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Chrystal Creek Wetland Design Project

Final Report

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Abstract

This project involves an assessment of a portion of the Chrystal Creek watershed on Galiano Island, and makes recommendations for the restoration of wetland habitat in the area consistent with the goals of the Cedars for the Next Century project. Aerial imagery, site visits, and personal communication helped define the impacts of logging, grazing, water diversion, and compaction of soil in the project area. A laser level was used to survey the terrain and delineate an area to be excavated for a shallow wetland based on slope constraints to minimize erosion. We surveyed the vegetation in the project area and made note of native species, wet site indicators, and invasive species. We also surveyed all the stumps in the area to assess the size distribution of woody debris found on the site pre-disturbance. In addition we visited a reference wetland site on Porlier Pass Road and assessed vegetation and woody debris. We make recommendations on the wetland location, microsite creation for red cedar (*Thuja plicata)*, a revegetation strategy, habitat for red-legged frog (*Rana aurora aurora)*, and the introduction of woody debris.

Acknowledgments

We would like to thank the Galiano Conservancy staff, particularly Adam Huggins and Sara Yeomans for their support throughout this project.

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Introduction

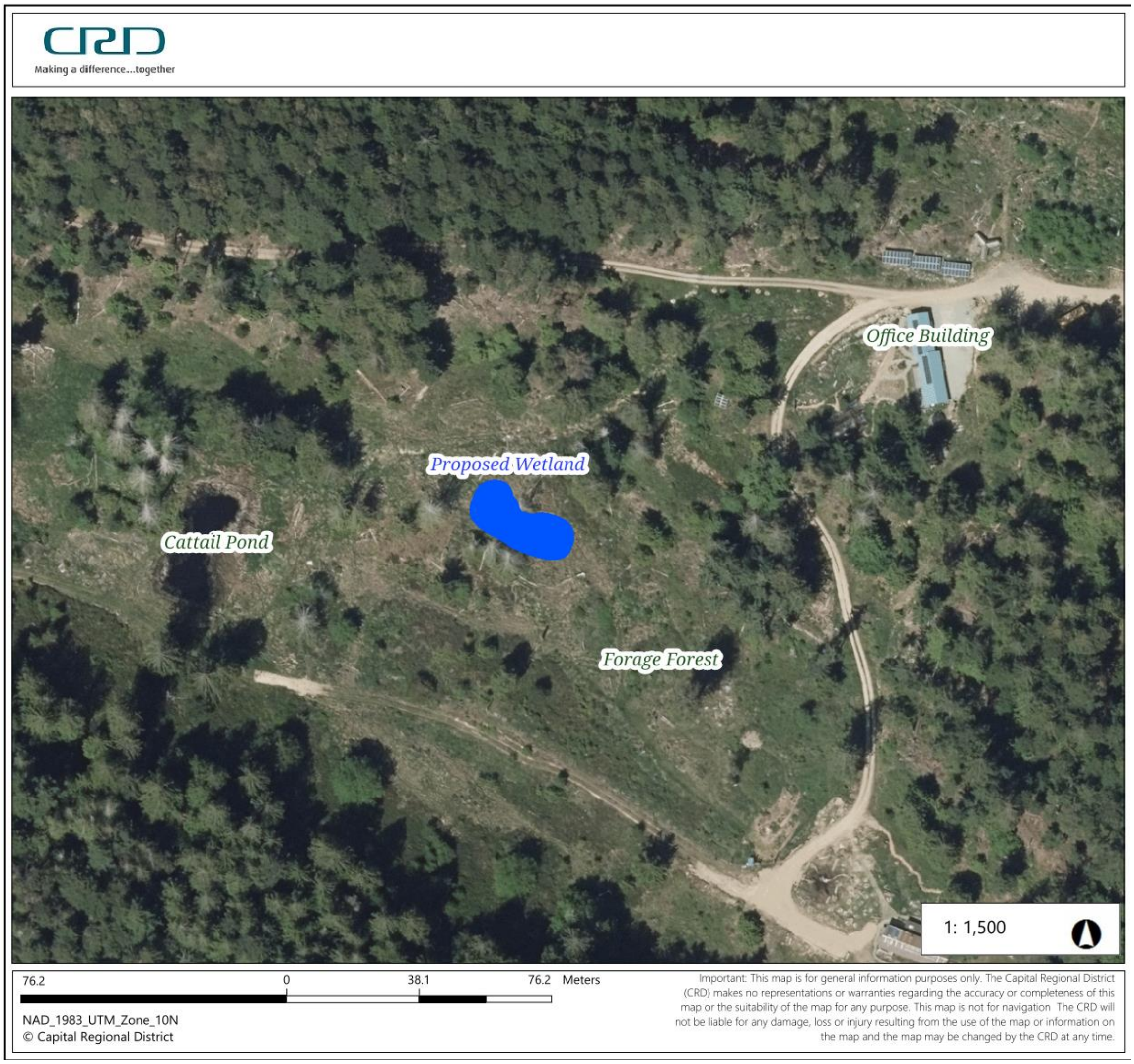
The Galiano Conservancy has received a grant to restore and protect a culturally and biologically significant species on the West Coast of North America: the western redcedar (*Thuja plicata*). The Conservancy's main hub for its activities is at the Millard Learning Centre, which is land that has experienced various human disturbances but still retains some intact ecosystem fragments. There are multiple restoration efforts ongoing at the Centre and one of the central projects is to restore the Chrystal Creek Watershed, which is entirely located on this property. Current restoration efforts include designing wetlands where they have been drained or degraded, controlling the spread of invasive plants, proliferating native plants and reducing the impact of ungulate overgrazing. All of these efforts will have multiple benefits including restoring culturally significant and endangered species, creating wildlife habitat, mitigating climate change and providing a learning space for the surrounding community.

The project described in this report forms part of the Cedars for the Next Century grant, and proposes creating a wetland pool between the Nuts'a'maat Forage Forest (see Map 1) and an existing cattail pond with the goal of retaining water in the landscape throughout the year. The initiative is comprised of three phases that address different sections of the watershed. This wetland design project is part of the second phase, which focuses on Southeastern reach of the watershed. Phase 2 builds upon the promising wetland restoration in Phase 1 that has been occurring at the Northwestern reach of the watershed in the floodplain beside Chrystal Creek (GCA, 2021). During phase 1, a number of ephemeral ponds have been restored and amphibians have been breeding (Personal communications, Huggins et Yeomans). With the addition of this larger wetland, we hope to create the necessary habitat connectivity and complexity to increase the habitat for multiple native species including the Western red cedar, red-legged frog (*Rana aurora aurora*), beavers (*Castor canadensis*) and a plethora of wetland plants.

Defining the problem

The study area is located between the back of the Nuts'a'maat Forage Forest and an artificial pond surrounded by Cattail (*Typha latifolia*) which was potentially dug for irrigation, but the exact purpose is not known (see Map 1). An old logging road running from the Millard Learning Centre currently used as a trail delineates the Southern boundary, while the Northern slope marks the upper boundary. The proposed wetland is located within the study area at the bottom of the Northern slope immediately behind the Nuts'a'maat Forage Forest. This site was chosen for its flat terrain and suitable slope to build a future wetland, as well as the relatively intact native vegetation.

The Millard Learning Centre property and the proposed wetland site have been affected by different human disturbances with important implications for the project design. Small-scale farming occurred during the late 19^{th} and early 20th centuries, and the lower Chrystal creek watershed was converted into farmland. Under new ownership by Bill Campbell starting in 1958, the property was affected by logging activities conducted by the owner himself in the early 2000s. The selected site has not been directly farmed. However, the hydrology has been altered by drainage structures including pipes and ditches. Furthermore, agronomic grasses and other plants introduced by farming activities have spread on the property. As such, invasive reed canary grass (*Phalaris arundinacea*) occurs in a few pockets on the site and is an important challenge to address. But the bulk of the disturbance occurred with logging on this site. Indeed, logging and associated disturbances --notably, extensive road building and use of heavy machinery-- led to soil compaction, and disruption of vegetation with the removal of the old growth cedars, which in turn caused further hydrological alteration. The shift in vegetation and hydrology has also caused a shift in the local microclimate. This has shifted the trajectory of the historical ecosystem believed to be a Cedar swamp (Huggins, personal communication) to a sunny open meadow with only a few remaining cedars.



Map 1: Aerial map of the study area including the proposed wetland. Source: Capital Regional District.

Goals and Objectives

The overarching goal for this project stems from Objective 3 outlined in the Cedars for the Century project, which is to restore diverse seasonal and permanent freshwater wetlands within the Chrystal Creek Watershed to provide habitat for sensitive species, store winter precipitation, and sequester carbon. This restoration project aims to restore the overall ecological integrity of the upper watershed through improving the hydrological conditions and creating year-round wetland habitat to support native species. Our specific project seeks to create a large permanent wetland site downslope from the Forage Forest, which is one of the few areas around the property with year-round water availability provided by multiple drainage corridors (surface and possibly sub-surface) that connect on site. In doing so, this project would support multiple sensitive wetland related species of importance including the red-legged frog, Western redcedar, and beaver. This will partly be supported by importing large woody debris (LWD) to the wetland site to provide habitat and refugia. By improving hydrological function, this project also seeks to slow the flow of water through the soils that have historically been degraded by various settler activities including agriculture, livestock grazing, and small-scale logging. These activities have compounding impacts that affect soil ability to slow the movement of water through the system, causing high rates of soil erosion as freshwater moves towards the ocean. Wetlands are topographically complex, influencing water to slow down while moving through the system, decreasing the rate of erosion. Wetlands also collect freshwater during the winter months when there is high precipitation, providing an area for water to collect and be present year-round. This would prevent drought conditions during future summer heat events on an already water-insecure island. The project also includes natural regeneration and planting additional native wetland vegetation to retain moisture, such as skunk cabbage (*Lysichiton americanus*). In order to support native species, a management plan for reed canary grass will be created to reduce its presence within the site.

Goals #1: Slow the movement of water and restore hydrological conditions within the restoration site to increase ecosystem resilience in the context of climate change.

Objective: Excavate a large shallow wetland of approximately 500 square meters.

Objective: Deactivate ditches and old roads in the area.

Goal #2: Enhance habitat for cedars and diverse wetland vegetation.

Objective: Treat the area with the rough and loose technique to decompactify the soil.

Objective: Create elevated microsites with excavator for red cedar seedlings.

Objective: Using natural revegetation and planted rare and pioneer species, restore the vegetation to a red cedar/skunk cabbage swamp plant community.

Objective: Control and limit the spread of reed canary grass on the site.

Goal #3: Improve habitat and refugia for wildlife on the site.

Objective: Introduce a high density (>80 tons/acre) of large (50-150cm diameter) woody debris (LWD).

Objective: Plant fast growing pioneer tree species to restore ecological functions for wildlife including red-legged frog and beaver.

Objective: Install two amphibian corridors made of LWD to provide connectivity between the wetland and mature upland forest**.**

Methods and Materials

a) Aerial imagery preliminary analysis

Before visiting the site we observed aerial imagery of the Chrystal Creek watershed from 1932, 1962, 1996, and 2002. The image from 1932 portrays a heterogeneous landscape in the watershed, with open areas that are potentially saturated and marshy. By 1962, the area has filled in with trees and appears homogeneous from above. It is likely that ditches or other land use changes had by that point diverted some of the water from the site and made the area more suitable for tree growth.

b) Site visits

To design the wetland, we did multiple site visits.

- During the first visit on June 14th 2022, we made general observations about the site, and took note of features such as slope, wetland indicator vegetation, presence of native vegetation, standing water, ditches, compaction, and old stumps. We recorded information on surface water flowing down the west facing slope from a perennial spring. Considering this first collected information, we envisioned a potential site, with suitable characteristics for the future wetland (e.g. a relatively large flat terrain with potential suitable slopes with standing water surrounded by native vegetation including western red cedars).

- During the second site visit on June 15th, we walked from the eastern side of our potential site up the west-facing slope with Sara Yeomans, a GCA staff member. We followed the slope up to a well site and a spring. We took observations of seepages and water flows along the slope. Eric Higgs later confirmed that the spring is a year round water source for the watershed. We followed the drainage pathways as high as the GCA Admin building, at which point there was no longer any surface water to be observed. There are multiple old roads/skid trails which were probably used to transport logs from the valley to the mill site. Along the slope, we followed one of these roads which has been restored by an excavator with the rough and loose method.

- During the third and fourth site visits on June 16th and 17th, we surveyed the site with a laser level to find an area with suitable slopes to build the wetland, and to delineate the contours of the site to be excavated. We were introduced to the laser level technique by Adam Huggins. We set up the laser level at the highest point in our site and took elevation readings at different points. A 50 meter tape was then used to measure out the distance between these points so that slope could be calculated. We were looking for slopes of 2 degrees or less across the wetland to minimize erosion. Furthermore, the excavated pond had to follow a 5 to 10 degrees slope from the edges to its center to become a suitable habitat for the Red-legged frog. To delineate such a pond, we did some trigonometric calculations based on different field measurements of possible pond edges. The edges of the selected excavation site were marked with rebar and flagging.

  To assess the pre-disturbance size and composition of woody debris in the wetland, we surveyed the stumps in the area. Most of the largest overstory trees in the site had been removed by timber operations, but the stumps were remaining. We measured the 12 stumps in the area with a tape and recorded the values.

  We also made a quick non-exhaustive vegetation survey and sketched a rough map of the existing vegetation with an attention to native species, wetland indicator species, and invasive species. We have used *Plants of Coastal British-Columbia* (Pojar & MacKinnon, 2004) and iNaturalist to identify certain plants especially grasses.

Figure 1: Fin and Karlis near the laser level during the slope survey on the potential wetland site. Photo: Coline Laurent.

c) Reference site visit

To get a better understanding of pre-disturbance conditions in the wetland, we visited a “reference” ecosystem on the north side of Porlier Pass Road around one kilometer from the Galiano Conservancy entrance. The site was not a perfect reference ecosystem because many of the large cedars had been removed. Some helpful observations were made. We took notes of the site microclimate, hydrology, vegetation composition and structure, woody debris, physical characteristics, and wildlife.

Results & Interpretation

Hydrology

The project area is shown on a 2012 Galiano Conservancy map as Marsh Wetland of Very High Ecological Value (GLCMC 2013). Maps from the original 2012 Management Plan can be found in Appendix 1. The area is supplied with water from a perennial spring which is located on the slope to the north. There is also a solar powered well on the slope, indicating the presence of groundwater. However it is unknown whether the well is currently functioning and how it may be affecting the groundwater of the site. Water also drains from the vicinity of the Nuts'a'maat Forage Forest, as indicated by standing water and *Juncus spp.*. Our assessment took place in June, which is a drier time of the year, but standing water was still present, indicating a high water table in the area. Any wetlands created on the site will be influenced by both high groundwater and surface water flow, primarily in the wet season.

Hydrology on the site has been impacted by compaction, ditches, roads, and logging. Compaction by logging machinery varies throughout the site, with some areas more heavily impacted and other areas relatively undisturbed. Compaction increases surface runoff and inhibits growth of native vegetation. There is evidence of ditching in the area that is no longer functional but continues to alter the hydrology by concentrating surface water flow. Active roads on the slope above the site alter hydrology by increasing the flashiness of surface water and reducing absorption into the soil. Decommissioned roads further down the slope have been decompacted by an excavator in recent years to increase water penetration and vegetation growth. In addition to compaction of soil, logging has resulted in the removal of large tree species, which impacts the hydrology by a) reducing canopy cover, leading to increased evaporation and increased velocity of rainfall moving on to the soil, and b) reduced root mass in the soil, leading to reduced evapotranspiration and increased erosion of soil. While the hydrology of the site has been heavily impacted, the site is well situated to receive year round water for high value wetland habitat, after the soil and vegetation have been carefully restored.

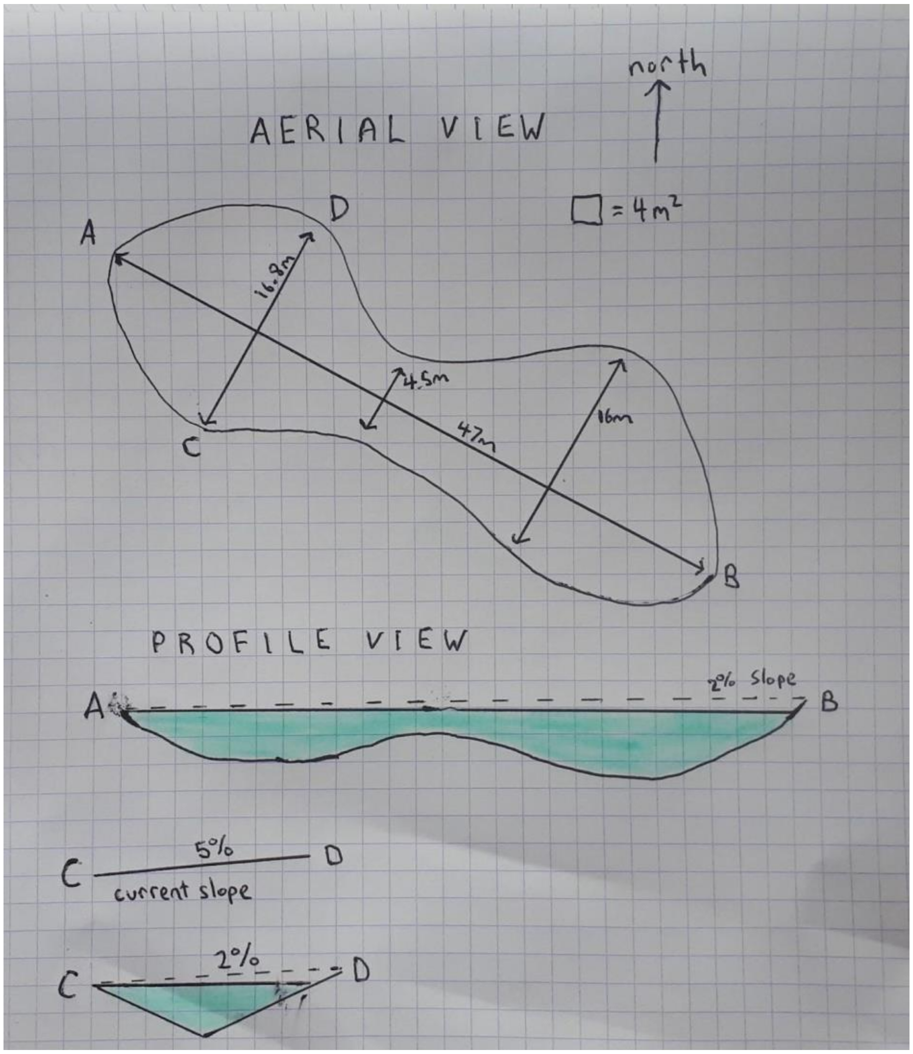


Figure 2: Wetland Delineation with Slopes. Source: F. Smith.

Vegetation

A diversity of native plant was observed during the vegetation survey on the proposed wetland site. The site is dominated by an open meadow with an abundance of slough sedge (*Carex obnupta*), common (native and introduced) rush (*Juncus effusus*), and Bolander's rush (*Juncus bolanderi*). There are a few mature western redcedars (*Thuja plicata*), surrounded by large patches of sword fern (*Polystichum munitum*). There were numerous bushes of Salmonberry (*Rubus spectabilis*) within the meadow and near the redcedars. We also observed many seedlings of Red alder (*Alnus Rubra*) particularly on the Western side of the site near the ditch and the mature redcedars.

Although we did not observe any yellow-flag iris (*Iris pseudacorus*), there are two patches of invasive reed canarygrass on the Northwestern edge of the site that require specific attention. A detailed list of plants observed during the vegetation survey is available in the appendices.

Figure 3: View of western side of the site from the eastern edge showcasing the existing vegetation with the Western redcedars on both sides and patches of sword fern and common rush on the foreground. Photo: C. Laurent.

Figure 4: View of Eastern side of the site taken from the Western edge with the salmonberry, and red alder and Western red cedars seedlings visible on the foreground (Note: the Grandmother cedar in the Nuts'a'maat Forage Forest and learning classroom are visible in the background). Photo: C. Laurent.

Reference Ecosystem

Walking into the reference cedar wetland from the road, the cool and moist microclimate was immediately noticeable. We observed a diversity of wetland types, including redcedar/skunk cabbage swamp, slough sedge/small-flowered bulrush (*Scirpus microcarpus*)/slender foot sedge (*Carex leptopoda*) marsh (see figure 5), Pacific crabapple (*Malus fusca*) thickets, Pacific willow (*Salix lucinda*) and hardhack (*Spiraea Douglasii*) swamp, all existing in a small area. We also noticed a large amount of woody debris: there were an important quantity of logs and branches of different sizes (including big logs) into the water (see figure 6). Another notable feature at the reference site was the high "canopy" coverage of the water surface in the ponds with skunk cabbage, lady fern (*Athyrium filix-femina*), Pacific water parsley (*Oenanthe sarmentosa*), and duckweed (*Lemna sp.*) (see figure 7). The redcedars were growing mostly on the edges of the ponds on benches, or on elevated soil mounds. Skunk cabbage associations were more common in shady conditions while the rush and sedges were more present in sunny and open ponds. During the reference site visit, we observed one frog in the water of a small creek running along the wetland, likely a chorus frog (*Pseudacris regilla*).

Figure 5: Slough sedge marsh, with alders and willows. Photo: C. Laurent.

Figure 6: Large Woody Debris (LWD) in the wetland. Photo: C. Laurent.

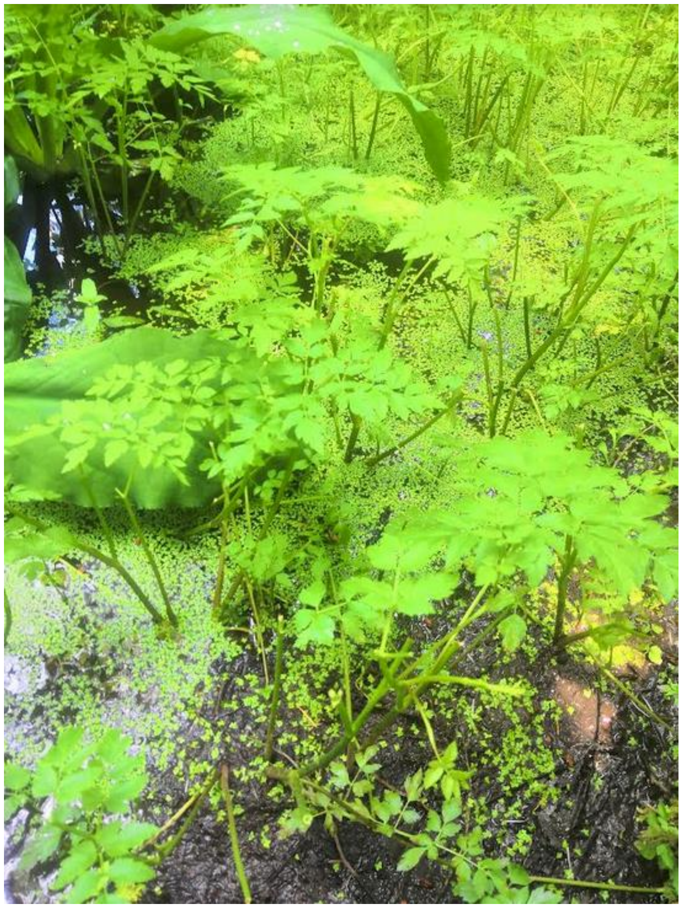


Figure 7: High herbaceous coverage within the reference wetland. Photo: C. Laurent.

Stump assessment

Of the 12 stumps recorded in the wetland site, diameters ranged from 50-150cm, with an average diameter of 82cm. Species were primarily red cedar with occasional Douglas fir and red alder. Logging in the area resulted in the removal of large quantities of biomass from the watershed, and restoration activities should restore the role of Coarse Woody Debris (CWD) in the terrestrial/wetland interface. The stump measurements provide a baseline for the size and composition of wood to be restored.

The importance of woody debris for facilitating structural and biological diversity in temperate forests and streams is well documented. CWD in forests provides refugia from browsing for understory plants, and drives carbon and nutrient cycles as decomposition occurs. In streams, wood is referred to as Large woody debris (LWD) and recognized as integral for creating complex habitat for invertebrates-which form the base of the aquatic food chain- and spawning and refuge areas for fish and amphibians. The wetland faunal food web begins with invertebrates. Invertebrates work to decompose woody debris and are separated into terrestrial and aquatic categories. Woody debris in submerged areas is decomposed by aquatic collector gatherers. The aquatic shredders, grazers, scrapers, gougers, and borers found in streams are absent from wetlands (Braccia and Batzer 1999). Woody debris decomposition in wetlands is faster than in streams, but slower than terrestrial habitats. Terrestrial decomposition is faster in wetlands than upland areas because of the moisture contained in woody debris through the dry season (Braccia and Batzer 1999).

Large pieces of decomposing wood will eventually become nurse logs, and these increased moisture content growing sites may become even more crucial in a warming climate (Johnson and Yeakley 2008). LWD is also used intentionally in hugelkultur systems, a German food growing practice that uses buried woody debris for moisture retention throughout summer (Laffoon 2016). In a warming climate woody debris will likely decompose at a faster rate (Russell et. al. 2014).

Discussion & Recommendations

Overall Design

Because the site is relatively flat, we were able to delineate a large wetland (47m long, and approximately 500 square meters). The delineated pond consists of two deep pools connected together by a shallower section (Figure 8).

The shape was determined by three factors:

a. Slope: An effort was made to minimize erosion by limiting the overall slope of the wetland to 2%, and the angle of the excavation to 5%.
b. Avoiding red cedar root zones: The excavation borders curve around the root zones of existing red cedars, to minimize impacts of machine work.
c. Maximize heterogeneity: The curving edges of the wetland maximize edge habitat, and also create deep and shallow water areas.

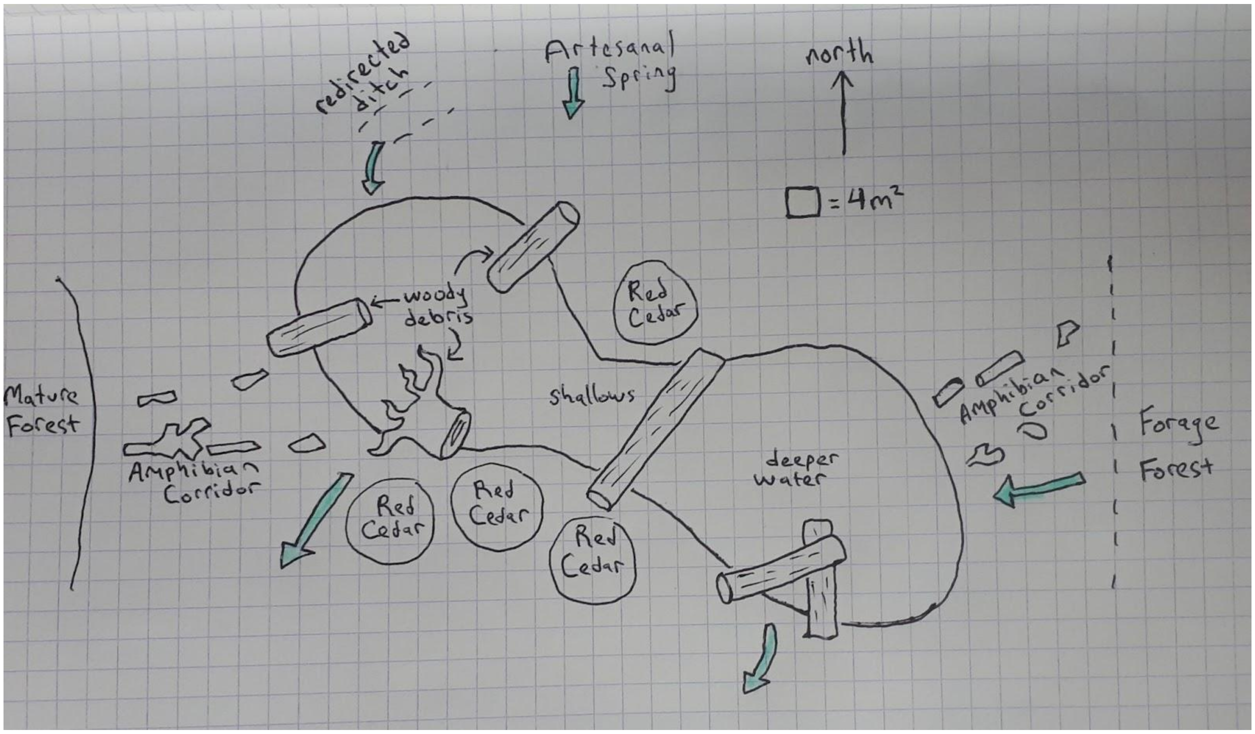


Figure 8: *Conceptual design of the proposed wetland (Note: blue arrows indicate surface water flow direction).*

Vegetation

a. *Reed canary grass removal*

A first priority is to remove the two relatively small patches of reed canary grass observed on the Western side of the future wetland. The patches can be removed with different methods, including removing them and burying them into the soil of the newly constructed site during the rough and loose technique with the excavator, as it has been done successfully previously on the property (Huggins, personal communication). Covering the patches with shade cloth or cardboard is another suitable method for specific targeted control of reed canary grass that can be kept over an entire year and preceded by mowing to remove the seed (Soll & Lipinski, 2004). Eventually, the growth of native evergreen trees in the wetland such as Western redcedars will shade out the invasive grass which does not tolerate year-round shady conditions (Soll & Lipinski, 2004). However, continued monitoring with adaptive management should be done over the next 5 to 10 years so as to remove potential new specimens, and to confirm the removal of the invasive species on site (Soll & Lipinski, 2004).

b. *Natural regeneration*

Following the vegetation site survey, natural regeneration is the main strategy recommended on the site following the pond excavation. Indeed, this site underwent less disturbance than the lower watershed where farming occurred (Huggins & Yeomans, personal communications), and has retained an abundance and diversity of native species.

The ecosystem prior disturbance was likely a western redcedar/skunk cabbage swamp (Huggins, personal communication). When comparing the vegetation survey on the site with the from the corresponding site series Ws53 "Western redcedar – sword fern – skunk cabbage" (MacKenzie & Moran, 2004), the site appears to have retained some of the typical species assemblage for this site series including western redcedar, red alder, salmonberry, sword fern, and lady fern. This survey suggests that the native seed bank is relatively intact, therefore native species may have the potential to colonize the site naturally following the excavation.

c. Conserving existing vegetation

Valuable native species currently occur on site that can be saved during the rough and loose technique and kept within the new wetland. As such, conserving the seedlings of red alder occurring on the edges on the pond will allow natural succession to start on site (MacKenzie & Moran, 2004), and additional planting of western red cedar seedlings could accelerate the successional pathway towards a coniferous swamp. The few salmonberry shrubs growing within the perimeter of the excavation site can also be transplanted around the pond as this species is an important wetland species and is abundant within the corresponding site series (MacKenzie & Moran, 2004). Besides, we recommend that some of the large patches of slough sedge growing around the Western red cedars be conserved. Indeed, this native species is adapted to slightly drier conditions and may develop and provide some resilience to the site in case moisture levels and surface water decrease in the wetland in the context of a changing climate.

In South Coastal British Columbia, temperatures are predicted to increase for all seasons, particularly in the winter, while summers are expected to extend and become drier, and the region will face an increase in the frequency and severity of droughts (Vines et al., 2017). Therefore, retaining native species with a different moisture tolerance will allow to improve the wetland resilience in face of uncertainty caused by climate change.

d. Specific recommendations for western redcedars

As part of the Galiano Conservancy's *Cedars for the Next Century* project, one goal of this restoration is to retain existing western redcedars specimens and improve local conditions by restoring native forests and wetlands ecosystems watershed (Huggins, 2021). Besides contributing to enhance water storage within the Chrystal Creek watershed and creating moister conditions for cedars in the watershed through the creation of an additional wetland, the design specifically attempts to improve conditions for cedars to persist and grow on site.

During field visits, a clump of dead cedars was observed besides the artificial pond near the future wetland site. Reasons for this die-off are not clearly identified (Huggins, personal communication). Western redcedar is known for its high tolerance to flooding and strongly fluctuating water table, however it is less tolerant to drought periods (B.C. Government, n.d.). One hypothesis is that a combination of flooding of the root system in proximity with the pond and later acute drought events may have caused this die-off. Besides, during the reference site visit, Western redcedars were observed growing on the edges of the different ponds on elevated benches, and not at the level of the pond. Therefore, direct contact of Western redcedar roots with water is avoided within the wetland design. Existing trees on site are to be protected by keeping them elevated relatively to the excavated wetland. It is also recommended that additional Western redcedar seedlings be planted around the excavated pond on soil mounds (e.g. mounds created during the rough and loose method). As redcedar seedlings and saplings can experience browsing by deer which can impair their establishment (Martin & Daufresne, 1999; Martin et al., 2011). Thus, it is recommended to fence newly planted specimens individually to protect them from this disturbance during the first growth years.

e. Planting nursery stock

In addition to natural regeneration and conserving existing vegetation, some planting or transplanting may be done for wetland species that were rare or not observed on site following the plant composition of the corresponding "Western redcedar – sword fern – skunk cabbage" site series (MacKenzie & Moran, 2004), and species observed at the reference sites. Planting should occur provided that suitable conditions are ensured for these species. In particular, moisture, soil and shade characteristics on the site should be adapted to these plants if planting is to be successful. Planting species which best grow in shady conditions is not recommended given the lack of shade on the current site (apart from the ground around the sparse redcedars) and could be achieved whenever these conditions will be provided in the future following an annual vegetation monitoring program. Besides Western redcedar, some species to consider planting include:

- Western hemlock (*Tsuga heterophylla*), a conifer growing best in moist to dry conditions, that could be planted on the edges of the wetland site in drier conditions;
- Bigleaf maple (*Acer macrophyllum*), a deciduous tree growing in mesic to moist conditions that could also be planted on the edges of the wetland site;
- Stink currant (*Ribes bracteosum*), a shrub that requires moist to wet conditions but does not tolerate full shade and therefore could be planted immediately on the site;
- Red-osier dogwood (*Cornus stolonifera*), a shrub that grows in mesic to wet conditions and thrive in full sun to part shade and could be planted immediately on the site;
- Red elderberry (*Sambucus racemosa*), a shrub growing in mesic to moist conditions, and can be planted around the excavated pond;

- Skunk cabbage, a herb growing in wet conditions that is shade and sun tolerant and can be planted directly into the water and on the edges of the pond;
- False-lily-of-the-valley (*Maianthemum dilatum*), a groundcover species that requires part-shade to full-shade moist to wet conditions, and can be planted whenever such conditions are provided;
- Foamflower (*Tiarella trifoliata*), a groundcover species that grows in part-shade to full-shade mesic to wet conditions, which can be planted when such conditions will be provided on site;
- Pacific water-parsley (*Oenanthe sarmentosa),* a perennial herb that grows in wet conditions in part to full shade, and which can be planted in the pond and on its edges as soon as shady conditions are provided.
- Sitka willow (*Salix sitchensis*), a tree species growing in moist conditions, which can be planted in the form of stakes on the site,
- Scouler's willow (*Salix scouleriana*), a tree species growing in moist conditions, which can also be planted in stakes.

The planting recommendations follow local availability constraints as many of these species are available at the Conservancy nursery (or were out of stock but are still produced at the nursery) (Galiano Conservancy, 2021).

Besides existing red alder, Sitka willow and Scouler's willow are fast-growing species that will provide an attractive food source for potential beavers to come and settle in the wetland (Gerwing et al., 2013).

Seedlings planting is recommended in the fall or in the spring when plants are dormant to facilitate their establishment (Trotter, 2012). For seeding, sowing in the fall is recommended when species require cold stratification such as the Pacific water-parsley.

Finally, considering the high density of Columbian black-tailed deer (Odocoileus hemionus) on Galiano Island and subsequent implications in terms of vegetation overbrowsing (Martin et al., 2011), it is recommended that some individual fencing be put around species known to be preferred by deer such as Western redcedar seedlings, red alder seedlings, willows seedlings, and salmonberry (Martin et al., 2011, Khan & Howse, 2020). A large fencing around the whole wetland -as done in phase one of the project- is not recommended as the local community wishes that ecosystem access by wildlife be the least restricted (Huggins, personal communications).

Woody Debris

It is recommended that a large quantity of large woody debris be restored to the wetland and adjacent terrain. While debris of any size will be beneficial, workers should aim to bring in large diameter logs (50-150cm) to reflect the structure previously found on the site. Woody debris should be placed both in the wetland and buried in the water table where it can absorb water in the wet season and hold moisture into the dry season. Similar to a nurse log or a hugelkultur, LWD will provide some level of drought resilience to the landscape as the wood decomposes and holds water in the tissue. In a warming climate LWD may be increasingly important for moisture retention, and novel methods inspired by hugelkultur that can retain groundwater in the soil may be beneficial. One model used by researchers estimated pre-logging LWD volume in a Pacific Northwest Douglas Fir forest to be 80 tons per acre (Spies and Cline 1988). For increased climate resilience a greater density of LWD may be desirable for this site. There are some mature cedars in the area which appear to be in decline, which will also contribute to LWD on the site in the years following restoration.

Recommendations for Amphibians

The Millard Learning Centre currently hosts a population of the red-legged frog, which is a Blue-Listed species of special concern. This species is found in coastal lowlands between Oregon and British Columbia however their habitats have been shrinking for decades due to the loss of wetlands from industrial development, agriculture and urban expansion. This species can be found in a variety of wetland habitats including swamps, marshes, bogs, fens, lake edges and slow moving rivers but they also migrate to forested areas for much of their life cycle (Maxcy, 2004). The Millard Learning Centre is an ideal area to conserve for this species because (1) the land currently hosts a population, (2) the management regime prioritizes conservation and (3) because of the absence of the Eastern bullfrog which can have negative impacts on the viability of red-legged frog populations (Maxcy, 2004).

The proposed wetland is in a site that is likely to have been prime habitat before it was logged. By de-compacting the soil and digging pools to create a wetland, the habitat will be enhanced for the red-legged frog among other amphibians. Although the current conditions of the site are wet, the water moves downslope faster than it likely would have historically because of soil compaction and the clearing of vegetation. The proposed pool will slow the movement of water and create a permanently wet habitat throughout the year. This site is meant to serve as a breeding site and refuge from predators.

One design factor meant to specifically benefit the red-legged frog are the two amphibian corridors made by strategically placed CWD. Downed debris in forests are well known refugia for amphibians and can protect them during periods of low moisture and high heat (Parks & Olson, 2011). One of the proposed corridors reaches from the south end of the wetland to the forage forest so that the frogs can migrate to an area with plenty of vegetative cover. The proposed northern corridor leads through a sedge dominated area (ideal vegetation for laying their eggs) towards a remnant forested patch that remains intact since logging (Maxcy, 2004).

This patch contains cedar trees which dominate the canopy, and sword ferns and Oregon grape are found in the understory. We did not design a corridor upslope to a larger forested patch because this is a very dry and warm site since it has a south facing aspect and a rocky substrate. Also, red-legged frog populations become less common at higher elevations (Maxcy, 2004). Adding woody debris beside the wetland as well as within it will create the necessary habitat complexity that should attract and benefit this species. The planting of willows to attract beavers is another design feature which could improve habitat for red-legged frogs since beavers are positively associated with red-legged frog habitat (Maxcy, 2004).

The proposed wetland will improve habitat connectivity between multiple wetlands on this site including the cattail pond which is found downslope and the smaller, ephemeral ponds created in the floodplain beside Chrystal Creek. We expect that these design features will improve the likelihood of a long term, sustainable population of red-legged frogs on this site.

Climate Considerations for red-legged frog

Red-legged frogs typically rely on ephemeral ponds for laying their eggs (Abney et al., 2019). Some amphibian ecologists have suggested that warmer temperatures will benefit red-legged frogs because of increased food abundance in wetlands and faster larval development (Abney et. al., 2019). However Abney et al. (2019) did not find evidence for this hypothesis in their analysis of this species in the Little Campbell River watershed. Ephemeral ponds are unpredictable and can dry up before larva are developed enough to migrate out of a pond. The proposed wetland is designed to stay wet throughout the dry summer months, which will provide redundancy in case ephemeral ponds dry up too quickly. This is an important habitat feature which will help this species adapt and become more resilient to climate change. Another benefit to a permanently wet site is that deeper ponds maintain cooler temperatures than ephemeral ponds. Cooler temperatures are vital for amphibians, especially during extreme heat events. One of the concerns of this site is that because of the current lack of tree cover, the temperature fluctuation of the pond may be extreme and it may be in danger of drying up because of the initial lack of shade. That is why we propose planting fast growing species like Willow as well as the slower growing western red cedar. This will provide shade and eventually coarse woody debris. However, some UV exposure is an important factor of wetland habitat for red-legged frogs in order for the wetland to be productive and provide the algae necessary for larval feeding (Abney et al., 2019). The remnant patches of trees on this site are likely too small to immediately provide prime habitat for a large population of red-legged frogs but could be expanded over time with planting and caging to prevent deer grazing. Chan-McLeod & Moy (2007) recommend a minimum forest patch size of 0.8ha to provide optimal habitat for this species. Therefore, this site requires significant reforestation once the wetland has been created. Overtime, with greater habitat complexity, the development of microclimates and increased habitat connectivity at this site will increase the chances of this species to adapt to climatic variations. We hope that habitat restoration at this site can help make the Millard Learning Centre become a source population to other areas on Galiano Island.

Recommendations for beavers

Beavers are ecosystem engineers that play a pivotal role in wetland habitats. Although they can be considered a nuisance to some humans, beavers use trees and shrubs to build dams that create multi-thread channels and form ponds, radically altering wetland sites and creating habitats for many other species (Polvi & Wohl, 2011). Logged stumps and deep pools of cool water created by dams provide habitat for waterfowl, turtles, amphibians, otters, muskrats, fish, and other animals, and dams are often seen in association with increased diversity of songbirds (Polvi & Wohl, 2011). Wetlands dominated the landscape of Turtle Island/'north america' prior to European arrival, who quickly sought to drain wetlands for colonization. Nowadays there is an estimated reduction of over 50% of previous wetland landscapes (Dahl & Allord, n.d). The United States alone loses about 80,000 acres of wetlands annually, about the equivalent of losing a football field of wetlands every nine minutes.

Dams provide ecosystem benefits that occur naturally and free of charge, providing a service that often comes with a hefty price tag when humans attempt to simulate the same service using technology. The buildup of sediment, branches, and rocks that collects behind an intact beaver dam is an effective way to sequester carbon, reducing greenhouse gas emissions from releasing into the atmosphere (Polvi & Wohl, 2011). The water table behind a dam is elevated, slowing the decomposition of organic matter as oxygen is unable to reach it as easily (Wright et al, 2002). Studies suggest that soggy debris in beaver meadows can last about 600 years longer than woody debris in a forest (Dahl & Allord, n.d). Ecosystem benefits are only available with intact beaver dams - requiring live beavers living within lodges.

Beavers require a steady source of water, and often leave sites that lack water or become water-insecure as a result of climate change. Improving the hydrological conditions will create water channels of slow-moving water that will hopefully provide the right conditions for beavers to build lodges. We don't propose to reintroduce beavers to the area, but hope that by having fast-growing tree species that beavers prefer, like willow and red alder, and creating a water source will attract beavers to the site in the future.

Conclusion

The proposed wetland is designed to provide many co-benefits including enhancing wetland habitat for wildlife, restoring historic hydrological patterns, mitigating climate impacts, and conserving specific species such as the western red cedar and red-legged frog. This project is meant to assist in the recovery of the ecosystem from past human disturbances that have degraded it such as logging and farming. Some ecosystem patches remain undisturbed and this wetland should help assist the recovery of these species and build a more functional ecosystem over time. This proposal will fulfill part of Phase 2 of the *Cedar for the Next Century* grant and contribute to the larger restoration work at the Millard Learning Centre.

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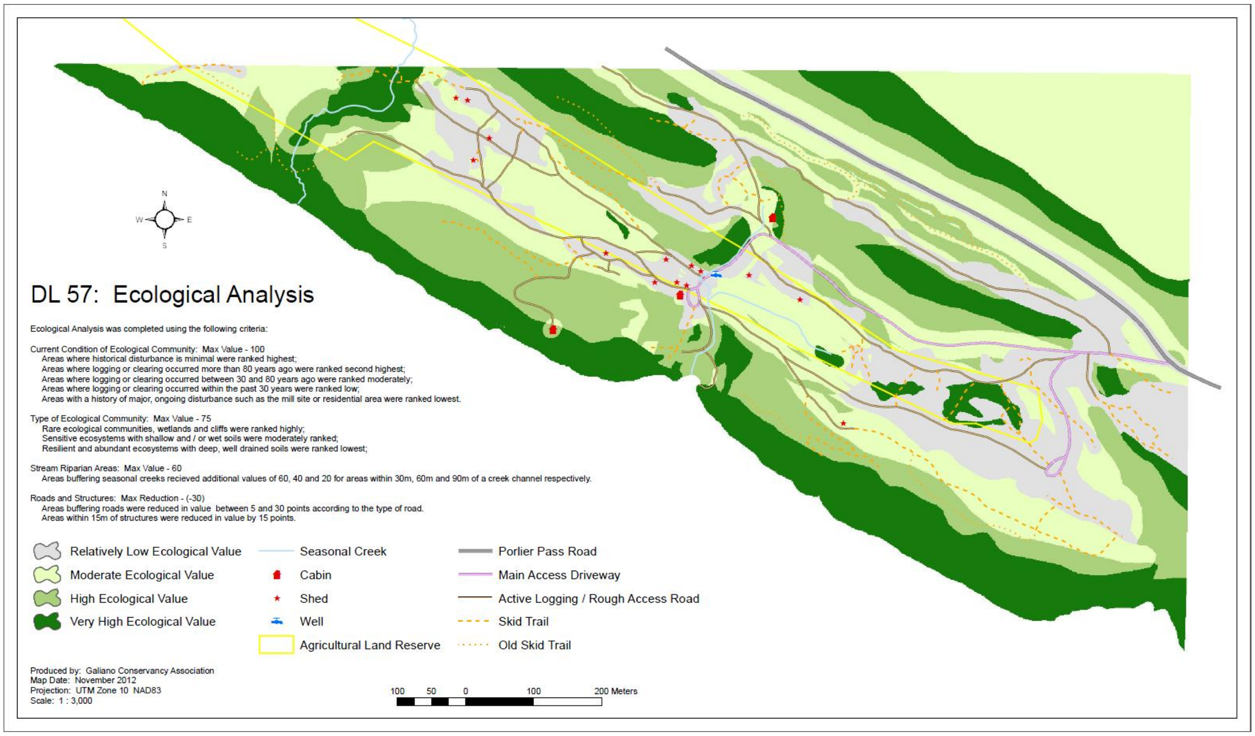
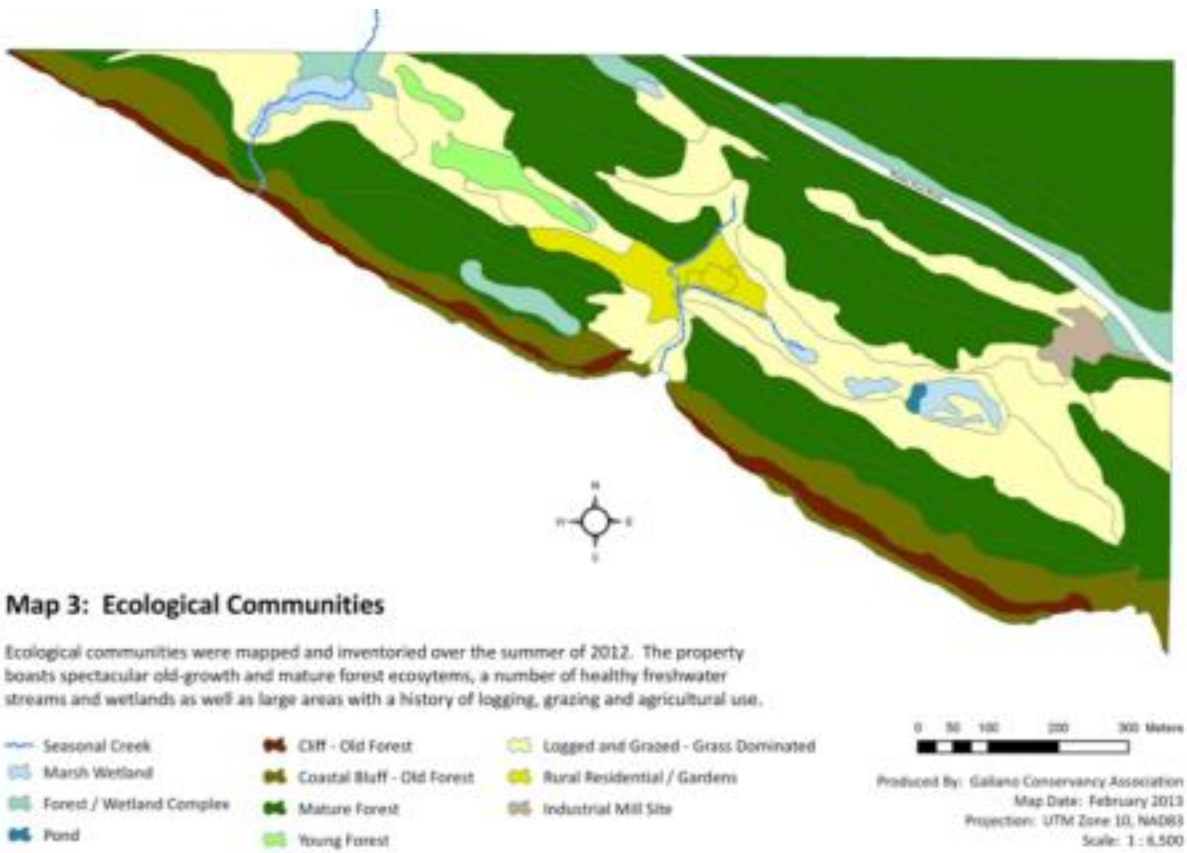
Appendices

Appendix 1: Maps from the GCA 2012 Management plan.

The project area is located in the light blue area in the vicinity of the pond in Map 3.


N
W
E
S
DL 57: Ecological Analysis
Ecological Analysis was completed using the following criteria:
Current Condition of Ecological Community: Max Value - 100
Areas where historical disturbance is minimal were ranked highest;
Areas where logging or clearing occurred more than 80 years ago were ranked second highest;
Areas where logging or clearing occurred between 30 and 80 years ago were ranked moderately;
Areas where logging or clearing occurred within the past 30 years were ranked low;
Areas with a history of major, ongoing disturbance such as the mill site or residential area were ranked lowest.
Type of Ecological Community: Max Value - 75
Rare ecological communities, wetlands and cliffs were ranked highly;
Sensitive ecosystems with shallow and / or wet soils were moderately ranked;
Resilient and abundant ecosystems with deep, well drained soils were ranked lowest;
Stream Riparian Areas: Max Value - 60
Areas buffering seasonal creeks recieved additional values of 60, 40 and 20 for areas within 30m, 60m and 90m of a creek channel respectively.
Roads and Structures: Max Reduction - (-30)
Areas buffering roads were reduced in value between 5 and 30 points according to the type of road.
Areas within 15m of structures were reduced in value by 15 points.
Relatively Low Ecological Value
Moderate Ecological Value
High Ecological Value
Very High Ecological Value
Seasonal Creek
Cabin
Shed
Well
Agricultural Land Reserve
Porlier Pass Road
Main Access Driveway
Active Logging / Rough Access Road
Skid Trail
Old Skid Trail
Produced by: Galiano Conservancy Association
Map Date: November 2012
Projection: UTM Zone 10 NAD83
Scale: 1 : 3,000
100 50 0 100 200 Meters


Map 3: Ecological Communities
Ecological communities were mapped and inventoried over the summer of 2012. The property boasts spectacular old-growth and mature forest ecosytems, a number of healthy freshwater streams and wetlands as well as large areas with a history of logging, grazing and agricultural use.
Seasonal Creek
Marsh Wetland
Forest / Wetland Complex
Pond
Cliff - Old Forest
Coastal Bluff - Old Forest
Mature Forest
Young Forest
Logged and Grazed - Grass Dominated
Rural Residential / Gardens
Industrial Mill Site
Produced By: Galiano Conservancy Association
Map Date: February 2013
Projection: UTM Zone 10, NAD83

Appendix 2: List of plants observed on the proposed wetland site.

The species are native unless stated otherwise.

Plant Name	**Rough Location**	**Notes (abundance, vigor, stage)**
Trees		
Western Redcedar (*Thuja plicata*)	One mature tree in the middle of the site, a clump of trees aligned on the southern side, and another clump at the base of the slope on the northern side. Saplings all across the site.	Both mature specimens (including one with visible diminished vigor) and few saplings.

Red alder (*Alnus Rubra*)	Different locations around the chosen site for excavation, particularly on the western side, and along the ditch.	Seedlings only.
Shrubs		
Salmonberry (*Rubus spectabilis*)	Different locations across the site, including outside of and within the chosen excavated pond.	A dozen of specimens observed.
Red Huckleberry (*Vaccinium parvifolium*)	Eastern side of the site close to the forage forest.	A few specimens growing on stumps.
Herbs		
Sword Fern (*Polystichum munitum*)	Around the chosen excavated site.	Many patches around the Redcedars.
Bracken Fern (*Pteridium aquilinum*)	Around the chosen excavated site, especially the northwestern edge.	Some clumps around the Redcedars.
Lady Fern (*Athyrium filix-femina*)	Southwestern side.	A small patch.
Horsetail sp. (*Equitum sp.*)	Spread across the site, concentrated in the center.	Do not know whether it is common or giant horsetail.
Stinging nettle (*Urtica dioica*)	In patches at different locations.	NA.
Salal (*Gaultheria shallon*)	Different locations.	Some patches around the Redcedars.

Trailing Blackberry (*Rubus ursinus*)	Widespread throughout the site.	NA.
Canada Mint (*Mentha canadensis*)	North- and Southwestern sides.	A few small patches.
Thistle species (*Cirsium sp.*)	Different locations.	Likely introduced species.
Monkeyflower species (*Erythranthe sp.*)	Southwestern edge of the chosen excavated site.	One big patch.
Veronica sp.	Southwestern edge of the chosen excavated site.	NA.
Purple Foxglove (*Digitalis purpurea*)	Different locations.	A few specimens near the stumps. Introduced species.
Grasses		
Slough Sedge (*Carex obnupta*)	Widespread on the site, but concentrated on the southwestern side, southern side, and in the center.	Many dense large patches around some cedars, and in the meadow.
Common native and introduced Rush (*Juncus effusus*)	Widespread throughout the site.	NA.
Bolander's Rush (*Juncus bolanderi*)	Widespread throughout the site.	NA.
Small-flowered bulrush (*Scirpus microcarpus*)	Different locations.	NA.
Reed Canarygrass (*Phalaris arundinacea*)	Northwestern side.	Two small patches (roughly 3x3m). Invasive species.

Appendix 3: Site series used for the wetland vegetation design: Ws53 “Western redcedar – Sword fern – Skunk cabbage” (MacKenzie & Moran, 2004).

Ws09	Ws10	Ws11	Ws50	Ws51	Ws52	Ws53	Ws54	Ws55	Common Name
▮▮	▮▮▮	▮▮▮							spruce
▮▮▮	|	|							black spruce
▮▮▮▮	▮▮▮	▮▮▮▮▮							subalpine fir
▮	▮▮▮▮				|	▮▮▮	▮▮▮▮▮	▮▮▮▮▮	western hemlock
|	▮▮▮▮▮			|	▮▮	▮▮▮▮▮	▮▮▮▮	▮	western redcedar
				▮	|	▮▮	▮▮▮	|	Sitka spruce
			|	▮	▮▮▮▮▮	▮▮▮▮	▮	|	red alder
					▮▮	▮▮▮			bigleaf maple
							▮	▮▮▮▮▮	yellow-cedar
							|	▮▮▮▮▮	mountain hemlock
							▮▮	▮▮▮▮	amabilis fir
		|							Bebb's willow
				|					Drummond's willow
									MacCalla's willow
▮▮▮	▮	▮▮▮▮		|					mountain alder
▮	▮	▮▮▮	|	▮▮	|	|	|		black twinberry
▮▮▮	|	▮▮	▮▮▮▮▮	▮▮	|		|		pink spirea
|	▮	▮	|	▮▮	▮	▮	|		red-osier dogwood
▮▮	▮▮▮	▮▮		|			▮▮▮▮	▮▮▮▮▮	Alaska/oval-leaved blueberry
|				▮▮▮▮▮					Sitka willow
			|	▮▮▮▮▮					Pacific willow
		|	|	▮▮▮	▮▮▮▮▮	▮▮▮▮	▮▮▮	▮▮	salmonberry
	|			|	▮▮▮▮	▮▮▮	|		red elderberry
			|	|		▮	▮▮▮	|	salal
				|	▮▮▮	▮	|		stink currant
								▮▮	copperbush
▮▮	▮	▮	|	|			|	|	bluejoint
|			▮▮▮	|				|	water/Sitka sedge
			▮						beaked sedge
▮	▮▮▮	▮▮▮		|	|		▮	▮	oak fern
									Sitka valerian
|	|			▮▮		|	|		small-flowered bulrush
▮▮▮	▮▮▮	▮▮▮	|	▮▮	|	|	|		common horsetail
▮▮▮▮▮	▮▮▮▮	▮▮▮▮▮	▮	▮▮▮▮▮	▮▮▮▮▮	▮▮▮▮	▮▮▮▮	▮▮▮▮	skunk cabbage
▮▮	▮▮▮▮	▮▮▮▮	|	▮▮▮	▮▮▮▮	▮▮▮▮	▮▮▮	▮▮	lady fern
|	▮▮	▮▮▮		|	▮▮	▮▮	▮▮	▮	foamflower
▮	▮▮	▮▮		|	|		▮	▮	rosy twistedstalk
				|	▮▮▮	▮▮▮	▮	▮	false lily-of-the-valley
			|	▮▮▮	▮	|	|		Pacific water-parsley
					▮▮	▮▮▮	|	|	sword fern
				|	▮	▮▮▮	|		giant horsetail
				|	|	|	▮▮▮	▮▮	deer fern
	|	|			|		|	▮▮	Indian hellebore
							|	▮▮	deer-cabbage
								|	hook-mosses
▮▮	▮▮▮▮	▮▮▮▮	|	▮▮	▮▮▮	▮▮▮	▮▮▮	▮▮▮	leafy mosses
▮	|		▮	|					glow moss
▮▮▮▮	▮▮▮	▮▮	▮	|	|		▮▮	▮▮▮	peat-mosses
|	▮▮	|		|		|	▮▮▮	▮▮	step moss
▮▮▮	▮▮	▮							red-stemmed feather-moss
				▮	▮▮▮▮	▮▮▮▮	▮	|	beak moss
	|			|	|	|	▮▮▮	▮▮▮	lanky moss