# Inflow Design Flood and Dam Break Analysis for a Small Hydroelectric Project in Ontario

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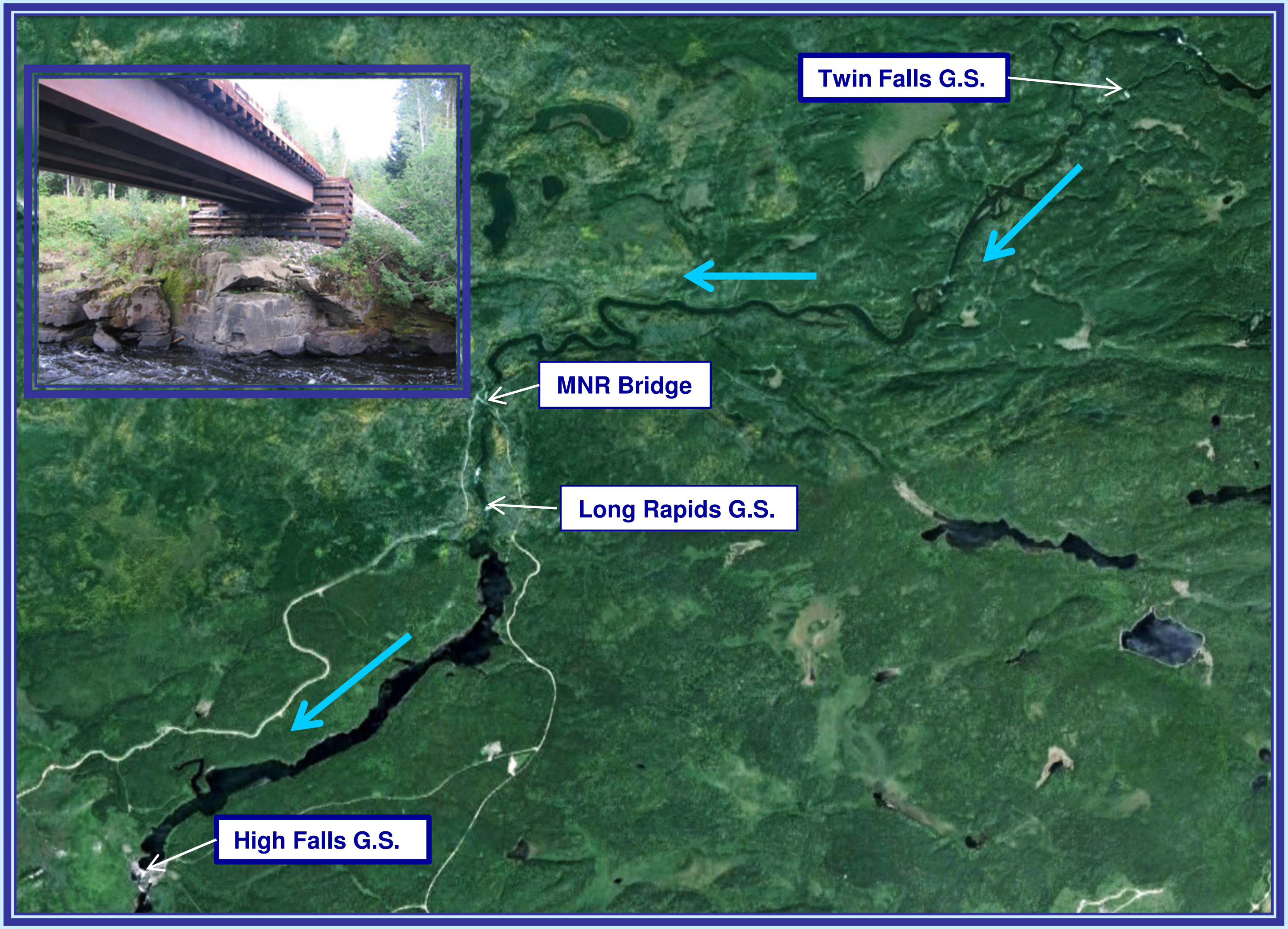
# Agenda

1. Introduction
2. Overview of Proposed Project
3. Field Investigations
4. Hydrologic Study
5. Inflow Design Flood
6. Discharge Capacity Optimization
7. Conclusions

**Note: Material for the presentation was provided by courtesy of AXOR**

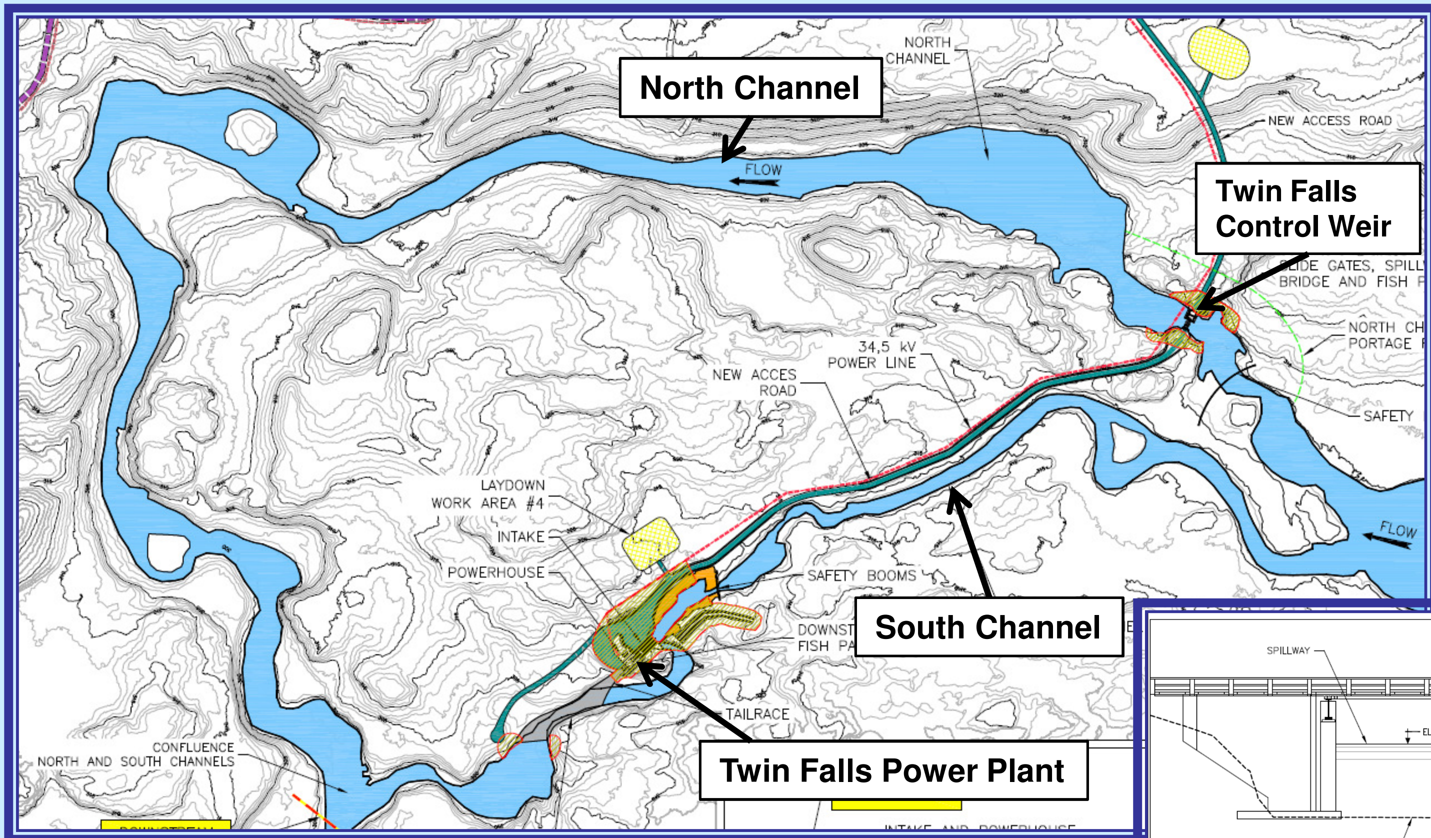
# Namewaminikan Hydro Project Location

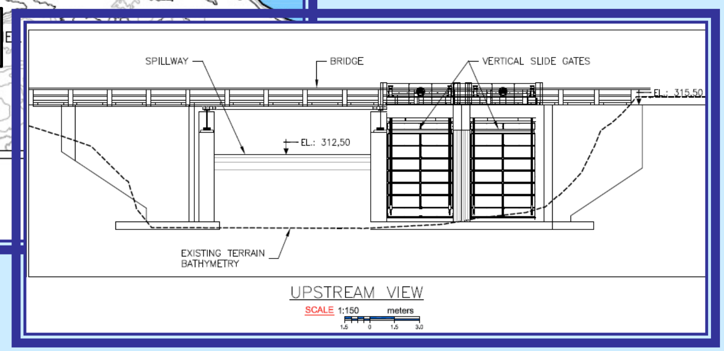
# Development Sites and existing facilities




Map Source:
Google earth

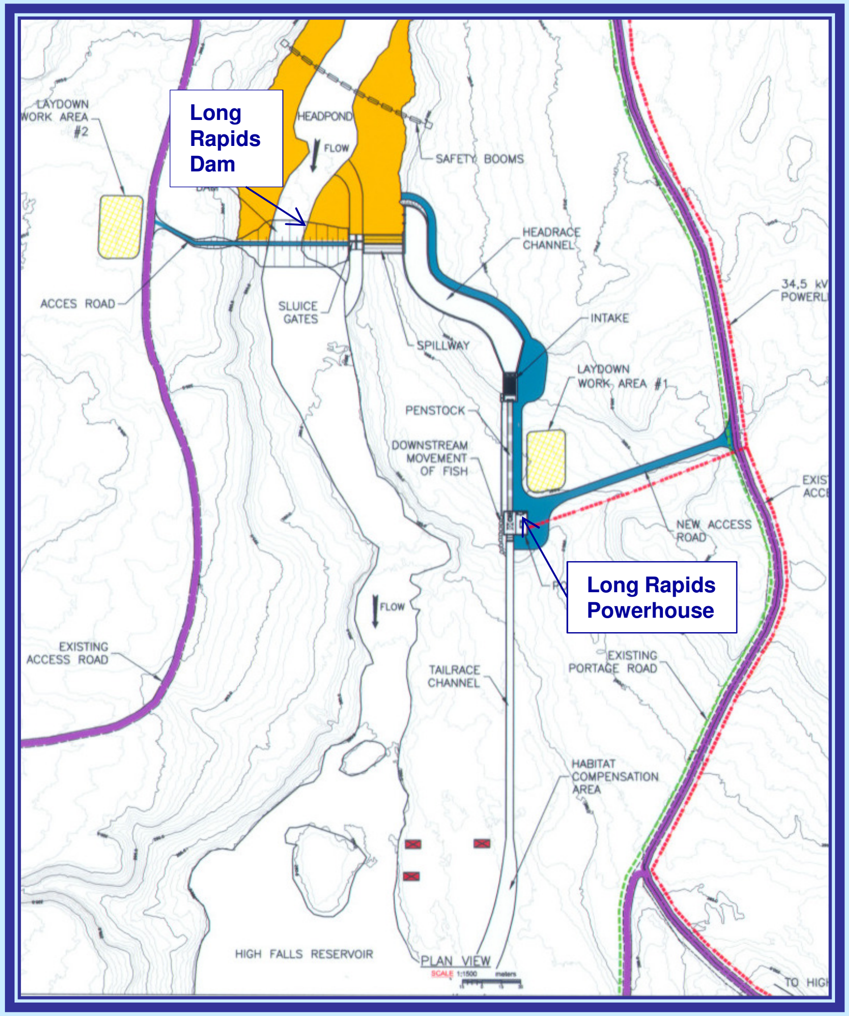
# Twin Falls Site Characteristics



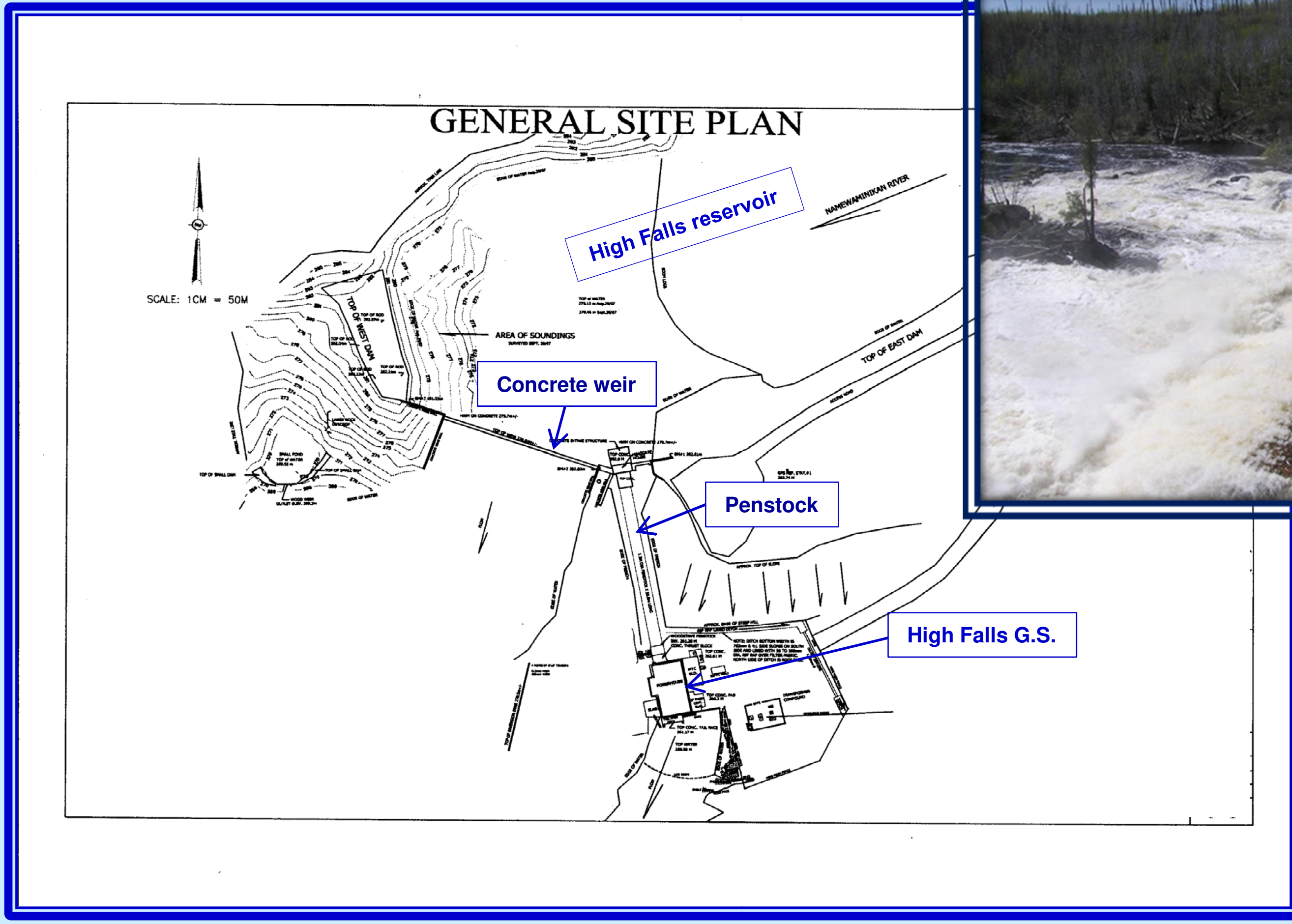




TF North Channel Weir X-Section

# Long Rapids Site Characteristics



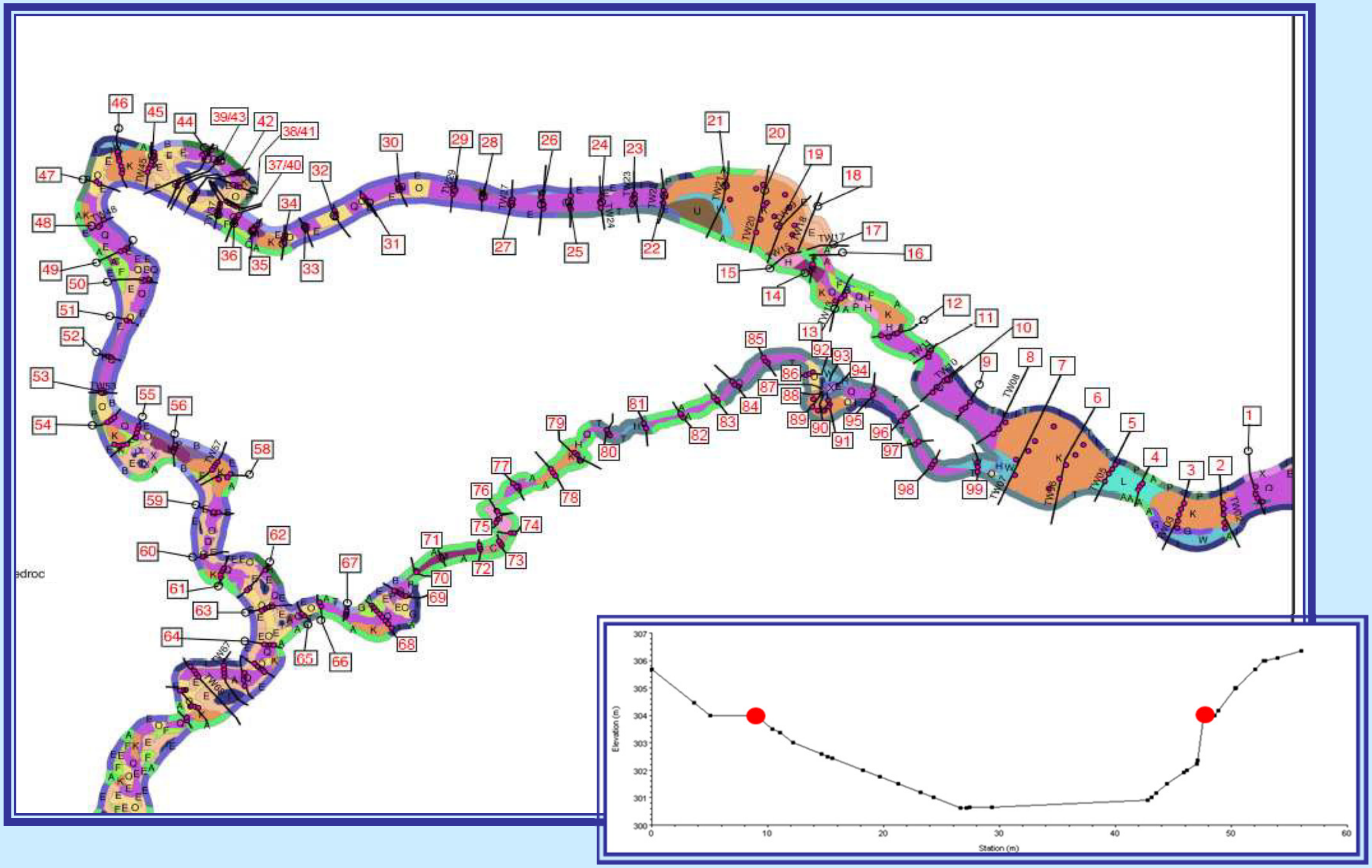
# High Falls G.S. Site Characteristics



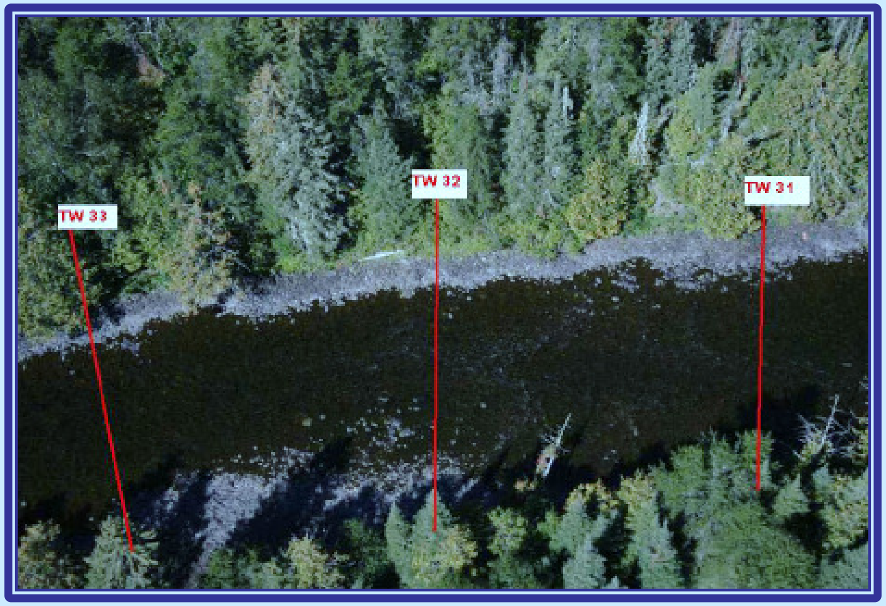

# Field Investigations

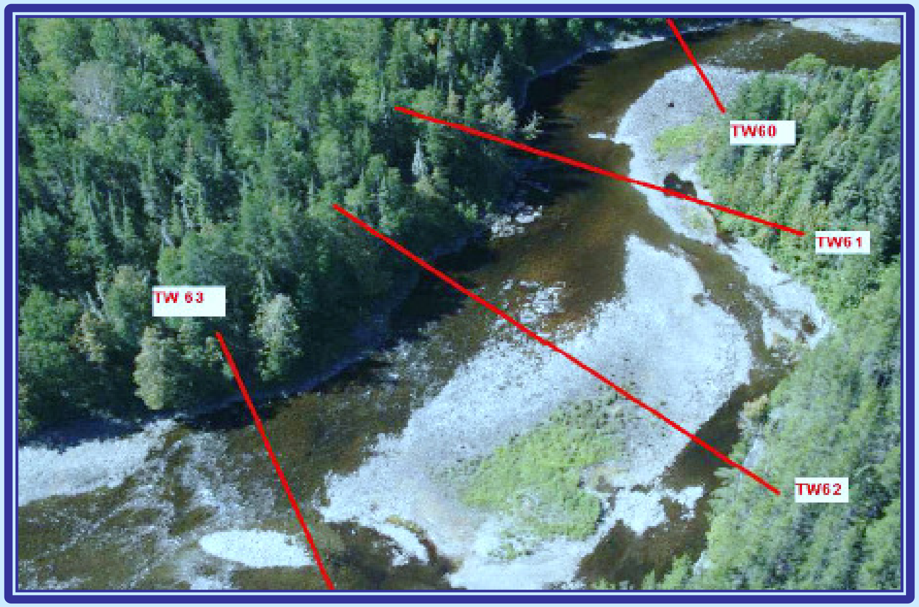
- Topography
- Bathymetry
- LiDAR
- Aerial Photographs
- Hydrologic Measurements

# Twin Falls Site with X-Sections



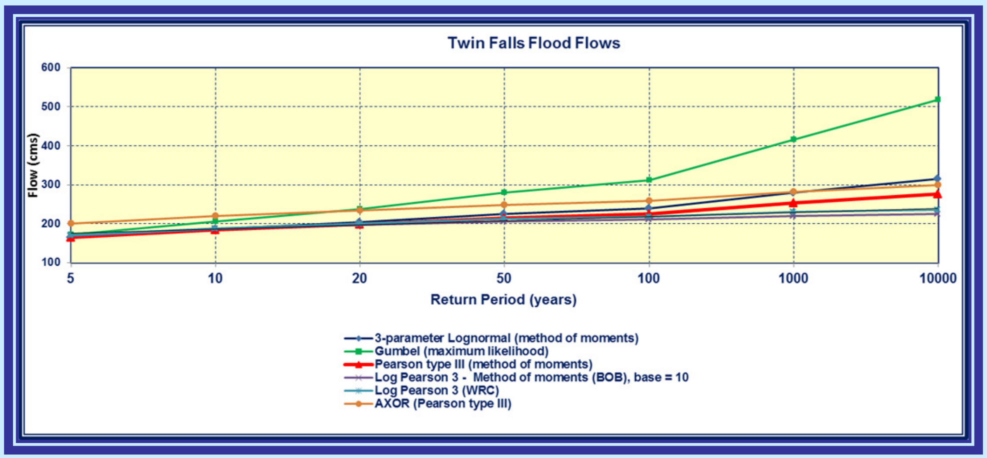
# Aerial photos with overlay of X-Sections

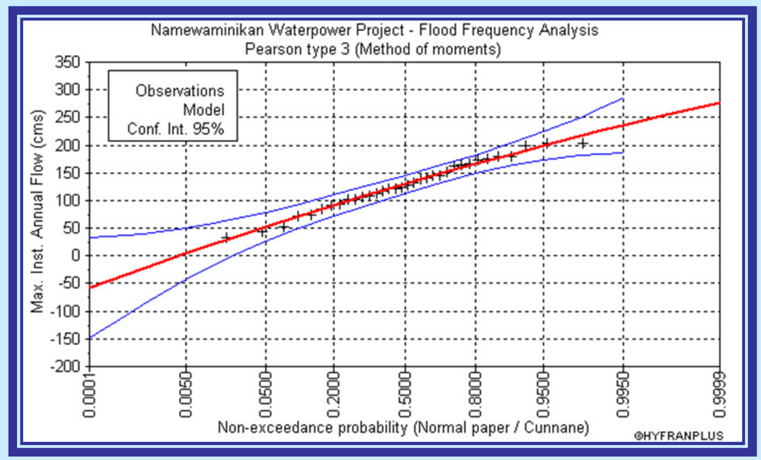


# Frequency Analysis

- **HYFRAN-PLUS program**
- **Hypothesis tests accepted at 5% significance level**
  - **Independence test - there is no relationship between the annual flows**
  - **Stationarity test - there is no apparent trend in the annual flow values**
  - **Homogeneity test - the flows before and after 2007 are homogeneous, the averages of the two samples can be assumed equal.**



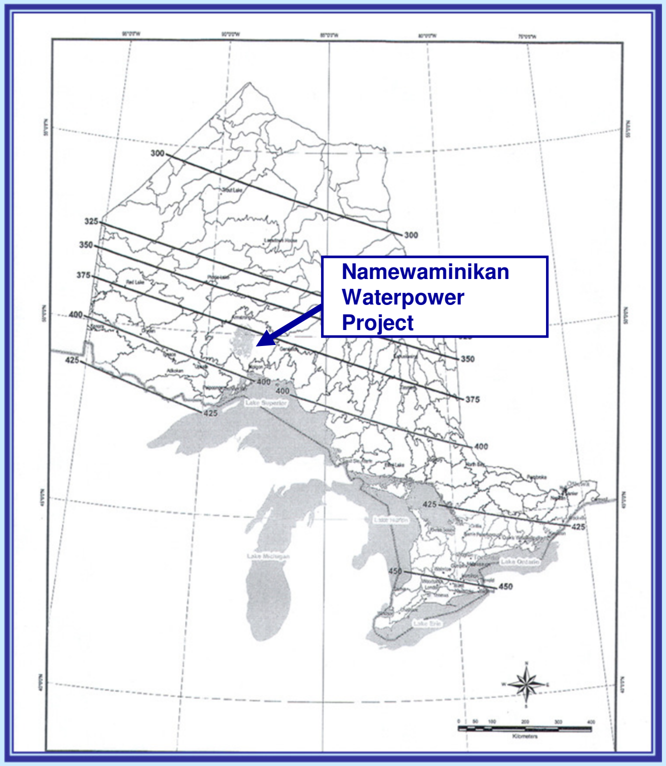

| Distribution | Return Period | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 10 | 20 | 50 | 100 | 1000 | 10000 |
| Flows for Pearson type 3 ($m^3/s$) | 166 | 185 | 199 | 216 | 226 | 254 | 276 |

# Other High Flows

- Actual maximum instantaneous flow (2008)
- Regional flow – based on Transposed Timmins flood (MNR-TG 2002)

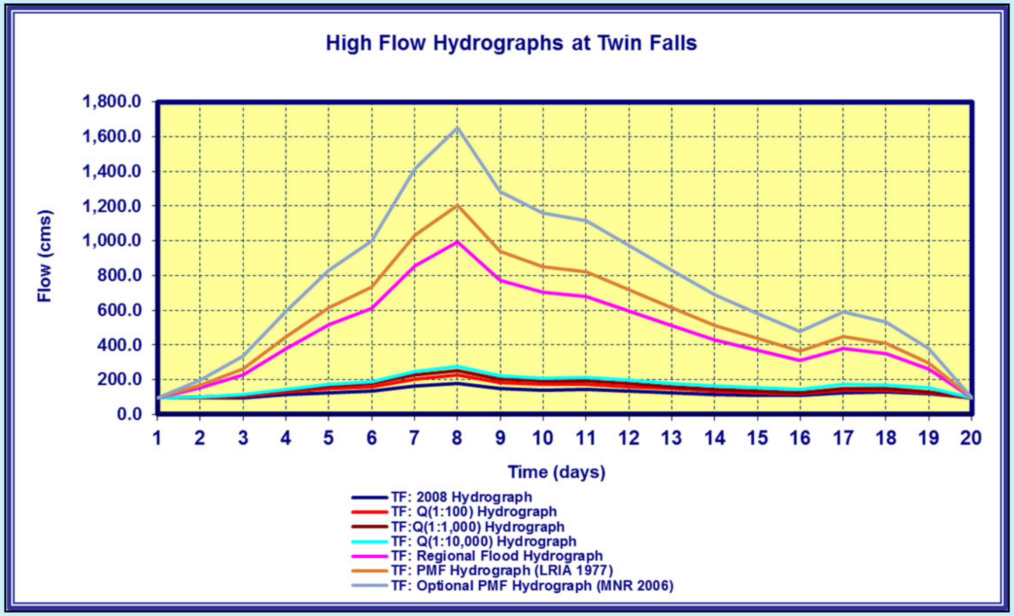
  "Timmins" is the name applied to the 12-hr. summer storm which occurred over Timmins, Ontario on Sept. 1, 1961. The storm created severe property damage and resulted in loss of life.

- PMF based on PMP in the MNR-TG 2002
- PMF based on PMP published by MNR in 2006 (not mandatory, figure to the right)




Map with 24-hr PMP spatial distribution in Ontario for areas of 2,000 sq. Km. Source: MNR – PMP for Ontario, 2006

# Summary of Peak Flows




| Peak flow estimates | Twin Falls (cms) | Long Rapids (cms) |
|---|---|---|
| Actual 2008 peak flow | 180 | 187 |
| Flood flow with a return period of 1:100 years | 226 | 236 |
| Flood flow with a return period of 1:1,000 years | 254 | 265 |
| Flood flow with a return period of 1:10,000 years | 276 | 288 |
| Regional/Regulatory Food (RF),Transposed Timmins Storm | 992 | 1,036 |
| PMF under (MNR 2002 PMP) | 1,204 | 1,256 |
| Optional PMF (MNR 2006 PMP) | 1,652 | 1,712 |

# Inflow Design Flood

## LRIA 2011 (MNR–TG, 2011)

| Hazard Potential Classification | Range of Minimum Inflow Design Floods | | | |
|---|---|---|---|---|
| | Life Safety | | Property and Environment | Cultural – Built Heritage |
| Very High | Greater than 100 | PMF | 1/3 between the 1000 Year Flood and PMF to PMF | |
| | 11-100 | 2/3 between the 1000 year Flood and PMF | | |
| High | 1-10 | 1/3 between the 1000 year Flood and PMF | 1000 Year Flood or RF whichever is greater to 1/3 between the 1000 year flood and PMF | 1000 Year Flood or RF, whichever is greater |
| Moderate | 100 Year Flood to 1000 year flood or RF whichever is greater | | | |
| Low | 25 Year Flood to 100 Year Flood | | | |

## LRIA 1977 (MNR–TG, 2002) requires: 100-year to RF

# Incremental Hazard Evaluation (IHE)

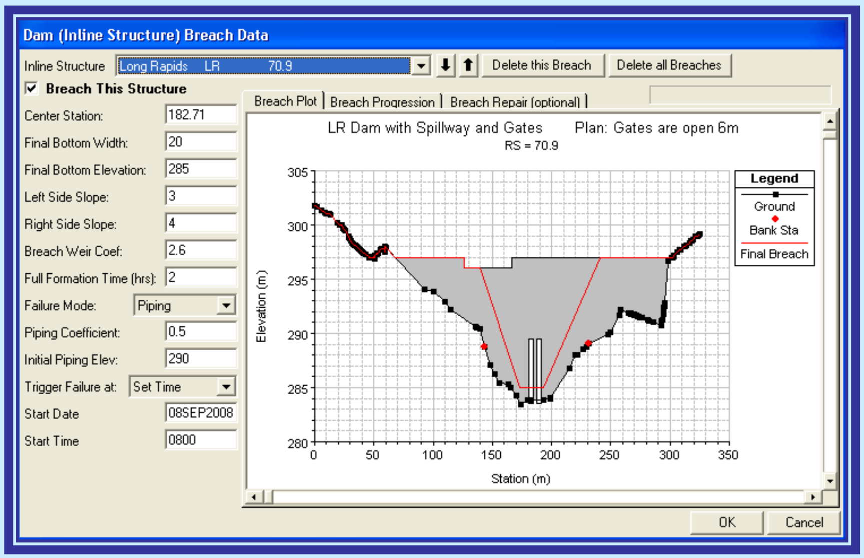
- IHE is used to explore the possibility of selecting a lower magnitude IDF than the one required by MNR's 2011 Technical Guidelines
- IHE was started by simulating the flow in the river for a 1:10,000-year flood
- Simulations would continue iteratively with increments of 20% between the 1:10,000-year flood and the Regional Flood
- The iterative process will stop when the incremental increase in losses caused by a dam break or cascading dam breaks, when compared to the losses produced by the same flood under pre-development conditions, will be judged to be acceptable i.e. no significant incremental increases in damages to property, environment, and cultural heritage sites (no loss of life is assumed for Moderate HPC)
- Incremental increases in losses resulting from dam breaks will be judged on the basis of their impact at the High Falls G.S. and the MNR bridge

# Assumptions (1 of 2)

- All water control gates at TF and LR were assumed operational at all time in post-development conditions
- The control gates were assumed to be raised up to 5m rather than to the maximum design opening of 6m
- The turbines at TF and LR were assumed out-of–service when running HEC-RAS with the dam break assumptions
- The dam breaks at TF and at LR were simulated such as to occur at the time of the flood peak
- Cascade dam breaks were considered
- The TF dam is a concrete structure and was assumed to fail almost instantly

# Assumptions (2 of 2)

- **Large dam breaches were assumed at both sites**
- **During the flood, the gates were raised gradually as the flood flow in the river increased**



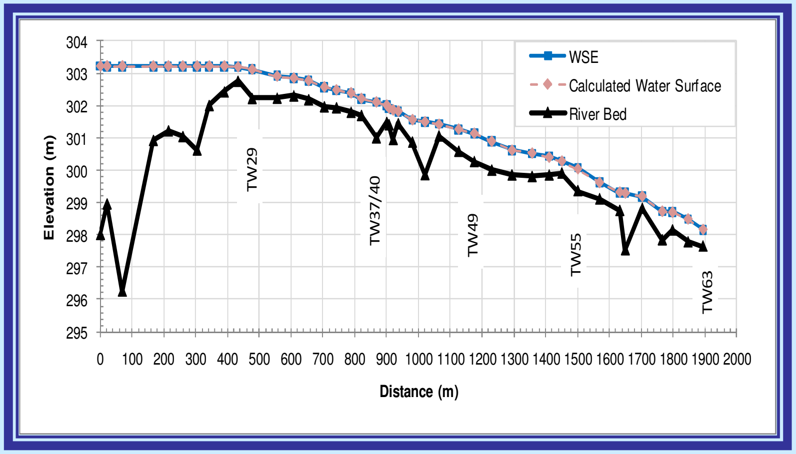

**Assumed TF weir breach**

| Inflow into Twin Falls or Long Rapids reservoir (cms) | Gate opening at the Twin Falls North Channel, South Channel, and Long Rapids (m) |
|---|---|
| 100 | 1 |
| 115 | 2 |
| 130 | 3 |
| 145 | 4 |
| 160 and more | 5 |

**TF : Assumed gate operation plan**

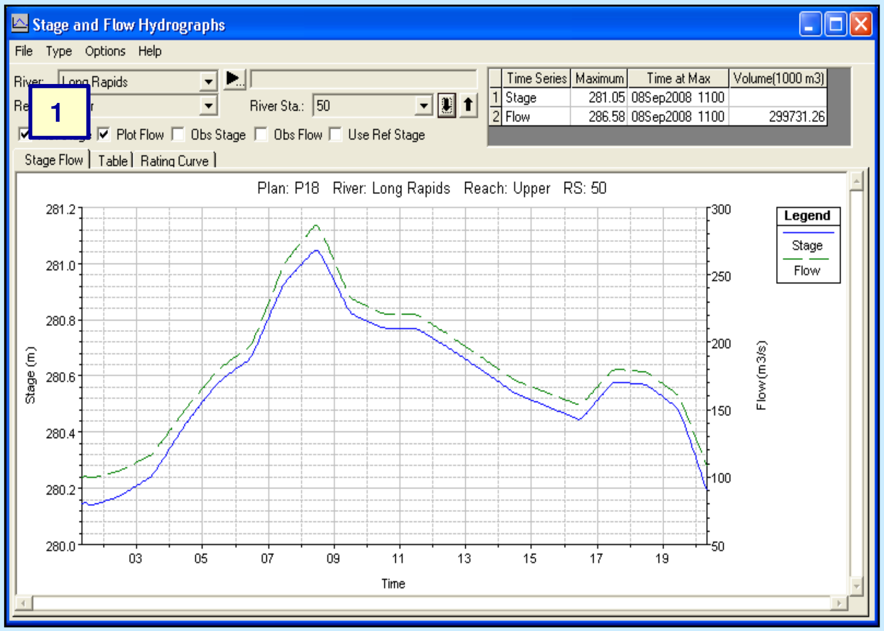
# HEC-RAS Model Setup

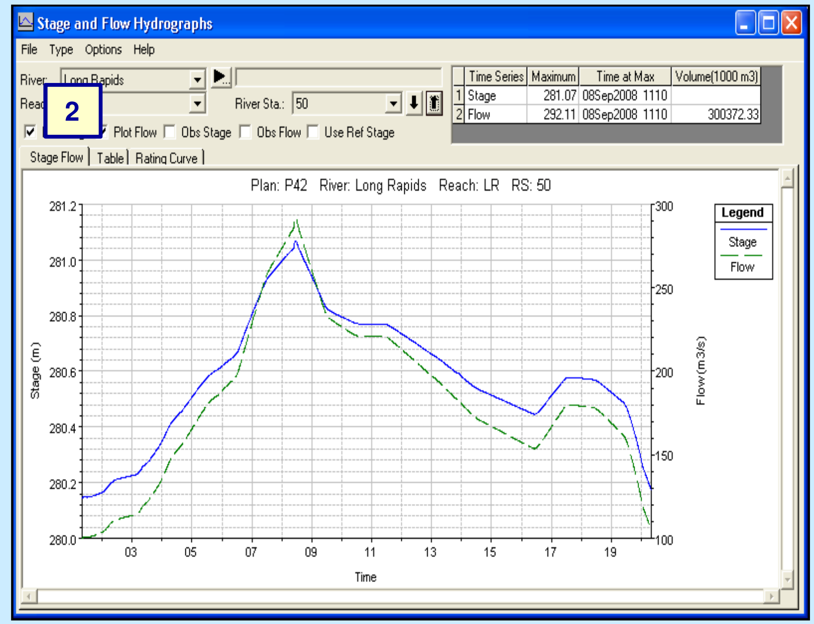
- Preparing the GIS files with X-Section geometry
- Elimination of high flow velocity reaches
- Eliminating excess points in X-sections
- Defining channel stations
- Assuming initial Manning Coefficients
- Interpolating between X-sections
- Stability tests
- Model calibration




**TF North Channel model calibration**

# Simulation results at High Falls G.S.



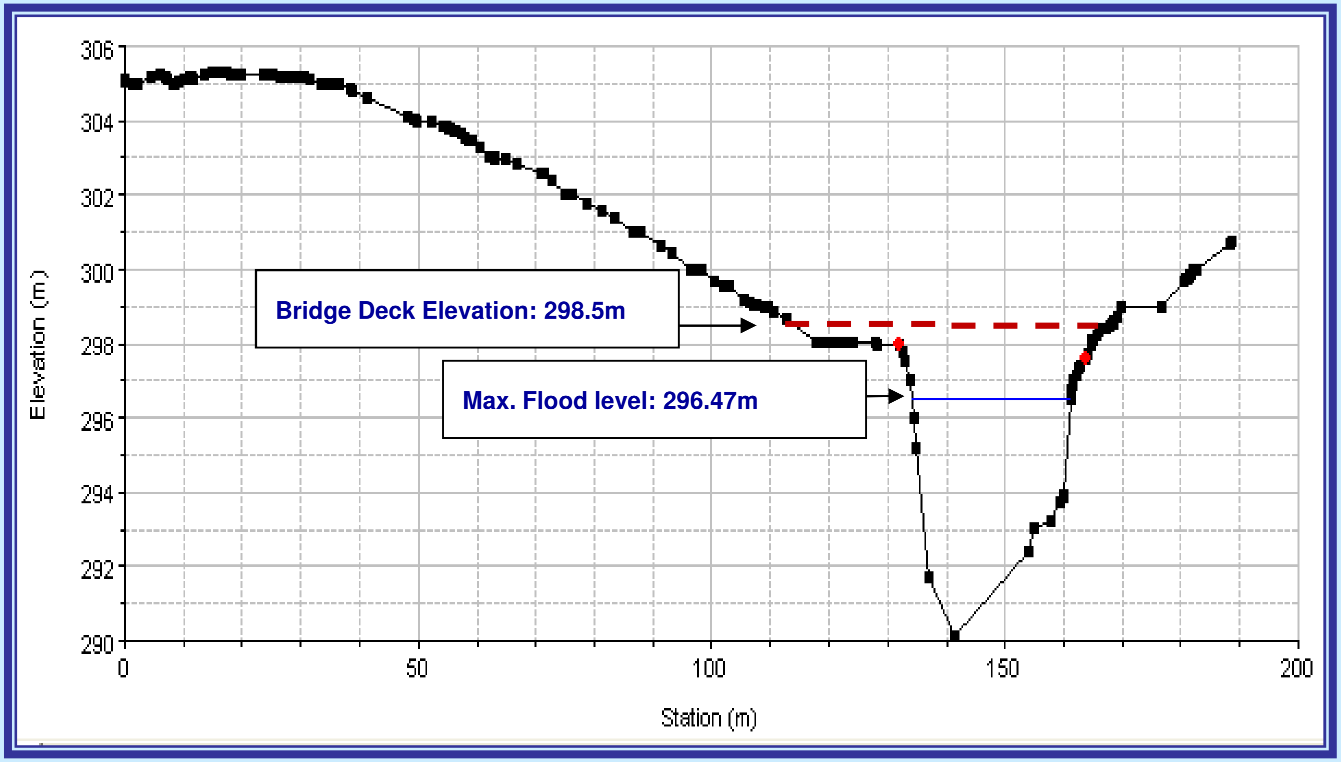




**Q = 285.96 cms**
**S = 281.04 m**

**Q = 292.11 cms (+6.15 cms; +2.1%)**
**S = 281.07 m (+3cm)**

**T = 1:10,000; 1- pre-development; 2 – post-development: cascading dam breaks**

# Example of simulation at the MNR Bridge




T = 1:10,000; Post-development simulation with cascade dam breaks.

# Summary of results

## Pre-development results

| Simulation Scenario | High Falls G.S. Peak Flow (cms) | High Falls G.S. Max. Water Level Elevation (m) | MNR Camp 72 bridge Max. Water Level Elevation (m) |
|---|---|---|---|
| Long Rapids to High Falls simulation | 285.96 | 281.04 | 295.10 |
| Twin Falls to High Falls simulation | 286.58 | 281.05 | 295.10 |
| Difference | 0.62 | 0.01 | 0.00 |
| **Values retained for comparison with the post-development condition** | **285.96** | **281.04** | **295.10** |

## Post-development results

| Dam condition scenario | Simulation Scenario | High Falls G.S. Peak Flow (cms) | High Falls G.S. Max Water Level Elevation (m) | MNR Camp 72 bridge Max. Water Level Elevation (m) |
|---|---|---|---|---|
| No dam break | Long Rapids to High Falls simulation | 285.94 | 281.04 | 296.40 |
| | Twin Falls to High Falls simulation | 286.53 | 281.05 | 296.47 |
| Single Dam Break | Dam Break at LR: Long Rapids to High Falls simulation | 291.24 | 281.07 | 296.40 |
| | Dam Break at TF: Twin Falls to High Falls simulation | 286.61 | 281.05 | 296.47 |
| Cascade Dam Break | Dam Break at TF and LR: Twin Falls to High Falls simulation | 292.11 | 281.07 | 296.47 |
| **Values retained for comparison with pre-development conditions** | | **292.11** | **281.07** | **296.47** |

# Impact Analysis

1. **High Falls G.S.**
   - There is no practical increase in peak flows between the pre-development and post-development conditions without dam breaks. A cascade dam break would result in an increase of 6.15cms or 2.1% in peak flow.
   - Water level elevations, in pre and post-development conditions without dam breaks are identical. A cascade dam break would result in an elevation increase of 3cm. This increase meets the WMP and LUP requirements. The water level would remain below the crest of the dam and would satisfy freeboard requirements.
   - The small impact that would be produced by a cascade dam break on flows and water levels was judged not to produce any significant incremental increases in losses at High Falls G.S.

2. **MNR Bridge**
   - The bridge will not be damaged by the worst dam-break scenario in post-development conditions .
   - The existing 1.9m clearance at the bridge would be reduced to 0.53m. If the existing clearance is to be preserved in post-development conditions, the bridge will have to be reconstructed at an 1.4m higher elevation.

# Discharge Capacity Optimization (1 of 2)

- The maximum discharge capacities at the two proposed development sites are significantly higher than the respective peak flows of the recommended IDF: 39% at TF and 55% at LR. This clearly indicates that there is scope in reducing the maximum discharge capacities
- A study was conducted to determine a conservative discharge capacity at each of the two sites that should:
  - Consider cost-optimized gate sizes;
  - Reduce discharge capacities below the initial design values of 383.3cms at TF and 446.7cms at LR;
  - Ensure that the updated discharge capacities remain higher than the IDF flows of 276cms at TF and 288cms at LR.

# Discharge Capacity Optimization (2 of 2)

- **First step**
  - **Reduce discharge capacities from 383.3cms (139% of IDF) to 356.2 (129% of IDF) at TF, and from 446.7cms (155% of IDF) to 319cms (111% of IDF) at LR. Result: potential of dam break by overtopping with significant downstream impact.**
- **Second step**
  - **Increase the LR discharge capacity from 319cms (111% of IDF) to 384cms (133% of IDF)**

| River condition | Dam condition | Simulation Information | Maximum flow at High Falls (cms) | Maximum Stage at High Falls (m) | Max. water elevation at the MNR bridge (m) |
|---|---|---|---|---|---|
| Pre-development condition | N/A | LR to HF simulation | 285.96 | 281.04 | 295.10 |
| Worst case scenario for post-development condition with initial gate design (incl. 4mX6m gates at LR) | Cascade dam breaks: | TF to HF simulation | 292.11 | 281.07 | 296.47 |
| Worst case scenario for post-development condition with cost-optimized gate design (incl.4m x4m gates at LR) | | TF to HF simulation | 314.48 | 281.16 | 296.46 |
| Worst case scenario for post-development condition with alternate gate design (4m x 5m gates at LR) | | | 292.23 | 281.07 | 296.46 |

# Conclusions

- The two dams, TF and LR, are in the "Moderate" Hazard Potential Class (HPC) as per the MNR-TG, 2011
- The minimum IDF for the "Moderate" HPC is the 100 to 1000 year flood or Regional Flood, whichever is greater
- The Incremental Hazard Evaluation (IHE) procedure described in the MNR-TG, 2011 was utilized to explore the possibility of selecting a lower magnitude IDF
- The HEC-RAS model was utilized to determine pre and post-development conditions in the river for the 1:10,000-year flood. Simulations were carried out for scenarios without dam breaks, single dam breaks, and cascade dam breaks
- The 1:10,000-year flood flow was retained as the Inflow Design Floods (IDF) for the proposed small waterpower project since no significant incremental increases in losses were identified. This is subject to:
  - Provision of a rigorous sluice gate maintenance manual to ensure that the gates are kept operational at all times
  - the gates are operated by use of the proposed operating plan
- The cost of the project was reduced by decreasing the initial discharge capacities of the control gates by 7% at TF and by 14% at LR

# Thanks

- The authors would like to thank Namewaminikan Hydro and AXOR Group staff, for the numerous significant contributions made to the studies referred to in this presentation
- More information can be obtained from:
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