10^{-5}	0.739×10^{-5}	0.949
120°F	1.92	61.72	1.17×10^{-5}	0.609×10^{-5}	1.69
140°F	1.91	61.38	0.981×10^{-5}	0.514×10^{-5}	2.89
160°F	1.90	61.00	0.838×10^{-5}	0.442×10^{-5}	4.74
180°F	1.88	60.58	0.726×10^{-5}	0.385×10^{-5}	7.51
200°F	1.87	60.12	0.637×10^{-5}	0.341×10^{-5}	11.53
212°F	1.86	59.83	0.593×10^{-5}	0.319×10^{-5}	14.70

*Notes: Bulk modulus E_v of water is approximately 2.2 GPa (3.2×10^5 psi).

Data source: R. E. Bolz and G. L. Tuve, *Handbook of Tables for Applied Engineering Science*, CRC Press, Inc., Cleveland, 1973. Copyright © 1973 by The Chemical Rubber Co., CRC Press, Inc.

APPENDIX B

2006 VHB Manchester Street Sewer Flow Report

Transportation
Land Development
Environmental
Services

Vanasse Hangen Brustlin, Inc.

Kilton Road
Six Bedford Farms, Suite 607
Bedford, New Hampshire 03110-6532
603 644-0888
FAX 603 644-2385

RECEIVED
DEC 21 2006
ENGINEERING SERVICES DIV.
CONCORD, N.H.

RECEIVED
SEP 21 2009
ENGINEERING SERVICES DIV.
CONCORD, N.H.

Memorandum

To: Ms. Martha Drukker
Engineering Services Division
City Hall
41 Green St
Concord, NH 03301

Date: December 20, 2006

Project No.: 51531.00

From: Bryant A. Anderson, P.E.
Project Manager

Re: Manchester Street Sewer Flow
Monitoring Results
Garvins Falls Sewer Study
Concord, New Hampshire

As requested, Vanasse Hangen Brustlin, Inc. (VHB) has coordinated sewer flow monitoring of a single sewer manhole located in Manchester Street (refer to Figure 1 for location). The monitoring was conducted by Severn Trent Pipeline Services (Auburn, NH) over a four week period in June/July 2006.

VHB has prepared this memorandum to provide a brief summary of the flow monitoring results, a comparison to the flows estimated from the Garvins Falls Sewer Study (VHB, 2004), and an estimate of the current flow capacity of the Manchester Street sewer system.

Flow Monitoring Summary

The following provides a summary of the flow monitoring results. For additional information please refer to the enclosed Flow Monitoring Report.

Monitoring Period: 06/23/06 thru 07/21/06

Performed By: Severn Trent Pipeline Services/ADS Environmental Services

Location: SMH in front of Carlson's Motor Sales (refer to Figure 1)
Manchester Street, Concord, NH

Flow Monitoring Results:	Min. Daily Flow =	0.008 mgd	8,000 gpd
	Average Daily Flow =	0.155 mgd	155,000 gpd
	Max. Daily Flow =	0.523 mgd	523,000 gpd
Estimated Average Daily Flow for Full Build Out of Existing Tributary Area (w/o Garvins Falls Phase I):	619,308 gpd		(from 2004 Sewer Study)
Percent of Estimated Avg. Daily Flow:	25 percent		(Monitored Flow/Estimated Flow)

The flow monitoring results indicate that the current flows in the Manchester Street Sewer System are at approximately 25 percent of the potential full build-out flow of the existing contributing area. The average monitored daily flow was approximately 155,000 gpd compared to the average estimated daily design flow of 619,308 gpd from the Garvins Falls Sewer Study.

Manchester Street Sewer Capacity

Table 1 (Manchester Street Sewer Capacity Estimate) was developed to assist the City in their evaluation of the existing Manchester Street sewer system to determine if and when system upgrades will be required. Table 1 and the attached Sewer Flow Calculations were based on the information provided in the Garvins Falls Sewer Study. They are intended to provide an estimate of the maximum flow that the three main segments of the system can handle and still provide a Q/Qfull ratio of 0.75 or less.

Table 1: Manchester Street Sewer Capacity Estimate

Sewer Section(s)	Avg. Daily Flow (gpd)	Peak Daily Flow (gpd)*	Comments**
1 thru 11	460,000	1,840,000	Section 3 at Design Capacity
12 thru 17	412,500	1,650,000	Section 15 at Design Capacity
18 thru 29	337,500	1,350,000	Sections 20 & 29 at Design Capacity

* Based on a peaking factor of 4.
** Peak design flow estimated based on assumption that Q/Qfull ratios > 0.75 exceed sewer design capacity.

The flow monitoring data indicates that the current flows in the sewer system are below the system's design capacity. However, as the contributing area continues to develop and as the Garvins Falls Area starts to develop, the additional sewer flows generated will likely exceed the existing capacity of sections of the Manchester Street sewer system. As such, system upgrades may be required to handle future flows.

Enclosures: *(paper and electronic PDF copies of following items)*
Manchester Street Sewer Flow Monitoring Results Memorandum (12/20/06)
Flow Monitoring Report (ADS Environmental, June-July 2006)
Figure 1 – Flow Meter Location
Figure 2 – Manchester Street Sewer System
Sewer Flow Calculations (Manchester Street Sewer Capacity)
Garvins Falls Sewer Feasibility Study (VHB, March 2004) – *electronic copy only*

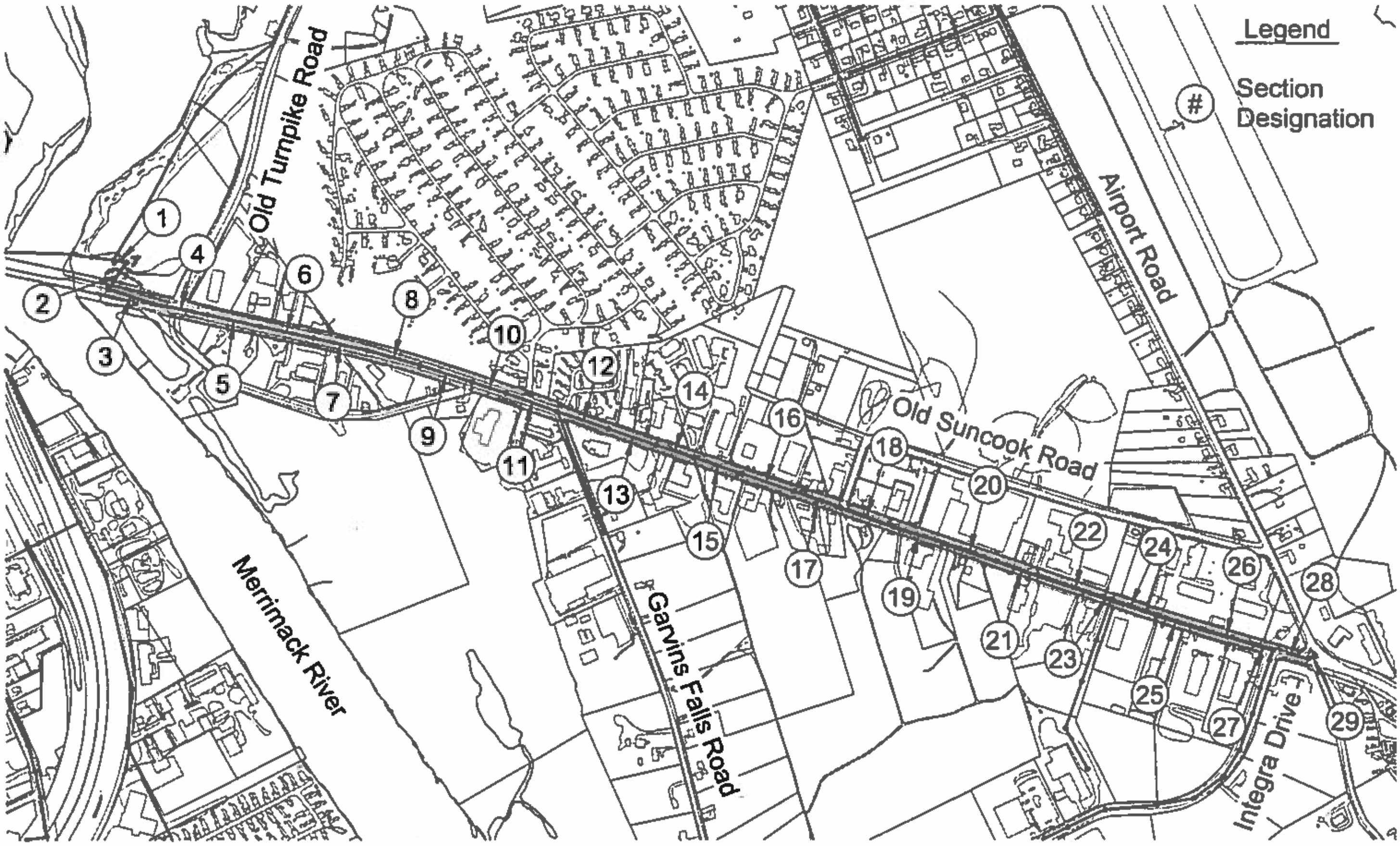
0 250 500 Feet

Vanasse Hangen Brustlin, Inc.

Flow Meter Location

Figure 1

June - July 2006
Manchester Street
Concord, New Hampshire



Section	Material	Size (in)	Approx. Length (ft)	Invert		Rim	
				Downstream	Upstream	Downstream	Upstream
1	VCP	15	72	318.09	318.33	324.22	324.76
2	VCP	15	176		318.09		324.22
3	VCP	15	255	317.49			
4	VCP	15	301	316.83	317.49	327.18	
5	VCP	15	292	316.06	316.83		327.18
6	VCP	15	294		316.06		
7	VCP	15	299	315.51			
8	VCP	15	299	314.87	315.51	326.99	
9	VCP	15	299	314.25	314.87	327.18	326.99
10	VCP	15	192	313.68	314.25		327.18
11	VCP	15	293	312.99	313.68	326.93	
12	VCP	15	293	312.34	312.99	326.70	326.93
13	VCP	15	270	311.50	312.34		326.70
14	VCP	15	215	310.57	311.50	324.03	
15	VCP	15	275	309.82	310.57	323.03	324.03
16	VCP	15	297	308.85	309.82	321.86	323.03
17	VCP	15	268	305.71	308.85	314.37	321.86
18	VCP	15	300	289.56	305.71	303.36	314.37
19	VCP	15	292	282.24	289.56	291.76	303.36
20	VCP	15	305	272.28	282.24	280.94	291.76
21	VCP	15	295	254.78	272.28	264.52	280.94
22	VCP	15	300	240.19	254.78	248.19	264.52
23	VCP	15	52	225.67	240.19	234.58	248.19
24	VCP	15	202	223.95	225.67	231.21	234.58
25	VCP	15	305	222.63	223.95	232.29	231.21
26	VCP	15	298	221.34	222.63	234.60	232.29
27	VCP	15	65	220.47	221.34		234.60
28	VCP	15	200	219.83	220.47	230.69	
29	VCP	15	40		219.83		230.69

Source: City of Concord GIS Data and Record Plans

Vanasse Hangen Brustlin, Inc.

Manchester Street Sewer System

Figure 2

Garvins Falls
Sewer Feasibility Study
Concord, New Hampshire

0 1,000 2,000 Feet

Sewer Flow Calculations

Manchester Street Sewer Capacity

Project #:	51531.00		
Project:	Garvins Falls Sewer Study		
Location:	Concord, New Hampshire		
Calculated by:	B. Anderson	Date:	12/1/06
Checked by:		Date:	

Sewer Section	Design Flow (gpd)	Pipe Type	Manning Number	Diameter (in)	Length (ft)	Slope (ft/ft)	Full-Flow Capacity (gpd)	Full-Flow Velocity (ft/sec)	Q/Qfull	d/D (depth/dia)	V/Vfull	Estimated Velocity (ft/s)	Upstream Invert	Downstream Invert	Upstream Rim Elevation	Downstream Rim Elevation	Comments
29	1,350,000	VCP	0.013	12	40	0.006	1,788,341	3.5	0.75	0.7	0.94	3.3	318.33	318.09	324.76	324.22	Q/Qfull approx. 0.75. Pipe segment at capacity.
28	1,350,000	VCP	0.013	15	200								318.09		324.22		Invert information not available
27	1,350,000	VCP	0.013	15	65									317.49			Invert information not available
26	1,350,000	VCP	0.013	15	298	0.002	1,969,996	2.5	0.69	0.6	0.88	2.2	317.49	316.83		327.18	
25	1,350,000	VCP	0.013	15	305	0.003	2,103,279	2.7	0.64	0.6	0.88	2.3	316.83	316.06	327.18		
24	1,350,000	VCP	0.013	15	202								316.06				Invert information not available
23	1,350,000	VCP	0.013	15	52									315.51			Invert information not available
22	1,350,000	VCP	0.013	15	300	0.002	1,933,441	2.4	0.70	0.6	0.88	2.1	315.51	314.87		326.99	
21	1,350,000	VCP	0.013	15	295	0.002	1,919,050	2.4	0.70	0.6	0.88	2.1	314.87	314.25	326.99	327.18	
20	1,350,000	VCP	0.013	15	305	0.002	1,809,627	2.3	0.75	0.7	0.94	2.1	314.25	313.68	327.18		Q/Qfull approx. 0.75. Pipe segment at capacity.
19	1,350,000	VCP	0.013	15	292	0.002	2,034,860	2.6	0.66	0.6	0.88	2.3	313.68	312.99		326.93	
18	1,350,000	VCP	0.013	15	300	0.002	1,948,487	2.5	0.69	0.6	0.88	2.2	312.99	312.34	326.93	326.70	
17	1,650,000	VCP	0.013	15	268	0.003	2,343,547	3.0	0.70	0.6	0.88	2.6	312.34	311.50	326.70		
16	1,650,000	VCP	0.013	15	297	0.003	2,342,420	3.0	0.70	0.6	0.88	2.6	311.50	310.57		324.03	
15	1,650,000	VCP	0.013	15	275	0.003	2,186,079	2.8	0.75	0.7	0.94	2.6	310.57	309.82	324.03	323.03	Q/Qfull approx. 0.75. Pipe segment at capacity.
14	1,650,000	VCP	0.013	15	215	0.005	2,811,695	3.5	0.59	0.6	0.88	3.1	309.82	308.85	323.03	321.86	
13	1,650,000	VCP	0.013	15	270	0.012	4,514,238	5.7	0.37	0.4	0.71	4.0	308.85	305.71	321.86	314.37	
12	1,650,000	VCP	0.013	15	293	0.055	9,827,747	12.4	0.17	0.3	0.61	7.6	305.71	289.56	314.37	303.36	
11	1,840,000	VCP	0.013	15	293	0.025	6,616,423	8.3	0.28	0.4	0.71	5.9	289.56	282.24	303.36	291.76	
10	1,840,000	VCP	0.013	15	192	0.052	9,534,119	12.0	0.19	0.3	0.61	7.3	282.24	272.28	291.76	280.94	
9	1,840,000	VCP	0.013	15	299	0.059	10,127,096	12.8	0.18	0.3	0.61	7.8	272.28	254.78	280.94	264.52	
8	1,840,000	VCP	0.013	15	299	0.049	9,246,845	11.7	0.20	0.3	0.61	7.1	254.78	240.19	264.52	248.19	
7	1,840,000	VCP	0.013	15	299	0.049	9,224,636	11.6	0.20	0.3	0.61	7.1	240.19	225.67	248.19	234.58	
6	1,840,000	VCP	0.013	15	294	0.006	3,201,784	4.0	0.57	0.6	0.88	3.6	225.67	223.95	234.58	231.21	
5	1,840,000	VCP	0.013	15	292	0.005	2,814,473	3.5	0.65	0.6	0.88	3.1	223.95	222.63	231.21	232.29	
4	1,840,000	VCP	0.013	15	301	0.004	2,740,395	3.5	0.67	0.6	0.88	3.0	222.63	221.34	232.29	234.60	

Sewer Flow Calculations

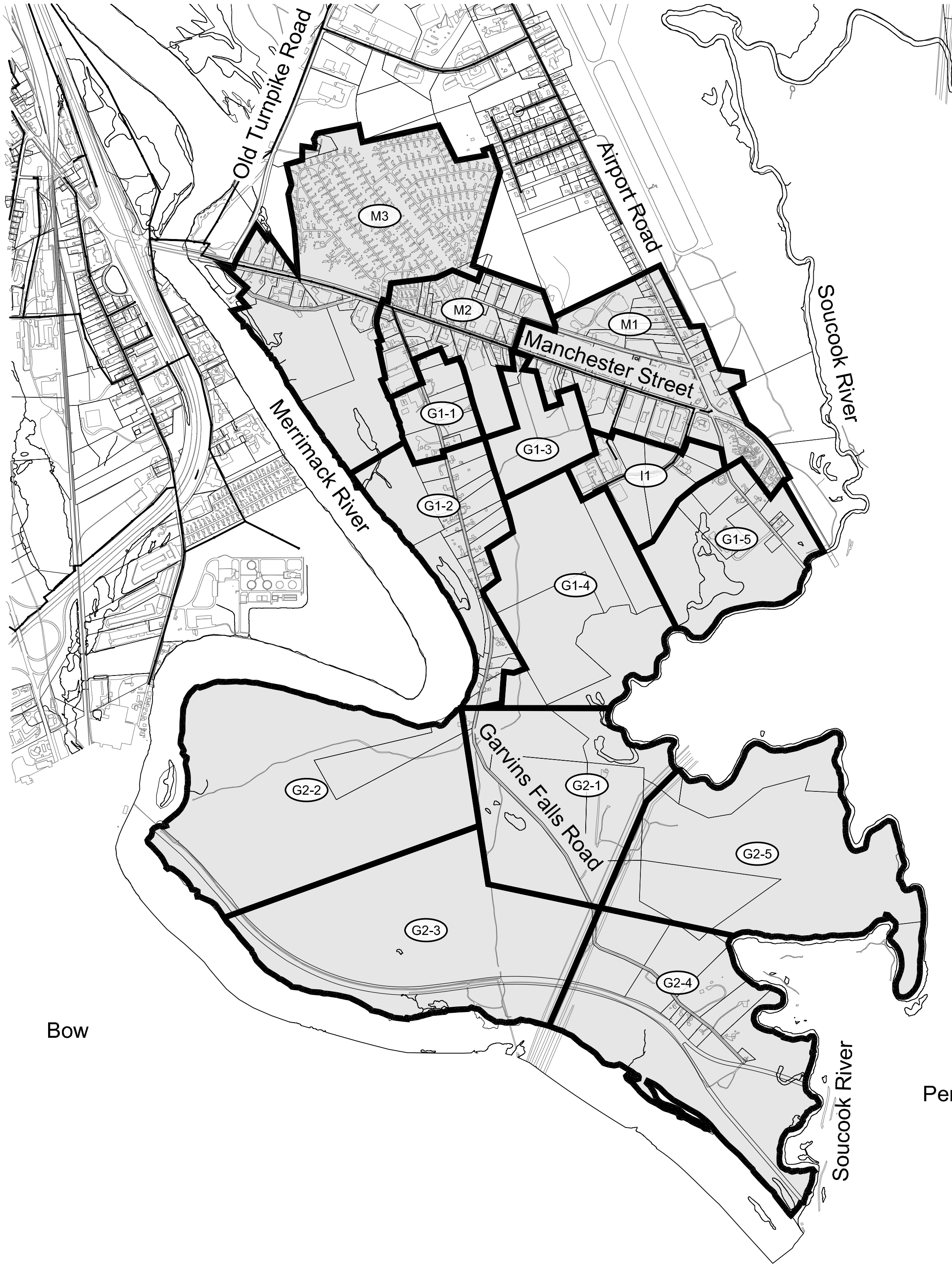
Manchester Street Sewer Capacity

Project #:	51531.00		
Project:	Garvins Falls Sewer Study		
Location:	Concord, New Hampshire		
Calculated by:	B. Anderson	Date:	12/1/06
Checked by:		Date:	

Sewer Section	Design Flow (gpd)	Pipe Type	Manning Number	Diameter (in)	Length (ft)	Slope (ft/ft)	Full-Flow Capacity (gpd)	Full-Flow Velocity (ft/sec)	Q/Qfull	d/D (depth/dia)	V/Vfull	Estimated Velocity (ft/s)	Upstream Invert	Downstream Invert	Upstream Rim Elevation	Downstream Rim Elevation	Comments
3	1,840,000	VCP	0.013	15	255	0.003	2,445,069	3.1	0.75	0.7	0.94	2.9	221.34	220.47	234.60		Q/Qfull approx. 0.75. Pipe segment at capacity.
2	1,840,000	VCP	0.013	15	176	0.004	2,524,266	3.2	0.73	0.7	0.94	3.0	220.47	219.83		230.69	
1	1,840,000	VCP	0.013	15	72								219.83		230.69		Invert information not available

APPENDIX C

2004 Garvins Falls Sewer Feasibility Study Figure 3 “Sewer Flow Areas” by VHB



Vanasse Hangen Brustlin, Inc.

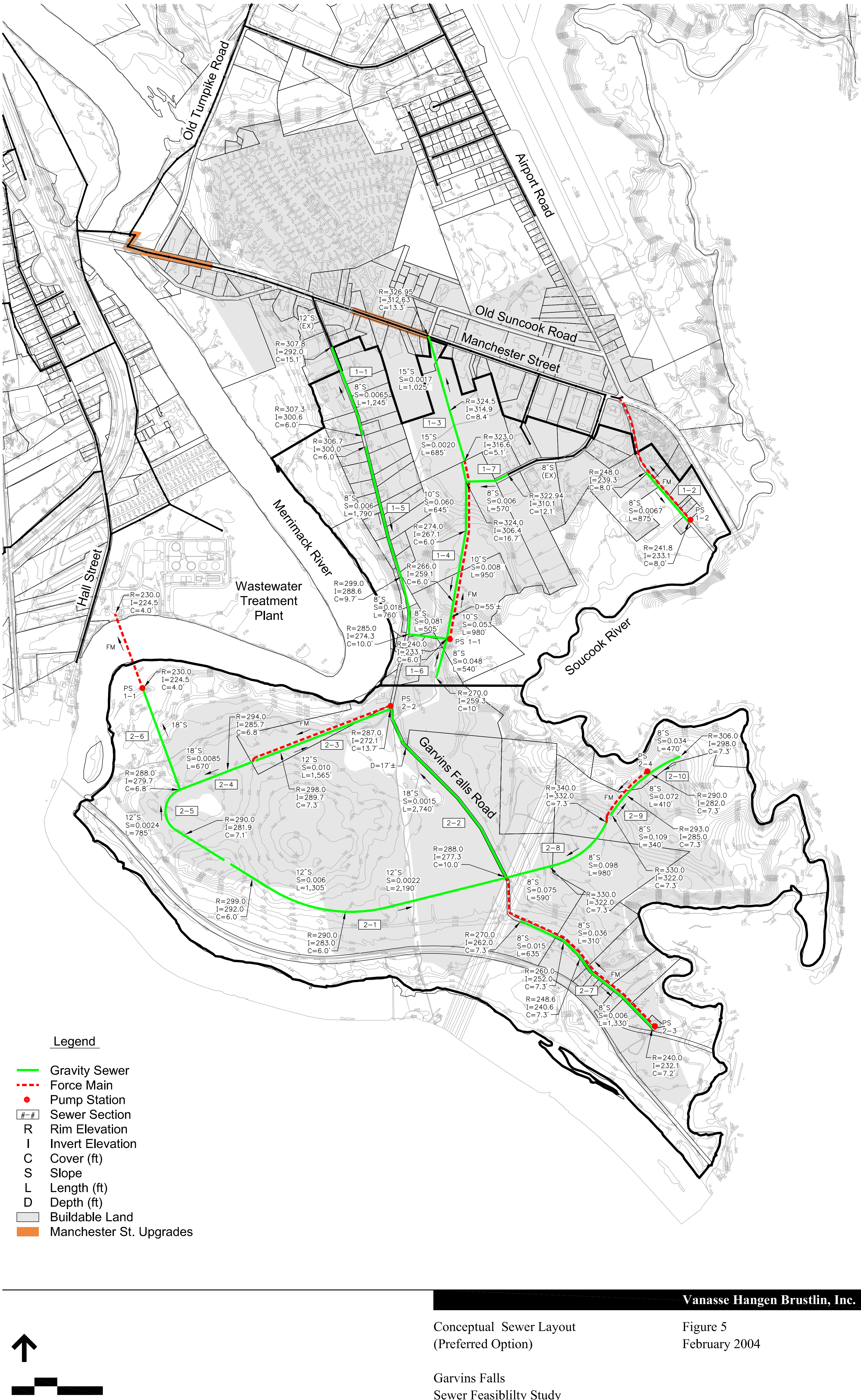
Sewer Flow Areas

Garvins Falls
Sewer Feasibility Study
Concord, New Hampshire

Figure 3
February 2004

APPENDIX D

2004 Garvins Falls Sewer Feasibility Study Figure 5
“Conceptual Sewer Layout” by VHB



Vanasse Hangen Brustlin, Inc.

Conceptual Sewer Layout
(Preferred Option)

Figure 5
February 2004

Garvins Falls
Sewer Feasiblilty Study
Concord, New Hampshire