APPENDIX

APPENDIX E

Stormwater Engineering Feasibility Assessment | Stone Environmental, October 2018

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October 11, 2018; Revised May 20, 2019

MEMO

To: Eleni Churchill, Chris Dubin, CCRPC
Megan Moir, Jenna Olson, City of Burlington

From: Gabe Bolin, PE, Branden Martin, EI, Amy Macrellis

Stone Project No. 17-061-B
Subject: Future Railyard Enterprise Project, Stormwater Engineering Feasibility Assessment, Final Technical Memo

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Stone Environmental, Inc. (Stone) has prepared the following technical memo to summarize our efforts regarding the Stormwater Engineering Feasibility Assessment for the Future Railyard Enterprise Project (REP). As discussed in our proposal dated December 21, 2017 (Proposal), the purpose of this assessment is to evaluate the engineering feasibility of separating stormwater runoff flows from the combined sewer system in the REP project area to mitigate existing and potential flooding, via a new separate storm sewer system network that runs along the proposed Connector Road (RSG 2016), which would discharge via one or more outfalls to Lake Champlain.

As presented in our Phase I Technical Memo dated April 4, 2018, and as discussed during our meeting with CCRPC and the City on May 3, 2018, a feasible separate storm sewer system route has been determined via an initial hydraulic analysis. Following the May meeting, Stone completed the remaining project tasks including the cost and risk analysis of feasible alternatives (Phase II), and the water quality treatment evaluation (Phase III). Stone also performed additional hydraulic analysis (Phase I) to further evaluate the separate storm sewer system with respect to flooding and safe roadway operation. The following presents work performed under each task, analysis results, and conceptual design and opinions of probable construction cost for the proposed separate storm sewer system.

1. Phase I – Additional Hydraulic Analysis

The Phase I Technical Memo presented two potential storm sewer networks, with outfalls discharging just south of Perkins Pier, located to the west of the existing railroad tracks (Route #1), and to the Pine Barge Canal (Route #2). Due to significant risks and constraints related to construction of the system discharging to the canal, it was agreed during the May meeting to eliminate Route #2. Therefore, only Route #1 was advanced through the remainder of Phase 1 and into Phases II and III (see Sheets 1, 2 and 3 of the attached engineering drawings for system layout, profile and catch basin details, respectively).

1.1 Modifications to the Design

Stone received input on the Phase I Technical Memo from the City via email following submission on April 4, 2018, and at the May meeting. The majority of input was specific to the design of the separate storm sewer system. Stone made the following design modifications:

- The project watershed model was converted from HydroCAD to PCSWMM; Stone received a copy of the City's Main Plant PCSWMM model, which facilitated this process.
- Pipe size was increased from 24" to 36" diameter, to mitigate flooding identified along the Connector Road in the initial hydraulic analysis, and to provide capacity for additional flows from adjacent drainages.
- Pipe type was changed from ADS corrugated polyethylene (smoothed lined) to ADS SaniTite HP, following concerns expressed by the City related to failures of polyethylene pipe in the past and City materials preferences.
- Manning's coefficient (n) was changed from 0.013 for the corrugated polyethylene to 0.012 for the SaniTite HP pipe.
- The minimum pipe slope was reduced to 0.046% to maintain a scour velocity of 2 ft/sec consistent with the Recommended Standards for Wastewater Facilities (GLUMRB, 2014) rather than 3 ft/sec as specified in Stone's initial hydraulic analysis. This minimum slope was selected assuming that the system will include some degree of water quality treatment, and that introduction of sediment to the system will be minimized.
  - With this revision, Stone was able to revise the invert elevation at the proposed outfall from 98 feet to 99 feet NAVD88.
- Nitrile fittings for the SaniTite pipe, designed to prevent intrusion of contaminated groundwater from entering the piping system, are specified in the cost estimates.

1.2 Topographic Surveying

Due to winter weather conditions, Stone was not able to complete topographic survey work prior to submission of the interim Phase I (April 4, 2018) memo. Publicly available LiDAR data were used in lieu of site-specific data to support the initial hydraulic analysis.

During Phase I work, Stone learned that RSG conducted a topographic survey of the REP project area. This survey was provided by RSG in late March and provided the majority of topographic data needed for Stone's work. The area near Perkins Pier and Roundhouse Park, where the final run of stormwater pipe and outfall are proposed, was not surveyed by RSG. Stone performed a supplemental survey of this area in June, and incorporated the supplemental and RSG survey data into the project base map. All design plans attached to this memo include the RSG/Stone survey data.

1.3 Additional Analysis – Identification of Needs

During the May meeting additional H&H analysis needs were identified, to evaluate:

- Which design storm events would cause flooding within the limits of the Connector Road and render it impassable
  - The flooding analysis was performed for an array of scenarios that included the incremental addition of flows from surrounding drainages, to investigate potential mitigation of flooding within the REP extents, and to potentially reduce combined flows conveyed to the WWTP during runoff events
- Extreme water surface elevations at Lake Champlain, the potential for blockage of the proposed outfall during extreme events, and resulting effects on roadway flooding upstream of the outfall

Below, we discuss the approach, methodology, and results of the two analyses described above. The first is an evaluation of roadway flooding under different scenarios of adjacent drainage area inclusion, where the simulations do not include blockage of the outfall pipe by extreme water surface elevations at Lake Champlain. The second evaluation is a replica of the first, but includes varying degrees of outfall submergence, simulating extreme water surface elevations at the lake.

1.4 Additional Analysis - Connector Road Flooding

A definition of what may be considered 'impassable' relative to safe vehicular passage and roadway flooding was required to perform the first analysis. To quantify this, Stone performed research on road flooding relative to vehicular velocity and impassable conditions. In particular, Pregnolato et al. (2017) developed a relationship between depth of road floodwater to vehicle speed, integrating experimental, observational, and modeling studies reviewed by the authors. Their 'depth-disruption' function is provided in **Error! Reference source not found.** below.

The speed v(w) (y-axis) is the maximum acceptable velocity that ensures safe control of the vehicle, given a depth of floodwater (x-axis). The figure also provides upper and lower bounds to reflect variations in the 'fleet', or an account of variability in vehicles, and their capability of driving through flooded roads (i.e. 2WD vs. 4WD, vehicle ground clearance, etc.); however, the author lists limitations regarding interpretation of these bounds.

Our analysis assumes that as soon as traffic starts to slow down due to floodwaters, and cars perform unpredictably relative to each other, conditions are unsafe and the road is considered impassable. For the sake of developing a critical flood depth, it was assumed that the Connector Road would have a speed limit of 25 mph. It was also assumed that if traffic was able to travel at the speed limit the road would be passable, and if traffic was not able to keep up with the speed limit, the road would be unpassable.

The depth-disruption function (**Error! Reference source not found.**) indicates that a flood depth of 4 inches (100 mm) corresponds with a passable vehicle speed of 25 miles/hour (40 km/hour). Therefore, a depth of roadway flooding (i.e. ponding at catch basins or edge of road) less than or equal to 4 inches was determined to be passable at 25 mph, while flood depths greater than 4 inches were defined as impassable due to safety concerns and would require road closing.

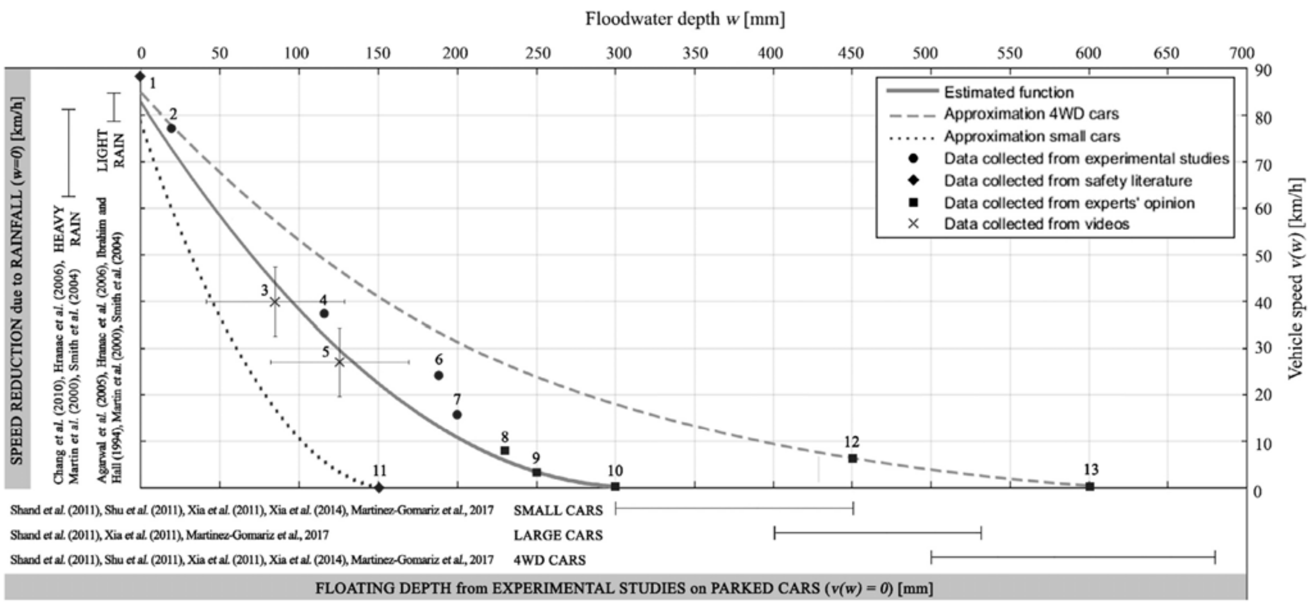

Fig. 2. The depth-disruption function that relates flood depth on a road with vehicle speed.

Figure 1. Depth-disruption function that relates roadway flood depth with vehicle speed (Pregnolato et al. 2017).

Having defined the flood depth threshold value, Stone then developed a plan for incremental addition of stormwater flows from adjacent drainages into the proposed system, to evaluate feasible alternatives for mitigating flooding within and adjacent to the REP extents and reducing combined flows conveyed to the WWTP. The following outlines the incremental inclusion of stormwater flows simulated via the PCSWMM model (with abbreviations made to facilitate results presentation):

- Connector Road drainage only (2.11 total acres, abbreviated as 'CR')
- Connector Road + railyard drainage (10.48 total acres, 'CR + RY')
- Connector Road + Pine Street stormwater flows (14.74 total acres, 'CR + PS')
- Connector Road + railyard drainage + Pine Street stormwater flows (23.11 total acres, 'CR+RY+PS')

Stone's evaluation included a portion of the railyard drainage, and of separate stormwater flows along Pine Street, each on an individual basis to allow comparison of these scenarios as singular mitigation options, given the competing needs for stormwater management in the railyard and in the combined system, respectively. The final scenario combines all three drainages, to assess the potential for addressing all major drainage management concerns.

The railyard drainage (RY) incorporates 8.37 acres (7.51 impervious acres) of drainage located directly east of the rail, extending past the limits of the Connector Road, from Maple Street to the north and in line with Curtis Lumber to the south, as shown in Figure 2. Stone split subcatchment S3 in the City's PCSWMM model along the eastern limits of the rail line to create the 8.37-acre subcatchment. The drainage was previously connected to catch basin MPY-1.4_ICD, but the drainage outlet was redirected to Stone's catch basin SU1, or the catch basin just upstream from the proposed outfall. Although portions of this drainage overlap the Connector Road geospatially, the goal of these runs was to route a sizeable portion of the railyard drainage area (i.e. 8-10 acres) through the Connector Road system, and to evaluate capacity and flooding on a relative basis. Refined delineation of drainage areas can be performed in future design phases.

Stormwater flows added from the separate storm sewer system on Pine Street (PS) included flows from subcatchments S293, S159, and S139 in the City's PCSWMM model, totaling 12.63 acres (10.81 impervious acres), as shown in Figure 3. All three of these drainages originally connected to the STM310.01 manhole in the combined system. In the model, Stone disconnected the existing 15-inch separate stormwater conduit from that manhole and directed it to a new stormwater manhole created just upstream (Junction J1; see standard stormwater manhole detail on Sheet 3 of the attached engineering drawings). A proposed run of 36-inch diameter SaniTite pipe was added from J1 to the catch basin at the head of the Connector Road and round-about at Pine Street (adjacent to Curtis Lumber), routing the flow from the City's existing separate storm sewer system into the Connector Road system.

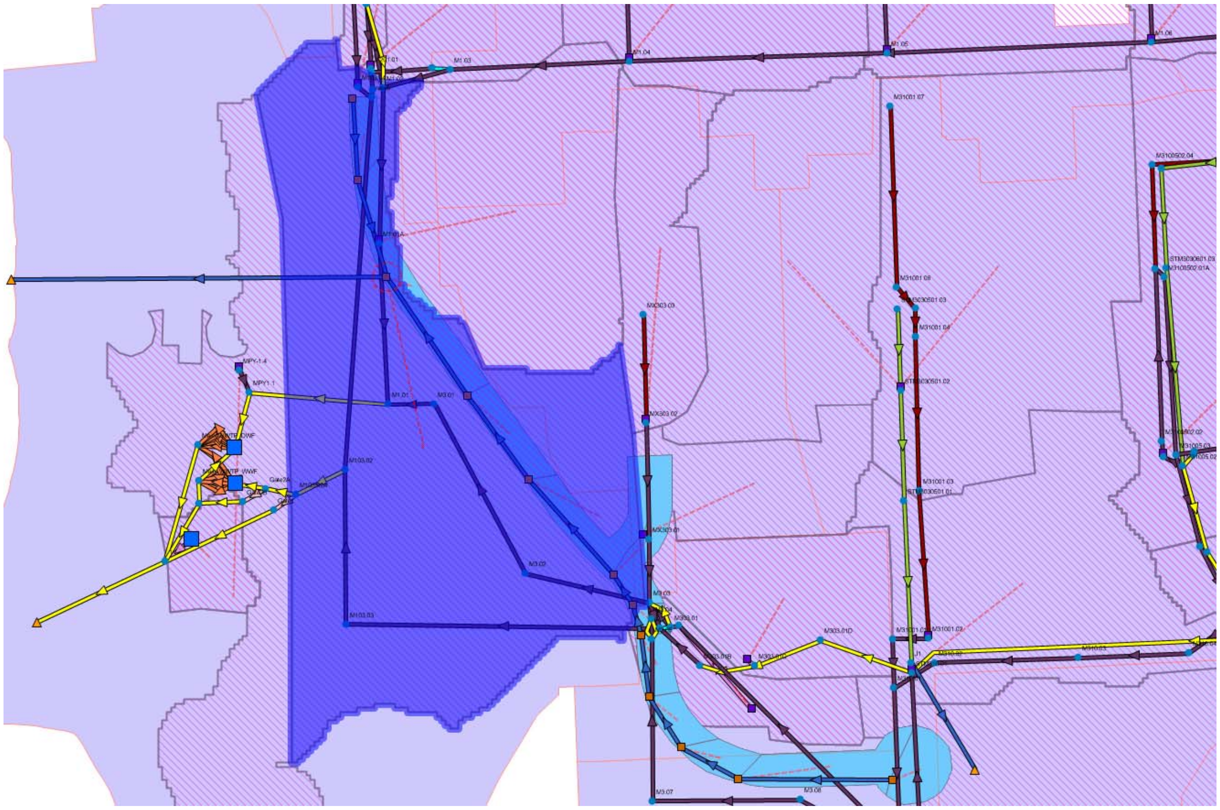

Figure 2. Screen shot from PCSWMM model showing railyard drainage area included in the evaluation (blue), Connector Road (cyan), proposed drainage pipe (dark blue lines), proposed catch basins (orange squares), proposed outfall (orange triangle).

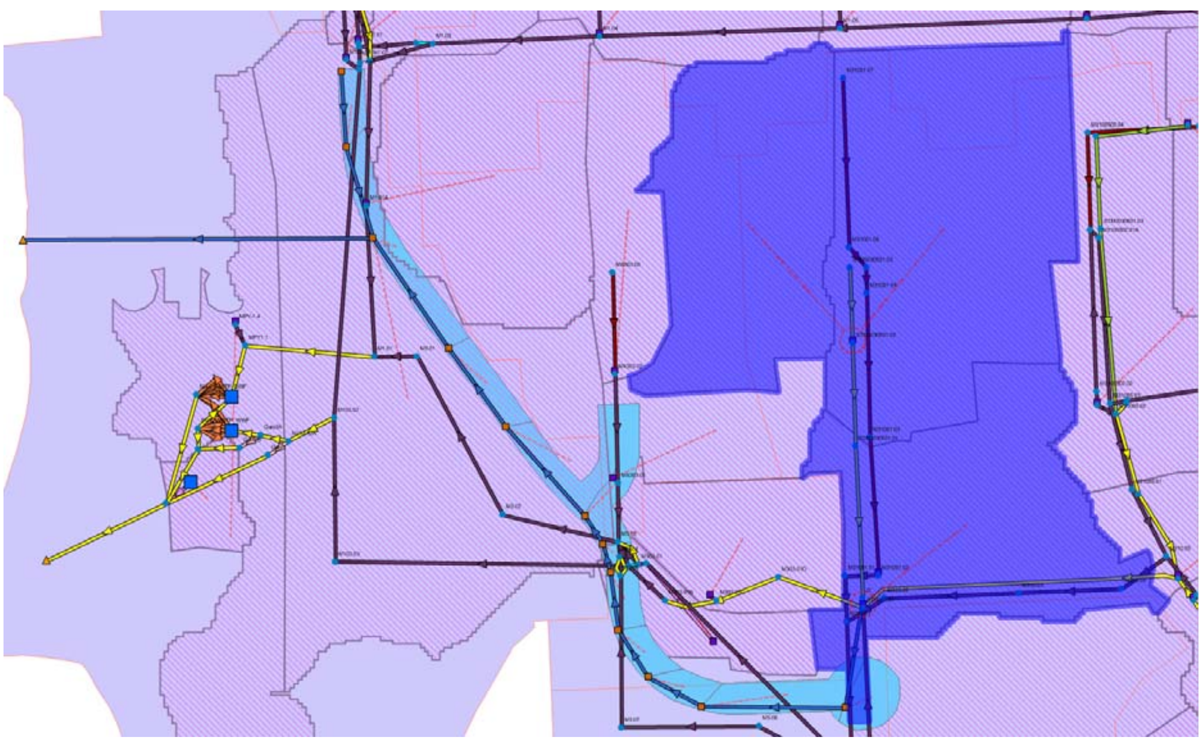

Figure 3. Screen shot from PCSWMM model showing Pine Street drainage areas included in the evaluation (blue)), Connector Road (cyan), proposed drainage pipe (dark blue lines), proposed catch basins (orange squares), proposed outfall (orange triangle).

For each incremental scenario, the model was run for the 1- through 100-year design storm events. After each model run, all catch basins along the Connector Road were checked for ponding or flooding above any of the catch basin rims. Model results are summarized in Table 1. Green colored cells indicate that peak storm flows were passed with no flooding at catch basins; orange cells indicate there was flooding at catch basins under the 4-inch threshold (or that flooding occurred at Stone's proposed 'J1' junction manhole on Pine Street); and red cells indicate the peak flows caused flooding exceeding the 4-inch threshold at one or more catch basins.

Table 1. Peak flows at the proposed outfall for varying design storm events and under certain drainage scenarios, with colors indicating degree of resulting flooding

Design Storm (year)	Probability of Storm Occurrence in a Given Year	Rainfall (in)	Peak Flows at Proposed Outfall			
			CR Only (cfs)	CR + RY (cfs)	CR + PS (cfs)	CR + RY + PS (cfs)
1	100%	1.93	4.49	21.93	23.03	38.44
2	50%	2.2	5.24	25.30	25.00	42.33
5	20%	2.67	6.53	30.68	28.36	49.38
10	10%	3.09	7.64	35.00	31.24	55.30
25	4%	3.76	9.42	41.08	34.92	60.72
50	2%	4.36	11.01	48.49	37.18	63.86
100	1%	5.06	12.84	55.97	39.27	66.67

Source: Output from Stone-modified PCSWMM model (PCSWMM file: MainSWMM_V2)
Abbreviations: in = inches; cfs = cubic feet per second
Date and Author: (6-27-2018), G. Bolin

1.5 Additional Analysis – Extreme Water Surface Elevations

Finally, the model was used to evaluate the effects of extreme water surface elevations in Lake Champlain, associated blockage of discharges at the proposed outfall via outfall submergence, and resultant flooding within the limits of the Connector Road to due flow blockages. A tide gate was added to the outfall in the model to prevent backflow of lake waters into the system. Three extreme water surface elevations were defined as boundary conditions at the outfall: elevations at 100.5' (pipe half submerged), 102.0' (pipe fully submerged) and at 103.19' (the record high of May 6, 2011). Model runs, identical to those discussed in Section 1.4, were re-run, with the addition of the three boundary conditions. The goal of this assessment was to evaluate effects on roadway flooding upstream of the outfall under extreme lake water surface elevation conditions.

Model results for each boundary condition are summarized in Table 2. The color scheme applied is the same as in Table 1. For design storm events and drainage scenarios where Table 1 indicates there was no flooding in the absence of a boundary condition, if Table 2 indicates flooding occurred under those same conditions, the presence of the boundary condition is the cause of flooding. The probability of each design storm occurring in a given year is included in Tables 1 and 2 to provide a realistic perspective of event frequency and relative risk.

Table 2. Flooded condition in Connector Road by color, for varying design storm events and under certain drainage scenarios and submerged outfall conditions

Design Storm (year)	Probability of Storm Occurrence in a Given Year	WSEL = 100.5' (1/2 Submerged)				WSEL = 102' (Fully Submerged)				WSEL = 103.19' (Max WSEL)			
		CR	CR + RY	CR + PS	CR + RY + PS	CR	CR + RY	CR + PS	CR + RY + PS	CR	CR + RY	CR + PS	CR + RY + PS
1	100%												
2	50%												
5	20%												
10	10%												
25	4%												
50	2%												
100	1%												

Source: Output from Stone-modified PCSWMM model (PCSWMM file: MainSWMM_V2)
Abbreviations: WSEL = water surface elevation
Water surface elevations reference the NAVD88 vertical datum
103.19' was the record high on May 6, 2011 at USGS Gage 04294500, Lake Champlain at Burlington, VT
Date and Author: (6-27-2018), G. Bolin

In order to put the boundary conditions into perspective with historical data, Stone reviewed long term water surface elevation data at the Lake Champlain Burlington VT USGS gage (#04294500). Figure 4 summarizes lake surface elevations for 112 years of elevation data (1907-2018). Daily maximum lake elevations (blue line), mean elevations (green line) and minimum elevations (orange line) are plotted, referencing the NVGD 29 vertical datum. The Route #1 outfall invert elevation is added to the plot as a dashed burgundy line (revised from 99.0' to 99.48' to convert from NAVD88 to NGVD29). The boundary conditions were added to the plot as dashed gray lines.

The maximum daily lake elevation is higher than the Route #1 invert elevation for roughly 30% of the year (reduced from the 80% reported in Stone's Phase I technical memo). The maximum daily lake elevation is higher than the half- and fully-submerged conditions for roughly 21% and 8% of the year, respectively. The daily mean and minimum lake elevations do not exceed the invert elevation of the proposed outfall.

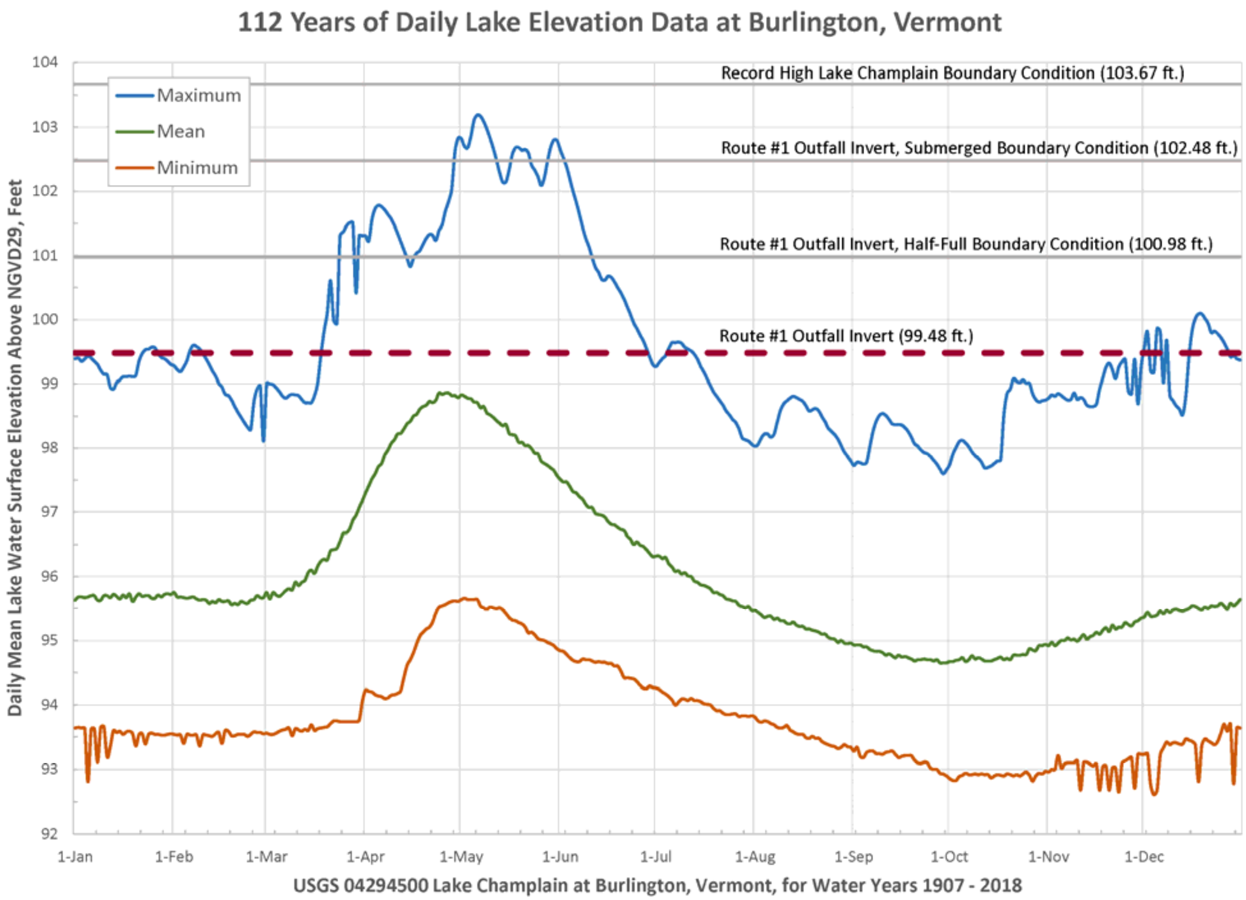

Figure 4. Daily Minimum, Average, and Maximum Water Surface Elevations at Lake Champlain for Water Years 1907-2018. Datum: NGVD 29 (Source: USGS National Water information System: Web Interface and Stone Environmental, Inc.)

1.6 Modeling Details

24-hour rainfall volumes were obtained from the Northeast Regional Climate Center's (NRCC) Extreme Precipitation in New York & New England, developed by Cornell University and the Natural Resources Conservation Service (NRCS). A SCS Type II rainfall distribution was specified for each design storm. Values for PCSWMM model parameters such as subcatchment width, flow length, percent impervious, depression storage, manning coefficients, infiltration, etc., followed the default values included in the City's PCSWMM model, with minor modifications where appropriate. Manning's coefficients for pipe were provided by the manufacturer, and pipe slopes and inverts are illustrated in the attached plans.

2. Phase II – Cost and Risk Analysis

2.1 Risk Analysis and Cost Considerations

Stone developed 30% designs and conceptual costs for Route #1, considering the following project constraints and their relative risks. A brief explanation of how each constraint was incorporated into the conceptual costs is provided:

1. Existing railroad – the railbed and tracks pose a significant obstacle to storm pipe installation along Route #1, along the pipe running from east to west towards the proposed outfall at Lake Champlain. The estimate includes costs to install the pipe under the rail via a jack and bore approach. Stone researched jack and bore projects in New England and across the country to develop a conservative cost per linear foot of pipe installed via this method. Costs for jacking and receiving pits, and costs for dewatering those pits, are included. An engineering detail is provided on Sheet 3 of the attached plans, providing a typical illustration of a jack and bore operation.
2. Contaminated soils - soils in several locations within the REP boundary are known or suspected to be contaminated. Stone has assumed that 50% of any soil excavated to install the closed drainage system (stormlines, catch basins/manholes, and water quality treatment measures) will be contaminated, and require transport to an appropriate disposal facility. The transport and disposal cost per cubic yard provided in the cost estimate incorporates trucking and disposal fees for the Casella landfill in Coventry, VT, approximately 75 miles from the REP project. Costs for disposal at this facility assume that soils will contain moderate levels of contamination (PAHs, lead, and arsenic), typical of urban soils. If soils are found to have a higher degree of contamination during future design phases, other disposal options do exist, and Stone can update transport and disposal costs as needed. Nitrile pipe gaskets were included in the estimate to provide a seal between pipe joints that should greatly reduce or eliminate migration of potentially contaminated groundwater into the storm drainage system. Nitrile has been shown to be resistant to corrosion and breakdown in the presence of gasoline-contaminated water (Cheng et al., 2012).
3. Utility conflicts – A number of utility conflicts (in addition to the rail system) are likely to be encountered. Specifically, the contractor may encounter electrical and gas lines in the parking lot near Roundhouse Park. The cost estimate includes a utility conflict contingency, calculated as 5% of the construction cost, which is reasonable given the number and type of potential conflicts indicated by existing data. Additional utility conflicts may be absorbed in the overall construction project contingency, currently calculated as 20% of the construction cost.
4. Cultural and archeological resources – Cultural and archaeological resources within the REP project limits include a historic roundhouse which has been identified as a contributing resource. The REP project area is also located within the Pine Street Industrial Historic District, a portion of the City

recently added to the National Register of Historic Places (https://www.nps.gov/nr/). The cost estimate includes 5% of the construction cost to cover permit processing costs and fees.

5. Lake Champlain water surface elevations – Historic lake elevations range from 93' to 103' NGVD29, and substantial concerns exist regarding the influence of lake elevation on drainage from the proposed outfall. As discussed in Section 1.1, the minimum pipe slope was adjusted, allowing adjustments to pipe slopes and invert elevations that increased positive drainage and overall capacity of the pipe network to convey runoff during storm events. The proposed outfall invert is at 99' NAVD88, which will allow stormwater to drain during the majority of storm event and lake water surface elevation conditions. Section 1.5 summarized the relation between extreme water surface elevations at Lake Champlain and potential flooding along the Connector Road.
6. Adequate cover for proposed closed drainage system – The Sanitite pipe included in the design requires 12" minimum cover to meet vehicle loading requirements. The design maximizes cover relative to existing grades, but it was not feasible to provide adequate cover to existing grade in portions of the REP Connector Road (Sheet 2, stations 1+00 to 2+00, 4+00 to 5+00, and 8+00 to 9+00 on the Roadway Conveyance System profile). Considering the 1' of additional cover anticipated to be added during construction of the proposed road, the stormwater pipe system should be adequately covered over the length of the roadway. The proposed pipe run in the 'Outlet to Perkins Pier' profile on the same sheet as designed does not include adequate cover from approximate stations 3+00 to 3+50, and from station 4+25 to the discharge at the lake. An additional 3-4" is needed to maintain 12" of cover along stations 3+00 to 3+50. Requisite material can be placed over the pipe and feathered into existing grades adjacent to the trees and path along the pipe alignment. While the last 20-30' of pipe may be exposed and lay on the stone revetment adjacent to the seawall at the pipe discharge, additional cover on the order of 10-12" is required along stations 4+25 to 5+25. This area would require moderate regrading, with the highest grade along the top of pipe and fine grading on either side of the pipe, to maintain drainage of stormwater runoff in this area towards the lake. Costs for additional placed fill, grading, and reconstruction of the path are included in the estimate.
7. Pine Street Barge Canal Superfund site – the Superfund site abuts the southern boundary of the REP project area. During the May meeting, the project team agreed that Route #2, which discharged to the Barge Canal, would not be pursued further due to numerous risks associated with discharging stormwater to the canal, and potential impacts to the remedy.
8. Federalization – The introduction of federal regulatory constraints to the project is a major risk, and would most likely become a factor if the project affects or impacts the Barge Canal Superfund site. By avoiding Route #2 and minimizing disturbance in the southern portion of the project extents, the current concept design attempts to minimize this risk. Additionally, the cost estimate incorporates the

outcomes of discussions concerning avoidance of including design elements that would potentially require the preparation of an environmental impact statement (EIS).

2.2 Construction Cost Estimates

Tables 3 through 5 provide opinions of probable construction costs for closed drainage system improvements for the Connector Road, the railyard connection to the Connector Road system, and the Pine Street connection to the Connector Road system, respectively. Costs for the railyard and Pine Street extensions of the closed drainage system are provided separately; each of these may be considered as singular mitigation options, given the competing needs for stormwater management in the railyard and combined system, respectively.

The costs presented below account for the relative risk and cost constraints discussed in Section 2.1. They also include components included to meet water quality treatment objectives to the extent practicable, as discussed in Section 3 below. The cost estimates include a project contingency of 20%.

Table 3. REP Connector Road Closed Drainage System – Opinion of Probable Construction Cost

ITEM #	ITEM	AMOUNT		UNIT COST	TOTAL
1	PROJECT DEMARCATION FENCING	4000	LF	$1.00	$4,000.00
2	TRENCH EXCAVATION	4213	CY	$15.11	$63,663.47
3	CONTAMINATED SOIL TRANSPORT AND DISPOSAL	3185	TONS	$60.00	$191,116.80
4	PIPE BEDDING, 3/4" CRUSHED STONE	442	CY	$35.00	$15,485.56
5	INSTALL 36" ADS SANITITE PIPE	2082	LF	$68.75	$143,137.50
6	NITRILE GASKETS FOR ADS SANITITE PIPE	2082	LF	$5.05	$10,514.10
7	GRANULAR BACKFILL FOR STRUCTURES	1136	CY	$41.27	$46,866.25
8	FINE GRADING	1	LS	$5,000.00	$5,000.00
9	JACK & BORE, 48" CASING UNDER RAIL	120	LF	$810.00	$97,200.00
10	JACKING & RECEIVING PITS	2	EA	$3,922.00	$7,844.00
11	PRECAST RC DEEP SUMP CATCH BASIN W/CAST IRON COVER	12	EA	$6,000.00	$72,000.00
12	OFFLINE STC 2400 STORMCEPTORS	5	EA	$20,500.00	$102,500.00
13	CIP CONCRETE HEADWALL, 36" 30 DEGREE SKEWED WINGALL	1	EA	$3,000.00	$3,000.00
14	OUTFALL STONE APRON (STONE FILL, TYPE II)	2	CY	$45.00	$90.00
15	DEWATERING	1	EA	$10,000.00	$10,000.00
16	SEED	100	LB	$7.08	$708.00
17	MULCH	500	LB	$0.30	$151.25
18	EROSION CONTROLS	1	LS	$3,000.00	$3,000.00
19	TRAFFIC CONTROL	1	LS	$2,500.00	$2,500.00
20	RECONSTRUCT PATH	1	LS	$12,000.00	$12,000.00
				CONSTRUCTION TOTAL	***$790,777***
				UTILITY CONFLICT CONTINGENCY (5%)	***$39,539***
				FINAL DESIGN (10%)	***$79,078***
				PERMITTING (5%)	***$39,539***
				STAKE OUT (1%)	***$7,908***
				MOBILIZATION / DEMOBILIZATION (5%)	***$39,539***
				CONSTRUCTION OVERSIGHT (5%)	***$39,539***
				CONTINGENCY (20%)	***$158,155***
				TOTAL (ROUNDED TO NEAREST $100)	***$1,194,100***

Table 4. Railyard Connection to REP Connector Road Closed Drainage System – Opinion of Probable Construction Cost

ITEM #	ITEM	AMOUNT	UNIT COST		TOTAL
1	TRENCH EXCAVATION	754	CY	$15.11	$11,389.58
2	CONTAMINATED SOIL TRANSPORT AND DISPOSAL	570	TONS	$60.00	$34,191.36
3	PIPE BEDDING, 3/4" CRUSHED STONE	79	CY	$35.00	$2,758.52
4	INSTALL 36" ADS SANITITE PIPE	400	LF	$68.75	$27,500.00
5	NITRILE GASKETS FOR ADS SANITITE PIPE	400	LF	$5.05	$2,020.00
6	GRANULAR BACKFILL FOR STRUCTURES	230	CY	$41.27	$9,471.57
7	PRECAST RC DEEP SUMP CATCH BASIN W/CAST IRON COVER	1	EA	$6,000.00	$6,000.00
8	OFFLINE STC 2400 STORMCEPTORS	1	EA	$20,500.00	$20,500.00
9	DEWATERING	1	EA	$2,000.00	$2,000.00
10	EROSION CONTROLS	1	LS	$1,000.00	$1,000.00
11	TRAFFIC CONTROL	1	LS	$1,500.00	$1,500.00
				CONSTRUCTION TOTAL	***$118,331***
				CONTINGENCY (25%)	***$29,583***
				TOTAL (ROUNDED TO NEAREST $100)	***$148,000***

Table 5. Pine Street Connection to Stormwater System – Opinion of Probable Construction Cost– 30% Design

ITEM #	ITEM	AMOUNT	UNIT COST		TOTAL
1	EXCAVATION OF SURFACES AND PAVEMENTS	59	CY	$15.11	$884.21
2	STRUCTURE EXCAVATION	10	CY	$22.79	$227.90
3	DISCONNECTION OF CONDUIT AT EXISTING MANHOLE	2	EA	$2,000.00	$4,000.00
4	TRENCH EXCAVATION	329	CY	$15.11	$4,969.51
5	CONTAMINATED SOIL TRANSPORT AND DISPOSAL	249	TONS	$60.00	$14,918.40
6	PIPE BEDDING, 3/4" CRUSHED STONE	34	CY	$35.00	$1,199.07
7	INSTALL 36" ADS SANITITE PIPE	185	LF	$68.75	$12,718.75
8	NITRILE GASKETS FOR ADS SANITITE PIPE	185	LF	$5.05	$934.25
9	GRANULAR BACKFILL FOR STRUCTURES	116	CY	$41.27	$4,787.80
10	PRECAST RC MANHOLE W/CAST IRON COVER	1	EA	$3,730.00	$3,730.00
11	DEWATERING	1	EA	$2,500.00	$2,500.00
12	EROSION CONTROLS	1	LS	$1,500.00	$1,500.00
13	TRAFFIC CONTROL	1	LS	$5,000.00	$5,000.00
				CONSTRUCTION TOTAL	***$57,370***
				CONTINGENCY (25%)	***$14,342***
				TOTAL (ROUNDED TO NEAREST $100)	***$71,800***

3. Phase III – Water Quality Treatment Evaluation

Route #1 was further evaluated for the inclusion of water quality treatment of runoff to the extent practicable, for impervious surfaces associated with the drainages discussed in Section 1. Stone reviewed proposed roadway cross sections produced by RSG to identify opportunities for inclusion of water quality treatment practices within the roadway right-of-way limits. One such cross section is provided as Figure 5. Of the five cross sections provided in the 2016 RSG report, four include two 6' wide tree belts, and all have 10-15' of sidewalk and/or shared use path.

Use of the tree belts as a linear water quality treatment measure, such as a bioretention swale or linear gravel wetland, was considered. Surface practices such as these generally require at least a 7' wide green space to allow for a 2-foot-wide flat treatment surface, minimum 2:1 side slopes, and adequate ponding depth. Tree box filters were also evaluated as an option for water quality treatment. Given the amount of impervious surface to be treated, the required tree box vaults to be installed underground would require significant excavation and removal of shallow soils. To treat the runoff associated with only the Connector Road in full compliance with the Water Quality Treatment Standard (the 1-inch storm event, or an estimated WQv of 7,280 CF), a series of tree box filter vaults could be installed that extend beneath the proposed shared use path. A shallow 384 CF (8x16x3 feet) theoretical tree box vault that sits beneath a 12-inch thickness of shared path pavement and subgrade, and on top of 12 inches of bedding stone for a total excavation volume of 640 CF per tree box filter vault, could theoretically be implemented without excavating much deeper than 5 feet

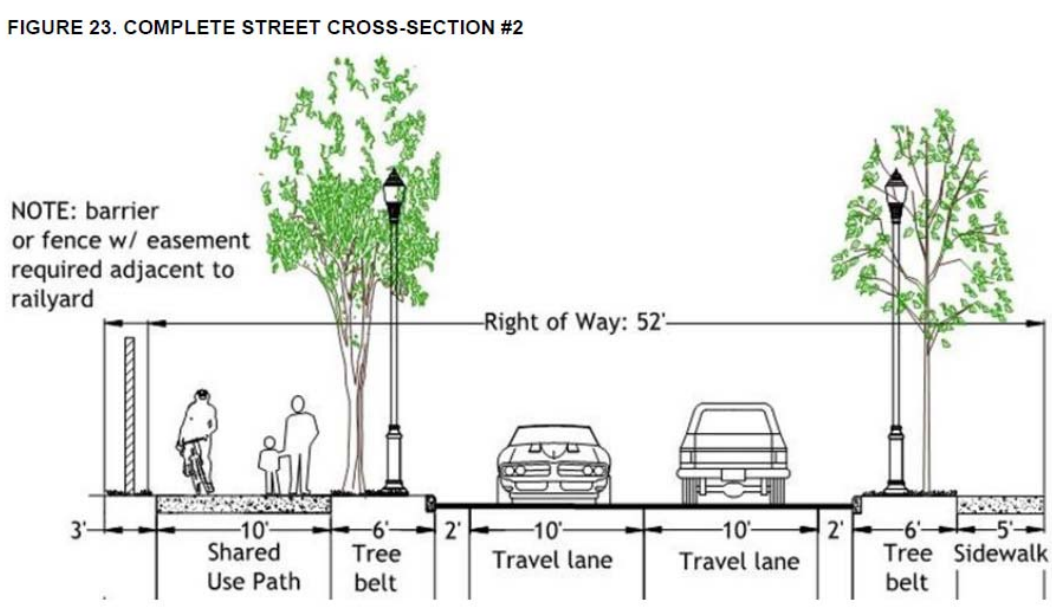

Figure 5. One example of a roadway cross section proposed for a portion of the Connector Road (RSG, 2016)

below grade and potentially disturbing Institutional Controls. A total of 19 of these tree box vaults would be required to fully manage the WQv. Assuming half of the excavated soils associated with tree box install would be contaminated, this would result in an additional 225 CY of material requiring transport and disposal at an approved facility at an additional cost of approximately $20,000. While the increased cost associated with disposal of contaminated soils appears to be reasonable at this rough feasibility stage, the tree box filters would necessarily be designed to capture and treat surface runoff from REP impervious cover only, and thus have no capacity to treat runoff from other areas of contributing impervious cover, whether from Pine Street or from the railyard area.

As an potential alternative or addition to tree box filters, Stone has included specifications and cost estimates for installation of six STC2400 Stormceptor units, installed at alternating stormwater catch basins along the Connector Road, to provide water quality treatment for REP redeveloped impervious surfaces and runoff from contributing drainages routed to the new separate storm drainage system (i.e. from the Railyard plus Pine Street drainages discussed above). We make no assumption about how the full-depth reconstruction of existing impervious surfaces will be classified during the operational stormwater permitting process, and instead assume that 100% of the WQv from the 20.4 impervious acres in the project drainage areas would be treated through the Stormceptors. The units would be installed 'offline' from the storm sewer system catch basins. Runoff from small to moderate storm events would be directed to the Stormceptor via a simple weir structure constructed in the catch basins for treatment within the hydrodynamic separator. Flows exceeding the elevation of the weir in the catch basins would bypass the units. Recent research has shown that the offline configuration can increase sediment removal rates (up to 75%), since larger flows bypass the hydrodynamic separator and therefore do not resuspend sediment trapped in previous storms (UNH Stormwater Center, 2012).

Considering the number of proposed Stormceptors providing for treatment along the Connector Road, Stormceptor design guidelines indicate that we can expect ~50% removal rates for total suspended solids (TSS) associated with flows from the road, the Railyard and Pine Street connections, for dry weather and small to moderate storm events. As this manufacturer-provided removal rate only accounts for removal of sediment for an in-line system, removal rates will likely exceed the manufacturer-provided benefits due to the proposed offline configuration. The units would also remove free oils and nutrients associated with sediments. However, if a choice is made to use a hydrodynamic separator or other proprietary unit as a water quality treatment practice in this context, we recommend further evaluation of the units' ability to remove both particulate and dissolved phosphorus species. The University of New Hampshire research was inconclusive regarding the phosphorus removal benefits of such units, in part because the influent phosphorus concentrations to the practices were already low.

The manufacturer suggests quarterly inspections during the first year of operation to establish a maintenance schedule. Maintenance is recommended once the stored volume reaches 15% of the total volume of the lower chamber, or immediately in the event of spill. Maintenance can be performed without entry into the unit, and material is typically removed with a vactor truck. A plan and section view of the unit specified for this project is provided as an attachment to this memo, along with a specification sheet.

As an alternative to hydrodynamic separators, off-line, deep sump catch basin (DSCB) with hooded outlets have recently been shown to perform at least as well as Stormceptors and similar proprietary stormwater treatment devices with respect to sediment and total petroleum hydrocarbon removal (Niles and Houle, 2017). In this research, removal rates for both constituents exceeded 70% and the DSCB was determined to be the most cost-effective option. Along the Connector Road and in the railyard, DSCBs could be used in place of Stormceptors, resulting in cost savings and similar treatment performance. Again, while the sediment, TSS, and free oil removal benefits of DSCBs are reasonably well documented, the phosphorus—and particularly dissolved phosphorus—removal benefits of these practices is less well understood and further investigation is warranted.

Since ancillary water quality benefits may be realized, DSCBs are included in our proposed drainage system design at the catch basins proposed along the Connector Road (12 total, see Table 3) and at the head of the Railyard connection stormwater line (1 total, see Table 4). Off-line DSCBs are proposed wherever new catch-basins would be required (e.g., not on Pine Street). Field geotechnical work completed in June-July 2017 at 339 Pine Street, along the southern extent of the proposed Connector Road, indicated that no non-aqueous phase liquids (NAPL) or coal tar was encountered, but that shallow soils (upper two feet) contained moderate to high levels of PAHs, meaning that soils excavated in this area would need to be managed as urban development soils (WHEM, 2017). The increased cost of such soil management strategies has been factored into our cost and risk assessments as described above.

It appears there are multiple means through which water quality treatment may be accomplished for contributing impervious surfaces associated with the connector road and other drainages. We recommend deeper exploration of costs and benefits related to these water quality practices in future design phases.

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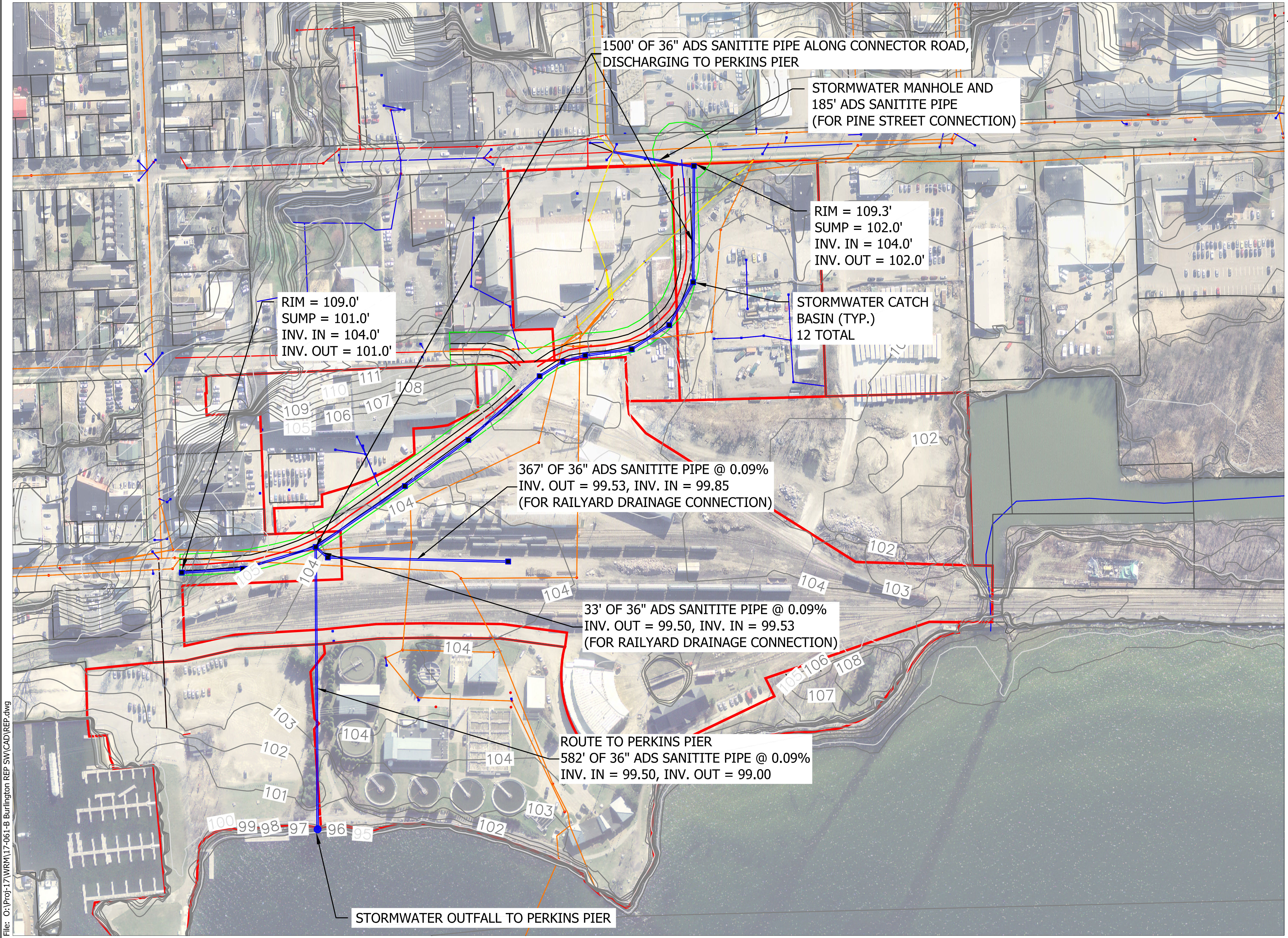

LEGEND

- MAJOR CONTOUR
- MINOR CONTOUR
- PARCELS
- EX. STORMWATER SYSTEM
- EX. COMBINED WASTEWATER SYSTEM
- EX. WASTEWATER SYSTEM
- EX. STORMWATER COMBINED SEWER SYSTEM RELIEF
- EX. SEWER MANHOLE
- EX. STORMWATER CATCH BASIN
- PR. REP EXTENTS
- PR. EDGE OF TRAVELED LANE
- PR. ROADWAY CENTERLINE
- IMPACTED PARCELS
- PR. STORMWATER DRAINAGE
- PR. STORMWATER OUTFALL
- PR. STORMWATER CATCH BASIN

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DRAWING CREDITS
Drawn On: 07/17/2018
Drawn By: BAM
Checked On: 7/30/2018
Checked By: GMB
Project No.: 17-061-B

REVISIONS

#	Date	Drwn	Chk'd	App'd	Description

DRAWING SCALE
0 200 400 Feet
1" = 200'

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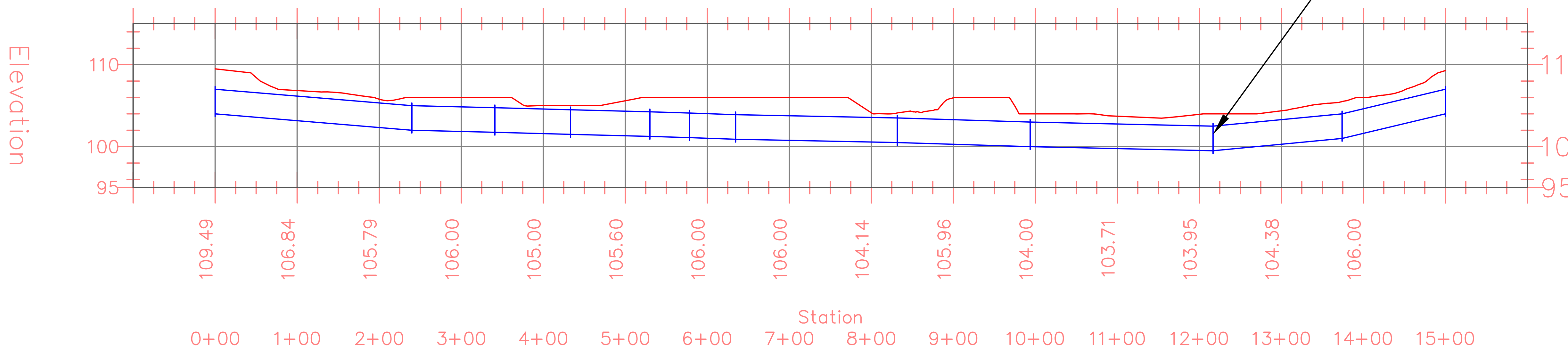
RAILYARD ENTERPRISE PROJECT
STORMWATER ENGINEERING FEASIBILITY ASSESSMENT
LAYOUT

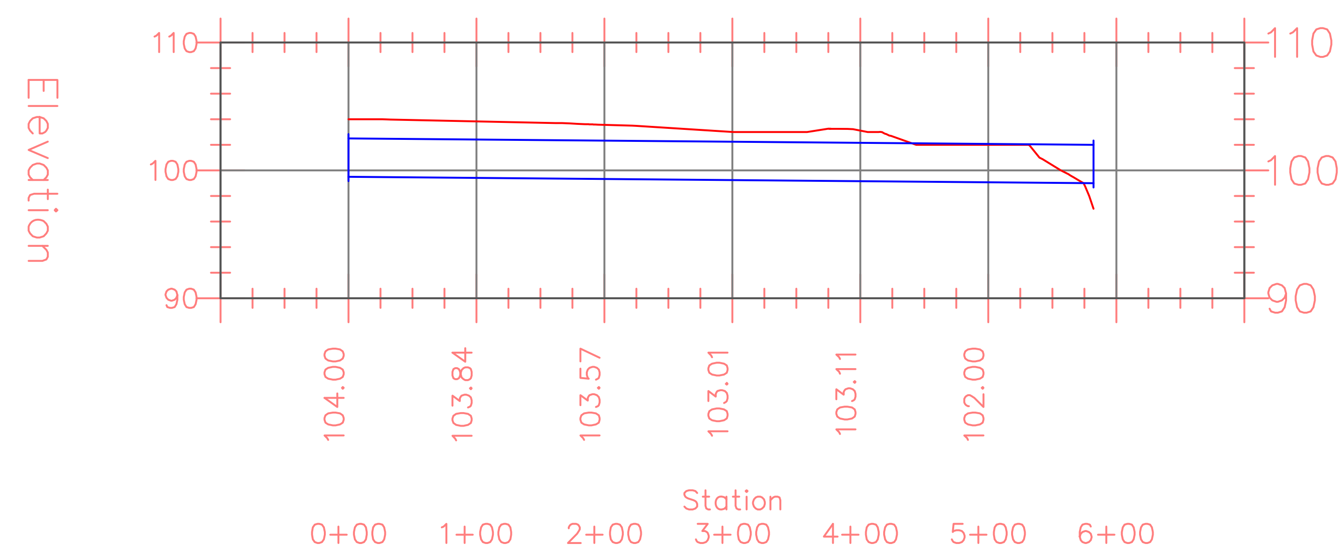
BURLINGTON VERMONT

FIGURE NO. 1

ROADWAY CONVEYANCE SYSTEM



OUTLET TO PERKINS PIER - SLOPE = 0.09%



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0 150 300 Feet

1" = 150'

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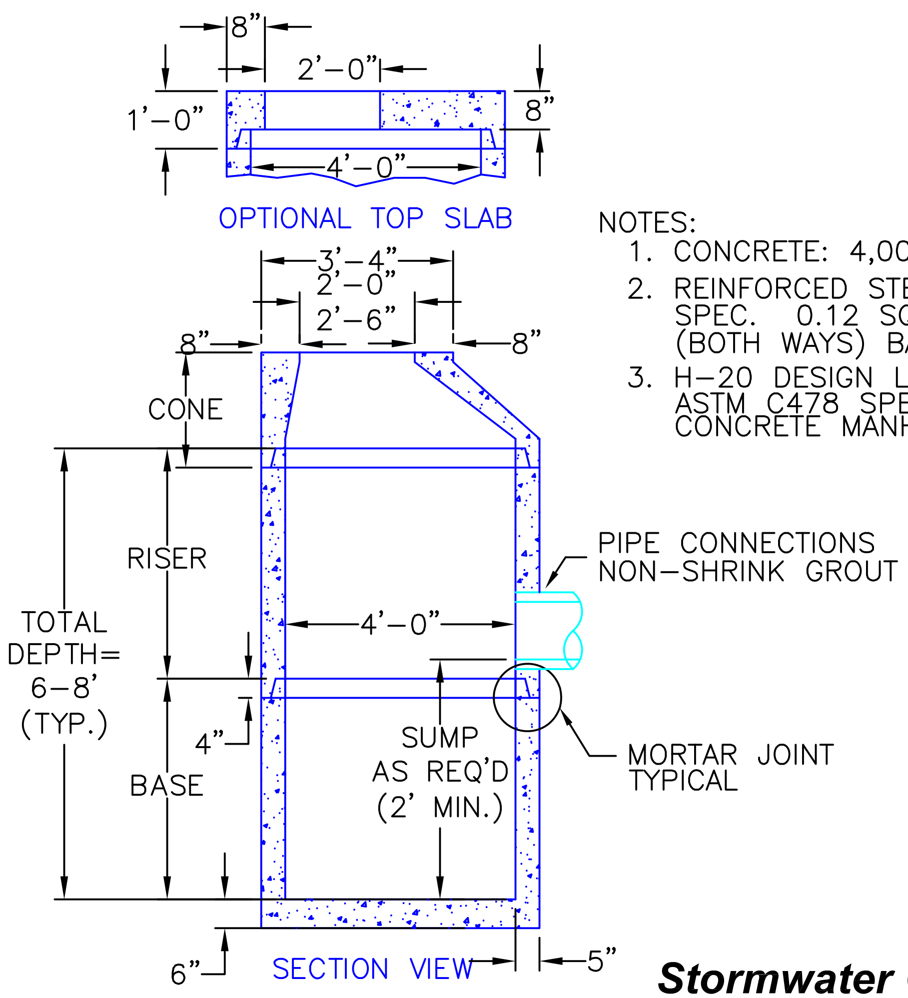
RAILYARD ENTERPRISE PROJECT
STORMWATER ENGINEERING FEASIBILITY ASSESSMENT
DRAINAGE PROFILE - OUTLET TO PERKINS PIER

BURLINGTON VERMONT

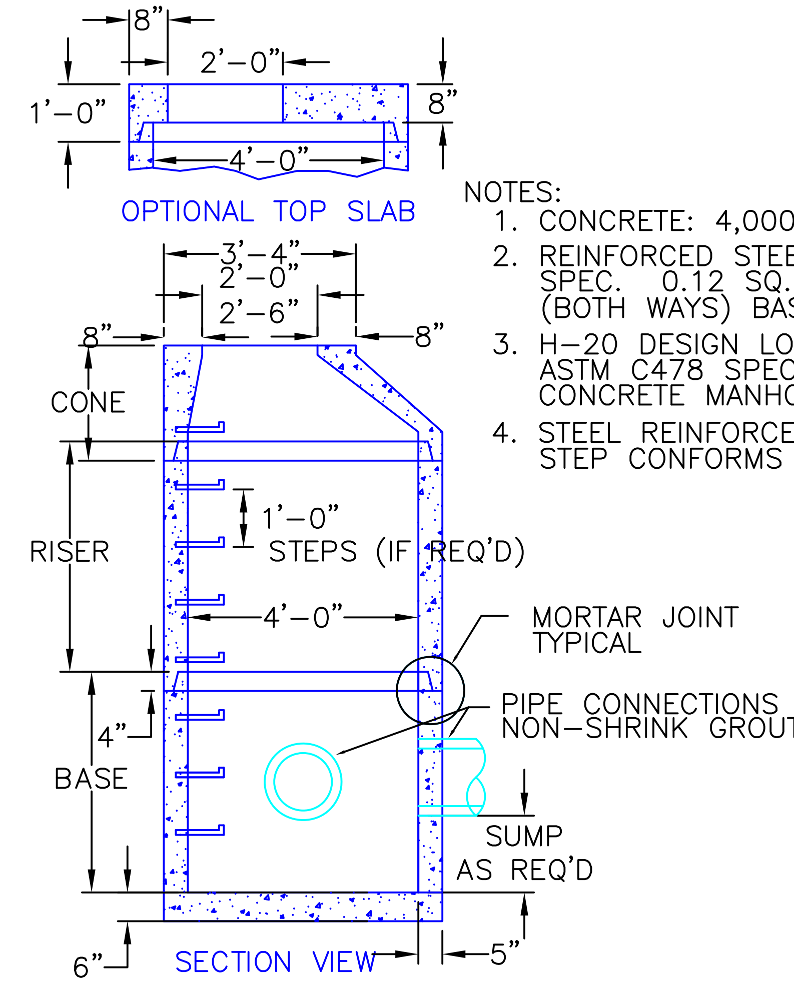
FIGURE NO.
2



NOTES:
1. CONCRETE: 4,000 PSI MINIMUM AFTER 28 DAYS.
2. REINFORCED STEEL CONFORMS TO LATEST ASTM A185 SPEC. 0.12 SQ. IN./LINEAL FT. AND 0.12 SQ. IN. (BOTH WAYS) BASE BOTTOM.
3. H-20 DESIGN LOADING PER AASHTO HS-20-44; ASTM C478 SPEC FOR "PRECAST REINFORCED CONCRETE MANHOLE SECTIONS."

Stormwater Catch Basin - 48" Ø

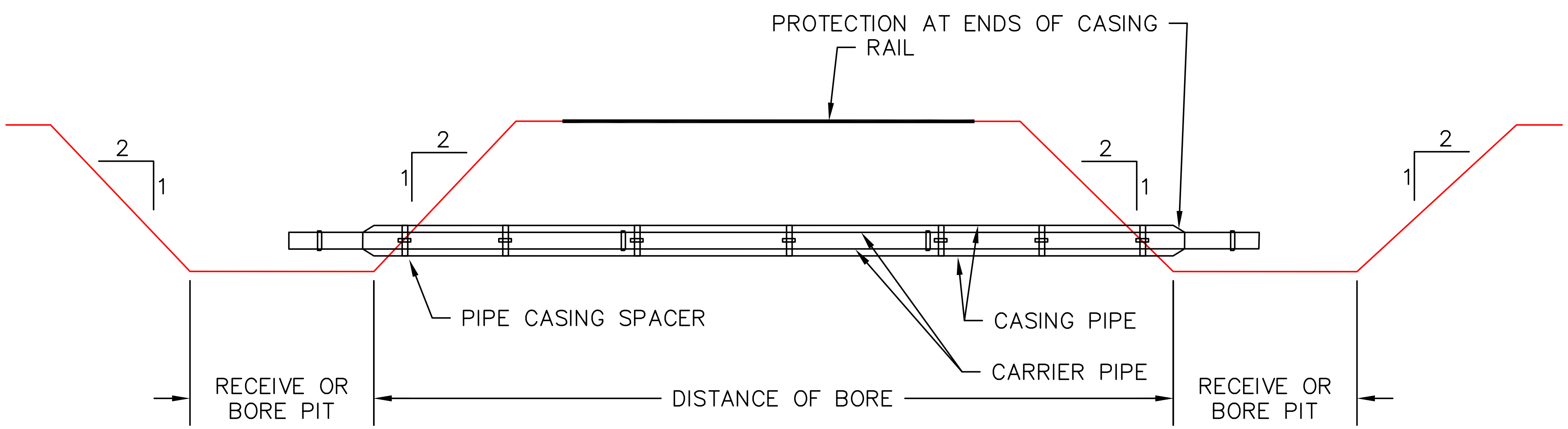
Scale: NTS



NOTES:
1. CONCRETE: 4,000 PSI MINIMUM AFTER 28 DAYS.
2. REINFORCED STEEL CONFORMS TO LATEST ASTM A185 SPEC. 0.12 SQ. IN./LINEAL FT. AND 0.12 SQ. IN. (BOTH WAYS) BASE BOTTOM.
3. H-20 DESIGN LOADING PER AASHTO HS-20-44; ASTM C478 SPEC FOR "PRECAST REINFORCED CONCRETE MANHOLE SECTIONS."
4. STEEL REINFORCED COPOLYMER POLYPROPYLENE PLASTIC STEP CONFORMS TO LATEST ASTM C478 SPEC.

Stormwater Manhole - 48" Ø

Scale: NTS



Typical Jack and Bore Section

Scale: NTS

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Project No.:	17-061-B

REVISIONS

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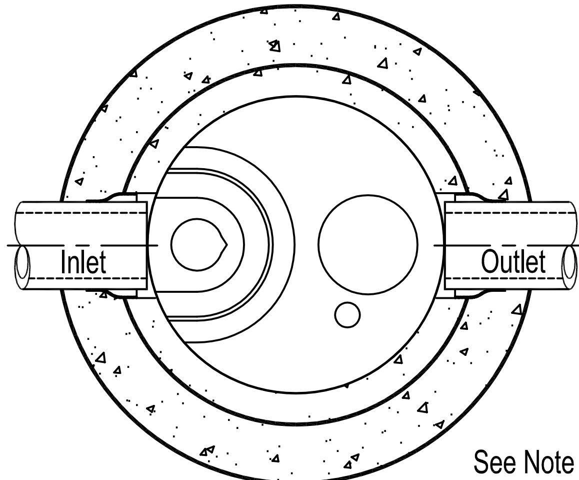
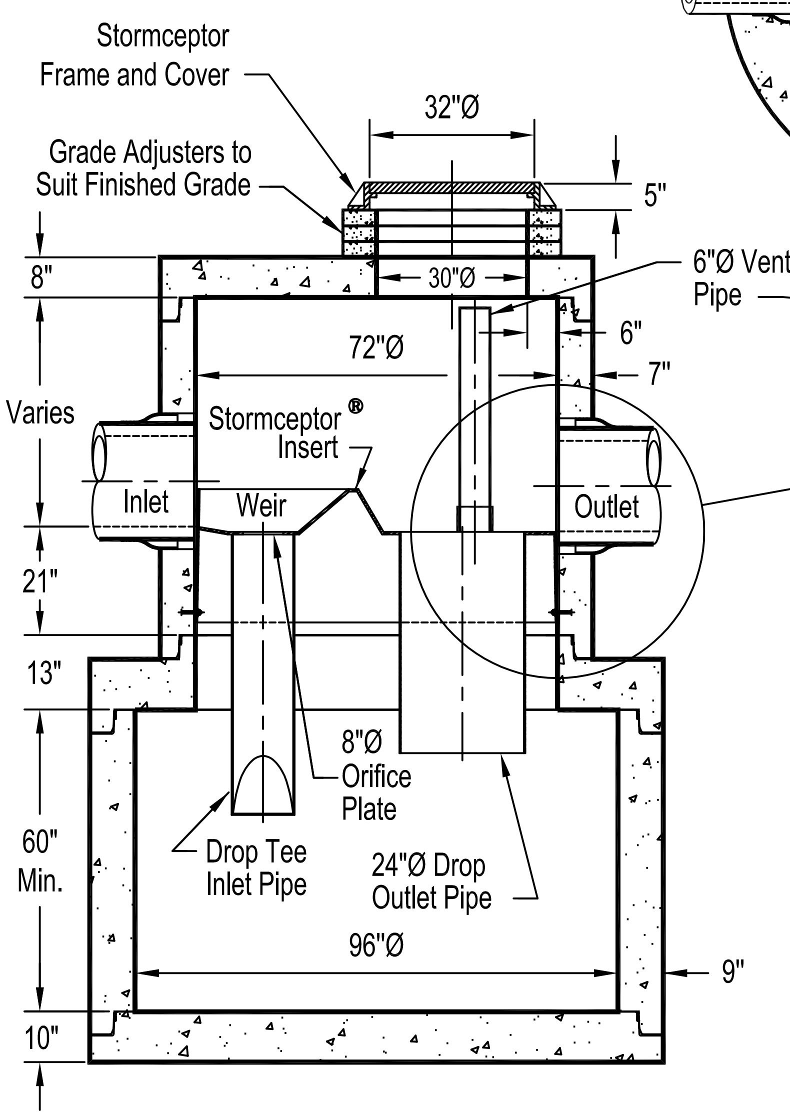
RAILYARD ENTERPRISE PROJECT
STORMWATER ENGINEERING FEASIBILITY ASSESSMENT
DETAILS
BURLINGTON VERMONT

FIGURE NO.
3

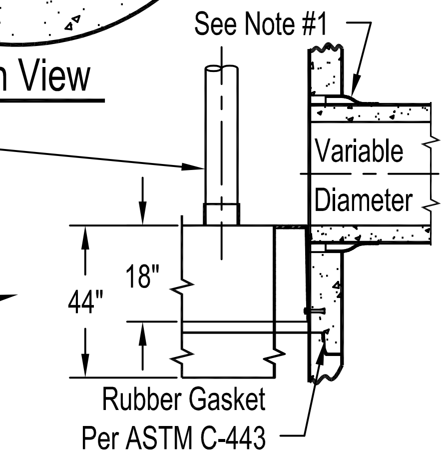
STC 2400 Precast Concrete Stormceptor®
(2400 U.S. Gallon Capacity)



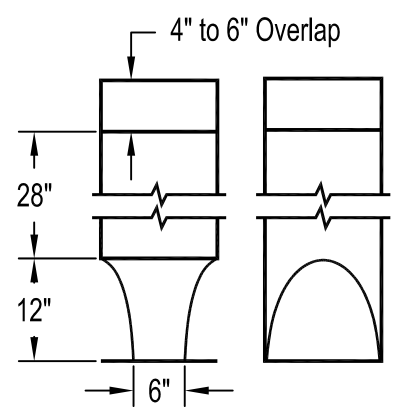
Plan View



Section Thru Chamber



Outlet Connection Detail

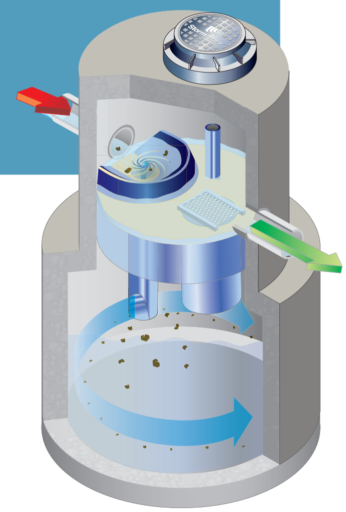


Enlarged Inlet Tee Drop Pipe

Notes:

1. The use of a Flexible Connection is recommended at The Inlet and Outlet Pipe.
2. The Cover should be positioned over The Outlet Drop Pipe and The Vent Pipe.
3. The Stormceptor System is protected by one or more of the following U.S. Patents: #4985148, #5498331, #5725760, #5753115, #5849181, #6068765, #6371690.
4. Contact a Hydro Conduit representative for further details not listed on this sheet.

Stormceptor® STC



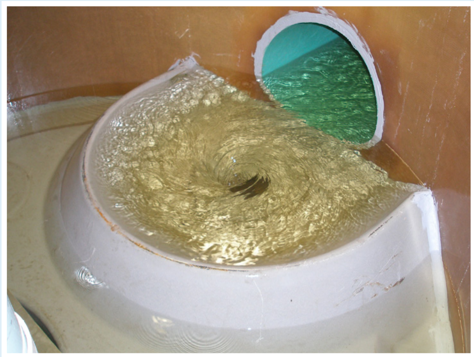
The calm *during* the storm

When it rains, oils, sediment and other contaminants are washed from paved surfaces directly into our storm drains and waterways. Non-point source pollution such as stormwater now accounts for 80% of water pollution in North America and governments are responding with demanding regulations to protect our water resources.

Removing more pollutants

Stormceptor removes more pollutants from stormwater than any other separator.

- Maintains continuous positive treatment of total suspended solids (TSS) year-round, regardless of flow rate
- Designed to remove a wide range of particle sizes, as well as free oils, heavy metals and nutrients that attach to fine sediment
- Can be designed to remove a specific particle size distribution (PSD)



A calm treatment environment

- Stormceptor slows incoming stormwater to create a non-turbulent treatment environment, allowing free oils and debris to rise, and sediment to settle
- Scour prevention technology ensures pollutants are captured and contained during all rainfall events, even extreme storms

Proven performance

With more than 20 years of industry experience, Stormceptor has been performance tested and verified by some of the most stringent technology evaluation programs in North America. Stormceptor has been performance verified through numerous verification programs, including;

- NJCAT
- Washington ECOLOGY
- EN858 Class 2

PCSWMM for Stormceptor – *Advanced online sizing & design software*

The most accurate, easy to use design tool available.

- This continuous simulation modeling software combines localized rainfall data from over 1,900 weather stations across North America allowing for region-specific design with a selection of particle sizes to design the best Stormceptor for your site
- Within a single project, multiple Stormceptor units can be sized and the information revisited as project parameters change
- Provides a summary report that includes projected performance calculations

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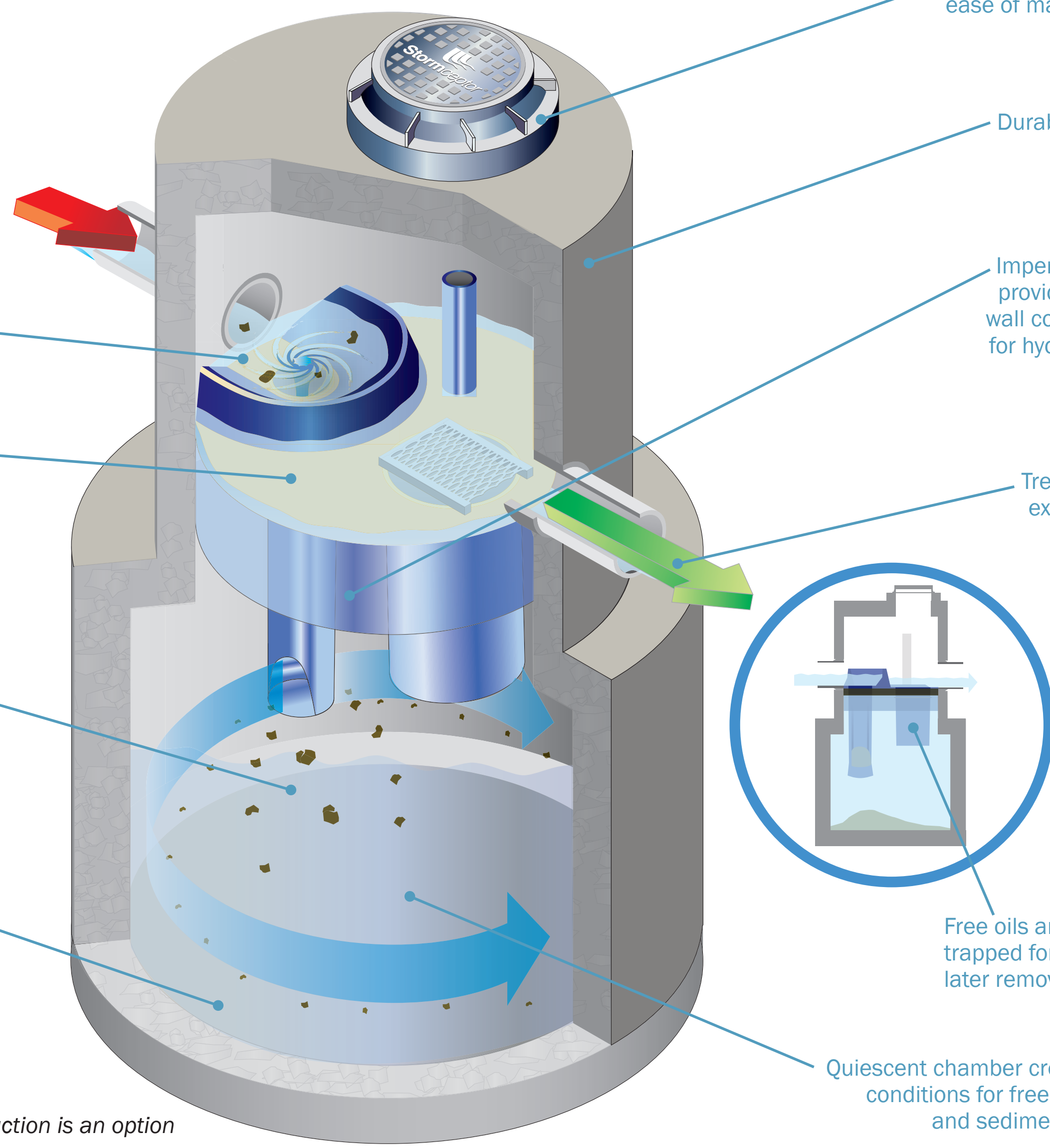
Stormceptor® STC

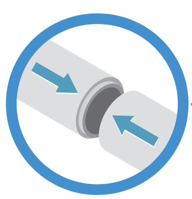
The calm *during* the storm



* *Fiberglass construction is an option*

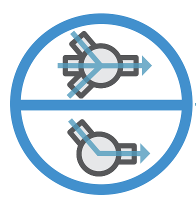
Easy to install

Small footprint saves time and money with limited disruption to your site.



Seamless

Minimal drop between inlet and outlet pipes makes Stormceptor ideal for retrofits and new development projects.



Flexible

Multiple inlets can connect to a single unit.

Can be used as a bend structure.

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