DECISION SUPPORT APPLICATIONS FOR EVALUATING PLACEMENT REQUISITES AND EFFECTIVENESS OF WILDLIFE CROSSING STRUCTURES

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Abstract

Traffic on the Trans Canada Highway (TCH) in Banff National Park has created a barrier to movement of multiple wildlife species. Fencing and faunal passageways on mitigated sections of the TCH currently have exacerbated this barrier effect for sensitive species, such as lynx. We observed temporal fluxes in movement and suggest that the TCH (mitigated and unmitigated) may pose a demographic threat, by reducing dispersal opportunities. Moreover, we concluded that existing mitigation in Banff disregards the spatial requisites of wildlife communities. We observed normal wildlife movement often to be characterized by multiple crossings over short distances. The limited crossing opportunities provided by existing mitigation on the TCH prohibit this type of movement. Normal wildlife movement is replicated most appropriately by maintaining large contiguous tracts of habitat. This design can only be achieved by elevating and/or burying large sections of a highway and placing mitigation frequently. We examined two decision support systems (DSS) for assessing crossing structure effectiveness and found both to be highly suitable for such a complex resource allocation decision.

Introduction

Highway corridors in natural areas are a growing concern for wildlife conservation. Among a host of other effects, highways dissect contiguous habitat into smaller patches and create barriers to wildlife movement between adjacent habitat (Reed *et al*. 1996, Forman and Alexander 1998). This barrier effect has documented demographic consequences, including the alteration of animal communities, the creation of meta-populations, the reduction of biological diversity, and the increased threat of extinction (Forman and Alexander 1998, Noss and Csuti1997). Despite widespread recognition of the problems, Athe barrier effect remains little studied with regards to roads@ (Forman and Alexander 1998).

Traffic on the Trans-Canada Highway (TCH) in Banff National Park impedes wildlife movement and results in wildlife injury and mortality. We contend that effective highway mitigation must approximate normal wildlife movement. Hence, it is critical for managers to understand the placement and site requisites that most aptly reflect normal movement, and to determine the attributes of the most effective crossing structures. This paper is arranged in two components. Section I addresses road crossing frequencies and spatial attributes of crossings. Section II employs a decision support system (DSS) to detail explicitly how managers might select optimal crossing structures.

Study Area

This research was conducted in Banff National Park (BNP), Alberta. BNP is approximately 6640 km^2 in area and is the most heavily visited national park in Canada with over 5 million visitors per year (Banff-Bow Valley Study 1996). The study region is characterised by rugged mountainous terrain, steep valleys and narrow (2-5 km), flat valley bottoms. Roads and other human development primarily occur along the valley floors.

Findings of this paper reflect two years of study of the non-twinned (2 lane), unfenced section of the Trans-Canada Highway from Castle Junction to the British Columbia border (Phase IIIB) and along the Bow Valley Parkway (1A). See Figure 1. Data was collected from November to April (1997/98 B 1998/99). Research also was conducted along the Smith Dorrien Trail and Highway 40 in Kananaskis Country, Alberta. Kananaskis data are not summarized in this article. All study roads currently are not mitigated, except for wildlife warning signs. A third field season will commence in October 1999.

Three road sections were surveyed, each approximately 30 km in length. Summer average daily traffic volume on the TCH is 11,000c (Alexander 1998). Summer average daily traffic volume on the 1A is 3000c. BNP road survey sections are classified as:

B1: Bow Valley Parkway (Hwy 1A) from 5 mile bridge to Castle Junction
B2: Bow Valley Parkway (Hwy 1A) from Castle Junction to Lake Louise
B3: Trans-Canada Highway from Castle Junction to the British Columbia Border
(Unfenced, non-twinned section of the TCH)

SECTION 1: Road Crossing Analysis

Methodology

Roads were surveyed 24-48 hours after fresh snowfall. Tracks entering or exiting the road right of way were recorded for coyote (*Canis latrans*), fox (*Vulpes vulpes*), wolf (*Canis lupus*), cougar (*Felis concolor*), bobcat (*Lynx rufus*), lynx (*Felis lynx*), marten (*Martes Americana*), fisher (*Martes pennanti*), wolverine (*Gulo gulo*), elk (*Cervus elaphus*), moose (*Alces alces*), sheep (*Ovis canadensis*) and deer *(Odocoileus virginianus and Odocoileus hemionus*). Repeat surveys were conducted at approximately 3-4 days after initial surveys, at which time only observations of large carnivore crossings were recorded. We did not attempt to differentiate deer species. Tracks were observed from a field vehicle, while driving slowly (15-20 km/hr) and verified on the ground.

Data collected at crossing sites included: species type; GPS location (UTM-Nad27); direction of travel; travel direction relative to vegetation and road; distance travelled on the road; vegetation characteristics; and whether the animal was crossing the road multiple times or had aborted a crossing attempt. If no obvious tracks existed on the road surface, we assumed that tracks entering/exiting the road surface were crossing attempts. If no companion tracks exiting/entering the road were found within 300 meters, the crossing was marked as unconfirmed. Same species tracks recorded past that interval were identified as separate crossing attempts.

Transects consisting of twenty, 50 meter sub-transects (each 1km total length), were fixed perpendicular to each road type. Forty transects were surveyed in BNP, 20 in Kananaskis Country. Transects were surveyed randomly between 24-108 hours after snow, immediately following road surveys. Tracks were recorded on transects for all road crossing species in addition to squirrel, weasel and hare. Transect survey data provides an estimate of available populations and is critical to explaining variances in movement at different traffic volumes. Transect data have not been analysed for this paper.

Results

Tables 1 and 2 summarize crossing counts for all species surveyed during the winter seasons 1998/99 and 1997/98. Table 3 compares track counts on sections B2 (1A east of Castle) and B3 (Phase IIIB of TCH B unmitigated) with results summarized by Clevenger (1998) for Phase IIIA on the TCH (mitigated). Habitat along section B2 is contiguous with habitat adjacent to the Phase IIIA. We argue these two sections bisect one community of species and may be readily compared. Section B3 provides contrast of the Abarrier effect@ caused by traffic volume versus fencing and mitigation.

Crossing frequencies were compared by highway section using the Chi-square statistic at the 99% confidence interval. We tested for a uniform distribution of crossings between highway sections, with the following results.

1997/98

B1 vs B3: ? 2 = 27.268, df = 9, Cramers V = 0.31. Significant difference at 99% level.

B2 vs B3: ? 2 = 11.314, df = 5, Cramers V = 0.35. **No** Significant difference at 99% level

Significant difference at 95% level.

IIIA vs B3: ? 2 = 393.775, df = 6, Cramers V = 0.66. Significant difference at 99% level.

IIIA vs B2: ? 2 = 455.355, df = 8, Cramers V = 0.44. Significant difference at 99% level.

B1 vs B3 vs B3: ? 2 = 224.585, df = 18, Cramers V = 0.54. Significant at 99% level.

1998/99

B1 vs B3: ? 2 = 72.276, df = 8, Cramers V = 0.35. Significant at 99% level.

B2 vs B3: ? 2 = 9.734, df = 7, Cramers V = 0.19 **No** Significant difference

at 99% or 95% level

B1 vs B2 vs B3: ? 2 = 120.603, df = 20, Cramers V = 0.29. Significant at 99% level.

Discussion

Traffic on the TCH impedes movement and dispersal in the Bow River Valley, as shown by statistically lower crossing frequencies along the TCH (B3) and relative abundance of potential migrants. A three-way comparison of frequencies for B1, B2 and B3 indicated a significant difference at 99% confidence between highway crossing frequencies in 1997/98 and 1998/99 (? 2 = 224.585, *df* = 18: ? 2 = 120.603, *df* = 20). This difference is explained primarily by variation between B1 (1A East) and B3 (TCH). A high crossing frequency by marten, coyote, cougar, wolf, wolverine and elk on B1 (1A East) contributed most to the differences between highway segments.

Pairwise comparisons showed a significant difference at 99% confidence between the TCH (B3) and the 1A East (B1) in 1997/98 and 1998/99 (? 2 = 27.268, *df* = 9:? 2 = 72.276, *df* = 8,). In 1997/98 a significant difference was observed between B2 and B3 at the 95% confidence level, but not at the 99% level (? 2 = 11.314, *df* = 5). In 1998/98 no significant difference was observed between B2 and B3, at either the 95% or 99% confidence level (? 2 = 9.734, *df* = 7).

A preliminary analysis of transect data shows that species richness and abundance was comparable in habitat adjacent to the B3 (TCH) and B1 (1A East), and low neighboring B2 (1A West). This finding supports the conclusion of a barrier effect along B3 (TCH). Variation in habitat suitability and topographic relief may explain the lack of statistical difference between B2 and B3. In contrast to habitat bordering sections B1 and B3, that adjacent to B2 is more steep and rugged. A formal analysis of transect data will provide an index of habitat suitability in these regions.

In 1997/98, corrected crossing frequencies along the TCH (B3) and the 1A East (B1) differ significantly from those on the Phase IIIA of the TCH (currently mitigated) (? 2 = 393.775, *df* = 6, 99% confidence: ? 2 = 455.355, *df* = 8, 99% confidence). The variability in part is explained by higher crossing frequencies on the B3 (TCH-unmitigated) and B1 (1A East) for coyote, cougar, lynx, wolf and wolverine, compared with IIIA (TCH-mitigated). All species, excluding cougar, have been detected adjacent to B1, B2, B3 and IIIA. Higher crossing frequencies for elk and deer on Phase IIIA explain variation from B3. This suggests that crossing structures currently have not alleviated the highway barrier effect for any species but elk and deer.

Lynx crossings unexpectedly were higher on the TCH (B3) compared to other highway sections and increases in movement appear to coincide with the dispersal period. Lynx were present in habitat adjacent to all road sections. In 1998 Clevenger (1998) reported no lynx crossings on the Phase IIIA section of the TCH. This disparity implies that lynx currently remain free to disperse along unmitigated sections of the TCH. This conclusion does not warrant the abandonment of mitigation on the TCH, but suggests that the extent and type of mitigation in BNP is inadequate for sensitive species.

Finally, we observed that wildlife crossings on a community level are not spatially clustered, but are spatially continuous. See Figure 2. In contrast, the existing TCH wildlife mitigation constrains movement to narrow and infrequent sites: Crossing opportunities are reduced further by design inadequacies, such as narrow culverts. Moreover, crossings for many species (e.g. coyote, sheep, elk, wolves, and cougar) have been routinely observed to parallel roads and to be characterized by a high frequency of intercepts with the road. Concern for the conservation of communities should be paramount in protected areas like BNP. Thus, to capture community level movements crossing structures must be spatially extensive and frequent. Continuous spatial movement is not replicated by the punctuated placement of crossing structures on mitigated sections of the TCH (Phase IIIA). Refer to Figure 2.

SECTION 2: DSS Applications In Highway Mitigation

The following section details the use of a DSS to evaluate the effectiveness of wildlife crossing structures. The approach can be extended to the selection of optimal sites for future mitigation. A multiple-criteria, multiple-objective approach was used, which considered four objective groups (parks administration, engineering, public, and wildlife). Each group was assumed to have equal importance in the decision making process. Each crossing structure (site) was evaluated using 7 criteria (see below).

Methodology

Our objective was to determine the most effective crossing structure based on multiple stakeholder needs. The most effective solution maximizes frequency of use. Economic, engineering and public effectiveness is defined as the greatest wildlife use relative to cost. The most ecologically efficient solution accounts for the distribution of potential migrants relative to the frequency of crossings on each structure.

For analysis, we assumed that all objective groups have equal importance in the decision process. We also assumed that potential migrants are uniformly distributed and have equal likelihood of encountering a crossing structure. The latter assumption was relaxed to determine the most ecologically efficient solution.

Stakeholders

1. Parks Canada Administration: Banff National Park is a *de jure* region, administered by Parks Canada, and governed by the National Parks Act (1988). Parks administrators must be involved in the decision making process.

2. Public: Parks Canada=s Guiding Principles and Operational Policy (1994) states that public consultation and participation is a required component of the decision making process.

3. Engineering: The structural design of faunal passages must meet engineering design standards, in order to ensure their structural integrity and to safeguard the public.

4. Wildlife: Ecological integrity and conservation is fundamental to the management of park wildlife resources, as defined by the National Parks Act (1988). The effectiveness of each structure should be considered to ensure that effective dispersal and colonization of wildlife is facilitated.

Evaluation Criteria

Evaluation criteria are the measures by which the alternative crossing structures can be compared. Criteria must be expressed as >operational definitions=. For example, the criteria Aeffectiveness for wildlife@ may be expressed as a set of operational definitions, such as: diversity of species, crossing frequency and ratio of sensitive species crossing (see points below). These >measurable= definitions are necessary to ensure the decision process is >traceable= and can be replicated. The evaluation criteria follow:

1. Cost ($1000): Cost of construction of structure is basic to economic decision making. Highway engineers will wish to build the most effective structure (in terms of use), with the least expenditure.
2. Diversity: Number of species using the structure. Biodiversity is one measure of dynamic long-term stability in ecosystems (Noss *et al.* 1996, Weaver *et al.* 1996).
3. Indicator: Number of indicator species using structure. We assumed there are 6 possible indicators (grizzly bear, black bear, cougar, lynx, wolf and wolverine). Conservation of indicator species should ensure that other species are considered in planning. Indicator species are sensitive to human disturbance (Noss *et al.* 1996) and their presence on the structure should indicate the perceived security of the structure for passage.
4. Crossings: Frequency of crossings at each structure. The total number of crossings (successful migrations) provides a measure of resiliency (Weaver *et al.* 1996), but is dependent upon the abundance of potential migrants in the vicinity of each structure.
5. Maintenance ($1000): Cost of annual maintenance is important as it is a long-term expense that must be borne by the Federal Government and the taxpayer.
6. Ratio sensitive (x1000): This measure is the frequency of crossings by sensitive species (e.g. wolves, grizzly bears, cougar and lynx) over the total number of crossings. Total number of crossings alone is insufficient to judge ecological importance (total crossings may be made up largely of ungulates B non-sensitive species).
7. # Failed crossings: The total number of aborted crossing attempts provides an index of rejection and is of equal importance to passage rate. There may be underlying reasons why species reject a structure, such as sound disturbance or lack of security.

Solution Alternatives (Sites)

Solution alternatives are the various crossing structures. In this study we used crossing structures along the TCH Phase IIIA for ease of demonstration (see Clevenger 1998). Mitigation name is followed by type, indicated by the abbreviations BC (Box Culvert), MC (Metal Culvert), CR (Creek Underpass) and OP (Overpass).

Data types

This procedure is demonstrative only. Data on wildlife crossing frequencies, costs (construction and maintenance) relative abundance and structural preference measures (See Table 4) were estimated from Clevenger (1998). Data are ratio, with the exception of measures of aesthetic impact, which are rank data. The latter was assumed to be ratio to allow for analysis in MATS (Multi-Attribute Trade Off System) and DAS (Decision Analysis System), described below.

DSS Used in Analysis

MATS: MATS (Brown *et al.* 1986) employs a simple additive weighting (SAW) method. It has the capability of handling 40 criteria/factors and 40 alternate plans (sites). A SAW is a compensatory DSS, in that there is a trade of scores for each objective group and criteria.

DAS: DAS (Armada Systems 1988) houses two separate systems: DMM (Decision Matrix Method), which handles up to 50 criteria and alternative plans and PCM (Pairwise Comparison Matrix), which uses a semantic scale to rank alternatives and handles 16 different attributes at 5 different hierarchical levels.

DMM: DMM output can be used to analyze rank or ratio data. DMM provides an output showing SAW/NAW (Simple/Normalized Additive Weighting) and TOPSIS (Technique for Ordered Preference by Similarity to Ideal Solution) analytical results.

Finding the Most Effective Solution

In the first stage of analysis we used MATS and DMM to evaluate the most effective structure based on criteria defined previously. The decision matrix is shown in Table 4. Criteria are listed as column headers and the alternatives are shown as row headers. The output of this analysis is shown in Output A and B below.

The first stage of the DSS process did not account for the distribution and abundance of potential migrants, which may bias the final solution. To determine if there are more or less crossings than expected, we created a second matrix in DMM and compared ranked structures by abundance of species within a 1km radius of the structure, visibility for wildlife, distance to vegetation, and sound disturbance (See Table 5). These criteria were chosen from the literature (Forman and Alexander 1998). The output is shown as Output C on Table 5.

Sensitivity Analysis

Sensitivity analysis is an important step in the assessment of spatial models (McMaster 1997, Massam and Robinson 1996). The use of different DSS is a form of sensitivity analysis. Consistent rankings across DSS indicate stability. Another method to examine solution robustness is to consider the effect of modifying weights. If slight changes in weights cause radical shifts in the model, then the model is unstable (Massam and Robinson 1996).

Discussion

The objective of this study was to develop an explicit methodology for applying DSS technology to the analysis of crossing structures. In future analyses, we will extend this procedure to determine the optimal placement of future crossing structures.

The best site for Phase IIIA was Wolverine MC. This solution was consistent for both DSS. A sensitivity analysis of criteria weights also found the solution to be a robust.

The crossing frequencies were estimated for each structure, but are realistic approximates. We examined why wolverine MC and OP might be more effective than other structures. We ground- truthed the sites and found that both structures correspond spatially with the pre-existing end of exclusion fencing. Wildlife may have become habituated to crossing at these sites over 10 years of encountering the fence end. In this case high crossing frequency may be interpreted incorrectly to represent effectiveness of a structure, when in fact it is an artifact of previous human intervention.

Strengths of the DSS

? It can be used within the existing framework of decision making in National Parks.
? The DSS allowed the problem to be organized easily.
? It allows for the inclusion of a number of stakeholders, and thereby meets the regulations of the National Parks Act and Parks Canada=s Guiding Principles and Operational Policy.
? It is flexible and allows for the changes in stakeholders, factors or sites.
? The DSS provides an adaptive model for decision making and management.
? The process can be easily traced and replicated, which is important for public and expert acceptance of results.

Weaknesses of the DSS:

? The DSS cannot account for sites where wildlife may have been habituated to crossings. This may lead to incorrect assumptions regarding the actual effectiveness of structures.
? The assumption of SAW procedure, that variables can be linearly added, may be violated when variables are correlated, which is often the case in natural resource problems.

Conclusions

We conclude that the TCH, Phase IIIB, is a barrier to movement and dispersal for most species. Moreover, we argue that the mitigation approach employed in BNP fails to approximate natural movement and does not accommodate wildlife communities. We conclude Phase IIIA mitigation functions selectively for a narrow set of highly tolerant species and at present has exacerbated the barrier effect for sensitive species, such as lynx and wolves. An effective strategy will require crossing structures with greater spatial extent and more frequent intervals. We conclude that spatial movements observed for many individual species and wildlife communities are best achieved by elevating and/or burying large stretches of highway.

The complex nature of resource problems lends itself to analysis with DSS. MATS and DMM were useful DSS for tackling the question of optimal crossing structure. Both procedures were straightforward to employ and yielded robust solutions. DMM has the additional advantage of being able analyze rank and ratio data. We conclude that the use of DSS enhances the objectivity and credibility of decision making in highway planning.

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TABLE 1: Banff Road Crossing Summary: Total for 1998/1999 (17 surveys)

SPECIES	1A:East (B1) (Unmitigated)	1A:West (B2) (Unmitigated)	Phase IIIB (B3) (Unmitigated)
MARTEN	219	106	65
COYOTE	76	36	28
WOLF	30	5	1
LYNX	0	2	6
COUGAR	18	0	0
WOLVERINE	0	0	0
ELK	69	8	2
MOOSE	0	1	0
SHEEP	6	0	0
DEER	57	1	0
FOX	1	0	0
FISHER	0	1	0

TABLE 2: Banff Road Crossing Summary: Total for 1997/1998 (12 surveys)

SPECIES	1A:East (B1) (Unmitigated)	1A:West (B2) (Unmitigated)	Phase IIIB (B3) (Unmitigated)
MARTEN	68	15	16
COYOTE	77	9	23
WOLF	14	7	1
LYNX	3	6	5
COUGAR	12	0	0
WOLVERINE	6	0	1
ELK	50	3	2
MOOSE	0	0	0
SHEEP	3	0	0
DEER	7	0	0
FOX	1	0	0
FISHER	0	0	0

TABLE 3: TCH/1A (Alexander 1998) vs Mitigated TCH (Clevenger 1998)

SPECIES	Phase IIIB (1998) (Unmitigated)		Phase IIIB (1999) (Unmitigated)		1A (East) (1998) (Unmitigated)		1A (East) (1999) (Unmitigated)		Phase IIIA (Clevenger 1998) (MITIGATED)
MARTEN	16	*160*	65	*455*	68	*680*	219	*1533*	Not surveyed
COYOTE	23	*230*	28	*196*	77	*770*	76	*532*	168
WOLF	1	*10*	1	*7*	14	*140*	30	*210*	2
LYNX	5	*50*	6	*42*	3	*30*	0	*0*	0
COUGAR	0	*0*	0	*0*	12	*120*	18	*126*	1
WOLVERINE	1	*10*	0	*0*	6	*60*	0	*0*	0
ELK	2	*20*	2	*14*	50	*500*	69	*483*	229
MOOSE	0	*0*	0	*0*	0	*0*	0	*0*	0
SHEEP	0	*0*	0	*0*	3	*30*	6	*42*	0
DEER	0	*0*	0	*0*	7	*70*	57	*399*	179
FOX	0	*0*	0	*0*	1	*10*	1	*7*	0
FISHER	0	*0*	0	*0*	0	*0*	0	*0*	0

Correction Factor (x10-1998/x7-1999) to standardize sampling between unmitigated and mitigated projects (provides estimate only) B Corrected values shown in italics.

nb: Movement is recorded at point of entry for crossings in cases of single and multiple crossings. Hence values shown may under-represent movement. For instance, correction factor for wolves under-represents actual movement (Callaghan, pers. comm. 1999). Factor correction may be inappropriate for seasonal residents, such as the wolverine.

TABLE 4: Impact Matrix: Phase IIIA, TCH

	Cost Structure ($1000)	Species Diversity	Number of indicators	Number of crossings	Maintain. Cost ($1000)	Sensitive/ /Total (x1000)	# failed crossings
Johnson BC	350	5	1	88	5	15	4
Pilot BC	350	6	2	59	5	43	0
Red Earth BC	350	5	1	66	5	118	12
Sawback MC	350	5	1	37	5	35	0
Borgeau MC	275	3	1	25	5	158	11
Copper MC	275	5	1	87	5	15	2

Massive MC	275	6	2	74	5	53	7
Wolverine MC	275	6	2	54	5	143	6
Wolverine CR	300	5	1	60	10	65	2
Red earth CR	300	6	2	40	10	129	4
Wovlerine OP	1850	6	2	99	25	39	1
Red earth OP	1850	5	1	132	25	10	4
MATS Function Form	Negative Linear	Positive Linear	Positive linear	Positive linear	Negative linear	Positive linear	Negative linear
DMM Column Value(+/-)	Negative	Positive	Positive	Positive	Negative	Positive	Negative

OUTPUT A. PHASE IIIA (MATS) OUTPUT B. PHASE IIIA (DMM)

Site	**Score**	**Site**	**Rank**
Wolverine MC	0.834	Wolverine MC	1
Pilot BC	0.813	Pilot BC	2
Red Earth CR	0.788	Red Earth CR	3
Massive MC	0.765	Copper MC	4
Copper MC	0.644	Sawback BC	5
Wolverine CR	0.622	Massive MC	6
Sawback BC	0.614	Wolverine CR	7
Johnson BC	0.609	Red Earth BC	8
Red Earth BC	0.592	Johnson BC	9
Wolverine OP	0.532	Borgeau MC	10
Borgeau MC	0.500	Wolverine OP	11
Red Earth OP	0.349	Red Earth OP	12

TABLE 5: Impact Matrix Considering Distribution of Migrants

	Rank from (Table 4: Output A)	**Visibility (1-4: low to v.high)**	**Sound (db)**	**Abundance <1km radius**	Distance To veg (metres)
Wolverine MC	-1 (*)	2.0	-30.0	213	-10.0
Pilot BC	-2	1.0	-25.0	89	-12.0
Red Earth CR	-3	3.0	-15.0	93	-13.0
Massive MC	-4	2.0	-40.0	100	-5.0
Copper MC	-5	2.0	-25.0	45	-15.0
Wolverine CR	-6	3.0	-18.0	208	-23.0
Sawback MC	-7	1.0	-10.0	195	-15.0

Johnson BC	-8	1.0	-15.0	43	-12.0
Red Earth BC	-9	1.0	-35.0	93	-15.0
Wolverine OP	-10	4.0	-22.0	203	-5.0
Borgeau MC	-11	2.0	-50.0	112	-12.0
Red Earth OP	-12	4.0	-45.0	89	-7.0

(Negative sign indicates reduced suitability with increasing numeric value)*

OUTPUT C: (DMM) Ecologically Effective Solution

Site	**Rank**
Wolverine OP	1
Wolverine MC	2
Red Earth CR	3
Wolverine CR	4
Sawback BC	5
Massive MC	6
Pilot BC	7
Red earth OP	8
Copper MC	9
Johnson BC	10
Borgeau MC	11
Red Earth BC	12

FIGURE 1: BNP STUDY AREA