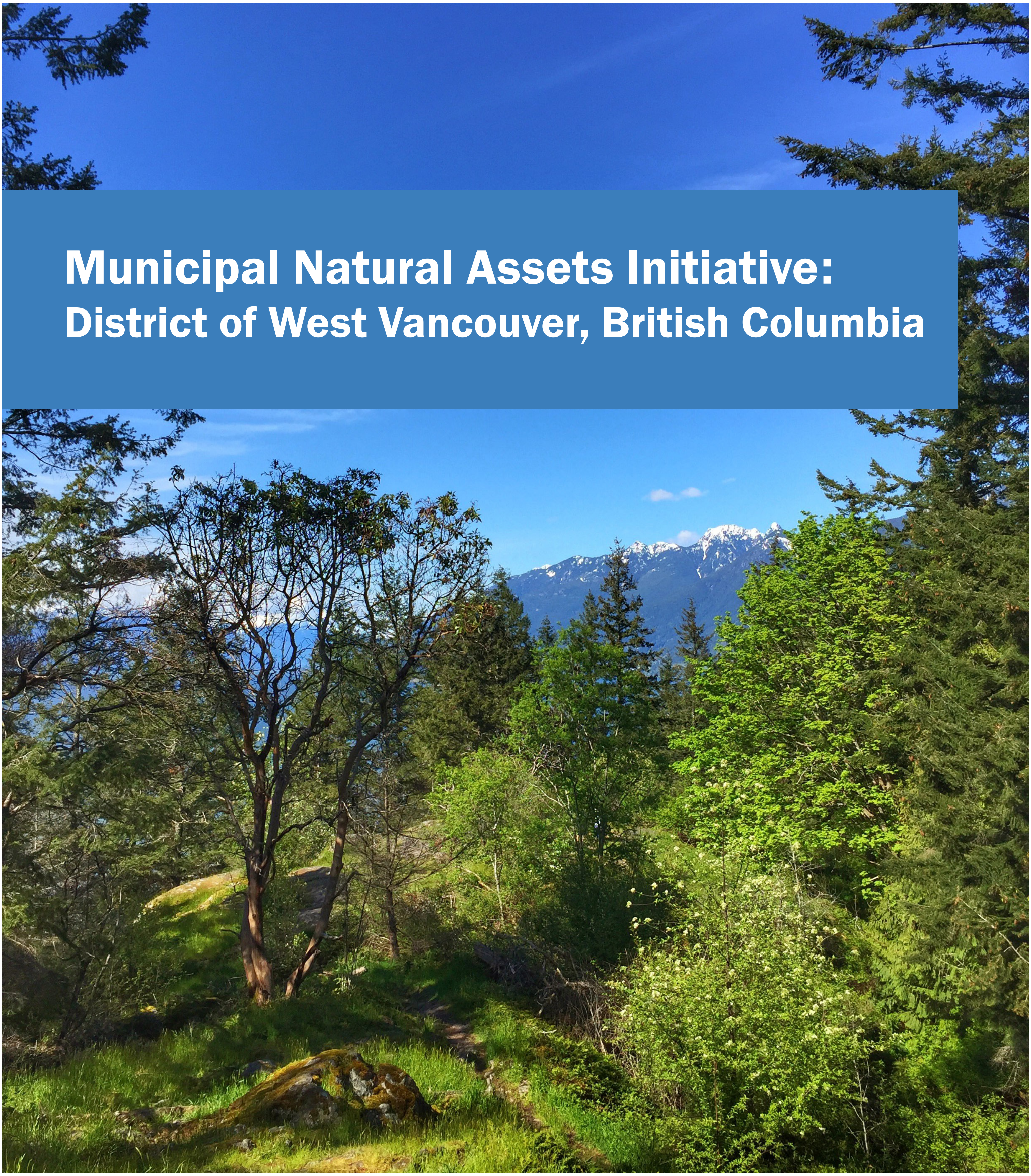
Municipal Natural Assets Initiative:
District of West Vancouver, British Columbia



Making Nature Count

The Municipal Natural Assets Initiative is changing the way municipalities deliver everyday services, increasing the quality and resilience of infrastructure at lower costs and reduced risk. The MNAI team provides scientific, economic and municipal expertise to support and guide local governments in identifying, valuing and accounting for natural assets in their financial planning and asset management programs and developing leading-edge, sustainable and climate resilient infrastructure.

Acknowledgements

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Acronyms

DWV	District of West Vancouver
GIS	Geographic Information System
ISMP	Integrated Stormwater Management Plan
KWL	Kerr Wood Leidal
LiDAR	Light Detection and Ranging
masl	Metres above sea level
MCDA	Multi-criteria decision analysis
ROW	Right of way

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Executive summary

The term "municipal natural asset" refers to the stock of natural resources or ecosystems that is relied upon, managed or could be managed by a municipality, regional district or other form of local government for the sustainable provision of one or more municipal services. Examples include wetlands, rivers, forests and foreshores. The Municipal Natural Assets Initiative (MNAI) is working to develop resources and help municipalities incorporate natural assets into asset management and financial decision-making processes.

As part of the MNAI pilot project, the District of West Vancouver (DWV) undertook a project to begin to assign financial value to its natural assets, using a buried creek to be daylighted as the first example. The buried creek of interest is a 90-metre section of a tributary to Brothers Creek near Westcot Elementary School. The study area included the covered creek, the open green space surrounding it and the soils and vegetation. This section of creek was chosen because it is an opportunity to restore or enhance habitat for anadromous salmon and cutthroat trout. The creek below the covered portion has been restored to allow fish access but the covered portion limits fish movement to areas upstream that are also potential habitat. The objective of the project was to determine financial issues related to daylighting streams by:

1. Determining the value of the services provided by the stream in its natural (daylighted) state versus the value of the services in its current covered form, and versus the required engineered infrastructure that would be required to meet current stormwater standards.

2. Developing a simple model that can be used elsewhere in the District and in other areas, to identify candidate streams for daylighting.

Modelling used in this project was previously completed during the Integrated Stormwater Management Plan (ISMP) development process. No new modelling was conducted, though the daylighted creek was designed with the 200-year storm requirement in mind. Because the creek runs under a school playground, the daylighting design required realignment of the creek. Given this scenario, total construction cost to restore the covered section of the creek is $327,200. In comparison, the construction cost to replace the existing underground culvert to meet the same stormwater requirements is $300,000. Neither figure includes the long-term operation and maintenance costs or co-benefits of daylighting the stream.

This initial project demonstrated that the natural asset of focus — the covered portion of the Brothers Creek — would provide stormwater management benefits commensurate with the upgraded engineered infrastructure required to meet current stormwater standards (i.e. 1 in 200 year event), and that the capital costs of restoring the creek are similar to those of upgrading the culvert to meet stormwater requirements.

Furthermore, the MNAI technical team prepared a guidance document for identifying candidate streams for day-lighting (see Annex B). This is a strong foundation for a tool that the District and other local governments can apply during selection and planning of future daylighting projects.

Introduction

1.1 Municipal Natural Assets Initiative

The term “municipal natural assets” refers to the stock of natural resources or ecosystems that is relied upon, managed or could be managed by a municipality, regional district or other form of local government for sustainable provision of one or more municipal services.[1] Municipalities such as the District of West Vancouver (DWV) are recognizing that it’s equally important to account for and manage natural assets as engineered ones. The most important factor is whether the services from the asset, whether natural or engineered, are delivered reliably and cost-effectively. If this fact is not recognized and incorporated into new planning practices, decisions on how to invest will be incomplete.

The Municipal Natural Assets Initiative (MNAI) is developing resources to incorporate natural capital (i.e., natural or vegetated assets) that form part of the urban landscape into asset management plans. Through MNAI, the District of West Vancouver is exploring options to refine, replicate and scale up the approach of a small number of municipalities that are integrating natural capital considerations into asset management and financial planning.

MNAI has completed an Overview Guidance Document for Stormwater Management for municipalities. This report details application of the guidance document for one particular asset, a culverted creek in the District of West Vancouver. It is important to first establish the value in monetary terms of services natural assets provide. Without this information, there is no rational basis to make financial management choices. DWV’s efforts to cost out the services related to daylighting a creek are a vital starting point for future financial planning and reporting. The goal of this project is to illustrate the application of the guidance document and to provide technical details on the approach.

1.2 District of West Vancouver

The District of West Vancouver is a municipality northwest of the City of Vancouver, British Columbia, located on the northern side of Burrard Inlet and the southeast shore of Howe Sound (see Figure 1). It is one of three municipalities that make up the North Shore (with the District of North Vancouver and the City of North Vancouver).

The District supports a population of 42,473[2], which has declined by 4.6 per cent since 2011. Based on a 2016 population analysis the District completed, it is predicted that the municipality will experience a 10,000-person increase in population by 2041. This equates to an annual growth of 0.74 per cent; one of the lowest population projections in the region.

1 O’Neill et al., 2017.

2 Canada 2016 Census

Figure 1: District of West Vancouver

1.2.1 Policy/governance context

DWV is committed to an asset management approach that incorporates resilience to climate change and extreme weather events as a key objective. For instance, all major drainage facilities and flood control works are required to consider 200-year storm events in their design and should employ naturalized engineering strategies where possible.[3]

A high-level infrastructure management study was completed for DWV in 2010 that outlined sustainable infrastructure replacement funding levels over the next 100 years.[4] As it relates to drainage, this study has formed the basis for expanding the DWV’s asset management program to include condition assessments of drainage infrastructure, coordinated capital planning between infrastructure renewal projects and development of integrated stormwater master plans.

As part of the asset management program, the MNAI pilot could assist DWV by providing economic and risk analysis to inform it of the implications of daylighting the covered portion of Brothers Creek in terms of avoided future asset replacement costs.

1.2.2 Natural asset of interest

The District of West Vancouver contains more than 40 watersheds, each with numerous tributaries. Most of the land below 366 metres is zoned residential with high impervious areas, whereas most of the land above 366 metres is zoned for community use with low impervious areas. DWV is interested in understanding the financial case for daylighting as it relates to a 90-metre tributary of Brothers Creek near Westcot Elementary School, and potentially applying the methodology to other streams with potential for daylighting.

The area immediately surrounding the covered portion of the Brothers Creek tributary at Westcot Elementary School is

3 District of West Vancouver 2018.

4 AECOM, 2010.

the primary site of interest. The natural assets include the open green space around the covered portion of the stream, the stream itself and the soil and vegetation in the vicinity. There are no structures or roads on top of the covered portion of the stream. At the start of the pilot, it was not confirmed if the stream has year-round permanent flow that would support fish populations.

The pilot project was initially identified within the context of developing the District's Integrated Storm Water Management Plan (ISMP) for that watershed because it represents an opportunity to restore and/or enhance habitat for anadromous salmon and resident cutthroat trout within the middle reaches of Brothers Creek. Although fish access into the lower part of the tributary has been restored through construction of a concrete/wood weir fishway at its confluence with Brothers Creek, a 90-metre piped section along the edge of the Westcot School grass playing field limits fish access much further upstream. Approximately 160 metres of moderate value fish habitat upstream of the piped section would be made accessible by daylighting. Furthermore, and subject to modelling, there may be additional benefits related to water quality and flood mitigation.

1.3 Pilot objective(s)

Key objectives for DWV relate to determining the financial implications related to daylighting streams, with an initial focus on a tributary of Brothers Creek. The team scoped this into the following two objectives:

1. Determining the value of the services provided by the stream in its natural (daylighted) state versus the value of the services in its current covered form, and versus the required engineered infrastructure that would be required to meet current stormwater standards.

2. Developing a simple model that can be used elsewhere in the District and in other areas, to identify candidate streams for daylighting.

2. Methods

The methods associated with this project have focused on assessing and comparing the value of services provided by the creek in its natural state against the current state (i.e., culverted) to meet the future requirements of the one-in-200-years storm. These methods were then expanded upon to develop a guidance document for identifying candidate streams for daylighting.

It is important to note that no separate modelling of the designed open channel was completed, per DWV's request. The MNAI technical team reviewed the modelling of the study area that was completed for the ISMP. As such, although the open channel was designed with the 200-year storm requirement in mind, the design was not verified through modelling as it was deemed an unnecessary step at the conceptual design stage.

2.1 Site visit

The MNAI technical team completed two separate site visits to assess the study area. The first occurred November 9, 2016, with the goal of assessing potential for salmon habitat. The second occurred on March 10, 2017, to assess the potential location of the open channel.

Michelle Molnar (MNAI technical team), John Werring (DSF staff biologist) and John Barker (president, West Vancouver Streamkeepers Society) attended the first site visit on November 9, 2016. The group walked the length of the creek path from where it branches off from Brothers Creek on the west side of Westcot Road to the northeast corner of the Westcot Elementary Playground (see Figure 2). We determined that the site holds potential spawning and rearing habitat for coho salmon and cutthroat trout if daylighting could be achieved. Additional notes of the visit included:

1. There are two sections of a fish ladder on the west side of Westcot Road. The first is made of concrete and leads from Brothers Creek. The second is made of wood and leads to the road. Both look in reasonable condition and were functioning adequately during the site visit.

2. The lower section of the creek path from the culvert adjacent to the playground fence to the confluence with Brothers Creek is in need of some remediation (removing silt, placing gravel, some complexing[5] and planting of native plants along the streamside).

Michelle Molnar and Michael Thompson (MNAI technical team), Olivia Taje (DWV staff), and Rich Ketchen (DWV Streamkeepers) attended the second site visit on March 10, 2017. They walked the length of the creek path to identify the proposed location of the open channel, from the lower section (where the culvert lies adjacent to the playground fence) to the confluence with Brothers Creek. An alignment was identified that runs along the periphery of the schoolyard using the utility right-of-way (ROW) between the yard and the private residences. This requires a sharp turn in the stream, up to 90 degrees, to return the stream to its present outlet downstream of the schoolyard. At the turn, a sanitary sewer currently exists, which is addressed in the proposed design (also see Section 2.4).

The visit also included viewing a rearing pond created by the Streamkeepers in the small park near the parking lot at St. David's Church. Although it never functioned consistently and has since been abandoned, revitalizing the rearing pond was discussed as a component of the project design.

5 The soils and substrates of wetlands have hydrologic conductivities, which can facilitate or hamper the transport of substances to the vegetative root zone. Complexing refers to restoration approaches that provide considerable reactive surface area for nutrient cycling and microorganisms.

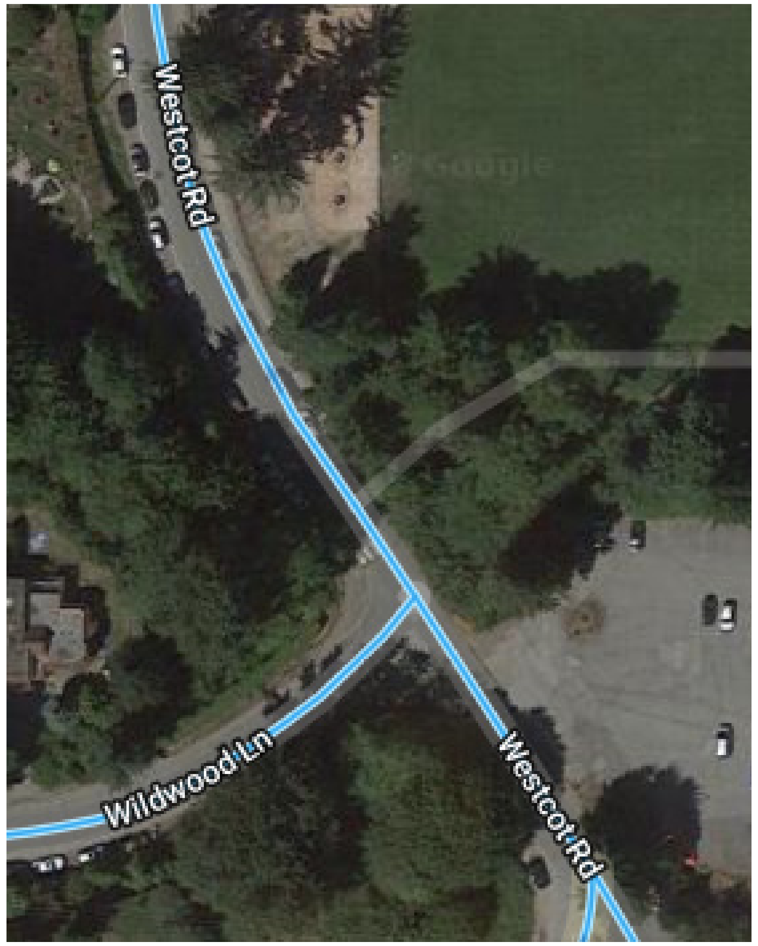


Figure 2: Study site

2.2 Water flow monitoring

The West Vancouver Streamkeepers conducted water flow monitoring for this project. Over the period from June to October 2017, a simplified technique was used, which entailed calculating the time required to fill a 20-litre pail and then dividing the volume by the time. The sampling location was at the base of the fish ladder where this tributary joins the main branch of Brothers Creek.

Table 1: Brothers Creek tributary flow record, summer 2017

Date	Time	Temperature		Time – seconds 20 litres
		Air	Water	
11-Jun	3:15 pm	19.1	12.7	9.57
18-Jun	10:15 am	11.9	11.7	6.86
25-Jun	4:37 pm	22.5	15.0	25.11
01-Jul	9:30 am	16.8	13.4	28.62
07-Jul	3:00 pm	21.9	15.3	40.37
16-Jul	6:15 pm	19.4	14.6	52.41
31-Jul	10:00 am	18.9	14.4	43.68
04-Aug	1:38 pm	23.1	16	37.95
11-Aug	2:40 pm	24.6	17.1	56.97
18-Aug	2:40 pm	19.7	15.4	41.63
25-Aug	12:40 pm	18.5	14.5	61.22
31-Aug	3:00 pm	19.4	15.7	44.68
08-Sep	12:20 pm	17.1	16.8	20.39
15-Sep	11:15 am	17.9	12.5	118.62
26-Sep	2:35 pm	20.2	14.8	53.86
03-Oct	3:30 pm	16.2	12.5	53.75
11-Oct	3:15 pm	12.2	10.8	24.08
19-Oct	3:40 pm	High flow – no room for bucket		

2.3 Design of open channel

The design procedure presented below assumes the streams have been subjected to a high-level screening process that identifies the necessary characteristics required for a successful daylighting project such as connectivity downstream, local government and community support, funding, etc. In addition, the screening process should identify "fatal flaws" of sites that have characteristics that do not support a successful daylighting project.

Conceptual design steps that should be taken once a site has been selected or identified for future design and analysis include:

1. Determine channel design criteria in terms of flood, normal and base design flows; aquatic organism and fish species and life stages considered in the design; and other objectives. Stakeholders and design professionals should work together to complete this task.

2. Review aerial photographs, reports and other data to determine the historic stream route and properties.

3. Review property maps and current land use to determine if historic route can be re-established for stream daylight route.

4. If the existing land use cannot be modified to re-establish the stream's historic route, identify other routes that may be applicable. If no other routes are available the project may not be able to proceed.

5. Characterize historic, existing and potential future conditions and uses of the site based on field and desktop assessment. The assessment should include characterization of hydrology, hydrogeology, natural and invasive flora, aquatic and terrestrial organisms including fisheries, expected uses beyond flow conveyance and habitat

(e.g., education, pathways, off-leash area), slopes and topography (survey or LiDAR), geotechnical properties and concerns (earth materials, slope stability), underground utilities, property boundaries and ownership, potential future concerns (e.g., beaver activity) and cultural resources.

6. Determine additional constraints and concerns based on characterization assessment results. If constraints cannot be addressed, reassess if project should proceed.
7. Develop conceptual design of channel based on constraints and characteristics of site. Where possible, focus on natural stream design and/or downstream/upstream analogues if applicable in terms of site characteristics. If downstream/upstream reaches are not appropriate, apply state-of-art design techniques in terms of natural stream design where possible, if sufficient space and constraints permit. If constraints don't permit natural design techniques, apply hydraulic engineering design methods to ensure a stable channel design. In this instance, habitat objectives may not be achievable.
8. Conceptual design should consider all flows, including base flows for fish passage and flood flows to prevent local flooding and channel erosion. Base flows and groundwater should be considered in terms of sustainable base flows.
9. Areas above the active channel and along the banks should include appropriate landscape design, which includes vegetation restoration, habitat enhancement, pathways, etc.
10. Once conceptual design is complete, prepare design, construction and maintenance/operation cost estimates for review in parallel with the conceptual design to determine feasibility.
11. In addition to the cost-benefit review, conduct a review of the conceptual design with appropriate stakeholders. The review should include a material and constructability review as well as review for public support of the design concept.

A design basis memorandum was developed in April 2017 for consideration. Multiple meetings were held between the MNAI technical team, DWV, the West Vancouver Streamkeepers and Kerr Wood Leidal (the consultants DWV enlisted for the Brothers Creek ISMP), with a final revised design presented September 2017 (see Figure 8).

2.4 Multiple criteria decision analysis

The MNAI technical team proposed the use of multi-criteria decision analysis to assess candidate streams for daylighting. Multi-criteria decision analysis (MCDA) is a tool that can be applied to problems characterized as a choice among alternatives.[6] It is both an approach and a set of techniques for complex problems that are characterized by any mixture of monetary and non-monetary objectives, by breaking the problem into more manageable pieces for judgment, and then of reassembling the pieces to present a coherent overall picture to decision-makers. The purpose of MCDA is to serve as a decision-making aide, not to dictate the decision.

Several meetings were conducted with DWV to develop the MCDA for identifying candidate streams. Appendix B presents the guidance document of which the MCDA is a part.

6 Natural Resources Leadership Institute, 2011.

3. Results

3.1 Open channel design for Brothers Creek tributary

This tributary of Brothers Creek currently flows for approximately 92 metres in a 450-millimetre diameter concrete culvert under the playground of Westcot Elementary School. The objective of the restoration program is to daylight the creek such that it provides passage and habitat for coho salmon and cutthroat trout. The approximate alignment of the inlet and outlet of the culvert suggest that it passes under the playground as illustrated below in Figure 3.

Figure 3: Approximate alignment of culvert

Daylighting the creek along this presumed alignment of the stormwater culvert would eliminate its use as a playground and require permission from the West Vancouver School District, which owns the playground. The public right-of-way running south of the culvert inlet then west to the culvert outlet (around the perimeter of the existing field) was selected as the next best alternative alignment to the presumed culvert alignment.

The creek alongside Westcot School is a natural watercourse that also catches stormwater runoff from the mostly urban watershed above, and northeast of the school. The total drainage area above the culvert inlet is estimated at 11.584 hectares. The estimated peak rainfall-driven flow regime of the creek at the culvert inlet in the current urbanized watershed is characterized in Table 2 below.

Table 2: Estimated flow regime of Brothers tributary (at culvert inlet)

Return period (years)	Peak instantaneous flow (m^3/s)
2	0.30
5	0.51
10	0.65
200	1.17

The design parameters for the daylighted creek are:

1. Overall length of the alignment ~ 140 m
2. Overall slope from culvert inlet to outlet ~ 2.3%
3. Upstream thalweg elevation = 80.27 masl
4. Downstream thalweg elevation = 77.103 masl
5. Low flow for fish passage = 0.10 m^3/s
6. Low flow channel capacity = 0.30 m^3/s
7. Flood flow channel capacity = 1.17 m^3/s
8. Provide fish passage as primary objective and spawning and rearing habitat for cutthroat trout and coho salmon as a secondary objective.

The creek channel that replaces the culvert beneath the school playground will remain within the 6.7-metre ROW as shown in Figure 4 below.

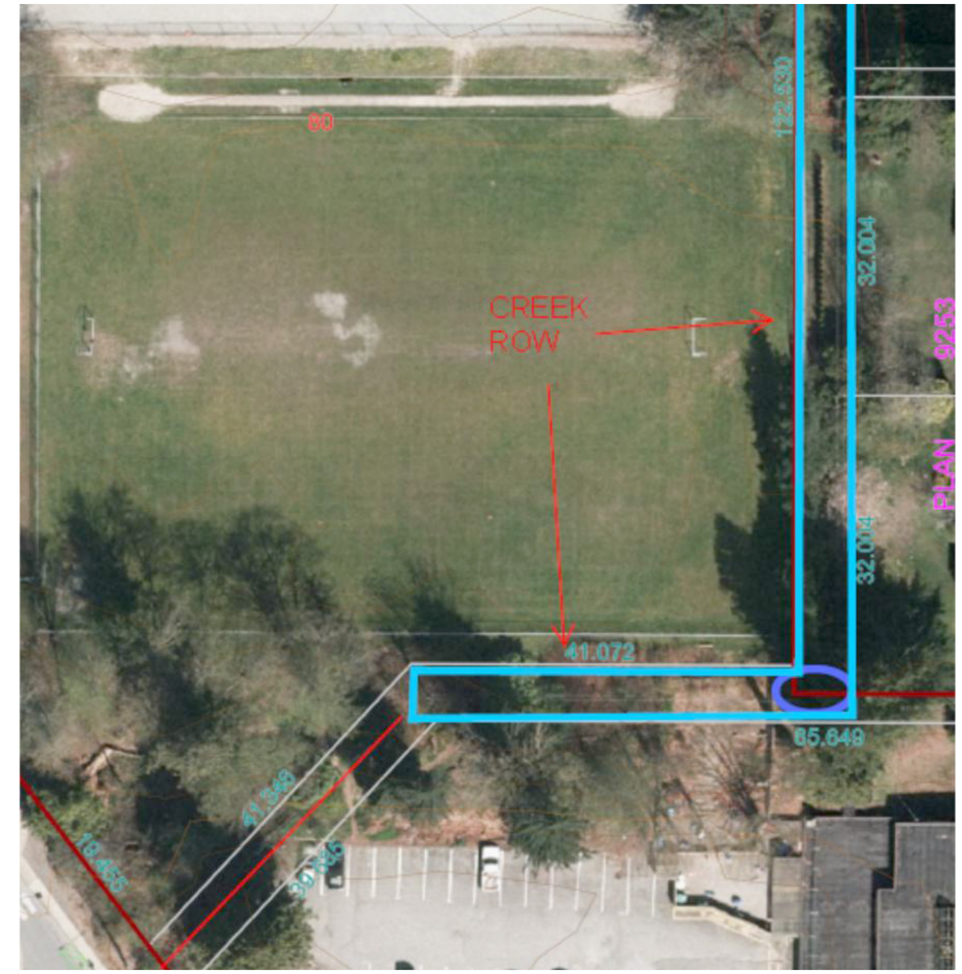


Figure 4: Restored tributary of Brothers Creek — right-of-way

3.1.1 Design rationale

For design purposes, the creek has been divided into a lower-gradient (2-3%) upstream reach and higher-gradient (9-10%) downstream reach based on boundary conditions (e.g., slopes) of the chosen restoration route (see Figure 4 and Sketch 3).

Gradients above two to three per cent (and up to approximately 10 per cent) are considered relatively steep in terms of fisheries use and are often associated with significant confinement and roughness (in the form of wood and larger rock) as the steeper streams migrate downward within a valley located on a mid to lower mountain or hill slope. Hence, including confinement and roughness as part of the design is essential. In addition to these factors, each reach was also designed considering hydrologic and fish habitat requirements.

The downstream reach applies a step-pool morphology for design (see Sketch 1 and Photo 1 and Photo 2 for examples). This type of morphology naturally occurs in streams ranging from approximately three to 10 per cent. These streams can form in areas with little vegetation or in heavily forested areas in upper watersheds. In a natural context, large rock is the key component that creates "steps" in step-pool streams. Large rocks within the channel are naturally arranged during significant floods (e.g., one-in-25-year event) to create steps, which are stable at lower flood and normal flows. Steps have been observed to re-occur systematically creating the re-occurring structure. Flow drops over each step creating pools below. The flow then impinges on another downstream step with the sequence repeating, creating a step-pool morphology. As discussed, this type of system tends to be confined with rock and large wood creating bank stability.

In terms of fish presence and use, step-pool systems are most often used by coho salmon as passage to access better habitat upstream for spawning and rearing.

Some evidence has been found that trout use this type of morphology for spawning and rearing if habitat conditions are suitable. The step-pool system was applied because of the steep topography associated with this specific site.

Considering the information above, specific design elements of the downstream stream reach include:

1. Step pools (as shown in the attached photos) at a spacing of approximately four metres (pools spaced approximately every one channel width);
2. Step height of 0.8 metres; scour depth of 0.4 metres and step drop of 0.4 metres;
3. Well-graded gravel-cobble-boulder substrate;
4. Steps (and anchor rocks) created with large rock with diameters ranging from 0.75- to one-metre step height;
5. Roughened steep (i.e. 1.5H:1V) banks created with wood and rock (in general, the more wood used, the better the habitat);
6. BioD-Block applied at the active channel-vegetation interface to promote stability;
7. Local riparian vegetation planted above the active channel; and a BioD-Block to promote stability at the active bank-vegetation interface; and
8. Channel dimensions (average depth: 0.7 m; width 4.0 to 4.5 m) that provide low-flow passage and use, while confining the maximum design flow within the active banks of the channel.

The upstream reach applies a forced-pool riffle morphology for design (see Sketch 2 and Photos 3 and 4 for examples). This type of morphology naturally occurs in streams ranging from two to four per cent in heavily forested areas. In a natural context, large wood is recruited by the stream through erosional (migration and down-cutting) processes. Large wood within the stream stabilizes the bed and banks, forcing pools at locations where several larger wood pieces become anchored (i.e., complexes). Areas upstream and downstream of the large wood complex are associated with gravel-cobble deposition. In addition to wood complexes, large rock, wood and thick vegetation cover along the banks are often associated with these streams, promoting stability.

In terms of fish presence and use, forced pool-riffle streams are often associated with rearing as well as some spawning in the Pacific Northwest. Salmon prefer these relatively low-gradient headwater reaches when compared to steeper step-pool and cascade morphologies.

Considering the information above, specific design elements of the upstream reach include:

1. Forced pools (as shown in Appendix A photos) at a spacing of approximately eight metres (i.e., pools spaced approximately every two channel widths);
2. Well-graded gravel-cobble substrate;
3. Grade control (wood log) at every second wood structure;
4. Roughened steep (i.e., 1.5H:1V) banks created with wood and rock (in general, the more wood used, the better the habitat);
5. BioD-Block applied at the active channel-vegetation interface to promote stability;
6. Local riparian vegetation planted above the active channel; and channel dimensions (average depth: 0.8 m; top width 4.5 to 5.0 m) that provide low-flow passage and use, while confining the maximum design flow within the active banks.

3.1.2 Utility interaction with right-of-way

A sanitary sewer is located within both legs of the ROW as shown on Figure 5 below

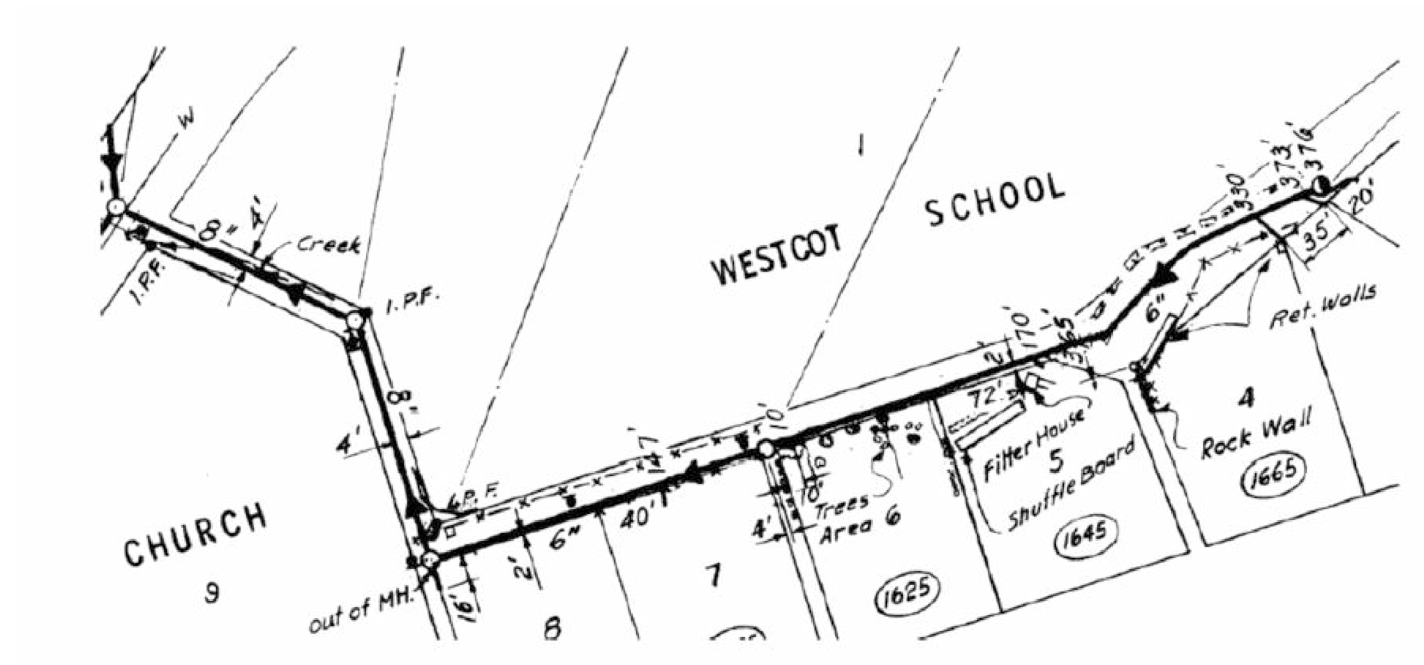


Figure 5: Sanitary sewer in proposed ROW for creek (restored)

It can be noted that sanitary sewer lies 150 millimetres within the north-south boundary of the proposed creek ROW and 1.2 metres within the east-west boundary of the proposed creek ROW (see Figure 4 for proposed ROW). The profile of the sanitary sewer is such that the proposed creek cross-section can be designed to avoid the sewer pipe except at the 90° bend between the east-west and north-south legs of the sewer alignment. MH 667 is also located at this bend. A turning pool is proposed at the bend, which places the sewer under the pool. One solution to the potential conflict between the two utilities – stormwater drain and sanitary – would be to move the sewer from the east boundary of the N-S ROW to within 150 millimetres of the west boundary. Acceptance of the current sewer alignment or relocation is the jurisdiction of the District of West Vancouver.

Two typical cross-sections of the restored creek are shown on Figures 6 and 7. These sections show the overall geometry of the cross-section relative to the sanitary sewer. The rock or woody debris required to produce the fishery features are not illustrated in these sections (see Sketches 1 and 2 for illustration of fish habitat features). The final concept plan and profile is shown in Figure 8.

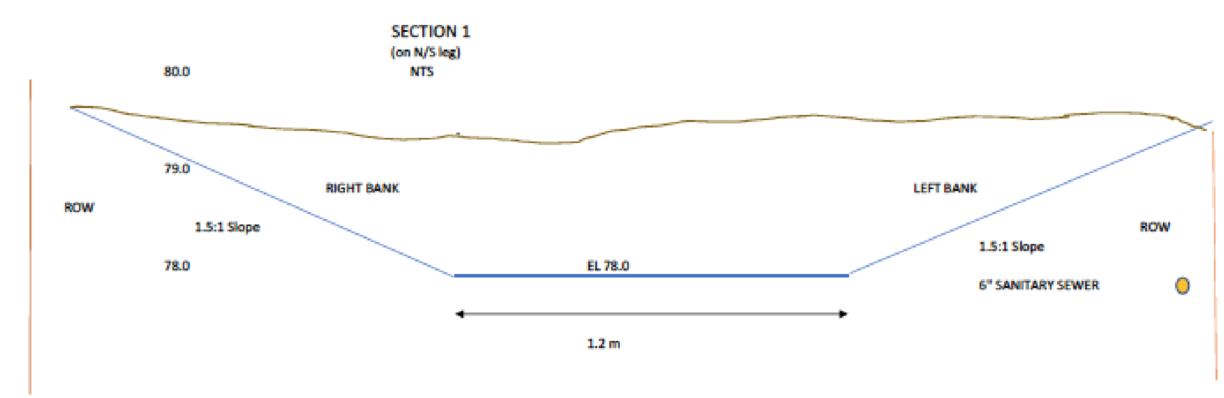


Figure 6: Cross-section of restored creek

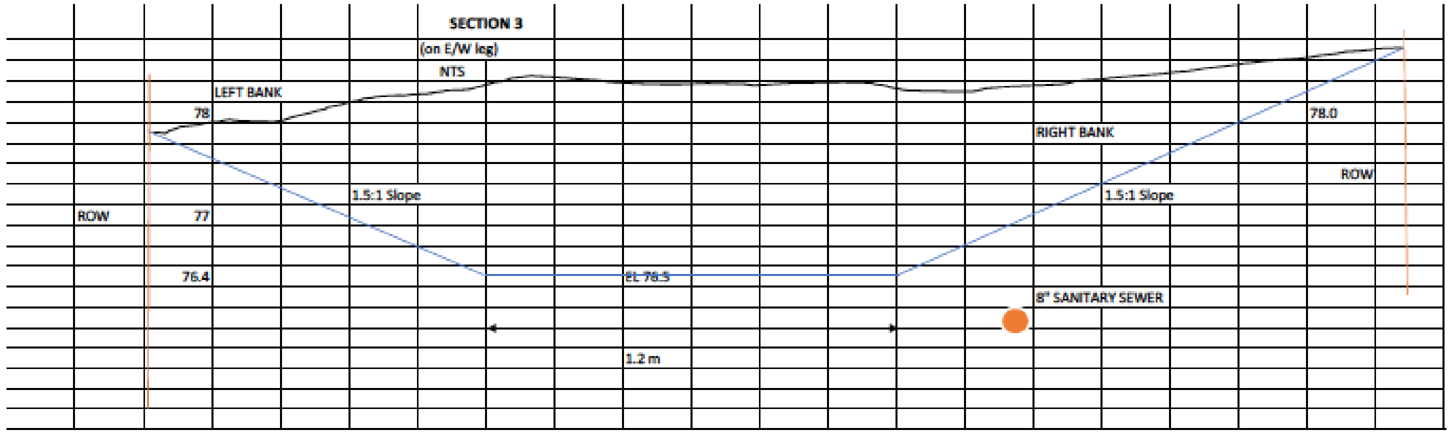


Figure 7: Cross-section of restored creek

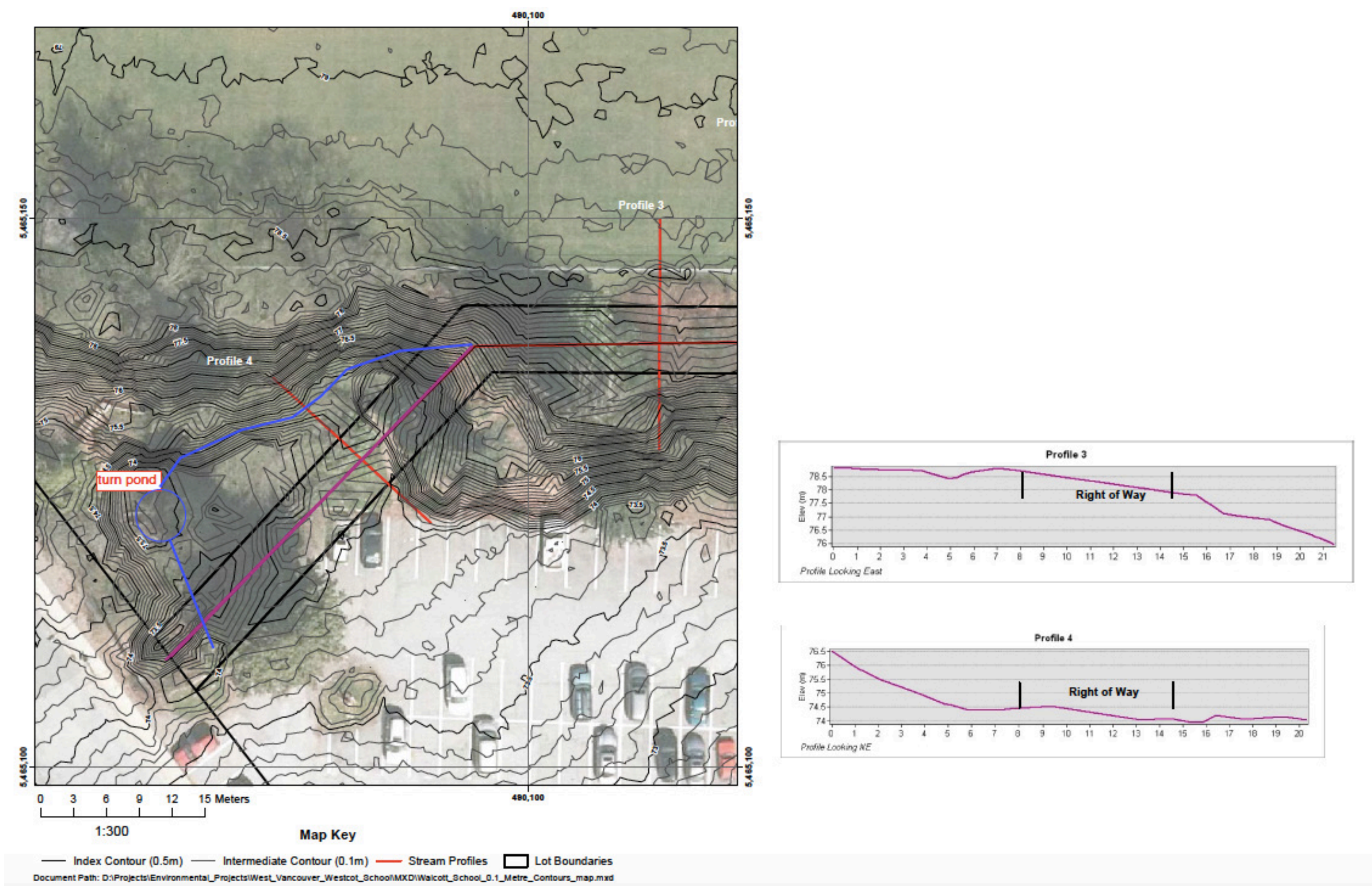


Figure 8: Concept plan and profile

3.2 Economic valuation of Brothers Creek tributary

3.2.1 Capital costs

A summary of the construction cost for restoration of the creek at Westcot School corresponding to this design is presented in Table 3 below. It represents a Class D estimate.

Table 3: Restoration of creek at Westcot School: Summary cost estimate

Item	Forced Pool-Riffle	Step Pool
Earthmoving	$9,800	$7,500
Rock	$42,000	$45,800
Root wades and boles	$39,400	$12,500
Geotextile	$20,800	$9,900
Vegetation and landscaping	$22,700	$10,800
Chain-link fence (108 metres)	$6,000	
Moving of sanitary sewer	$100,000	
Total	$240,700	$86,500
Grand Total		$327,200

The above cost is based on the supply of rootwads and boles[7] from a developer at no cost to the project.[8] Rock has been priced at commercial rates but could be obtained in a similar arrangement with residential land developers. Costs for moving the sanitary sewer, as well as fencing, have been supplied by DWV. Costs for engineering design and construction services have not been included. In addition, any costs associated with requirements from the Ministry of Forests, Lands and Natural Resources have not been included.

Table 4 provides comparative costs for upsizing the culvert to 1.35 metres. All cost estimates have been provided by DWV.

Table 4: Estimated cost of upsizing culvert

Item	Cost
Mobilization, excavation/import material, construction (includes a materials quotation) and de-mobilization	$200,000
Moving sanitary sewer	$100,000
Total	$300,000

The above estimate does not take into account that the sanitary sewer relocation would likely also require new right-of-way registrations. As it is challenging to quantify at this stage, and would be a component of both options, we have excluded this from the cost considerations for both estimates.

7 Root wads are the root systems of upended trees, which provide microhabitats for fish and aquatic invertebrates, filter debris and reduce erosion. Bole refers to the tree trunk.

8 As per discussion with West Vancouver Streamkeepers

3.2.2 Operating and maintenance costs

The effectiveness of a natural asset within a stormwater management plan needs to be measured periodically to ensure that the natural asset is functioning as expected and unimpeded over time. The operating and maintenance costs related to daylighting streams entails a number of costs over the short-term (one to three years) as the site matures, with significantly less over the medium to long-term (three or more years). The cost items and required skills are captured in tables 5 and 6 below:

Table 5: Inspection skill level descriptions

Skill level	Description
1	No special skills or prior experience required, but some basic training is necessary (via manual, video, in-person training)
2	Inspector, maintenance crew member or citizen with prior experience with ponds, stream channels and wetlands
3	Inspector or contractor with extensive experience with pond and wetland maintenance issues
4	Professional engineering consultant and lotic biologist

Table 6: Proposed inspection/maintenance frequencies for Brothers tributary project

Frequency	Inspection item (skill level required)	Maintenance items	Projected cost(s)
1 – 2 times per year for first 3 years following completion of project	Monitor riparian plant composition and health (1 - 2) Identify invasive plants (1 - 2) High and low stream flows (2 - 3)	Replant wetland vegetation Remove invasive species Add riprap or large woody debris	TBD – minimal. Could be carried out and/or supervised by streamkeepers (Note: might require training) Plant budget
1 – 2 times per year	Monitoring and evaluation of channel and bank stability (2 - 3) Monitor stability of large woody debris (2 - 3)	Armour eroding bank and replant vegetation if necessary Identify if channel is choked, obstructed or presents a flood risk Add or replace anchors on large woody debris	Personnel costs
1 – 2 times per year	Signage inspection (1 - 2)	Advise of missing/damaged educational and/or safety signage Replace missing signage	Personnel costs

For comparison, the following culvert operations and maintenance costs were identified by DWV:

Table 7: Culvert operations and maintenance

Frequency	Inspection item (skill level required)	Maintenance items	Projected cost(s)
Every 6 months	Clean screens (2 - 3)	Clean or replace screens	Cost of new screens Personnel costs
Every 6 months	Walk creek to monitor for hazards and/or items requiring maintenance (1 - 3)	Walk creek to monitor for hazards and/or items requiring maintenance	Personnel costs Maintenance costs

Operations and maintenance costs were not estimated due to DWV time restrictions. Nonetheless, both options require personnel monitoring a few times per year, with the potential for some hard costs (i.e., screens or additional planting). In addition, the West Vancouver Streamkeepers indicated a willingness to provide their services for the daylighting option, where appropriate, which would likely render the operations and maintenance costs comparable for the two options under consideration.

4. Project limitations

Limitations that can have an impact on the certainty of the results need to be recognized with the work presented in this report. It should be noted, however, that this was a pilot project to test the approach.

1. The design of the open channel was based on theoretical engineering calculations to handle the one-in-200-year storm event. It is recommended that modelling be completed before proceeding with any creek restoration to ensure the creek is capable of handling peak flows. In addition, modelling will refine knowledge of flood attenuation, providing increased knowledge of downstream impacts.

2. The design procedure presented in this pilot assumes the streams have been subjected to a high-level screening process that identifies the necessary characteristics required for a successful daylighting project, such as downstream connectivity, local government and community support, funding, etc. This was not completed for the pilot, as DWV did not deem it necessary at this stage. Should the District proceed with daylighting, it is recommended that a high-level screening process be completed.

5. Conclusions and next steps

The pilot project has demonstrated that the natural asset of focus — a tributary of Brothers Creek — would, in an uncovered state, provide stormwater management benefits commensurate with the upgraded engineered infrastructure required to meet current stormwater standards (i.e. 1 in 200-year event). As the current culvert in the study area is insufficient to meet this standard, the economic analysis considered the costs to upgrade the culvert.

The above conclusions have been arrived at after completing site visits, a review of ISMP modelling results for the watershed, preparation of an open-channel design, and costing. An asset value was assigned to the uncovered creek based on the costs associated with a replacement culvert to handle the 200-year storm event (to account for local climate change projections). This replacement cost methodology was used to compute an estimated value of roughly $300,000. In addition, the construction costs associated with the daylighting project were calculated at $327,000. Lastly, a review of operating and maintenance requirements demonstrated that costs related to daylighting streams entails a number of costs over the short-term (one to three years) as the site matures, with significantly less over the medium to long-term (more than three years).

The MNAI technical team also prepared a guidance document (Appendix B) for identifying candidate streams for daylighting.

The guidance document should be used as a practical reference during the siting, planning and design process for daylighting streams. DWV's engineering department, environmental department, parks sustainability team members and finance should work through the relevant steps provided herein to identify and assess daylighting options for final decision-makers, which include DWV and affected landowners. The guidance document can be used in one of two ways:

1. Comprehensive assessment: A comprehensive assessment considers the suitability of streams within a watershed for daylighting. It provides a broader analysis, suitable for a regional approach. One should follow the full suite of steps [i.e., Steps 1 through 6] to complete a comprehensive assessment.

2. Project-based assessment: For those situations where a smaller set of potential candidate streams are already identified, such as through existing infrastructure or development projects, a more condensed assessment can be followed. In such instances, the assessment can be confined to Steps 3 to 6.

Importantly, MNAI will adapt the guidance material and share with other partners who may wish to determine the implications of stream daylighting.

Multi-criteria decision analysis is a tool that can be applied to problems involving a choice between alternatives where a number of (often conflicting) priorities must be considered. It is both an approach and a set of techniques for solving complex problems that are characterized by any mixture of monetary and non-monetary objectives, involving breaking the problem into more manageable pieces for judgment before reassembling the pieces to present a coherent picture to decision-makers. The purpose of MCDA is to serve as a decision-making aide, but not to make the decisions. This allows for inclusion of different values while recognizing complex trade-offs.

5.1 Next steps

The MNAI pilot with the District of West Vancouver has concluded the technical aspects required to identify, manage and value natural assets.

The sample MCDA analysis has created a strong foundation for a tool the District can apply during selection and planning of future daylighting projects. To translate the results into workable core management and financial processes, further refinement of the analysis is necessary to enhance the effectiveness of the MCDA tool's ability to assess the benefits and drawbacks of daylighting District creeks. With conclusion of the pilot project, the following next steps will be required to finalize the tool:

1. Further refinement of the input costs used for each benefit category to provide confidence in the accuracy of the analysis.

2. Additional analysis of the sensitivities of each input factor and their influence on the final output to achieve further certainty in the model.

3. Include a beneficiary analysis in the assessment as well as a funding plan for individuals and groups that will experience economic gains from the project.

4. Further review of the benefits and costs that should be considered for daylighting projects.

Appendix A:

Figure 9: Example 1 of step-pool morphology

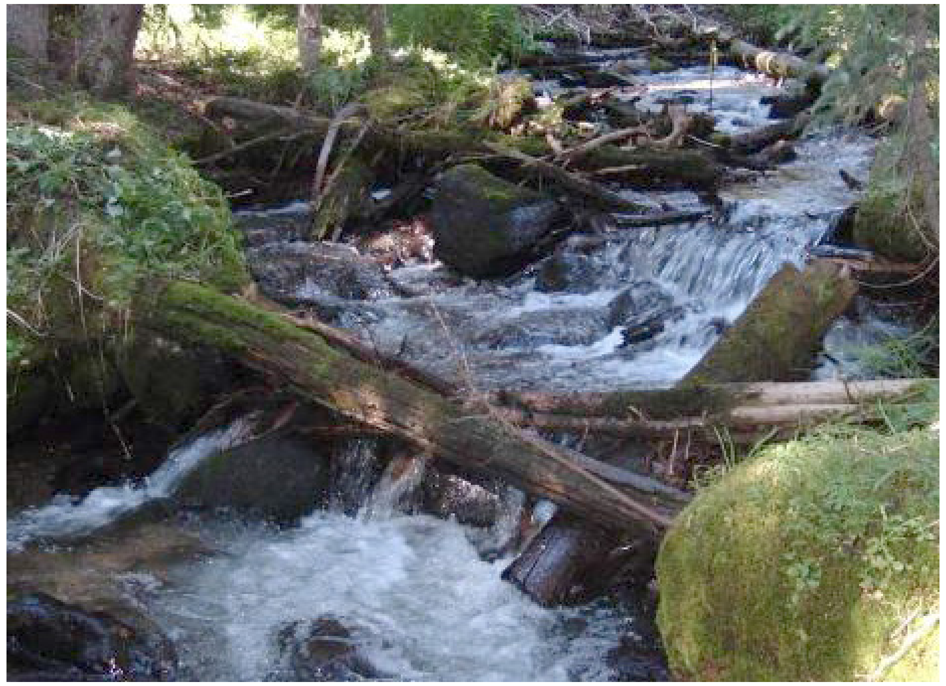


Figure 10: Example 2 of step-pool morphology

Figure 11: Example 3 of step-pool morphology

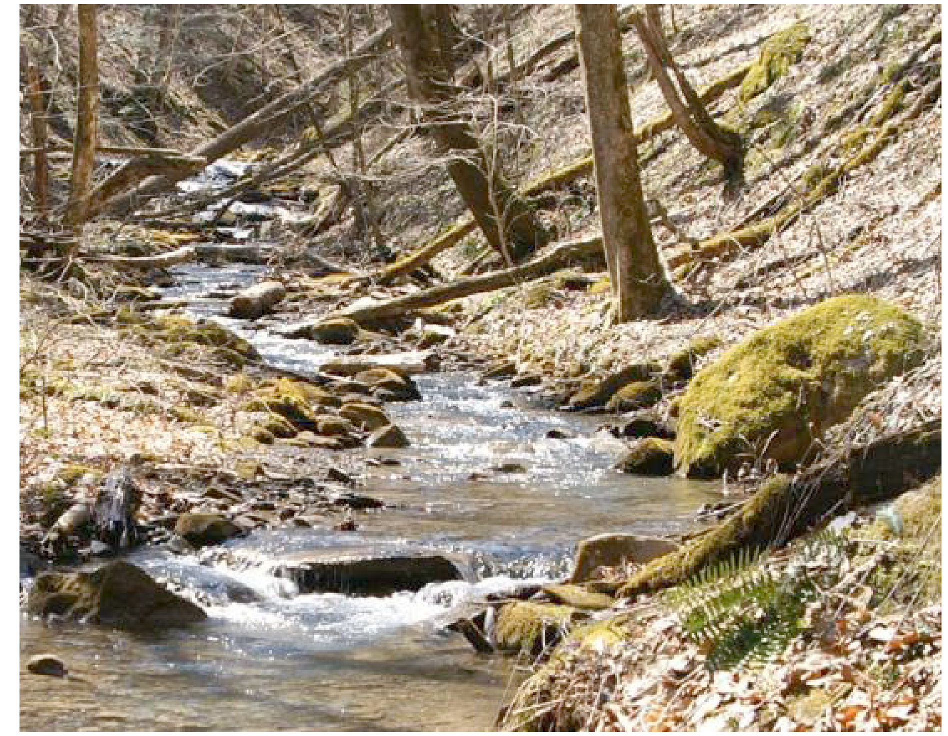
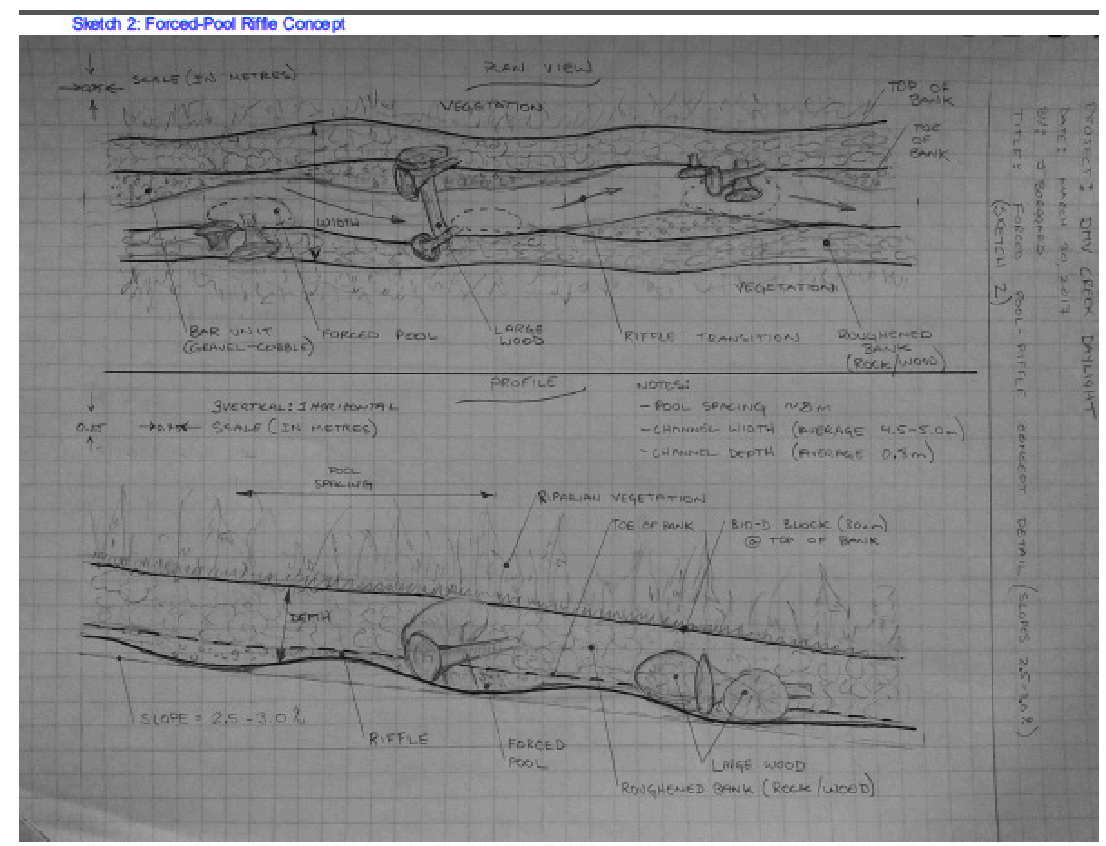


Figure 12: Example 4 of step-pool morphology



Sketch 2: Step-pool concept

Appendix B: Guidance document

Purpose of the guidance document

This document will support local governments in deciding whether to daylight streams.

The purpose of this guidance document is to outline a process for identifying candidate streams for daylighting. It provides broad advice for following an identified process but does not provide a set of precise requirements or standards. Its intention is to assist professionals who possess proficiency in environmental sciences, engineering, planning, hydrology and geographic information system (GIS) analysis by laying out a step-by-step process to identify potential sites for daylighting. In addition, it will be of interest to decision-makers as it describes a tool (multi-criteria decision analysis), to provide a holistic understanding of the potential value of daylighting.

It is our intention that this guidance will identify opportunities and encourage development of daylighting demonstration sites. This document takes a strategic, conceptual approach, which is structured to be iterative and replicable, both within sub-areas of DWV and as a model that can be applied elsewhere. Furthermore, this document is based on an asset management framework, where emphasis is placed on how daylighting can increase the base of natural and built infrastructure assets of the region.

What is daylighting?

The concept of 'daylighting' rivers, streams or creeks refers to the process of uncovering all or part of a waterway that is buried in culverts, pipes, drainage systems or other impervious materials. The ultimate goal is to re-establish a stream system above ground, ideally within the original channel. When development impedes the original channel, a new channel may be created. Typically, this process helps to restore a waterway to a more natural state, improving ecosystem health by reconnecting a stream with its surroundings.

Daylighting occurs in several forms, including:

1. Natural restoration – restoring a stream to its natural conditions;
2. Architectural restoration – a stream is returned to open air with flowing water, but within a constructed channel; or
3. Cultural restoration – recognition of a buried stream through markers or public art to inform public of the historic stream path.

This document addresses natural restoration in urban environments.

The legacy of buried streams dates back to the development of cities, which often redirected and/or covered waterways below roads, parking lots and buildings to create more buildable surfaces and protect properties from flooding. Unfortunately, covering streams had unintended consequences, including increased nutrient pollution, increased downstream flooding and degraded fish habitat. Fortunately, with the growing realization of the importance of small streams, rivers and creeks, we are developing ways to revitalize these systems.

Daylighting can bring many benefits for every dollar spent. These include improvements to urban stormwater systems through increased hydraulic capacity for flood control, reduced downstream erosion, improved water quality and improved aquatic and riparian habitat. Revitalized watercourses can increase property values and benefit local businesses. Daylighting can also bring educational benefits and foster stewardship of environmental resources.

Urban daylighting projects can be confronted with a number of challenges, however. Technical challenges related to siting in highly urbanized areas, short-term cost feasibility and political and community opposition can act as barriers to daylighting projects. Additionally, the concept of daylighting is a relatively new approach in the field of stream restoration, and although the number of case studies is growing, there is minimal long-term monitoring data to address questions regarding how long it took, on average, for projects to successfully restore stream health; how and when stream health was determined; how and when projects met their objectives; and whether or not projects were cost-effective and affordable and how they were paid for.

Development of document

This document is a product of the Municipal Natural Asset Initiative pilot project with the District of West Vancouver. The overall pilot purpose is to address the District's interest in understanding if and how natural assets within their jurisdiction can be integrated into their asset management and financial planning processes. A number of potential outcomes were identified to meet this goal.

These include:

1. A holistic understanding of the potential value of daylighting the covered portion of the stream compared to asset replacement with the use of a pipe.
2. Management options for the District to apply to Brothers Creek and other streams that can be daylighted to maximize benefits.
3. Furthering local government's understanding of how to place a value on reclaimed natural assets and to account for this within current financial and asset management processes.
4. A model that can be applied elsewhere in the District and by other local governments to estimate the financial value of daylighting streams.
5. An operations and maintenance plan for the stream should the District proceed with daylighting.
6. Local public/student engagement in the process of daylighting and awareness of the value of natural assets.

This document has been developed to meet an additional outcome requested by DWV: to provide a simple guidance document that can be used elsewhere in DWV, and in other areas, to identify candidate streams for daylighting. The costs and benefits outlined in the report relate to projects that strive for natural restoration daylighting. That is, it addresses the form of daylighting that aims to restore the characteristics of natural steams, including permeable stream bottom and stream banks. In practice, the degree of "naturalness" may vary on the stream bottom and/or banks, requiring reinforcing or manipulating to accommodate landform obstacles.

How to use this document

This guidance document should be used as a practical reference during the siting, planning and design process for daylighting streams. The District of West Vancouver engineering department, environmental department, parks sustainability team members and finance should work through the relevant steps provided herein to identify and assess daylighting options for final decision-makers, which include DWV and affected landowners.

The guidance document can be used in one of two ways:

1. Comprehensive assessment: A comprehensive assessment considers the suitability of streams within a watershed for daylighting. It provides a broader analysis, suitable for a regional approach. One should follow the full suite of steps [i.e., Steps 1 through 6] to complete a comprehensive assessment.
2. Project-based assessment: For those situations where a smaller set of potential candidate streams are already identified, such as through existing infrastructure or development projects, a more condensed assessment can be followed. In such instances, the assessment can be confined to Steps 3 to 6.

Step 1: Characterize watershed and stream conditions in the study area

A comprehensive assessment of candidate streams for daylighting should begin by assessing the general ecological health of the upstream watershed, with the objective of identifying projects with the largest net gain. This can be accomplished in a number of ways, two of which are outlined below:

Option 1: Net gain of pre-development stream network returned to open channels.

This option entails developing a comprehensive "open versus buried" map of streams in the watershed to identify potential projects that will result in the greatest net gain in length of connected, open stream channel in the watershed.

This analysis requires a complete map of the drainage network in the region, including open and covered streams. As such, this option is preferable if the region has a solid understanding of its original hydrologic endowment and how much has been lost to pipes and culverts.

Option 2: Assess measures of stream and watershed health to categorize each watershed, against which projections of the potential for ecological improvement are compared to arrive at largest net gain.

To understand the baseline condition for each watershed, one should gather and review measures of stream and watershed ecological health to categorize the watersheds into various classes of ecological integrity. For example, a high-integrity stream/watershed would have relatively healthy benthic macro invertebrate communities; the watershed would be largely undeveloped with a high percentage of permeable surfaces; streams would be connected to rivers (i.e., few dams and diversion structures); and development in headwater areas would be extremely limited.

The expertise of a hydrologist and/or water resources engineer will be necessary to determine the baseline condition, as well as to project the net gain in ecological health resulting from the proposed project. Once this is understood, the net gain of a project is determined by identifying the project with the highest differential between the original condition and the projected condition, depending on whether any key ecological thresholds are being crossed. For example, if DWV is considering a 90 per cent integrity watershed and a 70 per cent integrity watershed; and the actions will take one to 95 per cent (i.e., a five per cent improvement on a good resource) and one to 85 per cent (i.e., a 15 per cent improvement on an average resource) it could be argued that the best net gain is associated with the lower integrity watershed.

Step 2: Identify potential daylighting sites

The second step to identify candidate daylighting sites is to synthesize, to the extent possible, knowledge of stream quality and its flow regime with knowledge of sewer and stormwater infrastructure to determine if daylighting is a possible solution to an infrastructure problem. If GIS data exist on stream quality and location, these can be overlaid onto existing GIS data on sewer and stormwater infrastructure to refine the results of Step 1. If the region does have access to the relevant data, the following information sources could be reviewed to narrow the list of potential sites:

1. Flood hazards maps
2. Engineering reports of drainage issues
3. Local knowledge of damaged infrastructure possessed by local engineers, public officials and citizens

This step may require the expertise of a GIS analyst, a water resources engineer and individuals with institutional knowledge of infrastructure issues.

Step 3: Select and study example daylighting sites

In many cases, local governments will not have the resources and/or data to conduct Steps 1 and 2. In these cases, daylighting projects can arise due to citizen action or as an addition to a previously planned construction project. In such cases, local governments may require a set of screening criteria for assessing whether the identified site is a good candidate for daylighting.

The following set of negative and positive screening criteria can be employed as Step 3 of a comprehensive assessment or as the initial step when the potential site is known. The negative screening criteria are designed to flag factors that can make a daylighting project difficult or impossible. Conversely, the positive screening criteria indicate where a daylighting project may be ecologically effective, feasible and supported.

Negative screening criteria:

- Extensive infrastructure and buildings over the culvert or areas of possible stream relocation
- High land values that preclude purchase of land for open development
- Seasonal low flow that is below fisheries/biotic requirements
- Barriers to fish access from streams downstream
- Steep slopes that would result in overly erosive stream velocities and/or that do not support fish populations
- High discharge rates, due to upstream conditions that cannot be managed (e.g., high degree of imperviousness) "naturally"
- Sunk costs in recently culverted streams
- Limited public or available land for surface expression of stream. A good rule of thumb is a minimum width of six metres
- Opposition of local landowners

Positive screening criteria:

- Local support. What groups are likely to support a project? What groups might be opposed to it?
- Funding opportunities. Are one or many means to access grants or other potential funding programs likely? Could a daylighting project at this site be an adjunct to some other existing or likely project by public or private parties with interests in development, parks, transportation, water management or other areas?
- Technical feasibility. Are the potential technical challenges at this site likely to be more manageable than other potential sites? Is a project here likely to be robust in the sense it is unlikely to impair other values or to otherwise fail? Does a project on this site seem doable?
- Demonstration value (environmental/social/economic). Is the potential project in a high-visibility location? Will the before/after change be significant and apparent? Is the project likely to have demonstrable positive benefits for habitat creation, water quality improvement, amenity development, flood control, educational benefits or other public goals?

This step will require the expertise of engineers, biologists, hydrologists, public engagement specialists and finance staff.

Step 4: Engage the community

The available literature on daylighting projects shows that few happen without community involvement and support.[9] Consequently, it is essential to create community dialogue about daylighting to educate the public and key stakeholder groups about specific opportunities and assess if the project is desired or should proceed, based on the needs and interests of the affected communities. Engagement methods can include:

1. Questionnaires (hard copy and telephone)
2. Public meetings: Invite community and key stakeholder to public meetings via email, flyers and shared communications with community groups
3. Site tour: Include participation from experts in stream ecology, landscape architecture, city planning and other relevant disciples
4. Website development: Use to post information on daylighting

This step will require the expertise of public engagement specialists who are informed, and ideally accompanied, by project staff.

Step 5: Develop concept design

The concept design for the daylighted channel must incorporate features that are appropriate for the enhancement goals of the daylighting project, be they fish habitat enhancement, development of riparian vegetation, aesthetics and safe enjoyment, while providing the conveyance capacity necessary for the design flow — normally the one-in-200-year peak flood flow. For slopes that are steep (greater than two to three per cent) in a hydraulic sense, features such as a forced-pool riffle sequence for slopes between two and four per cent and steep pool morphology for stream slopes between three and 10 per cent should be considered. Forced-pool riffle configurations are created in nature by large woody debris transported during flood flows that become anchored as debris complexes in the bed and banks of a stream. Pools are created between the debris complexes. Large rock is the key component that creates “steps” in step-pool streams. Flow drops over each step, creating pools below. The flow then impinges on another downstream step with the sequence repeating, creating a step-pool morphology. This type of system tends to be confined with rock and large wood for bank stability.

Step 6: Multi-criteria decision analysis

The final step to identify candidate streams for daylighting in DWV is to perform a multi-criteria decision analysis (MCDA). Whereas the first five steps narrow the list of possible streams for daylighting, the purpose of this final step is to identify the preferred candidate stream.

MCDA is a tool that can be applied to problems involving a choice between alternatives where a number of (often conflicting) priorities must be considered. It is both an approach and a set of techniques for solving complex problems that are characterized by any mixture of monetary and non-monetary objectives, involving breaking the problem into more manageable pieces for judgment before reassembling the pieces to present a coherent picture to decision-makers. The purpose of MCDA is to serve as a decision-making aide, but not to make the decisions. This allows for inclusion of different values, while recognizing complex trade-offs. MCDA generally comprises the following steps:

1. Establish the decision context
2. Identify the options to be appraised
3. Identify the criteria to be used to compare options
4. Score the expected performance of each option against the criteria

9 Pinkham, 2000; Smith, 2007

5. Assign weights for each of the criterion to reflect their relative importance to the overall decision
6. Combine the weights and scores for each option to derive an overall value
7. Examine the results
8. Conduct sensitivity analysis

6.1 Establish the decision context

The MCDA should begin with a clear understanding of the decision-making process. This includes identifying the social, political and technological context of the analysis, clear objectives for the analysis and key players and decision-makers.

Through discussions with Andy Kwan (manager of utilities, DWV) and Olivia Taje (assistant utilities engineer, DWV), the following information was provided:

1. DWV is interested in naturalizing the community. Environmental benefits are the impetus for this, but positive cost-benefit results are also desirable.
2. The social context will be determined by the location of the candidate creeks. Public input will be sought out. The means of doing so could vary from targeted stakeholder engagement to open houses.
3. The technical context for completing the analysis is this guidance document. DWV does not utilize cost-benefit or MCDA software. A multi-disciplinary team will complete the analysis.
4. The objective of this MCDA is to identify the candidate stream(s) for daylighting that best meets the environmental, economic and social goals identified below.
5. Environmental: Protect and enhance creek habitat and corridors[10]
6. Economic: Ensure financial sustainability of DWV’s infrastructure in perpetuity[11]
7. Social: Advance community connections and well-being in DWV through leadership and innovation in social responsibility[12]

6.2 Identify the options to be appraised

An MCDA is designed to compare two or more options. DWV may consider two different sets of options for this analysis:

Option 1: Comparison of daylighting a creek versus upgrading (or maintaining) a culvert.

Option 2: Comparison of candidate streams for daylighting. Steps one through five are designed to identify a shortlist of viable streams. These identified streams will become the options for this analysis.

6.3 Identify the criteria to be used to compare options

The next stage is determine how each option contributes to the identified objectives. This requires selecting criteria to reflect the degree to which the relevant objective is met. Each criterion must be measurable and quantifiable.

10 source: DWV Environmental Strategy

11 source: DWV Water Infrastructure Long Range Capital Renewal Forecast

12 source: DWV: A Blueprint for Social Responsibility and Change

The MNAI project team was asked to identify monetary criteria to the extent possible. While this is a straightforward exercise for those objectives with clear market values, measuring the value of a specific non-market good or service can range from easy but possible to difficult to impossible.

Economists have developed a number of techniques for putting dollar values on the non-market goods and services provided by ecosystems. Different approaches are used depending on the ease of obtaining direct measures of the flow of ecosystem services. There is no universal best approach. An approach that is suitable to assess the health of one service — for instance, the market cost of artificially providing flood mitigation — may not be appropriate for others. Accepted techniques can be grouped into three broad categories: 1) direct market valuation approaches; 2) revealed preference approaches; and 3) stated preference approaches. Direct market valuation methods derive estimates of ecosystem goods and services from related market data. Revealed preference methods estimate economic values for ecosystem goods and services that directly affect the market prices of some related good, and stated preference methods obtain economic values by asking people to make trade-offs among sets of ecosystem or environmental services or characteristics.

Ideally, a valuation of the ecosystem services affected by a daylighting project would involve detailed ecological and economic studies of each ecosystem of interest for each land-cover type, utilizing one or more of the above valuation techniques. This process has been undertaken through the MNAI project for a subset of environmental objectives related to stormwater management. That is, the MNAI approach considers, where possible, the values related to flood reduction, improvements to freshwater habitat and water quality, and reduced erosion. In those cases where the MNAI process has been followed, one can choose to utilize the market-based replacement cost as a proxy for these values. The practitioner would still need to follow the MCDA framework for economic and social values.

In those circumstances where undertaking such primary studies or MNAI studies are found to be expensive and time-consuming, an alternative approach is provided. Benefit transfer can be used to evaluate non-market ecosystem services by transferring existing benefit estimates from primary studies already completed for another study area. When using this method, care must be taken to ensure values being transferred exhibit similarities within the specific ecosystem good or service characteristics.

Economic: The criterion used to determine economic viability is the life cycle cost of each option. This should incorporate the costs to purchase, own, operate, maintain and, finally, dispose of the infrastructure in question. As such, for the purposes of this document, the relevant costs include:

1. Capital costs
2. Replacement costs
3. Operations, maintenance and monitoring costs
4. Salvage value

The relevant life cycle of a culvert is: concrete pipes 75 to 100 years.

The relevant life cycle of a daylighted stream is indefinite.[13]

Social: Social goals are represented through two separate sets of criteria: political viability and social viability. Each is addressed separately below:

Political viability seeks to answer the question: Does the public understand the issue and support action to address it? This is measured through public opinion polling. The poll should clearly explain the issue the project is seeking to address and assess whether the proposed action to address it (i.e., daylighting) is supported.

13 Assuming proper maintenance and managing of upstream conditions to maintain a baseline similar to conditions the daylighted reach was designed for.

Social viability seeks to capture the benefits of a project to the wider community. To do this three questions are posed:

1. Does the project provide educational benefits? If so, what is the value?
2. Does the project provide recreational benefits? If so, what is the value?
3. Does the project support community and economic vitalization? If so, what is the value?

Educational benefits: The estimated value of nature-based education is based on the 2012 Canadian Nature Survey[14], which provided a per person value ($33.24 in 2012) for this service. To arrive at a value, one would multiply the per person value ($35.64 in 2017 dollars) by the total population of regional schools plus the local population of the study area. The 2012 Canadian Nature Survey defines the local population as the population within 20 kilometres of the study site, based on its definition of “near-home nature activities”.

Recreational benefits: A wide number of studies exist that estimate the recreational value of streams and rivers. In choosing a representative study, the project team considered preferred methodologies, location and valuation context and determined Loomis’s 2002 study (Quantifying recreation use values from removing dams and restoring free-flowing rivers: A contingent behavior travel cost demand model for the Lower Snake River) best matched the study area. This study employed a travel-cost demand model that used intended recreational trips under the condition of removed dams and river restoration. The tool was used to evaluate the potential recreation benefits in the Lower Snake River in Washington State using data from mail surveys of households in the Pacific Northwest region. The analysis suggests this extension of the standard travel-cost method may be suitable for evaluating the gain in river recreation associated with river system restoration.

The project estimated the yearly per hectare value to range from $38,457 to $68,059 (2017 dollars). The value of a project can be determined by converting the per hectare estimate to a square metres estimate.

Community and economic vitalization: The estimated value of community and economic vitalization is based on a 1995 study by Streiner and Loomis (Estimating the Benefits of Urban Stream Restoration Using the Hedonic Price Method). This study used the hedonic price method to estimate residents’ willingness to pay for improvements in urban streams. The study examined California’s Department of Water Resources Urban Stream Restoration Program to determine the economic value of stream restoration measures. It found that property prices in areas with restored streams increased by three to 13 per cent of the mean property price in the study located within 335 metres of the creek.

To calculate the benefit of community and economic vitalization:

1. A GIS exercise would need to identify the number of properties within 335 metres of the daylighted creek.
2. The mean property price for residential homes in this area must be identified.
3. The mean value of residential homes would be multiplied by the number of homes.
4. The resulting value would be multiplied by three per cent and 13 per cent to arrive at a range of value.

NOTE: This is a one-time value and while it could be spread over a number of years (e.g., five years), it should not be calculated annually.

Environmental: To capture the range of potential environmental benefits resulting from daylighting projects, four questions were identified for those instances when a full MNAI assessment is not available:

1. Does the project improve freshwater habitat? If so, what is the value?
2. Does the project improve water quality? If so, what is the value?
3. Does the project reduce erosion? If so, what is the value?

14 Federal, Provincial, and Territorial Governments of Canada. (2014).

Improvements to freshwater habitat: To estimate the value of freshwater habitat, a study by Knowler et al (2003) was used that estimated the value of protecting watersheds for salmon habitat. The authors present a framework for valuing the benefits for fisheries from protecting areas from degradation, using the example of the Strait of Georgia coho salmon fishery in southern British Columbia. The authors use a bio-economic model of the coho fishery to derive estimates of value that are consistent with economic theory. Then they estimate the value of changing the quality of fish habitat by using empirical analyses to link fish population dynamics with indices of land use in surrounding watersheds. The values determined by their study ranged from $1,595 to $8,459 (2007 C$) per kilometre of salmon stream length per year, depending on the extent of degradation in the watershed. The value of improvements to water quality can be determined by converting the per hectare estimate to a square metres estimate.

It is important to note this benefit only applies to salmon streams with no downstream impediments to salmon migration below the reach being restored. Also, no benefit would be provided if the restored reach does not provide access to viable spawning habitat upstream (dependent on water temperatures, substrate material, etc.).

Improvements to water quality: To estimate the value of water purification and waste treatment, we relied on a study completed by Olewiler (2004), who used a market-based approach that relies on estimates of the amount of phosphorus and nitrogen that wetlands treat. This was then used to calculate the savings in waste treatment costs at Vancouver's primary and secondary waste treatment plants. The value per year per hectare in 2017 dollars is $561.

The value of improvements to water quality can be determined by converting the per hectare estimate to a square metres estimate.

Erosion reduction: To estimate the value of improved erosion regulation, we relied on estimates from Krantzberg and de Boer (2006), who estimated the cost of engineered stormwater best management practices (i.e., grass swales and bioengineered buffer strips), assuming that this serves as a minimum value for soil erosion regulation. The values per year per hectare in 2017 dollars range from $200 to $4,000 for riparian wetlands.

The value of erosion reduction can be determined by converting the per hectare estimate to a square metres estimate.

Table 8 below provides a summary of the proposed criteria.

Table 8: MCDA Criteria

Benefit	Study	Methodology	Annual value (2017 C$)
Economic	n/a	Life cycle cost	
Social: political viability	n/a	Public opinion polls	
Social: educational benefits	2012 Canadian Nature Survey	Travel cost	$35.64/person
Social: recreational benefits	Loomis, 2002	Travel cost	$38,457 - $68,059/ hectare /year
Social: community and economic vitalization	Streiner and Loomis, 1995	Hedonic pricing	3% - 13% increase in local property values
Environmental: improvements to freshwater habitat	Knowler et al., 2003	Production function	$1,595 to $8,459/ hectare/ year
Environmental: water quality improvements	Olewiler, 2004	Market-based	$561/ hectare/ year
Environmental: erosion-reduction benefits	Krantzberg and de Boer, 2006	Market-based	$200 - $4,000 / hectare/year

6.4 Score the expected performance of each option against the criteria

Once the criteria are agreed to, the next step is to complete the range of calculations for each option under consideration. Section 6.3 above provides guidance on how calculations are arrived at. Care should be taken to ensure prices are counted in inflation-adjusted dollars (the Bank of Canada's Inflation Calculator is a useful site: www.bankofcanada.ca/rates/related/inflation-calculator/), per hectare benefits are converted into relevant measurement units, and consideration of when benefits are anticipated to be realized (for example, many riparian benefits will take two to three years to be realized but will occur each year thereafter, whereas some of the economic benefits are one-time benefits).

Once the values are determined, each criterion will be ranked on a one to five scale, where one represents a low value and five represents a high value. In the vast majority of cases, this will be a subjective ranking that considers the relative value of the options under consideration. The exception is with the political viability criterion. In this case, the following ranking is recommended:

Score 1: 85 per cent agree or strongly agree with daylighting in proposed area

Score 2: 70 per cent agree or strongly agree with daylighting in proposed area

Score 3: 50 per cent agree or strongly agree with daylighting in proposed area

Score 4: 70 per cent disagree or strongly disagree with daylighting in proposed area

Score 5: 85 per cent disagree or strongly disagree with daylighting in proposed area

6.5 Weighting

To avoid bias in the results, each category of project objectives (i.e., economic, social and environmental) should be weighted.

Once the appropriate weighting of categories has been determined, the project team should combine the weighted scores for each category to derive an overall value for each option. If required, sensitivity analysis can be completed to determine the sensitivity of a category to change or weighting.

6.6 Sensitivity analysis

Sensitivity analysis is used to understand how the different values for a set of independent variables affect a dependent variable under specific conditions. It addresses questions around whether the results of the project will change if other assumptions are used and how sure we can be of the assumptions. It allows one to check the robustness of project results.

For the MCDA, key variables can be tested to determine how sensitive the results are to changes in the variable. This can be completed by simply changing the variable under consideration by 10 per cent, 20 per cent or the anticipated range of uncertainty. Each variable should be tested independently and noted.

When sensitivity analyses reveal that the overall result and conclusions are not affected by changes to key variables, the results of the project can be regarded with a higher degree of certainty. Where sensitivity analyses identify particular variables or missing information that greatly influence the findings of the project, greater resources can be deployed to try to resolve uncertainties and obtain extra information. If this cannot be achieved, the results must be interpreted with an appropriate degree of caution. Such findings may generate proposals for further investigations and future research.

References

AECOM. (2010). Stormwater Infrastructure Asset Management Plan. District of West Vancouver. Accessed online November 2016: https://westvancouver.ca/sites/default/files/AECOM%20Stormwater%20AMP%20-%20Final%20Report.pdf.

American Rivers (2017). What exactly is stream daylighting? Accessed online November 2017: https://www.americanrivers.org/threats-solutions/restoring-damaged-rivers/what-exactly-is-stream-daylighting/.

Bair, B. (2005). Stream Restoration Cost Estimates. USDA Forestry Service. https://www.st.nmfs.noaa.gov/st5/Salmon Workshop/11 Bair.pdf.

District of West Vancouver. 2018. Draft Official Community Plan: Part One Higher Level Objectives and Policies. https://westvancouver.ca/sites/default/files/dwv/assets/home-building-property/docs/major-projects/ocp/Draft%20Official%20Community%20Plan-%20Part%201-Higher%20Level%20Objectives.pdf. Retrieved March 2018.

Federal, Provincial, and Territorial Governments of Canada. (2014). 2012 Canadian Nature Survey: Awareness, participation, and expenditures in nature-based recreation, conservation, and subsistence activities. Ottawa, ON: Canadian Councils of Resource Ministers.

Knowler, D.J., MacGregor, B.W., Bradford, M.J., and Peterman, R.M. (2003). Valuing freshwater salmon habitat on the west coast of Canada. Journal of Environmental Management, 69(3), 261-273.

Krantzberg, G. and de Boer, C. (2006). A Valuation of Ecological Services in the Great Lakes Basin Ecosystem to Sustain Healthy Communities and a Dynamic Economy. Prepared for the Ontario Ministry of Natural Resources.

Leschine, T. M., Wellman, K.F., and Green, T.H. (1997). The Economic Value of Wetlands: Wetlands' Role in Flood Protection in Western Washington. Washington State Department of Ecology. 68pp.

Loomis, J. (2002). Quantifying recreation use values from removing dams and restoring free-flowing rivers: A contingent behavior travel cost demand model for the Lower Snake River. Water Resources Research, 38(6), 1066, doi:10.1029/2000Wr000136.

Natural Resources Leadership Institute. (2011). Multi-Criteria Decision Analysis. Accessed online November 2017: https://projects.ncsu.edu/nrli/decision-making/MCDA.php.

Olewiler, N. (2004). The Value of Natural Capital in Settled Areas of Canada. Ducks Unlimited and Nature Conservancy of Canada.

O'Neill, S.J., Cairns, S., and Brooke, R. (2017). Defining and Scoping Municipal Natural Assets. http://mnai.ca/media/2018/02/finaldesignedsept18mnai.pdf.

Pinkham, Richard (2001). Stream restoration and daylighting: Opportunities in the Pittsburgh Region. Carnegie Mellon University. Accessed online October 2017: http://3r2n.collinsandgoto.com/revalued/stream-restoration-daylighting/stream-restoration-and-daylighting.pdf .

Rein, F. A. (1999). An Economic Analysis of Vegetative Buffer Strip implementation. Case Study: Elkhorn Slough, Monterey Bay, California. Coastal Management, 27(4), 377-390.

Smith, Brooke Ray (2007). Assessing the Feasibility of Creek Daylighting in San Francisco, Part 1: A Synthesis of Lessons Learned from Existing Urban Daylighting Projects. University of California, Berkeley.

Statistics Canada. Census Profile, 2016 Census: West Vancouver, DM [Census subdivision], British Columbia and British Columbia [Province]. http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CSD&Code1=5915055&Geo2=PR&Code2=59&Data=Count&SearchText=West%20Vancouver&SearchType=Begins&SearchPR=01&B1=All&GeoLevel=PR&GeoCode=5915055&TABID=1 . Retrieved March 2018.

Streiner, C.F. and Loomis, J.B. (1995). Estimating the Benefits of Urban Stream Restoration Using the Hedonic Price Method. Rivers, 5, 267-278.