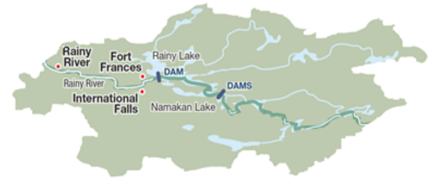
International Rainy and Namakan Lakes Rule Curves Study Board

Fact Sheet Series



Factsheet #3

Title: Control of Outflow from Rainy Lake

Background

The water level of Rainy Lake rises or falls according to the balance of flow into the lake (inflow) and out of the lake (outflow). As with any container of water, like a bathtub, if water enters faster than it exits, then the water level rises. If water exits faster than it enters, the water level drops.

When inflow is much greater than outflow, the lake level rises swiftly and there is a risk of reaching high water levels. This risk exists because there are natural and artificial features below the outlet of Rainy Lake that limit how fast water can flow. This factsheet explains what these limitations are and describes how the International Dam downstream of the outlet of the lake can and cannot be used to adjust the water level of Rainy Lake.

Location and Description of Key Features

Rainy Lake is a boundary water between Canada and the United States. Approximate ¾ of the lake is in Ontario, and ¼ in Minnesota. The sole outlet for water flowing out of the lake is at the southwest corner of the lake, below the Ranier railway bridge. Water can also exit the lake through evaporation.

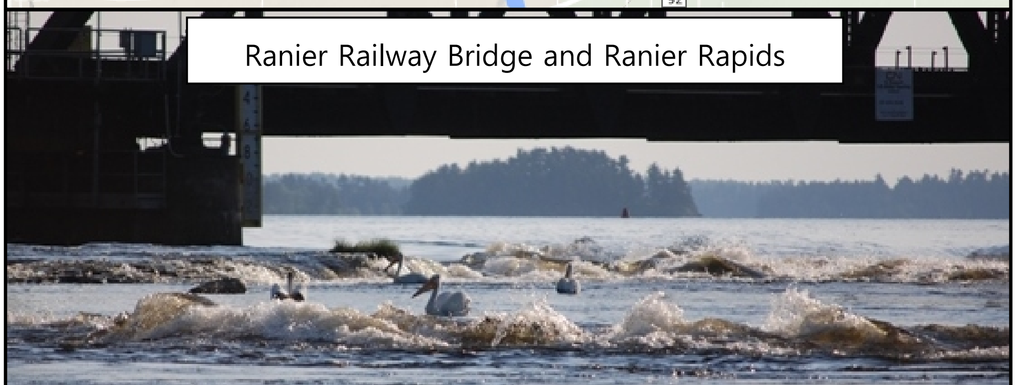
At the Ranier railway bridge, the outlet of the lake is relatively narrow and the channel is deep. Supporting the bridge is a series of piers which are fixed in the river bed. A short distance downstream of the bridge is the Ranier Rapids, where the river bed rises steeply. These features - the piers, the narrow channel, and the changing bed depth - all restrict the flow of water out of the lake.

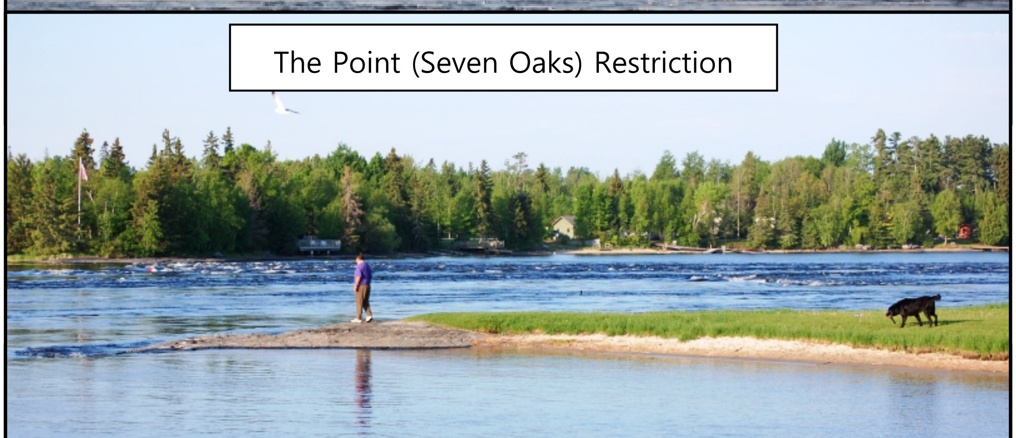
About 400 yards downstream of the railway bridge, near Seven Oaks and the Point, Ontario, is another area where the uneven river bed and narrow width restrict the flow of water. Downstream of this area the river channel is relatively wide and the bed slope changes gradually until reaching the international bridge between Fort Frances and International Falls. This is the site of the former Koochiching Falls, which was submerged by the building of the dam. Here again, the narrowing channel and the river bed features of the former falls restrict the rate of flow through this area.

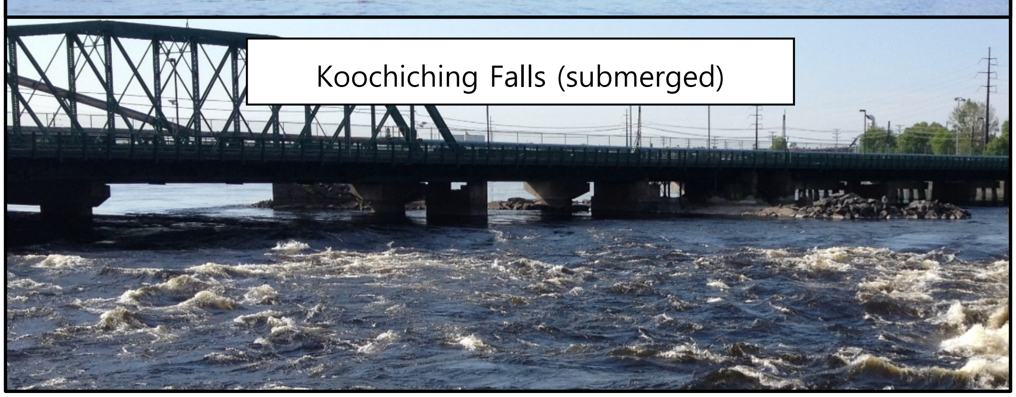
The International Dam

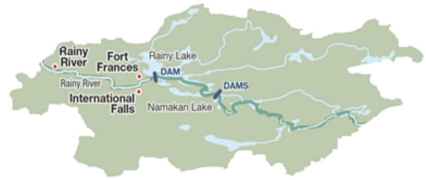
The International Dam, completed in 1910, spans the Rainy River between Fort Frances and International Falls, just below the former Koochiching Falls. Water can pass through the dam in several ways. First, both the American and Canadian sides have powerhouses, where falling water powers turbines to generate electrical power. The maximum amounts of flow and power that can be generated are both dependent on how far the water drops from above the dam into the river below. The greater this height, the more flow that can be pushed through the turbines.

Upper Rainy River Channel


Ranier Railway Bridge and Ranier Rapids


The Point (Seven Oaks) Restriction


Koochiching Falls (submerged)



When the turbines are running at maximum flow, outflow can be increased by passing water through spill sluices. There are ten sluices along the center of the dam on the Canadian side, and five additional sluices at the head of a canal that separates the Canadian powerhouse from the shore. Flow through all of the fifteen sluices is controlled by manually operated gates that can be set either to be fully opened or fully closed.

When the water level in the upper river gets extremely high, the dam is designed to allow for water to flow over a spillway built into the center of the U-shaped dam. This has happened in only two years over the past century, 1950 and 2014.

Flow Control

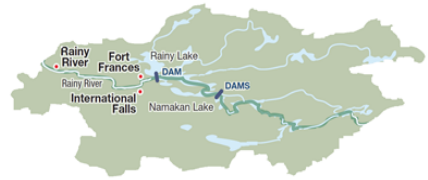
Under normal flow conditions, the operators of the International Dam can raise or lower the level of the Rainy Lake. This is done by adjusting the flow so that water is leaving the lake faster than it enters (to lower the level), or so that water is leaving the lake more slowly than it enters (to raise the level). There are limits on how fast the lake can be raised or lowered however, and these limits are related to how fast water is entering Rainy Lake.

When raising the lake level, the flow past the dam could, in theory, be reduced to zero (in practice, the International Joint Commission requires minimum flows for the river downstream). With zero outflow, the lake will rise only as fast as water is supplied from tributaries into Rainy Lake or direct rainfall on the lake. When raising the lake level, the control on the outflow from the lake is at the dam. As the water backs up from the dam along the upper Rainy River, the restrictions at Koochiching Falls, the Point, and Ranier Rapids are submerged.

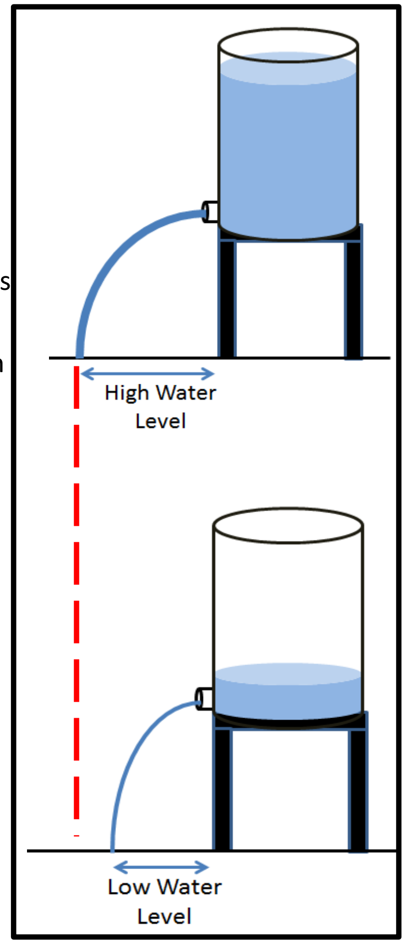
Under normal conditions, lowering the lake level is simply the reverse of raising it: flows are increased out of the dam (through turbines or gates) and the water level in the river between the dam and the lake drops. As long as water is leaving the lake faster than it is flowing in, the lake drains and the water level falls.

There is a limit, however, to the maximum rate of flow out of the lake, and this limit changes with the lake level. The higher the lake level, the greater the maximum flow rate out of the lake. This is because passing flow out of the lake, under the railway bridge, through the constrictions at Ranier Rapids and the Point requires energy. This energy comes from the height of the water in Rainy Lake. To understand why, consider the example of a large container of water with a spigot at the bottom, for instance a barrel or a water cooler. If the container is full, opening the spigot will release a strong stream of flow. However, as the water level above the spigot falls, this stream gets weaker and weaker. When the water level is nearing the bottom of the barrel, the stream is just a dribble – the low water level does not provide the energy to push flow out as quickly as it did when full.

Outflow from Rainy Lake is like that from the barrel, with the outlet under the railway bridge and through the restrictions at Ranier Rapids and the Point being the spigot. For a given lake level, there is a maximum flow rate that can be pushed through this area. Downstream at the dam, flows can be



increased through the turbines or by opening gates to match this maximum flow out of the lake. What happens if the maximum flow out of the lake is already being matched at the dam and more gates are opened? This would increase the flow out of the river above the dam for a short while, but since water is passing through the dam faster than it is arriving from the lake, the river is starved of water and the water level near the dam drops. This has no effect on the rate of flow out of the lake – the lower river level at the dam does not draw water out of the lake at Ranier any faster. The lower river level does, however, hamper the flow through the powerhouses and reducing it too much can risk damage to the turbines.



When wet conditions develop in the spring it is not uncommon for the maximum outflow rate from the lake to be less than the rate of water flowing into the lake from all the tributaries. In such situations, the lake level always rises. The best that the dam operators can do in such situations is to keep opening gates as the lake level rises to match the maximum outflow. Only once the level of Rainy Lake has risen to the All Gates Open level (337.90 m or 1108.6 ft) is having all gates open necessary to efficiently pass the maximum flow out of Rainy Lake. Even with all gates open, the lake level will continue to rise until the outflow from the lake matches the inflow to the lake, at which point the lake level will be stable. The lake will only start declining once the inflows drop to be less than the maximum outflow.

Visualizing Outflow Controls

Since 2010, the IJC has funded a series of detailed hydraulic investigations of the outlet of Rainy Lake and the upper Rainy River from Ranier to the dam. This included the development of a complex hydraulic model of the river. Based on this work, an interactive animation has been developed as part of this work which allows the user to adjust the number of open gates at the dam and to see the effect this has on the flow out of the lake and out of the river. The Rule Curves Study Board invites you to use this tool to explore the relationships between lake levels, river levels, dam gates and flows along the upper Rainy River. It is available on the IJC website.

Conclusions

The control of flow out of Rainy Lake is a complex problem. Despite this, under normal conditions, the International Dam can be effectively used to lower or raise the level of the lake. The maximum flow out of the lake is, however, limited by natural channel features in the upper river and is directly related to the level of the lake. Under extremely wet conditions, particularly in the spring when the level or Rainy Lake is relatively low, lake levels rise uncontrollably. Only with declining inflow will the lake level eventually stabilized and then fall.