Zeitschrift: Ingénieurs et architectes suisses

Band: 116 (1990)

Heft: 18

Artikel: Innovative preservation of the New England wetland

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DOI: https://doi.org/10.5169/seals-77304

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INNOVATIVE PRESERVATION OF A NEW ENGLAND WETLAND

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ABSTRACT Gunstock Ski Area in Gilford, NH, USA planned a major snowmaking expansion for 1986-1987. Sources of water were carefully examined, and the ponding of a 10.1 hectares wetland was determined to be the only reasonable source of an adequately large body of water. This paper is a case history of this completed project with discussions on the institutional considerations for planning such an impoundment, but with special emphasis on the innovative methods used to mitigate impacts to the diverse wetland. The key to the project's implementation was the development of a Wetland, Fish and Wildlife hitigation Plan which reduced the impacts. The centerfold of the plan was a design which allowed the seasonal flooding of the impoundment. Growing season finds the impoundment gone while winter brings a full pond forwater extraction for snowmaking. Haybail subimpoundments were built to provide winter cover for hibernating animals. Data from two of the three years of post-construction monitoring are explored. Rather than create another steep-sided pond this project attempts to allow man the use of a wetland during a part of the year and in a manner that will not compromise the wetland's overall value. The application of this project and its special mitigation to other developments that do not require year-round water supply is discussed.

INTRODUCTION

This paper is a case history of a solution to a dilemma at Gunstock Ski Area in Gilford, New Hampshire. Gunstock planned to expand their snowmaking capacity from 6800 to 15,140 liters per minute, and therefore needed a large additional water source. Review of several alternatives such as 1) pumping water from Lake Winnipesaukee (a large nearby lake) uphill for 2.5 miles; 2) establishing a well field in, or near, the 10.1 hectare on-site wetland; and 3) impounding the 10.1 hectare wetland, then extracting water from the reservoir as needed, made it apparent that the only practical alternative was number 3, impounding the waters of Poor Farm Brook at the downstream edge of the 10.1 hectare wetland.

This wetland, a 10.1 hectare wet meadow/red maple (*Acer rubrum*) swamp/beaver pond complex, had previously been designated a "prime wetland" by the Gilford Conservation Commission and therefore enjoyed an additional measure of statutory protection beyond that normally afforded wetlands. Impoundment of Poor Farm Brook at the proposed location would flood the bulk of this prime wetland with as much as 4.9 meters of water. Furthermore, as originally proposed, water would be pumped out of this impoundment as needed for snowmaking purposes, which could result in great fluctuations in the winter-time impoundment water levels.

Permanent flooding of this valuable wetland and the inherent large water level fluctuations would significantly impact the ecology of this valuable wetland. Our challenge was therefore to design the impoundment system, and to adapt the water regime, so that impacts to the stream, wetland, and wildlife would be minimal, and to mitigate for unavoidable environmental damage.

The potential and unacceptable impacts of simple, permanent, and unmitigated impoundment of this stream and wetland would be:

- Permanently (year-round) impounded stream water would warm and hold less oxygen thereby converting the impounded area and the tailwater stretch of the stream from a cold-water to a warm-water fishery.
- Decomposition of organic matter in the recently impounded reservoir could increase B.O.D. and decrease summer dissolved oxygen content of the reservoir and stream.
- "Prime wetland" would be flooded, forming a 4.9 meter deep reservoir and converting 10.1 hectares of sedge/grass wet meadow marsh and swamp to a pond.
- Declining wintertime water levels with water extraction for snowmaking would congregate fish in a small area thereby increasing competition for space, food, and oxygen, increasing predation, and stranding or freezing others.
- Insects and burrowing animals that normally live in the mud of pond bottoms, and animals that overwinter in the substrates of ponds and streams, such as hibernating amphibians and reptiles, would be exposed to freezing tempera-

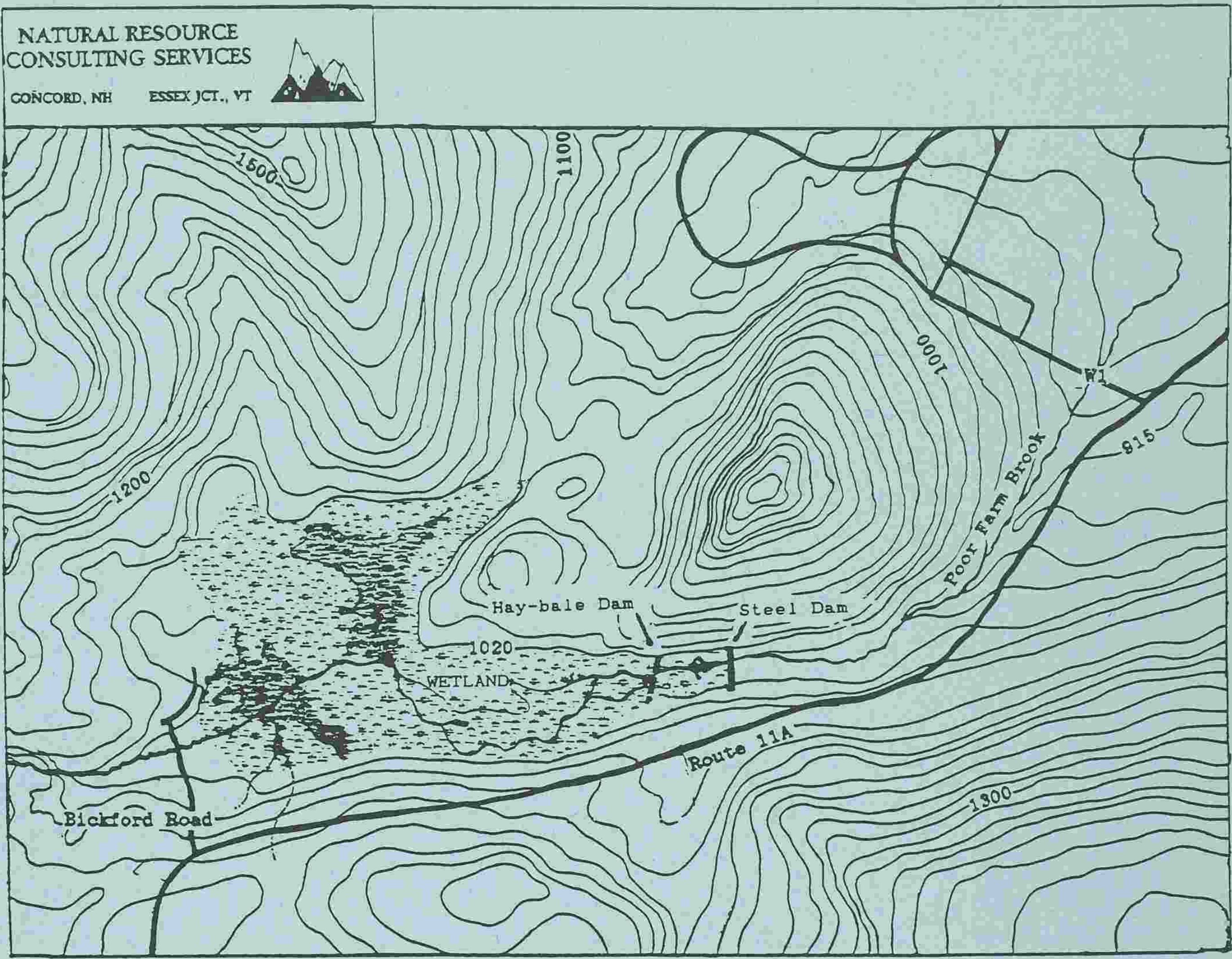

Fig. 1. Wetland, Steel Dam, and Hay-bale Dam for the Subimpoundment at Poor Farm Brook at Gunstock Ski Area, Gilford, New Hampshire.

tures with subsequent mortality, if the water level is drawn too low during snowmaking activities.

- Reduced winter water flow in the stream below the dam would decrease the amount of aquatic wetted habitat available to aquatic insects and fish.
- Sedimentation at the dam construction site could harm downstream aquatic habitat.
- Woody vegetation in the wetland would die if it was permanently flooded thus altering the vegetative composition of the area.

NRCS devised an alternative reservoir management strategy which when carried out with complimentary mitigation measures, would reduce these impacts to manageable levels. The idea was to manage the impounded reservoir as a seasonal pond, filling it in late fall and draining it in late winter. Because the reservoir would be drained, there would be no impounded water to heat up and become depleted of oxygen in the summer. Low water temperatures and high dissolved oxygen are essential to good trout habitat. A minimum flow of approximately 0.014 cubic meters per second was to be maintained at the dam to sustain the quality of downstream fish habitat. Delaying the fill period until wetland plants and animals are dormant in the fall reduces impacts to them.

A dike made of hay bales (hay-bale check-dam) was also to be constructed in the wetland just upstream of the main dam. This system would create a subimpoundment at the head of the impoundment which would othervise be devatered earliest and in most years. The subimpoundment would terrace water in the wetland during the winter. The outflow structure of this check-dam was to be closed prior to the filling of the main impoundment. Because the snowmaking water was pumped out of the impoundment at a location between the main dam and the check-dam, the water in the subimpoundment area could not be drawn down to an elevation lower than the check-dam itself. This would prevent the subimpoundment water from freezing from surface to bottom, and it would prevent the substrate in the subimpoundment portion of the wetland, and animals within it, from freezing and dying when large amounts of water are withdrawn for snowmaking. Figure 1 is a schematic representation of how this technique was designed.

Modest follow-up surveys of fish, wildlife, plant life and water chemistry were designed to monitor and evaluate these mitigation measures.

STUDY AREA

Gunstock Recreation Area is a 809 hectar reservation operated by a branch of Belknap County, New Hampshire. The area ranges from 274-610 meters MSL in elevation and receives an annual precipitation of about 1 meter, including 2.28 meters of average annual snowfall. Mean elevation of the wet meadow is 309 meters feet MSL.

The drainage basin for the wetland and upstream portions of Poor Farm Brook encompasses approximately 647 hectars. Poor Farm Brook is a typical small, riffly, cold-water stream with a naturally reproducing brook trout *(Salvelinus fontinalis)* population. Mean year-round flow in the stream is 13250 liters per minute.

Within the wetland, the 2 meter-wide stream is deep, and meandering, with a dense growth of grasses and sedges along its undercut banks. Beaver activity is primarily responsible for 1.7 hectars of open-water ponded areas at the head end of that section. The stream substrate is one percent cobble, ten percent gravel, eighty-four percent sand, and five percent organic material, with a riffle-to-pool ratio of 1:99. In the forested section, downstream of the wetland, the stream bed is often three to six meters wide with shallow riffles and deeper pools. The forest vegetation on the banks shades the stream almost completely. Stream substrate is forty percent boulder, fifty percent cobble, and ten percent gravel, with a riffle-to-pool ratio of 6:1. Brook trout are stocked about 900 meters below the wetland.

Most of the wetland is a grass/sedge vet meadow dominated by such species as blue-joint grass *(Calamagrostis canadensis)*, fringed sedge *(Carex crinita)*, lurid sedge *(Carex lurida)*, and tussock sedge *(Carex stricta)*, with sparse clumps of sweet gale *(nyrica gale)*, and hardhack *(Spiraea tomentosa)*. The wetland edges and areas where beavers have extended the wetland are dominated by trees and shrubs such as red maple *(Acer rubrum)*, maleberry *(Lyonia liqustrina)*, and highbush blueberry *(Vaccinium corymbosum)*, with a dense grass/sedge/fern understory.

METHODS

Construction, operation, and mitigation methods proposed by NRCS, Gunstock Ski Area, and their civil engineers, Rist-Frost Associates, were eventually accepted by the regulating agencies (U.S. Army Corp of Engineers, New Hampshire Wetlands Board, and the Gilford Conservation Commission) and statutory permits were issued.
In the fall of 1986, a steel, sheet-pile dam, with a denil-type fishway to insure ingress and egress, was constructed on Poor Farm Brook at the downstream edge of the wetland. This dam was 26 meters long with a maximum head of 4.9 meters. A 175 meter long, permeable hay-bale check-dam with 0.9 meter of head, was also constructed in the wetland approximately 353 meters upstream from the steel dam.
Erosion and sedimentation control measures such as the erection of hay-bale and synthetic fabric silt barriers, were instituted around the construction area. However, a near 100-year flood event was experienced, and considerable sedimentation occurred in the stream below the dam site. Most of this sediment was subsequently removed with a hydraulic dredge. The banks at the dam construction site were stabilized with a mulch, and then seeded with wildlife food plants (like, wild rice *[Zizania aquatica]* and millet *[Setaria italica]*), and planted with wetland shrubs (Alder *[Alnus rugosa]*, shad bush *[Amerlonchier laevis]*, willow *[Salix spp.]*, and high bush blueberry) that were salvaged from the wetland destroyed during dam construction.
Trout habitat improvements were made in the stream below the dam. Several rock wing-dams and one log shear were constructed in the stream channel, stream configuration was improved, stream banks and overflow areas were stabilized with boulders, logs, and riprap, and some pools were deepened. Twenty wood duck and twenty passerine bird nesting boxes were erected in the wetland to enhance its value to those species.
Gunstock Ski Area officials closed the check-dam outflow, and subsequently began impounding water at the steel dam on 12 December 1986. Gradual release of the impounded water at the steel dam commenced on 4 March 1987 but water was held in the subimpoundment until released on 15 May 1987. During that winter, 59, 733, 600 liters of water were pumped from the impoundment for snow-making. The greatest extent of the impoundment was 9.3 hectares of which approximately 75 percent was within the subimpoundment. Since the water level fluctuated an average of 1 meter of water flooded the wetland with a winter maximum of 1.6 meters (1986-87).
A similar water regime was maintained for the 1987-1988 season. Impoundment commenced on 11 December 1987 and continued until 15 March 1988 at the steel dam, and 15 May 1988 at the check-dam. hean water depth in the impoundment (at the steel dam) was 2.4 meters (maximum = 3.0 meters) and 53,600,000 liters of water were pumped from the impoundment for snowmaking.
NRCS monitored the ecological effects of the construction and utilization of the dam and impoundment on Poor Farm Brook, its wetland, and wildlife. To determine the extent of change, if any, we measured certain environmental parameters in the stream and wetland, before construction (1986), and each summer for the two following years (1987 and 1988). Water quality was measured annually at stations in the stream above the wetland, in the subimpoundment portion of the stream, between the two dams, and at several locations below the steel dam. Aquatic invertebrate populations were also sampled near these stations. Fish populations were sampled with minnow traps, gill nets, seines, and back-pack electro-shocker, in the same stream sections. Wildlife observations and nest box uses were recorded. Botanical information was gathered each year at four, fixed, permanent meter square plots, three of which were flooded when water was impounded, and one of which was not. Canopy cover of the vegetation in each plot was estimated, by species, with a pin frame variation of the point-intercept sampling method, and with visual estimates. Woody vegetation in the plots was mapped with a coordinate system.
At the time this paper was written, we had data from the preconstruction period (summer 1986), and from two years following construction and use (summers of 1987 and 1988). Data will be collected in 1989.

RESULTS

Our study of ecological impacts at the snowmaking pond was not designed to measure small changes in the wetland. Sample sizes and study techniques were not sufficient to state whether or not small changes were statistically significant. The study should, however, determine if gross changes in the ecology of Poor Farm Brook and the wetland have occurred due to seas-

Table 1. Water Quality heasurements and Fishery Data from Poor Farm Brook, Gunstock Ski Area, Gilford, New Hampshire

Indicator	1986	1987	1988
Mean Summer D.O. ppm *			
Wetland Section	8.1 (n=3)	6.6 (n=4)	5.7 (n=3)
(range)	(7.8-8.4)	(6.5-7.0)	(4.0-7.0)
Forested Section	10.7 (n=2)	10.1 (n=4)	8.3 (n=3)
(range)	(10.3-11.0)	(9.5-10.5)	(8.0-9.0)
Mean Summer Water Temp. C			
Wetland Section	16.2 (n=3)	16.9 (n=4)	22.5(n=3)
(range)	(13.6-17.9)	(15.0-18.0)	(20.0-24.5)
Forested Section	9.9 (n=2)	16.8 (n=4)	21.5 (n=3)
(range)	(9.8-9.9)	(16.0-17.0)	(22.0-24.0)
Mean Summer Air Temp. C			
Wetland Section	18.3 (n=3)	17.6 (n=4)	27.3 (n=3)
(range)	(17.0-19.0)	(12.0-22.5)	(21.0-32.0)
Forested Section	15.5 (n=2)	18.3 (n=4)	23.0 (n=3)
(range)	(15.5-15.5)	(16.0-20.5)	(20.0-27.0)
Mean Summer pH			
Impounded Section	6.1 (n=3)	6.3 (n=4)	6.5 (n=2)
(range)	(6.0-6.2)	(6.0-6.5)	(6.5-6.5)
Forested Section	6.2 (n=2)	6.5 (n=4)	6.5 (n=2)
(range)	(6.0-6.5)	(6.5-6.8)	(6.5-6.5)
No. Trout **			
Wetland Section	2 (2%)	2 (1%)	0 (0%)
Forested Section	35 (32%)	12 (5%)	2 (2%)
No. Forage Fish ***	71 (66%)	209 (94%)	115 (98%)

Note:
* D.O is dissolved oxygen in parts per million
** Trout is eastern brook trout
*** Forage fish is primarily black-nosed dace (Rhinichthys atratulus)

onal impoundment. We also feel that after only two years of post-project data, the results should be viewed cautiously and that firm conclusions should not be drawn for some time. This is because some potential ecological effects such as changes in plant communities occur slowly.

There were some trends in the data thus far that would indicate possible negative environmental impacts (Table 1). At this time, we view these trends cautiously but are not alarmed as the differences are not great.

Vegetation in the wetland has not changed significantly since the construction of the dam. Canopy cover of plant species in the fixed plots has remained similar over the three years of the study and gross observations of the wetland indicate no change. One impact on the vegetation that was observed in 1987, was that a number of trees in the wetland had sustained damage to thelr bark. Apparently the surface ice in the impoundment oscillates as water is removed for snow-making and then refills, thereby scraping the bark from trees. This damage could result in tree mortality although none has been observed. Damage to low tree limbs and shrubs was heawier in 1988. Tree mortality could lead to impacts by the resultant loss of tree-top foliar habitats, and by an increase in sunlight reaching the water (less shade) with subsequent warming. On the other hand, tree mortality would increase availability of snags and cavity trees which are important and often limiting habitat factors for many wildlife species.

Water quality does not appear to be seriously degraded in Poor Farm Brook. It is still a cold, clear, stream with high dissolved oxygen content and a slightly acid but near neutral pH. Our data do however, indicate a decrease in D.O. and an increase in water temperature. These trends may be due to natural variation, and warying sample dates. For example, mean ambient air temperature at the stations increased more than did mean water temperature, and 1988 had above-average summer temperatures. Samples were taken from the stream on June 5 in 1986, on August 7 and September 17 in 1987, and on July 7 and 8 in 1988.

The diversity of terrestrial and aquatic organisms in and around the stream and wetland has not exhibited any clear trend over the three study years. There have been some changes in the species of aquatic invertebrates in our samples since 1986 but there is no pattern to these changes. It would appear that the populations were undersampled.

There was a steady decrease in relative and absolute abundance of brook trout in our fish samples. This may also be an artificial trend as less than one half as many trout were stocked by the New Hampshire Fish and Game Department in the stream in 1988, as vere stocked in 1986 and 1987. This stocking is conducted at the bridge on the main access road approximately 1190 meters downstream from the steel dam. Stocked trout as well as wild trout were captured with the electro-shocker although stocked fish were taken only about 100 meters above their stocking point. Stocking dates may have also been closer to sampling periods in the two earlier years. In 1988, electro-shocking was conducted at a time of very high water. Stream water was over the banks in the wetland, hindering the process. There were many avenues of escape for trout and it was extremely difficult to see fleeing or shocked fish.

On the negative side, we did have a sediment problem in 1987 which could have adversely affected trout reproduction, as could the trends in D.O. and temperature.

Wildlife usage of artificial nesting structures was high indicating their efficacy and that avian populations continue to thrive in the wetland. Of the nest boxes that were checked, 75 percent of the passerine boxes received some use, and 50 percent of the duck nest boxes were utilized.

CONCLUSIONS

Despite some cautionary trends in the data, we remain optimlstic that check-dam subimpoundments and dormant-season-only flooding regimes are effective methods for mitigating the potential ecological impacts of snow-making ponds and other typeg of water source impoundments. Skiing is done on mountains, and by definition mountainous terrain is high in a watershed. That means that only modest amounts of water will be available naturally, and that the water that is there, will be in ecologically sensitive and valuable, cold-water streams and wetlands. There are ever-increasing pressures protection. We feel that alternative designs and mitigation techniques such as these may, in some cases, be viable alternatives by which we can maintain these streams and wetlands as they are, without significant ecological damage. Without techniques such as these, either the wetland would have been destroyed converted to a pond, and the stream undergone ecological changes (possible warming), or, the project would have been denied the appropriate permits, thus depriving the county of the additional recreation opportunities.

We are not at this time drawing firm conclusions on the degree of success of our mitigation efforts. Some trends in the data are disconcerting, and the variability of the results indicates that we need greater sample sizes and more years of post-project data. If at all possible, we will intensify our monitoring efforts in the future and with additional, years of data be able to firmly evaluate their effectiveness.

ECOLOGICAL EFFECTS AND FISHERY PROBLEMS RELATED TO RESERVOIRS IN THE ALPS: THE PRESENT SITUATION

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ABSTRACT In Switzerland, a total of over 1100 hydroelectric power plants generate 60% of the electric energy consumed domestically. Main conflicts between hydroelectric power production and ecological interests arise from the negative effects on fish and invertebrates of dam construction, water level fluctuation in the reservoirs, alteration and diversion of flow, the creation of dry river sections, and sediment discharge into rivers. For each of these problems, the situation in the alpine region is briefly discussed by giving a number of examples mainly from Switzerland. Possible measures for mitigating the most negative effects are discussed.

INTRODUCTION

Sixty percent of the electric energy produced in Switzerland is generated by hydroelectric power plants (SWV, 1988). Out of the approximately 1150 hydroelectric plants existing in 1990, 449 had an energy output of more than 300 kW. High pressure is used in mountainous regions, while the power plants on the lowland rivers operate on low head. In addition to dhe existing plants, 9 new power plants of over 300 kW are presendy under construction (pers. comm. by Bundesamt für Wasserwirtschaft, Bern).

Potential conflicts arising from hydroelectric power production in mountainous