DISCUSSION PAPER

Arrowsmith Water Service
Englishman River Water Intake Study
Phase 1 - Conceptual Planning

Discussion Paper 8-2– Triple Bottom Line + Risk Siting Option Analysis

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1 Introduction

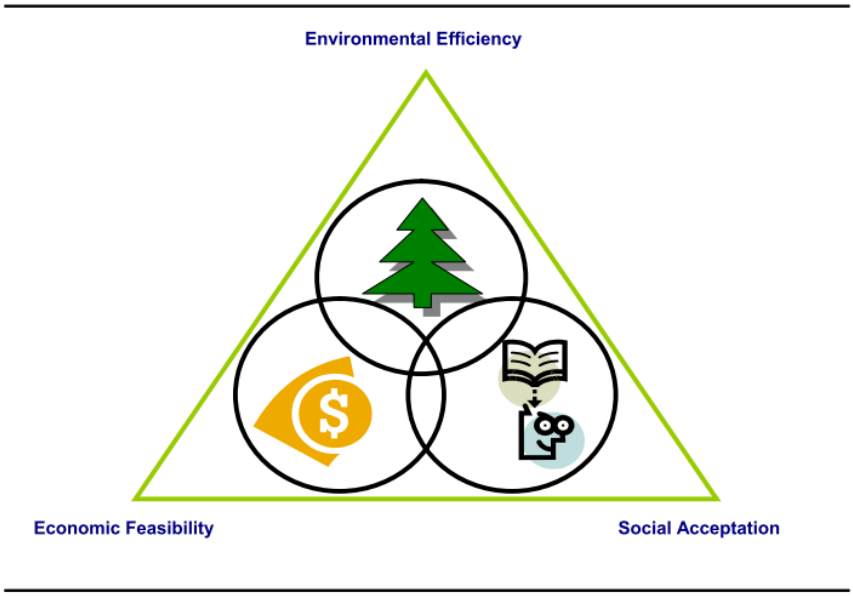
This discussion paper defines the concept of a Triple Bottom Line (TBL) approach, introduces a powerful TBL model, and details the results of the TBL when applied to selecting a preferable site for the proposed Englishman River intake and water treatment plant.

2 Triple Bottom Line

In DP 8-1 Class 'D' cost estimates were developed for four different intake and water treatment plant site options. In some cases a cost comparison is all that is needed to determine the preferable option, but in this situation the proposed infrastructure will affect the Englishman River, an important natural feature of Parksville and the surrounding area. The Englishman River was listed by the Outdoor Recreation Council of B.C. in 2005 as second in the B.C. top ten endangered rivers list. A wide number of federally-supported and grassroots environmental groups hold an active interest in preserving or improving the condition of the river and its fish-spawning population. The Englishman River is also heavily used for recreational purposes in the summer and is a key feature of the local park areas. Capital cost alone does not incorporate the importance of these non-qualitative features which are critical to the success of this project. The qualitative and non-qualitative features must be integrated and evaluated to determine the optimal site locations.

The TBL model reflects what is often described as the sustainability triangle (**Figure 2-1**), which recognizes that the balance between environmental efficiency, social acceptation and economic feasibility of a solution must consider and accommodate stakeholder values. In other words, a truly "sustainable" solution seeks to maximize environmental benefits in a socially acceptable manner while at the same time being affordable. This framework recognizes that the best idea in the world is worthless if people will not embrace it or is beyond their financial means.

Figure 2-1
Sustainability Triangle

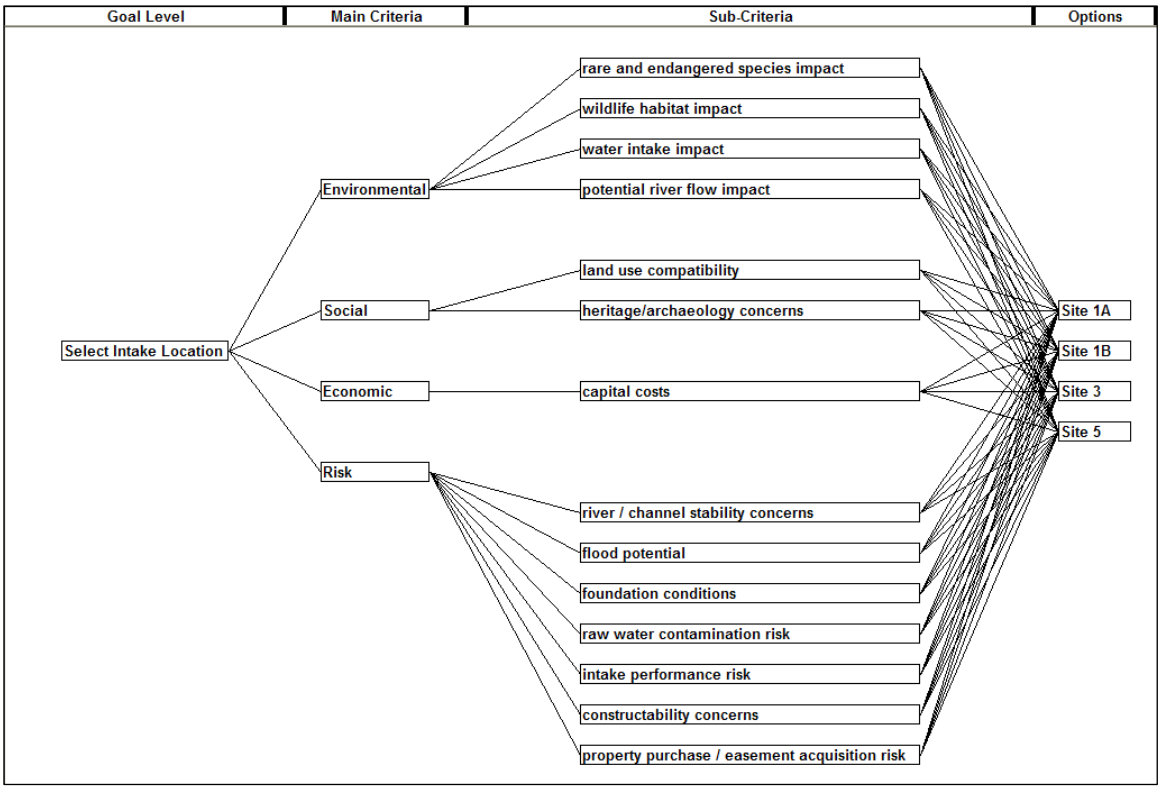


While the idea of TBL is relatively new, the underlying mechanics of their conduct is based on classic multi-criteria decision theory. Spreadsheet-based models are often used to construct the decision hierarchy that represents the evaluation framework. For this project, the Criterium Decision Plus® (CDP) software package was selected due to its clarity, ease of use and ability to conduct sensitivity analysis on the importance of each factor to the TBL results.

2.1 Criteria Selection and Weighting

The underlying approach of TBL involves weighting the ranks of the different criteria to produce a final score for each option. Within each criterion there can be a sub-level of factors that are used to determine the criterion's value. The hierarchy of criteria used is illustrated in **Figure 2-2**. This particular hierarchy is often termed "Triple Bottom Line + Risk", which incorporates the three components of a sustainability evaluation but recognizes that potential risks can substantially alter the suitability of a given option. By separating risk from the other three criteria, the impact that the risk factors have on selecting a preferred option can be easily determined and clearly illustrated through sensitivity analysis.

Figure 2-2
Triple Bottom Line + Risk Criteria



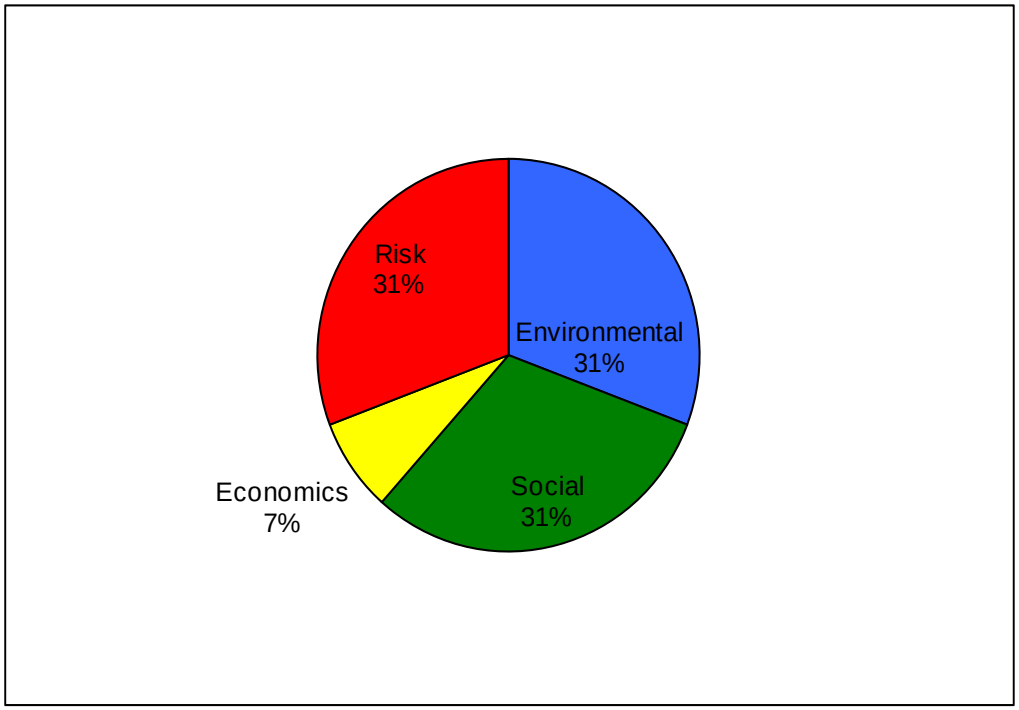
The TBL analysis of the Englishman River intake and treatment plant siting evaluation involves a combination of quantitative (Economic) and qualitative (Environmental, Social and Risk) factors. To incorporate these factors into a single evaluation model, a means to compare the qualitative factors needs to be developed. For this particular analysis the qualitative parameters were ranked using intuitive pairwise comparisons. For each sub-criterion the options were compared individually to each other. That is, Site 1A was compared to Site 3, then Site 5, then Site 1B. Site 3 was compared to Site 5, then Site 1B, and so on. For each possible combination of pairing options it was determined which site was more favourable for the given sub-criterion. The pairings are assigned a number to reflect the degree by which a given site may be superior to another site, with a higher number indicating an increasingly superior site, as shown in the following preference scale:

- 1 - Equal
- 2 - Barely better
- 3 - Weakly better
- 4 - Moderately better
- 5 - Definitely better
- 6 - Strongly better

- 7 - Very strongly better
- 8 - Critically better
- 9 - Absolutely better

The CDP model incorporates all the paired comparisons to determine the overall ranking of each site. The rankings have a score between 0 and 100, with the most preferable site scoring a 100 and the worst site scoring a 0 for each sub-criterion. Weightings can be used to assign greater or less importance to each sub-criterion and criterion. As illustrated in **Figure 2-3**, equal weighting for this analysis was given to the Environmental, Social, and Risk criteria. The Economic criterion was given a lesser weighting to reflect that the difference in capital costs between the site options was relatively small. The sub-criteria within each criterion were weighted equally. The impact of using these weightings is examined in Section 3.1.

Figure 2-3
Criteria Weighting



It is important when developing the TBL model that there be no overlap in the sub-criteria. Not only would this lead to "double-counting" the severity of some factors but would mask the importance of the particular sub-criterion when performing sensitivity analyses.

2.2 Risk Assessment and Triple Bottom Line + Risk

Beyond the typical TBL categories of Environmental, Social and Economic criteria, the Risk attributes of the scenarios were also important to understand. Scoring for each risk incorporated the likelihood of their occurrence and the severity of their impact.

An important concept to grasp with respect to risks is the separation of risks that are "inherent" to a scenario from those that are "practically mitigable". Those in the latter category can be accommodated by system design and should only appear in the evaluation where they impact other sub-criteria. Alternately, risks that are inherent to a scenario should be identified as specific risk factors and become part of the Risk sub-criteria.

The concept leads to the TBL + Risk approach. The inherent risks are grouped within a single risk assessment attribute, while the cost of resolving mitigable risks are included in the economic criterion, thus integrating all scenario attributes into a single evaluation with an easy-to-understand presentation of results. This approach avoids the potentially confusing situation where a scenario might have the highest TBL score (i.e., most favourable scenario from an environmental/social/economic view), but the independent risk assessment found the scenario to have a very high risk score (i.e., less favourable scenario from a risk perspective).

2.3 Model Inputs

Tables 2-1, **2-2**, and **2-3** list the inputted relationships for the paired comparisons for the Environmental, Social, and Risk criteria, respectively. An abbreviated comparison was made, in that the relationship of only some of the paired comparisons is inputted. The model then infers the relationships between the unlisted pairs based on the results of the inputted relationships. For each paired comparison, the favourable site is listed as being "greater than" the less favourable site. The degree by which the first site is superior to the second is indicated by the number in the parentheses, corresponding to the preference scale in Section 2.2 and where a higher number means an increasingly superior site.

Table 2-1
Environmental Criteria

Sub Criteria	Site 1A vs. Site1B	Site 1B vs. Site 3	Site 3 vs. Site 5
Rare and Endangered Species Impact	1B > 1A (3)	3 > 1B (3)	3 > 5 (7)
Justification	Potential for endangered species along the 1A raw water main path.	No endangered species at 3, while some potential for endangered species at 1B treatment plant site.	One species-at-risk flagged and another observed at Site 5.

Sub Criteria	Site 1A vs. Site1B	Site 1B vs. Site 3	Site 3 vs. Site 5
Wildlife Habitat Impact	1B > 1A (5)	1B = 3 (1)	3 > 5 (9)
Justification	Two areas of sensitive habitat along 1A raw water main.	Both sites involve heavily disturbed sites, with no sensitive habitat identified.	Site 3 is heavily disturbed while 50% of Site 5 is heavy foliage. Water body found at Site 5.
Water Intake Impact	1A = 1B (1)	1B = 3 (1)	5 > 3 (3)
Justification	Similar intake type, not near specific spawning areas.	Same intake type and location.	Riverbank filtration intake has slightly less impact on fish.
Potential River Flow Impact	1B > 1A (5)	1B = 3 (1)	5 > 3 (3)
Justification	Intake for 1A much further upstream; withdrawals will impact a greater stretch of river spawning area	Same intake location.	Site 5 is slightly downstream of 3, and intake at 5 is downstream of location where MOE has a minimum flow requirement.

Table 2-2
Social Criteria

Sub Criteria	Site 1A vs. Site1B	Site 1B vs. Site 3	Site 3 vs. Site 5
Land Use Compatibility	1A > 1B (5)	1B > 3 (6)	3 = 5 (1)
Justification	1B intake in very prominent area while all of 1A is in a less public area	Site 3 is a very prominent public area, and confined for the entire treatment plant to fit; 1B intake can be more easily added to public area.	Both sites are prominent to public.
Heritage / Archaeology Concerns	1A = 1B (1)	1B = 3 (1)	3 > 5 (3)

Sub Criteria	Site 1A vs. Site1B	Site 1B vs. Site 3	Site 3 vs. Site 5
Justification	1A raw water main crosses undisturbed areas but at a location where heritage sites are unlikely.	Both sites only impact areas already disturbed.	Potential of heritage sites in remaining non-disturbed portion of site.

Table 2-3
Risk Criteria

Sub Criteria	Site 1A vs. Site1B	Site 1B vs. Site 3	Site 3 vs. Site 5
River / Channel Stability Concerns	1B > 1A (5)	1B = 3 (1)	3 = 5 (1)
Justification	Unstable banks upstream of Site 1A intake, Site 1B intake is in stable bedrock.	Same intake location.	Site 3 intake to be built on stable bedrock, site 5 intake not impacted by bank stability.
Flood Potential	1A > 1B (3)	1B = 3 (1)	3 > 5 (7)
Justification	1A well above flood plain, intake for 1B close to flood plain.	Same intake site, which is close to flood plain.	Site 5 is well within the 200-yr flood plain.
Foundation Conditions	1B > 1A (5)	3 > 1B (5)	3 > 5 (7)
Justification	Site 1B intake on more stable soils and less vulnerable to seismic activity.	Site 3 has more stable soils and less vulnerable to seismic activity.	Liquefaction a concern at Site 5.
Raw Water Contamination Risk	1A > 1B (9)	1B = 3 (1)	3 > 5 (3)
Justification	1A intake upstream of Hwy 19A and Hwy 19, abandoned landfill, and sewer main crossing at Despard Avenue.	Same intake location.	Site 5 downstream of Hwy 19A, a fuel spill may contaminate riverbank filtration intake for longer period of time .
Intake Performance Risk	1B > 1A (3)	1B = 3 (1)	3 > 5 (7)

Sub Criteria	Site 1A vs. Site1B	Site 1B vs. Site 3	Site 3 vs. Site 5
Justification	Deeper riverbed at Site 1B.	Same intake type and location.	Uncertainty in performance of riverbank filtration system at Site 5.
Constructability Concerns	1B > 1A (3)	1B > 3 (3)	5 > 3 (3)
Justification	Access road to Site 1A in recreational area and in flood plain.	Site 3 has small footprint available.	Site 3 has small footprint available.
Property Purchase / Easement Acquisition Risk	1A > 1B (3)	1B > 3 (3)	3 = 5 (1)
Justification	Intake for 1B requires currently occupied property.	Site 3 requires multiple properties currently occupied.	No property purchasing issues identified.

The capital costs, derived in DP 8-1, are reiterated in **Table 2-4**. The costs do not include the incorporation of Aquifer Storage and Recharge into the water supply system. As with the non-qualitative criteria the most favourable site, that is, the site with the lowest capital cost, was given a full score of 100, while the least favourable site, that is, the most expensive site, was given a score of 0. This may seem extreme when considering that the lowest and highest cost are within $2 million of each other, less than 10% of the site total costs. At the Class 'D' level of cost estimates, one could consider the capital costs for each site not significantly different.

Table 2-4
Site Capital Cost

Site 1A	Site 3	Site 5	Site 1B
$43,021,000	$44,480,000	$44,526,000	$43,320,000

There are several different ways to compensate for the relatively small difference in capital costs. The recommended method is to recognize that capital cost is not a significant factor when contrasting the site options, and therefore reduce the importance or weighting of cost in the site comparisons. This does not disregard cost as an important consideration when planning for the proposed intake and treatment plant, but recognizes that the difference in costs are too small to be a significant decision-making factor in this circumstance. The impact of varying the Economic criterion's weighting are addressed in Section 3.1.

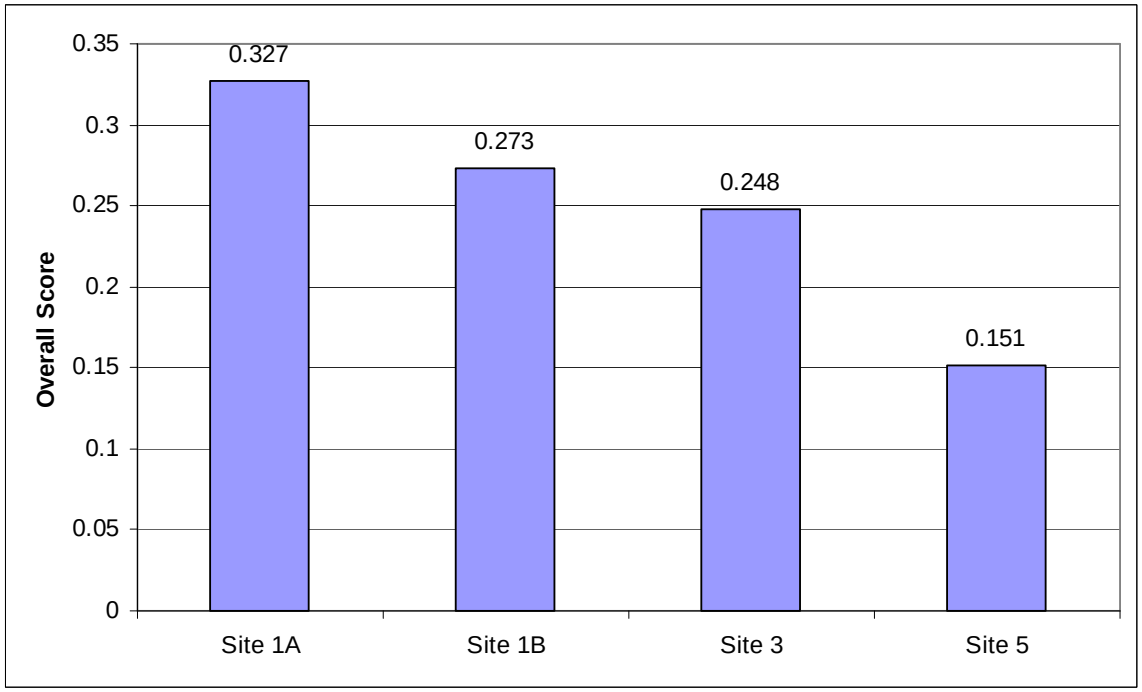
2.4 Application

In the end, it is important to recognize that the outcome of the TBL + Risk evaluation exercises is not a decision. Rather, the analysis is used as a tool to help understand how the different attributes of the four siting options relate to one another. What is learned from the evaluation can ultimately be used by the AWS to arrive at a decision on how to move the project forward.

3 Results of TBL + Risk Analysis

Figure 3-1 illustrates the results of the analysis. With the criteria and sub-criteria weightings shown in Figure 2-4,the overall scoring of the four options leans in the favour of Sites 1A and 1B, with Site 5 being the least preferable.

Figure 3-1
Overall Analysis Ranking

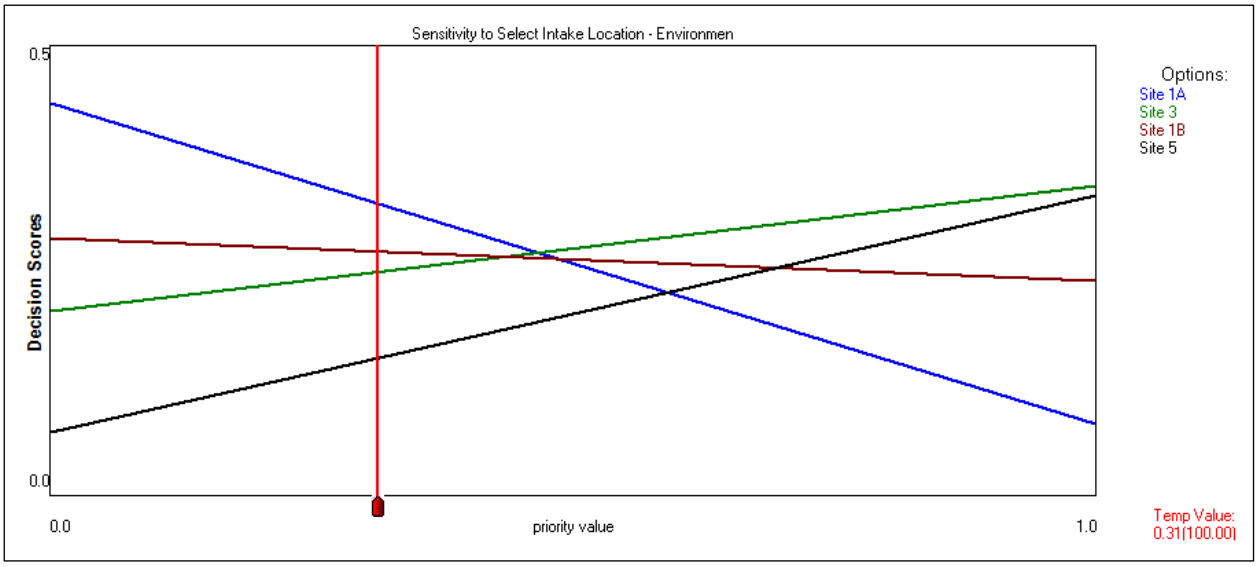


Site 1A had many favourable social aspects and was overall less vulnerable to the identified risks. Site 1B ranked consistently well in all four criteria. Sites 3 and 5 ranked more favourably than Sites 1A and 1B in terms of environmental impact, but were more vulnerable to risk and are much more exposed to the public.

3.1 Sensitivity Analysis

In performing sensitivity analysis, the CPD model is able to clearly illustrate the impact of a single criterion on the overall evaluation and answer the question: “Would the most favourable option be different if the importance of the criteria changed?” **Figure 3-2** presents the sensitivity analysis results for the Environmental criterion, adjusting the criterion’s importance to the overall score. The x-axis shows the relative weighting of the criterion; at 0.0 the criterion has no impact on the overall scoring, while at 1.0 this criterion alone determines the overall score. The current weighting of the environmental criteria, that is, approximately 31%, is shown by the vertical red line.

Figure 3-2
Sensitivity Analysis – Environmental



The y-axis indicates the overall score of each option, with the highest line at a given point being the highest scoring option overall. The highest line may change when moving along the x-axis, demonstrating how sensitive the overall score of an option is to the particular criterion. At the current criteria weighting, Site 1A retains the highest overall score. If the Environmental criterion is deemed of greater importance, a higher weighting could be assigned, which translates to moving towards the right along Figure 3-2. A change in the highest scoring option does not occur until the weighting for this criterion is at 47% or higher, at which point the Environmental criterion would be twice as important as either the Social considerations or Risk elements. At this weighting Sites 1A, 1B, and 5 converge to all become the highest scoring options. Above 47% Site 3 becomes the highest scoring option, primarily due to Site 3 already being a highly disturbed area and therefore having a minimum impact on pre-existing habitat. Site 1B remains the second highest scoring option unless the Environmental criterion weighting is increased to account for 70% of the total overall score.

Within the Environmental criterion, if the sub-criteria related to fish protection at the intake and to river flows are given greater weighting than the habitat and endangered species impact sub-criteria, the sensitivity plot changes slightly. Site 1A remains the highest scoring option unless the Environmental criterion weighting is increased to 45%. At this point Site 5 becomes the highest scoring option. Site 5 scores well in the revised Environmental criterion because the intake would be located the furthest downstream and would use a riverbank filtration gallery, which would pose less of a threat to nearby fish. For this revised weighting the Environmental criterion downplays that a significant amount of undisturbed habitat at Site 5 that would need to be removed, and that endangered species have been flagged or visually confirmed at the site.

Based on Figure 3-2 the overall scoring is sensitive to the weighting of the Environmental criterion if the criterion is deemed to be considerably more important, roughly as important as the Social aspects and Risk factors combined. If this is the case three of the Sites appear equally viable in the analysis.

Figure 3-3 displays the sensitivity analysis performed for the Social criterion. In general, Site 1A retains the highest overall score, with Site 1B being the second-best choice, unless the Social criterion weighting is reduced to only 10% of the overall score. At this point, Sites 1A, 1B, and 3 converge with roughly equal scores. Therefore, the results of the overall evaluation are not sensitive to the importance of the Social criterion unless this criterion is considered largely irrelevant when compared to Environmental and Risk considerations.

Figure 3-3
Sensitivity Analysis – Social

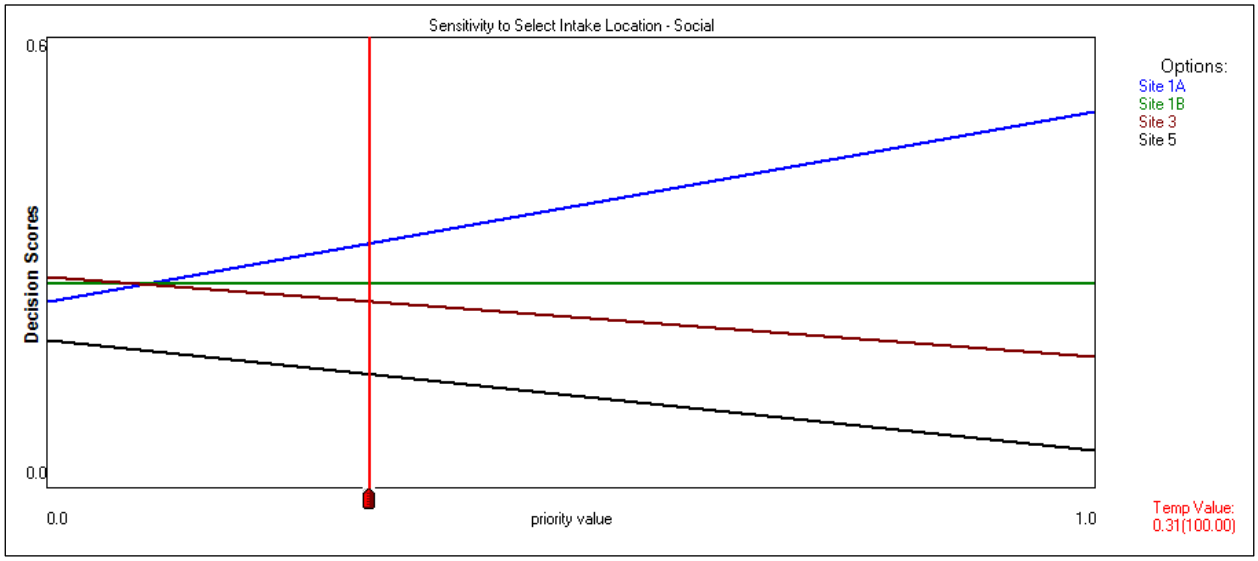


Figure 3-4 shows the sensitivity analysis performed for the Economic criterion. For all weightings for this criterion, Site 1A remains the highest scoring option. Site 1B stays as the second highest scoring option, unless the criterion's weighting is reduced from the current 8% to only 2%, at which point Site 1B and Site 3 converge. Otherwise the lines for the different sites never cross, indicating that the overall evaluation for site selection is not sensitive to the importance of capital cost.

Figure 3-4
Sensitivity Analysis – Economic

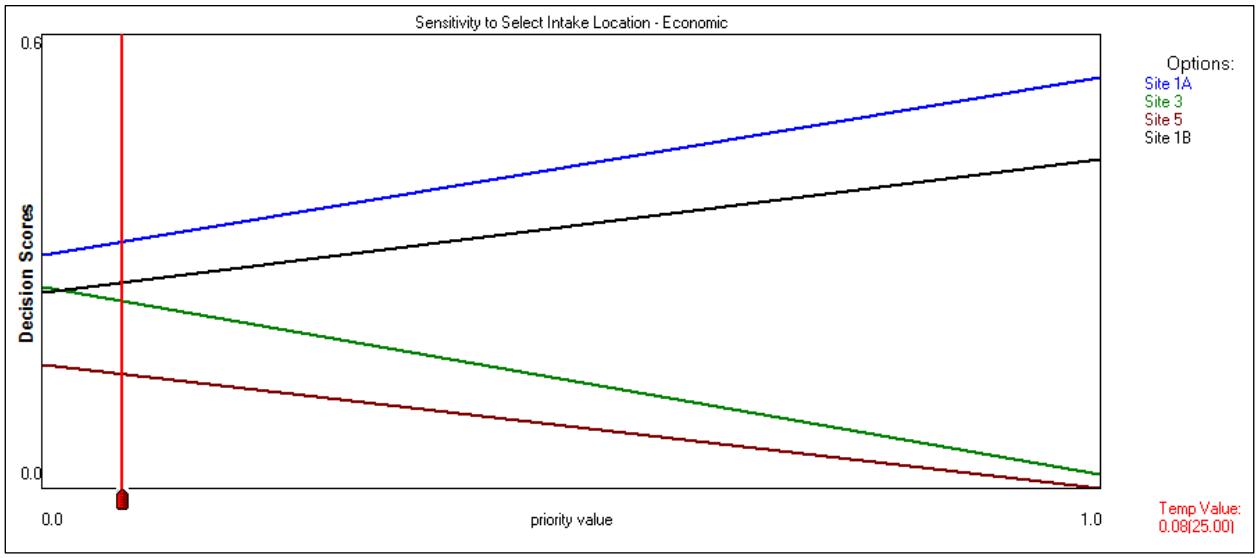
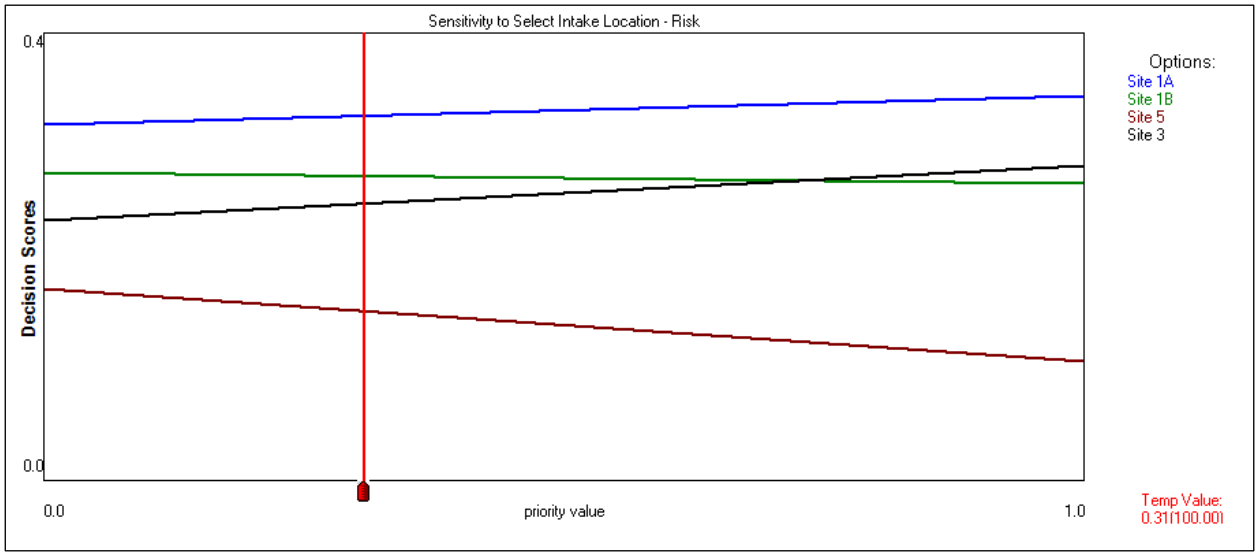


Figure 3-5 presents the sensitivity analysis performed for the Risk assessment. Site 1A remains the highest scoring location overall for all weightings of Risk. Site 1B remains the second highest scoring option unless the weighting for Risk increases to 72% of the total evaluation score, at which point Site 3 becomes the second best choice, due to Site 3 having more favourable seismic conditions and a deeper riverbed. The results of the overall evaluation are not sensitive to the importance of risk.

Figure 3-5
Sensitivity Analysis – Risk



If the risk of raw water contamination is given a greater weighting than the other Risk sub-criteria, the shape of the plot remains the same. The only difference is that Site 1A would have a higher overall score, since the Site 1A intake is upstream of the point source locations for possible raw water contamination, while the intakes for the other options are downstream of most of these sources.

3.2 Summary

Along the chosen criteria Sites 1A generally remained the optimal location for the proposed intake and water treatment plant for the different combinations of criteria weighting, with Site 1B consistently remaining the second best option. The results of the analysis were not sensitive to altering the relative weighting of the criteria, with the two exceptions:

- If the Environment criterion is considered as important as the social impacts and elements of risk combined, Sites 1A, 1B and 3 begin to score similarly.
- If the Social criteria, particularly the impact that a new plant will have on Parkville residents, is considered of relatively low importance, Sites 1A, 1B, and 3 begin to score similarly.

Based on the results of the TBL + Risk analysis, Sites 1A and 1B are the most favourable locations for the proposed intake and water treatment plant. While it can be debated the intake should be constructed upstream of either Highway 19 (Site 1A) or Highway 19A (Site 1B), it is recommended that the treatment plant be constructed at Site 1, behind the Public Works Yard.

4 Next Steps

The next step would be to confirm that the properties required for the recommended sites can be reasonably acquired. If a critical property is not available, the site must be reconsidered to first determine whether the site can still be reasonably used without the property or whether the site is no longer feasible.