Off the Shelf: Modeling and Management of Historical Resources

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Introduction

In Canada, historical resources concerns, apart from federally administered lands, are regulated by individual provinces and territories. In the Province of Alberta (Figure 1), historical resources concerns are administered through the Alberta Historical Resources Act. The Act stipulates that all historical sites and objects are the property of the crown (state) on both private and public lands, and that it is illegal to disturb or destroy historical places without regulated consent of the provincial historical regulator. In Alberta, as in most Canadian provinces, it is the responsibility of the developer to ensure that historical resources, either known or unknown, are not disturbed or destroyed by planned developments. If such are threatened, the developer must take steps to determine if historical resources are present in the development area, and fund efforts to mitigate their potential disturbance either

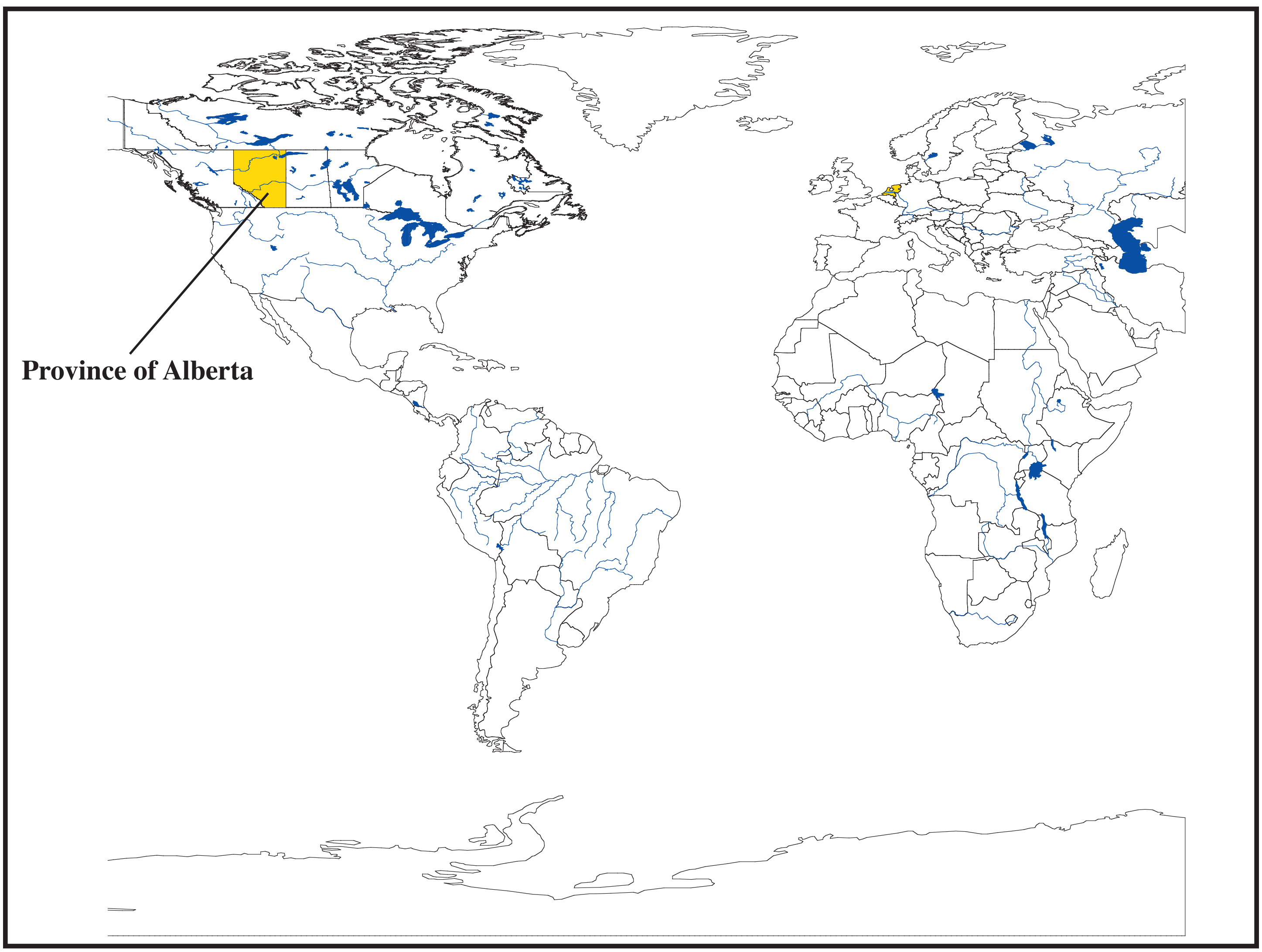

Figure 1. Location of the Province of Alberta, in Western Canada.

through avoidance or various levels of data recovery up to and including archaeological excavation.

This paper addresses two key issues arising from the above: how do developers determine if and where known and unknown historical resources are located in their proposed development areas, and how can they take steps to minimize disturbance of these known or potential resources in an expedient and economical way. These issues are dealt with in reference to the boreal forest region of Alberta, specifically the Alberta Green Zone - a vast extent of land that is crown-owned and where urban and agricultural development is restricted (Figure 2).

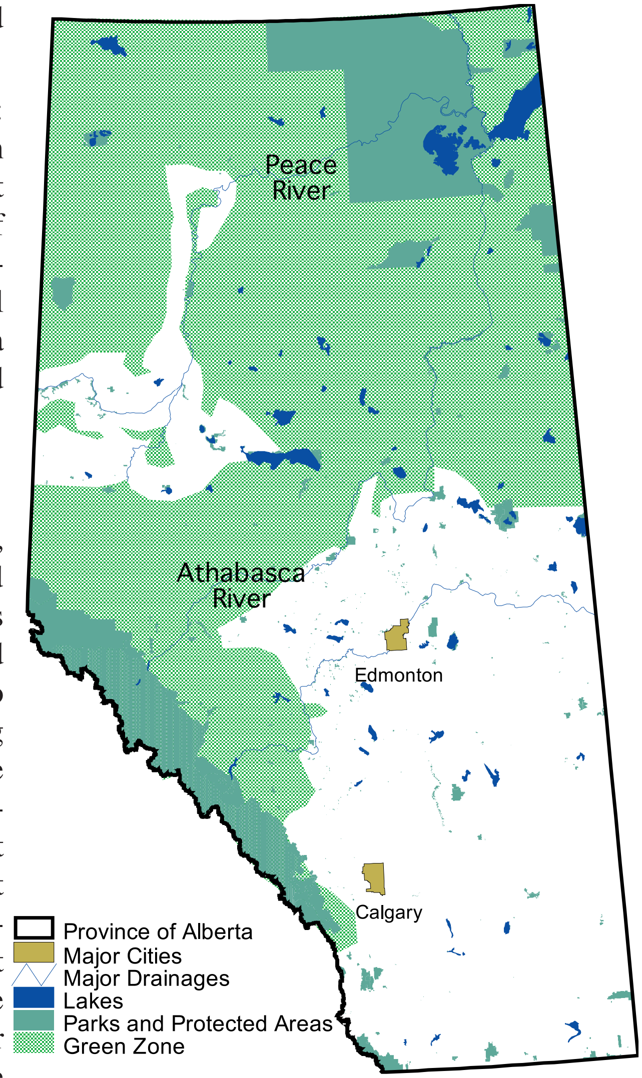

Figure 2. Location of the Green Zone in Alberta

Alberta Boreal Forest Environment

Although Alberta exhibits a diverse environmental landscape, the boreal forest comprises over 50% of provincial land and covers most of the northern half of the province. The region is characterized by a series of broad, gently undulating, lowland plains entrenched by a number of major valley systems. It also contains several upland areas that rise above the surrounding lowlands. Significant terrain features are the result of intense Pleistocene glaciation. The most recent advance occurred during the Late Wisconsonan Period, and extended across almost the entire province, withdrawing from northern Alberta about 11,000 years ago. The region is drained by the Peace and Athabasca drainage basins, which comprise 52% of its total area. It also contains many of the province's largest lakes, including the Peace-Athabasca Delta, one of the world's largest freshwater deltas (Figure 2). The transition from south to north across the forest zone is marked by increasing precipitation and decreasing temperatures, with a gradual progression from mixed wood forest stands of poplar, spruce and pine to conifer dominated forests in northern Alberta. A key characteristic of the boreal forest in Alberta is the abundance of wetland fens and bogs, comprising an estimated 40-50% of the landscape (Alberta Environmental Protection 1998).

Alberta Boreal Forest Historical Resources

The vast majority of historic sites in the Alberta boreal forest are associated with subarctic Athapaskan and Algonquian speaking peoples and their ancestors, who lived for at least a portion of the year within the region. These people subsisted on fluctuating populations of large animals such as the moose, woodland caribou, and woodland bison, and small game such as hare, grouse and beaver. Fish were also important, and provided a more stable, albeit seasonal, food source. The social and economic organization of these people centered on a seasonal round of subsistence activities tied in great part to resource availability. As a result, population densities in the northern forests remained extremely low, with small, mobile bands of 20-100 people being spaced widely across the landscape, for the most part, but coming together in greater numbers when local resources were temporarily more abundant. The types of archaeological and historical sites associated with these groups are of generally limited extent.

Much of northern Alberta is covered by soils which are acidic and rapidly destroy organic materials such as bone and wood. Consequently, a typical archaeological site consists of only a scattering of non-perishable stone artifacts lost or left behind by the people who made and used them, and traces of features such as fire hearths and occasional pits. Archaeological interpretation of these remains is greatly complicated by the minimal post-glacial depositional processes present in Alberta's boreal forest zone. As a consequence, archaeological components are usually found only a few centimetres below the organic component of the forest soils, and are extremely vulnerable to any kind of artificial or natural disturbance which disturbs the forest ground surface (Provincial Museum of Alberta 2003). The generally small size and ephemeral nature of most archaeological sites in the Alberta forest, and the low artifact densities associated with them, make discovery of such sites very difficult. As a consequence of this, and a paucity of previous directed research, the archaeological site inventory of forested portions of Alberta is small and not especially comprehensive. Archaeological surveys in the forest are difficult because of restricted access and poor archaeological visibility. Thus most of the known archaeological sites tend to be located in areas where it is easy to find them – along the shores of major rivers and lakes (Gibson and Finnigan 1998).

The Alberta Forest Industry and Historical Resources Protection

Human activities within and adjacent to the Alberta Green Zone present a continual and growing threat to boreal forest historical resources. Although the oil and gas industry presents the greatest potential impacts to archaeological remains, this paper deals in large part with the effects of the forest industry on archaeological sites. The industry in Alberta has expanded greatly since the late 1980's and as much as 75% of the boreal forest in Alberta is presently open to forestry development (Alberta Environmental Protection 1998). Clear cutting is the most common form of harvesting in the province, with cuts ranging from a few to several hundred hectares in size.

The timber harvest process is generally highly mechanized, with tread-mounted mechanical fellers and wheeled log skidders responsible for the bulk of wood product procurement. Wood transport figures heavily in all forestry operations, and road building is one of the most significant activities associated with forestry. Extensive reforestation is practiced, with hand replanting often being preceded by varying levels of ground disturbance, such as plowing or disking, to encourage seedling regeneration and reduce competition. In terms of archaeological site impact, harvesting and wood collection produce minor to moderate disturbances to archaeological sites, while road construction and reforestation can easily destroy them (Gibson and Finnigan 1998).

The early 1990's saw a major ideological change occurring within many Canadian forestry companies, with Alberta forestry firms being no exception. Foresters began to consider forests as a community of ecological and socioeconomic values, not just trees from which fiber could be extracted. The driving force behind this change was the need to export forestry products to foreign markets that placed increasing preference for more responsible stewardship of forested land. Part of this re-evaluation was a need to consider non-economic forest values, including the traditional values of aboriginal Canadians (First Nations) and historical resources. Historical concerns are now being integrated into Alberta forestry planning practices, starting with base-line studies addressing the effect of forestry activities on heritage resources and programs to aid forestry developers in predicting where archaeological sites will most likely be encountered in the forest (Finnigan et. al. 1995; Gibson et. al.1999; Gibson 2002; Gibson 2003). Given the vast area of the forest landscape, the use of predictive models for determining local historical sensitivity is a key component in integrating historical resources concerns into the sustainable forestry ethos.

Heritage Potential Modeling of the Alberta Boreal Forest

History of Development in Alberta

Albertan archaeologists have long used intuitive modeling approaches for mapping heritage potential in the Alberta Forest. These methods are commonly used by CRM personnel to identify heritage potential on a development specific basis. These intuitive methods rely in great part on subjective professional judgement although many examples of this approach present the development overviews using simple additive frequencies of identified local environmental attributeds that lends an air of objectivity to the results.

The application of GIS-based, statistical modeling approaches for predicting historical resource potential has only recently occurred in Alberta. Heritage potential models did not originate from academic circles but rather were the product of private enterprises working within the Cultural Resource Management (CRM) field. The adoption of GIS-based heritage potential models in Alberta was a direct response to the renewed commitment by the provincial government to enforce Historical Resource Act compliance of forest product manufacturers operating within Alberta's Green Zone and the concomitant necessity of CRM companies to predict site location and manage historical resources across vast areas of the province. Despite the late development of GIS-based approaches in Alberta, the utility of multivariate statistical approaches for elucidating historical resources potential and site location criteria had been demonstrated earlier by Magne (1987) for the Peace Region and Damkjar (1987) in southeastern portions of the province.

In the early 1990's, Dalla Bona applied a rigorous GIS-based heritage potential modeling approach for a portion of the Souris River in Saskatchewan while working with Western Heritage Services (WHS). The results of this study became the subject of his Master's thesis research at the University of Manitoba (Dalla Bona 1993). Subsequently he adapted his "Weighted Values" approach to a pilot modeling program, which sought to use heritage potential modeling for cultural value mapping for the northwestern Ontario forest industry (Dalla Bona 1994a,1994b,1994c).

The Weighted Values model works by assigning values to individual variables and then assigning weights to those values. For example, areas located 100 metres from lakes and rivers might be coded as "3", 100 to 200 metres as "2", and over 200 metres as "1". In this example, lakes are considered more important than streams so the specific codes for lakes would be weighted by a factor of "3" and streams by a factor of "1". Thus, modeling potential would be equal to 1 * "distance to streams" plus 3 * "distance to lakes". The advantage of this approach is that relationships are defined in an explicit manner. In this case it is assumed that being closer to a significant water body is important and the model therefore rates the influence of lakes three times more heavily than streams.

Using Dalla Bona's Weighted Values methodology, Western Heritage Services (WHS) began developing heritage potential models for forested and grassland regions in Saskatchewan and in northeastern British Columbia, primarily for the forestry and oil and gas industries. Relying on experience gained by modeling landscapes in those regions, WHS began production of digital heritage potential models in Alberta beginning with the development of a Weighted Values predictive model of the Whitecourt/Lesser Slave Lake region, 150 km northwest of Edmonton. Soon after the initiation of this pilot modeling project, WHS began evaluating alternative digitial modeling methods in order to improve their predictive capabilities and statistical testability. The result of this research was the adoption of heritage potential modeling applications that used logistic regression analysis (Kvamme 1992) as the basis for determining historical resources potential. The first application of this modeling strategy accompanied the implementation of an historical resources management strategy for a forestry products firm (Gibson et. al. 1999). Since this time. digital models have now been produced by WHS for much of the boreal forest area of Alberta, amounting to approximately 28 million hectares of land (Figure 3).

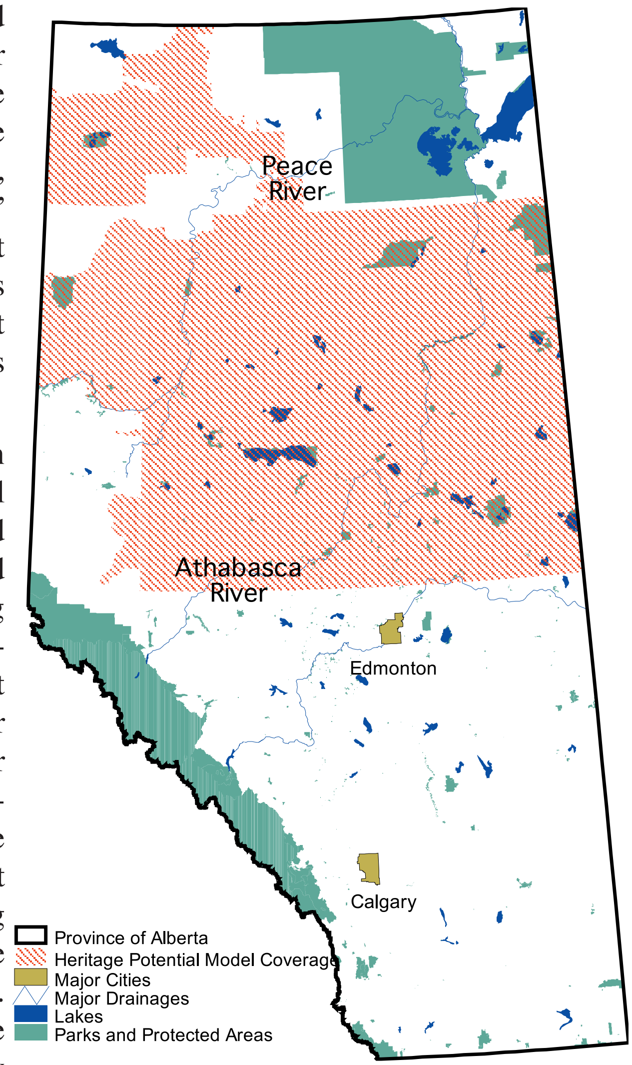

Figure 3. Extent of WH heritage potential model coverage in Alberta.

The WHS Modeling Approach

All GIS-based predictive models created by WHS are designed to be part of an integrated historical resources management strategy that developers use to plan their projects. This integration is fundamental to the successful use of the model, as will be explained below. The WHS modeling approach is inductive, in that it relies on data from known sites in a region in order to develop a prediction about where other sites may be found on a landscape.

The modeling methodology has changed over time, and continues to improve as new data sets and new modeling strategies are applied. Currently, WHS has developed three evolutionary models, referred to as Stage 1, Stage 2 and Stage 3 models. Stage 1 models use standard modeling variables derived from digital elevation data and hydrology for the most part. Stage 2 models use additional data derived from specially classified LandSat satellite imagery, principally to identify wetland/dryland terrain associations. Stage 3 models depart from the purely statistical approach by adding special rules to the modeling equation to place more emphasis on certain terrain and hydrology conditions as determined through the results of archaeological assessment and excavation and analysis of archaeological sites.

Although WHS used the Weighted Values heritage potential modeling approach for its its initial Alberta modeling, succeeding models (Stage 1, 2 and 3 models) made use of logistic regression as an alternative digital modeling method. This approach, first used by Kvamme (1992) and Warren (1990), has been used with success to explore the varying strengths of association of dependent and multiple independent variables. The logistic regression technique does present some constraints and underlying requirements that must be dealt with. One of the major requirements is that a logistic regression model must be developed using a sample of locations where sites are not located, to compare with a sample of known site locations. Although at the outset this would seem to be a fairly tedious data set to acquire, in fact, Kvamme has argued that in any large region sites are such a rare occurrence that any random sample of locations can be used as a non-site sample (Kvamme 1992). In the Alberta boreal forest, which has vast amount of landscape that is considered uninhabitable year round (i.e. muskeg), such a negative site sample would not be difficult to acquire.

Modeling Methodology

WHS data sources used for modeling terrain in northern Alberta include a relatively limited data set, derived from several primary terrain feature themes. These are hydrology, terrain condition and terrain elevation. Hydrology refers to stream and lake data, with locational accuracies of better than plus or minus 15 m. Terrain condition is determined from classification of LandSat imagery into dryland, mesic and wetland categories, with terrain pixels of 30 m accuracy. Terrain elevation for northern Alberta is the most limiting data set. Nearly all digital elevation model data for the region are available as points taken every 100 m on a grid, meaning that data are no better than 100 m in accuracy. This is the reason that most models of northern Alberta only calculate heritage potential on a hectare by hectare basis. Despite their relatively coarse resolution, digital terrain data are used to derive important habitation charactistics, including slope and aspect. In addition to environmental variables, individual known site locations are used as representative locations of high habitation potential zones, as well as a similar set of randomly obtained non-site data points.

As inferred from the above, the spatial unit of analysis for WHS Alberta boreal forest models is dictated by digital elevation model data. Each unit is 100 x 100 m in size, and referred to as a *cell*. Each cell has a number of environmental coefficients associated with it, derived from the preceding environmental data sets. These variables are actually measurements of association, usually expressed in distances (in metres) to a particular feature, such as a river, lake or archaeological site. Consequently, the feature itself (be it a river or a site) is not the variable of importance, it is the distance to a feature that is the critical measurement. For some types of modeling, buffers of predetermined size are used as variable coefficients (*i.e.,* 100 m from water, *etc*.). For logistic regression modeling, variables have greater predictive capability if they are distributed continuously across the landscape. Therefore, for each type of feature variable, the distance to the feature is spread over the landscape, to the edge of the modeled universe. On the resulting digital coverages, each cell contains a coefficient representing the distance to that feature set.

Once these matrices are generated for each variable, they must be compared against a similarly generated matrix of known archaeological site locations. If there are very few archaeological sites known for an area, then making this comparison becomes very difficult. In addition, this method of modeling requires a comparative, similar-size sample of non-site data. This is provided through the generation of a random sample of locations from the modeling area. The measure of success of the model is demonstrated by how well it can separate the site and random non-site data given the available variables.

The first inclination for the modeler is to amass every variable matrix that is available and incorporate each one into the modeling equation, processing the results. A resulting matrix is generated, representing the combined heritage potential for the modeled universe. Experience shows that this "shotgun" approach does not produce good modeling results. The problem is that some variables are not suitable candidates for developing a model and others are simply reflections of an underlying variable (*i.e.,* certain vegetation classes are dependant on soil types, which may already be accounted for in the model). Some variables also become invalid if extreme values in the matrices become abundant. For example, slope values in mountainous areas become highly skewed, and tend to mask out certain important topographic features that a good model requires to build up its accuracy. The modeler must inspect each candidate variable in turn, evaluating its predictive capability against the site matrix and decide if the variable should be discarded or simply transformed to make it more model-friendly. The result is that many ostensibly crucial data sets prove ultimately to be unsuitable for incorporation into the final modeling process.

When a model is finally produced, it is represented by a matrix of cell values falling between 0 and 1, with 1 being the highest level of heritage potential. If the model is to be used as a tool for heritage management, it is necessary to subdivide the cell matrix of continuous heritage potential values (*i.e.,* ranging between 0 and 1) into categorical units (*i.e.*, High, Moderate, Low) that are more suitably employed in the heritage management process. From a planning perspective, the goal is to define levels of heritage potential that are consistent with the aim of maximizing site counts while at the same time minimizing land area within high potential zones. A typical heritage potential classification result follows:

	Heritage Potential	% Land Area	% Site Density
(1) High Potential	1.000 to 0.800	6.34%	67.68%
(2) Mod Potential	0.799 to 0.600	16.98%	18.13%
(3) Low Potential	0.599 to 0.000	76.98%	14.24%.

In this model classification, the needs of efficient land management must be balanced against the needs of heritage preservation. Through successive analytical steps, the modeler must fix the heritage potential zones to yield a land management approach that land managers such as forestry planners and heritage regulators can accept. To do this one measures the model's performance across a variety of criteria in order to define appropriate zones of heritage potential. Criteria vary from modeled region to modeled region, and are based on a rigourous univariate and multivariate statistical analysis of site and non-site data, plus reference to general habitation capability observations made by professional archaeologists for a given locality.

Summary

In summary, the WHS modeling process consists of three steps: (1) an examination of the distribution of each variable in relation to the site and non-site classes; (2) a multivariate logistic regression analysis of these landscape variables to determine their utility for discriminating between the sample of site and non-site location classes within the model region; and, (3) classification of the raw heritage potential values to create a useful modeling tool for historical resources management.

The logistic regression approach has led to the development of predictive models that produce reasonable statements of heritage potential in the northern Alberta boreal forest In this regard, the models exhibit the desirable characteristics of maximizing site density while minimizing land area within high heritage potential value zones. The successful GIS-based predictive model provides a management platform from which development planners can plan their operations so as to minimize potential impacts to heritage resources sites (and reduce associated field survey costs related to compliance with the Historical Resources Act of Alberta). The goal is to place as many sites as possible in cells classified as high potential, and as many cells as possible in terrain classified as low potential. A good working model results in approximately 70% of sites appearing in less than 10% of the landscape, resulting in less than 10% of the landscape being classified as high potential for management purposes.

Theoretically, the predictive capability of a model as described above should improve as new and improved data are incorporated into it. This is particularly the case given the low known archaeological site count for the region and the associated potential for greater standard error of association. Assuming the model is predicting correctly, new site data should enable high potential localities to be defined more precisely. Negative discovery results should help augment the random non-site data, pointing to deficiencies in the predictive capability of the model and eventually allowing more precise model classifications that shrink the uncertainty of the model. In fact, empirical testing through field assesment is a critical requirement if this kind of predictive model is to evolve, and a mechanism must be developed to ensure that such empirical data are in fact acquired. This is elaborated upon below.

Evaluating Development Impacts

As indicated in the preceding section, WHS predictive models are designed to work within the framework of an integrated historical resource management process. The overall approach involves predicting the location of potential historical resources, determining to what degree development practices may disturb known and potential archaeological resources and devising a solution to prevent or minimize the chances of their disturbance.

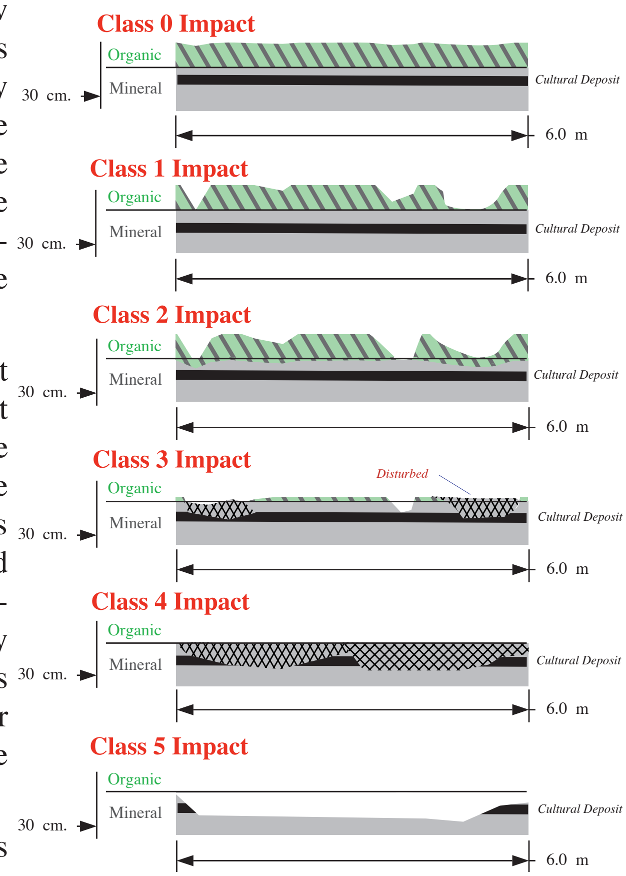

Figure 4. Graphical summary of Cultural Resources Impact Classification System used for management of modelled terrain.

From a land management perspective, information about how development activities can cause impacts on heritage resources is extremely important. The kind of impact a particular activity will subject to a site, and its degree of intensity, will dictate the kinds of responses that can be taken to minimize site disturbance or mitigation cost. Essentially, if a development does not pose a threat to a potential historical resource, then there is no reason to curtail the development, at least from a cultural resource management perspective.

The amount of damage that is caused by a given development activity depends on the activity being undertaken. Therefore, it is necessary to devise some kind of general classification scheme which can codify the severity of site disturbance. Disturbance would entail the alteration of a site in any manner from its natural state. Although the best information can be obtained from a site which has not been disturbed at all since it was created, in practice all sites become degraded to some extent by natural transformational processes. Furthermore, some kinds of alterations, both natural and artificial, may ostensibly appear severe, but in fact may not constitute significant disturbance from the perspective of historical data recovery.

An impact evaluation scale called CRICS (Cultural Resources Impact Classification System; Gibson 2002) is used to evaluate the level of damage that a cultural resource such as a buried archaeological site can sustain. Since impact classification is considered an integral component of historical resources management, it is important that the scheme be inclusive of all types of heritage resources, and yet not be so complicated that ambiguity render it imprecise. The CRICS classes (summarized in Figure 4) are:

<u>Classification 0</u> - No Impact - Result of activities which do not physically disturb the surface organic or subsurface mineral soil of a site.

<u>Classification 1</u> - Incidental Contact -Result of activities which affect the organic surface of a site but do not

disturb the integrity of the subsurface mineral soil.

<u>Classification 2</u> - Incidental Impact - This kind of impact is present when the organic soil layer of the forest floor is removed, exposing and compressing the mineral layer which can contain a cultural deposit.

<u>Classification 3</u> - Regular Impact - This class of impact applies to any kind of activity which regularly exposes and disturbs the mineral soil layer.

<u>Classification 4</u> - Severe Impact - When the near-surface mineral soil subsurface is completely modified, with virtually no evidence of the original surface present, this would be considered a Class 4 Impact.

<u>Classification 5</u> - Total Impact - If all or portions of a potential or known archaeological site contained within the mineral soil horizon are removed, this would constitute the most serious kind of impact, Class 5.

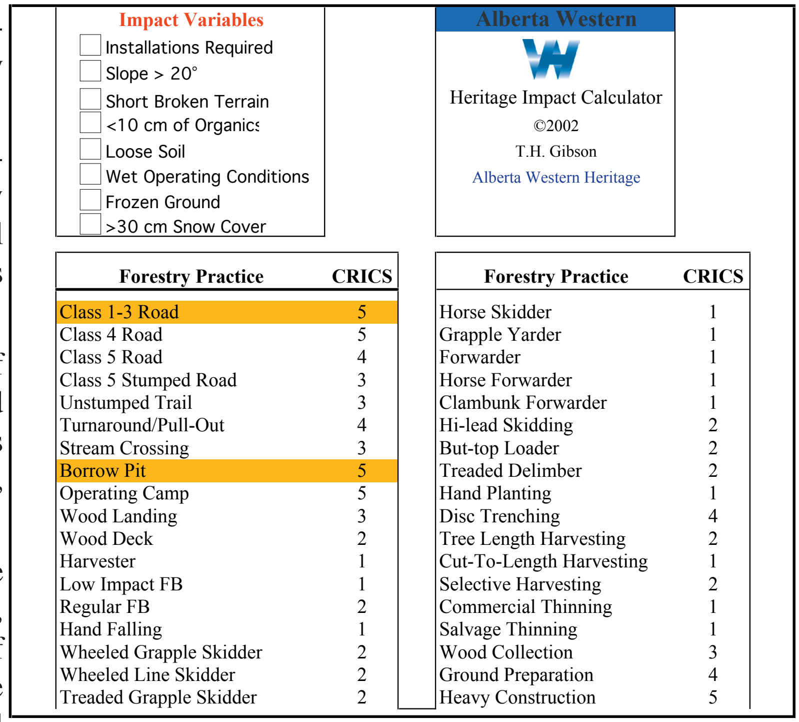

Figure 5. Typical CRICS impact calculator designed for foresty industry use. Clicking on the impact variable buttons changes the CRICS levels for each forestry practice.

CRICS classes for a given development practice change under different environmental conditions, such as the amount of organic cover or degree of soil firmness for a particular landscape, or its slope for example. For certain boreal forest industrial operations, such as forestry, a CRICS classification calculator is used to determine what practices pose a threat to potential historical resources at any given time (Figure 5). From an archaeologist's perspective, the purpose of the calculator is to encourage developers to minimize ground impact for a sensitive area by providing them with options to create less severe impacts during development.

Determining Archaeological Responses Using Modeling and Projected Impact Data

Once the heritage potential of a given area is indicated (using information from the heritage potential model) and various levels of development practice impacts are understood, heritage management responses can be articulated for individual developments. For planning purposes, an objective method is used to determine what level of archaeological inspection is required for each development. Thus, for a given location and a proposed development type, the CRICS classification must be considered in conjunction with the evaluated heritage potential and known historical resources to enable a cultural resource management decision.

For any given parcel of land:

Archaeological Response = Heritage Potential + Projected Impact

Before solving the equation, various archaeological responses must be articulated. In Alberta, as in most jurisdictions in Canada, planned developments which threaten known or suspected historical resources must be preceded by some form of archaeological assessment by qualified professional archaeologists. Some industries have complex planning and multi-staged development phases where archaeological inspection can take place after a certain level of impact has occurred and before a more serious impact is scheduled. At a basic level, however, three heritage mitigation procedures (called heritage prescriptions) can be identified:

1) <u>No Assessment</u> - The proposed development will not require any form of field inspection. Development may proceed up to Class 5 impacts.

2) Post-impact Heritage Audit - This kind of field inspection will take place after a development has been completed.

3) Pre-impact Assessment - This kind of archaeological field inspection must take place before any kind of development can proceed.

In order to apply these prescriptions to a development based on its predicted level of impact and potential for harbouring heritage resources, these prescriptions are linked to Heritage Potential and Projected Impact using an additive coefficient arrangement as follows:

Heritage Potential	Index
Low	0
Moderate	2
High	3

CRICS impacts are indexed as follows:

Impact	Index
Class 0	0
Class 1	1
Class 2	2
Class 3	3
Class 4	4
Class 5	5

Heritage prescriptions (archaeological responses) are indexed to reflect the additive combination of Heritage Potential and CRICS Impact:

Prescription	Index Range
No Concerns	0-5
Post-impact Audit	6
Pre-impact Assessment	>6

Armed with the preceding heritage potential and development impact coefficients and corresponding archaeological response index, heritage prescriptions for any development on any landscape are determined by adding the coefficients and referring to the resultant prescription index value. For example, on terrain classified as Moderate Potential (coefficient of 2) where CRICS impacts of Class 3 are planned (coefficient of 3), no archaeological response is triggered. If CRICS class 4 impacts are planned then a Post-Impact Audit is triggered. In High Potential terrain, any impact greater than CRICS Class 2 (at which point mineral soil is affected) requires minimally a Post-Impact Audit.

This is a simplistic version of the evaluation method. In the real world, other historical values must be accommodated for every piece of land. However, coefficients for other values can be added to the basic formulae; for example proximity to a known historical resource could easily raise the combined "sensitivity" of an area to an index range requiring archaeological pre-impact assessment work. This makes the calculation slightly more complex. However, CRICS impact levels and resulting heritage prescriptions can be determined using a single spreadsheet-based tool that permits land managers to anticipate the level of archaeological inspection that will be required if a development is planned for a specific locality. An example of such a tool is shown in Figure 6.

One problem with this management methodology revolves around the issue of modeled terrain exhibiting low potential. Practical implementation of the CRICS/Model-based management system discourages archaeological

Impact Variables

- Installations Required
- Slope > 20°
- Short Broken Terrain
- <10 cm of Organics
- Loose Soil
- Wet Operating Conditions
- Frozen Ground
- >30 cm Snow Cover

Heritage Potential

- Low Potential
- Moderate Potential
- High Potential

Heritage Resource Proximity

- Within Historic Boundary
- <500 m from Trail
- <250 m from Cabin
- <250 m from Arch Site
- <100 m from Arch Site
- Palaeontological Zone
- Sensitive Heritage Zone

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Forestry Practice	CRICS	Heritage Prescription
Class 1-3 Road	5	Low-impact Assessment
Class 4 Road	5	Low-impact Assessment
Class 5 Road	4	Moderate-impact Assessment
Class 5 Stumped Road	3	Post-impact Audit
Unstumped Trail	3	Post-impact Audit
Turnaround/Pull-Out	4	Moderate-impact Assessment
Stream Crossing	3	Post-impact Audit
Borrow Pit	5	Low-impact Assessment
Operating Camp	5	Low-impact Assessment
Wood Landing	3	Post-impact Audit
Wood Deck	2	No Concerns
Harvester	1	No Concerns
Low Impact FB	1	No Concerns
Regular FB	2	No Concerns
Hand Falling	1	No Concerns
Wheeled Grapple Skidder	2	No Concerns
Wheeled Line Skidder	2	No Concerns
Treaded Grapple Skidder	2	No Concerns

Forestry Practice	CRICS	Heritage Prescription
Horse Skidder	1	No Concerns
Grapple Yarder	1	No Concerns
Forwarder	1	No Concerns
Horse Forwarder	1	No Concerns
Clambunk Forwarder	1	No Concerns
Hi-lead Skidding	2	No Concerns
But-top Loader	2	No Concerns
Treaded Delimber	2	No Concerns
Hand Planting	1	No Concerns
Disc Trenching	4	Moderate-impact Assessment
Tree Length Harvesting	2	No Concerns
Cut-To-Length Harvesting	1	No Concerns
Selective Harvesting	2	No Concerns
Commercial Thinning	1	No Concerns
Salvage Thinning	1	No Concerns
Wood Collection	3	Post-impact Audit
Ground Preparation	4	Moderate-impact Assessment
Heavy Construction	5	Low-impact Assessment

Figure 6. Typical cultural resources management calculator designed for forest industry planning. Clicking on the impact variable buttons changes the CRICS levels for each forestry practice. Model-based heritage potential is subsequently selected, as well as other known historical criteria.

assessment on low heritage potential terrain. As models improve, the amount of low potential terrain should increase over time. Since the low potential terrain has no archaeological assessment requirement, the model predictions become ever more self-fulfilling with each interation. This fundamental flaw was acknowledged at the outset, and revolves around a specific clause in the Alberta Historical Resources Act that stipulates that historical resources assessments are not required on terrain determined to be of low archaeological potential. Since the CRICS/Model process attempts to weld theoretical tenents of heritage potential modeling with the practical needs of industrial historical management, within the context of legal historical regulatory requirements, this ideosyncracy was an inevitable outcome. There have been several solutions that have been implemented to circumvent this flaw. One was to create a new prescriptive action called the Sample Post-impact Audit that would direct archaeological survey on low potential land receiving high impacts. Such a prescription would be invoked on a parcel of land that received an Index of 5, which would, for example, trigger assessment on roads or borrow pits being built across low potential terrain. Original sample sizes for such field audits were set as high as 25%, meaning that one quarter of high impact developments crossing low potential land required inspection (Millar Western Forest Products 2001). A significant proportion of this terrain was found, during survey, to be in fact barely traversible, consisting of dense spruce forest interspersed with muskeg and low flow drainages. The traversible portions were located far from water sources, often on sloping uplands where even isolated hunting activities would not be expected to occur with any documentable frequency. After several years of implementation, the sample size was reduced, and then, after consultation with the provincial regulator, replaced with a subjective sampling approach that allowed more flexibiliity in choosing low potential sample survey areas where moderate as well as high impact developments were planned. This subjective sampling approach is not required by law, but has been accepted by developers as an acceptable way of ensuring that the historical modeling and management process does not become self-fulfilling.

Model Improvement Within a Management Process

One of the major attractions of using digital heritage potential models is their amenability to improvement through addition of new or updated digital data, and introduction of new modeling theory. All WHS models are designed to facilitate rapid updating, which has been made a fundamental requirement by clients and the Alberta government. In fact, the need to improve model performance is the primary reason that the post-impact heritage prescription assessment approach has been made part of the model-based heritage management process. Acquisition of properly acquired field inspection data are considered as important as the discovery of new archaeological sites when historical compliance work is undertaken in the field.

The data collection process

As part of the archaeological impact assessment process, a considerable quantity of standardized archaeological data are acquired whenever a ground survey is undertaken. This information is collected at judgementally selected spot locations along a survey route, with coordinate data being obtained using a global positioning system instrument (gps) capable of recording a live track of the assessment route, and able to store specific point coordinate locations (waypoints) to an accuracy of plus or minus 5 to 10 m or better. A special data recovery form is used to collect systematic data from a location, which is tied to the gps waypoint. Information regarding local environmental conditions (terrain situation, overstorey and understorey vegetation, local hydrology, soil conditions etc.), the kind and intensity of archaeological inspection, surface exposure conditions and other data are logged for every waypoint collected. As well, a subjective evaluation of heritage potential is also made by the recorder, including reasons for the judgement. Finally, in areas believed to be worthy of the effort, subsurface shovel testing is undertaken as well. The matrix from the tests is always run through 6 mm mesh to enhance small artifact recovery. Following field work, the waypoints and tracks are transferred to a computer and the standardized waypoint data are appended to the spatial data sets in spreadsheet tables. The annotated tables are loaded directly into the management GIS.

Newly acquired terrain and site data are critical for determining the predictive capability of a model and also are used for its improvement. Additions to the site database also improve statistical confidence for reprocessing model classifications. Recovery of negative data permits re-evaluation of high and moderate potential thresholds (as much a judgemental as a statistical operation), allowing high potential land to be converted incrementally to moderate potential land, and terrain identified as moderate potential to revert to low potential. Occasionally the reverse may occur as well, if archaeological sites are found in lower potential terrain during random audits of such land. Perhaps most importantly, recovery of ground-based empirical survey data permits a heritage potential model to transcend its statistical bounds through the introduction of special modeling rules.

Moving Beyond Statistics: An Enhanced Modeling Approach

Stage 1 and Stage 2 models are based on environmental and geographic data, and use an explicitly statistical approach to identify locations of highest habitation potential on a landscape. This is because the target site type they are designed to predict for is hypothesized to be the product of a nomadic hunting and gathering group who lived within a boreal forest environment that influenced their subsistence practices, residence and general mobility in a significant manner. As such all Stage 1 and Stage 2 models are environmentally deterministic. They are not designed to identify locations that are behaviourally idiosyncratic (such as animal kill locations) or culturally determined (such as ceremonial localities or religious centres).

A Stage 3 model moves away from the explicitly statistical distillation of human behaviour by adding arbitrary rule-based enhancement to the modeling equation. As an example, Stage 1 statistical models indicate that pre-contact nomadic hunting and gathering sites have the greatest probability of occurring within a certain distance of hydrological features with suitable terrain characteristics such as flat terrain and a southern aspect. Stage 2 models add information about wetland/dryland conditions, enhancing the hydrological data set. Addition of empirical archaeological field data permit the construction of a Stage 3 model.

Implementation of the CRICS/Model-based heritage management process during the past three years yielded considerable new archaeological field data from the boreal forest. Analysis of the new information indicated that precontact sites were found with diminishing frequency on minor drainages a certain distance away from major drainages, and were rarely found when drainages or sources of water were not present in a locality. In fact, headwaters of minor drainages were interpreted to exhibit low heritage potential for the most part, unless they flowed from muskegs with surrounding habitable landforms. Figure 7 shows a summary of archaeological data collected for forestry cutblocks and access roads that were assessed on the basis of a management plan using a Stage 2 heritage potential model. Positive and negative data were collected through pre-impact and post-impact compliance audit assessments, and sample audits of low potential terrain. No archaeological sites were found in the headwaters of minor drainages; in fact most waypoint records indicated that the local terrain exhibited subjectively determined low heritage potential. However, several new sites were found adjacent to higher order drainages, as predicted by the Stage 2 model.

Another iteration of the model was then processed, using the new site data coupled with a modification made to the main modeling equation that altered model cell values once certain distance thresholds from various drainages were attained. The modified modeling equation created significant improvements in modeling performance by providing a better fit for known site locations, while reducing areas identified as being of elevated habitation potential where no sites had been found (Figure 8).

Other modeling enhancements could conceivably be added to the model by adjusting the model equation, or by addressing entirely new data sets. For example, if the locations of medicinal plant recoveries could be isolated systematically across the landscape, and they could be shown to be correlated with enduring landscape features (i.e. they didn't move about the landscape as a consequence of natural vegetational change characteristic of the boreal forest), then a probability raster could be constructed and merged with the main equation. If traditional oral history data from First Nations elders indicated that medicinal plants were always collected on flat locations providing a good overview of the surrounding country, then a rule could be inserted into the main location that would invoke the consideration of this raster data set when such conditions arose. Unfortunately, although this would be a fairly simple improvement to make to the model, there is no real way to know whether it is a valid modeling parameter to introduce to the main equation. Since we have no current statistical means of determining the validity of the probability raster, this kind of modeling variable would normally be discarded. Furthermore, can traditional plant locations be considered the same as actual archaeological sites? Such site types are not addressed under current historical resources legislation and therefore are not protected from disturbance. However, political considerations may in fact dictate that such a variable be included in future models, as these tools move from relatively simple aids to assist in industrial compliance to instruments of public policy.

Conclusion

When heritage potential models were first seized upon by Canadian industry and government as a means of classifying the historical potential of a landscape, it was assumed that the models would be self-explanatory in terms of their practical application. From Quebec to British Columbia during the 1990's, vast effort (at considerable cost) was expended in discussing the methodological theory behind modeling, compiling environmental and cultural data for digital processing and solving the technical problems relating to processing of huge data sets. Over the years the theory matured, data sets were built and improved and advances in software and hardware made crunching the numbers a relatively trivial computational task. Nevertheless, even as the predictive capabilities of heritage potential models improved, the actual number of models that were used for their intended purpose remained few. In fact almost all models that were built in Canada during the 1990's saw little or no use at all.

There were many reasons for model neglect, much of it resting with the inability of government regulators to adapt them to their needs. Regulatory staff often did not have the resources to use the digital products very effectively, and found the printed model products almost impossible to compare with submitted development maps. Since there were no mechanisms in place to update the model results, obvious errors could not be corrected easily, engendering doubts about the whole modeling approach. One after another, regulators eschewed the objective evaluation approach provided by a model, and fell back to subjective evaluation of heritage potential. Private sector planners

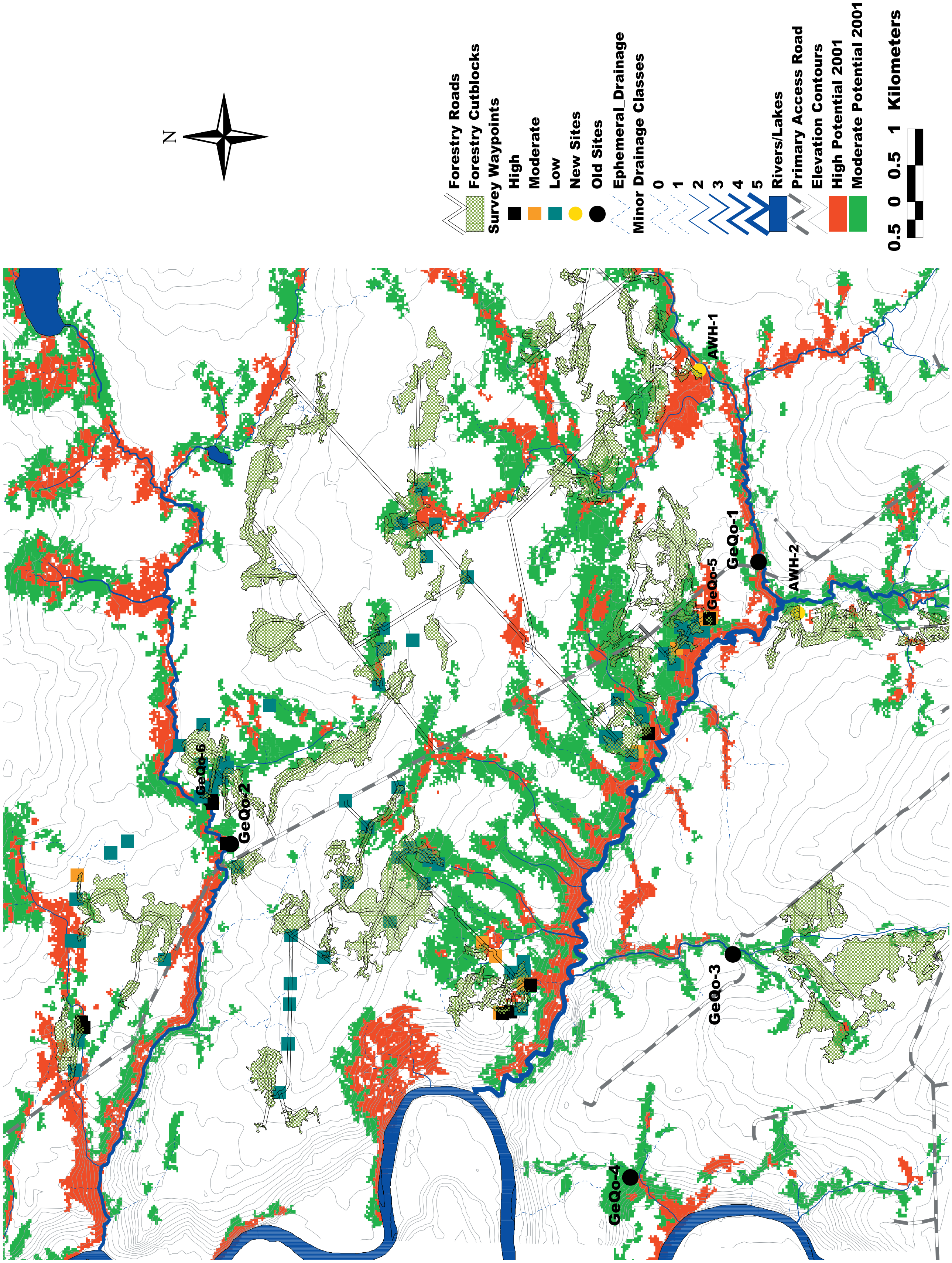

Figure 7. *Boreal forest terrain, showing a Stage 2 model overlaid by known and newly discovered archaeological sites and archaeological inspection waypoints collected during assessment of forestry developments.*

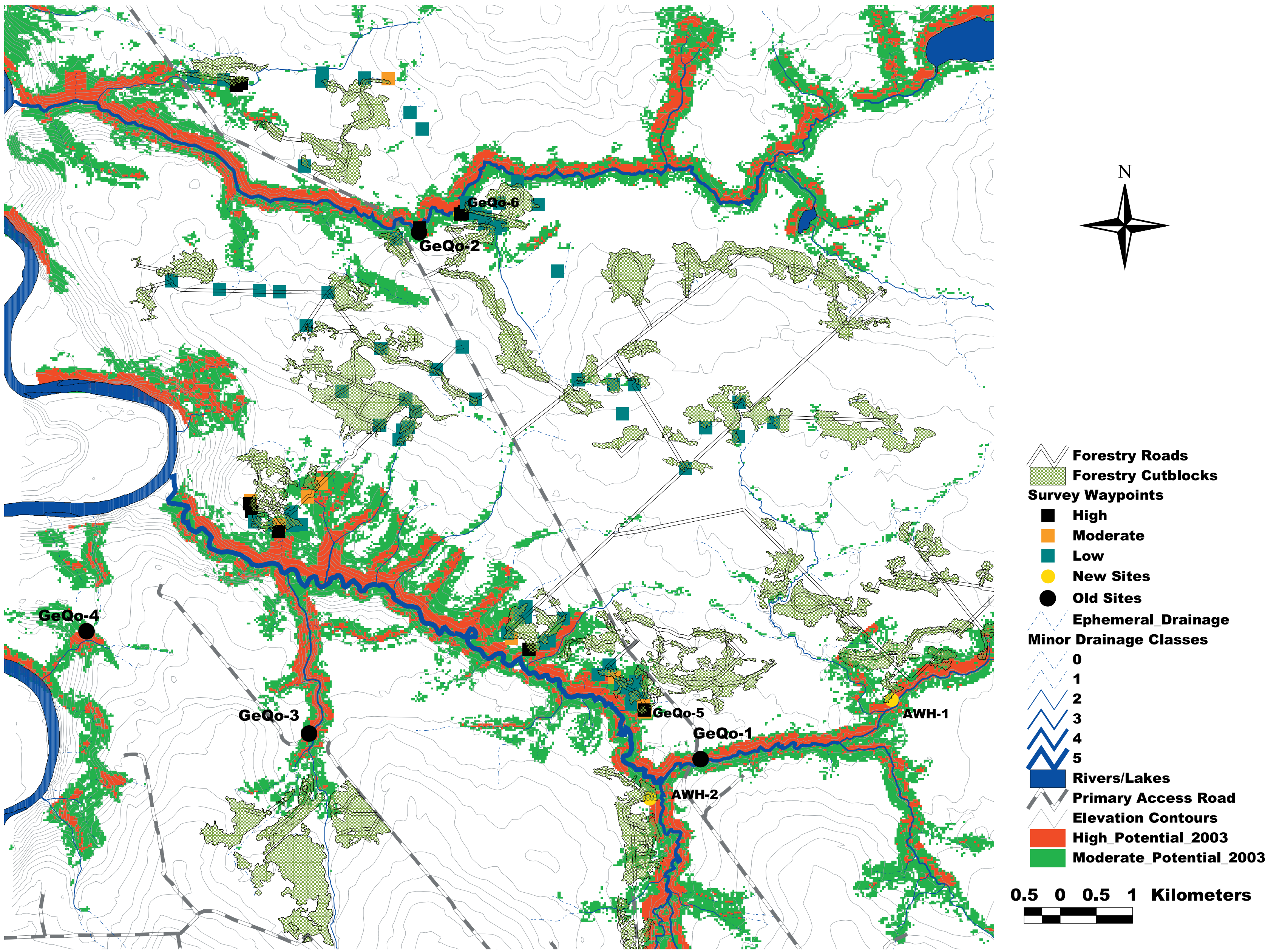

Figure 8. *The same terrain as Figure 7, showing a reprocesseed Stage 3 model, with smaller amounts of High and Moderate Potential terrain being identified as a consequence of improved statistical manipulation and implementation of rules limiting the flow of potential up lesser drainages.*

faired no better. Having no real experience in cultural resource management when attempting to use the models for their own planning purposes, they quickly realized that they had no idea what the model values meant in terms of action requirements and fell back to relying on government historical regulators for direction. Ultimately, most models were put on a shelf as it were, and abandoned.

To be sure, WHS has had its share of models misapplied, ignored or rejected outright because the target users could not or would not make proper use of the product. Through experience it was learned that the only way that modeling products could be not only used but also improved was to embed them in an enabling management approach that complemented the point of view of both the regulator and the developer. Its fundamental tenents: reduce potential site impacts by minimizing ground disturbance on objectively determined historically sensitive terrain, use legal historical compliance requirements (archaeological assessment and audit) to validate historically sensitive terrain (and selected historidally insensitive terrain), and use compliance results to improve historical sensitivity modeling.

The role of the government regulator in this approach is extremely important. In Alberta, the historical regulatory agency has maintained a vigilant yet purposefully non-interfering presence in the evolution of this process, encouraging innovation while maintaining ultimate authority in ensuring that historical resources remain protected from disturbance or destruction in all provincial lands. This has allowed land managers in the province (within the forest industry in particular) to develop and implement internal management procedures that conform to the provincial requirements for historical resources protection and yet remain compatible with their own operating procedures and corporate guidelines.

In the end, the WHS experience with over a decade of modeling has demonstrated that heritage potential models as stand-alone products stand an excellent chance of being misused or never used at all. However, if they are created as critical components within an historical management process that provides feedback for their continual improvement, then their adoption by land managers and planners is much more likely, and the value of the models as planning tools becomes beyond question.

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