# APPENDIX A

## Additional Photos of Flooding in Pembroke

Additional Flooding Photos


2017


2017

2017

2003 Doran Street and D’Arcy Street Intersection

2003 Doran Street and D’Arcy Street Intersection

# APPENDIX B

## Floodlines for the 100-year Ottawa River Flow Event

# Riverside Park

Apr 27, 2019


Scale 1: 5,000

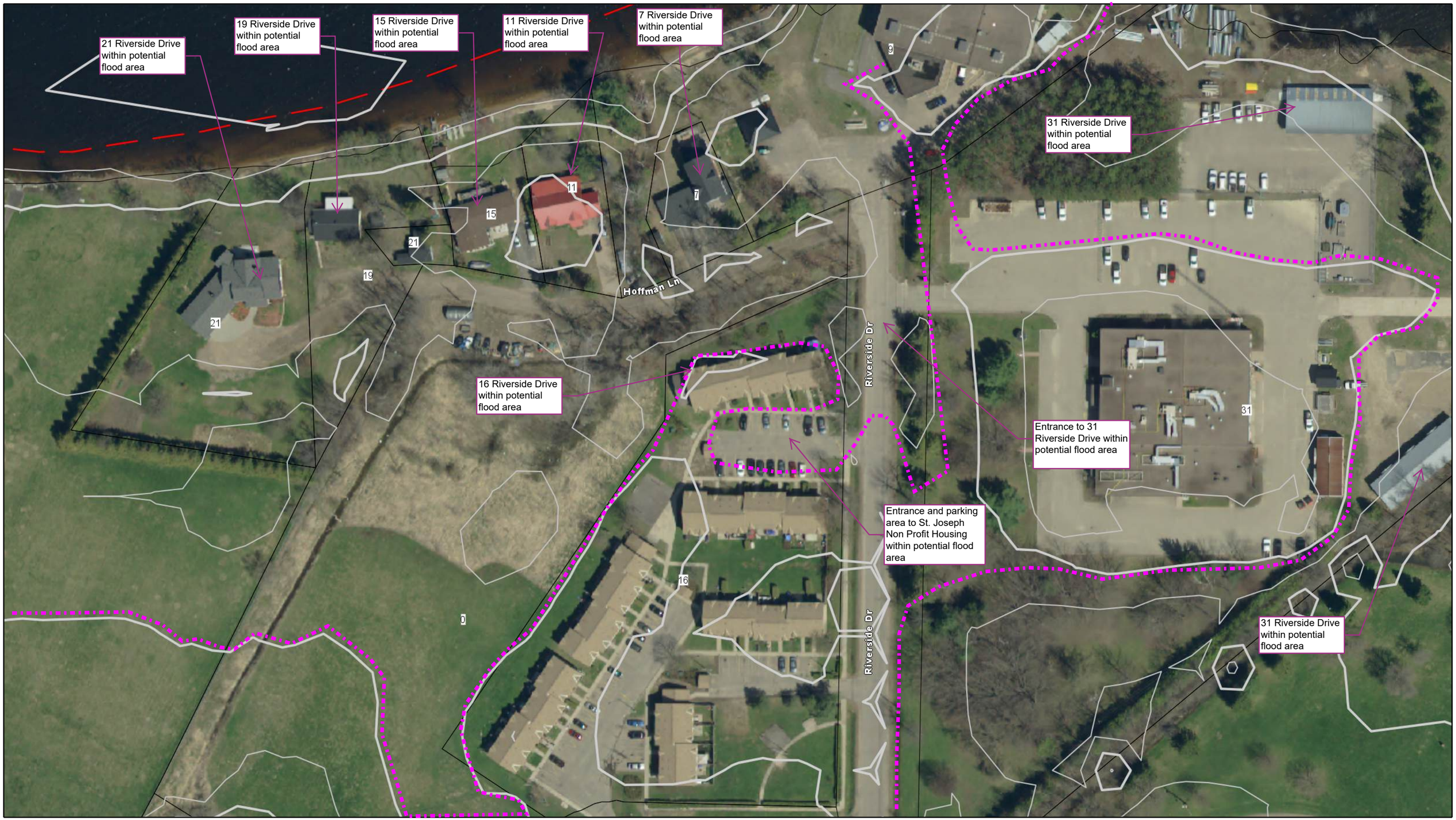
0 200 400 metres

N

# Hoffman Lane Residences

Flood Elevation  of 113.90

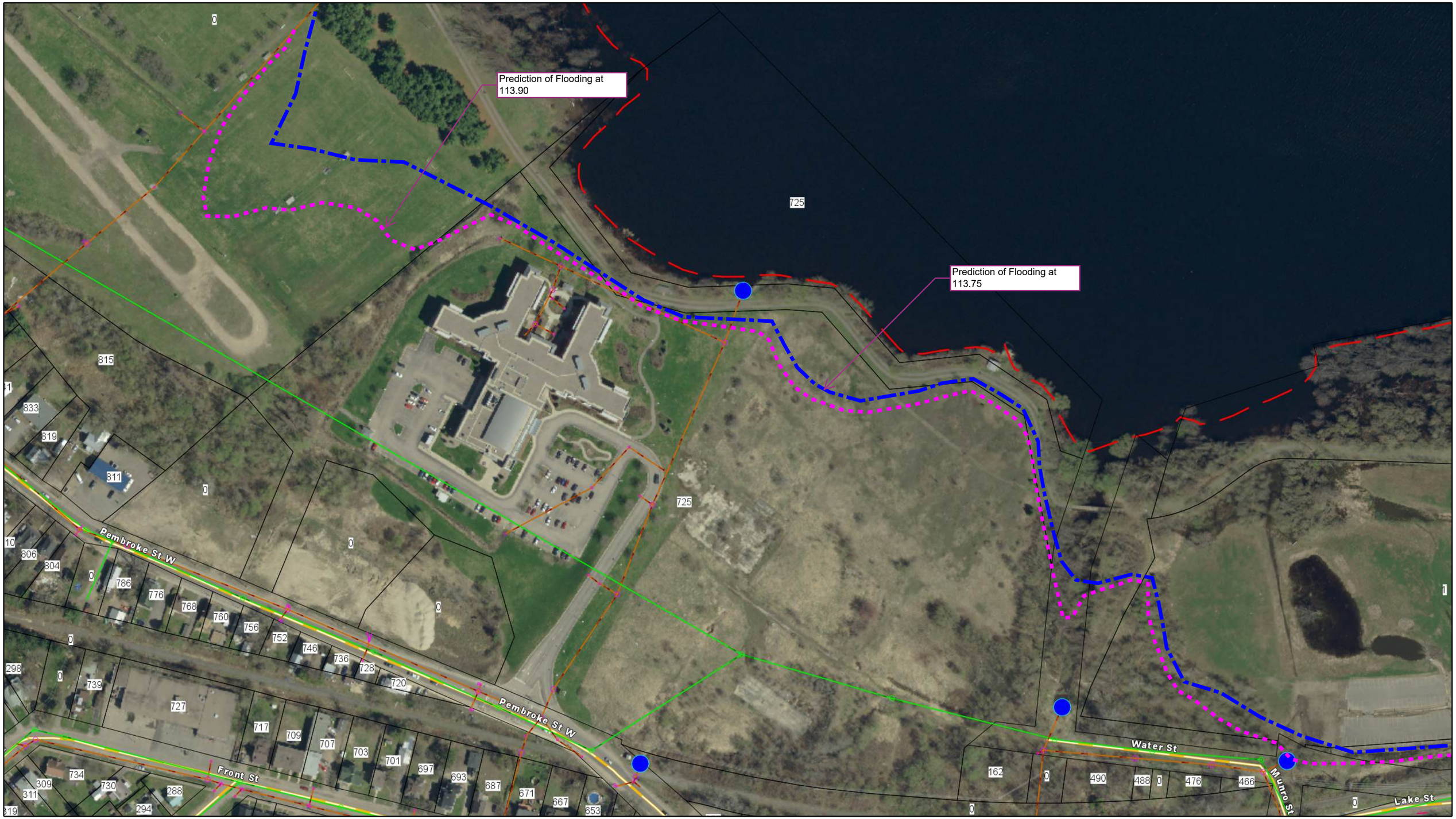
May 8, 2019




Scale 1: 1,000

0 50 100 metres

Apr 26, 2019




Scale 1: 2,000

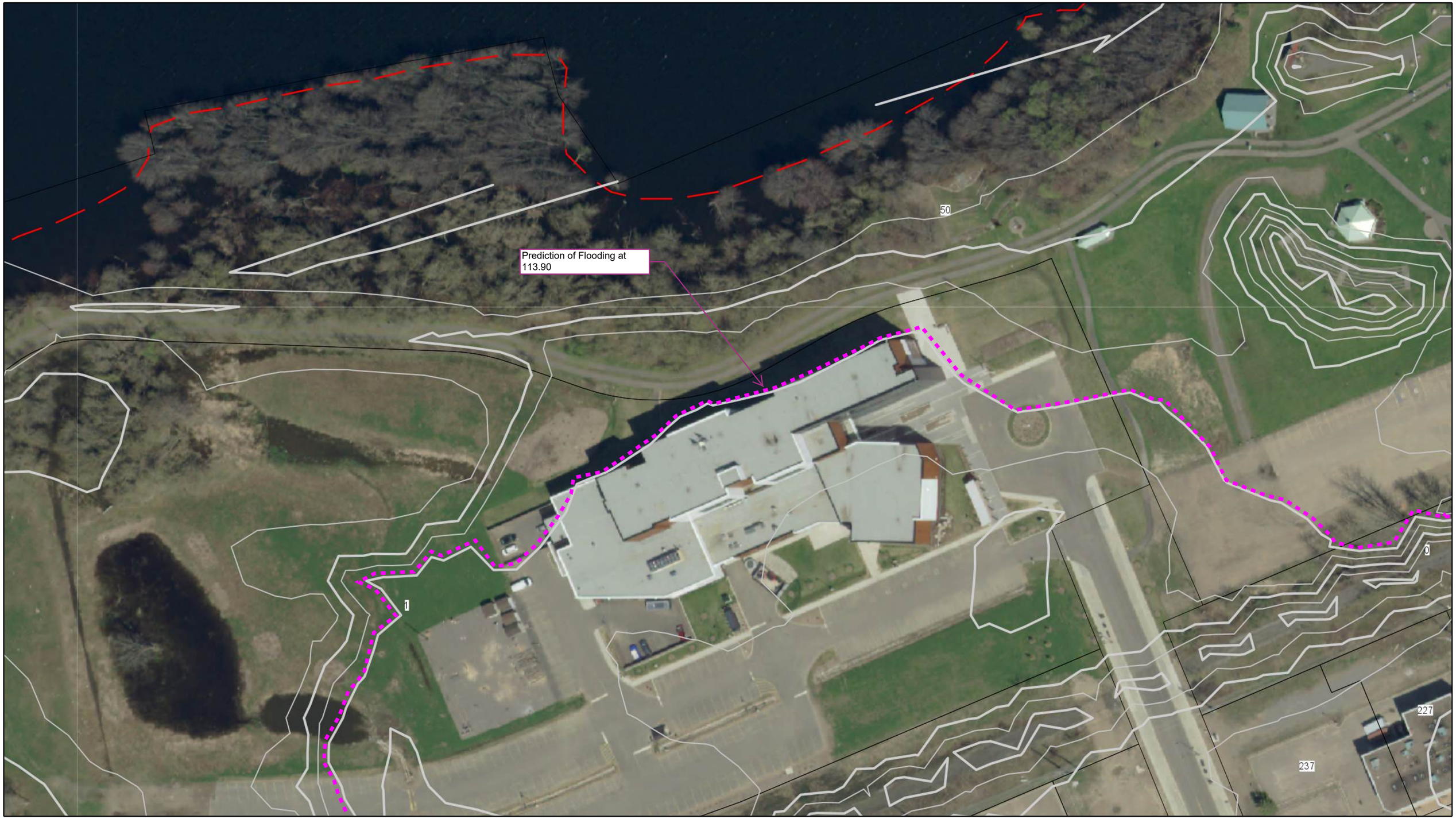
0 100 200 metres

N

**Algonquin College**

Flood Elevation of 113.90

May 8, 2019




Scale 1: 1,000

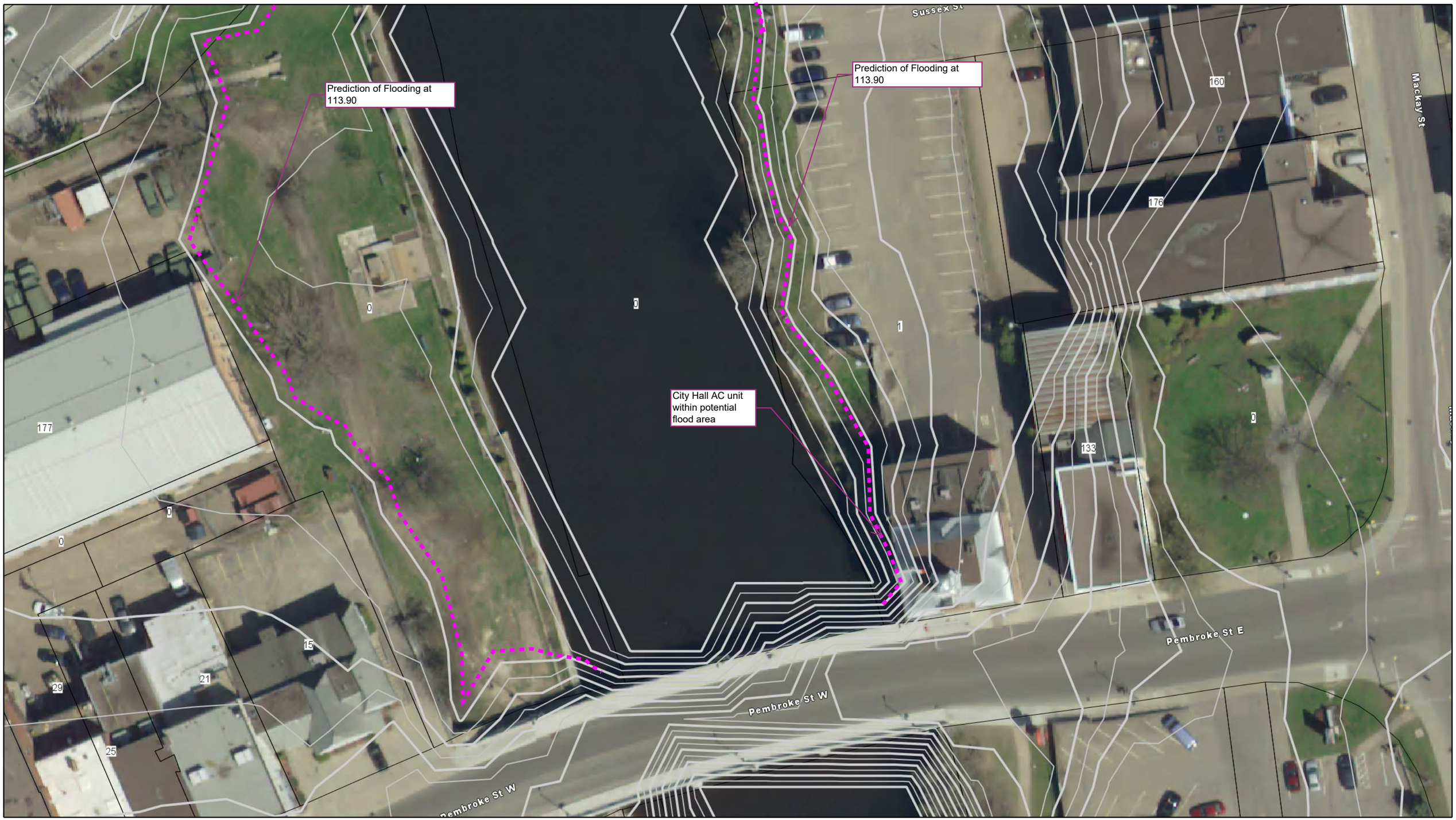
0 50 100 metres

N

## Cornation Park and City Hall

Flood Elevation of 113.90

May 8, 2019




Scale 1: 500

0 40 80 metres

N

Apr 26, 2019

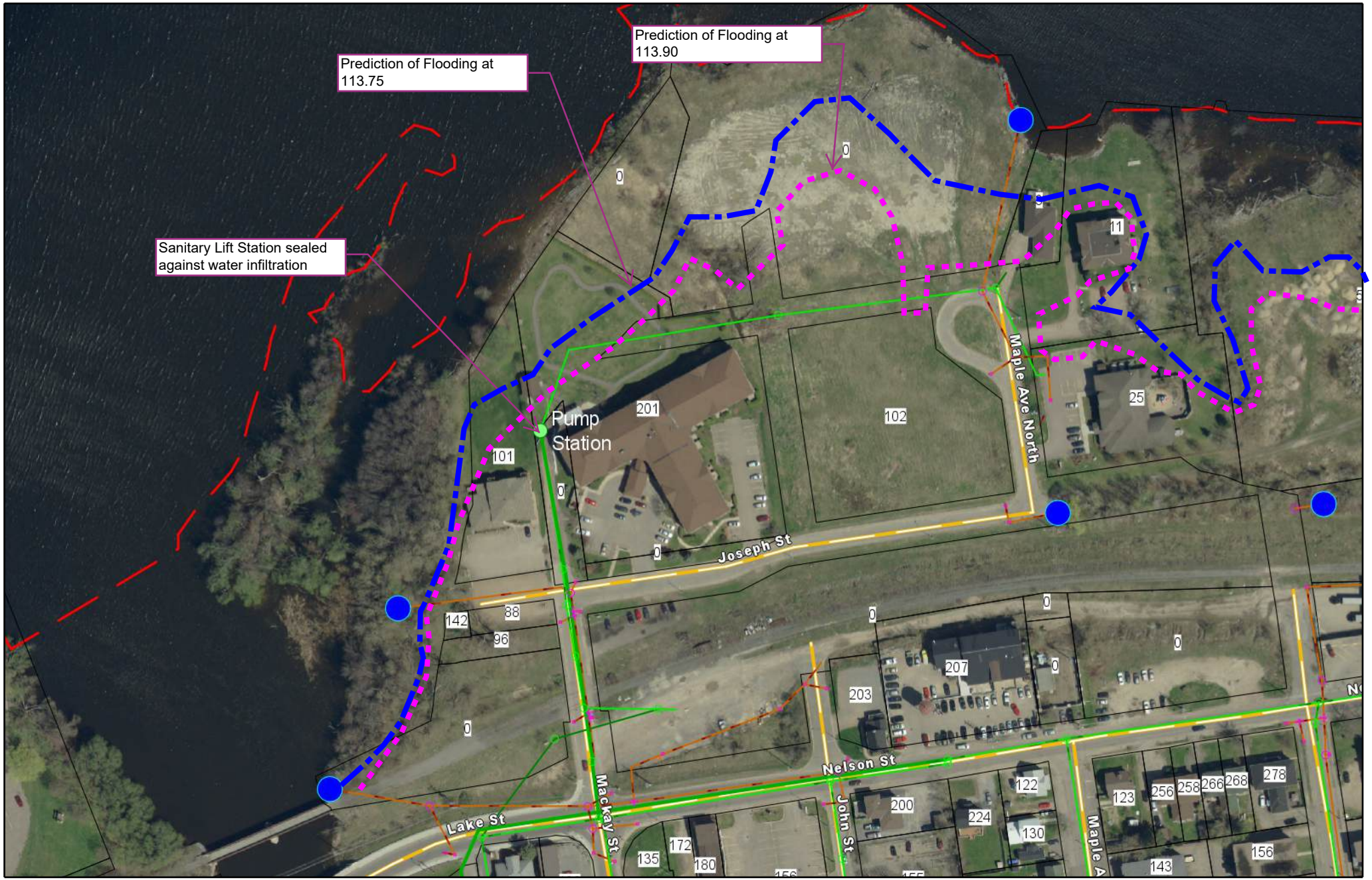

Scale 1: 2,000

0 100 200 metres

N

# Supples Landing

Apr 27, 2019

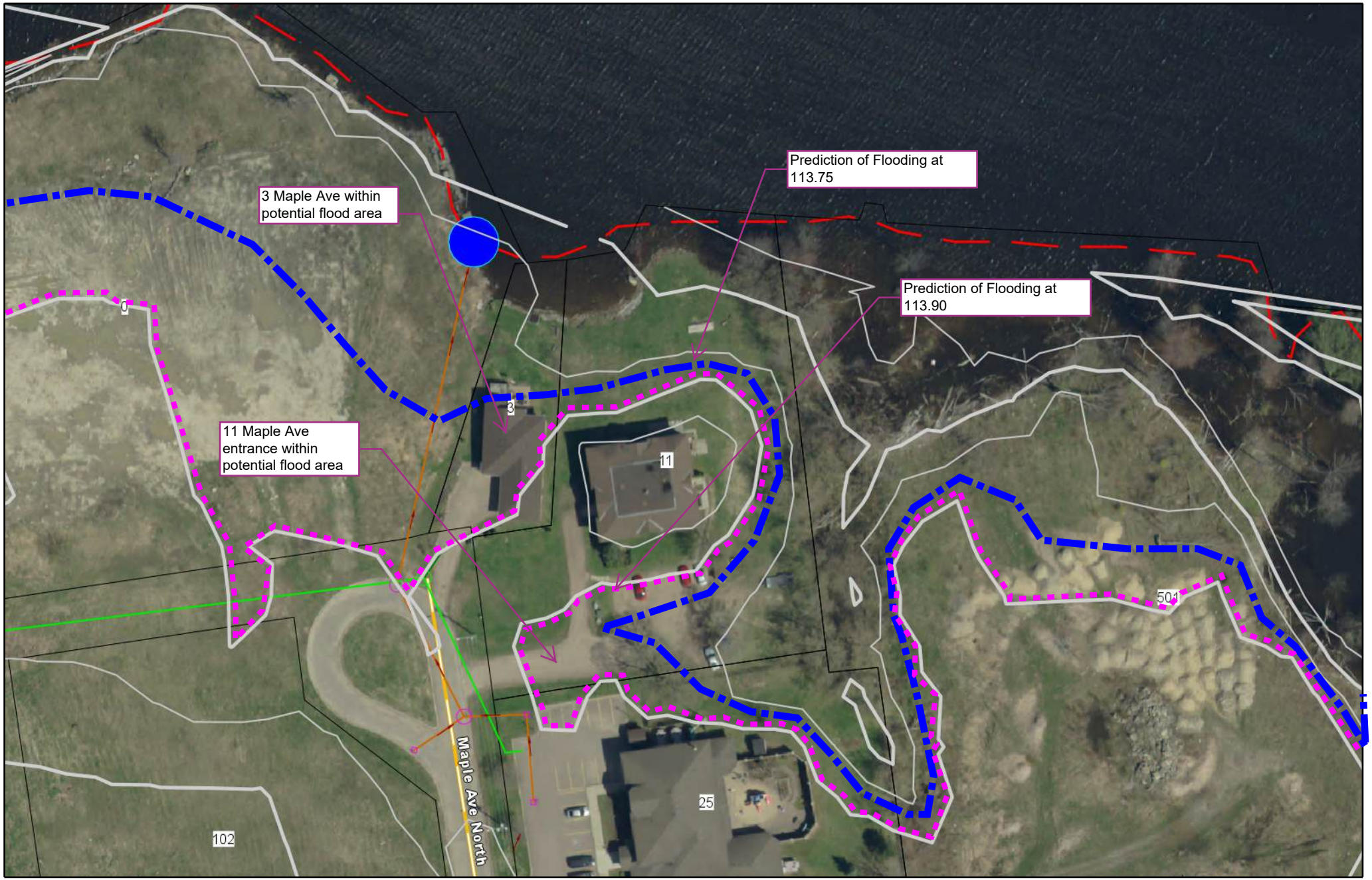



Scale 1: 2,000

0 100 200 metres

N

Apr 29, 2019




Scale 1: 1,000

0 40 80 metres

N

## Nelson Street Residences

Flood Elevation of 113.90

May 8, 2019


Scale 1: 500

0 40 80 metres

N

Pembroke

## Cedar Lane Residences

Water Elevation of 113.90

May 8, 2019


Scale 1: 1,000

0 50 100 metres

N

## APPENDIX C

## Details of the Hydrological Model Inputs, Setup, Calibration, and Results

### Table C.1: Summary of Channel Slope Variation

| Chainage (US to DS) | Average Channel Slope (m/m) |
|---|---|
| Indian River | |
| 0 m - 5,100 m | 0.03140 |
| 5,100 m – 58,050 m | 0.00199 |
| 58,050 m – 74,830 m | 0.00058 |
| Muskrat River (main branch) | |
| 0 m – 6,350 m | 0.01229 |
| 6,350 m - 30,590 m | 0.00275 |
| 30,590 m - 39,430 m (Doré Lake and marshes) | 0.00001 |
| 39,430 m - 56,040 m | 0.00107 |
| 56,040 m - 92,090 m (Muskrat Lake and marshes) | 0.00005 |
| 92,090 m - 97,990 m | 0.00193 |
| 97,990 m - 99,060 m | 0.00021 |

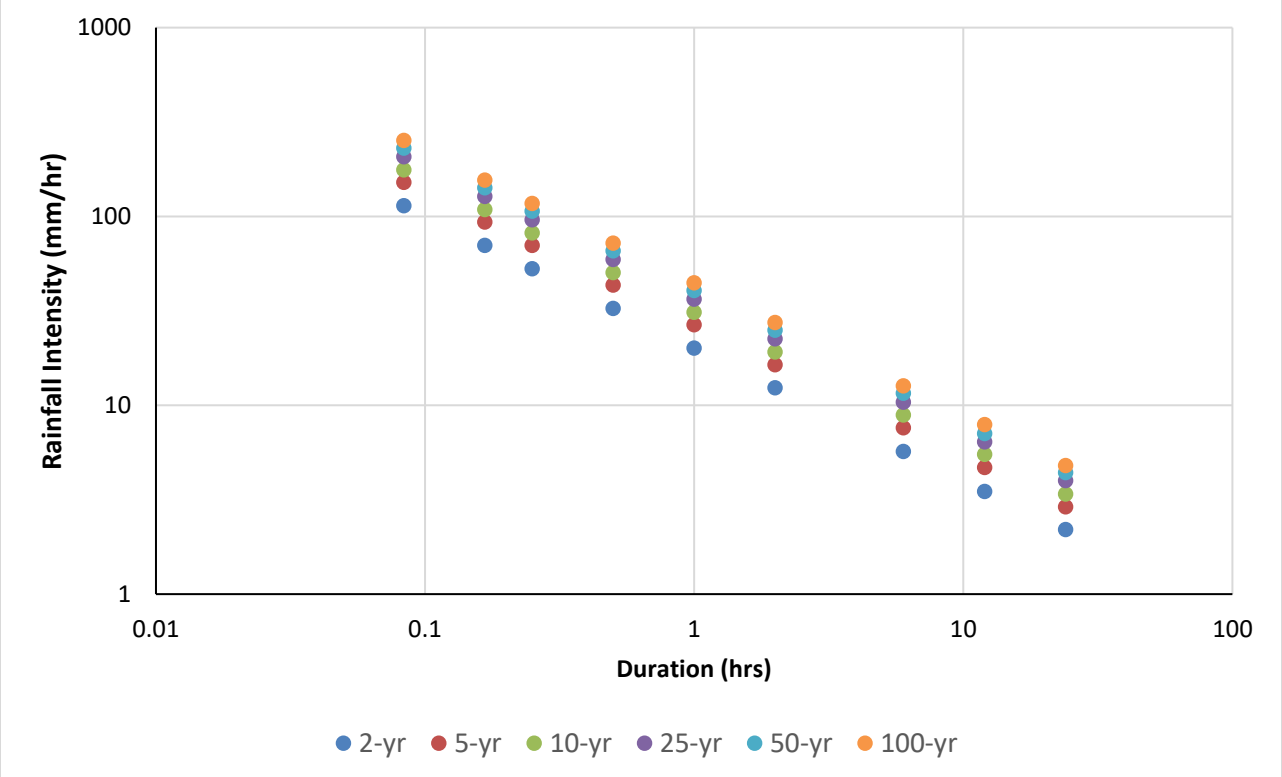



**Figure C.1: IDF Curves for the Muskrat Watershed**

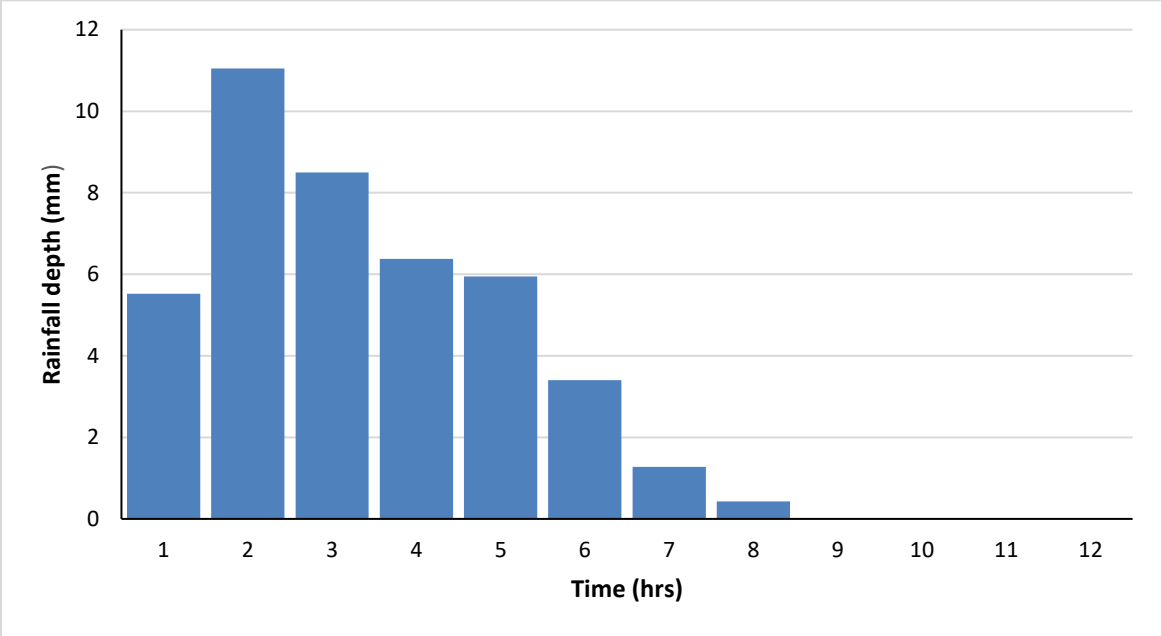



**Figure C.2: Hyetograph for the 2-yr, 12-hr AES 30% Design Storm for Southern Ontario**

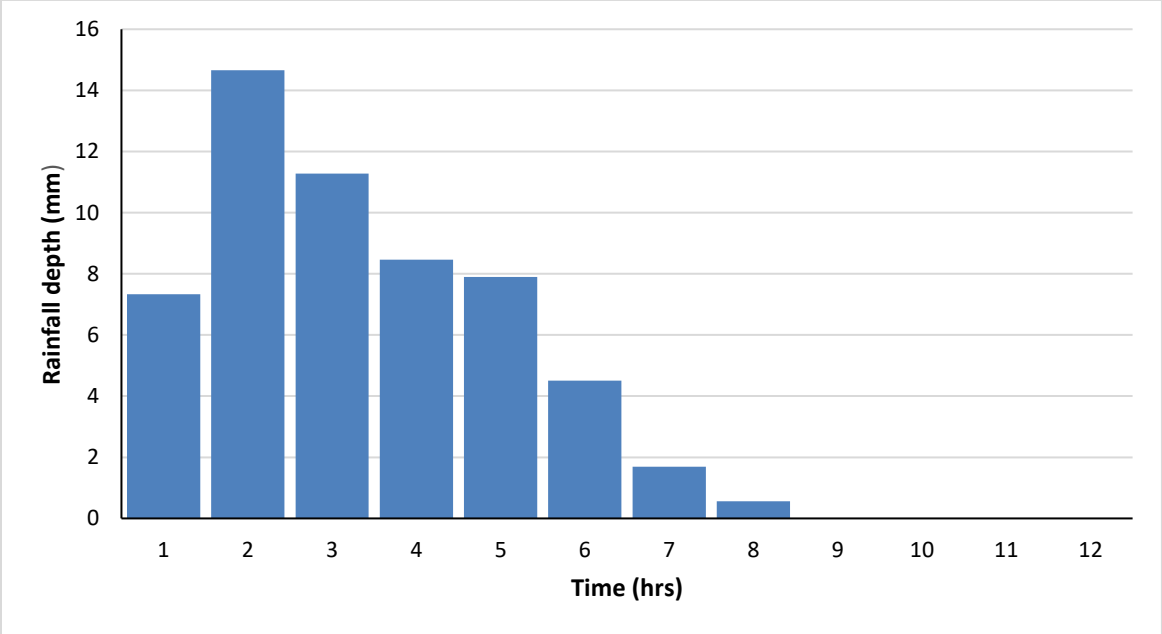



**Figure C.3: Hyetograph for the 5-yr, 12-hr AES 30% Design Storm for Southern Ontario**

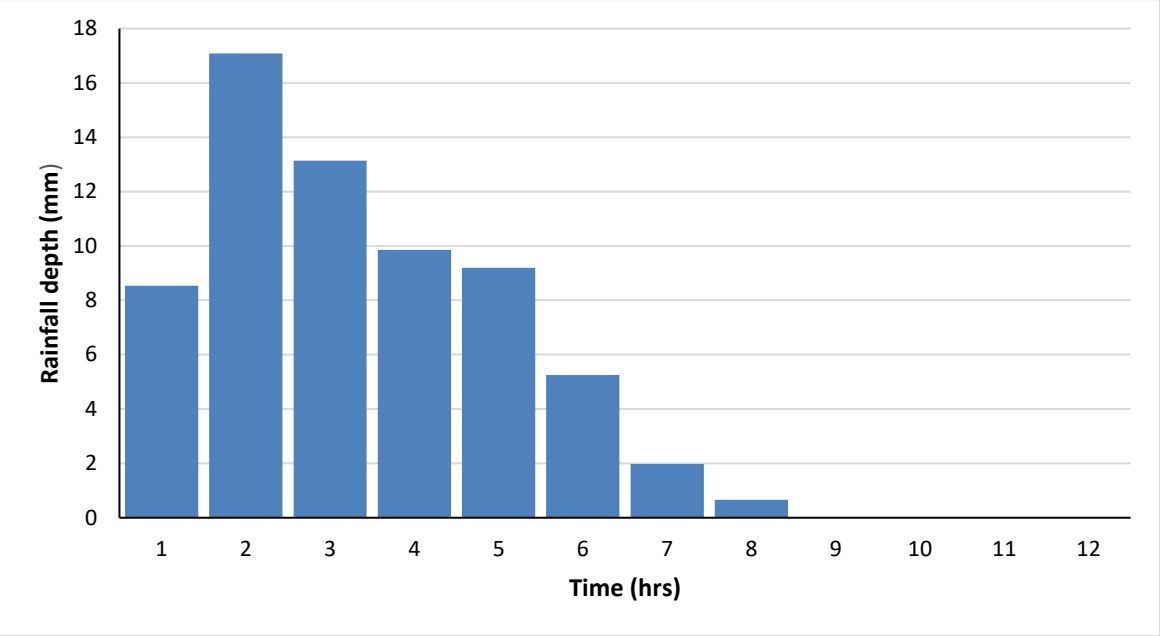



**Figure C.4: Hyetograph for the 10-yr, 12-hr AES 30% Design Storm for Southern Ontario**

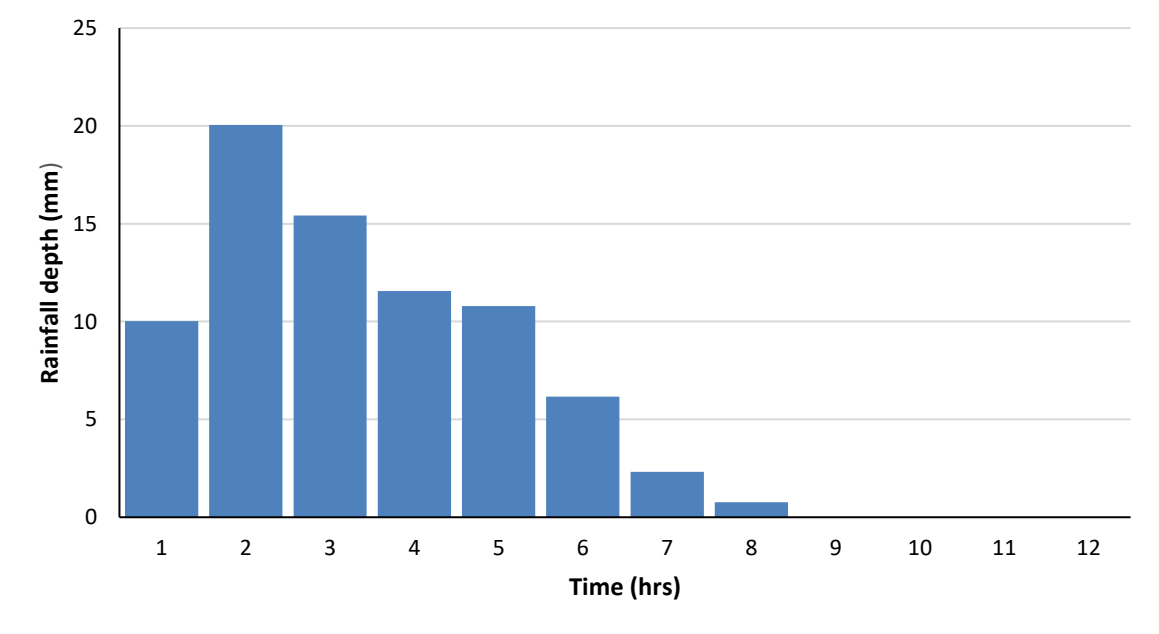



**Figure C.5: Hyetograph for the 25-yr, 12-hr AES 30% Design Storm for Southern Ontario**

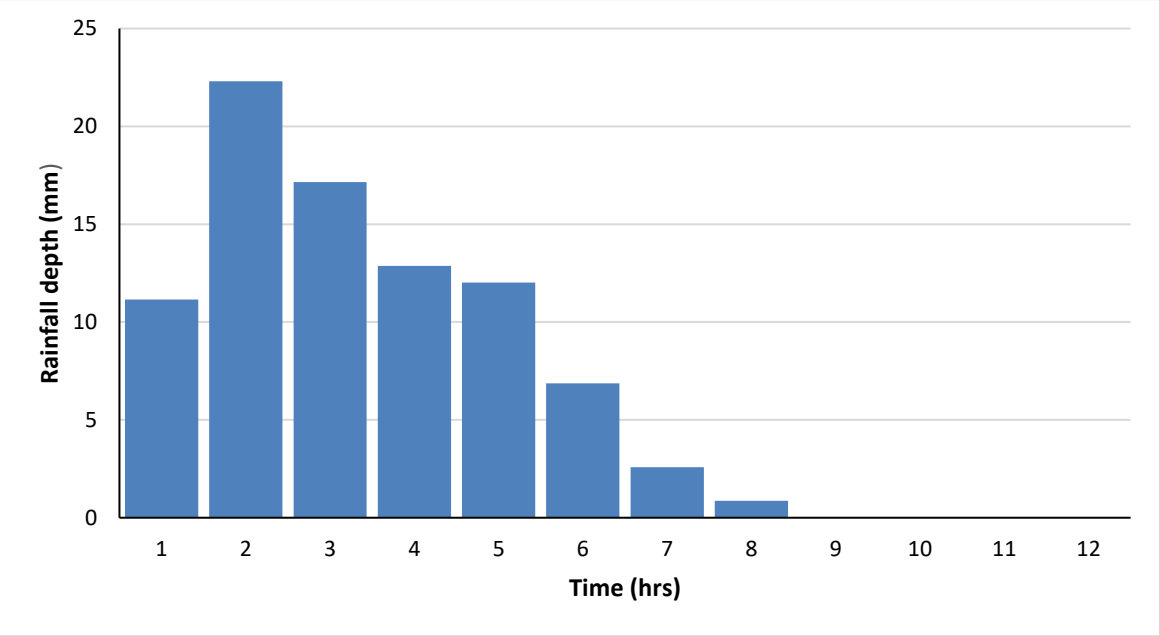



**Figure C.6: Hyetograph for the 50-yr, 12-hr AES 30% Design Storm for Southern Ontario**

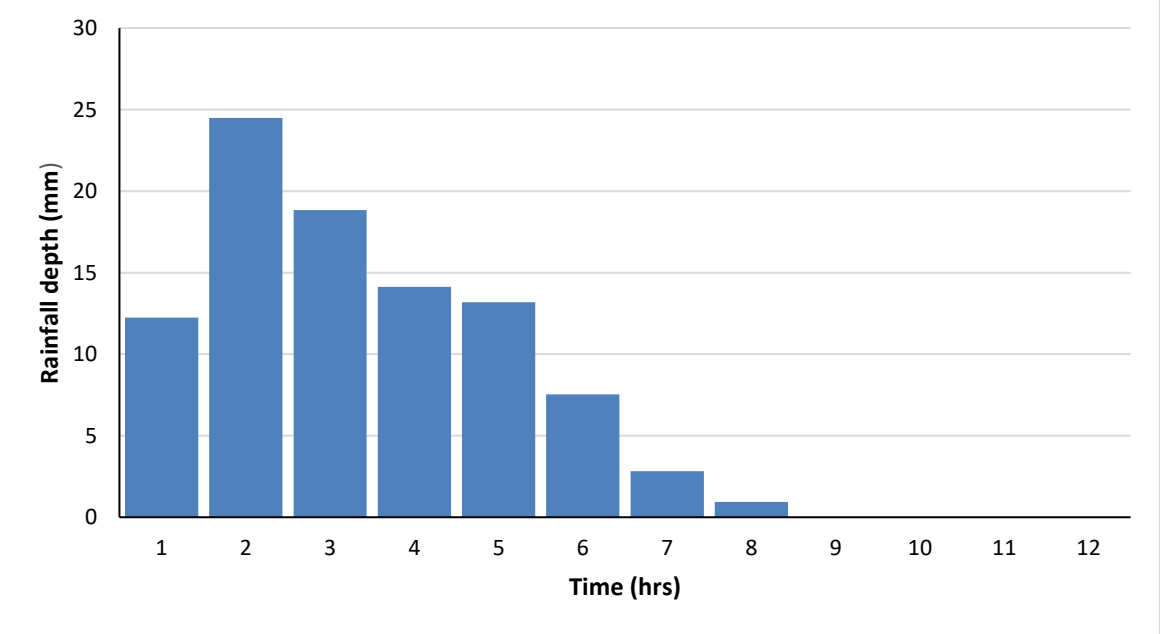



**Figure C.7: Hyetograph for the 100-yr, 12-hr AES 30% Design Storm for Southern Ontario**

**Table C.2: Subbasin Properties and Inputs**

| Subbasin ID | Area ($km^2$) | Slope (m/m) | Initial Abstraction (mm) | Composite CN, Summer | Composite CN, Winter | Impervious Surface (%) | Lag Time (min) |
|---|---|---|---|---|---|---|---|
| Sub-1 | 1.27 | 0.06062 | 4.93 | 75.32 | 92.83 | 29.53 | 12.01 |
| Sub-2 | 21.72 | 0.08698 | 9.77 | 50.87 | 76.96 | 5.36 | 412.00 |
| Sub-3 | 40.65 | 0.05361 | 8.94 | 54.39 | 80.38 | 2.07 | 112.43 |
| Sub-4 | 22.36 | 0.07521 | 9.25 | 50.01 | 76.69 | 7.09 | 1242.88 |
| Sub-5 | 10.01 | 0.03300 | 10.12 | 58.20 | 83.10 | 0.39 | 699.02 |
| Sub-6 | 17.97 | 0.08296 | 9.60 | 47.55 | 74.51 | 3.65 | 111.30 |
| Sub-7 | 35.79 | 0.10260 | 9.65 | 52.90 | 79.27 | 4.10 | 197.22 |
| Sub-8 | 32.74 | 0.04006 | 9.27 | 51.67 | 78.08 | 3.46 | 266.39 |
| Sub-9 | 30.80 | 0.08219 | 8.85 | 51.79 | 77.99 | 13.11 | 2379.30 |
| Sub-10 | 30.54 | 0.02353 | 8.59 | 54.08 | 80.03 | 1.08 | 146.18 |
| Sub-11 | 88.93 | 0.06744 | 9.23 | 50.80 | 77.23 | 8.13 | 3989.40 |
| Sub-12 | 77.23 | 0.02569 | 8.61 | 56.43 | 81.65 | 1.59 | 551.22 |
| Sub-13 | 23.95 | 0.02535 | 8.38 | 56.93 | 82.52 | 1.43 | 589.11 |
| Sub-14 | 24.89 | 0.06158 | 9.37 | 47.50 | 74.48 | 1.43 | 894.19 |
| Sub-15 | 79.30 | 0.04183 | 7.13 | 50.77 | 77.37 | 21.49 | 6651.30 |
| Sub-16 | 100.68 | 0.04928 | 8.10 | 45.04 | 72.06 | 13.73 | 7776.00 |
| Sub-17 | 83.29 | 0.02981 | 8.22 | 54.46 | 80.05 | 7.45 | 4848.60 |
| Sub-18 | 61.07 | 0.08993 | 9.04 | 53.30 | 79.93 | 10.16 | 5153.70 |
| Sub-19 | 17.37 | 0.09233 | 9.58 | 52.43 | 79.08 | 4.54 | 908.25 |
| Sub-20 | 34.80 | 0.02951 | 8.74 | 53.96 | 79.99 | 1.92 | 819.72 |
| Sub-21 | 2.07 | 0.07256 | 9.46 | 47.13 | 74.76 | 1.00 | 134.64 |
| Sub-22 | 4.00 | 0.06161 | 8.82 | 46.32 | 73.66 | 1.21 | 90.93 |
| Sub-23 | 117.00 | 0.10881 | 9.61 | 53.16 | 79.85 | 4.64 | 1504.50 |
| Sub-24 | 3.61 | 0.10505 | 9.79 | 50.09 | 77.13 | 0.85 | 139.59 |
| Sub-25 | 24.37 | 0.06097 | 9.40 | 53.89 | 80.53 | 5.57 | 4533.90 |
| Sub-26 | 31.66 | 0.03408 | 8.73 | 48.83 | 75.32 | 1.36 | 263.06 |
| Sub-27 | 4.97 | 0.03193 | 5.84 | 63.21 | 85.86 | 15.44 | 215.97 |
| Sub-28 | 35.88 | 0.02489 | 8.34 | 53.54 | 79.60 | 0.37 | 155.82 |
| Sub-29 | 16.55 | 0.04056 | 9.79 | 57.65 | 82.82 | 1.85 | 706.48 |
| Sub-30 | 23.76 | 0.05223 | 8.57 | 49.57 | 75.54 | 13.40 | 2538.90 |
| Sub-31 | 18.07 | 0.02208 | 7.97 | 59.83 | 84.49 | 2.81 | 2312.40 |
| Sub-32 | 2.62 | 0.03152 | 5.48 | 70.23 | 89.81 | 25.77 | 36.70 |
| Sub-33 | 23.91 | 0.02760 | 7.59 | 58.62 | 83.38 | 0.97 | 363.48 |

**Table C.3: Reach Properties**

| Reach ID | Length (m) | Slope (m/m) |
|---|---|---|
| Reach-1 | 1842.7 | 0.00045 |
| Reach-2 | 4409.7 | 0.00046 |
| Reach-3 | 11339.6 | 0.0002 |
| Reach-4 | 11101.7 | 0.00046 |
| Reach-5 | 2639.0 | 0.0008 |
| Reach-6 | 1125.8 | 0.00061 |
| Reach-7 | 6126.0 | 0.00042 |
| Reach-8 | 3456.3 | 0.0005 |
| Reach-9 | 4316.9 | 0.00185 |
| Reach-9-1 | 1176.1 | 0.00016 |
| Reach-9-2 | 3511.9 | 0.00302 |
| Reach-10 | 1914.6 | 0.0011 |
| Reach-11 | 7955.3 | 0.0001 |
| Reach-12 | 8015.9 | 0.00001 |
| Reach-12-1 | 4028.5 | 0.00001 |
| Reach-13-1 | 2094.0 | 0.00001 |
| Reach-13-2 | 2507.0 | 0.00001 |
| Reach-14 | 6480.1 | 0.00002 |
| Reach-15 | 8065.5 | 0.00048 |
| Reach-15-1 | 8728.2 | 0.00006 |
| Reach-16-1 | 11148.2 | 0.00125 |
| Reach-17 | 6929.7 | 0.00033 |

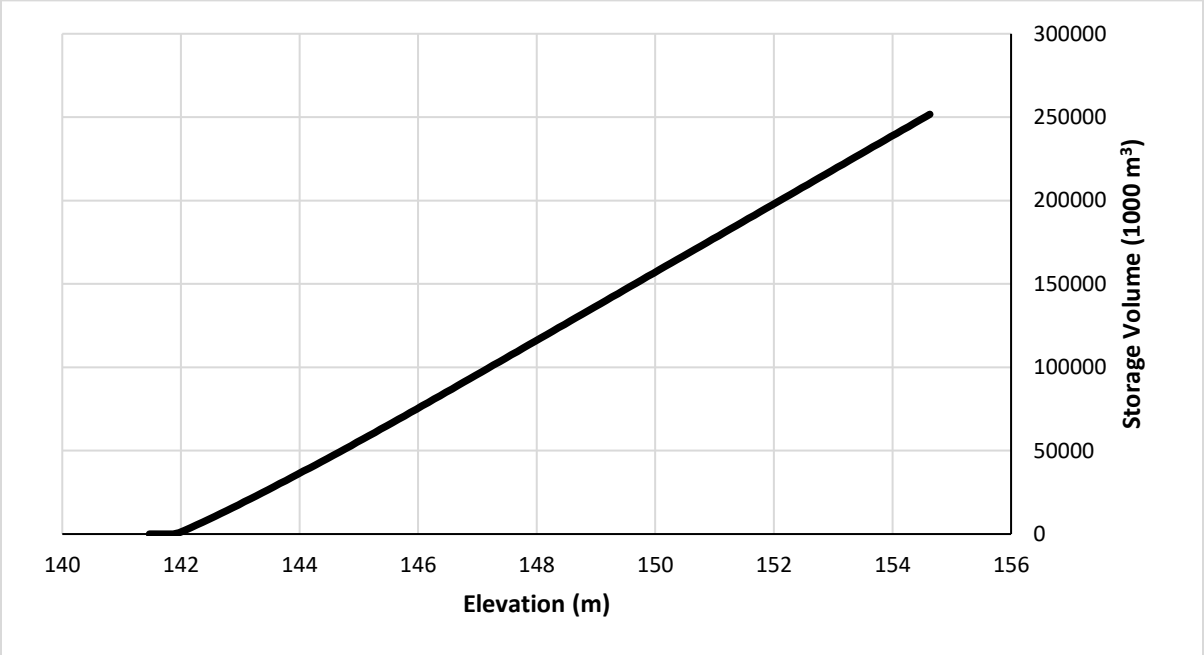



**Figure C.8: Doré Lake Elevation-Storage Curve**

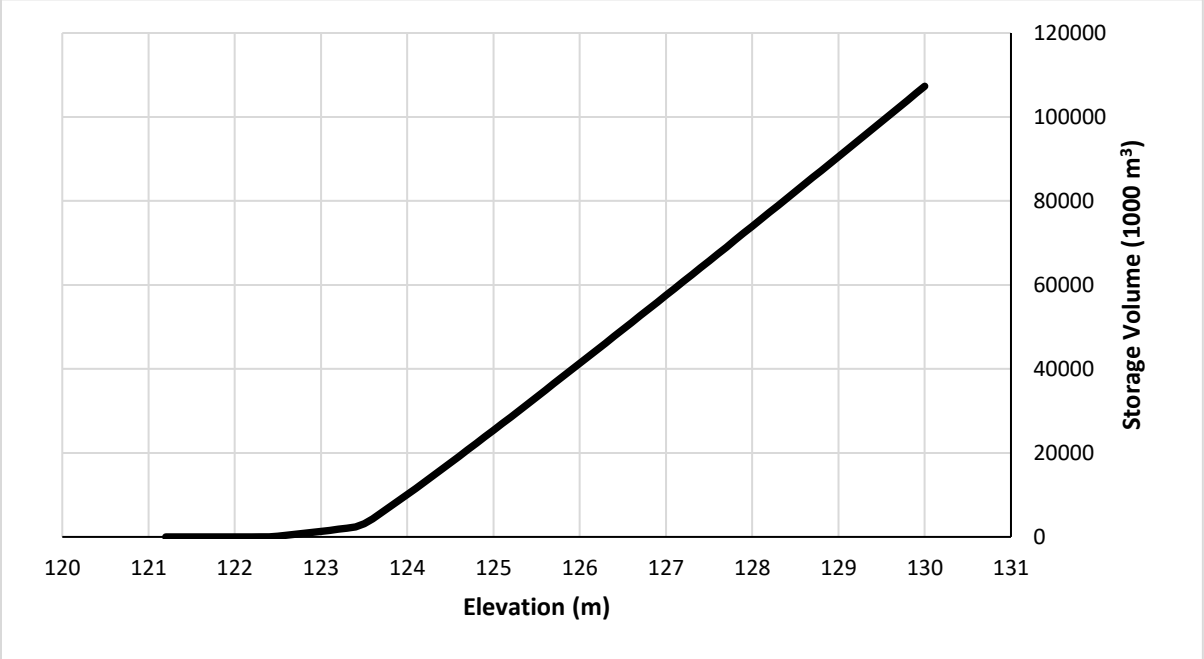



**Figure C.9: Muskrat Lake Elevation-Storage Curve**

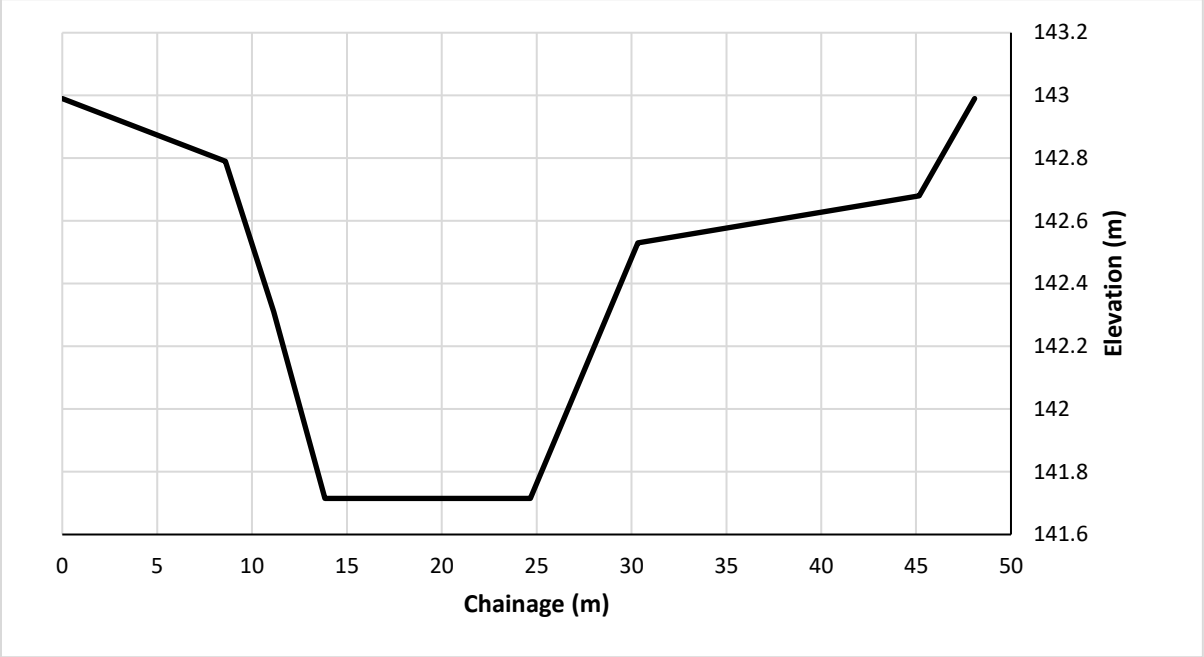



**Figure C.10: Doré Lake Outlet 8-Point Cross-Section**

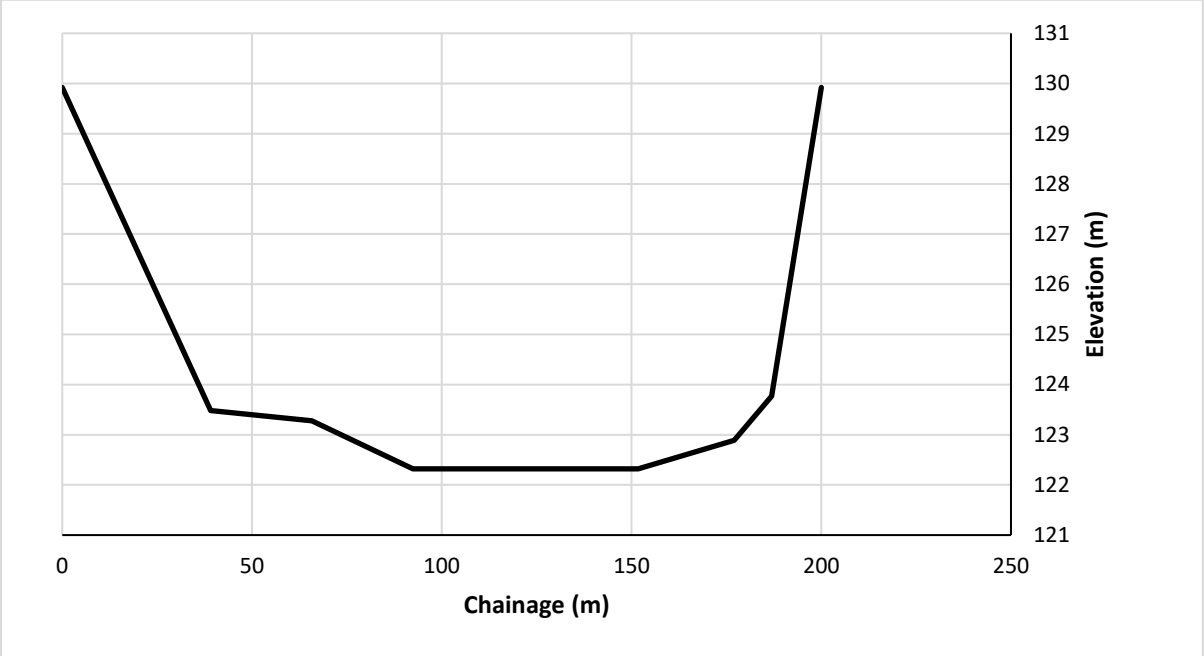



**Figure C.11: Muskrat Lake Outlet 8-Point Cross-Section**

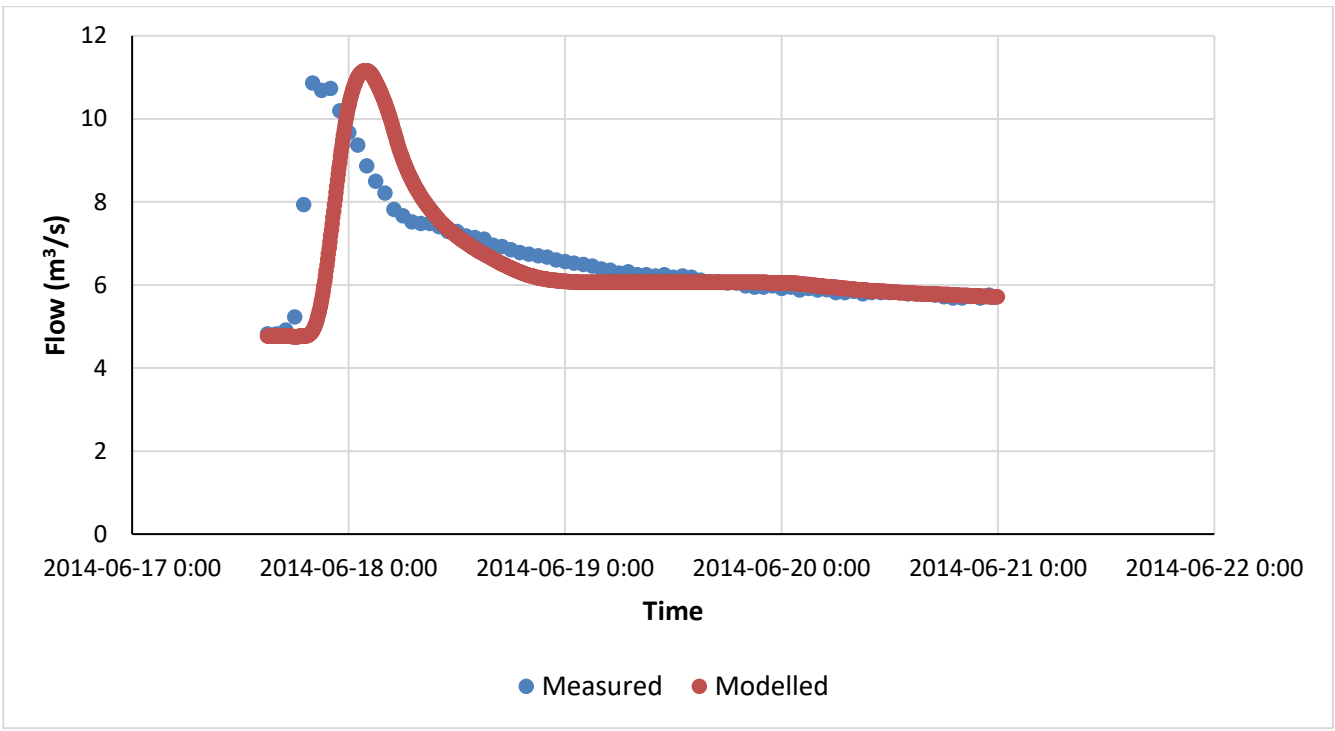



**Figure C.12: Comparison of the Measured and Calibrated Model Flows for the Cal-1 Event in Muskrat River**

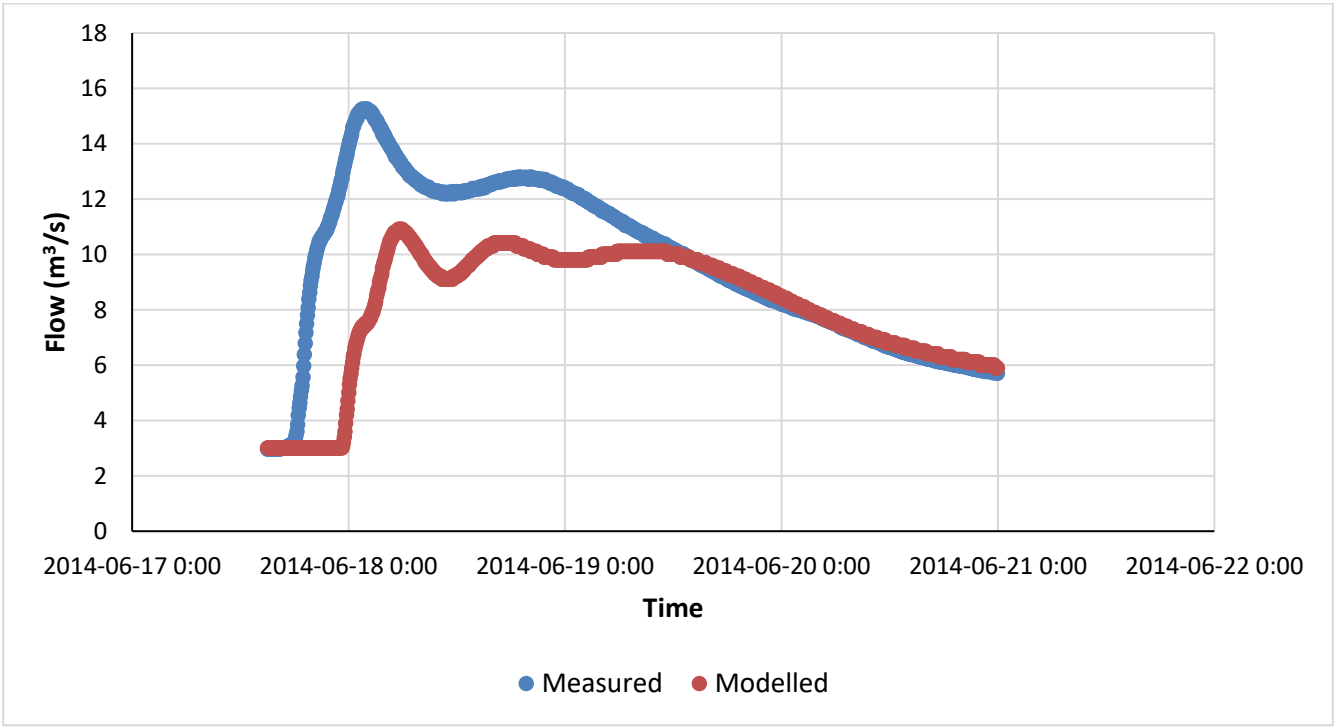



**Figure C.13: Comparison of the Measured and Calibrated Model Flows for the Cal-1 Event in Indian River**

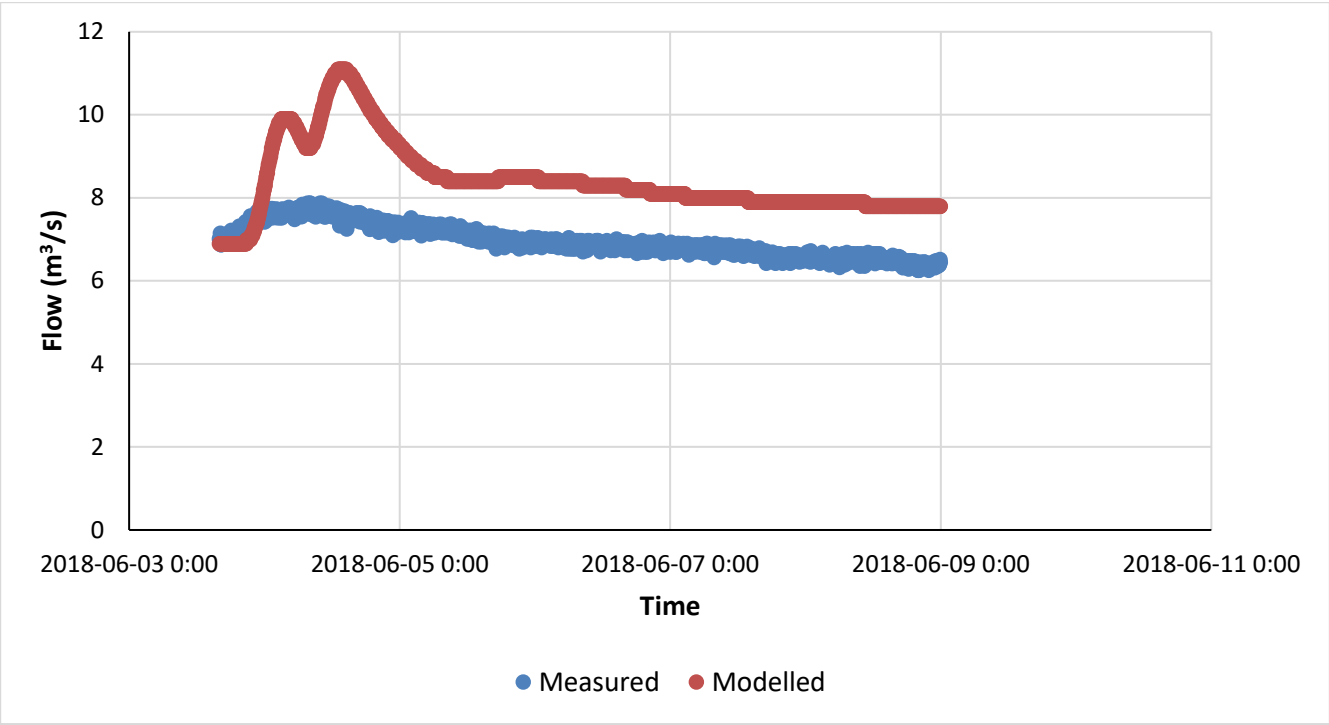



**Figure C.14: Comparison of the Measured and Calibrated Model Flows for the Cal-2 Event in Muskrat River**

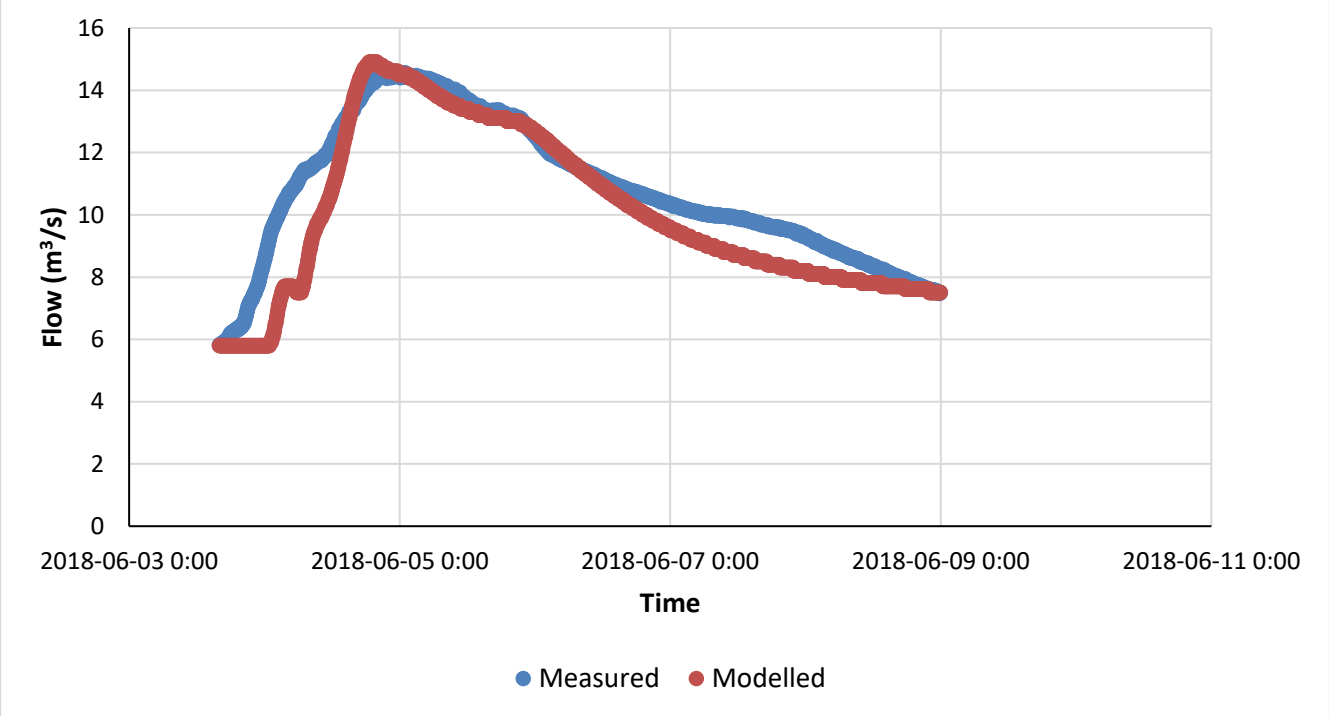



**Figure C.15: Comparison of the Measured and Calibrated Model Flows for the Cal-2 Event in Indian River**

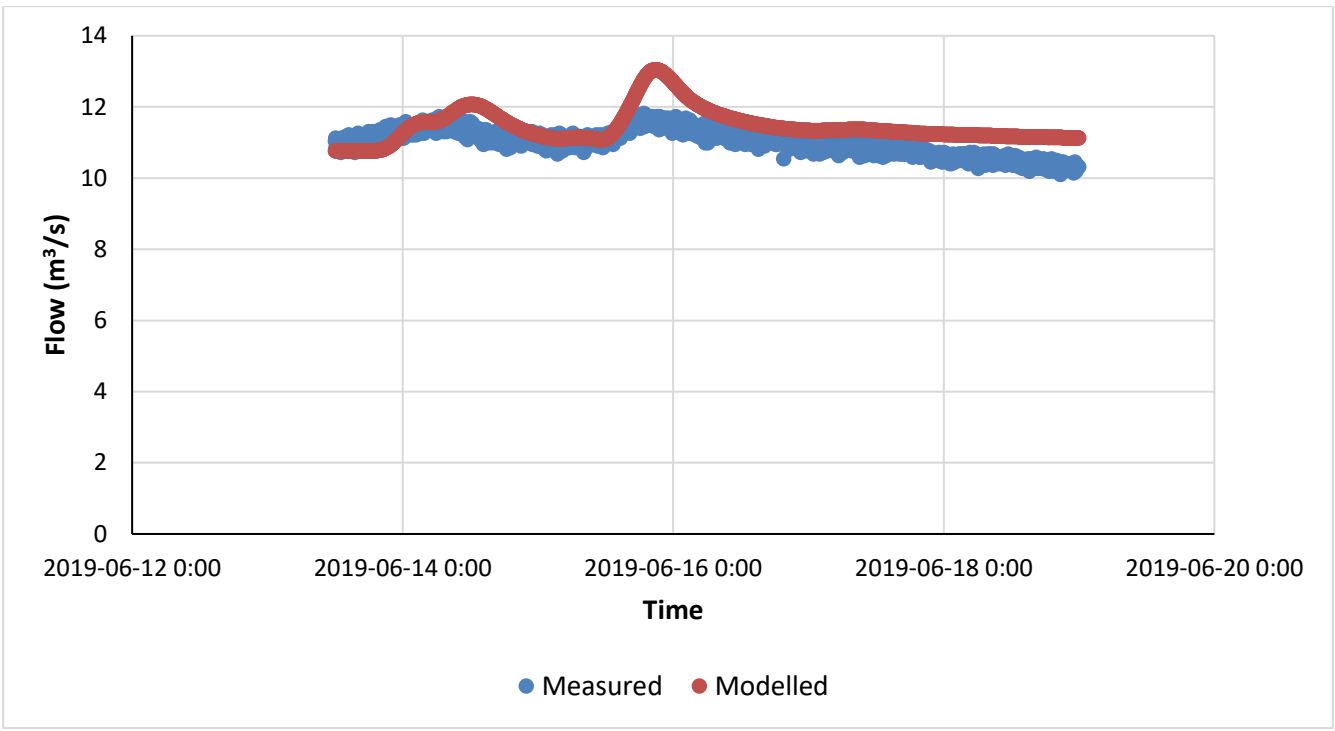



**Figure C.16: Comparison of the Measured and Calibrated Model Flows for the Cal-3 Event in Muskrat River**

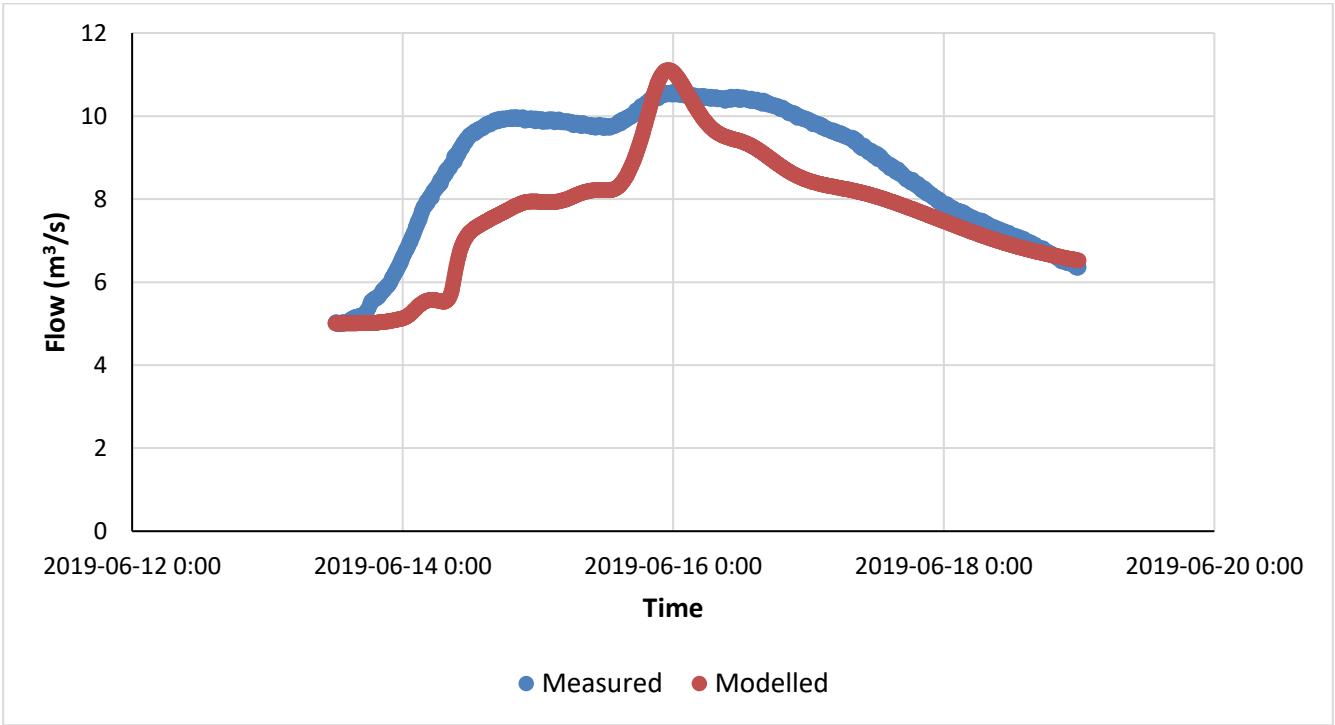



**Figure C.17: Comparison of the Measured and Calibrated Model Flows for the Cal-3 Event in Indian River**

**Table C.4: Variation in SCS Curve Number based on Antecedent Moisture Conditions (from CLOCA, 2017)**

| Dry Conditions | Average Conditions | Wet Conditions |
|---|---|---|
| 100 | 100 | 100 |
| 97 | 99 | 100 |
| 94 | 98 | 99 |
| 91 | 97 | 99 |
| 89 | 96 | 99 |
| 87 | 95 | 98 |
| 85 | 94 | 98 |
| 83 | 93 | 98 |
| 81 | 92 | 97 |
| 80 | 91 | 97 |
| 78 | 90 | 96 |
| 76 | 89 | 96 |
| 75 | 88 | 95 |
| 73 | 87 | 95 |
| 72 | 86 | 94 |
| 70 | 85 | 94 |
| 68 | 84 | 93 |
| 67 | 83 | 93 |
| 66 | 82 | 92 |
| 64 | 81 | 92 |
| 63 | 80 | 91 |
| 62 | 79 | 91 |
| 60 | 78 | 90 |
| 59 | 77 | 89 |
| 58 | 76 | 89 |
| 57 | 75 | 88 |
| 55 | 74 | 88 |
| 54 | 73 | 87 |
| 53 | 72 | 86 |
| 52 | 71 | 86 |
| 51 | 70 | 85 |
| 51 | 69 | 85 |
| 48 | 68 | 84 |
| 47 | 67 | 83 |
| 46 | 66 | 82 |
| 45 | 65 | 82 |
| 44 | 64 | 81 |
| 43 | 63 | 80 |
| 42 | 62 | 79 |
| 41 | 61 | 78 |

| Dry Conditions | Average Conditions | Wet Conditions |
|---|---|---|
| 40 | 60 | 78 |
| 39 | 59 | 77 |
| 38 | 58 | 76 |
| 37 | 57 | 75 |
| 36 | 56 | 75 |
| 35 | 55 | 74 |
| 34 | 54 | 73 |
| 33 | 53 | 72 |
| 32 | 52 | 71 |
| 31 | 51 | 70 |
| 31 | 50 | 70 |
| 30 | 49 | 69 |
| 29 | 48 | 68 |
| 28 | 47 | 67 |
| 27 | 46 | 66 |
| 26 | 45 | 65 |
| 25 | 44 | 64 |
| 25 | 43 | 63 |
| 24 | 42 | 62 |
| 23 | 41 | 61 |
| 22 | 40 | 60 |
| 21 | 39 | 59 |
| 21 | 38 | 58 |
| 20 | 37 | 57 |
| 19 | 36 | 56 |
| 18 | 35 | 55 |
| 18 | 34 | 54 |
| 17 | 33 | 53 |
| 16 | 32 | 52 |
| 16 | 31 | 51 |
| 15 | 30 | 50 |
| 12 | 25 | 43 |
| 9 | 20 | 37 |
| 6 | 15 | 30 |
| 4 | 10 | 22 |
| 2 | 5 | 13 |
| 0 | 0 | 0 |

**Table C.5: Calibrated CN Values for Average Antecedent Moisture Conditions (AMC I)**

| Land use | A | B | C | D |
|---|---|---|---|---|
| Woods* | 21 | 44 | 58 | 64 |
| Meadows | 21 | 45 | 58 | 64 |
| Cultivated* | 31 | 39 | 46 | 51 |
| Lawns | 30 | 51 | 62 | 68 |
| Dirt Lot | 53 | 66 | 73 | 76 |
| Gravel Lot | 58 | 70 | 76 | 80 |
| Bedrock | 63 | 63 | 63 | 63 |
| Bog | 4 | 4 | 4 | 4 |
| Fen | 4 | 4 | 4 | 4 |
| Marsh | 31 | 31 | 31 | 31 |
| Swamp | 16 | 40 | 54 | 62 |

*Calibrated values

**Table C.6: Calibrated CN Values for Average Antecedent Moisture Conditions (AMC II)**

| Land use | A | B | C | D |
|---|---|---|---|---|
| Woods* | 39 | 64 | 76 | 81 |
| Meadows | 38 | 65 | 76 | 81 |
| Cultivated* | 50 | 59 | 66 | 69 |
| Lawns | 49 | 69 | 79 | 84 |
| Dirt Lot | 72 | 82 | 87 | 89 |
| Gravel Lot | 76 | 85 | 89 | 91 |
| Bedrock | 80 | 80 | 80 | 80 |
| Bog | 10 | 10 | 10 | 10 |
| Fen | 10 | 10 | 10 | 10 |
| Marsh | 50 | 50 | 50 | 50 |
| Swamp | 32 | 60 | 73 | 79 |

*Calibrated values

**Table C.7: Calibrated CN Values for Average Antecedent Moisture Conditions (AMC III)**

| Land use | A | B | C | D |
|---|---|---|---|---|
| Woods* | 59 | 81 | 89 | 92 |
| Meadows | 58 | 82 | 89 | 92 |
| Cultivated* | 70 | 77 | 82 | 85 |
| Lawns | 69 | 85 | 91 | 93 |
| Dirt Lot | 86 | 92 | 95 | 96 |
| Gravel Lot | 89 | 94 | 96 | 97 |
| Bedrock | 91 | 91 | 91 | 91 |
| Bog | 22 | 22 | 22 | 22 |
| Fen | 22 | 22 | 22 | 22 |
| Marsh | 70 | 70 | 70 | 70 |
| Swamp | 52 | 78 | 87 | 91 |

*Calibrated values

**Table C.8: Calibrated CN Values for Moderately Dry Antecedent Moisture Conditions (Between AMC I and II)**

| Land use | A | B | C | D |
|---|---|---|---|---|
| Woods* | 30 | 54 | 67 | 72.5 |
| Meadows | 29.5 | 55 | 67 | 72.5 |
| Cultivated* | 40.5 | 49 | 56 | 60 |
| Lawns | 39.5 | 60 | 70.5 | 76 |
| Dirt Lot | 62.5 | 74 | 80 | 82.5 |
| Gravel Lot | 67 | 77.5 | 82.5 | 85.5 |
| Bedrock | 71.5 | 71.5 | 71.5 | 71.5 |
| Bog | 7 | 7 | 7 | 7 |
| Fen | 7 | 7 | 7 | 7 |
| Marsh | 40.5 | 40.5 | 40.5 | 40.5 |
| Swamp | 24 | 50 | 63.5 | 70.5 |

*Calibrated values

**Table C.9: Summer Peak Flows under the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr Events**

| Junction ID | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|
| Jun-1 | 24.9 | 45.8 | 63.6 | 89.7 | 111.2 | 132.3 |
| Jun-2 | 25.1 | 46.2 | 64 | 90.2 | 111.7 | 132.9 |
| Jun-3 | 16.9 | 30 | 40.3 | 54.5 | 67.8 | 85.1 |
| Jun-4 | 10.7 | 19.2 | 26.4 | 36.6 | 45.5 | 55.1 |
| Jun-5 | 10.7 | 19.2 | 26.4 | 36.6 | 45.4 | 54.8 |
| Jun-6 | 10.1 | 18.4 | 25.4 | 35.4 | 44 | 53.1 |
| Jun-7 | 9.8 | 17.2 | 23.1 | 31.2 | 37.9 | 44.9 |
| Jun-8 | 9.4 | 16.5 | 22 | 29.7 | 36.1 | 42.6 |
| Jun-9 | 3.5 | 6 | 8 | 10.7 | 13 | 15.3 |
| Jun-9-1 | 3.5 | 6 | 8 | 10.7 | 12.9 | 15.3 |
| Jun-9-2 | 3.3 | 5.6 | 7.5 | 10.1 | 12.2 | 14.5 |
| Jun-10 | 13.7 | 21.3 | 27.3 | 35.6 | 42.5 | 49.7 |
| Jun-11 | 10.6 | 17.9 | 24.6 | 35.1 | 44.4 | 54.4 |
| Jun-12 | 10.8 | 17.7 | 23.6 | 31.9 | 39.1 | 46.6 |
| Jun-13 | 15.6 | 25.3 | 33 | 43.7 | 52.6 | 61.7 |
| Jun-14 | 6.3 | 8.4 | 10.1 | 12.3 | 14.2 | 16.1 |
| Jun-15 | 7.1 | 10.2 | 13.3 | 18.9 | 24.3 | 30.6 |
| Jun-16 | 8.4 | 15.1 | 20.4 | 27.8 | 34 | 40.4 |
| Jun-17 | 12.4 | 25.8 | 38 | 57.4 | 72.3 | 87.5 |
| Jun-18 | 13.2 | 20.1 | 25.6 | 33.3 | 39.7 | 46.3 |
| Jun-19 | 3.5 | 3.5 | 3.5 | 3.9 | 4.2 | 4.6 |
| Jun-20 | 9.1 | 13.5 | 17.6 | 23.7 | 29.2 | 35.1 |
| Jun-21 | 8.9 | 13 | 16.9 | 22.8 | 28.1 | 33.9 |
| Jun-22 | 6.3 | 8.4 | 10.1 | 12.3 | 14.2 | 16.1 |

**Table C.10: Winter Peak Flows under the 2-yr, 5-yr, 10-yr, 25-yr, 50-yr, and 100-yr Events**

| Junction ID | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|
| Jun-1 | 57.2 | 105.4 | 139.1 | 183.7 | 219.9 | 256.1 |
| Jun-2 | 57.7 | 105.9 | 139.8 | 184.9 | 221.5 | 258 |
| Jun-3 | 38.6 | 65.2 | 92 | 130.7 | 162.9 | 194.1 |
| Jun-4 | 23.8 | 43 | 58.1 | 80 | 97.1 | 113.7 |
| Jun-5 | 23.8 | 42.6 | 57.6 | 78.9 | 95.5 | 112 |
| Jun-6 | 23 | 41.1 | 55.8 | 76.2 | 92.3 | 108.4 |
| Jun-7 | 21.5 | 36.7 | 48 | 62.7 | 74.9 | 86.5 |
| Jun-8 | 20.6 | 34.9 | 45.6 | 59.4 | 70.4 | 81.4 |
| Jun-9 | 7 | 11.9 | 15.6 | 20.5 | 24.4 | 28.3 |
| Jun-9-1 | 7 | 11.9 | 15.6 | 20.5 | 24.4 | 28.3 |
| Jun-9-2 | 6.5 | 11.3 | 14.8 | 19.5 | 23.2 | 27 |
| Jun-10 | 25.2 | 40.9 | 52.6 | 67.7 | 79.8 | 91.8 |
| Jun-11 | 21.8 | 41.5 | 57.6 | 79.3 | 97 | 115.1 |
| Jun-12 | 21.2 | 36.8 | 48.8 | 64.7 | 77.5 | 90.3 |
| Jun-13 | 30.9 | 50.8 | 65.5 | 84.4 | 99.5 | 114.5 |
| Jun-14 | 8.3 | 12.1 | 15 | 18.8 | 21.8 | 24.8 |
| Jun-15 | 9.5 | 19.8 | 29.7 | 44.3 | 57.1 | 70.7 |
| Jun-16 | 20.3 | 34.3 | 44.6 | 57.9 | 68.6 | 79.1 |
| Jun-17 | 34.5 | 69.6 | 94.3 | 127.4 | 153.6 | 179.8 |
| Jun-18 | 22.8 | 36.8 | 47.3 | 61.1 | 72.1 | 83.2 |
| Jun-19 | 2.7 | 3.5 | 4.1 | 4.9 | 5.5 | 6.2 |
| Jun-20 | 15.4 | 26.9 | 36.4 | 49.7 | 60.9 | 72.6 |
| Jun-21 | 14.7 | 25.8 | 35 | 48 | 59 | 70.5 |
| Jun-22 | 8.2 | 12.1 | 15 | 18.8 | 21.8 | 24.8 |

# APPENDIX D

## Hydraulic Structure Inventory Sheets

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| Date (Month DD, YYYY) | November 9, 2021 |
| Field Crew Initial | D.M., G.D. |
| Municipality | City of Pembroke |
| Watershed Name | Muskrat |
| Creek or Tributary Name | Indian River |
| UTM Co-ordinates | N: 5075651 m, E: 334600 m |
| Street Name | Boundary Road |
| **Structure Information** | |
| Structure Type | Bridge |
| Number of Cells | 1 |
| Each Cell Shape | Flat |
| Each Cell Material | Concrete |
| Each Cell Dimension in Meters (Height x Width or Diameter) | 4.88 m x 26.04 m |
| Open Footing (Y/N) | Y |
| Structure Length in Meters (inlet to outlet) | 11.55 m |
| **Additional Information where applicable** | |
| Pier Width in Meters | |
| Parapet Present (Y/N) | Y |
| Parapet Length in Meters | 38.91 m |
| Parapet Height in Meters | 0.83 m |
| Skew Angle in Degrees | |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| Date (Month DD, YYYY) | November 10, 2021 |
| Field Crew Initial | D.M., G.D. |
| Municipality | City of Pembroke |
| Watershed Name | Muskrat |
| Creek or Tributary Name | Indian River |
| UTM Co-ordinates | N: 507602 m, E: 335053 m |
| Street Name | Christie Street |
| **Structure Information** | |
| Structure Type | Bridge |
| Number of Cells | 1 |
| Each Cell Shape | Arched |
| Each Cell Material | Concrete |
| Each Cell Dimension in Meters (Height x Width or Diameter) | 6.68 m x 16.72 m |
| Open Footing (Y/N) | Y |
| Structure Length in Meters (inlet to outlet) | 13.5 m |
| **Additional Information where applicable** | |
| Pier Width in Meters | |
| Parapet Present (Y/N) | N |
| Parapet Length in Meters | |
| Parapet Height in Meters | |
| Skew Angle in Degrees | |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| **Date (Month DD, YYYY)** | **November 11, 2021** |
| **Field Crew Initial** | **D.M., G.D.** |
| **Municipality** | **City of Pembroke** |
| **Watershed Name** | **Muskrat** |
| **Creek or Tributary Name** | **Indian River** |
| **UTM Co-ordinates** | **N: 5076270 m, E: 335449 m** |
| **Street Name** | **N/A, near Miller Street @ Indian Lane** |
| **Structure Information** | |
| **Structure Type** | **Pedestrian bridge** |
| **Number of Cells** | **1** |
| **Each Cell Shape** | **Flat** |
| **Each Cell Material** | **Concrete** |
| **Each Cell Dimension in Meters (Height x Width or Diameter)** | **3.27 m x 26.44 m** |
| **Open Footing (Y/N)** | **Y** |
| **Structure Length in Meters (inlet to outlet)** | **1.85 m** |
| **Additional Information where applicable** | |
| **Pier Width in Meters** | |
| **Parapet Present (Y/N)** | **N** |
| **Parapet Length in Meters** | |
| **Parapet Height in Meters** | |
| **Skew Angle in Degrees** | |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

Small wingwalls present on both U/S and D/S of bridge, and on both right and left sides

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| Date (Month DD, YYYY) | November 11, 2021 |
| Field Crew Initial | D.M., G.D. |
| Municipality | City of Pembroke |
| Watershed Name | Muskrat |
| Creek or Tributary Name | Muskrat River |
| UTM Co-ordinates | N: 5075177 m, E: 335730 m |
| Street Name | Bennett Street |
| **Structure Information** | |
| Structure Type | Bridge |
| Number of Cells | 3 |
| Each Cell Shape | Flat |
| Each Cell Material | Concrete |
| Each Cell Dimension in Meters (Height x Width or Diameter) | From left to right (looking D/S), without piers:<br>1. 7.97 m x 13.01 m<br>2. 8.05 m x 14.91 m<br>3. 5.82 m x 13.10 m |
| Open Footing (Y/N) | Y |
| Structure Length in Meters (inlet to outlet) | 11.86 m |
| **Additional Information where applicable** | |
| Pier Width in Meters | 1.1 m |
| Parapet Present (Y/N) | Y |
| Parapet Length in Meters | 52.14 m |
| Parapet Height in Meters | 0.9 m |
| Skew Angle in Degrees | |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| Date (Month DD, YYYY) | November 10, 2021 |
| Field Crew Initial | D.M., G.D. |
| Municipality | City of Pembroke |
| Watershed Name | Muskrat |
| Creek or Tributary Name | Muskrat River |
| UTM Co-ordinates | N: 5076619 m, E: 335980 m |
| Street Name | Mary Street |
| **Structure Information** | |
| Structure Type | Bridge |
| Number of Cells | 4 |
| Each Cell Shape | Flat |
| Each Cell Material | Concrete |
| Each Cell Dimension in Meters (Height x Width or Diameter) | From left to right (looking D/S), without piers::<br>1. 5.74 m x 11.88 m<br>2. 9.56 m x 28.14 m<br>3. 9.38 m x 25.68 m<br>4. 9.20 m x 29.52 m |
| Open Footing (Y/N) | Y |
| Structure Length in Meters (inlet to outlet) | 14.2 m |
| **Additional Information where applicable** | |
| Pier Width in Meters | 1.5 m |
| Parapet Present (Y/N) | N |
| Parapet Length in Meters | |
| Parapet Height in Meters | |
| Skew Angle in Degrees | 25 |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| Date (Month DD, YYYY) | November 9, 2021 |
| Field Crew Initial | D.M., G.D. |
| Municipality | City of Pembroke |
| Watershed Name | Muskrat |
| Creek or Tributary Name | Muskrat River |
| UTM Co-ordinates | N: 5076939 m, E: 335946 m |
| Street Name | Pembroke Street W |
| **Structure Information** | |
| Structure Type | Bridge |
| Number of Cells | 3 |
| Each Cell Shape | Arched |
| Each Cell Material | Concrete |
| Each Cell Dimension in Meters (Height x Width or Diameter) | Without piers: 5.49 m x 14.53 m |
| Open Footing (Y/N) | Y |
| Structure Length in Meters (inlet to outlet) | 15.59 m |
| **Additional Information where applicable** | |
| Pier Width in Meters | 4.68 m |
| Parapet Present (Y/N) | Y |
| Parapet Length in Meters | U/S: 58.33 m<br>D/S: 68.87 m |
| Parapet Height in Meters | Small "lip": 0.19 m, Additional height: 0.7 m<br>Width: 1.20 m, Gap width: 2.58 m |
| Skew Angle in Degrees | |

**Photographs**

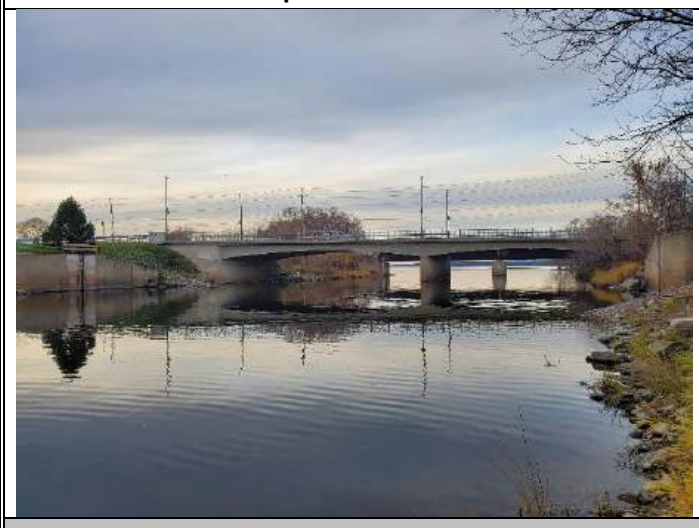
| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| Date (Month DD, YYYY) | November 9, 2021 |
| Field Crew Initial | D.M., G.D. |
| Municipality | City of Pembroke |
| Watershed Name | Muskrat |
| Creek or Tributary Name | Muskrat River |
| UTM Co-ordinates | N: 5077095 m, E: 335902 m |
| Street Name | Lake Street |
| **Structure Information** | |
| Structure Type | Bridge |
| Number of Cells | 2 |
| Each Cell Shape | Arched |
| Each Cell Material | Concrete |
| Each Cell Dimension in Meters (Height x Width or Diameter) | Without pier: 5.51 m x 26.42 m |
| Open Footing (Y/N) | Y |
| Structure Length in Meters (inlet to outlet) | 14.96 m |
| **Additional Information where applicable** | |
| Pier Width in Meters | 0.75 m |
| Parapet Present (Y/N) | N |
| Parapet Length in Meters | |
| Parapet Height in Meters | |
| Skew Angle in Degrees | 29 |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

# Hydraulic Structure Data Sheet

| General Information | |
|---|---|
| **Date (Month DD, YYYY)** | **November 9, 2021** |
| **Field Crew Initial** | **D.M., G.D.** |
| **Municipality** | **City of Pembroke** |
| **Watershed Name** | **Muskrat** |
| **Creek or Tributary Name** | **Muskrat River** |
| **UTM Co-ordinates** | **N: 5077137 m, E: 335890 m** |
| **Street Name** | **N/A (Old Railway Bridge)** |
| **Structure Information** | |
| **Structure Type** | **Old Railway Bridge Converted into Pedestrian Bridge** |
| **Number of Cells** | **2** |
| **Each Cell Shape** | **Flat** |
| **Each Cell Material** | **Steel** |
| **Each Cell Dimension in Meters (Height x Width or Diameter)** | **Without pier: 5.16 m x 23.44 m** |
| **Open Footing (Y/N)** | **Y** |
| **Structure Length in Meters (inlet to outlet)** | **4.46 m** |
| **Additional Information where applicable** | |
| **Pier Width in Meters** | **2.51 m** |
| **Parapet Present (Y/N)** | **Y** |
| **Parapet Length in Meters** | **51.95 m** |
| **Parapet Height in Meters** | **2.66 m** |
| **Skew Angle in Degrees** | |

**Photographs**

| Upstream Face | Downstream Face |
|---|---|
|  |  |

**Additional Comments**

Pier width estimated from photographs to be approx. equal to parapet height

# APPENDIX E

## HEC-RAS Model Output Results

HEC-RAS Profile: Winter 100yr

| River | Reach | River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| Muskrat River | Main_2 | 2572 | Winter 100yr | Winter - 113.621m | 83.00 | 116.61 | 118.88 | | 119.13 | 0.002746 | 2.24 | 40.07 | 24.81 | 0.52 |
| Muskrat River | Main_2 | 2572 | Summer 100yr | Summer - 113.621m | 46.50 | 116.61 | 118.19 | | 118.40 | 0.004198 | 2.03 | 23.67 | 22.53 | 0.60 |
| Muskrat River | Main_2 | 2572 | Summer 100yr | Summer - 112 m | 46.50 | 116.61 | 118.19 | | 118.40 | 0.004198 | 2.03 | 23.67 | 22.53 | 0.60 |
| Muskrat River | Main_2 | 2572 | Summer 100yr | Summer - 111.082m | 46.50 | 116.61 | 118.19 | | 118.40 | 0.004198 | 2.03 | 23.67 | 22.53 | 0.60 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2532 | Winter 100yr | Winter - 113.621m | 83.00 | 116.17 | 118.78 | 117.97 | 119.03 | 0.002215 | 2.26 | 41.85 | 23.11 | 0.49 |
| Muskrat River | Main_2 | 2532 | Summer 100yr | Summer - 113.621m | 46.50 | 116.17 | 118.09 | 117.53 | 118.26 | 0.002524 | 1.88 | 26.78 | 20.48 | 0.49 |
| Muskrat River | Main_2 | 2532 | Summer 100yr | Summer - 112 m | 46.50 | 116.17 | 118.09 | 117.53 | 118.26 | 0.002524 | 1.88 | 26.78 | 20.48 | 0.49 |
| Muskrat River | Main_2 | 2532 | Summer 100yr | Summer - 111.082m | 46.50 | 116.17 | 118.09 | 117.53 | 118.26 | 0.002524 | 1.88 | 26.78 | 20.48 | 0.49 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2521 | | | Bridge | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2506 | Winter 100yr | Winter - 113.621m | 83.00 | 116.43 | 118.60 | 117.87 | 118.84 | 0.002373 | 2.17 | 40.37 | 24.35 | 0.49 |
| Muskrat River | Main_2 | 2506 | Summer 100yr | Summer - 113.621m | 46.50 | 116.43 | 117.89 | 117.47 | 118.08 | 0.003307 | 1.90 | 24.74 | 20.70 | 0.54 |
| Muskrat River | Main_2 | 2506 | Summer 100yr | Summer - 112 m | 46.50 | 116.43 | 117.89 | 117.47 | 118.08 | 0.003307 | 1.90 | 24.74 | 20.70 | 0.54 |
| Muskrat River | Main_2 | 2506 | Summer 100yr | Summer - 111.082m | 46.50 | 116.43 | 117.89 | 117.47 | 118.08 | 0.003307 | 1.90 | 24.74 | 20.70 | 0.54 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2494 | Winter 100yr | Winter - 113.621m | 83.00 | 116.59 | 118.63 | | 118.76 | 0.001526 | 1.65 | 53.29 | 34.84 | 0.39 |
| Muskrat River | Main_2 | 2494 | Summer 100yr | Summer - 113.621m | 46.50 | 116.59 | 117.88 | | 118.01 | 0.002878 | 1.59 | 29.62 | 29.56 | 0.49 |
| Muskrat River | Main_2 | 2494 | Summer 100yr | Summer - 112 m | 46.50 | 116.59 | 117.88 | | 118.01 | 0.002878 | 1.59 | 29.62 | 29.56 | 0.49 |
| Muskrat River | Main_2 | 2494 | Summer 100yr | Summer - 111.082m | 46.50 | 116.59 | 117.88 | | 118.01 | 0.002878 | 1.59 | 29.62 | 29.56 | 0.49 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2430 | Winter 100yr | Winter - 113.621m | 83.00 | 116.37 | 118.56 | | 118.67 | 0.001081 | 1.49 | 58.06 | 34.21 | 0.33 |
| Muskrat River | Main_2 | 2430 | Summer 100yr | Summer - 113.621m | 46.50 | 116.37 | 117.75 | | 117.85 | 0.001885 | 1.40 | 33.37 | 28.64 | 0.41 |
| Muskrat River | Main_2 | 2430 | Summer 100yr | Summer - 112 m | 46.50 | 116.37 | 117.75 | | 117.85 | 0.001884 | 1.40 | 33.37 | 28.64 | 0.41 |
| Muskrat River | Main_2 | 2430 | Summer 100yr | Summer - 111.082m | 46.50 | 116.37 | 117.75 | | 117.85 | 0.001884 | 1.40 | 33.37 | 28.64 | 0.41 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2351 | Winter 100yr | Winter - 113.621m | 83.00 | 115.97 | 118.49 | | 118.59 | 0.000923 | 1.51 | 79.63 | 55.08 | 0.32 |
| Muskrat River | Main_2 | 2351 | Summer 100yr | Summer - 113.621m | 46.50 | 115.97 | 117.58 | | 117.71 | 0.001857 | 1.55 | 33.03 | 39.63 | 0.41 |
| Muskrat River | Main_2 | 2351 | Summer 100yr | Summer - 112 m | 46.50 | 115.97 | 117.58 | | 117.71 | 0.001857 | 1.55 | 33.03 | 39.63 | 0.41 |
| Muskrat River | Main_2 | 2351 | Summer 100yr | Summer - 111.082m | 46.50 | 115.97 | 117.58 | | 117.71 | 0.001857 | 1.55 | 33.03 | 39.63 | 0.41 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2284 | Winter 100yr | Winter - 113.621m | 83.00 | 115.77 | 118.47 | | 118.53 | 0.000575 | 1.23 | 105.94 | 56.96 | 0.25 |
| Muskrat River | Main_2 | 2284 | Summer 100yr | Summer - 113.621m | 46.50 | 115.77 | 117.52 | | 117.59 | 0.001172 | 1.27 | 52.95 | 54.33 | 0.33 |
| Muskrat River | Main_2 | 2284 | Summer 100yr | Summer - 112 m | 46.50 | 115.77 | 117.52 | | 117.59 | 0.001172 | 1.27 | 52.95 | 54.33 | 0.33 |
| Muskrat River | Main_2 | 2284 | Summer 100yr | Summer - 111.082m | 46.50 | 115.77 | 117.52 | | 117.59 | 0.001172 | 1.27 | 52.95 | 54.33 | 0.33 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2201 | Winter 100yr | Winter - 113.621m | 83.00 | 115.16 | 118.45 | | 118.50 | 0.000296 | 1.01 | 96.83 | 46.32 | 0.19 |
| Muskrat River | Main_2 | 2201 | Summer 100yr | Summer - 113.621m | 46.50 | 115.16 | 117.50 | | 117.53 | 0.000362 | 0.87 | 57.50 | 34.22 | 0.19 |
| Muskrat River | Main_2 | 2201 | Summer 100yr | Summer - 112 m | 46.50 | 115.16 | 117.50 | | 117.53 | 0.000362 | 0.87 | 57.51 | 34.22 | 0.19 |
| Muskrat River | Main_2 | 2201 | Summer 100yr | Summer - 111.082m | 46.50 | 115.16 | 117.50 | | 117.53 | 0.000362 | 0.87 | 57.51 | 34.22 | 0.19 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2137 | Winter 100yr | Winter - 113.621m | 83.00 | 115.41 | 118.39 | 116.71 | 118.47 | 0.000529 | 1.30 | 76.69 | 39.11 | 0.25 |
| Muskrat River | Main_2 | 2137 | Summer 100yr | Summer - 113.621m | 46.50 | 115.41 | 117.44 | 116.33 | 117.50 | 0.000678 | 1.12 | 45.83 | 30.31 | 0.26 |
| Muskrat River | Main_2 | 2137 | Summer 100yr | Summer - 112 m | 46.50 | 115.41 | 117.44 | 116.33 | 117.50 | 0.000678 | 1.12 | 45.83 | 30.31 | 0.26 |
| Muskrat River | Main_2 | 2137 | Summer 100yr | Summer - 111.082m | 46.50 | 115.41 | 117.44 | 116.33 | 117.50 | 0.000678 | 1.12 | 45.83 | 30.31 | 0.26 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_2 | 2030 | Winter 100yr | Winter - 113.621m | 83.00 | 114.96 | 118.41 | 115.98 | 118.43 | 0.000116 | 0.67 | 165.00 | 64.56 | 0.12 |
| Muskrat River | Main_2 | 2030 | Summer 100yr | Summer - 113.621m | 46.50 | 114.96 | 117.44 | 115.69 | 117.46 | 0.000128 | 0.56 | 104.36 | 61.20 | 0.12 |
| Muskrat River | Main_2 | 2030 | Summer 100yr | Summer - 112 m | 46.50 | 114.96 | 117.44 | 115.69 | 117.46 | 0.000128 | 0.56 | 104.36 | 61.20 | 0.12 |
| Muskrat River | Main_2 | 2030 | Summer 100yr | Summer - 111.082m | 46.50 | 114.96 | 117.44 | 115.69 | 117.46 | 0.000128 | 0.56 | 104.36 | 61.20 | 0.12 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1931 | Winter 100yr | Winter - 113.621m | 259.90 | 115.05 | 117.85 | | 118.31 | 0.003042 | 3.02 | 92.44 | 40.87 | 0.59 |
| Muskrat River | Main_1 | 1931 | Summer 100yr | Summer - 113.621m | 138.10 | 115.05 | 117.11 | | 117.36 | 0.002570 | 2.24 | 63.49 | 36.57 | 0.51 |
| Muskrat River | Main_1 | 1931 | Summer 100yr | Summer - 112 m | 138.10 | 115.05 | 117.11 | | 117.36 | 0.002570 | 2.24 | 63.50 | 36.57 | 0.51 |
| Muskrat River | Main_1 | 1931 | Summer 100yr | Summer - 111.082m | 138.10 | 115.05 | 117.11 | | 117.36 | 0.002570 | 2.24 | 63.50 | 36.57 | 0.51 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1764 | Winter 100yr | Winter - 113.621m | 259.90 | 114.67 | 117.38 | 116.68 | 117.79 | 0.002986 | 2.89 | 115.75 | 82.87 | 0.58 |
| Muskrat River | Main_1 | 1764 | Summer 100yr | Summer - 113.621m | 138.10 | 114.67 | 116.65 | 116.04 | 116.91 | 0.002867 | 2.26 | 63.59 | 39.67 | 0.54 |
| Muskrat River | Main_1 | 1764 | Summer 100yr | Summer - 112 m | 138.10 | 114.67 | 116.65 | 116.04 | 116.91 | 0.002865 | 2.26 | 63.61 | 39.68 | 0.54 |
| Muskrat River | Main_1 | 1764 | Summer 100yr | Summer - 111.082m | 138.10 | 114.67 | 116.65 | 116.04 | 116.91 | 0.002865 | 2.26 | 63.61 | 39.68 | 0.54 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1638 | Winter 100yr | Winter - 113.621m | 259.90 | 114.51 | 116.46 | 116.39 | 117.18 | 0.008074 | 3.79 | 75.72 | 50.82 | 0.90 |
| Muskrat River | Main_1 | 1638 | Summer 100yr | Summer - 113.621m | 138.10 | 114.51 | 116.04 | 115.78 | 116.40 | 0.005712 | 2.67 | 54.58 | 49.25 | 0.72 |
| Muskrat River | Main_1 | 1638 | Summer 100yr | Summer - 112 m | 138.10 | 114.51 | 116.04 | 115.78 | 116.40 | 0.005778 | 2.68 | 54.35 | 49.23 | 0.73 |
| Muskrat River | Main_1 | 1638 | Summer 100yr | Summer - 111.082m | 138.10 | 114.51 | 116.04 | 115.78 | 116.40 | 0.005778 | 2.68 | 54.35 | 49.23 | 0.73 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1562 | Winter 100yr | Winter - 113.621m | 259.90 | 114.25 | 115.92 | 115.85 | 116.49 | 0.009041 | 3.34 | 79.83 | 63.99 | 0.91 |
| Muskrat River | Main_1 | 1562 | Summer 100yr | Summer - 113.621m | 138.10 | 114.25 | 115.45 | 115.40 | 115.83 | 0.010425 | 2.71 | 51.09 | 57.78 | 0.91 |
| Muskrat River | Main_1 | 1562 | Summer 100yr | Summer - 112 m | 138.10 | 114.25 | 115.46 | 115.40 | 115.83 | 0.010159 | 2.69 | 51.49 | 57.83 | 0.90 |
| Muskrat River | Main_1 | 1562 | Summer 100yr | Summer - 111.082m | 138.10 | 114.25 | 115.46 | 115.40 | 115.83 | 0.010159 | 2.69 | 51.49 | 57.83 | 0.90 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1496 | Winter 100yr | Winter - 113.621m | 259.90 | 113.68 | 115.74 | 115.28 | 116.05 | 0.003566 | 2.55 | 120.57 | 85.99 | 0.60 |
| Muskrat River | Main_1 | 1496 | Summer 100yr | Summer - 113.621m | 138.10 | 113.68 | 115.17 | 114.83 | 115.38 | 0.003855 | 2.06 | 72.42 | 69.90 | 0.59 |
| Muskrat River | Main_1 | 1496 | Summer 100yr | Summer - 112 m | 138.10 | 113.68 | 115.24 | 114.83 | 115.42 | 0.003175 | 1.94 | 78.91 | 78.21 | 0.54 |
| Muskrat River | Main_1 | 1496 | Summer 100yr | Summer - 111.082m | 138.10 | 113.68 | 115.24 | 114.83 | 115.42 | 0.003175 | 1.94 | 78.91 | 78.21 | 0.54 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1365 | Winter 100yr | Winter - 113.621m | 259.90 | 112.78 | 115.44 | | 115.67 | 0.002201 | 2.39 | 170.77 | 130.41 | 0.49 |
| Muskrat River | Main_1 | 1365 | Summer 100yr | Summer - 113.621m | 138.10 | 112.78 | 114.51 | 114.18 | 114.82 | 0.004632 | 2.50 | 62.64 | 82.53 | 0.66 |
| Muskrat River | Main_1 | 1365 | Summer 100yr | Summer - 112 m | 138.10 | 112.78 | 114.25 | 114.18 | 114.74 | 0.009145 | 3.10 | 45.91 | 44.32 | 0.90 |
| Muskrat River | Main_1 | 1365 | Summer 100yr | Summer - 111.082m | 138.10 | 112.78 | 114.25 | 114.18 | 114.74 | 0.009145 | 3.10 | 45.91 | 44.32 | 0.90 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1233 | Winter 100yr | Winter - 113.621m | 259.90 | 111.36 | 115.33 | | 115.47 | 0.000781 | 1.89 | 234.65 | 160.66 | 0.32 |
| Muskrat River | Main_1 | 1233 | Summer 100yr | Summer - 113.621m | 138.10 | 111.36 | 114.42 | | 114.54 | 0.000808 | 1.59 | 108.04 | 71.45 | 0.31 |
| Muskrat River | Main_1 | 1233 | Summer 100yr | Summer - 112 m | 138.10 | 111.36 | 114.13 | | 114.29 | 0.001204 | 1.81 | 90.31 | 52.83 | 0.37 |
| Muskrat River | Main_1 | 1233 | Summer 100yr | Summer - 111.082m | 138.10 | 111.36 | 114.13 | | 114.29 | 0.001204 | 1.81 | 90.32 | 52.83 | 0.37 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1170 | Winter 100yr | Winter - 113.621m | 259.90 | 110.91 | 115.30 | | 115.44 | 0.000603 | 1.83 | 244.99 | 171.80 | 0.28 |
| Muskrat River | Main_1 | 1170 | Summer 100yr | Summer - 113.621m | 138.10 | 110.91 | 114.40 | | 114.50 | 0.000512 | 1.44 | 112.62 | 73.83 | 0.25 |
| Muskrat River | Main_1 | 1170 | Summer 100yr | Summer - 112 m | 138.10 | 110.91 | 114.10 | | 114.22 | 0.000719 | 1.60 | 97.24 | 45.01 | 0.29 |
| Muskrat River | Main_1 | 1170 | Summer 100yr | Summer - 111.082m | 138.10 | 110.91 | 114.10 | | 114.22 | 0.000719 | 1.60 | 97.24 | 45.01 | 0.29 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 1102 | Winter 100yr | Winter - 113.621m | 259.90 | 110.81 | 115.12 | | 115.38 | 0.001148 | 2.46 | 191.11 | 154.57 | 0.39 |
| Muskrat River | Main_1 | 1102 | Summer 100yr | Summer - 113.621m | 138.10 | 110.81 | 114.26 | | 114.44 | 0.000957 | 1.92 | 87.20 | 52.50 | 0.34 |
| Muskrat River | Main_1 | 1102 | Summer 100yr | Summer - 112 m | 138.10 | 110.81 | 113.91 | | 114.15 | 0.001438 | 2.19 | 72.28 | 35.67 | 0.41 |
| Muskrat River | Main_1 | 1102 | Summer 100yr | Summer - 111.082m | 138.10 | 110.81 | 113.91 | | 114.15 | 0.001438 | 2.19 | 72.28 | 35.67 | 0.41 |
| | | | | | | | | | | | | | | |
| Muskrat River | Main_1 | 971 | Winter 100yr | Winter - 113.621m | 259.90 | 110.88 | 115.08 | | 115.23 | 0.000663 | 1.86 | 203.65 | 95.03 | 0.29 |
| Muskrat River | Main_1 | 971 | Summer 100yr | Summer - 113.621m | 138.10 | 110.88 | 114.24 | | 114.33 | 0.000487 | 1.36 | 129.39 | 75.90 | 0.24 |
| Muskrat River | Main_1 | 971 | Summer 100yr | Summer - 112 m | 138.10 | 110.88 | 113.85 | | 113.98 | 0.000816 | 1.62 | 100.44 | 69.60 | 0.31 |
| Muskrat River | Main_1 | 971 | Summer 100yr | Summer - 111.082m | 138.10 | 110.88 | 113.85 | | 113.98 | 0.000816 | 1.62 | 100.44 | 69.60 | 0.31 |

HEC-RAS Profile: Winter 100yr (Continued)

| River | Reach | River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| Muskrat River | Main_1 | 871 | Winter 100yr | Winter - 113.621m | 259.90 | 110.79 | 114.87 | | 115.13 | 0.001149 | 2.38 | 143.50 | 61.67 | 0.38 |
| Muskrat River | Main_1 | 871 | Summer 100yr | Summer - 113.621m | 138.10 | 110.79 | 114.14 | | 114.27 | 0.000702 | 1.62 | 100.69 | 55.23 | 0.29 |
| Muskrat River | Main_1 | 871 | Summer 100yr | Summer - 112 m | 138.10 | 110.79 | 113.69 | | 113.87 | 0.001200 | 1.91 | 79.42 | 36.63 | 0.37 |
| Muskrat River | Main_1 | 871 | Summer 100yr | Summer - 111.082m | 138.10 | 110.79 | 113.69 | | 113.87 | 0.001200 | 1.91 | 79.42 | 36.63 | 0.37 |
| Muskrat River | Main_1 | 832 | Winter 100yr | Winter - 113.621m | 259.90 | 110.24 | 114.78 | | 115.08 | 0.001240 | 2.58 | 136.21 | 55.55 | 0.40 |
| Muskrat River | Main_1 | 832 | Summer 100yr | Summer - 113.621m | 138.10 | 110.24 | 114.12 | | 114.24 | 0.000632 | 1.64 | 105.19 | 37.28 | 0.28 |
| Muskrat River | Main_1 | 832 | Summer 100yr | Summer - 112 m | 138.10 | 110.24 | 113.65 | | 113.82 | 0.001040 | 1.91 | 88.50 | 35.07 | 0.35 |
| Muskrat River | Main_1 | 832 | Summer 100yr | Summer - 111.082m | 138.10 | 110.24 | 113.65 | | 113.82 | 0.001040 | 1.91 | 88.50 | 35.07 | 0.35 |
| Muskrat River | Main_1 | 812 | Winter 100yr | Winter - 113.621m | 259.90 | 110.27 | 114.57 | 113.22 | 115.03 | 0.002059 | 3.14 | 116.76 | 54.74 | 0.51 |
| Muskrat River | Main_1 | 812 | Summer 100yr | Summer - 113.621m | 138.10 | 110.27 | 114.04 | 112.43 | 114.22 | 0.000949 | 1.93 | 93.56 | 37.99 | 0.34 |
| Muskrat River | Main_1 | 812 | Summer 100yr | Summer - 112 m | 138.10 | 110.27 | 113.53 | 112.43 | 113.78 | 0.001741 | 2.33 | 74.54 | 35.44 | 0.45 |
| Muskrat River | Main_1 | 812 | Summer 100yr | Summer - 111.082m | 138.10 | 110.27 | 113.53 | 112.43 | 113.78 | 0.001741 | 2.33 | 74.54 | 35.44 | 0.45 |
| Muskrat River | Main_1 | 797 | | | Bridge | | | | | | | | | |
| Muskrat River | Main_1 | 785 | Winter 100yr | Winter - 113.621m | 259.90 | 110.89 | 114.18 | | 114.85 | 0.003873 | 3.77 | 82.24 | 42.03 | 0.68 |
| Muskrat River | Main_1 | 785 | Summer 100yr | Summer - 113.621m | 138.10 | 110.89 | 113.92 | | 114.15 | 0.001503 | 2.22 | 72.00 | 35.05 | 0.42 |
| Muskrat River | Main_1 | 785 | Summer 100yr | Summer - 112 m | 138.10 | 110.89 | 113.01 | | 113.58 | 0.005823 | 3.39 | 43.73 | 27.39 | 0.77 |
| Muskrat River | Main_1 | 785 | Summer 100yr | Summer - 111.082m | 138.10 | 110.89 | 113.01 | | 113.58 | 0.005817 | 3.39 | 43.74 | 27.40 | 0.77 |
| Muskrat River | Main_1 | 726 | Winter 100yr | Winter - 113.621m | 259.90 | 110.76 | 114.31 | | 114.51 | 0.000977 | 2.01 | 139.90 | 45.55 | 0.35 |
| Muskrat River | Main_1 | 726 | Summer 100yr | Summer - 113.621m | 138.10 | 110.76 | 113.96 | | 114.03 | 0.000400 | 1.19 | 123.95 | 44.99 | 0.22 |
| Muskrat River | Main_1 | 726 | Summer 100yr | Summer - 112 m | 138.10 | 110.76 | 113.08 | | 113.23 | 0.001250 | 1.69 | 85.47 | 43.17 | 0.36 |
| Muskrat River | Main_1 | 726 | Summer 100yr | Summer - 111.082m | 138.10 | 110.76 | 113.08 | | 113.23 | 0.001249 | 1.69 | 85.49 | 43.17 | 0.36 |
| Muskrat River | Main_1 | 581 | Winter 100yr | Winter - 113.621m | 259.90 | 110.67 | 114.11 | | 114.38 | 0.001403 | 2.33 | 121.54 | 44.01 | 0.41 |
| Muskrat River | Main_1 | 581 | Summer 100yr | Summer - 113.621m | 138.10 | 110.67 | 113.89 | | 113.98 | 0.000504 | 1.33 | 112.00 | 42.63 | 0.24 |
| Muskrat River | Main_1 | 581 | Summer 100yr | Summer - 112 m | 138.10 | 110.67 | 112.82 | | 113.04 | 0.002220 | 2.09 | 68.62 | 38.88 | 0.48 |
| Muskrat River | Main_1 | 581 | Summer 100yr | Summer - 111.082m | 138.10 | 110.67 | 112.83 | | 113.04 | 0.002217 | 2.09 | 68.66 | 38.88 | 0.48 |
| Muskrat River | Main_1 | 549 | Winter 100yr | Winter - 113.621m | 259.90 | 109.85 | 114.07 | | 114.29 | 0.000830 | 1.98 | 135.52 | 42.08 | 0.33 |
| Muskrat River | Main_1 | 549 | Summer 100yr | Summer - 113.621m | 138.10 | 109.85 | 113.88 | | 113.95 | 0.000285 | 1.12 | 127.29 | 41.62 | 0.19 |
| Muskrat River | Main_1 | 549 | Summer 100yr | Summer - 112 m | 138.10 | 109.85 | 112.76 | | 112.92 | 0.001103 | 1.72 | 82.62 | 38.44 | 0.35 |
| Muskrat River | Main_1 | 549 | Summer 100yr | Summer - 111.082m | 138.10 | 109.85 | 112.77 | | 112.92 | 0.001102 | 1.72 | 82.66 | 38.45 | 0.35 |
| Muskrat River | Main_1 | 470 | Winter 100yr | Winter - 113.621m | 259.90 | 110.11 | 114.08 | 112.04 | 114.21 | 0.000583 | 1.60 | 171.54 | 51.97 | 0.27 |
| Muskrat River | Main_1 | 470 | Summer 100yr | Summer - 113.621m | 138.10 | 110.11 | 113.88 | 111.52 | 113.92 | 0.000201 | 0.91 | 161.11 | 51.86 | 0.16 |
| Muskrat River | Main_1 | 470 | Summer 100yr | Summer - 112 m | 138.10 | 110.11 | 112.73 | 111.52 | 112.83 | 0.000847 | 1.41 | 102.25 | 51.15 | 0.30 |
| Muskrat River | Main_1 | 470 | Summer 100yr | Summer - 111.082m | 138.10 | 110.11 | 112.73 | 111.52 | 112.83 | 0.000846 | 1.41 | 102.31 | 51.15 | 0.30 |
| Muskrat River | Main_1 | 455 | | | Bridge | | | | | | | | | |
| Muskrat River | Main_1 | 436 | Winter 100yr | Winter - 113.621m | 259.90 | 110.32 | 113.92 | 112.29 | 114.08 | 0.000838 | 1.76 | 154.29 | 71.06 | 0.32 |
| Muskrat River | Main_1 | 436 | Summer 100yr | Summer - 113.621m | 138.10 | 110.32 | 113.84 | 111.77 | 113.88 | 0.000260 | 0.96 | 149.67 | 70.90 | 0.18 |
| Muskrat River | Main_1 | 436 | Summer 100yr | Summer - 112 m | 138.10 | 110.32 | 112.57 | 111.77 | 112.71 | 0.001628 | 1.68 | 84.38 | 50.36 | 0.40 |
| Muskrat River | Main_1 | 436 | Summer 100yr | Summer - 111.082m | 138.10 | 110.32 | 112.57 | 111.77 | 112.71 | 0.001623 | 1.68 | 84.46 | 50.36 | 0.40 |
| Muskrat River | Main_1 | 381 | Winter 100yr | Winter - 113.621m | 259.90 | 109.69 | 113.90 | 111.57 | 114.02 | 0.000489 | 1.59 | 179.22 | 60.52 | 0.25 |
| Muskrat River | Main_1 | 381 | Summer 100yr | Summer - 113.621m | 138.10 | 109.69 | 113.83 | 110.99 | 113.86 | 0.000147 | 0.86 | 175.19 | 59.05 | 0.14 |
| Muskrat River | Main_1 | 381 | Summer 100yr | Summer - 112 m | 138.10 | 109.69 | 112.53 | 110.99 | 112.62 | 0.000584 | 1.32 | 110.00 | 46.63 | 0.26 |
| Muskrat River | Main_1 | 381 | Summer 100yr | Summer - 111.082m | 138.10 | 109.69 | 112.53 | 110.99 | 112.62 | 0.000583 | 1.32 | 110.07 | 46.64 | 0.26 |
| Muskrat River | Main_1 | 319 | Winter 100yr | Winter - 113.621m | 259.90 | 109.63 | 113.82 | 111.81 | 113.97 | 0.000685 | 1.81 | 154.89 | 51.40 | 0.30 |
| Muskrat River | Main_1 | 319 | Summer 100yr | Summer - 113.621m | 138.10 | 109.63 | 113.81 | 111.19 | 113.85 | 0.000195 | 0.96 | 154.39 | 51.14 | 0.16 |
| Muskrat River | Main_1 | 319 | Summer 100yr | Summer - 112 m | 138.10 | 109.63 | 112.45 | 111.19 | 112.57 | 0.000928 | 1.56 | 92.62 | 44.18 | 0.32 |
| Muskrat River | Main_1 | 319 | Summer 100yr | Summer - 111.082m | 138.10 | 109.63 | 112.45 | 111.19 | 112.57 | 0.000925 | 1.56 | 92.70 | 44.19 | 0.32 |
| Muskrat River | Main_1 | 304 | | | Bridge | | | | | | | | | |
| Muskrat River | Main_1 | 291 | Winter 100yr | Winter - 113.621m | 259.90 | 109.77 | 113.78 | 111.81 | 113.95 | 0.000736 | 1.91 | 154.69 | 80.47 | 0.31 |
| Muskrat River | Main_1 | 291 | Summer 100yr | Summer - 113.621m | 138.10 | 109.77 | 113.79 | 111.13 | 113.84 | 0.000205 | 1.01 | 155.47 | 81.69 | 0.16 |
| Muskrat River | Main_1 | 291 | Summer 100yr | Summer - 112 m | 138.10 | 109.77 | 112.39 | 111.13 | 112.53 | 0.001039 | 1.69 | 87.91 | 47.02 | 0.34 |
| Muskrat River | Main_1 | 291 | Summer 100yr | Summer - 111.082m | 138.10 | 109.77 | 112.39 | 111.13 | 112.53 | 0.001036 | 1.69 | 88.01 | 47.04 | 0.34 |
| Muskrat River | Main_1 | 266 | Winter 100yr | Winter - 113.621m | 259.90 | 110.68 | 113.77 | 112.34 | 113.92 | 0.000945 | 1.80 | 156.85 | 184.86 | 0.33 |
| Muskrat River | Main_1 | 266 | Summer 100yr | Summer - 113.621m | 138.10 | 110.68 | 113.79 | 111.80 | 113.83 | 0.000260 | 0.95 | 158.18 | 185.02 | 0.18 |
| Muskrat River | Main_1 | 266 | Summer 100yr | Summer - 112 m | 138.10 | 110.68 | 112.25 | 111.80 | 112.47 | 0.003376 | 2.10 | 68.20 | 62.34 | 0.56 |
| Muskrat River | Main_1 | 266 | Summer 100yr | Summer - 111.082m | 138.10 | 110.68 | 112.25 | 111.80 | 112.48 | 0.003350 | 2.10 | 68.37 | 62.39 | 0.56 |
| Muskrat River | Main_1 | 256 | | | Bridge | | | | | | | | | |
| Muskrat River | Main_1 | 242 | Winter 100yr | Winter - 113.621m | 259.90 | 110.69 | 113.59 | 112.04 | 113.70 | 0.000697 | 1.48 | 176.39 | 118.96 | 0.28 |
| Muskrat River | Main_1 | 242 | Summer 100yr | Summer - 113.621m | 138.10 | 110.69 | 113.61 | 111.63 | 113.64 | 0.000192 | 0.78 | 177.69 | 119.14 | 0.15 |
| Muskrat River | Main_1 | 242 | Summer 100yr | Summer - 112 m | 138.10 | 110.69 | 112.06 | 111.63 | 112.22 | 0.003009 | 1.78 | 77.71 | 91.42 | 0.52 |
| Muskrat River | Main_1 | 242 | Summer 100yr | Summer - 111.082m | 138.10 | 110.69 | 111.94 | 111.63 | 112.14 | 0.004255 | 1.98 | 70.01 | 88.59 | 0.60 |
| Muskrat River | Main_1 | 213 | Winter 100yr | Winter - 113.621m | 259.90 | 109.78 | 113.62 | 111.32 | 113.66 | 0.000178 | 0.90 | 373.73 | 149.02 | 0.15 |
| Muskrat River | Main_1 | 213 | Summer 100yr | Summer - 113.621m | 138.10 | 109.78 | 113.62 | 110.84 | 113.63 | 0.000050 | 0.48 | 373.52 | 149.00 | 0.08 |
| Muskrat River | Main_1 | 213 | Summer 100yr | Summer - 112 m | 138.10 | 109.78 | 112.09 | 110.84 | 112.14 | 0.000487 | 1.03 | 157.70 | 129.65 | 0.23 |
| Muskrat River | Main_1 | 213 | Summer 100yr | Summer - 111.082m | 138.10 | 109.78 | 111.97 | 110.84 | 112.03 | 0.000625 | 1.12 | 135.59 | 95.84 | 0.25 |
| Muskrat River | Main_1 | 146 | Winter 100yr | Winter - 113.621m | 259.90 | 110.64 | 113.62 | 111.74 | 113.64 | 0.000177 | 0.75 | 523.88 | 300.00 | 0.14 |
| Muskrat River | Main_1 | 146 | Summer 100yr | Summer - 113.621m | 138.10 | 110.64 | 113.62 | 111.40 | 113.63 | 0.000050 | 0.40 | 524.64 | 300.00 | 0.08 |
| Muskrat River | Main_1 | 146 | Summer 100yr | Summer - 112 m | 138.10 | 110.64 | 112.01 | 111.40 | 112.08 | 0.001431 | 1.20 | 117.72 | 111.39 | 0.35 |
| Muskrat River | Main_1 | 146 | Summer 100yr | Summer - 111.082m | 138.10 | 110.64 | 111.86 | 111.40 | 111.96 | 0.002283 | 1.38 | 101.25 | 107.79 | 0.44 |
| Muskrat River | Main_1 | 1 | Winter 100yr | Winter - 113.621m | 259.90 | 110.62 | 113.62 | 111.27 | 113.63 | 0.000031 | 0.32 | 808.99 | 300.00 | 0.06 |
| Muskrat River | Main_1 | 1 | Summer 100yr | Summer - 113.621m | 138.10 | 110.62 | 113.62 | 111.13 | 113.62 | 0.000009 | 0.17 | 808.99 | 300.00 | 0.03 |
| Muskrat River | Main_1 | 1 | Summer 100yr | Summer - 112 m | 138.10 | 110.62 | 112.00 | 111.13 | 112.01 | 0.000169 | 0.41 | 329.75 | 286.77 | 0.12 |
| Muskrat River | Main_1 | 1 | Summer 100yr | Summer - 111.082m | 138.10 | 110.62 | 111.13 | 111.13 | 111.27 | 0.014154 | 1.66 | 84.79 | 272.51 | 0.91 |
| Indian River | Main_1 | 3247 | Winter 100yr | Winter - 113.621m | 181.90 | 116.94 | 121.18 | | 121.38 | 0.000857 | 2.11 | 117.57 | 46.81 | 0.33 |
| Indian River | Main_1 | 3247 | Summer 100yr | Summer - 113.621m | 92.90 | 116.94 | 119.93 | | 120.07 | 0.000852 | 1.65 | 64.30 | 37.70 | 0.31 |
| Indian River | Main_1 | 3247 | Summer 100yr | Summer - 112 m | 92.90 | 116.94 | 119.93 | | 120.07 | 0.000852 | 1.65 | 64.30 | 37.70 | 0.31 |
| Indian River | Main_1 | 3247 | Summer 100yr | Summer - 111.082m | 92.90 | 116.94 | 119.93 | | 120.07 | 0.000852 | 1.65 | 64.30 | 37.70 | 0.31 |
| Indian River | Main_1 | 3075 | Winter 100yr | Winter - 113.621m | 181.90 | 116.95 | 121.01 | | 121.23 | 0.000922 | 2.12 | 105.94 | 39.28 | 0.34 |
| Indian River | Main_1 | 3075 | Summer 100yr | Summer - 113.621m | 92.90 | 116.95 | 119.78 | | 119.92 | 0.000893 | 1.63 | 61.17 | 28.70 | 0.31 |

HEC-RAS Profile: Winter 100yr (Continued)

| River | Reach | River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| Indian River | Main_1 | 3075 | Summer 100yr | Summer - 112 m | 92.90 | 116.95 | 119.78 | | 119.92 | 0.000893 | 1.63 | 61.17 | 28.70 | 0.31 |
| Indian River | Main_1 | 3075 | Summer 100yr | Summer - 111.082m | 92.90 | 116.95 | 119.78 | | 119.92 | 0.000893 | 1.63 | 61.17 | 28.70 | 0.31 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2884 | Winter 100yr | Winter - 113.621m | 181.90 | 115.87 | 120.82 | | 121.06 | 0.000812 | 2.23 | 103.03 | 31.75 | 0.33 |
| Indian River | Main_1 | 2884 | Summer 100yr | Summer - 113.621m | 92.90 | 115.87 | 119.65 | | 119.77 | 0.000597 | 1.57 | 68.70 | 26.73 | 0.27 |
| Indian River | Main_1 | 2884 | Summer 100yr | Summer - 112 m | 92.90 | 115.87 | 119.65 | | 119.77 | 0.000597 | 1.57 | 68.70 | 26.73 | 0.27 |
| Indian River | Main_1 | 2884 | Summer 100yr | Summer - 111.082m | 92.90 | 115.87 | 119.65 | | 119.77 | 0.000597 | 1.57 | 68.70 | 26.73 | 0.27 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2861 | Winter 100yr | Winter - 113.621m | 181.90 | 116.61 | 120.68 | 119.20 | 121.02 | 0.001544 | 2.68 | 81.92 | 30.81 | 0.44 |
| Indian River | Main_1 | 2861 | Summer 100yr | Summer - 113.621m | 92.90 | 116.61 | 119.55 | 118.40 | 119.74 | 0.001396 | 2.01 | 53.37 | 26.59 | 0.40 |
| Indian River | Main_1 | 2861 | Summer 100yr | Summer - 112 m | 92.90 | 116.61 | 119.55 | 118.40 | 119.74 | 0.001396 | 2.01 | 53.37 | 26.59 | 0.40 |
| Indian River | Main_1 | 2861 | Summer 100yr | Summer - 111.082m | 92.90 | 116.61 | 119.55 | 118.40 | 119.74 | 0.001396 | 2.01 | 53.37 | 26.59 | 0.40 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2845 | | | Bridge | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2832 | Winter 100yr | Winter - 113.621m | 181.90 | 116.56 | 120.52 | 119.25 | 120.96 | 0.002033 | 3.04 | 74.18 | 27.42 | 0.50 |
| Indian River | Main_1 | 2832 | Summer 100yr | Summer - 113.621m | 92.90 | 116.56 | 119.45 | 118.36 | 119.70 | 0.001732 | 2.25 | 47.15 | 23.03 | 0.44 |
| Indian River | Main_1 | 2832 | Summer 100yr | Summer - 112 m | 92.90 | 116.56 | 119.45 | 118.36 | 119.70 | 0.001732 | 2.25 | 47.15 | 23.03 | 0.44 |
| Indian River | Main_1 | 2832 | Summer 100yr | Summer - 111.082m | 92.90 | 116.56 | 119.45 | 118.36 | 119.70 | 0.001732 | 2.25 | 47.15 | 23.03 | 0.44 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2798 | Winter 100yr | Winter - 113.621m | 181.90 | 116.76 | 120.55 | | 120.81 | 0.001238 | 2.35 | 98.74 | 41.86 | 0.39 |
| Indian River | Main_1 | 2798 | Summer 100yr | Summer - 113.621m | 92.90 | 116.76 | 119.43 | | 119.60 | 0.001229 | 1.84 | 56.30 | 30.57 | 0.37 |
| Indian River | Main_1 | 2798 | Summer 100yr | Summer - 112 m | 92.90 | 116.76 | 119.43 | | 119.60 | 0.001229 | 1.84 | 56.30 | 30.57 | 0.37 |
| Indian River | Main_1 | 2798 | Summer 100yr | Summer - 111.082m | 92.90 | 116.76 | 119.43 | | 119.60 | 0.001229 | 1.84 | 56.30 | 30.57 | 0.37 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2746 | Winter 100yr | Winter - 113.621m | 181.90 | 116.46 | 120.56 | | 120.73 | 0.000733 | 1.90 | 126.86 | 56.99 | 0.30 |
| Indian River | Main_1 | 2746 | Summer 100yr | Summer - 113.621m | 92.90 | 116.46 | 119.43 | | 119.54 | 0.000685 | 1.47 | 72.16 | 38.13 | 0.28 |
| Indian River | Main_1 | 2746 | Summer 100yr | Summer - 112 m | 92.90 | 116.46 | 119.43 | | 119.54 | 0.000685 | 1.47 | 72.16 | 38.13 | 0.28 |
| Indian River | Main_1 | 2746 | Summer 100yr | Summer - 111.082m | 92.90 | 116.46 | 119.43 | | 119.54 | 0.000685 | 1.47 | 72.16 | 38.13 | 0.28 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2646 | Winter 100yr | Winter - 113.621m | 181.90 | 116.37 | 120.57 | | 120.66 | 0.000373 | 1.39 | 163.89 | 52.47 | 0.22 |
| Indian River | Main_1 | 2646 | Summer 100yr | Summer - 113.621m | 92.90 | 116.37 | 119.42 | | 119.48 | 0.000312 | 1.02 | 107.97 | 46.87 | 0.19 |
| Indian River | Main_1 | 2646 | Summer 100yr | Summer - 112 m | 92.90 | 116.37 | 119.42 | | 119.48 | 0.000312 | 1.02 | 107.97 | 46.87 | 0.19 |
| Indian River | Main_1 | 2646 | Summer 100yr | Summer - 111.082m | 92.90 | 116.37 | 119.42 | | 119.48 | 0.000312 | 1.02 | 107.97 | 46.87 | 0.19 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2613 | Winter 100yr | Winter - 113.621m | 181.90 | 116.39 | 120.55 | | 120.64 | 0.000419 | 1.46 | 175.42 | 70.04 | 0.23 |
| Indian River | Main_1 | 2613 | Summer 100yr | Summer - 113.621m | 92.90 | 116.39 | 119.41 | | 119.46 | 0.000369 | 1.10 | 104.87 | 53.44 | 0.21 |
| Indian River | Main_1 | 2613 | Summer 100yr | Summer - 112 m | 92.90 | 116.39 | 119.41 | | 119.46 | 0.000369 | 1.10 | 104.87 | 53.44 | 0.21 |
| Indian River | Main_1 | 2613 | Summer 100yr | Summer - 111.082m | 92.90 | 116.39 | 119.41 | | 119.46 | 0.000369 | 1.10 | 104.87 | 53.44 | 0.21 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2576 | Winter 100yr | Winter - 113.621m | 181.90 | 116.41 | 120.54 | 118.23 | 120.62 | 0.000371 | 1.37 | 227.50 | 116.76 | 0.22 |
| Indian River | Main_1 | 2576 | Summer 100yr | Summer - 113.621m | 92.90 | 116.41 | 119.39 | 117.60 | 119.45 | 0.000382 | 1.11 | 109.55 | 67.32 | 0.21 |
| Indian River | Main_1 | 2576 | Summer 100yr | Summer - 112 m | 92.90 | 116.41 | 119.39 | 117.60 | 119.45 | 0.000382 | 1.11 | 109.55 | 67.32 | 0.21 |
| Indian River | Main_1 | 2576 | Summer 100yr | Summer - 111.082m | 92.90 | 116.41 | 119.39 | 117.60 | 119.45 | 0.000382 | 1.11 | 109.55 | 67.32 | 0.21 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2492 | Winter 100yr | Winter - 113.621m | 181.90 | 116.46 | 120.48 | 118.74 | 120.58 | 0.000612 | 1.72 | 249.08 | 157.47 | 0.28 |
| Indian River | Main_1 | 2492 | Summer 100yr | Summer - 113.621m | 92.90 | 116.46 | 119.24 | 117.96 | 119.39 | 0.001077 | 1.77 | 64.11 | 35.82 | 0.35 |
| Indian River | Main_1 | 2492 | Summer 100yr | Summer - 112 m | 92.90 | 116.46 | 119.24 | 117.96 | 119.39 | 0.001077 | 1.77 | 64.11 | 35.82 | 0.35 |
| Indian River | Main_1 | 2492 | Summer 100yr | Summer - 111.082m | 92.90 | 116.46 | 119.24 | 117.96 | 119.39 | 0.001077 | 1.77 | 64.11 | 35.82 | 0.35 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2443 | Winter 100yr | Winter - 113.621m | 181.90 | 116.42 | 120.47 | 118.55 | 120.55 | 0.000475 | 1.53 | 269.59 | 159.08 | 0.25 |
| Indian River | Main_1 | 2443 | Summer 100yr | Summer - 113.621m | 92.90 | 116.42 | 119.21 | 117.80 | 119.33 | 0.000842 | 1.57 | 70.13 | 36.56 | 0.31 |
| Indian River | Main_1 | 2443 | Summer 100yr | Summer - 112 m | 92.90 | 116.42 | 119.21 | 117.80 | 119.33 | 0.000842 | 1.57 | 70.13 | 36.56 | 0.31 |
| Indian River | Main_1 | 2443 | Summer 100yr | Summer - 111.082m | 92.90 | 116.42 | 119.21 | 117.80 | 119.33 | 0.000842 | 1.57 | 70.13 | 36.56 | 0.31 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2341 | Winter 100yr | Winter - 113.621m | 181.90 | 116.43 | 120.39 | 118.41 | 120.50 | 0.000557 | 1.64 | 203.61 | 108.20 | 0.27 |
| Indian River | Main_1 | 2341 | Summer 100yr | Summer - 113.621m | 92.90 | 116.43 | 119.13 | 117.72 | 119.25 | 0.000805 | 1.51 | 68.48 | 34.28 | 0.30 |
| Indian River | Main_1 | 2341 | Summer 100yr | Summer - 112 m | 92.90 | 116.43 | 119.13 | 117.72 | 119.25 | 0.000805 | 1.51 | 68.48 | 34.28 | 0.30 |
| Indian River | Main_1 | 2341 | Summer 100yr | Summer - 111.082m | 92.90 | 116.43 | 119.13 | 117.72 | 119.25 | 0.000805 | 1.51 | 68.48 | 34.28 | 0.30 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2308 | Winter 100yr | Winter - 113.621m | 181.90 | 116.44 | 120.33 | 118.58 | 120.48 | 0.000772 | 1.89 | 168.75 | 83.18 | 0.31 |
| Indian River | Main_1 | 2308 | Summer 100yr | Summer - 113.621m | 92.90 | 116.44 | 119.07 | 117.83 | 119.21 | 0.001122 | 1.74 | 70.10 | 71.67 | 0.35 |
| Indian River | Main_1 | 2308 | Summer 100yr | Summer - 112 m | 92.90 | 116.44 | 119.07 | 117.83 | 119.21 | 0.001122 | 1.74 | 70.10 | 71.67 | 0.35 |
| Indian River | Main_1 | 2308 | Summer 100yr | Summer - 111.082m | 92.90 | 116.44 | 119.07 | 117.83 | 119.21 | 0.001122 | 1.74 | 70.10 | 71.67 | 0.35 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2283 | Winter 100yr | Winter - 113.621m | 181.90 | 115.74 | 120.31 | 117.93 | 120.46 | 0.000569 | 1.79 | 149.29 | 57.73 | 0.27 |
| Indian River | Main_1 | 2283 | Summer 100yr | Summer - 113.621m | 92.90 | 115.74 | 119.09 | 117.20 | 119.18 | 0.000523 | 1.38 | 83.29 | 47.63 | 0.25 |
| Indian River | Main_1 | 2283 | Summer 100yr | Summer - 112 m | 92.90 | 115.74 | 119.09 | 117.20 | 119.18 | 0.000523 | 1.38 | 83.29 | 47.63 | 0.25 |
| Indian River | Main_1 | 2283 | Summer 100yr | Summer - 111.082m | 92.90 | 115.74 | 119.09 | 117.20 | 119.18 | 0.000523 | 1.38 | 83.29 | 47.63 | 0.25 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2187 | Winter 100yr | Winter - 113.621m | 181.90 | 115.64 | 120.25 | 117.97 | 120.40 | 0.000636 | 1.90 | 164.05 | 76.23 | 0.29 |
| Indian River | Main_1 | 2187 | Summer 100yr | Summer - 113.621m | 92.90 | 115.64 | 119.00 | 117.22 | 119.12 | 0.000650 | 1.55 | 77.12 | 57.84 | 0.28 |
| Indian River | Main_1 | 2187 | Summer 100yr | Summer - 112 m | 92.90 | 115.64 | 119.00 | 117.22 | 119.12 | 0.000650 | 1.55 | 77.12 | 57.84 | 0.28 |
| Indian River | Main_1 | 2187 | Summer 100yr | Summer - 111.082m | 92.90 | 115.64 | 119.00 | 117.22 | 119.12 | 0.000650 | 1.55 | 77.12 | 57.84 | 0.28 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2108 | Winter 100yr | Winter - 113.621m | 181.90 | 115.66 | 120.20 | 117.95 | 120.35 | 0.000629 | 1.89 | 163.50 | 68.85 | 0.29 |
| Indian River | Main_1 | 2108 | Summer 100yr | Summer - 113.621m | 92.90 | 115.66 | 118.96 | 117.16 | 119.07 | 0.000628 | 1.52 | 84.76 | 55.69 | 0.27 |
| Indian River | Main_1 | 2108 | Summer 100yr | Summer - 112 m | 92.90 | 115.66 | 118.96 | 117.16 | 119.07 | 0.000628 | 1.52 | 84.76 | 55.69 | 0.27 |
| Indian River | Main_1 | 2108 | Summer 100yr | Summer - 111.082m | 92.90 | 115.66 | 118.96 | 117.16 | 119.07 | 0.000628 | 1.52 | 84.76 | 55.69 | 0.27 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2068 | Winter 100yr | Winter - 113.621m | 181.90 | 115.70 | 120.20 | 117.89 | 120.32 | 0.000526 | 1.72 | 168.75 | 73.59 | 0.26 |
| Indian River | Main_1 | 2068 | Summer 100yr | Summer - 113.621m | 92.90 | 115.70 | 118.94 | 117.14 | 119.04 | 0.000586 | 1.45 | 84.14 | 60.70 | 0.26 |
| Indian River | Main_1 | 2068 | Summer 100yr | Summer - 112 m | 92.90 | 115.70 | 118.94 | 117.14 | 119.04 | 0.000586 | 1.45 | 84.14 | 60.70 | 0.26 |
| Indian River | Main_1 | 2068 | Summer 100yr | Summer - 111.082m | 92.90 | 115.70 | 118.94 | 117.14 | 119.04 | 0.000586 | 1.45 | 84.14 | 60.70 | 0.26 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2040 | Winter 100yr | Winter - 113.621m | 181.90 | 115.65 | 120.15 | 117.78 | 120.30 | 0.000589 | 1.81 | 144.03 | 64.49 | 0.28 |
| Indian River | Main_1 | 2040 | Summer 100yr | Summer - 113.621m | 92.90 | 115.65 | 118.93 | 117.05 | 119.02 | 0.000542 | 1.39 | 80.49 | 43.43 | 0.25 |
| Indian River | Main_1 | 2040 | Summer 100yr | Summer - 112 m | 92.90 | 115.65 | 118.93 | 117.05 | 119.02 | 0.000542 | 1.39 | 80.49 | 43.43 | 0.25 |
| Indian River | Main_1 | 2040 | Summer 100yr | Summer - 111.082m | 92.90 | 115.65 | 118.93 | 117.05 | 119.02 | 0.000542 | 1.39 | 80.49 | 43.43 | 0.25 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1966 | Winter 100yr | Winter - 113.621m | 181.90 | 115.66 | 120.03 | 118.15 | 120.24 | 0.000892 | 2.18 | 122.58 | 50.42 | 0.34 |
| Indian River | Main_1 | 1966 | Summer 100yr | Summer - 113.621m | 92.90 | 115.66 | 118.84 | 117.28 | 118.97 | 0.000830 | 1.68 | 70.41 | 33.09 | 0.31 |
| Indian River | Main_1 | 1966 | Summer 100yr | Summer - 112 m | 92.90 | 115.66 | 118.84 | 117.28 | 118.97 | 0.000830 | 1.68 | 70.41 | 33.09 | 0.31 |
| Indian River | Main_1 | 1966 | Summer 100yr | Summer - 111.082m | 92.90 | 115.66 | 118.84 | 117.28 | 118.97 | 0.000830 | 1.68 | 70.41 | 33.09 | 0.31 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1921 | Winter 100yr | Winter - 113.621m | 181.90 | 115.65 | 120.09 | 117.80 | 120.18 | 0.000389 | 1.47 | 183.61 | 80.76 | 0.22 |
| Indian River | Main_1 | 1921 | Summer 100yr | Summer - 113.621m | 92.90 | 115.65 | 118.83 | 117.05 | 118.93 | 0.000571 | 1.41 | 85.43 | 64.84 | 0.26 |
| Indian River | Main_1 | 1921 | Summer 100yr | Summer - 112 m | 92.90 | 115.65 | 118.83 | 117.05 | 118.93 | 0.000571 | 1.41 | 85.43 | 64.84 | 0.26 |
| Indian River | Main_1 | 1921 | Summer 100yr | Summer - 111.082m | 92.90 | 115.65 | 118.83 | 117.05 | 118.93 | 0.000571 | 1.41 | 85.43 | 64.84 | 0.26 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1888 | Winter 100yr | Winter - 113.621m | 181.90 | 115.59 | 120.03 | 117.69 | 120.16 | 0.000530 | 1.70 | 150.29 | 65.12 | 0.26 |

HEC-RAS Profile: Winter 100yr (Continued)

| River | Reach | River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| Indian River | Main_1 | 1888 | Summer 100yr | Summer - 113.621m | 92.90 | 115.59 | 118.82 | 116.99 | 118.91 | 0.000490 | 1.31 | 88.05 | 44.02 | 0.24 |
| Indian River | Main_1 | 1888 | Summer 100yr | Summer - 112 m | 92.90 | 115.59 | 118.82 | 116.99 | 118.91 | 0.000490 | 1.31 | 88.05 | 44.02 | 0.24 |
| Indian River | Main_1 | 1888 | Summer 100yr | Summer - 111.082m | 92.90 | 115.59 | 118.82 | 116.99 | 118.91 | 0.000490 | 1.31 | 88.05 | 44.02 | 0.24 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1868 | Winter 100yr | Winter - 113.621m | 181.90 | 114.90 | 119.87 | 117.52 | 120.13 | 0.000856 | 2.32 | 85.64 | 25.39 | 0.34 |
| Indian River | Main_1 | 1868 | Summer 100yr | Summer - 113.621m | 92.90 | 114.90 | 118.77 | 116.68 | 118.89 | 0.000547 | 1.56 | 64.78 | 23.73 | 0.26 |
| Indian River | Main_1 | 1868 | Summer 100yr | Summer - 112 m | 92.90 | 114.90 | 118.77 | 116.68 | 118.89 | 0.000547 | 1.56 | 64.78 | 23.73 | 0.26 |
| Indian River | Main_1 | 1868 | Summer 100yr | Summer - 111.082m | 92.90 | 114.90 | 118.77 | 116.68 | 118.89 | 0.000547 | 1.56 | 64.78 | 23.73 | 0.26 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1859 | | | Bridge | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1849 | Winter 100yr | Winter - 113.621m | 181.90 | 115.16 | 119.77 | 117.70 | 120.05 | 0.001013 | 2.39 | 81.18 | 26.41 | 0.37 |
| Indian River | Main_1 | 1849 | Summer 100yr | Summer - 113.621m | 92.90 | 115.16 | 118.73 | 116.89 | 118.86 | 0.000670 | 1.62 | 60.98 | 23.96 | 0.29 |
| Indian River | Main_1 | 1849 | Summer 100yr | Summer - 112 m | 92.90 | 115.16 | 118.73 | 116.89 | 118.86 | 0.000670 | 1.62 | 60.98 | 23.96 | 0.29 |
| Indian River | Main_1 | 1849 | Summer 100yr | Summer - 111.082m | 92.90 | 115.16 | 118.73 | 116.89 | 118.86 | 0.000670 | 1.62 | 60.98 | 23.96 | 0.29 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1829 | Winter 100yr | Winter - 113.621m | 181.90 | 114.48 | 119.85 | 117.08 | 119.94 | 0.000377 | 1.47 | 188.25 | 73.89 | 0.22 |
| Indian River | Main_1 | 1829 | Summer 100yr | Summer - 113.621m | 92.90 | 114.48 | 118.75 | 116.38 | 118.81 | 0.000305 | 1.11 | 114.01 | 61.82 | 0.19 |
| Indian River | Main_1 | 1829 | Summer 100yr | Summer - 112 m | 92.90 | 114.48 | 118.75 | 116.38 | 118.81 | 0.000305 | 1.11 | 114.01 | 61.82 | 0.19 |
| Indian River | Main_1 | 1829 | Summer 100yr | Summer - 111.082m | 92.90 | 114.48 | 118.75 | 116.38 | 118.81 | 0.000305 | 1.11 | 114.01 | 61.82 | 0.19 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1799 | Winter 100yr | Winter - 113.621m | 181.90 | 114.29 | 119.79 | | 119.93 | 0.000464 | 1.82 | 168.88 | 90.14 | 0.26 |
| Indian River | Main_1 | 1799 | Summer 100yr | Summer - 113.621m | 92.90 | 114.29 | 118.72 | | 118.80 | 0.000337 | 1.32 | 96.80 | 54.32 | 0.21 |
| Indian River | Main_1 | 1799 | Summer 100yr | Summer - 112 m | 92.90 | 114.29 | 118.72 | | 118.80 | 0.000337 | 1.32 | 96.80 | 54.32 | 0.21 |
| Indian River | Main_1 | 1799 | Summer 100yr | Summer - 111.082m | 92.90 | 114.29 | 118.72 | | 118.80 | 0.000337 | 1.32 | 96.80 | 54.32 | 0.21 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1748 | Winter 100yr | Winter - 113.621m | 181.90 | 114.63 | 119.84 | | 119.88 | 0.000165 | 1.04 | 206.75 | 110.42 | 0.15 |
| Indian River | Main_1 | 1748 | Summer 100yr | Summer - 113.621m | 92.90 | 114.63 | 118.72 | | 118.78 | 0.000243 | 1.06 | 103.75 | 64.09 | 0.18 |
| Indian River | Main_1 | 1748 | Summer 100yr | Summer - 112 m | 92.90 | 114.63 | 118.72 | | 118.78 | 0.000243 | 1.06 | 103.75 | 64.09 | 0.18 |
| Indian River | Main_1 | 1748 | Summer 100yr | Summer - 111.082m | 92.90 | 114.63 | 118.72 | | 118.78 | 0.000243 | 1.06 | 103.75 | 64.09 | 0.18 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1608 | Winter 100yr | Winter - 113.621m | 181.90 | 114.02 | 119.78 | 117.21 | 119.85 | 0.000333 | 1.48 | 205.20 | 116.40 | 0.21 |
| Indian River | Main_1 | 1608 | Summer 100yr | Summer - 113.621m | 92.90 | 114.02 | 118.61 | 116.34 | 118.72 | 0.000488 | 1.50 | 79.79 | 84.34 | 0.25 |
| Indian River | Main_1 | 1608 | Summer 100yr | Summer - 112 m | 92.90 | 114.02 | 118.61 | 116.34 | 118.72 | 0.000488 | 1.50 | 79.79 | 84.34 | 0.25 |
| Indian River | Main_1 | 1608 | Summer 100yr | Summer - 111.082m | 92.90 | 114.02 | 118.61 | 116.34 | 118.72 | 0.000488 | 1.50 | 79.79 | 84.34 | 0.25 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1516 | Winter 100yr | Winter - 113.621m | 181.90 | 115.21 | 119.76 | 117.43 | 119.82 | 0.000311 | 1.33 | 206.18 | 104.46 | 0.20 |
| Indian River | Main_1 | 1516 | Summer 100yr | Summer - 113.621m | 92.90 | 115.21 | 118.58 | 116.65 | 118.67 | 0.000497 | 1.37 | 87.41 | 90.83 | 0.24 |
| Indian River | Main_1 | 1516 | Summer 100yr | Summer - 112 m | 92.90 | 115.21 | 118.58 | 116.65 | 118.67 | 0.000497 | 1.37 | 87.41 | 90.83 | 0.24 |
| Indian River | Main_1 | 1516 | Summer 100yr | Summer - 111.082m | 92.90 | 115.21 | 118.58 | 116.65 | 118.67 | 0.000497 | 1.37 | 87.41 | 90.83 | 0.24 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1429 | Winter 100yr | Winter - 113.621m | 181.90 | 115.22 | 119.73 | 117.33 | 119.79 | 0.000291 | 1.29 | 270.79 | 143.39 | 0.20 |
| Indian River | Main_1 | 1429 | Summer 100yr | Summer - 113.621m | 92.90 | 115.22 | 118.54 | 116.60 | 118.63 | 0.000476 | 1.34 | 83.23 | 47.64 | 0.24 |
| Indian River | Main_1 | 1429 | Summer 100yr | Summer - 112 m | 92.90 | 115.22 | 118.54 | 116.60 | 118.63 | 0.000476 | 1.34 | 83.23 | 47.64 | 0.24 |
| Indian River | Main_1 | 1429 | Summer 100yr | Summer - 111.082m | 92.90 | 115.22 | 118.54 | 116.60 | 118.63 | 0.000476 | 1.34 | 83.23 | 47.64 | 0.24 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1313 | Winter 100yr | Winter - 113.621m | 181.90 | 114.10 | 119.72 | 116.77 | 119.75 | 0.000241 | 1.00 | 283.14 | 134.47 | 0.14 |
| Indian River | Main_1 | 1313 | Summer 100yr | Summer - 113.621m | 92.90 | 114.10 | 118.51 | 115.91 | 118.57 | 0.000439 | 1.14 | 120.48 | 112.70 | 0.18 |
| Indian River | Main_1 | 1313 | Summer 100yr | Summer - 112 m | 92.90 | 114.10 | 118.51 | 115.91 | 118.57 | 0.000439 | 1.14 | 120.48 | 112.70 | 0.18 |
| Indian River | Main_1 | 1313 | Summer 100yr | Summer - 111.082m | 92.90 | 114.10 | 118.51 | 115.91 | 118.57 | 0.000439 | 1.14 | 120.48 | 112.70 | 0.18 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1308 | | | Bridge | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1301 | Winter 100yr | Winter - 113.621m | 181.90 | 114.66 | 119.70 | 117.46 | 119.74 | 0.000161 | 0.92 | 284.36 | 140.99 | 0.13 |
| Indian River | Main_1 | 1301 | Summer 100yr | Summer - 113.621m | 92.90 | 114.66 | 118.49 | 116.58 | 118.55 | 0.000395 | 1.19 | 115.21 | 116.61 | 0.20 |
| Indian River | Main_1 | 1301 | Summer 100yr | Summer - 112 m | 92.90 | 114.66 | 118.49 | 116.58 | 118.55 | 0.000395 | 1.19 | 115.22 | 116.61 | 0.20 |
| Indian River | Main_1 | 1301 | Summer 100yr | Summer - 111.082m | 92.90 | 114.66 | 118.49 | 116.58 | 118.55 | 0.000395 | 1.19 | 115.22 | 116.61 | 0.20 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1220 | Winter 100yr | Winter - 113.621m | 181.90 | 115.04 | 119.63 | 117.08 | 119.70 | 0.000333 | 1.37 | 232.04 | 121.01 | 0.21 |
| Indian River | Main_1 | 1220 | Summer 100yr | Summer - 113.621m | 92.90 | 115.04 | 118.44 | 116.43 | 118.51 | 0.000370 | 1.17 | 101.16 | 59.79 | 0.21 |
| Indian River | Main_1 | 1220 | Summer 100yr | Summer - 112 m | 92.90 | 115.04 | 118.44 | 116.43 | 118.51 | 0.000370 | 1.17 | 101.16 | 59.79 | 0.21 |
| Indian River | Main_1 | 1220 | Summer 100yr | Summer - 111.082m | 92.90 | 115.04 | 118.44 | 116.43 | 118.51 | 0.000370 | 1.17 | 101.16 | 59.79 | 0.21 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 1125 | Winter 100yr | Winter - 113.621m | 181.90 | 115.08 | 119.59 | 117.23 | 119.67 | 0.000381 | 1.47 | 208.71 | 92.02 | 0.22 |
| Indian River | Main_1 | 1125 | Summer 100yr | Summer - 113.621m | 92.90 | 115.08 | 118.40 | 116.51 | 118.47 | 0.000439 | 1.27 | 106.15 | 79.16 | 0.23 |
| Indian River | Main_1 | 1125 | Summer 100yr | Summer - 112 m | 92.90 | 115.08 | 118.40 | 116.51 | 118.47 | 0.000439 | 1.27 | 106.15 | 79.16 | 0.23 |
| Indian River | Main_1 | 1125 | Summer 100yr | Summer - 111.082m | 92.90 | 115.08 | 118.40 | 116.51 | 118.47 | 0.000439 | 1.27 | 106.15 | 79.16 | 0.23 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 974 | Winter 100yr | Winter - 113.621m | 181.90 | 115.02 | 119.49 | 117.04 | 119.61 | 0.000472 | 1.62 | 144.15 | 50.96 | 0.25 |
| Indian River | Main_1 | 974 | Summer 100yr | Summer - 113.621m | 92.90 | 115.02 | 118.34 | 116.36 | 118.41 | 0.000401 | 1.22 | 89.54 | 43.42 | 0.22 |
| Indian River | Main_1 | 974 | Summer 100yr | Summer - 112 m | 92.90 | 115.02 | 118.34 | 116.36 | 118.41 | 0.000401 | 1.22 | 89.54 | 43.42 | 0.22 |
| Indian River | Main_1 | 974 | Summer 100yr | Summer - 111.082m | 92.90 | 115.02 | 118.34 | 116.36 | 118.41 | 0.000401 | 1.22 | 89.54 | 43.42 | 0.22 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 888 | Winter 100yr | Winter - 113.621m | 181.90 | 113.98 | 119.39 | | 119.56 | 0.000566 | 1.87 | 126.07 | 40.10 | 0.27 |
| Indian River | Main_1 | 888 | Summer 100yr | Summer - 113.621m | 92.90 | 113.98 | 118.29 | | 118.38 | 0.000375 | 1.28 | 84.63 | 35.15 | 0.21 |
| Indian River | Main_1 | 888 | Summer 100yr | Summer - 112 m | 92.90 | 113.98 | 118.29 | | 118.38 | 0.000375 | 1.28 | 84.63 | 35.15 | 0.21 |
| Indian River | Main_1 | 888 | Summer 100yr | Summer - 111.082m | 92.90 | 113.98 | 118.29 | | 118.38 | 0.000375 | 1.28 | 84.63 | 35.15 | 0.21 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 829 | Winter 100yr | Winter - 113.621m | 181.90 | 115.08 | 119.33 | 117.19 | 119.52 | 0.000750 | 1.98 | 118.70 | 43.77 | 0.31 |
| Indian River | Main_1 | 829 | Summer 100yr | Summer - 113.621m | 92.90 | 115.08 | 118.24 | 116.47 | 118.35 | 0.000593 | 1.44 | 73.65 | 37.69 | 0.26 |
| Indian River | Main_1 | 829 | Summer 100yr | Summer - 112 m | 92.90 | 115.08 | 118.24 | 116.47 | 118.35 | 0.000593 | 1.44 | 73.65 | 37.69 | 0.26 |
| Indian River | Main_1 | 829 | Summer 100yr | Summer - 111.082m | 92.90 | 115.08 | 118.24 | 116.47 | 118.35 | 0.000593 | 1.44 | 73.65 | 37.69 | 0.26 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 671 | Winter 100yr | Winter - 113.621m | 181.90 | 115.01 | 119.24 | 117.10 | 119.40 | 0.000674 | 1.86 | 142.24 | 60.54 | 0.29 |
| Indian River | Main_1 | 671 | Summer 100yr | Summer - 113.621m | 92.90 | 115.01 | 118.16 | 116.40 | 118.25 | 0.000565 | 1.39 | 83.11 | 50.05 | 0.26 |
| Indian River | Main_1 | 671 | Summer 100yr | Summer - 112 m | 92.90 | 115.01 | 118.16 | 116.40 | 118.25 | 0.000565 | 1.39 | 83.11 | 50.05 | 0.26 |
| Indian River | Main_1 | 671 | Summer 100yr | Summer - 111.082m | 92.90 | 115.01 | 118.16 | 116.40 | 118.25 | 0.000565 | 1.39 | 83.11 | 50.05 | 0.26 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 532 | Winter 100yr | Winter - 113.621m | 181.90 | 115.05 | 119.09 | | 119.29 | 0.000837 | 2.02 | 111.40 | 41.36 | 0.32 |
| Indian River | Main_1 | 532 | Summer 100yr | Summer - 113.621m | 92.90 | 115.05 | 118.07 | | 118.17 | 0.000634 | 1.44 | 72.91 | 34.50 | 0.27 |
| Indian River | Main_1 | 532 | Summer 100yr | Summer - 112 m | 92.90 | 115.05 | 118.07 | | 118.17 | 0.000634 | 1.44 | 72.91 | 34.50 | 0.27 |
| Indian River | Main_1 | 532 | Summer 100yr | Summer - 111.082m | 92.90 | 115.05 | 118.07 | | 118.17 | 0.000634 | 1.44 | 72.91 | 34.50 | 0.27 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 368 | Winter 100yr | Winter - 113.621m | 181.90 | 115.08 | 118.94 | 117.07 | 119.15 | 0.000917 | 2.06 | 106.24 | 38.55 | 0.34 |
| Indian River | Main_1 | 368 | Summer 100yr | Summer - 113.621m | 92.90 | 115.08 | 117.95 | 116.38 | 118.06 | 0.000700 | 1.47 | 70.05 | 34.33 | 0.28 |
| Indian River | Main_1 | 368 | Summer 100yr | Summer - 112 m | 92.90 | 115.08 | 117.95 | 116.38 | 118.06 | 0.000700 | 1.47 | 70.05 | 34.33 | 0.28 |
| Indian River | Main_1 | 368 | Summer 100yr | Summer - 111.082m | 92.90 | 115.08 | 117.95 | 116.38 | 118.06 | 0.000700 | 1.47 | 70.05 | 34.33 | 0.28 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 274 | Winter 100yr | Winter - 113.621m | 181.90 | 115.08 | 118.82 | | 119.05 | 0.001139 | 2.23 | 119.14 | 67.96 | 0.38 |
| Indian River | Main_1 | 274 | Summer 100yr | Summer - 113.621m | 92.90 | 115.08 | 117.84 | | 117.98 | 0.000978 | 1.67 | 65.55 | 42.79 | 0.33 |
| Indian River | Main_1 | 274 | Summer 100yr | Summer - 112 m | 92.90 | 115.08 | 117.84 | | 117.98 | 0.000978 | 1.67 | 65.55 | 42.79 | 0.33 |

HEC-RAS Profile: Winter 100yr (Continued)

| River | Reach | River Sta | Profile | Plan | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | (m3/s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m2) | (m) | |
| Indian River | Main_1 | 274 | Summer 100yr | Summer - 111.082m | 92.90 | 115.08 | 117.84 | | 117.98 | 0.000978 | 1.67 | 65.55 | 42.79 | 0.33 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 217 | Winter 100yr | Winter - 113.621m | 181.90 | 115.07 | 118.79 | | 118.98 | 0.000949 | 2.04 | 142.15 | 75.64 | 0.34 |
| Indian River | Main_1 | 217 | Summer 100yr | Summer - 113.621m | 92.90 | 115.07 | 117.79 | | 117.92 | 0.000909 | 1.61 | 70.53 | 54.75 | 0.32 |
| Indian River | Main_1 | 217 | Summer 100yr | Summer - 112 m | 92.90 | 115.07 | 117.79 | | 117.92 | 0.000909 | 1.61 | 70.54 | 54.75 | 0.32 |
| Indian River | Main_1 | 217 | Summer 100yr | Summer - 111.082m | 92.90 | 115.07 | 117.79 | | 117.92 | 0.000909 | 1.61 | 70.54 | 54.75 | 0.32 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 157 | Winter 100yr | Winter - 113.621m | 181.90 | 115.06 | 118.74 | | 118.92 | 0.001002 | 2.07 | 150.64 | 84.77 | 0.35 |
| Indian River | Main_1 | 157 | Summer 100yr | Summer - 113.621m | 92.90 | 115.06 | 117.71 | | 117.86 | 0.001097 | 1.73 | 69.24 | 71.18 | 0.35 |
| Indian River | Main_1 | 157 | Summer 100yr | Summer - 112 m | 92.90 | 115.06 | 117.71 | | 117.86 | 0.001097 | 1.73 | 69.24 | 71.18 | 0.35 |
| Indian River | Main_1 | 157 | Summer 100yr | Summer - 111.082m | 92.90 | 115.06 | 117.71 | | 117.86 | 0.001097 | 1.73 | 69.24 | 71.18 | 0.35 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 64 | Winter 100yr | Winter - 113.621m | 181.90 | 115.05 | 118.61 | | 118.82 | 0.001136 | 2.17 | 122.92 | 58.65 | 0.37 |
| Indian River | Main_1 | 64 | Summer 100yr | Summer - 113.621m | 92.90 | 115.05 | 117.61 | | 117.76 | 0.001108 | 1.71 | 66.39 | 53.34 | 0.35 |
| Indian River | Main_1 | 64 | Summer 100yr | Summer - 112 m | 92.90 | 115.05 | 117.61 | | 117.76 | 0.001108 | 1.71 | 66.39 | 53.34 | 0.35 |
| Indian River | Main_1 | 64 | Summer 100yr | Summer - 111.082m | 92.90 | 115.05 | 117.61 | | 117.76 | 0.001108 | 1.71 | 66.39 | 53.34 | 0.35 |
| | | | | | | | | | | | | | | |
| Indian River | Main_1 | 2 | Winter 100yr | Winter - 113.621m | 181.90 | 114.32 | 118.42 | | 118.73 | 0.001447 | 2.61 | 94.41 | 38.44 | 0.43 |
| Indian River | Main_1 | 2 | Summer 100yr | Summer - 113.621m | 92.90 | 114.32 | 117.53 | | 117.69 | 0.001012 | 1.82 | 61.65 | 34.57 | 0.34 |
| Indian River | Main_1 | 2 | Summer 100yr | Summer - 112 m | 92.90 | 114.32 | 117.53 | | 117.69 | 0.001012 | 1.82 | 61.65 | 34.58 | 0.34 |
| Indian River | Main_1 | 2 | Summer 100yr | Summer - 111.082m | 92.90 | 114.32 | 117.53 | | 117.69 | 0.001012 | 1.82 | 61.65 | 34.58 | 0.34 |

# APPENDIX F

## PCSWMM Model Parameters and Design Storm Parameters

### Table F.1: Subcatchment Information of Amalgamated Model

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| A_001 | 0.8099 | 90 | 89.989 | 4.403 | 69.212 | 127 | 120 |
| A_002 | 0.3734 | 40 | 93.35 | 4.699 | 75.815 | 127 | 120 |
| A_003 | 0.1224 | 40 | 30.6 | 6.028 | 75.143 | 127 | 120 |
| A_004 | 0.4767 | 70 | 68.1 | 7.661 | 68.476 | 127 | 119.75 |
| A_005 | 0.2591 | 35 | 74.029 | 4.945 | 68.768 | 125 | 97.31 |
| A_006 | 0.2803 | 40 | 70.075 | 3.975 | 69.114 | 122 | 72.52 |
| A_007 | 0.1821 | 30 | 60.7 | 4.383 | 71.451 | 120 | 55.55 |
| A_008 | 3.5933 | 140 | 256.664 | 5.094 | 43.536 | 126 | 117.07 |
| A_011 | 0.9121 | 60 | 152.017 | 4.617 | 73.92 | 124 | 90.77 |
| A_012 | 0.0558 | 8 | 69.75 | 6.209 | 71.11 | 120 | 55 |
| A_013 | 0.5451 | 40 | 136.275 | 4.478 | 74.644 | 120 | 55 |
| A_014 | 0.3111 | 30 | 103.7 | 4.728 | 73.441 | 120 | 55 |
| A_015 | 0.9438 | 70 | 134.829 | 5.576 | 71.409 | 131 | 37.38 |
| A_016 | 0.3602 | 50 | 72.04 | 6.657 | 73.115 | 150 | 7.5 |
| A_017 | 0.0096 | 5 | 19.2 | 3.292 | 80.444 | 150 | 7.5 |
| A_018 | 0.3674 | 40 | 91.85 | 5.772 | 67.51 | 130 | 36.87 |
| A_019 | 0.0092 | 5 | 18.4 | 2.543 | 85.169 | 120 | 55 |
| A_020 | 0.6947 | 70 | 99.243 | 3.895 | 3.73 | 127 | 120 |
| A_021 | 0.0104 | 5 | 20.8 | 4.658 | 80.863 | 127 | 120 |
| A_022 | 0.3707 | 80 | 46.337 | 3.38 | 30.555 | 127 | 120 |
| A_023 | 0.0214 | 8 | 26.75 | 2.109 | 81.682 | 127 | 120 |
| A_024 | 0.4184 | 60 | 69.733 | 4.203 | 76.082 | 127 | 120 |
| A_025 | 0.0294 | 8 | 36.75 | 3.804 | 80.128 | 127 | 120 |
| A_026 | 0.1536 | 20 | 76.8 | 5.545 | 73.442 | 127 | 120 |
| A_027 | 0.5417 | 60 | 90.283 | 4.888 | 70.767 | 127 | 116.43 |
| A_028 | 0.2942 | 30 | 98.067 | 5.711 | 72.944 | 121 | 63.79 |
| A_029 | 0.2398 | 30 | 79.933 | 5.397 | 70.922 | 120 | 55.05 |
| A_030 | 0.0109 | 5 | 21.8 | 3.797 | 78.312 | 120 | 55 |
| A_031 | 0.0094 | 7 | 13.429 | 1.749 | 90.143 | 120 | 55 |
| A_032 | 0.7203 | 55 | 130.964 | 5.481 | 73.187 | 121 | 65.53 |
| A_033 | 0.2086 | 20 | 104.3 | 6.06 | 68.788 | 126 | 105.54 |
| A_034 | 0.5554 | 80 | 69.425 | 5.219 | 67.628 | 127 | 120 |
| A_035 | 0.3082 | 25 | 123.28 | 3.883 | 70.744 | 127 | 119.16 |
| A_036 | 0.1371 | 20 | 68.55 | 3.791 | 73.415 | 121 | 66.98 |
| A_037 | 0.7359 | 60 | 122.65 | 4.037 | 70.892 | 120 | 55.36 |

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| A_038 | 0.9934 | 80 | 124.175 | 4.197 | 58.824 | 120 | 56.94 |
| A_039 | 1.8753 | 90 | 208.367 | 5.512 | 71.019 | 124 | 89.06 |
| A_040 | 0.0095 | 8 | 11.875 | 3.19 | 90.493 | 120 | 55 |
| A_041 | 0.3145 | 40 | 78.625 | 4.665 | 72.334 | 120 | 55 |
| A_042 | 1.7183 | 200 | 85.915 | 5.906 | 71.863 | 120 | 55 |
| A_043 | 1.7626 | 60 | 293.767 | 4.705 | 32.745 | 123 | 82.14 |
| A_044 | 0.6551 | 70 | 93.586 | 7.412 | 69.827 | 120 | 55 |
| A_045 | 1.1887 | 60 | 198.117 | 6.594 | 54.18 | 122 | 69.84 |
| A_046 | 0.948 | 60 | 158 | 7.099 | 71.708 | 124 | 89.92 |
| A_047 | 0.2275 | 20 | 113.75 | 5.105 | 70.499 | 120 | 55.37 |
| A_048 | 0.905 | 60 | 150.833 | 7.504 | 64.08 | 124 | 91.95 |
| A_049 | 0.5998 | 40 | 149.95 | 7.248 | 62.367 | 125 | 104.33 |
| A_050 | 0.1462 | 20 | 73.1 | 9.155 | 68.39 | 123 | 84.71 |
| A_051 | 0.0076 | 8 | 9.5 | 5.509 | 80.457 | 120 | 61.28 |
| A_052 | 1.2377 | 50 | 247.54 | 5.573 | 70.344 | 125 | 101.47 |
| A_053 | 0.4944 | 50 | 98.88 | 3.533 | 81.432 | 120 | 55 |
| A_054 | 0.424 | 50 | 84.8 | 3.839 | 79.7 | 120 | 55 |
| A_055 | 1.7536 | 180 | 97.422 | 6.867 | 68.24 | 127 | 116.88 |
| A_056 | 0.0287 | 8 | 35.875 | 4.303 | 75.821 | 120 | 55 |
| A_057 | 0.3099 | 30 | 103.3 | 5.061 | 79.742 | 121 | 59.56 |
| A_058 | 0.3662 | 30 | 122.067 | 3.983 | 79.983 | 122 | 73.73 |
| A_059 | 0.2457 | 25 | 98.28 | 5.664 | 81.545 | 123 | 81 |
| A_060 | 0.4817 | 50 | 96.34 | 5.242 | 78.038 | 127 | 119.84 |
| A_061 | 0.3775 | 50 | 75.5 | 6.283 | 71.825 | 127 | 120 |
| A_062 | 0.4576 | 50 | 91.52 | 6.405 | 72.01 | 127 | 120 |
| A_063 | 0.4936 | 60 | 82.267 | 7.711 | 73.593 | 126 | 114.87 |
| A_064 | 0.3522 | 40 | 88.05 | 8.392 | 78.199 | 120 | 55 |
| A_065 | 2.1559 | 90 | 239.544 | 7 | 63.168 | 120 | 55 |
| A_066 | 0.053 | 10 | 53 | 7.854 | 69.543 | 120 | 55 |
| A_067 | 0.8771 | 110 | 79.736 | 7.565 | 81.719 | 127 | 114.84 |
| A_068 | 0.5429 | 70 | 77.557 | 6.714 | 80.249 | 127 | 120 |
| A_069 | 0.2622 | 35 | 74.914 | 5.906 | 81.082 | 127 | 120 |
| A_070 | 0.1052 | 20 | 52.6 | 6.718 | 82.025 | 127 | 120 |
| A_071 | 1.9256 | 90 | 213.956 | 8.203 | 72.076 | 126 | 107.26 |
| A_072 | 1.5051 | 80 | 188.138 | 9.349 | 72.259 | 129 | 53.93 |
| A_073 | 0.3587 | 40 | 89.675 | 5.344 | 79.558 | 136 | 29.43 |
| A_074 | 0.0458 | 10 | 45.8 | 4.054 | 79.376 | 123 | 48.51 |
| A_075 | 0.4291 | 90 | 47.678 | 5.993 | 73.339 | 145 | 13.76 |
| A_076 | 0.27 | 60 | 45 | 3.991 | 74.633 | 150 | 7.5 |
| A_077 | 3.8693 | 120 | 322.442 | 4.068 | 66.339 | 145 | 5.75 |
| A_078 | 0.0502 | 10 | 50.2 | 3.243 | 73.728 | 150 | 7.5 |
| A_079 | 0.0201 | 5 | 40.2 | 2.198 | 81.7 | 150 | 7.5 |

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| A_080 | 0.0354 | 8 | 44.25 | 2.397 | 83.114 | 150 | 7.5 |
| A_081 | 0.243 | 40 | 60.75 | 5.863 | 80.68 | 150 | 7.5 |
| A_082 | 1.2666 | 100 | 126.66 | 5.88 | 41.924 | 150 | 7.5 |
| A_083 | 0.2407 | 30 | 80.233 | 3.957 | 66.155 | 150 | 7.5 |
| A_084 | 0.0264 | 7 | 37.714 | 4.371 | 72.68 | 150 | 7.5 |
| A_085 | 3.4079 | 120 | 283.992 | 4.884 | 40.907 | 150 | 7.5 |
| A_086 | 0.2642 | 30 | 88.067 | 6.851 | 64.904 | 150 | 7.5 |
| A_087 | 1.3673 | 80 | 170.912 | 6.012 | 52.643 | 150 | 7.5 |
| A_088 | 0.0655 | 20 | 32.75 | 5.778 | 78.803 | 150 | 7.5 |
| A_089 | 0.6369 | 60 | 106.15 | 5.059 | 71.936 | 150 | 7.5 |
| A_090 | 0.4573 | 70 | 65.329 | 5.735 | 68.372 | 146 | 10.91 |
| A_091 | 0.6787 | 60 | 113.117 | 6 | 72.995 | 133 | 33.68 |
| A_092 | 1.743 | 110 | 158.455 | 5.396 | 74.26 | 149 | 6.28 |
| A_093 | 0.4918 | 60 | 81.967 | 4.721 | 70.367 | 150 | 7.5 |
| A_094 | 0.9006 | 100 | 90.06 | 7.991 | 69.161 | 140 | 21.95 |
| A_095 | 0.2148 | 40 | 53.7 | 6.587 | 70.867 | 150 | 7.5 |
| A_096 | 0.4094 | 40 | 102.35 | 7.33 | 70.967 | 150 | 7.5 |
| A_097 | 0.4322 | 50 | 86.44 | 6.776 | 70.098 | 150 | 7.5 |
| A_098 | 0.266 | 50 | 53.2 | 5.008 | 73.217 | 150 | 7.5 |
| A_099 | 0.8825 | 100 | 88.25 | 6.898 | 48.131 | 150 | 7.5 |
| A_100 | 0.5359 | 60 | 89.317 | 4.4 | 67.686 | 150 | 7.5 |
| A_101 | 0.0978 | 15 | 65.2 | 3.893 | 64.33 | 150 | 7.5 |
| A_102 | 0.3095 | 30 | 103.167 | 6.853 | 67.846 | 150 | 7.5 |
| A_103 | 0.059 | 15 | 39.333 | 3.738 | 67.739 | 150 | 7.5 |
| A_104 | 0.2502 | 40 | 62.55 | 3.58 | 70.182 | 150 | 7.5 |
| A_105 | 0.5688 | 120 | 47.4 | 3.946 | 74.698 | 150 | 7.5 |
| A_106 | 0.2588 | 30 | 86.267 | 3.779 | 78.85 | 150 | 7.5 |
| A_107 | 1.438 | 120 | 119.833 | 3.377 | 74.473 | 150 | 7.5 |
| A_108 | 1.5897 | 120 | 132.475 | 3.784 | 70.396 | 150 | 7.5 |
| A_109 | 0.9205 | 65 | 141.615 | 4.48 | 70.156 | 150 | 7.5 |
| A_110 | 0.2907 | 25 | 116.28 | 9.168 | 81.104 | 150 | 7.5 |
| A_111 | 0.2985 | 30 | 99.5 | 6.17 | 76.428 | 150 | 7.5 |
| A_112 | 0.081 | 8 | 101.25 | 5.783 | 78.705 | 150 | 7.5 |
| A_113 | 0.0128 | 7 | 18.286 | 2.161 | 85.332 | 150 | 7.5 |
| A_114 | 0.0469 | 12 | 39.083 | 3.95 | 78.308 | 150 | 7.5 |
| A_115 | 0.2115 | 40 | 52.875 | 8.609 | 77.733 | 150 | 7.5 |
| A_116 | 0.0838 | 20 | 41.9 | 9.192 | 72.323 | 150 | 7.5 |
| A_117 | 0.0445 | 20 | 22.25 | 15 | 59.973 | 150 | 7.5 |
| A_118 | 0.2517 | 60 | 41.95 | 13.286 | 60.519 | 150 | 7.5 |
| A_119 | 0.183 | 45 | 40.667 | 11.637 | 59.984 | 150 | 7.5 |

**Table F.2: Subcatchment Information for the Darcy Model**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| D_01 | 0.7208 | 90 | 80.089 | 5 | 69.809 | 150 | 5 |
| D_02 | 0.0015 | 2 | 7.5 | 3.536 | 94.287 | 150 | 5 |
| D_03 | 0.5365 | 60 | 89.417 | 5 | 69.971 | 150 | 5 |
| D_04 | 0.9031 | 70 | 129.014 | 5 | 68.181 | 123 | 3.76 |
| D_05 | 0.0041 | 5 | 8.2 | 4.018 | 86.194 | 150 | 5 |
| D_06 | 0.004 | 4 | 10 | 1.709 | 92.95 | 150 | 5 |
| D_07 | 0.3142 | 50 | 62.84 | 5 | 65.967 | 135 | 4.31 |
| D_08 | 0.293 | 50 | 58.6 | 4.056 | 73.434 | 77 | 1.7 |
| D_09 | 0.0094 | 4 | 23.5 | 5.331 | 75.804 | 50 | 0.51 |
| D_10 | 0.1013 | 30 | 33.767 | 5.015 | 63.86 | 50 | 0.51 |

**Table F.3: Subcatchment Information for the Lake Street Area Model**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| L_01 | 1.9858 | 120 | 165.483 | 3.353 | 71.044 | 50 | 0.51 |
| L_02 | 0.3315 | 30 | 110.5 | 3.614 | 72.398 | 50 | 0.51 |
| L_03 | 0.00005 | 0.5 | 0.98 | 2.771 | 81.686 | 50 | 0.51 |
| L_04 | 0.1958 | 20 | 97.9 | 3.322 | 66.219 | 50 | 0.51 |
| L_05 | 0.0845 | 10 | 84.5 | 3.411 | 68.503 | 50 | 0.51 |
| L_06 | 0.0205 | 5 | 41 | 2.54 | 81.397 | 50 | 0.51 |
| L_07 | 0.3804 | 50 | 76.08 | 5.417 | 73.082 | 50 | 0.51 |
| L_08 | 0.3577 | 40 | 89.425 | 4.357 | 74.302 | 50 | 0.51 |
| L_09 | 0.4464 | 50 | 89.28 | 2.652 | 73.715 | 50 | 0.51 |
| L_10 | 0.0005 | 2 | 2.5 | 1.534 | 93.074 | 50 | 0.51 |
| L_11 | 0.0675 | 15 | 45 | 5.083 | 62.233 | 50 | 0.51 |
| L_12 | 0.0858 | 30 | 28.6 | 3.118 | 75.306 | 50 | 0.51 |
| L_13 | 0.0697 | 15 | 46.467 | 3.563 | 68.19 | 50 | 0.51 |
| L_14 | 0.0317 | 8 | 39.625 | 4.519 | 68.237 | 50 | 0.51 |
| L_15 | 0.0621 | 18 | 34.5 | 4.835 | 69.855 | 50 | 0.51 |
| L_16 | 0.0217 | 8 | 27.125 | 2.59 | 76.431 | 50 | 0.51 |
| L_17 | 0.6703 | 80 | 83.788 | 3.162 | 78.271 | 50 | 0.51 |
| L_18 | 0.0108 | 7 | 15.429 | 1.475 | 94.774 | 50 | 0.51 |
| L_19 | 0.2848 | 60 | 47.467 | 3.065 | 76.243 | 50 | 0.51 |
| L_20 | 0.598 | 50 | 119.6 | 3.434 | 81.283 | 50 | 0.51 |
| L_21 | 0.3804 | 50 | 76.08 | 4.193 | 88.33 | 50 | 0.51 |
| L_22 | 0.0076 | 5 | 15.2 | 2.033 | 92.295 | 50 | 0.51 |
| L_23 | 2.3039 | 90 | 255.989 | 8 | 69.861 | 50 | 0.51 |
| L_24 | 4.2446 | 150 | 282.973 | 3.685 | 42.354 | 50 | 0.51 |
| L_25 | 0.2984 | 40 | 74.6 | 2.961 | 78.897 | 50 | 0.51 |
| L_26 | 0.4818 | 40 | 120.45 | 3.907 | 77.793 | 50 | 0.51 |

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| L_27 | 0.1233 | 30 | 41.1 | 3.982 | 80.087 | 50 | 0.51 |
| L_28 | 0.1687 | 25 | 67.48 | 5.4 | 70.649 | 50 | 0.51 |
| L_29 | 0.2879 | 40 | 71.975 | 8 | 69.646 | 50 | 0.51 |
| L_30 | 0.2474 | 40 | 61.85 | 5.074 | 66.003 | 50 | 0.51 |
| L_31 | 0.5998 | 60 | 99.967 | 2.006 | 59.992 | 50 | 0.51 |
| L_32 | 0.2566 | 40 | 64.15 | 5.442 | 67.983 | 50 | 0.51 |
| L_33 | 0.5735 | 50 | 114.7 | 5.593 | 77.479 | 50 | 0.51 |
| L_34 | 0.465 | 60 | 77.5 | 5.722 | 81.67 | 50 | 0.51 |
| L_35 | 0.3176 | 35 | 90.743 | 6 | 76.016 | 50 | 0.51 |

**Table F.4: Subcatchment Information for the Trafalgar Model**

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| T_01 | 1.5233 | 120 | 126.942 | 4.929 | 70.986 | 150 | 5 |
| T_02 | 0.2192 | 40 | 54.8 | 4.949 | 74.549 | 150 | 5 |
| T_03 | 0.0166 | 8 | 20.75 | 5.654 | 80.33 | 150 | 5 |
| T_04 | 0.5603 | 80 | 70.038 | 7.19 | 70.503 | 150 | 5 |
| T_05 | 0.0231 | 8 | 28.875 | 4.38 | 80.476 | 150 | 5 |
| T_06 | 0.8884 | 60 | 148.067 | 4.952 | 69.818 | 96 | 2.57 |
| T_07 | 0.9211 | 60 | 153.517 | 5.971 | 69.896 | 95 | 2.56 |
| T_08 | 0.0104 | 4 | 26 | 3.83 | 79.372 | 50 | 0.51 |
| T_09 | 0.0189 | 8 | 23.625 | 2.928 | 90.193 | 50 | 0.51 |
| T_10 | 1.2501 | 70 | 178.586 | 7.107 | 68.44 | 143 | 16.01 |
| T_11 | 0.0173 | 5 | 34.6 | 6 | 80.624 | 150 | 5 |
| T_12 | 0.4351 | 70 | 62.157 | 5.452 | 72.603 | 113 | 3.34 |
| T_13 | 0.691 | 70 | 98.714 | 4.347 | 69.079 | 55 | 0.73 |
| T_14 | 1.22 | 80 | 152.5 | 3.873 | 71.681 | 150 | 5 |
| T_15 | 0.4719 | 45 | 104.867 | 6.204 | 69.244 | 150 | 5 |
| T_16 | 0.5204 | 60 | 86.733 | 7.135 | 70.686 | 150 | 5 |
| T_17 | 0.562 | 60 | 93.667 | 8.289 | 70.257 | 148 | 4.91 |
| T_18 | 0.6727 | 60 | 112.117 | 3.402 | 69.146 | 50 | 0.51 |
| T_19 | 1.0056 | 100 | 100.56 | 3.311 | 72.022 | 50 | 0.51 |
| T_20 | 0.9058 | 90 | 100.644 | 4.289 | 67.116 | 50 | 0.51 |
| T_21 | 0.0678 | 30 | 22.6 | 4.263 | 82.624 | 50 | 0.51 |
| T_22 | 0.244 | 35 | 69.714 | 4.293 | 68.691 | 50 | 0.51 |
| T_23 | 0.0348 | 10 | 34.8 | 6.588 | 69.308 | 50 | 0.51 |
| T_24 | 0.4243 | 60 | 70.717 | 4.009 | 70.641 | 50 | 0.51 |
| T_25 | 0.2928 | 35 | 83.657 | 3.304 | 69.181 | 50 | 0.51 |
| T_26 | 0.2236 | 25 | 89.44 | 2.202 | 71.862 | 50 | 0.51 |
| T_27 | 0.3748 | 50 | 74.96 | 2.984 | 72.165 | 50 | 0.51 |
| T_28 | 0.2026 | 20 | 101.3 | 6.741 | 75.032 | 50 | 0.51 |

| Name | Area (ha) | Width (m) | Flow Length (m) | Slope (%) | Imperv. (%) | Max. Infil. Rate (mm/hr) | Min. Infil. Rate (mm/hr) |
|---|---|---|---|---|---|---|---|
| T_29 | 0.1821 | 15 | 121.4 | 3.517 | 75.426 | 50 | 0.51 |
| T_30 | 0.2933 | 45 | 65.178 | 4.149 | 75.421 | 50 | 0.51 |
| T_31 | 0.046 | 7 | 65.714 | 5.136 | 75.235 | 50 | 0.51 |
| T_32 | 0.3931 | 50 | 78.62 | 5.001 | 73.346 | 50 | 0.51 |
| T_33 | 0.1996 | 40 | 49.9 | 4.698 | 75.551 | 50 | 0.51 |
| T_34 | 0.3327 | 20 | 166.35 | 5.6 | 74.845 | 50 | 0.51 |
| T_35 | 0.5374 | 40 | 134.35 | 5.721 | 67.351 | 50 | 0.51 |
| T_36 | 0.2044 | 40 | 51.1 | 5.503 | 83.446 | 50 | 0.51 |
| T_37 | 0.1927 | 35 | 55.057 | 4.813 | 77.088 | 50 | 0.51 |
| T_38 | 0.1353 | 20 | 67.65 | 4.973 | 78.645 | 50 | 0.51 |
| T_39 | 1.7895 | 80 | 223.688 | 4.699 | 72.784 | 50 | 0.51 |
| T_40 | 0.0808 | 15 | 53.867 | 6.074 | 76.452 | 50 | 0.51 |
| T_41 | 0.0224 | 10 | 22.4 | 6.856 | 70.721 | 50 | 0.51 |
| T_42 | 0.105 | 50 | 21 | 8 | 75.657 | 50 | 0.51 |
| T_43 | 3.8802 | 80 | 485.025 | 7.827 | 74.717 | 50 | 0.51 |
| T_44 | 0.0239 | 10 | 23.9 | 6.233 | 74.614 | 50 | 0.51 |
| T_45 | 0.0559 | 40 | 13.975 | 5 | 86.347 | 50 | 0.51 |
| T_46 | 1.1491 | 60 | 191.517 | 2.219 | 75.237 | 53 | 0.63 |
| T_47 | 0.0081 | 5 | 16.2 | 2.52 | 84.324 | 50 | 0.51 |
| T_48 | 2.6441 | 120 | 220.342 | 2.972 | 85.647 | 50 | 0.51 |
| T_49 | 0.0499 | 40 | 12.475 | 4.834 | 87.974 | 50 | 0.51 |
| T_50 | 0.0422 | 30 | 14.067 | 4.611 | 88.82 | 50 | 0.51 |
| T_51 | 0.0331 | 20 | 16.55 | 5 | 82.386 | 50 | 0.51 |
| T_52 | 0.5291 | 50 | 105.82 | 4.369 | 64.313 | 50 | 0.51 |
| T_53 | 0.5212 | 70 | 74.457 | 2.987 | 72.009 | 50 | 0.51 |
| T_54 | 0.0685 | 10 | 68.5 | 2.475 | 77.835 | 50 | 0.51 |
| T_55 | 0.6208 | 60 | 103.467 | 8.18 | 77.797 | 50 | 0.51 |
| T_56 | 1.9492 | 120 | 162.433 | 4.929 | 73.691 | 50 | 0.51 |
| T_57 | 0.2537 | 25 | 101.48 | 3.547 | 70.838 | 50 | 0.51 |
| T_58 | 0.5225 | 100 | 52.25 | 4.242 | 73.572 | 50 | 0.51 |
| T_59 | 0.4609 | 120 | 38.408 | 8 | 76.255 | 50 | 0.51 |
| T_60 | 0.0871 | 30 | 29.033 | 7.327 | 79.535 | 50 | 0.51 |
| T_61 | 1.145 | 60 | 190.833 | 5.619 | 76.232 | 50 | 0.51 |
| T_62 | 0.211 | 65 | 32.462 | 10 | 74.994 | 50 | 0.51 |
| T_63 | 0.1659 | 55 | 30.164 | 10 | 74.978 | 50 | 0.51 |
| T_64 | 0.2954 | 20 | 147.7 | 3.41 | 86.103 | 50 | 0.51 |
| T_65 | 0.1419 | 80 | 17.738 | 3.11 | 75.014 | 50 | 0.51 |
| T_66 | 1.145 | 150 | 76.333 | 4.732 | 79.392 | 50 | 0.51 |
| T_67 | 0.0531 | 30 | 17.7 | 8.496 | 74.921 | 50 | 0.51 |
| T_68 | 0.0001 | 0.5 | 2 | 3.417 | 84.329 | 61 | 1 |

**Table F.5: Sewer Pipe Information for the Amalgamated Model**

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 18_0001 | 45.887 | 0.013 | 111.033 | 110.494 | 0.9 |
| 18_0002 | 63.155 | 0.013 | 111.557 | 111.033 | 0.9 |
| 18_0003 | 23.29 | 0.013 | 112.807 | 111.557 | 0.9 |
| 18_0004 | 20.248 | 0.013 | 114.074 | 112.807 | 0.9 |
| 18_005 | 64.174 | 0.013 | 117.454 | 114.074 | 0.9 |
| 18_008 | 68.906 | 0.013 | 118.355 | 117.966 | 1.5 |
| 18_012 | 13.264 | 0.013 | 119.679 | 117.671 | 0.525 |
| 18_014 | 8.35 | 0.013 | 119.907 | 119.818 | 0.525 |
| 18_016 | 32.723 | 0.013 | 120.09 | 119.907 | 0.525 |
| 18_017 | 23.227 | 0.013 | 120.309 | 120.066 | 0.525 |
| 18_019 | 66.234 | 0.013 | 120.574 | 120.309 | 0.525 |
| 18_045 | 37.134 | 0.013 | 120.692 | 117.454 | 0.9 |
| 18_051 | 43.153 | 0.013 | 121.321 | 120.726 | 0.9 |
| 18_054 | 108.915 | 0.013 | 123.664 | 121.321 | 0.9 |
| 18_058 | 38.852 | 0.013 | 124.606 | 123.684 | 0.9 |
| 18_059 | 9.222 | 0.013 | 124.636 | 124.606 | 0.9 |
| 18_060 | 3.523 | 0.013 | 124.7 | 124.636 | 0.9 |
| 18_063 | 13.236 | 0.013 | 124.89 | 124.7 | 1 |
| 18_078 | 24.992 | 0.013 | 126.377 | 126.233 | 1 |
| 18_079 | 60.11 | 0.013 | 127.034 | 126.377 | 0.9 |
| 18_1 | 36.772 | 0.013 | 120.706 | 120.578 | 0.8 |
| 18_129a | 6.991 | 0.013 | 147.556 | 147.503 | 0.75 |
| 18_129b | 14.898 | 0.013 | 147.503 | 147.454 | 0.75 |
| 18_170 | 9.144 | 0.013 | 150.495 | 150.362 | 0.3 |
| 18_171 | 35.139 | 0.013 | 150.693 | 150.495 | 0.3 |
| 18_174 | 44.099 | 0.013 | 149.872 | 149.647 | 0.3 |
| 18_176 | 13.831 | 0.013 | 149.366 | 148.758 | 0.3 |
| 18_178 | 89.425 | 0.013 | 148.758 | 146.297 | 0.3 |
| 18_179 | 38.283 | 0.013 | 146.287 | 145.812 | 0.5 |
| 18_180 | 41.3 | 0.013 | 145.812 | 145.87 | 0.5 |
| 18_2 | 33.722 | 0.013 | 120.578 | 120.522 | 0.8 |
| 18_201 | 21.184 | 0.013 | 144.876 | 143.695 | 0.45 |
| 18_202 | 41.402 | 0.013 | 145.202 | 144.876 | 0.45 |
| 18_203 | 22.696 | 0.013 | 128.011 | 127.897 | 0.625 |
| 18_204 | 49.743 | 0.013 | 128.38 | 128.011 | 0.675 |
| 18_3 | 24.985 | 0.013 | 117.782 | 117.671 | 1.5 |
| 18_4 | 19.243 | 0.013 | 117.671 | 117.454 | 1.5 |
| 18_5 | 42.502 | 0.013 | 139.09 | 137.52 | 0.6 |
| 18_6 | 34.127 | 0.013 | 137.52 | 136.26 | 0.6 |
| C1_1 | 81.155 | 0.013 | 126.048 | 124.832 | 0.675 |
| C1_2 | 8.568 | 0.013 | 124.832 | 124.734 | 0.675 |
| C20 | 22.753 | 0.013 | 118.765 | 118.355 | 1.2 |

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| C24 | 56.269 | 0.013 | 124.734 | 123.115 | 0.9 |
| C35 | 18.551 | 0.013 | 122.838 | 122.556 | 0.31 |
| C8_1 | 31.878 | 0.013 | 119.482 | 119.042 | 1.5 |
| C8_2 | 17.397 | 0.013 | 119.042 | 118.765 | 1.5 |
| C2 | 73.139 | 0.01 | 145.628 | 145.202 | 1 |
| 18_086 | 9.451 | 0.013 | 136.21 | 136.21 | 0.75 |
| 18_091 | 62.629 | 0.013 | 139.52 | 139.09 | 0.75 |
| 18_093 | 32.193 | 0.013 | 139.75 | 139.52 | 0.75 |
| 18_095 | 22.772 | 0.013 | 139.91 | 139.75 | 0.75 |
| 18_097 | 52.934 | 0.013 | 142.2 | 140.06 | 0.6 |
| 18_099 | 71.053 | 0.013 | 144.7 | 142.2 | 0.6 |
| 18_101 | 61.596 | 0.013 | 145.34 | 145.03 | 0.75 |
| 18_103 | 86.793 | 0.013 | 145.77 | 145.34 | 0.75 |
| 18_106 | 77.424 | 0.013 | 146.15 | 145.77 | 0.75 |
| 18_117 | 86.515 | 0.013 | 146.9 | 146.496 | 0.75 |
| 18_119A | 10.341 | 0.013 | 147.05 | 147.018 | 0.75 |
| 18_119B | 31.86 | 0.013 | 147.018 | 146.92 | 0.75 |
| 18_121 | 30.198 | 0.013 | 148.408 | 147.749 | 0.3 |
| 18_159 | 65.147 | 0.013 | 147.895 | 147.57 | 0.75 |
| 18_160 | 4.997 | 0.013 | 147.919 | 147.9 | 0.75 |
| 18_216 | 71.782 | 0.013 | 138.1 | 135.73 | 0.3 |
| 18_125 | 56.547 | 0.013 | 147.45 | 147.166 | 0.75 |
| 18_214 | 67.338 | 0.013 | 135.73 | 131.942 | 0.3 |
| 18_109 | 13.176 | 0.013 | 146.22 | 146.15 | 0.75 |
| 18_123 | 23.081 | 0.013 | 147.166 | 147.05 | 0.75 |
| 18_163 | 20.597 | 0.013 | 148.364 | 147.932 | 0.75 |
| 18_165 | 37.927 | 0.013 | 149.349 | 148.63 | 0.5 |
| 18_207 | 97.1 | 0.013 | 128.708 | 128.46 | 0.675 |
| 18_0114 | 85.588 | 0.013 | 146.45 | 145.979 | 0.75 |
| 18_026 | 99.747 | 0.013 | 120.99 | 120.573 | 0.45 |
| 18_037 | 118.081 | 0.013 | 121.66 | 121.052 | 0.375 |
| 18_038 | 20.47 | 0.013 | 122.032 | 121.845 | 0.375 |
| 18_046 | 101.437 | 0.013 | 120.158 | 120.021 | 0.9 |
| 18_048 | 14.909 | 0.013 | 120.246 | 120.226 | 0.9 |
| 18_081 | 85.164 | 0.013 | 127.798 | 126.958 | 0.7 |
| 18_082 | 19.504 | 0.013 | 128.16 | 127.938 | 0.6 |
| 18_084 | 63.431 | 0.013 | 132.534 | 128.344 | 0.6 |
| 18_085 | 59.119 | 0.013 | 136.153 | 133.116 | 0.6 |
| 18_110 | 33.481 | 0.013 | 146.366 | 146.28 | 0.45 |
| 18_130 | 6.972 | 0.013 | 147.751 | 147.659 | 0.36 |
| 18_132 | 40.054 | 0.013 | 148.207 | 147.75 | 0.46 |
| 18_137 | 44.504 | 0.013 | 148.612 | 148.21 | 0.45 |
| 18_140 | 15.028 | 0.013 | 148.73 | 148.597 | 0.43 |

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 18_142 | 32.003 | 0.013 | 148.966 | 148.835 | 0.29 |
| 18_143 | 9.4 | 0.013 | 149.118 | 149.062 | 0.28 |
| 18_144 | 67.138 | 0.013 | 149.73 | 149.106 | 0.28 |
| 18_147 | 15.388 | 0.013 | 149.047 | 148.966 | 0.36 |
| 18_149 | 66.449 | 0.013 | 149.445 | 149.134 | 0.28 |
| 18_151 | 9.961 | 0.013 | 149.43 | 149.45 | 0.28 |
| 18_154 | 69.84 | 0.013 | 149.86 | 149.499 | 0.27 |
| 18_167 | 42.537 | 0.013 | 150.117 | 149.715 | 0.3 |
| 18_169 | 15.415 | 0.013 | 150.277 | 150.202 | 0.3 |
| 18_175 | 51.168 | 0.013 | 149.634 | 149.213 | 0.3 |
| 18_181 | 47.57 | 0.013 | 145.863 | 145.719 | 0.5 |
| 18_183 | 69.607 | 0.013 | 140.25 | 136.617 | 0.6 |
| 18_184 | 50.304 | 0.013 | 141.345 | 140.218 | 0.6 |
| 18_187 | 47.379 | 0.013 | 141.521 | 141.328 | 0.6 |
| 18_188 | 46.516 | 0.013 | 141.714 | 141.56 | 0.675 |
| 18_189 | 22.453 | 0.013 | 141.822 | 141.758 | 0.675 |
| 18_190 | 46.093 | 0.013 | 142.026 | 141.81 | 0.675 |
| 18_193 | 47.953 | 0.013 | 142.282 | 142.109 | 0.675 |
| 18_195 | 16.559 | 0.013 | 142.591 | 142.54 | 0.35 |
| 18_196 | 55.931 | 0.013 | 144.122 | 142.662 | 0.3 |
| 18_199 | 55.814 | 0.013 | 143.583 | 143.018 | 0.45 |
| 18_208 | 123.498 | 0.013 | 130.746 | 128.818 | 0.525 |
| 18_210 | 12.565 | 0.013 | 130.911 | 130.847 | 0.525 |
| 18_212 | 42.348 | 0.013 | 131.959 | 130.902 | 0.6 |
| C108 | 90.078 | 0.013 | 121.602 | 120.903 | 0.675 |
| C28 | 61.123 | 0.013 | 121.791 | 120.685 | 0.9 |
| C31 | 92.118 | 0.013 | 121.956 | 121.625 | 0.675 |
| C36 | 67.783 | 0.013 | 120.338 | 119.599 | 1.2 |
| C37 | 61.862 | 0.013 | 125.341 | 123.271 | 0.45 |
| C38 | 71.103 | 0.013 | 123.18 | 120.698 | 0.45 |
| C41 | 64.165 | 0.013 | 122.507 | 122.357 | 0.5 |
| C6 | 56.689 | 0.013 | 122.21 | 122.012 | 0.675 |

**Table F.6: Sewer Pipe Information for the Darcy Model**

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 44_0001 | 67.375 | 0.013 | 115.897 | 113.277 | 0.3 |
| 44_0004 | 8.752 | 0.013 | 116.013 | 115.897 | 0.3 |
| 44_0005 | 3.845 | 0.013 | 116.925 | 116.827 | 0.2 |
| 44_0007 | 12.983 | 0.013 | 117.09 | 116.925 | 0.2 |
| 44_0013 | 48.3 | 0.013 | 118.814 | 116.075 | 0.2 |
| C41_2 | 7.67 | 0.013 | 116.91 | 116.741 | 0.2 |
| C43 | 40.6 | 0.013 | 116.693 | 115.839 | 0.2 |
| 44_0008 | 42.9 | 0.013 | 116.525 | 116.339 | 0.2 |
| C42 | 5.7 | 0.013 | 116.336 | 116.033 | 0.2 |
| C40 | 53.9 | 0.013 | 116.913 | 116.66 | 0.2 |

**Table F.7: Sewer Pipe Information for the Lake Street Area Model**

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 09_0004 | 9.203 | 0.013 | 110.841 | 110.704 | 0.9 |
| 09_0005 | 18.426 | 0.013 | 110.983 | 110.841 | 0.9 |
| 09_0007 | 7.917 | 0.013 | 111.036 | 110.983 | 0.9 |
| 09_0008 | 15.13 | 0.013 | 111.208 | 111.036 | 0.9 |
| 09_0009 | 40.722 | 0.013 | 111.69 | 111.208 | 0.9 |
| 09_0014 | 4.164 | 0.013 | 111.964 | 111.92 | 0.75 |
| 09_0015 | 6.728 | 0.013 | 112.123 | 111.964 | 0.75 |
| 09_0019 | 17.605 | 0.013 | 112.234 | 112.123 | 0.75 |
| 09_0021 | 0.65 | 0.013 | 112.238 | 112.234 | 0.75 |
| 09_0022 | 35.062 | 0.013 | 112.501 | 112.238 | 0.75 |
| 09_0023 | 17 | 0.013 | 112.86 | 112.501 | 0.45 |
| 09_0042 | 89 | 0.013 | 112.65 | 111.729 | 0.6 |
| 09_0043 | 10.829 | 0.013 | 111.237 | 111.199 | 0.3 |
| 09_0044 | 78.466 | 0.013 | 111.568 | 111.237 | 0.6 |
| 09_0048 | 14.622 | 0.013 | 112.081 | 111.84 | 0.3 |
| 09_0049 | 28.403 | 0.013 | 112.491 | 112.081 | 0.3 |
| 10_0001 | 67.4 | 0.013 | 110.655 | 109.936 | 0.375 |
| 10_0002 | 54 | 0.013 | 111.182 | 110.655 | 0.375 |
| 21_0001 | 34.7 | 0.013 | 111.725 | 109.686 | 0.675 |
| 10_0010 | 4 | 0.013 | 112.895 | 112.879 | 0.25 |
| 09_0012 | 39.407 | 0.013 | 111.92 | 111.758 | 0.75 |
| 10_0008 | 40.3 | 0.013 | 112.874 | 112.32 | 0.25 |
| C50 | 34 | 0.013 | 113.28 | 113.11 | 0.3 |
| C52 | 42.5 | 0.013 | 113.11 | 112.9 | 0.3 |
| C53 | 3.5 | 0.013 | 112.9 | 112.623 | 0.3 |
| 09_0001 | 127.2 | 0.013 | 110.932 | 109.279 | 0.75 |
| 09_0002 | 95.6 | 0.013 | 111.1 | 110.969 | 0.75 |
| 09_0036 | 13.043 | 0.013 | 112.651 | 112.42 | 0.3 |

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 09_0040 | 14.7 | 0.013 | 111.792 | 111.593 | 0.6 |
| 10_0004 | 52.7 | 0.013 | 111.343 | 111.182 | 0.375 |
| 10_0006 | 26.3 | 0.013 | 111.833 | 111.362 | 0.375 |
| 10_0007 | 40.7 | 0.013 | 112.32 | 111.874 | 0.375 |
| 21_0003 | 70 | 0.013 | 111.893 | 111.725 | 0.675 |
| 21_0006 | 40 | 0.013 | 112.217 | 112.04 | 0.43 |
| 21_0008 | 55.2 | 0.013 | 112.522 | 112.207 | 0.525 |

**Table F.8: Sewer Pipe Information for the Trafalgar Model**

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 06_0001 | 32.9 | 0.013 | 111.766 | 109.705 | 0.6 |
| 06_0019 | 18 | 0.013 | 118.016 | 116.297 | 0.6 |
| 06_0048 | 105.979 | 0.013 | 127.282 | 125.617 | 0.375 |
| 06_0050 | 38.224 | 0.013 | 127.822 | 127.416 | 0.3 |
| 06_0082 | 11.283 | 0.013 | 120.34 | 119.995 | 0.6 |
| 06_0083 | 50.2 | 0.013 | 122.022 | 120.34 | 0.6 |
| 06_0085 | 17.512 | 0.013 | 122.545 | 122.492 | 0.75 |
| 06_0086 | 23.017 | 0.013 | 122.657 | 122.545 | 0.75 |
| 06_0087 | 28.123 | 0.013 | 122.807 | 122.715 | 0.75 |
| 06_0089 | 36.553 | 0.013 | 122.916 | 122.807 | 0.75 |
| 06_0091 | 40.373 | 0.013 | 123.201 | 122.916 | 0.75 |
| 06_0092 | 12.584 | 0.013 | 123.278 | 123.201 | 0.525 |
| 06_0093 | 8.122 | 0.013 | 123.328 | 123.278 | 0.525 |
| 06_0098 | 46.319 | 0.013 | 125.361 | 124.836 | 0.675 |
| 06_0100 | 10.088 | 0.013 | 125.447 | 125.361 | 0.675 |
| 06_0101 | 6.224 | 0.013 | 125.523 | 125.447 | 0.675 |
| 06_0103 | 53.52 | 0.013 | 125.838 | 125.575 | 0.675 |
| 06_0104 | 27.563 | 0.013 | 126.013 | 125.838 | 0.375 |
| 06_0105 | 35.455 | 0.013 | 126.297 | 126.013 | 0.375 |
| 06_0129 | 68.714 | 0.013 | 126.699 | 126.55 | 0.45 |
| 06_0131 | 0.729 | 0.013 | 126.714 | 126.699 | 0.375 |
| 06_0132 | 10.314 | 0.013 | 126.782 | 126.714 | 0.375 |
| 06_0134 | 70.342 | 0.013 | 130.196 | 126.86 | 0.375 |
| 06_0135 | 46.244 | 0.013 | 131.838 | 130.196 | 0.375 |
| 08_0051 | 8.505 | 0.013 | 126.702 | 126.5 | 0.25 |
| 08_0052 | 6.825 | 0.013 | 127.24 | 126.702 | 0.25 |
| 08_0062 | 8.291 | 0.013 | 132.762 | 132.564 | 0.2 |
| 08_0063 | 9.302 | 0.013 | 132.939 | 132.762 | 0.2 |
| 08_0072 | 22.3 | 0.013 | 132.306 | 131.759 | 0.2 |
| ABL-P1 | 4.409 | 0.013 | 127.416 | 127.362 | 0.3 |
| ABL-P2 | 8.757 | 0.013 | 127.362 | 127.282 | 0.3 |
| 06_0020 | 40.5 | 0.013 | 119.31 | 119.18 | 0.31 |

| Name | Length (m) | Roughness | Inlet Elev. (m) | Outlet Elev. (m) | Diameter (m) |
|---|---|---|---|---|---|
| 06_0106 | 18.5 | 0.013 | 126.61 | 126.297 | 0.2 |
| 06_0136 | 49.1 | 0.013 | 132.466 | 131.957 | 0.3 |
| 08_0050 | 84.9 | 0.013 | 126.5 | 126.31 | 0.25 |
| 08_0054 | 67.1 | 0.013 | 127.57 | 127.24 | 0.2 |
| 08_0056 | 73.7 | 0.013 | 127.95 | 127.57 | 0.2 |
| 08_0057 | 9.1 | 0.013 | 128.06 | 127.95 | 0.2 |
| 08_0059 | 102.6 | 0.013 | 132.503 | 128.58 | 0.2 |
| 08_0060 | 19.1 | 0.013 | 133.123 | 132.595 | 0.27 |
| 08_0067 | 96 | 0.013 | 130.436 | 127.01 | 0.25 |
| 08_0068 | 8.1 | 0.013 | 131.741 | 131.436 | 0.2 |
| 06_0124 | 101 | 0.013 | 125.922 | 125.072 | 0.375 |
| 06_0022 | 122.7 | 0.013 | 119.708 | 119.31 | 0.31 |
| 06_0002 | 106.5 | 0.013 | 112.952 | 112.252 | 0.575 |
| 06_0009_1 | 20.541 | 0.013 | 113.582 | 113.28 | 0.6 |
| 06_0009_2 | 83.079 | 0.013 | 113.28 | 112.052 | 0.6 |
| 06_0014 | 56.1 | 0.013 | 114.337 | 113.575 | 0.6 |
| 06_0018 | 66.7 | 0.013 | 116.297 | 114.333 | 0.6 |
| 06_0024 | 103 | 0.013 | 120.096 | 119.772 | 0.31 |
| 06_0025 | 29.7 | 0.013 | 120.247 | 120.126 | 0.31 |
| 06_0028 | 97.325 | 0.013 | 120.603 | 120.236 | 0.25 |
| 06_0031 | 90.487 | 0.013 | 120.868 | 120.601 | 0.375 |
| 06_0032 | 18.7 | 0.013 | 121.119 | 120.839 | 0.375 |
| 06_0033 | 81 | 0.013 | 121.291 | 121.138 | 0.9 |
| 06_0040 | 61.5 | 0.013 | 122.022 | 121.878 | 0.9 |
| 06_0043 | 26.813 | 0.013 | 123.61 | 122.891 | 0.375 |
| 06_0045 | 33 | 0.013 | 124.45 | 123.635 | 0.375 |
| 06_0047 | 41.262 | 0.013 | 125.548 | 124.463 | 0.45 |
| 06_0081 | 12.387 | 0.013 | 119.885 | 119.146 | 0.6 |
| 06_0084 | 38.6 | 0.013 | 122.438 | 121.998 | 0.6 |
| 06_0095 | 43.35 | 0.013 | 123.565 | 123.373 | 0.525 |
| 06_0095A | 59.867 | 0.013 | 123.822 | 123.561 | 0.525 |
| 06_0096 | 7.2 | 0.013 | 124.8 | 123.889 | 0.675 |
| 06_0118 | 12.5 | 0.013 | 122.245 | 122.072 | 0.45 |
| 06_0119 | 46.7 | 0.013 | 122.614 | 122.235 | 0.45 |
| 06_0122 | 35.4 | 0.013 | 122.868 | 122.635 | 0.45 |
| 06_0123 | 40.4 | 0.013 | 125.126 | 122.873 | 0.375 |

**Table F.9: IDF Coefficients**

| Return period | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
|---|---|---|---|---|---|---|
| A | 20.1 | 26.7 | 31.1 | 36.5 | 40.6 | 44.6 |
| B | -0.699 | -0.699 | -0.699 | -0.699 | -0.699 | -0.699 |

**Table F.10: IDF Curves**

| Duration | 5-min | 10-min | 15-min | 30-min | 1-hr | 2-hr | 6-hr | 12-hr | 24-hr |
|---|---|---|---|---|---|---|---|---|---|
| | Intensity (mm/h) | | | | | | | | |
| 2-yr | 114.2 | 70.3 | 53 | 32.6 | 20.1 | 12.4 | 5.7 | 3.5 | 2.2 |
| 5-yr | 151.7 | 93.4 | 70.4 | 43.3 | 26.7 | 16.4 | 7.6 | 4.7 | 2.9 |
| 10-yr | 176.6 | 108.8 | 82 | 50.5 | 31.1 | 19.2 | 8.9 | 5.5 | 3.4 |
| 25-yr | 207.3 | 127.7 | 96.2 | 59.3 | 36.5 | 22.5 | 10.4 | 6.4 | 4 |
| 50-yr | 230.6 | 142.1 | 107 | 65.9 | 40.6 | 25 | 11.6 | 7.1 | 4.4 |
| 100-yr | 253.3 | 156 | 117.5 | 72.4 | 44.6 | 27.5 | 12.7 | 7.9 | 4.8 |

**Table F.11: Design Storms**

| Time (Hr) | 5-yr Storm | 100-yr Storm |
|---|---|---|
| | Depth (m) | Depth (m) |
| 0 | 0 | 0 |
| 0.25 | 1.480246 | 2.47262 |
| 0.5 | 1.480246 | 2.47262 |
| 0.75 | 6.249926 | 10.43995 |
| 1 | 17.10506 | 28.5725 |
| 1.5 | 4.276265 | 7.143125 |
| 2 | 2.302604 | 3.846298 |
| 2.5 | 0 | 0 |

# APPENDIX G

## Outfall Assessment Field Notes

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Kakisa River Muskrat | 27 | Nov 8, 2021 11:39 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 1.2 m |
| Pipe-Arch ☐ | CMP ☒ | Three ☐ | Headwall ☒ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other: | Other: CSP + Cast iron | Other: | Other: | Other: | |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | |
| Sediment Blockage 1/3 to 3/4 of Rise | No | Good ☐ |
| Buoyancy or Crushing-Related Failure | No | |
| Poor Channel Alignment | No | Fair ☐ |
| Previous and/or Frequent Overtopping | Critical | |
| Local Scour | Critical | Poor ☐ |
| Embankment Piping | No | |
| Channel Degradation | ~~Poor~~ Critial | Critical ☒ |
| Headcut | No | |
| Embankment Slope Instability | Critial | Unknown ☐ |
| Sediment Blockage > 3/4 Rise | No | |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No | Performance Problems ☐ |
| Submerged / Ends Totally Buried | No | |
| Aggressive Abrasion / Corrosion / Chemical | No | |
| Exposed Footing (Open Bottom Culvert Only) | No | |

| Category | Rating |
|---|---|
| Invert Deterioration | Critical |
| Joint and Seams | Crit |
| Corrosion / Chemical | N/A |
| ~~Cross-Section Deformation~~ | |
| Cracking | Crit |
| Headwall / Wingwall | Crit |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Crit |

Notes

- ~ 50 m of CSP pipe missing between upstream cast iron pipe and headwall
- Large concrete blocks at outfall of cast iron pipe
- Manhole over appears to have fallen, possibly due to bank erosion, causing failure of pipe.

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian River, Christie St | 41 | Nov 8 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☒ | Two ☐ | Mitered ☐ | Mitered ☐ | 2 @ 53 cm |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☒ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other: | Other: | Other: | Other: outflanked | Other: | |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | Good ☐ |
| Sediment Blockage 1/3 to 3/4 of Rise | No | |
| Buoyancy or Crushing-Related Failure | No | |
| Poor Channel Alignment | N/A | Fair ☐ |
| Previous and/or Frequent Overtopping | Yes | |
| Local Scour | Yes | Poor ☐ |
| Embankment Piping | No | |
| Channel Degradation | ~ Yes (exposed foundation) | Critical ☒ |
| Headcut | No | |
| Embankment Slope Instability | No | |
| Sediment Blockage > 3/4 Rise | No | Unknown ☐ |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No | |
| Submerged / Ends Totally Buried | N/A | Performance Problems ☐ |
| Aggressive Abrasion / Corrosion / Chemical | No | |
| Exposed Footing (Open Bottom Culvert Only) | No | |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Critical |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | ~~No~~ |
| Cracking | Critical |
| Headwall / Wingwall | Good |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None / Poor |

Notes: • 1" Crack from settling, cracked all through wall, 3/4 of circumference
• leakage from crack
• Outflanked
• Another crack at seam, 1"

**Watercourse and Crossing Location** Muskrat

**ID Number** 35

**Date** Nov 10, 2021

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter 102 cm |
| Box ☒ | Concrete ☒ | Two ☐ | Mitered ☐ | Mitered ☐ | Circular |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☒ | Span 123 cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Box |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other: Armourstone headwall | Rise 125 cm |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | Yes |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | No |
| Aggressive Abrasion / Corrosion / Chemical | No |
| Exposed Footing (Open Bottom Culvert Only) | No |

Overall Rating

- Good ☐
- Fair ☐
- Poor ☐
- Critical ☒
- Unknown ☐
- Performance Problems ☐

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Critical |
| Corrosion / Chemical | Good |
| Cross-Section Deformation | Good |
| Cracking | Critical |
| Headwall / Wingwall | Good |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None/ Critical |

Notes:

- ~17 m of Box culvert failed, U/S end is now outlet under old road embankment, fair condition
- Box culvert appears to have fed into circular concrete pipe
- Failure of box culvert created chanel next to failed portion
- Several circular pipe sections disconnected from each other

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Muskrat | N/A | Nov 10, 2021 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☒ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 12" |
| Pipe-Arch ☐ | CMP ☒ | Three ☐ | Headwall ☐ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | Good ☐ |
| Sediment Blockage 1/3 to 3/4 of Rise | No | |
| Buoyancy or Crushing-Related Failure | No | |
| Poor Channel Alignment | No | Fair ☐ |
| Previous and/or Frequent Overtopping | No | |
| Local Scour | Yes | Poor ☒ |
| Embankment Piping | No | |
| Channel Degradation | No | |
| Headcut | No | Critical ☐ |
| Embankment Slope Instability | No | |
| Sediment Blockage > 3/4 Rise | No | Unknown ☐ |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No | |
| Submerged / Ends Totally Buried | No | Performance Problems ☐ |
| Aggressive Abrasion / Corrosion / Chemical | Yes | |
| Exposed Footing (Open Bottom Culvert Only) | N/A | |

| Category | Rating |
|---|---|
| Invert Deterioration | ~~Fair~~ Poor |
| Joint and Seams | Good |
| Corrosion / Chemical | Poor |
| Cross-Section Deformation | No |
| Cracking | No |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | ~~Fair~~ Poor |

- Roundstone used as scour protection but slope is very steep esp. at out fall. Washed out. Bottom of culvert is rusted through at outlet

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian | 31 | Nov 8, 2021 13:00 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 11.75^ |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☒ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | No (Yes for CSP) |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No/Yes (at CSP) |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | No |
| Aggressive Abrasion / Corrosion / Chemical | No/Yes (CSP) |
| Exposed Footing (Open Bottom Culvert Only) | No |

| Overall Rating | |
|---|---|
| Good | ☒ |
| Fair | ☐ |
| Poor | ☐ |
| Critical | ☐ |
| Unknown | ☐ |
| Performance Problems | ☐ |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | N/A |
| Corrosion / Chemical | Good/Fair (CSP) |
| ~~Cross-Section Deformation~~ | |
| Cracking | Good |
| Headwall / Wingwall | Fair |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Fair (CSP) |

Notes:
- CSP half-pipe converys water from outfall to channel
- Has very small headwall
- CSP is poor condition but: 1 section downstream is undermined, 1 fell fallen. Some rust corrosion.

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian River | 45 | Nov 8, 2021 10:12 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☒ | Diameter cm 7.75" |
| Box ☐ | Concrete ☒ | Two ☐ | Mitered ☐ | Mitered ☐ | |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other: | Other: | Other: | Other: | Other: None | |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | Yes |
| Local Scour | Yes |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | N/A |
| Aggressive Abrasion / Corrosion / Chemical | Yes |
| Exposed Footing (Open Bottom Culvert Only) | No |
| | N/A |

| Overall Rating | |
|---|---|
| Good | ☐ |
| Fair | ☐ |
| Poor | ☐ |
| Critical | ☒ |
| Unknown | ☐ |
| Performance Problems | ☐ |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Critical |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | |
| Cracking | Critical |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None/Poor |

Notes
- 30" broken / detached pipe section, 1 ft between sections
- At seam, pipe is in good condition but is recessed into the bank

**Watercourse and Crossing Location** | **ID Number** | **Date**

Indian | 42 | Nov 8, 2021 16:03

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☒ | Two ☐ | Mitered ☐ | Mitered ☐ | 24" |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☒ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | No |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | No |
| Aggressive Abrasion / Corrosion / Chemical | No |
| Exposed Footing (Open Bottom Culvert Only) | No |

Overall Rating

- Good ☐
- Fair ☒
- Poor ☒ ?
- Critical ☐
- Unknown ☐
- Performance Problems ☐

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | No Good |
| Corrosion / Chemical | Good |
| Cross-Section Deformation | No Good |
| Cracking | Fair |
| Headwall / Wingwall | Fair / Critical |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Fair |

Notes

- ~20 m recessed from channel
- Wingwalls failing
- Erosion along downstream outfall channel portion

**Watercourse and Crossing Location**: Indian River, Murray St

**ID Number**: ~~46~~ 46

**Date**: Nov 8, 2021 9:36 am

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☒ | Diameter |
| Box ☐ | Concrete ☒ | Two ☐ | Mitered ☐ | Mitered ☐ | 12.5" cm |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☐ | Span |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other: None | Rise cm |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | Yes |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | N/A |
| Aggressive Abrasion / Corrosion / Chemical | Yes |
| Exposed Footing (Open Bottom Culvert Only) | No |

| Overall Rating | |
|---|---|
| Good | ☐ |
| Fair | ☐ |
| Poor | ☒ |
| Critical | ☐ |
| Unknown | ☐ |
| Performance Problems | ☒ |

| Category | Rating |
|---|---|
| Invert Deterioration | ~~Poor~~ Good |
| Joint and Seams | Poor |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | ~~Good~~ |
| Cracking | Poor |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None/Good |

- Clay pipe seam into concrete pipe, 3/4" crack
- 10% sediment, fine sand (1" deep)
- Resident said it was out of commission
- Sediment buildup could support this

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian | 56 | Nov 8, 2021 15:40 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | ~~12"~~ |
| Pipe-Arch ☐ | CMP ☒ | Three ☐ | Headwall ☒ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | ~~No~~ Yes |
| Sediment Blockage 1/3 to 3/4 of Rise | Yes |
| Buoyancy or Crushing-Related Failure | No ~~Yes~~ |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | No |
| Local Scour | Yes |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | ~~No~~ Yes |
| Submerged / Ends Totally Buried | ~~Yes~~ NO |
| Aggressive Abrasion / Corrosion / Chemical | No |
| Exposed Footing (Open Bottom Culvert Only) | No |

| Overall Rating | |
|---|---|
| Good | ☐ |
| Fair | ☐ |
| Poor | ☒ |
| Critical | ☐ |
| Unknown | ☐ |
| Performance Problems | ☐ |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Fair |
| Cross-Section Deformation | ~~Good~~ Fair |
| Cracking | Good |
| Headwall / Wingwall | Critical |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None ~~Fair~~ |

Notes:

- Headwall destroyed
- End partially buried and ~~crushed~~ slightly crushed
- ~ 3-4 in above channel

NOT LOCATED - Likely buried under dumped veg/grass clippings

**Watercourse and Crossing Location** | **ID Number** | **Date**

Indian River | 43 | Nov 8, 2021 11:06

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☐ | Timber ☐ | One ☐ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | Rise cm |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | | Good ☐ |
| Sediment Blockage 1/3 to 3/4 of Rise | | |
| Buoyancy or Crushing-Related Failure | | Fair ☐ |
| Poor Channel Alignment | | |
| Previous and/or Frequent Overtopping | | Poor ☐ |
| Local Scour | | |
| Embankment Piping | | Critical ☐ |
| Channel Degradation | | |
| Headcut | | Unknown ☐ |
| Embankment Slope Instability | | |
| Sediment Blockage > 3/4 Rise | | Performance Problems ☐ |
| Sediment Blockage > 1/3 Rise Throughout Barrel | | |
| Submerged / Ends Totally Buried | | |
| Aggressive Abrasion / Corrosion / Chemical | | |
| Exposed Footing (Open Bottom Culvert Only) | | |

| Category | Rating |
|---|---|
| Invert Deterioration | |
| Joint and Seams | |
| Corrosion / Chemical | |
| Cross-Section Deformation | |
| Cracking | |
| Headwall / Wingwall | |
| Apron | |
| Flared End Section | |
| Scour Protection | |

Notes: Found remnants of broken concrete pipe

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian River, Christie | 55 | Nov 8<br>9:50 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☒ | 7cm 7.75" |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☒ | Rise cm |
| Other: | Other: | Other: | Other: | Other: | |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | Good ☒ |
| Sediment Blockage 1/3 to 3/4 of Rise | No | |
| Buoyancy or Crushing-Related Failure | No | |
| Poor Channel Alignment | No | Fair ☐ |
| Previous and/or Frequent Overtopping | Yes | |
| Local Scour | No | Poor ☐ |
| Embankment Piping | No | |
| Channel Degradation | No | Critical ☐ |
| Headcut | No | |
| Embankment Slope Instability | No | Unknown ☐ |
| Sediment Blockage > 3/4 Rise | No | |
| Sediment Blockage > 1/3 Rise Throughout Barrel | N/A | Performance Problems ☐ |
| Submerged / Ends Totally Buried | No | |
| Aggressive Abrasion / Corrosion / Chemical | No | |
| Exposed Footing (Open Bottom Culvert Only) | No | |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | N/A |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | ~~No~~ |
| Cracking | Good |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None / Good |

Notes:
- slight drop but no scour protection
- Pipe is mitered, concrete surrounding is critical condition

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian River, D'Arcy | 44 | Nov 8<br>10:30 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 11.75" |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other: N/A | Other: N/A | |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | Yes |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | N/A |
| Aggressive Abrasion / Corrosion / Chemical | Partially submerged |
| Exposed Footing (Open Bottom Culvert Only) | Yes |
| | N/A |

| Overall Rating | |
|---|---|
| Good | ☐ |
| Fair | ☒ |
| Poor | ☐ |
| Critical | ☐ |
| Unknown | ☐ |
| Performance Problems | ☐ |

| Category | Rating |
|---|---|
| Invert Deterioration | Minor Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | |
| Cracking | Poor |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None / Good |

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Indian River, Christie St | 47 | Nov 8, 2024 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 20 - 20.5" |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☒ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other: | Other: | Other: | Other: N/A | Other: | |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | Good ☒ |
| Sediment Blockage 1/3 to 3/4 of Rise | No | |
| Buoyancy or Crushing-Related Failure | No | |
| Poor Channel Alignment | N/A | Fair ☐ |
| Previous and/or Frequent Overtopping | Yes; Previous | |
| Local Scour | Yes (side of headwall) | Poor ☐ |
| Embankment Piping | No | |
| Channel Degradation | No | |
| Headcut | No | Critical ☐ |
| Embankment Slope Instability | No | |
| Sediment Blockage > 3/4 Rise | No | Unknown ☐ |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No | |
| Submerged / Ends Totally Buried | N/A | Performance Problems ☐ |
| Aggressive Abrasion / Corrosion / Chemical | No | |
| Exposed Footing (Open Bottom Culvert Only) | No | |
| | No | |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Fair (nuts) |
| ~~Cross-Section Deformation~~ | ~~Good~~ |
| Cracking | Good |
| Headwall / Wingwall | Good |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Good |

**Watercourse and Crossing Location** | **ID Number** | **Date**

Muskrat | 28 | Nov 8 14:48

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm 35-36" |
| Box ☐ | Concrete ☒ | Two ☐ | Mitered ☐ | Mitered ☐ | |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☐ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | Yes |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | No |
| Aggressive Abrasion / Corrosion / Chemical | Rust No |
| Exposed Footing (Open Bottom Culvert Only) | No |
| | N/A |

Overall Rating

- Good ☒
- Fair ☐
- Poor ☐
- Critical ☐
- Unknown ☐
- Performance Problems ☐

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Yes (grate) |
| ~~Cross-Section Deformation~~ | |
| Cracking | Good |
| Headwall / Wingwall | Good |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | None/Good |

Grate: - minor rust
- Partially submerged
- Overland flow erosion

**Watercourse and Crossing Location** | **ID Number** | **Date**

Muskrat | 30 | Nov 8 12:37

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☒ | 10" |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | Rise cm |

| Performance Problems | Location |
|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No |
| Sediment Blockage 1/3 to 3/4 of Rise | No |
| Buoyancy or Crushing-Related Failure | No |
| Poor Channel Alignment | No |
| Previous and/or Frequent Overtopping | No |
| Local Scour | No |
| Embankment Piping | No |
| Channel Degradation | No |
| Headcut | No |
| Embankment Slope Instability | No |
| Sediment Blockage > 3/4 Rise | No |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No |
| Submerged / Ends Totally Buried | No |
| Aggressive Abrasion / Corrosion / Chemical | No |
| Exposed Footing (Open Bottom Culvert Only) | No |

| Overall Rating | |
|---|---|
| Good | ☒ |
| Fair | ☐ |
| Poor | ☐ |
| Critical | ☐ |
| Unknown | ☐ |
| Performance Problems | ☐ |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | |
| Cracking | Good |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Good |

Notes:

- Cable - crete scour protection
- recessed ~ 30 m

**Watercourse and Crossing Location** | **ID Number** | **Date**

Indian River | 62 | Nov 8, 2021 10:53

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 11.75" |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☐ | Headwall ☐ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | |
| Other: | Other: Corrugated | Other: | Other: | Other: N/A | Rise cm |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | Good ☒ |
| Sediment Blockage 1/3 to 3/4 of Rise | No | |
| Buoyancy or Crushing-Related Failure | No | Fair ☐ |
| Poor Channel Alignment | No | |
| Previous and/or Frequent Overtopping | No | Poor ☐ |
| Local Scour | No | |
| Embankment Piping | No | Critical ☐ |
| Channel Degradation | No | |
| Headcut | No | Unknown ☐ |
| Embankment Slope Instability | No | |
| Sediment Blockage > 3/4 Rise | No | Performance Problems ☐ |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No | |
| Submerged / Ends Totally Buried | No | |
| Aggressive Abrasion / Corrosion / Chemical | No | |
| Exposed Footing (Open Bottom Culvert Only) | No | |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | |
| Cracking | Good |
| Headwall / Wingwall | N/A |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Good |

Notes:

Recessed from river ~50m

| Watercourse and Crossing Location | ID Number | Date |
|---|---|---|
| Muskrat | 29 | Nov 8 15:15 |

| Barrel Shape | Material | No. of Barrels | End Treatments Upstream | End Treatments Downstream | Dimension |
|---|---|---|---|---|---|
| Circular ☒ | Timber ☐ | One ☒ | Projecting ☐ | Projecting ☐ | Diameter cm |
| Box ☐ | Concrete ☐ | Two ☐ | Mitered ☐ | Mitered ☐ | 18.5 - 18.75 " |
| Pipe-Arch ☐ | CMP ☐ | Three ☐ | Headwall ☒ | Headwall ☒ | Span cm |
| Elliptical ☐ | PVC ☒ | Four ☐ | Wingwalls ☐ | Wingwalls ☐ | Rise cm |
| Other:_____ | Other:_____ | Other:_____ | Other:_____ | Other:_____ | |

| Performance Problems | Location | Overall Rating |
|---|---|---|
| Debris/Veg. Blockage > 1/3 of Rise | No | Good ☒ |
| Sediment Blockage 1/3 to 3/4 of Rise | No | |
| Buoyancy or Crushing-Related Failure | No | |
| Poor Channel Alignment | No | Fair ☐ |
| Previous and/or Frequent Overtopping | No | |
| Local Scour | No | Poor ☐ |
| Embankment Piping | No | |
| Channel Degradation | No | Critical ☐ |
| Headcut | No | |
| Embankment Slope Instability | No | |
| Sediment Blockage > 3/4 Rise | No | Unknown ☐ |
| Sediment Blockage > 1/3 Rise Throughout Barrel | No | Performance Problems ☐ |
| Submerged / Ends Totally Buried | No | |
| Aggressive Abrasion / Corrosion / Chemical | No | |
| Exposed Footing (Open Bottom Culvert Only) | N/A | |

| Category | Rating |
|---|---|
| Invert Deterioration | Good |
| Joint and Seams | Good |
| Corrosion / Chemical | Good |
| ~~Cross-Section Deformation~~ | |
| Cracking | Good |
| Headwall / Wingwall | Good |
| Apron | N/A |
| Flared End Section | N/A |
| Scour Protection | Good |

# APPENDIX H

## Design Briefs for Storm Outfall Reconstruction

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 27**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 27 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 27 are shown in **Figure 1-1**. The storm sewer has a diameter of 300 mm and extends off of the corner joining Margaret Street to Moffat Street, outletting into the Muskrat River. Outfall 27 was identified to be in need of rehabilitation and was ranked as the highest priority site, of the total 17 sites that were assessed.

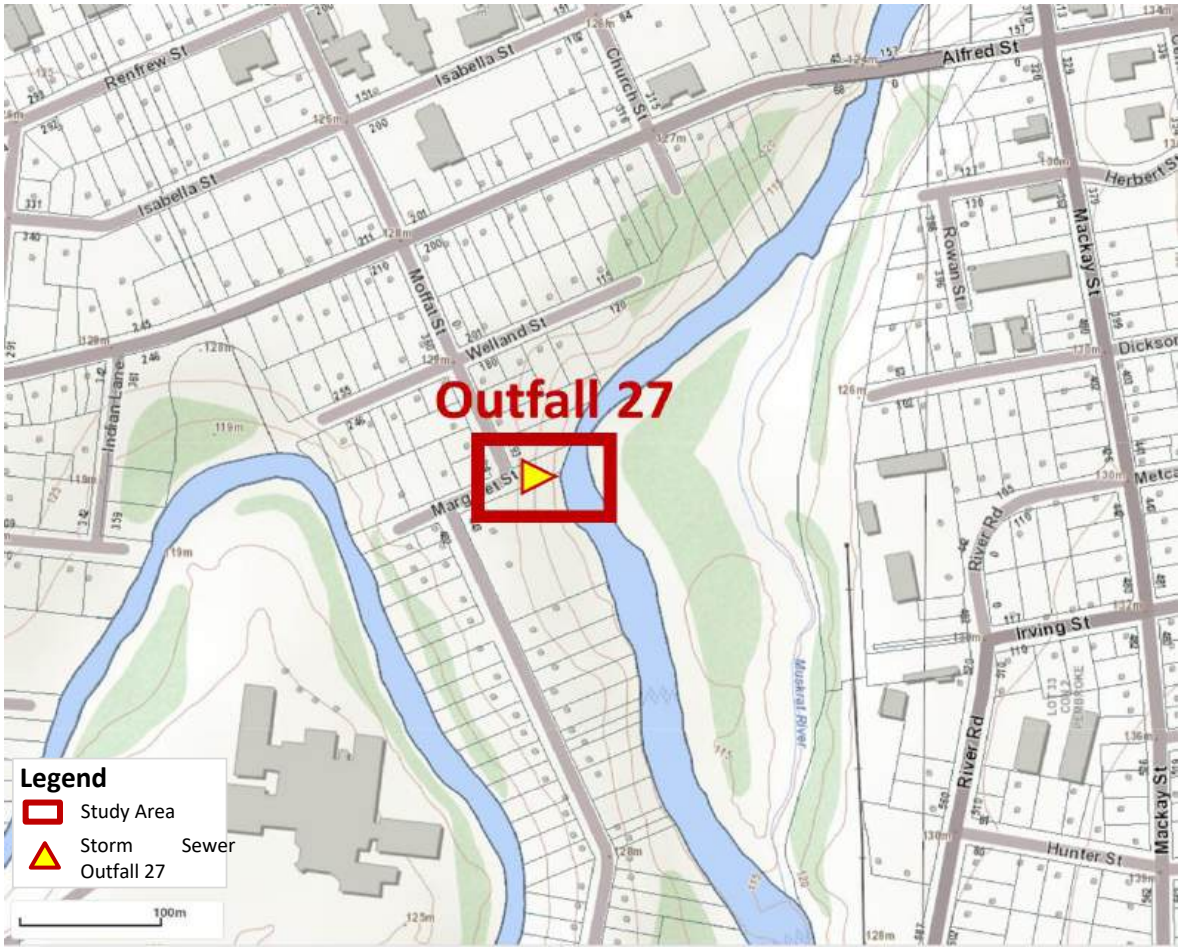



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 27**

## 2 EXISTING CONDITIONS

### 2.1 Overview

Outfall 27 has completely failed, with disconnected pipe segments and a concrete headwall strewn throughout the study area (**Figure 2-1** and **Figure 2-2**). Under current conditions, stormwater discharges from a failed 300 mm cast iron pipe protruding from the valley slope (**Figure 2-3**) approximately 27 m from the edge of the Muskrat River. Water exiting the pipe appears to have created a large scarp that has a maximum width of ~13 m and is characterized by steep slopes exceeding 1.4H:1V in some places. Large amounts of debris, including concrete rubble, sewer pipe segments, and woody debris are found within the scarp. Some of the concrete rubble found within the site appears to have belonged to a manhole and/or drop structure that may have helped stormwater overcome the steep vertical gradient before discharging into the Muskrat River (**Figure 2-4**).

**Figure 2-1: Debris within the Study Area**

**Figure 2-2: Failed Concrete Headwall and Pipe Segment**

**Figure 2-3: Remaining Pipe Protruding from the Slope**

**Figure 2-4: Possible Rubble from a Failed Manhole**

### 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface above and surrounding the storm sewer pipe, extending into the Muskrat River to capture streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, exposed pipe, headwall, etc.);
- Upstream maintenance hole lid and pipe invert;
- Top and bottom of bank elevations approximately 5-10 m upstream and downstream of the storm sewer outfall; and
- Ground shots at the edge of erosion scars and within the eroded areas.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

### 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on March 16th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-09 was advanced to a depth of 18.9 m below grade using a truck-mounted drill.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. In situ vane shear testing was carried out in the borehole to measure the undrained shear strength of the silty clay deposits. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

Fill material was encountered at the surface of the borehole, extending to 1.8 m below surface grade. The fill was variable but was described as brown sand and gravel to silty sand with trace asphaltic concrete. The fill material was underlain by native deposits of sandy silt (11 m thick), silty clay (5.8 m thick), and glacial till composed of grey sand and silt with gravel (extending to the termination depth of the borehole). Based on soil sample appearance, the groundwater level was estimated to be at approximately 12.2 m below surface grade at the time of the investigation.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 27 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 9 trees were

inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 6 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 27 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 831 | White Ash | *Fraxinus americana* | Fair |
| 832 | White Spruce | *Picea glauca* | Fair-Good |
| NT1 | Basswood | *Tilia americana* | Good |
| Bn1 | Butternut | *Juglans cinerea* | Good |
| NT2 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 833 | Sugar Maple | *Acer saccharum* | Good, Fair(12) |
| NT3 | White Spruce | *Picea glauca* | Good |
| NT4 | Manitoba Maple | *Acer negundo* | Fair |
| NT5 | Manitoba Maple | *Acer negundo* | Fair |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 27 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction should be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees should be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Slope Stabilization** – Slope erosion and failure should be restored by regrading to attain a natural long-term stable slope, followed by application of erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel bank are not compromised.

**Outlet Protection –** The design should consider appropriate protection to prevent erosion and scouring damage to the pipe, structures and associated channel works.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall 27 are provided under a separate cover. Due to the presence of an over-steepened slope (exceeding 1.4H:1V) between the upstream storm sewer and the Muskrat River, the design proposes to overcome most of the vertical gradient by installing three 1500 mm maintenance holes, each incorporating an internal 250 mm diam. PVC drop structure. The most upstream drop structure is specified to have a depth of ~5 m, while the two downstream drop structures are to be ~4 m deep.

PVC pipes having a diameter of 300 mm are to be used for connecting the maintenance holes and conveying stormwater to the river. The storm sewer outlet is to be located above water surface elevations that occur during frequent flow events within the Muskrat River. A short runoff channel consisting of 750 mm deep angular stone is to be constructed at the pipe outlet to prevent scouring near the confluence with the river. A concrete headwall is specified to mitigate erosion near the outlet pipe and prevent scouring of the slope, and to allow for a stable confluence of the outfall channel with the Muskrat River.

Specific elements of the design and construction include removing existing debris within the scarp and the failed 300 mm cast iron pipe protruding from the slope. The existing guard rail is to be removed prior to construction and relocated. The proposed maintenance holes and sewer pipes are to be backfilled and vegetated with native riparian seed mix, shrubs, and trees, which are intended to provide additional slope stability and resist erosion from overland flow during extreme storm events.

The reconstruction of Outfall 27 is to be co-ordinated with downstream slope restoration works (design and tender to be completed by others). Co-ordination between these projects will ensure a smooth transition between reconstructed slopes, and has the potential to increase construction efficiency (e.g., by undertaking construction works during the same timeframe).

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Muskrat River provides habitat to both spring and fall spawning species. As a major watercourse, the Muskrat River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

## 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 7 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Acer rubrum* | Red Maple | 3 | 5 gal. potted |
| *Acer saccharum* | Sugar Maple | 3 | 5 gal. potted |
| *Picea glauca* | White Spruce | 2 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 2 | 5 gal. potted |
| *Tilia americana* | Basswood | 2 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Amelanchier arborea* | Downy Juneberry | 8 | 2 gal. potted |
| *Cornus alternifolia* | Alternate-leaved Dogwood | 8 | 2 gal. potted |
| *Cornus racemosa* | Grey dogwood | 8 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 8 | 2 gal. potted |
| *Ribes hirtellum* | Smooth Gooseberry | 7 | 2 gal. potted |
| *Rubus odoratus* | Flowering Raspberry | 7 | 2 gal. potted |
| *Salix petiolaris* | Slender Willow | 7 | 2 gal. potted |
| *Sambucus racemosa* | Red-berried Elder | 7 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 9 live trees identified during the assessment (detailed previously in **Table 2-1**), 4 have been identified for removal. Trees identified for removal are listed in **Table 4-4** below and are shown on Sheet 6 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 5 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Trees Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 831 | White Ash | *Fraxinus americana* | Fair |
| NT1 | Basswood | *Tilia americana* | Good |
| NT4 | Manitoba Maple | *Acer negundo* | Fair |
| NT5 | Manitoba Maple | *Acer negundo* | Fair |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. As shown on Sheet 6 of the detailed design drawings, access routes and the staging and storage area are proposed within private property at 393 Moffat Street, for which an easement would be required. The reconstruction of Outfall 27 should be coordinated with downstream slope restoration works during the easement procurement process, as it may be possible to use the same easement on 393 Maffat Street for both projects. In all cases, an OLS should be retained to confirm property parcels and associated limits.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing

the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Muskrat River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access routes and the staging and storage area are shown on Sheet 6 of the drawing set. Access for construction is proposed from Moffat Street, passing through private property at 393 Moffat Street. The staging and storage area is also proposed to be located on 393 Moffat Street. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $647,520 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 27

| PEMBROKE OUTLETS - OUTLET # 27 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | $25,000 | $25,000 |
| **2** | Field Office | 1 | LS | $3,000 | $3,000 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $10,000 | $10,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $35,000 | $35,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $120,000 | $120,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $25,000 | $25,000 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 50 | m | $15 | $750 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $35,000 | $35,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of Concrete Headwall and Excess Pipe | 1 | LS | $10,000 | $10,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $268,750 |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $60,000 | $60,000 |
| **13** | Supply & Placement of Angular Channel Substrate | 25 | tonne | $200 | $5,000 |
| **14** | Supply & Placement of Concrete Headwall | 1 | ea | $15,000 | $15,000 |
| **14** | Supply & Placement of 300mm dia. PVC pipe including joint restraints | 30 | m | $2,500 | $75,000 |
| **15** | Supply & Placement of 1500mm dia. Maintenance Hole including 300mm dia. Drop pipe andWatertight Frame Cover | 3 | ea | $25,000 | $75,000 |
| **16** | Supply & Placement of Erosion Control Blanket - Coir Mat | 800 | $m^2$ | $8 | $6,400 |
| **17** | Supply & Placement of Topsoil for Restoration (300mm for terraseed area & 150mm for Sod) | 240 | $m^3$ | $50 | $12,000 |
| **18** | Supply & Application of Terraseed Mixture | 800 | $m^2$ | $8 | $6,400 |
| **19** | Supply & Application of Sod | 35 | $m^2$ | $10 | $350 |
| **20** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | ii) Red Maple | 3 | ea | $250 | $750 |
| | ii) Sugar Mapel | 3 | ea | $250 | $750 |
| | iii) White Spruce | 2 | ea | $250 | $500 |
| | iv) Eastern White Cedar | 2 | ea | $250 | $500 |
| | v) Basswood | 2 | ea | $250 | $500 |
| **21** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Grey Dogwood | 8 | ea | $45 | $360 |
| | ii) Chokecherry | 8 | ea | $45 | $360 |
| | iii) Alternate Leaved Dogwood | 8 | ea | $45 | $360 |
| | iv) Downy juneberry | 8 | ea | $45 | $360 |
| | v) Smooth Gooseberry | 7 | ea | $45 | $315 |
| | vi) Flowering Raspberry | 7 | ea | $45 | $315 |
| | vii) Slender Willow | 7 | ea | $45 | $315 |
| | iix) Red-berried Elder | 7 | ea | $45 | $315 |
| **Subtotal Section B (Excl of HST)** | | | | | $260,850 |

| | | | | | |
|---|---|---|---|---|---|
| **Section "C" – Provisional** | | | | | |
| **23** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **24** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $10,000 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **25** | Contingency (20%) | 1 | LS | $107,920 | $107,920 |
| **Subtotal Section D (Excl of HST)** | | | | | $107,920 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $268,750 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $260,850 |
| | Section "C" – Provisional | | | | $10,000 |
| | Section "D" – Contingency | | | | $107,920 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $647,520 |
| | HST @ 13% | | | | $84,178 |
| | Total Bid Price (Incl of taxes) | | | | $731,698 |
| | | | | | |
| | **Outlet # 27 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$647,520** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 31**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 31 as well as the Detailed Design of the proposed outfall reconstruction.

Outfall 31 extends off of Moffat Street, outletting into the Indian River (**Figure 1-1**). The storm sewer pipe has a diameter of 300 mm and is located approximately 140 m upstream of the confluence of Indian River with Muskrat River. Outfall 31 was identified to be in need of rehabilitation and was ranked as the 5th highest priority site, of the total 17 sites that were assessed.

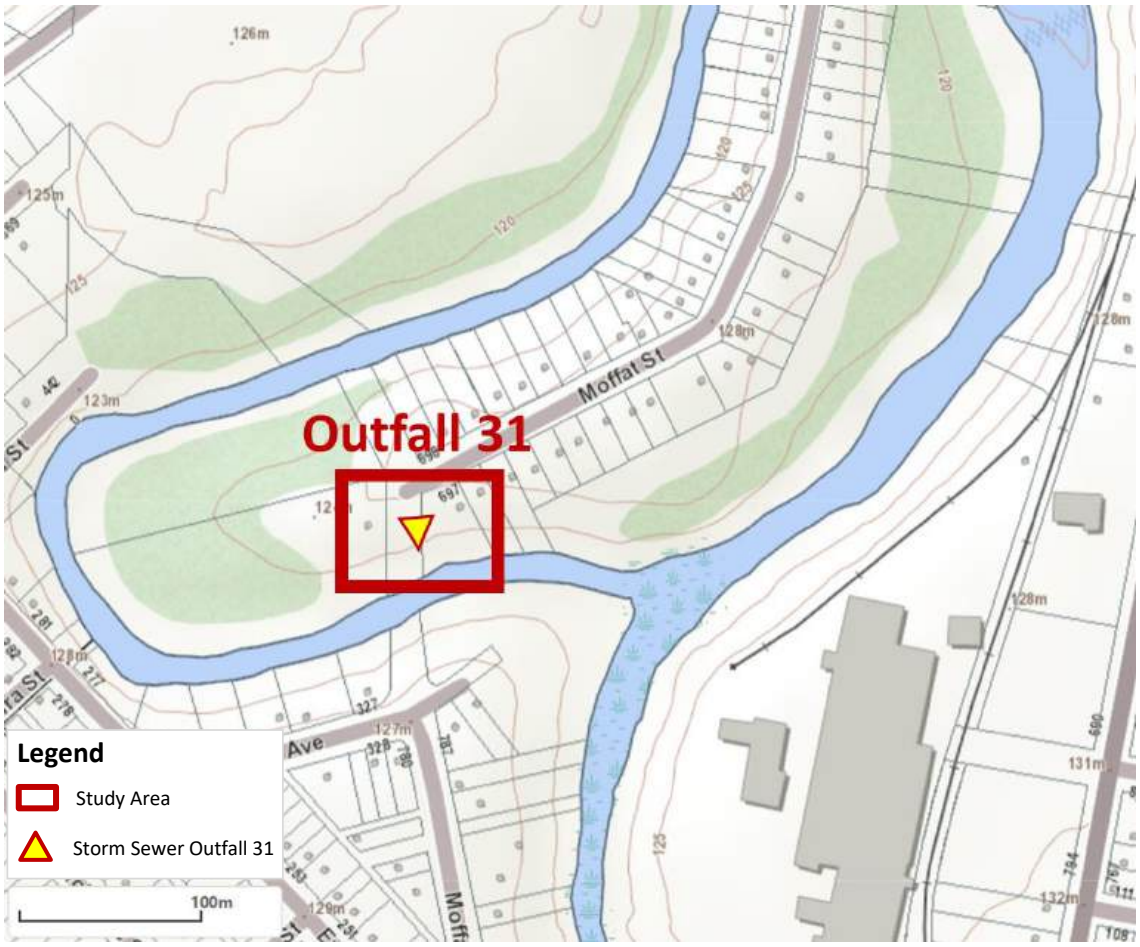



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 31**

## 2 EXISTING CONDITIONS

### 2.1 Overview

As can be seen in **Figure 2-1** and **Figure 2-2**, the existing outfall is composed of a 300 mm PVC pipe that discharges into a 525 mm CSP half-pipe extending past the bottom of bank and into the Indian River. The CSP is in poor condition, as one section downstream has been undermined, and another has become entirely detached (**Figure 2-3** and **Figure 2-4**). The CSP also displays evidence of rust corrosion, and bank erosion was noted beneath the pipe.

**Figure 2-1: PVC Pipe Outlet into the CSV Half-Pipe**

**Figure 2-2: CSV Half-Pipe**

**Figure 2-3: CSV Half-Pipe at the Edge of the Indian River (Looking Downstream)**

**Figure 2-4: CSV Half-Pipe at the Edge of the Indian River (Looking Upstream)**

## 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface along the PVC storm sewer pipe and CSP half-pipe, extending into the Indian River to capture streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, CSP half-pipe, headwall, etc.);
- Upstream maintenance hole lid and pipe invert;
- Top and bottom of bank elevations approximately 5-10 m upstream and downstream of the storm sewer outfall; and
- Ground shots at the edge of erosion scars and within the eroded areas.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

## 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on March 15th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-08 was advanced to a depth of 9.8 m below grade using a truck-mounted drill.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. In situ vane shear testing was carried out in the borehole to measure the undrained shear strength of the silty clay deposits. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

A 40 mm layer of asphaltic concrete was encountered at the surface, followed by a 200 mm layer of road base consisting of a brown crushed sand with gravel and some silt. Beneath the road base, a 1.9 m thick layer of fill was encountered, consisting of brown silty sand with trace clay. The fill material was underlain by native deposits of sand with some silt (2.8 m thick) and silty clay (extending to the termination depth of the borehole). Based on soil sample appearance, the groundwater level was estimated to be at approximately 4.3 m below surface grade at the time of the investigation.

## 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 31 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 12 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 5 in the

detailed design drawings shows the locations of the surveyed trees within the Outfall 31 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| NT1 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT2 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT3 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT4 | Siberian Elm | *Ulmus pumila* | Good |
| NT5 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT6 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT7 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT8 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT9 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT10 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT11 | Eastern White Cedar | *Thuja occidentalis* | Fair-Good |
| NT12 | White Ash | *Fraxinus americana* | Dead |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 31 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Slope Stabilization** – Slope erosion should be restored by regrading to attain a natural long-term stable slope, followed by application of erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel bank are not compromised.

**Outlet Protection –** The design should consider appropriate protection to prevent erosion and scouring damage to the pipe, structures and associated channel works.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall 31 are provided under a separate cover. Due to the presence of an existing steep slope (exceeding 2.2H:1V) between the PVC pipe outlet and the Indian River, the design proposes to overcome much of the vertical gradient by installing a 1500 mm maintenance hole incorporating an internal 2.5 m deep (250 mm diam.) PVC drop-structure that connects to a 300 mm PVC sewer pipe. Downstream of the proposed maintenance hole, the pipe outlet is to be located above water surface elevations that occur during frequent flow events within the Indian River. Flows exiting the sewer pipe are to be conveyed to the Indian River via a 12 m long outfall channel constructed with 750 mm deep angular stone. A concrete headwall is specified to mitigate erosion near the outlet pipe and prevent scouring of the slope, and to allow for a stable confluence of the outfall channel with the Indian River.

Other elements of the design and reconstruction include removing the existing CSP half pipe and 4 m of the existing PVC pipe. The proposed maintenance hole and sewer pipe are to be backfilled and vegetated with native upland seed mix and shrubs, which are intended to provide additional slope stability and resist erosion from overland flow during extreme storm events. A vegetated buttress having a total length of ~6 m is proposed in order to provide bank protection near the confluence of the outfall channel with the Indian River.

As an additional measure to deter failure of the storm sewer under potential bank erosion, it is proposed to install the 300 mm storm sewer with Class 150 PVC (DR-18) pipe, complete with mechanical joint restraints.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

No tree removals are anticipated for the restoration of Outfall 31. However, if any tree removals become necessary, they should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period. We note that for this site in particular, no tree removals are required and in turn this window restriction will not apply.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

## 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 6 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native shrubs within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1** and **Table 4-2**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Upland Mix (Application Rate: 25 kg/ha)** | | |
| *Asclepias syriaca* | Common Milkweed | 5% |
| *Clematis virginiana* | Virgin's Bower | 2% |
| *Fragaria virginiana* | Wild Strawberry | 3% |
| *Monarda fistulosa* | Wild Bergamot | 5% |
| *Panicum acuminatum (P.implicatum; P. lanuginosum)* | Hairy Panic Grass | 30% |
| *Rudbeckia hirta* | Black-eye Susan | 15% |
| *Solidago canadensis* | Canada Goldenrod | 8% |
| *Sporobolus cryptandrus* | Sand Dropseed | 30% |
| *Symphyotrichum cordifolium* | Heart-leaved Aster | 1% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| **Restoration Plantings** | | | |
| *Cornus rugosa* | Round-leaved Dogwood | 10 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 10 | 2 gal. potted |
| *Ribes hirtellum* | Smooth Gooseberry | 10 | 2 gal. potted |
| *Rubus ideaus* | Wild Red Raspberry | 10 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 10 | 2 gal. potted |
| **Vegetated Buttress Plantings** | | | |
| *Cornus sericea* | Red-osier Dogwood | 5 | 2 gal. potted |
| *Cornus rugosa* | Round-leaved Dogwood | 5 | 2 gal. potted |
| *Salix petiolaris* | Slender Willow | 5 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 5 | 2 gal. potted |
| *Viburnum lentago* | Nannyberry | 4 | 2 gal. potted |

No tree removals are planned during construction. However, shrub plantings at 1 m spacing are proposed to restore and stabilize portions of the slope that will be disturbed. A denser planting of shrubs at 0.5 m spacing is proposed overtop the vegetated buttress along the river bank, providing additional erosion protection to the bank.

### 4.3.1 Removal Timing Window and Protection Measures

No tree removals are planned during construction, and in turn no timing window restrictions will apply.

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 4 of the detailed design drawings, should be followed in order to mitigate against potential damages.

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. Any tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access for construction is proposed from Moffat Street. The access routes are shown on Sheet 5 of the drawing set. A staging and storage area has also been shown. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $226,148 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 31

| PEMBROKE OUTLETS - OUTLET # 31 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | | $0 |
| **2** | Field Office | 1 | LS | | $0 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $8,000 | $8,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $12,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $15,000 | $15,000 |
| **7** | Supply, Install & Remove Temporary Hoarding / Sediment Control Fence | 65 | m | $20 | $1,300 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 30 | m | $15 | $450 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $20,000 | $20,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of CSP Half Pipe, Excess Pipe | 1 | LS | $8,000 | $8,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $77,750 |
| | | | | | |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $10,000 | $10,000 |
| **13** | Supply & Placement of 300mm dia. PVC pipe | 10.6 | m | $1,800 | $19,080 |
| **14** | Supply & Placement of 250mm dia. PVC drop pipe | 6 | m | $1,650 | $9,900 |
| **15** | Supply & Placement of 1200mm dia. Maintenance Hole including Watertight Frame Cover | 1 | ea | $15,000 | $15,000 |
| **16** | Supply & Placement of Concrete Headwall | 1 | ea | $10,000 | $10,000 |
| **17** | Supply & Placement of Angular Channel Substrate | 55 | tonne | $200 | $11,000 |
| **18** | Supply & Placement of Vegetated Buttress | | | | |
| | Roundtstone as specified | 45 | tonne | $200 | $9,000 |
| | Topsoil to enhance vegetation | 10 | $m^3$ | $50 | $500 |
| | Stock Plantings (2 gal potted @ 0.5 spacing) | | | | |
| | i) Red-osier Dogwood | 5 | ea | $45 | $225 |
| | ii) Round Leaved Dogwood | 5 | ea | $45 | $225 |
| | iii) Slender Willow | 5 | ea | $45 | $225 |
| | iv) Nannyberry | 4 | ea | $45 | $180 |
| | v) Narrow-Leaved Meadowsweet | 5 | ea | $45 | $225 |
| **19** | Supply & Placement of Erosion Control Blanket - Coir Mat | 155 | $m^2$ | $8 | $1,240 |
| **20** | Supply & Placement of Topsoil for Restoration (300mm) | 50 | $m^3$ | $50 | $2,500 |
| **21** | Supply & Application of Terraseed Mixture (Upland) | 100 | $m^2$ | $8 | $800 |
| **22** | Supply & Application of Terraseed Mixture(Riparian) | 55 | $m^2$ | $8 | $440 |
| **23** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Round Leaved Dogwood | 10 | ea | $45 | $450 |
| | ii) Chokecherry | 10 | ea | $45 | $450 |
| | iii) Smooth Gooseberry | 10 | ea | $45 | $450 |
| | iv) Wild Red Raspberry | 10 | ea | $45 | $450 |
| | v) Narrow-Leaved Meadowsweet | 10 | ea | $45 | $450 |
| **Subtotal Section B (Excl of HST)** | | | | | $92,790 |

| | | | | | |
|---|---|---|---|---|---|
| **Section "C" – Provisional** | | | | | |
| **24** | Full Road Repair (Removal, Granular Placement, New Asphalt, Buffer Restoration) | 65 | $m^2$ | $250 | $16,250 |
| **25** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **26** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $26,250 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **27** | Contingency (20%) | 1 | LS | $39,358 | $39,358 |
| **Subtotal Section D (Excl of HST)** | | | | | $39,358 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $77,750 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $92,790 |
| | Section "C" – Provisional | | | | $26,250 |
| | Section "D" – Contingency | | | | $39,358 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $236,148 |
| | HST @ 13% | | | | $30,699 |
| | Total Bid Price (Incl of taxes) | | | | $266,847 |
| | | | | | |
| | **Outlet # 31 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$236,148** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 35**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 35 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 35 are shown in **Figure 1-1**. The outfall consists of a series of disconnected box culverts and concrete pipe segments that convey water from ditches upstream of a decommissioned road to a scour pool, which is connected to a 20 m long outfall channel that discharges into Muskrat River, approximately 35 m upstream of Boundary Road. The decommissioned road runs parallel to Upper Valley Drive and connects Boundary Road East to the backlot of O'Kenny Craft Spirits off of International Drive. Outfall 35 was identified to be in need of rehabilitation and was ranked as the 3rd highest priority site, of the total 17 sites that were assessed.

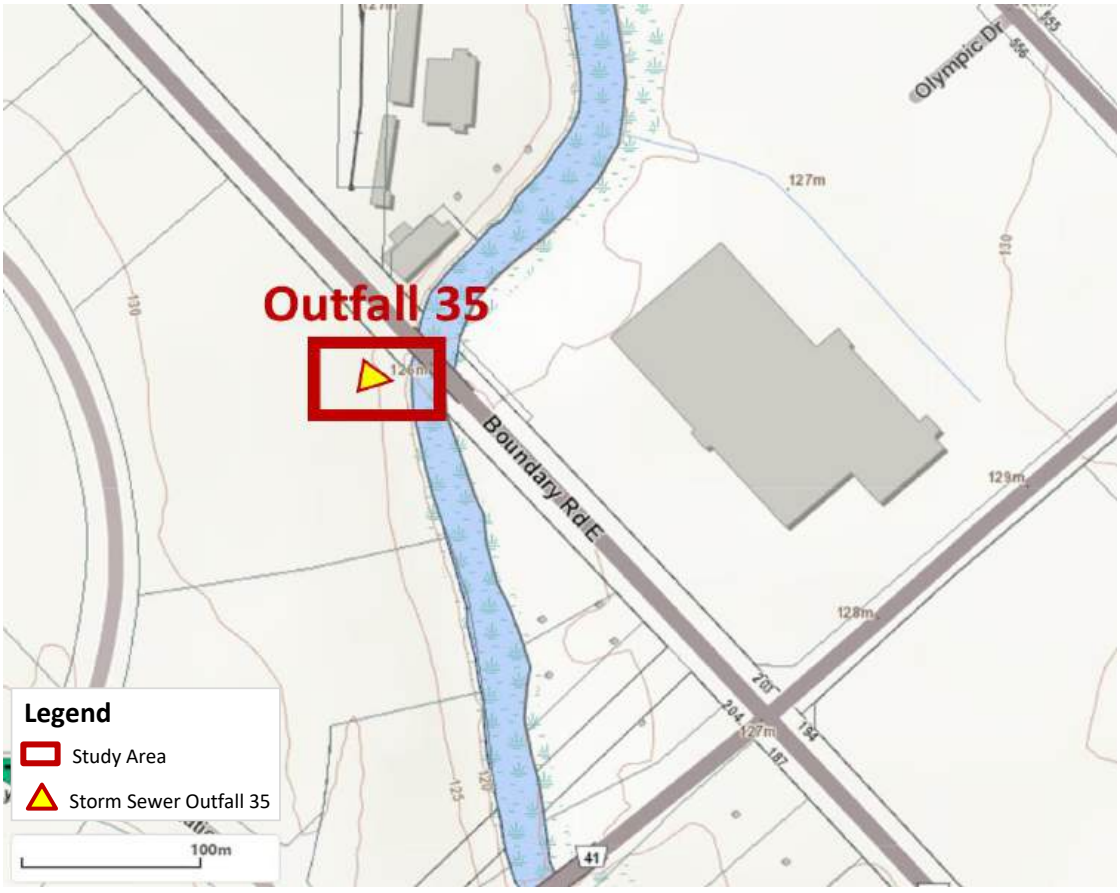



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 35**

# 2 EXISTING CONDITIONS

## 2.1 Overview

The assessment of Outfall 35 revealed that water is collected from upstream ditches by a concrete box culvert (Box Culvert #1, **Figure 2-1**) that is in fair condition and passes under a decommissioned asphalt road. On the downstream side of the road, it appears that both the box culvert and a ditch were intended to feed into a second concrete box culvert (Box Culvert #2, **Figure 2-2**), which is now severely deteriorated and segmented, causing water to flow around it. Water then passes into a series of disconnected 1050 mm concrete pipe segments (**Figure 2-3**), before discharging into a scour pool (**Figure 2-4**) that connects to the Muskrat River via a 20 m long outfall channel. Based on the observed existing conditions, it is unclear whether Box Culvert #2 and the concrete pipe were initially connected or simply joined by an open-air channel. Channel gradient is high throughout the study area, having an average of 10% between the outlet of Box Culvert 1 and the scour pool.

**Figure 2-1: Box Culvert under the Asphalt Road (Box Culvert #1)**

**Figure 2-2: Failed Box Culvert (Box Culvert #2)**

**Figure 2-3: Concrete Pipe Segments**

**Figure 2-4: Scour Pool**

### 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface above and surrounding the culverts and pipe segments, extending ~5 m past the outlet of the scour pool;
- Thalweg of the channel between disconnected culvert and pipe segments;
- Any visible storm sewer infrastructure near the outlet (inverts and obverts, top of culvert and pipe segments, etc.);
- Cross sections and thalweg shots of ditches that feed into the culverts; and
- Ground shots at the edge of erosion scars and within the eroded areas.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

### 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on February 14th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, as well as make recommendations regarding channel bank stabilization measures. One (1) borehole designated as 22-02 was advanced to a depth of 4.9 m below grade using portable drilling equipment.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

Fill material was encountered at the surface of the borehole, extending to 1.4 m below surface grade. The fill consisted of 200 mm of gravelly sand over brown silty clay fill with trace sand. The fill material was underlain by native deposits of silty clay, extending to the termination depth of the borehole. Based on soil sample appearance, the groundwater level was estimated to be at approximately 3.0 m below surface grade at the time of the investigation.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 35 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 8 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 6 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 35 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 860 | White Spruce | *Picea glauca* | Good |
| 861 | White Pine | *Pinus strobus* | Good |
| 862 | White Ash | *Fraxinus americana* | Fair |
| 863 | Black Ash | *Fraxinus nigra* | Fair-Good |
| 864 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 865 | White Pine | *Pinus strobus* | Good |
| NT1 | Common Apple | *Malus spp.* | Fair |
| NT2 | Willow sp. | *Salix spp.* | Good |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 35 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Channel Bank Stabilization** – Toe erosion and slope failures along the outfall channel should be restored by regrading to attain a long-term stable slope, followed by the application of channel bank and toe erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel banks are not compromised.

## 4 DETAILED DESIGN

### 4.1 Principal Design Components

Detailed design drawings for Outfall 35 are provided under a separate cover. The proposed design consists of restoring the outfall channel using a series of cascades and pools, allowing for a more gradual bed level change

than that achieved across the existing channel bed and deteriorated conveyance structures. This approach was selected over riffle-pool morphology because the gradient between the upstream and downstream tie-in points is 10%, whereas engineered riffle slopes do not usually exceed 3%.

Specific elements of the design and construction include removing the existing deteriorated and segmented concrete box culvert (Box Culvert 2) and sewer pipe. The proposed works will include substantial amounts of cutting in order to provide a more uniform channel gradient. Bank slopes are to be regraded and vegetated with native riparian seed mix, shrubs, and trees, which are intended to provide additional slope stability and resist erosion from overland flow during extreme storm events.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Muskrat River provides habitat to both spring and fall spawning species. As a major watercourse, the Muskrat River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

### 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 7 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Acer saccharum* | Sugar Maple | 3 | 5 gal. potted |
| *Picea glauca* | White Spruce | 3 | 5 gal. potted |
| *Pinus strobus* | White Pine | 2 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 2 | 5 gal. potted |
| *Tilia americana* | Basswood | 2 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Amelanchier arborea* | Downy Juneberry | 10 | 2 gal. potted |
| *Cornus alternifolia* | Alternate-leaved Dogwood | 10 | 2 gal. potted |
| *Cornus rugosa* | Round-leaved Dogwood | 10 | 2 gal. potted |
| *Lonicera canadensis* | Northern Fly Honeysuckle | 10 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 10 | 2 gal. potted |
| *Ribes hirtellum* | Smooth Gooseberry | 10 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 8 live trees identified during the assessment (detailed previously in **Table 2-1**), 4 have been identified for removal. Trees identified for removal are listed in **Table 4-4** below and are shown on Sheet 6 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 5 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Trees Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 860 | White Spruce | *Picea glauca* | Good |
| 862 | White Ash | *Fraxinus americana* | Fair |
| NT1 | Common Apple | *Malus spp.* | Fair |
| NT2 | Willow sp. | *Salix spp.* | Good |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on

requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Muskrat River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access for construction is proposed from Boundary Road East through the decommissioned asphalt road. The access routes are shown on Sheet 6 of the drawing set. A staging and storage area has also been shown. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $263,100 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 35

| PEMBROKE OUTLETS - OUTLET # 35 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | | $0 |
| **2** | Field Office | 1 | LS | | $0 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $8,000 | $8,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $15,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $25,000 | $25,000 |
| **7** | Supply, Install & Remove Temporary Erosion & Sediment Control Fence | 100 | m | $20 | $2,000 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 32 | m | $15 | $480 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $20,000 | $20,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of Concrete Headwalls and Concrete Sewer Pipe | 1 | LS | $20,000 | $20,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $100,480 |
| | | | | | |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $15,000 | $15,000 |
| **17** | Supply & Placement of Angular Channel Substrate | 120 | tonne | $200 | $24,000 |
| **17** | Supply & Placement of Boulder Ribs (Boulder size 1mx1mx1m) | 90 | tonne | $235 | $21,150 |
| **19** | Supply & Placement of Erosion Control Blanket - Coir Mat | 370 | $m^2$ | $8 | $2,960 |
| **20** | Supply & Placement of Topsoil for Restoration (300mm) | 110 | $m^3$ | $50 | $5,500 |
| **21** | Supply & Application of Terraseed Mixture | 370 | $m^2$ | $8 | $2,960 |
| **23** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | i) Sugar Maple | 3 | ea | $250 | $750 |
| | ii) White Spruce | 3 | ea | $250 | $750 |
| | iii) White Pine | 2 | ea | $250 | $500 |
| | iv) Eastern White Cedar | 2 | ea | $250 | $500 |
| | v) Basswood | 2 | ea | $250 | $500 |
| **23** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Round Leaved Dogwood | 10 | ea | $45 | $450 |
| | ii) Chokecherry | 10 | ea | $45 | $450 |
| | iii) Smooth Gooseberry | 10 | ea | $45 | $450 |
| | iv) Alternate-Leaved Dogwood | 10 | ea | $45 | $450 |
| | v) Downy juneberry | 10 | ea | $45 | $450 |
| | vi) Northern Fly Honeysuckle | 10 | ea | $45 | $450 |
| **Subtotal Section B (Excl of HST)** | | | | | $77,270 |

| | | | | | |
|---|---|---|---|---|---|
| **Section "C" – Provisional** | | | | | |
| **24** | Asphalt Road Repair (Removal, Granular Placement, New Asphalt, Buffer Restoration) | 126 | $m^2$ | $250 | $31,500 |
| **25** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **26** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $41,500 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **27** | Contingency (20%) | 1 | LS | $43,850 | $43,850 |
| **Subtotal Section D (Excl of HST)** | | | | | $43,850 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $100,480 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $77,270 |
| | Section "C" – Provisional | | | | $41,500 |
| | Section "D" – Contingency | | | | $43,850 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $263,100 |
| | HST @ 13% | | | | $34,203 |
| | Total Bid Price (Incl of taxes) | | | | $297,303 |
| | | | | | |
| | **Outlet # 35 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$263,100** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 41**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 41 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 41 are shown in **Figure 1-1**. The outfall pipe has a diameter of 600 mm and extends off of Eganville Road, outletting into the Indian River, immediately downstream of the Eganville Road bridge crossing. Outfall 41 was identified to be in need of rehabilitation and was ranked as the 2nd highest priority site, of the total 17 sites that were assessed.

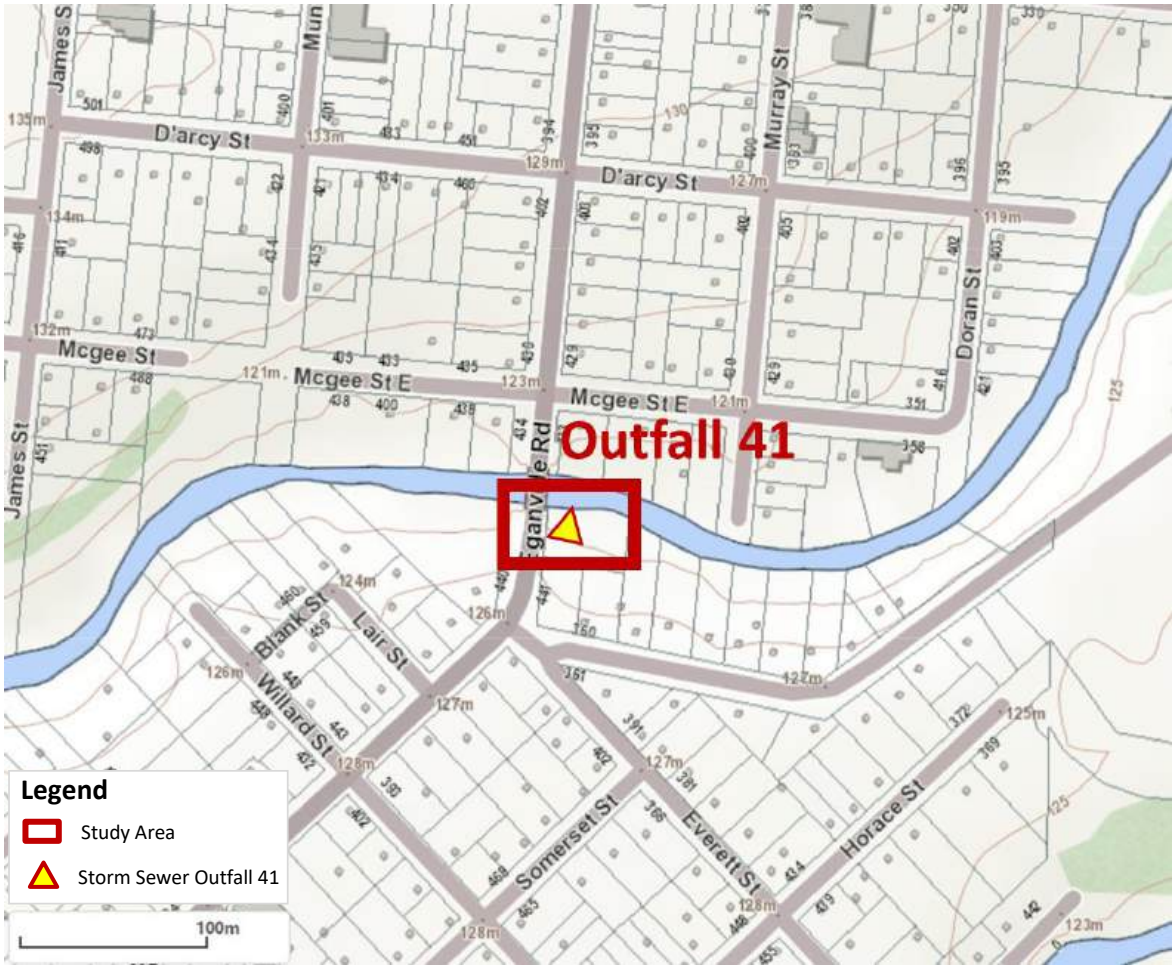



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 41**

## 2 EXISTING CONDITIONS

### 2.1 Overview

The assessment of Outfall 41 revealed that it has been outflanked and is in critical condition (**Figure 2-1** and **Figure 2-2**). The concrete headwall and 600 mm sewer pipe have been undermined, which appears to have caused settling of the outfall structure, thereby placing stress on the concrete pipe. Two points of failure were noted along the concrete pipes: a 1" wide crack along the exposed outlet pipe that was leaking water (**Figure 2-3**), and a 1" wide gap between two pipe segments (**Figure 2-4**).

**Figure 2-1: Outflanked Outlet Pipe**

**Figure 2-2: View of Outfall 41 Looking Downstream**

**Figure 2-3: Cracked Concrete Pipe**

**Figure 2-4: Disconnected Pipe Segments**

### 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface above the storm sewer pipe, extending into the Indian River to capture streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, exposed pipe, headwall, etc.);
- Upstream maintenance hole lid and pipe inverts;
- Top and bottom of bank elevations approximately 5-10 m upstream and downstream of the storm sewer outfall; and
- Ground shots beside the exposed pipe, i.e., within eroded areas.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

### 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on February 11th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-01 was advanced to a depth of 4.3 m below grade using portable drilling equipment.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

A 75 mm thick topsoil layer was encountered at the ground surface, followed by a 1 m layer of fill material composed of brown sand and silt with trace gravel. The fill material was underlain by native deposits of sand with silt (2.1 m thick) and silty clay (extending to the termination depth of the borehole). Based on soil sample appearance, the groundwater level was estimated to be at approximately 2.1 m below surface grade at the time of the investigation.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 41 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 15 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 5 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 41 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 846 | Manitoba Maple | *Acer negundo* | Good |
| 847 | Manitoba Maple | *Acer negundo* | Fair |
| 848 | Manitoba Maple | *Acer negundo* | Fair-Poor |
| 849 | Manitoba Maple | *Acer negundo* | Fair |
| 850 | Manitoba Maple | *Acer negundo* | Good, Fair(23), Fair-Poor(26) |
| 851 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 852 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 853 | White Ash | *Fraxinus americana* | Good |
| 854 | White Ash | *Fraxinus americana* | Good |
| 855 | Manitoba Maple | *Acer negundo* | Fair-Poor |
| 856 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 857 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 858 | Manitoba Maple | *Acer negundo* | Fair-Poor |
| 859 | Manitoba Maple | *Acer negundo* | Fair-Good |
| NT1 | Manitoba Maple | *Acer negundo* | Fair |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 41 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Channel Bank Stabilization** – Toe erosion and slope failures should be restored by regrading to attain a natural long-term stable slope, followed by the application of channel bank and toe erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel banks are not compromised.

**Outlet Protection –** The design should consider appropriate protection to prevent erosion and scouring damage to the pipe, structures and associated channel works.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall 41 are provided under a separate cover. The proposed design consists of removing the 5 m portion of exposed concrete pipe and the existing headwall, such that the outlet is recessed from the Indian River. A new concrete headwall is proposed to mitigate erosion near the outlet pipe and prevent scouring of the slope, and to allow for a stable confluence of the outfall channel with the Indian River.

Additional erosion protection works include a 5 m long rip-rap lined scour pool between the outlet and the Indian River. Furthermore, a vegetated buttress having a total length of ~13 m is proposed to provide bank protection near the outfall and to prevent exposure of the remaining sewer pipe.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

## 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 6 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |

| | | |
|---|---|---|
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Picea glauca* | White Spruce | 5 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 5 | 5 gal. potted |
| *Tilia americana* | Basswood | 5 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| **Restoration Plantings** | | | |
| *Amelanchier arborea* | Downy Juneberry | 15 | 2 gal. potted |
| *Cornus rugosa* | Round-leaved Dogwood | 15 | 2 gal. potted |
| *Lonicera canadensis* | Northern Fly Honeysuckle | 15 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 15 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 15 | 2 gal. potted |
| **Vegetated Buttress Plantings** | | | |
| *Cornus sericea* | Red-osier Dogwood | 8 | 2 gal. potted |
| *Salix petiolaris* | Slender Willow | 8 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 8 | 2 gal. potted |
| *Viburnum lentago* | Nannyberry | 8 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 15 live trees identified during the assessment (detailed previously in **Table 2-1**), 10 have been identified for removal. Trees identified for removal are listed in **Table 4-4** below and are shown on Sheet 5 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 4 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Trees Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 846 | Manitoba Maple | *Acer negundo* | Good |
| 847 | Manitoba Maple | *Acer negundo* | Fair |
| 848 | Manitoba Maple | *Acer negundo* | Fair-Poor |
| 852 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 853 | White Ash | *Fraxinus americana* | Good |
| 854 | White Ash | *Fraxinus americana* | Good |
| 855 | Manitoba Maple | *Acer negundo* | Fair-Poor |
| 856 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 857 | Manitoba Maple | *Acer negundo* | Fair-Good |
| NT1 | Manitoba Maple | *Acer negundo* | Fair |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species

or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water

around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access for construction is proposed from Eganville Road. The access routes are shown on Sheet 5 of the drawing set. A staging and storage area has also been shown. A section of the guard rail along Eganville Road is to be removed prior construction to facilitate site access, and is to be replaced upon completion of construction. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $220,386 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 41

| PEMBROKE OUTLETS - OUTLET # 41 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | | $0 |
| **2** | Field Office | 1 | LS | | $0 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $10,000 | $10,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $20,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $25,000 | $25,000 |
| **7** | Supply, Install & Remove Temporary Erosion & Sediment Control Fence | 65 | m | $20 | $1,300 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 60 | m | $15 | $900 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $15,000 | $15,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of Concrete Headwall and Excess Pipe | 1 | LS | $20,000 | $20,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $97,200 |
| | | | | | |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $10,000 | $10,000 |
| **13** | Supply & Placement of Angular Channel Substrate | 35 | tonne | $200 | $7,000 |
| **14** | Supply & Placement of Concrete Headwall | 1 | ea | $12,000 | $12,000 |
| **15** | Supply & Placement of Vegetated Buttress | | | | |
| | Roundtstone as specified | 75 | tonne | $200 | $15,000 |
| | Topsoil to enhance vegetation | 15 | $m^3$ | $50 | $750 |
| | Stock Plantings (2 gal potted @ 0.5 spacing) | | | | |
| | i) Red-osier Dogwood | 8 | ea | $45 | $360 |
| | ii) Slender Willow | 8 | ea | $45 | $360 |
| | iii) Nannyberry | 8 | ea | $45 | $360 |
| | iv) Narrow-Leaved Meadowsweet | 8 | ea | $45 | $360 |
| **16** | Supply & Placement of Erosion Control Blanket - Coir Mat | 90 | $m^2$ | $8 | $720 |
| **17** | Supply & Placement of Topsoil for Restoration (300mm for terraseed area & 150mm for Sod) | 75 | $m^3$ | $50 | $3,750 |
| **18** | Supply & Application of Terraseed Mixture | 90 | $m^2$ | $8 | $720 |
| **19** | Supply & Application of Sod | 295 | $m^2$ | $10 | $2,950 |
| **20** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | ii) White Spruce | 5 | ea | $250 | $1,250 |
| | ii) Eastern White Cedar | 5 | ea | $250 | $1,250 |
| | iii) Basswood | 5 | ea | $250 | $1,250 |
| **21** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Round Leaved Dogwood | 15 | ea | $45 | $675 |
| | ii) Chokecherry | 15 | ea | $45 | $675 |
| | iii) Narrow-Leaved Meadowsweet | 15 | ea | $45 | $675 |
| | iv) Downy juneberry | 15 | ea | $45 | $675 |
| | v) Northern Fly Honeysuckle | 15 | ea | $45 | $675 |
| **Subtotal Section B (Excl of HST)** | | | | | $61,455 |

| | | | | | |
|---|---|---|---|---|---|
| **Section "C" – Provisional** | | | | | |
| **22** | Replace/ Repair Concrete Sidewalk, Curb & Sod | 1 | LS | $15,000 | $15,000 |
| **23** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **24** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $25,000 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **25** | Contingency (20%) | 1 | LS | $36,731 | $36,731 |
| **Subtotal Section D (Excl of HST)** | | | | | $36,731 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $97,200 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $61,455 |
| | Section "C" – Provisional | | | | $25,000 |
| | Section "D" – Contingency | | | | $36,731 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $220,386 |
| | HST @ 13% | | | | $28,650 |
| | Total Bid Price (Incl of taxes) | | | | $249,036 |
| | | | | | |
| | **Outlet # 41 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$220,386** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 42**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 42 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 42 are shown in **Figure 1-1**. The storm sewer has a diameter of 600 mm that extends off of Everett Street, outletting into a 30 m long outfall channel that discharges into an outside bend of the Indian River, approximately 410 m upstream of the confluence with the Muskrat River. Outfall 42 was identified to be in need of rehabilitation and was ranked as the 7th highest priority site, of the total 17 sites that were assessed.

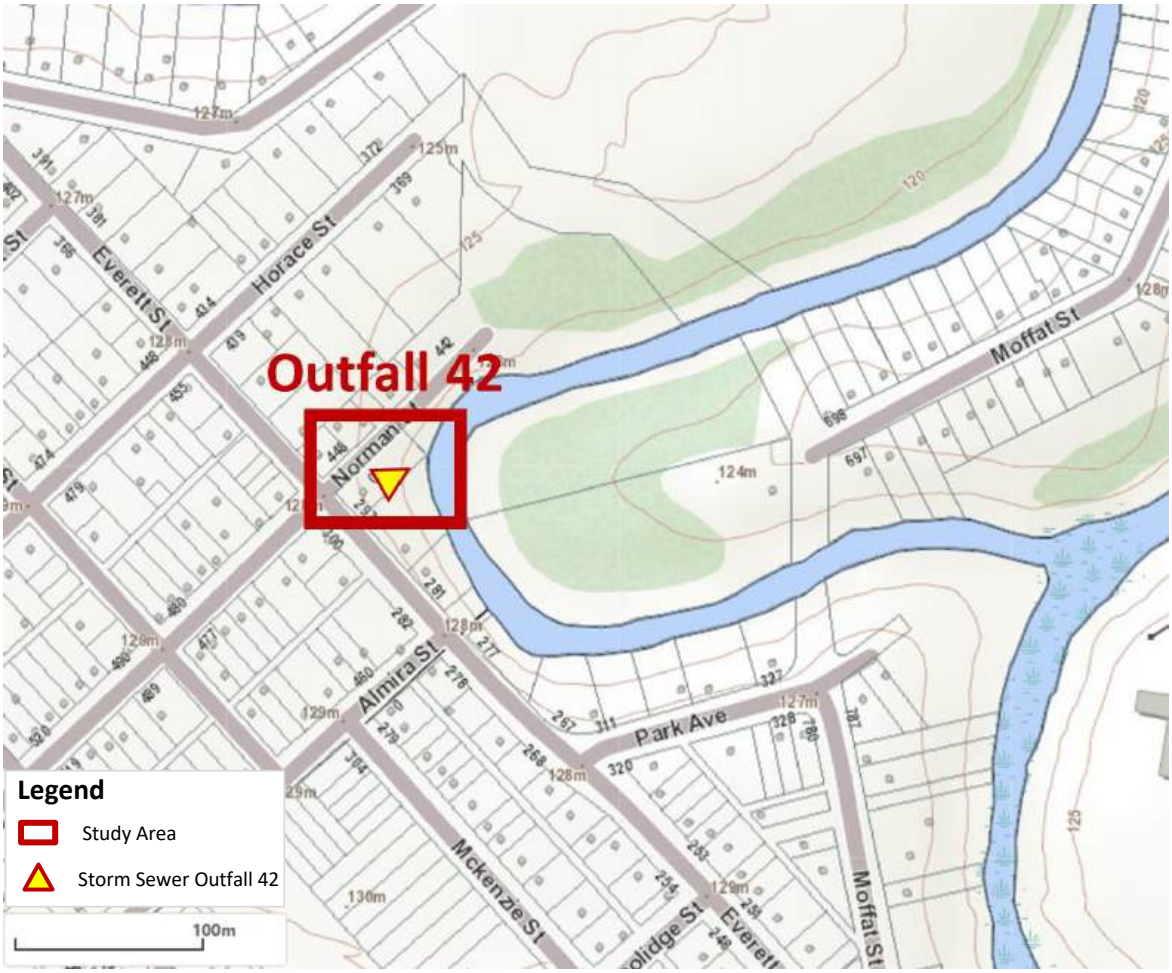



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 42**

## 2 EXISTING CONDITIONS

### 2.1 Overview

The existing outfall structure consists of a 600 mm concrete sewer pipe, a concrete headwall, and failed concrete wingwalls (**Figure 2-1**). The sewer pipe outlets into a 30 m long outfall channel (**Figure 2-2**), with substantial bank erosion and downcutting noted at the downstream extents of the channel (**Figure 2-3** and **Figure 2-4**). Channel gradient is very high throughout the study area, having an average of 19% between the outlet and the Indian River.

**Figure 2-1: Concrete Pipe Outlet with Headwall and Failed Wingwalls**

**Figure 2-2: Outlet and Upstream Extents of the Outfall Channel**

**Figure 2-3: Erosion at the Downstream Extents of the Outfall Channel (Looking Downstream)**

**Figure 2-4: Erosion at the Downstream Extents of the Outfall Channel (Looking Upstream)**

### 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface above the storm sewer pipe;
- Survey points to characterize the outfall channel (cross-sections, thalweg, top-of-bank, etc.), extending into the Indian River to capture streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, headwall, etc.);
- Top and bottom of bank elevations along the Indian River, extending approximately 5-10 m upstream and downstream of the confluence with the outfall channel; and
- Additional ground shots within the outfall channel to capture erosion.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

### 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on February 16th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-04 was advanced to a depth of 10.2 m below grade portable drilling equipment.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. In situ vane shear testing was carried out in the borehole to measure the undrained shear strength of the silty clay deposits. Dynamic cone penetration testing (DCPT) was also carried out in this borehole. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

Fill material was encountered at the surface of the borehole, extending to 1.2 m below surface grade. The fill consisted of dark brown sand and silt with some gravel. The fill material was underlain by native deposits of clayey sand (1.8 m thick), clayey silt (1.8 m thick), silty clay (1.5 m thick), and glacial till primarily composed of clayey sand and silt with some gravel (extending to the sampling termination depth at 7.0 m below surface grade). The borehole was further advanced by means of a DCPT and terminated at a depth of about 10.2 m due to refusal within the inferred glacial till on cobbles or boulders. Blow counts recorded during the DCPT test ranged from 14 to 58 blows per 300 mm. Based on soil sample appearance, the groundwater level was estimated to be at approximately 4.9 m below surface grade at the time of the investigation.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 42 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 11 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 6 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 42 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 835 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 836 | Manitoba Maple | *Acer negundo* | Good |
| 837 | Manitoba Maple | *Acer negundo* | Good |
| 838 | Manitoba Maple | *Acer negundo* | Good |
| 839 | Manitoba Maple | *Acer negundo* | Fair |
| 840 | Manitoba Maple | *Acer negundo* | Good |
| 841 | Manitoba Maple | *Acer negundo* | Good |
| 842 | Manitoba Maple | *Acer negundo* | Good |
| 843 | White Ash | *Fraxinus americana* | Fair |
| 844 | White Elm | *Ulmus americana* | Good |
| 845 | White Ash | *Fraxinus americana* | Fair-Good(26), Fair(20) |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 42 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Channel Bank Stabilization** – Toe erosion and slope failures should be restored by regrading to attain a natural long-term stable slope, followed by the application of channel bank and toe erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel banks are not compromised.

**Outlet Protection –** The design should consider appropriate protection to prevent erosion and scouring damage to the pipe, structures and associated channel works.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall 42 are provided under a separate cover. Due to the presence of a very high gradient (19%) between the existing outlet and the Indian River, the design proposes to reduce stormwater velocity by extending the storm sewer with 600 mm PVC pipes and incorporating a 1500 mm maintenance hole with an internal 8.5 m deep (300 mm diam.) PVC drop structure. A second maintenance hole having a diameter of 1200 mm is also proposed 7 m downstream of the first maintenance hole. A 3 m wide swale lined with rip-rap is to be constructed overtop the proposed pipe extension, with the intent of directing accumulated overland flow into the Indian River and protecting the sewer infrastructure from erosion.

The pipe outlet is to be located above water surface elevations that occur during frequent flow events within the Indian River. A 12 m long runoff channel consisting of 750 mm deep angular stone is to be constructed at the pipe outlet to prevent scouring near the confluence with the river. In addition, a concrete headwall is specified to mitigate erosion near the outlet pipe and prevent scouring of the slope, and to allow for a stable confluence of the outfall channel with the Indian River.

Specific elements of the design and construction include removing the existing concrete headwall and 4.6 m of the storm pipe to enable. Slopes along the existing outfall channel are to be regraded and vegetated with native riparian seed mix, trees, and shrubs, which are intended to provide additional slope stability and resist erosion from overland flow during extreme storm events. A vegetated buttress having a total length of ~8 m is proposed in order to provide bank protection near the confluence of the runoff channel with the Indian River.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

## 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 7 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Acer rubrum* | Red Maple | 6 | 5 gal. potted |
| *Quercus macrocarpa* | Bur Oak | 6 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 6 | 5 gal. potted |
| *Tilia americana* | Basswood | 6 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| **Restoration Plantings** | | | |
| *Amelanchier arborea* | Downy Juneberry | 18 | 2 gal. potted |
| *Cornus alternifolia* | Alternate-leaved Dogwood | 18 | 2 gal. potted |
| *Cornus rugosa* | Round-leaved Dogwood | 18 | 2 gal. potted |
| *Lonicera canadensis* | Northern Fly Honeysuckle | 18 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 16 | 2 gal. potted |
| *Rubus ideaus* | Wild Red Raspberry | 16 | 2 gal. potted |
| *Sambucus racemosa* | Red-berried Elder | 16 | 2 gal. potted |
| **Vegetated Buttress Plantings** | | | |
| *Cornus sericea* | Red-osier Dogwood | 5 | 2 gal. potted |
| *Salix petiolaris* | Slender Willow | 5 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 5 | 2 gal. potted |
| *Viburnum lentago* | Nannyberry | 5 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 11 live trees identified during the assessment (detailed previously in **Table 2-1**), 8 have been identified for removal. Trees identified for removal are listed in **Table 4-4** below and are shown on Sheet 6 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 5 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Trees Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 835 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 836 | Manitoba Maple | *Acer negundo* | Good |
| 837 | Manitoba Maple | *Acer negundo* | Good |
| 839 | Manitoba Maple | *Acer negundo* | Fair |
| 842 | Manitoba Maple | *Acer negundo* | Good |
| 843 | White Ash | *Fraxinus americana* | Fair |
| 844 | White Elm | *Ulmus americana* | Good |
| 845 | White Ash | *Fraxinus americana* | Fair-Good(26), Fair(20) |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access routes are shown on Sheet 6 of the drawing set, along with a staging and storage area. Access for construction is proposed from Everett Street, which will require temporary lane closure. A cedar hedge is to be removed prior construction to facilitate site access. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting.

If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $460,230 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 42

| PEMBROKE OUTLETS - OUTLET # 42 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | $12,000 | $12,000 |
| **2** | Field Office | 1 | LS | $3,000 | $3,000 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $10,000 | $10,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $20,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $25,000 | $25,000 |
| **7** | Supply, Install & Remove Temporary Erosion & Sediment Control Fence | 90 | m | $20 | $1,800 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 25 | m | $15 | $375 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $15,000 | $15,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of Concrete Headwall and Excess Pipe | 1 | LS | $15,000 | $15,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $107,175 |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $40,000 | $40,000 |
| **13** | Supply & Placement of Angular Channel Substrate | 320 | tonne | $200 | $64,000 |
| **14** | Supply & Placement of Concrete Headwall | 1 | ea | $15,000 | $15,000 |
| **14** | Supply & Placement of 600mm dia. PVC pipe including joint restraints | 25.7 | m | $2,500 | $64,250 |
| **15** | Supply & Placement of 1200mm dia. Maintenance Hole including Watertight Frame Cover | 1 | ea | $15,000 | $15,000 |
| **15** | Supply & Placement of 1500mm dia. Maintenance Hole including 300mm dia. Drop pipe andWatertight Frame Cover | 1 | ea | $25,000 | $25,000 |
| **15** | Supply & Placement of Vegetated Buttress | | | | |
| | Roundtstone as specified | 50 | tonne | $200 | $10,000 |
| | Topsoil to enhance vegetation | 10 | $m^3$ | $50 | $500 |
| | Stock Plantings (2 gal potted @ 0.5 spacing) | | | | |
| | i) Red-osier Dogwood | 5 | ea | $45 | $225 |
| | ii) Slender Willow | 5 | ea | $45 | $225 |
| | iii) Nannyberry | 5 | ea | $45 | $225 |
| | iv) Narrow-Leaved Meadowsweet | 5 | ea | $45 | $225 |
| **16** | Supply & Placement of Erosion Control Blanket - Coir Mat | 125 | $m^2$ | $8 | $1,000 |
| **17** | Supply & Placement of Topsoil for Restoration (300mm for terraseed area & 150mm for Sod) | 55 | $m^3$ | $50 | $2,750 |
| **18** | Supply & Application of Terraseed Mixture | 125 | $m^2$ | $8 | $1,000 |
| **19** | Supply & Application of Sod | 55 | $m^2$ | $10 | $550 |
| **20** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | ii) Red Maple | 6 | ea | $250 | $1,500 |
| | ii) Bur Oak | 6 | ea | $250 | $1,500 |
| | iii) Eastern White Cedar | 6 | ea | $250 | $1,500 |
| | iv) Basswood | 6 | ea | $250 | $1,500 |

| | | | | | |
|---|---|---|---|---|---|
| **21** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Round Leaved Dogwood | 18 | ea | $45 | $810 |
| | ii) Chokecherry | 16 | ea | $45 | $720 |
| | iii) Alternate Leaved Dogwood | 18 | ea | $45 | $810 |
| | iv) Downy juneberry | 18 | ea | $45 | $810 |
| | v) Northern Fly Honeysuckle | 18 | ea | $45 | $810 |
| | vi) Wild Red Raspberry | 16 | ea | $45 | $720 |
| | vii) Red-berried Elder | 16 | ea | $45 | $720 |
| **Subtotal Section B (Excl of HST)** | | | | | $251,350 |
| | | | | | |
| **Section "C" – Provisional** | | | | | |
| **22** | Replace/ Repair Asphalt Road | 1 | LS | $15,000 | $15,000 |
| **23** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **24** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $25,000 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **25** | Contingency (20%) | 1 | LS | $76,705 | $76,705 |
| **Subtotal Section D (Excl of HST)** | | | | | $76,705 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $107,175 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $251,350 |
| | Section "C" – Provisional | | | | $25,000 |
| | Section "D" – Contingency | | | | $76,705 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $460,230 |
| | HST @ 13% | | | | $59,830 |
| | Total Bid Price (Incl of taxes) | | | | $520,060 |
| | | | | | |
| | **Outlet # 42 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$460,230** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist

Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 45**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 45 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 45 are shown in **Figure 1-1**. The storm sewer has a diameter of 200 mm and extends off of the corner joining McGee Street East to Doran Street, outletting into the Indian River. Outfall 45 was identified to be in need of rehabilitation and was ranked as the 6th highest priority site, of the total 17 sites that were assessed.

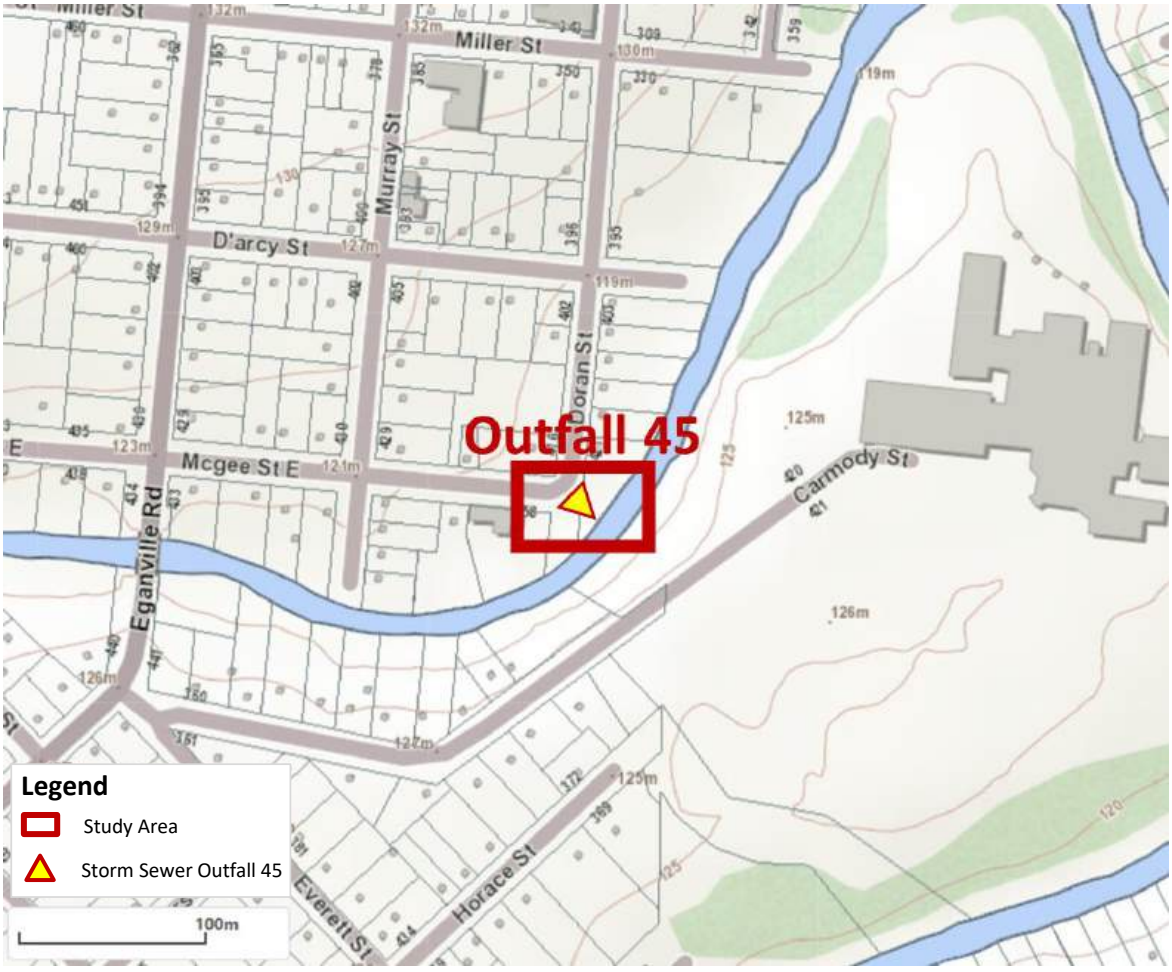



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 45**

## 2 EXISTING CONDITIONS

### 2.1 Overview

Outfall 45 consists of a 200 mm concrete sewer pipe that has failed at the downstream-most pipe joint, creating a 30 cm gap between the detached pipe segment and the upstream pipe (**Figure 2-1** and **Figure 2-2**). The concrete pipe upstream of the failed joint remains in good condition (**Figure 2-3**), though it is recessed into the channel bank, with scouring noted near the outlet (**Figure 2-4**). There is also evidence of bank erosion near the outfall (**Figure 2-1** and **Figure 2-2**), which has steeped the bank in this area and created a near-vertical slope.

**Figure 2-1: Detached Concrete Pipe Segment**

**Figure 2-2: Close-up Photo of the Detached Concrete Pipe Segment**

**Figure 2-3: Close-up Photo of the Recessed Concrete Pipe Outlet**

**Figure 2-4: Scouring at Recessed Concrete Pipe Outlet**

## 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface above the storm sewer pipe, extending into the Indian River to capture streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, exposed pipe, etc.);
- Upstream maintenance hole lid and pipe invert; and
- Top and bottom of bank elevations approximately 5-10 m upstream and downstream of the storm sewer outfall.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

## 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on February 15th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-07 was advanced to a depth of 4.6 m below grade using portable drilling equipment.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

Fill material was encountered at the surface of the borehole, extending to 1.0 m below surface grade. The fill was composed of dark brown to brown sand with some silt and trace gravel. The fill material was underlain by native deposits of silty sand with trace gravel (2.7 m thick) and silty clay (extending to the termination depth of the borehole). Based on soil sample appearance, the groundwater level was estimated to be at approximately 2.3 m below surface grade at the time of the investigation.

## 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 45 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 14 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 5 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 45 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 809 | Manitoba Maple | *Acer negundo* | Good |
| 810 | Hybrid Crack Willow | *Salix x rubens* | Poor |
| 811 | Manitoba Maple | *Acer negundo* | Good |
| 812 | White Elm | *Ulmus americana* | Good |
| 813 | White Elm | *Ulmus americana* | Good |
| 814 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 815 | White Ash | *Fraxinus americana* | Good |
| 816 | Manitoba Maple | *Acer negundo* | Good |
| 817 | Manitoba Maple | *Acer negundo* | Good |
| 818 | White Ash | *Fraxinus americana* | Good |
| 819 | Manitoba Maple | *Acer negundo* | Fair |
| 820 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 821 | Manitoba Maple | *Acer negundo* | Fair |
| NT1 | Manitoba Maple | *Acer negundo* | Fair-Good |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 45 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Channel Bank Stabilization** – Toe erosion and slope failures should be restored by regrading to attain a natural long-term stable slope, followed by the application of channel bank and toe erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel banks are not compromised.

**Outlet Protection –** The design should consider appropriate protection to prevent erosion and scouring damage to the pipe and associated channel works.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall 45 are provided under a separate cover. The proposed design consists removing a 3 m section of the existing 200 mm concrete pipe and replacing it with a 2 m concrete pipe segment of the same diameter. The new 2 m pipe segment is to be incorporated into a vegetated buttress having a total length of 14.5 m, which is intended to provide bank protection near the outfall and to prevent exposure of the remaining sewer pipe. This includes cutting back the existing near-vertical bank to accommodate a lower grade of 2H:1V for the proposed vegetated buttress.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study

area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

### 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 6 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Upland Mix (Application Rate: 25 kg/ha)** | | |
| *Asclepias syriaca* | Common Milkweed | 5% |
| *Clematis virginiana* | Virgin's Bower | 2% |
| *Fragaria virginiana* | Wild Strawberry | 3% |
| *Monarda fistulosa* | Wild Bergamot | 5% |
| *Panicum acuminatum (P.implicatum; P. lanuginosum)* | Hairy Panic Grass | 30% |
| *Rudbeckia hirta* | Black-eye Susan | 15% |
| *Solidago canadensis* | Canada Goldenrod | 8% |
| *Sporobolus cryptandrus* | Sand Dropseed | 30% |
| *Symphyotrichum cordifolium* | Heart-leaved Aster | 1% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |

| | | |
|---|---|---|
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Acer saccharum* | Sugar Maple | 6 | 5 gal. potted |
| *Picea glauca* | White Spruce | 5 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 5 | 5 gal. potted |
| *Tilia americana* | Basswood | 5 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| **Restoration Plantings** | | | |
| *Amelanchier arborea* | Downy Juneberry | 21 | 2 gal. potted |
| *Cornus alternifolia* | Alternate-leaved Dogwood | 21 | 2 gal. potted |
| *Lonicera canadensis* | Northern Fly Honeysuckle | 21 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 21 | 2 gal. potted |
| *Ribes hirtellum* | Smooth Gooseberry | 21 | 2 gal. potted |
| **Vegetated Buttress Plantings** | | | |
| *Cornus sericea* | Red-osier Dogwood | 12 | 2 gal. potted |
| *Cornus rugosa* | Round-leaved Dogwood | 12 | 2 gal. potted |
| *Salix petiolaris* | Slender Willow | 12 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 12 | 2 gal. potted |
| *Viburnum lentago* | Nannyberry | 12 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 14 live trees identified during the assessment (detailed previously in **Table 2-1**), 7 have been identified for removal. Trees identified for removal are listed in **Table 4-4** below and are shown on Sheet 5 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of filter fence specified on Sheet 4 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Trees Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition | |
|---|---|---|---|---|
| 809 | Manitoba Maple | *Acer negundo* | Good | **Remove** |
| 810 | Hybrid Crack Willow | *Salix x rubens* | Poor | **Remove** |
| 813 | White Elm | *Ulmus americana* | Good | **Remove** |
| 814 | Manitoba Maple | *Acer negundo* | Fair-Good | **Remove** |
| 815 | White Ash | *Fraxinus americana* | Good | **Remove** |
| 816 | Manitoba Maple | *Acer negundo* | Good | **Remove** |
| NT1 | Manitoba Maple | *Acer negundo* | Fair-Good | **Remove** |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing

the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access for construction is proposed from McGee Street. The access routes are shown on Sheet 5 of the drawing set. A staging and storage area has also been shown. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $151,506 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 45

| PEMBROKE OUTLETS - OUTLET # 45 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | $6,000 | $6,000 |
| **2** | Field Office | 1 | LS | $3,000 | $3,000 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $8,000 | $8,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat, Steel Plates & Staging Areas | 1 | LS | $12,000 | $12,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $10,000 | $10,000 |
| **7** | Supply, Install & Remove Temporary Erosion & Sediment Control Fence | 35 | m | $20 | $700 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 90 | m | $15 | $1,350 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $10,000 | $10,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of Excess Pipe | 1 | LS | $3,000 | $3,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $69,050 |
| | | | | | |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials (~70 m3) | 1 | LS | $6,000 | $6,000 |
| **15** | Supply & Placement of Vegetated Buttress | | | | |
| | Roundtstone as specified | 90 | tonne | $200 | $18,000 |
| | Topsoil to enhance vegetation | 20 | $m^3$ | $50 | $1,000 |
| | Stock Plantings (2 gal potted @ 0.5 spacing) | | | | |
| | i) Red-osier Dogwood | 12 | ea | $45 | $540 |
| | ii) Slender Willow | 12 | ea | $45 | $540 |
| | iii) Nannyberry | 12 | ea | $45 | $540 |
| | iv) Narrow-Leaved Meadowsweet | 12 | ea | $45 | $540 |
| | v) Round Leaved Dogwood | 12 | ea | $45 | $540 |
| **16** | Supply & Placement of Erosion Control Blanket - Coir Mat | 180 | $m^2$ | $8 | $1,440 |
| **17** | Supply & Placement of Topsoil for Restoration (300mm for terraseed area & 150mm for Sod) | 75 | $m^3$ | $50 | $3,750 |
| **21** | Supply & Application of Terraseed Mixture (Upland) | 80 | $m^2$ | $8 | $640 |
| **22** | Supply & Application of Terraseed Mixture(Riparian) | 100 | $m^2$ | $8 | $800 |
| **19** | Supply & Application of Sod | 145 | $m^2$ | $20 | $2,900 |
| **20** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | ii) Sugar Maple | 6 | ea | $250 | $1,500 |
| | ii) White Spruce | 5 | ea | $250 | $1,250 |
| | iii) Eastern White Cedar | 5 | ea | $250 | $1,250 |
| | iv) Basswood | 5 | ea | $250 | $1,250 |

| | | | | | |
|---|---|---|---|---|---|
| **21** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Alternate Leaved Dogwood | 21 | ea | $45 | $945 |
| | ii) Chokecherry | 21 | ea | $45 | $945 |
| | iii) Smooth Gooseberry | 21 | ea | $45 | $945 |
| | iv) Downy juneberry | 21 | ea | $45 | $945 |
| | v) Northern Fly Honeysuckle | 21 | ea | $45 | $945 |
| **Subtotal Section B (Excl of HST)** | | | | | $47,205 |
| | | | | | |
| **Section "C" – Provisional** | | | | | |
| **23** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **24** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $10,000 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **25** | Contingency (20%) | 1 | LS | $25,251 | $25,251 |
| **Subtotal Section D (Excl of HST)** | | | | | $25,251 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $69,050 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $47,205 |
| | Section "C" – Provisional | | | | $10,000 |
| | Section "D" – Contingency | | | | $25,251 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $151,506 |
| | HST @ 13% | | | | $19,696 |
| | Total Bid Price (Incl of taxes) | | | | $171,202 |
| | | | | | |
| | **Outlet # 45 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$151,506** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist

Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 46**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 46 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 46 are shown in **Figure 1-1**. The storm sewer has a diameter of 250 mm and extends off of Murray Street, outletting into Indian River approximately 105 m downstream of Eganville Road. Outfall 46 was identified to be in need of rehabilitation and was ranked as the 8th highest priority site, of the total 17 sites that were assessed.

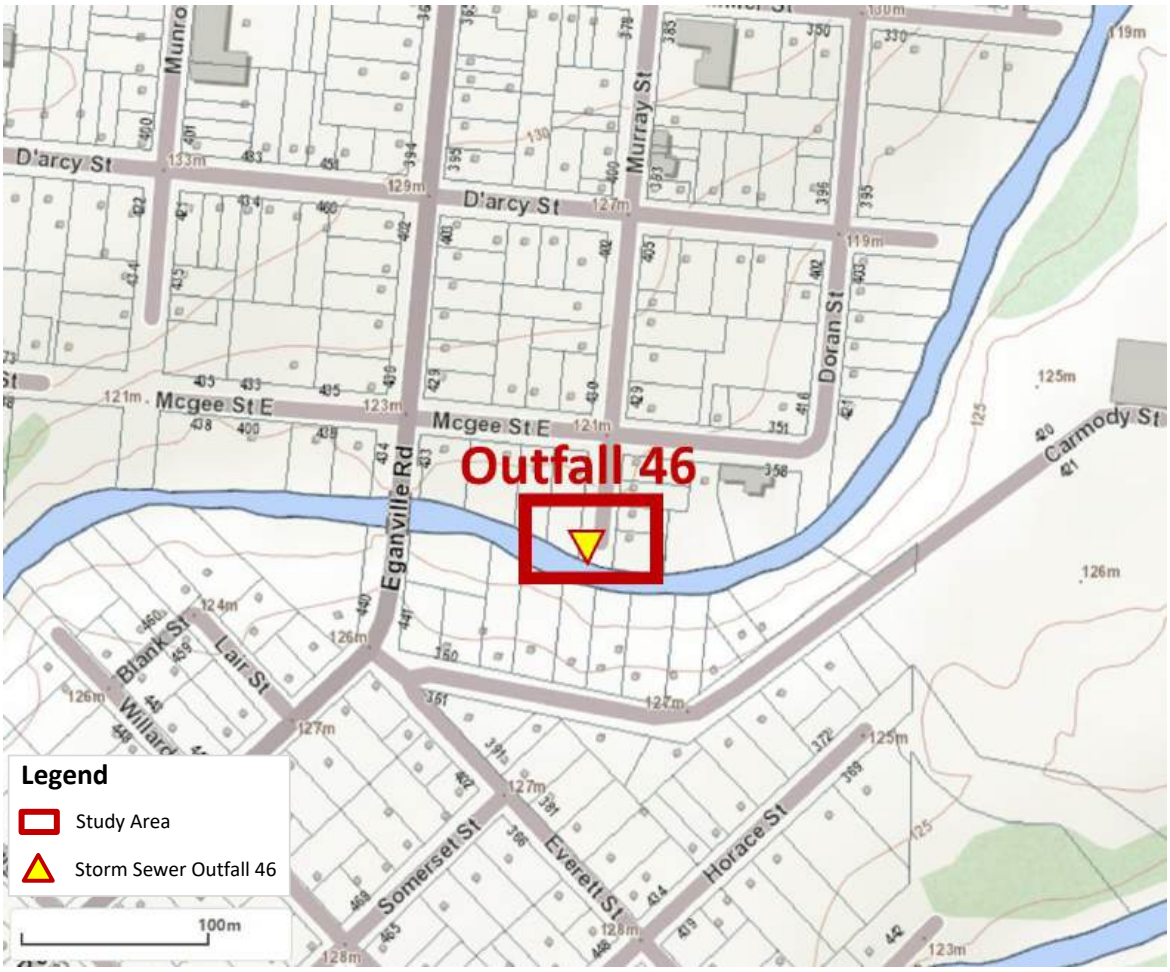



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 46**

## 2 EXISTING CONDITIONS

### 2.1 Overview

Outfall 46 consists of a 250 mm pipe that was originally connected to a 250 mm cast iron pipe, though a 2 cm gap has since developed at the joint of the two pipe segments (**Figure 2-1**). The cast iron pipe extents well past the channel bank into the Indian River, with the outlet completely submerged and partially filled with a 2.5 cm deep deposit of fine sand (**Figures 2-2, 2-3 and 2-4)**. It is unclear whether the cast iron pipe was intended to extend into the Indian River or whether it became exposed due to recession of the channel bank.

**Figure 2-1: Gap Between the Cast Iron and Clay Pipe Segments**

**Figure 2-2: Cast Iron Pipe Extending into the Indian River (Looking Upstream)**

**Figure 2-3: Close-up View of the Cast Iron Pipe**

**Figure 2-4: Submerged End of the Cast Iron Pipe**

### 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface along, extending into the Indian River to capture the submerged end of the cast iron pipe and streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, exposed pipe, etc.);
- Upstream maintenance hole lid and pipe invert; and
- Top and bottom of bank elevations approximately 5-10 m upstream and downstream of the storm sewer outfall.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

### 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on February 14th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-06 was advanced to a depth of 4.6 m below grade using portable drilling equipment.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

A 50 mm layer of asphaltic concrete was encountered at the surface, followed by a 160 mm thick road base layer and an 800 mm subbase layer. The road base layer consisted of brown crushed sand with gravel and some silt, and the subbase layer was composed of brown sand with some gravel and some silt. The subbase material was underlain by native deposits of silty sand (2.2 m thick) and silty clay (extending to the termination depth of the borehole). Based on soil sample appearance, the groundwater level was estimated to be at approximately 3.2 m below surface grade at the time of the investigation.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 46 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 10 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 5 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 46 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| NT1 | Manitoba Maple | *Acer negundo* | Fair |
| 801 | White Elm | *Ulmus americana* | Good |
| 802 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 803 | White Ash | *Fraxinus americana* | Fair-Good |
| 804 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 805 | White Elm | *Ulmus americana* | Fair-Good |
| Bn1 | Butternut | *Juglans cinerea* | Good |
| 806 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 807 | White Ash | *Fraxinus americana* | Good |
| 808 | White Ash | *Fraxinus americana* | Good |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 46 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Channel Bank Stabilization** – Toe erosion and slope failures should be restored by regrading to attain a natural long-term stable slope, followed by the application of channel bank and toe erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel banks are not compromised.

**Outlet Protection –** The design should consider appropriate protection to prevent erosion and scouring damage to the pipe and associated channel works.

## 4 DETAILED DESIGN

### 4.1 Principal Design Components

Detailed design drawings for Outfall 46 are provided under a separate cover. The proposed design consists of constructing an armourstone retaining wall, with the intention of stabilizing the channel bank and providing protection against erosion. This selected as the preferred alternative for stabilizing and protecting the river bank, rather than a sloped vegetated buttress, due to limited space between Murray Street and the river bank.

Specifics of the design include removing the exposed 250 mm cast iron pipe and incorporating the remaining 250 mm clay pipe within the armourstone retaining wall. Angular stone is specified at the base of the armourstone wall, so as to provide protection against scouring from stormwater exiting the pipe.

### 4.2 Wildlife Mitigation Measures

#### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

#### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

#### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

#### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

### 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 6 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Acer rubrum* | Red Maple | 1 | 5 gal. potted |
| *Acer saccharum* | Sugar Maple | 1 | 5 gal. potted |
| *Picea glauca* | White Spruce | 1 | 5 gal. potted |
| *Tilia americana* | Basswood | 1 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Amelanchier arborea* | Downy Juneberry | 4 | 2 gal. potted |
| *Cornus rugosa* | Round-leaved Dogwood | 4 | 2 gal. potted |
| *Lonicera canadensis* | Northern Fly Honeysuckle | 4 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 4 | 2 gal. potted |
| *Spirea alba* | Narrow-leaved Meadowsweet | 4 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 10 live trees identified during the assessment (detailed previously in **Table 2-1**), 4 have been identified for removal. Trees identified for removal are listed in **Table 4-4** below and are shown on Sheet 5 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of hoarding fence specified on Sheet 4 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Trees Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 801 | White Elm | *Ulmus americana* | Good |
| 802 | Manitoba Maple | *Acer negundo* | Fair-Good |
| 803 | White Ash | *Fraxinus americana* | Fair-Good |
| 804 | Manitoba Maple | *Acer negundo* | Fair-Good |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on

requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access for construction is proposed from Murray Street. The access routes are shown on Sheet 6 of the drawing set. A staging and storage area has also been shown. The existing guard rail and sign post are to be removed prior construction to facilitate site access, and are to be replaced upon completion of construction. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $169,104 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 46

| PEMBROKE OUTLETS - OUTLET # 46 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | | $0 |
| **2** | Field Office | 1 | LS | | $0 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $8,000 | $8,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $12,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal Including Removal and Reinstalling Guard Rail | 1 | LS | $10,000 | $10,000 |
| **7** | Supply, Install & Remove Temporary Tree Hoarding Fence | 18 | m | $20 | $360 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 30 | m | $15 | $450 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $12,000 | $12,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **11** | Removal & Disposal of Excess Sewer Pipe | 1 | LS | $10,000 | $10,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $65,810 |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $8,000 | $8,000 |
| **17** | Supply & Placement of Angular Channel Substrate | 50 | tonne | $200 | $10,000 |
| **17** | Supply & Placement of Armourstone Retaining Wall | 140 | tonne | $235 | $32,900 |
| **19** | Supply & Placement of Erosion Control Blanket - Coir Mat | 35 | $m^2$ | $8 | $280 |
| **20** | Supply & Placement of Topsoil for Restoration (300mm) | 10 | $m^3$ | $50 | $500 |
| **21** | Supply & Application of Terraseed Mixture | 35 | $m^2$ | $8 | $280 |
| **23** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | i) Sugar Maple | 1 | ea | $250 | $250 |
| | ii) White Spruce | 1 | ea | $250 | $250 |
| | iii) Red Maple | 1 | ea | $250 | $250 |
| | v) Basswood | 1 | ea | $250 | $250 |
| **23** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Round Leaved Dogwood | 4 | ea | $45 | $180 |
| | ii) Chokecherry | 4 | ea | $45 | $180 |
| | iii) Narrow leaved Meadowsweet | 4 | ea | $45 | $180 |
| | iv) Downy juneberry | 4 | ea | $45 | $180 |
| | v) Northern Fly Honeysuckle | 4 | ea | $45 | $180 |
| **Subtotal Section B (Excl of HST)** | | | | | $53,860 |

| | | | | | |
|---|---|---|---|---|---|
| **Section "C" – Provisional** | | | | | |
| **24** | Asphalt Road Repair (Removal, Granular Placement, New Asphalt, Buffer Restoration) | 45 | $m^2$ | $250 | $11,250 |
| **25** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **26** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $21,250 |
| | | | | | |
| **Section "D" – Contingency** | | | | | |
| **27** | Contingency (20%) | 1 | LS | $28,184 | $28,184 |
| **Subtotal Section D (Excl of HST)** | | | | | $28,184 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $65,810 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $53,860 |
| | Section "C" – Provisional | | | | $21,250 |
| | Section "D" – Contingency | | | | $28,184 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $169,104 |
| | HST @ 13% | | | | $21,984 |
| | Total Bid Price (Incl of taxes) | | | | $191,088 |
| | | | | | |
| | **Outlet # 46 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$169,104** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall 56**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall 56 as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall 56 are shown in **Figure 1-1**. The sewer pipe has a diameter of 300 mm and conveys water under Noman Street, outletting into an outside bend of the Indian River, approximately 440 m upstream of the confluence with the Muskrat River. Outfall 56 was identified to be in need of rehabilitation and was ranked as the 9th highest priority site, of the total 17 sites that were assessed.

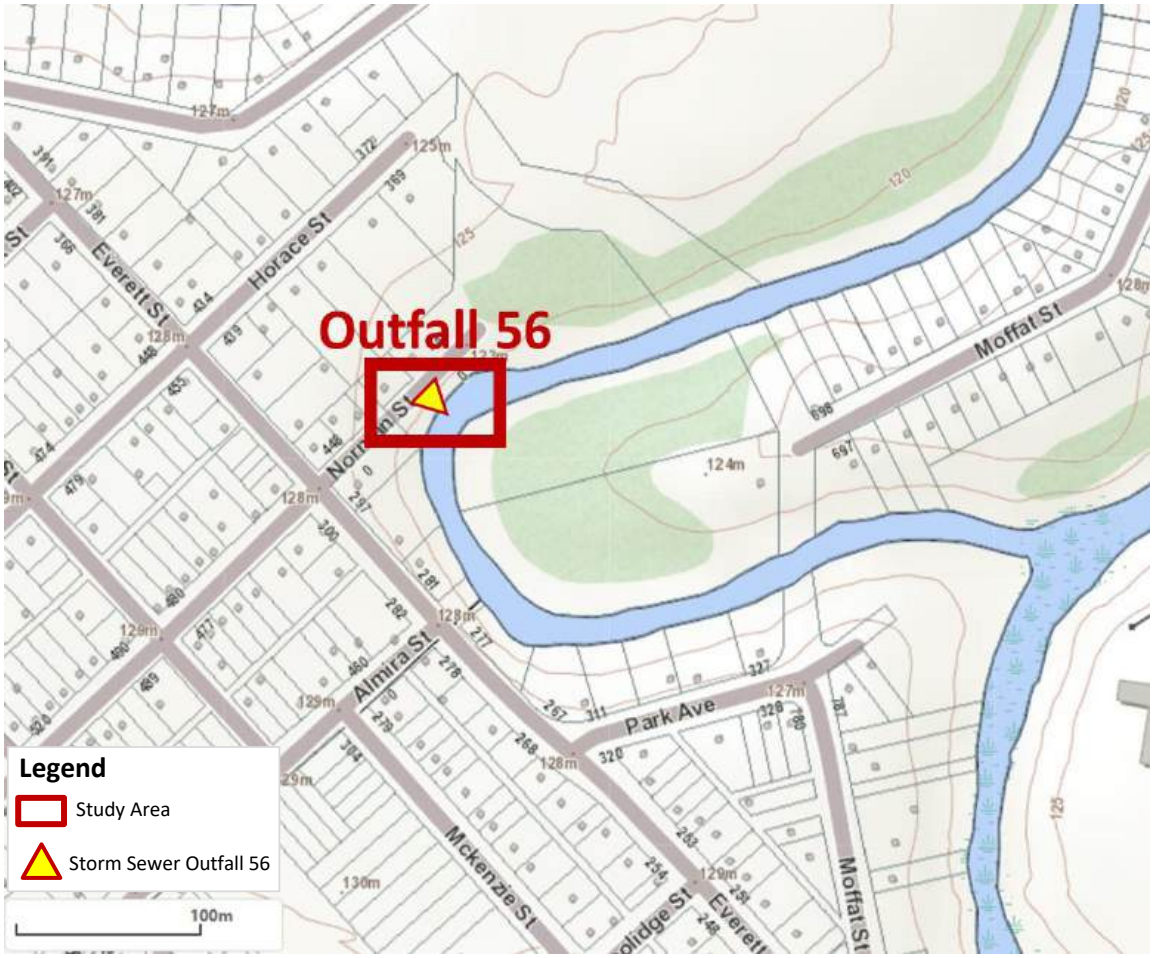



**Figure 1-1: Location of Study Area for Storm Sewer Outfall 56**

## 2 EXISTING CONDITIONS

### 2.1 Overview

Outfall 56 consists of a 300 mm CSP sewer pipe that passes under Norman Street and was intended to collect water from an upstream box culvert, which has collapsed (**Figure 2-1**). However, a local resident informed Aquafor that very little water flows through the collapsed box culvert during storm event under existing conditions. The collapsed culvert passes under private property belonging to 444 Norman Street and is connected to the inlet of the CSP via a small ditch (**Figure 2-2**).

Approximately 30% of the CSP rise is filled with sediment (**Figure 2-3**). The outlet is recessed into the slope and is slightly crushed (**Figure 2-4**), with concrete rubble located near the outlet that appears to belong to a failed headwall. The outlet is located approximately 8 m away from the edge of the river, such that water existing the CSP flows down the channel slope. This has caused erosion scarring downstream of the outlet, particularly due to the high slope, which is approximately 1H:1V.

As shown in the detailed design drawings, much of the study area – including Norman Street – is located on private property belonging to 442 Norman Street.

**Figure 2-1: Upstream Collapsed Box Culvert**

**Figure 2-2: CSP Inlet**

Figure 2-3: Sediment Deposits Inside the CSP

Figure 2-4: Crushed and Recessed CSP Outlet, Surrounded by Concrete Rubble

## 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface overtop the CSP, extending down the slope and into the Indian River to capture streambed tie-in elevations;
- Any visible storm culvert/pipe infrastructure near the outlet (e.g., invert and obvert);
- Top and bottom of bank elevations approximately 5-10 m upstream and downstream of the storm sewer outfall; and
- Ground shots at the edge of erosion scars and within the eroded areas.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

## 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on March 14th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-05 was advanced to a depth of 8.2 m below grade using a truck-mounted drill.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. In situ

vane shear testing was carried out in the borehole to measure the undrained shear strength of the silty clay deposits. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

A 50 mm layer of asphaltic concrete was encountered at the surface, followed by a 150 mm thick road base layer and a 300 mm subbase layer. The road base layer consisted of brown crushed sand with gravel and some silt, and the subbase layer was composed of brown gravelly sand with trace silt. Beneath the road base, a 1.0 m thick layer of fill was encountered, consisting of brown sand and silt with trace gravel. The fill material was underlain by native deposits of silty sand (0.9 m thick), silty clay (3.4 m thick), and glacial till composed of clayey sand and gravel (extending to the termination depth of the borehole). Based on soil sample appearance, the groundwater level was estimated to be at approximately 7.2 m below surface grade at the time of the investigation.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall 56 study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 3 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet 4 in the detailed design drawings shows the locations of the surveyed trees within the Outfall 56 study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| NT1 | Manitoba Maple | *Acer negundo* | Fair |
| NT2 | Hybrid Crack Willow | *Salix x rubens* | Fair-Poor |
| NT3 | Manitoba Maple | *Acer negundo* | Poor |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall 56 were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Slope Stabilization** – Slope erosion and failures should be restored by regrading to attain a natural long-term stable slope, followed by application of erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope is not compromised.

**CSP Protection –** The design should consider appropriate protection to prevent damage to the ends of the CSP and sediment buildup within the pipe.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall 56 are provided under a separate cover. The proposed design consists of placing galvanized end sections on each end of the existing CSP running under Norman Street and removing existing sediment deposits within the pipe. The galvanized sections are intended to protect the ends of the CSP, as well as to reduce the sediment load passing through the pipe. Rip rap is proposed both upstream and downstream of the CSP to protect against erosion. Due to the high slope (roughly 1H:1V) downstream of the CSP, a boulder weir is specified at the toe of the rip rap to prevent displacement of the substrate.

Rehabilitation of the collapsed upstream box culvert is beyond the scope of this project. However, Aquafor recommends undertaking future design and construction works to ensure proper conveyance of stormwater to the inlet of the CSP.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year

to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

## 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 5 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Acer rubrum* | Red Maple | 1 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 1 | 5 gal. potted |
| *Tilia americana* | Basswood | 1 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Amelanchier arborea* | Downy Juneberry | 3 | 2 gal. potted |
| *Cornus alternifolia* | Alternate-leaved Dogwood | 3 | 2 gal. potted |
| *Lonicera canadensis* | Northern Fly Honeysuckle | 3 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 2 | 2 gal. potted |
| *Rubus ideaus* | Wild Red Raspberry | 2 | 2 gal. potted |
| *Sambucus racemosa* | Red-berried Elder | 2 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 3 live trees identified during the assessment (detailed previously in **Table 2-1**), 1 has been identified for removal. The tree identified for removal is shown in **Table 4-4** below and on Sheet 4 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 3 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Tree Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| NT3 | Manitoba Maple | *Acer negundo* | Poor |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. As shown on Sheet 4 of the detailed design drawings, access routes and construction activities are proposed within private property at 442 Norman Street, for which an easement would be required. In all cases, an OLS should be retained to confirm property parcels and associated limits.

# 6 PERMITS AND APPROVALS

## 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

## 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

## 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

# 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
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Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access for construction is proposed from Norman Street, which will require temporary singe-lane closure. The access routes are shown on Sheet 4 of the drawing set. Any changes to the access routes must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $99,204 which includes a 20% contingency but is exclusive of

HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall 56

| PEMBROKE OUTLETS - OUTLET # 56 | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | $8,000 | $8,000 |
| **2** | Field Office | 1 | LS | $3,000 | $3,000 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $8,000 | $8,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $8,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal | 1 | LS | $5,000 | $5,000 |
| **8** | Supply, Install & Remove Temporary Construction Fence | 25 | m | $15 | $375 |
| **9** | Supply, Install & Remove Silt Socks | 35 | m | $20 | $700 |
| **10** | Removal & Disposal of Sediment | 1 | LS | $3,000 | $3,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $48,075 |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **11** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $2,000 | $2,000 |
| **12** | Supply & Placement of Angular Channel Substrate | 35 | tonne | $200 | $7,000 |
| **13** | Supply & Placement of Galvanised End Section fro 12" CSP | 2 | ea | $600 | $1,200 |
| **14** | Supply & Placement of Boulders | 3 | ea | $500 | $1,500 |
| **15** | Supply & Placement of Erosion Control Blanket - Coir Mat | 45 | $m^2$ | $8 | $360 |
| **16** | Supply & Placement of Topsoil for Restoration (300mm for terraseed area & 150mm for Sod) | 15 | $m^3$ | $50 | $750 |
| **17** | Supply & Application of Terraseed Mixture | 45 | $m^2$ | $8 | $360 |
| **18** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | ii) Red Maple | 1 | ea | $250 | $250 |
| | ii) Eastern White Cedar | 1 | ea | $250 | $250 |
| | iii) Basswood | 1 | ea | $250 | $250 |
| **19** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Alternate Leaved Dogwood | 3 | ea | $45 | $135 |
| | ii) Chokecherry | 2 | ea | $45 | $90 |
| | iii) Downy juneberry | 3 | ea | $45 | $135 |
| | iv) Northern Fly Honeysuckle | 3 | ea | $45 | $135 |
| | v) Wild Red Raspberry | 2 | ea | $45 | $90 |
| | vi) Red-berried Elder | 2 | ea | $45 | $90 |
| **Subtotal Section B (Excl of HST)** | | | | | $14,595 |
| **Section "C" – Provisional** | | | | | |
| **20** | Replace/ Repair Asphalt Road | 1 | LS | $10,000 | $10,000 |
| **21** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **22** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $20,000 |
| **Section "D" – Contingency** | | | | | |
| **23** | Contingency (20%) | 1 | LS | $16,534 | $16,534 |
| **Subtotal Section D (Excl of HST)** | | | | | $16,534 |

| | | | | | |
|---|---|---|---|---|---|
| | Section "A" – Site Preparation & Removals | | | | $48,075 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $14,595 |
| | Section "C" – Provisional | | | | $20,000 |
| | Section "D" – Contingency | | | | $16,534 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $99,204 |
| | HST @ 13% | | | | $12,897 |
| | Total Bid Price (Incl of taxes) | | | | $112,101 |
| | | | | | |
| | **Outlet # 56 Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$99,204** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

**Technical Memo for Design and Reconstruction of Storm Sewer Outfall # Unknown**

## 1 INTRODUCTION

As part of the City-Wide Flood Risk Assessment and Storm Outlet Review, the City of Pembroke has requested an assessment of the condition on 17 of the City's storm sewer outfalls, complete with an inventory of the findings. After conducting the outfall assessment, Aquafor Beech reported a total of 9 outfalls in poor condition and in need of repair. The following Technical Memo provides an overview of the existing conditions of Outfall # Unknown as well as the Detailed Design of the proposed outfall reconstruction.

The study area and location of Outfall # Unknown are shown in **Figure 1-1**. The outfall pipe has a diameter of 300 mm and extends off of Paul Martin Drive, outletting atop a steep road embankment that connects to an outfall channel, which ultimately discharges into the Muskrat River immediately downstream of the Paul Martin Drive bridge crossing. Outfall # Unknown was identified to be in need of rehabilitation and was ranked as the 4th highest priority site, of the total 17 sites that were assessed.


**Figure 1-1: Location of Study Area for Storm Sewer Outfall # Unknown**

## 2 EXISTING CONDITIONS

### 2.1 Overview

Outfall # Unknown consists 300 mm CSP sewer pipe that outlets atop the embankment of Paul Martin Drive (**Figure 2-1**). Holes have developed at the bottom of the CSP due to rust corrosion. Water exiting the pipe flows down the steep embankment slope (exceeding 1.35H:1V), over which a geotextile erosion blanket has been placed to mitigate erosion (**Figure 2-2**).

An outfall channel (**Figure 2-3**) collects water from both from Outfall # Unknown and from a culvert passing under International Drive. The total length of the channel is roughly 110 m, though the length of channel extending from Outfall # Unknown to the Muskrat River is only ~23 m. Despite erosion control consisting of roundstone placed overtop geotextile, severe erosion was noted along the downstream extents of the outfall channel, affecting a continuous channel length of 34 m. This included bank erosion as well as scouring of roundstone, which exposed the underlying geotextile erosion protection. Much the displaced roundstone settled as an outwash fan at the confluence with the Muskrat River (**Figure 2-4**).

**Figure 2-1: Outlet and Eroded Bank**

**Figure 2-2: Eroded Bank at Outlet**

**Figure 2-3: Bank Erosion and Exposed Geotextile**

**Figure 2-4: Washed Out Swale**

### 2.2 Topographic Survey

A detailed topographic survey was completed from November 8th to November 19th in 2021 to record existing site conditions. Sufficient detail was captured to support the detailed design of the outfall reconstruction. Key parameters captured during the survey include:

- Longitudinal profile of the ground surface above the storm sewer pipe;
- Survey points to characterize the outfall channel (cross-sections, thalweg, top-of-bank, etc.), extending into the Muskrat River to capture streambed tie-in elevations;
- Any visible storm sewer infrastructure near the outlet (invert and obvert, exposed pipe, etc.);
- Top and bottom of bank elevations along the Muskrat River, extending approximately 5-10 m upstream and downstream of the confluence with the outfall channel; and
- Additional ground shots within the outfall channel to capture erosion.

The survey was completed using a high-precision GPS instrument that was referenced to the NAD83 UTM Zone 18N horizontal coordinate system and the CGVD2013 vertical datum. A DEM derived from LiDAR data collected between 2019-2020 by Natural Resources Canada was used to complement the topographic survey data, allowing for elevations to be determined beyond the extents of the survey.

### 2.3 Geotechnical Investigation

A detailed geotechnical investigation was undertaken by GEMTEC within the study area on February 15th, 2022. The assessment was intended to define and characterize the subsurface soil conditions, inform the design of the proposed outfall reconstruction, and make recommendations regarding slope stabilization measures. One (1) borehole designated as 22-03 was advanced to a depth of 6.1 m below grade using portable drilling equipment.

Soil samples were obtained at regular intervals in the overburden soils with a 51 mm diameter Standard Penetration Test split-spoon sample. This was done in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing. Dynamic cone penetration testing (DCPT) was also carried out in this borehole. The results of the geotechnical investigation, along with a borehole location plan, are included in **Appendix I.**

Fill material was encountered at the surface of the borehole, extending to 1.7 m below surface grade. The fill consisted of brown sand and gravel with some silt. The fill material was underlain by native deposits of sandy clay, extending to the sampling termination point of 4.3 m. The borehole was further advanced by means of a DCPT to the termination depth of 6.1 m. Blow counts recorded during the DCPT ranged from 30 to 52 blows per 300 mm. No groundwater was observed within the open borehole.

### 2.4 Tree Inventory

A comprehensive tree inventory was undertaken in the Outfall # Unknown study area in February, 2022 to identify trees that may potentially be removed or damaged to accommodate construction activities. A total of 10 trees were inventoried in the study area, including at any potentially suitable access and staging areas. Sheet

5 in the detailed design drawings shows the locations of the surveyed trees within the Outfall # Unknown study area. **Table 2-1** provides a summary of the tree inventory results by species.

**Table 2-1: Tree Inventory Summary by Species**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 822 | Bur Oak | *Quercus macrocarpa* | Good |
| 823 | Manitoba Maple | *Acer negundo* | Fair |
| 824 | Eastern White Cedar | *Thuja occidentalis* | Good |
| 825 | Eastern White Cedar | *Thuja occidentalis* | Good |
| 826 | Eastern White Cedar | *Thuja occidentalis* | Good |
| 827 | Eastern White Cedar | *Thuja occidentalis* | Good |
| 828 | Eastern White Cedar | *Thuja occidentalis* | Good |
| 829 | Eastern White Cedar | *Thuja occidentalis* | Good |
| 830 | Eastern White Cedar | *Thuja occidentalis* | Good |
| NT1 | Eastern White Cedar | *Thuja occidentalis* | Good |

## 3 DESIGN FACTORS

At the outset of the design process, all opportunities, constraints, and considerations for the reconstruction of Outfall # Unknown were identified. This ensured that they were adequately considered during development of the detailed design. Constraints and considerations identified within the study area were as follows:

**Disturbance to Terrestrial Vegetation** – Some of the trees and other vegetation located within the study area may be harmed or removed during construction. However, space allowing, any mature trees that are required for removal to facilitate construction will be compensated with trees plantings at a 3:1 ratio, along with 5 shrubs planted for every 1 tree planted. If there is insufficient space near the study area to meet this replanting target, trees will be planted at a minimum 1:1 ratio, with 5 shrubs planted for every 1 tree planted. Tree species selection will be based on their nativity within the City of Pembroke, and seed mix composition will reflect typical vegetation found within Plant Hardiness Zone 4b (Natural Resources Canada, 2021).

**Utilities** – In addition to the storm sewer infrastructure identified during the background review of base mapping provided by the City, Aquafor has also completed an Ontario One Call utility locate request for the entire site identify all other utilities and any potential design conflicts.

**Channel Bank Stabilization** – Toe erosion and slope failures should be restored by regrading to attain a natural long-term stable slope, followed by the application of channel bank and toe erosion protection.

**Upstream and Downstream Tie-In Points** – Care must be taken to ensure that there is a smooth transition into, and out of, the proposed outfall design, such that the stability of the slope and channel banks are not compromised.

# 4 DETAILED DESIGN

## 4.1 Principal Design Components

Detailed design drawings for Outfall # Unknown are provided under a separate cover. The proposed design consists of rehabilitating the downstream extents of the outfall channel by placing angular stone fill, which is intended to resist scouring. The reconstructed channel is to be 3 m wide and is to have a uniform gradient of 16%, before entering the Muskrat River at a 3H:1V slope. Banks are to be graded to 3H:1V and vegetated with native riparian seed mix, shrubs, and trees, in order to provide additional slope stability and resist erosion during high flow periods. The slope connecting the Outfall # Unknown to the outfall channel, which currently exceeds 1.35H:1V, is to be filled with angular stone and regraded to 3H:1V.

## 4.2 Wildlife Mitigation Measures

### 4.2.1 Breeding Birds

Tree removals should occur outside of the bird nesting window (generally April 1st to August 31st) to ensure that active nests of protected species are not harmed or destroyed and that the project is compliant with the *Migratory Birds Convention Act*. Individual trees or areas of low-complexity habitat could potentially be removed during the nesting window following an inspection to confirm the absence of active nesting in the area. However, this method is not recommended for complex habitats (e.g., mature woodland) due to the low detectability of nests in such areas, and is further not permitted if a restriction is placed on tree removal due to SAR bat habitat.

### 4.2.2 Bat Maternity Roosts

The active window for Ontario's SAR bats extends from April 1st to September 30th. The study area is inclusive of potential SAR bat habitat, and as such, tree removal is prohibited during this period.

### 4.2.3 In-Water Works Timing Windows and Fisheries Act

Discussions with MNRF (personal communication, March 15, 2022) confirmed that the Indian River provides habitat to both spring and fall spawning species. As a major watercourse, the Indian River contains fish at any time during any given year. Thus, no in-water works may occur between October 1 to July 15 of any given year to avoid works within the spring and fall spawning windows for the MNR Southern Region (March 15 - July 15 and October 1 - May 21, respectively).

### 4.2.4 DFO Self-assessment

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. As noted above, the study area does contain fish at any time during any given year. Therefore, the *Fisheries Act* applies to works conducted in or near water at the site.

As the proposed works include minor regrading and rock placement within the high-water mark of the channel, Aquafor will undertake a request for regulatory review under the federal *Fisheries Act*.

### 4.3 Vegetation Removals and Restoration

A detailed restoration plan is shown on Sheet 6 of the design drawings. As soon as possible following construction, all disturbed areas should be revegetated through application of an annual cover crop and native herbaceous seed mix in areas of disturbance. Native seed mix should include wildflowers (preferably including milkweed species) to promote wildlife habitat. Terraseeding is the preferred application to hydroseeding. The recommended annual cover crop consists of Canada Wild Rye (*Elymus canadensis*) (40%) and Annual Oats (*Avena sativa*) (60%) applied at a rate of 33 kg/ha. after the risk of frost (i.e., after March 31 and before October 31); if applied during the time of frost risk, the cover crop should be 100% Annual Oats at a rate of 33kg/ha.

In addition, interplanting with native trees and shrubs is recommended within the coastal floodplain where appropriate. Restoration within disturbed areas should be in keeping with existing communities, and interplanting should utilize vegetation appropriate to the target community. Such interplanting will aid in stabilizing the banks and will also enhance habitat for wildlife and aquatic species.

All species selected should be native, suitable to the site conditions, and reflect the diversity of species commonly found in local natural areas. Based on native species within Pembroke and the site's location within Plant Hardiness Zone 4b, suggested species and sizes are listed in **Table 4-1**, **Table 4-2**, and **Table 4-3**.

**Table 4-1: Native Seed Mixes**

| Scientific Name | Common Name | % by Weight |
|---|---|---|
| **Nurse Crop Mix (Application Rate: 33 kg/ha)** | | |
| *Elymus canadensis* | Canada Wild Rye | 40% |
| *Avena sativa* | Annual Oats | 60% |
| **Riparian Mix (Application Rate: 25 kg/ha)** | | |
| *Anemonastrum canadensis* | Canada Anemone | 1% |
| *Apocynum cannibinum* | Indian-hemp Dogbane | 5% |
| *Asclepias incarnata ssp. incarnata* | Swamp Milkweed | 5% |
| *Bidens cernua* | Nodding Beggarticks | 2% |
| *Bidens frondose* | Devil's Beggarticks | 2% |
| *Carex granularis* | Meadow/Open Field Sedge | 20% |
| *Clematis viginiana* | Virgin's Bower | 4% |
| *Elymus virginicus var. virginicus* | Virginia Wild Rye | 10% |
| *Euthamia graminifolia* | Grass-leaved Goldenrod | 5% |
| *Juncus dudleyi* | Dudley's Rush | 10% |
| *Poa palustris* | Fowl Bluegrass | 25% |
| *Solidago canadensis* | Canada Goldenrod | 4% |
| *Symphyotrichum novae-angliae* | New England Aster | 1% |
| *Symphyotrichum puniceum* | Purple Stemmed Aster | 1% |
| *Verbena hastata* | Blue Vervain | 5% |

**Table 4-2: Native Tree Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Picea glauca* | White Spruce | 1 | 5 gal. potted |
| *Quercus macrocarpa* | Bur Oak | 1 | 5 gal. potted |
| *Thuja occidentalis* | Eastern White Cedar | 1 | 5 gal. potted |

**Table 4-3: Native Shrub Plantings**

| Scientific Name | Common Name | Amount | Size |
|---|---|---|---|
| *Amelanchier arborea* | Downy Juneberry | 3 | 2 gal. potted |
| *Cornus racemosa* | Grey dogwood | 3 | 2 gal. potted |
| *Cornus stolonifera* | Red osier dogwood | 3 | 2 gal. potted |
| *Prunus virginiana* | Chokecherry | 2 | 2 gal. potted |
| *Salix lucida* | Shining Willow | 2 | 2 gal. potted |
| *Salix petiolaris* | Slender Willow | 2 | 2 gal. potted |

### 4.3.1 Removal Timing Window and Protection Measures

It will be necessary to remove some trees and other vegetation to facilitate the proposed works. Of the 10 live trees identified during the assessment (detailed previously in **Table 2-1**), 1 has been identified for removal. The tree identified for removal is shown in **Table 4-4** below and on Sheet 5 of the detailed design drawings. Tree removals on the site should take place outside of the typical bird nesting and bat maternity roost season (collectively April 1 to September 30).

Construction activities can have adverse effects on nearby trees that are to remain in place and should not be disturbed by the proposed works. Tree protections measures, consisting of page wire hoarding specified on Sheet 4 of the detailed design drawings, should be followed in order to mitigate against potential damages.

**Table 4-4: Tree Identified for Removal**

| Tag # | Species Common Name | Species Botanical Name | Condition |
|---|---|---|---|
| 824 | Eastern White Cedar | *Thuja occidentalis* | Good |

## 5 EASEMENT REQUIREMENTS

Aquafor was provided the property fabric by the City of Pembroke on March 7, 2022. In all cases, an OLS should be retained to confirm property parcels and associated limits. In some cases, it may be necessary to require temporary or permanent easements.

## 6 PERMITS AND APPROVALS

### 6.1 MNRF Fish Collection Permit

As de-watering will be required to accommodate construction, a fish rescue must be conducted. It will therefore be necessary to obtain a fish collection permit from the MNRF prior to construction. In addition, the dewatering and fish rescue must be conducted in accordance with MNRF timing windows to reduce harm to aquatic species, with no in-water works occurring between October 1 to July 15 (as discussed in **Section 4.2.3**). In the event that the work area becomes inundated following a significant rainfall event, fish rescues will be required prior to continuing instream works.

### 6.2 Provincial Species at Risk – MECP 17(2) (b/c) Species at Risk Permit

Prior to implementation, the study area should be subject to a Species at Risk (SAR) screening to identify any potential conflicts and ensure compliance with applicable legislation. Screening should be completed by consulting background information and agencies (MECP) to identify potential species associations, and assessing the potential for those species to occur in the study area based on their habitat requirements as compared to the habitat present on site. Mitigation measures to prevent or minimize impacts to species should be developed. If endangered or threatened species will potentially be impacted by the project, an Information Gathering Form (IGF) should be prepared and submitted to the MECP so that they may review the project and advise on requirements under the *Endangered Species Act*. Such requirements may include: implementation of additional mitigation measures as specified by MECP; registering the project via a Notice of Activity under a regulatory exemption; or preparation of an Overall Benefit Permit (OBP) package to address impacts to protected species

or habitat. Please note that the review period for an OBP, if such is required, is currently estimated at nine months to one year.

### 6.3 Department of Fisheries and Oceans Request for Review

As noted in **Section 4.2.4**, the detailed design will be submitted to DFO for review under the federal *Fisheries Act*.

## 7 CONSTRUCTION REQUIREMENTS

**Construction Supervision** – To ensure that the objectives of the outfall rehabilitation design are realized, it is important that someone with experience in channel design and restoration be part of the construction supervision (i.e., a qualified professional or representative of Aquafor Beech Ltd.). The supervision will enable construction issues to be addressed quickly and appropriately and ensure that important design details such as those listed below are implemented:

- Implementation of functional erosion and sediment control measures, including dewatering and pumping procedures;
- Removal of existing vegetation within, and protection of vegetation in close proximity to, the works area and access route;
- Confirmation of stone size gradation;
- Construction of an appropriate transition at the upstream and downstream tie-in points; and
- Restoration planting of native shrubs and trees, and Terraseeding of native seed mix.

**Erosion and Sediment Control Measures** – Erosion protection shall be used on regraded banks to provide erosion protection prior to the establishment of a vegetative cover.

Inspection of ESC measures should be completed regularly during the construction process to ensure that erosion and sediment control measures are functioning as intended and to address any immediate concerns. Similarly, monitoring of erosion control works should be completed following any flooding event to ensure that erosion control blankets and plantings are not compromised as a result of the event. The inspection and monitoring should be completed by an engineer, environmental inspector, or representative of Aquafor Beech Ltd.

**Timing** – Construction timing is restricted for fisheries protection. The Indian River provides habitat to both spring and fall spawning species. As such, no in-water works may occur between October 1 to July 15 of any given year to respect spring and fall spawning species for the MNR Southern Region. All tree removals on the site must take place outside of the period from April 1 to September 30, which is inclusive of the typical bird nesting season (April 1 to August 31) and the typical maternity roost season (April 1 - September 30).

**Fish Removal** – An initial fish rescue will be required once the in-water work area has been isolated; the fish rescue will be completed prior to dewatering the work area. Subsequent fish rescues will be required if the coffer dam isolating the work area is overtopped by high flows in the river. The contractor will be responsible for coordinating with the qualified aquatic biologist for fish rescues.

**Construction Methodology** – The channel bank and bed works must be undertaken in the dry. Dry working conditions will be created by blocking the perimeter of the work zone with coffer dams and routing the water

around the work zone (dam and flume techniques). Additional precautions and procedures, specified in the detailed drawings, include:

- All practical measures will be implemented to maintain the work zone in good condition;
- Utilities will be located and protected;
- Equipment refuelling will take place in the designated staging area, a minimum of 30 m from the watercourse; and
- All erosion and sediment control measures will be maintained in good working order.

**Site Access** – Access routes are shown on Sheet 6 of the drawing set, along with a staging and storage area. Access for construction is proposed from Paul Martin Drive, which will require temporary lane closure. The existing 5 m long guard rail is to be removed prior construction to facilitate site access, and is to be replaced upon completion of construction. Any changes to the access routes or staging area locations must be approved by the City and the field engineer.

**Vegetation** – To minimize the rate of erosion, it is desirable to establish vegetation quickly where it has been specified. Potted shrubs, potted trees, and a native seed mix (to be applied by Terraseeding) will be used to restore the site. Onsite consideration should be given to the season and prevailing light conditions for planting. If construction occurs after October, plantings should be completed as soon as possible in the following spring season.

## 8 CONSTRUCTION COST ESTIMATION

Preliminary construction costs have been estimated based on a schedule of quantities from the detailed design presented here. The construction cost estimate is $341,940 which includes a 20% contingency but is exclusive of HST. The detailed schedule of quantities showing the breakdown of costs is provided on the following page in **Table 8-1**.

## Table 8-1: Construction Cost Estimate for Reconstruction of Outfall # Unknown

| PEMBROKE OUTLETS - OUTLET # UNKNOWN | | | | | |
|---|---|---|---|---|---|
| City of Pembroke | | | | | |
| **Item** | **Description** | **Qty** | **Unit** | **Unit Price** | **Extended Price (Excl. HST)** |
| **Section "A" – Site Preparation & Removals** | | | | | |
| **1** | Bonds and Insurance | 1 | LS | $10,000 | $10,000 |
| **2** | Field Office | 1 | LS | $3,000 | $3,000 |
| **3** | Construction Layout, Utility & Locates | 1 | LS | $8,000 | $8,000 |
| **4** | Mobilization & Demobilization | 1 | LS | $10,000 | $10,000 |
| **5** | Access Route, Mud Mat & Staging Areas | 1 | LS | $12,000 | $10,000 |
| **6** | Clearing, Grubbing, and Vegetation Removal Including Removal and Reinstalling Guard Rail | 1 | LS | $10,000 | $10,000 |
| **7** | Supply, Install & Remove Temporary Tree Hoarding/Construction Fence | 15 | m | $15 | $225 |
| **8** | Supply, Install & Remove Temporary Erosion and Sediment Control Fence | 80 | m | $20 | $1,600 |
| **9** | Stream Control, Bypass Pumping & Dewatering | 1 | LS | $12,000 | $12,000 |
| **10** | MNRF Fish Collection Permit and Fish Rescues | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section A (Excl of HST)** | | | | | $69,825 |
| **Section "B" – Sewer Works, Channel Works and Restoration** | | | | | |
| **12** | Excavate, Earthwork, Grading & Disposal of Materials | 1 | LS | $8,000 | $8,000 |
| **17** | Supply & Placement of Angular Channel Substrate | 780 | tonne | $200 | $156,000 |
| **19** | Supply & Placement of Erosion Control Blanket - Coir Mat | 315 | $m^2$ | $8 | $2,520 |
| **20** | Supply & Placement of Topsoil for Restoration (300mm) | 95 | $m^3$ | $50 | $4,750 |
| **21** | Supply & Application of Terraseed Mixture | 315 | $m^2$ | $8 | $2,520 |
| **23** | Supply & Planting of Trees (5 gal potted @ min 2.5m spacing) | | | | |
| | i) Bur Oak | 1 | ea | $250 | $250 |
| | ii) White Spruce | 1 | ea | $250 | $250 |
| | iii) Eastern White Cedar | 1 | ea | $250 | $250 |
| **23** | Supply & Planting of Shrubs (2 gal potted @ 1m spacing) | | | | |
| | i) Red Osier Dogwood | 3 | ea | $45 | $135 |
| | ii) Chokecherry | 2 | ea | $45 | $90 |
| | iii) Grey Dogwood | 3 | ea | $45 | $135 |
| | iv) Downy juneberry | 3 | ea | $45 | $135 |
| | v) Shining Willow | 2 | ea | $45 | $90 |
| | vi) Slender Willow | 2 | ea | $45 | $90 |
| **Subtotal Section B (Excl of HST)** | | | | | $175,125 |
| **Section "C" – Provisional** | | | | | |
| **24** | Asphalt Road Repair (Removal, Granular Placement, New Asphalt, Buffer Restoration) | 1 | LS | $30,000 | $30,000 |
| **25** | Migratory Nesting Bird Survey | 1 | LS | $5,000 | $5,000 |
| **26** | Retain Certified Arborist | 1 | LS | $5,000 | $5,000 |
| **Subtotal Section C (Excl of HST)** | | | | | $40,000 |

| | | | | | |
|---|---|---|---|---|---|
| **Section "D" – Contingency** | | | | | |
| **27** | Contingency (20%) | 1 | LS | $56,990 | $56,990 |
| **Subtotal Section D (Excl of HST)** | | | | | $56,990 |
| | | | | | |
| | Section "A" – Site Preparation & Removals | | | | $69,825 |
| | Section "B" – Sewer Works, Channel Works and Restoration | | | | $175,125 |
| | Section "C" – Provisional | | | | $40,000 |
| | Section "D" – Contingency | | | | $56,990 |
| | | | | | |
| | Sub Total (Exc of taxes) | | | | $341,940 |
| | HST @ 13% | | | | $44,452 |
| | Total Bid Price (Incl of taxes) | | | | $386,392 |
| | | | | | |
| | **Outlet # UNKNOWN Engineering Estimate (Inc. Contingency, Exc. HST)** | | | | **$341,940** |

## 9 REFERENCES

Natural Resources Canada (2021). Plant hardiness of Canada. Retrieved from http://planthardiness.gc.ca/

Department of Fisheries and Oceans. (2021). Projects near water. Retrieved from Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/pnw-ppe/index-eng.html

## 10 SIGNATURES

This project is being completed with input from the following consulting staff:

Dave Maunder – Project Manager
Robert Amos – Water Resources Lead
Golmar Golmohammadi – Water Resources Engineer
Gabriel Dubé – Water Resources Specialist
Yun Xia – Water Resources Specialist
Palka Sharma – CAD Technician
Julie Scott – Terrestrial Ecologist
Jakub Ripley – GIS Specialist
Darcy LaFramboise – Certified Arborist
Graham Eby – Aquatic Biologist

Upon your review, should you have any questions or comments, please do not hesitate to contact the undersigned.

David Maunder

Dave Maunder, M.Sc., P.Eng
Project Manager
Aquafor Beech Limited

# APPENDIX I

## Draft Geotechnical Investigation Report

GEMTEC
www.gemtec.ca



# Geotechnical Investigation for the City of Pembroke Flood Risk Assessment and Storm Outlets

Pembroke, Ontario

GEMTEC
www.gemtec.ca



Submitted to:

Aquafor Beech Ltd.
55 Regal Road, Unit 3
Guelph, Ontario
N1K 1B6

# Geotechnical Investigation for the City of Pembroke Flood Risk Assessment and Storm Outlets

Pembroke, Ontario

March 25, 2022
Project: 101078.001

GEMTEC Consulting Engineers and Scientists Limited
142 Industrial Avenue
Petawawa ON, Canada
K8H 2W8

March 25, 2022

File: 101078.001

Aquafor Beech Ltd.
55 Regal Road, Unit 3
Guelph, Ontario
N1K 1B6

Attention: Mr. Dave Maunder

**Re: Geotechnical Investigation for the City Wide Flood Risk Assessment and Storm Outlets, Pembroke, Ontario**



Please find enclosed the GEMTEC Consulting Engineers and Scientists Limited (GEMTEC) Geotechnical Investigation report for the City Wide Flood Risk Assessment and Storm Outlets as described in the City of Pembroke Request For Proposal No. P-21-09 located in Pembroke, Ontario.

A geotechnical investigation was conducted to assess the existing subsurface soil conditions at the requested stormwater outlets in order to present geotechnical recommendations pertaining to the reconstruction and stabilization design of the new outlets.

We trust that this report provides sufficient information for your purposes. Should you have any questions or require additional information concerning this report, please do not hesitate to contact the undersigned.

Sincerely,

**GEMTEC Consulting Engineers and Scientists Limited**

Brent Wiebe, P.Eng
Vice President of Operations - Ontario

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## LIST OF APPENDICES

# 1.0 INTRODUCTION

## 1.1 General

This report presents the results of a geotechnical investigation for the City of Pembroke's Flood Risk Assessment and Storm Outlet project. The purpose of the investigation was to identify the general subsurface conditions at nine outlet locations by means of a limited number of boreholes and, based on the factual information obtained, to:

a) Provide engineering guidelines on the geotechnical design aspect of the proposed outlet reconstruction including construction considerations that could influence design decisions, and;

b) Develop possible slope stabilization alternatives, where applicable.

The storm outlet locations are located along the Muskrat and Indian Rivers within the City of Pembroke. The nine outlet locations investigated are as follows:

| | |
|---|---|
| Christie Street – Outlet 41 | Boundary Road Pathway – Outlet 35 |
| Paul Martin Drive – No Outlet # | Everett Street – Outlet 42 |
| Norman Street – Outlet 56 | Murray Street – Outlet 46 |
| Doran Street – Outlet 45 | Moffatt Street – Outlet 31 |
| Margaret Street – Outlet 27 | |

A Site Plan and Cross-Section for each outlet location is provided in the Appendices of this report. It is noted that these plans were provided to GEMTEC by Aquafor Beech Limited. GEMTEC has not carried out surveying of the slope profiles at the outlet locations.

## 1.2 Background Information

It is noted that GEMTEC has previously carried out an extensive slope stability investigation for Moffatt Street in the City of Pembroke. This work was carried out directly for the City of Pembroke. It is noted that portions of the current investigation are within the boundaries of the scope of work previously carried out by GEMTEC, namely Outlet 31. The recommendations provided herein are in no way intended to supersede global recommendations provided for the Moffatt street slope stability report previously provided by GEMTEC to the City of Pembroke. Discussions regarding implementations of remediation at Outlet 31 in conjunction with any other work carried out by the City of Pembroke as part of wider slope stabilization measures could be provided as required and it is recommended GEMTEC be contacted to ensure that recommendations have been interpreted as intended and align with recommendations provided for the broader Moffatt Street investigation.

### 1.3 Review of Geology Maps

Based on our review of available geology maps, the subject sites are underlain by alluvial deposits composed of clay, silt, sand, and gravel and fine-textured glaciomarine deposits of silt and clay. The bedrock is mapped as sandstone, shale, limestone, and dolostone of the Rockcliffe formation.

## 2.0 METHODOLOGY

### 2.1 Geotechnical Field Investigation

The geotechnical field investigation consisted of advancing nine (9) boreholes designated 22-01 to 22-09 at the locations shown on the Borehole Location Plans, presented as Figure A1 thru I1 in the Appendices. A complete description of the stratigraphy encountered at each borehole location is presented on the Record of Borehole sheets.

The geotechnical investigation was completed between February 11 and 16, 2022 using portable drilling equipment and March 14 to 16, 2022 using a truck-mounted drill operating under the supervision of experienced GEMTEC personnel. Soil samples were obtained at regular intervals in the overburden soils with a 51-millimetre diameter Standard Penetration Test split-spoon sampler. Sampling procedures were performed in accordance with ASTM Standard D-1586, which provides the penetration resistance (N-value) of the soils. In situ vane shear testing was carried out in the boreholes to measure the undrained shear strength of the silty clay deposits. Dynamic cone penetration testing (DCPT) was carried out in boreholes 22-03 and 22-04.

Soil samples were examined in the field for type, texture and colour to classify each soil layer identified. The samples were sealed in air tight plastic bags and transferred to GEMTEC's laboratory for further examination and selection of appropriate samples for laboratory testing.

Groundwater conditions within the boreholes were observed during the course of the field investigation and prior to backfilling.

The borehole locations were determined using a Trimble R10 GPS survey instrument. The elevations are referenced to Geodetic datum.

Table 3.1 summarizes the borehole numbers and final termination depths.

**Table 3.1: Borehole Numbers and Termination Depths**

| Street/ Outlet No. | Borehole No. | Depth Below Ground Surface (m) | Comment |
|---|---|---|---|
| Christie / 41 | 22-01 | 4.3 | Borehole terminated within silty clay |
| Boundary / 35 | 22-02 | 4.9 | Borehole terminated within lean clay |
| Paul Martin / NA | 22-03 | 6.1 | Borehole terminated at termination depth with DCPT |
| Everett / 42 | 22-04 | 10.2 | Borehole terminated due to DCPT refusal |
| Norman / 56 | 22-05 | 8.2 | Borehole terminated within glacial till |
| Murray / 46 | 22-06 | 4.6 | Borehole terminated within silty clay |
| Doran / 45 | 22-07 | 4.6 | Borehole terminated within silty clay |
| Moffatt / 31 | 22-08 | 9.8 | Borehole terminated within silty clay |
| Margaret / 27 | 22-09 | 18.9 | Borehole terminated within glacial till |

## 3.0 SUBSURFACE CONDITIONS

### 3.1 General

As previously indicated, the soil and groundwater conditions identified in the test holes are given on the Record of Borehole sheets. The logs indicate the subsurface conditions at the specific test locations only. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of exploration, the frequency and recovery of samples, the method of sampling, and the uniformity of the subsurface conditions. Subsurface conditions at other than the test locations may vary from the conditions encountered in the test holes. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the sites or on adjacent properties.

The groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities in the area.

The soil descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil

involves judgement and GEMTEC does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

The following presents an overview of the subsurface conditions encountered in the test holes advanced during the field investigation.

## 3.2 Soil Stratigraphy

### 3.2.1 Borehole 22-01 (Christie Street – Outlet 41)

The following provides a summary of the soil stratigraphy encountered at borehole 22-01:

- A 75 millimetre thick topsoil layer was encountered at ground surface. The topsoil is underlain by about one metre of fill material composed of brown sand and silt with trace gravel. The fill was found to be frozen at the time of the investigation.
- Native deposits of brown becoming grey sand with silt were encountered below the fill material at a depth of about 1.1 metres. The sand with silt deposits have a thickness of about 2.1 metres and extend to a depth of about 3.2 metres below existing grade. Standard Penetration Test results (N values) recorded in the sand with silt ranged from 3 to 9 blows per 300 millimetres indicating a very loose to loose relative density. One grain size distribution test was carried out on a sample of the sand and silt (refer to the Soil Grading Chart in Appendix A).
- The sand with silt is underlain by grey silty clay which extends to the termination depth of borehole 22-01 at a depth of 4.3 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty clay were 8 blows per 300 millimetres indicating a stiff to very stiff consistency. One particle size distribution analysis was carried out on a sample of the grey silty clay (refer to the Soil Grading Chart in Appendix A).
- Based on soil sample appearance, the groundwater level was estimated at about 2.1 metres below surface grade at the time of the investigation.

### 3.2.2 Borehole 22-02 (Boundary Road Pathway – Outlet 35)

The following provides a summary of the soil stratigraphy encountered at borehole 22-02:

- Fill material having a thickness of about 1.4 metres was encountered at ground surface. The fill material consists of about 200 millimetres of gravelly sand over brown silty clay fill with trace sand. The fill was frozen at the time of the investigation.
- Native deposits of dark grey to brown silty clay were encountered below the fill material at a depth of about 1.4 metres. The silty clay deposits were found to extend to the termination depth of borehole 22-02 at about 4.9 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty clay ranged from 9 to 12 blows per 300 millimetres indicating a very stiff consistency. One particle size distribution analysis was

carried out on a sample of the brown silty clay (refer to the Soil Grading Chart in Appendix B)

- Based on soil appearance, the groundwater level was estimated to be at about 3.0 metres below surface grade at the time of the investigation.

### 3.2.3 Borehole 22-03 (Paul Martin Drive – No Outlet Number)

The following provides a summary of the soil stratigraphy encountered in borehole 22-03:

- Fill material was encountered at ground surface, extending to about 1.7 metres below surface grade. The fill material consists of brown sand and gravel with some silt. The fill was frozen at the time of our investigation. One grain size distribution test was carried out on a sample of fill (refer to the Soil Grading Chart in Appendix C).
- Native deposits of brown sandy clay were encountered below the fill material at a depth of about 1.7 metres. The sandy clay deposits extend to the sampling termination point of borehole 22-03 at a depth of about 4.3 metres below ground surface. Standard Penetration Test results (N values) recorded in the sandy clay ranged from 32 to 48 blows per 300 millimetres indicating a compact relative density. One particle size distribution analysis was carried out on a sample of sandy clay (refer to the Soil Grading Chart in Appendix C).
- Borehole 22-03 was further advanced by means of a dynamic cone penetration test (DCPT) to the termination depth of 6.1 metres. Blow counts recorded during the DCPT test ranged from 30 to 52 blows per 300 millimetres.
- Groundwater infiltration was not observed within the open borehole.

### 3.2.4 Borehole 22-04 (Everett Street – Outlet 42)

The following provides a summary of the soil stratigraphy encountered in borehole 22-04:

- A 1.2 metre thick fill layer was encountered at ground surface. The fill consists of dark brown sand and silt with some gravel. Large pieces of concrete debris were observed on the surface directly downstream of the outlet.
- Native deposits of dark grey clayey sand were encountered below the fill material at a depth of about 1.2 metres. The clayey sand was found to have a thickness of about 1.8 metres and extends to a depth of about 3.0 metres below existing grade. Standard Penetration Test results (N values) recorded in the clayey sand ranged from 7 to 9 blows per 300 millimetres indicating a loose relative density. One grain size distribution test was carried out on a sample of the clayey sand (refer to the Soil Grading Chart in Appendix D).

- The dark clayey sand is underlain by dark grey clayey silt, which has a thickness of about 1.8 metres and extends to a depth of about 4.9 metres below ground surface. Standard Penetration Test results (N values) recorded in the clayey silt ranged from 12 to 44 blows per 300 millimetres indicating a stiff to very stiff consistency. One particle size distribution test was carried out on a sample of the clayey silt (refer to the Soil Grading Chart in Appendix D).
- The dark grey clayey silt is underlain by a deposit of dark grey silty clay which has a thickness of about 1.5 metres and extends to a depth of about 6.4 metres below surface grade. Standard Penetration Test results (N values) recorded in the silt clay ranged from 7 to 12 blows per 300 millimetres. In-situ shear vane testing was performed in the silty clay deposit. The values of undrained shear strength were recorded as 168 kilopascals which indicates a very stiff consistency. One particle size distribution test was carried out on a sample of the silty clay (refer to the Soil Grading Charts in Appendix D).
- The dark grey silty clay is underlain by a deposit of glacial till primarily composed of grey clayey sand and silt with some gravel. The glacial till was found to extend to the sampling termination depth of the borehole at about 7.0 metres below surface grade. A Standard Penetration Test Result (N value) recorded in the glacial till was 30 blows per 300 millimetres which indicates a compact relative density. One grain size distribution test was carried out on a sample of the glacial till (refer to the Soil Grading Chart in Appendix D).
- Borehole 22-04 was further advanced by means of a dynamic cone penetration test (DCPT) and terminated at a depth of about 10.2 metres due to refusal within the inferred glacial till on cobbles or boulders. Blow counts recorded during the DCPT test ranged from 14 to 58 blows per 300 millimetres.
- Based on soil sample appearance, the groundwater level was estimated to be at about 4.9 metres below surface grade at the time of the investigation.

### 3.2.5 Borehole 22-05 (Norman Street – Outlet 56)

The following provides a summary of the soil stratigraphy encountered in borehole 22-05:

- From the surface, a 50 millimetre layer of asphaltic concrete was encountered. Underlying the surficial layer of asphaltic concrete, a road base and subbase material was observed. The road base consisted of a brown crushed sand with gravel and some silt and has a thickness of about 150 millimetres. The subbase consists of a brown gravelly sand with trace silt and has a thickness of about 300 millimetres. The road base and subbase was frozen at the time of the investigation.
- Underlying the pavement structure, a fill material consisting of brown sand and silt with trace gravel was encountered. The fill was found to have a thickness of about 1.0 metre and extends to a depth of about 1.5 metres below surface grade. Standard Penetration Test results (N values) recorded in the fill were recorded as 35 blows per 300 millimetres indicating a dense relative density.

- Native deposits of brown silty sand were encountered below the fill material at a depth of about 1.5 metres. The silty sand deposit has a thickness of about 0.9 metres and extends to a depth of about 2.4 metres below surface grade. A Standard Penetration Test (N value) recorded in the silty sand was 6 blows per 300 millimetres, indicating a loose relative density. One grain size distribution test was carried out on a sample of the silt (refer to the Soil Grading Charts in Appendix E).
- The silty sand is underlain by brown to grey silty clay. The silty clay has a thickness of about 3.4 metres and extends to a depth of about 5.8 metres below existing grade. Standard Penetration Test results (N values) recorded in the silty clay ranged from 1 to 9 blows per 300 millimetres. In-situ shear vane testing was performed in the silty clay deposit. The undrained shear strength values ranged from 91 to 104 kilopascals which indicates a stiff to very stiff consistency. One particle size distribution analysis was carried out on a sample of the silty clay (refer to the Soil Grading Chart in Appendix E).
- The silty clay is underlain by glacial till composed of grey clayey sand and gravel. The glacial till was found to extend to the termination depth of borehole 22-05 at about 8.2 metres below surface grade. Standard Penetration Test results (N values) recorded in the glacial till ranged from 11 to 21 blows per 300 millimetres indicating a compact relative density.
- Based on soil sample appearance, the groundwater level was estimated to be at about 7.2 metres below surface grade at the time of the investigation.

#### 3.2.6 Borehole 22-06 (Murray Street – Outlet 46)

The following provides a summary of the soil stratigraphy encountered in borehole 22-06:

- From the surface, a 50 millimetre layer of asphaltic concrete was encountered. Underlying the surficial layer of asphaltic concrete, a road base and subbase material was observed. The road base consisted of a brown crushed sand with gravel and some silt and has a thickness of about 160 millimetres. The subbase consists of a brown sand with some gravel and some silt and has a thickness of about 800 millimetres. The road base and subbase was frozen at the time of the investigation.
- Native deposits of brown silty sand were encountered below the pavement structure at a depth of about 1.0 metre. The silty sand deposit has a thickness of about 2.2 metres and extends to about 3.2 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty sand ranged from 2 to 4 blows per 300 millimetres indicating a very loose relative density. One grain size distribution test was carried out on a sample of the silty sand (refer to the Soil Grading Charts in Appendix F).
- The silty sand is underlain by grey silty clay. The silty clay extends to the termination depth of borehole 22-06 at about 4.6 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty clay ranged from 1 to 5 blows per 300

millimetres indicating a firm consistency. One particle size distribution analysis was carried out on a sample of the silty clay (refer to the Soil Grading Chart in Appendix F).

- Based on soil sample appearance, the groundwater level was estimated to be about 3.2 metres below surface grade at the time of the investigation.

### 3.2.7 Borehole 22-07 (Doran Street – Outlet 45)

The following provides a summary of the soil stratigraphy encountered in borehole 22-07:

- From the surface, a fill material consisting of dark brown to brown sand with some silt and trace gravel was encountered. The fill has a thickness of about 1.0 metre. The fill was frozen at the time of the investigation.
- Native deposits of brown silty sand with trace gravel were encountered below the fill. The silty sand deposits have a thickness of about 2.7 metres and extend to a depth of about 3.7 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty sand range from 3 to 12 blows per 300 millimetres indicating a very loose to compact relative density. Split spoon sampler refusal was encountered at a depth of about 3.3 metres below surface grade on organic wood material. One grain size distribution test was carried out on a sample of the silty sand (refer to the Soil Grading Chart in Appendix G).
- The silty sand is underlain by grey silty clay. The silty clay extends to the termination depth of borehole 22-07 at about 4.6 metres below surface grade. A Standard Penetration Test (N values) recorded in the silty clay was 7 blows per 300 millimetres indicating a stiff consistency. One particle size distribution analysis was carried out on a sample of the silty clay (refer to the Soil Grading Charts in Appendix G).
- Based on soil sample appearance, the groundwater level was estimated to be at about 2.3 metres below surface grade at the time of the investigation.

### 3.2.8 Borehole 22-08 (Moffatt Street – Outlet 31)

The following provides a summary of the soil stratigraphy encountered in borehole 22-08:

- From the surface, a 40 millimetre layer of asphaltic concrete was encountered. Underlying the surficial layer of asphaltic concrete, a road base material was observed. The road base consisted of a brown crushed sand with gravel and some silt and has a thickness of about 200 millimetres.
- Underlying the pavement structure, a layer of fill consisting of brown silty sand with trace clay was encountered. The fill has a thickness of about 1.9 metres and extends to about 2.1 metres below surface grade. Standard Penetration Test results (N values) recorded in the fill range from 6 to 20 blows per 300 millimetres indicating a loose to compact relative

density. One grain size distribution test was carried out on a sample of the fill (refer to the Soil Grading Chart in Appendix H).

- A native deposit of brown sand with some silt was encountered below the fill material. The sand deposit has a thickness of about 2.8 metres and extends to a depth of about 5.0 metres below surface grade. Standard Penetration Test results (N values) recorded in the sand range from 4 to 15 blows per 300 millimetres indicating a loose to compact relative density. One grain size distribution test was carried out on a sample of the sand (refer to the Soil Grading Chart in Appendix H).
- The sand is underlain by grey silty clay. The silty clay extends to the termination depth of borehole 22-08 at about 9.8 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty clay range from 2 to 14 blows per 300 millimetres. In-situ shear vane testing was performed in the silty clay deposit. The values of undrained shear strength were greater than 108 kilopascals which indicates a very stiff consistency. One particle size distribution analysis was carried out on a sample of the silty clay (refer to the Soil Grading Chart in Appendix H).
- Based on soil sample appearance, the groundwater level was estimated to be at about 4.3 metres below surface grade at the time of the investigation.

### 3.2.9 Borehole 22-09 (Margaret Street – Outlet 27)

The following provides a summary of the soil stratigraphy encountered in borehole 22-09:

- Fill material was encountered at surface, extending to about 1.8 metres depth. The fill is variable but can be described as brown sand and gravel to silty sand with trace asphaltic concrete. The upper portion of the fill was frozen at the time of our investigation. Standard Penetration Test results (N values) recorded in the fill range from 4 to 9 blows per 300 millimetres indicating a loose relative density. One grain size distribution test was carried out on a sample of the fill (refer to the Soil Grading Chart in Appendix I).
- A native deposit of brownish grey sandy silt were encountered below the fill material. The sandy silt deposit has a thickness of about 11.0 metres and extends to a depth of about 12.8 metres below surface grade. Standard Penetration Test results (N values) recorded in the sandy silt range from 4 to 15 blows per 300 millimetres indicating a loose to compact relative density. One particle size distribution test was carried out on a sample of the sandy silt (refer to the Soil Grading Charts in Appendix I).
- The sandy silt is underlain by grey silty clay. The silty clay has a thickness of about 5.8 metres and extends to a depth of about 18.6 metres below surface grade. Standard Penetration Test results (N values) recorded in the silty clay indicated 2 blows per 300 millimetres. In-situ shear vane testing was performed in the silty clay deposit. The values of undrained shear strength were recorded as being greater than 108 kilopascals which

indicates a very stiff consistency. One particle size distribution analysis was carried out on a sample of the silty clay (refer to the Soil Grading Chart in Appendix I).

- The silty clay is underlain by glacial till comprised of grey sand and silt with gravel. The glacial till extends to the termination depth of borehole 22-09 at about 18.9 metres below surface grade. A Standard Penetration Test result (N value) recorded in the glacial till was 13 blows per 300 millimetres, indicating a compact relative density.

- Based on soil sample appearance, the groundwater level was estimated to be at about 12.2 metres below surface grade at the time of the investigation.

## 4.0 GEOTECHNICAL RECOMMENDATIONS

### 4.1 General

As discussed in Section 1.0, the project may include reconstruction and replacement of the existing storm outlets and pipes.

### 4.2 Excavations

For the proposed reconstruction of the storm outlets and pipes, it is anticipated that the replacement pipes and outlets will be of similar size and depth below surface grade. The depth of excavation will vary from outlet to outlet based on existing slope of surface grade and the slope of the outlet pipe. The maximum depth of pipe is not anticipated to exceed 4 metres below surface grade at any of the sites.

The sides of the excavations in the overburden should be sloped in accordance with the requirements in Ontario Regulation 213/91 under the Occupational Health and Safety Act. According to the Act, the overburden soils can be classified as Type 3 and, accordingly, allowance should be made for excavation side slopes of 1 horizontal to 1 vertical, or flatter. As an alternative or where space constraints dictate, the service installations could be carried out within a tightly fitting, braced steel trench box, specifically designed for this purpose.

During the excavation process, no excavated material should be piled, nor machinery or equipment placed, closer than 2.0 metres from the edge of the top of slope. No vertical unbraced excavations should be performed in the soil.

An examination of the excavation slopes should be performed by a qualified geotechnical personnel before any worker enters the excavation. The exposed soil should be protected against erosion from water run-off or rain. Excavation side slopes should not be left exposed to inclement weather.

### 4.3 Pipe Bedding, Cover and Trench Backfill

The bedding for the proposed services should be in accordance with OPSD 802.010 and 802.031 for flexible and rigid pipes in overburden excavations. The pipe bedding material should consist of at least 150 millimetres of well-graded crushed stone meeting OPSS 1010 for Granular A.

In areas where the subsoils are disturbed or where unsuitable material (such as fill material, organic soil or existing trench backfill material) exists below the pipe subgrade level, the disturbed/unsuitable material should be removed and replaced with engineered granular fill such as OPSS Granular A or Granular B Type II or III. To provide adequate support for pipes in the long term in areas where subexcavation of material is required below design subgrade level, the excavations should be sized to allow a 1 horizontal to 2 vertical spread of granular material down and out from the bottom of the pipes. The use of clear crushed stone as bedding or subbedding material should not be permitted.

Cover material, from pipe spring line to at least 300 millimetres above the top of the pipe, should consist of granular material, such as OPSS Granular A.

The granular bedding and cover materials should be compacted in maximum 200-millimetre thick lifts to at least 95 percent of the Standard Proctor Maximum Dry Density (SPMDD) of the material.

In areas were the pipes are below or near hard surfaced areas, consideration should be given to the composition of the trench backfill and the potential for differential frost heaving between the area over the service trench and the adjacent asphalt surface. In these areas, acceptable native materials should be used as backfill between the roadway subgrade level and the depth of seasonal frost protection (ie. 1.8 metres below finished grade). The backfill materials within the zone of frost penetration should match the materials exposed on the trench walls. Backfill below the zone of seasonal frost penetration could consist of either acceptable native material or imported granular material conforming to OPSS Granular B Types I, II or III.

To minimize future settlement of the backfill and achieve an acceptable subgrade for any roadways, curbs, etc., the trench backfill should be compacted in maximum 300-millimetre thick lifts to at least 95 percent of the SPMDD.

### 4.4 Construction Dewatering

It is anticipated that any groundwater inflow from the overburden or surface water runoff into the excavation should be handled by pumping from within the excavations. Flatter side slopes or tightly fitting trench boxes may be necessary for excavations below the groundwater level due to sloughing of the excavation sidewalls. It is not expected that short term pumping during excavation will have a significant effect on nearby structures and services.

Water levels can be expected to vary on a seasonal basis with the highest levels occurring in the spring. In order to reduce the potential for groundwater pumping during excavation, consideration should be given to conducting construction during drier periods of the year (i.e. June to October).

Table 4.1 below provides the estimated groundwater level at each of the nine outlet locations based on soil sample appearance and observations within the open boreholes during the field investigation.

**Table 4.1: Summary of Estimated Groundwater Levels (at Time of Investigation)**

| Location | Estimated Groundwater Level (mbgs) | Geodetic Elevation |
|---|---|---|
| Christie Street - Outlet 41 | 2.1 mbgs | 116.6 m |
| Boundary St Pathway- Outlet 35 | 3.0 mbgs | 122.3 m |
| Paul Martin Drive - No Outlet # | No Infiltration Observed | n/a |
| Everett Street - Outlet 42 | 4.9 mbgs | 117.7 m |
| Norman Street - Outlet 56 | 7.2 mbgs | 115.2 m |
| Murray Street - Outlet 46 | 3.2 mbgs | 115.4 m |
| Doran Street - Outlet 45 | 2.3 mbgs | 116.5 m |
| Moffatt Street - Outlet 31 | 4.3 mbgs | 119.5 m |
| Margaret Street - Outlet 27 | 12.2 mbgs | 116.4 m |

Notes:

1. As indicated above, the estimated groundwater levels are based on visual and tactile observations at the time of the field investigation. No standpipe piezometers were installed as part of this investigation.



## 4.5 Erosion Protection

The outlets should be protected from erosion and scour using rip rap (refer to OPSD 810.010). The rip rap should be suitably sized and graded to prevent damage to the rip rap. The sizing and grading should take into consideration the flow velocities, ice buildup, ice damming effects, etc. at each individual outlet.

The rip rap should meet the requirements of OPSS 1004 and should be placed in accordance with OPSS 511. A non-woven geotextile meeting OPSS 1860 Class II requirements should be placed between the subgrade surface and the rip rap. All seams in the geotextile should be sewn or provided with at least 0.5 metres of overlap.

The geotextile and rip rap should be placed on undisturbed, native soil. All disturbed or deleterious material, such as construction debris, organic material, etc., should be removed from below the rip rap. Removal of vegetation may also be required. Excavation at the toe of the slope should be carefully planned and controlled to ensure excavation at the toe does not reduce the stability of the existing slope. For example, excavation and backfilling near the toe of the slope should be carried out in short sections. Excavation below the water level, where required, could be carried out "in the wet", provided that in water work is permitted and necessary permits have been obtained.

The rip rap should be placed to 0.5 metres above the high water mark and should be compacted by tamping with the bucket of the excavator. The thickness of the rip rap should be at least 1.5 times the maximum particle size.

To prevent undermining (i.e., erosion of the soil below the rock fill), we recommend that the underside of the rock fill extend to the approximate elevation of the creek bed adjacent to the slope.

The rock fill should be placed with a slope not steeper than 1.5 horizontal to 1 vertical and should be underlain by a nonwoven geotextile meeting OPSS 1860 Class II with 0.5 metre overlaps.

Consideration should be given to the carrying out the work at a time of year when the water level in the rivers are expected to be low, such as late summer/early fall.

## 5.0 SLOPE STABILIZATION ASSESSMENT

### 5.1 Overview

The nine storm outlets included as part of this investigation all terminate into the Indian and Muskrat Rivers. The banks of the rivers surrounding the outlets vary significantly in slope and height. The nine outlet locations were assessed by GEMTEC personnel using rating charts in Table 4.2 of the Ontario Ministry of Natural Resources Technical Guide – River and Stream Systems; Erosion Hazard Limit (2002). These assessments were used as a preliminary guide, to determine if any of the slopes within the vicinity of the outlets present a potential for slope stability failure and to identify where detailed assessments of the existing factor of safety is required.

Table 5.1 below summarizes the findings of the slope assessment using the MNR rating charts:

**Table 5.1: Summary of Slope Assessment at Outlets**

| Location | Comments | Potential for Slope Failure |
|---|---|---|
| Christie Street Outlet 41 | No active erosion; minimal slope height; pipe outlets near bottom of river bank | Low |

| | | |
|---|---|---|
| Boundary Street Pathway Outlet 35 | Minimal slope inclination; pipe outlet is broken and deteriorated contributing to active surface erosion | Low |
| Paul Martin Drive No Outlet # | Active surface erosion, pipe outlet is at top of slope; minimal slope inclination | Low |
| Everett Street Outlet 42 | Active surface erosion; minimal slope inclination; pipe outlet is near top of slope | Low |
| Norman Street Outlet 56 | Active surface erosion of river bank; steep slope inclination; pipe outlet is at top of slope | Moderate |
| Murray Street Outlet 46 | No active erosion; minimal slope height; pipe outlets near bottom of river bank | Low |
| Doran Street Outlet 45 | No active erosion; minimal slope height; pipe outlets near bottom of river bank | Low |
| Moffatt Street Outlet 31 | Active surface erosion of river bank, moderate slope inclination, pipe outlet near top of slope | Slight |
| Margaret Street Outlet 27 | Active bank erosion, steep slope inclination; pipe outlets near top of slope | Moderate |



Based on the slope assessment for each of the nine outlets, three locations were identified as requiring further slope analysis to determine the existing factor of safety and possible remediation alternatives. They include Norman Street – Outlet 56; Moffatt Street – Outlet 31; and, Margaret Street – Outlet 27.

Furthermore, three locations were also identified as exhibiting active surface erosion from surface water runoff. These locations include Boundary Road Pathway – Outlet 35; Paul Martin Drive – No Outlet #; and, Everett Street – Outlet 42.

### 5.1.1 Slope Stabilization Alternatives

#### 5.1.1.1 Outlet and Riverbank Support

Christie Street – Outlet 41, Murray Street – Outlet 46 and Doran Street – Outlet 45 were identified as having little to no erosion of the river bank or slope immediately adjacent to the outlet. In all three cases, the pipe outlet is below the water level or near the level of the adjacent river.

As mentioned in Section 4.5, the use of rip-rap should be considered around the outlet and river bank to provide protection from erosion and scour.

### 5.1.2 Slope Erosion Protection

Erosion from surface water runoff was identified at the Boundary Road Pathway – Outlet 35, Paul Martin Drive – No Outlet # and Everett Street – Outlet 42. In all three cases, the outlets are located near the top of the slope which was also found to have minimal slope inclination at all three locations. Based on the slope assessment, there is also a low potential for future slope failure based on the existing conditions.

To reconstruct the slope and protect it from future erosion the following alternatives are suggested:

| Alternative | Strategy | Comments |
|---|---|---|
| Slope Re-grading | Re-grading the eroded slope by moving the crest of the slope into the tablelands. The location of the toe could be maintained. | In order to flatten the existing slopes, earth excavation and removal of any remaining vegetation is required. Furthermore, loss of the tableland area is required in order to construct the stabilization alternative. |
| Blast Rock / Rip-Rap Buttress | The eroded soil downstream of the outlets could be replaced with well graded blast rock or rip-rap inclined at 1.5 horizontal to 1 vertical, or flatter. | The location of the toe could be maintained which would prevent encroachment of the slope into the adjacent river. Some loss of the table land area and removal of existing vegetation may be required in order to accommodate an inclination of 1.5H:1V while maintain the location of the toe. |
| Reinforced Soil Slope | A reinforced soil slope could be constructed along the slope. A reinforced slope generally consists of excavating portions of the slope and rebuilding with compacted granular materials reinforced with plastic or steel grid reinforcement. A permanent erosion blanket is generally incorporated into the design to prevent erosion and promote vegetative growth. | In order to construct the reinforced slope, earth excavation and removal of existing vegetation (including trees) is required. |

The slope erosion and stabilization alternatives presented above should be implemented and combined with the following erosion control measures:

- Following regrading or where a vegetated slope face is desired, a thin layer of topsoil could be placed along the slope face and seeded. A suitable erosion control blanket (i.e. double net, straw and coconut fibre blanket) should then be installed on the surface and secured using wood stakes. It is important that suitable vegetation be established over the slope. This could include special perennials such as crown vetch which is ideal for steep slopes and is commonly used along roadway embankments.
- Installation of toe erosion protection to prevent erosion of the toe of the slope (e.g. rip rap, riverstone, etc.). The type of toe erosion protection will depend on the anticipated flow velocities of the adjacent river and ice scour effects.

### 5.1.3 Slope Stability Assessment

Based on the preliminary assessment using Table 4.2 of the Ontario Ministry of Natural Resources Technical Guide – River and Stream Systems; Erosion Hazard Limit (2002) as a guide, three slopes within the vicinity of the outlets were determined to have a low to moderate potential for future slope instability and possible slope failure. These locations include Norman Street – Outlet 56, Moffat Street – Outlet 31 and Margaret Street – Outlet 27.

Active soil and bank erosion was observed at each of the three outlet locations. The slopes or river banks are relatively steep with a slope inclination ranging from about 16 degrees to 34 degrees and height of slope ranging from about 8 metres to 16 metres.

Based on the preliminary assessment, it is recommended that further slope stability analysis be completed using slope stability software to determine such factors as the existing slope factor of safety and the stability of the slope under seismic loading conditions. A more in-depth analysis will allow for the implementation of slope stabilization measures in order to decrease the probability of occurrence for a deeper slope failure. Such measures could include:

- **Avoidance:** This approach is essentially the “do nothing” alternative. For this case, no effort is made to reduce the probability of occurrence for a slope failure. In the higher risk areas, demolition of existing dwellings could be considered to reduce the consequences of a failure.
- **External Toe Berm:** Involves the construction of an external rock berm at the bottom of the slope, while maintaining the geometry and vegetation along the upper portion of the slope. The rock berm will encroach into the river. The berm also protects the toe from erosion.
- **Slope Flattening:** Involves re-grading the slope at a shallower angle that will be stable. Removal of the existing vegetation and loss of horizontal, tableland area is required in

order to accommodate the shallower slope angle. Not feasible in areas where existing structures and dwellings are located in close proximity to the slope. Re-vegetation of the regraded slope is required. Erosion protection measures are required at the toe of the slope.

- **Horizontal Drains:** Involves the installation of 4 metre long horizontal wick drains through the slope face using hand operated equipment in order to reduce the groundwater levels. The drains could be installed on a regularly spaced grid pattern and inclined from the horizontal to promote gravity drainage. Erosion protection measures should be implemented at the toe of the slope.

- **Full Slope Reconstruction:** This method involves excavating the existing slope and rebuilding with rock fill in benches. Similar to construction of an external toe berm; however, for full slope reconstruction, the rock fill extends up to the crest of the slope. Full slope reconstruction also protects the toe from erosion.

- **Structural Elements:** Involves the installation of sheet piling and tie-backs to strengthen and stabilize the slope. The sheet piling could be installed near the upper portion of the slope and driven to refusal. Tie-backs, installed into bedrock, will likely be required to restrain the top of the piles. Erosion protection measures are required at the toe of the slope.

Further comments on the selection of an appropriate remediation alternative could be provided following the detailed slope stability assessment at each location.

### 5.2 Detailed Design

It is recommended that GEMTEC be consulted during the detailed design stage to confirm that the information in this report has been interpreted as intended. If required, permitting for in-water stabilization works, such as a Fisheries Act authorization from DFO and a permit under the Endangered Species Act, 2007 associated with potential impacts to SAR habitat, should also be finalized during the detailed design stage.

### 5.3 Disposal of Excess Soil

The presence or implications of possible surface and/or subsurface contamination, including naturally occurring source of contamination, are outside the terms of reference for this report. This report does not constitute a Phase II Environmental Site Assessment (ESA) nor does it constitute a contaminated material management plan.

## 6.0 CLOSURE

It is noted that the information provided in this report pertain only to the geotechnical aspects of the project. It is recommended that the final design drawings be reviewed by the geotechnical engineer to ensure that the guidelines provided in this report have been interpreted as intended.

We trust this report provides sufficient information for your present purposes. If you have any questions concerning this report, please do not hesitate to contact our office.

Respectfully,

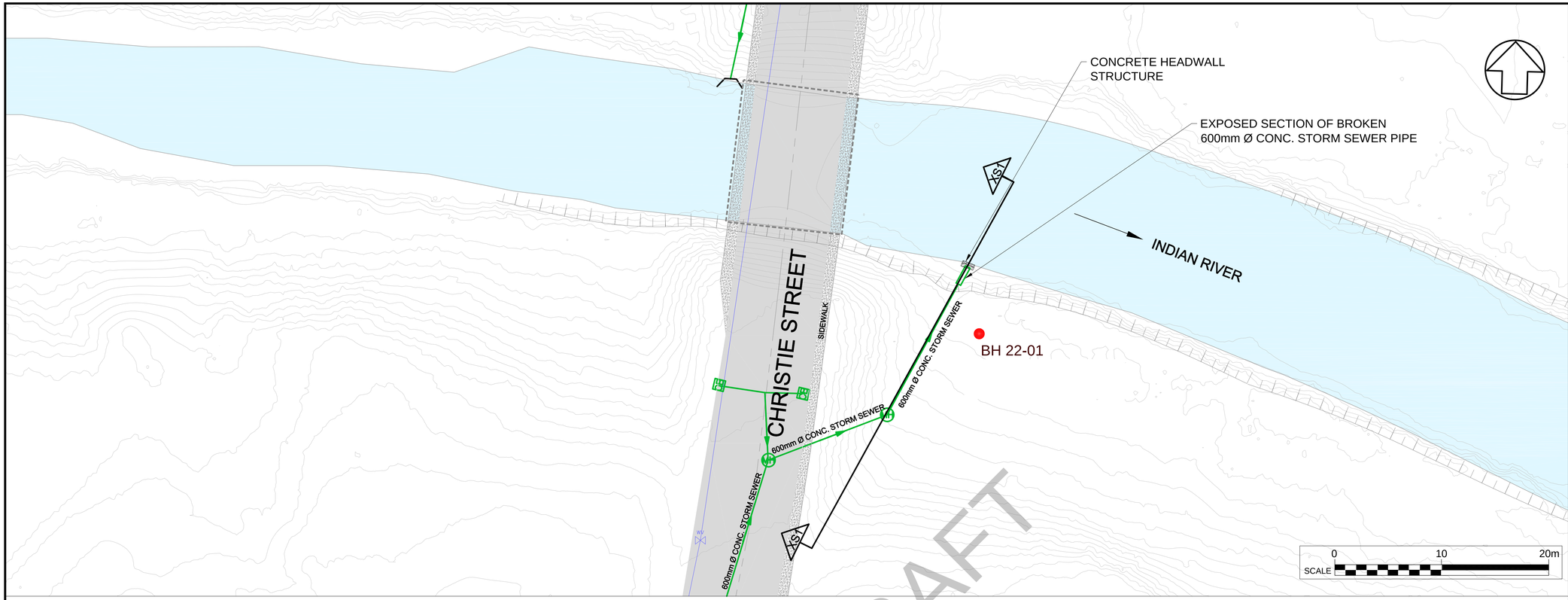
**GEMTEC Consulting Engineers and Scientists Limited**


Adam Stamplicoski, C.E.T.
Senior Geotechnical Technologist

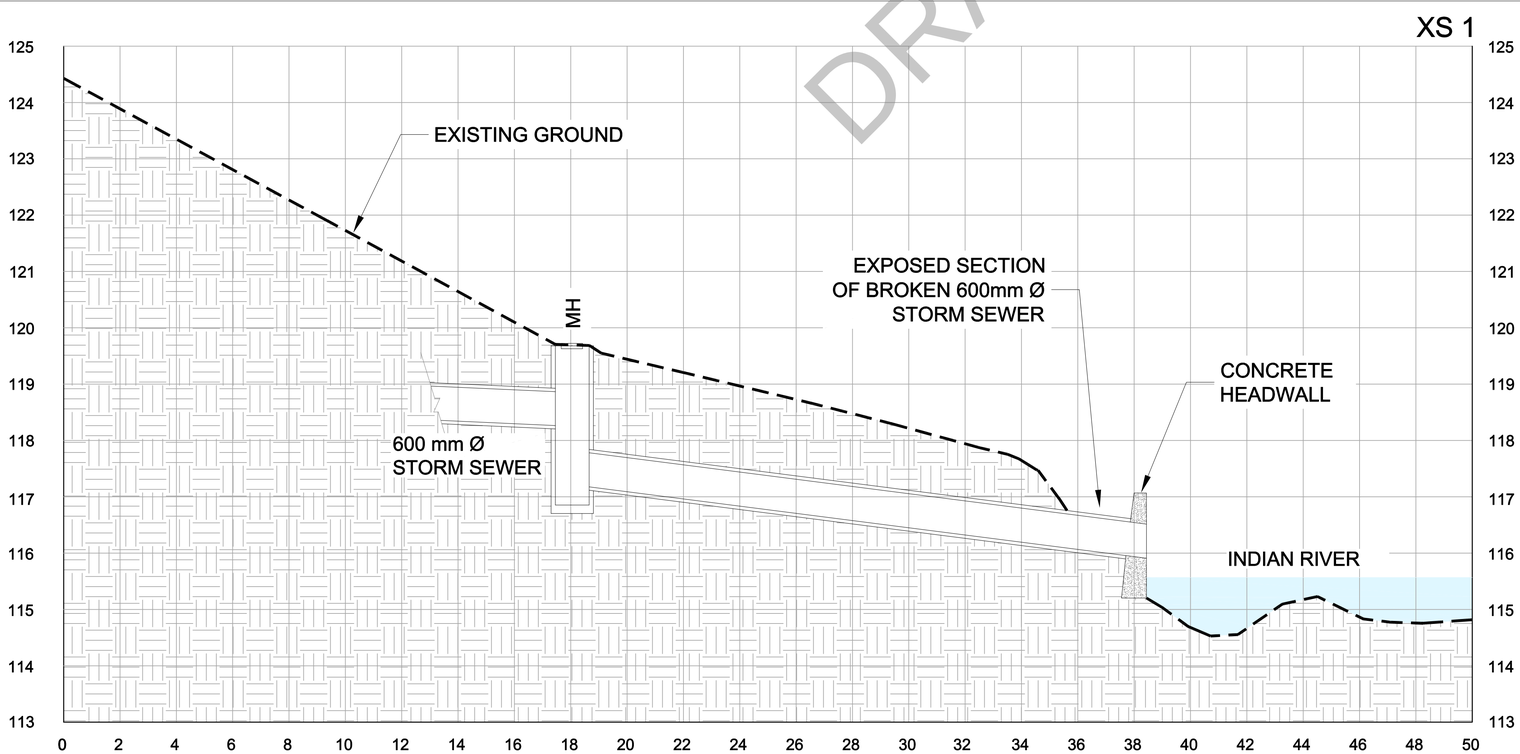
Brent Wiebe, P.Eng
Vice President of Operations – Ontario
Senior Geotechnical Engineer

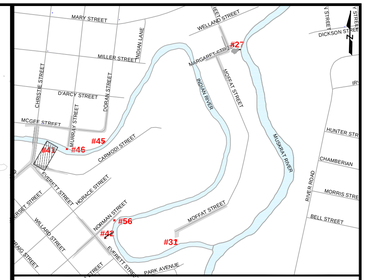
# APPENDIX A

Christie Street – Outlet 41
Site Plan – Figure A1
Record of Borehole Sheets
Laboratory Test Results






Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- MH STORM MANHOLE
- MH SANITARY MANHOLE

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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 41

**General Plan & Cross Section**

DESIGNED BY:

APPROVED BY:

Pembroke
the heart of the ottawa valley

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MISSISSAUGA, ONTARIO, L4W 582
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| | | | |
|---|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. | |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. | |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | | |

# RECORD OF BOREHOLE 22-01

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Christie Street - Outlet 41

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Feb 11 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 118.67 | | | | |
| 0 | | TOPSOIL (75mm) | | 0.08 | | | | |
| | | FILL: sand and silt with trace gravel, compact, moist | | | 1 | SS | 500 | - |
| | | | | | 2 | SS | 500 | 18 |
| 1 | | | | 117.60 | | | | |
| | | Brown becoming grey SAND with SILT, very loose to loose, moist | | 1.07 | 3 | SS | 300 | 9 |
| 2 | | - becoming wet at 2.1 metres | | | 4 | SS | 500 | 3 |
| | | | | | 5 | SS | 400 | 4 |
| 3 | | | | 115.47 | | | | |
| | | Grey SILTY CLAY, wet | | 3.20 | 6 | SS | 500 | 8 |
| | | | | | 7 | SS | 200 | 8 |
| 4 | | | | 114.40 | | | | |
| | | End of Borehole 22-01 at 4.3 metres within silty clay | | 4.27 | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: $W_P$ — W — $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

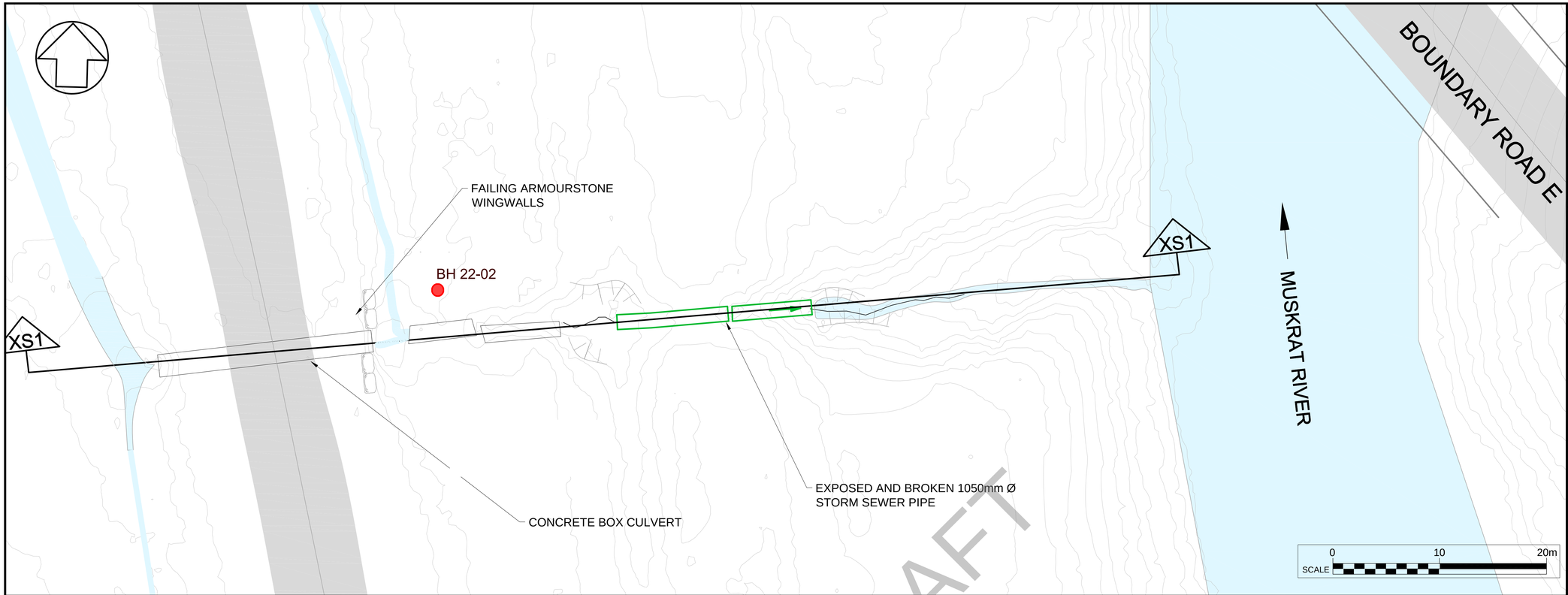


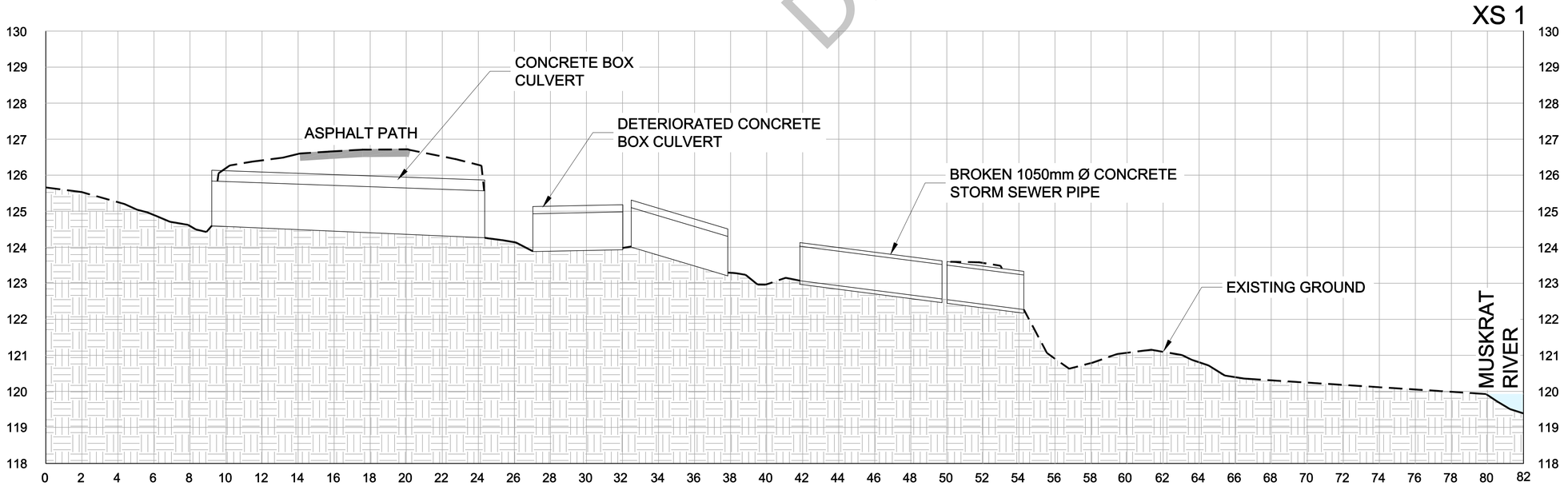
GEMTEC
Consulting Engineers and Scientists

LOGGED: AS
CHECKED: BW

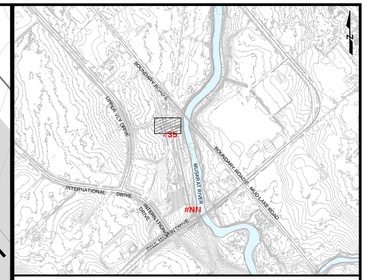
# APPENDIX B

Boundary Road Pathway – Outlet 35
Site Plan – Figure B1
Record of Borehole Sheets
Laboratory Test Results






Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- STORM MANHOLE
- SANITARY MANHOLE

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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 35

## General Plan & Cross Section

| DESIGNED BY: | APPROVED BY: |
|---|---|
| | |

Pembroke
the heart of the ottawa valley

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#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
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| SCALE: 1:250 | REVIEWED BY: | PROJECT No. |
|---|---|---|
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | |

# RECORD OF BOREHOLE 22-02

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Boundary Road Pathway - Outlet 35

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Feb 14 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 125.30 | | | | |
| 0 | | FILL: brown gravelly sand with some silt, frozen | | 125.10 / 0.20 | 1 | SS | 400 | - |
| | | FILL: brown silty clay with trace sand, frozen | | | 2 | SS | 300 | - |
| 1 | | | | | | | | |
| | | Dark grey to brown SILTY CLAY with trace sand and trace organics (wood) | | 123.93 / 1.37 | 3 | SS | 350 | 9 |
| 2 | | | | | 4 | SS | 400 | 9 |
| | | | | | 5 | SS | 400 | 10 |
| 3 | | Brown LEAN CLAY, stiff, wet | | 122.25 / 3.05 | 6 | SS | 600 | 11 |
| | | - becoming wet at 3.0 metres | | | 7 | SS | 600 | 10 |
| 4 | | | | | 8 | SS | 600 | 12 |
| | | End of Borehole 22-02 at 4.9 metres within lean clay | | 120.42 / 4.88 | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

SAMPLES

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: $W_P$ — W — $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

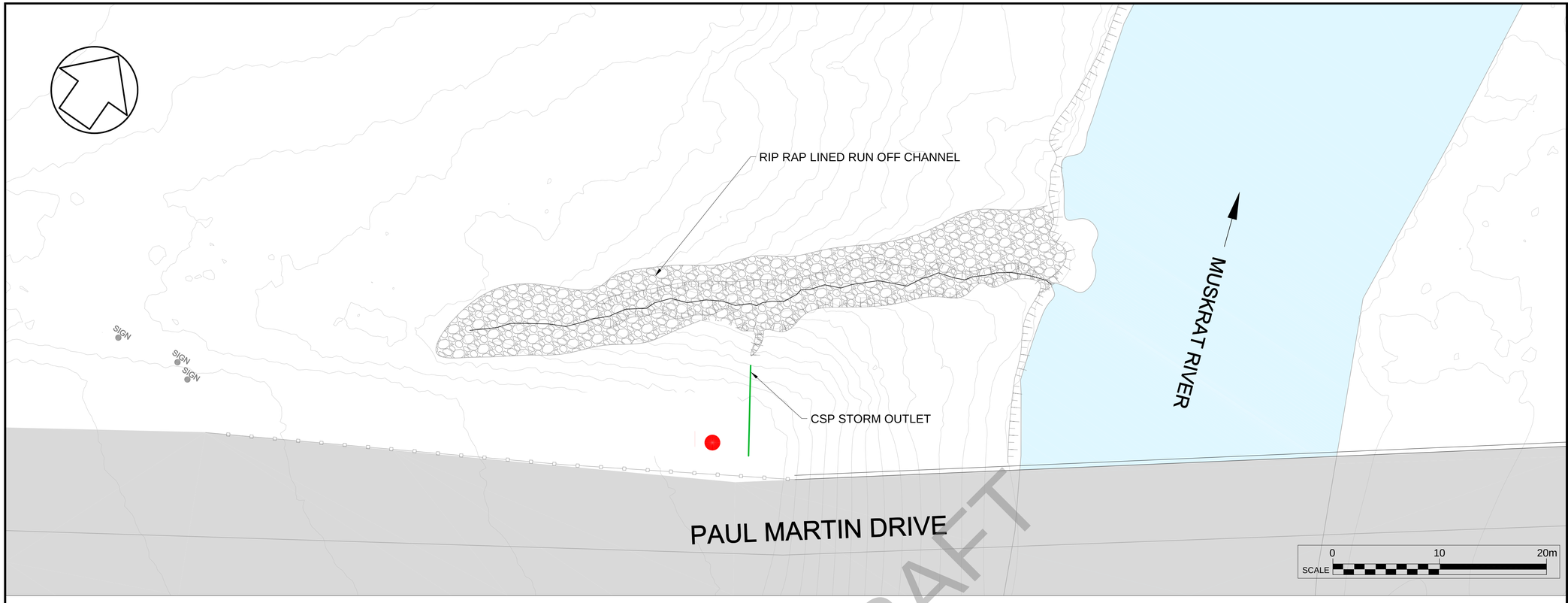


GEMTEC
Consulting Engineers and Scientists

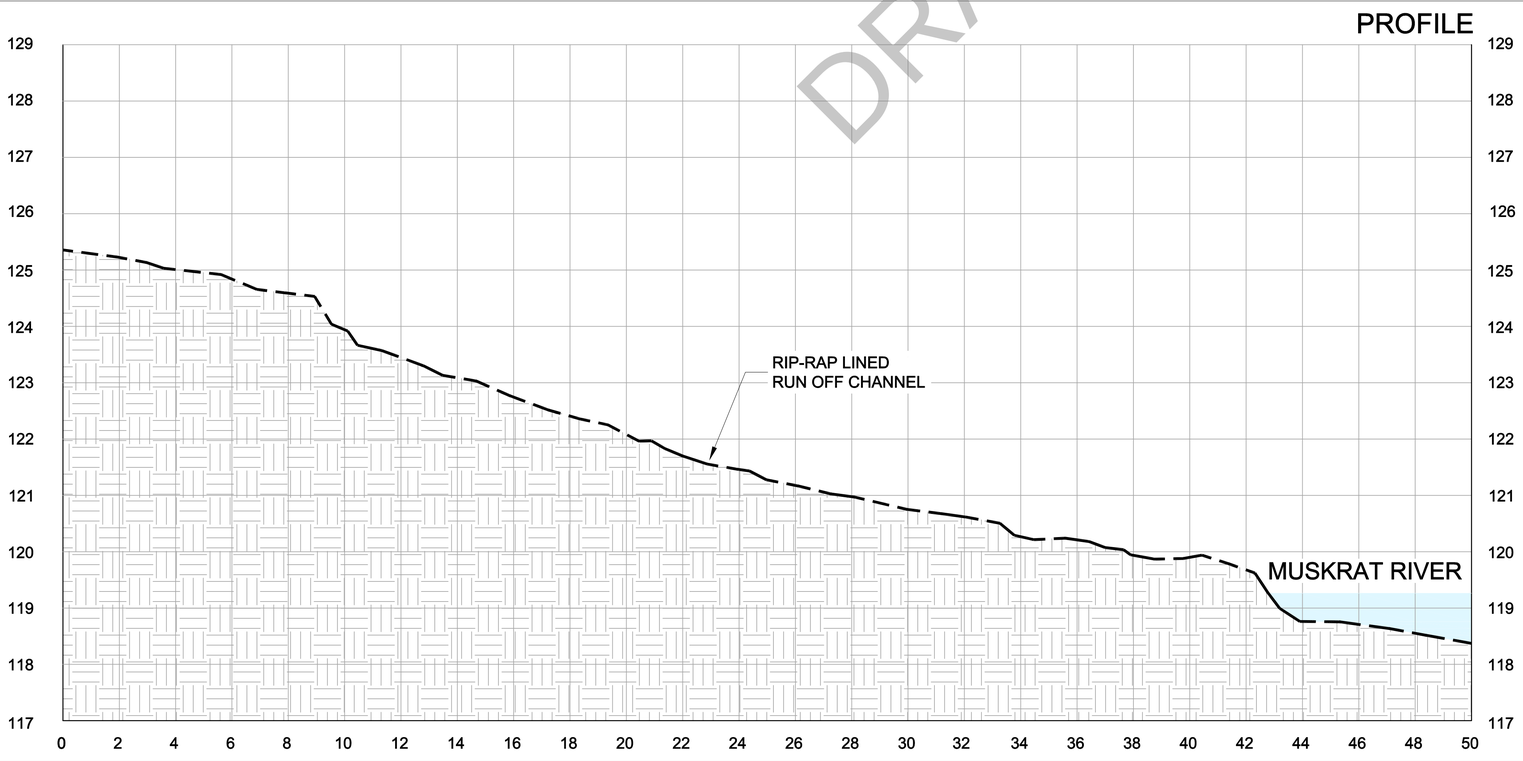
LOGGED: AS
CHECKED: BW

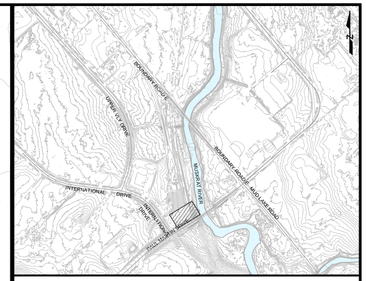
# APPENDIX C

Paul Martin Drive – No Outlet #
Site Plan – Figure C1
Record of Borehole Sheets
Laboratory Test Results






Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # UNKNOWN

## General Plan & Cross Section

DESIGNED BY:

APPROVED BY:

Pembroke
the heart of the ottawa valley

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#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

| | | |
|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | |

# RECORD OF BOREHOLE 22-03

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Paul Martin Drive - No Oulet #

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Feb 15 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 125.42 | | | | |
| 0 | | FILL: brown gravelly sand and silt, frozen | | 124.82 / 0.60 | 1 | SS | 450 | - |
| 1 | | FILL: brown sand and gravel with some silt, compact, moist | | | 2 | SS | 350 | 32 |
| | | | | | 3 | SS | 350 | 12 |
| | | | | 123.69 / 1.73 | | | | |
| 2 | | Brown SANDY CLAY, dense, moist | | | 4 | SS | 100 | 32 |
| | | | | | 5 | SS | 0 | 48 |
| 3 | | | | | 6 | SS | 150 | 44 |
| | | | | | 7 | SS | 150 | 36 |
| 4 | | | | 121.12 / 4.30 | | | | |
| | | Dynamic Cone Penetration Test (DCPT) | | | | | | |
| 5 | | | | | | | | |
| | | | | | | | | |
| 6 | | | | 119.32 / 6.10 | | | | |
| | | End of Borehole 22-03 at termination depth of 6.1 metres | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

SAMPLES

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: $W_P$ — W — $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

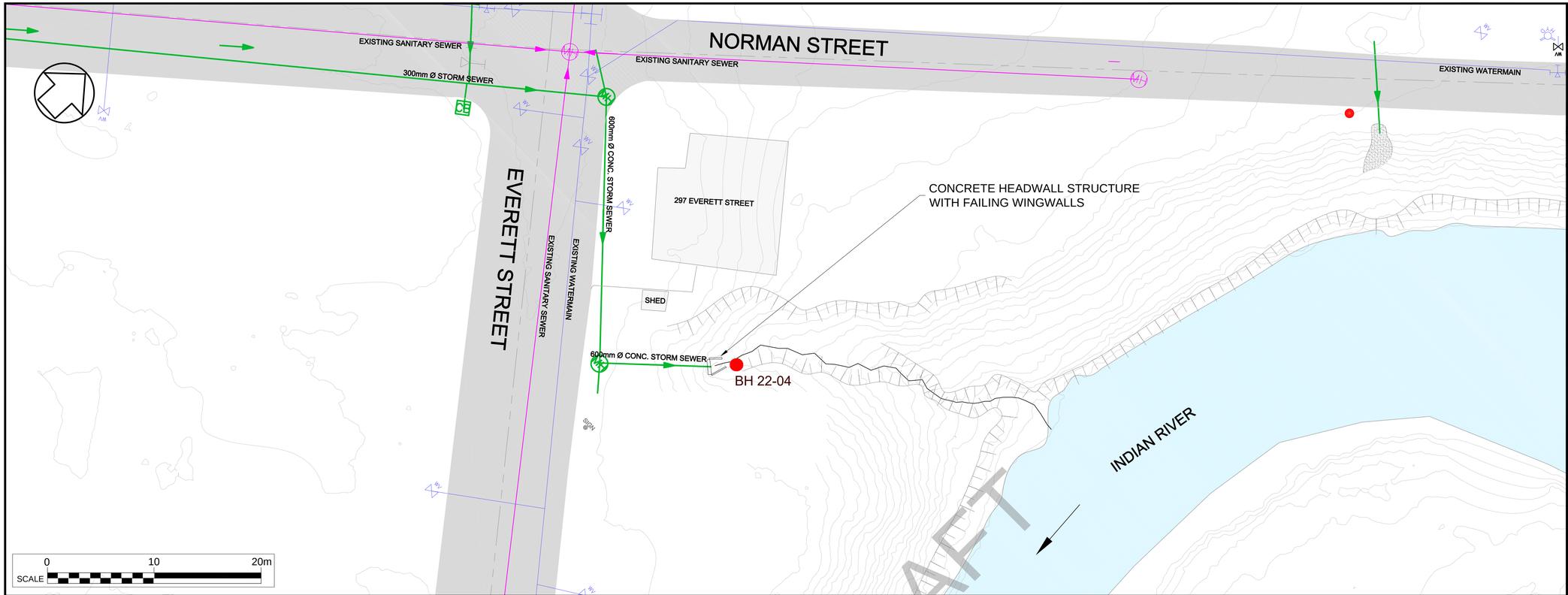


GEMTEC
Consulting Engineers and Scientists

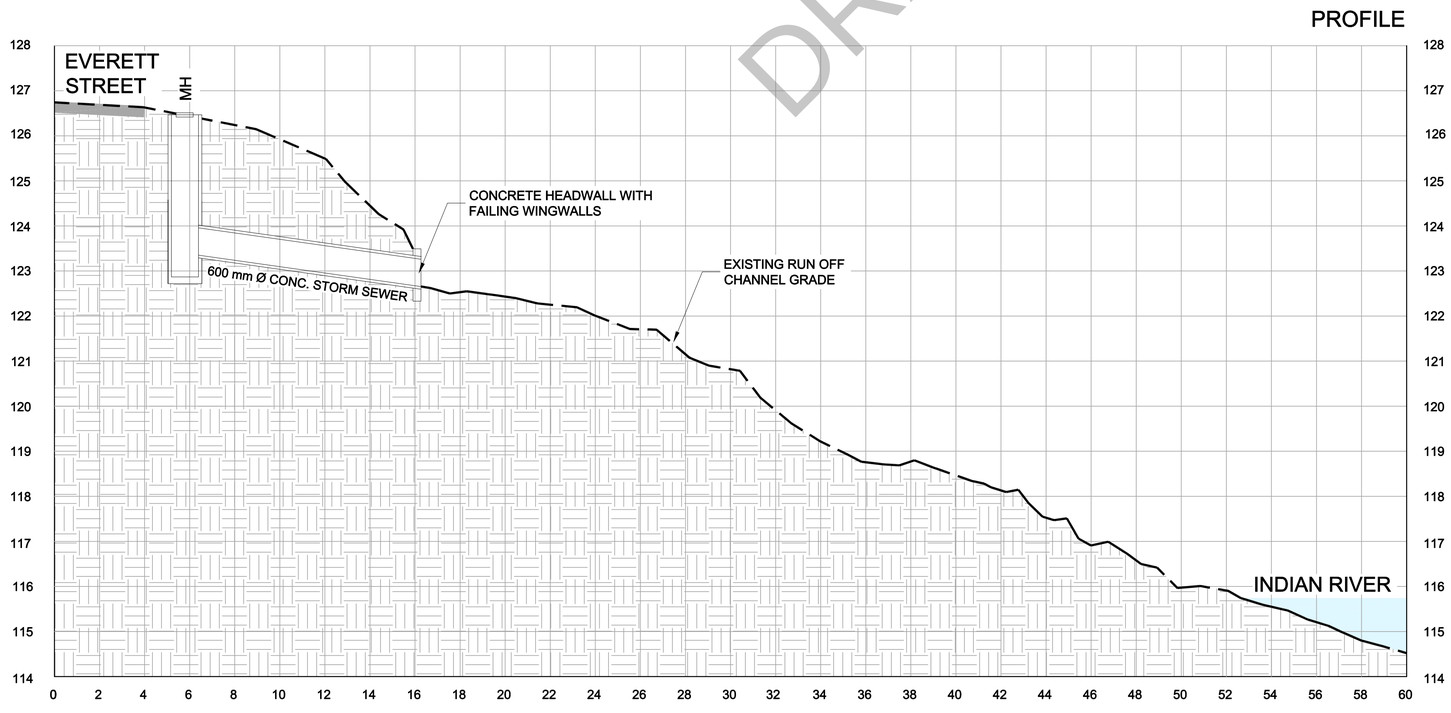
LOGGED: AS
CHECKED: BW

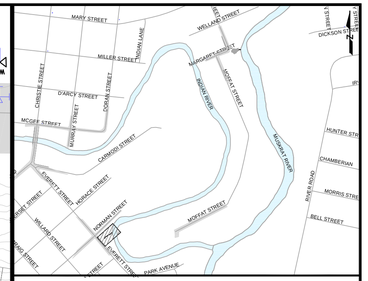
# APPENDIX D

Everett Street – Outlet 42
Site Plan – Figure D1
Record of Borehole Sheets
Laboratory Test Results






Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CATHBASIN
- STORM MANHOLE
- SANITARY MANHOLE

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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 42

## General Plan & Cross Section

DESIGNED BY:

APPROVED BY:

Pembroke
the heart of the ottawa valley

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

| | | | |
|---|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. | |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. | |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | | |

# RECORD OF BOREHOLE 22-04

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Everett Street - Outlet 42

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Feb 16 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 122.55 | | | | |
| 0 | | FILL: Dark brown sand and silt, some gravel, trace concrete debris | | | 1 | SS | 300 | - |
| | | | | | 2 | SS | 150 | 35 |
| 1 | | | | 121.33 | | | | |
| | | Dark grey CLAYEY SAND, loose, moist | | 1.22 | 3 | SS | 0 | 9 |
| | | | | | 4 | SS | 200 | 7 |
| 2 | | | | | 5 | SS | 200 | 7 |
| 3 | | | | 119.50 | | | | |
| | | Dark Grey CLAYEY SILT, firm, moist | | 3.05 | 6 | SS | 250 | 12 |
| | | | | | 7 | SS | 450 | 52 |
| 4 | | | | | 8 | SS | 350 | 44 |
| | | | | 117.67 | | | | |
| 5 | | Dark Grey SILTY CLAY, stiff, wet - becoming wet at 4.9 metres | | 4.88 | 9 | SS | 500 | 12 |
| | | | | | 10 | SS | 400 | 7 |
| 6 | | | | 116.15 | | | | |
| | | Grey clayey sand and silt with some gravel (GLACIAL TILL), compact, moist | | 6.40 | 11 | SS | 300 | 30 |
| | | | | 115.55 | | | | |
| 7 | | Dynamic Cone Penetation Test (DCPT) | | 7.00 | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | 112.31 | | | | |
| | | End of Borehole 22-04 at 10.2 metres due to DCPT refusal | | 10.24 | | | | |

SOIL PROFILE | SAMPLES

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, % — $W_P$ — W — $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

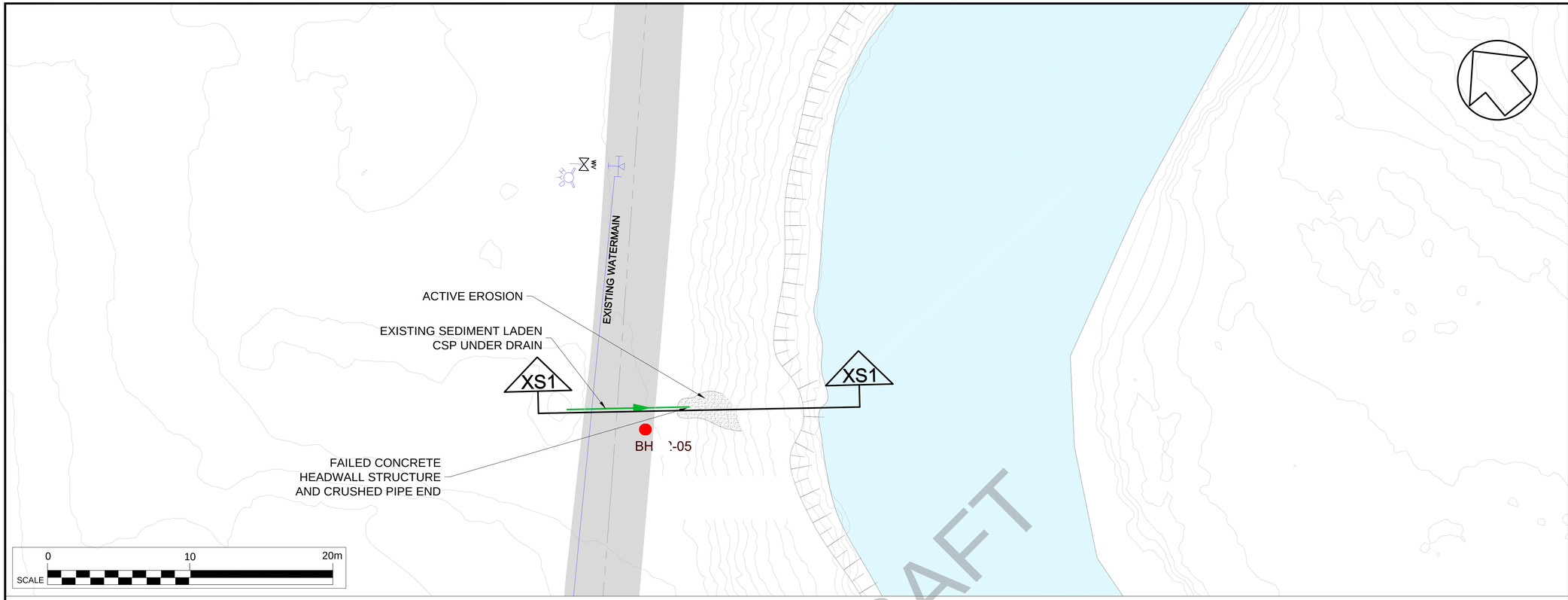


GEMTEC
Consulting Engineers and Scientists

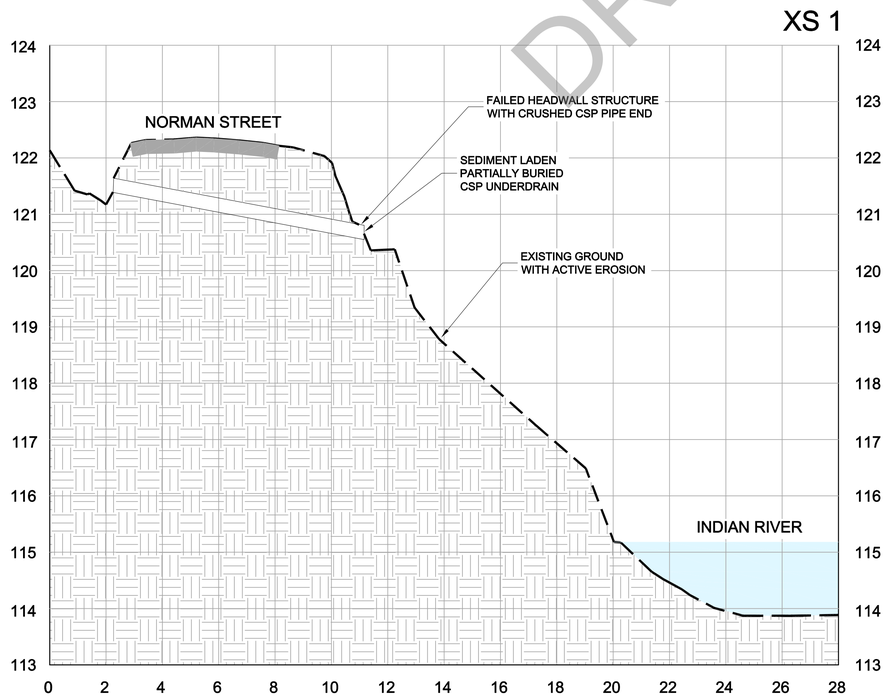
LOGGED: AS
CHECKED: BW

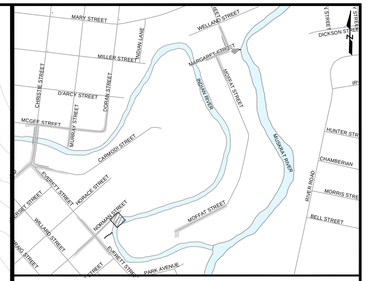
# APPENDIX E

Norman Street – Outlet 56
Site Plan – Figure E1
Record of Borehole Sheets
Laboratory Test Results






Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- STORM MANHOLE
- SANITARY MANHOLE

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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

CITY OF PEMBROKE, ONTARIO

SHEET TITLE

# OUTLET # 56

## General Plan & Cross Section

DESIGNED BY:

APPROVED BY:

Pembroke
the heart of the ottawa valley

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 582
PHONE: (905) 629-0099, FAX: (905) 629-0089

| | | |
|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | |

# RECORD OF BOREHOLE 22-05

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Norman Street - Outlet 56

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Mar 14 2022

| DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE: DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | SAMPLES: NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m | PENETRATION RESISTANCE (N), BLOWS/0.3m / DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH (Cu), kPA (NATURAL, REMOULDED) / WATER CONTENT, % | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | Ground Surface | | 122.44 | | | | | | | |
| | | ASPHALTIC CONCRETE (50mm) | | 0.05 | | | | | | | |
| | | ROAD BASE: brown crushed sand with gravel and some silt, frozen | | 0.20 | | | | | | | |
| | | ROAD SUBBASE: brown gravelly sand with trace silt, frozen | | 121.94 0.50 | 1 | GS | | - | | | |
| 1 | | FILL: brown sand and silt with trace gravel, compact | | | 2 | SS | 350 | 35 | | | |
| | | | | 120.94 | | | | | | | |
| | | Brown SILTY SAND, loose, moist | | 1.50 | 3 | SS | 450 | 6 | | | |
| 2 | | | | 120.00 | | | | | | | |
| | | Brown becoming grey SILTY CLAY, stiff to very stiff, moist | | 2.44 | 4 | SS | 450 | 9 | | | |
| 3 | | | | | 5 | SS | 500 | 7 | | | |
| 4 | | | | | 6 | SS | 500 | 4 | | | |
| 5 | | | | | | | | | | | |
| | | | | 116.64 | 7 | SS | 500 | 1 | | | |
| | | Grey clayey sand and gravel (GLACIAL TILL), compact, moist | | 5.80 | | | | | | | |
| 6 | | | | | 8 | SS | 300 | 21 | | | |
| 7 | | - becoming wet at 7.2 metres | | | 9 | SS | 300 | 15 | | | |
| 8 | | | | | 10 | SS | 300 | 11 | | | |
| | | | | 114.24 | | | | | | | |
| | | End of Borehole 22-05 at 8.2 metres within glacial till | | 8.20 | | | | | | | |
| 9 | | | | | | | | | | | |
| 10 | | | | | | | | | | | |



GEMTEC
Consulting Engineers and Scientists

LOGGED: AS
CHECKED: BW

## - SLOPE STABILITY RATING CHART

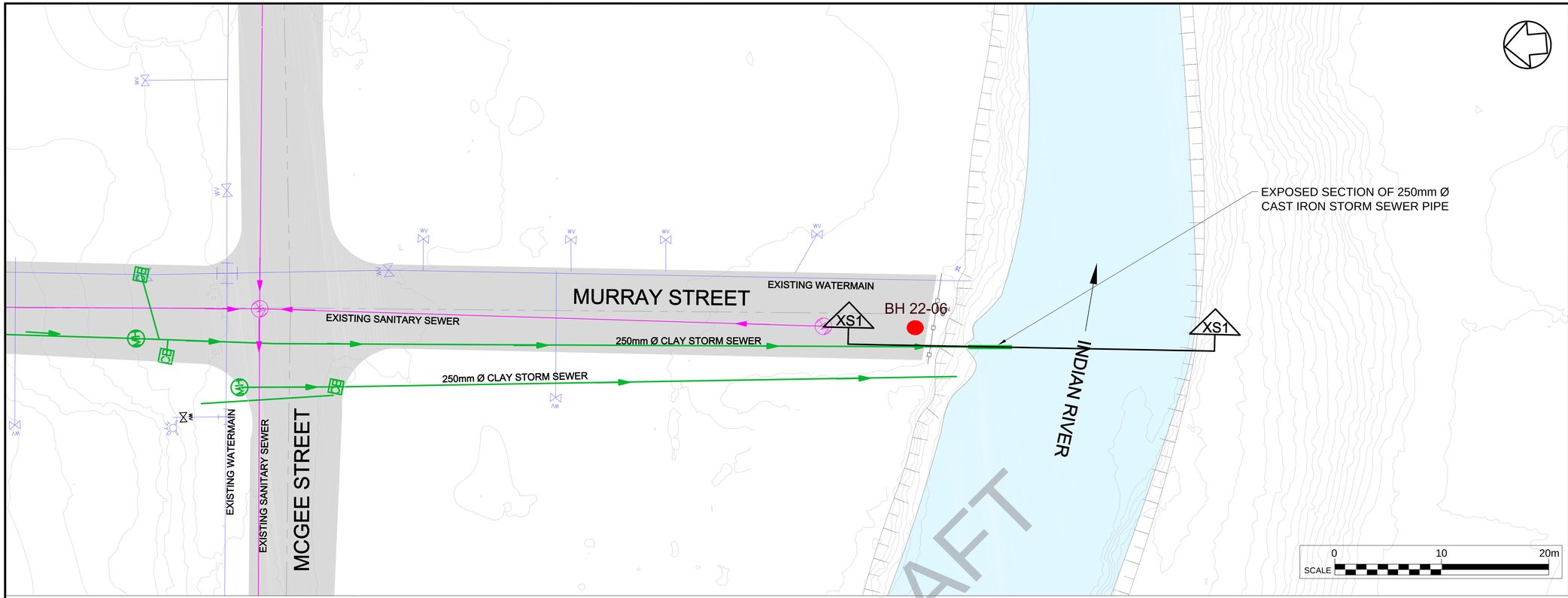
Site Location: Norman Street - Outlet 56 File No.
Property Owner: Inspection Date:
Inspected By: Weather:

| | | | | Rating Value |
|---|---|---|---|---|
| 1. | **SLOPE INCLINATION** | | | |
| | | **degrees** | **horiz. : vert.** | |
| | a) | 18 or less | 3 : 1 or flatter | 0 |
| | b) | 18 - 26 | 2 : 1 to more than 3 : 1 | 6 |
| | c) | more than 26 | steeper than 2 : 1 | 16 |
| 2. | **SOIL STRATIGRAPHY** | | | |
| | a) | Shale, Limestone, Granite (Bedrock) | | 0 |
| | b) | Sand, Gravel | | 6 |
| | c) | Glacial Till | | 9 |
| | d) | Clay, Silt | | 12 |
| | e) | Fill | | 16 |
| | f) | Leda Clay | | 24 |
| 3. | **SEEPAGE FROM SLOPE FACE** | | | |
| | a) | None or Near bottom only | | 0 |
| | b) | Near mid-slope only | | 6 |
| | c) | Near crest only or, From several levels | | 12 |
| 4. | **SLOPE HEIGHT** | | | |
| | a) | 2 m or less | | 0 |
| | b) | 2.1 to 5 m | | 2 |
| | c) | 5.1 to 10 m | | 4 |
| | d) | more than 10 m | | 8 |
| 5. | **VEGETATION COVER ON SLOPE FACE** | | | |
| | a) | Well vegetated; heavy shrubs or forested with mature trees | | 0 |
| | b) | Light vegetation; Mostly grass, weeds, occasional trees, shrubs | | 4 |
| | c) | No vegetation, bare | | 8 |
| 6. | **TABLE LAND DRAINAGE** | | | |
| | a) | Table land flat, no apparent drainage over slope | | 0 |
| | b) | Minor drainage over slope, no active erosion | | 2 |
| | c) | Drainage over slope, active erosion, gullies | | 4 |
| 7. | **PROXIMITY OF WATERCOURSE TO SLOPE TOE** | | | |
| | a) | 15 metres or more from slope toe | | 0 |
| | b) | Less than 15 metres from slope toe | | 6 |
| 8. | **PREVIOUS LANDSLIDE ACTIVITY** | | | |
| | a) | No | | 0 |
| | b) | Yes | | 6 |
| | **SLOPE INSTABILITY RATING** | **RATING VALUES TOTAL** | **INVESTIGATION REQUIREMENTS** | **TOTAL** 46 |
| 1. | Low potential | < 24 | Site inspection only, confirmation, report letter. | |
| 2. | Slight potential | 25-35 | Site inspection and surveying, preliminary study, detailed report. | |
| 3. | Moderate potential | > 35 | Boreholes, piezometers, lab tests, surveying, detailed report. | |

**NOTES:** a) Choose only one from each category; compare total rating value with above requirements.
b) If there is a water body (stream, creek, river, pond, bay, lake) at the slope toe; the potential for toe erosion and undercutting should be evaluated in detail and, protection provided if required.

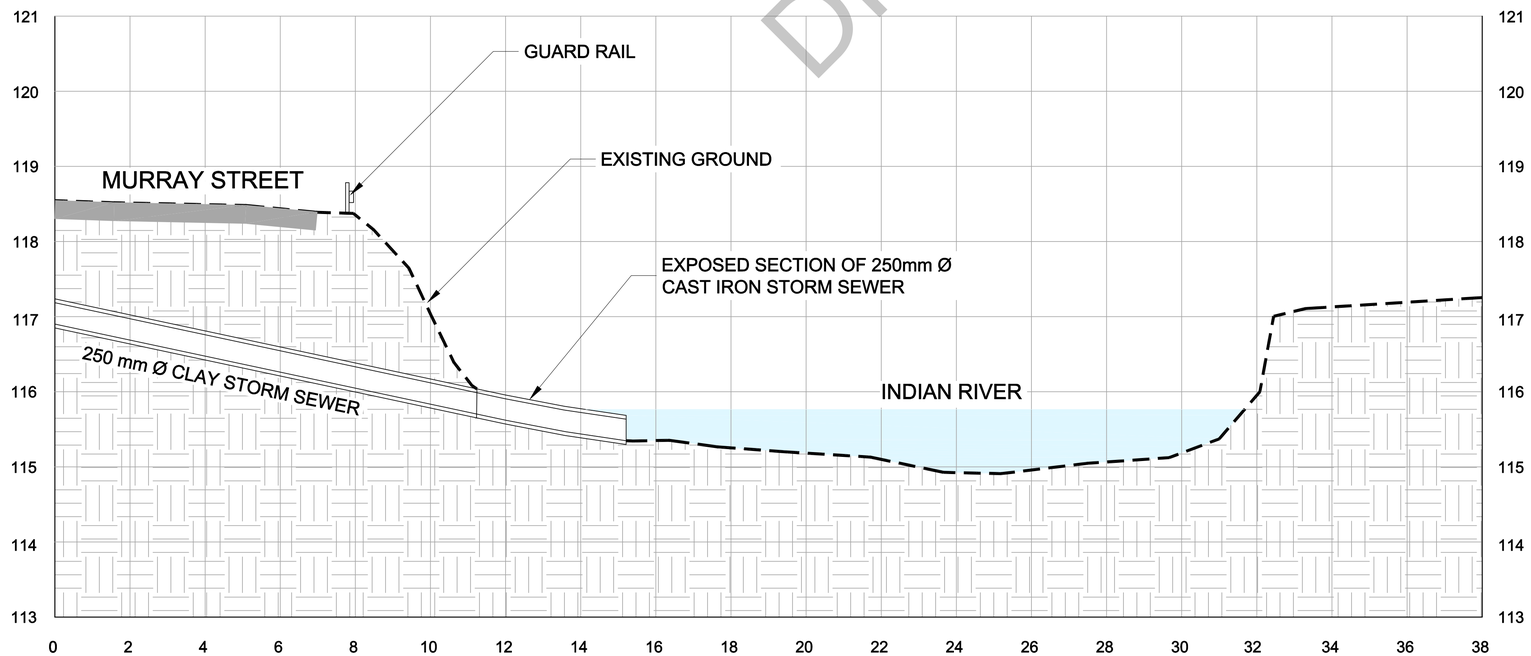
# APPENDIX F

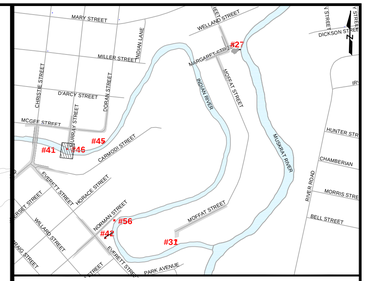
Murray Street – Outlet 46
Site Plan – Figure F1
Record of Borehole Sheets
Laboratory Test Results






## XS 1




Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- STORM MANHOLE
- SANITARY MANHOLE

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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 46

**General Plan & Cross Section**

DESIGNED BY:

APPROVED BY:

Pembroke
the heart of the ottawa valley

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 582
PHONE: (905) 629-0099, FAX: (905) 629-0089

| | | | |
|---|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. | |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. | |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | | |

# RECORD OF BOREHOLE 22-06

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Murray Street - Outlet 46

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Feb 14 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 118.58 | | | | |
| 0 | | ASPHALTIC CONCRETE (50mm) | | 0.05 | | | | |
| | | ROAD BASE: brown crushed sand with gravel and some silt, frozen<br>ROAD SUBBASE: brown sand with some gravel and some silt, frozen | | 0.21 | 1 | GS | | - |
| 1 | | | | 117.56 | 2 | SS | 600 | 36 |
| | | Brown SILTY SAND, loose, moist | | 1.02 | | | | |
| 2 | | | | | 3 | SS | 400 | 4 |
| | | | | | 4 | SS | 400 | 2 |
| 3 | | | | 115.38 | | | | |
| | | Grey SILTY CLAY with sand seams, firm, wet<br><br>- becoming wet at 3.2 metres | | 3.20 | 5 | SS | 400 | 5 |
| 4 | | | | | 6 | SS | 600 | 1 |
| | | | | 114.01 | | | | |
| | | End of Borehole 22-06 at 4.6 metres within silty clay | | 4.57 | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

SAMPLES

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: $W_P$ — W — $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

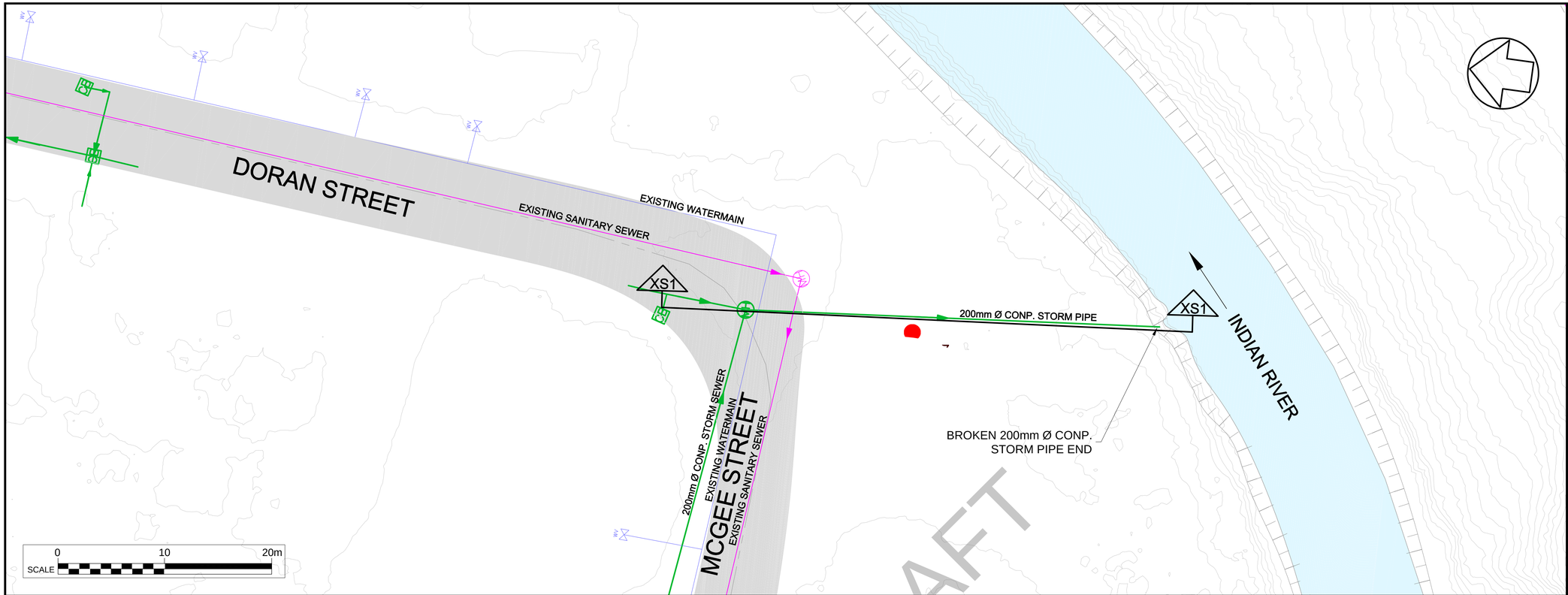


GEMTEC
Consulting Engineers and Scientists

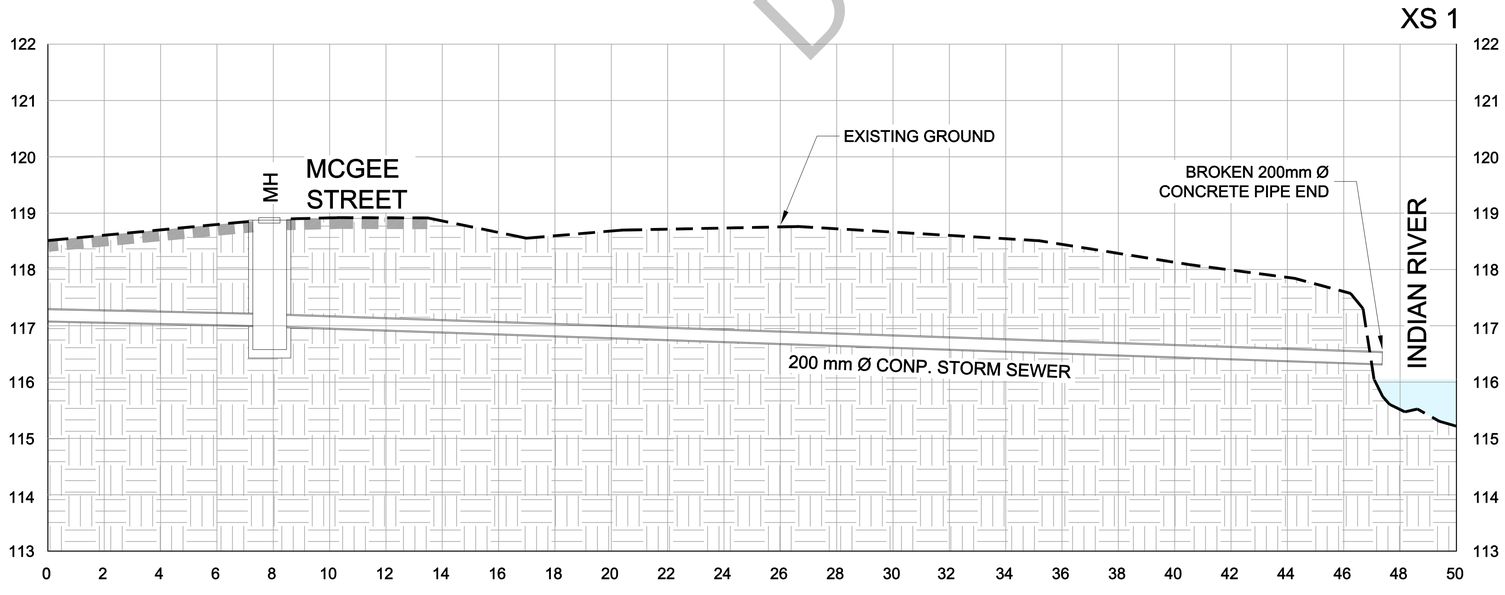
LOGGED: AS
CHECKED: BW

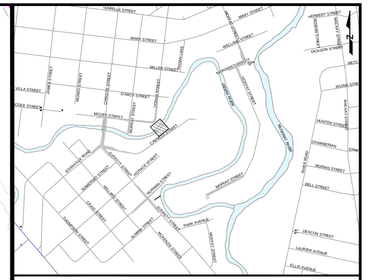
# APPENDIX G

Doran Street – Outlet 45
Site Plan – Figure G1
Record of Borehole Sheets
Laboratory Test Results





Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- STORM MANHOLE
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JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 45

## General Plan & Cross Section

| DESIGNED BY: | APPROVED BY: |
|---|---|
| | |

Pembroke
the heart of the ottawa valley

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

| | | | |
|---|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. | |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. | |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | | |

# RECORD OF BOREHOLE 22-07

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Doran Street - Outlet 45

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Feb 15 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 118.78 | | | | |
| 0 | | FILL: dark brown to brown sand with some silt and trace gravel, frozen | | | 1 | GS | | - |
| | | | | 117.82 | | | | |
| 1 | | Brown SILTY SAND with trace gravel, moist | | 0.96 | 2 | SS | 400 | 12 |
| | | | | | 3 | SS | 400 | 7 |
| 2 | | - becoming wet at 2.3 metres | | | 4 | SS | 400 | 3 |
| 3 | | | | | 5 | SS | 200 | 50/25mm |
| | | - split-spoon refusal due to organic wood material at about 3.3 metres | | 115.12 | | | | |
| | | Grey SILTY CLAY, firm, wet | | 3.66 | | | | |
| 4 | | | | | 6 | SS | 400 | 7 |
| | | | | 114.21 | | | | |
| | | End of Borehole 22-07 at 4.6 metres within silty clay | | 4.57 | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

SAMPLES

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: + NATURAL ⊕ REMOULDED
WATER CONTENT, %: $W_P$ — W — $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

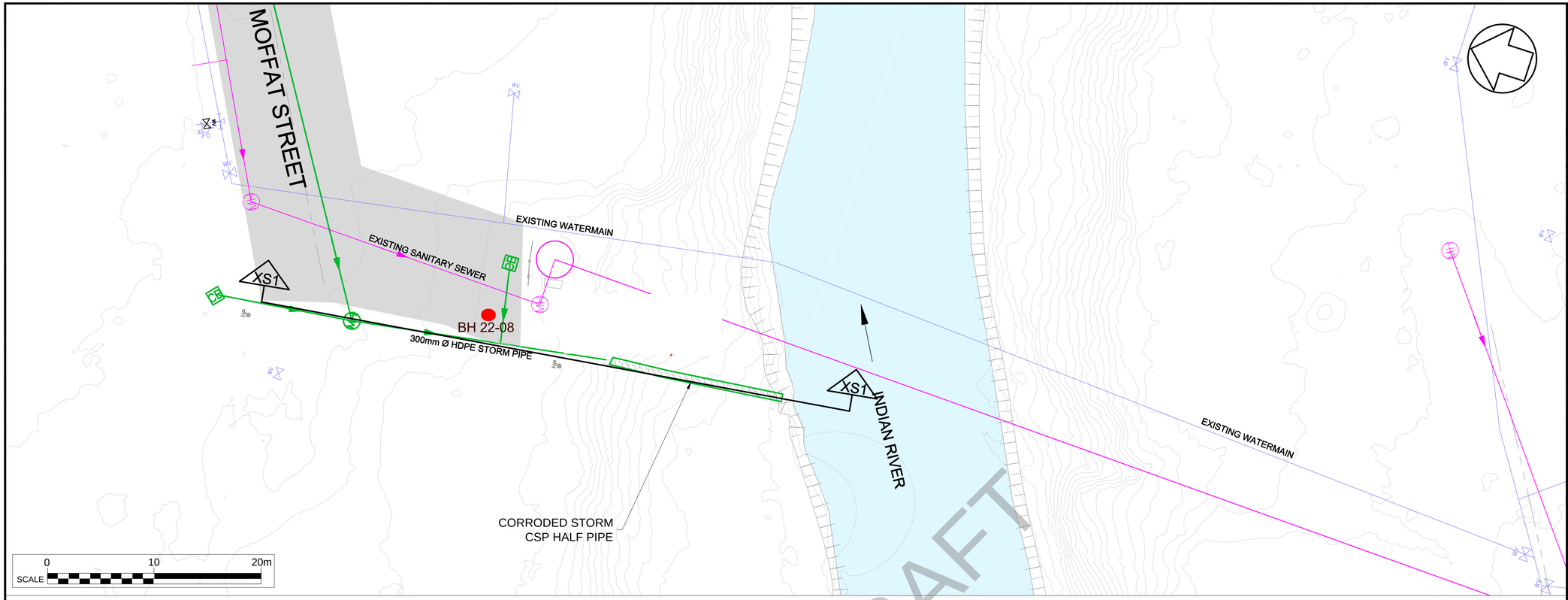


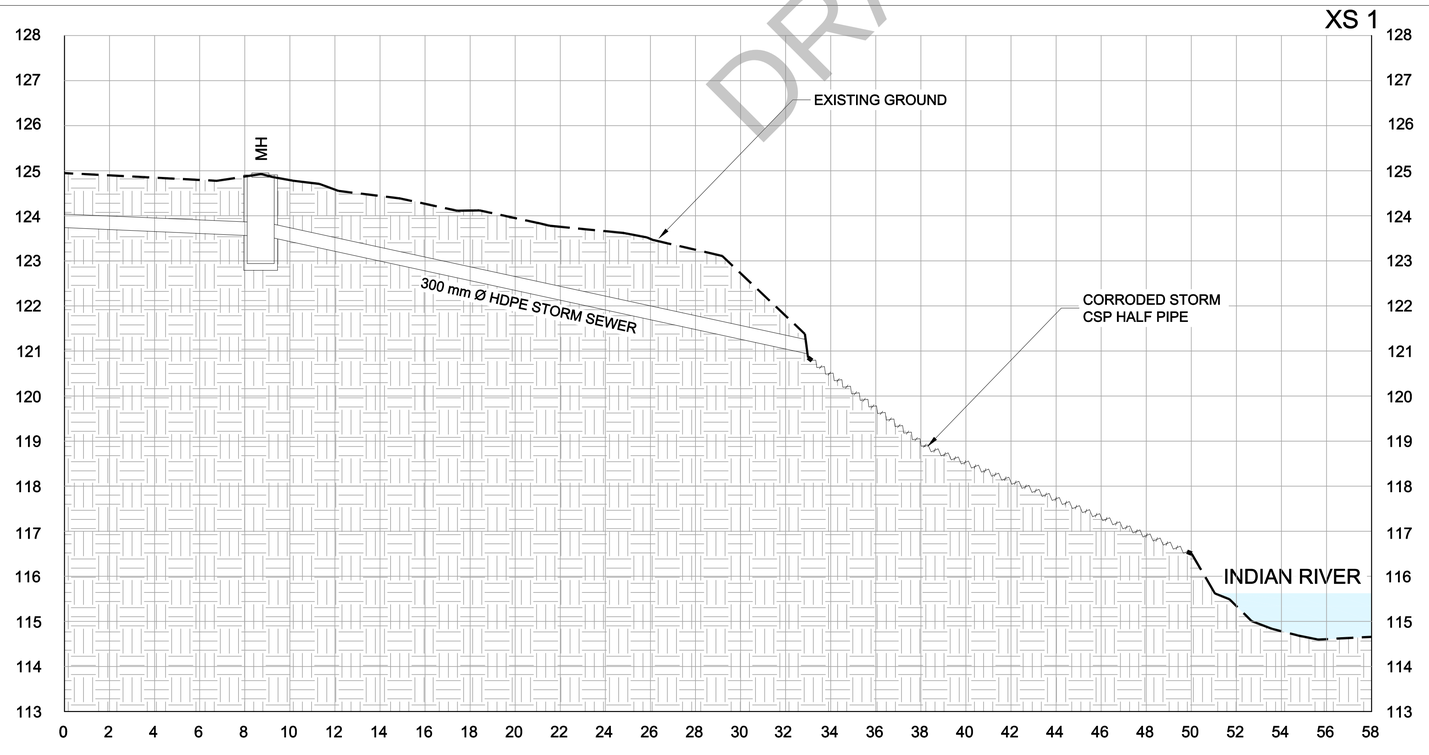
GEMTEC
Consulting Engineers and Scientists

LOGGED: AS
CHECKED: BW

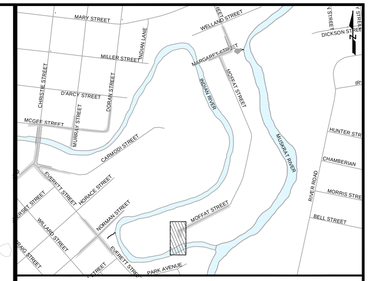
# APPENDIX H

Moffatt Street – Outlet 31
Site Plan – Figure H1
Record of Borehole Sheets
Laboratory Test Results






Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- STORM MANHOLE
- SANITARY MANHOLE

THE POSITION OF THE POLE LINES, CONDUITS, WATERMAINS, SEWERS, AND OTHER UTILITIES AND STRUCTURES ARE NOT NECESSARILY SHOWN ON THE CONTRACT DRAWINGS, AND WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED.

**BEFORE STARTING WORK**

THE CONTRACTOR SHALL CONFIRM THE POSITION AND EXACT LOCATION OF ALL SUCH UTILITIES, AND SHALL ASSUME ALL LIABILITY FOR ANY DAMAGE TO THEM MADE DURING THE COURSE OF THE CONTRACT WORK.

JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 31

**General Plan & Cross Section**

| DESIGNED BY: | APPROVED BY: |
|---|---|
| | |

Pembroke
the heart of the ottawa valley

Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089

| SCALE: 1:250 | REVIEWED BY: | PROJECT No. |
|---|---|---|
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | |

# RECORD OF BOREHOLE 22-08

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Moffatt Street - Outlet 31

SHEET: 1 OF 1
DATUM: CGVD2013
BORING DATE: Mar 15 2022

| DEPTH SCALE METRES | BORING METHOD | DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m |
|---|---|---|---|---|---|---|---|---|
| | | Ground Surface | | 123.80 | | | | |
| 0 | | ASPHALTIC CONCRETE (40mm) | | 0.04 | | | | |
| | | ROAD BASE: brown crushed sand with gravel and some silt, frozen | | 0.24 | 1 | GS | | - |
| 1 | | FILL: brown silty sand with trace clay, loose, frozen becoming moist | | | 2 | SS | 450 | 20 |
| | | | | | 3 | SS | 600 | 6 |
| 2 | | | | 121.67 | | | | |
| | | Brown SAND with some silt, loose to compact, moist | | 2.13 | 4 | SS | 400 | 8 |
| 3 | | | | | 5 | SS | 350 | 15 |
| 4 | | - becoming wet at 4.3 metres | | | 6 | SS | 400 | 4 |
| | | | | 118.82 | 7 | SS | 400 | 15 |
| 5 | | Grey SILTY CLAY, very stiff, wet | | 4.98 | 8 | SS | 200 | 14 |
| 6 | | | | | 9 | SS | 600 | 5 |
| 7 | | | | | 10 | SS | 600 | 3 |
| 8 | | | | | 11 | SS | 600 | 6 |
| 9 | | | | | 12 | SS | 600 | 2 |
| | | | | 114.04 | | | | |
| 10 | | End of Borehole 22-08 at 9.8 metres within silty clay | | 9.76 | | | | |

PENETRATION RESISTANCE (N), BLOWS/0.3m
DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m
SHEAR STRENGTH (Cu), kPA: NATURAL, REMOULDED
WATER CONTENT, %: $W_P$, W, $W_L$
10 20 30 40 50 60 70 80 90

ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION



GEMTEC
Consulting Engineers and Scientists

LOGGED: AS
CHECKED: BW

## - SLOPE STABILITY RATING CHART

Site Location: Moffatt Street - Outlet 31 File No.
Property Owner: Inspection Date:
Inspected By: Weather:

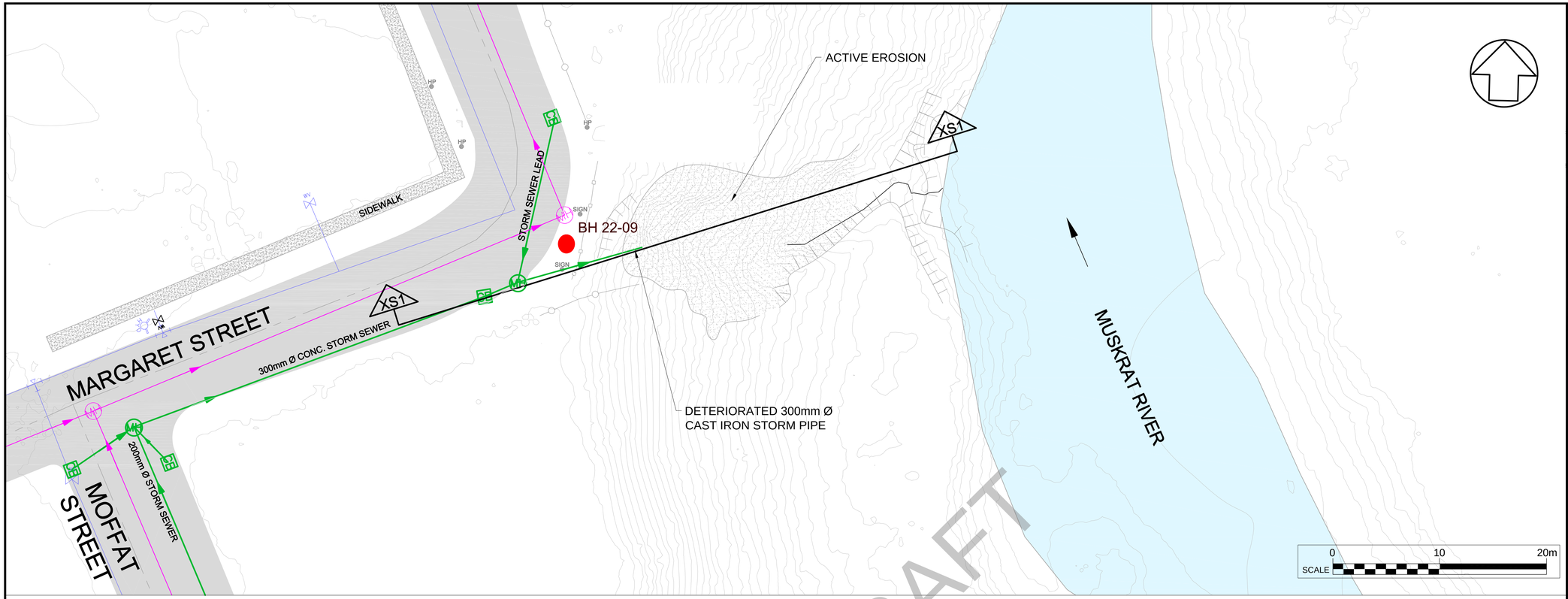
| | | | | Rating Value |
|---|---|---|---|---|
| 1. | **SLOPE INCLINATION** | | | |
| | | **degrees** | **horiz. : vert.** | |
| | a) | 18 or less | 3 : 1 or flatter | 0 |
| | b) | 18 - 26 | 2 : 1 to more than 3 : 1 | 6 |
| | c) | more than 26 | steeper than 2 : 1 | 16 |
| 2. | **SOIL STRATIGRAPHY** | | | |
| | a) | Shale, Limestone, Granite (Bedrock) | | 0 |
| | b) | Sand, Gravel | | 6 |
| | c) | Glacial Till | | 9 |
| | d) | Clay, Silt | | 12 |
| | e) | Fill | | 16 |
| | f) | Leda Clay | | 24 |
| 3. | **SEEPAGE FROM SLOPE FACE** | | | |
| | a) | None or Near bottom only | | 0 |
| | b) | Near mid-slope only | | 6 |
| | c) | Near crest only or, From several levels | | 12 |
| 4. | **SLOPE HEIGHT** | | | |
| | a) | 2 m or less | | 0 |
| | b) | 2.1 to 5 m | | 2 |
| | c) | 5.1 to 10 m | | 4 |
| | d) | more than 10 m | | 8 |
| 5. | **VEGETATION COVER ON SLOPE FACE** | | | |
| | a) | Well vegetated; heavy shrubs or forested with mature trees | | 0 |
| | b) | Light vegetation; Mostly grass, weeds, occasional trees, shrubs | | 4 |
| | c) | No vegetation, bare | | 8 |
| 6. | **TABLE LAND DRAINAGE** | | | |
| | a) | Table land flat, no apparent drainage over slope | | 0 |
| | b) | Minor drainage over slope, no active erosion | | 2 |
| | c) | Drainage over slope, active erosion, gullies | | 4 |
| 7. | **PROXIMITY OF WATERCOURSE TO SLOPE TOE** | | | |
| | a) | 15 metres or more from slope toe | | 0 |
| | b) | Less than 15 metres from slope toe | | 6 |
| 8. | **PREVIOUS LANDSLIDE ACTIVITY** | | | |
| | a) | No | | 0 |
| | b) | Yes | | 6 |

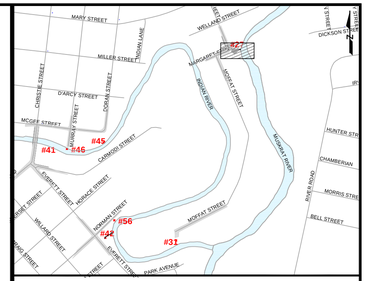
| **SLOPE INSTABILITY RATING** | **RATING VALUES TOTAL** | **INVESTIGATION REQUIREMENTS** | **TOTAL** |
|---|---|---|---|
| 1. Low potential | < 24 | Site inspection only, confirmation, report letter. | 27 |
| 2. Slight potential | 25-35 | Site inspection and surveying, preliminary study, detailed report. | |
| 3. Moderate potential | > 35 | Boreholes, piezometers, lab tests, surveying, detailed report. | |

**NOTES:** a) Choose only one from each category; compare total rating value with above requirements.
b) If there is a water body (stream, creek, river, pond, bay, lake) at the slope toe; the potential for toe erosion and undercutting should be evaluated in detail and, protection provided if required.

# APPENDIX I

Margaret Street – Outlet 27
Site Plan – Figure I1
Record of Borehole Sheets
Laboratory Test Results



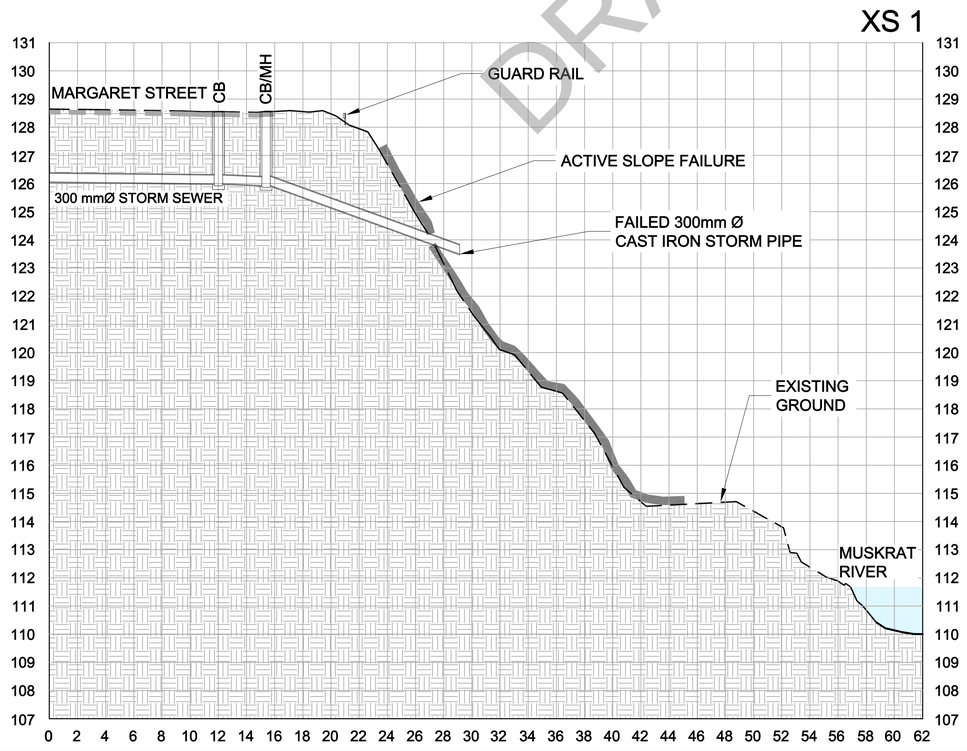

Key Map – NTS

| No. | REVISION | By | DATE |
|---|---|---|---|
| 1 | ISSUED FOR REVIEW | D.M. | 2021-11-25 |

LEGEND

- STORM SEWER
- SANITARY SEWER
- WATERMAIN
- CB CATHBASIN
- STORM MANHOLE
- SANITARY MANHOLE








JOB TITLE

**CITY WIDE FLOOD RISK ASSESSMENT AND STORM OUTLET REVIEW**

**CITY OF PEMBROKE, ONTARIO**

SHEET TITLE

# OUTLET # 27

## General Plan & Cross Section

| DESIGNED BY: | APPROVED BY: |
|---|---|
| | |

Pembroke
the heart of the ottawa valley


Aquafor Beech Limited
#6-202-2600 SKYMARK Ave,
MISSISSAUGA, ONTARIO, L4W 5B2
PHONE: (905) 629-0099, FAX: (905) 629-0089


| | | | |
|---|---|---|---|
| SCALE: 1:250 | REVIEWED BY: | PROJECT No. | |
| DRAWN BY: P.S. | DESIGNED BY: R.A. | FILE No. | |
| DATE: 25 NOV., 2021 | SHEET NO: 1 | | |

# RECORD OF BOREHOLE 22-09

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Margaret Street - Outlet 27

SHEET: 1 OF 2
DATUM: CGVD2013
BORING DATE: Mar 16 2022

| DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE: DESCRIPTION | STRATA PLOT | ELEV. / DEPTH (m) | SAMPLES: NUMBER | TYPE | RECOVERY, mm | BLOWS/0.3m | PENETRATION RESISTANCE (N), BLOWS/0.3m / DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m / SHEAR STRENGTH (Cu), kPA (NATURAL, REMOULDED) / WATER CONTENT, % | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | Ground Surface | | 128.61 | | | | | | | |
| | | FILL: brown crushed sand with gravel and some silt, frozen | | 128.36 | | | | | | | |
| | | | | 0.25 | 1 | GS | | - | | | |
| | | FILL: brown sand and gravel with some silt, frozen | | 128.01 | | | | | | | |
| | | | | 0.60 | | | | | | | |
| 1 | | FILL: brown silty sand with trace asphalt particles, loose, moist | | | 2 | SS | 450 | 9 | | | |
| | | | | | | | | | | | |
| | | | | | 3 | SS | 500 | 4 | | | |
| 2 | | | | 126.78 | | | | | | | |
| | | Brownish grey SANDY SILT, loose to compact, moist | | 1.83 | | | | | | | |
| | | | | | 4 | SS | 400 | 4 | | | |
| | | | | | | | | | | | |
| 3 | | | | | 5 | SS | 500 | 6 | | | |
| | | | | | | | | | | | |
| 4 | | | | | 6 | SS | 500 | 9 | | | |
| | | | | | | | | | | | |
| | | | | | 7 | SS | 500 | 4 | | | |
| 5 | | | | | | | | | | | |
| | | | | | 8 | SS | 400 | 10 | | | |
| | | | | | | | | | | | |
| 6 | | | | | 9 | SS | 350 | 10 | | | |
| | | | | | | | | | | | |
| 7 | | | | | | | | | | | |
| | | | | | 10 | SS | 450 | 14 | | | |
| | | | | | | | | | | | |
| 8 | | | | | | | | | | | |
| | | | | | 11 | SS | 400 | 14 | | | |
| 9 | | | | | | | | | | | |
| | | | | | | | | | | | |
| 10 | | | | | | | | | | | |



GEMTEC
Consulting Engineers and Scientists

LOGGED: AS
CHECKED: BW

# RECORD OF BOREHOLE 22-09

CLIENT: Aquafor Beech Ltd.
PROJECT: Geotechnical Investigation - City of Pemroke Storm Outlet Review
JOB#: 101078.001
LOCATION: Margaret Street - Outlet 27

SHEET: 2 OF 2
DATUM: CGVD2013
BORING DATE: Mar 16 2022

| DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE: DESCRIPTION | SOIL PROFILE: STRATA PLOT | SOIL PROFILE: ELEV. / DEPTH (m) | SAMPLES: NUMBER | SAMPLES: TYPE | SAMPLES: RECOVERY, mm | SAMPLES: BLOWS/0.3m | PENETRATION RESISTANCE (N), BLOWS/0.3m ● / DYNAMIC PENETRATION RESISTANCE, BLOWS/0.3m ▲ / SHEAR STRENGTH (Cu), kPA + NATURAL ⊕ REMOULDED / WATER CONTENT, % $W_P$ W $W_L$ | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | | | | | 12 | SS | 450 | 12 | ● | | |
| 12 | | - becoming wet at 12.2 metres | | | 13 | SS | 400 | 15 | ● | | |
| | | | | 115.81 | | | | | | | |
| 13 | | Grey SILTY CLAY, very stiff, wet | | 12.80 | | | | | | | |
| 14 | | | | | 14 | SS | 600 | 2 | ● | | |
| 15 | | | | | | | | | | | |
| 16 | | | | | | | | | >> + >> + | | |
| 17 | | | | | 15 | SS | 500 | 2 | ● | | |
| 18 | | | | | | | | | | | |
| | | | | 110.01 | 16 | SS | 600 | 13 | ● | | |
| | | Grey sand and silt with gravel (GLACIAL TILL), compact, wet | | 18.60 | | | | | | | |
| 19 | | | | 109.71 | | | | | | | |
| | | End of Borehole 22-01 at 18.9 metres within glacial till | | 18.90 | | | | | | | |
| 20 | | | | | | | | | | | |
| 21 | | | | | | | | | | | |



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CHECKED: BW

## - SLOPE STABILITY RATING CHART

Site Location: Margaret Street - Outlet 27 File No.
Property Owner: Inspection Date:
Inspected By: Weather:

| | | | | Rating Value |
|---|---|---|---|---|
| 1. | **SLOPE INCLINATION** | | | |
| | | **degrees** | **horiz. : vert.** | |
| | a) | 18 or less | 3 : 1 or flatter | 0 |
| | b) | 18 - 26 | 2 : 1 to more than 3 : 1 | 6 |
| | c) | more than 26 | steeper than 2 : 1 | 16 |
| 2. | **SOIL STRATIGRAPHY** | | | |
| | a) | Shale, Limestone, Granite (Bedrock) | | 0 |
| | b) | Sand, Gravel | | 6 |
| | c) | Glacial Till | | 9 |
| | d) | Clay, Silt | | 12 |
| | e) | Fill | | 16 |
| | f) | Leda Clay | | 24 |
| 3. | **SEEPAGE FROM SLOPE FACE** | | | |
| | a) | None or Near bottom only | | 0 |
| | b) | Near mid-slope only | | 6 |
| | c) | Near crest only or, From several levels | | 12 |
| 4. | **SLOPE HEIGHT** | | | |
| | a) | 2 m or less | | 0 |
| | b) | 2.1 to 5 m | | 2 |
| | c) | 5.1 to 10 m | | 4 |
| | d) | more than 10 m | | 8 |
| 5. | **VEGETATION COVER ON SLOPE FACE** | | | |
| | a) | Well vegetated; heavy shrubs or forested with mature trees | | 0 |
| | b) | Light vegetation; Mostly grass, weeds, occasional trees, shrubs | | 4 |
| | c) | No vegetation, bare | | 8 |
| 6. | **TABLE LAND DRAINAGE** | | | |
| | a) | Table land flat, no apparent drainage over slope | | 0 |
| | b) | Minor drainage over slope, no active erosion | | 2 |
| | c) | Drainage over slope, active erosion, gullies | | 4 |
| 7. | **PROXIMITY OF WATERCOURSE TO SLOPE TOE** | | | |
| | a) | 15 metres or more from slope toe | | 0 |
| | b) | Less than 15 metres from slope toe | | 6 |
| 8. | **PREVIOUS LANDSLIDE ACTIVITY** | | | |
| | a) | No | | 0 |
| | b) | Yes | | 6 |
| | **SLOPE INSTABILITY RATING** | **RATING VALUES TOTAL** | **INVESTIGATION REQUIREMENTS** | **TOTAL** 52 |

| | | | |
|---|---|---|---|
| 1. | Low potential | < 24 | Site inspection only, confirmation, report letter. |
| 2. | Slight potential | 25-35 | Site inspection and surveying, preliminary study, detailed report. |
| 3. | Moderate potential | > 35 | Boreholes, piezometers, lab tests, surveying, detailed report. |

**NOTES:** a) Choose only one from each category; compare total rating value with above requirements.
b) If there is a water body (stream, creek, river, pond, bay, lake) at the slope toe; the potential for toe erosion and undercutting should be evaluated in detail and, protection provided if required.

experience • knowledge • integrity

| | |
|---|---|
| civil | civil |
| geotechnical | géotechnique |
| environmental | environnementale |
| field services | surveillance de chantier |
| materials testing | service de laboratoire des matériaux |



expérience • connaissance • intégrité

## APPENDIX J

### Proposed Solutions of Sewer Pipes and Catchbasins in the PCSWMM Model

This appendix includes the detailed proposed works for each storm sewer system. All the sewer pipes listed below have modifications in pipe size upgrades and/or inlet/outlet invert elevations in order to meet the 100-year level of service. The orange highlights indicate the modifications in sewer pipe sizes or inverts.

All the catchbasins listed in the tables below have changes in the type of catchbasins and/or the number of catchbasins to increase the flow rate of flood water entering the storm sewer system and reduce flooding on streets. More details can be found in the PCSWMM models for each area with Tag "MOD" to show proposed solutions.

**Table J.1: Proposed Sewer Pipe Information of Amalgamated Model**

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 18_0001 | 111.033 | 110.494 | 0.9 | 111.033 | 110.494 | 1.8 |
| 18_0002 | 111.557 | 111.033 | 0.9 | 111.557 | 111.033 | 1.8 |
| 18_0003 | 112.807 | 111.557 | 1.2 | 112.807 | 111.557 | 1.65 |
| 18_0004 | 114.074 | 112.807 | 1.2 | 114.074 | 112.807 | 1.5 |
| 18_005 | 117.454 | 114.074 | 1.2 | 117.454 | 114.074 | 1.35 |
| 18_008 | 118.355 | 117.966 | 1.2 | 118.355 | 117.966 | 1.35 |
| 18_0114 | 146.45 | 146.22 | 0.75 | 146.062 | 145.6 | 1.05 |
| 18_012 | 119.679 | 117.671 | 0.525 | 119.679 | 117.671 | 0.75 |
| 18_014 | 119.907 | 119.818 | 0.525 | 119.907 | 119.818 | 0.75 |
| 18_016 | 120.09 | 119.907 | 0.525 | 120.09 | 119.907 | 0.75 |
| 18_017 | 120.309 | 120.066 | 0.525 | 120.309 | 120.066 | 0.75 |
| 18_019 | 120.574 | 120.309 | 0.525 | 120.574 | 120.309 | 0.75 |
| 18_026 | 120.99 | 120.573 | 0.45 | 120.99 | 120.573 | 0.675 |
| 18_037 | 121.66 | 121.052 | 0.375 | 121.66 | 121.052 | 0.525 |
| 18_045 | 120.021 | 117.454 | 1.35 | 117.989 | 117.454 | 1.5 |
| 18_046 | 120.158 | 120.021 | 1.35 | 119.452 | 117.989 | 1.65 |
| 18_048 | 120.246 | 120.226 | 0.9 | 119.667 | 119.452 | 1.65 |
| 18_051 | 121.321 | 120.726 | 0.9 | 120.971 | 119.667 | 1.5 |
| 18_054 | 123.664 | 121.321 | 0.9 | 123.664 | 120.971 | 1.5 |
| 18_058 | 124.606 | 123.684 | 0.9 | 124.606 | 123.684 | 1.5 |
| 18_059 | 124.636 | 124.606 | 0.9 | 124.636 | 124.606 | 1.65 |
| 18_060 | 124.7 | 124.636 | 0.9 | 124.7 | 124.636 | 1.65 |
| 18_063 | 124.89 | 124.7 | 0.9 | 124.89 | 124.7 | 1.65 |
| 18_078 | 126.377 | 126.233 | 0.9 | 125.321 | 124.89 | 1.65 |
| 18_079 | 126.958 | 126.377 | 0.9 | 126.356 | 125.321 | 1.5 |
| 18_081 | 127.798 | 126.958 | 0.9 | 127.683 | 126.356 | 1.5 |
| 18_082 | 128.16 | 127.938 | 0.75 | 128.16 | 127.824 | 1.35 |
| 18_084 | 132.534 | 128.344 | 0.75 | 132.234 | 128.344 | 1.05 |

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 18_085 | 136.153 | 133.116 | 0.75 | 135.75 | 132.234 | 1.05 |
| 18_086 | 136.21 | 136.21 | 0.75 | 136.21 | 135.75 | 1.05 |
| 18_091 | 139.52 | 139.09 | 0.75 | 139.52 | 138.8 | 1.2 |
| 18_093 | 139.75 | 139.52 | 0.75 | 139.75 | 139.52 | 1.2 |
| 18_095 | 139.91 | 139.75 | 0.75 | 139.91 | 139.75 | 1.2 |
| 18_097 | 142.2 | 140.06 | 0.6 | 142.2 | 140.06 | 0.825 |
| 18_099 | 144.7 | 142.2 | 0.6 | 144.7 | 142.2 | 0.825 |
| 18_101 | 145.34 | 145.03 | 0.75 | 144.932 | 144.7 | 1.2 |
| 18_103 | 145.77 | 145.34 | 0.75 | 145.259 | 144.932 | 1.2 |
| 18_106 | 146.15 | 145.77 | 0.75 | 145.55 | 145.259 | 1.2 |
| 18_109 | 146.22 | 146.15 | 0.75 | 145.6 | 145.55 | 1.2 |
| 18_110 | 146.366 | 146.28 | 0.45 | 145.8 | 145.6 | 1.05 |
| 18_117 | 146.9 | 146.496 | 0.75 | 146.528 | 146.062 | 1.05 |
| 18_119A | 147.05 | 147.018 | 0.75 | 146.762 | 146.7 | 0.975 |
| 18_119B | 147.018 | 146.92 | 0.75 | 146.7 | 146.528 | 1.05 |
| 18_123 | 147.166 | 147.05 | 0.75 | 146.9 | 146.762 | 0.9 |
| 18_125 | 147.45 | 147.166 | 0.75 | 147.137 | 146.9 | 0.9 |
| 18_129a | 147.556 | 147.503 | 0.75 | 147.243 | 147.2 | 0.825 |
| 18_129b | 147.503 | 147.454 | 0.75 | 147.2 | 147.137 | 0.825 |
| 18_159 | 147.895 | 147.57 | 0.75 | 147.643 | 147.243 | 0.75 |
| 18_160 | 147.919 | 147.9 | 0.75 | 147.674 | 147.643 | 0.75 |
| 18_163 | 148.364 | 147.932 | 0.75 | 147.8 | 147.674 | 0.75 |
| 18_165 | 149.349 | 148.63 | 0.5 | 148.5 | 147.8 | 0.45 |
| 18_167 | 150.117 | 149.715 | 0.3 | 149.087 | 148.5 | 0.45 |
| 18_169 | 150.277 | 150.202 | 0.3 | 149.3 | 149.087 | 0.375 |
| 18_170 | 150.495 | 150.362 | 0.3 | 149.465 | 149.3 | 0.375 |
| 18_171 | 150.693 | 150.495 | 0.3 | 150.1 | 149.465 | 0.375 |
| 18_180 | 145.812 | 145.87 | 0.525 | 145.812 | 145.528 | 1 |
| 18_181 | 145.863 | 145.719 | 0.525 | 145.528 | 145.464 | 1 |
| 18_183 | 140.25 | 136.617 | 0.6 | 139.8 | 135.75 | 0.825 |
| 18_184 | 141.345 | 140.218 | 0.6 | 140.7 | 139.8 | 0.825 |
| 18_187 | 141.521 | 141.328 | 0.675 | 140.9 | 140.7 | 1.05 |
| 18_188 | 141.714 | 141.56 | 0.675 | 141.1 | 140.9 | 1.05 |
| 18_189 | 141.822 | 141.758 | 0.675 | 141.293 | 141.1 | 1.05 |
| 18_190 | 142.026 | 141.81 | 0.675 | 141.688 | 141.293 | 1.05 |
| 18_193 | 142.282 | 142.109 | 0.675 | 142.1 | 141.688 | 1.05 |
| 18_195 | 142.591 | 142.54 | 0.375 | 142.591 | 142.54 | 0.45 |
| 18_196 | 144.122 | 142.662 | 0.3 | 143.7 | 142.662 | 0.375 |
| 18_199 | 143.583 | 143.018 | 0.6 | 142.683 | 142.1 | 0.825 |
| 18_2 | 120.578 | 120.522 | 0.825 | 120.578 | 120.158 | 0.825 |
| 18_201 | 144.876 | 143.695 | 0.6 | 142.75 | 142.683 | 0.9 |
| 18_202 | 145.202 | 144.876 | 0.6 | 142.9 | 142.75 | 0.9 |
| 18_203 | 128.011 | 127.897 | 0.675 | 127.751 | 127.683 | 1.2 |
| 18_204 | 128.38 | 128.011 | 0.675 | 127.9 | 127.751 | 1.05 |
| 18_207 | 128.708 | 128.46 | 0.675 | 128.5 | 127.9 | 0.825 |

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 18_208 | 130.746 | 128.818 | 0.525 | 130.746 | 128.5 | 0.525 |
| 18_3 | 117.782 | 117.671 | 1.2 | 117.782 | 117.671 | 1.35 |
| 18_4 | 117.671 | 117.454 | 1.2 | 117.671 | 117.454 | 1.35 |
| 18_5 | 139.09 | 137.52 | 0.6 | 138.8 | 137.52 | 0.9 |
| 18_6 | 137.52 | 136.26 | 0.6 | 137.52 | 136.26 | 0.9 |
| C2 | 145.628 | 145.202 | 1 | 145.464 | 144.703 | 1 |
| C108 | 121.602 | 120.903 | 0.6 | 121.602 | 120.903 | 0.75 |
| C20 | 118.765 | 118.355 | 1.2 | 118.765 | 118.355 | 1.35 |
| C31 | 121.956 | 121.625 | 0.6 | 121.956 | 121.625 | 0.75 |
| C35 | 122.838 | 122.556 | 0.3 | 122.838 | 122.556 | 0.375 |
| C6 | 122.21 | 122.012 | 0.525 | 122.21 | 122.012 | 0.675 |

**Table J.2: Proposed Catchbasin Information of Amalgamated Model**

| Catchbasin Name | Existing Condition | Proposed Condition |
|---|---|---|
| 18_CB_235 | FB-CB-x2 | HCI-CB-x2 |
| 18_CB_236 | HC-CB-x1 | HCI-CB-x2 |
| 18_MH_0005 | HC-CB-x1 | HCI-CB-x1 |
| 18_MH_0039 | FB-CB-x2 | HCI-CB-x2 |
| 18_MH_0051 | FB-CB-x2 | HCI-CB-x2 |
| 18_MH_0072 | FB-CB-x1 | HCI-CB-x1 |
| 18_MH_0113 | FB-CB-x2 | HCI-CB-x3 |
| 18_MH_0115 | HC-CB-x1 | HCI-CB-x2 |
| 18_MH_0129 | HC-CB-x1 | TFB-CB-x1 |
| 18_MH_0151 | FB-CB-x1 | HCI-CB-x1 |
| 18_MH_0153 | HC-CB-x1 | TFB-CB-x2 |
| 18_MH_0155 | FB-CB-x1 | HCI-CB-x3 |
| 18_MH_0176 | FB-CB-x1 | TFB-CB-x1 |
| 18_MH_0178 | HC-CB-x1 | HCI-CB-x1 |
| 18_MH_0180 | TFB-CB-x1 | HCI-CB-x3 |
| 18_MH_0194 | FB-CB-x1 | HCI-CB-x1 |
| 18_MH_0196 | FB-CB-x1 | TFB-CB-x1 |
| 18_MH_0197 | FB-CB-x2 | TFB-CB-x2 |
| 18_MH_0207 | HC-CB-x1 | HCI-CB-x1 |
| 18_MH_0208 | HC-CB-x1 | TFB-CB-x1 |
| J8 | HC-CB-x1 | TFB-CB-x1 |
| STT-2-Amal-ABL | FB-CB-x5 | HCI-CB-x2 |
| VN_25-Amal_ABL | FB-CB-x1 | TFB-CB-x2 |

**Table J.3: Proposed Sewer Pipe Information of Darcy Model**

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 44_0001 | 115.897 | 113.277 | 0.3 | 115.6 | 113.277 | 0.525 |
| 44_0004 | 116.013 | 115.897 | 0.3 | 115.7 | 115.6 | 0.525 |
| 44_0005 | 116.925 | 116.827 | 0.2 | 116.625 | 116.527 | 0.3 |
| 44_0007 | 117.09 | 116.925 | 0.2 | 116.79 | 116.625 | 0.3 |
| 44_0008 | 116.525 | 116.339 | 0.2 | 115.9 | 115.723 | 0.525 |
| 44_0013 | 118.814 | 116.075 | 0.2 | 118.814 | 116.075 | 0.3 |
| C40 | 116.913 | 116.66 | 0.2 | 116.6 | 116.4 | 0.375 |
| C41_2 | 116.91 | 116.741 | 0.2 | 116.51 | 116.4 | 0.3 |
| C42 | 116.336 | 116.033 | 0.2 | 115.723 | 115.7 | 0.525 |
| C43 | 116.693 | 115.839 | 0.2 | 116.4 | 115.839 | 0.375 |

**Table J.4: Proposed Catchbasin Information of Darcy Model**

| Catchbasin Name | Existing Condition | Proposed Condition |
|---|---|---|
| 44_CB_0005 | FB-CB-x2 | HCI-CB-x1 |
| 44_MH_0003 | HC-CB-x1 | HCI-CB-x1 |
| VN-1--DD-ABL | FB-CB-x1 | TFB-CB-x1 |

**Table J.5: Proposed Sewer Pipe Information of Lake St Model**

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 09_0001 | 110.932 | 109.279 | 0.75 | 110 | 109.279 | 1.2 |
| 09_0002 | 111.1 | 110.969 | 0.75 | 111 | 110 | 1.05 |
| 09_0004 | 111.402 | 111.37 | 0.9 | 111.052 | 111 | 0.9 |
| 09_0005 | 111.467 | 111.402 | 0.9 | 111.155 | 111.052 | 0.9 |
| 09_0007 | 111.494 | 111.467 | 0.9 | 111.2 | 111.155 | 0.9 |
| 09_0008 | 111.547 | 111.494 | 0.9 | 111.295 | 111.2 | 0.9 |
| 09_0009 | 111.69 | 111.547 | 0.9 | 111.551 | 111.295 | 0.9 |
| 09_0012 | 111.92 | 111.758 | 0.75 | 111.798 | 111.551 | 0.75 |
| 09_0014 | 111.964 | 111.92 | 0.75 | 111.824 | 111.798 | 0.75 |
| 09_0015 | 112.123 | 111.964 | 0.75 | 111.866 | 111.824 | 0.75 |
| 09_0019 | 112.234 | 112.123 | 0.75 | 111.977 | 111.866 | 0.75 |
| 09_0021 | 112.238 | 112.234 | 0.75 | 111.981 | 111.977 | 0.75 |
| 09_0022 | 112.501 | 112.238 | 0.75 | 112.201 | 111.981 | 0.75 |
| 09_0023 | 112.86 | 112.501 | 0.45 | 112.33 | 112.201 | 0.6 |
| 09_0036 | 112.651 | 112.42 | 0.3 | 112.23 | 112.1 | 0.45 |
| 09_0043 | 111.237 | 111.199 | 0.3 | 111.237 | 111.199 | 0.6 |
| 09_0048 | 112.081 | 111.84 | 0.3 | 112 | 111.84 | 0.375 |
| 09_0049 | 112.491 | 112.081 | 0.3 | 112.1 | 112 | 0.375 |
| 10_0001 | 110.655 | 109.936 | 0.375 | 110.655 | 109.936 | 0.6 |
| 10_0002 | 111.182 | 110.655 | 0.375 | 111.182 | 110.655 | 0.6 |

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 10_0004 | 111.343 | 111.182 | 0.375 | 111.343 | 111.182 | 0.6 |
| 10_0006 | 111.833 | 111.362 | 0.375 | 111.833 | 111.362 | 0.525 |
| 10_0007 | 112.32 | 111.874 | 0.375 | 112.32 | 111.874 | 0.45 |
| 10_0008 | 112.874 | 112.32 | 0.3 | 112.874 | 112.32 | 0.375 |
| C50 | 113.28 | 113.11 | 0.3 | 113.28 | 112.71 | 0.3 |
| C52 | 113.11 | 112.9 | 0.3 | 112.71 | 112.29 | 0.375 |
| C53 | 112.9 | 112.623 | 0.3 | 112.29 | 112.23 | 0.375 |

**Table J.6: Proposed Catchbasin Information of Lake St Model**

| Catchbasin Name | Existing Condition | Proposed Condition |
|---|---|---|
| 09_MH_0001 | FB-CB-x3 | HCI-CB-x3 |
| 09_MH_0007 | FB-CB-x4 | HCI-CB-x3 |
| 10_MH_0005 | FB-CB-x1 | TFB-CB-x2 |

**Table J.7: Proposed Sewer Pipe Information of Trafalgar Model**

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 6 | 125.126 | 122.873 | 0.45 | 125.126 | 122.873 | 0.75 |
| 06_0001 | 111.766 | 109.705 | 0.9 | 111.6 | 109.705 | 1.35 |
| 06_0009_1 | 113.582 | 113.28 | 0.9 | 113.092 | 112.796 | 1.35 |
| 06_0009_2 | 113.28 | 112.052 | 0.9 | 112.796 | 111.6 | 1.35 |
| 06_0014 | 114.337 | 113.575 | 0.9 | 113.9 | 113.092 | 1.35 |
| 06_0018 | 116.297 | 114.333 | 0.9 | 116.297 | 113.9 | 1.2 |
| 06_0019 | 118.016 | 116.297 | 0.9 | 118.016 | 116.297 | 1.05 |
| 06_0020 | 119.31 | 119.18 | 0.9 | 118.673 | 118.5 | 1.2 |
| 06_0022 | 119.708 | 119.31 | 0.9 | 119.198 | 118.673 | 1.2 |
| 06_0024 | 120.096 | 119.772 | 0.9 | 119.639 | 119.198 | 1.2 |
| 06_0025 | 120.247 | 120.126 | 0.9 | 119.766 | 119.639 | 1.2 |
| 06_0028 | 120.603 | 120.236 | 0.9 | 120.183 | 119.766 | 1.2 |
| 06_0031 | 120.868 | 120.601 | 0.9 | 120.57 | 120.183 | 1.05 |
| 06_0032 | 121.119 | 120.839 | 0.9 | 120.65 | 120.57 | 0.9 |
| 06_0033 | 121.291 | 121.138 | 0.9 | 121.291 | 120.65 | 0.9 |
| 06_0043 | 123.61 | 122.891 | 0.375 | 123.61 | 122.891 | 0.45 |
| 06_0045 | 124.45 | 123.635 | 0.375 | 124.45 | 123.635 | 0.45 |
| 06_0048 | 127.282 | 125.617 | 0.375 | 127.282 | 125.617 | 0.45 |
| 06_0081 | 119.885 | 119.146 | 0.6 | 119.002 | 118.016 | 0.9 |
| 06_0082 | 120.34 | 119.995 | 0.6 | 119.9 | 119.002 | 0.9 |
| 06_0083 | 122.022 | 120.34 | 0.6 | 122.022 | 119.9 | 0.825 |
| 06_0084 | 122.438 | 121.998 | 0.6 | 122.438 | 121.998 | 0.825 |
| 06_0085 | 122.545 | 122.492 | 0.75 | 122.545 | 122.492 | 0.9 |
| 06_0086 | 122.657 | 122.545 | 0.75 | 122.657 | 122.545 | 0.9 |

| Name | Existing Condition | | | Proposed Condition | | |
|---|---|---|---|---|---|---|
| | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) | Inlet Elev (m) | Outlet Elev (m) | Diameter (m) |
| 06_0087 | 122.807 | 122.715 | 0.75 | 122.807 | 122.715 | 0.825 |
| 06_0089 | 122.916 | 122.807 | 0.75 | 122.916 | 122.807 | 0.825 |
| 06_0091 | 123.201 | 122.916 | 0.75 | 123.201 | 122.916 | 0.825 |
| 06_0092 | 123.278 | 123.201 | 0.675 | 123.278 | 123.201 | 0.75 |
| 06_0093 | 123.328 | 123.278 | 0.675 | 123.328 | 123.278 | 0.75 |
| 06_0104 | 126.013 | 125.838 | 0.375 | 126.013 | 125.838 | 0.45 |
| 06_0105 | 126.297 | 126.013 | 0.375 | 126.297 | 126.013 | 0.45 |
| 06_0106 | 126.61 | 126.297 | 0.2 | 126.61 | 126.297 | 0.375 |
| 06_0118 | 122.245 | 122.072 | 0.45 | 122.245 | 122.072 | 0.825 |
| 06_0119 | 122.614 | 122.235 | 0.45 | 122.614 | 122.235 | 0.825 |
| 06_0122 | 122.868 | 122.635 | 0.45 | 122.868 | 122.635 | 0.825 |
| 06_0124 | 125.922 | 125.072 | 0.45 | 125.922 | 125.072 | 0.75 |
| 06_0129 | 125.922 | 126.55 | 0.45 | 126.699 | 125.922 | 0.75 |
| 06_0131 | 126.714 | 126.699 | 0.375 | 126.714 | 126.699 | 0.675 |
| 06_0132 | 126.782 | 126.714 | 0.375 | 126.782 | 126.714 | 0.675 |
| 06_0134 | 130.196 | 126.86 | 0.375 | 130.196 | 126.86 | 0.45 |
| 06_0135 | 131.838 | 130.196 | 0.375 | 131.838 | 130.196 | 0.45 |
| 06_0136 | 132.466 | 131.957 | 0.3 | 132.2 | 131.957 | 0.45 |
| 08_0050 | 126.5 | 126.31 | 0.525 | 126.5 | 126.052 | 0.9 |
| 08_0051 | 126.702 | 126.5 | 0.45 | 126.702 | 126.5 | 0.9 |
| 08_0052 | 127.24 | 126.702 | 0.45 | 127.24 | 126.702 | 0.6 |
| 08_0054 | 127.57 | 127.24 | 0.45 | 127.57 | 127.24 | 0.6 |
| 08_0056 | 127.95 | 127.57 | 0.45 | 127.95 | 127.57 | 0.525 |
| 08_0057 | 128.06 | 127.95 | 0.2 | 128.06 | 127.95 | 0.45 |
| 08_0059 | 132.503 | 128.58 | 0.2 | 132.503 | 128.58 | 0.375 |
| 08_0060 | 133.123 | 132.595 | 0.2 | 133.123 | 132.595 | 0.3 |
| 08_0062 | 132.762 | 132.564 | 0.2 | 132.762 | 132.564 | 0.3 |
| 08_0063 | 132.939 | 132.762 | 0.2 | 132.939 | 132.762 | 0.3 |
| 08_0067 | 130.436 | 127.01 | 0.3 | 130.436 | 127.01 | 0.375 |
| 08_0068 | 131.741 | 131.436 | 0.2 | 131.741 | 131.436 | 0.375 |
| 08_0072 | 132.306 | 131.759 | 0.2 | 132.306 | 131.759 | 0.375 |

**Table J.8: Proposed Catchbasin Information of Trafalgar Model**

| Catchbasin Name | Existing Condition | Proposed Condition |
|---|---|---|
| 06_MH_0038 | FB-CB-x5 | TFB-CB-x4 |
| 06_MH_0046 | FB-CB-x3 | HCI-CB-x2 |
| 06_MH_0049 | HC-CB-x1 | HCI-CB-x1 |
| 06_MH_0057 | FB-CB-x1 | HCI-CB-x1 |
| 06_MH_0059A | HC-CB-x1 | HCI-CB-x1 |
| 06_MH_0069 | FB-CB-x2 | TFB-CB-x2 |
| 06_MH_0077 | FB-CB-x2 | HCI-CB-x2 |
| 06_MH_0080 | HC-CB-x1 | TFB-CB-x1 |
| 06_MH_0099 | FB-CB-x1 | HCI-CB-x2 |

| Catchbasin Name | Existing Condition | Proposed Condition |
|---|---|---|
| 06_MH_0101 | FB-CB-x2 | HCI-CB-x1 |
| 08_MH_0044 | HC-CB-x1 | HCI-CB-x1 |
| 08_MH_0046 | FB-CB-x1 | HCI-CB-x1 |
| 08_MH_0048 | FB-CB-x1 | TFB-CB-x1 |
| J1 | HC-CB-x1 | HCI-CB-x1 |
| STT-11-ABL | HC-CB-x1 | HCI-CB-x1 |
| STT-15-ABL | HC-CB-x1 | TFB-CB-x1 |
| VN-10-ABL | HC-CB-x1 | HCI-CB-x2 |