

Technical Memo

December 10, 2009

To: Bruce Reid, P.Eng., Director
Watershed Science and Engineering Services, RVCA

Subject: **Van Gaal Drain - Potential Impact of the Berms North of Perth Street**

RVCA staff has completed an analysis of the potential impact of the two berms constructed recently upstream of Perth Street on flood elevations in the Van Gaal Drain. The analysis and findings are presented in this memo.

The calculations were done using the HEC-RAS model of the Van Gaal Drain developed by J. F. Sabourin and Associates (JFSA) in November 2009 for mapping the flood risk areas.

Three model scenarios were considered as listed in Table 1.

Table 1 - Scenarios Modeled in HEC-RAS

Scenario	Description
A	The existing conditions in the Richmond area - using the HEC-RAS model developed by JFSA
B	<i>Scenario A plus:</i> - Recently constructed berm west of Van Gaal Drain
E	<i>Scenario A plus:</i> - Recently constructed berm west of Van Gaal Drain <u>and</u> - Recently constructed berm east of Van Gaal Drain

For all scenarios, the model was run to generate the 1:100 year water surface elevations corresponding to three hydrological conditions as listed in Table 2. The maximum of the three water elevations was taken as the regulatory flood elevation.

Table 2 - Flow combinations used to determine max 100 year water surface elevations

Event	Description
VG SUM	When the Van Gaal Drain (VGD) 1:100 year summer peak flow occurs –in advance of peak flow on the Jock
VG SPR	When VGD 1:100 year spring peak flow occurs – in advance of peak flow on the Jock
JR SPR	When Jock River 1:100 year spring peak flow occurs - after the peak VGD flow

The original Scenario (A) utilizes HEC-RAS files from J.F. Sabourin & Associates Inc. and extracts the maximum 100 year water elevations from the above mentioned events. Note that the original files were not modified in any way for Scenario A and the values are shown in Table 3. This is the base condition, i.e., the “pre-berm” condition.

For the analysis of the Berm to the north of Perth Street, along the west bank of the Van Gaal drain (see Figure 1), the HEC-RAS files were modified (Scenario B). The Berm was modeled by inserting ineffective flow areas in the cross-sections 1416 through 2157, approximately 30 m to the west of the Van Gaal drain. The layout of the berm was provided to us by DSEL. The model was run for all three series of flow combinations and the maximum water levels were extracted. Table 4 shows the resulting water surface elevations for Scenario B.

Scenario E includes the berm along the west bank of Van Gaal Drain as well as the berm along the east bank. The alignment and dimensions of the east bank berm were provided by ASL (see Figure 2). The elevations for the berm were extracted from this drawing. Cross-sections 1340-1615 in the JFSA HEC-RAS model were modified to incorporate the changes to the land and to include an ineffective flow area. The cross-sections for Scenario E are shown in Appendix A. Again, the model was run for all three series of flow combinations and the maximum water levels were extracted (Table 5).

Table 6 compares the maximum water surface elevations of all three scenarios at each cross-section. It can be seen that the maximum increase in water elevation, due to the installation of the berm to the west of the drain, is 11 cm at cross-section 1833. When both berms, to the west and east of the drain, are included in the analysis the maximum water level increase is 12 cm at cross-section 1922. The impact of the berm to the east of the drain is not as large as the impact of the berm to the west. The addition of the ‘east berm’ alone raises the water elevations by a maximum of 6 cm.

HEC-RAS is also capable of calculating the average velocity of flow in the main channel of each cross-section. Table 7 shows the average computed channel velocities for different scenarios. In general the channel velocities will increase with the installation of the berms. However, the velocities are usually less than 1.2 m/s and are not expected to cause channel erosion.

Conclusion

Based on the analyses reported in this memo, it is concluded that the berms will, both individually and jointly, increase flood risk. Both berms have measurable, adverse impact on flood elevations.

Stephanie Schreiner, B.Eng., M.Sc.
Engineering Assistant

Ferdous Ahmed, Ph.D., P.Eng.
Senior Water Resources Engineer

References

J.F. Sabourin and Associates Inc. *Floodplain Mapping for the Van Gaal and Arbuckle municipal drains, in the village of Richmond*. November 2009.

Table 3 – 100 year Water Surface Elevations for Scenario A, All flow combinations

River	River Station	VG SPR	VG SUM	JR SPR	MAX	Dominant Event	
		W.S. Elev (m)					
Van Gaal Drain	3494	97.6	97.56	97.16	97.6	VG SPR	
Van Gaal Drain	3322	97.47	97.43	97.05	97.47	VG SPR	
Van Gaal Drain	3312	97.45	97.42	97.05	97.45	VG SPR	
Van Gaal Drain	3311	Culvert					
Van Gaal Drain	3302	97.35	97.33	97.01	97.35	VG SPR	
Van Gaal Drain	3297	97.32	97.27	96.98	97.32	VG SPR	
Van Gaal Drain	3185	97.25	97.17	96.56	97.25	VG SPR	
Van Gaal Drain	3175	97.23	97.15	96.59	97.23	VG SPR	
Van Gaal Drain	3174	Culvert					
Van Gaal Drain	3165	96.74	96.75	96.55	96.75	VG SUM	
Van Gaal Drain	3149	96.71	96.72	96.51	96.72	VG SUM	
Van Gaal Drain	3086	96.63	96.64	96.4	96.64	VG SUM	
Van Gaal Drain	3016	96.59	96.61	96.33	96.61	VG SUM	
Van Gaal Drain	2980	96.56	96.57	96.28	96.57	VG SUM	
Van Gaal Drain	2851	96.42	96.41	96.03	96.42	VG SPR	
Van Gaal Drain	2808	96.39	96.38	96.01	96.39	VG SPR	
Van Gaal Drain	2658	96.29	96.28	95.95	96.29	VG SPR	
Van Gaal Drain	2554	96.28	96.27	95.94	96.28	VG SPR	
Van Gaal Drain	2478	96.15	96.16	95.88	96.16	VG SUM	
Van Gaal Drain	2157	95.48	95.47	95.03	95.48	VG SPR	
Van Gaal Drain	2076	95.27	95.26	94.88	95.27	VG SPR	
Van Gaal Drain	1974	95.11	95.1	94.79	95.11	VG SPR	
Van Gaal Drain	1922	94.98	94.99	94.75	94.99	VG SUM	
Van Gaal Drain	1833	94.87	94.89	94.7	94.89	VG SUM	
Van Gaal Drain	1796	94.84	94.86	94.69	94.86	VG SUM	
Van Gaal Drain	1735	94.78	94.79	94.62	94.79	VG SUM	
Van Gaal Drain	1728	94.72	94.74	94.53	94.74	VG SUM	
Van Gaal Drain	1727	U/S Perth St. Culvert					
Van Gaal Drain	1717	94.73	94.74	94.29	94.74	VG SUM	
Van Gaal Drain	1615	94.61	94.6	94.22	94.61	VG SPR	
Van Gaal Drain	1555	94.55	94.53	94.19	94.55	VG SPR	
Van Gaal Drain	1488	94.45	94.45	94.16	94.45	VG SPR & VG	

						SUM
Van Gaal Drain	1416	94.41	94.39	94.12	94.41	VG SPR
Van Gaal Drain	1400	94.36	94.36	94.12	94.36	VG SPR & VG SUM
Van Gaal Drain	1364	94.29	94.31	94.11	94.31	VG SUM
Van Gaal Drain	1340	94.19	94.21	94.1	94.21	VG SUM
Van Gaal Drain	1339	Perth St. Culvert				
Van Gaal Drain	1312	94.12	94.13	94.09	94.13	VG SUM
Van Gaal Drain	1302	94.14	94.15	94.09	94.15	VG SUM
Van Gaal Drain	1268	94.13	94.14	94.09	94.14	VG SUM
Van Gaal Drain	1212	94.11	94.1	94.09	94.11	VG SPR
Van Gaal Drain	1169	94.08	94.04	94.09	94.09	JR SPR
Van Gaal Drain	1091	94.04	93.97	94.09	94.09	JR SPR
Van Gaal Drain	1002	94.02	93.92	94.09	94.09	JR SPR
Van Gaal Drain	961	94.02	93.92	94.09	94.09	JR SPR
Van Gaal Drain	910	94.02	93.91	94.09	94.09	JR SPR
Van Gaal Drain	840	94.02	93.91	94.09	94.09	JR SPR
Van Gaal Drain	746	94.01	93.9	94.09	94.09	JR SPR
Van Gaal Drain	705	94.01	93.89	94.09	94.09	JR SPR
Van Gaal Drain	668	93.99	93.84	94.08	94.08	JR SPR
Van Gaal Drain	666	93.68	93.32	94.07	94.07	JR SPR
Van Gaal Drain	656	Fortune St. Culvert				
Van Gaal Drain	647	93.58	93.07	94.07	94.07	JR SPR
Van Gaal Drain	645	93.67	93.23	94.07	94.07	JR SPR
Van Gaal Drain	592	93.7	93.28	94.07	94.07	JR SPR
Van Gaal Drain	521	93.7	93.26	94.07	94.07	JR SPR
Van Gaal Drain	277	93.66	92.96	94.07	94.07	JR SPR
Van Gaal Drain	275	93.51	92.87	94.06	94.06	JR SPR
Van Gaal Drain	269	Fowler St. Culvert				
Van Gaal Drain	263	93.39	92.58	94.06	94.06	JR SPR
Van Gaal Drain	226	93.44	92.4	94.06	94.06	JR SPR
Van Gaal Drain	0	93.45	91.28	94.06	94.06	JR SPR
Moore Drain	555	94.63	94.67	94.33	94.67	VG SUM
Moore Drain	500	94.41	94.44	94.23	94.44	VG SUM
Moore Drain	298	94.02	93.9	94.09	94.09	JR SPR
Moore Drain	130	94.02	93.91	94.09	94.09	JR SPR

Joys Road Trib	705	97.79	97.59	97.1	97.79	VG SPR
Joys Road Trib	664	97.79	97.6	97.04	97.79	VG SPR
Joys Road Trib	635	97.67	97.5	97	97.67	VG SPR
Joys Road Trib	634	Joy's Rd. Culvert				
Joys Road Trib	622	97.26	97.21	96.96	97.26	VG SPR
Joys Road Trib	602	97.27	97.21	96.95	97.27	VG SPR
Joys Road Trib	322	96.71	96.65	96.45	96.71	VG SPR
Joys Road Trib	275	96.56	96.5	96.2	96.56	VG SPR
Joys Road Trib	30	96.29	96.29	95.95	96.29	VG SPR & VG SUM
Moore Drain Trib	311	94.58	94.6	94.5	94.6	VG SUM
Moore Drain Trib	90	94.18	94.2	94.08	94.2	VG SUM

Table 4 – 100 year Water Surface Elevations for Scenario B, All flow combinations

River	River Station	VG SPR	VG SUM	JR SPR	MAX	Dominant Event	
		W.S. Elev (m)					
Van Gaal Drain	3494	97.6	97.56	97.16	97.6	VG SPR	
Van Gaal Drain	3322	97.47	97.43	97.05	97.47	VG SPR	
Van Gaal Drain	3312	97.45	97.42	97.05	97.45	VG SPR	
Van Gaal Drain	3311	Culvert					
Van Gaal Drain	3302	97.35	97.33	97.01	97.35	VG SPR	
Van Gaal Drain	3297	97.32	97.27	96.98	97.32	VG SPR	
Van Gaal Drain	3185	97.25	97.17	96.56	97.25	VG SPR	
Van Gaal Drain	3175	97.23	97.15	96.59	97.23	VG SPR	
Van Gaal Drain	3174	Culvert					
Van Gaal Drain	3165	96.74	96.75	96.55	96.75	VG SUM	
Van Gaal Drain	3149	96.71	96.72	96.51	96.72	VG SUM	
Van Gaal Drain	3086	96.63	96.64	96.4	96.64	VG SUM	
Van Gaal Drain	3016	96.59	96.61	96.33	96.61	VG SUM	
Van Gaal Drain	2980	96.56	96.57	96.28	96.57	VG SUM	
Van Gaal Drain	2851	96.42	96.41	96.03	96.42	VG SPR	
Van Gaal Drain	2808	96.39	96.38	96.01	96.39	VG SPR	
Van Gaal Drain	2658	96.29	96.28	95.95	96.29	VG SPR	
Van Gaal Drain	2554	96.29	96.27	95.94	96.29	VG SPR	
Van Gaal Drain	2478	96.17	96.17	95.88	96.17	VG SPR & VG SUM	
Van Gaal Drain	2157	95.49	95.49	95.03	95.49	VG SPR & VG SUM	
Van Gaal Drain	2076	95.36	95.34	94.89	95.36	VG SPR	
Van Gaal Drain	1974	95.21	95.18	94.81	95.21	VG SPR	
Van Gaal Drain	1922	95.09	95.08	94.77	95.09	VG SPR	
Van Gaal Drain	1833	95	94.99	94.72	95	VG SPR	
Van Gaal Drain	1796	94.92	94.93	94.71	94.93	VG SUM	
Van Gaal Drain	1735	94.83	94.84	94.62	94.84	VG SUM	
Van Gaal Drain	1728	94.79	94.78	94.56	94.79	VG SPR	
Van Gaal Drain	1727	U/S Perth St. Culvert					
Van Gaal Drain	1717	94.78	94.78	94.29	94.78	VG SPR & VG SUM	

Van Gaal Drain	1615	94.63	94.61	94.22	94.63	VG SPR
Van Gaal Drain	1555	94.55	94.53	94.19	94.55	VG SPR
Van Gaal Drain	1488	94.46	94.46	94.16	94.46	VG SPR & VG SUM
Van Gaal Drain	1416	94.4	94.38	94.12	94.4	VG SPR
Van Gaal Drain	1400	94.36	94.36	94.12	94.36	VG SPR & VG SUM
Van Gaal Drain	1364	94.29	94.31	94.11	94.31	VG SUM
Van Gaal Drain	1340	94.19	94.21	94.1	94.21	VG SUM
Van Gaal Drain	1339	Perth St. Culvert				
Van Gaal Drain	1312	94.12	94.13	94.09	94.13	VG SUM
Van Gaal Drain	1302	94.14	94.15	94.09	94.15	VG SUM
Van Gaal Drain	1268	94.13	94.14	94.09	94.14	VG SUM
Van Gaal Drain	1212	94.11	94.1	94.09	94.11	VG SPR
Van Gaal Drain	1169	94.08	94.04	94.09	94.09	JR SPR
Van Gaal Drain	1091	94.04	93.97	94.09	94.09	JR SPR
Van Gaal Drain	1002	94.02	93.92	94.09	94.09	JR SPR
Van Gaal Drain	961	94.02	93.92	94.09	94.09	JR SPR
Van Gaal Drain	910	94.02	93.91	94.09	94.09	JR SPR
Van Gaal Drain	840	94.02	93.91	94.09	94.09	JR SPR
Van Gaal Drain	746	94.01	93.9	94.09	94.09	JR SPR
Van Gaal Drain	705	94.01	93.89	94.09	94.09	JR SPR
Van Gaal Drain	668	93.99	93.84	94.08	94.08	JR SPR
Van Gaal Drain	666	93.68	93.32	94.07	94.07	JR SPR
Van Gaal Drain	656	Fortune St. Culvert				
Van Gaal Drain	647	93.58	93.07	94.07	94.07	JR SPR
Van Gaal Drain	645	93.67	93.23	94.07	94.07	JR SPR
Van Gaal Drain	592	93.7	93.28	94.07	94.07	JR SPR
Van Gaal Drain	521	93.7	93.26	94.07	94.07	JR SPR
Van Gaal Drain	277	93.66	92.96	94.07	94.07	JR SPR
Van Gaal Drain	275	93.51	92.87	94.06	94.06	JR SPR
Van Gaal Drain	269	Fowler St. Culvert				
Van Gaal Drain	263	93.39	92.58	94.06	94.06	JR SPR
Van Gaal Drain	226	93.44	92.4	94.06	94.06	JR SPR
Van Gaal Drain	0	93.45	91.28	94.06	94.06	JR SPR
Moore Drain	555	94.63	94.67	94.33	94.67	VG SUM

Moore Drain	500	94.41	94.44	94.23	94.44	VG SUM
Moore Drain	298	94.02	93.9	94.09	94.09	JR SPR
Moore Drain	130	94.02	93.91	94.09	94.09	JR SPR
Joys Road Trib	705	97.79	97.59	97.1	97.79	VG SPR
Joys Road Trib	664	97.79	97.6	97.04	97.79	VG SPR
Joys Road Trib	635	97.67	97.5	97	97.67	VG SPR
Joys Road Trib	634	Joy's Rd. Culvert				
Joys Road Trib	622	97.26	97.21	96.96	97.26	VG SPR
Joys Road Trib	602	97.27	97.21	96.95	97.27	VG SPR
Joys Road Trib	322	96.71	96.65	96.45	96.71	VG SPR
Joys Road Trib	275	96.56	96.5	96.2	96.56	VG SPR
Joys Road Trib	30	96.3	96.29	95.95	96.3	VG SPR
Moore Drain Trib	311	94.58	94.6	94.5	94.6	VG SUM
Moore Drain Trib	90	94.18	94.2	94.08	94.2	VG SUM

Table 5 – 100 year Water Surface Elevations for Scenario E, All flow combinations

River	River Station	VG SPR	VG SUM	JR SPR	MAX	Dominant Event
		W.S. Elev (m)				
Van Gaal Drain	3494	97.6	97.56	97.16	97.6	VG SPR
Van Gaal Drain	3322	97.47	97.43	97.05	97.47	VG SPR
Van Gaal Drain	3312	97.45	97.42	97.05	97.45	VG SPR
Van Gaal Drain	3311	Culvert				
Van Gaal Drain	3302	97.35	97.33	97.01	97.35	VG SPR
Van Gaal Drain	3297	97.32	97.27	96.98	97.32	VG SPR
Van Gaal Drain	3185	97.25	97.17	96.56	97.25	VG SPR
Van Gaal Drain	3175	97.23	97.15	96.59	97.23	VG SPR
Van Gaal Drain	3174	Culvert				
Van Gaal Drain	3165	96.74	96.75	96.55	96.75	VG SUM
Van Gaal Drain	3149	96.71	96.72	96.51	96.72	VG SUM
Van Gaal Drain	3086	96.63	96.64	96.4	96.64	VG SUM
Van Gaal Drain	3016	96.59	96.61	96.33	96.61	VG SUM
Van Gaal Drain	2980	96.56	96.57	96.28	96.57	VG SUM
Van Gaal Drain	2851	96.42	96.41	96.03	96.42	VG SPR
Van Gaal Drain	2808	96.39	96.38	96.01	96.39	VG SPR
Van Gaal Drain	2658	96.29	96.28	95.95	96.29	VG SPR
Van Gaal Drain	2554	96.29	96.27	95.94	96.29	VG SPR
Van Gaal Drain	2478	96.17	96.17	95.88	96.17	VG SPR & VG SUM
Van Gaal Drain	2157	95.49	95.49	95.03	95.49	VG SPR & VG SUM
Van Gaal Drain	2076	95.36	95.34	94.89	95.36	VG SPR
Van Gaal Drain	1974	95.22	95.18	94.81	95.22	VG SPR
Van Gaal Drain	1922	95.11	95.09	94.77	95.11	VG SPR
Van Gaal Drain	1833	95	95	94.72	95	VG SPR & VG SUM
Van Gaal Drain	1796	94.92	94.93	94.71	94.93	VG SUM
Van Gaal Drain	1735	94.86	94.86	94.62	94.86	VG SPR & VG SUM
Van Gaal Drain	1728	94.84	94.83	94.56	94.84	VG SPR
Van Gaal Drain	1727	U/S Perth St. Culvert				

Van Gaal Drain	1717	94.84	94.83	94.29	94.84	VG SPR	
Van Gaal Drain	1615	94.65	94.62	94.22	94.65	VG SPR	
Van Gaal Drain	1555	94.59	94.57	94.19	94.59	VG SPR	
Van Gaal Drain	1488	94.52	94.5	94.16	94.52	VG SPR	
Van Gaal Drain	1416	94.35	94.35	94.12	94.35	VG SPR & VG SUM	
Van Gaal Drain	1400	94.36	94.36	94.12	94.36	VG SPR & VG SUM	
Van Gaal Drain	1364	94.29	94.31	94.11	94.31	VG SUM	
Van Gaal Drain	1340	94.19	94.21	94.1	94.21	VG SUM	
Van Gaal Drain	1339	Perth St. Culvert					
Van Gaal Drain	1312	94.12	94.13	94.09	94.13	VG SUM	
Van Gaal Drain	1302	94.14	94.15	94.09	94.15	VG SUM	
Van Gaal Drain	1268	94.13	94.14	94.09	94.14	VG SUM	
Van Gaal Drain	1212	94.11	94.1	94.09	94.11	VG SPR	
Van Gaal Drain	1169	94.08	94.04	94.09	94.09	JR SPR	
Van Gaal Drain	1091	94.04	93.97	94.09	94.09	JR SPR	
Van Gaal Drain	1002	94.02	93.92	94.09	94.09	JR SPR	
Van Gaal Drain	961	94.02	93.92	94.09	94.09	JR SPR	
Van Gaal Drain	910	94.02	93.91	94.09	94.09	JR SPR	
Van Gaal Drain	840	94.02	93.91	94.09	94.09	JR SPR	
Van Gaal Drain	746	94.01	93.9	94.09	94.09	JR SPR	
Van Gaal Drain	705	94.01	93.89	94.09	94.09	JR SPR	
Van Gaal Drain	668	93.99	93.84	94.08	94.08	JR SPR	
Van Gaal Drain	666	93.68	93.32	94.07	94.07	JR SPR	
Van Gaal Drain	656	Fortune St. Culvert					
Van Gaal Drain	647	93.58	93.07	94.07	94.07	JR SPR	
Van Gaal Drain	645	93.67	93.23	94.07	94.07	JR SPR	
Van Gaal Drain	592	93.7	93.28	94.07	94.07	JR SPR	
Van Gaal Drain	521	93.7	93.26	94.07	94.07	JR SPR	
Van Gaal Drain	277	93.66	92.96	94.07	94.07	JR SPR	
Van Gaal Drain	275	93.51	92.87	94.06	94.06	JR SPR	
Van Gaal Drain	269	Fowler St. Culvert					
Van Gaal Drain	263	93.39	92.58	94.06	94.06	JR SPR	
Van Gaal Drain	226	93.44	92.4	94.06	94.06	JR SPR	
Van Gaal Drain	0	93.45	91.28	94.06	94.06	JR SPR	

Moore Drain	555	94.63	94.67	94.33	94.67	VG SUM
Moore Drain	500	94.41	94.44	94.23	94.44	VG SUM
Moore Drain	298	94.02	93.9	94.09	94.09	JR SPR
Moore Drain	130	94.02	93.91	94.09	94.09	JR SPR
Joys Road Trib	705	97.79	97.59	97.1	97.79	VG SPR
Joys Road Trib	664	97.79	97.6	97.04	97.79	VG SPR
Joys Road Trib	635	97.67	97.5	97	97.67	VG SPR
Joys Road Trib	634	Joy's Rd. Culvert				
Joys Road Trib	622	97.26	97.21	96.96	97.26	VG SPR
Joys Road Trib	602	97.27	97.21	96.95	97.27	VG SPR
Joys Road Trib	322	96.71	96.65	96.45	96.71	VG SPR
Joys Road Trib	275	96.56	96.5	96.2	96.56	VG SPR
Joys Road Trib	30	96.3	96.29	95.95	96.3	VG SPR
Moore Drain Trib	311	94.58	94.6	94.5	94.6	VG SUM
Moore Drain Trib	90	94.18	94.2	94.08	94.2	VG SUM

Table 6 – Maximum 100 year Water Surface Elevations for Scenarios A, B and E

River	River Station	Scenario A	Scenario B		Scenario E			
		W.S. Elev (m)	W.S. Elev (m)	Diff (B - A) (m)	W.S. Elev (m)	Diff (E - A) (m)	Diff (E - B) (m)	
Van Gaal Drain	3494	97.6	97.6	0	97.6	0	0	
Van Gaal Drain	3322	97.47	97.47	0	97.47	0	0	
Van Gaal Drain	3312	97.45	97.45	0	97.45	0	0	
Van Gaal Drain	3311	Culvert						0
Van Gaal Drain	3302	97.35	97.35	0	97.35	0	0	
Van Gaal Drain	3297	97.32	97.32	0	97.32	0	0	
Van Gaal Drain	3185	97.25	97.25	0	97.25	0	0	
Van Gaal Drain	3175	97.23	97.23	0	97.23	0	0	
Van Gaal Drain	3174	Culvert						0
Van Gaal Drain	3165	96.75	96.75	0	96.75	0	0	
Van Gaal Drain	3149	96.72	96.72	0	96.72	0	0	
Van Gaal Drain	3086	96.64	96.64	0	96.64	0	0	
Van Gaal Drain	3016	96.61	96.61	0	96.61	0	0	
Van Gaal Drain	2980	96.57	96.57	0	96.57	0	0	
Van Gaal Drain	2851	96.42	96.42	0	96.42	0	0	
Van Gaal Drain	2808	96.39	96.39	0	96.39	0	0	
Van Gaal Drain	2658	96.29	96.29	0	96.29	0	0	
Van Gaal Drain	2554	96.28	96.29	0.01	96.29	0.01	0	
Van Gaal Drain	2478	96.16	96.17	0.01	96.17	0.01	0	
Van Gaal Drain	2157	95.48	95.49	0.01	95.49	0.01	0	
Van Gaal Drain	2076	95.27	95.36	0.09	95.36	0.09	0	
Van Gaal Drain	1974	95.11	95.21	0.1	95.22	0.11	0.01	
Van Gaal Drain	1922	94.99	95.09	0.1	95.11	0.12	0.02	
Van Gaal Drain	1833	94.89	95	0.11	95	0.11	0	
Van Gaal Drain	1796	94.86	94.93	0.07	94.93	0.07	0	
Van Gaal Drain	1735	94.79	94.84	0.05	94.86	0.07	0.02	
Van Gaal Drain	1728	94.74	94.79	0.05	94.84	0.1	0.05	
Van Gaal Drain	1727	U/S Perth St. Culvert						0
Van Gaal Drain	1717	94.74	94.78	0.04	94.84	0.1	0.06	
Van Gaal Drain	1615	94.61	94.63	0.02	94.65	0.04	0.02	
Van Gaal Drain	1555	94.55	94.55	0	94.59	0.04	0.04	
Van Gaal Drain	1488	94.45	94.46	0.01	94.52	0.07	0.06	
Van Gaal Drain	1416	94.41	94.4	-0.01	94.35	-0.06	-0.05	
Van Gaal Drain	1400	94.36	94.36	0	94.36	0	0	
Van Gaal Drain	1364	94.31	94.31	0	94.31	0	0	
Van Gaal Drain	1340	94.21	94.21	0	94.21	0	0	
Van Gaal Drain	1339	Perth St. Culvert						0

Van Gaal Drain	1312	94.13	94.13	0	94.13	0	0	
Van Gaal Drain	1302	94.15	94.15	0	94.15	0	0	
Van Gaal Drain	1268	94.14	94.14	0	94.14	0	0	
Van Gaal Drain	1212	94.11	94.11	0	94.11	0	0	
Van Gaal Drain	1169	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	1091	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	1002	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	961	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	910	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	840	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	746	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	705	94.09	94.09	0	94.09	0	0	
Van Gaal Drain	668	94.08	94.08	0	94.08	0	0	
Van Gaal Drain	666	94.07	94.07	0	94.07	0	0	
Van Gaal Drain	656	Fortune St. Culvert						0
Van Gaal Drain	647	94.07	94.07	0	94.07	0	0	
Van Gaal Drain	645	94.07	94.07	0	94.07	0	0	
Van Gaal Drain	592	94.07	94.07	0	94.07	0	0	
Van Gaal Drain	521	94.07	94.07	0	94.07	0	0	
Van Gaal Drain	277	94.07	94.07	0	94.07	0	0	
Van Gaal Drain	275	94.06	94.06	0	94.06	0	0	
Van Gaal Drain	269	Fowler St. Culvert						0
Van Gaal Drain	263	94.06	94.06	0	94.06	0	0	
Van Gaal Drain	226	94.06	94.06	0	94.06	0	0	
Van Gaal Drain	0	94.06	94.06	0	94.06	0	0	
Moore Drain	555	94.67	94.67	0	94.67	0	0	
Moore Drain	500	94.44	94.44	0	94.44	0	0	
Moore Drain	298	94.09	94.09	0	94.09	0	0	
Moore Drain	130	94.09	94.09	0	94.09	0	0	
Joys Road Trib	705	97.79	97.79	0	97.79	0	0	
Joys Road Trib	664	97.79	97.79	0	97.79	0	0	
Joys Road Trib	635	97.67	97.67	0	97.67	0	0	
Joys Road Trib	634	Joy's Rd. Culvert						0
Joys Road Trib	622	97.26	97.26	0	97.26	0	0	
Joys Road Trib	602	97.27	97.27	0	97.27	0	0	
Joys Road Trib	322	96.71	96.71	0	96.71	0	0	
Joys Road Trib	275	96.56	96.56	0	96.56	0	0	
Joys Road Trib	30	96.29	96.3	0.01	96.3	0.01	0	
Moore Drain Trib	311	94.6	94.6	0	94.6	0	0	
Moore Drain Trib	90	94.2	94.2	0	94.2	0	0	

Table 7 – Maximum Channel Velocities for 100 year event for Scenarios A, B and E

River	River Station	Scenario A	Scenario B		Scenario E		
		Vel (m/s)	Vel (m/s)	Diff (B-A) (m/s)	Vel (m/s)	Diff (E-A) (m/s)	
Van Gaal Drain	3494	0.69	0.69	0	0.69	0	
Van Gaal Drain	3322	0.87	0.87	0	0.87	0	
Van Gaal Drain	3312	0.93	0.93	0	0.93	0	
Van Gaal Drain	3311	Culvert					
Van Gaal Drain	3302	0.92	0.92	0	0.92	0	
Van Gaal Drain	3297	1.23	1.23	0	1.23	0	
Van Gaal Drain	3185	0.62	0.62	0	0.62	0	
Van Gaal Drain	3175	0.85	0.85	0	0.85	0	
Van Gaal Drain	3174	Culvert					
Van Gaal Drain	3165	1.02	1.02	0	1.02	0	
Van Gaal Drain	3149	1.09	1.09	0	1.09	0	
Van Gaal Drain	3086	0.59	0.59	0	0.59	0	
Van Gaal Drain	3016	0.47	0.47	0	0.47	0	
Van Gaal Drain	2980	0.63	0.63	0	0.63	0	
Van Gaal Drain	2851	0.75	0.75	0	0.75	0	
Van Gaal Drain	2808	0.53	0.53	0	0.53	0	
Van Gaal Drain	2658	0.72	0.72	0	0.72	0	
Van Gaal Drain	2554	0.82	0.81	-0.01	0.81	-0.01	
Van Gaal Drain	2478	1.03	1.08	0.05	1.08	0.05	
Van Gaal Drain	2157	1.03	1.2	0.17	1.2	0.17	
Van Gaal Drain	2076	1.19	0.93	-0.26	0.93	-0.26	
Van Gaal Drain	1974	0.92	1.02	0.1	1	0.08	
Van Gaal Drain	1922	1.12	1.18	0.06	1.13	0.01	
Van Gaal Drain	1833	0.73	0.77	0.04	0.85	0.12	
Van Gaal Drain	1796	0.72	1.01	0.29	1.01	0.29	
Van Gaal Drain	1735	0.8	0.94	0.14	0.87	0.07	
Van Gaal Drain	1728	1.17	1.18	0.01	0.84	-0.33	
Van Gaal Drain	1727	U/S Perth St. Culvert					
Van Gaal Drain	1717	1.18	1.23	0.05	0.84	-0.34	
Van Gaal Drain	1615	0.65	0.82	0.17	1.02	0.37	
Van Gaal Drain	1555	0.92	0.97	0.05	0.9	-0.02	
Van Gaal Drain	1488	1.03	1	-0.03	0.89	-0.14	
Van Gaal Drain	1416	0.71	0.82	0.11	1.44	0.73	
Van Gaal Drain	1400	0.96	0.96	0	0.96	0	
Van Gaal Drain	1364	0.92	0.92	0	0.93	0.01	
Van Gaal Drain	1340	1.46	1.46	0	1.46	0	
Van Gaal Drain	1339	Perth St. Culvert					
Van Gaal Drain	1312	1.5	1.5	0	1.5	0	
Van Gaal Drain	1302	1.23	1.23	0	1.23	0	
Van Gaal Drain	1268	0.52	0.52	0	0.52	0	
Van Gaal Drain	1212	0.56	0.56	0	0.56	0	
Van Gaal Drain	1169	0.19	0.19	0	0.19	0	
Van Gaal Drain	1091	0.14	0.14	0	0.14	0	
Van Gaal Drain	1002	0.1	0.1	0	0.1	0	

Van Gaal Drain	961	0.06	0.06	0	0.06	0
Van Gaal Drain	910	0.05	0.05	0	0.05	0
Van Gaal Drain	840	0.05	0.05	0	0.05	0
Van Gaal Drain	746	0.09	0.09	0	0.09	0
Van Gaal Drain	705	0.09	0.09	0	0.09	0
Van Gaal Drain	668	0.2	0.2	0	0.2	0
Van Gaal Drain	666	0.47	0.47	0	0.47	0
Van Gaal Drain	656	Fortune St. Culvert				
Van Gaal Drain	647	0.44	0.44	0	0.44	0
Van Gaal Drain	645	0.22	0.22	0	0.22	0
Van Gaal Drain	592	0.08	0.08	0	0.08	0
Van Gaal Drain	521	0.04	0.04	0	0.04	0
Van Gaal Drain	277	0.13	0.13	0	0.13	0
Van Gaal Drain	275	0.33	0.33	0	0.33	0
Van Gaal Drain	269	Fowler St. Culvert				
Van Gaal Drain	263	0.3	0.3	0	0.3	0
Van Gaal Drain	226	0.12	0.12	0	0.12	0
Van Gaal Drain	0	0.01	0.01	0	0.01	0
Moore Drain	555	0.38	0.38	0	0.38	0
Moore Drain	500	1.21	1.21	0	1.21	0
Moore Drain	298	0.06	0.06	0	0.06	0
Moore Drain	130	0.01	0.01	0	0.01	0
Joys Road Trib	705	0.66	0.66	0	0.66	0
Joys Road Trib	664	0.23	0.23	0	0.23	0
Joys Road Trib	635	1.4	1.4	0	1.4	0
Joys Road Trib	634	Joy's Rd. Culvert				
Joys Road Trib	622	1.47	1.47	0	1.47	0
Joys Road Trib	602	0.72	0.72	0	0.72	0
Joys Road Trib	322	0.78	0.78	0	0.78	0
Joys Road Trib	275	0.9	0.9	0	0.9	0
Joys Road Trib	30	0.59	0.59	0	0.59	0
Moore Drain Trib	311	0.33	0.33	0	0.33	0
Moore Drain Trib	90	1.16	1.16	0	1.16	0

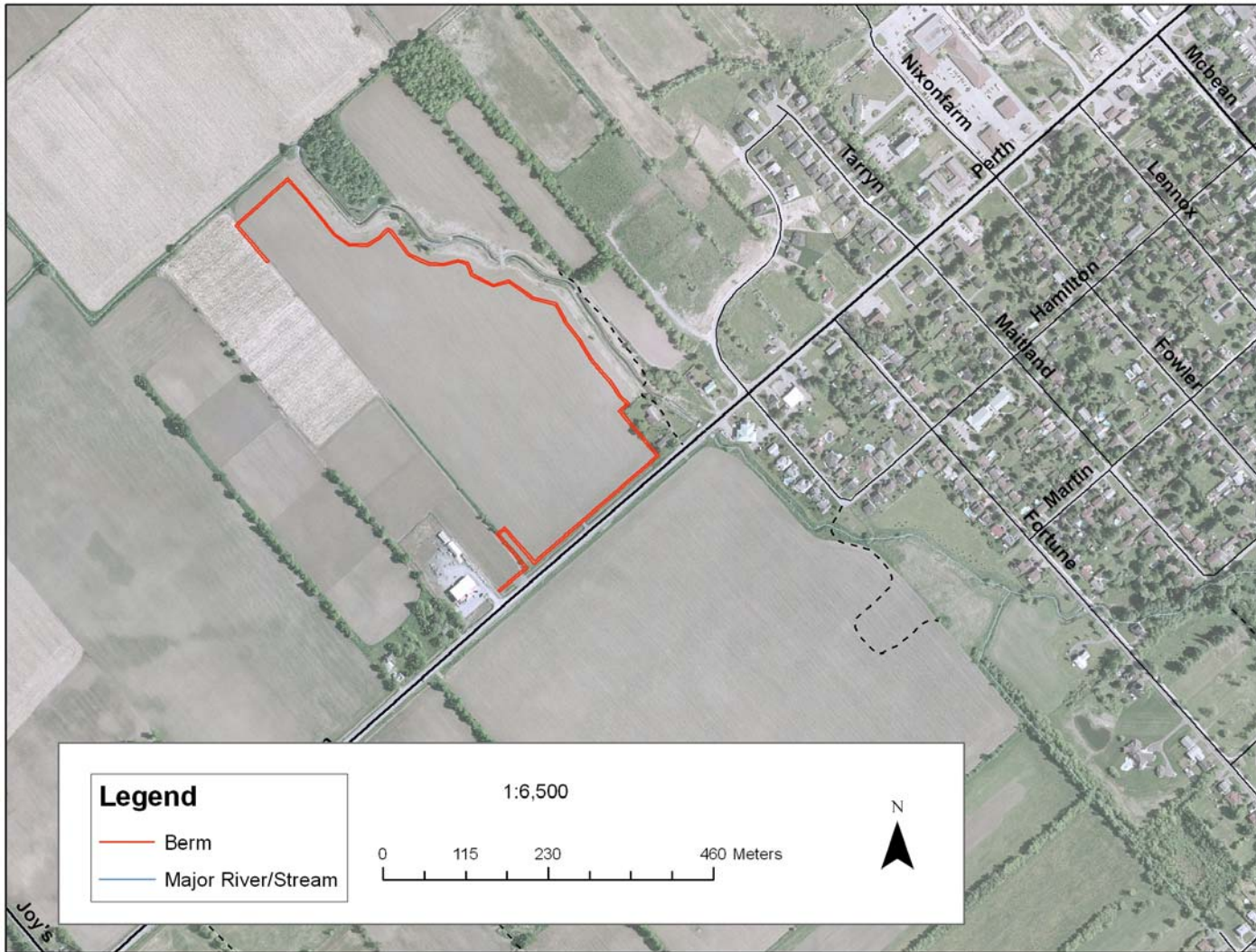


Figure 1 – Location of the ‘West Berm’ in Scenario B and E (Van Gaal Drain, Richmond)

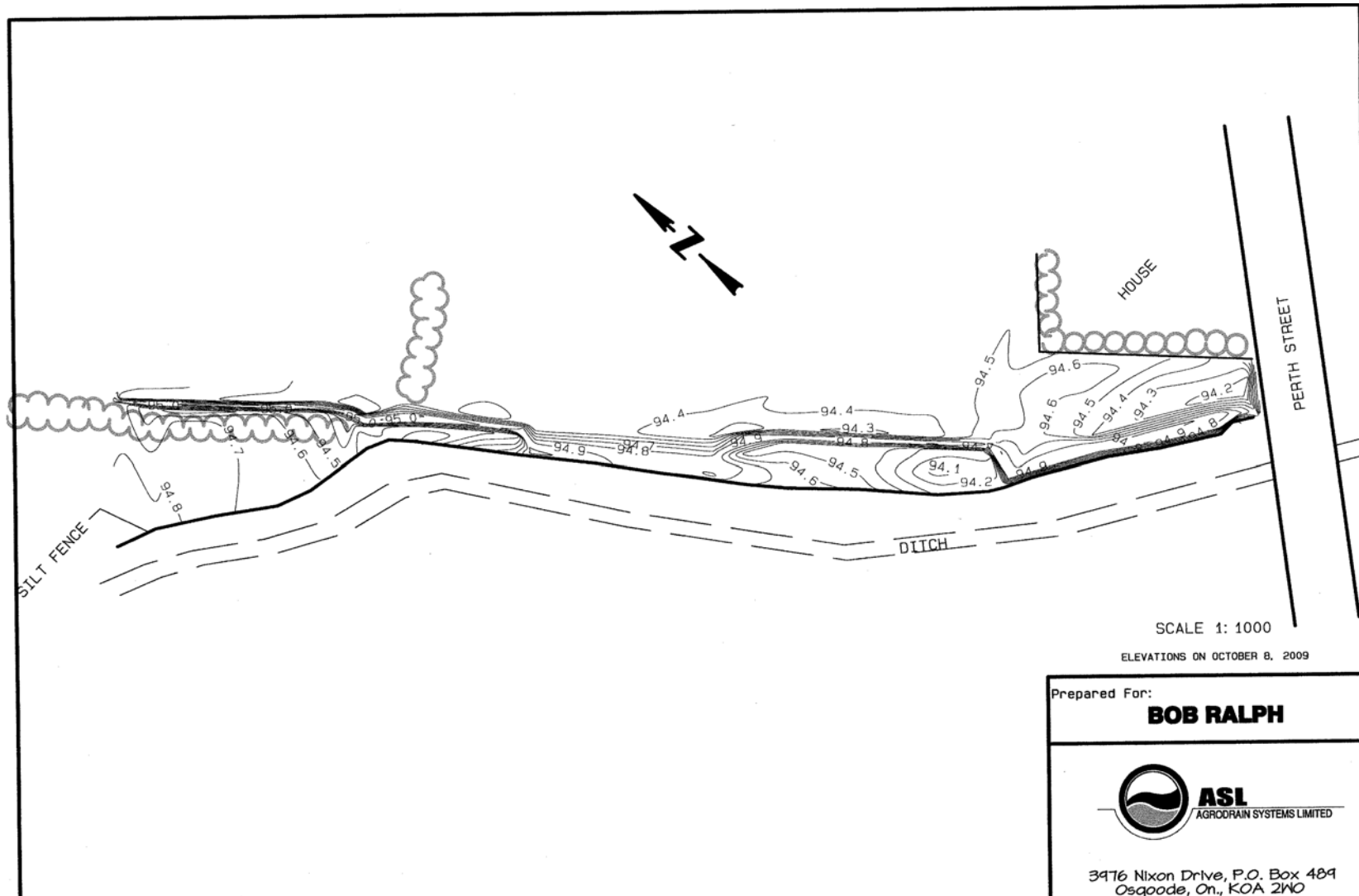
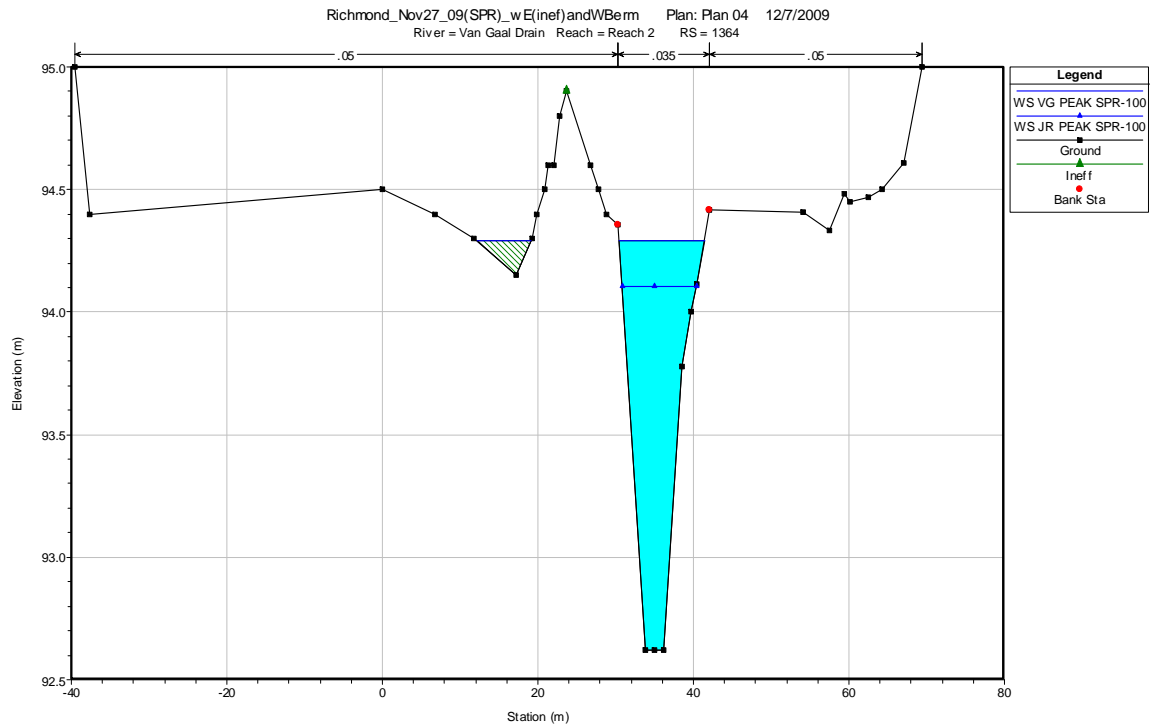
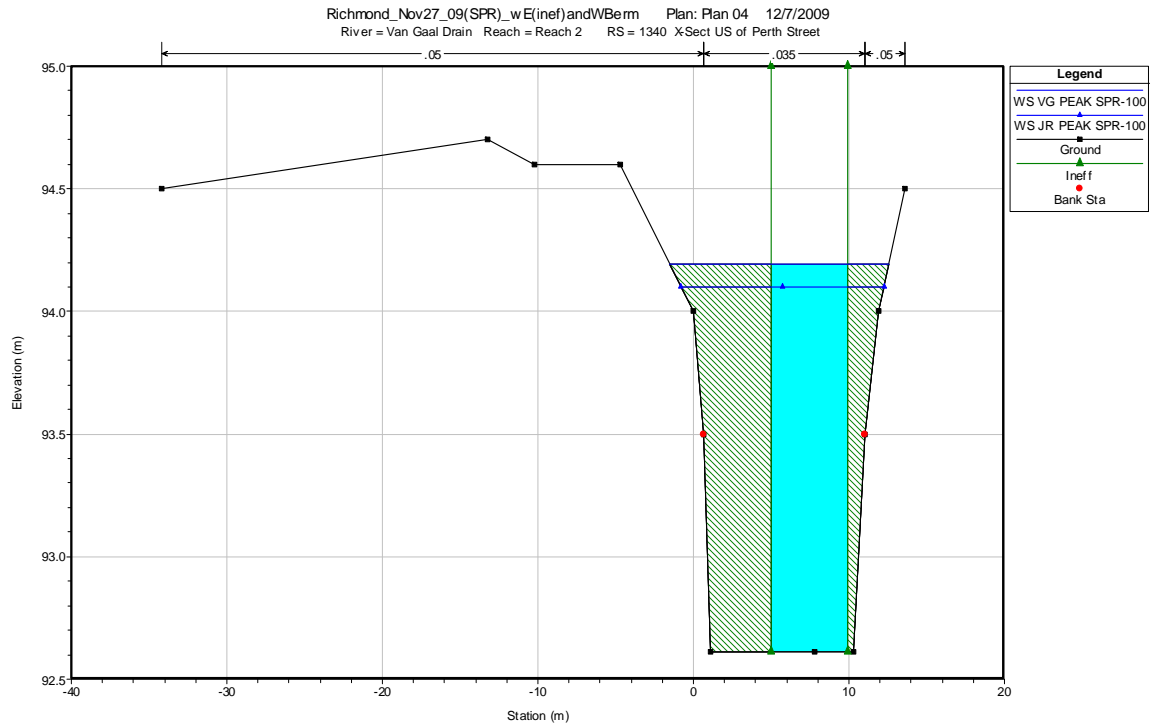
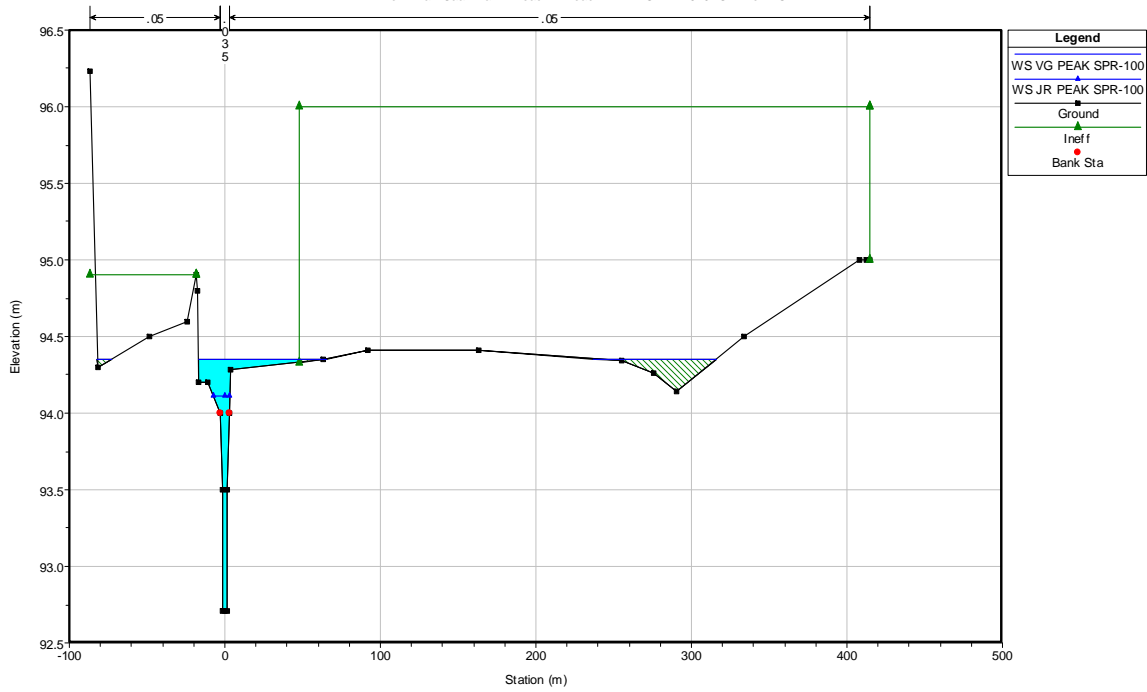


Figure 2 – Location of the 'East Berm' in Scenario E (Van Gaal Drain, Richmond)

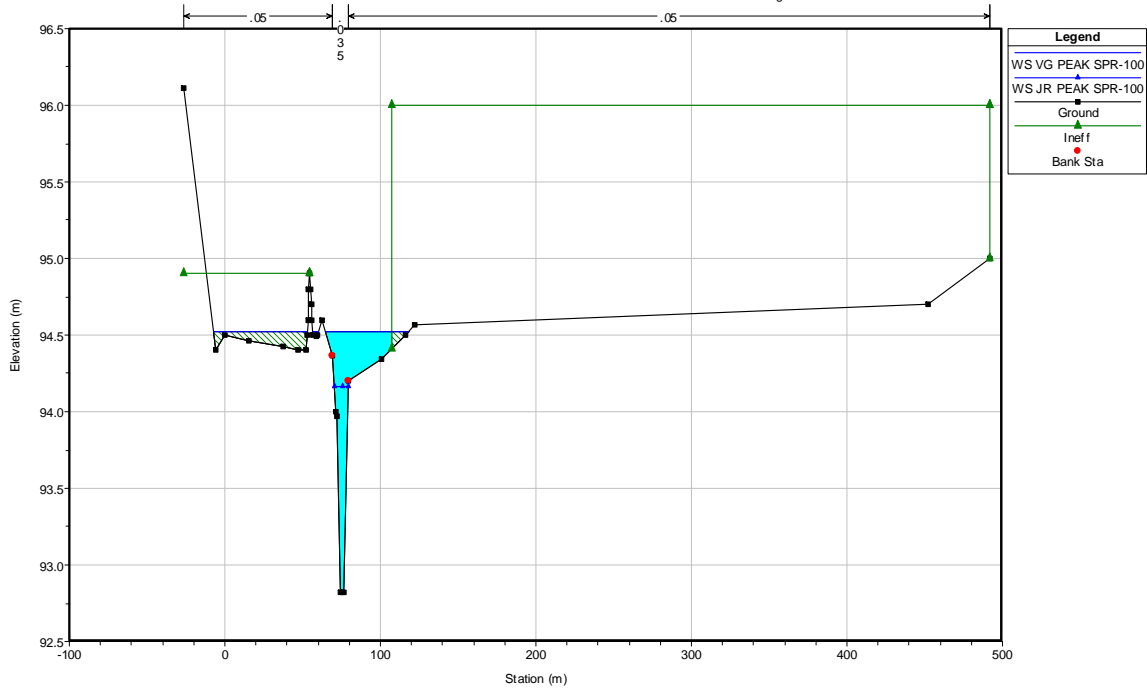
Appendix A – Cross-sections for Scenario E



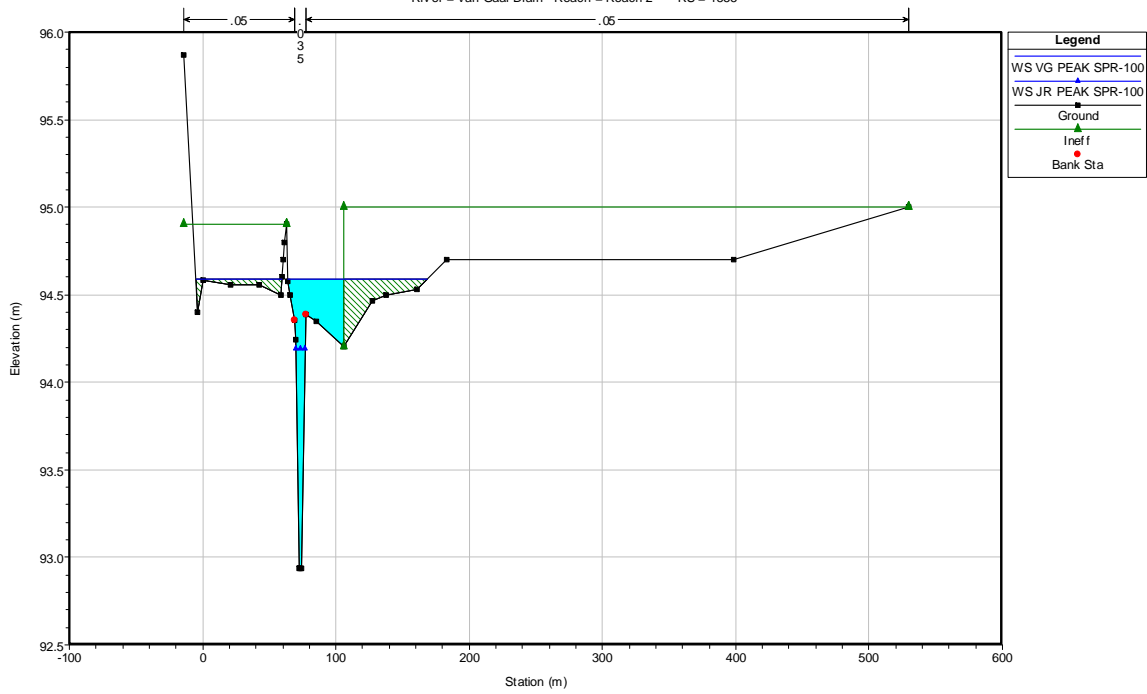
Richmond_Nov27_09(SPR)_wE(inef)andWBerm Plan: Plan 04 12/7/2009
 River = Van Gaal Drain Reach = Reach 2 RS = 1416 JFSA: New XS



Richmond_Nov27_09(SPR)_wE(inef)andWBerm Plan: Plan 04 12/7/2009
 River = Van Gaal Drain Reach = Reach 2 RS = 1488 JFSA: subtract 52m from Reach Lengths to account for new XS



Richmond_Nov27_09(SPR)_wE(ineff)andWBerm Plan: Plan 04 12/7/2009
 River = Van Gaal Drain Reach = Reach 2 RS = 1555



Richmond_Nov27_09(SPR)_wE(ineff)andWBerm Plan: Plan 04 12/7/2009
 River = Van Gaal Drain Reach = Reach 2 RS = 1615

