Management Options, Monitoring Programs, and Research Designs for Controlling Parrots Feather in Somenos Creek

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Executive Summary

- Parrot's Feather is an invasive aquatic weed introduced to Somenos Creek in 2014.
- Within two years Parrot's Feather had reach such abundance and density that it now poses a threat to salmon migration, trout habitat, recreational uses by residents and assessed property value.
- Somenos Creek is very shallow sloped and is therefore predisposed to slow and unpredictable drainage between Somenos Lake and the Cowichan River.
- In the winter Somenos Creek is subject to reverse flow during storm events because of the more rapid increase of water level in the Cowichan River.
- In the Summer Somenos Creek is subject to reverse and even divergent flow patterns due to unpredictable changes of ground water input, lake level, and gravel deposition by the river.
- Repeated dredging and ditching operations in and around Somenos Creek have failed to create a long-term resolution to poor drainage in the Somenos watershed.
- The removal of trees from the banks of Somenos Creek has allowed excessive light penetration to the stream channel and thus promoted historic overabundances of aquatic vegetation. Parrot's Feather abundance reflects this light availability.
- Runoff from deforestation, agriculture, and urban development in the Somenos watershed have raised nutrient levels in Somenos Lake and Creek and allowed explosive growth of blue-green algae and aquatic plants.
- The high biomass, and extensive infestation area of Parrot's Feather in Somenos Creek, is a consequence of the combination of a very low stream gradient, an absence of riparian vegetation, and very high nutrient levels. This combination of factors is unique to Somenos Creek among infested areas in British Columbia.
- The depth and width of different stretches of Somenos Creek also likely contribute to local variations of Parrot's Feather abundance.
- Management options to control Parrot's Feather include dredging, herbicides and shading.
- Experience in other jurisdictions suggests that, in the absence of drying infested habitat for three or more years, none of the available management options is likely to yield total eradication of Parrot's Feather in Somenos Creek.
- While the use of herbicides would quickly reduce Parrot's Feather abundance, re-infestation is almost certain and the use of chemicals in the aquatic environment would come only at a high administrative and social cost.
- Previous scientific and engineering advice suggests that trees and shading would be effective in reducing aquatic plant biomass over a time span of years to decades.
- Senior levels of government are unlikely to directly respond to invasive aquatic plants like Parrot's Feather so the Municipality of North Cowichan will need to take a leadership role in coordinating a coherent management response.
- A large pool of expertise in dealing with aquatic habitat remediation and invasive plant management exists within local NGOs, *e.g.*, the Somenos Marsh Wildlife Society and the Cowichan Land Trust, and within Cowichan Tribes members and staff.

Recommendations

- The Municipality of North Cowichan should partner with Cowichan Tribes, local environmental stewardship groups to establish a Parrot's Feather management group.
- The group can develop a management program with public input to help identify management goals and priorities for Parrot's Feather in Somenos Creek.
- Public education efforts may be needed to help minimize future introductions of aquatic invasive plants and the goals and work established to control Parrot's Feather. This should include signs at strategic locations like boat launches, trails along Somenos Creek, and the mouth of Somenos Creek advising on Parrot's Feather and averting its spread elsewhere in the watershed,
- A partnership led by the Municipality of North Cowichan with participation by Cowichan Tribes and local environmental stewardship groups would be the most effective model for crafting Parrot's Feather monitoring and management programs and targets.
- Monitoring of Somenos Creek should begin as soon as possible to establish baseline conditions of water quality, Parrot's Feather abundance and distribution, and stream bathymetry.
- A combination of shading approaches and strategic dredging would be the most cost-effective approach to controlling Parrot's Feather growth so that it does not interfere with biological, social and economic values of Somenos Creek. These methods would be particularly suited to smaller areas ~20-40m^2.
- For larger areas of infestation ≥50m^2 it may be necessary to employ suction dredging. The financial and administrative costs of suction dredging will be much higher than shading and repeated rounds of dredging may be required every few years. Costs and benefits of suction dredging should be investigated more closely by the management group in consultation with invasive species experts from provincial agencies.
- Implementation of a Parrot's Feather management plan will require both control projects and monitoring to ensure that progress is being made to control Parrot's Feather and that biological, social, and economic values are being improved.
- Management targets need not focus only on Parrot's Feather abundance *per se*, but also its effects. For example, targets for Parrot's Feather control could include indexes like, dissolved oxygen, nutrients, and fish presence in the water column, light levels at the surface and water depth. Targets could also include human indexes like navigability by canoe or boat.
- Monitoring and control work can be done in conjunction with local environmental stewardship organisations and Cowichan Tribes to offset personnel and financial costs to the municipality.
- Federal and Provincial agencies and ministries are not likely to act unilaterally on Parrots Feather control work. However, the successful establishment of a management program and commencement of monitoring and control work will likely attract financial support from senior levels of government.
- A management program with community volunteers as a component will create communication channels to educate the larger public about the management plan and thus help foster public support.
- Reporting on the progress of the management program should be done annually and engage the public to communicate management achievements and changes in priorities.

Introduction

Parrots Feather (*Myriophyllum aquaticum*), also known as Brazilian Water Milfoil is an aquatic plant native to the Amazon River basin (King County 2011, Kelly and Maguire 2009), see figure 1. Due to its ability to quickly colonise disturbed stream and pond habitats it is considered an invasive species in many jurisdictions outside of its native range, see, *e.g.*, Euphresco DeClaim (2011), Kelly and Maguire (2009) and Moreira *et al.* (1999). In North Cowichan it has become established in Somenos Creek to such an extent that as much as 25% of the surface area of the stream is covered with mats of this plant (Preikshot 2018) for much of the year. Parrot's Feather was first noted in Somenos Creek in 2014 (Simpson 2015) and was first recorded by technicians from the British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development in 2015 (FLNRORD 2018). The almost viral ability of this plant to spread can be seen in that it was not noticed before 2014 and within a year became abundant enough to be an impediment to paddling in the creek (Simpson 2015).

The Municipality of North Cowichan engaged the author of this report to assess local environmental, social and economic factors to develop a cost effective and achievable monitoring and management approaches to Parrot's Feather. There are a surprisingly large number of options available to manage invasive aquatic plants like Parrot's Feather. However limitations to these options may arise from limitations of social license by the community, federal and provincial legislation, and financial constraint in governmental agencies.

It is anticipated that upon delivery of this document, the author and North Cowichan Staff will report to North Cowichan Council, North Cowichan Municipal Committees, *e.g.*, the Environmental Advisory Committee, and Committees to Which North Cowichan has representation, *e.g.*, the Somenos Management Committee. It is further expected that this report will be presented to local stakeholders like Cowichan Tribes, property owners in the Somenos basin and members of the agricultural community for consideration and feedback. Upon review of the report by these groups and the adoption of feedback by staff it is expected that a management plan will be developed by the Municipality of North Cowichan which includes partnerships with Federal, Provincial and provincial agencies, Cowichan Tribes and local non-governmental organisations.

This report is divided into 5 sections. The first is an introduction to Somenos Creek with a focus on the ecological setting to contextualise the natural framework within which monitoring and management activities will take place. The first section will also identify social and economic factors that will need to be considered in monitoring and managing Parrots Feather. The second section will be a review of the ecology of Parrots Feather and draw upon observations in the Somenos basin as well as experiences from other jurisdictions. The third section will review the physical, chemical, and biological approaches that have been used in other places to manage Parrots Feather. These approaches will be qualitatively assessed for suitability of use in the Somenos Basin based upon their relative financial cost, efficacy of reducing Parrot's Feather Biomass, appeal to social acceptability and time frame of action. The fourth section will discuss monitoring activities that will be required in order to track progress of management and

mitigation efforts to control Parrots Feather. The last section will provide a road map for moving forward with recommendations on management, mitigation and monitoring activities for Parrot's Feather in the Somenos Basin.

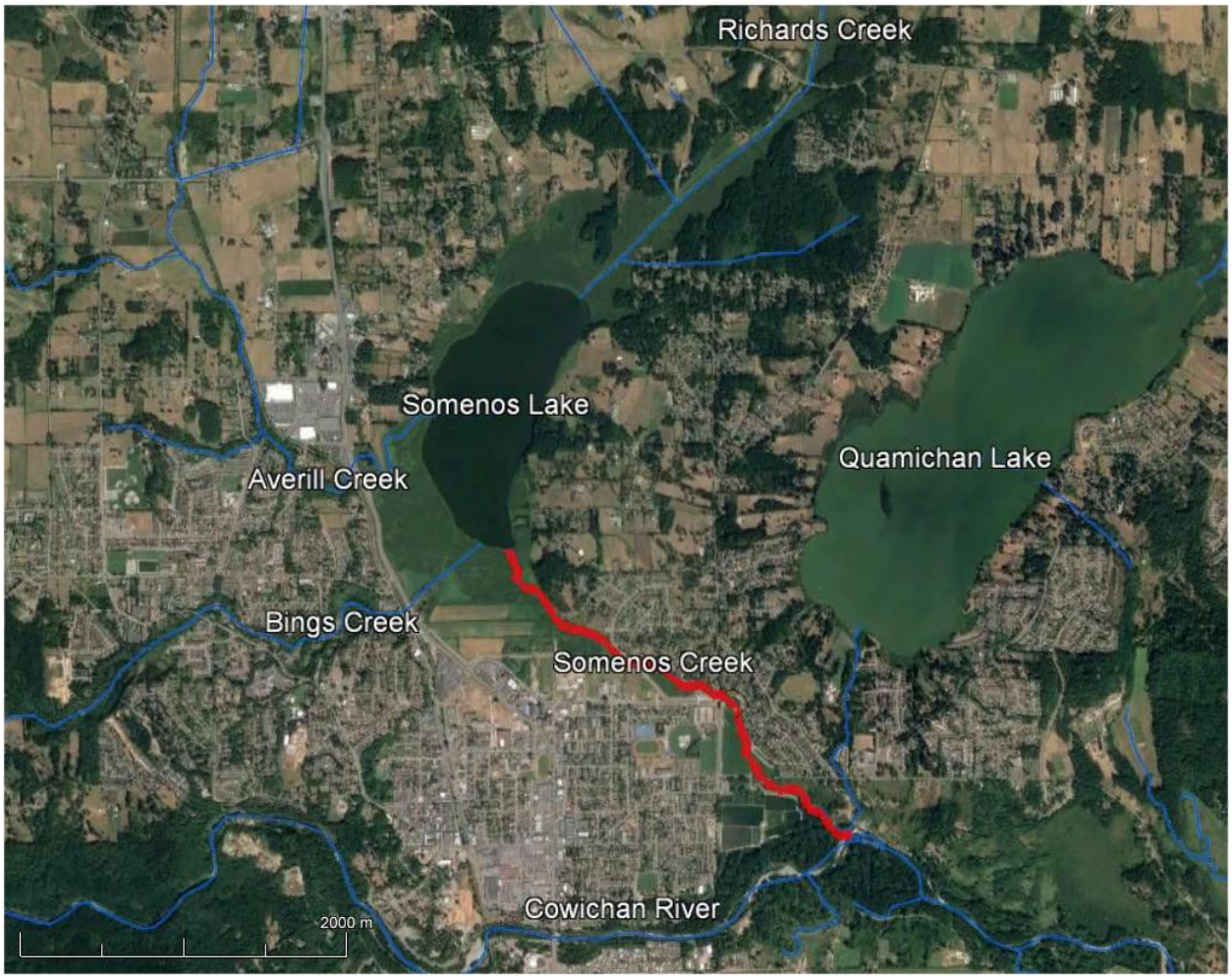


Figure 1: The Location of Somenos Creek (red line) within the Somenos Basin. The City of Duncan is seen as the gray area near the centre of the bottom of the picture. Somenos Creek integrates drainage from Somenos Lake and its three tributary streams. Image made with Google Earth.

Geographic and Biological Characteristics of Somenos Creek

Geography

Somenos Creek, Figure 1, is just over 3100m long yet the difference in elevation of the creek bed between the head and the mouth of the creek is only about 0.6m (Chilibeck 2005). Therefore, the slope of the creek is approximately 0.011°. Seasonal water levels in Somenos Lake and Somenos Creek are, therefore, influenced by small changes in topography in the creek channel and deposition of sediment by the Cowichan River at the mouth of the creek (Lyle and O'Connor 2009). Water levels of Somenos Lake and Somenos Creek are highly correlated (Chilibeck 2005) and are highest during fall and winter storms during December and January, Figure 1. Historically, there appears to have been a relatively slower spring drawdown of water level in the lake than at present. Also note that the summer minimum is longer at present than that which existed historically. Recent data from North Cowichan engineering suggests that during the period 2015-2018 there has been an increase of about 30cm in the recorded summer minimum (Chadburn pers. comm. 2018).

The slight difference in stream bed elevation between the head and mouth of Somenos Creek is reflected in the poor drainage that has often been associated with Somenos Lake (Vander Sluys 1986,

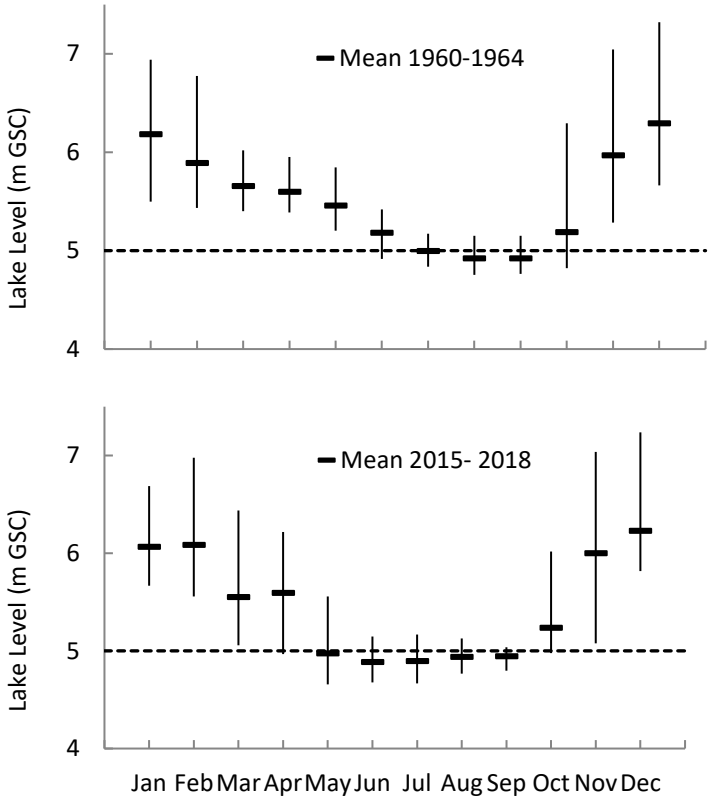


Figure 2: Comparison of Monthly average, maximum and minimum Somenos Lake level during the period 1960-1964 (top) versus 2015-2018 (bottom). The early period was just after the failure of the first Somenos Drainage Board in the late 1950s (Vander Sluys 1986). The latter period is during the time of Parrot's Feather in Somenos Creek.

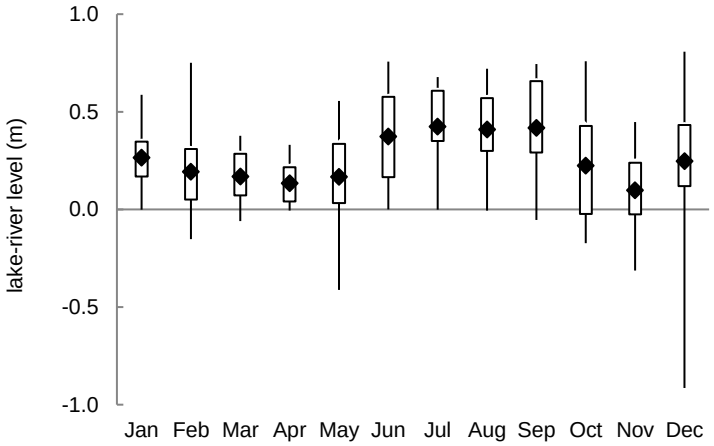


Figure 3: Box-whisker plot of the difference between Somenos Lake level, measured at the Forest Discovery Centre Trestle, and Somenos Creek level, measured at the mouth near the Cowichan River. Data are monthly averages for the period from 2004 to 2018. Black diamonds represent the overall period mean. Boxes represent the ±50th percentiles of the data and the lines represent the maximum and minimum data recorded over the entire period. Data is from Municipality of North Cowichan Engineering.

Chilibeck 2005 and Lyle and O'Connor 2009). Upstream flow, also referred to as 'backwatering' is a common occurrence in Somenos Creek. Figure 2 shows the long term seasonal differences between water level at the head of Somenos Creek, at the lake, and its mouth, at the Cowichan River. Although the difference in elevation of the creek bed between these two points is 600mm, the difference in water level is most often less than half that. In most years, between October and February, there are frequent extended periods in which the water level of the river is significantly higher than that on Somenos Lake.

These backwatering situations develop when the Cowichan River rises more swiftly than Somenos Lake during winter storms. This difference is due to the much larger drainage basin integrated by the Cowichan River. It should also be noted that historical maps show that there were as many as three channels for the Cowichan River Running through what is now the area south of Duncan and North Cowichan, see, *e.g.*, the maps of d'Heureuse (1860) and Land and Works (1898) portions of which are reproduced in the appendix to this report. These morphological changes mean that discharge is now concentrated in one channel where before there had been two or three. This difference is exacerbated by the low elevation of Somenos Lake relative to sea level. During most summers, the surface of Somenos Lake is only 4.5-5.5m above mean sea level.

Another contributing factor to excess water in the Somenos basin arises from the changed nature of Bings Creek's drainage. In both 19th Century maps of the Cowichan Valley it would appear that the majority of what is now defined as Bings Creek used to enter the Cowichan River directly by veering south and travelling down what is now roughly Canada Avenue in Duncan (d'Heureuse 1860 and Land and Works 1898). At some time in the early 20th Century the route of Bings Creek was altered to go into Somenos Lake and hence the Cowichan River via Somenos Creek. Such a step would have been a logical course of action to protect downtown Duncan from winter floods. The net effect on the Somenos Basin would have been to increase the net input of tributary water by about 50%. Because most of the land between Somenos Lake and the Cowichan River was wetlands, marshes and regularly flooded it may not have seemed a bad idea to direct the flow of Bings Creek there.

There is a second period when upstream flow is common in Somenos Creek: in the month of May. This period likely reflects slower drawdown in the surface level of the Cowichan River than in Somenos Lake. This late spring phenomenon was observed by the author in 2018 (Preikshot 2018). It was hypothesised that evaporation on Somenos Lake was in the order of 3mm per day which helped explain why there was upstream discharge in Somenos Creek. Therefore, it seems likely that with earlier and warmer summers becoming more common given predicted climate change effects in British Columbia, the tendency of reverse flow in the early summer may become more common and larger in magnitude.

The effects of this channel morphology were exacerbated in the late 1950s or early 1960s when the confluence of Somenos Creek with the Cowichan River was moved several hundred meters upstream thus reducing Somenos Creek's overall gradient (Lyle, 2009). Engineering diagrams prepared by the Federal Department of Agriculture (McCallum and Thomson 1958) show that in 1958, near the JUB lagoons, the main channel of the Cowichan River turned southeast, see

appendix Map 3 and Map 4. After this time the main channel of the Cowichan River shifted northeast in the area, thus capturing the last 500m of the old Somenos Creek Channel. This had the combined effect of decreasing the total drop of Somenos Creek and subjecting the confluence to more sedimentation than had been the case previously (Lyle and O'Connor 2009).

There has been extensive debate between different stakeholder groups within the municipality as to the underlying cause of 'poor' drainage in the Somenos watershed, in general, and Somenos Creek, in particular. The discussion presented above suggests that pre-existing geographical, hydrological and geological conditions in the Somenos basin have consistently yielded frequent winter and early summer back watering events. It has also been suggested by some members of both the residential and agricultural community that in the summers, beaver dams, aquatic plants and the accumulation of debris in Somenos Creek may be primarily responsible for impeding water movement. However, historical evidence suggests that the issue of poor summer drainage is not new and that it has been associated with other natural mechanisms by biologists, engineers and local farmers.

In 1940 a retired Admiral of the Royal Navy, Rowland Nugent, wrote the following to North Cowichan Municipal Council:

> Gentlemen,
>
> I regret that I have again to call your attention to the congested state of Somenos Creek. On 15th July, I tried to enter the creek in my boat, but found an impenetrable mass of water lilies extending from bank to bank and as far as I could see down the creek, almost completely blocking the flow of water from the lake. These water lilies with roots four inches in diameter will not grow in moving water. They have been encouraged to grow by the neglect of the Cowichan Municipal Council in allowing a private dam across the creek to exist for five years (now removed) also the remains of some old piles under the Trunk road bridge (these have also been removed after some agitation). This dam and the piles almost completely stopped the flow of water down the creek during the summer months.
>
> Though the last two months have been especially dry, the end of my pier is still under water and the water in the lake is at least 18 inches above the former summer level when the pier was built – 10 years ago.
>
> Also, my marsh which used to dry off early in April does not dry off until the first week in June which allows the reeds and canary grass to extend their former limits, and I lose a considerable amount of good grazing ground (Nugent 1940).

This letter is significant in that it points to a situation that would be recognisable to the current day observer: water level in the lake being higher than 'normal'. Obstructions in the creek (piles) were identified as the cause of poor drainage which was exacerbated by the presence of a nuisance aquatic plant (water lilies) which grew in such profusion as to be an impediment to both creek discharge and small water craft. Similarly, M. Miles and Associates Ltd. (2005) note that poor discharge in Somenos and Richards creek was reflected and exacerbated by dense aggregations of Reed Canary Grass in both stream channels.

It may not be too surprising that in a report to the British Emigration Board on the suitability of Vancouver island to colonisation by British subjects, Wells (1859) reported that most of the area in the Cowichan Valley would easily be brought into cultivation with the exception of lands "…lying immediately at the foot of Mount Prevost and Quamichan Mountains [i.e., Mt.

Tzouhalem], where the soil resting on massive rock, has been converted into a spongy wet pabulum, bearing sub-aquatic plants and good for nothing." [sic.] That is to say, the land around Somenos Creek and the south end of Somenos Lake was observed to be mostly wet and poorly drained.

In order to address the drainage situation several programs of diking, dredging and ditching have been implemented in the Somenos Basin over the last 100 years, Chilibeck (2005). References to such work can also be found in the Municipal archives of North Cowichan. An early example of such archival records can be seen in legal advice on the collection of taxes to pay for a bylaw regarding the periodic clearing of Somenos Creek (MacLean 1922). The Somenos basin drainage program created by that bylaw is also referred to in a letter describing the goals of that clearing program (Townend 1940).

The Townend (1940) letter was written in reply to the complaint by Admiral Nugent, see above. Mr. Townend, a local farmer, states that in his experience the lack of discharge in Somenos Creek in the summer was quite normal. In his observations water originating in springs at various points along Somenos creek resulted in odd patterns of apparent 'up' or 'down' stream movement of water at different places along Somenos creek during summer months. In the following quote he describes the complex flow of groundwater into Somenos Creek in the summer (current-day geographic references are in square parentheses):

> People seeing the water under Jaynes Bridge [Trunk Road] imagine it comes from the lake. It does not at this time of year, *i.e.*, summer. If you go up the creek to Kingston's Bridge [near the terminus of York Road] you will find nearly stagnant water. The little flow comes from a spring on McKinnons boundary [Near the Garry Oak Preserve]. At Lakes Road Bridge you will find a very little water flowing. The increase comes from springs on Alexanders [just upstream of the dog park]. At Jaynes Bridge there is quite a nice little flow, mainly from a spring opposite Truesdales [near the foot bridge]. (Townend 1940)

Townend goes on to say that clearing of Somenos Creek was intended to facilitate the movement of winter flood water out of the lake to ensure ample time for farmers to plant in the spring:

> …the idea was to clean out the creek so that the winters flood waters could get away in time for the farmer to get his crops in early enough to be able to cut them in Sept. There was no intention of lowering the summer water level of the lake. Our only objective was the spring level (Townend 1940).

Townend's conclusion as to the apparent persistence of water in Somenos Lake in the summer was that:

> … I WOULD LIKE TO POINT OUT THAT IN THIS HOT DRY DISTRICT [sic.] it is not desirable to reduce the size and depth of our lakes… There is less than two feet drop from the lake to the river, a distance of about one mile. ONLY THE [sic.] most optimistic can hope to accomplish much in the way of lowering the level of the lake.

Thus at a time when Somenos Creek was regularly being cleared the level of water in the lake and the seasonal behaviour of flow in the creek is much the same as that observed in the present, see, *e.g.*, (Preikshot 2018).

Significant dredging and clearing of Somenos Creek began in the early part of the 20th century. Correspondence with a lawyer in Victoria (MacLean 1922) refers to options available to the municipality in collecting taxes from landowners to continue funding clearing operations in

Somenos Creek. This clearing and dredging is the program referred to in Townend's letter. It appears that this work was conducted annually to facilitate drawdown of lake level in the spring from its winter maximum (Townend 1940).

In 1951 the Somenos Drainage Board was established with the goal reducing flood risk in agricultural properties around Richards Creek Somenos Lake and Somenos Creek (Vander Sluys 1986). In the 1980s, under the Agricultural and Rural Development Subsidiary Agreement (ARDSA), the federal government funded significant dredging operations in the Somenos basin (Vander Sluys 1986). This work was responsible for the straightening of Richards Creek and continued the policy of clearing Somenos Creek between the lake and the Cowichan River. More dredging occurred in the early 2000s when a significant portion of Somenos Creek between Tzouhalem Road and the Garry Oak Preserve was re-excavated in the summer or fall of 2004 (Miles 2005). However, Reed Canary Grass was observed growing across the channel very soon after this (Miles 2005) and in the longer term (Lyle and O'Connor 2009). This lush vegetation within the aquatic environment recalls the abundant growth of water lily observed by Nugent (1940). Therefore, it is likely that persistent observations of abundant vegetation in Somenos Creek, despite various dredging and clearing programs, is a product of poor summer drainage conditions, rather than its cause. In 1999 Ted Burns, a fisheries scientist with decades of experience in the Cowichan Valley, noted that:

> Lower Somenos Creek is now largely uninhabitable for salmonids in the summer months due to elevated temperature and oxygen constraints. This is aggravated by low outflows and lack of flushing which is partly caused by large volumes of vegetation clogging the channel. A lack of shade vegetation allows the overabundant growth of grasses in-stream (reed canary grass, sedges, iris, smartweed, and other aggressive aquatic vegetation)" (Burns 1999).

Somenos Creek has been subjected to various activities to improve drainage and keep water flowing through the channel to the Cowichan River in all seasons. The historic record shows that Somenos Creek has been choked with plants regardless of whether it was being dredged or not. Furthermore, dredging and clearing of Somenos creek has not succeeded in promoting the long-term discharge of water from Somenos Lake during the summer. Dredging and clearing in Somenos Creek appear to succeed in lowering the summer lake level for a few years. However, the low grade of Somenos Creek combined with sediment deposition by the Cowichan River in the lower reaches of the Creek work quickly to decrease this effect. As long as the confluence of Somenos Creek with the Cowichan River maintains its current position it appears that continued semi-annual dredging and clearing would be needed to keep summer lake levels similar to their state after the last dredging operation in 2004.

This is not to say that there is nothing that can be done to decrease the prevalence of aquatic plants in the channel of Somenos Creek. Regardless of whether the channel is dredged or not, several studies have suggested that if the channel was shaded by a canopy of large trees there would likely be a significant decline in the abundance of aquatic plants (Preikshot 2016, Lyle and O'Connor 2009, Chilibek 2005, and Burns 1999). This suggestion also has the benefit of improving the quality of salmon and trout habitat in Somenos Creek. This concept will form a large part of the suggested management and research response to Parrots Feather in the subsequent chapters. Although Somenos Creek has always been slow moving we know from oral history that trout and salmon were regular summer inhabitants and that the creek was clean

enough that it was used as a recreational swimming area. Anne Springford, a long-time resident of the Duncan area grew up on Jayne's Road. She recalls that her father cleared a pool in Somenos Creek which they and neighbors used as a swimming hole. She also remembers being taught to fly fish in Somenos Creek (Springford, pers. comm. 1997). Both these activities would be considered challenging at present.

Biology

In addition to being the backbone of a series of wetlands and marshes between Somenos Lake and The Cowichan River, Somenos Creek acts as a migration corridor for juvenile and adult trout and salmon. Somenos Creek harbours a variety of mammals like North American Beavers (*Castor canadensis*), Muskrats (*Ondatra zibethicus*), Minks (*Neovison vison*) and North American River Otters (*Lontra canadensis*) (Williams and Radcliffe 2001). Several species of ducks and geese are also found in Somenos Creek and it is a place where predatory birds like Great Blue Herons (*Ardea herodias*) and Bald Eagles (*Haliaeetus leucocephalus*) come to forage for fish and amphibians. The biology of Somenos Creek is a reflection of its geography. The persistence of water in a valley that is otherwise dry draws many aquatic animals which are found nowhere else in bordering urban and rural environments. This situation was reflected in the intensive use of Somenos Creek and its wetlands by the Ancestors of Cowichan Tribes. Historically, First Nations residents of villages in the area used Somenos Creek as a transportation highway for communication and to access natural resources like fish for food and reeds for crafts (Kulchyski pers. comm. 2018).

Fish

The Somenos Watershed is home to four species of Pacific Salmon: Chum Salmon (*Oncorhynchus keta*), Coho Salmon (*O. kisutch*), Cutthroat Trout (*O. clarkii*) and Rainbow Trout (*O. mykiss*). Somenos Creek, Somenos Lake, its tributaries (Bings, Averill and Richards Creeks), and wetlands form a complex of spawning and rearing habitats as well as adult and juvenile migration corridors for Pacific Salmon.

Chum Salmon adults enter Somenos Creek in October and November and are known to spawn in Bings, Averill and Richards Creeks (Burns 1999). Chum Salmon will also spawn in the channels off Somenos Creek like the creek leading to the Chesterfield area, the wetted areas near the Garry Oak preserve and the channels between the Lakes Road dike and the Creek in the York Road area (Burns 1999). Chum Salmon are very enterprising and the author of this paper has seen them spawning in the ditch running along Canada Avenue which connects to Bings Creek. Chum Salmon fry hatch in late winter and early spring and quickly make their way to the Cowichan Estuary to begin the marine phase of their life history. Somenos Creek thus provides an important migration corridor for both Chum Salmon juveniles and adults.

Adult Coho Salmon ascend the tributaries of Somenos Lake in relatively large numbers to spawn in the late fall and early winter. As many as 150 spawning adults have been observed in Bings Creek and in a good year more than 1000 spawn in Richards Creek (Burns 1999).

Juvenile Coho Salmon spend the first year of their lives in freshwater and Somenos Creek was observed to have some of the highest winter densities of juvenile Coho Salmon in the Cowichan Valley (Fielden and Holtby 1987). These juvenile fish were observed to come from not just the Somenos watershed but the entire Cowichan Valley. Burns (1999) argues that Somenos Creek serves as one of the key overwintering habitats for juvenile Coho Salmon in the Cowichan Valley. Fielden and Holtby (1987) associated the increased use of Somenos Creek as habitat in the fall with the increase in flow in the main stem of the Cowichan River at that time. The authors further noted that the preferred habitat for juvenile Coho Salmon had a riparian tree canopy and woody debris in the channel. This type of riparian habitat is more common in the lower reach of Somenos Creek, south of Tzouhalem Road.

Cutthroat and Rainbow Trout live their entire lives within the Lake and its surrounding streams. Because they remain in fresh water the adult Cutthroat and Rainbow Trout remain quite small ~ 4-6 inches throughout their life in the area (Preikshot 2016). It is likely that each creek around Somenos Lake supports many hundreds of these two trout species. As discussed by Burns (1999) most of Somenos Creek is marginal habitat for Cutthroat and Rainbow Trout in the summer. However, it has been established that the shaded pond in Chesterfield Park supports many trout and salmon throughout the summer (Burns 1999). Also, in the summer of 2018, the lower reaches of Somenos Creek were observed to have many juvenile trout and salmon in a 100m reach between two beaver dams (Preikshot and Kulchyski 2018). It should be noted that both the Chesterfield and lower Somenos Creek areas are heavily wooded and that the water is shaded for most of the day. The water in these two areas is relatively clear and has far less aquatic plant growth than the rest of Somenos Creek

Several other fish species are known to live in Somenos Creek. Wightman (1982) found Somenos Creek to contain Threespine Stickleback (*Gasterosteus aculeatus*), and Prickly Sculpin (*Cottus asper*) in addition to the trout and salmon (discussed above) in a spring survey. A survey by Preikshot *et al.* (2015) found that Threespine Stickleback and Sculpins continued to be found in Somenos Creek as well as the invasive Pumpkinseed (*Lepomis Gibbosus*). In the latter survey Pumpkinseed were observed to be, by far, the most abundant fish species. The success of invasive fish species in Somenos Creek thus appears to mirror the success of the invasive aquatic weeds. The scale of dominance that Pumpkinseed exerts on aquatic habitats in the Somenos Watershed can be seen in results from a beach seine conducted in Somenos Lake in June 2015 (Preikshot 2016). A beach seine conducted on a $100m^2$ plot yielded 1257 adult Pumpkinseed, 1272 juvenile Pumpkinseed, 405 Peamouth Chub and 24 Brown Bullheads. Therefore, in the nearshore of Somenos Lake, Pumpkinseed may represent 85% of the fish present by number and (given estimated weights) 97% of the total fish biomass in the summer. It is likely that the situation in Somenos Creek is similar for much of the year.

Mammals

Beavers are known to be native residents of Somenos Creek (Burns 1999) and they are found along the entire run of Somenos Creek. Their present-day damming activity, however, appears to be confined to the lower reaches of the Creek (Preikshot and Kulchyski 2018). It is likely that a portion of the recent rise in the mean summer level can be attributed to the activity of these

creatures. Although it was common in the past to remove dams and/or trap beavers to reduce the summer minimum level of Somenos Lake, Cowichan Tribes has recently expressed reticence towards the continuation of this policy (Kulchyski pers. comm.). Preikshot and Kulchyski (2018) note that removal of the beaver dams could facilitate the spread of Parrots Feather into the Cowichan River and Fish Gut Alley (an important juvenile fish rearing area). It is unclear whether the complete cessation of beaver management might encourage damming activities in other parts of the Somenos watershed.

One partial solution to the conflict between lake drainage and creek conservation may be the use of a 'beaver baffler'. This device consists of a pipe connecting the upstream dammed area to the downstream channel and can serve to increase flow across the dam without dam removal. The upstream side of the pipe can be surrounded by a protective cage in order to prevent the beavers or random debris from clogging the pipe. Use of a cage or mesh would also reduce the possibility of downstream movement of Parrots Feather fragments. A caged pipe system may thus be effective in promoting summer drainage from Somenos Creek to the Cowichan River while reducing the risk of spreading Parrots Feather beyond Somenos Creek. However, the expense of such a policy may be increased if there is an increase in the number of beaver dams if the current trapping policy is suspended.

There is a possibility that beaver dams may impede the passage of salmon during their adult and juvenile migrations. The height of the beaver dams in 2018 was estimated to be about 20cm, downstream dam, and 50cm, upstream dam (Preikshot and Kulchyski 2018). Given that the creek level rises about 2m (200cm) during the winter, fish passage is unlikely to be affected by the dams if they remain in place. It is also likely that significant portions of the dams are carried away during high flow events in the fall and winter thus facilitating the downstream movement of juvenile Coho, Chum and Chinook Salmon in the late winter and early spring. This sequence of events is consistent with observations of very high densities of Coho Salmon in lower Somenos Creek during the late winter by Fielden and Holtby (1987)

Aquatic Plants

By aquatic plants the author is referring to vascular plants not single celled algae. Single celled algae are most often seen in the creek as mats of diatoms growing on rocks or layers of cyano-bacteria (also called blue-green algae) on the surface of the water. An overabundance of aquatic plants can alter creek habitat and render it harmful to fish, interfering with recreational use by residents and visitors and compromising the aesthetics of surrounding properties.

There are eight prominent species of aquatic plant found in Somenos Creek; Parrots Feather (*Myriophllum aquaticum*), Mare's Tail (*Hippuris vulgaris*), Potamogeton (*Potamogeton richardsonii*), Common Duckweed (*Lemna minor*), Water Lily (*Nymphaea spp*.), Cattail (*Typha latifolia*), Eurasian Milfoil (*Myriophyllum spicatum*) and Reed Canary Grass (*Phalaris arundinacea*). These plants can be divided into three growth habits;

- primarily below the water surface, *e.g.*, Eurasian Milfoil and Potamogeton
- primarily on the water surface, *e.g.*, Common Duckweed and Water Lily and
- emergent from the water surface, *e.g.*, Mare's Tail, Cattail and Reed Canary Grass.

By dividing up the available aquatic habitat these plants can leverage their adaptations to specific niches to grow and reproduce. Parrot's Feather is remarkable in that is has two distinct growth phases, subsurface and emergent and is very tolerant to drying (Wersal and Madsen 2011). As we shall see below, this plasticity endows Parrot's Feather with an ability to change how it competes with other species for resources. Parrot's Feather's ability to grow on partially dried riparian habitat can give it a head start on other species before flooding events or allow it to persist when other aquatic plant species dry out.

Somenos Creek has long been subject to very low flow and high temperatures in the summer (Burns 1999, Preikshot 2016). This hydrological situation has been manifested in the abundant growth of aquatic plants. Indeed, a major justification for dredging in the early 2000s was to remove abundant plant material from the creek (Miles 2005, Lyle and O'Connor 2009). At various times Somenos Creek has been noted to be overgrown or choked by aquatic plants such as:

- Water Lily (Nugent 1940),
- Duckweed (Fielden and Holtby 1987),
- Sedges, Iris and Smartweed (Burns 1999),
- Reed Canary Grass (Miles 2005 and Lyle and O'Connor 2009), and
- Parrots Feather (Preikshot 2018).

While it might be suspected that such plant growth might improve aquatic habitat for fish the opposite is usually found o be the case. The most important consequence for fish in the summer is that in habitats overgrown by aquatic plants, oxygen concentrations can often be close to zero. It may seem counterintuitive that plants, which produce oxygen, could be associated with reducing oxygen concentration in the water column. However, in most small streams the movement of water over riffles and the creation of waves and ripples by the wind promote mechanical mixing and cause atmospheric oxygen to enter the water column. In slow moving streams the main way for atmospheric oxygen to enter the water column is by diffusion across the water/air boundary which is less efficient than mechanical mixing. This diffusion is more difficult in the summer because the solubility of oxygen in water declines as temperature rises. Therefore, the timing of inefficient mixing of oxygen into the water coincides with the time at which oxygen solubility is lowest.

Aquatic plants, like those noted above, concentrate their biomass at the surface of the water which creates a physical barrier that may further lower the diffusion rate of oxygen into the water column. Plant growth at or near the water surface results in much of the oxygen production being respired to the atmosphere. The small amount of oxygen that is makes its way into the water column is quickly consumed by bacteria that decomposes dying plant material.

General Ecology of Parrot's Feather

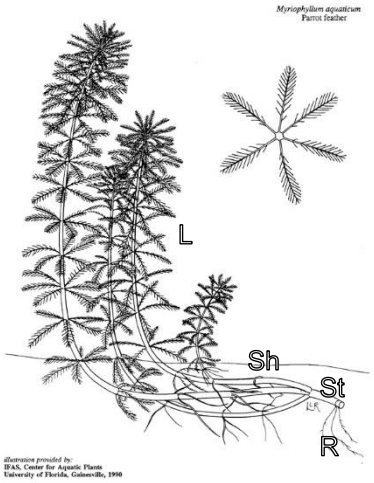


Figure 4: Parrot's Feather morphological characteristics. This drawing is courtesy of the University of Florida Center for Aquatic and Invasive Plants. Key parts of the plant are; the shoots (Sh), stolon (St) leaves (L), and roots (R). Not shown are submerged leaves which grow on the submerged shoots and stolon.

Parrot's Feather is an aquatic plant native to the Amazon Region of South America (Invasive Species Council of British Columbia 2015 and Rhode Island Department of Environmental Management 2017). Parrot's Feather is commonly found in eutrophic water bodies, *i.e*., high in nitrogen and or phosphorous compounds with a particular affinity for relatively high nitrogen concentrations, >1.8mg/l and high ratios of nitrogen to phosphorus (Euphresco Declaim 2011). It is also able to grow as a terrestrial plant during summer periods of very low water (Kelly and Maguire 2009). Both these observations are true of Parrot's Feather in Somenos Creek. M. aquaticum is capable of rapid growth and dispersal which allows it to displace native plant species, reduce biodiversity, limit recreation, diminish aesthetic value, and decrease water quality and flow. As described above, Parrot's Feather can grow across a variety of aquatic habitats. Given adequate sunlight it is almost constantly growing below water, above water and even on dried beaches. This ability allows Parrots Feather to have leverage a competitive advantage over other aquatic plants as water levels change rendering growth conditions suboptimal for those other species. In the aquatic environment, Parrot's Feather has two morphotypes, a single stem with relatively large leaves when submerged and a dense waxy canopy of fronds which extend above the water surface. Thus, the formerly submerged stems become long roots for the dense emergent canopy (Moreira *et al.* 1999).

Reviews of Parrot's Feather biology do agree that it does not thrive in water that remains relatively deep (> 1.5-2m). In Ireland, Parrot's Feather has become established in lakes and ponds but is observed to grow best in relatively shallow (<1.5m deep) and nutrient rich water bodies (Department of Conservation and Recreation, 2004). Moreira *et al.* (2011) present a review of studies that found best growth in waters less than 1m deep. In a study examining the effect of water depth on Parrot's Feather, Wersal and Madsen (2011) found that growth and biomass were both highest in shallow water and hypothesize this is a function of deeply submerged leaves (water depth >1.37 m) not receiving enough sunlight to grow at greater depths to get emergent shoots to the water surface.

Parrot's Feather does not grow well when the water temperature is below 8ºC. In the Somenos basin this would be the period between late October and early April, See Figure 5. Because it is native to the Amazon, Parrot's Feather has little protection from typical winter conditions on Vancouver Island. It has been observed that the emergent shoots die quickly in frost due to the rupturing of cell walls (Euphresco Declaim 2011). Evergreens native to Vancouver Island survive the winter freeze by moving water out of cells and replacing this with fat and by having cell walls that can withstand high pressures resulting from the crystallisation of water. In all of

the winters since the introduction of Parrot's Feather to Somenos Creek there have been significant die backs of emergent shoots (personal observation). This means that the extent of Parrot's Feather coverage of the creek will be at a minimum in April. This period will likely be

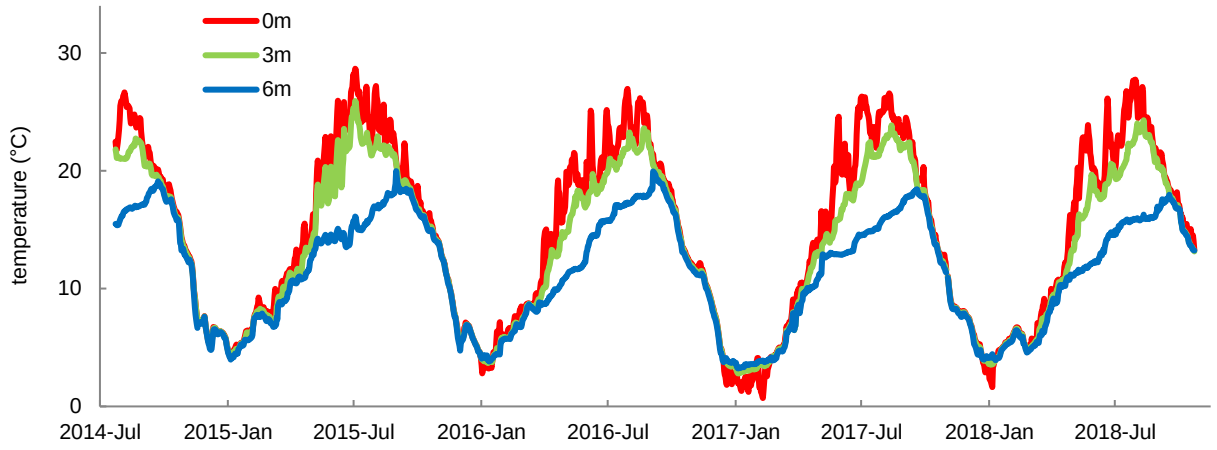


Figure 5: Daily Mean temperature in Somenos Lake at 0, 3, and 6m, July 2014-Oct 2018. Data collected hourly from temperature loggers maintained by the Somenos Marsh Wildlife Society at a station near the lake centre.

significant for many management policy options like shading and pulling.

A typical year the life history of Parrot's Feather is described by Euphresco Declaim (2011) as the following seasonal stages:

- Spring: when water temperatures rise above 10°C, adventitious roots develop at individual stolons usually with two or three roots per node. Submerged shoots develop only after these roots have formed (see below). New submerged type shoots start to develop from nodes on overwintering stolons. The stems and leaves are red in colour due to pigmentation to absorb excessive UV light. There are no obvious signs of emergent material at this time, and emergent leaves start to appear once all signs of frost have past, usually in mid to late May.
- Summer: the emergent leaves have formed and dense carpets of plant material grow close to the bank, with mounds appearing to spread outwards. The most active growth occurs at the apical tips of the plant, so the edges of the mat and the top surface of the mat tend to reach out into the water, followed by submersion of older stems which then grow more adventitious roots and more shoots which eventually become emergent, maintaining the apparent health of the mat.
- Fall: the growth rate declines and mats start to fragment, causing viable propagules to be spread within and between systems. Fragmentation in autumn, when the plant still retains the capacity to regenerate rapidly, is considered to be the most important time for vegetative spread. The underside of the dense mat will become senescent and start to die back, leaving only the stolons intact under the water. These survive through autumn and over winter and form the basis for new growth in the next spring.
- Winter: after the first frost, emergent leaves collapse because of damage to cell membranes that cause irreversible loss of turgor. The plant overwinters as submerged stems and stolons. Fragments released in autumn overwinter on the sediment surface and grow again in spring.

In aquatic ecosystems invaded by Parrot's Feather, dense floating mats form on the water's surface, restricting light, thereby excluding native plants. Decreasing the air exchange between

the water's surface and the atmosphere. Moreira *et al.* (1999) report that, in areas of Parrot's M. aquaticum• may form dense single species stands that often do not provide ideal habitat or food Parrot's Feather has several negative impacts on native plant and animal species:

- for native wildlife it may limit access to the water and native wildlife populations may be forced to relocate or perish,
- a loss of biodiversity,
- shading causing a decline in algae serving as the base of the local food web,
- disruption in the balance of the ecosystem.
- increase sedimentation degrading fish habitat,
- interference with fish production,
- interference with fish passage,
- potential increase of mosquito reproduction, and
- anoxia.

The thick mats of Parrot's Feather can prevent fishing, boating, swimming and other activities in a ponds and lakes resulting in economic losses to the surrounding community. The loss of recreational and aesthetic value can cause a decline in surrounding property values.

Effects of Parrots Feather in Somenos Creek

Parrots Feather was first recognised in the natural environment of British Columbia in 1980 (Invasive Species Council of BC 2015). In the years between then and the preparation of this report it is known to have been released into pond, ditches, and stream habitats of several jurisdictions in British Columbia including:

- the City of Richmond,
- the Town of View Royal,
- the City of Abbotsford,
- the City of Burnaby,
- the City of Pitt Meadows and
- the City of Chilliwack

Decision makers in these jurisdictions have come to realise that there are no management options for the swift and cost-effective eradication of this aquatic weed. At the time of preparation of this report, civic governments in the lower mainland of British Columbia were considering a special application to Health Canada to grant permission to use Triclopyr (3,5,6-Trichloro-2-pyridinyloxyacetic acid) (Chadburn pers. comm. 2018) The application of herbicides in aquatic environments is strictly controlled in Canada. Thus, the widespread desire of BC municipalities to explore the use of herbicides should indicate the gravity of the situation facing any jurisdiction in which Parrot's Feather has become established.

The likely mode of introduction of Parrot's Feather into Somenos Creek was fragments from a backyard pond or dumping of unwanted aquarium plants. As recently as 2017, Parrot's Feather has been known to be on sale in garden stores in the Cowichan Valley (personal observation). Not too surprisingly one the major selling features of Parrots Feather is its ability to thrive in ponds and provide lush expansive growth with limited maintenance. Its presence in backyard ponds of the Cowichan Valley is suggested by an online post on 'September gardening tips' by the Cowichan Valley Garden Club. In that post, Cowichan Valley gardeners with Parrots Feather in their water features were advised to "Remove excess parrot feather – leave the rest in a pot on the bottom." (Grahame, J. and Grahame, W. 2014). Given that the internet post was determined to have gone online in 2014 it is very likely that many gardeners in the Cowichan Valley had Parrot's Feather as a major component of ponds on private land. The regular winter flooding of Somenos Creek inundates significant portions of many backyards in adjacent properties. It is, therefore, easy to see how a fragment of Parrot's Feather in a backyard pond garden may have been carried by receding flood water back to Somenos Creek.

Figure 6: Extent of Parrot's Feather infestation in part of Somenos Creek based on monitoring sites visited in June 2017. The head of Somenos Creek, at Somenos Lake, can be seen just above the point of the North arrow. The yellow lines indicate the extent of continuous growth at Site 1 in the northwest and Site 14 in the southeast. Figure from Preikshot (2018).

Figure 5: Parrot's Feather patch in Somenos Creek near Seine Road. This raft is typical of patches between the Garry Oak Preserve and the Lakes Road footbridge

Parrots Feather in Somenos Creek occurs as patches usually between 10 to 20m^2, see Figure 5. Exceptions occur near the Garry Oak preserve and the Tzouhalem Road bridge. At these locales extensive Parrots Feather mats occur which cover the entire wetted width of the channel. The one near the Garry Oak preserve is by far the largest covering about one fifth of a hectare over 400 lineal meters of Somenos Creek. Two patches one North and the other South of the Tzouhalem Road Bridge Both of these patches cover several hundred square meters, see photo XX in the appendix.

Because of this situation several studies have recommended that a canopy of tall shade trees would be a simple and cost-effective long-term approach to mitigating the overabundance of aquatic plants in Somenos Creek (Burns 2009, Chilibeck 2005, Lyle and O'Connor 2009, and

Preikshot 2016). Such a shade canopy would also help restore salmon habitat by lowering water temperatures thus increasing oxygen solubility and removing the aquatic plant barrier to the atmosphere. If combined with beaver dam mitigation devices, see above, a shaded and slowly flowing Somenos Creek would provide greater opportunity for trout and salmon to find rearing habitat in the summer and facilitate their movement between habitats and migration as juveniles and adults.

Table 1: An inventory of the density and extent of Parrot's Feather at monitoring sites along Somenos Creek on 19 June, 2017, see Figure 6. Note that at Site one Parrot's feather was continuous for approximately 500m at site 1 and 150m at site 14. Estimations of total and infested area assumed that the wetted width of the creek was 5m at the time of the survey. Total index area was estimated as the distance from the head of the creek, at Somenos Lake to the observed end of the patch at site 14 (2,050m) multiplied by 5m wetted width.

Site	**Latitude**	**Longitude**	**% cover**	**m^2**
1start	48.7913	-123.7009	90	2025
1end	48.7889	-123.6961	25	62.5
2	48.7887	-123.6952	10	10
3	48.7878	-123.6937	10	10
4	48.7872	-123.6915	20	10
5	48.7869	-123.6900	10	20
6	48.7865	-123.6889	20	10
7	48.7858	-123.6874	10	5
8	48.7858	-123.6878	20	5
9	48.7858	-123.6871	10	5
10	48.7858	-123.6862	20	20
11	48.7858	-123.6862	20	20
12	48.7854	-123.6852	10	10
13	48.7850	-123.6839	33	20
14start	48.7848	-123.6838	30	60
14end	48.7837	-123.6832	80	400
		total Parrot's Feather area (m^2)		2,693
		total estimated index area (m^2)		10,250
		% infested area		**26.27**

Control Methods

Several control methods are available for Parrots Feather. A brief description of each is provided below. Management options for Parrots Feather control are generally categorised as physical, chemical and biological. The unique characteristics of the Parrot's Feather infestation in Somenos Creek means that much prior experience with control of this species are less likely to be effective here. For example, most Parrot's Feather infestations in BC are in small ponds and drainage ditches (ISC 2015). These types of systems can easily be isolated from their surrounding environment and subjected to rather vigorous intervention. For example, Ducks Unlimited has initiated a dewatering experiment at the East Marsh of the Serpentine Wildlife Management Area to eradicate Parrot's Feather (Ducks Unlimited Canada 2018). In this experiment the marsh was dried completely for several years and burlap put on remaining moist areas to kill remaining Parrot's Feather. Somenos Creek is also unique in that the extent of Parrot's Feather infestation is far large than any of the other instances. For small ponds and ditches options like chemical control or dredging can be conducted at a very fine scale which addresses each plant. Somenos Creek has side channels unlike ditches and covers a far larger area than the ponds infected elsewhere.

Therefore, Parrot's Feather is unlikely to be eradicated in Somenos Creek. However, by using a variety of the management options described below and engaging some low cost but informative research and monitoring it is likely that a plan can be enacted to effectively control Parrot's Feather. The benefits of Parrot's Feather control include restored function of the ecosystem to support trout and salmon, improved drainage, better access for recreational users and improved values for local properties.

Physical

Pulling, dredging, and vacuuming are expensive but can remove up to 95% of aquatic plant biomass from a given area in a relatively short time. However, dredging and vacuuming are also associated with a high financial cost which must be borne every 4 or 5 years, because Somenos Creek is subject to constant sedimentation and will experience regrowth of Parrot's Feather to its original extent. The provincial government has also informally expressed reluctance to engage in any management operations in which volunteers or paid workers physically pull out Parrot's Feather plants due to the potential threat of further colonisation by fragmentation Chadburn, Pers. Comm 2018). Dredging would also create large and significant disturbance to aquatic and riparian habitat. Past dredging in Somenos Creek has also been associated with disturbances to socially significant sites for Cowichan Tribes.

Smothering is simply putting materials such as pond liner and tarps over patches of Parrots Feather. The time required to completely kill the smothered Parrot's Feather can be up to two or three years to exhaust the energy stored by roots and rhizomes. Implementation of such a program would be very strait forward and very low cost.

As with smothering, shading is meant to deprive the Parrot's Feather of energy. Shading with tree's however is a long-term project that will require decades to restore the Creek to a state in which overhanging branches allow through little light and impede the growth of all aquatic

plants. Planting trees in the riparian zone of the creek would be low cost and could be an effective means to engage members of the community to participate in management activities by helping with planting efforts.

Portions of Somenos Creek remain relatively unaffected by Parrot's Feather. If the characteristics of these reaches could be identified, it may be possible to modify the creek channel in such a way to make currently infected reaches more hostile to Parrot's Feather. Limited channel dredging and deepening should have minor environmental impact but will likely carry a relatively high cost.

As described above for East Marsh in the Lower Mainland, dewatering may be an effective way to remove Parrot's Feather from and ecosystem. However, It is almost impossible to imagine how the connection between the Somenos watershed and the Cowichan River could be moved for three or four years to dry the creek bed. Therefore, we must assume that this option would carry extreme financial, social and capital costs rendering it moot.

Chemical

Although a range of candidate chemicals exist to control aquatic plants extensive research has demonstrated that only two appear to have some efficacy in controlling Parrots Feather Glyphosate and Triclopyr. Regardless of efficacy, the use of chemical agents to control Parrots Feather may prove to be difficult in Somenos Creek. Application of almost all aquatic herbicide will involve a special licensing and permitting process due to provincial and federal restrictions on the use of such chemicals in most aquatic habitats. However, many other countries do not have as stringent controls on the use of aquatic herbicides as Canada. Consequently, there is literature, especially from New Zealand and the United States, assess the success of these chemicals in controlling Parrot's Feather.

From a practical perspective the scale of application would be rather large. As indicated by the 2017 Parrots Feather covered at least 2700m^2 of the creek at the beginning of summer and it is likely that the infested area had doubled in size by the end of the summer based on subsequent observations by this researcher. As an estimate of the maximum potential application area, the total aquatic habitat of Somenos Creek in the winter is about 6 Ha. This is a relatively large area compared to experience with Parrots Feather in other jurisdictions in British Columbia. In most other municipalities Parrots Feather infestations have been noted in isolated ponds, drainage ditches and intermittently wetted streams. Therefore, experience gained in those places may not be helpful in formulating a control plan for Somenos Creek.

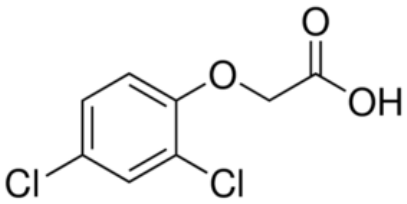
Due to its shallow gradient, see above, Somenos Creek has very low discharge and stream velocity. This may aid in the localisation of chemicals distributed to control Parrots Feather. It is, however, also possible that chemical agents may spread into Somenos Lake and agricultural ditches connected to Somenos Creek.

A significant portion of public opinion is likely to be strongly opposed to the application of chemicals, even in the cause of controlling an invasive aquatic weed. The position of other significant stakeholders such as Cowichan Tribes will also need to be taken into account.

Assuming that permission is granted by Health Canada to other jurisdictions to use Triclopyr it may be instructive to note the degree of public acceptance or rejection of the use of this chemical to control aquatic invasive plants. Integrated Pest Management Regulation (B.C. Reg. 604/2004).

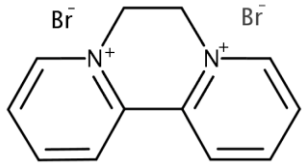
The four chemicals described below are the most commonly used in Parrot's Feather control programs elsewhere (Hofstra *et al.* 2006, Wersal and Madsen 2010, and Champion *et al.* 2011). However, studies show that while application of these chemicals can quickly and dramatically lower Parrot's Feather biomass, repeated application is often needed within days to kill missed spots. The likelihood of missing aggregations in Somenos Creek is likely quite high. Furthermore, studies also show that Parrot's feather is never entirely killed off and that applications may be needed as re-infestation occurs. Trials by Hofstra *et al.* (2006) showed that after one year most treated Parrots Feather sites had regrown to previous extents.

2,4-D



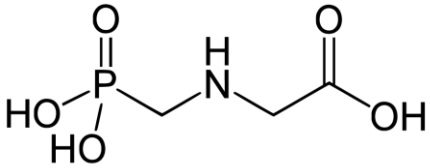
2,4-D (2,4-Dichlorophenoxyacetic acid), sold as AquaKleen, Navigate and Hardball, is one of the oldest herbicides available for use and has been in the market since the end of Word War 2.

Diquat



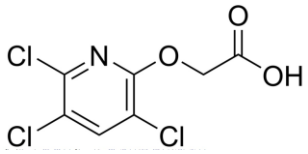
Reward, a commercially available form of Diquat (6,7-Dihydrodipyrido pyrazinediium dibromide), is currently the only herbicide registered for use in aquatic environments in Canada.

Glyphosate



Glyphosate (N-phosphonomethylglycine), sold as Roundup, Rodeo, and Aquapro, is registered for use by Health Canada, and is quite popular for use in agricultural applications. In B.C. glyphosate can only be used with an approved pest management plan, which includes public consultation and application is restricted such that there is a significant buffer between affected land and adjacent aquatic habitat. Testing indicates that Glyphosate does not give good control of a range of rhizomatous or stoloniferous species such as Alligator Weed (*Alternanthera philoxeroides*), Parrot's Feather (*Myriophyllum aquaticum*), Water Primrose (*Ludwigia spp*.) and Manchurian Wild Rice (*Zizania latifolia*) (Hofstra *et al.* 2003, 2006; Champion & Hofstra 2006; Meisler 2008 and Champion *et al.* 2011).

Triclopyr



Triclopyr (3,5,6-Trichloro-2-pyridinyloxyacetic acid), sold as Garlon 360 and Renovate 3, has become relatively popular in recent years to deal with invasive aquatic species like Parrot's Feather.

Table 2: Recommended application rates and total estimated application dose for Somenos Creek for commonly used herbicides and their commercial forms. Total dose is provided in the metric equivalent and assumes that Somenos Creek has a total surface are of ~6 Ha and an average depth of 1.5m. This table is adapted from information in Madsen and Wersal (2019).

Herbicide	Trade name(s)	Application rate	Type of Chemical	Min Dose	Max Dose
2,4-D	DMA-4 IVM	2-4 quarts/acre	Selective systemic	28 L	55 L
	Aqua-Kleen	100-200 lbs/acre		3213 kg	6426 kg
	Navigate	100-200 lbs/acre		3213 kg	6426 kg
	Hardball	10-20 quarts/acre		138 L	276 L
Diquat	Reward	8 quarts/acre	Broad spectrum contact	110 L	
Endothall	Aquathol K	4-8 quarts/acrefoot	Broad spectrum contact	272 L	543 L
	Auquathol Super K	8-13 pounds/acrefoot		1265 kg	2056 kg
Glyphosate	Rodeo	2-5 quarts/acre	Broad spectrum contact	28 L	69 L
	AquaPro	2-5 quarts/acre		28 L	69 L
Imazapyr	Habitat	1-3 quarts/acre	Broad spectrum systemic	14 L	41 L
Triclopyr	Renovate 3	3-8 quarts/acre	Selective systemic	41 L	110 L

Biological

North American Beaver

Recent research suggests that North American Beaver (*Castor canadensis*) can consume significant quantities of aquatic vegetation, including Parrots Feather. An enclosure study at a wetland near Atlanta Georgia demonstrated that North American beavers could remove up to 90% of Parrots Feather biomass (Parker *et al.* 2007). The authors suggest that such activity implies a significant contribution by aquatic herbivores to mitigating ecosystem effects of invading plant species. Despite this optimistic assessment it is uncertain that beavers in their natural habitat with an abundance of other, potentially more desirable food sources, would

consume Parrot's Feather at such rates. It is certainly the case that in the time since Parrot's Feather was introduced to Somenos Creek beavers appear to have done little to slow the spread of the invasive plant. It may also be possible that some time may be required for beavers to learn that Parrot's Feather is a viable food option. Another concern is the potential of beavers to move Parrot's Feather fragments to new habitats in watersheds surrounding the Somenos basin by attachment to the woody debris they use to construct dams and lodges.

In the case of Somenos Creek such herbivory may be useful as a means of limiting established Parrot's Feather colonies. Diet studies show that an adult North American Beaver can consume between 1 to 2 kg of plant material a day (Campbell-Palmer, R. and F. Rosell 2015). Research in Michigan suggests that about 50% of North American Beaver diet is floating aquatic plants (Severud 2011). North American Beavers therefore have the potential to remove a portion of the Parrots Feather biomass in Somenos Creek, but this portion is likely low given the observed growth of Parrots Feather up to the time of this report's preparation. It is quite likely that North American Beavers currently avoid Parrot's Feather as food in Somenos Creek, given the choice of other food items. It should also be noted, therefore, that any planting of trees in the riparian zone of Somenos Creek may be subject to the activities of beavers to remove them for construction material of dams and lodges.

The use of introduced parasites, viruses, and predators to control Parrot's Feather has been examined but here has been limited success with such programs Moreira et al. (1999) and Euphresco Declaim (2011). Furthermore, the federal and provincial governments would likely require an exhaustive research program to justify such a policy.

As a larger scale environmental program, the reduction of nitrate in in the water column would be an effective way to control the rapid growth of Parrot's Feather. As described by Wersal and Madsen (2011) Parrot's Feather growth is positively correlated to the concentration of Nitrogen compounds in the water. Many people in the Cowichan Valley are familiar with the positive correlation between phosphorous and blue-green algae in Somenos Lake (Preikshot 2016). The superabundance of nutrients like phosphorus and nitrogen therefore needs to be considered for any meaningful management response to invasive aquatic plants and cyanobacteria. Such nutrient control, however, will also require the attention of federal and provincial agencies and serious consideration of land use policies in the areas surrounding Somenos Lake and Somenos Creek. Control of nitrogen concentration will reduce the total possible biomass of Parrot's Feather and lower the cost of programs designed to control the spread and abundance of Parrot's Feather.

Legal Issues

Parrot's Feather is not currently on the list of noxious weeds within all regions or the list of noxious weeds within the boundaries of named regional districts in the *Weed Control Act* (Government of British Columbia 1996). Nor is Parrots Feather on the BC Proposed Prohibited Noxious Weeds List as of the last available revision (British Columbia Ministry of Forests Lands and Natural Resource Operations 2016). This means that, at present, there is no obligation on the part of either the municipal or provincial government to enact specific regulatory responses to the presence of Parrots Feather in Somenos Creek. Placement on the list would compel the

provincial government to allocate funding and enforcement activities to the control of Parrot's Feather. Given the extreme hesitancy that governments have place on the allocation of funds to environmental programs it seems unlikely that, even in the event of placement on the Noxious Weed List, the provincial government would actually be capable of allocating sufficient financial or capital assets to initiate long-term monitoring and management plans for Parrot's Feather.

By way of comparison, in Washington State Parrots Feather is classified as a Class B Noxious Weed (non-native species). This designation means that Parrot's Feather is recognised as being:

"…harmful to environmental and economic resources that landowners may be required to control based on distribution in the county and local priorities…" (*Noxious Weed Law, Revised Code of Washington 17.10*, Washington State Legislature 1975).

Therefore, it may be of some value to the municipality to consider lobbying the provincial government for inclusion of Parrots Feather on the Noxious Weeds List. Because the City of Richmond and the Town of View Royal have both had to deal with Parrots Feather infestations a strategic partnership could be developed. The partnership could demonstrate that the repeated infestation of aquatic and terrestrial habitats by invasive aquatic plants has very high costs associated with repeated management responses to repeated and preventable infestations. Collaboration with other municipalities on Parrot's Feather control and management would thus have four aspects:

- lobbying the provincial and federal government for funding to remediate Parrots Feather infestations,
- prohibition of the sale of Parrots Feather and other invasive species,
- provision of resources for enforcement of ban on invasive species sales, and
- pooling resources and personnel for the monitoring and management of Parrots Feather.

There are many Federal, Provincial and municipal laws, regulations, ministries, department agencies and bylaws that involve direct and indirect management and monitoring of invasive plants in British Columbia (Table 2). Unfortunately, action on invasive species has lagged the crafting of legislation. Regardless, there is a well-established set of rules within which local authorities and partners can decide how to best use their resources to act on invasive species like Parrots Feather.

Therefore, it seems prudent to expect that if the issue of Parrot's Feather is to be addressed, the initiative will likely rest in the Municipal rather than the federal or provincial governments. This is not to say that if the Municipality of North Cowichan takes the initiative in managing Parrot's Feather that it ill be left to its own devices. Because the majority of legislation on invasive species is generated at the federal and provincial levels, the senior level of government will likely be compelled to provide financial and capital assets to aid in a proactive, reasoned and responsible management plan to address Parrots Feather.

For example, *An Invasive Alien Species Strategy for Canada* (Government of Canada 2004) was tabled by the federal government but only appears to have been followed up with the

Invasive Alien Species Partnership Program which ran from 2005 to 2012. In that time $CDN 5.6 million was allocated to 170 projects across the country, i.e., about $CDN 33,000 per project. This modest level of funding has been discontinued so there has been no explicit federal funding dedicated to alien invasive species in Canada for seven years prior to the preparation of this report.

It is likely that the federal government will be compelled to provide support for a Parrots Feather management plan if it is demonstrated that Parrot's Feather poses a barrier to the migration of either adult or juvenile Pacific Salmon species like Chum and Coho salmon. Therefore, necessary components of a Parrot's Feather management plan will be:

- monitoring work to define the baseline extent of Parrot's Feather infestation in Somenos Creek,
- monitoring work to define annual changes in Parrot's Feather abundance in Somenos Creek to identify management successes and failures,
- research programs in the field to test the efficacy of different management options,
- adoption of a research-based management program which uses monitoring data to inform and refine management policy, and
- Development of a reporting protocol to keep the public apprised of the goals of a Parrot's Feather management program and the progress towards achieving those goals

Table 2: Agencies and departments tasked with preventing and responding to invasive species in Canada and British Columbia. Information taken from Invasive Species Council of British Columbia (2014) with elements highlighted that are of relevance to Parrot's Feather.

Government Level	**Legislation**	**Ministry/Department/Agency**	**Notes**
Federal	Pest Control Products Act	Health Canada's Pest Management Regulatory Agency	Responsible for the regulation of pest control products in Canada
Federal	Canada National Parks Act	Parks Canada	
Federal	An Invasive Alien Species Strategy for Canada, Canadian Environmental Protection Act	Environment Canada	Leading an Invasive Alien Species Strategy for Canada
First Nations	Various	Various	Numerous Acts. Many pertaining to land jurisdiction across Canada and BC. Nations, Councils or Bands involved in consultation regarding management of Aboriginal peoples and other lands
Provincial	Integrated Pest Management Act	Ministry of Environment and Climate Change Strategy	
	Weed Control Act/ Forest and Range Practices Act	Ministry of Forests, Lands and Natural Resource Operations	Compliance and Enforcement Division has authority to respond/ address multi-ministry legislation
Municipal	Local Government Act	Municipal Departments	
Non-governmental organisations	Societies Act	Invasive Species Council of BC, Non-Profit Organisations	Agencies and groups involved in invasive species management dealing with provincial-level issues, multiple agencies, and stakeholders

Baseline Monitoring, Control, and Research Operations

Baseline Monitoring

The quantitative and objective monitoring of Parrot's Feather and Somenos Creek is the single most important activity that can be carried out by the Municipality of North Cowichan and its partners. At present the majority of necessary monitoring work is already being conducted by the Somenos Marsh Wildlife Society (SMWS), see, *e.g.*, Preikshot (2018). The SMWS Parrot's Feather Program has initiated work to monitor the location of Parrot's Feather patches in Somenos Creek. This monitoring work will hopefully be augmented by partnerships with the Municipality of North Cowichan and Collaboration with federal agencies, *e.g.*, Fisheries and Oceans Canada, and provincial agencies, *e.g.*, Forests, Lands, Natural Resource Operations and Rural Development, Environment & Climate Change Strategy, and Agriculture.

Due to the negative effect that relatively deep water ≥2m has on Parrot's Feather growth, baseline monitoring work should also include a survey of bathymetry to identify where channel modification may be possible to discourage Parrot's Feather. Bathymetry investigations can either be done in direct association with Parrot's Feather or as a more formal and extensive engineering survey which may also be used to assess larger drainage questions in the watershed. An informal survey of channel characteristics in reaches with Parrots Feather is likely sufficient for the purposes of this management plan. However, Somenos Creek has likely undergone significant changes in its channel since the last survey (Chilibeck 2005).

At present SMWS has the capacity to monitor the following parameters in the aquatic environment:

- Temperature,
- Dissolved oxygen,
- Total dissolved solids,
- Conductance, and
- pH

These five parameters are very informative for determining the capacity of a given habitat to support trout and salmon (Preikshot 2016). Monitoring for these parameters should be conducted weekly in the summer and monthly in the winter in accordance with their likely response rates to physical, chemical, and biological signals in the changing seasons. An integrated monitoring program would also track nutrients in order to monitor the relative suitability of the environment to support Parrot's Feather growth. Because high nitrogen levels are a precursor to Parrot's Feather infestation it will be desirable to determine whether setting targets for nitrogen concentration in Somenos Creek is an attainable goal to aid in Parrot's Feather control.

Monitoring annual changes in the extent of Parrot's Feather and the annual cycles of Summer growth and winter die back is required to set achievable targets for the management plan. This monitoring work would use methodology established by Preikshot (2018) to identify and map individual plots of Parrots Feather. Such monitoring work will help identify what portion of the

total Parrot's Feather biomass may occur in temporary patches and/or if there are areas of persistent high density. Identification of areas of persistent high density will help in selecting management operations which will have a high likelihood of eradicating as much Parrot's Feather as possible and develop strategic planting to shade suitable creek reaches.

Table 3: Monitoring activities and cost estimates for Parrot's Feather in Somenos Creek. Many of these activities could be scaled back or even curtailed as management targets are met.

Activity	**Responsibility**	**Cost structure**	**Cost Per Year**
monitoring T, DO, TDS, SPC, pH	SMWS	three hours once per week summer (May 01 to Sep 30: 153 d), three hours once per month winter (Oct 01 to April 30: 30d) at $50/hour	4,050
monitoring phosphorus and nitrogen	SMWS	once per month year round: total phosphate ($12), orthophosphate ($10), ammonia ($15), nitrate ($15), nitrite ($10), total nitrogen ($30) at 3 sites. 3 hours for sampling @ $50 per hour	5,112
monitoring Parrots Feather extent	SMWS, Cowichan Tribes	Once in summer at max extent once in winter at max die back. 3 days (8 hours per day) for data collection and reporting for each event: biologist $50 per hour field assistant $30 per hour	1,920
channel bathymetry and morphology	SMWS	Once in summer at minimum lake level: 3 days (8 hours per day). Once in winter at maximum lake level: 3 days (8 hours oer day). Biologist $50 per hour, field assistant $30 per hour	3,840
baseline report	SMWS	once per year 5 days, 8 hours per day, biologist $50 per hour	2,000
Total			**16,922**

Shading, Control Operations, and Research

Shading policies, *i.e.*, planting trees on the stream banks and covering Parrot's Feather patches with tarps, need to first be investigated for overall effectiveness and whether given stretches are more suited to different or combined shading approaches. Lessons learned in the first year of shading trials can then be adapted to formal control work in year two and beyond. The shading program will include components that leverage ongoing activities on water quality to assess the efficacy of different shading treatments. In the summer of 2019 SMWS will be initiating experimental shading work with Cowichan Tribes. In the first year these experiments will focus on the use of tarps and/or pond liners to strategically darken and smother small, ~20m^2, patches of Parrot's Feather. A survey in 2016 (Preikshot 2017) showed that of the 14 identified Parrot's Feather patches 12 were 20m^2 or less. SMWS has currently obtained $10,000 funding for the first year of this research. This scale of funding is anticipated to allow trial to be run on 4 or 5 Parrots Feather patches. If funding is available from North Cowichan and/or other partners, the shading program could be expanded to encompass most, or all, of the smaller patches in Somenos Creek. For example, the Municipality of North Cowichan, Cowichan Tribes and SMWS have applied for funding from the BC Salmon Innovation Fund (offered by Fisheries and

Oceans Canada). If this funding is approved significant progress could be made to shading the majority of small Parrot's Feather Patches in Somenos Creek.

A related but longer-term project is shading of the Somenos Creek aquatic environment with trees planted in the riparian area. This policy has been recommended by several previous reports on hydrology and biology of Somenos Creek to improve salmon and trout habitat and promote better drainage by impairing aquatic plant growth, *e.g.*, (Preikshot 2016, Lyle and O'Connor 2009, Chilibeck 2005, and Burns 1999). Preparation for such research could be done by an examination of light levels in the Somenos Creek area and an analysis of how those levels compare to Parrot's Feather Density. Light meters are available at a cost of ~$200 and a dozen of these could be used to determine how light level correlates to Parrot's Feather growth and density. Results from this work could be overlaid on research on the association of depth with Parrot's Feather growth (see below) to determine where policy choices could overlap or be used exclusively to leverage conditions in different parts of the Somenos Creek environment.

Given that Parrot's Feather has an aversion to water deeper than 2m a valuable project will be a survey of bathymetry in Somenos Creek to look for associations between depth and abundance. If it proves to be the case that persistently deep channels are associated with low Parrot's Feather abundance, it may be valuable to use small scale dredging in order to create deeper pools in some areas. Such work would likely require the participation of Cowichan Tribes as well as representatives of agencies from senior levels of government. Strategic dredging would not likely commence until year two or three of a management plan due to the large amount of planning and logistics that would be required and obtain permissions from relevant agencies. The funding required for this type of work is likely to be in the upper tens of thousands of dollars given the personnel necessary to operate equipment, renting the equipment itself, preparing dredging sites, obtaining permissions, monitoring the dredging site and assessing operations. Strategic dredging to discourage Parrot's Feather should not be confused with suction dredging to remove Parrot's Feather biomass.

Table 4: Control activities and cost estimates for Parrot's Feather control in Somenos Creek. Note that planting and dredging operations are ideally one-time costs.

Activity	Responsibility	Cost structure	Cost Estimate
shading with liners	SMWS, Cowichan Tribes	Current funding of $10,000 is allocated to experiments on one quarter of Parrot's Feather patches ≤20m^2. Therefore, matching funding may allow half or more of the parrot's Feather patches to be involved in experimental treatments	10,000-20,000
shading experiments with planting	SMWS, Cowichan Tribes	given that the length of the area infected by Parrot's Feather is approximately 1.5 km and that tree planting commonly species trees at 3-5m we can assume that if planting were done on the north and south riparian area 600 to 1000 trees would be required. Nurseries typically sell suitable native trees for $10-$20.	6,000-20,000 one-time cost
channel modification	Municipality of North Cowichan, SMWS, Cowichan Tribes	Somenos Creek Channel is typically 10m wide. Infected area is @ 1500m long dredging would be to 2.5-3m to exceed Parrot Feather depth preference. Assume $25 per m^3 for operating a dredge. Note: this does not include monitoring costs for dredge set-up, operation and dismantling	≥300,000 to dredge 500m of infected areas one-time cost
suction dredging	Municipality of North Cowichan, SMWS, Cowichan Tribes	Somenos Creek Channel is typically 10m wide. Infected area is @ 1500m long dredging would be to 2.5-3m to exceed Parrot Feather depth preference. Assume $25 per m^3 for operating a dredge. Note: this does not include monitoring costs for dredge set-up, operation and dismantling	≥300,000 to dredge 500m of infected areas

Assessment of Management Options

Table 5, below, describes the relative advantages and disadvantages of management options for Parrot's Feather control options. Advantages and disadvantages are assessed in five attributes which are colour coded from green to red to indicate their relative efficacy:

- time scale of effect: what is the expected time over which a decline in parrot's Feather is likely to occur. Low cost-days to weeks, medium cost-weeks to months, high cost-months to years, very high cost-years to decades.
- social cost: what is the expected reaction from the community to implementing the program? Options in which significant public displeasure are likely to arise are rated as disadvantageous, Programs with likely public acceptance are rated as low cost
- ecosystem cost: what is the potential of significant and unpredictable ecosystem feedbacks from the option? Policies which are unlikely to degrade the situation to a worse state are low cost, whereas policies which have many likely side effects and a high potential for unforeseen consequences are rated as highly disadvantageous,
- financial cost: what is the likely cost of implementing the program? Low regarded as $10,000-50,000, medium as $50,000-$100,000, high as $100,000-$500,000 and very high as >$500,000
- administrative cost: what is the support cost to the Municipal Government of implementing the option? Will much of the administration be handled by NGOs or senior levels of government (low) or will the Municipality be obliged to devote significant numbers of both personnel and capital resources to the program (very high)

Table 5: Costs and overall effectiveness associated with different Parrot's Feather Control programs. Costs are scored in 5 factors: temporal, social, ecological, financial, and administrative. Red indicates higher cost and green lower cost. These costs were converted to numeric scores (1 - low, 2 - medium, 3 - high, 4 - very high). The overall effectiveness is the sum of the cost scores with green being most effective and red being least effective.

Activity	Time Scale of Effect	Social Cost	Ecosystem Cost	Financial Cost	Administrative Cost	Overall Effectiveness
Chemical						
Chemical Control	days-weeks	very high	high	medium	medium	12
Physical						
Suction Dredging	weeks-months	medium	high	very high	high	14
Dredging	weeks-months	medium	high	very high	very high	15
Pulling/vacuuming	months-years	low	medium	high	very high	13
Shading	years-decades	low	low	low	low	8
Smothering	months-years	low	low	low	low	7
Channel Modification	weeks-months	medium	medium	high	high	12
Dewatering	years	very high	very high	very high	very high	19
Biological						
Beavers	decades	high	low	low	low	10
Introduce Predators	years-decades	high	medium	low	very high	14
Reduce Nitrate	years-dcades	low	low	medium	low	9

At the right-hand side of Table 5 is a summary of the desirability scores (low=1, medium=2, high=3 very high=4) into a net desirability for that option. Of the options available shading, smothering and reducing nitrate were rated as the net most desirable. The drawback of all these is they are among the options with the longest likely time scale of efficacy. Note that beavers also score relatively well, but the expected likelihood of even partial Parrot's Feather control by beavers is low.

Although chemical and physical control options like dredging are expected to respond on short time scales the associates social, biological and economic costs are daunting.

This analysis suggests that a prudent and cost-effective course of action is to quickly develop a policy of Parrot's Feather control that engages smothering and shading as low cost, low risk options. More specific explorations could ensue in future years to examine the potential of chemical control or dredging as results come in from Parrot's Feather management programs elsewhere.

Successful management of Parrot's Feather can not be assessed without objective monitoring work. It is therefore crucial for the Municipality of North Cowichan to leverage existing monitoring and research work being conducted on Parrot's Feather in Somenos Creek by the Somenos Marsh Wildlife Society and Cowichan Tribes. This partnership will also serve as an important springboard to help engage the public in education and outreach efforts made under a new management program. As and example of the value of the synergy such partnerships can bring the Somenos Marsh Wildlife Society has been contacted by The Invasive Species Council of BC to say that it would like to make Somenos Creek a priority in 2020 to provide logistical and capital support for monitoring and management operations. Starting a Parrot's Feather management program as soon as possible will help ensure that these resources will be available to the management group.

Adapting to Future Conditions

Other activities that will complement the Parrot's feather management monitoring and research program as it progresses are:

- explore ways to restrict the sale of Parrot's Feather through garden centres, supermarkets, aquarists and other retail outlet,
- raise public awareness of the economic and environmental impacts Parrot's Feather could have in combination with education efforts targeted at key stakeholder groups linked to the import and spread of this and other aquatic plant species.
- encourage the removal and proper disposal of domestic plantings in ponds and aquaria and promote the use of native species,
- encouraging recording of the plant by the general public, gardeners, naturalists and water course users such as agriculturalists, anglers and canoeists,
- engage with stakeholders to provide advice and help, where appropriate, to eradicate populations in private gardens,
- restrict boats in Somenos Creek to reduce risk of spreading fragments

- engage the Invasive Species Committee of Metro Vancouver and the Coastal Invasive Species Committee to learn more about principles for controlling aquatic invasive species in BC,
- collaboration with Cowichan Tribes on Parrot's Feather monitoring and management,
- direct collaboration with other BC Municipalities dealing with Parrot's Feather to share knowledge and best practices,
- exploring funding opportunities from collaboration with federal and provincial agencies.

Road Map

Table 6: Proposed timeline of monitoring and management actions

Time Frame	Action	Participants	Goals
Year One	Present Draft Monitoring and Management Plan to Committees	Municipal Staff, Biological Consultant, Somenos Marsh management Committee, North Cowichan Environmental Advisory Committee	discuss potential goals, and monitoring options
Year One	Present Monitoring and Management Plan to Council	Municipal Staff, Biological Consultant	describe goals of management plan and potential monitoring and management options.
Year One	Present Monitoring and Management Plan to User Groups	Council, Municipal Staff, Biological Consultant, Somenos Marsh Wildlife Society, User Groups, Cowichan Tribes	describe goals of management plan and potential monitoring and management options to elicit feedback from First Nations, Agricultural and environmental organisations
Year One	Develop outreach program for public engagement and education, *e.g.*, signage and meetings	Council, Municipal Staff, Biological Consultant, Somenos Marsh Wildlife Society, User Groups	Allow the public to participate in selecting management options and participate in research and monitoring programs. Develop education program to reduce risk of Parrot's Feather spread
Year One	Approach other municipalities to develop a Parrots Feather response network	Council, Municipal Staff Biological Consultant	Collectively leverage funds from federal and Provincial sources. Learn from other experiences with Parrot's Feather and pool available resources.
Year One	Implement monitoring plan	Municipal Staff, Biological Consultant, Somenos Marsh Wildlife Society, Cowichan Tribes	Measure extent and density of Parrots Feather in index areas. Measure water quality parameters in index areas.
Year One	Implement research program	Somenos Marsh Wildlife Society, Cowichan Tribes, Municipal Staff	Experiment with different shading approaches to control Parrots Feather
Year Two	First Year report on research, monitoring and management	Municipal Staff, Biological Consultant	Use information from year one monitoring to begin mitigation activities and confirm management targets
Year Two	Continue outreach program for public engagement and education	Council, Municipal Staff, Biological Consultant, Somenos Marsh Wildlife Society, User Groups	Feedback to public to discuss successes and failures of Parrot's Feather control
Year Three	Second Year report on research, monitoring and management and first year attainment report on management goals	Municipal Staff, Biological Consultant,	Continue monitoring and report on progress and timeline to achieving management targets
Year Four	Review of program and decision to discontinue, continue or expand research and monitoring activities and continue annual reporting	Council, Municipal Staff, Biological Consultant, Somenos Marsh Wildlife Society, User Groups	Determine successes and failures to decide which programs to continue in the long-term or whether new approaches may be needed

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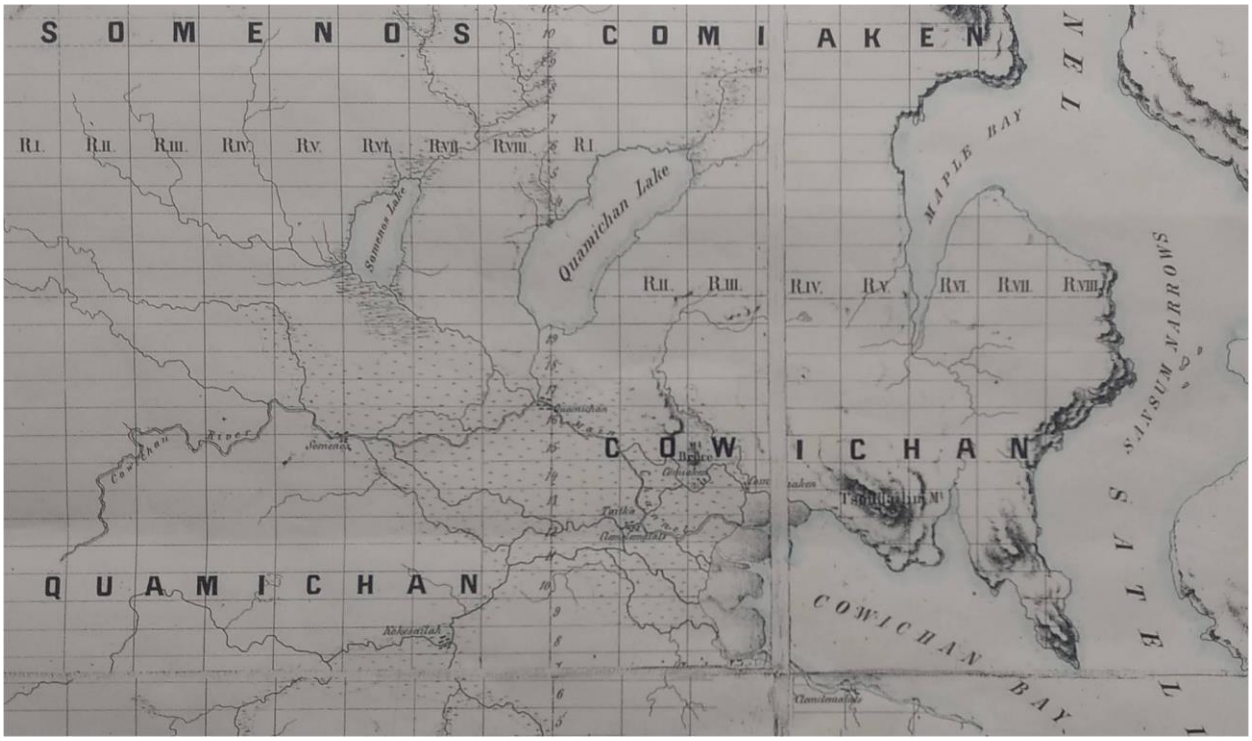
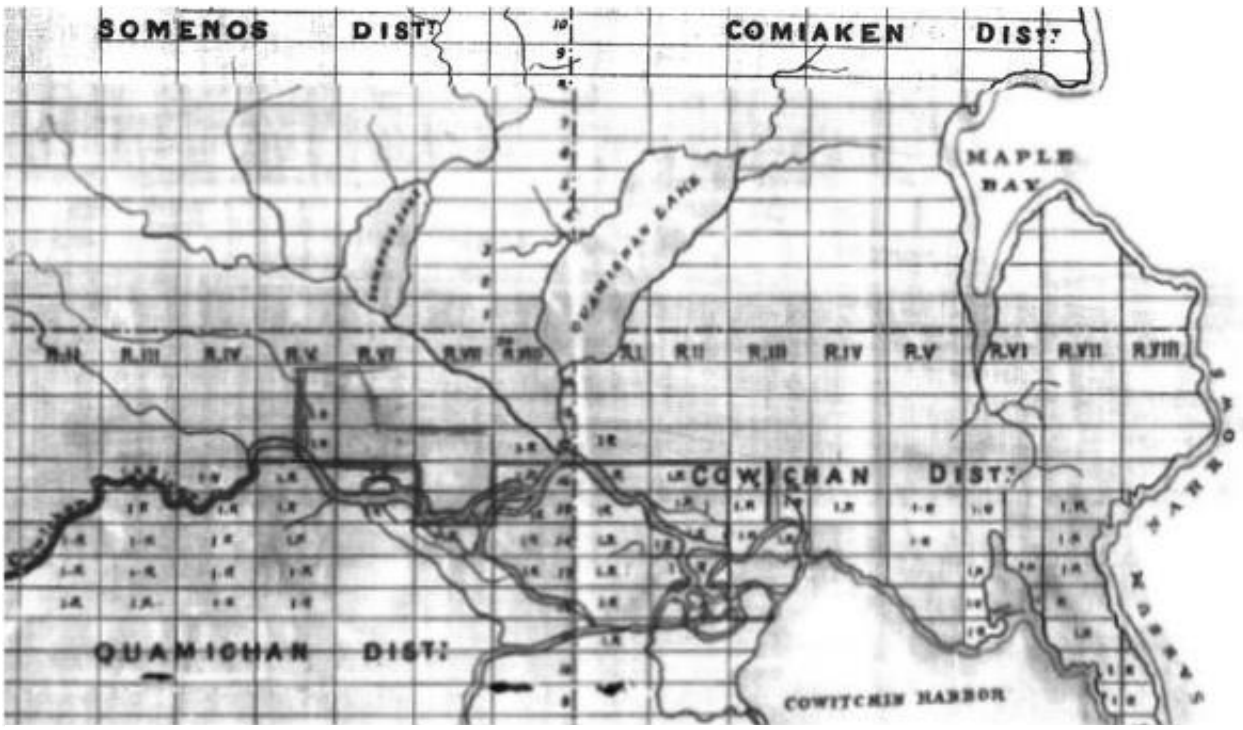
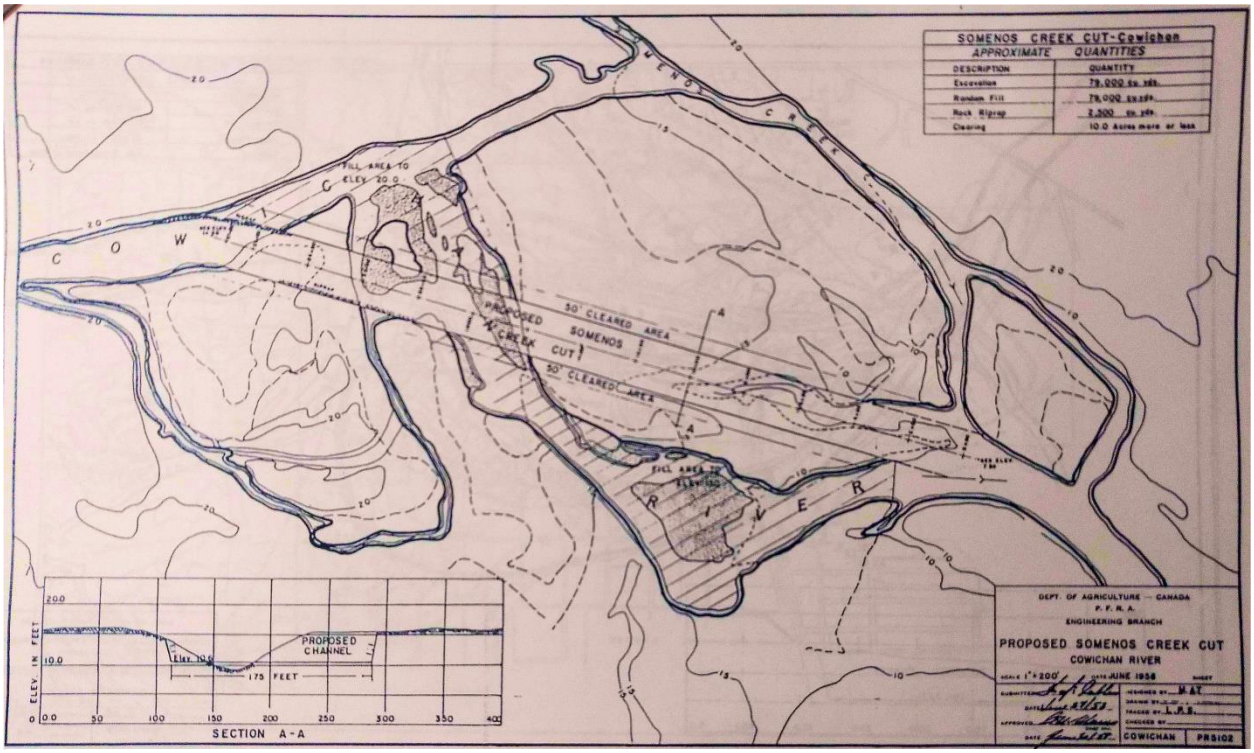
Appendix 1: Additional Maps



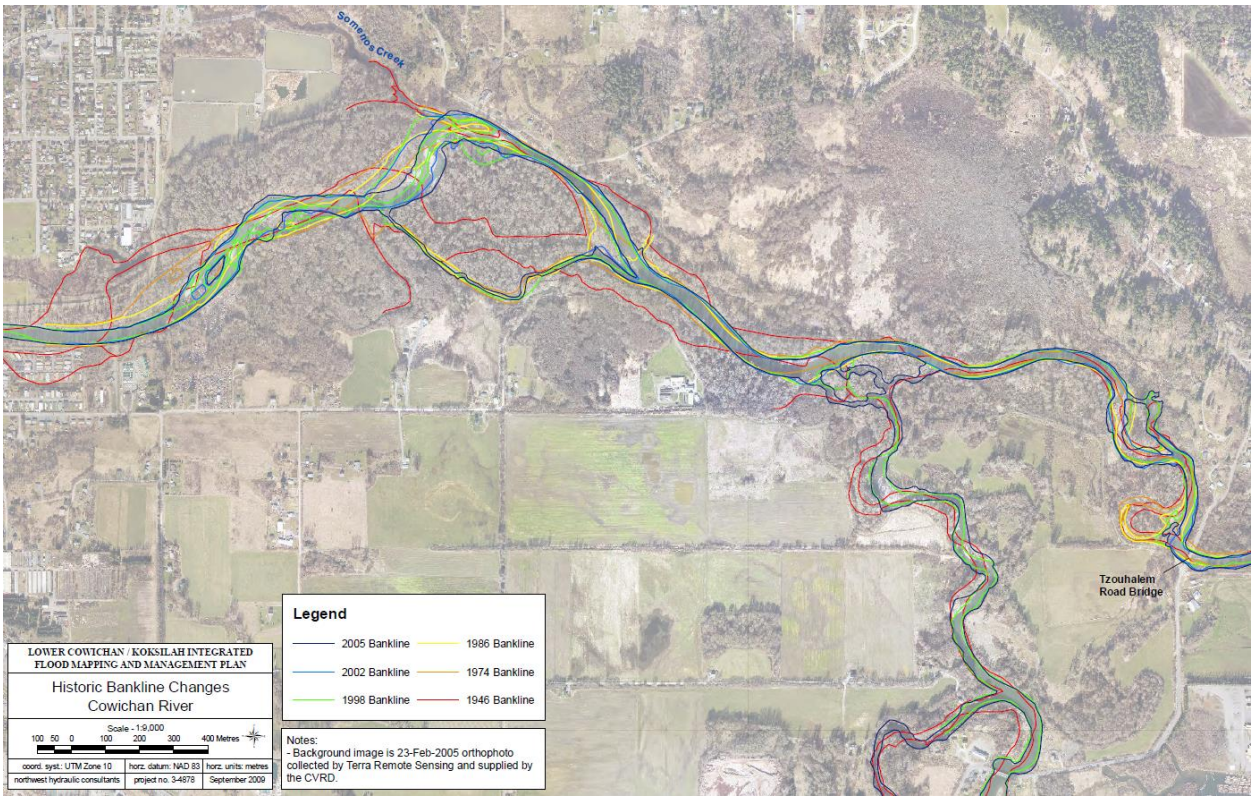
Appendix Map 1: A section of a map produced by d'Heureuse (1860). This map was based upon survey work completed by engineers from the British war department in 1859. The British maps are not reproduced here due to copyright. The British surveys developed annotated maps of five districts: Somenos, Quamichan, Cowichan, Comiaken and Shawnigan which were intended to be guides to the suitability of different parts of these districts for urban and agricultural development. This map provides some interesting contrast to the hydrological situation of the present. In the 1850s there were three channels for the Cowichan River starting at what is now the Allenby Road Bridge. What remains of those three channels is, at present, concentrated into the most northerly channel. The mode of entry of Somenos Creek into the Cowichan River was far more complex than the present and went through a far more complex marsh/wetland complex. These wetlands are indicated on this map by stippling. On the British war department surveys this area is labelled as 'low marshy ground'. A third significant difference is the situation of Bings Creek. Historically Bings Creek was a very short ~1km rill that entered Somenos Lake near its current bed. However, another stream appears to the south and west which empties directly into the Cowichan River. This may be what was referred to as Holmes Creek. If this is the case at some point in the early 1900s (see map below), this other Creek was rerouted into Bings Creek. Such an action would have been a practical response to periodic flooding in the developing core of Duncan. If water was indeed rerouted in this fashion it would help explain poor drainage in the area around Somenos Lake.



Appendix Map 2: A section of a map produced by Land and Works British Columbia (1898). In this map it can be seen that in the period between 1860 and 1898 Somenos Creek had been reduced to one channel entering the Cowichan River. Note also that what may have been Holmes creek still flows directly into the Cowichan River near the western border of the City of Duncan. The sketch of the city likely was done well after this map was produced. The author of this report has seen maps dated as early as 1920 which show Bings Creek occupying all of currently identified channel. The 'capture' of Holmes Creek by Bings may explain the persistence of the usage of Holmes and Bings/Holmes by locals. The official list of place names in British Columbia does not list Holmes Creek as a valid name. It would seem likely that at some point between 1898 and 1920 Holmes Creek was diverted into the channel of the small Creek near the southern end of Somenos Lake to form what is now recognised as Bings Creek.



Appendix Map 3: Map of a proposed cut for Cowichan River near confluence with Somenos Creek in 1958 to help reduce flooding on Cowichan Tribes Land. Note that the lowest 500m of Somenos Creek lay along what is now Quamichan Road (McCallum and Thomson 1958). In this map Somenos Creek runs parallel to the Cowichan River for about 400-500m before the confluence. At the time this map was prepared the Cowichan River diverted south just over one hundred meters before it does at present. Therefore at some time soon after this map was prepared the main channel of the Cowichan River captured the lowest 500m of Somenos Creek. This would have significantly reduced the grade of Somenos Creek and made the Somenos basin more susceptible to backwatering from the Cowichan River.



Appendix Map 4: Changes in the path of the main channel of the Cowichan River between 1946 and 2005 (Lyle and O'Connor 2009). Note that in the area of the confluence of the Cowichan River with Somenos Creek, the position of the Cowichan River main channel in 1946 is very similar to the channel mapped by McCallum and Thomson (1958).

Appendix 2: Additional Photographs

Appendix Photo 1: Parrot's Feather growth across the Somenos Creek channel. Photo taken at the Tzouhalem Road Bridge looking south in November 2017.

Appendix Photo 2: Parrot's Feather growth across the Somenos Creek channel during the high water event of January 2018. Photo taken at the Tzouhalem Road Bridge looking north in January 2018.

Appendix Photo 3a (left, close up) and 3b (habitat view): Mare's Tail (*Hippuris vulgaris*) growing in Somenos Creek near York Road. Mare's tail is a native plant with morphological similarities to Parrots Feather leading to potential misidentification.

Appendix Photo 4: The native aquatic plant Potamogeton (*Potamogeton richardsonii*) which can be observed growing in many extensive mats in Somenos Creek, often near to Parrot's Feather. Parrot's Feather can be seen as the bright green patch near the center of the picture.

Appendix Photo 5: Trout and salmon habitat created by beaver dams on Somenos Creek. One can be seen on the left of the photo. Downstream of the dam relatively clear water was seen to hold several hundred trout and salmon juveniles. Photo taken in June 2018.