GSNH Summer Field
August 24, 2019
Pawtuckaway Lake field trip

Pawtuckaway Lake: Formation and Management

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Itinerary:
Starting from Stop 6 of today's Pawtuckaway State Park Geology Tour, return to Rt. 107. Turn left on Rt. 107 and continue about 3 miles south to the junction of Rt. 27.
Continue 3.8 more miles to the junction with Rt. 156. (Taking note at 1.7 miles from the Rt. 107/27 junction of the USGS gage station 01073319 in Raymond.)
Turn left/north on Rt. 156 and continue 2.7 miles to Dolloff Dam Road, a sharp cutback turn onto a dirt road on the left.
Dolloff Dam is located 0.6 miles from Rt. 156. Follow Dolloff Dam Road about a half mile to a fork, take the left fork towards Dolloff Dam. Continue 300 feet to another fork at the dam's parking area. Turn left into the parking area.

Stop 1: Visit Dolloff Dam on Dolloff Dam Road off Rt. 156 in Nottingham, NH to observe the outlet structures of the dam; discuss the historical and current dam operations; and discuss the location of the dam relative to the Lamprey River.

From the Dolloff Dam parking area, return east on Dolloff Dam Road about 0.6 miles to Rt. 156.
Turn left onto Rt. 156 to head north. Continue 2.6 miles to Deerfield Road.
Turn left onto Deerfield Road. Continue for 0.8 miles to the Nottingham Town Beach access road on the left.
Continue for 0.4 miles to the Nottingham Town Beach parking area.

Stop 2: Visit Drowns Dam. Beach Road, Nottingham, NH to observe the outlet structure; discuss the outlet structures impact on lake management and discuss phosphorus inputs to the lake and the implications of the coffer dam on lake management. Also, discuss the impacts that the two dams' outlet structures have on current management.

Return to the day's initial starting point by Rt. 156 to Raymond to end the field trip.

Introduction

Pawtuckaway Lake as we know it today is much different from its natural condition. Various dams and dikes have created a single, large body of water from three small watersheds comprised of two streams and a small pond. Two operable dams and two dikes are the main controls that form today's lake.

The existing dams have been operated for different purposes since the early 1800s. Initially, the lake was managed for hydropower. Later, recreational uses defined the management operations, but other purposes like flood control were considered.

In recent years, changing purposes and interests have been accommodated by changes in management. Since 2013, Pawtuckaway Lake management has added protection of the Lamprey River stream flow and improvement of the lake's water quality to its operations. Management issues in the future will add to the complexity of even the current management operations.

The key dam structures forming Pawtuckaway Lake

Modern-day Pawtuckaway Lake is formed by four key structures. Without these dams, Pawtuckaway Lake would revert to its original form. Three small watersheds were flooded to form the lake. See Fig. 2.

Dolloff Dam drains the south end of the lake into the Pawtuckaway River, which flows 3.6 miles to its confluence with the Lamprey. The dam has three, five-foot wide stoplog bays and because of these bays was the chief means of managing the lake's annual, 7-foot fall drawdown.

Drowns Dam drains the north end of the lake. **Drowns Dike** forms an extension of Drowns Dam interrupted by some higher ground between them. Drowns Dam has a single 5-foot wide bay. Drowns Dam drains into a small tributary that flows 2 miles down to the North River, which then flows 8 miles to the Lamprey. This North-Lamprey confluence is about 11 miles downstream of the Pawtuckaway-Lamprey confluence.

Goves Dike stops water from flowing from the central part of Pawtuckaway Lake which would flow via a tributary to Pawtuckaway River and then to the Lamprey.

In the area immediately behind the 27-foot high Dolloff Dam, the current lake's deepest point is about 21 feet. (See the frontpiece map for locations in this part.) Streams flowed through this area with minor ponding until early dams at Dolloff formed Dolloff Pond. A two channels, north and south of the lake's largest island (Horse Island) form a tenuous link between Dolloff Pond and Pawtuckaway Pond. At lower water levels these formed a watershed divide. In the Pawtuckaway Pond section of the lake, Goves Dike holds in the current lake. The deepest part of the lake is 53 feet, so this was a pond prior to the dams being constructed. To the north, the third watershed area, which drains from Fundy to Drowns Dam, is a shallow, flat-bottomed area with maximum depths of 5 to 8 feet. Prior to the dams, this was a stream channel draining the largest subwatershed now feeding into Fundy Cove at the north end of the lake. Here too, several islands and shallow form a line of shallow waters suggesting this too was a separate watershed before the dams. Dam repairs required the state to drain the lake twice, in 1973, and again in 1985. Pictures from these times demonstrate the artificial nature of most of Pawtuckaway Lake and show near natural conditions as mainly exposed bottom as in the photo from 1986 below.

Operation for recreation

Camps were being developed on the lake in the late 1920s, frequently as fishing shacks on leased land. Commonly used only on weekends, over the decades, particularly through the 1950s and 1960s, the land was purchased and shacks evolved into cottages. Recreational interests began to seek management for their interests.

Water levels were drawn down for power production and left down through the fall and winter to be refilled in the spring. Lake front owners started campaigning for smaller drawdowns for fish and lake use. A lake association was started around 1935 to fight the power company. 2 According to lake property owner, Dwight Crow, the power company drained the lake 16 feet during each summer starting in June, so that by mid-summer the Dolloff end of the lake was a mud flat with a trickle of water from Pawtuckaway Pond. Pawtuckaway Pond, being deeper, persisted, but became isolated from the Drowns end of the lake. "Once they drained it they left the boards out until spring, so it stayed drained all fall too." According to Crow, "All of the islands on the south side of the lake were pushed up by a bulldozer, that's why they are just jumbled up boulders. They deepened the pond to create more water storage; the power company did that. They wanted more water available to generate power down in Newmarket. They did that right around 1920 after they bought the land and water rights from Newmarket Manufacturing Company.

Charlie Soroko interviewed by Jeff Gurrier[3] - "People don't realize how small the lake was before the manufacturing company started to raise the water level in the mid 1930's. . . . Around 1936-1937 the Newmarket Mills were crying for more water to run their turbines for power. At their own expense they raised the dam 10 feet. That's when our front yard was flooded, everybody's was. . . . After they raised the water level, in the spring time the water came right up to the house. The water was so high, all I had to do was open the front door and I could cast a line out and fish from there. By the end of the summer the water would be a good 60-70 feet out from the shoreline. During the summer they would slowly drain the water down to power the mills in Newmarket."

State ownership

Gradually, use of the lake for hydropower became less financially useful and the mills turned to other power supplies. The NH Electric Company deeded to the State of New Hampshire in December 1955, the Pawtuckaway Lake dams and certain tracts of land around the lake "both above and beneath the waters of Pawtuckaway and Dolloff Ponds." Because of state ownership and the development of Pawtuckaway State Park, the summer practice of draining the lakes for water power during the summer ended resulting in a building boom.

Joe Boudreau Interviewed by Jeff Gurrier[4] "In 1966 the State Park opened, they started taking the land for it in the late 1950's. It was the best thing they could've done. We were concerned at first but once we realized we weren't being crowded out then it was ok. The way development was then it was wicked. The Brussels, Mooers, and Cahill's all started their developments at that time too. They had stopped draining the lake for power and that started everyone building.

[2] http://pawtuckawaylake.com/dwight-crow/
[3] http://pawtuckawaylake.com/charlie-soroko/
[4] http://pawtuckawaylake.com/joe-boudreau/

Annual fall drawdown

Leaving the summer drawdown conditions to persist through the winter ended with the state's ownership, however, an annual fall drawdown replaced these operations. In an October 6, 1955 letter from the NH Water Resources Board's Francis C. Moore to E. Peterson, Secretary of the PLIA stated that he "hoped that the Lake will be down to 15 feet on the gage within a week or so." Fifteen feet on the gage represents 10 feet of drawdown from the full pool. This was the maximum drawdown allowable for this time of year under the former agreement with the NH Electric Company [DES Dam Bureau files 184.02.] At some point, this fall drawdown was standardized at 7 feet. The State operated the dams starting around Columbus Day to lower the water level by 7 feet in the fall and restore the lake by holding back water in the spring. This had a noticeable effect on the Lamprey River hydrograph.

Fig. 3. - Dock and boat removal for protection from ice are not required for much of the lake when an annual 7-foot drawdown is applied. Note the hole dug for the boat propeller. Much of the shallow parts of the lake expose wide lake bottoms during the drawdown. Photo taken November 26, 2012 at the 4.8-foot drawdown level.

Petition for changes for lake's benefit

A September 29, 1992 internal NHDES memo, from Robert Estabrook to Edward Schmidt re Lake Drawdown Pawtuckaway Lake, described Jonathan White's concerns that the drawdowns are having a negative impact on the fisheries and water quality.

From minutes of December 7, 1992 – First annual meeting of the Pawtuckaway Lake Fisheries Committee.

Topics of Discussion:

- Can the Pawtuckaway Lake drawdown be modified without a great impact to the lake and its property owners, if it would help the lake? Could the drawdown be alternated on a yearly basis?
- Would a 3-4 foot drawdown allow water to be present in areas that are now dry after the drawdown?
- Could a 1 or 2 year trial of a lesser drawdown be implemented? It could give us a comparison to go by.
- Were the negative aspects of this drawdown procedure ever considered such as algae blooms, decreased fish population, depleted oxygen levels in pools after the drawdown, and establishment of resistant species of plants that could harm the lake in the future? What weeds are the drawdown killing?

A petition to the State in 1999 resulted in a formal Lake Level Investigation to decide whether to reduce the annual 7-foot drawdown to 5 feet. The final determination was based in part on a NHDES survey of lake abutters. It also considered flood issues, existing dock construction and ice damage, ability to restore spring lake levels, aquatic life protection, growth of aquatic plants.

NHDES decided not to change the historical 7-foot fall drawdown: December 19, 2000 – NHDES Commissioner Varney signs Notice of Decision: "The annual drawdown for Pawtuckaway Lake shall be maintained at seven feet in order to achieve a lake level of 18 feet on the gauge at Dolloff Dam by November 30th and a lake level of 23 feet on the gauge by June 1st."

Management changes for downstream flow protection

In 2013, a Water Management Plan was adopted under the Instream Flow Program to protect stream flow in the Lamprey River and ensure equitable distribution of water among larger water users in the watershed. The lake's drainage area represents 10% of the Lamprey River drainage area. Holding or releasing water from Pawtuckaway can affect Lamprey River stream flows. Management of Pawtuckaway Lake was included as part of the Lamprey water management plan.

The Water Management Plan provides for relief pulses from the lake during drought periods. These pulses are intended to breakup extended durations of continued low flow conditions. Water is released if Lamprey stream flows fall below certain flow thresholds and exceed defined durations.[5] The plan limits how much water can be released and protects the nesting period of loons.

NHDES Dam Bureau manages the dam operations. Relief pulses last for 48 hours and are designed to represent a small rainstorm. Both dams are included in these pulses, but in practice Dolloff Dam on the south end of the lake is used instead of Drowns Dam on the north end.

Test relief pulses were applied prior to actual need for stream flow management. A winter test pulse was applied and the Lamprey's response was ideal and rapid. During relief pulses from Pawtuckaway Lake were applied four times during the 2016 drought. During relief pulses under actual low-flow conditions, the increased tortuosity of the Pawtuckaway and Lamprey Rivers at lower flows resulted in delayed and attenuated hydrograph responses.

[5] Lamprey Dam Management Plans - https://www.des.nh.gov/organization/divisions/water/wmb/rivers/instream/lamprey/documents/lr-appc-dmp.pdf.

Fig. 4 – Example of a relief pulse release at Dolloff Dam. On August 17, 2015, a release of ~11 cubic feet per second for two days resulted in a lake level change of 0.05 feet. Note the lighter colored stoplog: Dam Bureau staff designed and cut this log to provide the correct release rate.

Changes for lake water quality

A second Lake Level Investigation was completed in 2013 which changed the fall drawdown from 7 feet to 4.8 feet. The chief reason was for storing additional water for possible relief pulses during the winter. Dam Bureau had determined that a higher water level would be needed to provide sufficient head to support a winter relief pulse flow rate.

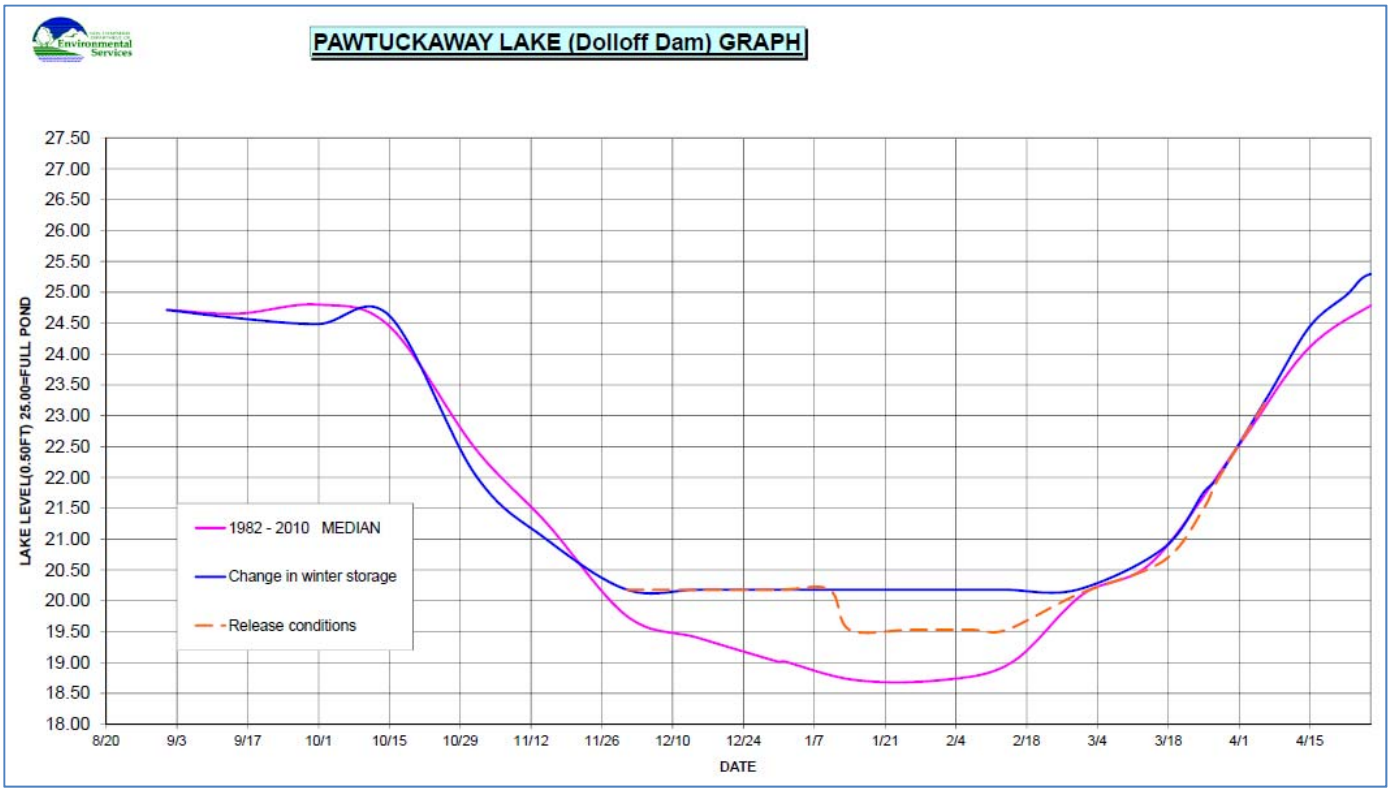

Fig. 5 - Historical median winter water levels and the changed fall drawdown to 4.8 feet. The lake level response to a relief pulse is presented.

Side benefits of reducing the drawdown were to improve lake habitat and water quality. The 7-foot drawdown was attributed with negative impacts on hibernating species, but no studies on the drawdown's effect were available to compare pre- and post-conditions. However, water quality was shown to be positively affected by increased outflow at the north end of the lake from Drowns Dam. The higher water level resulted in winter flow from Dolloff Dam that contributed to a larger export of phosphorus from the lake to reduce the nutrient loading.

A remnant structure, known as the coffer dam, lies just upstream of Drowns Dam resulting in a severe reduction in outflow at lake levels below 5.4 feet as were common most of each winter. The effects from the coffer dam affected both stream flow below the lake and water quality in the lake. Every year the large drawdown resulted in median 82 days with no outflow at Drowns Dam. (See the coffer dam and the resulting effect on Drowns Dam outflow in the following photos.)

Fig. 6 - Partially completed fall drawdown at 5.6 feet. Full drawdown averaged 6.3 feet between 1982 and 2014. Outflow at Drowns Dam at lake levels below -5.6 feet were effectively zero because of the coffer dam. At full drawdown, only a trickle of water left the lake from Drowns Dam.

Fig. 7 - A remnant coffer dam controls outflow at Drowns Dam when flow falls to 5.4 feet below full pool.

Fig. 8 – No outflow at Drowns Dam lasting much of the winter as a result of the coffer dam. Water level -5.98 ft. (January 9, 2013)

Fig. 9 – Drowns Dam outflow maintained through the winter when lake level held at -4.8 ft (November 26, 2012.)

In addition to the lack of downstream flow, the coffer dam restricted the release of phosphorus from the lake. The greatest mass of phosphorus (P) concentrations enters the lake at Fundy Cove in the north end from Back Creek B. Historical measured average outflow concentrations were 26 ug/L P at Drowns and 12 ug/L at Dolloff. Later sampling observed concentrations over 100 ug/L at Drowns with no change at Dolloff. Outflow from Drowns Dam would release much of the mass of P near where it enters the lake.

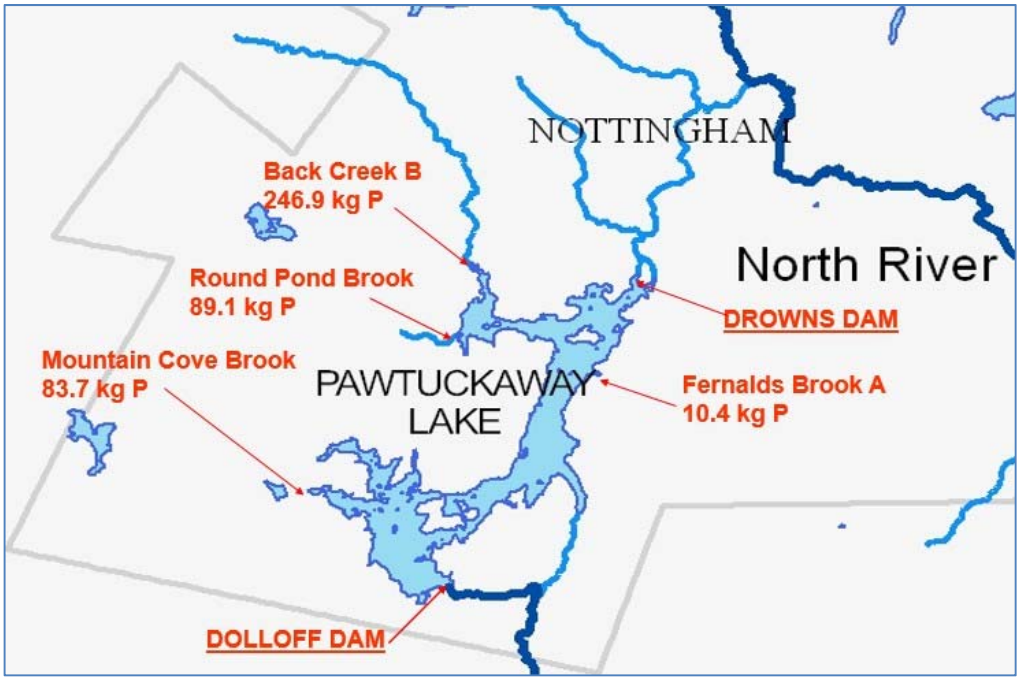

Fig. 10 - Tributary sources of phosphorus from Pawtuckaway Lake - Diagnostic/Feasibility Study conducted 1991-1992 (1995, Connor and Landry)

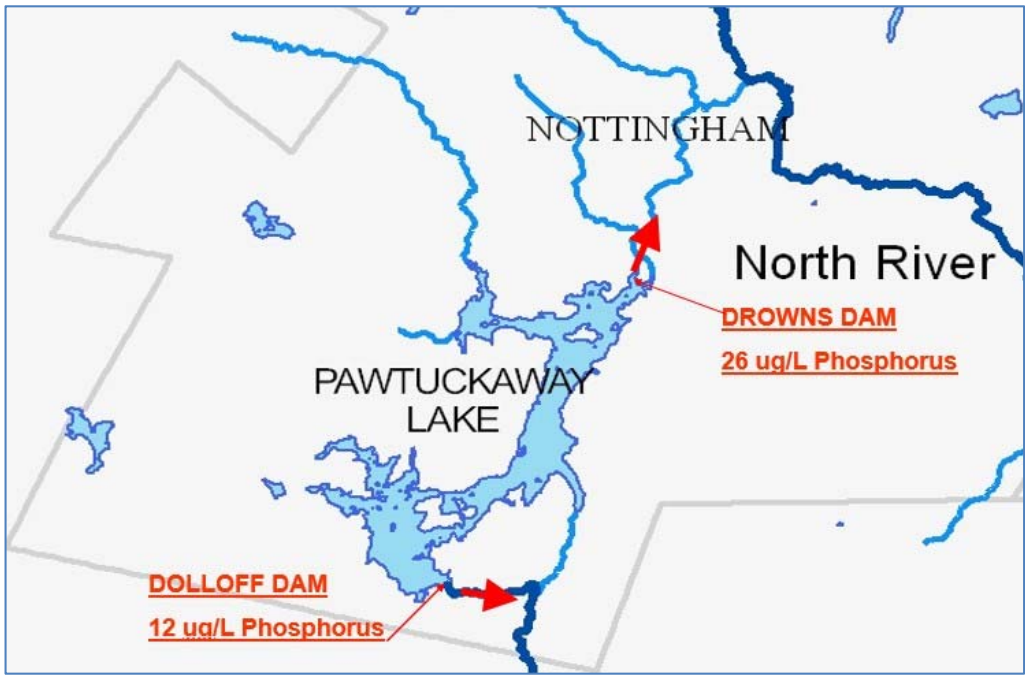

Fig. 11 - Average phosphorus outflow from Pawtuckaway Lake - Diagnostic/Feasibility Study conducted 1991-1992 (1995, Connor and Landry)

With no exit at Drowns Dam during the fall drawdown, P-laden water was rerouted to the center of the lake as it headed towards the remaining outlet at Dolloff Dam. Given 1) the reduced velocity as the stream enters Pawtuckaway Pond, 2) the restricted flow between Pawtuckaway Pond and Dolloff Pond, and 3) the steady P concentration at Dolloff Dam; the conjecture is that much of the P entering at Back Creek B and other tributaries was accumulating in the sediments of Pawtuckaway Pond's deep spot.

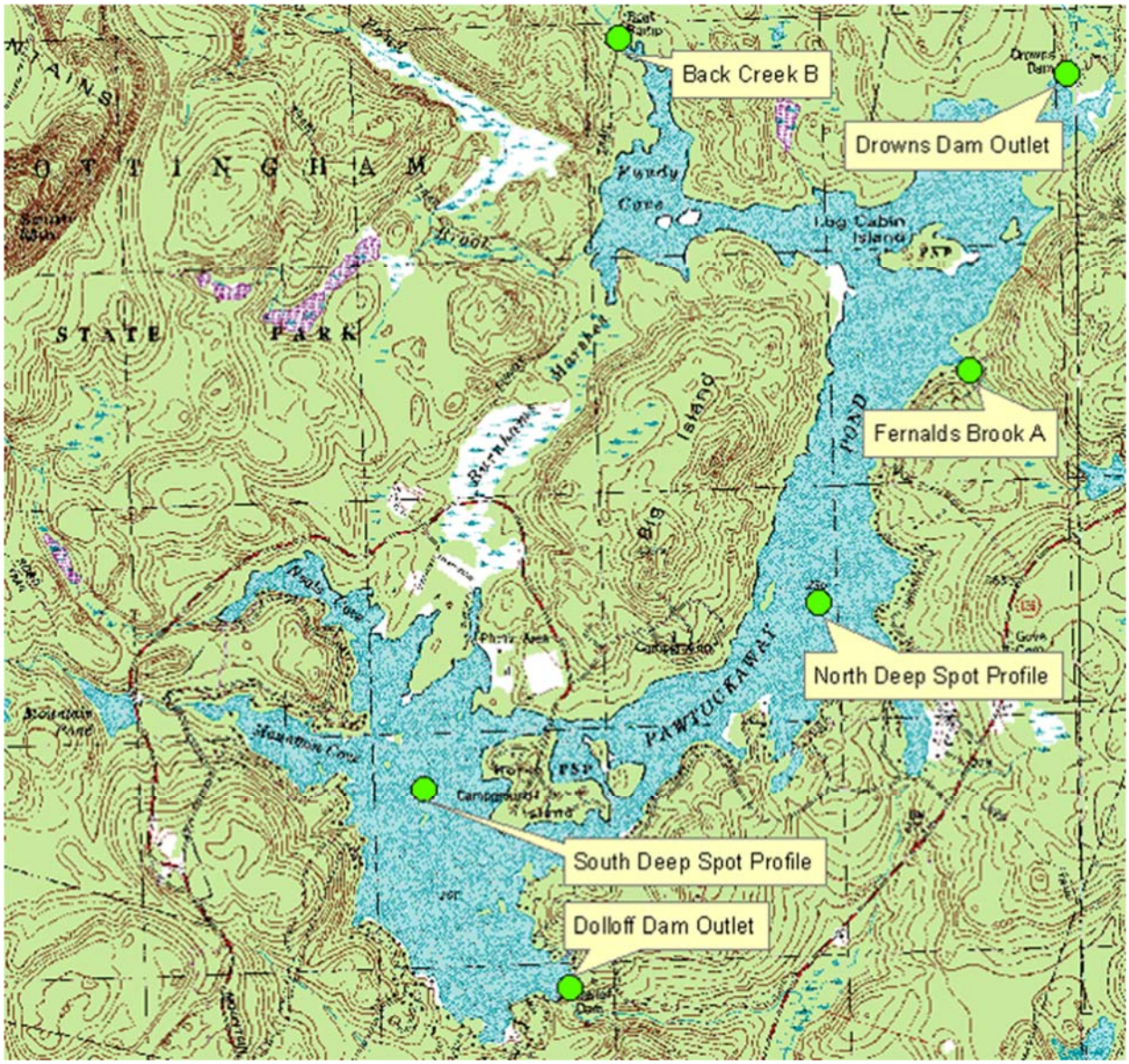

Fig. 12 - Map of Pawtuckaway Lake and 2012/13 phosphorus sampling locations. Phosphorus entering at Back Creek B / Fundy Cove could not exit at Drowns Dam for 82 days during the winter and was redirected towards Pawtuckaway Pond (North Deep Spot) and the outlet at Dolloff Dam.

The reduced drawdown allowed a continuous winter release of P-laden water from Drowns Dam. Measured P concentrations and outflows were used to determine P mass leaving the lake. In addition, P mass was calculated for the "what would have been" by calculating the flow as leaving via Dolloff Dam at the P concentrations measured there allowing a comparison of management effects on P loading.