

Silver Creek Drainage Study

Bristol, RI

Prepared for:

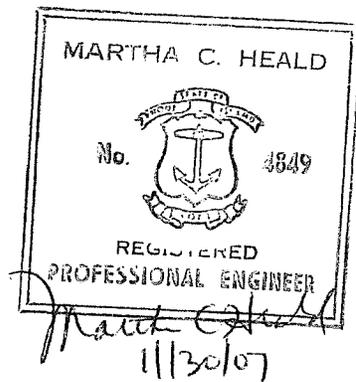
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Silver Creek Drainage Study

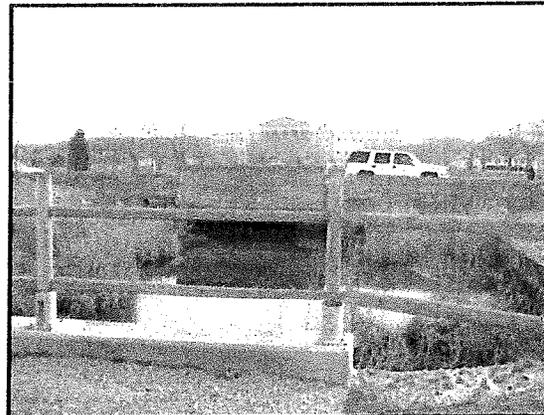
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Introduction and Project Scope

The Town of Bristol retained the services of BETA Group, Inc. to complete a drainage study of the Silver Creek watershed. The 2-square mile watershed extends from Tupelo Street near the Town's northerly border discharging into Bristol Harbor under Route 114 and the East Bay Bicycle Path. The study is one of several projects currently underway to identify existing drainage facilities within the Town and to improve the storm water infrastructure. The primary objective of the study was to determine the causes of flooding within the watershed, and to identify remedial projects which the Town may advance as money becomes available either through grants or bonds.

The Silver Creek watershed contains at least 66 subwatershed areas in 1,250 acres, and contains approximately 170 acres of regulated freshwater and saltwater wetlands. Runoff from approximately 60% of the watershed enters the creek and associated wetlands via closed drainage systems (i.e. pipes and drainage structures), while the runoff from the remaining 40% flows overland to the wetlands and



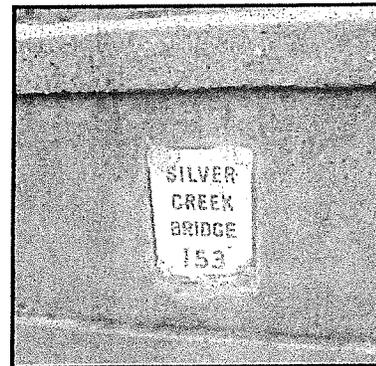
stream channels. Silver Creek begins as two (2) separate channels, identified as the East Branch and the West Branch, which merge into one creek south of Chestnut Street in the large marshy area north of the Guitaris School. The boundaries of the watershed were determined through the use of GIS, dry-weather opening of the drainage structures, and field observations of the wet-condition overland flows. The watershed is identified in Figure No. 1. The Silver Creek watershed falls under the jurisdiction of both the Coastal Resources Management Council (CRMC) and the Rhode Island Department of Environmental Management Freshwater Wetlands Section (RIDEM). The RIDEM regulates the wetlands within the watershed north of Chestnut Street and east of Sherry Avenue. Figure No. 2 illustrates the boundaries of the two (2) regulatory agencies.

There are numerous man-made ponds or detention basins which were built to contain or mitigate storm water flows to the receiving wetlands. Some of these have been modified by property owners over the years to improve local conditions, or not properly maintained, resulting in flooding downstream.

In addition to the flow of freshwater runoff via overland and piped flows, the Silver Creek is tidally influenced at the outfall at Bristol Harbor. High tides during storm events reduces the discharge capacity of Silver Creek at Route 114 preventing the upper watershed from draining, resulting in flooding at the fringes of the wetland areas and at the restrictions of piped sections under roadways and through private property. Displaced riprap under the Silver Creek bridge further restricts the flow of saltwater into and out of the salt marsh area adjacent to the Guitarius School and the recreation fields, resulting in insufficient salt water to maintain the marsh characteristics. Sediments have allowed phragmites to invade the area, reducing available flood storage. This is described in much greater detail in the discussion on sediments.

Coordination with Other Projects

The Natural Resources Conservation Services (NRCS) has conducted a study of the lower portion of the watershed including the restrictions under the Silver Creek Bridge No. 153 and the East Bay Bikepath Bridge, developing a HEC-RAS model of the marsh. This model was used in the development of the overall model for the Silver Creek watershed, described in the Methodology section of this report. The NRCS project looked at the effects of removing the rocks to allow for salt water intrusion into the lower creek area to kill off the freshwater invasive plants, and to re-establish the marsh characteristics south of the footbridge. This project is currently in the permitting stage, with construction expected in 2008.



The Town has several smaller projects either in the conceptual design stage, or under construction in 2007 which have either a direct or indirect impact on the study, as well as our recommendations. Chestnut Street, which runs in an east-west direction from Metacom Avenue (Route 136) to Hope Street (Route 114) is a major route within the watershed providing access to the Mount Hope High School, the Benjamin Church Manor, Naomi Street and the St. Mary Cemetery. The east and west branches of the Silver Creek pass under Chestnut Street, and there is an older closed drainage system within the roadway. The Town is currently constructing "1R Improvements" to Chestnut Street including new sidewalks, pavement overly, etc. No work to the drainage system is being done under this contract.

Elbow Street is an extension of Waterman Street, and is the location of chronic flooding problems. Caputo and Wick has designed and permitted a project which will replace the existing 12" CMP with

new pipes including an increase in the pipe conveying the flow under the road with an 18" HDPE. Construction on this project is scheduled for Fall 2007. This project is discussed in greater detail later in the report, as this area of Elbow Street has been identified as one of the problematic areas.

Also discussed in the report is Sherry Avenue. New sidewalks will be constructed in 2007. Caputo and Wick developed a Conceptual Plan for new drainage within the existing Right-of-Way, utilizing 48" pipes to provide storage. This plan would change the drainage patterns by conveying all the stormwater toward Chestnut Street, as opposed to the current route through private property toward Vamum Avenue. This project is also discussed in further detail.

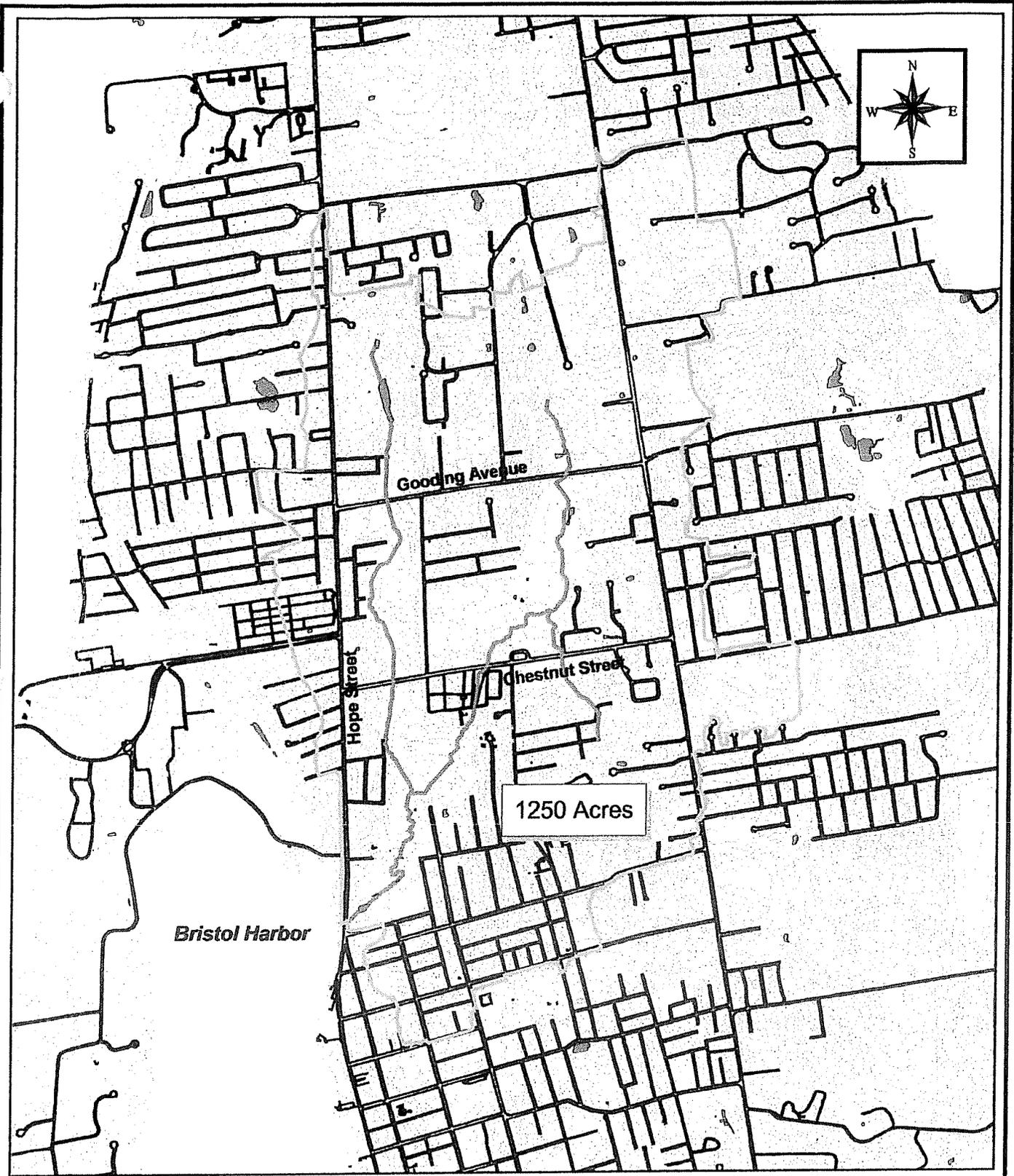
Data Collection and Field Observations

Data Collection

As part of the study and to determine accurate limits of the watershed, BETA completed an inventory of the existing drainage catch basins and manholes, as well as all outfalls and detention facilities within the 1,250 acre watershed. Catch basins were located using GPS equipment and opened to identify structure and pipe materials, pipe inverts and sizes, condition and the presence of silt or standing water. Approximately 1,000 catch basins were opened along with 250 drain manholes. Information collected regarding pipe size and invert elevations allows us to identify closed drainage systems which in turn can be used to calculate the system capacity.

As previously stated, it was determined that there are 66 separate drainage systems which collect runoff on local streets and developments, and then discharge to the Silver Creek. BETA used contour information provided by aerial mapping to determine the limits or reach of each individual subwatershed area. These subwatersheds have been compiled on a large scale map which is included in the report Appendix. Once the contributing areas are determined from this map, a hydrologic analysis was completed using Hydrocad software. The program calculates the watershed yield, or the rate of runoff directed to each individual closed drainage system. By comparing the capacity of each system with the calculated yield, we can determine those subsystems that are over-capacity and thus theoretically in a flooded state for storms of varying frequency (i.e. 2-year, 10-year, 100 year frequencies).

Figure 3 illustrates the town-owned parcels within the study area. This map is important in that it provides potential areas where improvements can be made without the acquisition of private property.



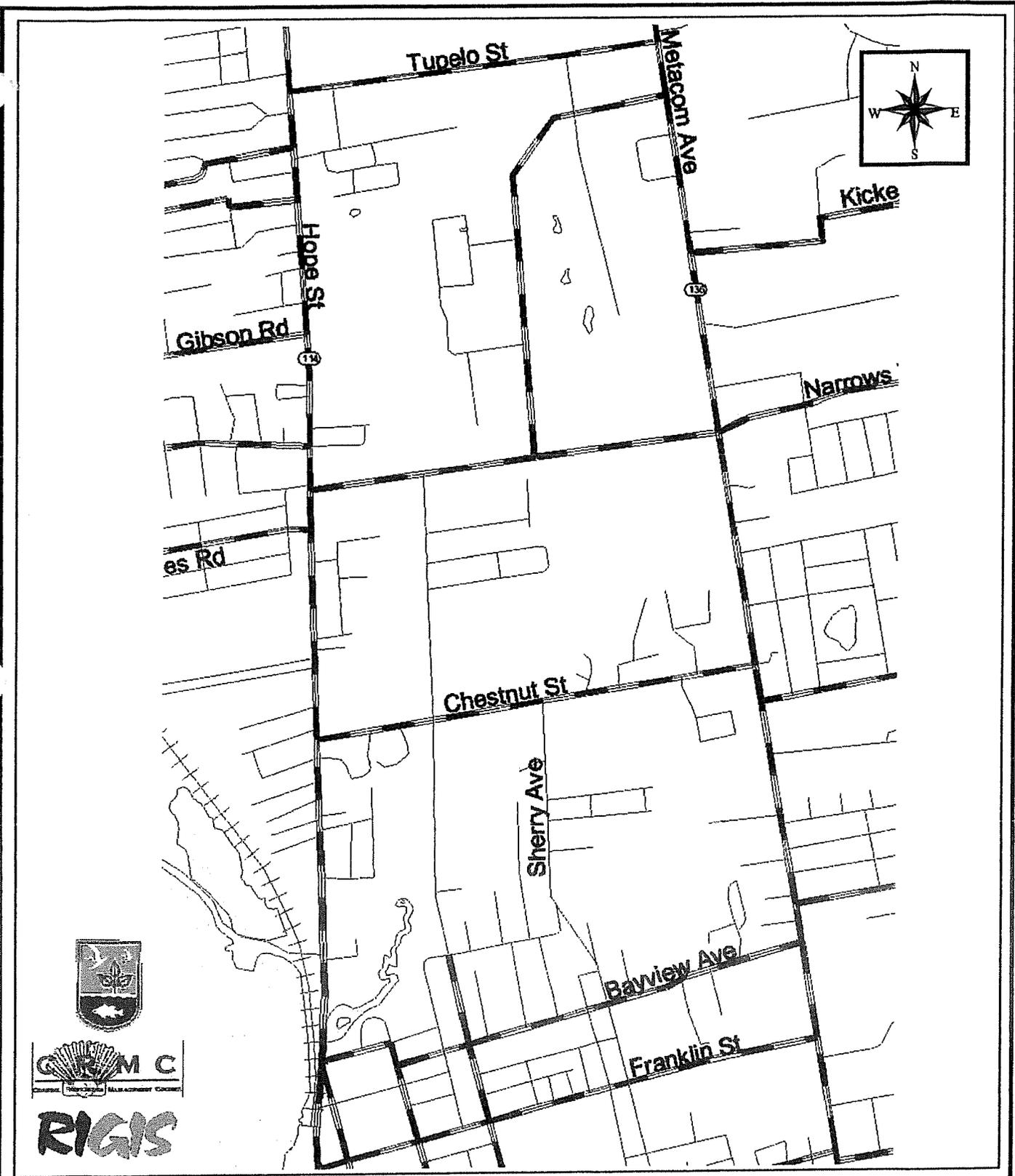
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-  Silver Creek Model Reaches
-  Silver Creek Watershed

**Town of Bristol
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Silver Creek
NOT TO SCALE

Figure 1
Silver Creek
Watershed



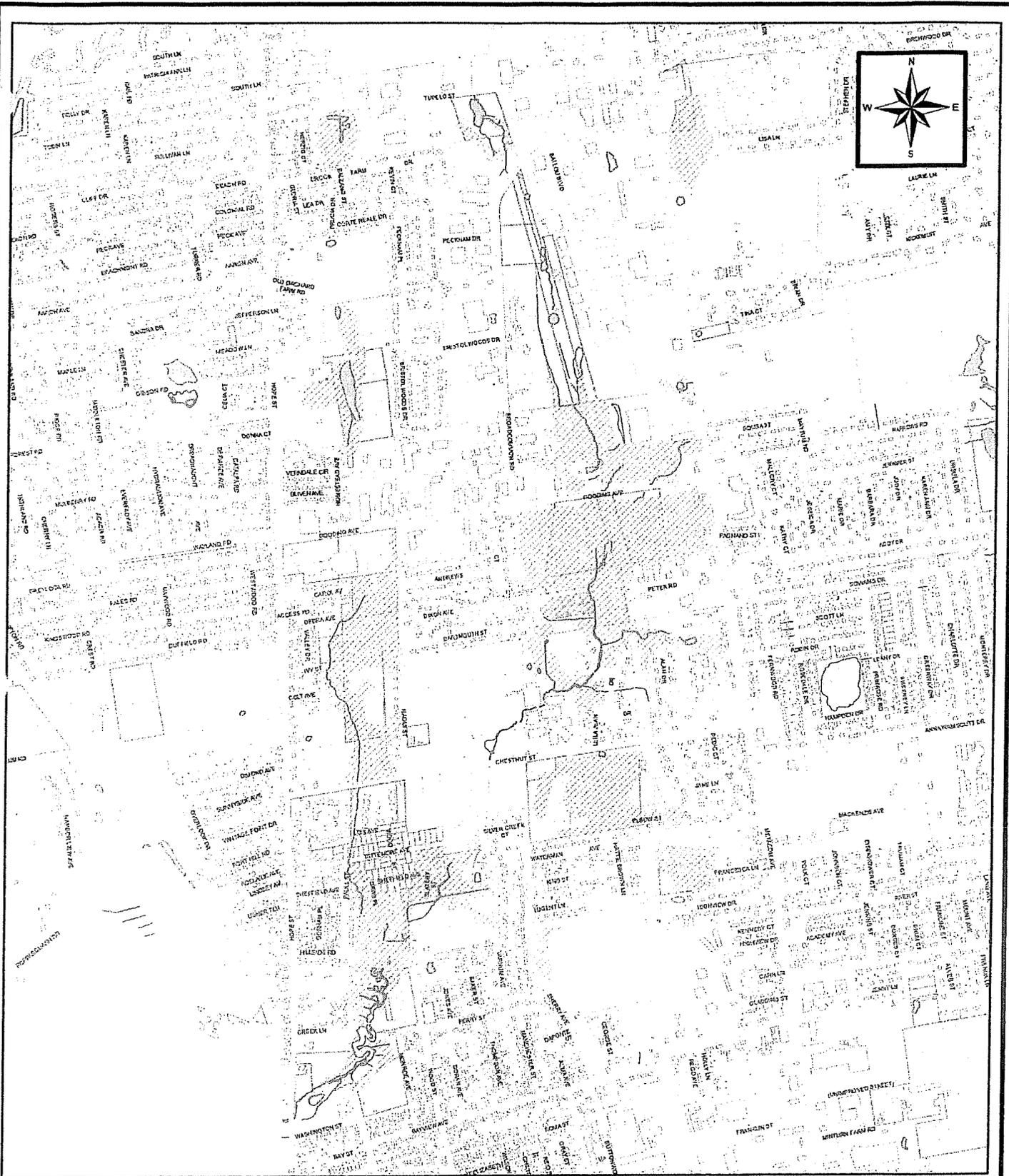
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-  CRMC
-  RIDEM

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Silver Creek
NOT TO SCALE

Figure 2
Jurisdictional
Boundary



Legend

-  Town-Owned Parcel
-  Wetland
-  River or Stream
-  Lake or Pond

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Silver Creek
NOT TO SCALE

Figure 3
Town-Owned
Property

Field Observations

In addition to the catch basin data and the plan development, BETA on several occasions inventoried much of the upland areas and the wetland conditions. It was observed that filling in of fringe areas or buffers was prevalent in several locations, including grass clippings, leaves, and small tree branches. Although "No Dumping" signs were observed at the end of several streets, this fill material, even though organic in nature, occupies space that would otherwise be used for flood storage.

Over the study period, the area experienced several measurable storm events, which provided the opportunity to witness the effects of the runoff throughout the watershed. During high-intensity, short duration storms, where the rain falls over a relatively short timeframe (i.e. heavy downpours), localized street flooding occurred on several of the major roadways including Gooding Avenue, Hope Street at the Silver Creek Bridge, Sherry Avenue and Washington Street. This indicated that there was a catchment problem on several of the streets. During long duration storms, where the rain continued to fall over a 24-hour period at a significantly lower rate, the flooding was confined to the lower watershed area, and the upper watershed and wetland areas were capable of containing the volume of water. This photo shows the water level approximately 2-3 feet above ground, with the bikepath and Route 114 completely covered.

During the period of high tide on March 3, 2007, the water level in Bristol Harbor was estimated to be approximately 4 feet above mean high tide level, and the entire area from Washington Street to the Topside Restaurant was flooded. RIDOT's efforts to pump the area were futile until the tide subsided. Also, during these storm events, sediments were observed in the open channels leading to the creek and associated wetlands. These included runoff from soil stockpiles with incorrect erosion controls, parking lots, and other paved areas.



Public Meetings

In addition to the field data collections and observations, BETA attended a Public Meeting with residents to hear first-hand of their perceived drainage problems, and the historical nature of the flooding. During

this meeting, the residents identified several areas where chronic flooding occurs and affects their private property and commercial businesses. In addition to the Public Meeting, BETA attended a meeting of the storm water committee to determine which projects currently under consideration fall within the Silver Creek watershed, and to gain insight into the problems which have been identified by the Town's engineer and planning department.

The Draft Report was presented to the Bristol Town Council on October 17, 2007. BETA summarized the findings and recommendations for members of the Town Council and local residents at this workshop, and answered questions from the audience. Input from this meeting has been used to modify the recommendations, emphasizing the improvements which can be done without extensive environmental permitting, and for relatively low costs.

Watershed Analysis

Hydrocad Analysis

The 1,250 acre watershed was separated into 66 subwatershed areas to review the capacity of each individual drainage system, and the actual rate of stormwater runoff flowing to each area. These subwatershed areas were analyzed using the Hydrocad software, which utilizes TR-20 technology to determine yield for storms of varying intensities, which can then be compared with the capacity of the existing pipe. As previously indicated, the pipe capacities were calculated based on the existing system characteristics (i.e. size, slope, inverts, etc.). The systems were analyzed for the 2-year and 10-year storms. In the 2-year storm, with 3.4 inches of rainfall in a 24-hour period, it was found that 32 of the 66 areas did not have sufficient capacity to handle the runoff. This included 5 areas where the capacity deficit exceeded 20 cubic feet per second (cfs), and 13 areas where the deficit was greater than 10 cfs.

The 10-year analysis (4.9 inches of rainfall in a 24-hour period) showed that an additional 12 watershed areas do not have existing capacity to handle the rate of runoff. The storms and watershed areas are summarized in Table 1. The figure demonstrating the watershed areas for the closed drainage systems can be found in the appendix.

HEC-RAS

The Hydraulic Engineering Centers River Analysis System (HEC-RAS) program was used to analyze the river and floodplain portions of the watershed. This program allows for both open-channel analysis of

Silver Creek Drainage Study

Pipe Capacity vs. Watershed Yield

Table 1

Watershed	Pipe Size (in.)	Pipe Capacity	Watershed Yield (cfs)			
			2 Year	10 Year	25 Year	100 Year
1	24	31	38	58	38	85
2	15	9	9	13	15	19
3	24	20	27	48	59	79
4	36	68	40	64	77	99
5	12	7	5	8	10	13
6	36*	67	23	36	44	57
6d	12*	5	2	3	4	4
6e	12	7	2	2	3	4
8	12	2	3	6	7	10
9	12	7	7	11	13	17
10	24	24	12	22	27	35
11	15	17	39	62	74	96
12	12	8	6	10	12	15
13	12	6	13	24	30	40
15	12	32	28	50	61	81
16	24	6	4	8	9	13
14 & 17	18	6	18	34	42	58
18	18	83	21	38	48	65
19	36*	4	17	33	42	58
20	12*	2	15	27	34	46
21	36*	67	8	12	14	18
22	18	8	18	28	33	41
23	12*	5	3	4	5	6
24	12*	4	12	19	23	29
25	18*	11	11	21	26	35
26	4	1	0.5	0.5	0.5	0.5
27	6*	1	0.5	0.5	0.5	0.5
28	12	12	5	9	12	16
29	18	14	17	29	36	48
30	10*	1	3	5	6	8
31	12*	4	25	48	61	84
32	18*	17	35	71	92	130
33	18*	6	44	79	99	133
34	12	2	8	14	17	23
35	15*	6	4	7	8	11
36	30*	41	136	235	290	386
37	18*	11	9	14	17	23
38	18*	8	4	7	8	11
39	15*	4	16	29	36	48
40	6*	1	0.5	0.5	1	1
41	8*	2	0.5	1	1	2
42	6*	1	0.5	0.5	0.5	0.5
43	24	20	5	8	11	14
44	6*	1	2	3	4	6
45	12*	2	3	6	8	12

ANDREWS
DARTMOUTH
DIXON

* Due to limited information about these systems, the slope was assumed to be 1%.

Silver Creek Drainage Study
Pipe Capacity vs. Watershed Yield
Table 1

Watershed	Pipe Size (in.)	Pipe Capacity	Watershed Yield (cfs)			
			2 Year	10 Year	25 Year	100 Year
46	12*	2	1	2	3	4
47	18*	6	13	23	30	40
48	12*	2	3	4	5	7
50	4*	0.50	3	5	6	9
51	18*	11	11	17	21	26
52	12*	2	9	14	17	22
53	12	4	12	19	22	28
54	12	4	1	2	3	4
55	8	2	4	6	7	9
56	24	36	11	20	25	33
57	12*	2	4	7	8	11
58	12*	2	5	8	10	14
59 & 60	54/36	240	72	124	152	203
61	24	20	27	48	60	80
62	12*	2	11	20	25	34
63	15*	4	15	27	34	46
64	12*	4	2	3	3	4
65	18*	11	6	10	13	18
66	18	7	6	10	13	17
67	18	5	4	7	8	11
68	12	2	26	48	60	81

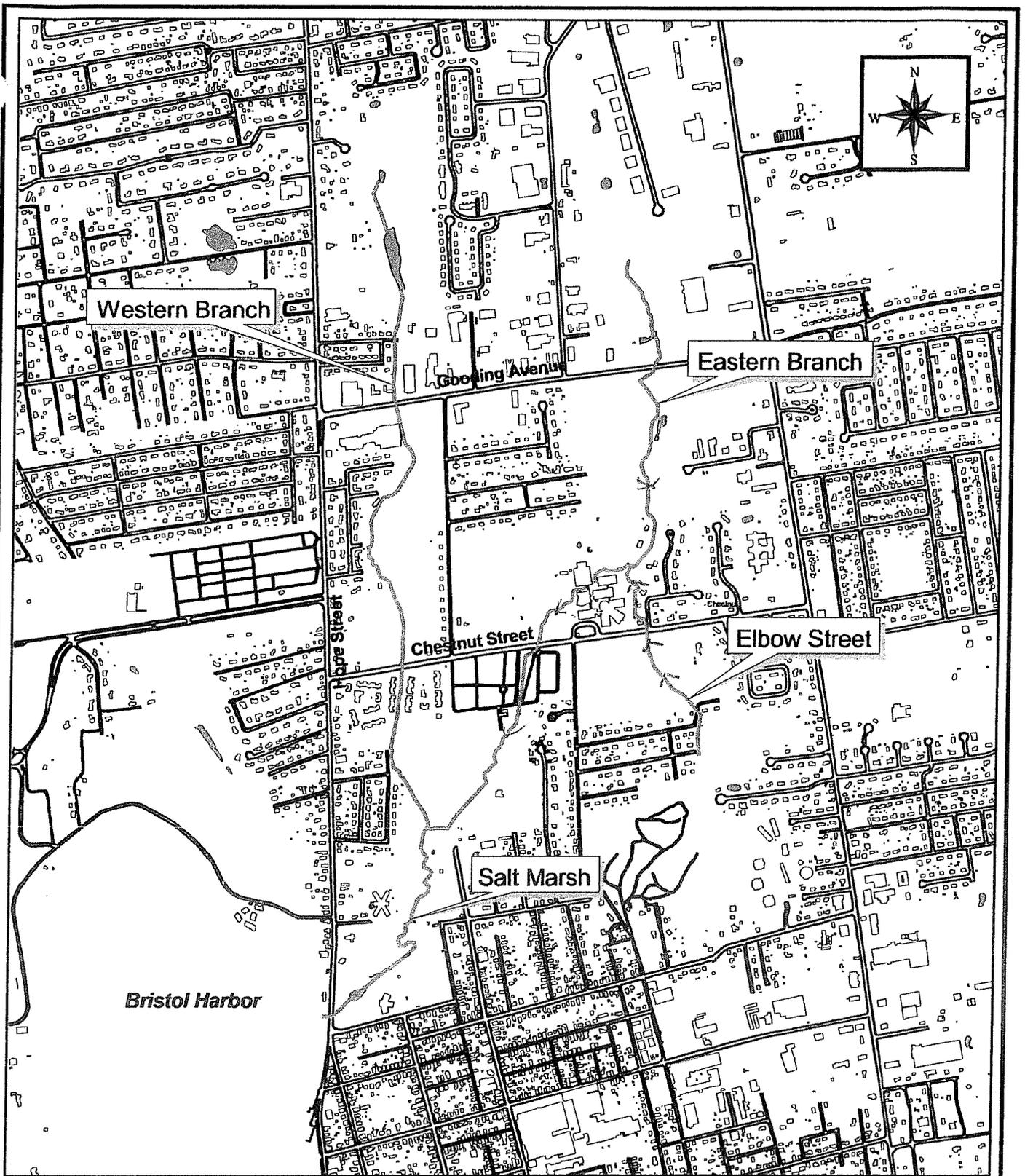
* Due to limited information about these systems, the slope was assumed to be 1%.

the river portions of the east and west branches (northern reaches), and the pond areas of the lower watershed as well as those areas where flows back up as a result of restrictions from piped sections. In order to calculate the input runoff at key locations, the total watershed area was broken down into 45 subwatershed areas, each with a discharge point and volume of stormwater runoff. It should be noted that these 45 subwatershed areas are different from the 66 subwatershed areas identified in the pipe-flow analysis as they have different discharge points and characteristics. The figure illustrating the subwatershed areas for the Silver Creek analysis can be found in the appendix.

To determine the open channel characteristics of the channel, the creek was analyzed from upstream of Gooding Avenue to the discharge point west of Hope Street. The creek was divided into four reaches: the Eastern Branch, Western Branch, Salt Marsh and Elbow Street. These reaches can be seen in Figure 4. The Eastern and Western Branches extend from north of Gooding Avenue to south of Chestnut Street where they converge in the salt marsh and continue to the outfall. The Elbow Street reach was modeled because many of the previously discussed problem areas discharge to the wetland north of Elbow Street. This wetland area flows to a culvert which crosses Chestnut Street and discharges on the northern side. The Elbow Street reach then converges with the Eastern Branch before flowing to the culverts under the high school. The model would help to determine if the problems in these areas were due to the hydraulic characteristics of the creek or the inadequate capacity of the individual drainage systems.

Methodology

The hydrologic and hydraulic analysis for this project was completed using HydroCad and HEC-RAS computer software. The overall watershed was divided into approximately 45 subwatersheds. HydroCAD was utilized to determine the watershed yield for each of the subwatersheds. The watershed yield assumes that the peak flow reaches the creek regardless of the restrictions the closed drainage systems may create. HydroCAD utilizes the Soil Conservation Services Technical Release 55 (TR-55). Additionally, the Rhode Island Intensity-Duration-Frequency (IDF) curve was used to determine intensity values based on the time of concentration. A lag time, ranging anywhere from 20 to 60 minutes, was calculated for each subwatershed based on the amount of time it would take to travel in the creek from the discharge point of one subwatershed to the next. The peak discharge for each subwatershed was determined for the 2, 10 and 100 year design storm events. The results of the HydroCad analysis for each storm event are included in the Appendix.



Legend



Silver Creek
Model Reaches

**Town of Bristol
Rhode Island**

Silver Creek
NOT TO SCALE

Figure 4

Silver Creek
Model Reaches

The hydraulic conditions in the creek were computed by a steady flow simulation in HEC-RAS using the derived peak flows for the 2, 10, and 100 year design storms obtained from HydroCad. The hydraulic analysis was completed for the existing condition and several alternatives to mitigate flooding during various design storm events.

Existing Condition

DESCRIPTION

The existing condition is defined as the existing creek channel, assuming that the rock sill upstream of the bike path has been lowered by the ongoing project. The alignment of the river channel and the cross sections were defined using the 2-foot contour intervals obtained from the Town's GIS. The geometry of the bridge crossings or hydraulic opening and cross culverts were defined and quantified using information obtained from the Town's GIS, the Natural Resources Conservation Service (NRCS) Silver Creek Study and Model, and field data obtained during this study. It is assumed that these culverts are not damaged or collapsed and able to convey flow at full capacity. For analysis purposes, if required information was not available, the characteristics of the system were assumed using the best available information and the topography of the area.

The river bed and wetland elevations were derived from the 2-foot contours except in the Salt Marsh reach. NRCS had performed a more detailed survey of the salt marsh area for their study of Silver Creek. The cross-sections from their HEC-RAS model through the salt marsh area were incorporated into our model. The hydraulic openings for the pedestrian, Hope Street and the bike path bridges were also taken from the NRCS model.

The outfall downstream of the bike path is tidally influenced. The tailwater only affects the creek from the outfall to just upstream of where the eastern and the western branches converge (approximately 3,000 feet), mostly through the marsh area. Upstream of this point, the elevation of the creek is higher than the tailwater elevation. The HEC-RAS simulation was performed for four different tailwater scenarios. The first scenario assumed the bike path culvert had no tailwater (empty), the second scenario assumed the culvert was half full, the third scenario assumed the culvert was fully submerged but not overtopping the bike path, and the last scenario assumed the culvert was fully submerged and overtopping the bike path by six inches. Each of these conditions was used as the boundary condition downstream for the

simulation. The only tailwater condition that affected the water surface elevation (more than 0.05 feet) or the discharging flow at Hope Street or the bike path was the last scenario representing the fully submerged culvert and overtopping of the bike path by six inches. The discharging flow from Hope Street causes the bike path to act as a weir which overtops and discharges to the harbor. Until the tailwater elevation is above the bike path, the weir flow from the bike path is able to discharge sufficient flow without increasing the water surface elevation upstream of Hope Street. Therefore, only the two extreme tailwater scenarios were used in the simulation: no tailwater and a tailwater elevation which overtops the bike path by six inches (referred to as the tailwater condition throughout the rest of this study).

The pedestrian bridge located upstream of Hope Street in the marsh is flooded for the 2, 10 and 100-year storm events. In agreement with the previous NRCS Study, it was determined that this bridge does not change the characteristics of the flow through this area and therefore will not be discussed further as part of the following results.

RESULTS

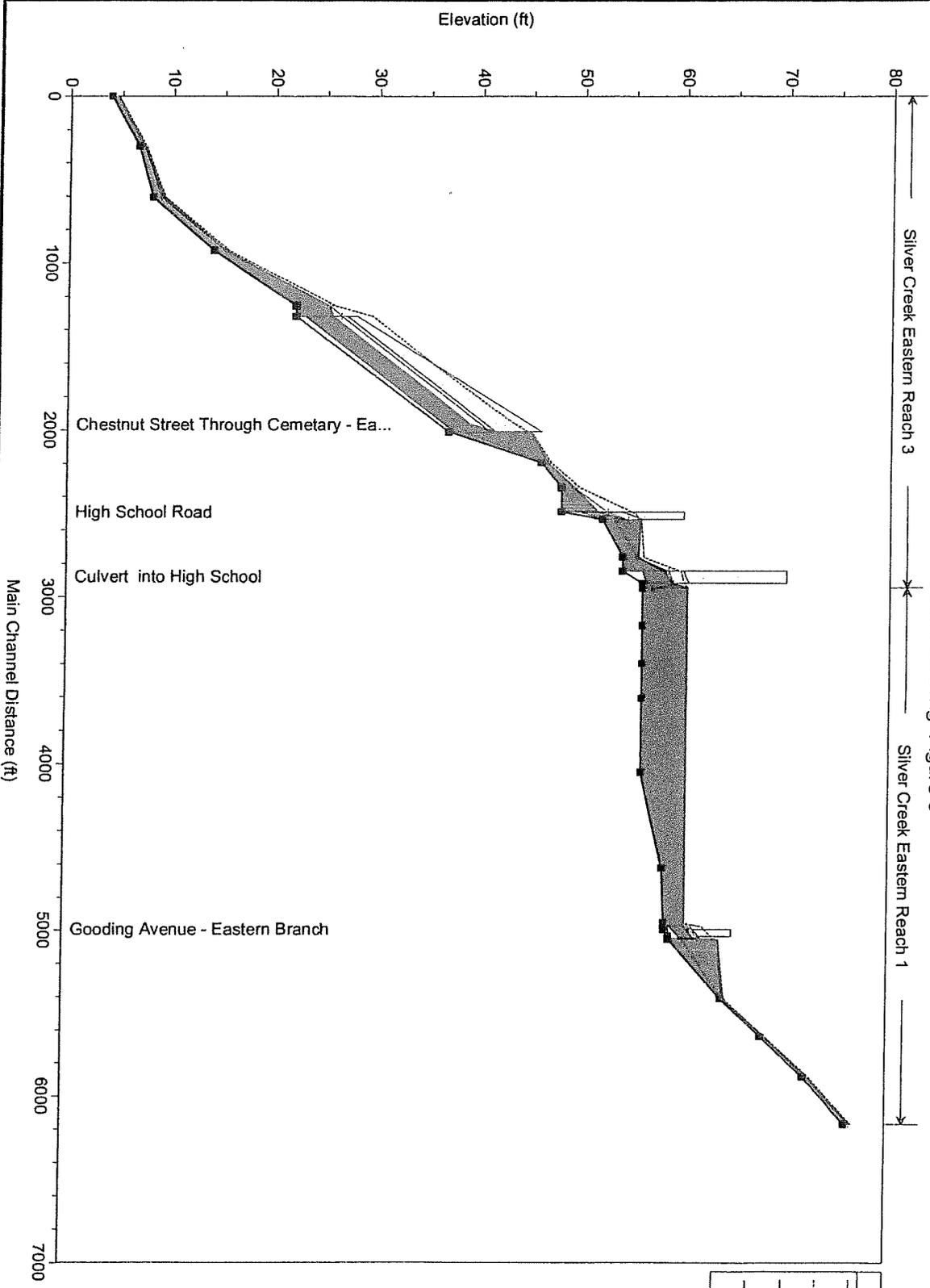
Based on the model, there are two areas throughout the watershed that seem to flood periodically. These areas are the marsh upstream of Hope Street and the area from the eastern branch between Gooding Ave and the high school. The topography is very flat in these areas and the creek is restricted downstream by culverts at Hope Street and the high school. The bike path bridge and the tidal influence at the outfall also impede the flow. Table 2 summarizes the elevations at the bike path, Hope Street, the marsh and the area between Gooding Avenue and Chestnut Street for the eastern branch for all three of the design storms with the tailwater condition and without. Each storm will have profiles to represent the eastern branch, western branch and Elbow Street and the marsh will have a profile with the tailwater condition and without if necessary. The results will also be presented in a summary table which can be found in the appendix with the output of the model.

Two-Year Design Storm

As previously mentioned, the creek was divided into four reaches: Eastern Branch, Western Branch, Salt Marsh and Elbow Street. The creek has the available capacity to convey the peak discharge of 210 cfs associated with a 2-year storm event. The culverts and hydraulic openings of the bridges are sufficient (see Figures 5-9). The only bridge that overtops is the bike path. The approximate elevations of the bike

Silver Creek Plan: Existing 2 Year

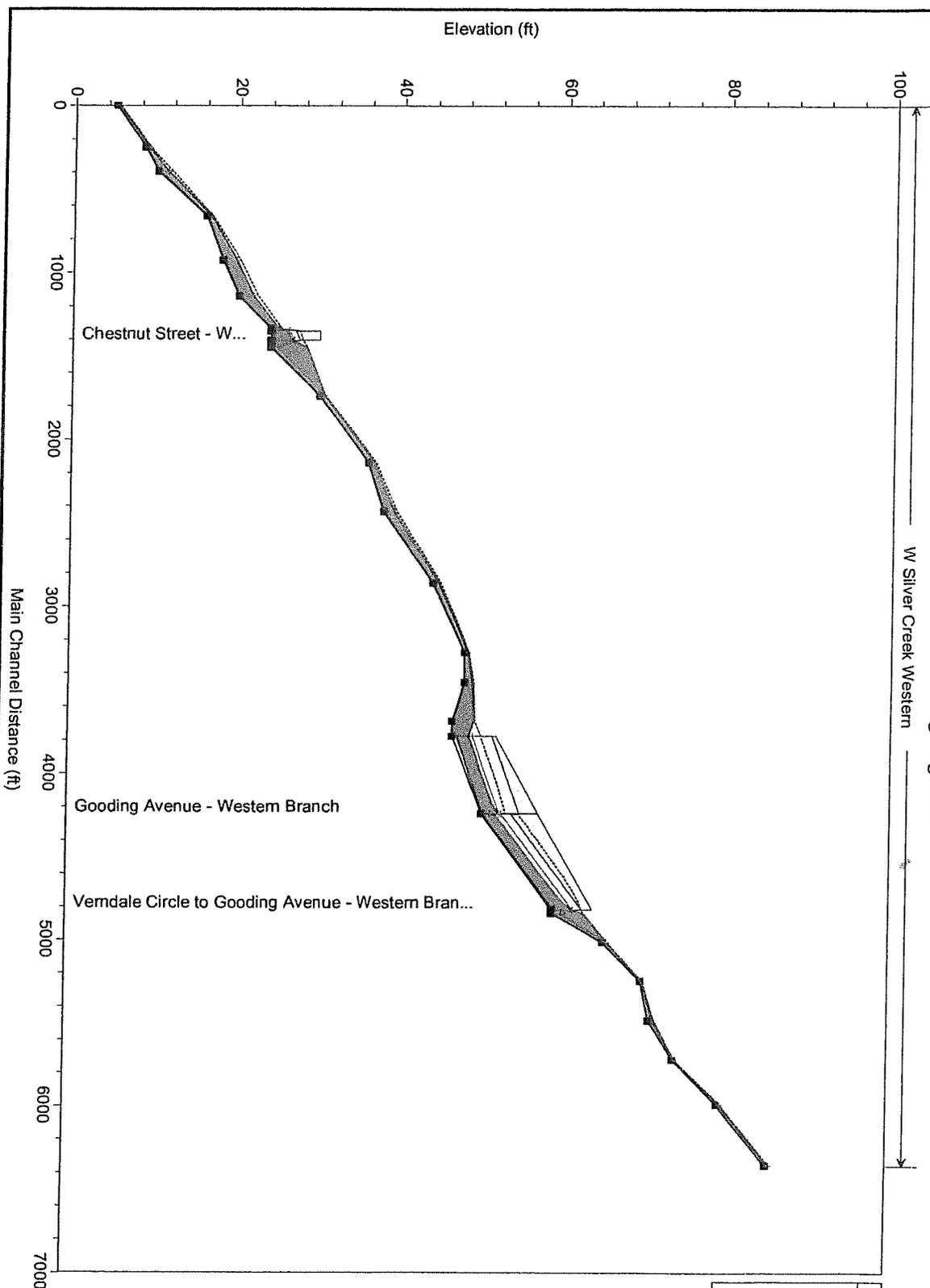
Geom: Existing Figure 5



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■	Ground

Silver Creek Plan: Existing 2 Year

Geom: Existing Figure 6

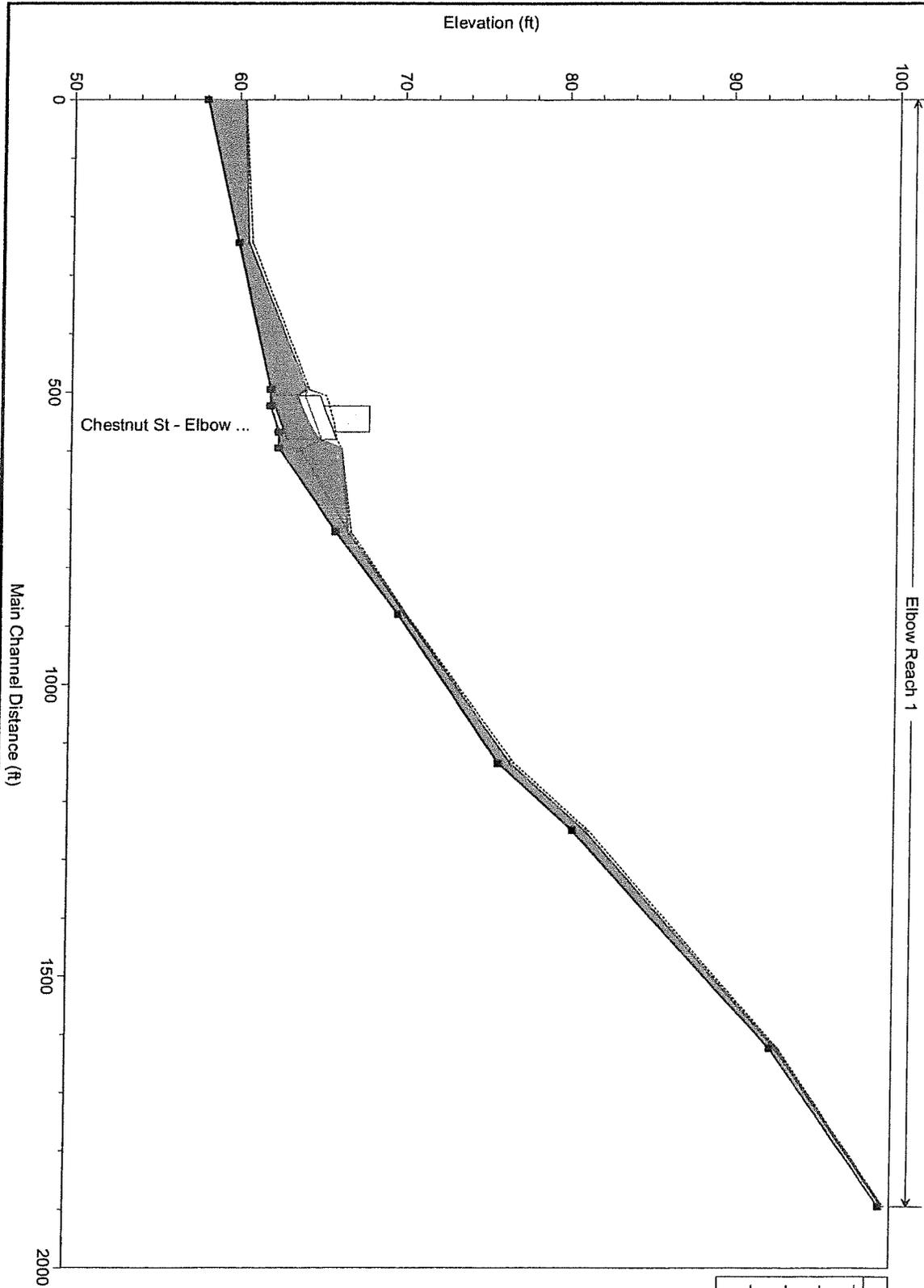


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Silver Creek Plan: Existing 2 Year

Geom: Existing Figure 7

Elbow Reach 1

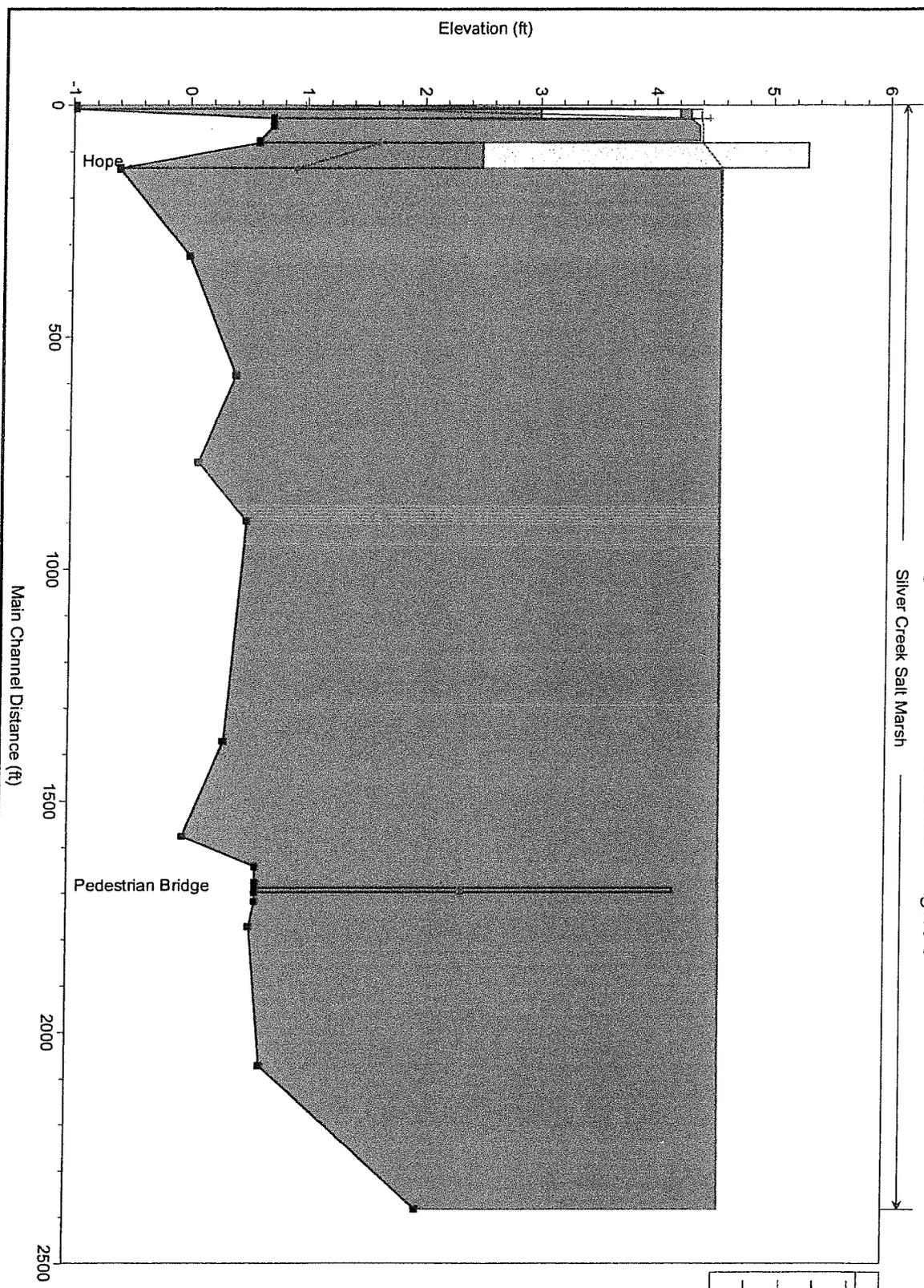


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—	WS PF 1
■	Ground

Silver Creek

Geom: Existing Flow: 2 Year - No Tailwater Figure 8

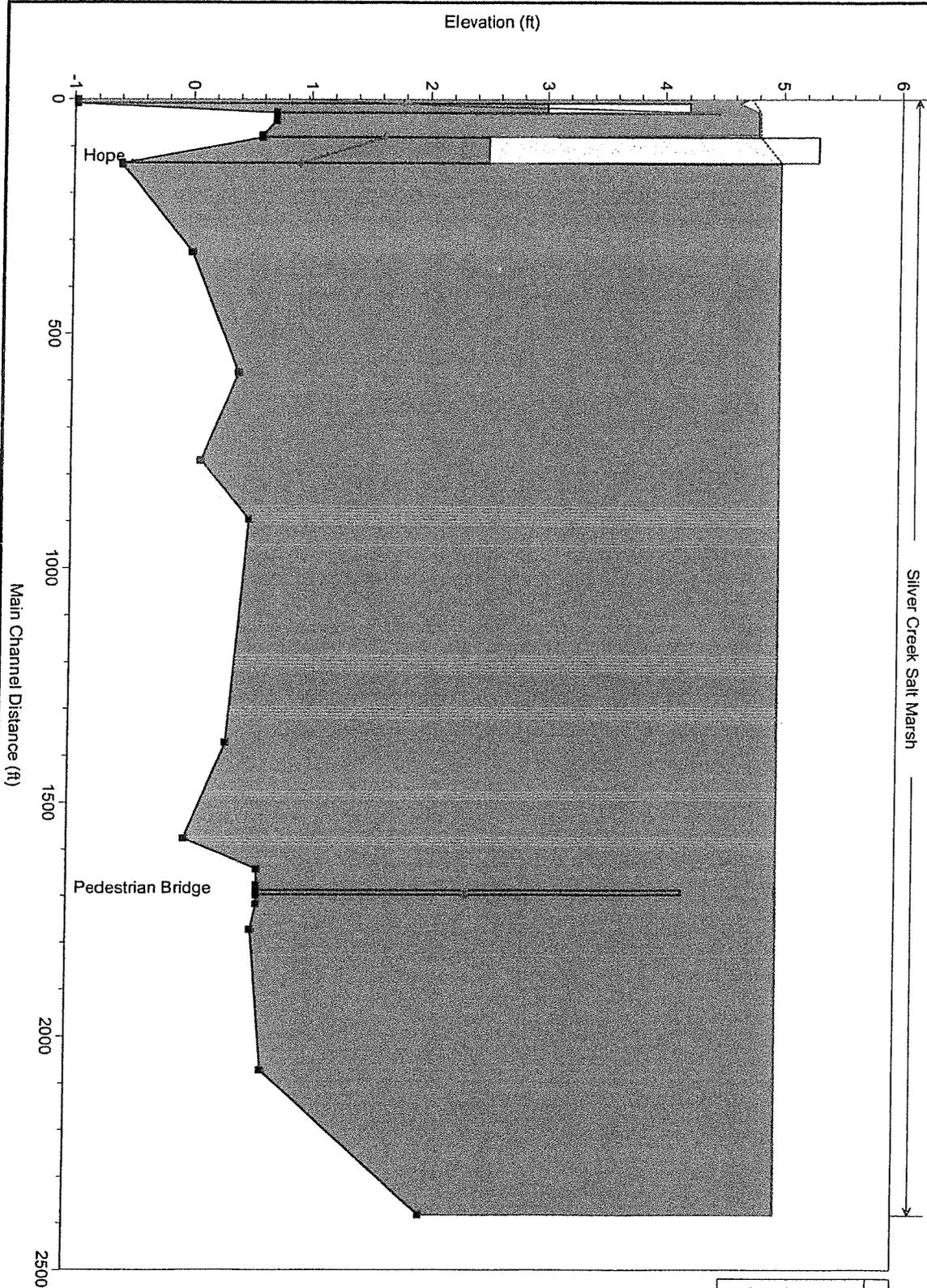
Silver Creek Salt Marsh



Silver Creek

Geom: Existing Flow: 2 Year - With Tailwater Figure 9

Silver Creek Salt Marsh



Legend	
EG PF 1
WS PF 1	-----
Crit PF 1	-----
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path and Hope Street are 4.2 feet and 5.3 feet, respectively. The water surface elevation is 0.10 feet above the bike path elevation with no tailwater and 0.5 feet above with the tailwater condition. Hope Street is not flooded by this design storm whether a tailwater condition is applied or not. The water surface elevation increases throughout the marsh to just upstream of Hope Street by 0.5 feet, bringing it to approximately 5.0 feet, when the tailwater condition is applied. As shown in Figure 5, the water surface elevation in the area between Gooding Avenue and the high school is approximately 60.4 feet. As previously mentioned, the tailwater does not affect the creek this far upstream.

Ten-Year Design Storm

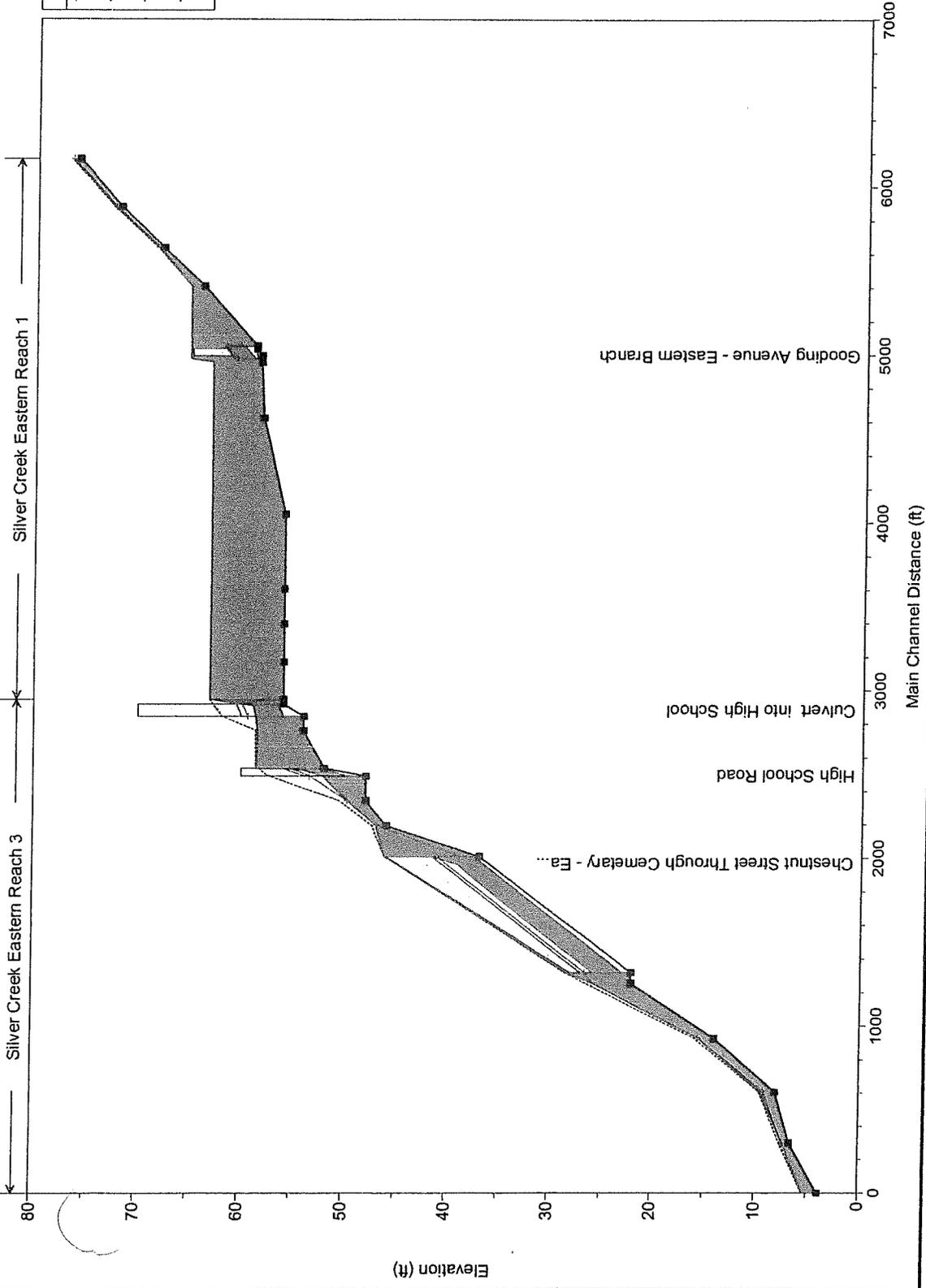
The ten-year storm, which produces a peak discharge of 377 cfs, overtops Gooding Avenue and Chestnut Street in the eastern branch (See Figure 10) and Verndale Circle (upstream of Gooding Avenue) and Chestnut Street in the western branch (See Figure 11) by approximately 0.10 feet. As shown in Figure 12, the flow from the Elbow Street area overtops Chestnut by less than 0.10 feet. These structures may not actually flood or overtop during this design storm. More detailed survey information would be needed to determine the exact elevations of the culverts and hydraulic openings in these areas. As shown in Table 2, the water surface elevation at the bike path with no tailwater condition is 4.4 feet and 4.7 feet with a tailwater condition (see Figures 13-14). Hope Street does not overtop until a tailwater (high tide) condition is applied with the ten-year design storm. Hope Street barely floods with the tailwater condition and the corresponding elevation in the marsh rises to 5.32 feet, which is 0.02 feet above the street's normal grade. The flood elevation between Gooding Avenue and the high school is approximately 63 feet.

One Hundred-Year Design Storm

As shown in Figures 15-18, the peak flow of 639 cfs from the one hundred-year design storm overtops all of the bridges and culverts except the high school. The water surface elevations are the same regardless of whether a tailwater condition was simulated. The water surface elevation at the bike path is 5.1 feet and 5.6 feet at Hope Street. The elevation throughout the marsh is 5.7 feet and 67.0 feet between Gooding Avenue and the high school for the eastern branch.

Silver Creek Plan: Existing 10 Year

Geom: Existing Figure 10



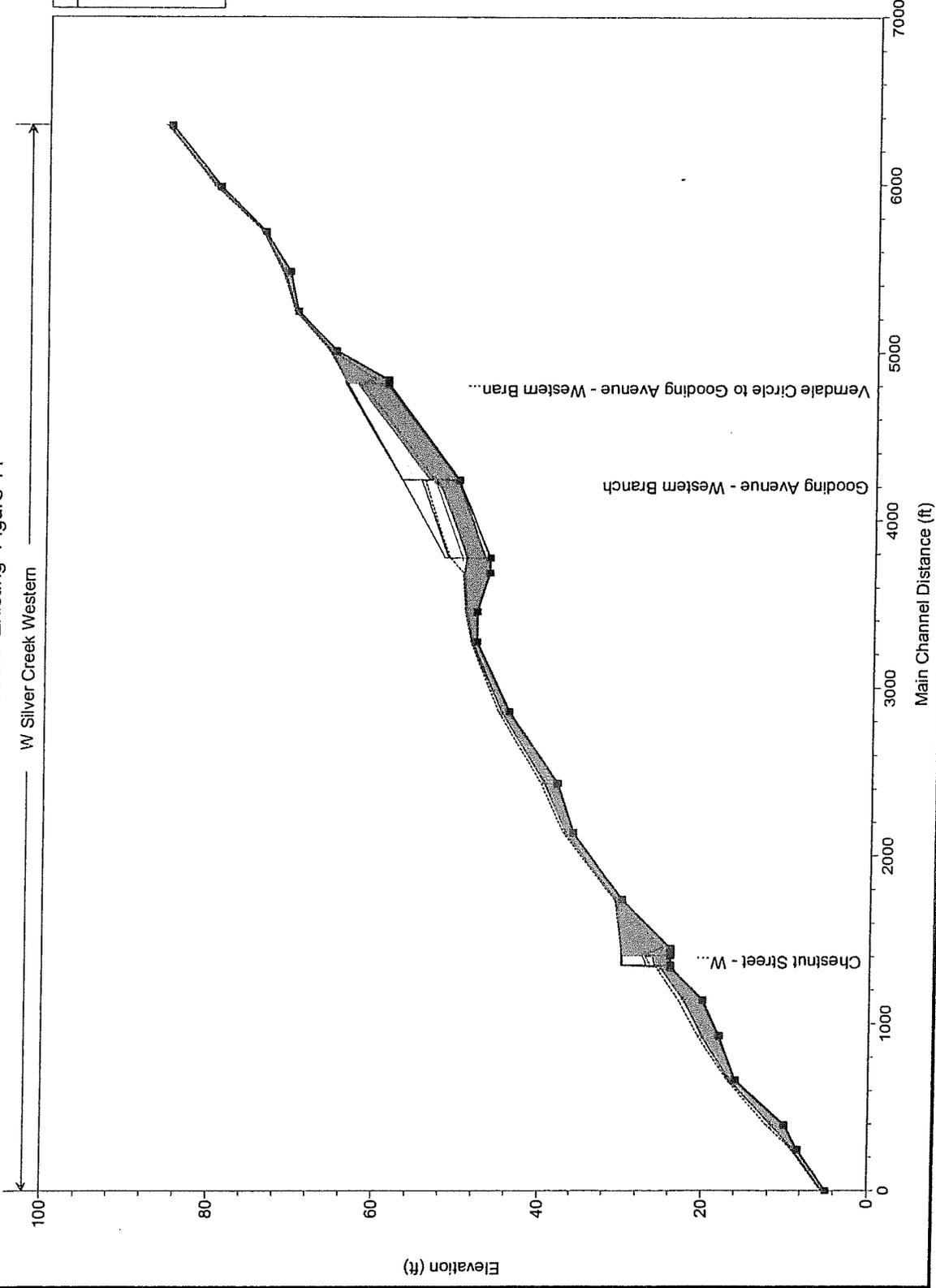
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Silver Creek Plan: Existing 10 Year

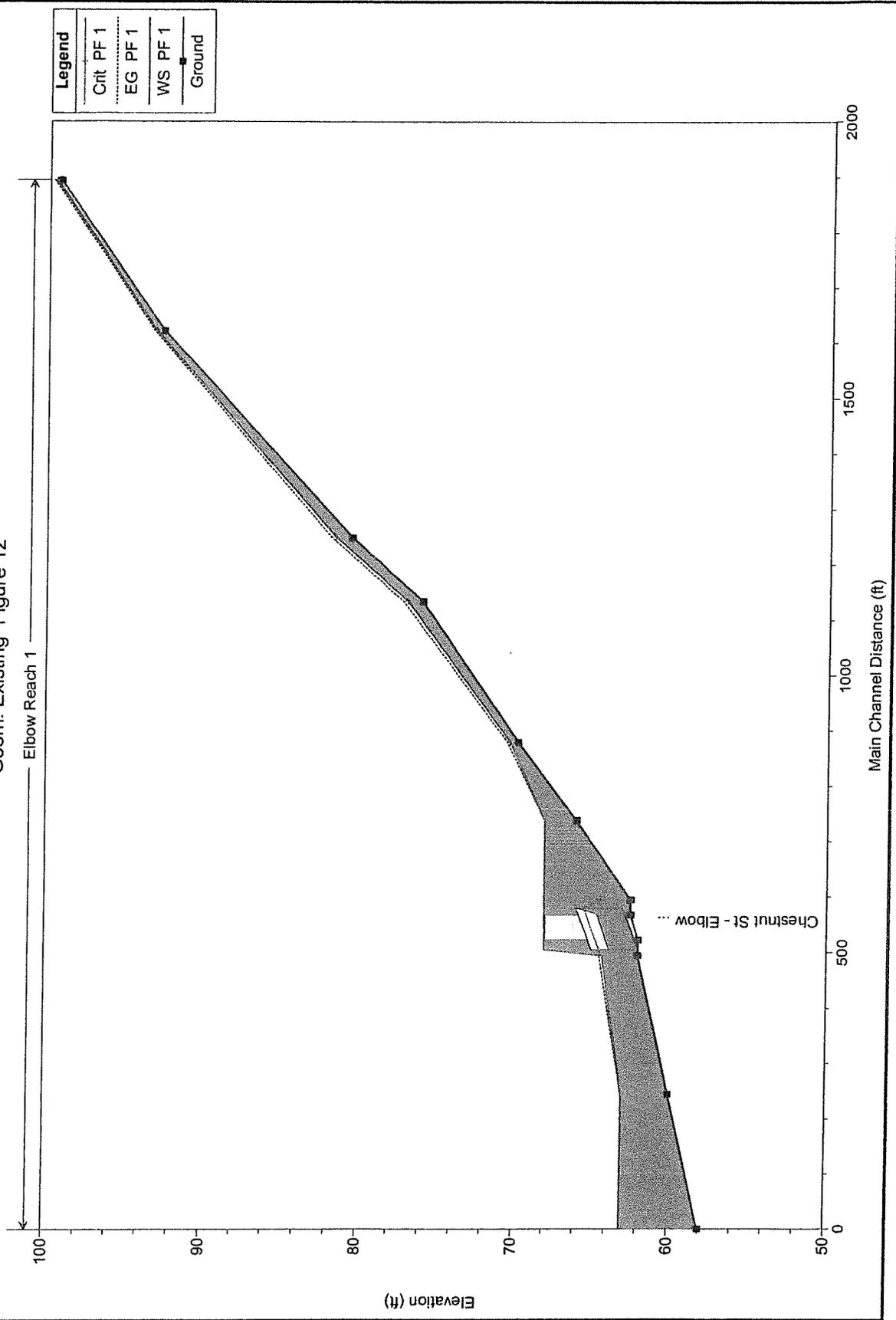
Geom: Existing Figure 11

W Silver Creek Western

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Silver Creek Plan: Existing 10 Year
Geom: Existing Figure 12



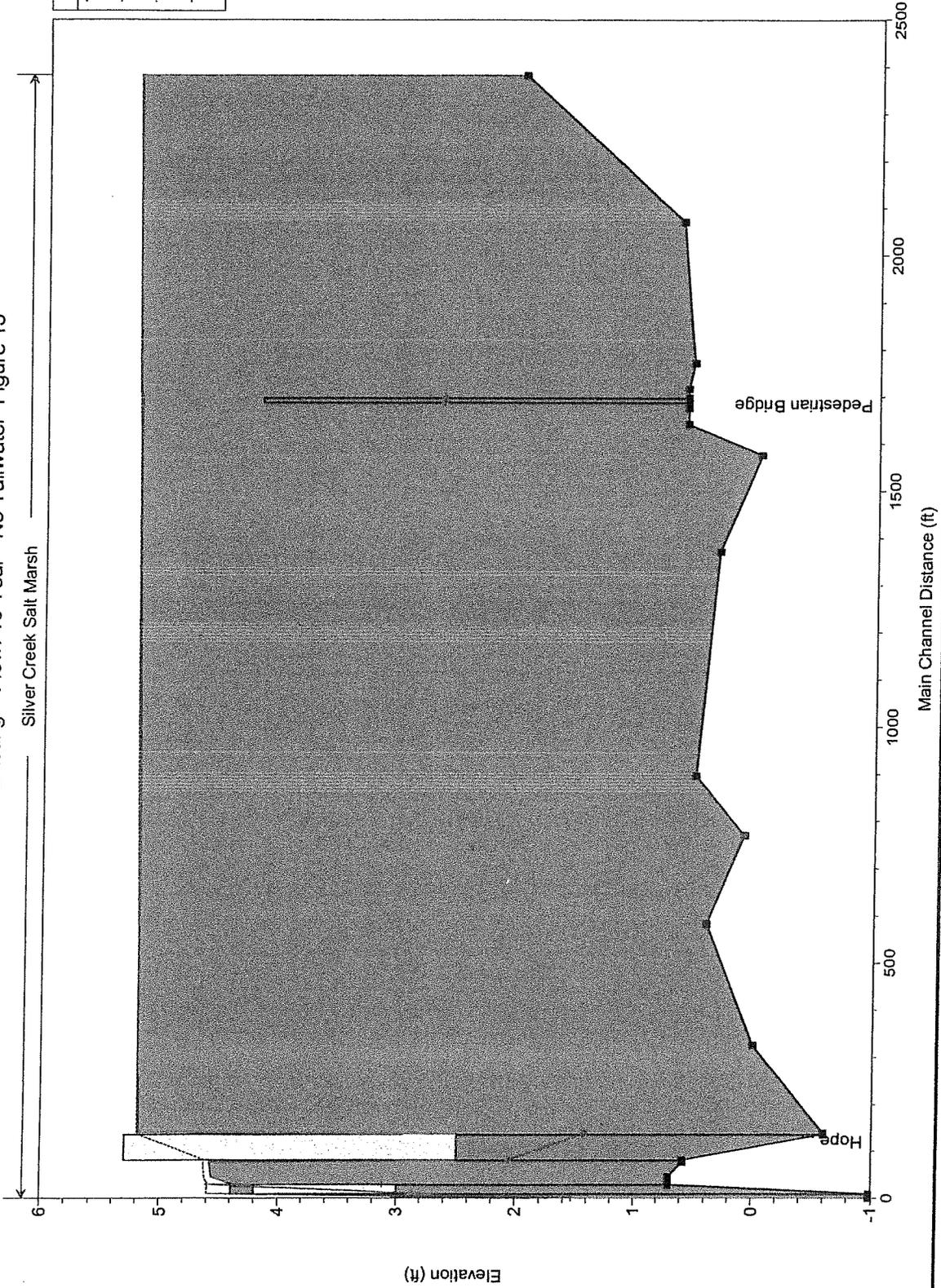
Legend	
—	Crit PF 1
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Silver Creek

Geom: Existing Flow: 10 Year - No Tailwater Figure 13

Silver Creek Salt Marsh

Legend	
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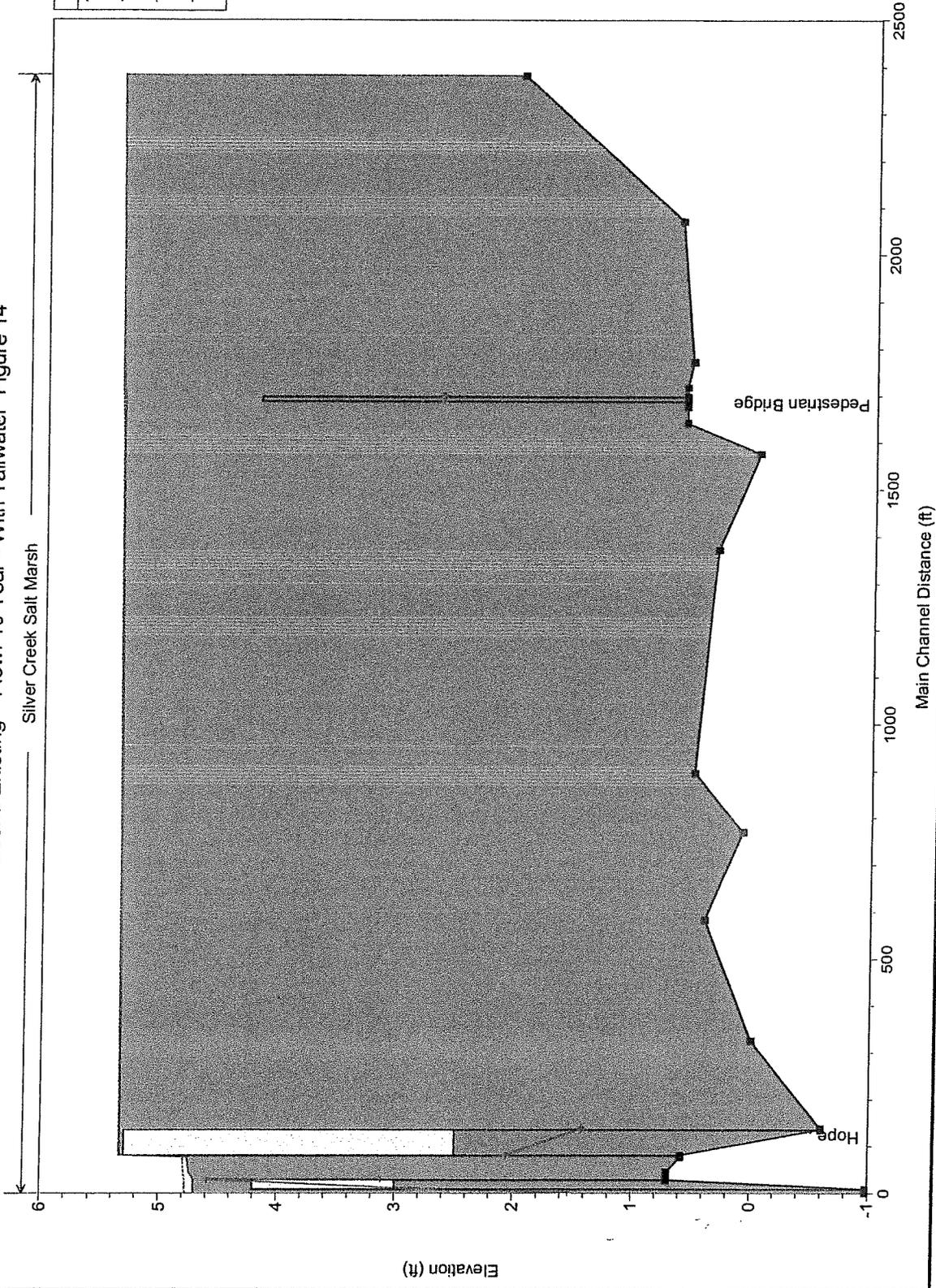


Silver Creek

Geom: Existing Flow: 10 Year - With Tailwater Figure 14

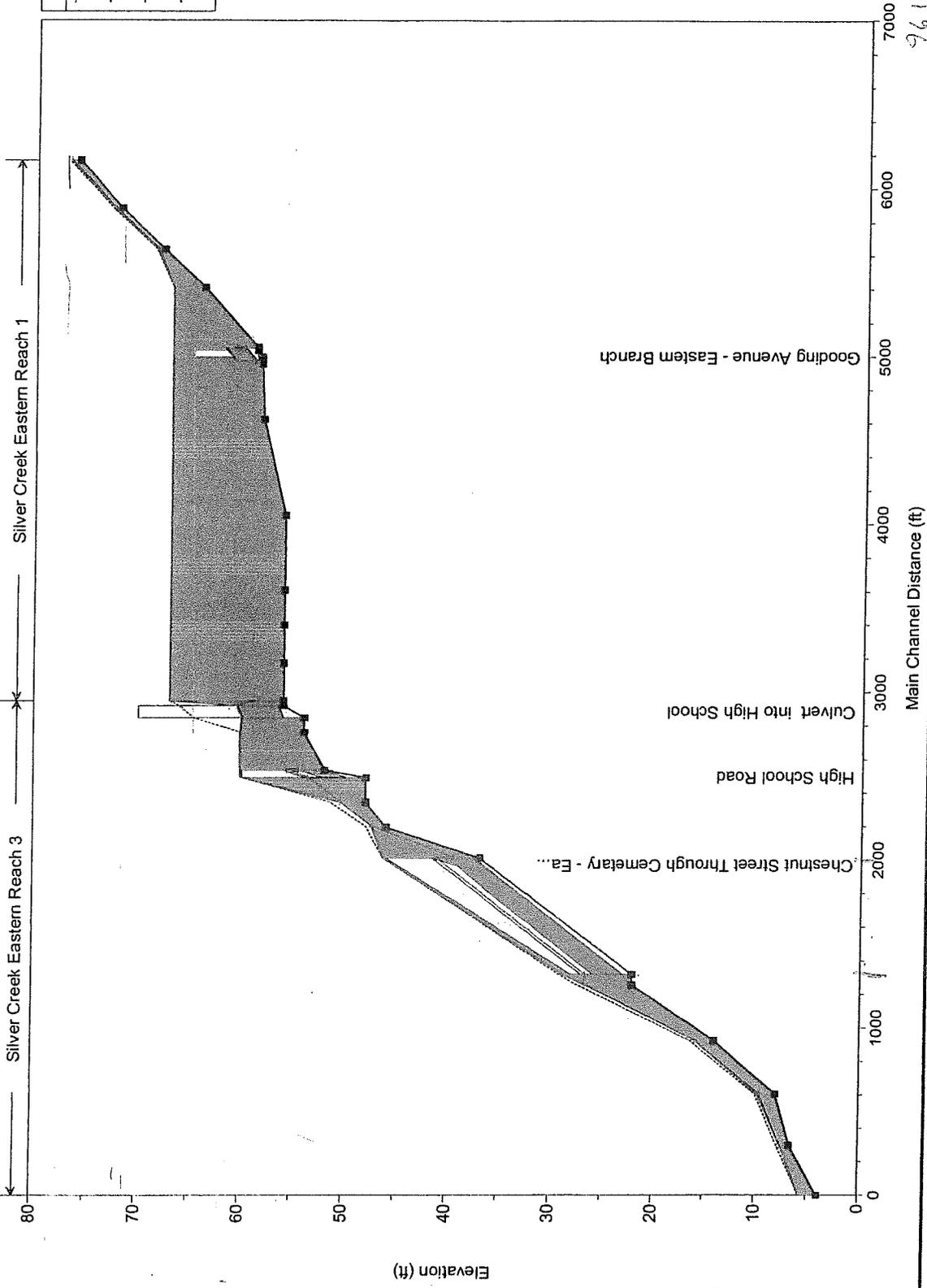
Silver Creek Salt Marsh

Legend	
EG PF 1	-----
WS PF 1	-----
Crit PF 1	-----
Ground	-----



Silver Creek Plan: Existing 100 Year

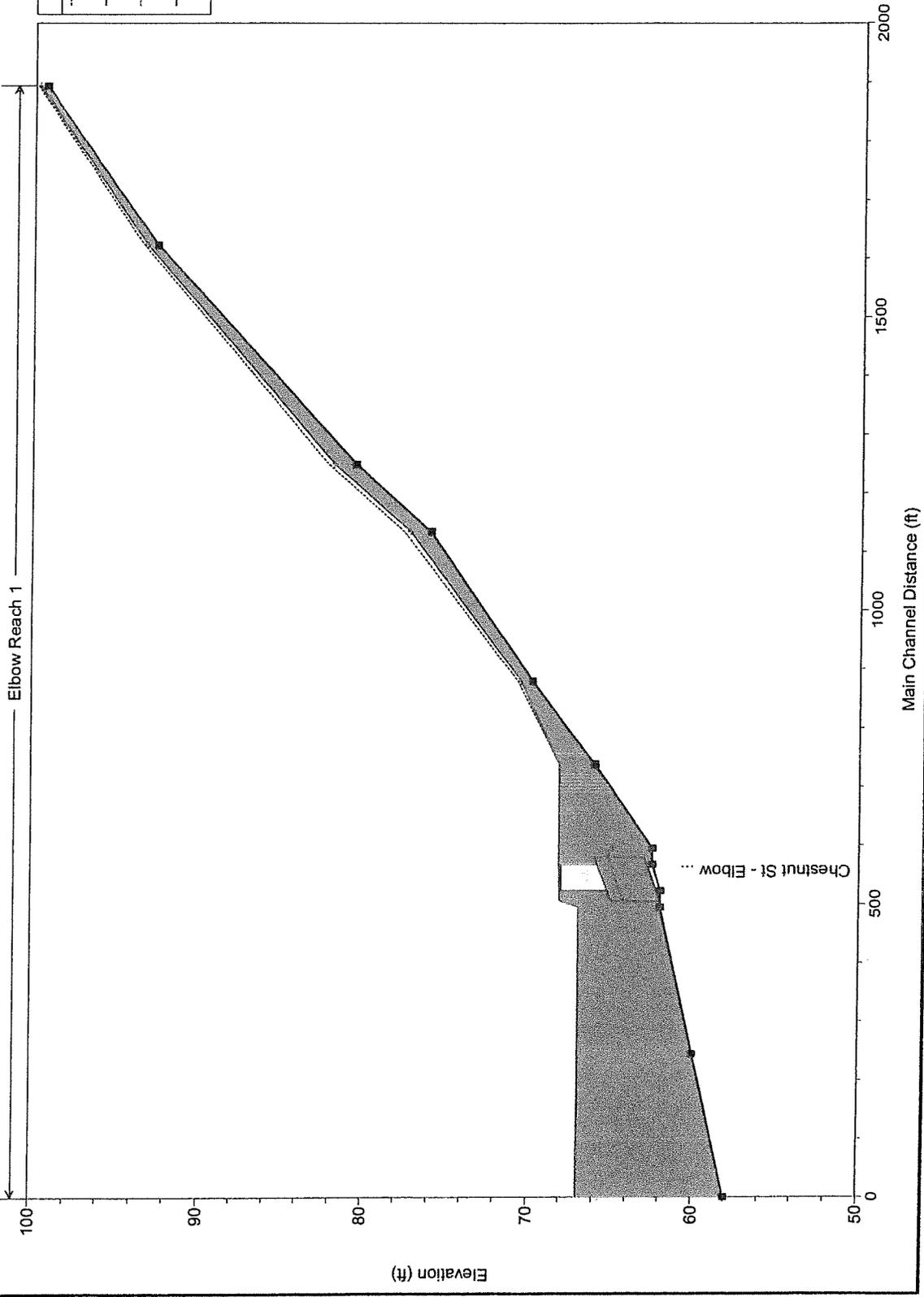
Geom: Existing Figure 15



Legend	
—	Crit PF 1
- - -	EG PF 1
—	WS PF 1
■	Ground

9611

Silver Creek Plan: Existing 100 Year
Geom: Existing Figure 17



Silver Creek Plan: Existing 100 Year
 Geom: Existing Figure 18

Silver Creek Salt Marsh

Legend	
EG PF 1	(Symbol)
WS PF 1	(Symbol)
Crit PF 1	(Symbol)
Ground	(Symbol)

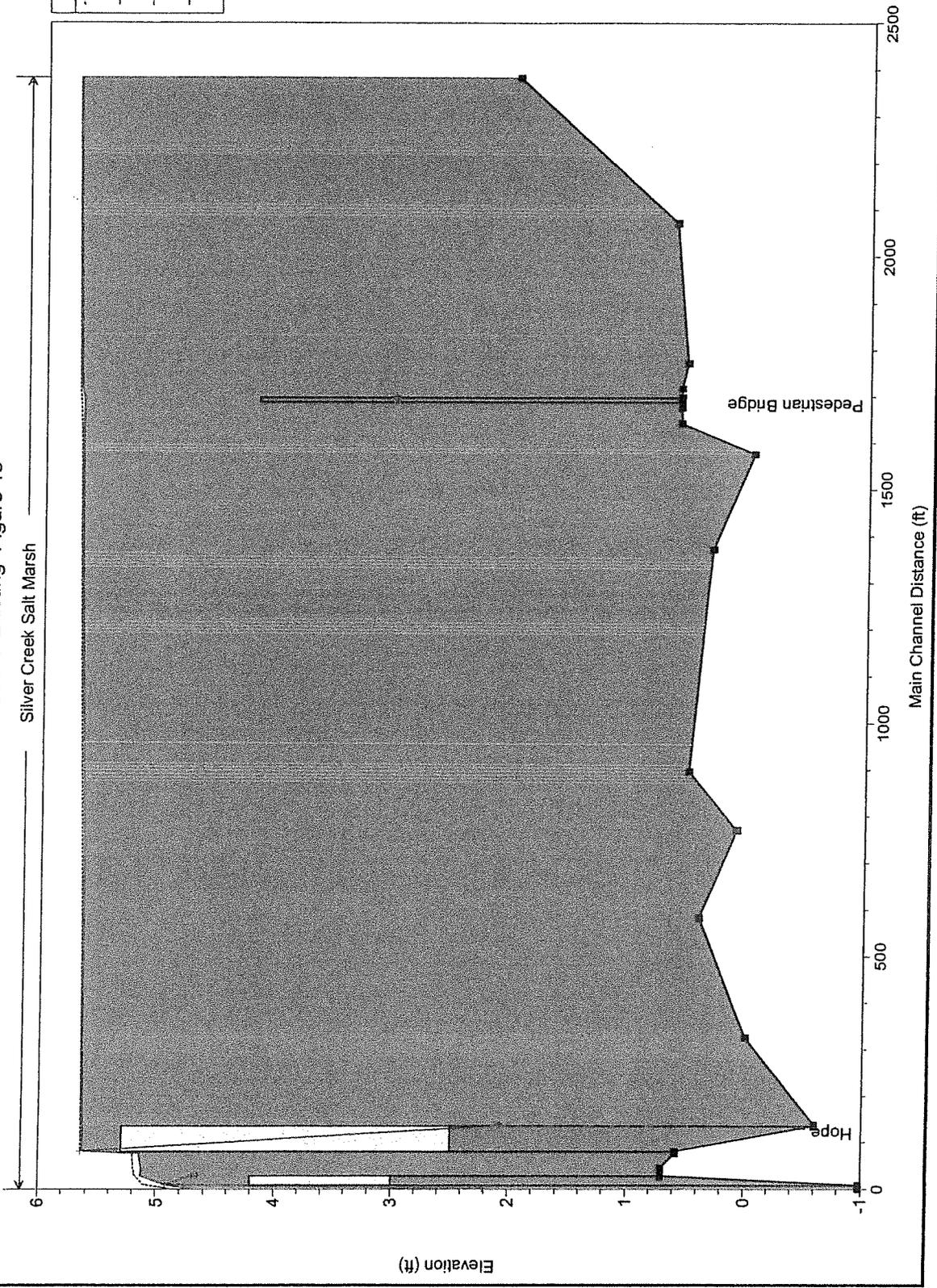


Table 2 Water Surface Elevations

Design Storm Event	Water Surface Elevations (Feet)			
	Bike Path (EL. 4.2)	Hope Street (EL. 5.3)	Marsh (Tidal)	Eastern Branch Between Gooding Ave and High School
2 Year No Tailwater	4.3	Does Not Overtop	4.6	60.4
2 Year Tailwater Condition	4.7	Does Not Overtop	5.0	60.4
10 Year No Tailwater	4.4	Does Not Overtop	5.2	63.0
10 Year Tailwater Condition	4.7	5.3	5.3	63.0
100 Year No Tailwater	5.1	5.6	5.7	67.0
100 Year Tailwater Condition	5.1	5.6	5.7	67.0

Sediment Removal from Marsh

DESCRIPTION

The model was used to determine what effect removing sediment from the marsh would have on the hydraulic capacity of the creek. The cross-sections through the marsh for the existing conditions were altered to represent removing 1 foot of sediment. The three design storms were simulated with a tailwater condition and without.

RESULTS

Two-Year Design Storm

As shown in Figure 19, the two year design storm without a tailwater condition does not overtop the bike path or Hope Street with the sediment removed. The level in the marsh does rise to 4.7 feet which is 0.10 feet above the existing condition elevation. The bike path is not acting as a weir and therefore less flow is being discharged and the elevation in the marsh rises. When the tailwater condition is simulated, the

Since the existing creek has the capacity to convey the two-year design storm, and this culvert would not be designed to convey the one hundred-year design storm, only the ten-year design storm was considered for this alternative. As previously stated, the tailwater condition at the outfall at Hope Street does not affect the creek this far upstream, and therefore was not taken into consideration.

RESULTS

Ten-Year Design Storm

The model was run while replacing the existing culverts with twin 6-foot wide by 4-foot deep box culverts. The feasibility of this option would have to be investigated in greater detail. As shown in Figure 24, increasing the culverts would decrease the water surface elevation between Gooding Avenue and the high school from 63.0 feet (existing) to 60.3 feet. This does not impact the creek downstream. The culvert through the cemetery south of Chestnut Street, assuming it is not damaged or collapsed, has an adequate capacity to the increased peak flow. The water surface continues to overtop Chestnut Street by 0.10 feet as it does in the existing model.

Diminished Capacity at Chestnut Street/Cemetery due to deteriorated pipe

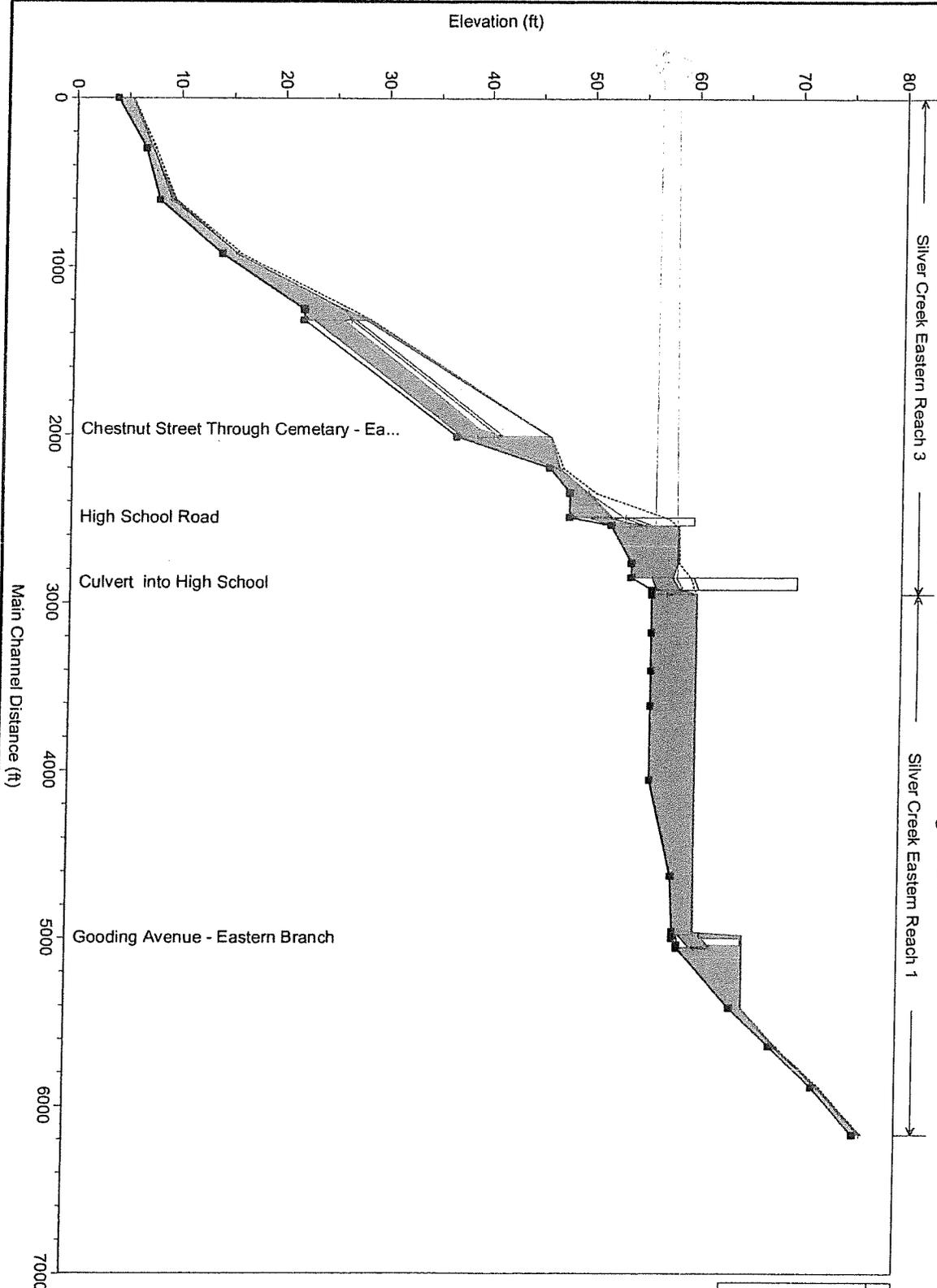
DESCRIPTION

There is a flooding problem along the Eastern branch of the creek downstream of Chestnut Street through the cemetery. There are many possible factors in this area to account for the flooding problems. Two 48-inch culverts flow from the northern side of Chestnut Street and discharge to one 48-inch pipe which then conveys flow through the cemetery. This area is a low point for about a 17 acre watershed that flows overland to the creek and is conveyed by a closed drainage system from Chestnut Street and Sherry Avenue. When the creek is surcharged the systems from Chestnut Street and Sherry Avenue can not discharge, so this area will flood and flow overland through the cemetery to the open channel portion of the creek south of the cemetery. Even if the creek is not surcharged, based on the topography of the area, if the basins on Sherry Avenue do not intercept all of the runoff generated in that area this runoff will continue to flow overland through the cemetery.

As stated previously, the HEC-RAS model is based on the assumption that the pipes and culverts are not damaged or collapsed and can physically convey their full capacity. Concerns about the condition of the 48-inch pipe which flows through the cemetery prompted the use of a camera to determine the condition

Silver Creek Plan: Increase High School Culvert 10 year

Geom: High School Culvert Figure 24



Legend	
—	Crt PF 1
...	EG PF 1
- - -	WS PF 1
■	Ground

of the pipe. The results of the television inspection revealed that the two-48" RCP culverts under Chestnut Street are at least one third full of debris and sediment, including large stones, and the bottom of the 48" corrugated metal pipe which runs through the cemetery pipe is extremely deteriorated, with the entire bottom of the pipe rotted away. The model was run with the 48-inch pipe being replaced with a 32-inch pipe to simulate the existing pipe being one third full of debris. Examination of the structure where the pipes are reduced from 2 -48" RCP to 1-48" CMP revealed that the brick cap originally constructed is intact despite the velocities through the drainage structure. Also noted by the Truax video inspection, there is a very large pile of sediment at the outfall south of the cemetery, as well as several trees which have fallen into the channel, indicating a lack of maintenance of the pipe and open channel.

RESULTS

Ten-Year Design Storm

The diminished capacity of the pipe due to the debris results in an increase in water surface elevation north of Chestnut Street of 0.10 feet. As shown in Table 3 and 4, the 48-inch culvert could convey approximately 154 cfs. When the pipe size is decreased to 32 inches, the conveyed flow is decreased to approximately 68 cfs. The condition of this pipe is a contributing factor to the flooding in this area.

HEC-RAS Plan: Existing 10 Yr River: Silver Creek Reach: Eastern Reach 3 Profile: PF 1 Table 3 48" Culvert Capacity 4947 Culvert 1

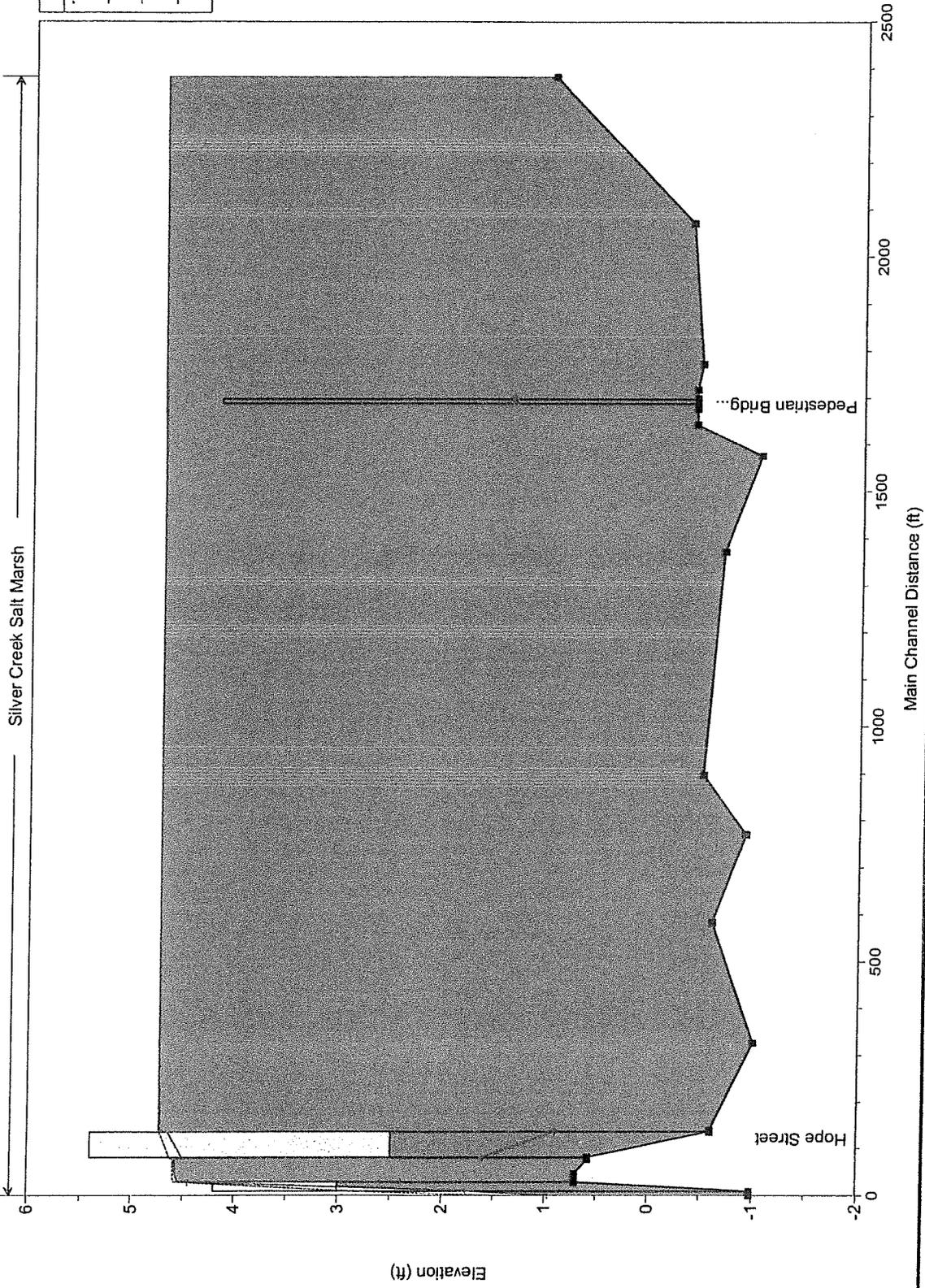
Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	E.G. IC (ft)	E.G. OC (ft)	Min El Weir Flow (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
Eastern Reach 3	5881 Culvert #1	PF 1	63.04	63.04	63.04	62.12	70.01	123.93		4.60	9.86	14.45
Eastern Reach 3	5881 Culvert #2	PF 1	63.04	63.04	63.04	62.12	70.01	123.93		4.60	9.86	14.45
Eastern Reach 3	5497 Culvert #1	PF 1	58.50	58.49	58.50	57.64	60.01	124.50		8.69	9.91	18.51
Eastern Reach 3	5497 Culvert #2	PF 1	58.50	58.49	58.50	57.64	60.01	124.50		8.69	9.91	18.51
Eastern Reach 3	4947 Culvert #1	PF 1	46.13	46.13	46.13	44.21	46.01	154.16	97.35	20.13	12.27	16.11

HEC-RAS Plan: Existing 10 Yr River: Silver Creek Reach: Eastern Reach 3 Profile: PF 1 Table 4 32" Culvert Capacity 4947 Culvert 1

Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	E.G. IC (ft)	E.G. OC (ft)	Min El Weir Flow (ft)	Q Culv Group (cfs)	Q Weir (cfs)	Delta WS (ft)	Culv Vel US (ft/s)	Culv Vel DS (ft/s)
Eastern Reach 3	5881 Culvert #1	PF 1	63.04	63.04	63.04	62.12	70.01	123.93		4.60	9.86	14.45
Eastern Reach 3	5881 Culvert #2	PF 1	63.04	63.04	63.04	62.12	70.01	123.93		4.60	9.86	14.45
Eastern Reach 3	5497 Culvert #1	PF 1	58.50	58.49	58.50	57.64	60.01	124.50		8.69	9.91	18.51
Eastern Reach 3	5497 Culvert #2	PF 1	58.50	58.49	58.50	57.64	60.01	124.50		8.69	9.91	18.51
Eastern Reach 3	4947 Culvert #1	PF 1	46.19	46.19	46.19	46.19	46.01	67.45	182.04	20.19	12.05	12.05

Silver Creek

Geom: Marsh Sediment Removal Flow: 2 Year - No Tailwater Figure 19



Legend

EG PF 1

WS PF 1

Crit PF 1

Ground

water surface level in the marsh is 0.10 feet lower than the existing condition, setting the elevation at 4.9 as opposed to 5.0 feet. As shown in Figure 20, the bike path bridge does flood.

Ten-Year Design Storm

As shown in Figure 21, the ten-year design storm without a tailwater condition does not overtop the bike path or Hope Street with the sediment removed. The level in the marsh does rise to 5.25 feet which is 0.05 feet above the existing condition elevation. When the tailwater condition is simulated, neither the bike path nor Hope Street are overtopped and therefore neither structure acts as a weir and the culverts are restrictions. This causes the water surface elevation in the marsh to rise to 5.74 feet which is 0.44 feet higher than the existing conditions. So Hope Street will not flood, but the level in the marsh will rise for a short period of time. This is also illustrated in Figure 22.

One Hundred-Year Design Storm

As shown in Figure 23, the flow from the one hundred-year design storm overtops the bike path and Hope Street. The water surface elevations are the same regardless of whether a tailwater condition was simulated. The elevation throughout the marsh is 6.07 feet which is 0.37 feet above the existing condition

Removing 1 foot of sediment from the marsh relieves the flooding at the bike path and Hope Street for the ten-year storm event. Hope Street floods under the existing condition for a ten-year design storm with the tailwater condition. Dredging the marsh allows for more storage and Hope Street does not appear to flood for these same conditions.

Increase Capacity of High School Culverts

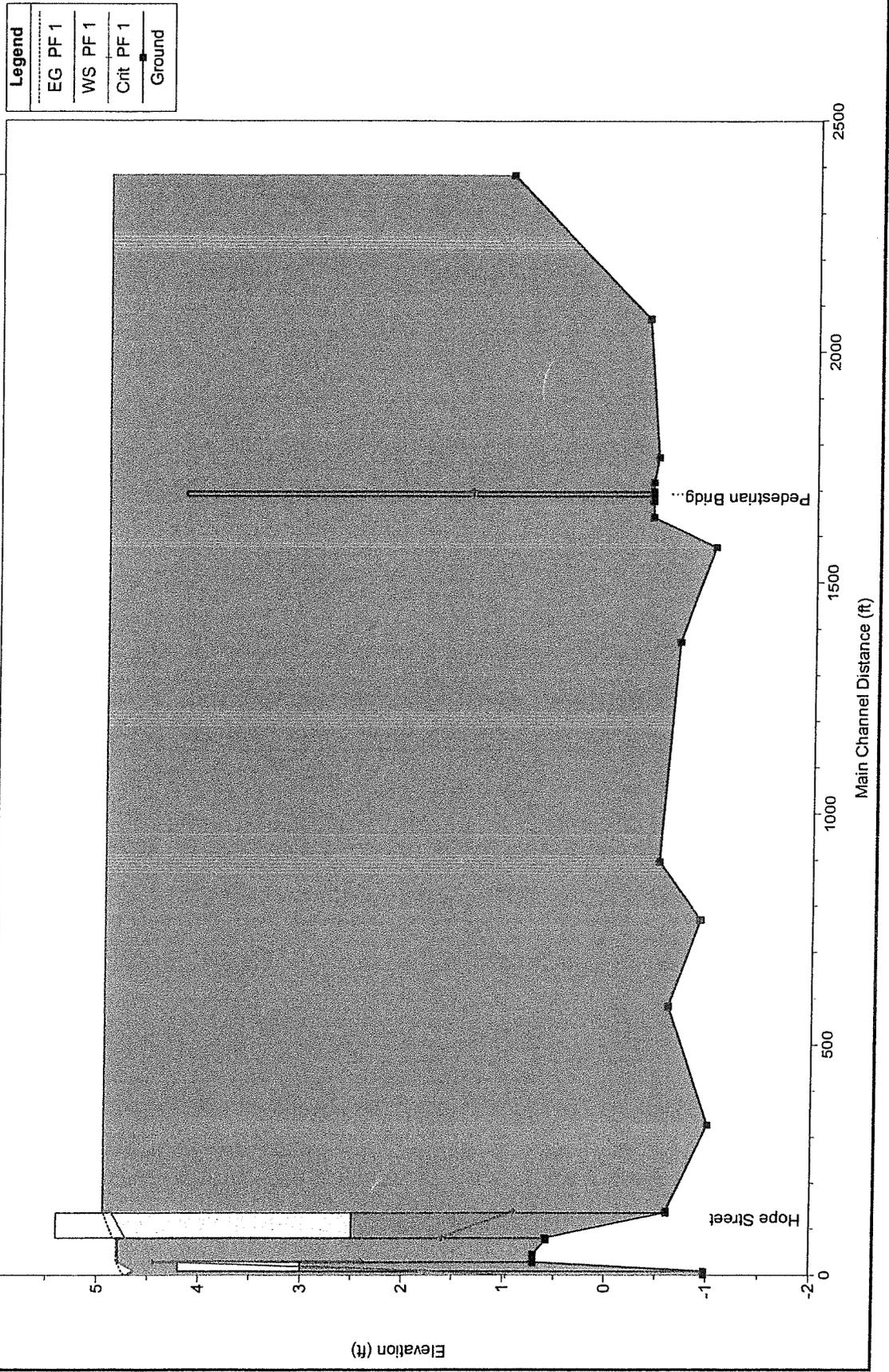
DESCRIPTION

The model was used to determine what effect increasing the capacity of the culverts through the high school would have on the hydraulic characteristics of the creek in this area. Only the size of the twin 48" culverts was altered from the existing condition model. The model shows that the existing culverts are the restriction in the upstream portion of the eastern branch of the creek. Some of the flooding between Gooding Avenue and the high school could be relieved by increasing the size of the existing culverts. Once the size was increased, the impacts downstream were examined. Residents from the Town have stated that there is a flooding problem through the cemetery south of the high school and Chestnut Street.

Silver Creek

Geom: Marsh Sediment Removal Flow: 2 Year - With Tailwater Figure 20

Silver Creek Salt Marsh

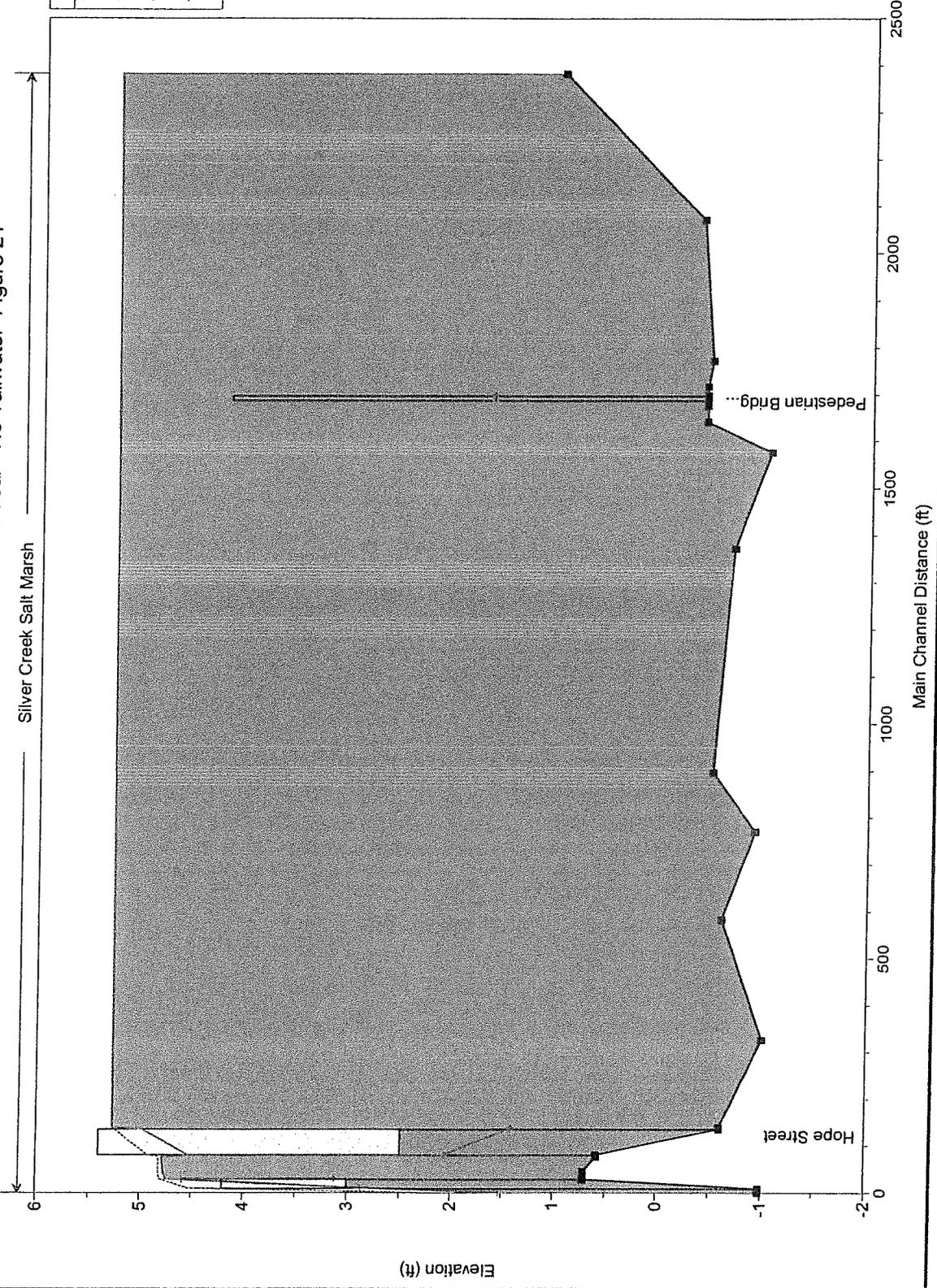


Silver Creek

Geom: Marsh Sediment Removal Flow: 10 Year - No Tailwater Figure 21

Silver Creek Salt Marsh

Legend	
EG PF 1
WS PF 1	-----
Crit PF 1
Ground	—●—

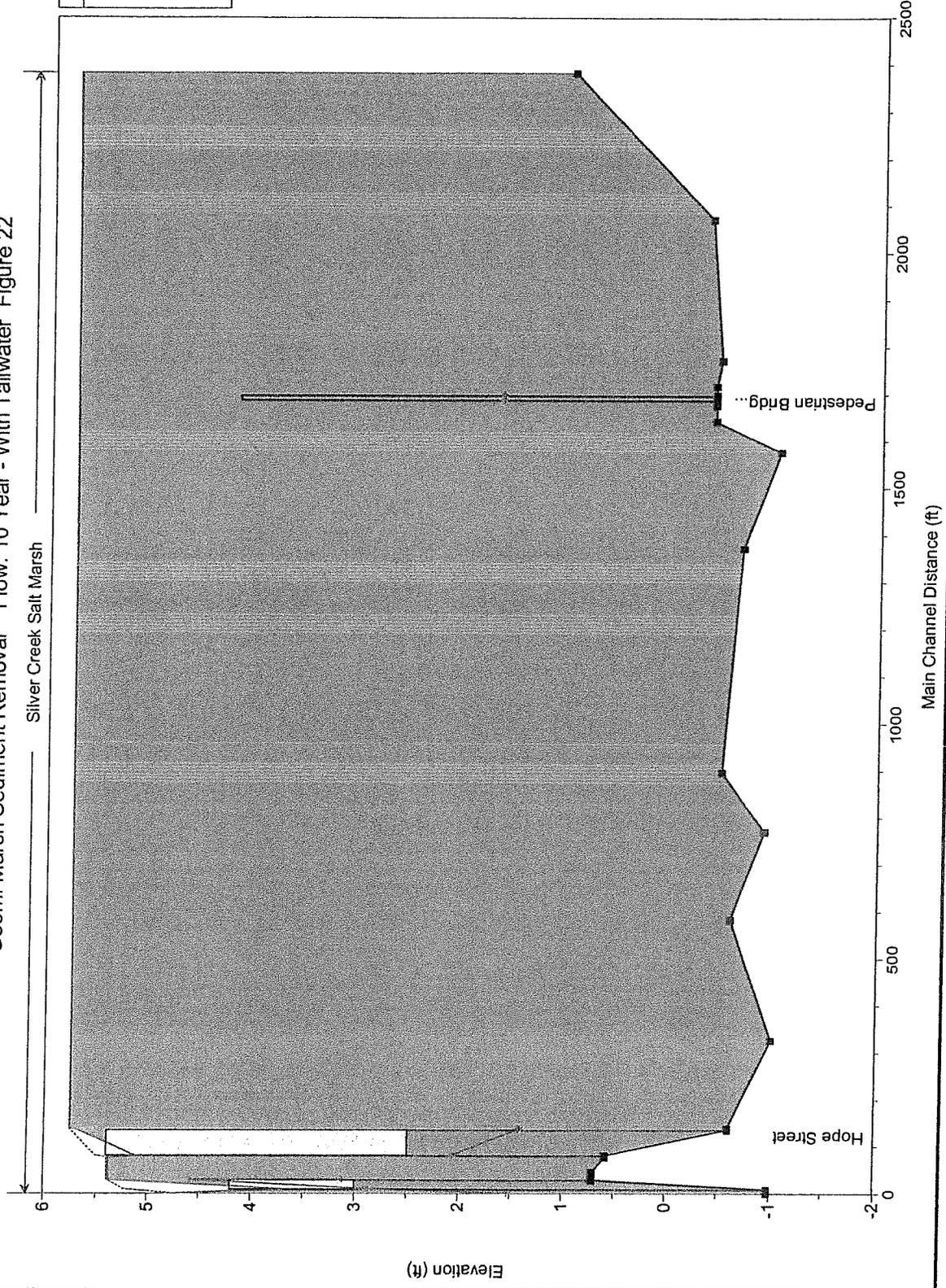


Silver Creek

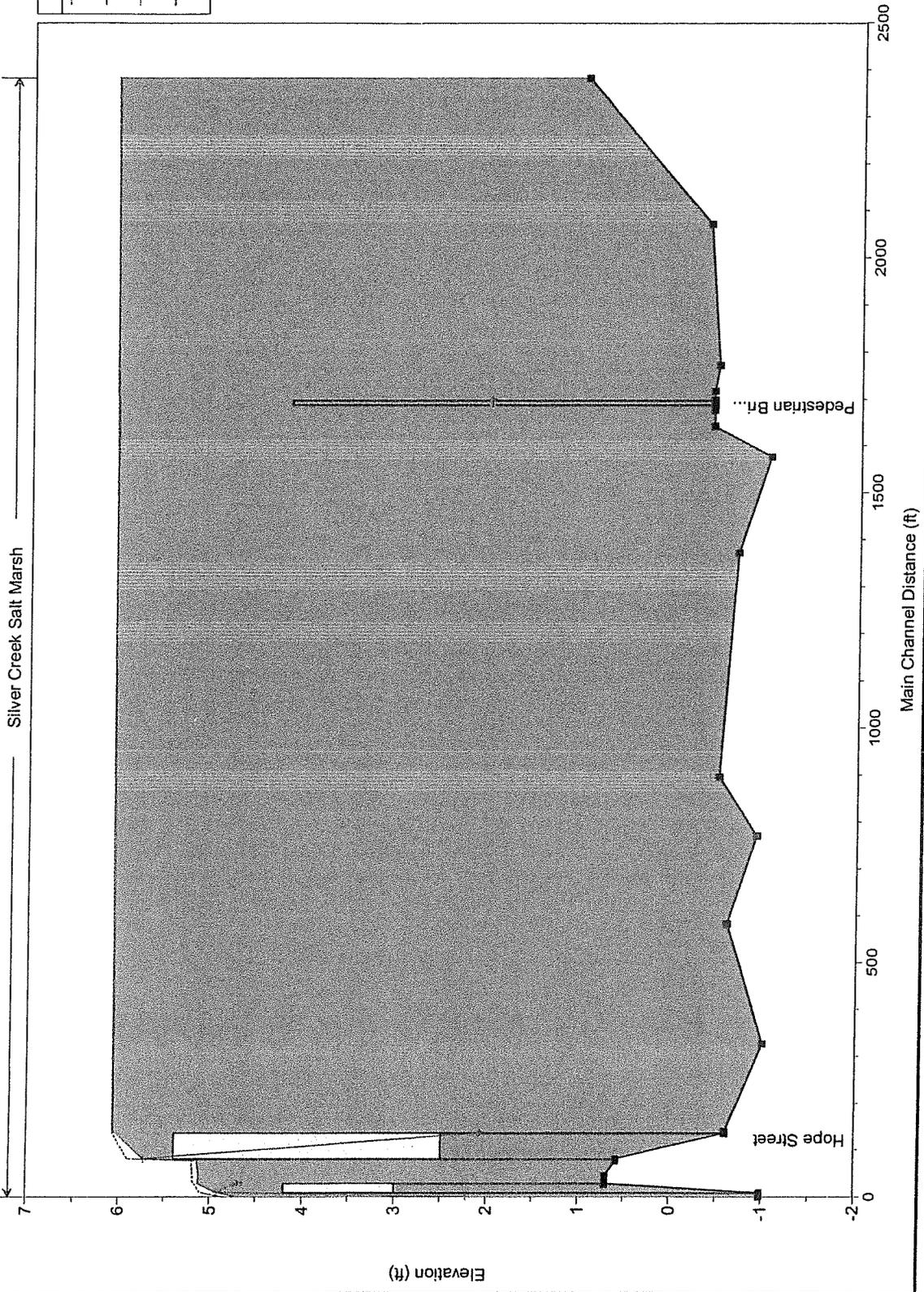
Geom: Marsh Sediment Removal Flow: 10 Year - With Tailwater Figure 22

Silver Creek Salt Marsh

Legend	
EG PF 1
WS PF 1	-----
Crit PF 1	-----
Ground	■



Silver Creek Plan: Sediment Removal 100 year
 Geom: Marsh Sediment Removal Figure 23



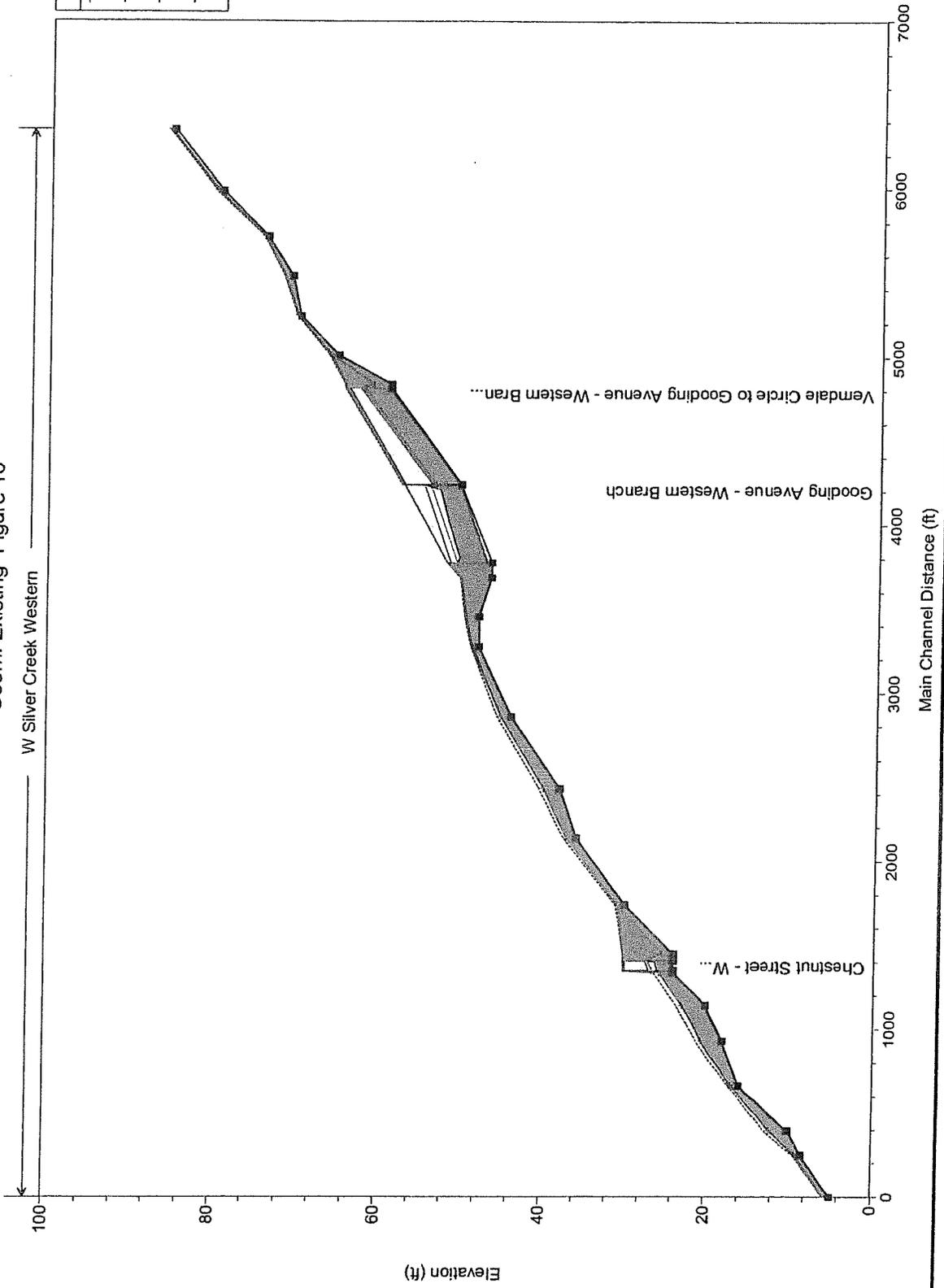
Legend	
EG PF 1	(Symbol)
WS PF 1	(Symbol)
Crit PF 1	(Symbol)
Ground	(Symbol)

Silver Creek Plan: Existing 100 Year

Geom: Existing Figure 16

W Silver Creek Western

Legend	
—	Crit PF 1
- - -	EG PF 1
—	WS PF 1
■	Ground



Problem Areas

Both the Hydrocad analysis and the HEC-RAS model identified several areas of particular concern, where the yields exceeded the existing pipe capacities and the areas require extensive attention. While these six (6) areas are by no means the only areas with flooding problems within the watershed, they have been identified as those most problematic, both from an analytical point as well as what was discussed at the Public Meeting.

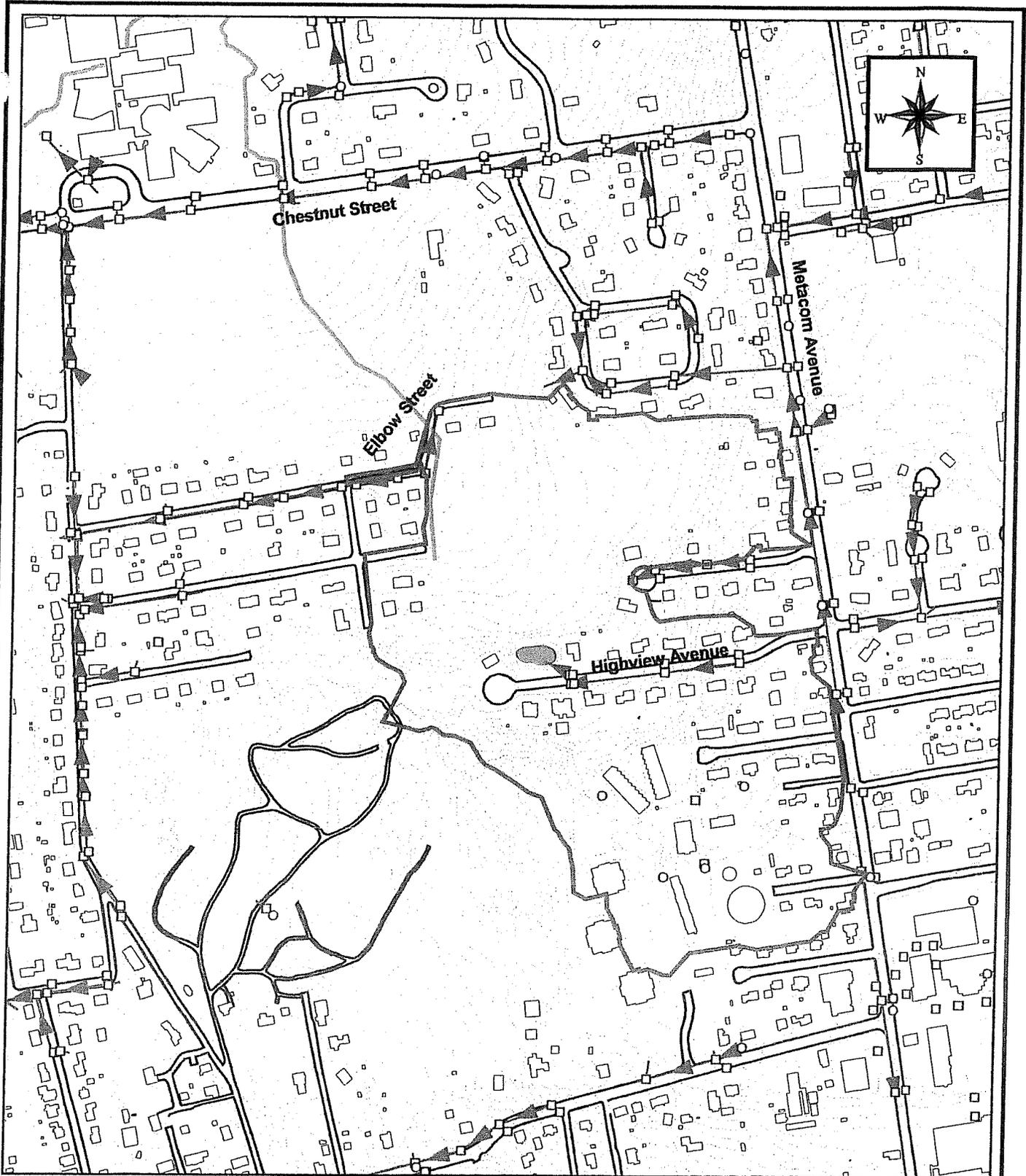
Area 1 – Elbow Street/Waterman Avenue

Existing Conditions

Elbow Street is an extension of Waterman Avenue, located east of Sherry Avenue. As shown in Figure 25, this 44-acre subwatershed area receives runoff from the south and east of Elbow Street, from Jane Lane, Highview Drive, Francesca Lane, Kennedy Court, Carr Lane and a portion of Hattie Brown Lane and King Street. A small detention pond was constructed at the end of Highview Drive. The pond was originally designed to retain the increase in runoff from the new subdivision only, and was not designed to detain the flows it is receiving from other areas upstream. This detention pond is discussed further in Area 4 – Highview Drive.



That issue aside, the runoff from the pond and other overland flow is directed to Elbow Street in a drainage channel, or as an intermittent stream, where it was designed to flow under Elbow Street to a wetland area north and west of the roadway. However, the existing 12" CMP under Elbow Street is crushed or collapsed, according to a report by Caputo and Wick, further reducing the capacity. The roadway is flat in this area, with a low point near the culvert. The stormwater runoff tops the roadway and flows across the pavement, as shown in the photographs.



Legend

-  Existing Drain Pipes
-  Problem Area
-  Watershed

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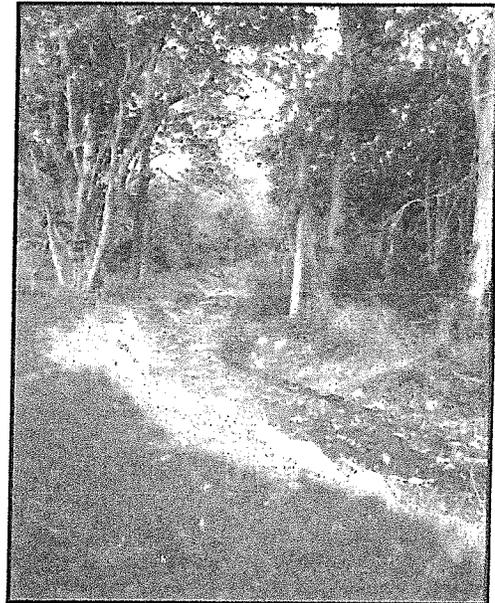
Figure 25
Elbow Street/
Waterman Avenue

Inspection of the basins on Elbow Street revealed that there was silt and water in most of the structures. Our calculations show that the flow to this area in the 2-year storm is approximately 30 cfs, and 60 cfs for the 10-year storm. The collapsed pipe results in the stormwater overtopping the pavement and entering the wetland via a swale along the northwesterly side of the road. It should be noted here that information from the Caputo and Wick report was used in our calculations as the pipe and invert information was not available due to sediments in the structures.

The Town has recently advertised and awarded a contract to replace the existing 12" CMP pipe with a new 18" HDPE pipe and a new flared end section to capture the intermittent stream flowing from south to north. It is anticipated that this work will be completed in the Fall 2007. This pipe will increase the capacity and provide improvement during minor storm events. However, our calculations show that this area will remain subject to flooding during major storms without additional improvements.

Recommended Improvements

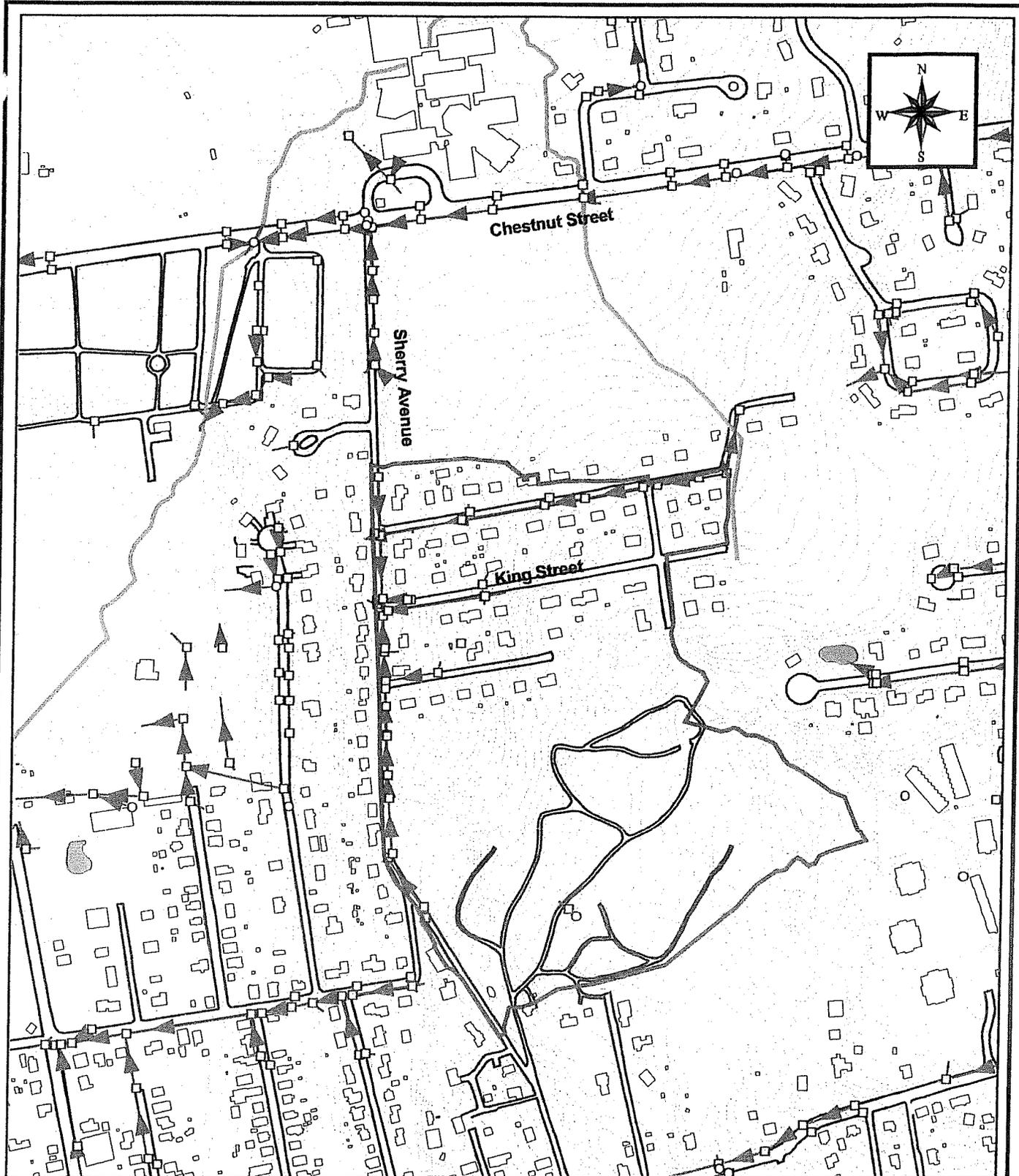
Because of the large rate of runoff generated from the areas east of Elbow Street, it is suggested that the Town attempt to identify possible property available for stormwater retention. Enlarging the existing detention pond on Highview Drive may alleviate some of the flooding downstream. Although the plans call for the existing 12" pipe to be replaced with an 18" HDPE pipe, our calculations indicate that 25 cfs is currently flowing across the pavement, and would require the capacity of a 30" pipe. This project should be considered a long-term goal as part of a complex upgrade of the drainage pipes from Elbow Street to Chestnut Street and through the cemetery.



Area 2 – Sherry Avenue

Existing Conditions

Sherry Avenue is a north-south roadway which provides an alternate route to Wood Street and the downtown area from Chestnut Street (See Figure 26). Located opposite Mount Hope High School, it borders the Saint Mary Cemetery to the west, and town-owned land to the north. The remaining length of the roadway, from Silver Creek Court south is residential. There is a closed drainage system in Sherry



Legend

-  Existing Drain Pipes
-  Problem Area Watershed

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Figure 26

Sherry Avenue

Avenue, with approximately 500 feet of the roadway draining toward Chestnut Street. The remaining roadway collects flows from the closed drainage systems in King Street and Lugent Lane, and conveys the flow to Varnum Street via a 16" corrugated metal pipe in a prescriptive easement area. However, our calculations indicate that these pipes are undersized and the drainage



structures are ineffective in collecting the runoff, resulting in overtopping of Sherry Avenue flooding local properties and Varnum Avenue to the west. The existing outfall, west of Varnum Avenue, flows to a stone swale, which in turn flows through a manmade pond on the DaPonte property. Although it appears that the Elbow Street and Waterman Street drainage system would be connected to the closed drainage system in Sherry Avenue, because of the crushed pipe under Elbow Street, and pipes with negative slopes, our analysis shows that minimal (if any) runoff from Elbow Street reaches Sherry Avenue, and therefore, the 44-acre subwatershed area was analyzed separately using Hydraflow.

Our field inspections revealed that 21 of the drainage structures were filled with sediment, and one structure was filled with water. Many of the pipes do not have sufficient capacity to convey the 2-year storm. The result is that the stormwater runoff floods Sherry Avenue, and then runs down the hill to Varnum Avenue, and through private property before entering the east branch of the Silver Creek.

The photos illustrate the private pond on Mr. Seraphin DaPonte's property, under dry conditions and flooded conditions.



Proposed Improvements

It is recommended that the existing closed drainage system on Sherry Avenue be replaced with a new closed drainage system consisting of RCP and new precast concrete structures with oversized sumps. The existing 16" outfall pipe should be replaced with a 30" RCP to provide sufficient capacity in a 10-year storm to safely convey the runoff from Sherry Avenue through the existing easement area to the discharge point. A new BMP (i.e. Vortechs or similar structure) is recommended prior to the cross-country run to remove sediments. Although it would appear that we are increasing the flow to this outfall, the increase in runoff should be negligible as the flows currently reach this point via overland (flooded) flow, due to the steepness of the properties and the well-manicured lawns. The proposed state would result in reduced flooding of private property as well as reduced erosion and removal of sediment. In addition to the 450 linear feet of 30" RCP, approximately 570 LF of 24" RCP and 1,050 LF of 18" RCP would replace the existing undersized pipes in Sherry Avenue and intersecting sidestreets. The remaining 300 LF of 12" corrugated pipe would be replaced with 12" RCP at slopes sufficient to increase the capacity to accommodate the 10 year storm. New structures and grates would provide sufficient storage for sediments while reducing the depth of stormwater on the roadway surfaces. The outfall would be located so as to pose no flooding to private property, with discharge to the open waters of the Silver Creek.

It is also recommended that additional storage be provided within this subwatershed area to reduce the rate and volume of water flowing downstream toward the Silver Creek. Possible areas include the town-owned land east of Sherry Avenue, and land west of Varnum Street. This land, since it currently is not town-owned, would need to be purchased for this purpose.

We have reviewed the conceptual design to place two 48" pipes within the existing Right-of-Way from Lugent Lane to Chestnut Street, with a control structure to be constructed in Chestnut Street to restrict the flow and use the 48" pipes as storage. BETA believes this design would be more costly and would require additional maintenance. In addition to the costs and maintenance issues, sending more water to the Chestnut Street system even at a reduced rate, would increase the volume of water in this already over-capacity system, resulting in greater flows as the longer peaks from the Sherry Avenue system would coincide with the peak flows coming from the High School.

Area 3 – Perry Street

Existing Conditions

As shown in Figure 27, Perry Street receives runoff from approximately 28 acres, extending from Sherry Avenue to Monroe Avenue. The grades are extremely steep (in excess of 7%), with no curbing or berm to contain the runoff within the roadway, resulting in flooding and erosion of abutting properties. The closed drainage system is ineffective with grates incapable of intercepting but a fraction of the existing gutter flow. The pipes seem to be an older system that has been modified over the years, with larger pipes being added to smaller pipes downstream, creating restrictions and surcharging basins. Pipe materials include 6" asbestos cement (AC) pipe, 24" RCP, 15" CMP, 4" cast iron pipe, and 10" vitrified clay (VC) pipe. In one instance, the capacity of a pipe is approximately 2 cfs, although the runoff is in excess of 28 cfs.

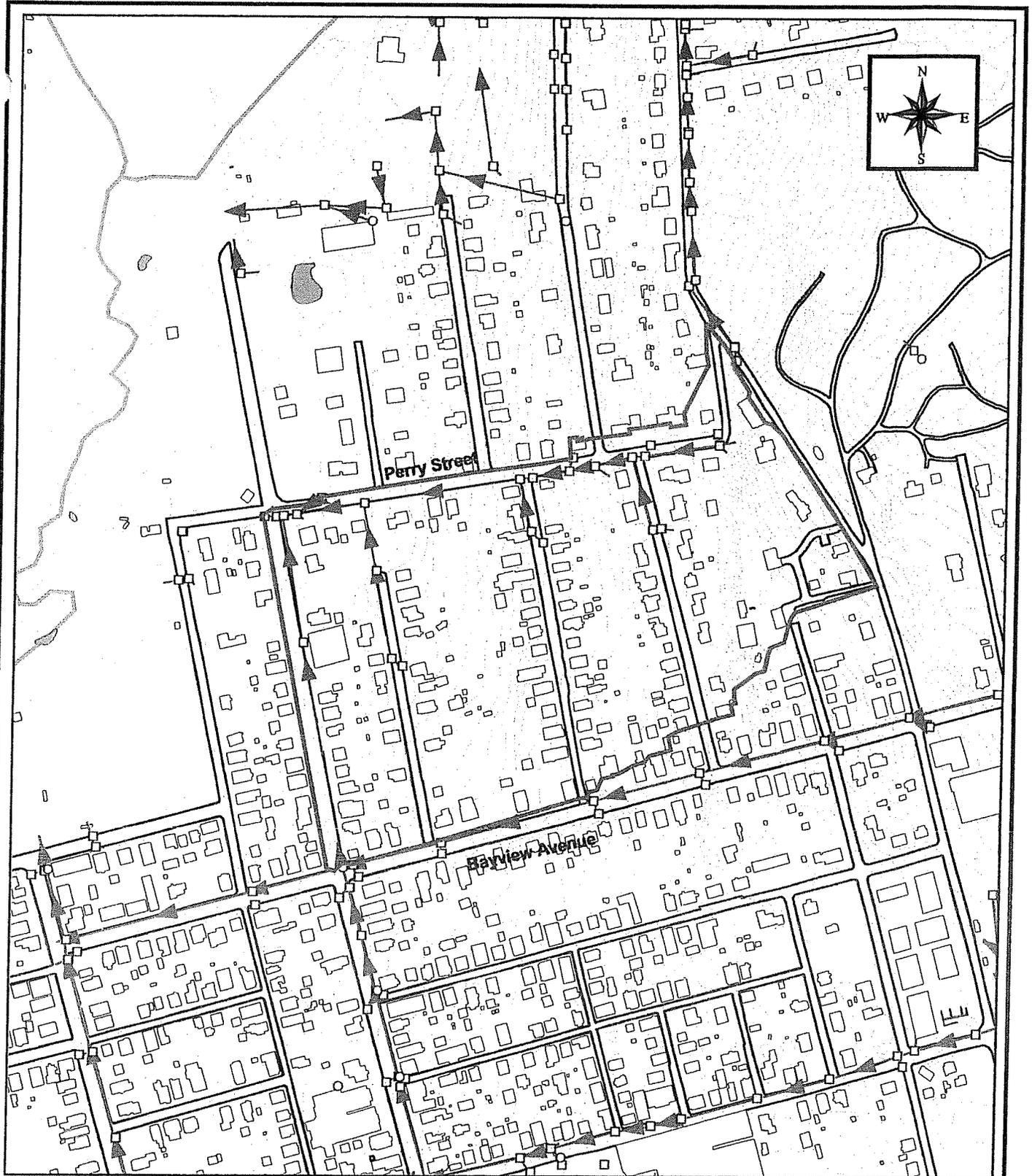
Proposed Improvements

It is recommended that a new trunkline be installed on Perry Street, gradually increasing in size from an 18" pipe to the east, to a 30" RCP near the outfall at Monroe Avenue. The lateral pipes would be replaced, requiring 180 LF of 24" RCP, 770 LF of 18" RCP, and 300 LF of 12" RCP. New structures would be proposed incorporating high-capacity double grates where warranted on the steep grades and at low points. Bituminous berm or curbing is recommended along both sides of the roadway to channelize the flows and prevent flooding of adjacent properties. Catch basins would be located upstream of all intersections and crosswalks to minimize localized flooding. High capacity grates are needed to catch the flow, reducing the splash-over velocity due to the steepness of the roadway. As this is a residential area in close proximity to schools, an alternate grate to the RI standard high capacity grate could be selected which would not create a trip hazard.

Area 4 – Highview Drive

Existing Conditions

Highview Drive is located off Metacom Avenue south of Chestnut Street (See Figure 28). This area has been mentioned as requiring improvements. The existing drainage system in Highview Drive includes a closed drainage system which is connected to the swale from Kennedy Lane and Carr Lane. Our data collection program revealed that 7 of the 8 structures on Highview Drive contained silt, and one structure surcharges during storm events. The existing system was analyzed using Hydraflow and this activity was reproduced in the model. The open channel flow from Carr Lane enters the closed drainage system via an 18" HDPE flared end section, with the connecting pipe at a 5% slope. This water rushes into the



Legend

-  Existing Drain Pipes
-  Problem Area Watershed

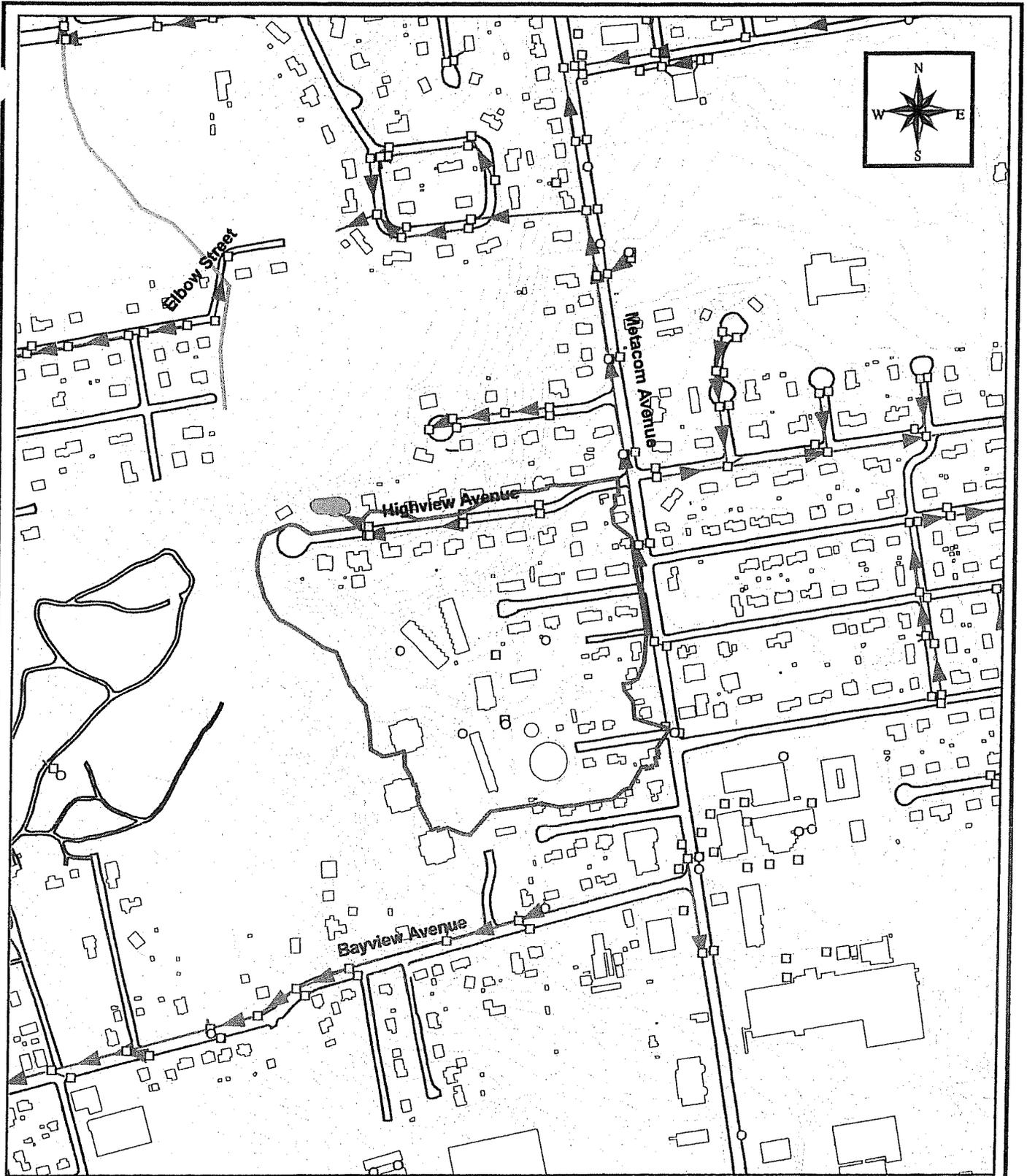
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Figure 27

Perry Street



Legend

-  Existing Drain Pipes
-  Problem Area Watershed

**Town of Bristol
Rhode Island**

Silver Creek
NOT TO SCALE

Figure 28

Highview Avenue

closed drainage system increasing the hydraulic grade line and surcharging the system. One pipe is under capacity for the 2 and 10 year storms, while two pipes are under capacity for the 10 year storms.

A detention pond exists at the end of Highview Drive and there have been some misconceptions about the pond including that the pond is not operating properly, and modifications have been performed on the northern wall of the pond. The pond has not been properly maintained, and the overgrown vegetation obstructed the inspection of the northern wall of the basin. The basin was cleaned by the Town during the week of July 16, 2007, removing accumulated silts and vegetation from the interior of the basin. Although it was first thought to have been modified, and not effective in the retention of runoff from this closed drainage system, a visual inspection of the basin revealed that it has not been modified by man; however, approximately 24" caliper trees are growing inside the detention pond. These trees are removing a portion of the storage volume.

An assessment of the design calculations, including a review of the inlet and outlet structures, indicates that in the original design, the pond was sized to mitigate the increase in runoff, but was not sized to hold the total volume of runoff which flows into the structure during the 2, 10 and 50 year storms. The runoff from the areas south of the detention pond was designed to pass through the detention pond. BETA analyzed the basin and the calculations and determined that the decrease in storage volume results in the pond overtopping, flooding out downstream properties (Elbow Street). A more detailed review of the basin, including a survey of the existing contours and inlet and outlet structures, would reveal the extent of the decrease in storage volume from the trees.

Proposed Improvements

It is recommended that the velocity of the flow from Carr Lane be reduced by increasing the pipe diameter and reducing the slope of the pipe from 5% to 1.25%. Other minor modifications include increasing one pipe from a 12" CMP to an 18" RCP, and changing the slope of a 24" pipe to increase the capacity.

As noted in the discussion of Elbow Street, it is recommended that the detention pond be reviewed to see if the size can be increased to retain or detain the volume of water which is directed to it from areas to the south. This will have a positive impact on properties downstream.

Area 5 – Jane Lane

Existing Conditions

As shown in Figure 29, Jane Lane is a looped roadway servicing approximately 20 homes off of Chestnut Street. The closed drainage system in Jane Lane is connected to the drainage system in Metacom Avenue (a State highway) via an 18" corrugated metal pipe. The flows from Metacom Avenue exceeds the pipe capacity for the 10 year storm by approximately 10%, yet the pipes in Jane Lane and connecting to Chestnut Street are insufficient to handle the 2 year storm, causing flooding within the subdivision. Also, our field inspections noted sump pumps connected to the catch basins with algae growth, indicating a chronic problem.

Proposed Improvements

It is recommended that the pipes from Metacom Avenue be video-inspected to identify possible collapse of the CMP. It is recommended that the 18" CMP be replaced with an 18" RCP, which would provide increased capacity and structural soundness. Other pipes within the roadway should be upgraded to 18" RCP, and the outlet pipe discharging to the wetland east of Elbow Street should be a 24" RCP. These improvements should alleviate the flooding in this immediate area.

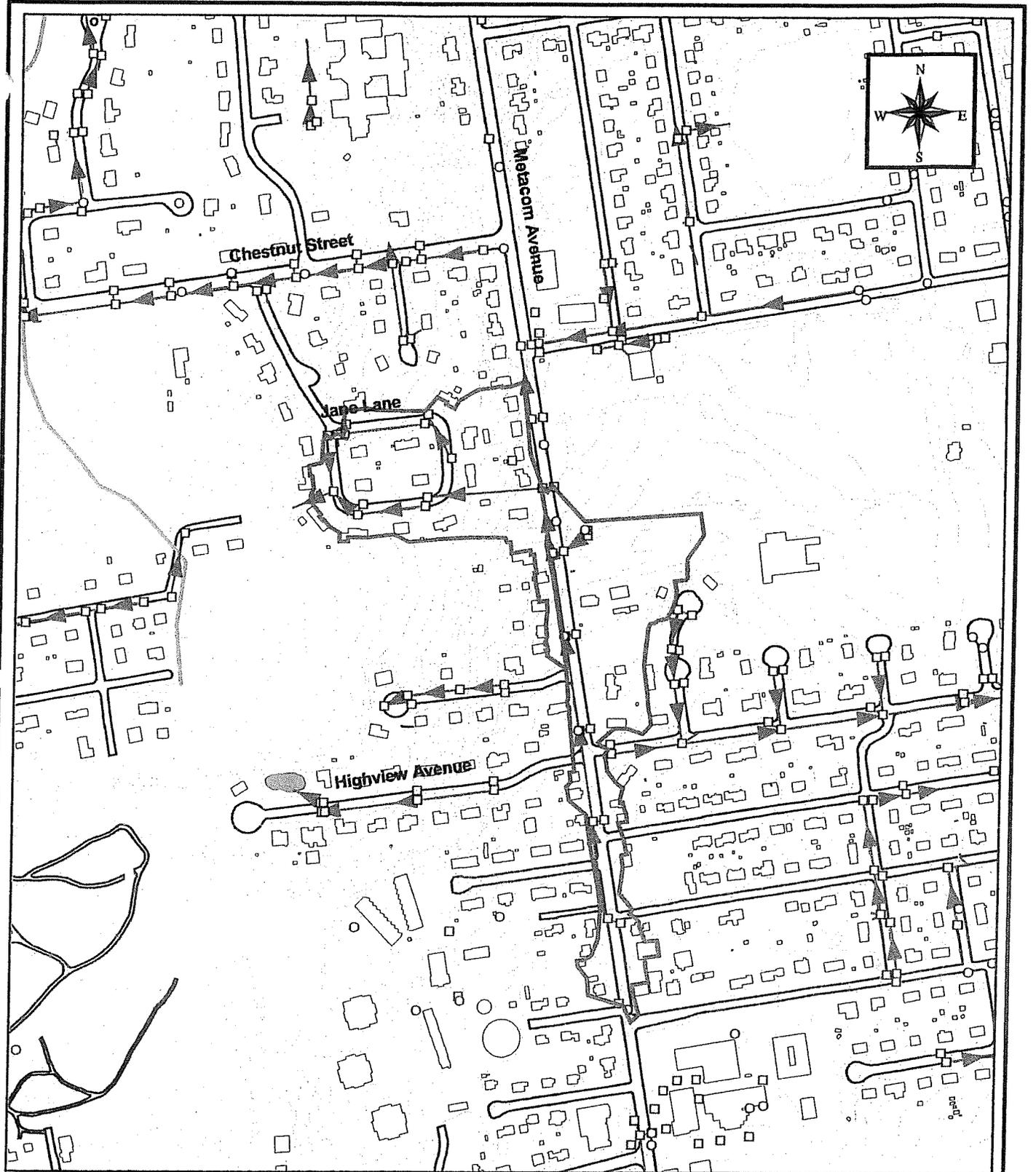
Area 6 – Paull Street/Hillside Road

Existing Conditions

This area is different from the other areas in that it is located adjacent to the Silver Creek wetlands area, and is located within an "AE Zone" as shown on the Flood Insurance Rate Map (RIRM) No. 44001C0014G. The roadways are located within a Special Flood Hazard Area, commonly referred to as the 100-year floodplain. As shown in Figure 30, there is an existing closed drainage system within the roadways consisting of approximately eight (8) catch basins, with several pipes undersized for the 2-year storm. Several of the basins are filled with silt, resulting in roadway flooding. Also, during storms, the Silver Creek and associated wetlands encroaches on the yards of the properties along Paull Street, particularly during periods of high tide when the water cannot flow out to the harbor.

Proposed Improvements

Cleaning and/or upgrading the pipes and catch basins within the roadways will reduce the roadway flooding somewhat, however, in order to alleviate the flooding from the east, additional flood storage area must be created either through dredging of the creek and marsh areas, or by constructing large retention areas in the upper reaches of the watershed.



Legend

-  Existing Drain Pipes
-  Problem Area Watershed

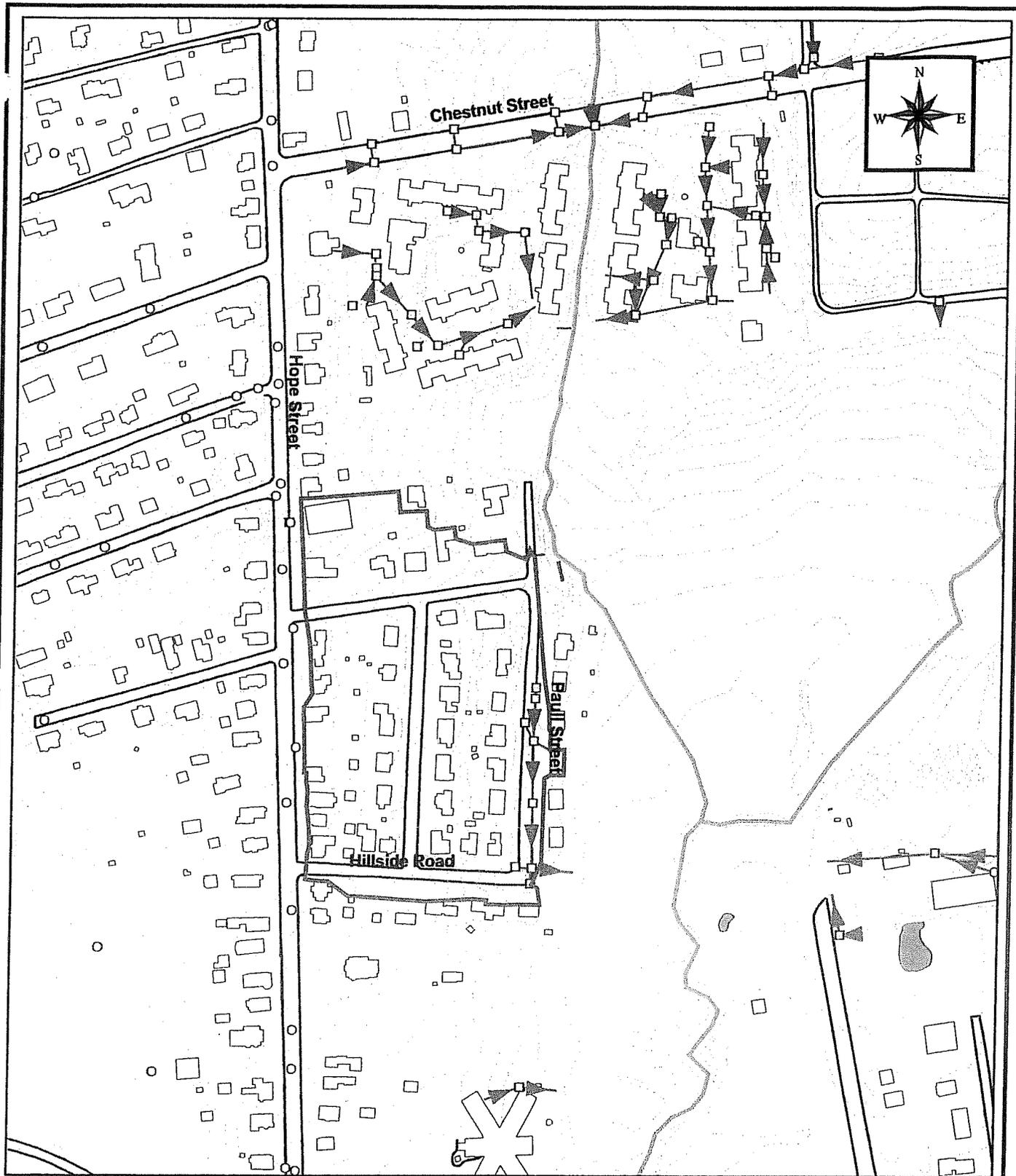
**Town of Bristol
Rhode Island**

Silver Creek

NOT TO SCALE

Figure 29

Jane Lane



Legend

-  Existing Drain Pipes
-  Problem Area Watershed

**Town of Bristol
Rhode Island**

Silver Creek
NOT TO SCALE

Figure 30
Paull Street/
Hillside Road

Additional Problem Areas

At the October 17 workshop, a resident from the area north of Perry Street, and west of Varnum Street noted a problem that had not previously been identified: This area is at the base of a very steep grade. Several of the roadways do not have catch basins in them, and the runoff flows down the hill via private property, at a high velocity. When the runoff reaches the bottom of the hill, where the ground is relatively flat prior to entering the creek, water accumulates and ponds in the roadway and on lawns. A review of the plans and a site visit resulted in the recommendation of placing new pipes and catch basins within the roadways, including Varnum Street, Baker Street and Jones Street. These pipes could be tied into the upgraded system proposed for Perry Street, as described in the report.

Silver Creek

Proposed Improvements

As the study progressed, it became increasingly clear that the solutions to reducing flooding associated with the Silver Creek would be complex. The 1,250 acre watershed was separated into 45 subwatershed areas for purposes of analysis, and the aerial mapping provided contour data to enable us to develop approximate cross sections of the creek from the outlet at Hope Street, up to the farthest reaches of the stream channels south of Tupelo Street. The storm water model identified areas where the open channel overtops roadways such as Gooding Avenue, Chestnut Street, and Hope Street near Washington Street. These restrictions upstream create localized flooding, however, if the restrictions were removed, downstream neighborhoods would receive stormwater runoff at a much quicker rate, increasing flooding associated with the tides and expanding the flood zones farther into the neighborhoods.

It is recommended that additional storage be constructed, ^{Increase Storage} particularly upstream of the local areas currently experiencing flooding, and on other vacant land, to retain stormwater runoff until the peak flows have safely passed and/or until the high tide period has passed. Possible locations include along Gooding Avenue, Naomi Street, within the Mount Hope High School campus, or within the Benjamin Church property. Enlarging existing detention ponds should also be considered at locations where it has been determined that doing so would reduce downstream flows.

Another means of increasing flood storage throughout the watershed is to remove and properly dispose of materials that have been dumped in wooded areas near outfalls. While signs are posted at several

locations where roadways dead-end near the stream and associated wetlands, this illegal activity continues, with the dumping of grass clippings, leaves, small trees and other organic materials. Removing this fill and re-establishing the outfalls with proper erosion controls (i.e. riprap) would enable local drainage systems to function better while reducing the sediments entering the drainage system.

Dredging the open waters section of the creek, from Hope Street to the point where the two branches converge behind Paull Street would provide additional storage, and allow for further salt water intrusion into the area, re-establishing the marsh and killing off the invasive fresh-water plants. This project would require an Assent from the CRMC, and would be a costly undertaking, but would have the greatest impact on the flooding problems experienced throughout the watershed.

The primary restriction identified through the model and the connection of individual closed drainage systems is related to the 48" corrugated metal pipe through the middle of the cemetery. The existing pipe has corroded, and the pipes under Chestnut Street are one-third filled with large rocks, most likely from displaced riprap upstream, reducing the capacity, and creating a restriction of the flows coming toward Chestnut Street from the high school and Gooding Avenue to the north, and Elbow Street to the east.

This would require a major undertaking, to replace the existing 48" corrugated metal pipe through the cemetery with 2-48" RCP pipes, or a concrete box culvert of sufficient capacity to convey the 100-year storm. Since upgrading the pipes under the high school is not a feasible option, a new pipe should be constructed in Chestnut Street to intercept the flow from the Elbow Street area, eliminating the crossing under Chestnut Street east of the high school. This will reduce the flow to the wetland behind the high school and reduce the flows through the high school property. Picking up the flow at Chestnut Street and carrying it down to the cemetery pipe would allow for additional pipes to be constructed under Elbow Street, to alleviate flooding during the major storm events without adverse effects downstream. This project would be a major undertaking, requiring permitting with CRMC and RIDEM, but would have the greatest impact on the watershed.

The other project which would also result in tangible improvements to the area would be to upgrade the pipes on Sherry Avenue and the intersecting sidestreets to convey the 10 year storm to a suitable discharge point where the outfall does not flood private properties. Intercepting the flow on Sherry would relieve the flow of surface water onto the St. Mary Cemetery property as well.

RECOMMENDATIONS

1. The Town should develop a Capital Improvements Plan to upgrade drainage systems within the Silver Creek Watershed that are currently under capacity. These pipes should be capable of carrying the runoff from at least a 10-year storm with no surcharge or overtopping of local roadways. Also as part of this Capital Improvement Plan, new detention/retention ponds should be constructed where practical to reduce flows downstream and increase flood storage throughout the watershed. Care must be taken when determining the order in which the improvements occur to make sure areas downstream have sufficient capacity to convey the increased runoff without damage to properties downstream.
2. Many of the problems identified in the easterly portion of the watershed are associated with runoff received from Metacom Avenue. As this is a State highway, the Town should approach RIDOT to try to get them to participate in the upgrading of several of these closed drainage systems to reduce flooding on local streets.
3. The Town should actively enforce the "No Dumping" policy at all areas within the Silver Creek Watershed. Residents should be made aware of this policy, including the ramifications of illegal dumping from both an environmental standpoint as well as from the enforcement angle. This education can be accomplished through the Public Meeting process as well as through local newspapers, flyers, etc.
4. The Town should implement Best Management Practices (BMPs) at the municipal discharges to reduce sediment loading into the channel. The suggested BMPs to reduce sediment, also known as total suspended solids (TSS) would be swirl concentrators, such as a Vortechinics® System. These systems have proven to reduce a net annual target of 80% TSS, if designed and sized properly, and maintained.
5. The Town should undertake a project to dredge the lower open water sections of the Silver Creek, to re-establish the salt marsh and increase available flood storage. This would allow for the large flows due to storms to flow out to Bristol Harbor more efficiently, resulting in a better eco-environment for the marsh and reduced flooding for property owners.

Cost Estimates

BETA has prepared preliminary cost estimates for the projects requiring replacement/installation of pipes or BMPs. Detailed breakdowns are included in the Appendix.

Sherry Avenue: Replace existing storm drains with pipes and drainage structures with capacity to convey the 10 year storm, with Vortechs : \$675,000.

Perry Street: Install bituminous berm along pavement edge, replace existing drainage system with new pipes and catch basins, and incorporate high capacity grates: \$550,000.

Highview Drive: Minor modifications to the existing closed drainage system, and possible increase in size of the existing drainage pond: \$100,000.

Jane Lane: Replace selected pipes to increase capacity: \$150,000.

Paul Street: Upgrade selected pipes: \$120,000.

Chestnut Street: Install new 48" pipe in Chestnut Street, and replace existing 48" pipe with box culvert through cemetery: \$1.1 million

Elbow Street: Install new pipes and erosion control, to be installed as same project as Chestnut Street: \$80,000.

Other recommendations that should be implemented as part of the annual maintenance of stormwater facilities include catch basin cleaning, removal of sediments from channels, and removal of dumped organic materials (i.e. grass clippings, trees, etc.). These are acceptable maintenance activities that do not require permits from RIDEM or CRMC, and will increase available storage and extend the life of the existing systems while improving water quality.