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RECLAIMING RESERVOIRS - NATIVE SPECIES REVEGETATION OF SHORELINES

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ABSTRACT

B.C.Hydro operates over 40 reservoirs in its utility system. In addition to supplying electricity, many of these reservoirs provide multiple uses to the local communities such as fishing, boating, swimming and wildlife viewing. The operation of a hydroelectric dams often produces fluctuations in reservoir levels due to inequalities in daily water use and seasonal inflows. These fluctuations, or drawdowns, limit the capability of native vegetation to survive along shorelines. Without the binding effects of plant roots, fine, silty materials are easily eroded by wind and water.

Recently, B.C.Hydro has experimented with the reclamation of drawdown zones using native wetland plant species. Studies began in the early 1980's in response to dust problems caused by wind erosion when reservoirs were at low water levels. The early findings indicated that local wetland species were limited in the drawdown zones largely by the inability to develop quickly enough to survive water inundation. There is often a plentiful seed supply, however, once seeds establish they cannot withstand the prolonged high water periods.

B.C.Hydro has used several simple methods to encourage seedling establishment in the drawdown zones of reservoirs. A broad nurse crop of local or temporary grass mixtures can protect young seedlings from wind and water erosion while providing necessary organic matter. Experimental nurse crops have been applied using broadcast, seed drills, hydro-seeding or heli-seeding methods. In addition, planting greenhouse grown seedlings in the drawdown zones has proven effective. The seed is collected from local plant communities to take advantage of the regional species adaptations to climate and soil conditions. Collected seeds are treated and germinated in a greenhouse to increase their chance of surviving inundation when replanted in the drawdown zone. There has also been some success with planting local willow cuttings in higher elevations of the drawdown zone.

Vegetated reservoir shorelines benefit the local community by decreasing water and wind erosion and increasing the quality of visual and recreation resources. The benefits to the ecosystem include an increase in habitat productivity and diversity, and greater riparian habitat for fish and wildlife use.

INTRODUCTION

Reservoirs form when a dam, constructed in a river valley, impounds river flows and floods the valley upstream of the dam. Reservoirs shorelines depend on the nature of the impounded river valley: steep, rocky shorelines in young river valleys, or broad open shorelines of alluvial material in more established

floodplains. This paper describes some of the environmental impacts associated with reservoirs that have the latter type of shoreline, and outlines mitigation options involving innovative revegetation techniques.

Under normal operating conditions, a reservoir experiences fluctuations in water level due to inequalities in the amount of water flowing in, and the amount of water used for generation (or flowing out). The result of fluctuating water levels is a dynamic shoreline, called the drawdown zone, where native vegetation is unable to survive successive flood/drought cycles in a single growing season (Figure 1). Ensuing environmental impacts affect both the local community (air quality and aesthetics) and natural resources in the area like wildlife habitat, recreation and fisheries. For local residents near the Arrow and Williston Reservoirs, the most significant impact is the occurrence of severe dust storms when reservoir levels are low and prevailing winds erode fine shoreline sediments.

In response to community concerns over dust control problems, B.C.Hydro began annual grass seeding programs in the mid 1970's with rapid-growing fall rye. In an effort to establish a more permanent solution with perennial vegetation, an intense research and development program on the Arrow Reservoir began in 1990. This program involved the trial planting of wetland sedges, willows and seasonal grasses as a form of erosion control. In 1994, the Upper Arrow Dust Control Program won the International Erosion Control Association's Environmental Achievement Grand Award. Prior to the work on Arrow Reservoir, very little scientific information existed on revegetation within large, regulated reservoirs.

This paper summarizes the methodology and results of the first three years of research conducted on the Arrow Reservoir followed by an outline of the program's current status, and recommendations for future monitoring and research. Also included are brief descriptions of other drawdown zone revegetation initiatives recently implemented or proposed by B.C.Hydro based on the Arrow Reservoir model. A final discussion provides insight into the trial and error of reservoir shoreline revegetation efforts and emphasizes some highlights of the research to date.

The Drawdown Zone

Fundamental to the operation of a dam is the amount of water flowing into the reservoir, and the amount of water leaving the reservoir as it passes through turbines in the impounding dam. Each of the over 40 reservoirs operated by B.C.Hydro have well-defined minimum and maximum water levels. The difference

between full pool (normal maximum operating level) and low pool (normal minimum operating level) is physically evident on the reservoir shoreline and defines the drawdown zone. Most reservoirs fluctuate on a 24-hour basis in response to daily customer electricity requirements. Reservoirs in coastal regions have two large annual drawdowns to make room for high inflows during spring freshet and heavy fall rains; interior reservoirs experience only one large drawdown prior to spring freshet. Daily fluctuations, relatively undetectable in reservoirs with steep shorelines, are extremely visible in those with broad, gradual slopes (Figure 2). Adding to the unattractiveness of an unvegetated drawdown zone in many reservoirs are tree stumps which become visible at low pool. These stumps remain from the forests that existed prior to initial reservoir raising.

UPPER ARROW DUST CONTROL PROGRAM

Background

Located 7 km north of the city of Castlegar, the Hugh Keenleyside Dam impounds the Columbia River upstream to Revelstoke forming the Arrow Reservoir. Built as a water storage project, the dam operates under guidelines established in the Columbia River Treaty. The Arrow Reservoir is 370 km long and receives large amounts of fine, glacial origin sediments from upstream tributaries (Carr et al, 1993). During low reservoir levels, prevailing winds erode these fine sediments in the drawdown zone creating dust storms in the communities of Revelstoke, Nakusp and Burton.

In 1990, B.C.Hydro, in cooperation with AIM Ecological Consultants and Terrasol Environmental Consulting, began the Upper Arrow Dust Control Program. B.C.Hydro sought input from local residents, discovering that they favoured a hard engineering solution (in the form of weirs to retain water in the reservoir) to control the dust problems. Initial studies indicated that the engineering solution was expensive and could negatively impact public safety and upstream fish migration. In pursuit of a more economical long-term solution with multiple environmental benefits, B.C.Hydro and their consultants participated in the following activities:

- detailed problem analysis and review of past programs
- visitation of other drawdown management programs in the United States
- initiation of a plant testing program to identify potential permanent vegetation, and suitable propagation methodology, for inclusion in the long-term dust control program (Carr et al, 1992).

FIGURE 1: SCHEMATIC PROFILE OF SHORELINE VEGETATION - NATURAL LAKE VS HYDROELECTRIC RESERVOIR

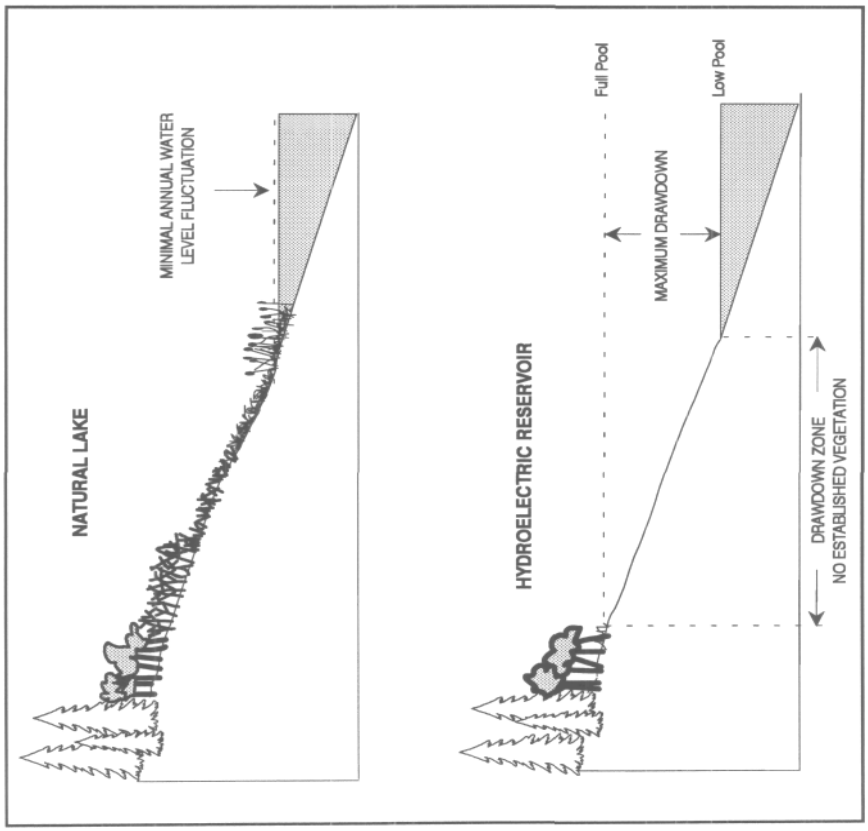
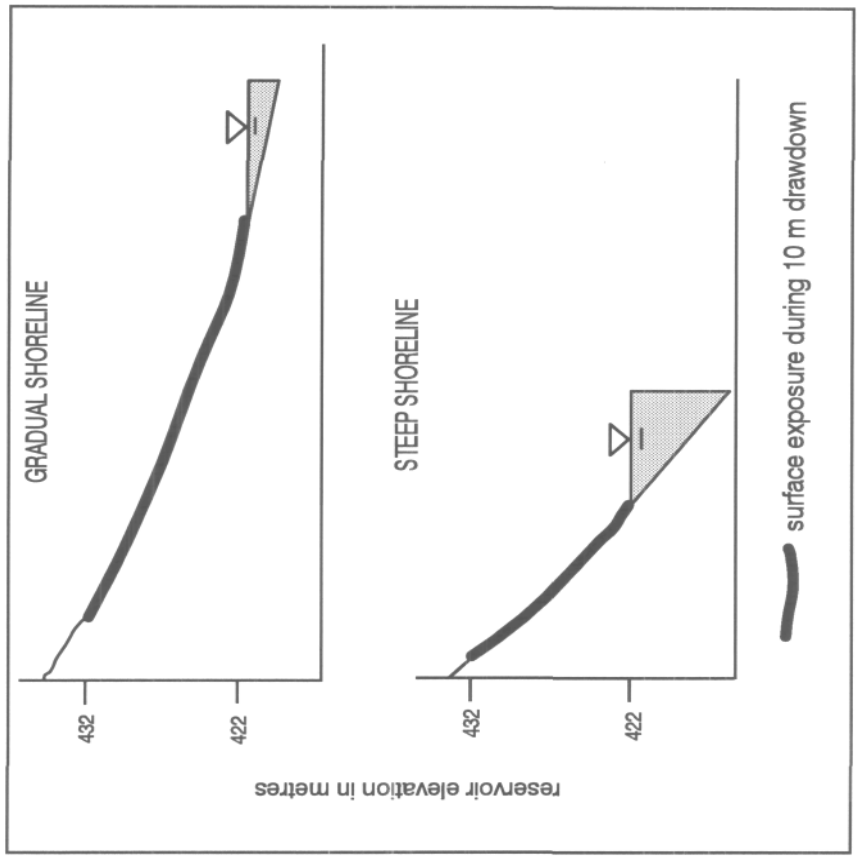


FIGURE 2: SCHEMATIC PROFILE OF RESERVOIR SHORELINE



As a temporary measure during wetland plant trials, the fall rye seeding continued over a total of 1000 ha of the drawdown zone identified as high-risk dust source areas.

Annual Water Levels

The Arrow Reservoir area experiences cold wet winters and warm dry summers. The Columbia River Treaty provides for a large annual drawdown of the Arrow Reservoir from approximately 440 m to 420 m elevation. The draw down begins in December with the reservoir remaining at low pool until late April when freshet inflows fill the reservoir again by June (see Figure 3).

Drawdown Zone: Environmental Impacts

The January to June drawdown exposes approximately 2850 ha of relatively barren shoreline and lake bottom sediments. Environmental impacts of this operating regime affect the local community in the following ways:

- provides source areas for generation of wind blown dust
- impedes recreational boat access to reservoir
- disrupts visual aesthetics of the area with undesirable views
- eliminates protective cover for wildlife wishing to access water
- prevents shoreline nesting by waterfowl

Of concern to local residents is the frequency and severity of dust storms which impact their daily lives.

Wetland Species Trials - Methodology

We used native wetland plant trials to determine which species have the potential for permanent establishment to provide long-term erosion control in the drawdown zone. Initial native wetland trials included the following:

- identification of existing, native plant communities of emergent species (those that live in a transition between aquatic and terrestrial environments)
- selection and propagation of potential candidate species for a planting program
- establishment of limits, both in elevation and soil type, for the candidate species
- identification of high risk dust source areas in which to locate trial plots (Carr et al, 1992)

Seeds and plant cuttings collected in the fall of 1990 were greenhouse grown to facilitate their planting as robust seedlings. The intent was that this treatment would give the plants added hardiness, improving

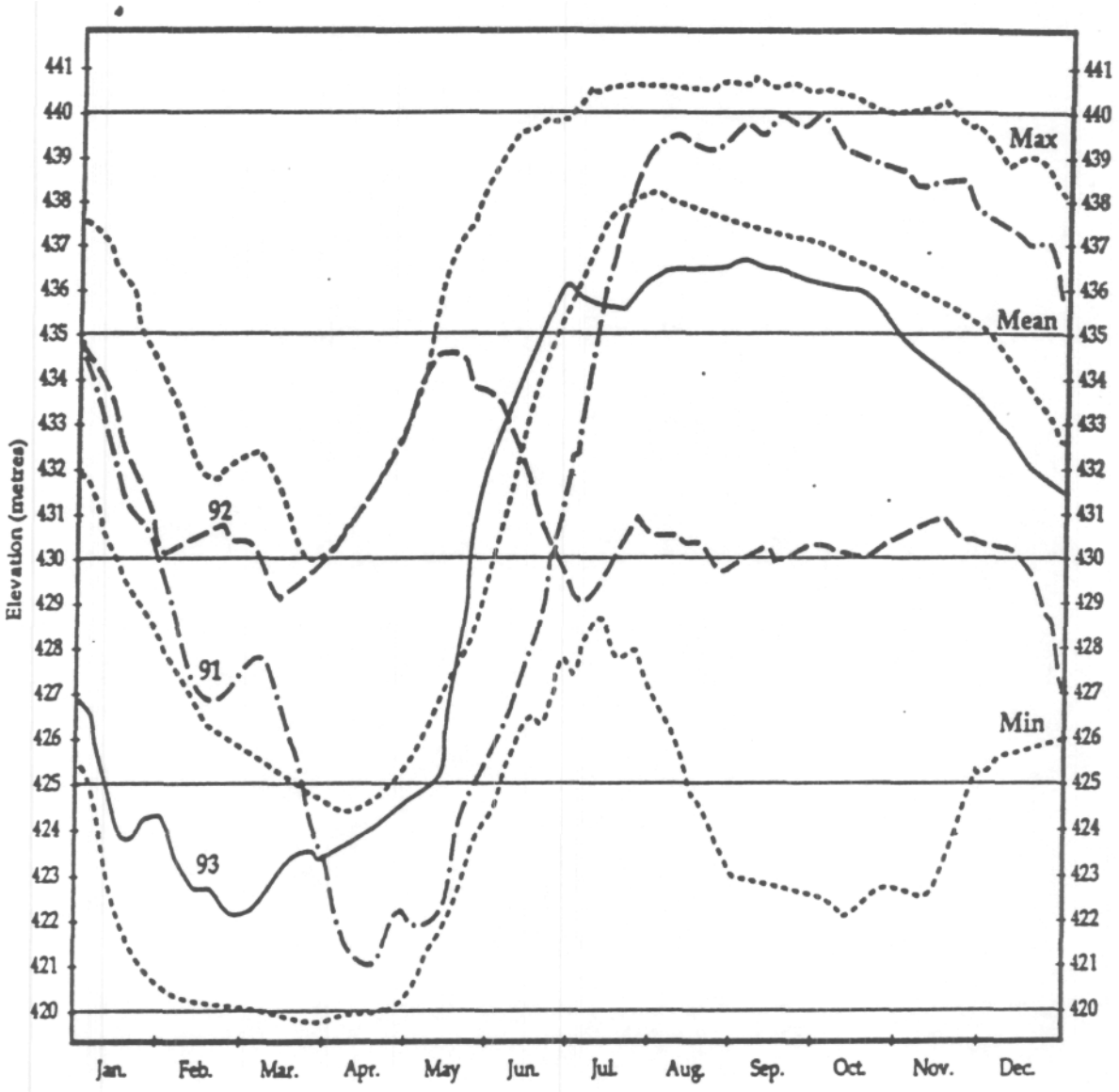


FIGURE 3: Water management regime of the Arrow Reservoir.

their survival rate during their first period of inundation.

With a knowledge of moisture requirements for wetland plants, the consultants determined that ideal elevations for trial plots within the drawdown zone fell between the elevations of 432 and 436 m. Field work in May of 1991 (replicated in 1992) included the planting of over 12,000 seedlings in standard plots, in four different high risk source areas around the reservoir. The plots contained 25 seedlings of each species listed in Table 1.

Table 1: Plant species cultivated for wetland 1991 wetland trials (Carr et al, 1992)

SCIENTIFIC NAME	COMMON NAME
Alopecurus aequalis	Water foxtail
Carex aquatilis	Water sedge
Carex aperta	Columbia sedge
Carex obnupta	Slough sedge
Carex rostrata	Beaked sedge
Carex sitchensis	Sitka sedge
Eleocharis palustris	Creeping spike-rush
Palgonum persicaria	Smartweed
Scirpus americanus	Three square bulrush
Scirpus lacustris	Soft-stemmed bulrush
Scirpus microcarpus	Small flowered bulrush
Scirpus maritimus	Seacoast bulrush
Triglochin maritima	Arrowgrass
Zizania aquatica	Wild rice

The 1993 program included experiments to determine the effectiveness of alternative propagation methods on seven of the most successful grass and sedge species from the 1991/1992 trials. Trial plots contained each of the seven species propagated three different ways: container grown seedlings, sprigs and direct seeding. Successful establishment with the latter two methods would diversify planting options for long-term revegation programs. In addition, native wetland grass trials took place over 40 ha of drawdown zone at elevations above 437 m. Four trial areas of commercially available grass seed (reed canary, creeping meadow foxtail and redtop) were drill seeded with and without fertilizer. The drill seeder planted swaths containing 16 rows of seed; adjacent swaths were separated by an unplanted swath of equal width.

Wetland Plant Trial - Results

In 1991, the number of growing days prior to inundation ranged from 25 for plots at low elevations, to 50 for the highest plots (Carr et al, 1992). All 1991 and 1992 plots experienced complete inundation for approximately six months. Initial monitoring of the 1991 trials took place two months after planting; subsequent, post-inundation monitoring in August 1992 revealed the survival results listed in Table 2.

Table 2: Percentage of 1991 seedling survival according to elevation (in metres) within the drawdown zone - August 1992 (Carr et al, 1992).

SPECIES	432	433	434	435	436
Carex aperta	1	8	21	10	6
Carex aquatilis	25	21	62	79	52
Carex obnupta	31	73	67	88	92
Carex rostrata	4	7	35	53	75
Carex sitchensis	0	39	31	38	36
Alopecurus aequalis	8	11	3	30	25
Eleocharis palustris	0	13	33	31	34
Polygonum persicaria	9	11	28	36	8
Triglochin maritima	0	7	21	27	17
Scirpus sp. (all)	0	2	1	3	0
Zizania aquatica	0	0	0	0	0

An additional two years of trial planting and monitoring revealed that the two most important factors affecting survival rates of wetland plants in the Upper Arrow drawdown zone are:

- elevation within the drawdown zone
- conditions during the first 60 days of planting

In general, slough, water, beaked and Sitka sedge varieties stand out as the most versatile and tolerant species, surviving over a range of elevations in a number of locations around the reservoir drawdown zone. Many of the sedges withstood 6 - 7 m of inundation. Trial planting of bulrush and wild rice plants proved unsuccessful with almost 100% mortality.

Due to an unexpected premature rise in reservoir levels immediately after the 1993 planting, all test plots suffered flooding. Limited data is available for alternative propagation methods as few of the plants survived. Of those tried, only Sitka sedge seed germinated and survived inundation, growing well at the 434 m level in the fall of 1994 (Moody, 1994).

The native wetland grass trials proved highly successful, with grasses filling in much of the unplanted

areas between seeded swaths. Planting every other row appears to create adequate windbreaks while providing a nurse crop which traps seeds and aids in the expansion of grasses and establishment of weedy species (Beer et al, 1994).

Willow Trials - Methodology

Review of other reservoir management programs revealed that willows could play a role in drawdown zone erosion control due to their rapid rate of establishment and ability to withstand considerable inundation. In order to better understand which species could survive prolonged inundation and associated elevational limits, willow trials of several species took place in late March of 1991, 1992 and 1993. Using a well-accepted method of driving 0.5 m long, 20 mm diameter cuttings (whips) directly into the ground, field crews established trial plots in eight locations within the reservoir, spanning elevations of 430 to 436 m. The majority of willow stock came from a Washington nursery supplemented with local cuttings of Hookers and Weeping Willows.

Willow Trials - Results

The willow trial results reflect a response to the following variables:

- timing and duration of inundation
- location within the reservoir
- winter ice conditions
- elevation within the drawdown zone
- type of substrate

The 1991 results indicate that Plumas Sitka and Placer Erect willow exhibit the strongest initial establishment, however only Plumas Sitka survived inundation in significant numbers over all test areas (Carr et al, 1993). Unusual water levels in 1992 (brief inundation early on followed by prolonged dry conditions) facilitated exceptional establishment and survival rates for all species except the local weeping willow. Unfortunately, the healthy 1992 plants suffered high mortality due to winter kill and ice damage in 1993-94. The 1993 trials performed very well in all locations with Hookers willow, Plumas Sitka and Cottonwood showing highest success in the first season. The 1993 success is likely due to a low inundation level that summer and higher average plot elevations, allowing the willows to mature and grow quickly (Beer et al, 1994).

Overall, the willows planted at elevations above 435 m displayed the best survival in successive years. Those willows planted in fine textured substrates of silty, clay loam faired poorer than those planted in sandy areas (Carr et al, 1993).

Upper Arrow Dust Control Program: Current Status

B.C.Hydro plans to continue monitoring of existing wetland plant and willow trials to obtain information on plant survival over successive reservoir management cycles. The water regime in 1992 and 1993 differed from historic norms; a few years of more "normal" conditions will better identify the limiting factors for wetland species' survival in the Arrow reservoir drawdown zone.

The trials indicate that willow rows form effective windbreaks, protecting the substrate from erosion as well as increasing the visual aesthetics and wildlife habitat of the drawdown zone. The identification of critical dust generation areas where willows could provide effective windbreaks will help to focus future willow establishment efforts.

Wetland plants and grasses thrive at a range of elevations; in general, growth rates improve with an increase in elevation within the drawdown zone. The plants, grasses and fall rye grain provide excellent erosion control, extremely positive visual impacts and effective nurse crops for the establishment of native, wind-borne seed. Recommendations for future work include expansion of wetland grass seeding at elevations above 437 m and continued monitoring of wetland plant performance above 432 m to evaluate survival rates over successive periods of inundation (Carr et al, 1993). Drill-seeding of fall rye grain continues annually and remains the largest part of the on-going program to control blowing dust.

RESERVOIR SHORELINE REVEGETATION INITIATIVES

Stave Falls

Included in B.C.Hydro's plan to replace the aging powerhouse at the Stave Falls Dam, near Mission, B.C., are several environmental mitigation proposals. One such proposal is to increase fisheries and wildlife habitat, recreation potential and visual aesthetics of the drawdown zone through shoreline revegetation efforts. A draft report prepared for B.C.Hydro by AIM Ecological Consultants, 1994, examines eight major areas around the reservoir and identifies suitable locations within those areas for experimental wetland species establishment. Critical to the identification of these locations is an understanding of the soil type, and hydrologic, biologic, topographic and climate characteristics of each area. Combining the knowledge gained in the Upper Arrow Dust Control Program with a study of native wetland plants in the Stave Lake area will allow B.C.Hydro to plan a progressive, effective revegetation program for the Stave reservoir drawdown zone.

Upper Campbell Lake/Buttle Lake Reservoir

Located on northern Vancouver Island partly within Strathcona Park, this coastal-region reservoir experiences two large annual drawdowns that expose a barren, stump-littered shoreline. To complement a stump removal program and improve the drawdown zone visual impacts in the park, B.C.Hydro initiated a revegetation program in 1992 based on results from the Upper Arrow Program. Focusing revegetation efforts where they would have the most visual benefits, the program included trial plots of willow and wetland plant species at various locations around the reservoir, concentrating on those areas already cleared of stumps.

This reservoir differs from the Arrow in that two large drawdowns occur within one growing season. This operational regime subjects the drawdown zone to increased wave action that erodes the substrate, making it very difficult for juvenile seedlings to take hold. Results from the first two years indicate that willow and cottonwood establish and grow well in the upper 2 to 3 m of the drawdown zone, providing a definite improvement to reservoir aesthetics. However, wave scour on the reservoir shoreline prevented the over 20,000 wetland plugs planted in spring and fall of 1993 from establishing successfully. As a result, they suffered 100% mortality. Recommendations for 1995 include a shift to using more advanced plant material in the form of ecopads or sods from local, native wetland communities (Carr, 1994).

Elsie Lake

Elsie Lake is part of the Ash River generating system located north west of Port Alberni, and is accessible to the public by numerous logging roads. Reservoir drawdowns of 7 m expose a drawdown zone approximately 550 ha in size from June to October each year. As in many other broad, shallow reservoirs, the hydro operations at Elsie lake render the shoreline an unvegetated, unstructured drawdown zone. B.C.Hydro environmental staff identified Elsie Lake as an area possessing high potential for recreational development; production staff recognized the potential for revegetating the drawdown zone to mitigate reservoir operations and enhance the shoreline habitat, visual aesthetics and recreation benefits of the area.

B.C.Hydro completed the first phase of a proposed revegetation program in 1994. Phase I included a detailed assessment of the drawdown zone to identify suitable slopes, substrates and seed sources for planting trials. Further work will include seed collection and propagation, wetland plant trial plots, and fall rye seeding (all based on the Upper Arrow Dust Control Program). Incorporating all of the trial information, the final phase would see large scale revegetation efforts transforming the drawdown zone into an area with high recreation capability, and improved visual aesthetics, fish and wildlife habitat and

erosion control.

Williston Reservoir Dust Control

An integrated group of B.C.Hydro environmental and operations staff plans to interface with the University of Northern B.C. and representatives of the Tsay Key Village to research dust control measures on the Williston Reservoir. Similar to the Arrow Reservoir dust control problem, summer drawdowns on Williston leave fine shoreline sediments exposed and vulnerable to wind erosion. Initial research, scheduled to begin in spring 1995, includes fall fye and mixed grass seeding trials in the lower elevations of the drawdown zone. Plans for long term research include: investigations into parameters influencing dust storm generation, vegetation strategies to control dust transport, an updated literature review of similar mitigation strategies worldwide and determining the range of feasible solutions and relative costs for dust control.

DISCUSSION

The Upper Arrow Dust Control Progam provides B.C.Hydro and others with scientific data necessary to the successful planning of shoreline revegetation on hydroelectric reservoirs. We based initial research on limited revegetation studies done in other locations. The actual wetland plant trials required an element of trial and error to determine the effectiveness of propagation techniques and various species over a range of elevation, local climate and substrate conditions. Future revegetation efforts in drawdown zones will benefit from the findings of the Upper Arrow and other B.C. Hydro revegetation programs.

One such important finding is that fall rye grain is a hardy, fast growing, and relatively inexpensive nurse crop that does not invade local, native plant communities (inundation in the fall prevents the crop from reaching maturity). Annual fall rye crops provide benefits of soil stabilization, increased organic matter, and stubble useful for nursing native species to establishment in lower elevations within the drawdown zone. The Upper Arrow program had mixed success with fall rye seeding methods. Drill seeding proves most effective for the fall rye as it places the seeds below the hard, dry surface into moist soils where roots can take hold. Aerial and broadcast seeding were least effective because the seeds dried out and couldn't germinate on the flat, windswept substrate; these methods may better suit inaccessible areas with a more rough, moist substrate (A.E. Brotherston, pers. comm).

Secondly, successful revegetation programs require a solid understanding of annual reservoir operations and their effect on shoreline stability. Wave scour, duration and frequency of inundation/drought cycles,

and depth of inundation are all operational factors that limit wetland plant survival in the drawdown zone. In the Arrow Reservoir, greenhouse sedge plugs survived a single flood event of up to 7 m of inundation; similar plugs could not tolerate the wave scour of two flood events on Upper Campbell/Buttle Lake Reservoir. A comprehensive study and assessment of all environmental factors effecting the drawdown zone is required for each reservoir prior to initiation of a revegetation program.

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