Manasan Ice Control Structures

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The Manasan control structures, located in northern Manitoba on the Burntwood River just above the Manasan Falls, were constructed in stages starting in 1975 as part of the Churchill River Diversion Project. An increase in flow due to the diversion led to the first stage of construction of two rockfill groins and an upstream ice boom to ensure the formation of an ice cover. This was done to avoid potential ice jamming and associated flooding problems at the downstream town of Thompson. However, in 1985 after 10 years of service, the ice boom broke during the spring break-up. The sudden release of ice and water caused erosion of the bottom rock pavement between the groins, resulting in a downward shift in the discharge rating curve of approximately 0.7 m during the critical ice formation period. In 1986, major rehabilitation work was done, based on a hydraulic model study conducted at La Salle Hydraulic Laboratory, to restore the rock pavement and thereby the water-control between the groins. In 1988, a bypass channel, concrete weir sections and an earth-fill fuse-plug were constructed to increase the flow capability of the ice control structures by up to 50%, if required. Discharge ratings were confirmed from field measurements for the successful operation of the structures under the open water, spring, and winter flow conditions.

1. Introduction

The Churchill River Diversion Project re-directs a major part of the river flow through the much smaller Burntwood River leading to the existing and future generating stations on the Nelson River in northern Manitoba. Natural winter discharges in the Burntwood River could be as low as 28 m^3/s (1,000 cfs) while the diversion increases the winter discharges to over 850 m^3/s (30,000 cfs). Control works were built on the Burntwood River just above the Manasan Falls to ensure that an ice cover will form with this greater flow and thereby avoid ice jamming problems and associated flooding at the downstream town of Thompson.

Initial construction of the control structures included two rockfill groins, one built out from each shore, leaving approximately a 50m (165ft) gap between them. These groins, along with the rock paving placed on the riverbed, restrain the flow, creating a pond upstream in which the velocities are low enough for an ice boom to build up and hold a stable ice cover. Lemke and Britner (1999) provide further information about the Manasan ice boom. The system functioned satisfactory for 9 years and then during the 10^{th} break-up, in 1985, the structures were damaged – the ice boom had broken due to structural reasons and the river bottom paving between the groins had eroded. Physical hydraulic model studies were used as an aid in developing rehabilitation procedures for Stage II Construction in 1986 to restore the rock paving.

Planning for future development of the Burntwood River introduces the possibility of flood flows exceeding the capacity of the groin structure gap. Thus, an additional bypass channel around and on the south side of the groins was constructed as Stage III Construction in 1988, as shown in Figure 1. The same physical model was used to refine the bypass discharge capacity of the 85 m (280 ft) long concrete weir. Also, a narrow and deep channel 27 m (90 ft) in width, blocked by an earth-fill fuse-plug, was developed as the final security feature guarding against structural damages from the 1:1,000 year flood of 1,700 m^3/s (60,000 cfs).

2. Stage I Construction in 1975

Figure 1 shows the plan layout of the complete ice control works along with the developed bypass channel just above the Manasan Falls. The Stage I Construction only included the arrangement of groins and the ice boom, which had been developed in earlier physical model studies. The raised pond, due to the groins and rock paving on the river bed, provides a water velocity at the boom of less than 0.6 m/s (2 ft/s). This allows an ice cover to develop and be held behind the ice boom. Janzen and Kuluk (1978) provide further details on these structures.

3. Field Conditions Following the 1985 Spring Breakup

Inspections of the works after the spring breakup noted that six boom sticks had been carried away. Automatic water level recording in the pond indicated that water levels had been lowered by approximately 0.6 m (2 ft), suggesting that the groins and/or the riverbed paving had also been eroded. Field inspections determined that the groins were sound above the water. Bathymetric surveys around the groins were performed from a helicopter using an impulse radar technique. The resulting contours were compared with the original conditions, and it was found that the riverbed paving in the gap and just upstream had been lowered. The shaded area on Figure 1 shows this zone.

4. Stage II Rehabilitation Construction in 1986

A physical model, shown in Figure 2, was constructed at the LaSalle Hydraulic Laboratory in Montreal to study the rehabilitation procedure of the damaged control structure. The 1985 bathemetric survey was used to provide the geometric conditions for

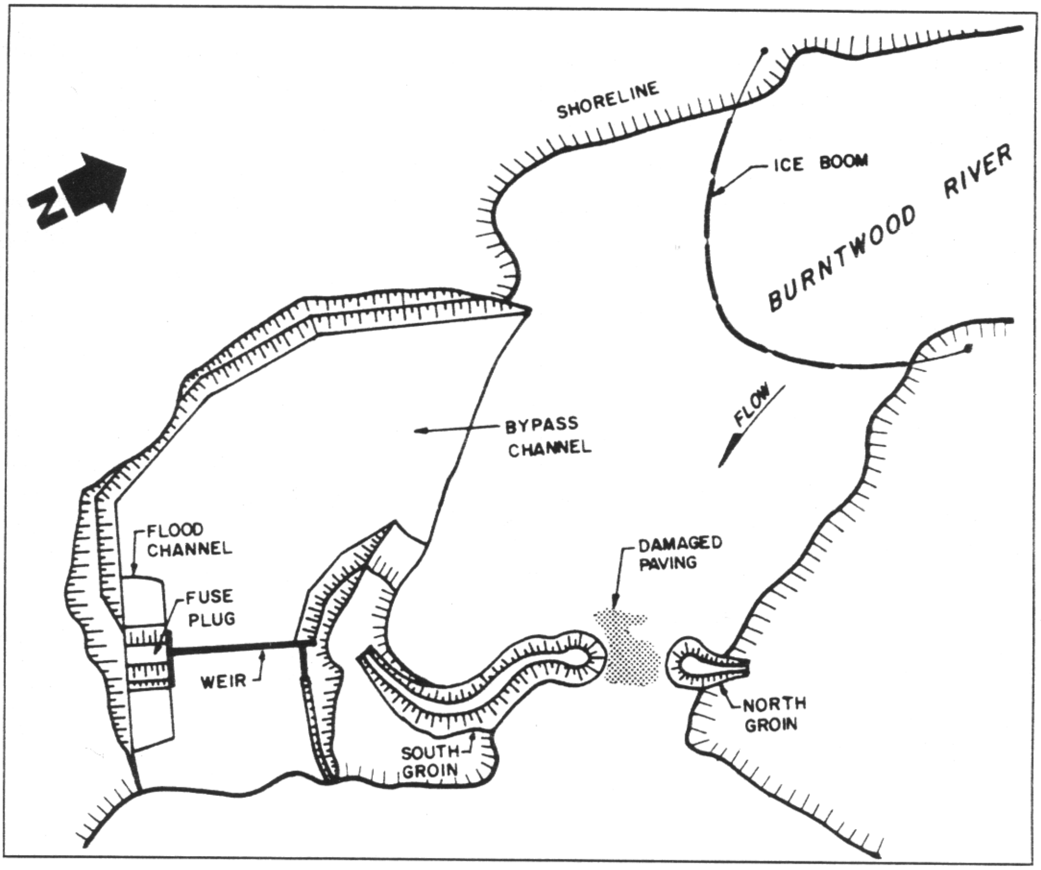

Figure 1 Manasan Control Structure Components

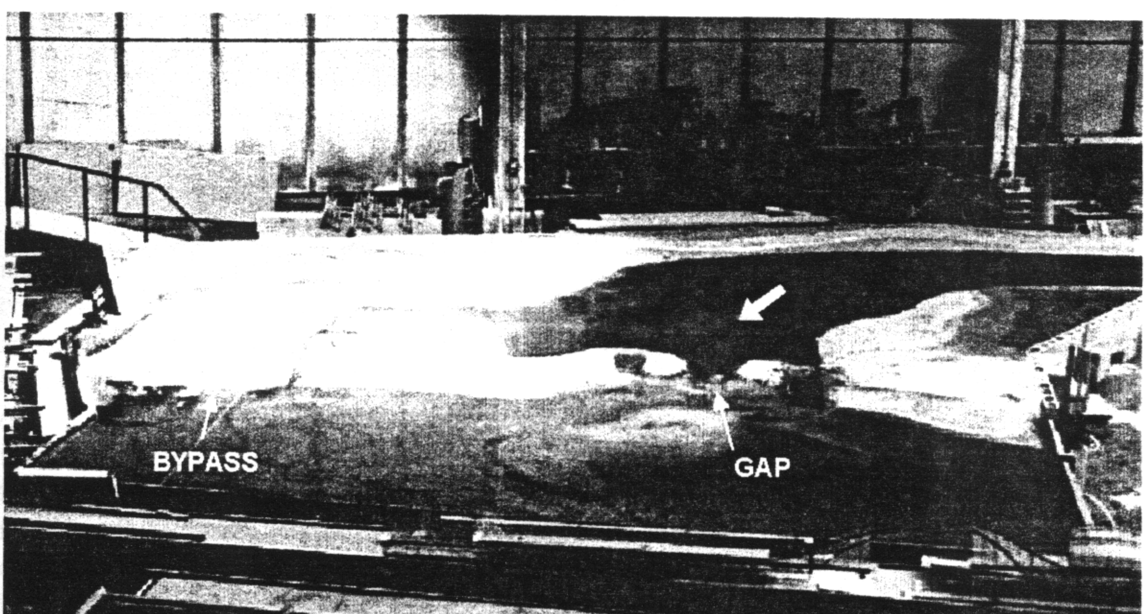

Figure 2 View of Hydraulic Model from Downstream

the model and successive testing was carried out over a range of discharge conditions until the model rating curve corresponded to that of the damaged structures. Placement of new paving rock in the field was to be achieved by cranes dropping appropriate sized rocks from the air in specified target areas. This rock placement process was studied in the model in terms of the rock release points in the air and the target areas on the riverbed. Careful study of the rock trajectories underwater was required in light of the rapidly changing current flow lines approaching and going through the gap. The quantities of rock and their dispositions were determined by their effects on the flow through the gap.

Stage II rehabilitation construction was started in June, 1986 after the spring breakup. The major task of the rehabilitation was to restore the paving rock between the groins with armour rocks having nominal sizes of 1 to 1.5 m (40 to 60 inches). A 150-ton crane with a maximum reach of 49 m (160 ft) was positioned on the south groin to place all the rocks. The procedure, based on physical model tests, consisted of 62 sequential operations planned in detail to place the total of 1,377 armour rocks in the 8 target zones, as shown in Figure 3.

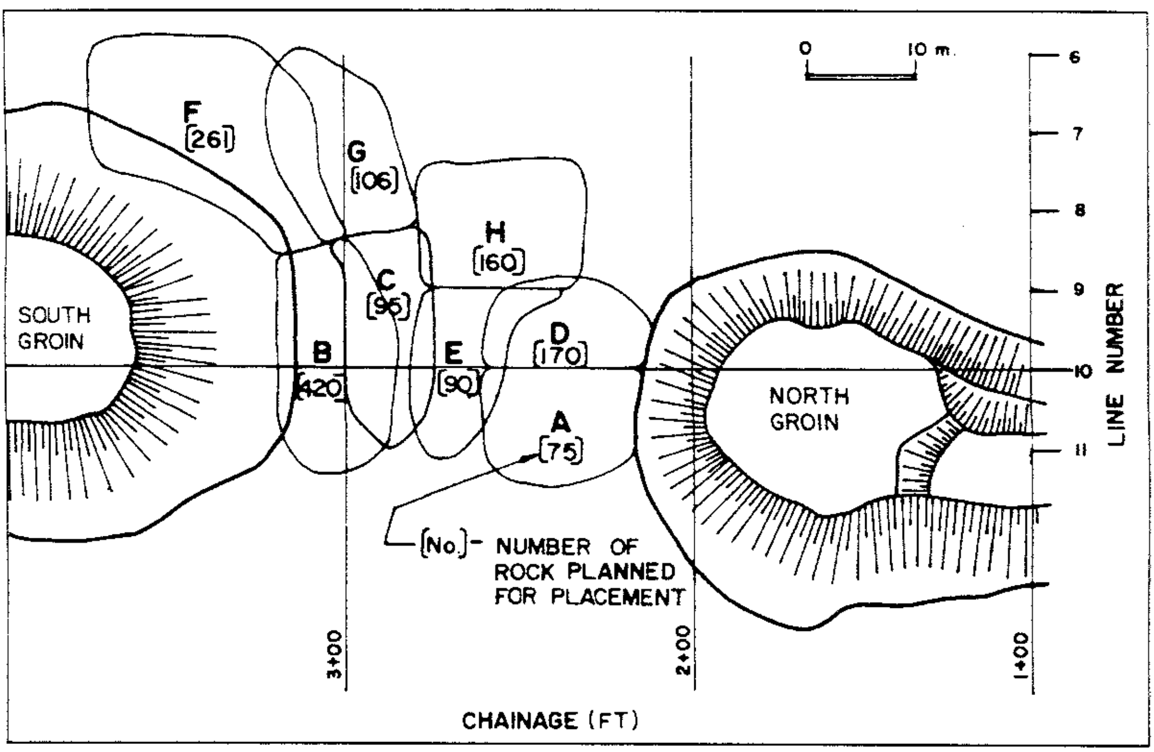

Figure 3 Rock Paving Target Zones (Placement Sequence A to H)

Prior to rehabilitation construction, additional soundings were taken using the crane and applying an accurate sounding technique that had not been available in 1985. The results showed some significant differences from those obtained in 1985 using the helicopter.

Therefore, the rock placement procedures and the required number of rocks had to be re-assessed and adjusted. The knowledge gained from the model studies was applied to the actual field conditions of drop positions and the target placement zones. After rock placement trials were successfully completed, a large-scale operation was undertaken for the next twelve days, placing a total of 795 armour rocks to complete the repair of the eroded rock paving. Figure 4 shows the cross section at line 10 for the rock paving elevations before and after the rehabilitation. The Stage II rehabilitation construction also included strengthening the north groin with an upstream berm and re-building the excavated south groin nose.

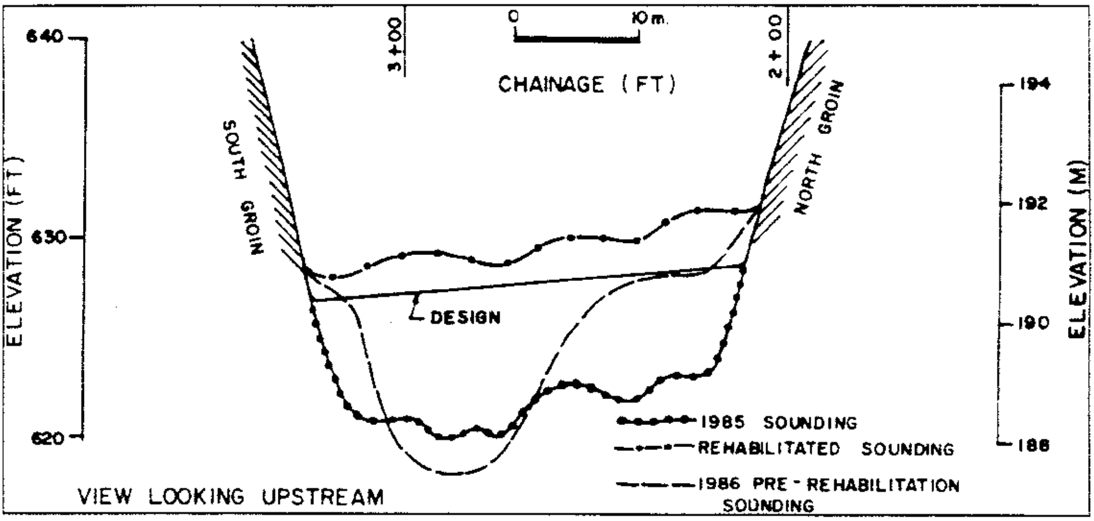

Figure 4 Gap Profile at Line 10

5. Stage III Bypass Construction in 1988

The original groins/gap structures had been developed to operate with a discharge of 850 m^3/s (30,000 cfs). However, during the first nine years of operation, flows as high as 1,130 m^3/s (40,000 cfs) had been put through resulting in an upstream water level of 179.9 m (649.3 ft). Furthermore, future development of the Burntwood River may necessitate increased capacity for flood flows through the groin structure gap. A bypass comprising of a main overflow weir and a flood channel was therefore developed to accommodate increased flows. Figure 5 shows the rating curves for the groins/gap and bypass works. The limiting criteria include a maximum upstream water level of 179.9 m (649.3 ft) with three discharge levels, and a minimum water level at 197.4 m (647.6 ft) for a discharge of 1,075 m^3/s (38,000 cfs) to ensure the formation of an ice cover by the ice boom. The design criteria also considered construction costs. The same physical model at the LaSalle Hydraulic Laboratory was used to study various shapes and sizes of concrete weirs in the bypass channel and to determine appropriate dimensions for the flood channel. The model was also used to study the requirements for and the behaviour of a granular-material fuse plug within the flood channel. This erodable fuse plug blocked the flow through the flood channel until the limiting discharge is reached.

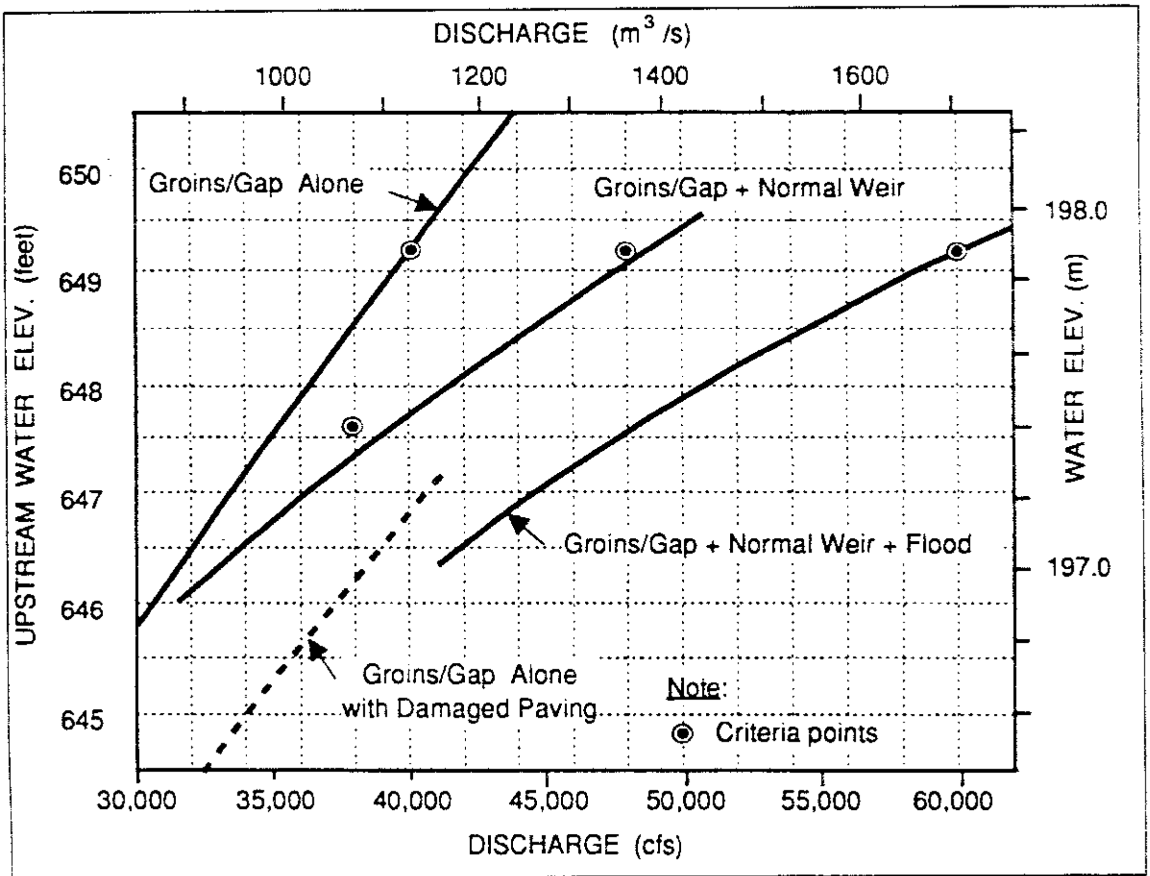

Figure 5 Groins/Gap, Weir and Flood Channel Rating Curves

The bypass channel construction was started in late May, 1988 and completed in early June, 1989. The work involved the construction of an upstream cofferdam, excavation of the material in the bypass channel and flood channel, construction of an erodable fuse plug in the flood channel, and construction of a 85 m (280 ft) control weir. The control weir consisted of a 12.2 m (40 ft) concrete overflow weir and a concrete stoplog weir with twelve 6.1 m (20 ft) sections. A single stoplog in each section was constructed and placed to bring the control weir elevation to 196.6 m (645 ft). The 27.4 m (90 ft) wide fuse plug was constructed of sand and mine slag in the rock cut flood channel to a crest elevation of 197.91m (649.3 ft). The fuse plug was protected with rip-rap on both sides, upstream and downstream. Eight dynamite tubes were installed on the top of the fuse plug for emergency blasting, if required in the future. A satellite Data Collection Platform was installed to transmit water level readings directly to Winnipeg to constantly monitor the upstream water level at the fuse plug. Figures 6 and 7 show a photos of the completed Manasan control structure in operation during open water and winter ice cover conditions. Additional details on the rehabilitation and bypass channel works can be found in the paper by Parkinson and Wang (1991).

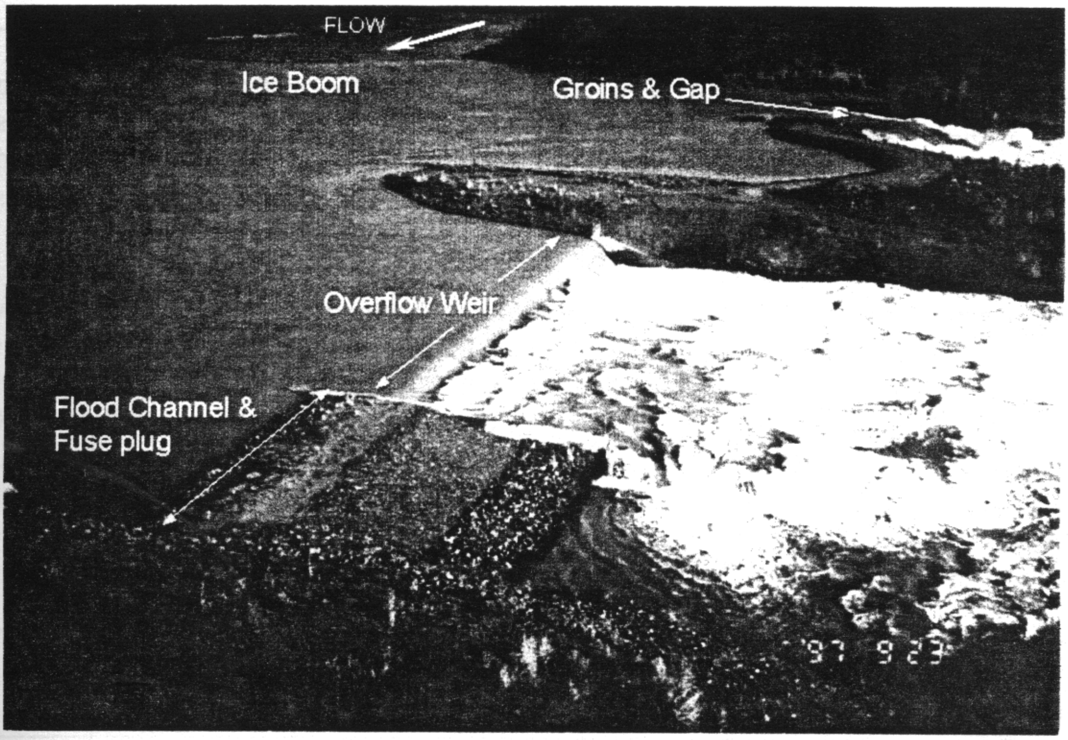

Figure 6 Manasan Control Structure in Operation

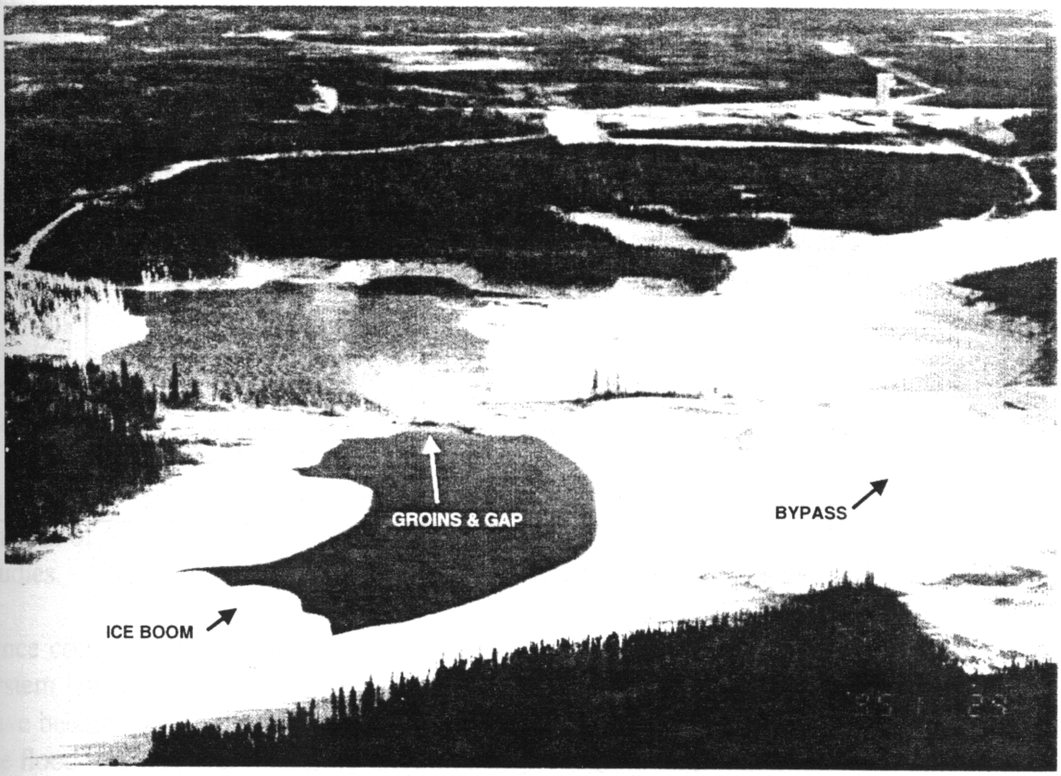

Figure 7 Manasan Control Structure in Winter (looking downstream)

6. Performance of Manasan Ice Control Structures

While spring floods have generally been light, flooding in 1998 tested the bypass weir to its limit without breaching the fuse plug, with flows reaching approximately 1,300 m^3/s (46,000 cfs). However, pond level control by the groin satisfies the design condition, and the ice cover formation and retention by the boom have worked correctly each winter, as demonstrated in Figure 7.

Discharge ratings were defined as shown in Figure 8 for the open water and winter flow conditions. The open circles indicate the open water metered data and the solid squares indicate the winter metered data from 1989 to 1998. The hydrograph in Figure 9 shows the water levels upstream of the overflow weir in the bypass channel from 1989 to 1998. The bypass carries flow when the water level exceeds elevation 196.6 m (645 ft) and is indicated by lower edge of the shaded portion of the hydrograph. The upper edge of the shaded area marks the fuse plug crest elevation of 197.91 m (649.3 ft) in the flood channel. The maximum water level on record was 197.75 m (648.8 ft) in June of 1998.

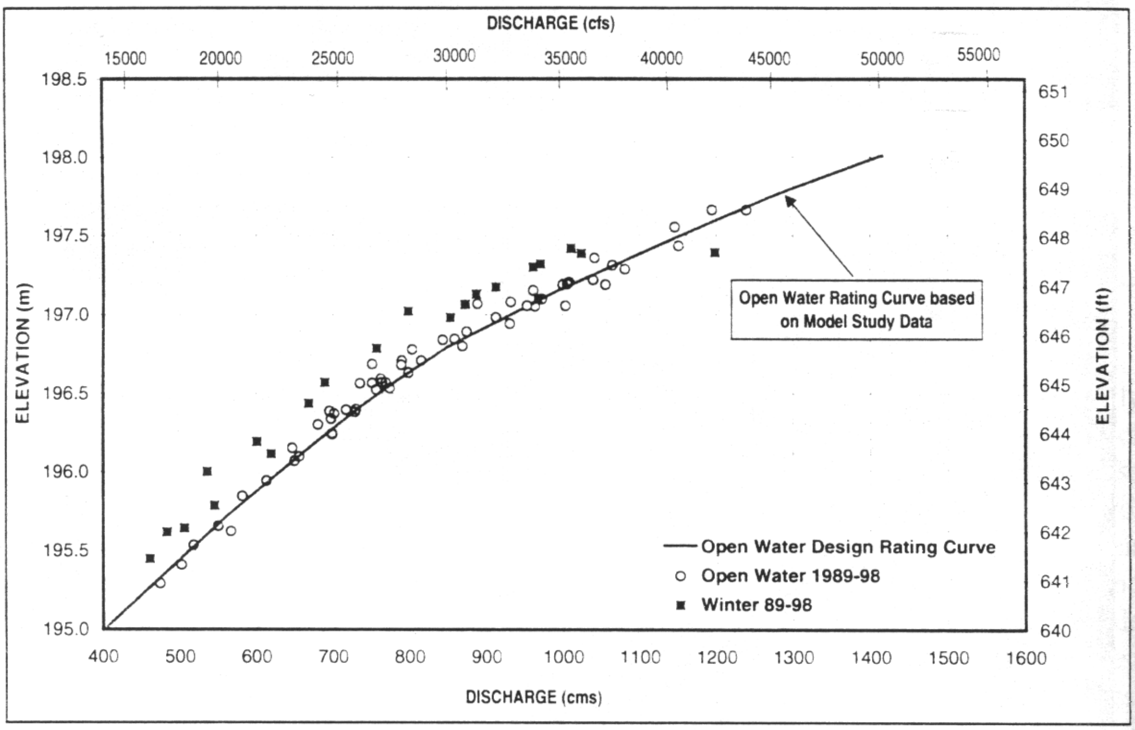

Figure 8 Open Water and Winter Rating Curves

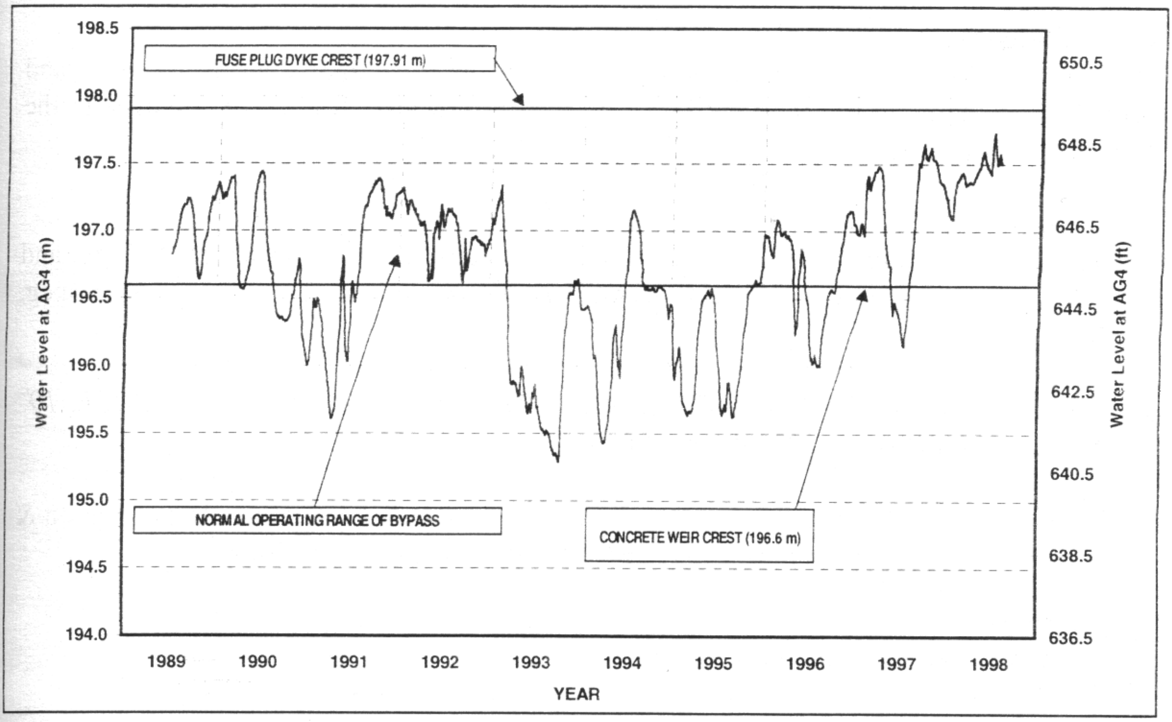

Figure 9 Upsteam Water Levels from 1989 to 1998

7. Conclusions

The ice control structures at Manasan Falls have been very effective and economical over their operating life. Damage that occurred to them after nine years in place was relatively light, and could be repaired without requiring a major construction effort.

Physical scale hydraulic model studies were a critical element in guiding the design decisions for the rehabilitation works. The same model was conveniently used to refine the designs for the bypass that was being considered at the time.

Construction of both Stage II and III works was carried out in the field in a minimum amount of time, according to the procedures and design that had been based on the model studies.

Since completion of all components of the Manasan Ice Control structures in 1989, the system has worked as designed and the ice cover formation and retention by the boom have been successful each winter. Even though high flood conditions prevailed in 1998, the flood channel and fuse plug have not been brought into operation thus far.

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