Stream Development at Wesbrook Place, UBC

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University of British Columbia

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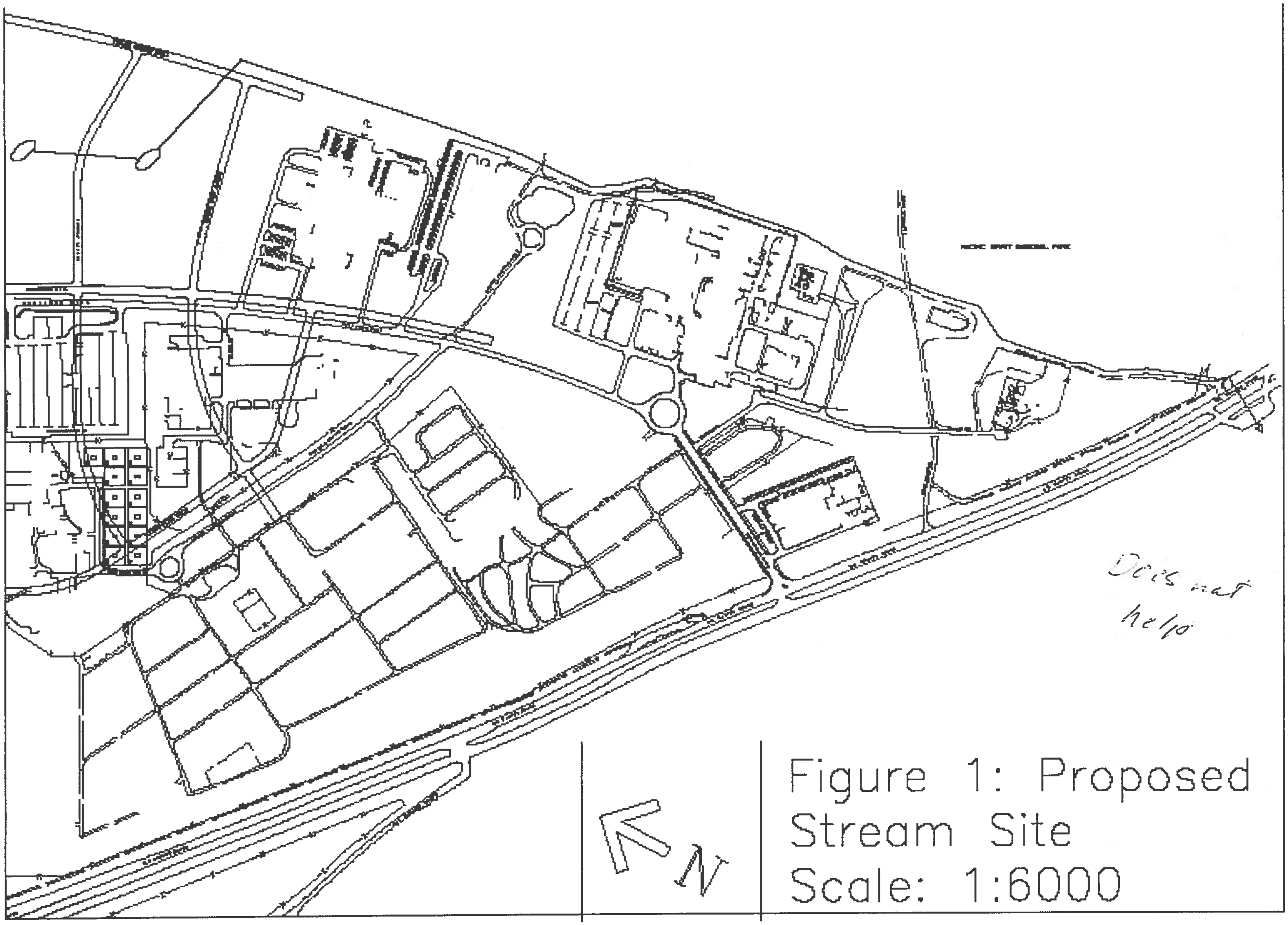
1.0 INTRODUCTION

The current development at Wesbrook Place, in the South Campus area of the West Point Grey Campus of the University of British Columbia raises many opportunities to explore sustainable development. One idea, which has been explored in two prior projects, is a stream to manage rooftop stormwater. This project would consist of a man-made stream, located primarily along the border of the campus with Pacific Spirit Park, two ponds to collect runoff, a piping system to carry runoff into the stream system, and a culvert to carry the flow beneath South West Marine Drive and into the Pacific Ocean. The previous papers have focused on a general approach to urban stream development, and a cost benefit analysis of the stream system. Both works conclude that such a stream would be feasible and beneficial addition to the South Campus Neighborhood. This paper will look further into the technical feasibility of such a stream, and suggest further recommendations for its development.

The previous technical paper on this subject, Kosta Sainis' Innovative Approach for Urban Stream Restoration approached this project in a more general way, specifically focusing on what the stream would require to provide appropriate habitat for cutthroat trout. Sainis laid out the route the stream course would follow, and a general picture of what the realization of the stream might look like. The main focus of this paper is the main stream segment of the stream and pool system laid out by Sainis. Issues relating to the ponds and the final culvert beneath South West Marine Drive will be addressed with further research.

The proposed stream would collect water from rooftops in two ponds incorporated into the current development in the South Campus area. The water would then flow from a spillway into a naturalized stream channel, where it would trace the border of Pacific Spirit Park alongside the current pedestrian greenway. At the southernmost end of the campus, where the greenway meets SW Marine Drive, the stream would be diverted beneath the roadway into a culvert which will deliver the flow into the Pacific Ocean (Figure 1). The main stream segment of the water system stretches from Gray Avenue to South West Marine Drive, along the border between UBC campus and Pacific Spirit Regional Park, and is the focus of this project.



Does not help

FIGURE 1: PROPOSED STREAM SITE

2.0 SITE ASSESSMENT

To assess the feasibility of developing a stream at Wesbrook Place, UBC, several aspects of the conditions in the proposed site were assessed. Firstly, it was required that general site observations were made regarding the current conditions, and their suitability to the proposed stream. The area is currently a pedestrian corridor, however, the path is far from uniform—widths range from a wide road to a narrow trail, and, in one place, a parking lot. Directly adjacent to the path's eastern edge is a drainage ditch which will form the basis of the stream channel, although the final channel will meander along the corridor. The following pictures show different sections of the proposed stream corridor, and correspond to the numbers in Figure 2.

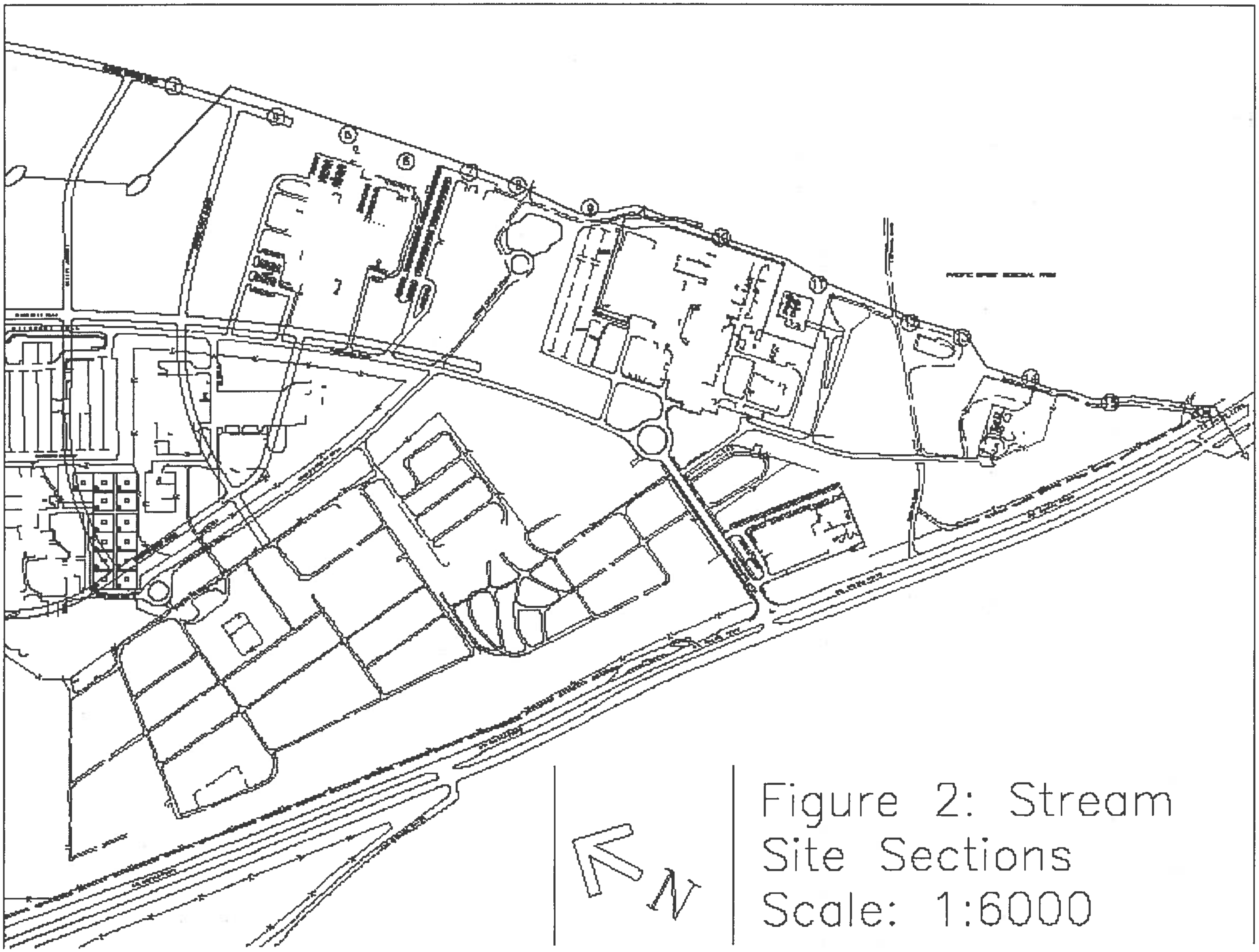


FIGURE 2: STREAM SITE SECTIONS

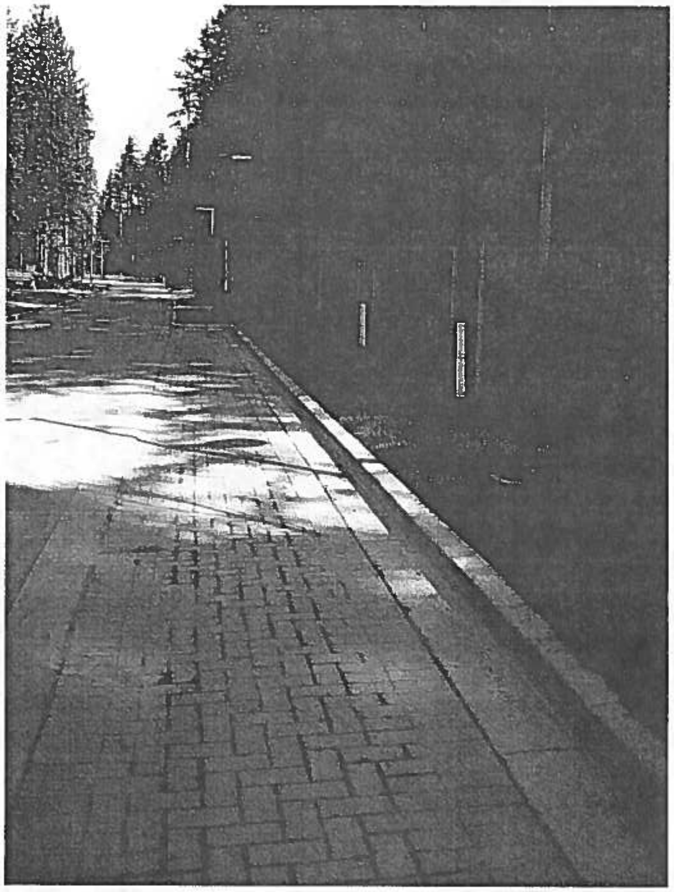


FIGURE 3: BINNING ROAD NORTH OF GRAY AVENUE

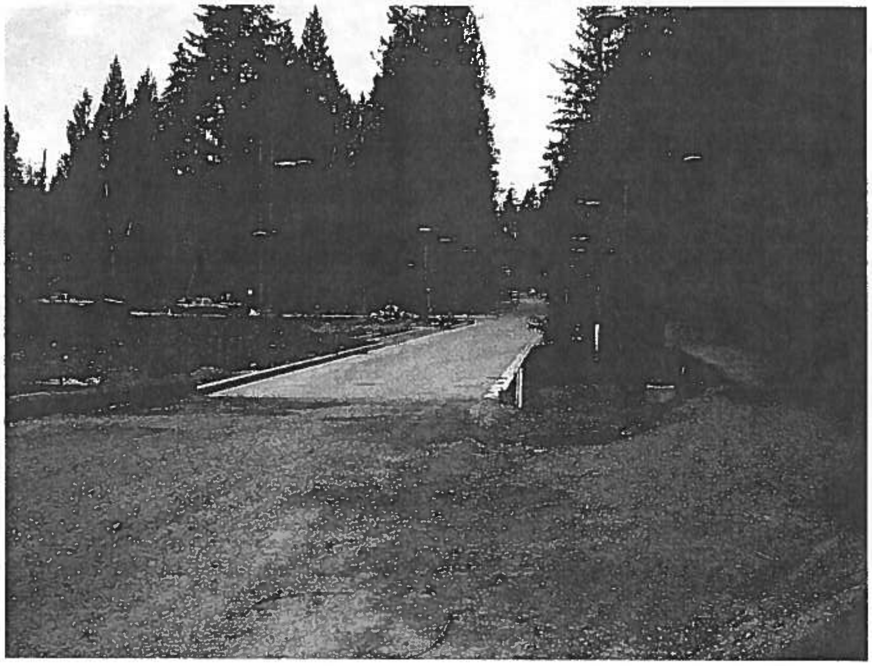


FIGURE 4: NORTH ALONG BINNING ROAD SOUTH OF GRAY AVENUE

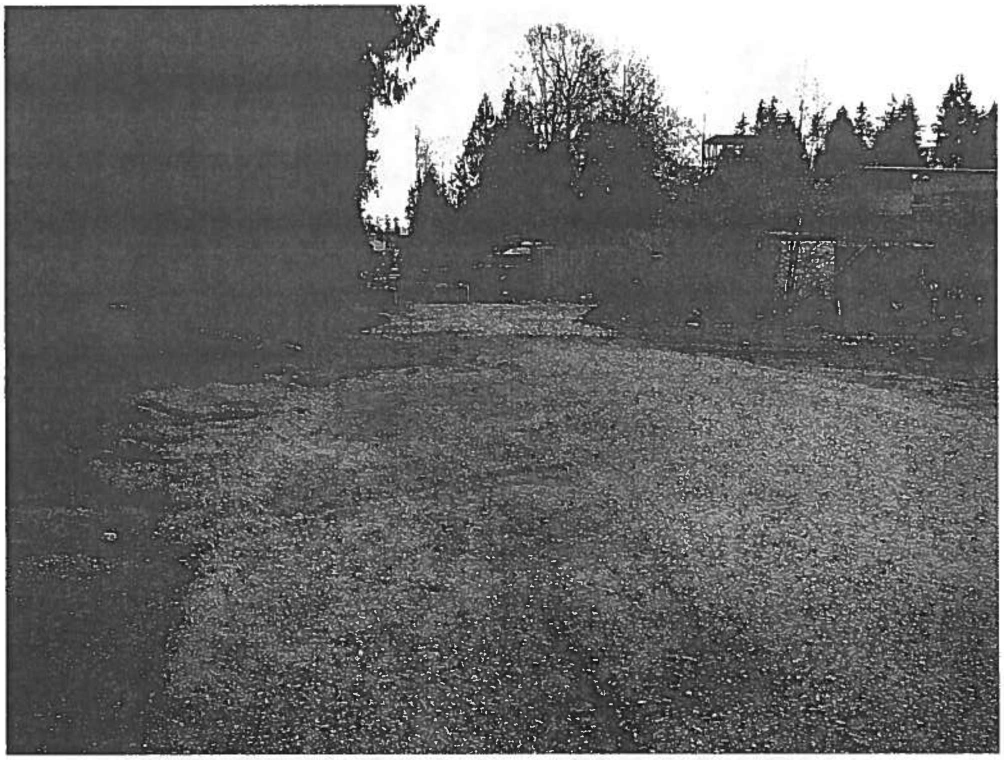


FIGURE 5: EAST OF B.C. RESEARCH FACILITY

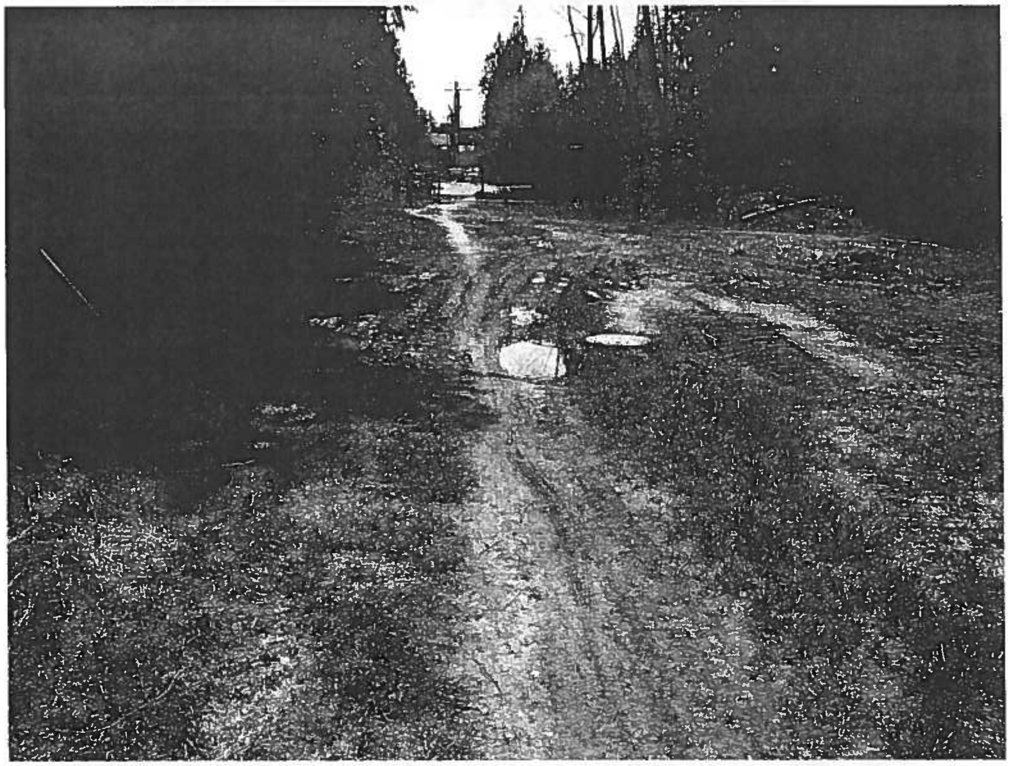


FIGURE 6: EAST OF OCEAN ENGINEERING FACILITY

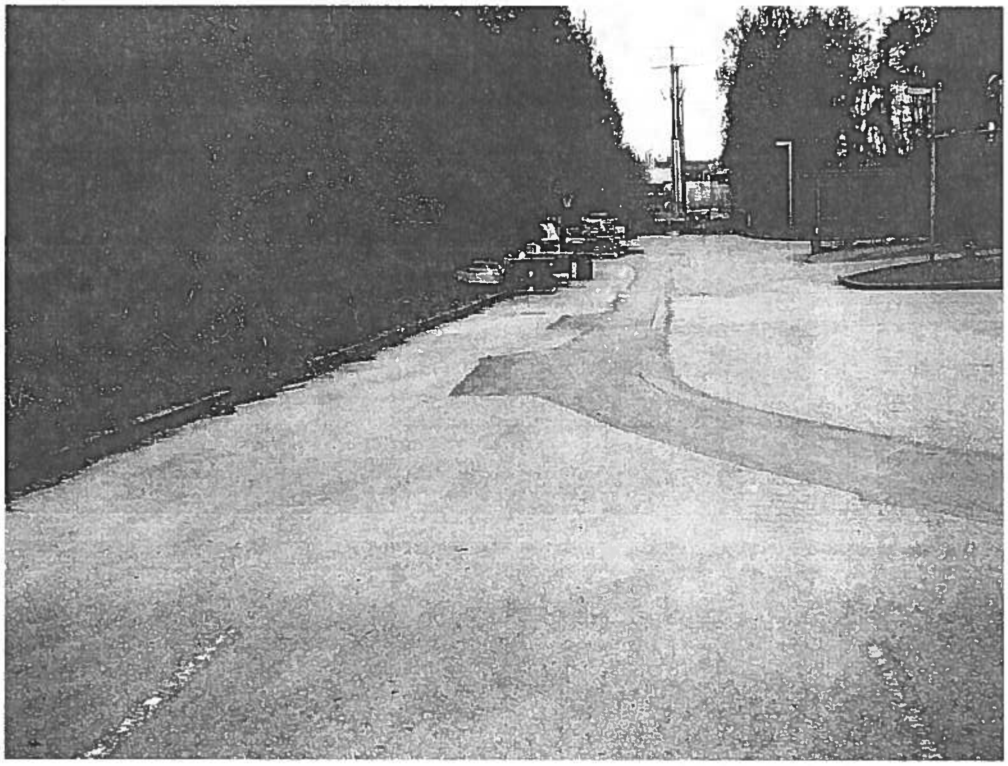


FIGURE 7: EAST OF PAPRICAN

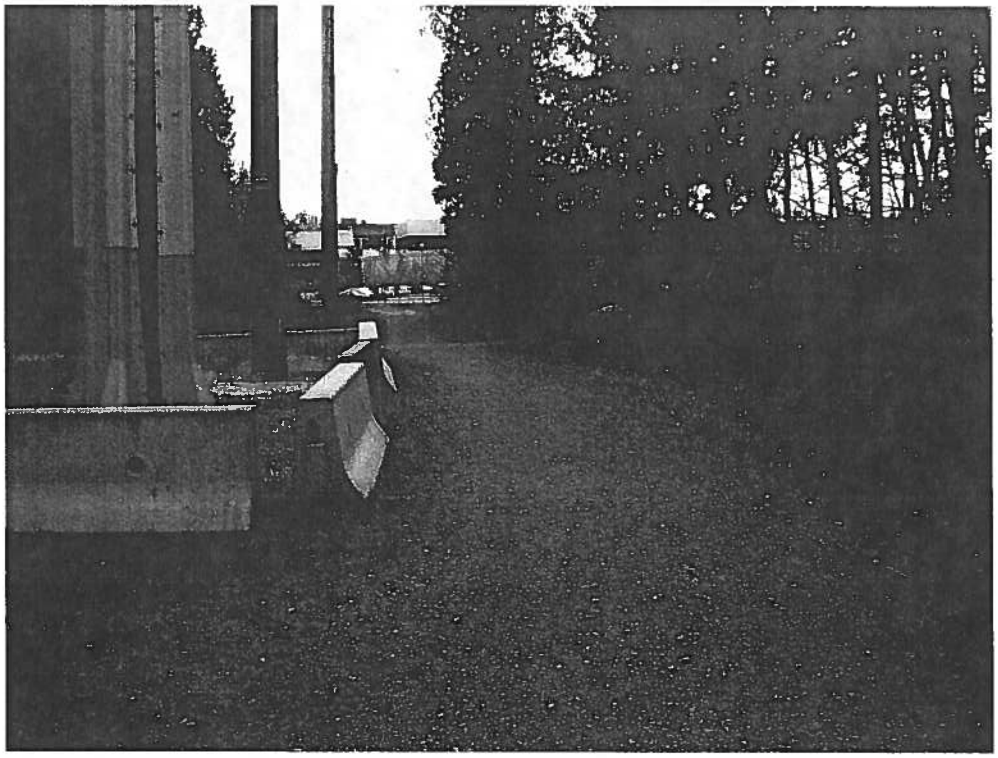


FIGURE 8: SOUTH OF PAPRICAN

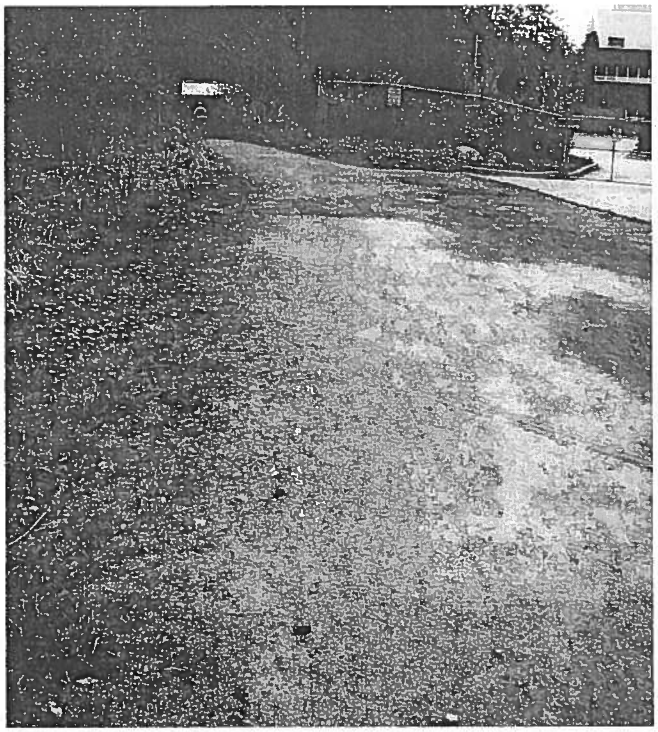


FIGURE 9: NORTH OF TRIUMF

FIGURE 10 EAST OF TRIUMF

FIGURE 11: SOUTH OF TRIUMF

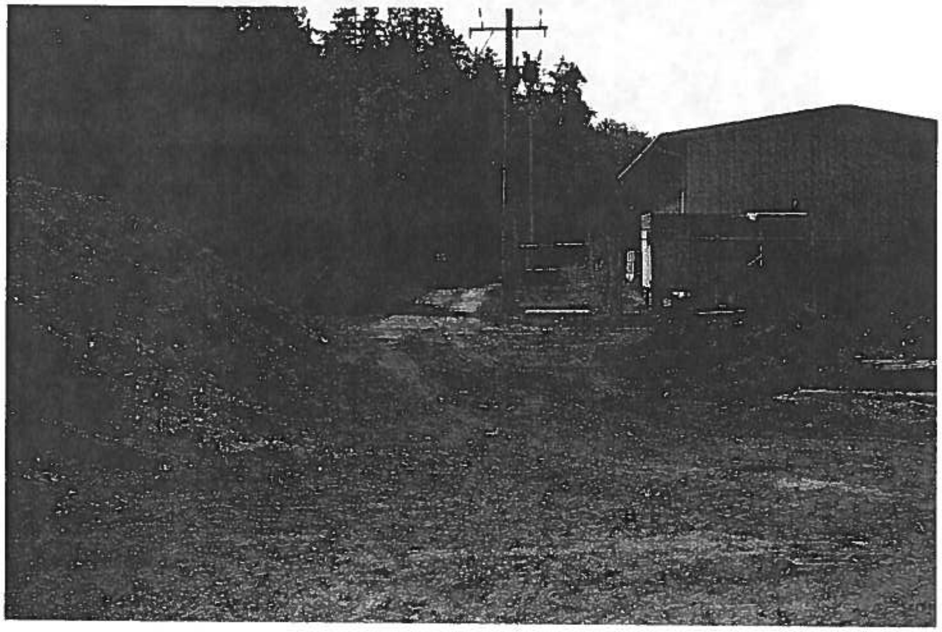


FIGURE 12: IN-VESSEL COMPOSTING FACILITY (NORTH END)

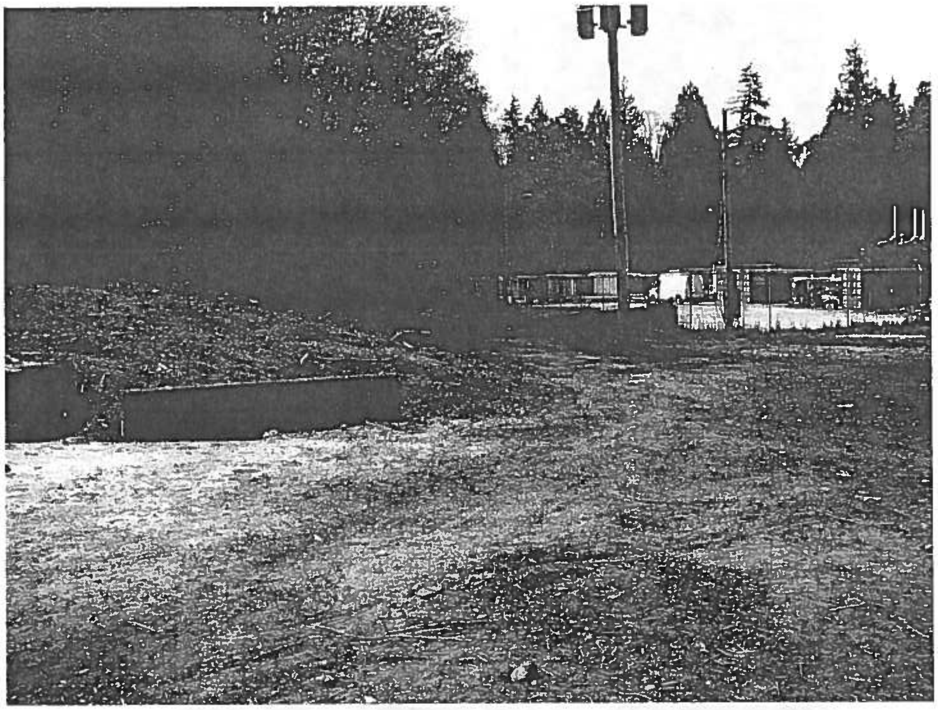


FIGURE 13: IN-VESSEL COMPOSTING FACILITY (SOUTH END)

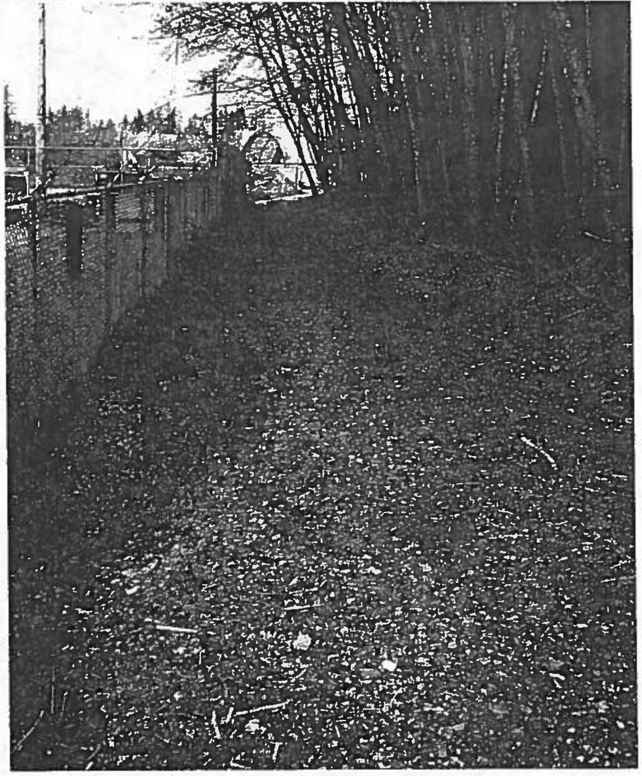


FIGURE 14: EAST OF THE UBC UTILITIES WORKS YARD

FIGURE 15: SOUTH OF THE UBC UTILITIES WORKS YARD

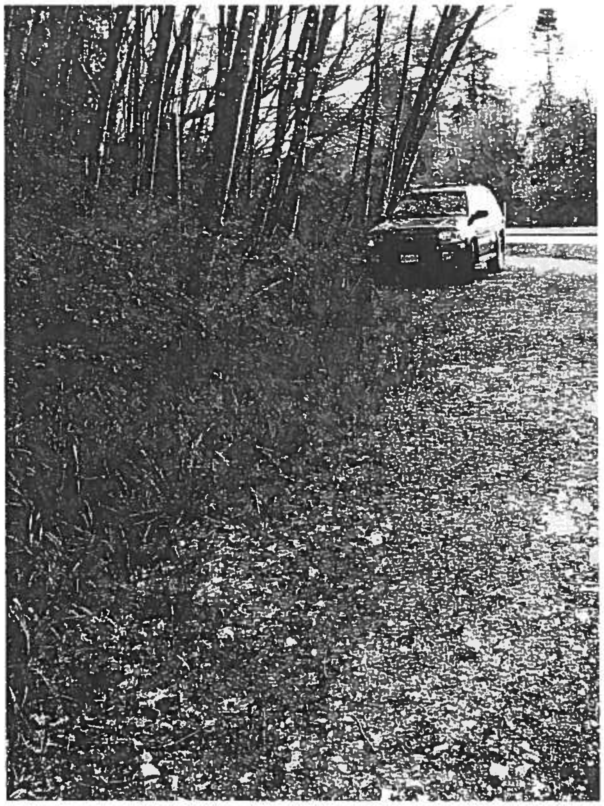


FIGURE 16: END OF THE PATH AT SW MARINE DRIVE

2.1 CORRIDOR WIDTHS

Given the area of land available between the fences, buildings and property lines, and the edge of Pacific Spirit Park (which is occasionally but inconsistently marked with stakes at the site), the ability to construct a meandering stream is somewhat limited. Instead, a riffle-pool or cascade-pool morphology could be constructed, consisting of mostly straight sections, and curving where space permits. However, if an agreement could be reached with Metro Vancouver, which oversees Pacific Spirit Park, to allow the stream to penetrate the park, a more natural and less channelized stream could be constructed. The widths of the path and ditch are shown in Figure 17.

However, there are areas where there is room for some meandering. Instead of the degree of meandering being determined randomly, as proposed by Sainis, a more realistic approach is to have the site conditions and features of each segment determine the degree. Some sections have enough space to negotiate wide curves and pools, but other areas will require a straight, narrow profile. A primary concern should be ensuring the stream does not become too channelized, a common issue with urban streams. The goal with this project is to take the ditch currently located in this area, and transform it into a natural-looking and useful stream; if erosion and channelization turn it back into a ditch, we will have wasted our efforts.

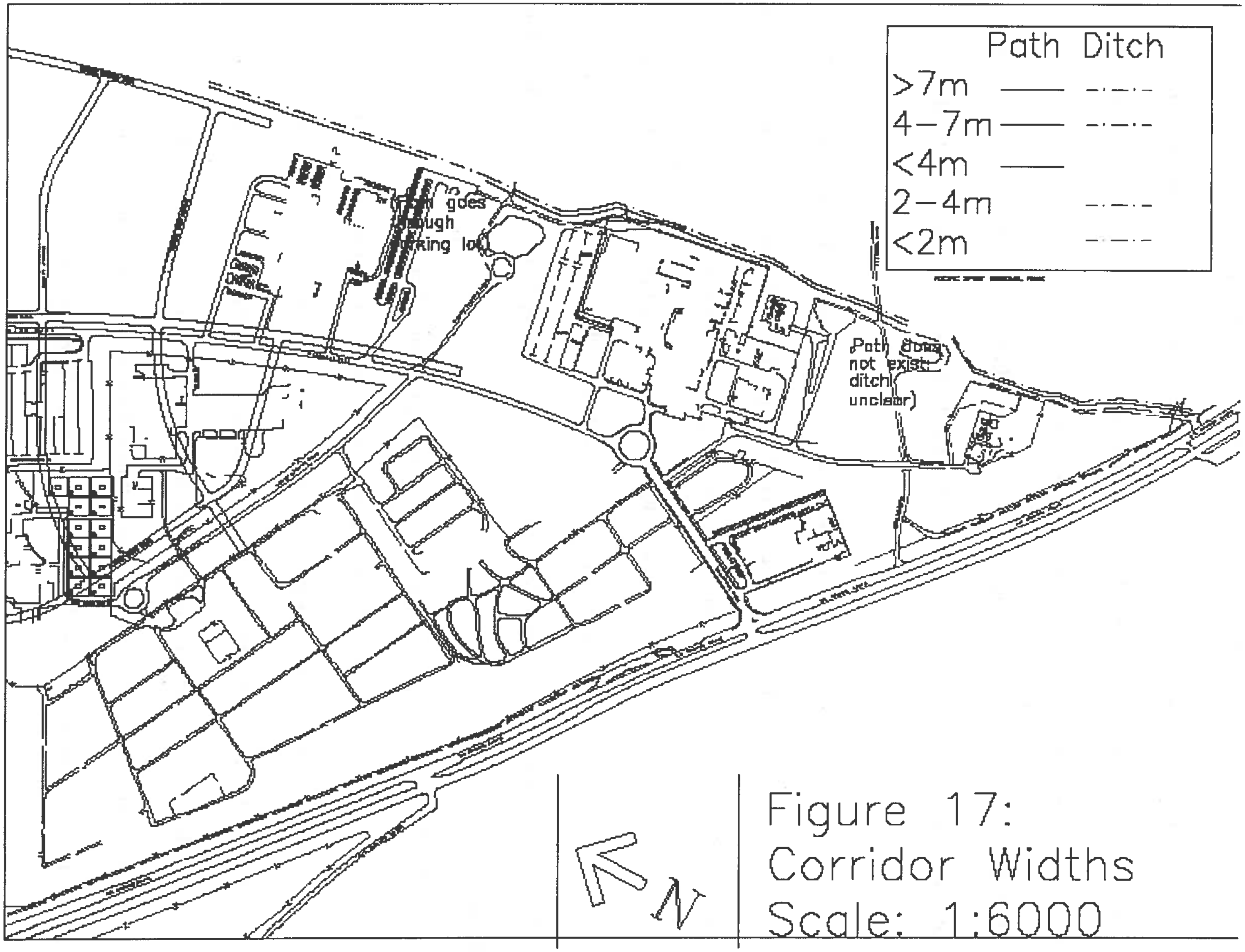


FIGURE 17: CORRIDOR WIDTHS

2.2 CULVERTS

Sainis' original design proposes a stream system coupled with three culverts: two crossing Birney Avenue and Binning Road at the upstream end, and one under SW Marine Drive to deliver the final flow into the Pacific Ocean. However, closer inspection of the site shows that four more small culverts will be required to cross paths that lead into Pacific Spirit Park (Figure 18). Three of these paths are trails in the park—Council, Long, and Imperial; the fourth is required to continue providing emergency access and access to a utility corridor north of TRIUMF.

The length of the Council Trail culvert will need to be around 3 meters. This is the shortest of the culverts. The culvert at Long Trail will need to be 5 meters long, and the Imperial Trail and utility corridor culverts will need to be longer, approximately 10 meters. The costs of these culverts should be significantly less than the cost of the road crossing culverts. Not only will they be shorter, thereby saving material costs, they should be easier and less disruptive to install. Still, the addition of these culverts will result in a noticeable increase in the cost of the stream.

Another factor to consider concerns positioning the culverts to ensure that the distance between the low water level and the lower edge of the culvert is less than the maximum jump distance for cutthroat trout, the target species of this stream. As it is still unclear whether the stream will continue to flow during the summer months, it is difficult to know what the culvert placement should be. However, knowing that at low flows, the water level may decrease to only a few centimeters (above 6 to insure proper cutthroat habitat is maintained) and that the maximum jump heights for adult, 125mm juvenile, and 50mm juvenile cutthroat trout are 1.5, .6, and .3 meters respectively, the bottom edge of the culvert should be placed no more than .3 meters above the downstream bed.

Should be below bed with open bottom.

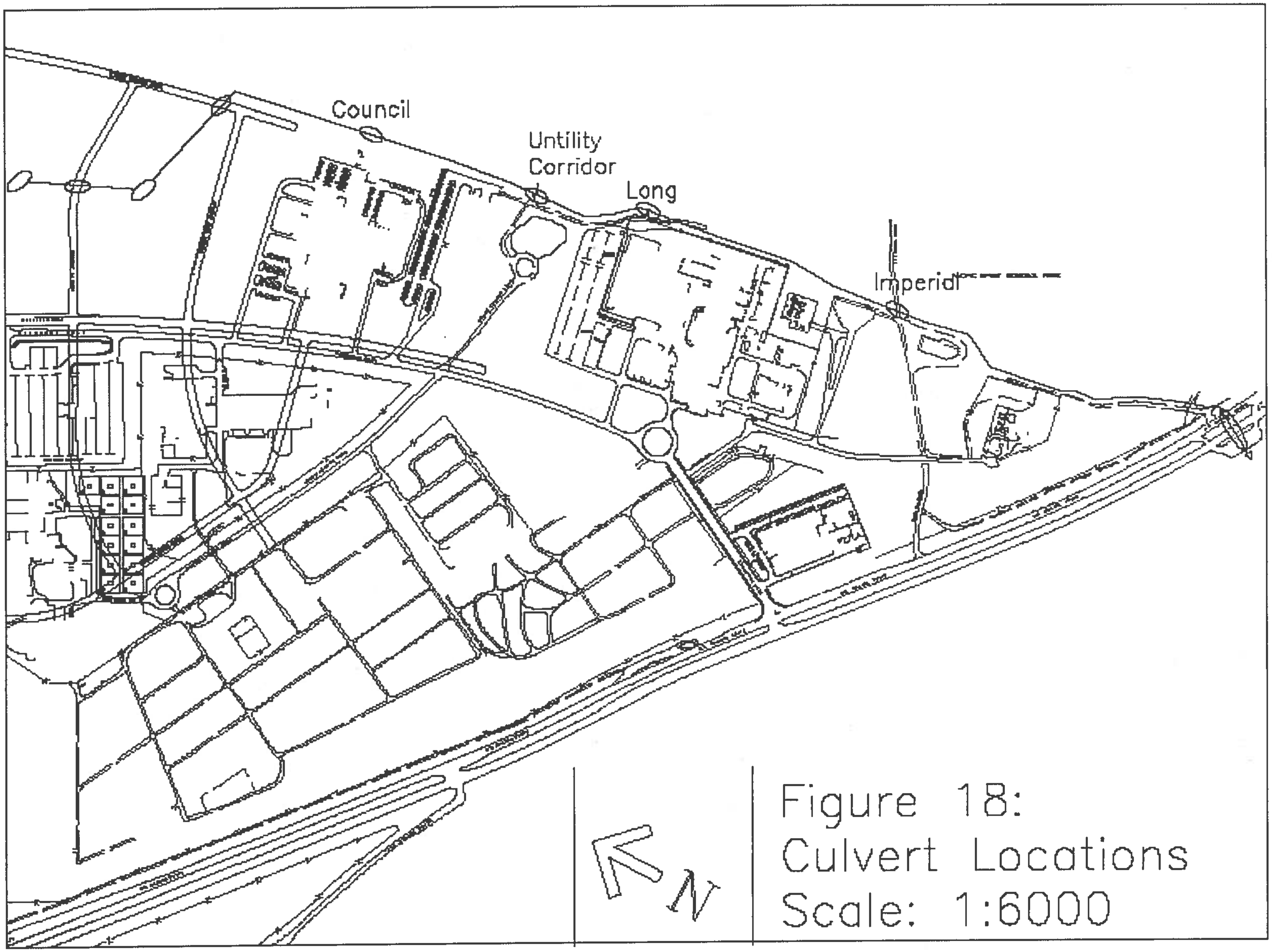


FIGURE 18: CULVERT LOCATIONS

2.3 Soil Conditions

Site observations and previous soil testing indicate that the current soil regime will be appropriate for stream placement. As Sainis notes, the testing of the soil at the site of the residential development in this area indicates a 3.5-4 meter layer of silt on top of sand. The sand has a hydraulic conductivity of 5-50 m/day, which is too high to permit standing water in a stream. However, the silt has a hydraulic conductivity of .1-.5 m/day, which should prove suitable for stream flow. Even if the stream erodes the bed below the original excavation level, the bed level will be well above the sand layer, so infiltration into the soil should not be a problem. A more in -depth soil survey must be undertaken to ensure that the hydrological properties of the soil in which the stream will be located match the data from the construction site.

Field observations also indicate the soil would hold water quite well. After a rain event, standing water was noted all along the stream corridor (Figure 19). Several days after a rain event, there was still standing water in certain locations. On dry days, water poured into a hole in the soil did not dissipate over the course of several minutes. All of these observations point to a soil with a low hydraulic conductivity, which would allow the stream to run without the flow infiltrating into the soil. However, as further information comes to light, it may be that certain areas do not hold water as well. This does not have to be a significant barrier to the stream development. The soil in these areas could be lined with bentonite clay, which would provide a highly impermeable bed for the stream flow. Gravel, cobble, boulders, logs and vegetation can be integrated into the bed to ensure the stream naturalistic and integrates well into the rest of the stream system.

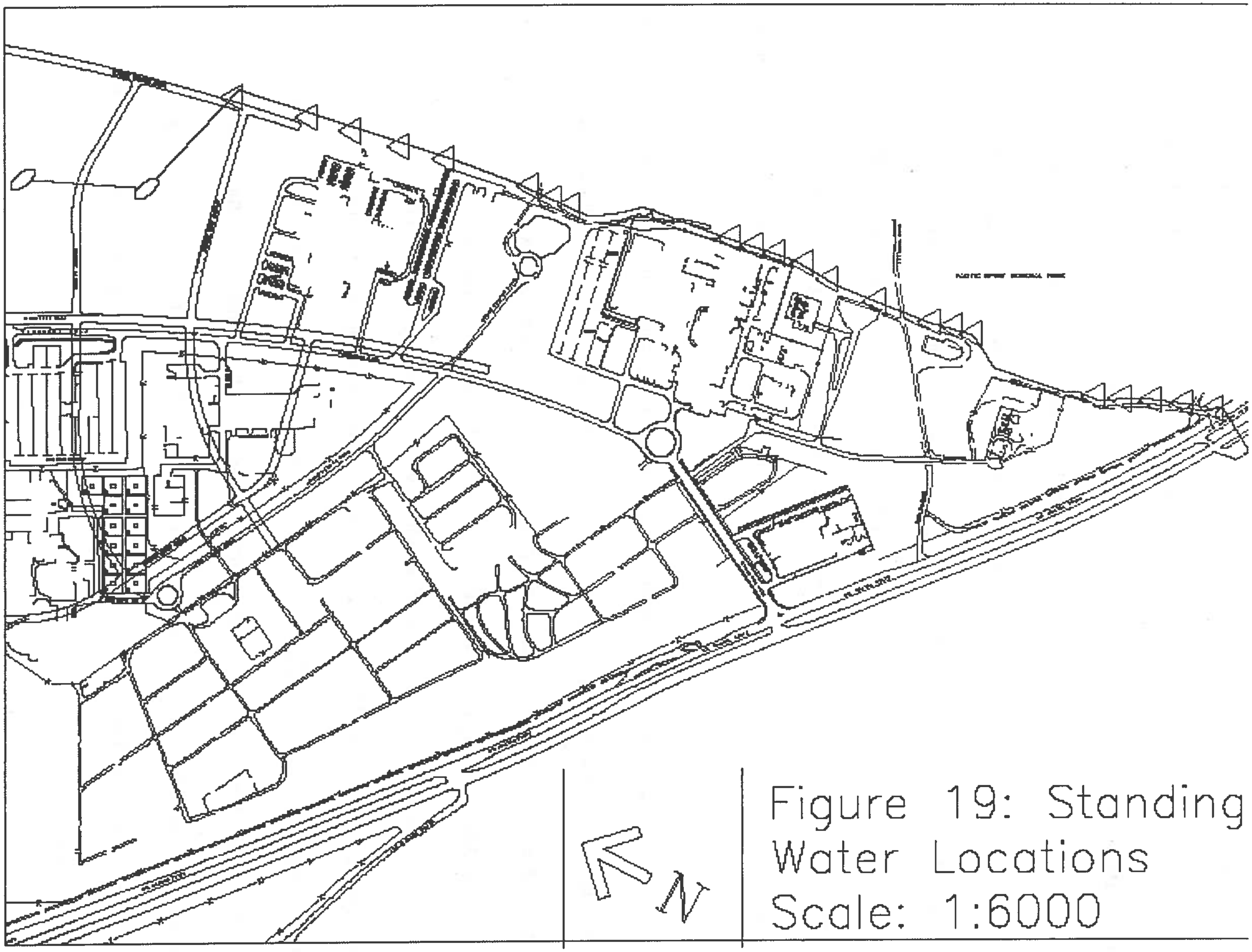


FIGURE 19: STANDING WATER LOCATIONS

2.4 PROBLEM AREAS

Several locations along the corridor pose particular concern for this project. These locations are shown in Figure 21. Any area where the ditch is east of the tree line poses a problem, as the tress may need to be removed in order to ensure that their roots are not undercut. This is an issue near the beginning of the stream and in the final stretch of the corridor before SW Marine Drive (Figure 20). Another obstacle comes in the form of power poles, which are generally located along the west side of the path. However, in a few places they are located on the east side, in or near the proposed stream site (Figure 22). It is preferable that the steam never be located directly beneath the power poles, as this would prove difficult should maintenance be required in that area.

FIGURE 20: TREES WEST OF DITCH NEAR GORE AVENUE

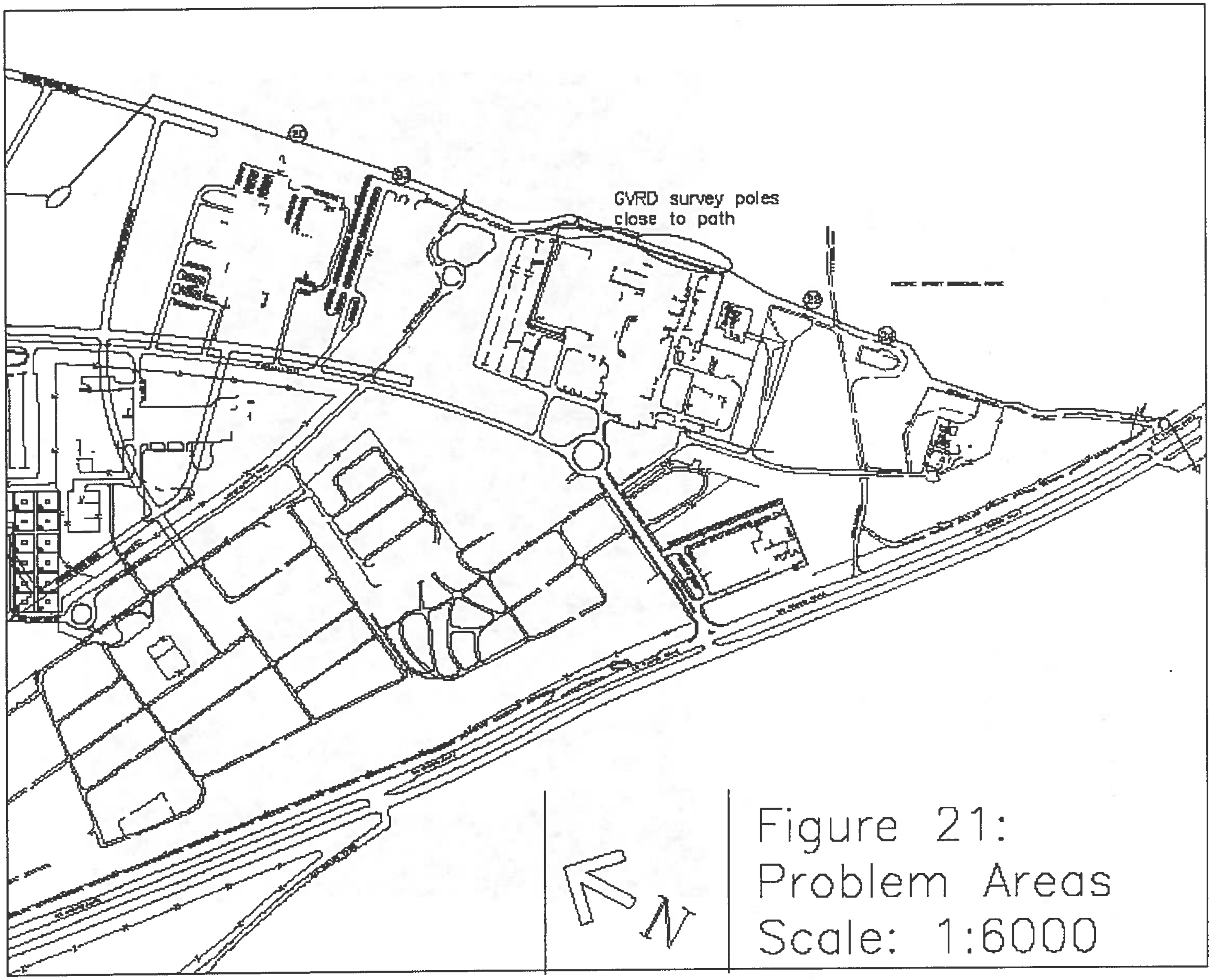


FIGURE 21: PROBLEM AREAS

FIGURE 22: POWER POLE ANCHOR IN STREAM DITCH

The area near Paprican, where the path dead-ends into parking lot, is another area of concern. The path picks up again on the south side of the lot, but the ditch and green space east of the parking lot is cluttered with debris and storage (Figure 23). Area for the stream to be constructed does exist, but clean-up would have to be coordinated with Paprican in order to create a suitable area. A similar area exists near the In-Vessel Composting Facility. The path ends at the facility, and pedestrians must go though the works area in order to access the path on the other side. This area is usually vacant, but is occasionally used by heavy machinery. In this area, the ditch is located beyond a sharp drop off at the edge of the facility (Figure 24). This makes it particularly difficult to both measure the grades and determine the location of the UBC-Metro Vancouver boundary. In fact, it appears that the natural break between UBC and Metro

Vancouver land in this area is this drop off. This would place the ditch and therefore, the creek, squarely in Pacific Spirit Park, a matter which would need to be negotiated with the GVRD.

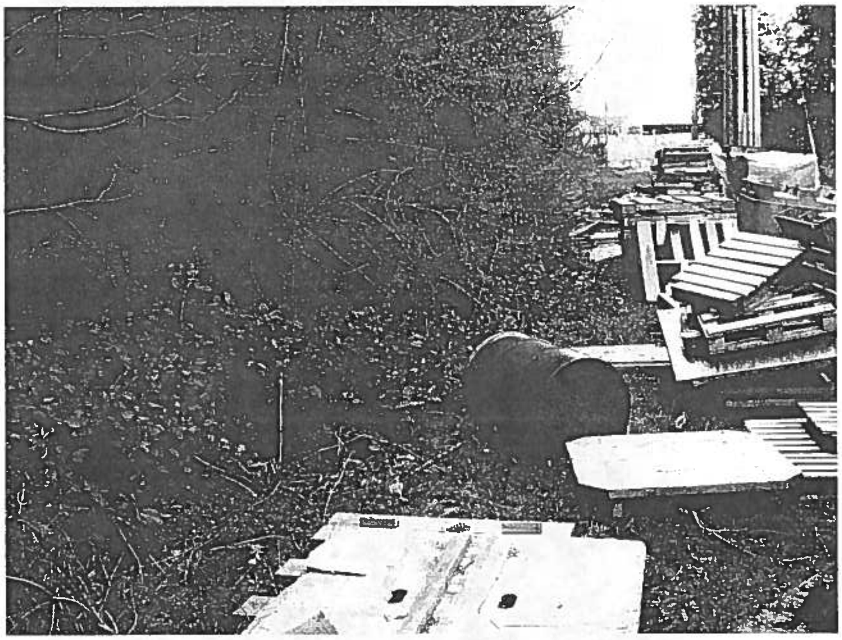


FIGURE 23: DEBRIS NEAR PAPRICAN PARKING LOT

FIGURE 24: DROP OFF NEAR IN-VESSEL COMPOSTING FACILITY

Nearly all of the corridor is unmarked in terms of where the Metro Vancouver/UBC property line lines. However, the few places that this boundary is marked are significantly close to the path and leave little room for the negotiating of the stream. If the park boundary is this close to the path in all areas, this will jeopardize the stream significantly. However, in most areas, the trees begin well away from the path edge; presumably the stream could meander to this edge even if some of this area falls within the park boundary. The locations of the GVRD (Metro Vancouver) survey markers are shown in Figure 20 21

3.0 TECHNICAL ANALYSIS

Using the data and observations taken in the field, along with data from the Sainis paper, a rough technical analysis of the major stream corridor was undertaken. These measurements give a rough idea of the velocities and depths of the flow under different conditions. This allows us to design the stream in order to ensure that it remains suitable for cutthroat trout habitat. In addition, these values can help us develop a naturalesque stream morphology that does not become too straight or channelized.

3.1 GRADE-

Slope measurements were taken from Gray Avenue to the In-Vessel Composting Facility, which composed the focus area for this project (Appendix A). The area north of Gray Avenue is currently being developed and landscaped along with the residential development in this area. At the composting facility, the pedestrian greenway path ceases, and, although the ditch continues, the feasibility of accurately measuring the slopes in this area was limited. Therefore, Sainis' slopes will be used for the areas where no slope measurements were taken.

In nearly all places, the slopes ranged from 1-5%, corresponding to a mild slope for the expected flow conditions. In a few places the slope is slightly more severe, 8-9%. However, since the slope was measured in 10-meter sections, the overall slope in these areas is still quite mild. A graph showing the slopes for different sections of the corridor is shown in Figure 25. During construction, these areas could be excavated to a more moderate slope to lie within the overall slope regime, around 2.5%, or they could be left with a more severe slope to create short, faster flowing regions. In none of these regions is the slope so severe that the velocity of the stream during high flow exceeds the maximum adult cutthroat trout burst speed.

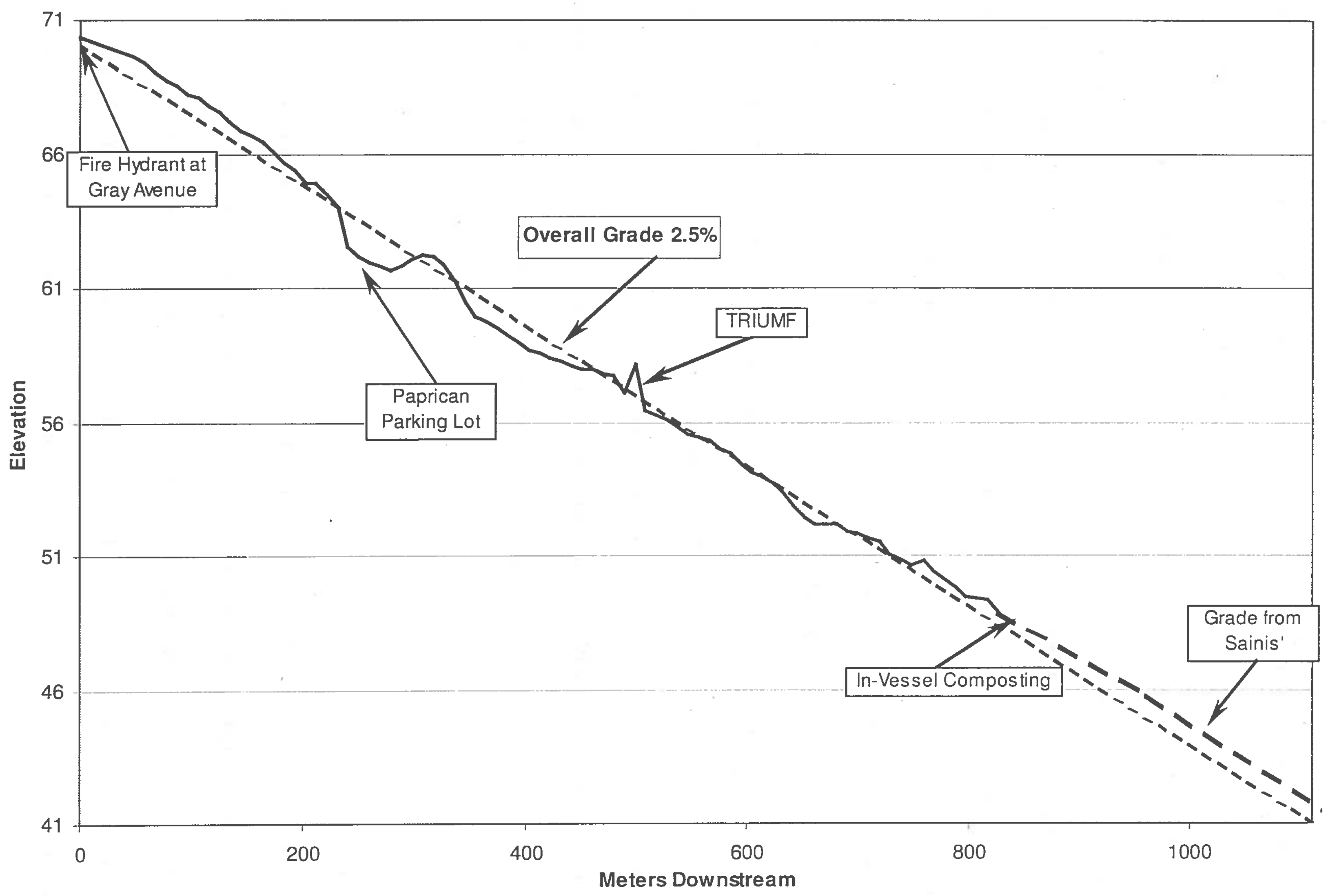


FIGURE 25: GROUND ELEVATION PROFILE

One cause for concern that the optimal velocity for spawning is between .11 and .72 m/s, and in many areas, the flow may exceed the upper bound on this velocity. Using Sainis' upper bounds for Manning's n for both gravel and cobble for high flow 17 m^3/s, give a velocity within this range. However, at high flow we expect Manning's n to be closer to the lower bound. Using the lower bound, the expected velocities do exceed the optimal values. This is a concern, as the spawning period should fall during the high flow season. However, it is unlikely that high flow will reach Sainis' upper bound, and in many places the stream will be wider than the lower bound of .75 m. .During the lower flow periods, the velocity should not exceed the maximum swim speeds for adult and larger juvenile (125mm) cutthroat (Appendix C).

Measures we can take to ensure that the velocity stays low include increasing the degree of meandering, increasing the roughness, decreasing the bed slope, or increasing the stream width. Unfortunately, many of these measures require increased stream area, which is difficult to achieve given the site conditions. An attempt should be made to make the stream as natural and meandering as possible within the site constraints. A possible vision of a meandering stream that works with our slope and width constraints will be discussed in Section 3.3, Possible Stream Systems.

3.2 FLOW CONDITIONS

A primary concern of urban streams is inconsistency of flow. In the summer months, it will be difficult to maintain the 6cm depth of flow required for the stream to remain a viable fish habitat. Sainis' report concluded that there would not be sufficient flow in the stream during the summer months, and that in fact parts of the stream would likely become dry during long dry periods. This was not considered a problem, as mosquitoes and West Nile Virus are of concern in this area, and a low flowing stream may provide breeding grounds. However, accurate year-round flow data was not incorporated into Sainis' report, and is not yet available. Such data may not be available until the development has been operational for several years.

However, using an estimated flow of 4 liters per second (.004 m^3/s), the depth of flow during the summer months in fact approaches the required 6 cm. When the stream is this low, we expect a much higher value for Manning's n, as the large boulders, logs, and vegetation that are characteristic of a riffle-pool stream will be more exposed, and therefore contribute more to the value of n. At this low flow, a very large estimate for Manning's n, .2-.3, was used, despite Sainis calculations of an n closer to .03. For year-round flow, where larger elements submerged, this estimate is reasonable. But for the lower flows, we expect a slower, deeper flow due to the increased roughness of these large objects.

If, with more accurate summer flow data, it would be feasible to keep the stream running year-round, the stream widths could be manipulated to ensure that the depths stay above the required levels. Given the 4 liters per second estimated flow, the stream would need to be narrowed to .4 meters at some points in order to suffice as fish habitat. However, narrowing the stream is not a viable option as this would cause flows to be too fast during spawning season. If the true value for summer flow is somewhat larger, it may need little or no manipulating beyond Sainis' recommended widths in order to provide sufficient depth. As a natural stream would have a varied width, this modification does not need to be a barrier to creating the stream. Additionally, in the excavation to create the stream, the bed slope could be modified to be less steep than the slope of the path.

3.3 POSSIBLE STREAM SYSTEMS

There are two possibilities for the realization of this stream system. In the first, the stream lies within the narrow corridor outside of Pacific Spirit Park, making use of wider areas to meander and curve (Figure 26). The second, more ideal design, imagines the stream if it were allowed to penetrate Pacific Spirit Park and meander more like a natural stream (Figure 27). In both streams, care is taken with regard to the widths and slopes in order to ensure that the stream is not too fast or shallow to provide proper cutthroat habitat. An idea of how the stream will look can be gained by looking at the similar stream explored in Appendix C.

Areas that have been identified as wide enough to accommodate a wider, more meandering stream include the area near B.C. Research and Ocean Engineering Centre, downstream from Paprican to TRIUMF, and south of the In-Vessel Composting Facility. Areas that will require a narrower, straighter stream include the areas near Paprican, TRIUMF, and the In-Vessel Composting Facility. In the meandering sections, the stream can be wider, more than 1 meter, with sections on the outsides of curves forming pools. In the straight and narrow sections, the stream will be .75 to 1 m wide, with the flow broken up by cascades and riffles, with frequent large bounders and logs in the stream to provide roughness.

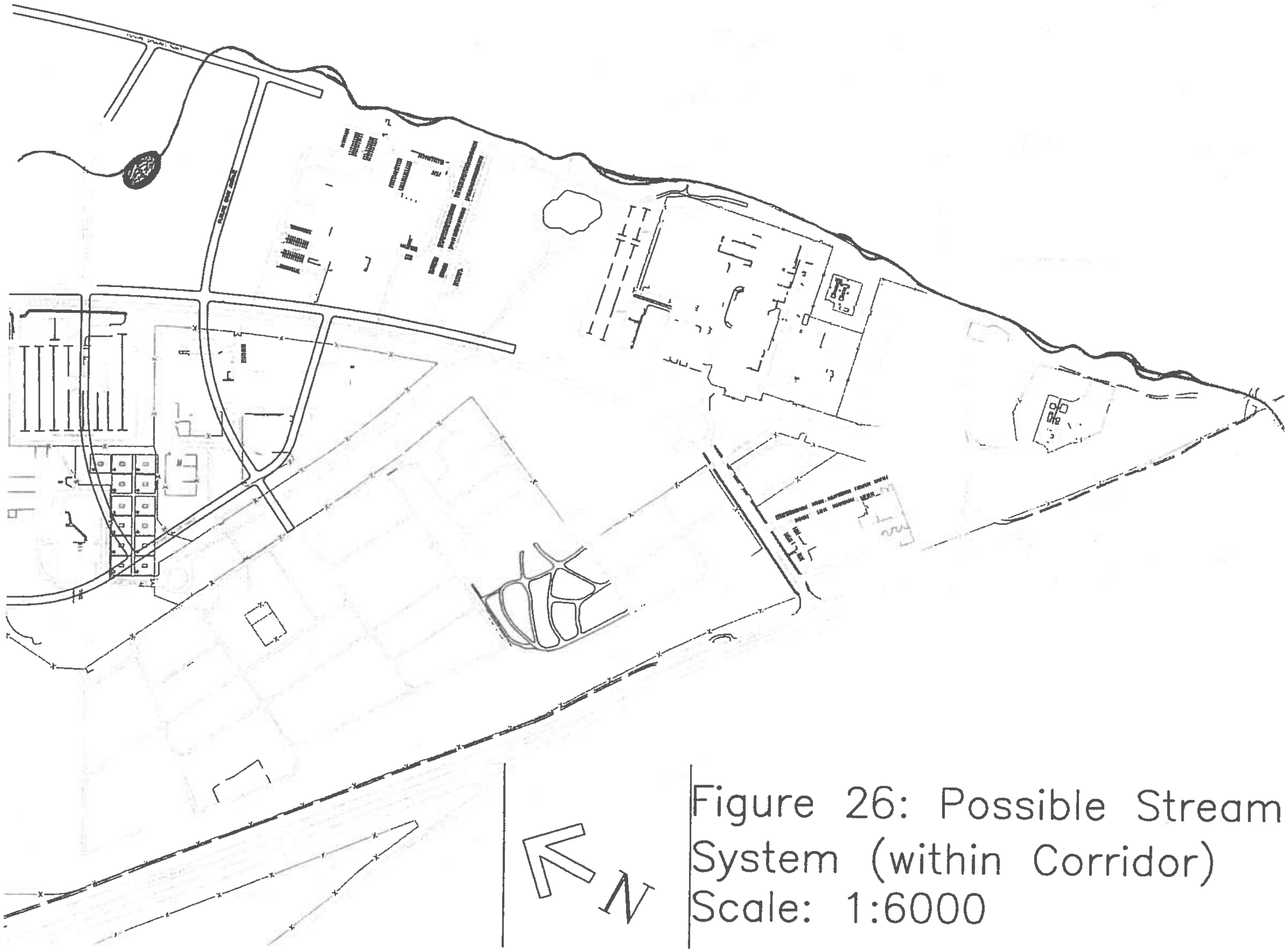


FIGURE 26: POSSIBLE STREAM SYSTEM (WITHIN CORRIDOR)

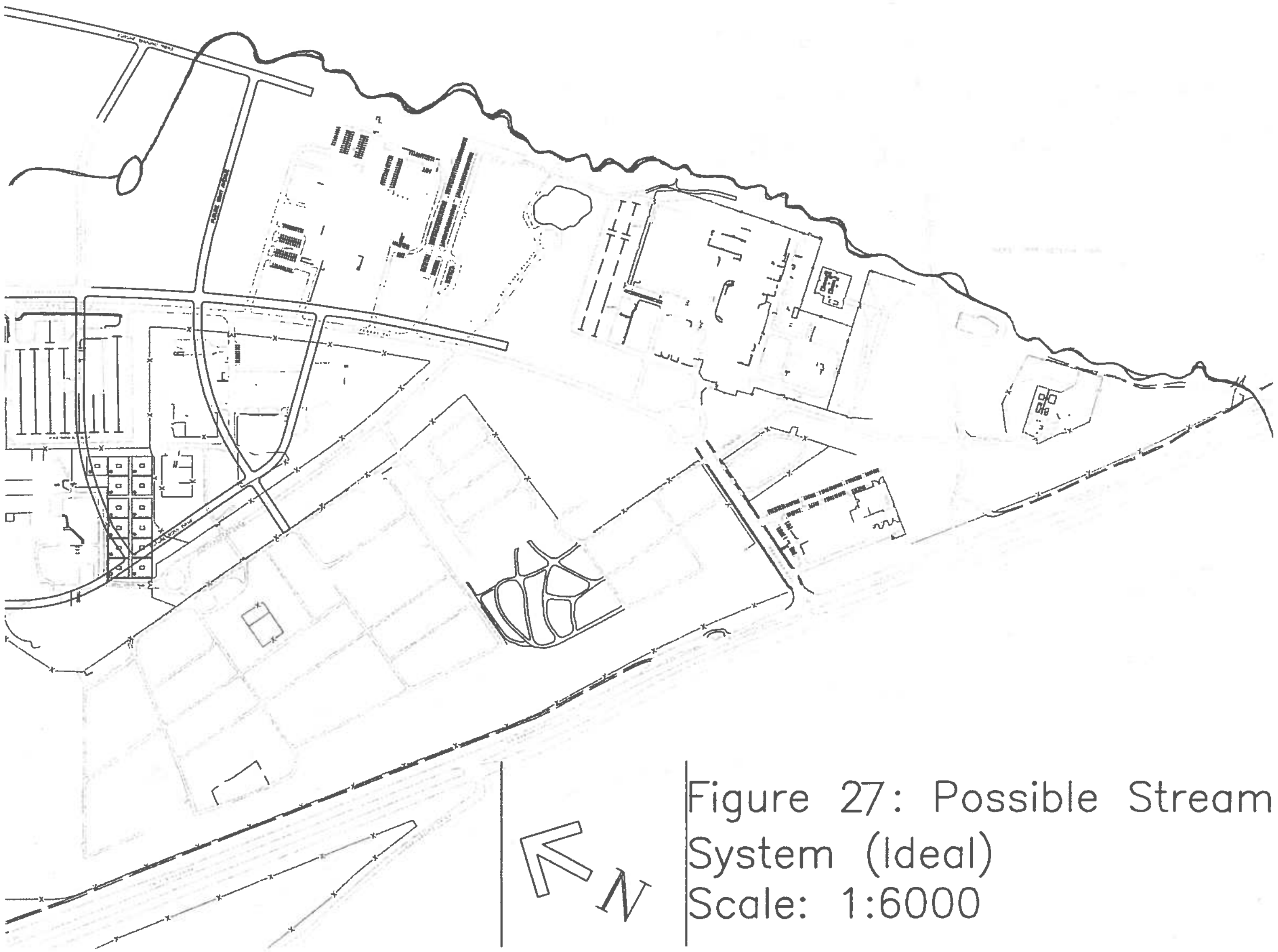


FIGURE 27: POSSIBLE STREAM SYSTEM (IDEAL)

4.0 RECOMMENDATIONS

There is still much work left to be done in order to realize this project. The most necessary work is for a complete and highly precise survey to be done of the stream corridor, focusing specifically on the locations of property lines, in order to accurately assess the space available to put into the stream. As the area we are looking at is on the order of 10-20 meter width, a difference of one or two meters in the survey would change the results dramatically. The rough slope estimates are adequate to assess stream flows, but the plan (meandering) aspect requires a more detailed site assessment.

To continue moving this project to realization, work must continue on each aspect of the technical design. Firstly, a detailed survey must be taken of the entire corridor and this information be added to the UBC maps of this area. The critical issue is to identify the location of the boundary with Pacific Spirit Park and ensure that there is enough room to place a natural, non-channelized stream. This survey should also give a further, more precise assessment of the grades, and the locations of any relevant barriers to stream development, such as a power pole or tree in the future channel. Lastly, the survey should mark any areas where standing water is present in the corridor, as these areas indicate soil suitable for stream flow.

Aside from the survey, soil testing should be conducted in the vicinity of the stream, specifically to measure the hydraulic conductivity of the soil. If the soil in areas has a hydraulic conductivity that is too high to allow water to flow without infiltrating, solutions such as a bentonite clay lining should be explored in terms of feasibility and cost. Additional cost concerns that should be analyzed include the cost of the culverts, including the SW Marine Drive culvert, which also needs to be addressed on the technical front. The inlet and piping structures proposed by Sainis also need further technical design. Lastly, accurate flow data for this area is required to complete much of the technical design of this project.

Another aspect of this we must begin to consider is the source of the funding to create the stream. Guimaraes and Littlejohn's *Scenic Streams Stormwater Management Cost Benefit Analysis* concludes that this stream would be an economic way to manage stormwater, however, it is several years out of date, and contains few dollar values. Therefore, the detailed technical design phase of this project should be coupled with a cost analysis. Additionally, we should begin to think about how we might "sell" this project to UBC, continuing with any further work needed to convince the University to fund this project. This may include a less technical, informational paper or a formal proposal.

5.0 CONCLUSIONS

The aim of this project was to complete further technical analyses of a proposed man-made stream to be located in the South Campus area of the University of British Columbia. The stream had been previously identified as a socially, environmentally, and economically sustainable measure to manage stormwater runoff and provide habitat for cutthroat trout. The stream is a feasible project, however, certain areas will be difficult to design due to space constraint in the proposed site. The most difficult challenge surrounds keeping the stream deep and slow enough to provide appropriate habitat, and to resist the tendency of urban streams to become straight, fast, erosive, and channelized.

Using the data gathered over the course of this project coupled with data used in a previous paper on this subject, an analysis of the major stream section was undertaken. This analysis corroborated Sainis' conclusion that the stream would not receive sufficient runoff to run in the summer months. However, these calculations were based on estimated flows and may not prove true when accurate flow data is used. Whether or not this is the case, the stream will receive enough flow during the wet months to achieve the appropriate depth for cutthroat trout to spawn. One issue of concern is that the stream may be too fast for optimal spawning conditions in places where the slope is steeper or the bed is smoother. In order to ensure the velocity of flow is mild enough for cutthroat to spawn, the steep areas should contain larger bed materials such as boulders and logs, to increase roughness. This fits with the riffle-pool and cascade-pool morphologies this stream should emulate.

Although several areas were identified as problematic, a preliminary stream system was designed to accommodate the space, flow, and slope issues. In addition, a second design was produced which imagines a more natural stream which crosses the boundary between Pacific Spirit Park and UBC. These designs will provide a basis upon which further research can build.

ACKNOWLEDGEMENTS

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APPENDIX A: GRADES

	Notes	Elevation	Change in Elevation	Horizontal Distance	Slope	Overall Slope
1	fire hydrant	70.360				
2		69.655	0.70	47.99		
3		69.415	0.24	9.60	0.03	
4	other end of huge blue bins	69.060	0.36	9.59	0.04	
5	gross gray trailer with brown crusty stripes	68.765	0.30	9.60	0.03	
6	moldy green-white plastic barrels	68.545	0.22	9.60	0.02	
7	sweet wooden tower structure	68.225	0.32	9.59	0.03	
8	white container full of some liquid	68.110	0.12	9.60	0.01	
9	first tree down form council trail	67.810	0.30	9.60	0.03	
10	row of blue barrels by tan shack/post	67.550	0.26	9.60	0.03	
11	in between gray barrel and tree	67.175	0.38	9.59	0.04	
12		66.830	0.34	9.59	0.04	
13	gray garage door on brown building	66.670	0.16	9.60	0.02	
14	pyramid on top of brown building (tree)	66.415	0.26	9.60	0.03	
15	back end of pyramid	66.115	0.30	9.60	0.03	
16	near end of building	65.665	0.45	9.59	0.05	
17	giant sweet mossy stump	65.355	0.31	9.59	0.03	
18	gap between tall barren deciduous and hedge	64.930	0.42	9.59	0.04	
19	hedge of sickly conifers	64.900	0.03	9.60	0.00	
20	in between two rows of parking stalls	64.495	0.41	9.59	0.04	
21		64.005	0.49	9.59	0.05	
22	by mysterious manholes	62.555	1.45	9.49	0.15	0.09
23	by storm sewer	62.180	0.38	9.59	0.04	0.09
24	dark gray garage door	61.955	0.23	9.60	0.02	
25	in between basketball hoop and cage	61.800	0.15	9.60	0.02	
26	storm drain	61.625	0.18	9.60	0.02	
27	lamppost	61.800	-0.18	9.60	-0.02	0.01
28	huge rock	62.075	-0.27	9.60	-0.03	0.01
29	giant tree with exposed trunk	62.215	-0.14	9.60	-0.01	0.01
30	yellow concrete thing	62.185	0.03	9.60	0.00	0.01
31	clean power manhole	61.875	0.31	9.59	0.03	
32	fork in the road (also huge pole)	61.315	0.56	9.58	0.06	
33		60.470	0.85	9.56	0.09	
34	clump of 4 trees	59.940	0.53	9.59	0.06	
35	stump	59.740	0.20	9.60	0.02	
36	pile of flotsam	59.525	0.22	9.60	0.02	
37	stump	59.235	0.29	9.60	0.03	
38	3 fence posts from end	58.985	0.25	9.60	0.03	
39	end of fence/clump of trees--in water	58.695	0.29	9.60	0.03	
40	end of raised dirt	58.585	0.11	9.60	0.01	
41	between two parking stalls	58.390	0.20	9.60	0.02	
42	row of lamp posts	58.255	0.13	9.60	0.01	
43		58.120	0.14	9.60	0.01	

	Notes	Elevation	Change in Elevation	Horizontal Distance	Slope	Overall Slope
44	row of lamp posts minus the lampposts--in water	57.960	0.16	9.60	0.02	
45	spindly shrubbery	57.960	0.00	9.60	0.00	
46	fence/private property sign	57.810	0.15	9.60	0.02	
47	freaking nothing	57.740	0.07	9.60	0.01	
48	pole in ground	57.100	0.64	9.58	0.07	
49		58.155	-1.05	9.54	-0.11	0.03
50	private property sign on fence	56.420	1.74	9.44	0.18	0.03
51	pole with two upside down horseshoes	56.240	0.18	9.60	0.02	
52	storm sewer	56.070	0.17	9.60	0.02	
53	air liquide tank (white)	55.840	0.23	9.60	0.02	
54	edge of brown building	55.565	0.27	9.60	0.03	
55	private property sign	55.450	0.12	9.60	0.01	
56	tall silver thingy that looks like a missile	55.290	0.16	9.60	0.02	
57	millionth private property sign	55.040	0.25	9.60	0.03	
58	huge pole	54.855	0.19	9.60	0.02	
59	millionth and one pp sign	54.415	0.44	9.59	0.05	
60		54.130	0.29	9.60	0.03	
61	pp	53.935	0.19	9.60	0.02	
62	gvrd survey post	53.715	0.22	9.60	0.02	
63	pp	53.355	0.36	9.59	0.04	
64	end of gray building monstrosity	52.860	0.50	9.59	0.05	
65	silvery chimney thing on blue building	52.405	0.45	9.59	0.05	
66	end of blue building	52.205	0.20	9.60	0.02	
67	pp	52.205	0.00	9.60	0.00	
68	Aa box/trailer	52.190	0.02	9.60	0.00	
69	sweet octagonal painting	51.865	0.33	9.59	0.03	
70		51.830	0.03	9.60	0.00	
71	barren wasteland	51.630	0.20	9.60	0.02	
72	end of shrubbery/pole	51.515	0.11	9.60	0.01	
73	white drainage pipes	51.050	0.47	9.59	0.05	
74	curve In the road	50.895	0.16	9.60	0.02	
75	lone tree in pile of branches	50.625	0.27	9.60	0.03	
76		50.815	-0.19	11.52	-0.02	0.01
77	monster stump with tree growing out of it	50.415	0.40	9.59	0.04	0.01
78	polka dot trees	50.120	0.29	9.60	0.03	
79	incredibly mossy tree	49.835	0.29	9.60	0.03	
80	forest	49.445	0.39	9.59	0.04	
81	big pile of junk behind fence	49.400	0.05	9.60	0.00	
82	tree by path #2	49.355	0.04	9.60	0.00	
83	forest	48.87	0.48	9.59	0.05	
	overall grade				0.026	

APPENDIX B: FLOW ANALYSIS

Using the Continuity and Manning Equations

$$Q = Bvy$$

$$v = \frac{R^{\frac{2}{3}} S_o^{\frac{1}{2}}}{n}$$

Q=.17 m^3/s B=.75m		Slope							
		0.01		0.025		0.05		0.08	
		y (m)	v (m/s)	y (m)	v (m/s)	y (m)	v (m/s)	y (m)	v (m/s)
Manning's n	0.041	0.30	0.74	0.22	1.03	0.17	1.31	0.15	1.54
	0.075	0.48	0.47	0.34	0.67	0.26	0.86	0.22	1.02
	0.092	0.57	0.40	0.40	0.57	0.31	0.74	0.26	0.88

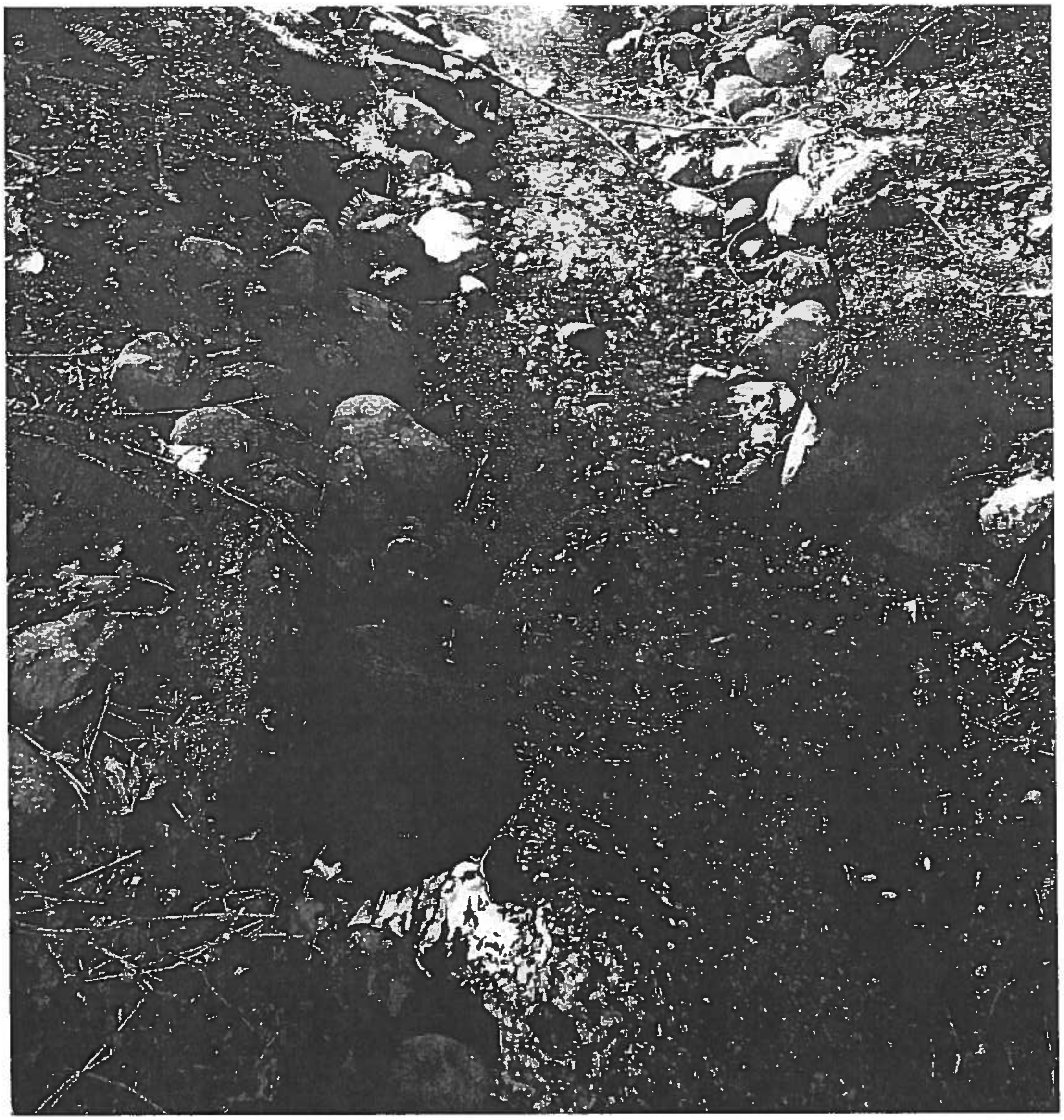
Q=.05 m^3/s B=.75m		Slope							
		0.01		0.025		0.05		0.08	
		y (m)	v (m/s)	y (m)	v (m/s)	y (m)	v (m/s)	y (m)	v (m/s)
Manning's n	0.041	0.13	0.51	0.10	0.69	0.08	0.86	0.07	1.00
	0.075	0.20	0.34	0.14	0.46	0.11	0.58	0.10	0.68
	0.092	0.23	0.29	0.17	0.40	0.13	0.51	0.11	0.59

Q=.004 m^3/s B=.75m		Slope							
		0.01		0.025		0.05		0.08	
		y (m)	v (m/s)	y (m)	v (m/s)	y (m)	v (m/s)	y (m)	v (m/s)
Manning's n	0.1	0.05	0.11	0.04	0.15	0.03	0.19	0.02	0.21
	0.2	0.07	0.07	0.05	0.10	0.04	0.12	0.04	0.14
	0.3	0.09	0.06	0.07	0.08	0.06	0.10	0.05	0.11

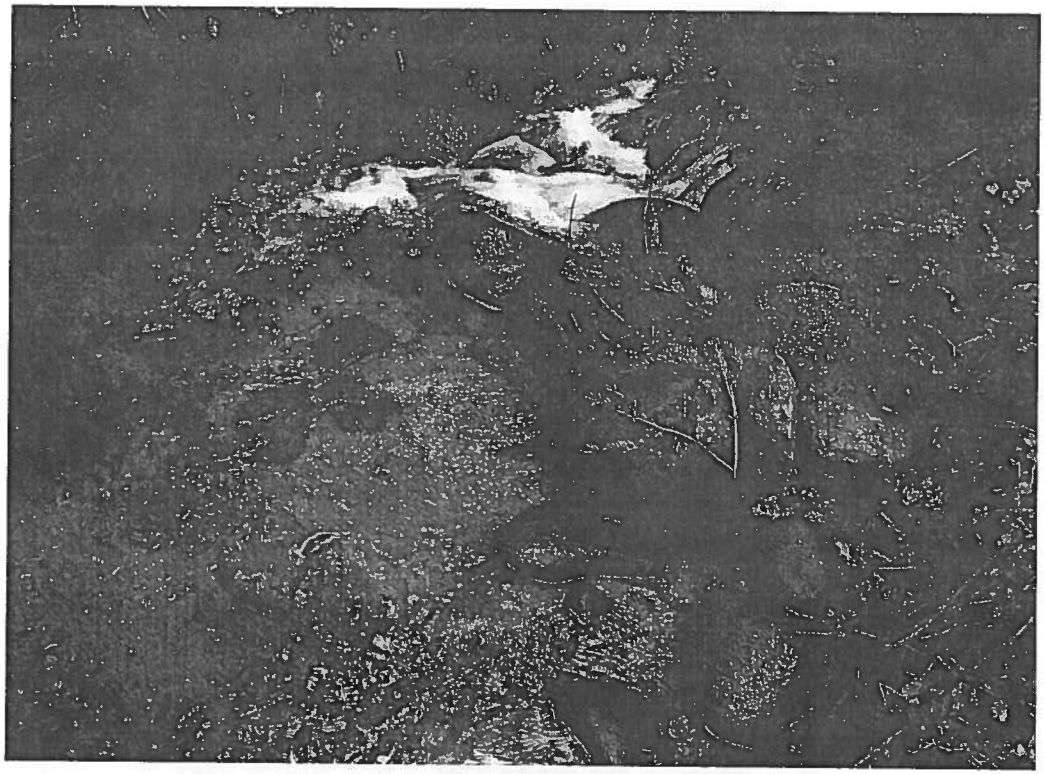
Red indicates values outside of range for acceptable cutthroat trout habitat.

APPENDIX C: MOSQUITO CREEK

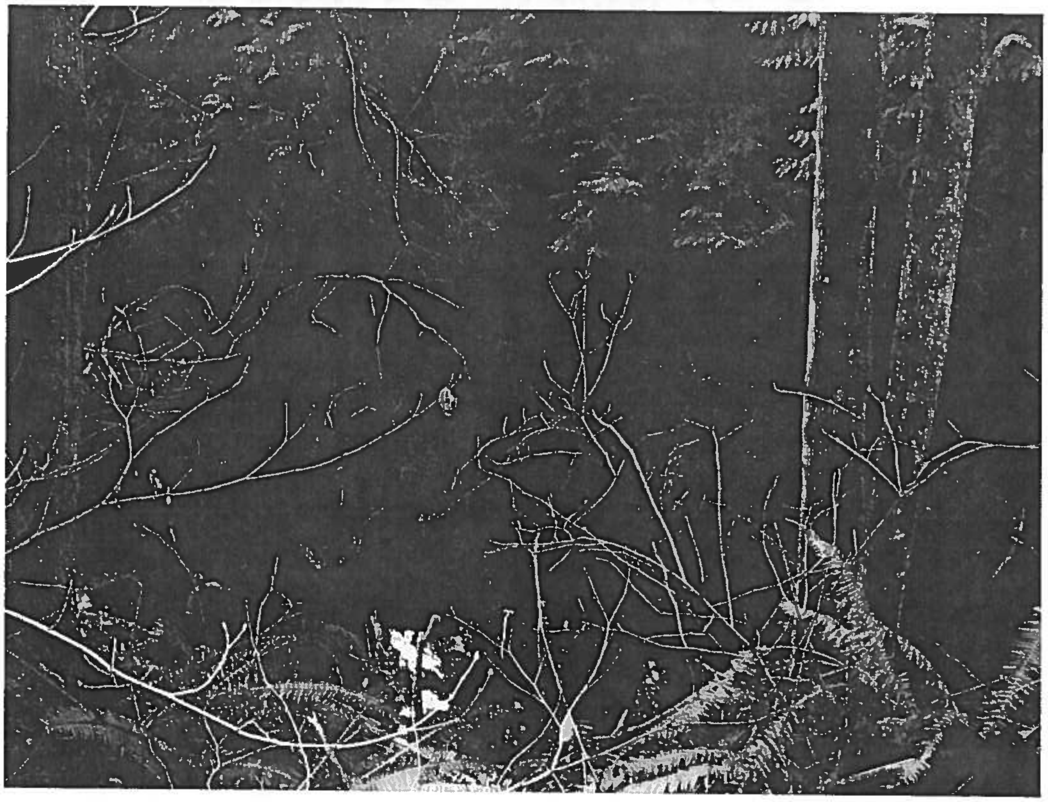
There are several similar man-made streams in the GVRD, including Spanish Banks Creek in Vancouver, Beecher Creek in Burnaby, and Mosquito Creek in North Vancouver. Of these, Mosquito Creek is the most similar to this project. Mosquito Creek provides an excellent example of the feel of a naturalized man-made stream, and can be used to aid in the design of the Wesbrook Place Stream.



MOSQUITO CREEK



RIFFLE MORPHOLOGY WITH LARGE BOULDERS



LARGE POOL

POOL BENEATH A CASCADE

FLOW INLET

RIFFLED CHANNEL INTO POOL SECTION