Fort Nelson Archaeological Overview Assessment Revision
Phase 3: LiDAR Model Revisions and Final Report

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Management Summary

Millennia Research Limited was contracted by Forsite Consultants Limited to revise the archaeological potential model for a portion of the Fort Nelson Forest District using 2 m resolution LiDAR data. The Fort Nelson Forest District Archaeological Overview Assessment Revision consisted of three phases. Phases 1 and 2 consisted of initial model development and correction of archaeological site locations for a portion of the study area, as well as ground-truthing and some model revision.

Phase 3 included completion of site location corrections for the remaining 150 uncorrected sites in the study area, as well as final model revisions. Model revisions were made based on the Phase 2 ground-truthing results and recommendations made in that phase, as well as on the results of the comparison of corrected site locations to the model.

Only five of the 150 site locations could not be determined with sufficient accuracy. A final sample of 205 corrected, accurately mapped site locations was available for testing final model performance. Model revisions consisted of the addition of three model layers to improve the model. The final model was broken into two versions, one a binary version with only High or Low potential, and the other, for use by archaeological professionals in the field, distinguishing between High and High-Moderate potential, as recommended in Phase 2.

The final revised model performance is excellent, with both very high accuracy and precision. A total of 2.2% of the land area is modelled as high and high-moderate potential and a total of 92% of the known sites are captured, for an extraordinarily high Kv Gain of 0.98.

It is recommended that:

- The new LiDAR model immediately replace the older, TRIM-based “Millennia Model” in areas where the two models overlap
- The model be loaded onto a map-capable GPS for use in archaeological field work
- Users be aware that some anthropogenic features are shown as having modelled potential, due to their similarity to natural, high potential landforms, and that appropriate base-mapping be used with the model to determine such situations.

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Introduction

Millennia Research Limited (Millennia) was contracted by Forsite Consultants Ltd. (Forsite) to create a model of archaeological potential for a portion of the Fort Nelson Forest District based on LiDAR data (Figure 1). A model known as the "Millennia model", based primarily on TRIM and forest cover data (Eldridge and Anaya 2005), is presently being used in the District. The current project follows from a Gap Analysis of the Millennia model that recommended the use of LiDAR data to improve performance (Eldridge and Pawlowski 2007). Phase 1 of the current project consisted of creating a preliminary model using LiDAR data for several test areas within the overall study area and the comparison of this model with the currently used AOA model. Initial model results were very promising, with exceptional accuracy and precision resulting in Kvamme's Gains of 0.97. Phase 2 consisted of applying the model to the entire study area, implementing revisions recommended during Phase 1 and conducting ground-truthing fieldwork to test the model. Phase 3, the final phase of this project, involved the implementation of additional revisions to improve the performance of the model, the correction of the remaining 150 uncorrected site locations in the study area, and a review of the model performance with reference to these sites.

The following report details the results of Phase 3 of the project, including the results of the site corrections and model performance based on the full set of corrected sites, as well as describing the revisions made to the model and summarizing the final model.

The interim reports for Phase 1 and Phase 2 have been appended to this document as Appendix A and Appendix B, respectively. Please refer to these appendices for details of the Phase 1 and Phase 2 work.

The primary data source for this project was 2 m LiDAR data provided by Encana Corporation. A roads layer was provided by Canfor, and additional roads and well site data was obtained from the OGC (Oil and Gas Commission) website for GIS data (http://www.ogc.gov.bc.ca/gis.asp). This data, along with provincial government WMS (Web Map Services) base mapping, was used to help check the mapped location of previously recorded archaeological sites.

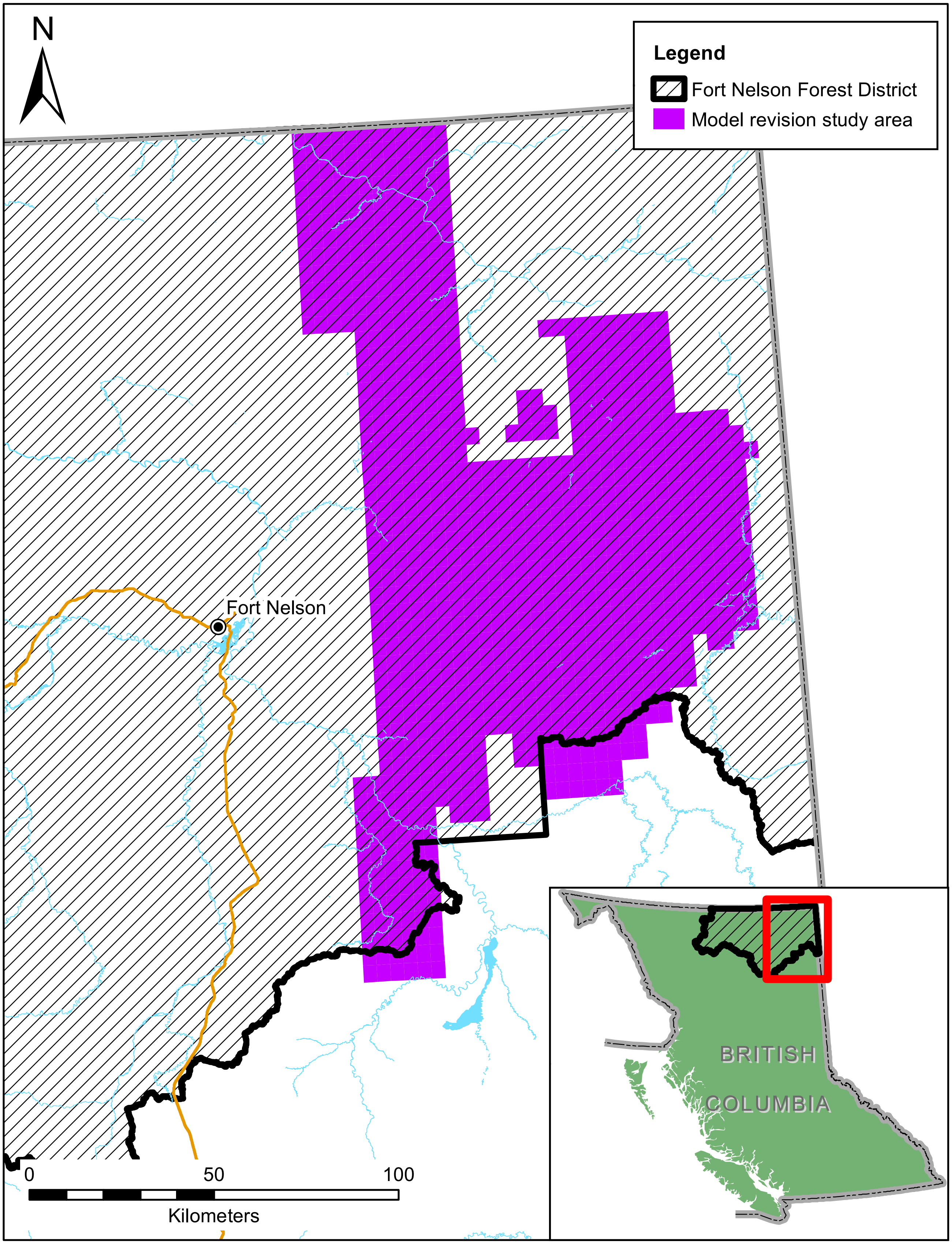

Figure 1. Study Area - Fort Nelson Forest District.

Study Area

The study area is comprised of the eastern portion of the Fort Nelson Forest District, for which LiDAR data has become available. This area is bordered to the north by the District of Mackenzie, Northwest Territories, to the east by Alberta and to the south by a portion of the Peace River Forest District. The area is comprised of a single biogeoclimactic zone, Boreal White and Black Spruce (BWBS) and five ecosections (Ministry of Sustainable Resource Management 2003). The ecosections are (north to south) the Trout Lake Plain, the Petitot Plain, the Etsho Plateau, the Fort Nelson Lowlands and the Sikanni Chief Uplands. The field reconnaissance was within the Fort Nelson Lowlands, the Etsho Plateau and the Petitot Plain. Forest cover in the BWBS zone is typically comprised of large tracts of black spruce, diamond willow, and paper birch in the low lying and wet areas. Where drainage is better, poplar, aspen, white spruce and lodgepole pine are all present.

For a discussion of archaeological site types and the typical landforms they are found in association with, please see the Archaeological Overview of Northeastern British Columbia: Year Two Report (Eldridge, et al. 2002), which provides detailed descriptions of a variety of sites and the landforms with which they are associated. Further discussion can be found in the years 4 and 5 report (Eldridge and Anaya 2005). Essentially, sites are found most often on landforms described by Keary Walde (Walde 1997; Walde n.d.): knolls, small ridges, rises, slope breaks, terraces and linear summit terrain.

Potential Activities within the Study Area

The study area is currently one of the most rapidly expanding areas for oil and gas exploration in Canada; the expected activities include forestry and forest management, seismic exploration, oil and gas extraction, pipeline and road construction. All these activities have the potential to impact archaeological sites that are located within development areas. The development of this model will assist archaeological consultants and industry alike in supporting the intention of the *Heritage Conservation Act*, as it will enable more accurate estimations of both archaeological potential and the likely costs of assessing developments.

Methods

Site Corrections

A large portion of the Phase 3 work was to check the locations, as mapped in the provincial registry, of recorded archaeological sites within the study area. An up-to-date shapefile of the 213 archaeological sites currently recorded in the study area was downloaded from the BC Archaeology Branch's RAAD (Remote Access to Archaeological Data) web application. This dataset included some 45 sites that had been recorded since the Phase 2 work. Overall, there were 150 sites that needed to be checked.

The same methodology used for the site corrections in Phases 1 and 2 was applied. Site maps and site recording form data were obtained through the RAAD and HRIA (Heritage Resource Inventory Application) utilities. The 2 m LiDAR was used to generate hillshades, contours at 50 cm or 20 cm intervals, and slopes. In addition to the LiDAR, base mapping used to identify site locations consisted of OGC mapping of wellsites, pipelines, rights-of-way and roads, as well as WMS TRIM (Terrain Resources Inventory Management) 1:20,000 base mapping (which includes rivers/streams, lakes, wetlands, seismic lines, and roads) and orthophotos. The steps for determining the correct location of site begin with using the overview maps included with the site recording forms (when available) to check that the general location of the site is correct. Where mid-range maps are available, these are used next to more accurately determine the location of the site. Finally, the detailed site maps, which typically show the landform the site is located on with vegetation changes, slope breaks and steepness of slopes indicated, are matched to the contours, hillshade, and sometimes slopes, in the general location identified from the previous smaller scale maps. Often these match very well, and the site location can be determined with high confidence (Figure 2, Figure 3). In this example, the site as located in the provincial inventory only needed to be moved only 20-30 metres to obtain a perfect match of site map and LiDAR and other map features. In other cases, the available maps are not as detailed, or the mapping is suspect, and the sites can't be located with as high a level of confidence. The sites are then located in the best matching spot that fits the site maps and site form descriptions. Where the mapping and description are insufficient to locate the site with any confidence, the mapped site location is not changed, and the site is marked for exclusion from model performance tests.

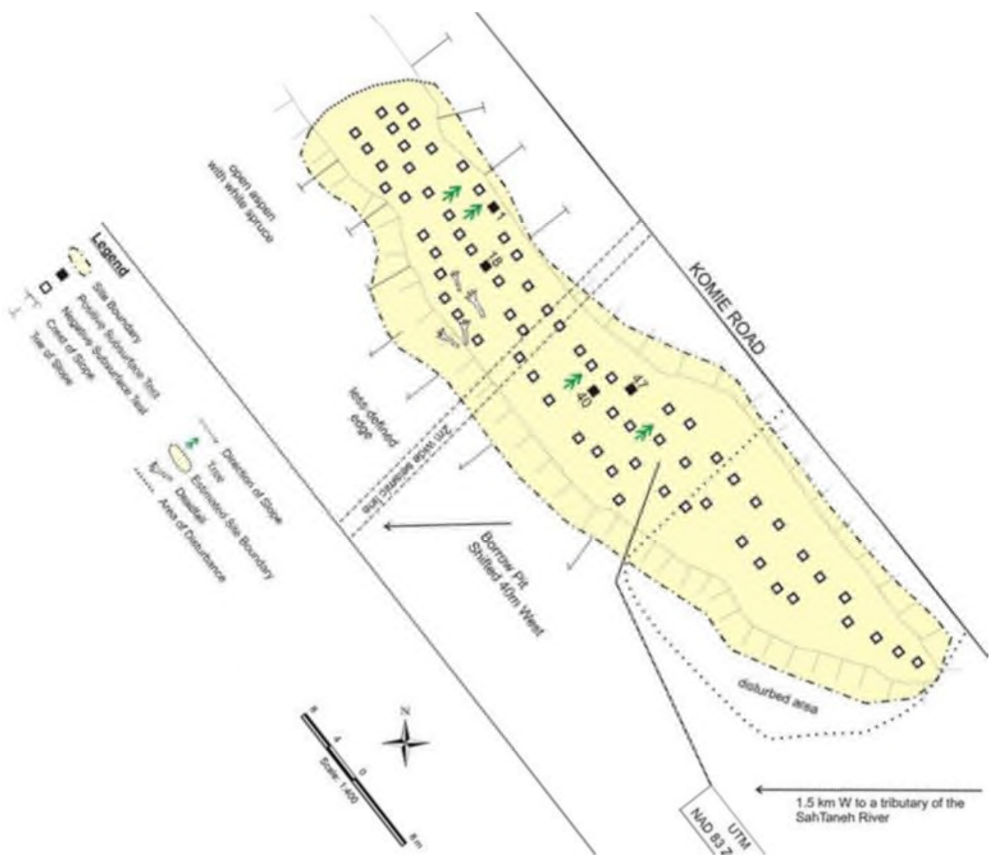

Figure 2. Detailed site map for IfRj-8 (map has been rotated to align North to top of page.). Note the detailed landform sketched on the map, as well as other locational indicators such as the road and seismic lines.

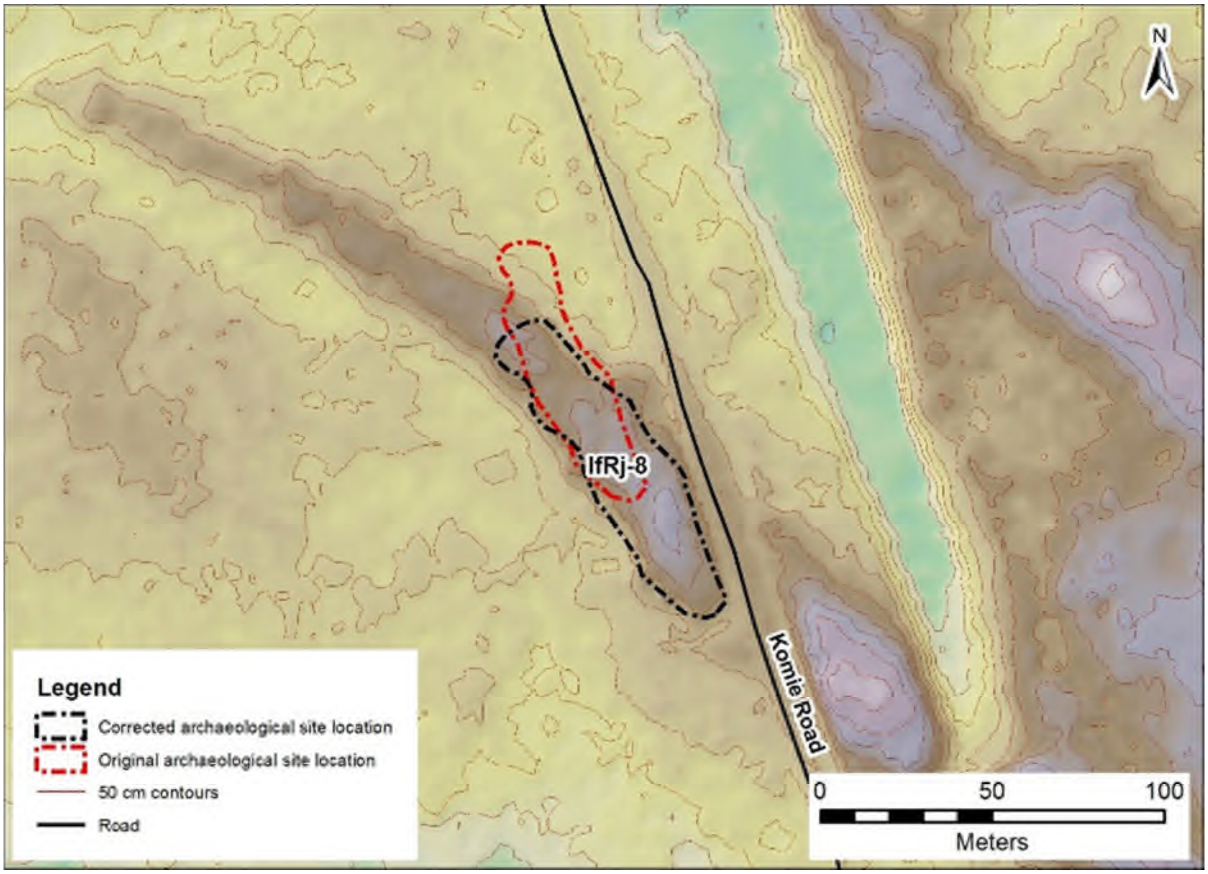

Figure 3. Original vs corrected location of IfRj-8. Note the excellent match between the landform visible in the LiDAR DEM/hillshade basemapping and 50 cm contours, and the landform shown in the site map.

In some cases the detailed site maps are loaded into the GIS, scaled and rotated to find the best match between the mapped landform and the landforms visible in the LiDAR data. However, this wasn't done for every site in the Phase 3 work, as it was in Phase 1, because many of the recently recorded site locations are clearly enough determined from simply visual comparison to the mapping data. Additional details of the methodology of site correction as well as additional examples are included in the Phase 1 Interim Report (Appendix A).

Model Revision

One of the Phase 2 recommendations, based on the results of the ground-truthing work, was to create two versions of the model – one version as a binary model of high/low potential, and the other version a three class model. In addition to low potential, these classes would represent high potential, readily identifiable features, and also moderate potential, marginal landforms that may be desirable to test in certain circumstances. The intent of this version of the model is to be used by archaeologists in the field. Acting on this recommendation, additional algorithms were developed to identify these marginal features. One of these algorithms consisted of the revision performed in Phase 2, following on Phase 1 recommendations (see Appendix B). The other was developed during Phase 3, to increase capture of these marginal landforms on which sites are occasionally situated. In addition to capturing marginal features, two other algorithms were developed in Phase 3 model revisions to add to the capture of larger landforms on which sites are frequently located. One of these was targeting terrace edges and river banks; the other targeted less well-defined portions of ridges and knolls. The final model, therefore, was made up of the layers summarized in Table 1 (please refer to Appendix A: Phase 1 Interim Report, for a description of the variables used).

Table 1. Final model algorithms.

Model*	Layer	Captured features	Algorithm
High	1	Well-defined ridges, knolls, terrace edges	Positive > 40 & Count > 50 & Slope (degrees) < 5 & Range (9 by 9) > 1.5
High	2	Less well-defined terrace edges (Figure 4)	Positive > 60 & Count > 40 & Slope (degrees) <= 5
High	3	Less well-defined portions of ridges and knolls (Figure 5)	Positive > 20 & Count > 40 & Slope (degrees) <= 1& Range (9 by 9) > 2
Moderate	4	Subdued knolls and ridges in overall very flat regions	Positive > 40 & Count > 50 & Slope (degrees) < 5 & Range (9 by 9) > 1.5 & Range (33 by 33) <= 3
Moderate	5	Marginal, poorly defined landforms in overall very flat regions (Figure 6)	Positive > 15 & Count > 45 7 Slope (degrees) < 2 7 Range (9 by 9) > 1 & Range (33 by 33) < 2)

* In the binary version of the model, the moderate potential and high potential are combined.

Some additional "clean-up" was done on layers 3 and 5 to reduce scattered, isolated pixels of modelled potential. For layer 3, isolated single pixels were identified and removed from the model; for layer 5, isolated groups of 2 to 3 pixels and single pixels were removed from the model.

In Phase 1 it was recommended that roads layers be used to remove potential modelled on roads, as in many areas the roads are built up or have large enough berms to be captured by the model algorithms. However, it was decided for the final model to leave out this step. The roads are not always mapped in exactly the position that appear in the LiDAR, so a buffer of the mapped roads doesn't always capture all of the false potential, and in some cases, would erroneously remove valid potential. In addition, there isn't available mapped line data for all roads. Even where it does exist and matches the LiDAR, some roads cut through genuine high potential features, for which the potential would be removed by the road buffering. Other anthropogenic features are also being captured by the model when they resemble natural features such as ridges or knolls. Borrow pits are one example of such anthropogenic features. It is advised that users of the model take these factors into consideration, and be aware that some modelled features may in fact be man-made and therefore not actually high potential for archaeological remains. Extra caution should be taken, as it is not always immediately apparent which features are natural and which are man-made, and in some portions of the forest district, there are very long, straight glacial landforms that may be mistaken for roads if the model is viewed without additional basemapping.

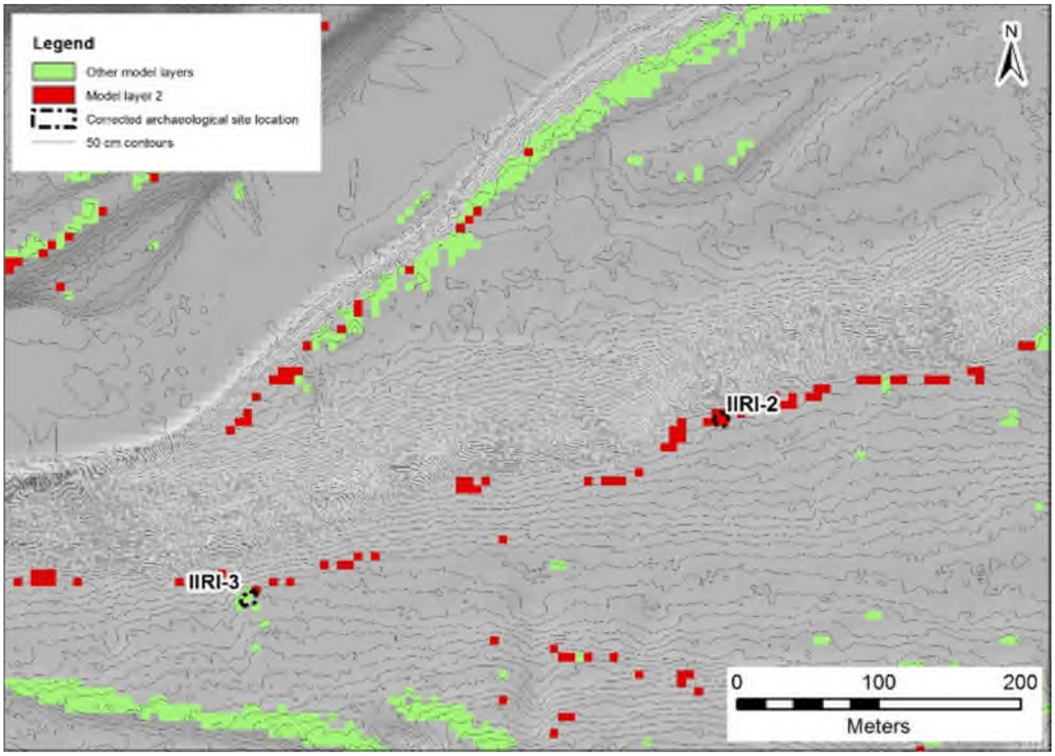

Figure 4. Model layer 2 captures additional, less well-defined terrace edges.

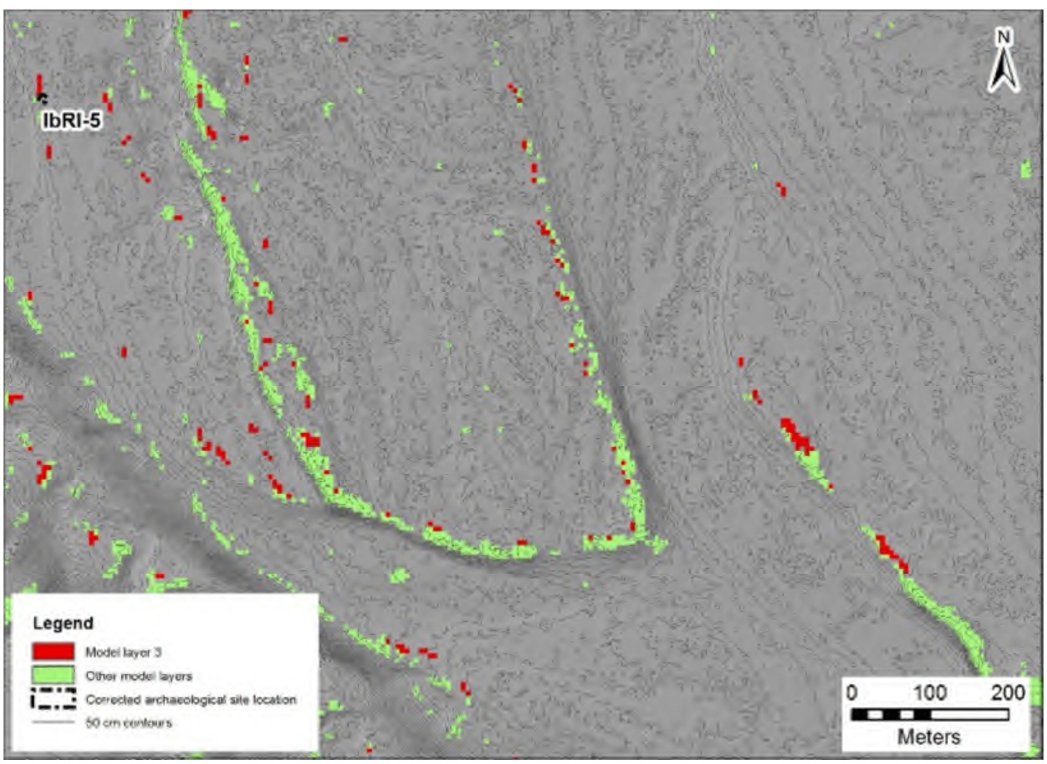

Figure 5. Model layer 3 captures less well-defined portions of ridges and knolls.

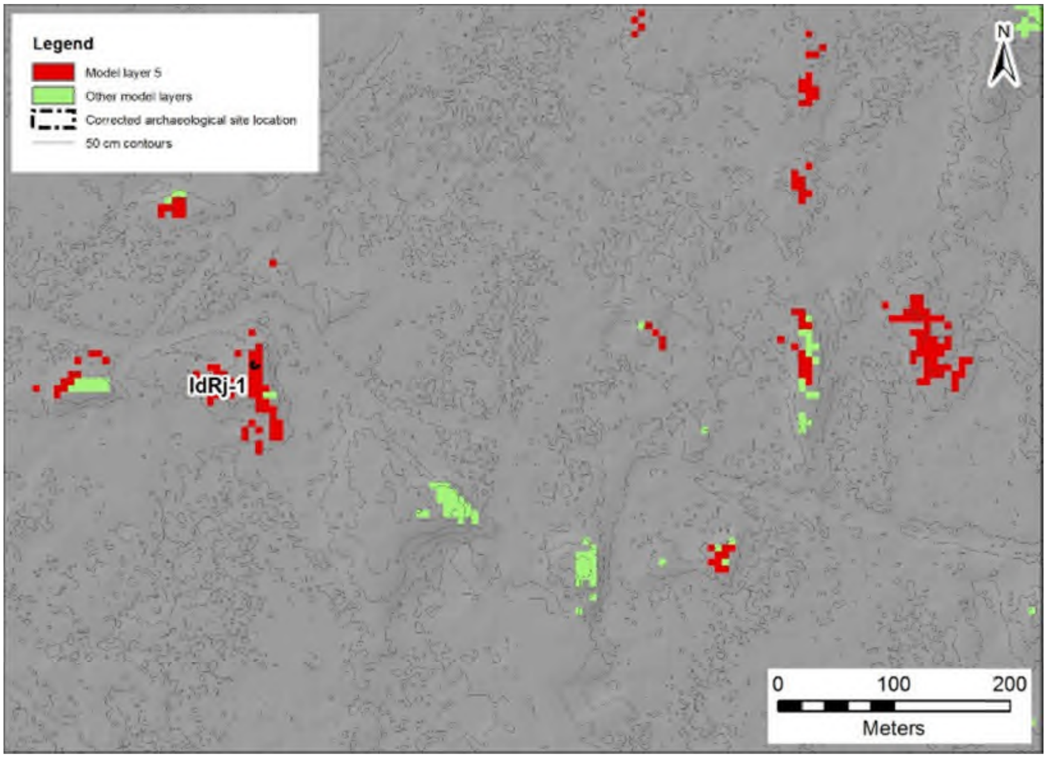

Figure 6. Model layer 5 captures marginal, poorly-defined landforms.

Trails

In an earlier phase a suggestion was made to include trails mapping as a part of the model. These trails were found to be highly predictive of archaeological site locations in the NE AOA project (Eldridge, et al. 2002). Therefore, for the current project, the trail mapping was brought into the GIS and compared to the site locations within the study area (Figure 7). Only two of the 213 sites in the study area were located within 100 m and one more was within 400 m (the buffer distances on trails used in the NE AOA "Millennia Model"). This is a total of three sites, or 1.5% of the recorded sites, that are located in proximity to trails. All of these sites are captured by the new LiDAR model, and it is unlikely that adding these trails into the model would improve performance. It should be noted as well, that there are few trails that intersect the study area. The NE AOA report noted that trails data for the area was incomplete. While there are a moderate number of trails for the overall NE AOA study area, that area was substantially larger than the current study area. It is possible that there are many more unrecorded or undigitized trails within the study area. The present data suggest that adding trail data would degrade model performance, by adding many 'false positive' locations compared to the excellent results achieved through LiDAR modeling alone. This conclusion should be revisited if additional data becomes available.

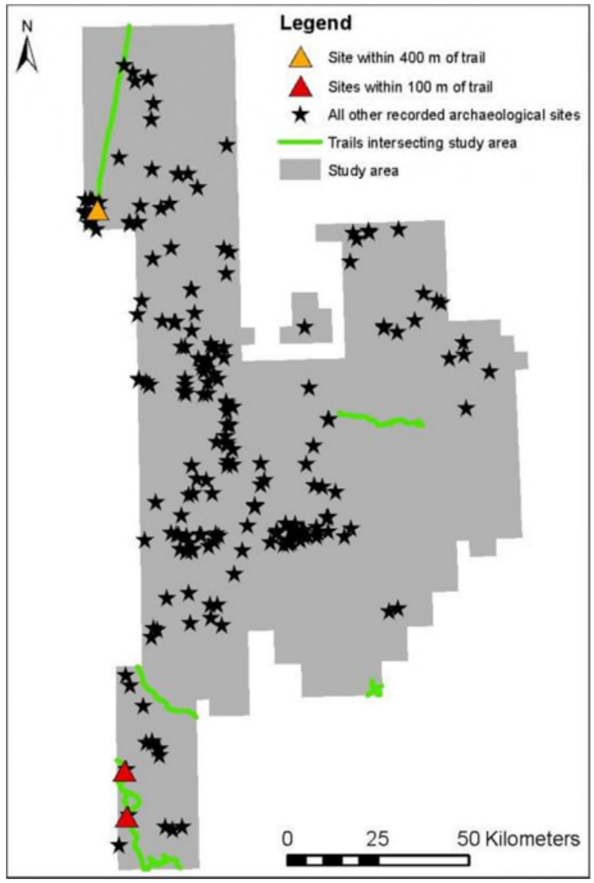

Figure 7. Locations of trails within study area, and sites in proximity to trails.

Results

Site Corrections

Site corrections were overall very successful. Of the 150 sites requiring checking, only five could not be resolved as to their accurate location. This was due to poor site information. Maps necessary to accurately locate the site were often missing, in particular the mid-range maps, which are very important to this process. In some cases, the landforms described by the maps and written description could not be identified in the LiDAR, or the descriptions provided of the site's location were inconsistent and couldn't be resolved.

In addition to these five sites that could not be corrected, three of the sites in the study area are on landforms that were destroyed due to construction activities, resulting in a total of eight sites deemed unusable for model testing. This, however, leaves the relatively large sample of 205 correctly mapped sites that can be used to test the performance of the model.

Model Performance

Model performance was analyzed by assessing accuracy through the percentage of sites captured by the model, and by assessing precision using Kvamme's Gain Statistic (Kv Gain) (Kvamme 1988). This statistic compares the percentage of sites captured to the percentage of land area captured, as described by Kv gain is a useful indicator of the precision of archaeological potential models.

$$\text{Kv Gain} = 1 - \left(\frac{\%\text{ land captured}}{\%\text{ sites captured}}\right)$$

The maximum Kv value possible is just less than 1.0. A high Kv gain is therefore indicative that the model captures a high proportion of sites while minimizing the land area modelled as high potential.

The final models produced in Phase 3 show both high accuracy and extraordinarily high precision. Of the 205 valid sites in the study area, 181 are captured in the high potential model, for a capture rate of 88%. At the same time, only 1.71 % of the total land area is captured. The Kv Gain value for this is 0.98. The moderate potential model adds another 7 sites in only an additional 0.49 % of land area, for a total of 92 % of sites captured in 2.2 % of overall land area. Because the land area increase is so small, this change doesn't significantly alter the Kv Gain, which remains at 0.98.

The improvement these results show over those from Phase 2 (Appendix B) bear out the recommendation to correct the remaining sites before reviewing model performance in Phase 3. The model far exceeds the guidelines specified by the Archaeology Branch for such models, which require a minimum of 70% of the sites with a gain of 0.8 for a moderate efficiency, and 0.9 for a high efficiency model (Archaeology Branch 2009).

Of the 17 uncaptured sites, four are within 5 m of modelled potential. Given that the cell size of the model inputs is 6 m, it is reasonable to consider these sites as also "captured", which is also appropriate based on the provincial standards. This would raise the overall capture of sites to 192 sites, which is 94% of the total sample. The remaining 13 uncaptured sites are invariably located on very small features, most of which are not apparent in even the 2 m LiDAR. It is likely that these landforms are small enough that even the 2 m resolution LiDAR, especially as it is resampled to 6 m cells to make analysis feasible, cannot accurately portray them. In at least one case, the LiDAR has a coarse, "TIN"-like (Triangulated Irregular Network) appearance, suggesting that there may have been fewer clean data points at that location in the raw, bare-earth LiDAR dataset, and therefore a loss of detail of the landform. Based on the observation of these uncaptured sites with the 2 m LiDAR and detailed contours, it is considered unlikely that the model could be revised to capture these locations, without capturing a large portion of the landscape and significantly decreasing the currently very high precision of the model.

Recommendations

Roads and other anthropogenic features are being captured by the model when they resemble natural features such as ridges or knolls. Therefore, it is advised that users of the model take this into consideration, and be aware that some modelled features may in fact be man-made and therefore not actually high potential for archaeological remains. Extra caution should be taken, as it is not always immediately apparent which features are natural and which are man-made, and in some portions of the forest district, there are very long, straight glacial landforms that may be taken for roads if the model is viewed without additional base mapping.

It is advised that the model be loaded into a GPS unit for archaeological field survey, and that siteforms for newly identified sites include notation of where the site is located with reference to the model. The model has been produced in two formats: one is the combined, binary model, in which all high and moderate potential are combined into a single class. This model should be used for making decisions on whether AIAs are appropriate. The other model is a three-class model, for use by archaeological professionals for field assessment. In this version, 'marginal' landforms are identified that may, in certain circumstances (such as the proximity of even higher potential landforms) be suitable for testing, or may require minimal testing to determine if further testing is warranted (e.g., the difference between a predominantly clay soil and predominantly sandy soil).

It is also recommended that this new LiDAR model immediately replace the Northeast AOA "Millennia Model" in areas where the two models overlap, as the new model is performing several orders of magnitude better than the older, TRIM-based model.

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Appendix A: Phase 1 Interim Report

Fort Nelson Archaeological Overview Assessment Revision Phase 1: LiDAR Test Modelling

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Introduction

Millennia Research (Millennia) was contacted by Forsite Consultants Ltd. (Forsite) to create a model of archaeological potential for a portion of the Fort Nelson Forest District based on LiDAR data (Figure 1). Phase 1 of the project was to include the creation of a model for several test areas within the overall study area, and to compare this model with the currently used AOA model (Benson, et al. 2003).

The primary data source for this project was 2 m LiDAR data provided by Encana Corporation. A roads layer was provided by Canfor, and additional roads and well site data was obtained from the OGC (Oil and Gas Commission) website for GIS data (http://www.ogc.gov.bc.ca/gis.asp). This data was used to help check the mapped location of previously recorded archaeological sites and will likely be useful in the future to clip out erroneous potential from the model, where the model captures a road or seismic.

Figure 1. Study area – Fort Nelson Forest District.

Methods

A subsample of 40 of the available LiDAR datasheets was taken and a test model created for these areas. The sampled areas were chosen so as to include as large a number of archaeological sites as possible in order to be able to test the model performance. The sampled areas were also well distributed over the entire area, to get a good representation of the different terrain types there may be within the study area (Figure 2).

The 2 m LiDAR data was provided in .xyz format, and was converted to ESRI GRID format by Forsite, who then resampled the 2 m data to a 6 m cell size to allow faster processing of the very large LiDAR dataset. This is not done by averaging, but by assigning the central value to the new cell. They then created scripts to be run to calculate two different variables:

- "Positive count" or "Count" – the COUNT of the cells which have a lower elevation relative to the central cell.
- "Positive" – the SUM of the difference in elevation relative to the central cell, for cells which have a lower elevation than the central cell.

A 9 by 9 moving window was used, so that for each cell, there are 80 neighbours. Thus, a maximum value for "Count" would be 80 (all neighbouring cells within a 9 by 9 cell window are lower elevation than the central cell).

Forsite then provided Millennia with the positive, count, and 6 m DEM layers for the test mapsheets in ESRI GRID format. The 6 m DEM was used to calculate both slope and a neighbourhood elevation range using a 9 by 9 cell window. These layers were then used to generate the model. A few different trial combinations of these variables were attempted on a single mapsheet. The one which seemed to best represent the archaeological potential was then applied to the remaining test areas. A visual inspection confirmed that the model appeared to be capturing the high potential landforms. At the same time, it was noted that man-made features such as roads and well development features were also being captured (Figure 3).

The following algorithm was used to generate the model:

Positive > 40 & Count > 50 & Slope (degrees) < 5 & Range (9 by 9) > 1.5

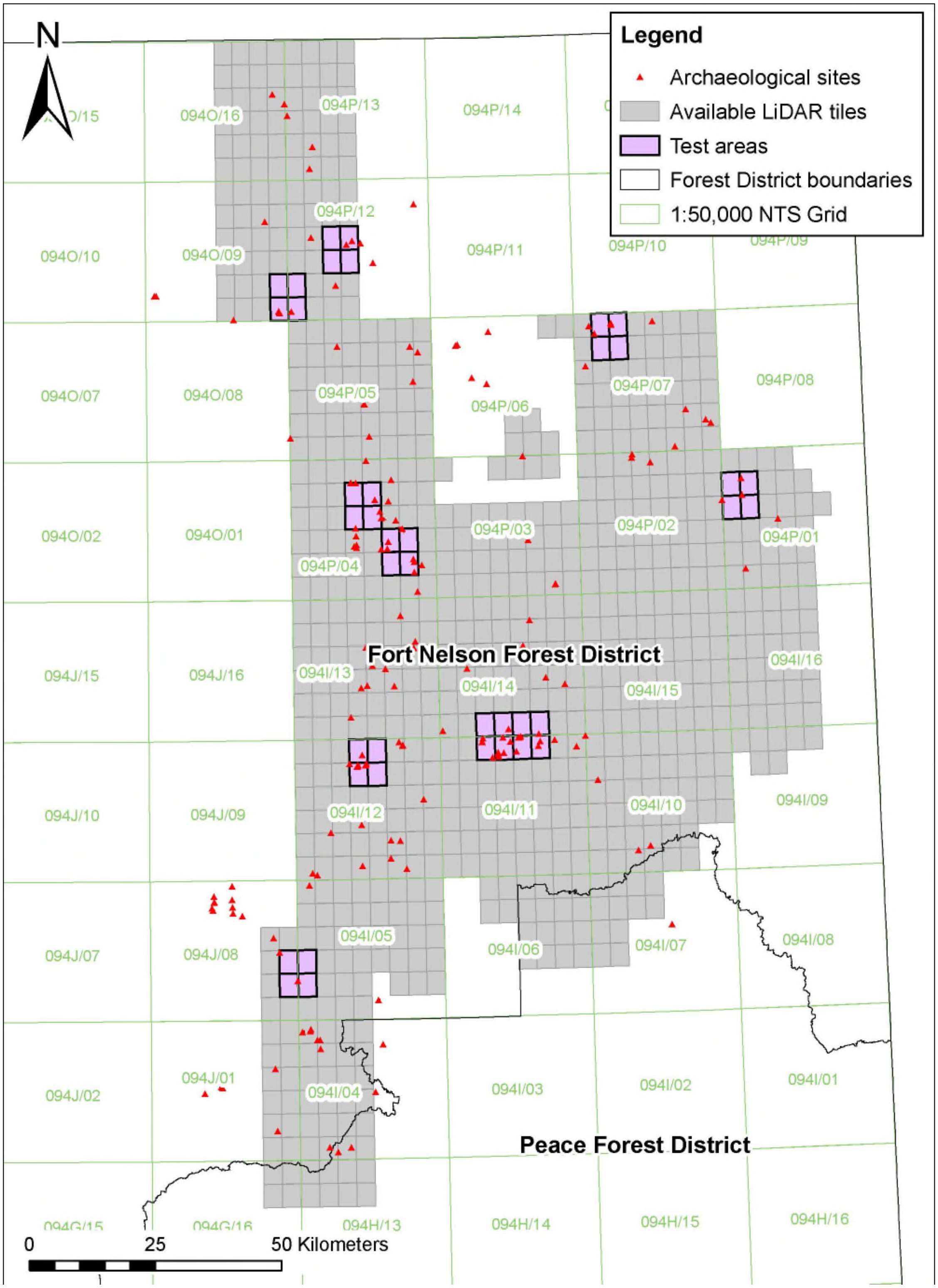


Figure 2. Location of test areas and archaeological sites in the study area and vicinity.

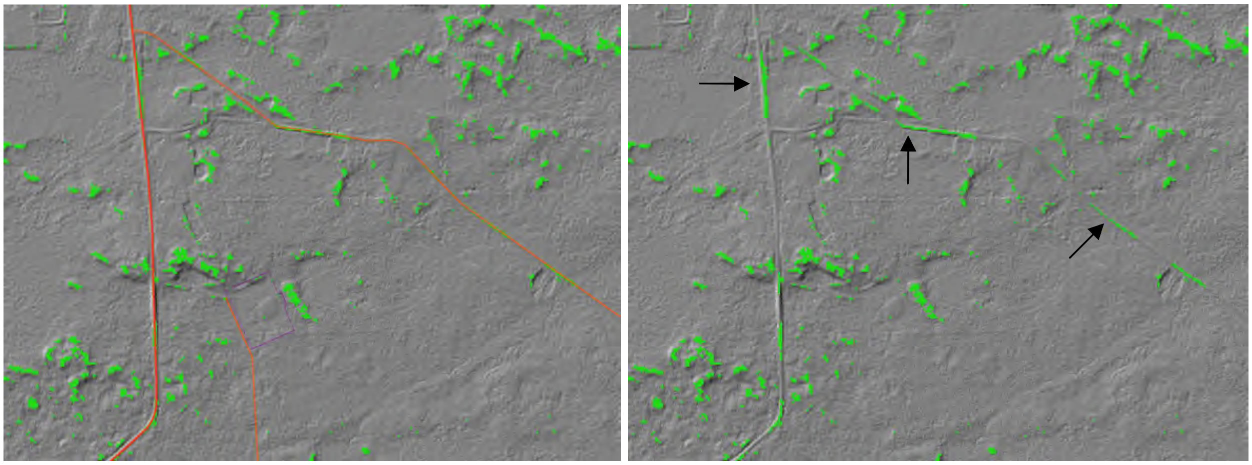


Figure 3. Example of LiDAR model capturing road embankments. Image on left is hillshade with model in green and mapped roads in red. Right image shows the same view without the mapped roads overlaid. Note where the model follows the roads (which are visible in the LiDAR); examples of this indicated by arrows.

Site location checking

This model was then tested using the locations of recorded archaeological sites, which were downloaded in shapefile format from the Provincial registry using the RAAD (Remote Access to Archaeological Data) application. However, prior to using the sites to test model performance, the mapping of site locations first had to be checked. Past projects (Benson, et al. 2003; Eldridge, et al. 2007) have found that archaeological sites, particularly those recorded more than about 3 years ago (before the widespread use of GPS units and other technological advances), may be mis-mapped by up to several hundred meters, and sometimes as much as several kilometers. Site checking is performed using several resources. Some of these resources are available GIS layers such as the OGC data (described above), the LiDAR data and its derivatives, and publicly available WMS layers including orthophotography and TRIM 1:20,000 mapping. Others are original site maps, which are submitted to the archaeology branch along with a site form. These maps often include an overview map at ~1:50,000 scale, a mid-scale map at ~1:20,000 scale, and a detailed map at about 1:500 or 1:1,000 scale. The mid-scale map is extremely useful for identifying the general site location, and usually allows us to narrow down the area in which the site is located. From there, the detailed site map can be used to identify specifically where the site is located. The detailed site map often shows a sketch of any landform on which the site is located. In recent years, the quality of these site maps has improved, primarily due to technological advances, and the inclusion of GPS coordinates on the maps or on the siteform has made it much easier to correctly map the site in a GIS. However, as will be shown below, this is not fool-proof, and sites are still mapped incorrectly. This greatly affects the test of model performance; if a site is mapped as little as 10 m incorrectly, it can make the difference between being captured by the model and not being captured. Therefore, it is necessary to correct at least a sample of sites in the area being modelled to determine what level of mapping error is occurring, in order to truly test the performance of the model.

For Phase 1, all of the 52 sites in the test model areas were checked. Site locations were checked using the best match to the landforms and features indicated on the site map, and did not reference the model itself. Comparison to the model was made after the site had been correctly positioned. Location confirmation usually starts with the mid-scale map, to identify the locale of the site. To determine the actual site location, the detailed site map is then brought into the GIS, scaled to match the scale bar shown on the site map, and then shifted to the approximate location of the site as shown on the mid-scale map. Then, the 2 m LiDAR data is used to generate slope (in percent) and 25 to 50 cm contours. These layers are compared to the site map, to attempt to find a match for the slopes shown on the site map. In some cases rotation of the site map is necessary to find the best fit. When the location is considered to be correct, the site map is rectified and the site is digitized in the new location.

Results

Overall, sites were well mapped, with most errors only visible at large scale (when zoomed in). There was commonly between 10 to 20 m of error; however, given that LiDAR data was not available when the site was originally input into the GIS, and also normal GPS error, this is not unexpected. In many cases the site was at least partially on the landform, and needed to be shifted only to the center of the landform. However, in a few cases, site mapping had large errors.

One such site, IeRg-3, is a case where GPS coordinates were provided, labelled as being NAD83 (North American Datum 1983) UTM coordinates. However, while the mapped location matched the NAD83 coordinates, the mid-scale site map showed the site in quite a different location. This map clearly showed the site as being located south of the pipeline (Figure 4) but the mapped location (as downloaded from RAAD) showed the site as being located north of the pipeline. A good match between the detailed site map and the LiDAR data was found in the area where the mid-scale site map placed the site.

Figure 5 and
Figure 6 show the site map overlaid with slope and with 50 cm contours. Once the site map was positioned in this location, the UTM coordinates were checked. Noticing the ~200 m distance between the location where we had just mapped the site, and the original site location (Figure 7), we were initially keyed to the possibility of a NAD shift error. In this area of BC, if NAD 27 coordinates are plotted in a NAD83 environment (without an appropriate geographic transformation applied), they will be ~200 m off, north-south. To test this possibility, the map coordinate system being used in our GIS was set to NAD 27, with no transformation set. When this was done, the location where we had placed the site by matching the site map to slope and contours, matched the UTM coordinates shown on the site map by less than 2 m differences. This means that the site was actually recorded using NAD 27 coordinates, though it was reported on the site map that they were NAD 83 coordinates. Thus, the site was mismapped by ~200 m. As can be seen in Figure 8, this shift moves the site from an uncaptured location to a captured location.

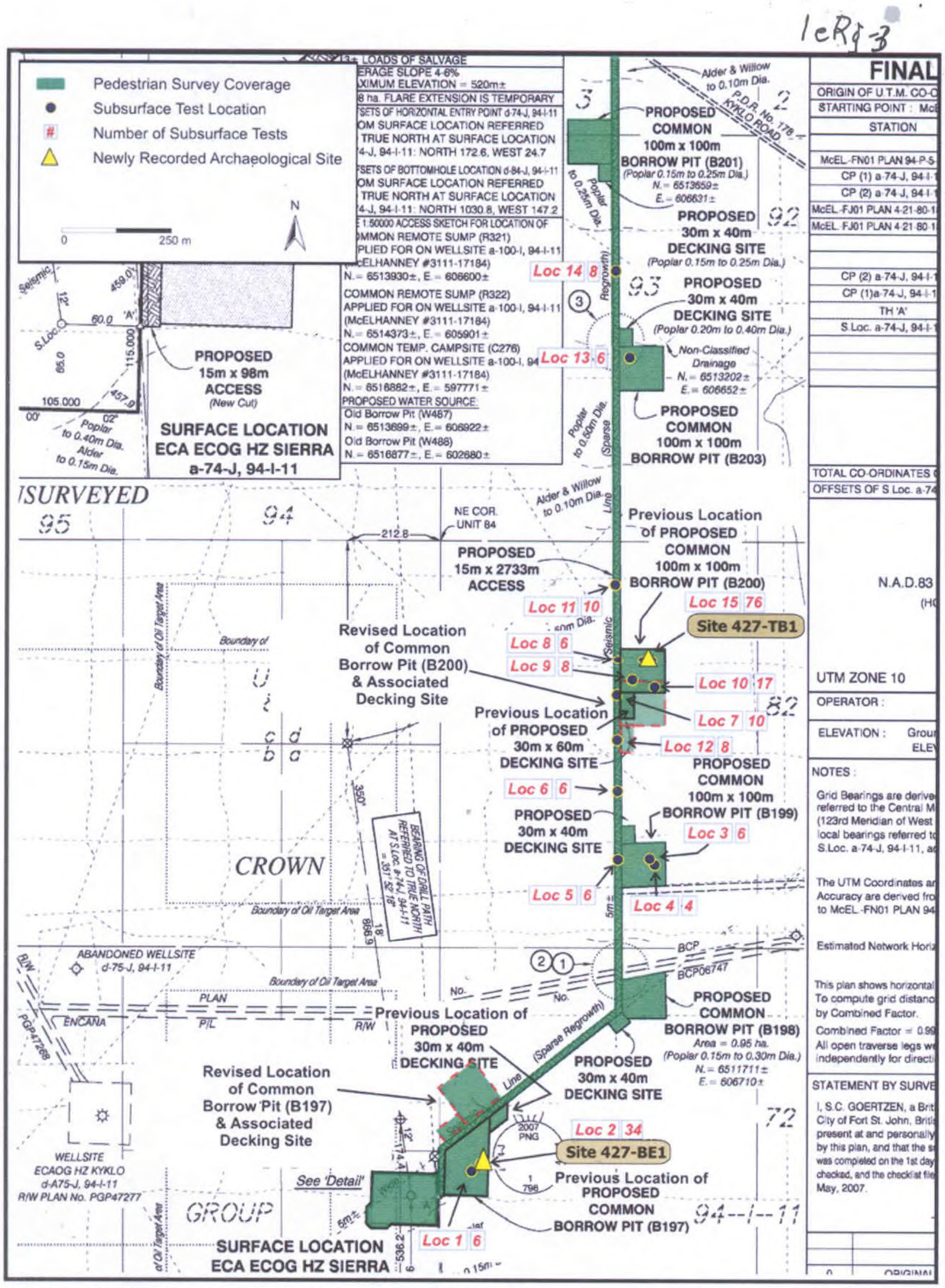


Figure 2. ECA ECOG HZ Sierra a-74-J / 94-I-11: pedestrian survey coverage, subsurface test locations and locations of newly identified archaeological sites **427-BE1** and **427-TB1** (1:12,500; from McElhanney Geomatics, May 15, 2007).

British Columbia Archaeological Site Inventory Form – 2(

Figure 4. Mid-scale site map for IeRg-3. Yellow triangle labelled "Site 427-BE1" is location of IeRg-3.

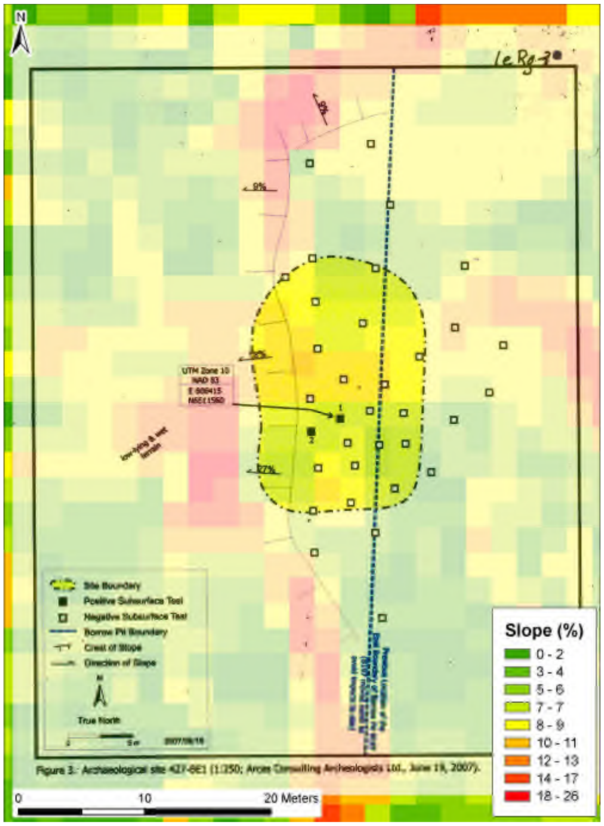


Figure 5. IeRg-3 detailed site map scaled and overlaid in GIS with slope, corrected location.

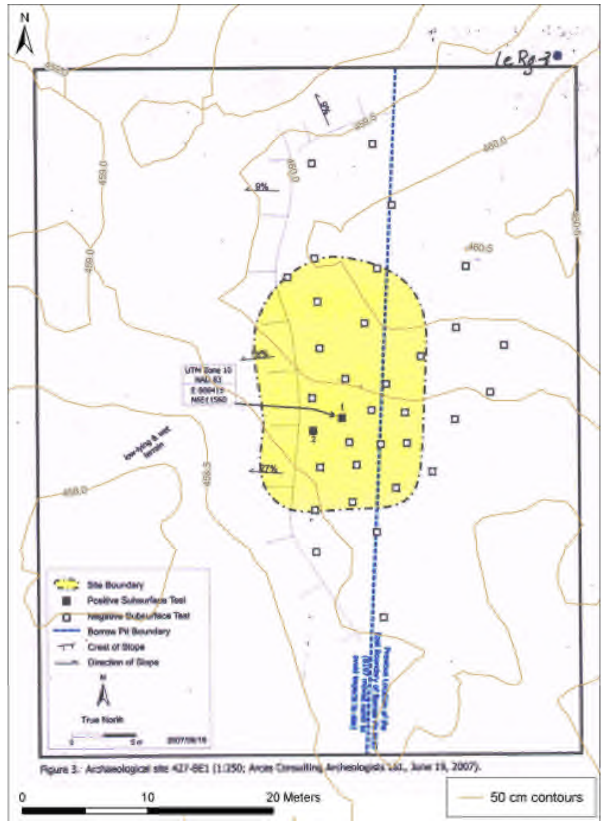


Figure 6. IeRg-3 site map shown with 50 cm contours, corrected location.

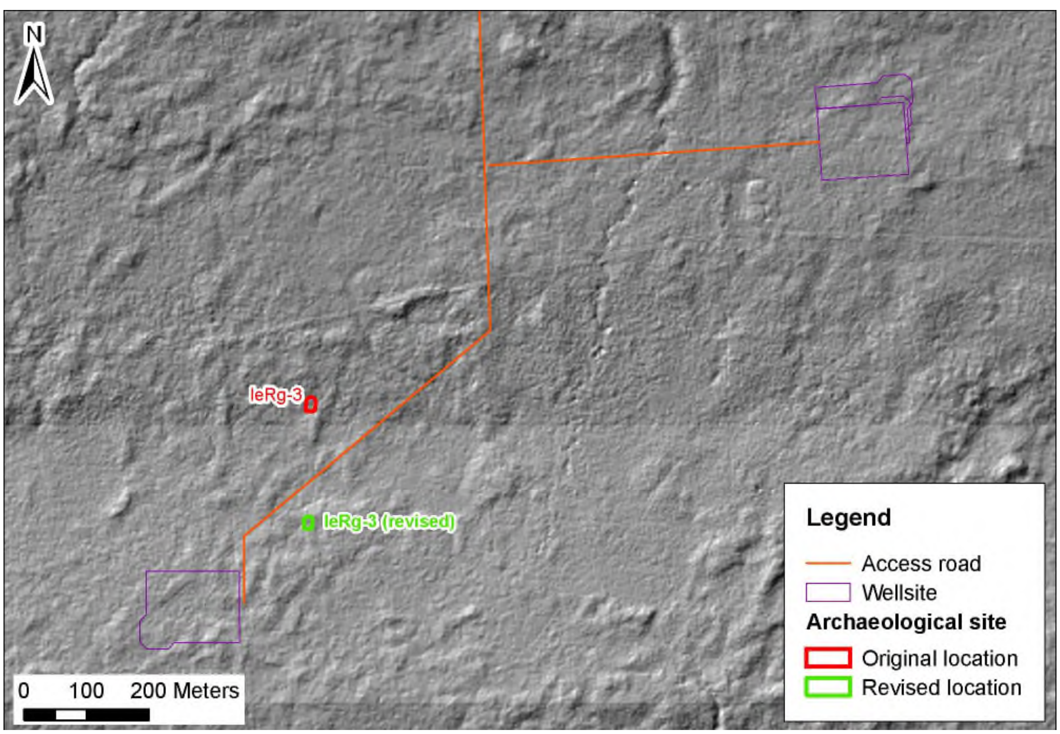


Figure 7. Original and corrected locations of IeRg-3, with 2 m hillshade and well site development.

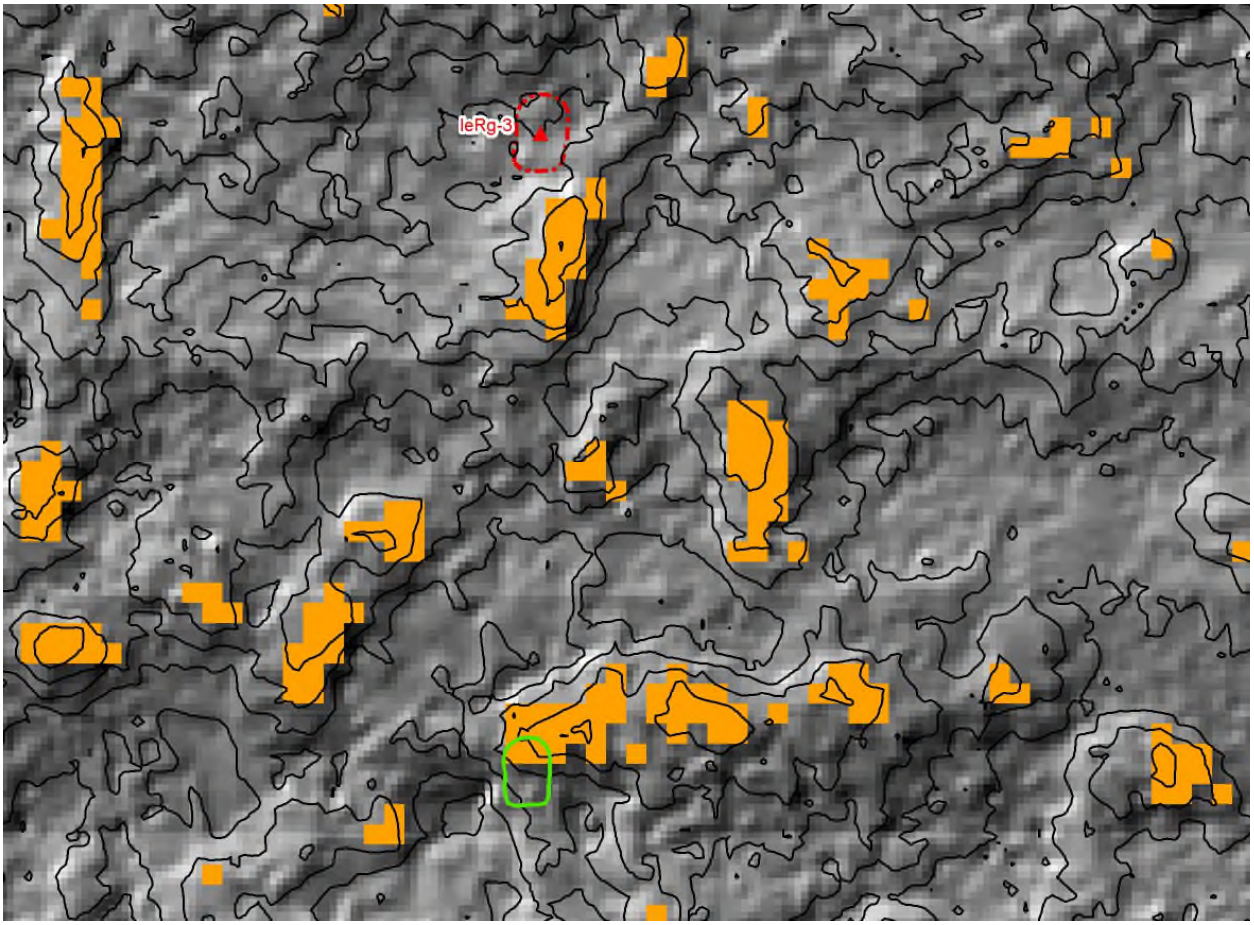


Figure 8. IeRg-3 original and corrected locations, with hillshade, contours, and model (in orange).

Another incidence of large error is in the case of site IjRk-5. In this case, the site was mapped 1170 m to the northeast of where it actually should have been mapped. As the GPS coordinates on the site map and mid-scale map both pointed to the correct location, it is unclear how this site came to be mapped so much in error. It is possible that different coordinates were included on the original site form in error, and these were used to place the site. These two sites, however, are the most extreme cases; usually errors in mapping were much less. IjRl-2 is an example of this. Here the site was mapped 18 m too far to the northwest, which placed the site on the slope, rather than on the top of the landform as the site map indicates it should be correctly located (Figure 9).

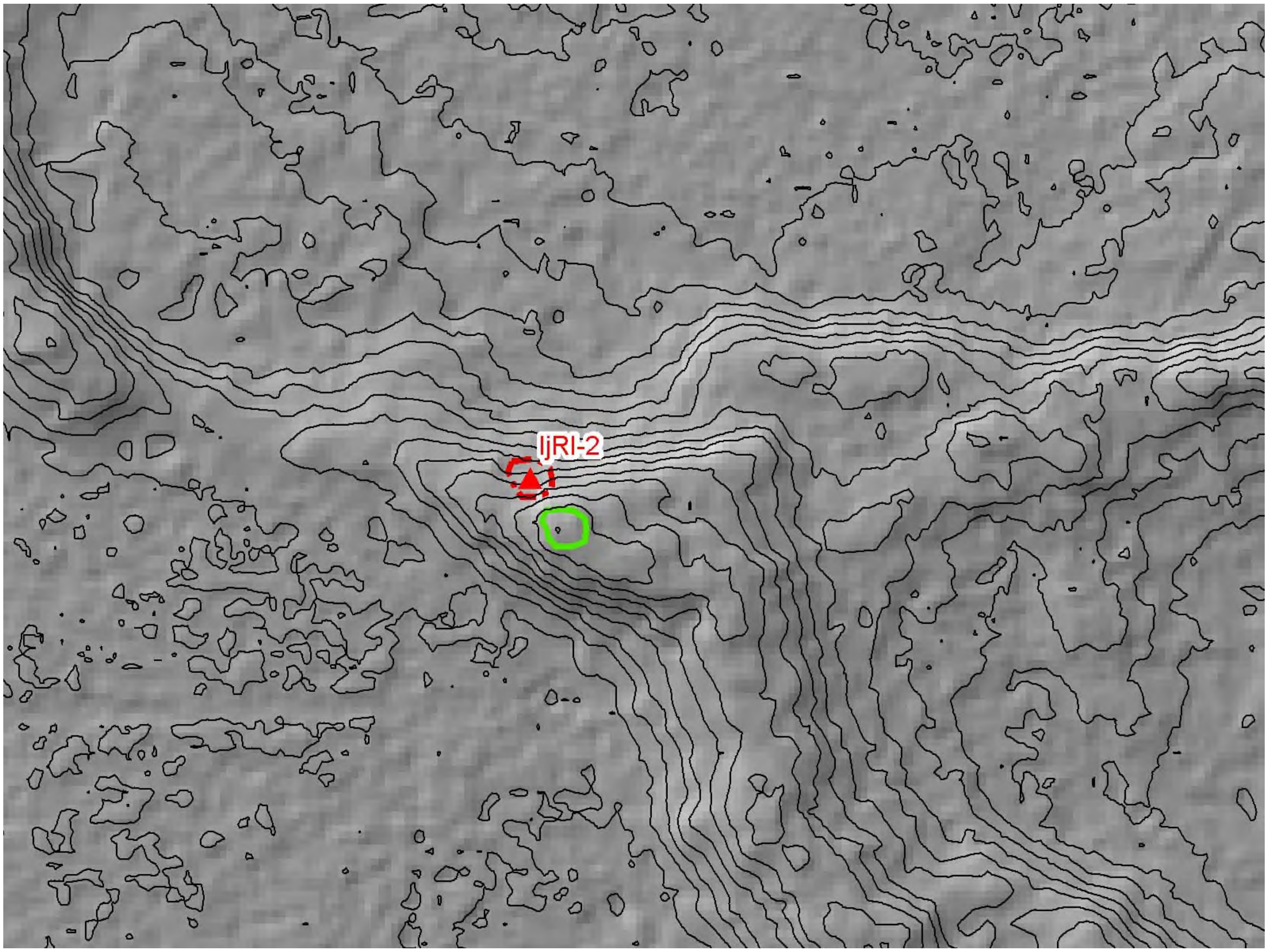


Figure 9. IjRl-2 original (red) and revised (green) locations. The shift from the side slope to the top of the landform was only 18 m (center to center).

Only one site could not be accurately located, due to the lack of a detailed site map. The site was mapped on a seismic cut (which was visible in the hillshade) and in general matched the mid-scale site map. However, the exact location could not be confirmed. Some of the site placements were somewhat uncertain – they were placed in the best-match location, but the match between the site map landform and the LiDAR landform was not very good; the landform indicated in the site map was not clear on the LiDAR. While, for the most part, correcting the site location resulted in moving it from an uncaptured location to a captured location, in a few cases the corrected site location actually moved the site off of a modelled landform, to a location where no potential was indicated in the model. Site IiRf-3 is an example of this (Figure 10). In this case, the GPS coordinates as well as the seismic line in the site map, were used to position the site. It would be beneficial to investigate the cases during ground-truthing, in order to confirm the site location and the ground potential.

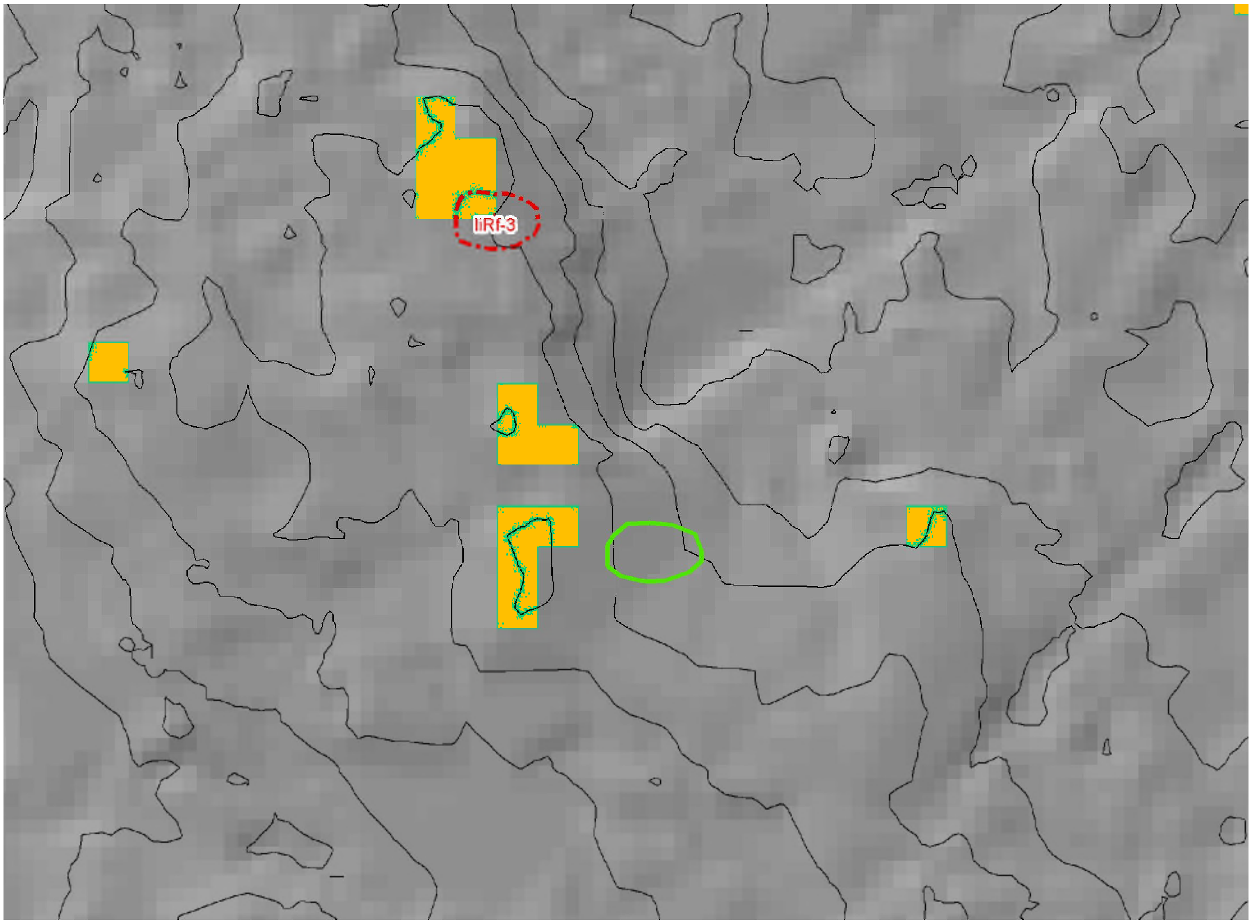


Figure 10. Site IiRf-3 original (red) and revised (green) locations, with model (orange). In this case, the site moved from a captured to a non-captured location.

In a couple of the cases where sites were not captured, the site was located on a seismic line, pipeline right-of-way, or access road, and in these cases it is possible that the disturbance to the landform prevented its capture by the model.

Out of the 52 sites, a total of 42 (81%) were captured by the LiDAR model. The model, in its current state, captures a total of 2.3 % of the modelled land area. By comparison, the NE AOA model captures 12 % of the same area and 16 out of the 52 sites (31%). Model performance was analyzed by comparing the percentage of sites captured to the percentage of land area captured, as described by Kvamme's Gain Statistic (Kv Gain) (Kvamme 1988) (Table 1). Kv gain is a useful indicator of the performance of archaeological potential models.

$$\text{Kv Gain} = 1 - \left(\frac{\%\ \text{land captured}}{\%\ \text{sites captured}}\right)$$

The maximum Kv value possible is 1.0 which would indicate all sites captured in land limited only to the area of the sites themselves. A high Kv gain is therefore indicative that the model captures a majority of sites, while minimizing the land area modelled as high potential.

Table 1. Comparison of model performance using Kvamme's Gain Statistic.

Model	% sites captured	% land captured	Kv gain
NE AOA	31	12	0.61
LiDAR	81	2.3	0.97

From these numbers, it is clear that the LiDAR model is more precisely and accurately identifying the locations where archaeological sites are currently recorded and where they might be expected to be, whereas the NE AOA model fails to predict more than ⅔ of the recorded archaeological sites, while modelling a relatively large area of land. The LiDAR model captures nearly three times the number of sites in one-sixth the land area. In Figure 11 below, the differences between the two models can be seen. The NE AOA model (in orange) captures larger areas, but misses many of the landforms. Of the 4 sites shown in this figure, all are captured by the LiDAR model, and 2 are captured by the NE AOA model.

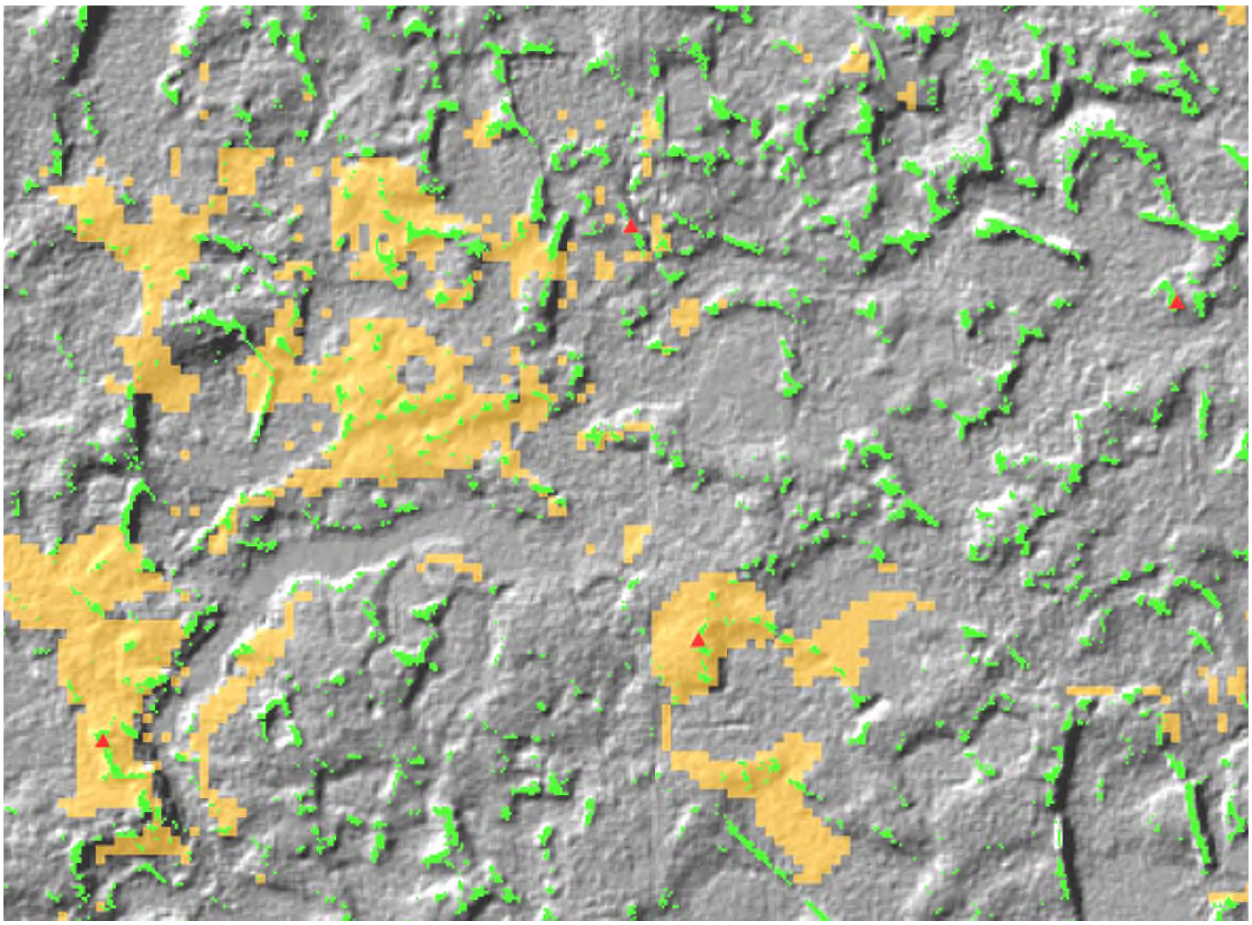


Figure 11. Comparison of NE AOA model (orange) and LiDAR model (green) with hillshade, and archaeological sites (red triangles).

Discussion and Recommendations

In order to remove erroneous potential, a roads layer provided by Canfor and well site data obtained from the OGC may be used to create a clip layer to clip out areas of the model which were capturing man-made features. This will have to be done carefully, as there are many landforms with genuine archaeological potential located adjacent to roads, seismic cuts, and well site development features. A simple buffer would be the easiest way to clip out erroneous potential, but this may also clip out genuine areas of potential.

There are several revisions which can be made to address currently uncaptured sites and other uncaptured areas with archaeological potential. At least 3, and possibly more, of the sites which are currently not being captured by the model, are located on very subdued landforms in very flat areas with little variation of terrain. In these areas, the elevation range part of the model could be lowered in order to capture small features which may be, in this terrain, the only raised landforms. This however, should only be applied in areas where the overall landscape is very flat, and where these very small landforms are in fact relatively significant features. In other areas with overall greater topographic variation and larger landforms, the model is currently capturing perhaps a bit too much, and lowering the elevation range would only increase the land capture without improving performance. Areas with relatively low overall elevation variation (very flat areas) could be selected by means of a neighbourhood range of elevation, applied over a fairly large area. The revisions could then be applied to this area only. Figure 12, Figure 13, and Figure 14 show an example of a location where two sites are missed in the current model, but could be captured with model revisions.

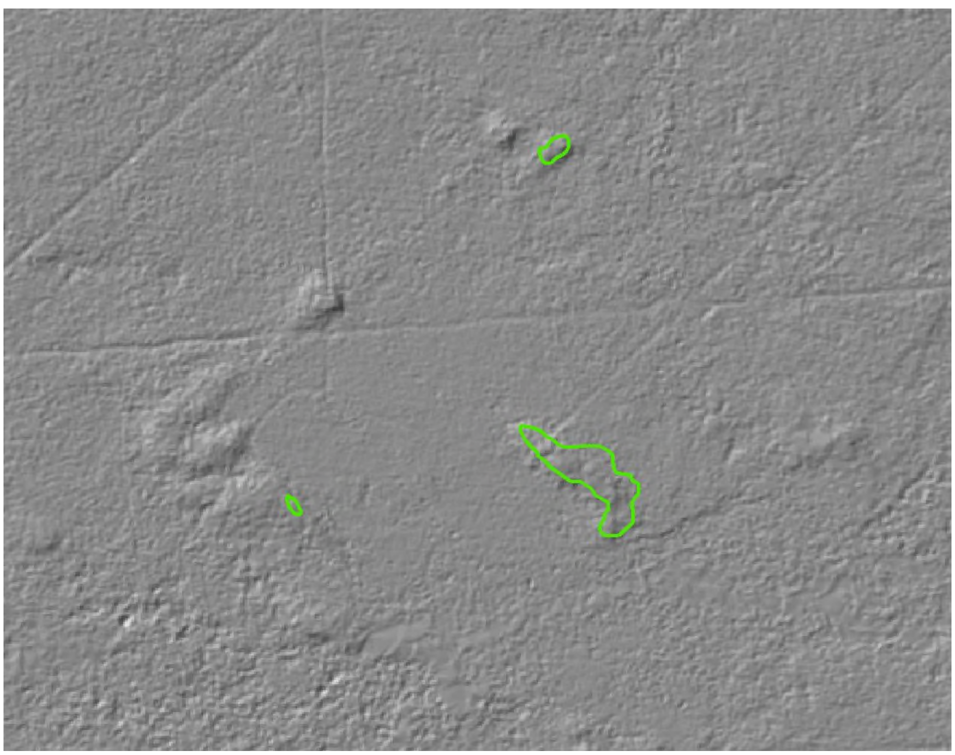
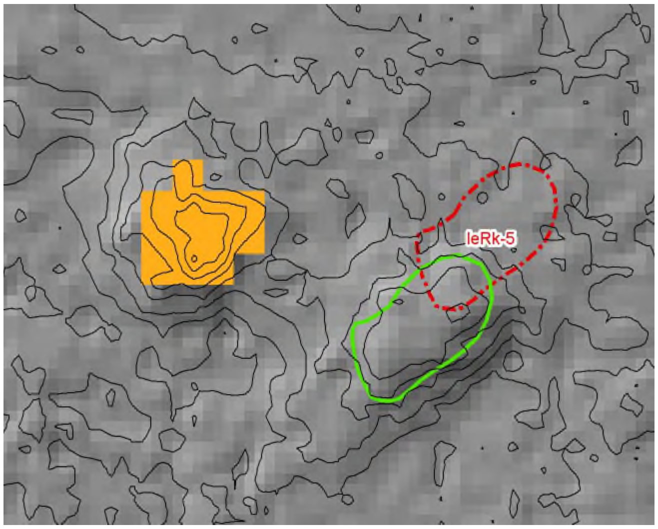
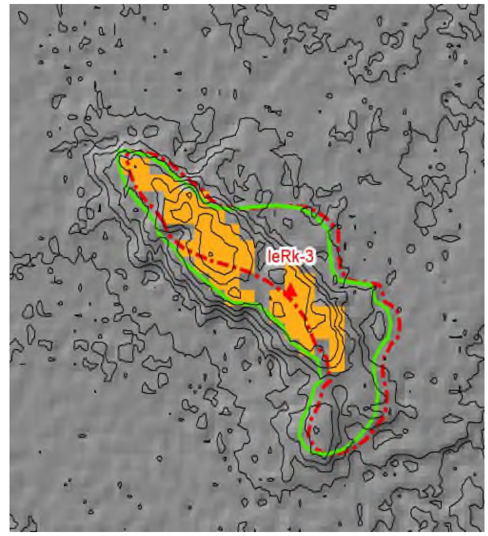


Figure 12. IeRk-3, 4, and 5 shown on hillshade. Note area overall is very flat, and landforms are not large.





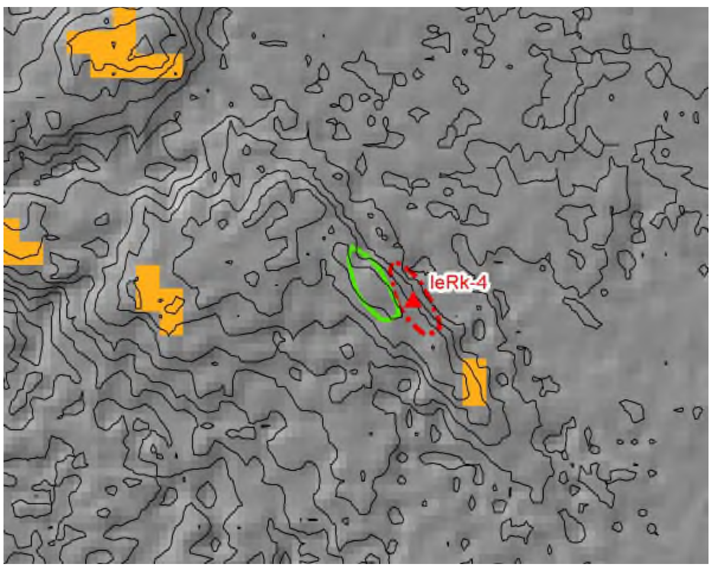


Figure 13. Close-up views of sites IeRk-3, 4, and 5, showing original (red) and revised (green) locations with 25 cm contours, and the model (orange).

Note that IeRk-5 is located on a landform that is quite apparent, though not captured by the model. Likewise, the south end of IeRk-3 is not captured. IeRk-4 is on a less-defined feature, but still an apparent landform. The model could be revised to capture these features but limited to only very low-relief landscapes.

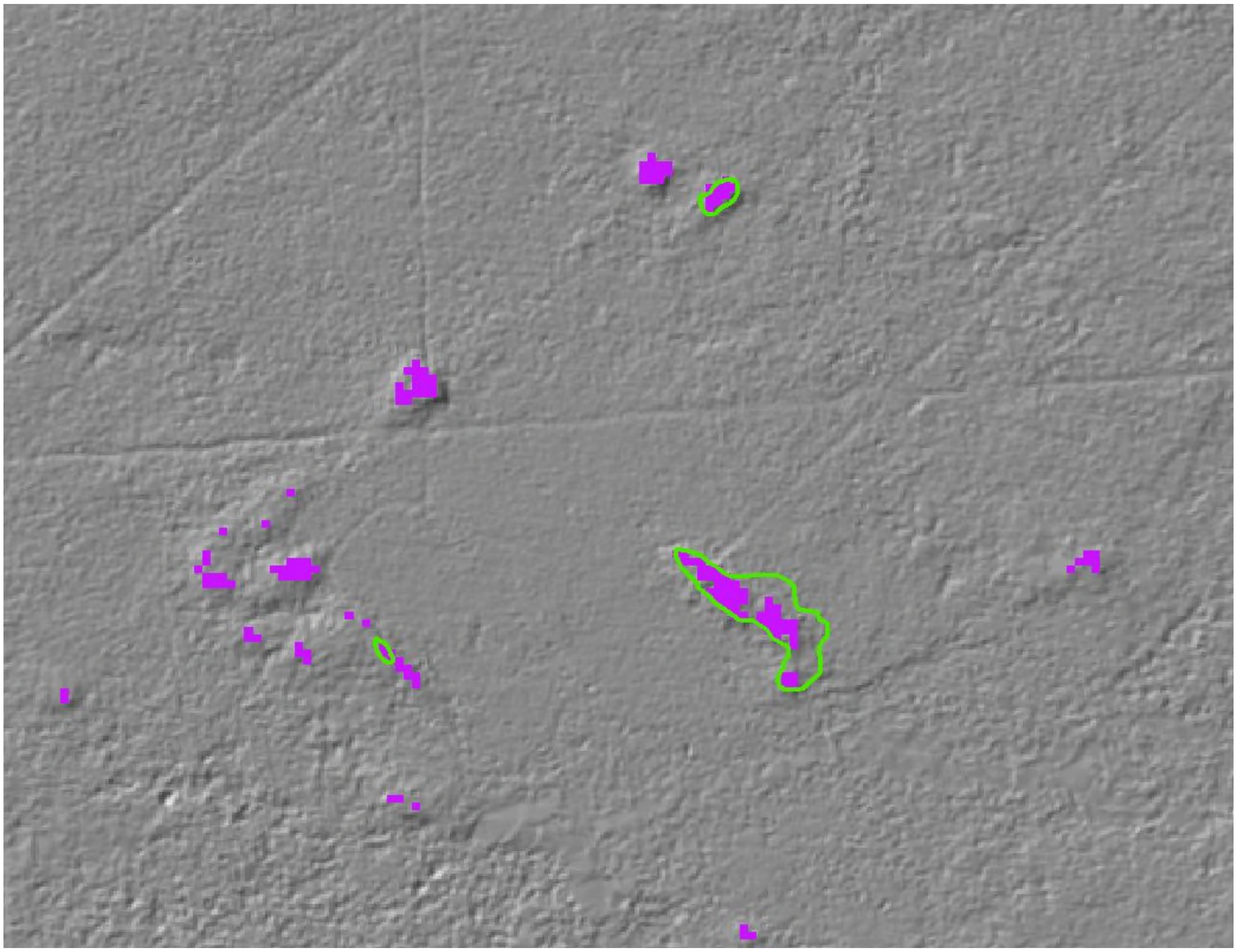


Figure 14. Sites IeRk-3, 4, and 5 shown with model revised to reduce the required elevation range to greater than or equal to 1 m (purple). Note that all of the sites are now captured, including the south end of IeRk-3.

When the figures above are compared to the very hummocky Figure 15 below, it is apparent that landscapes differ within the study area, and that the modelling approach must be tailored to these differences. In Figure 15 there is quite a bit of land being captured. While obvious landforms are being captured, there are places where the model is also occurring in one or two cell pieces (for example, in the location indicated by an arrow) which don't have an apparent significant landform. In areas such as this, lowering the elevation range would likely capture far too much land. In fact, it may be useful to revise the model to reduce the capture of smaller, lower potential features. This could be by increasing elevation range requirements or by clipping out single or even double pixels where they are not adjacent to a larger body of potential.

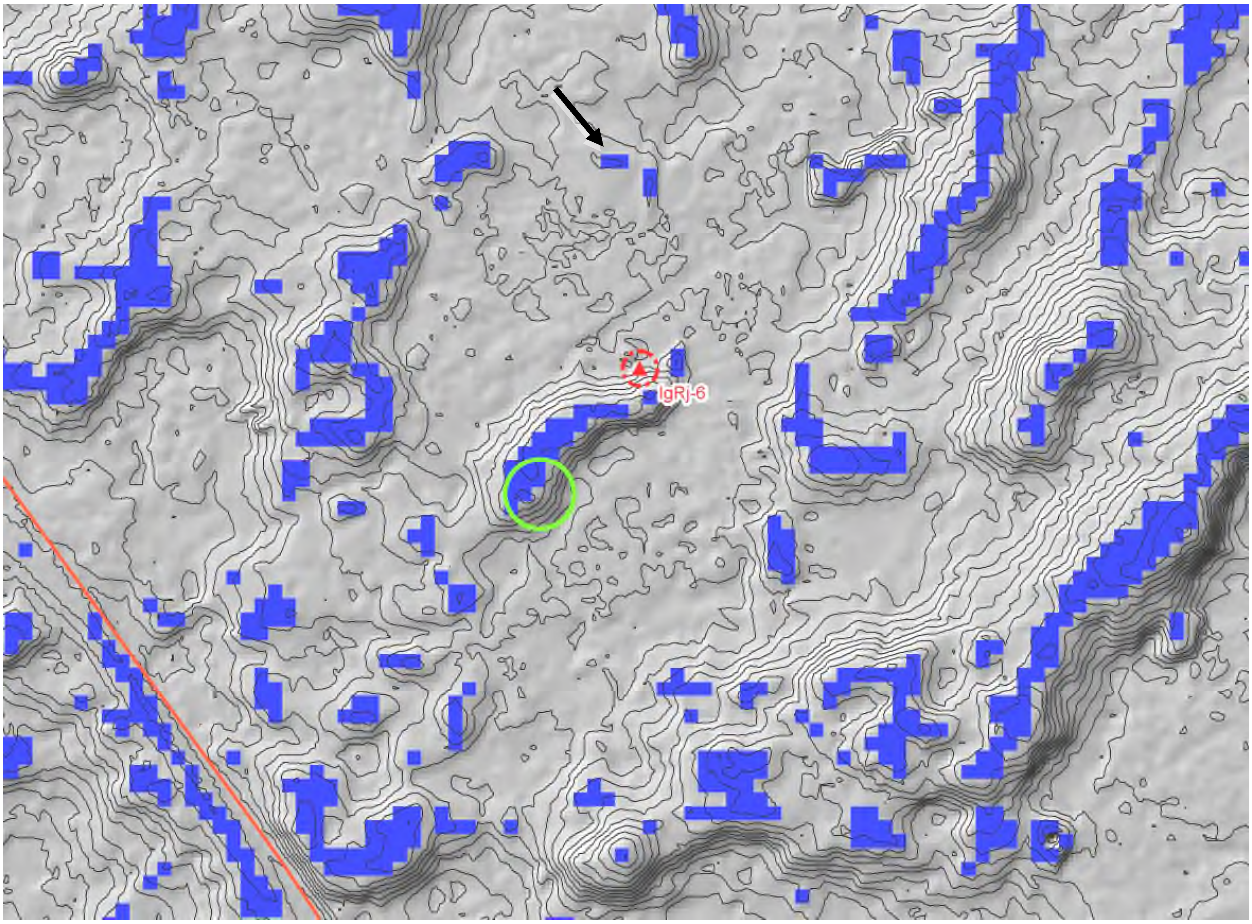


Figure 15. Site IgRg-6, located in a hummocky area with lots of terrain variation.

Other possible modifications to the model include buffering rivers and streams, to extend the potential further back from the riverbanks. It was previously noted in the Gunnell LiDAR ground truth testing that the initial model there did not extend back far enough from a larger creek to capture a site (Arcas Consulting Archeologists Ltd. and Eagle Valley Research Ltd. 2004). The site was on relatively level, well drained land about 60 m back from the creek. There was modelled potential here, but confined to a strip only about 12 m wide back from the creek cutbank slopebreak. The model was revised slightly to account for this by resampling the DEM to 24 m cells, and then calculating the "Positive" on this layer. The resulting positive_24m layer was limited to where the values were >90, and where slopes (from the 6 m DEM) were <5. This effectively buffers larger features, extending potential back away from slope breaks such as those beside larger rivers. This would also capture some of the sites missed by the current model while having a negligible effect on the amount of land captured as high potential. Some of these sites would also be captured by the other model 'tweaks' and it is uncertain which approach is most efficient.

It was suggested that trails used for the NE AOA could be incorporated into the LiDAR modelling. However, only a very small portion of one of the trails actually intersected with a test area, so trails were not incorporated at this stage. When the model is expanded to the entire study area, however, trails can be included in the revisions to the model. One possible way of including them is to buffer them, then revise the model within those buffers to capture smaller landforms. This will need to be tested in the next phase, when the model is applied to the entire study area.

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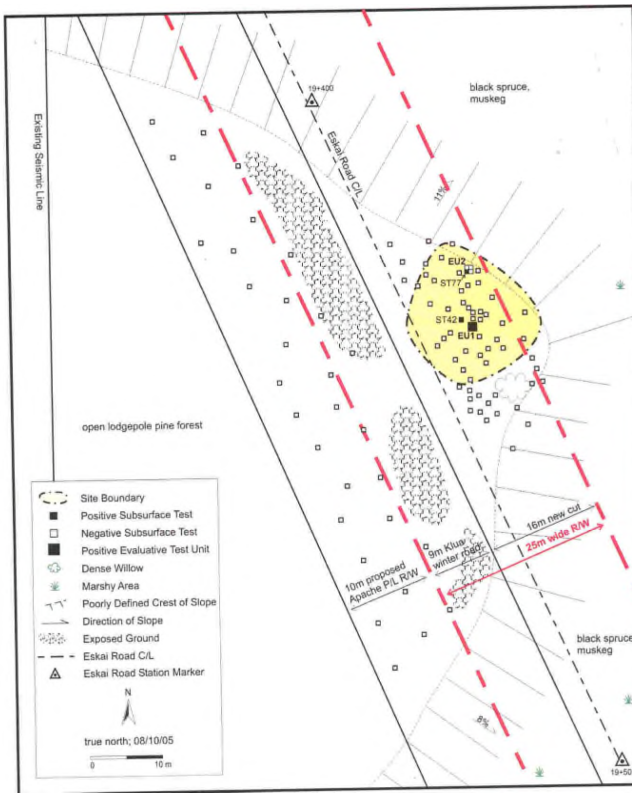
Eldridge, M., A. Parker, J. Brunsden and I. McKechnie
2007 *Campbell River Forest District Archaeological Overview Assessment*. Millennia Research Limited.

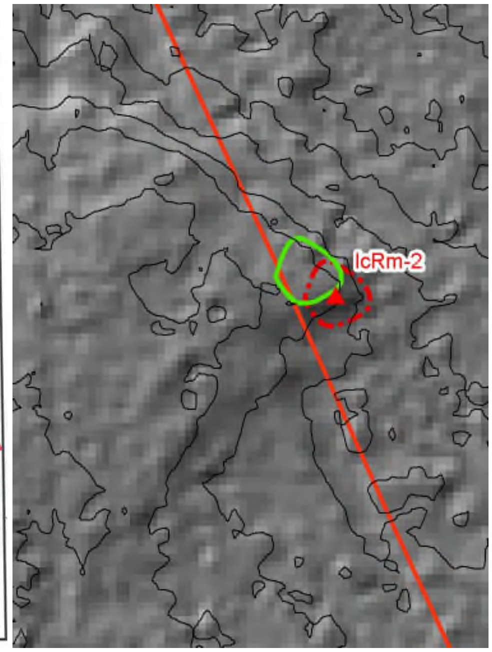
Kvamme, K. L.
1988 Development and testing of quantitative models. . In *Quantifying the Present and Predicting the Past: Theory, Method, and Application of Archaeological Predictive Modeling*, edited by W. J. Judge and L. Sebastian, pp. 325-428. US Department of the Interior, Bureau of Land Management Service Center, Denver, Co.

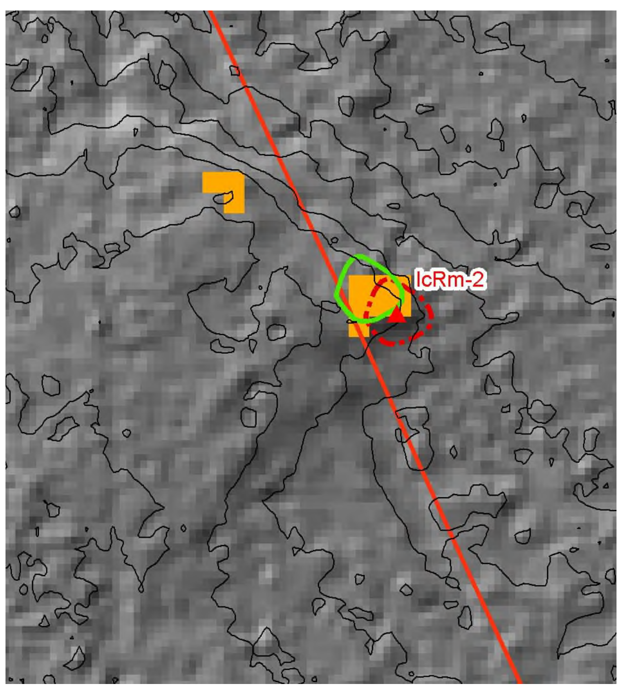
Appendix A: Corrected site location maps

Following are a series of maps showing the revisions made to the locations of sites. For each site, the site map is included, as well as a map showing the revised and original locations with hillshaded 2 m LiDAR data and 50 cm contours (unless otherwise stated), and a map showing the model with relation to the site locations. Original site locations are shown as a dashed red lines with a red triangle. Revised locations are shown as a solid green line. Sites which are illustrated in the report are excluded from this appendix.

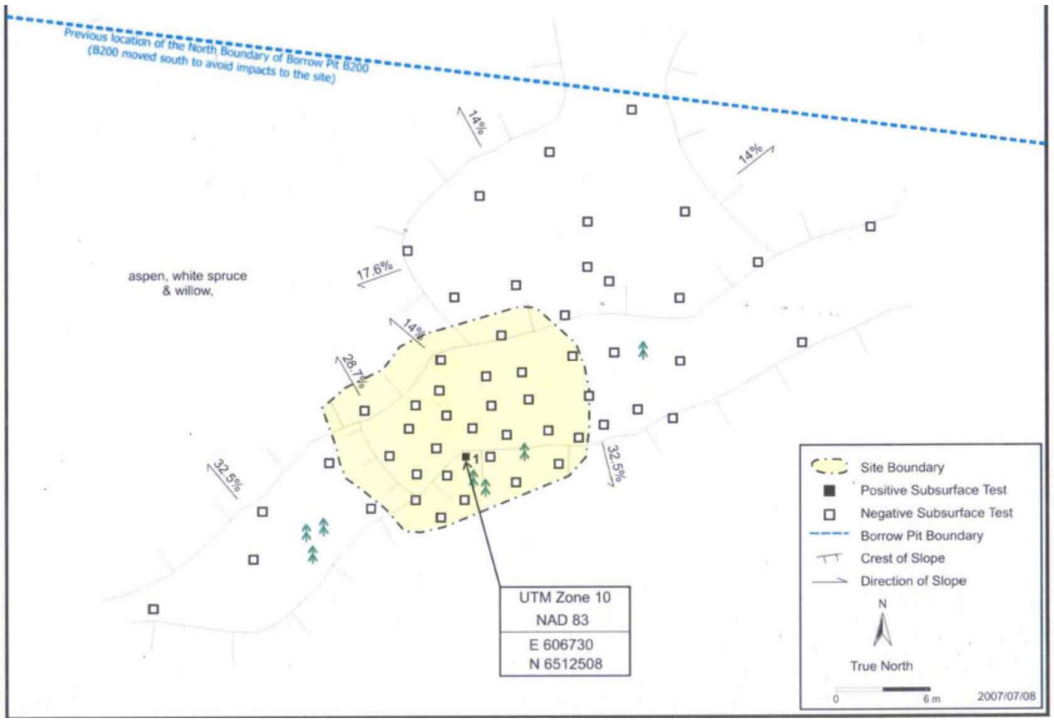
IcRm-2:


Existing Seismic Line
19+400
black spruce,
muskeg
Eskai Road C/L
11%
EU2
ST77
ST42
EU1
open lodgepole pine forest
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Positive Evaluative Test Unit
Dense Willow
Marshy Area
Poorly Defined Crest of Slope
Direction of Slope
Exposed Ground
Eskai Road C/L
Eskai Road Station Marker
N
true north; 08/10/05
0
10 m
10m proposed
Apache P/L R/W
9m Kluay
winter road
16m new cut
25m wide R/W
black spruce,
muskeg
8%
19+500

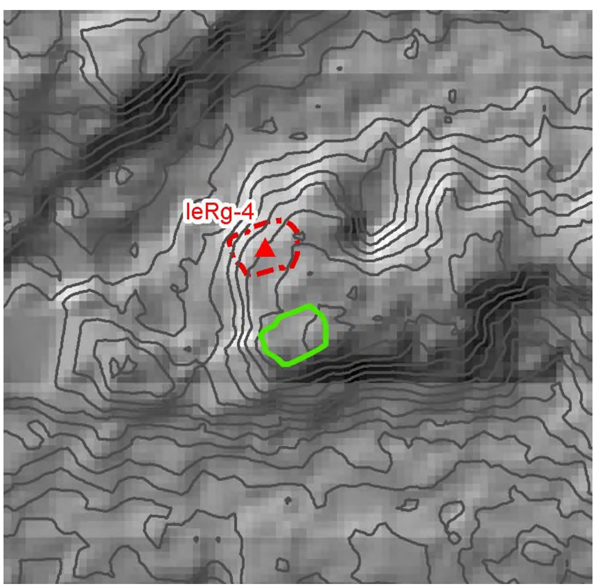

IcRm-2


IcRm-2

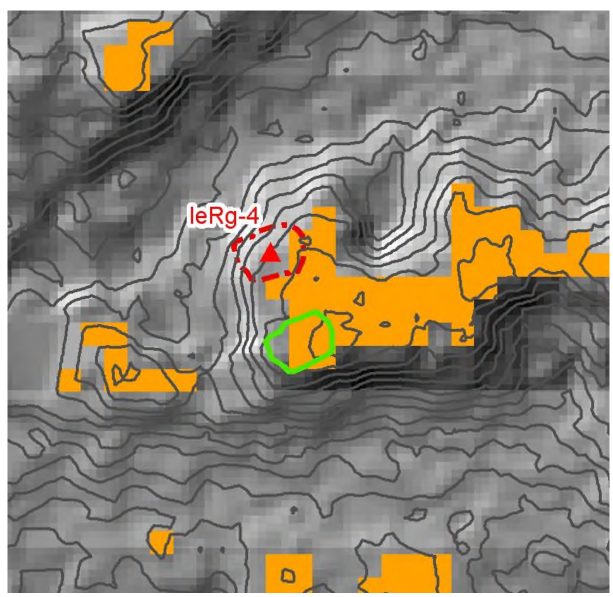
IeRg-4



Previous location of the North Boundary of Borrow Pit B200
(B200 moved south to avoid impacts to the site)
14%
14%
17.6%
14%
28.7%
32.5%
32.5%
aspen, white spruce
& willow,
1
UTM Zone 10
NAD 83
E 606730
N 6512508
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Borrow Pit Boundary
Crest of Slope
Direction of Slope
N
True North
0
6 m
2007/07/08



IeRg-4



IeRg-4

IeRg-5

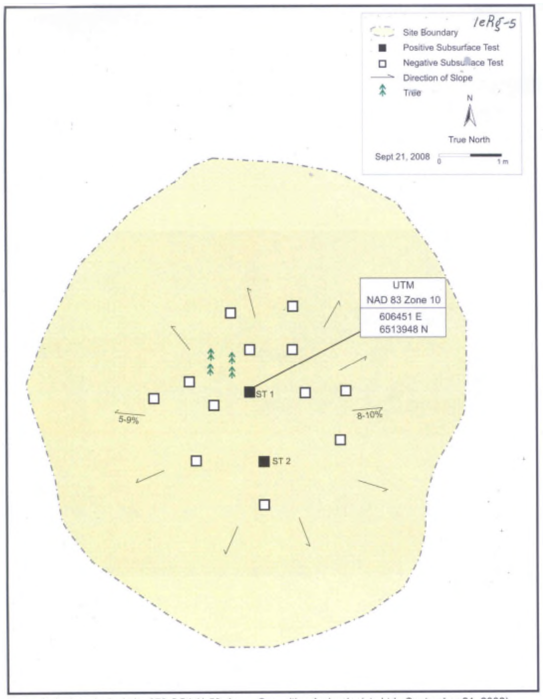
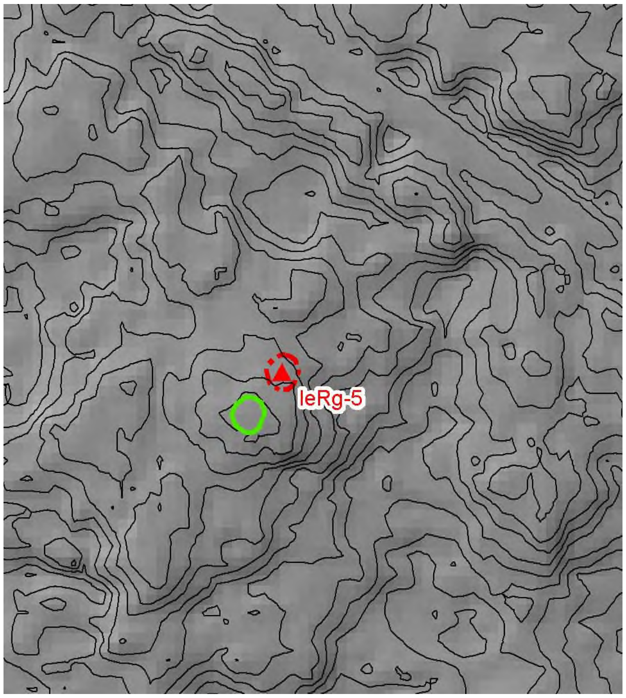
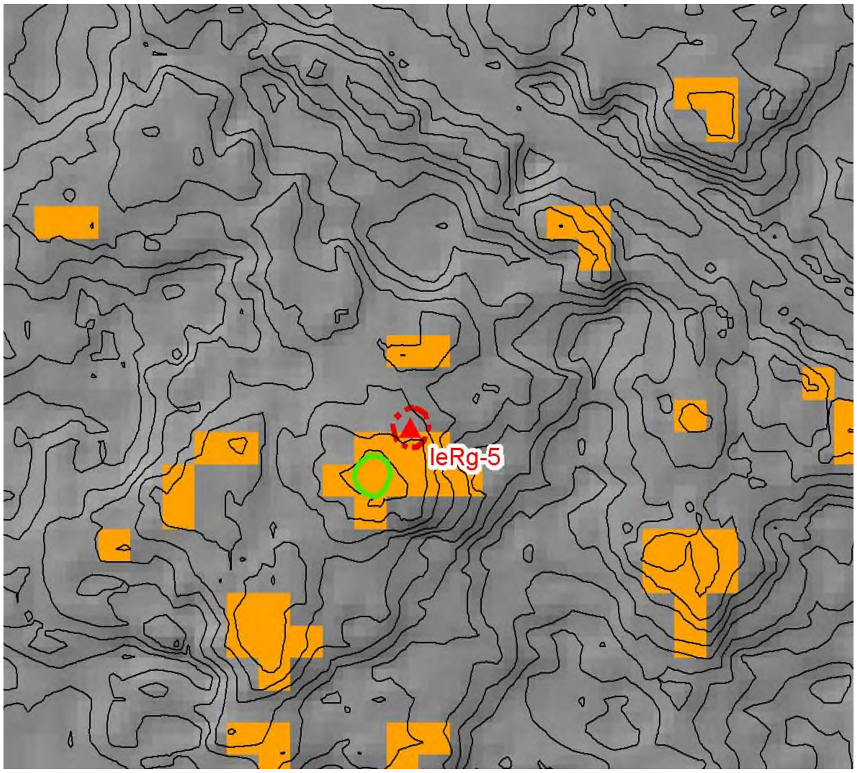


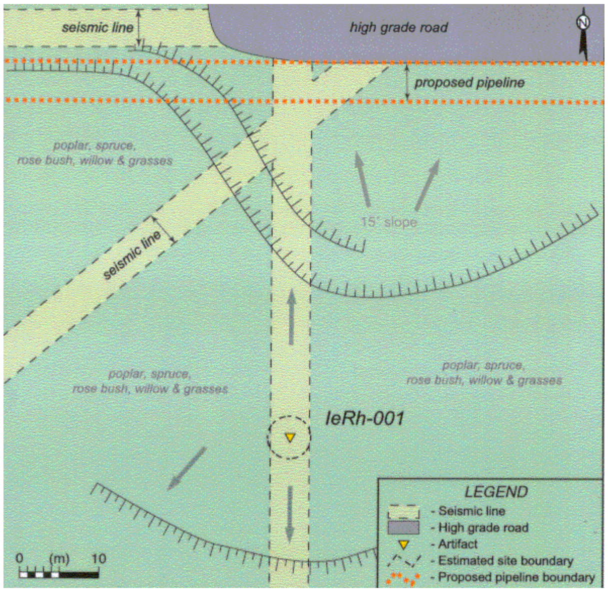
Figure 3. Archaeological site 076-SG1 (1:50; Arcas Consulting Archeologists Ltd., September 21, 2008).



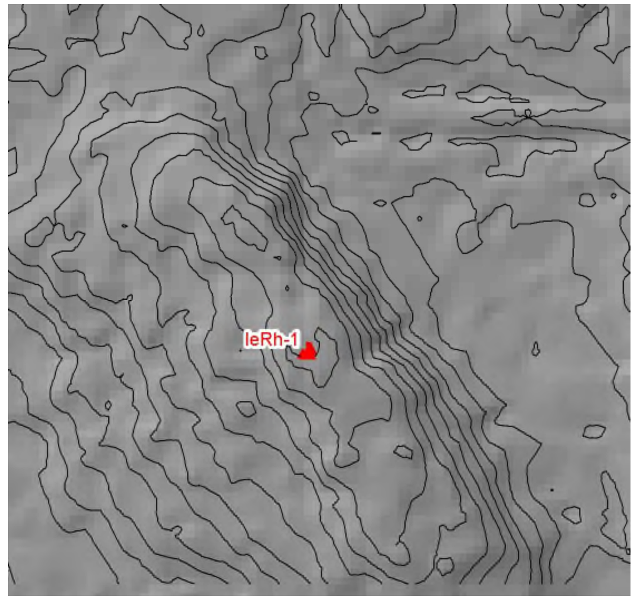
25 cm contours



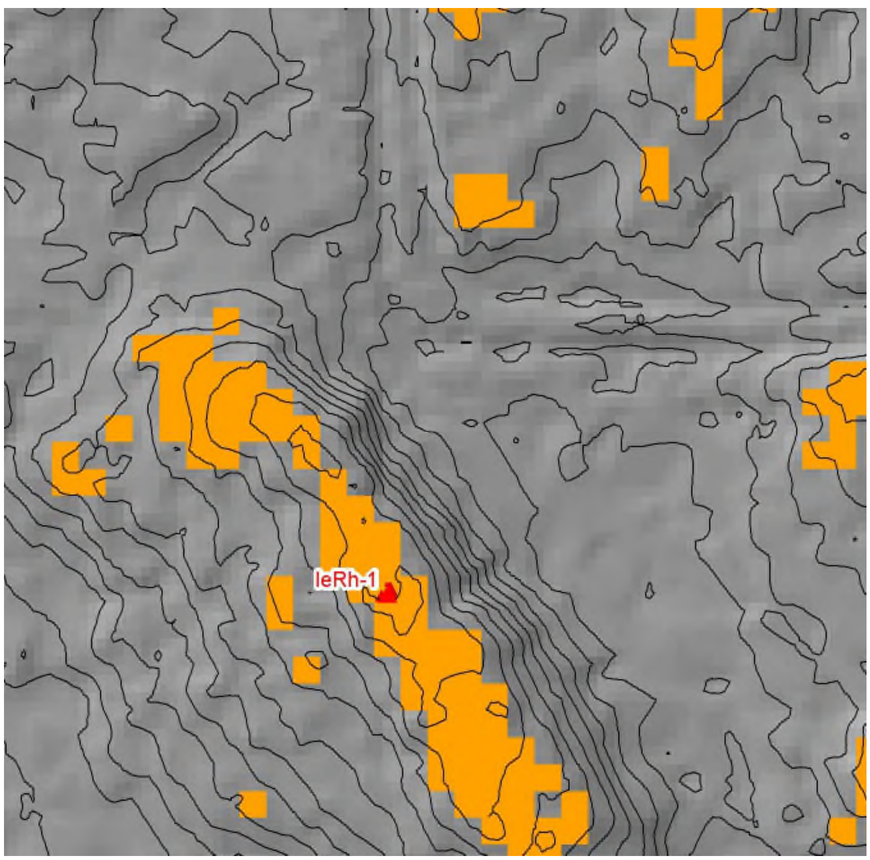
IeRh-1



seismic line
high grade road
proposed pipeline
poplar, spruce,
rose bush, willow & grasses
15˚ slope
seismic line
poplar, spruce,
rose bush, willow & grasses
poplar, spruce,
rose bush, willow & grasses
IeRh-001
LEGEND
- Seismic line
- High grade road
- Artifact
- Estimated site boundary
- Proposed pipeline boundary
0 (m) 10

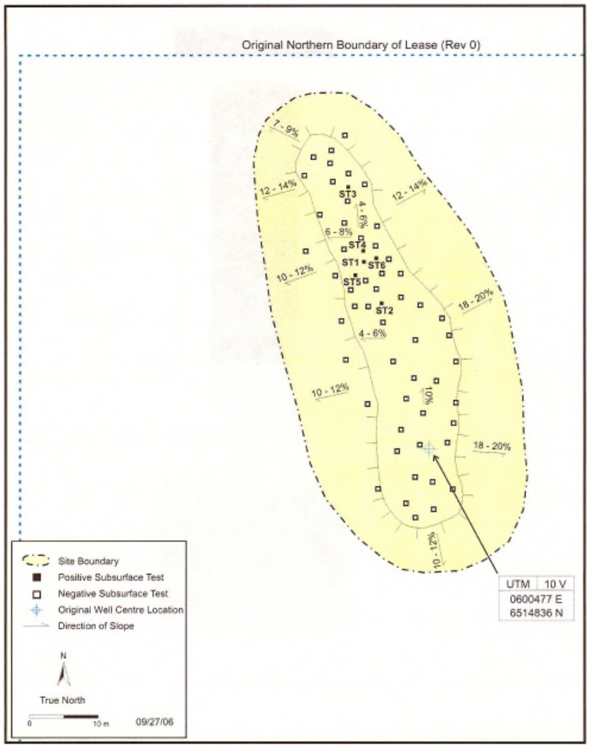


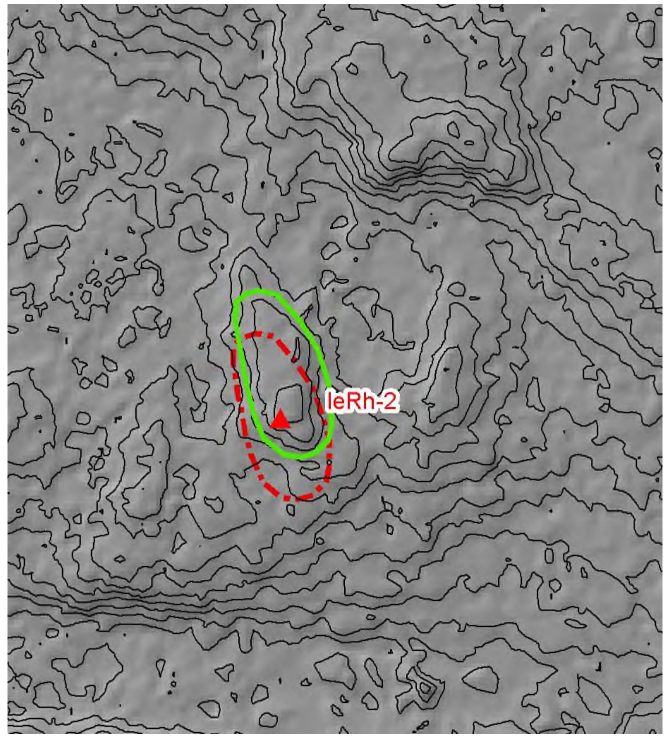
IeRh-1

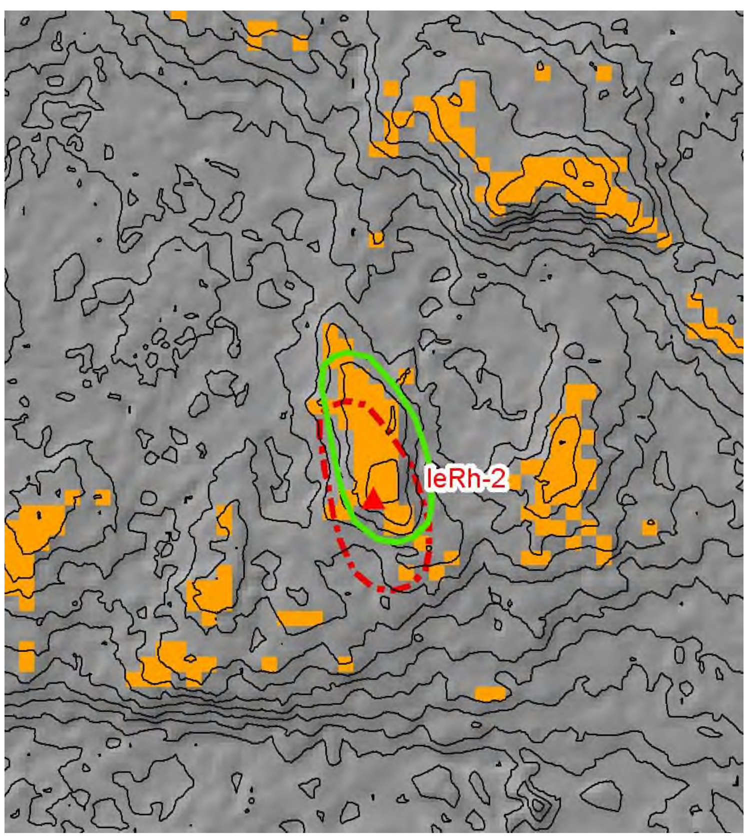


IeRh-1

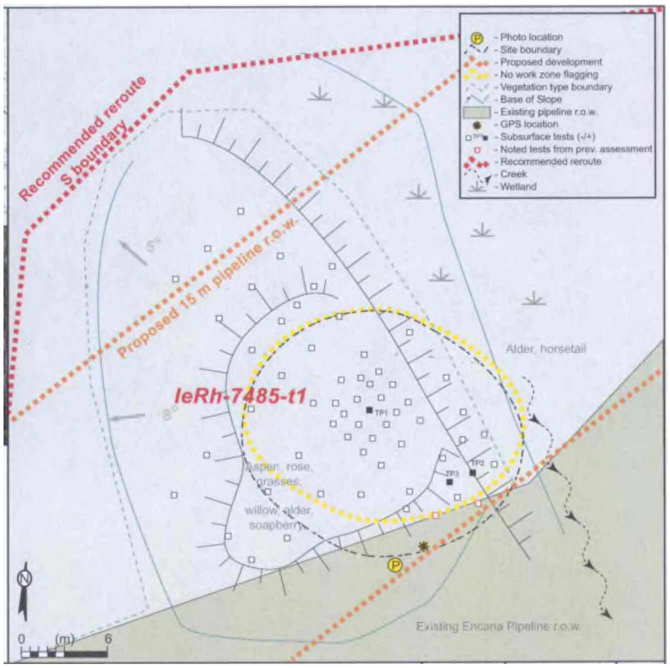
IeRh-2

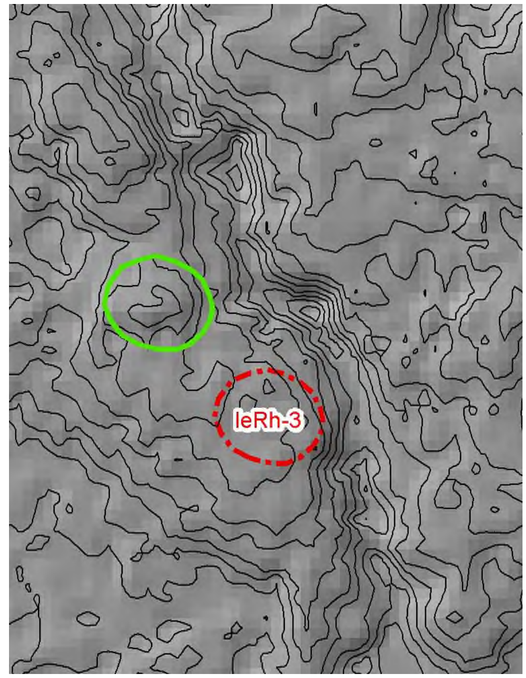

Original Northern Boundary of Lease (Rev 0)
7 - 9%
12 - 14%
12 - 14%
ST3
4 - 6%
6 - 8%
ST4
ST1
ST6
10 - 12%
ST5
ST2
18 - 20%
4 - 6%
10 - 12%
10%
18 - 20%
10 - 12%
UTM 10 V
0600477 E
6514836 N
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Original Well Centre Location
Direction of Slope
N
True North
0
10 m
09/27/06

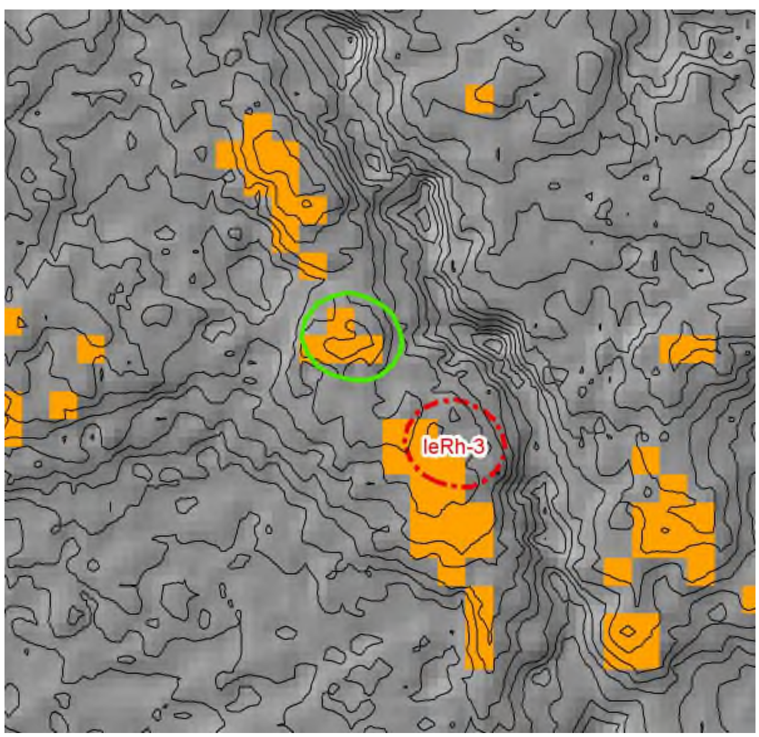

IeRh-2


IeRh-2

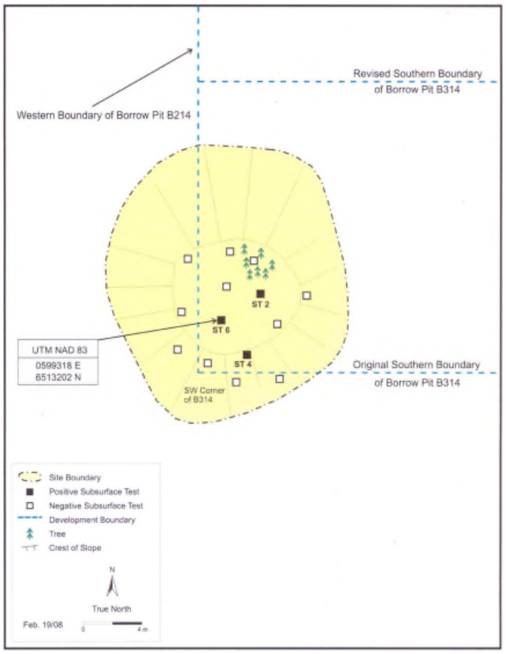
IeRh-3

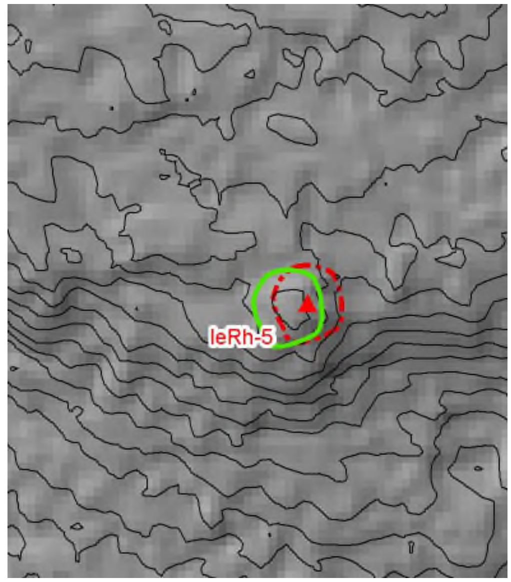

- Photo location
- Site boundary
- Proposed development
- No work zone flagging
- Vegetation type boundary
- Base of Slope
- Existing pipeline r.o.w.
- GPS location
- Subsurface tests (-/+)
- Noted tests from prev. assessment
- Recommended reroute
- Creek
- Wetland
Recommended reroute
S boundary
Proposed 15 m pipeline r.o.w.
IeRh-7485-t1
Alder, horsetail
Aspen, rose, grasses
willow, alder, soapberry
Existing Encana Pipeline r.o.w.
0 (m) 6

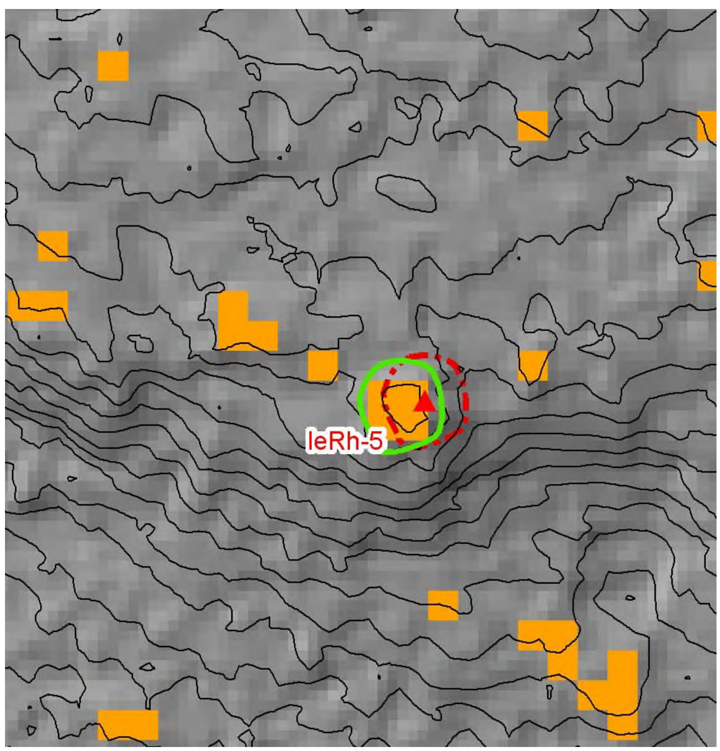

IeRh-3


IeRh-3

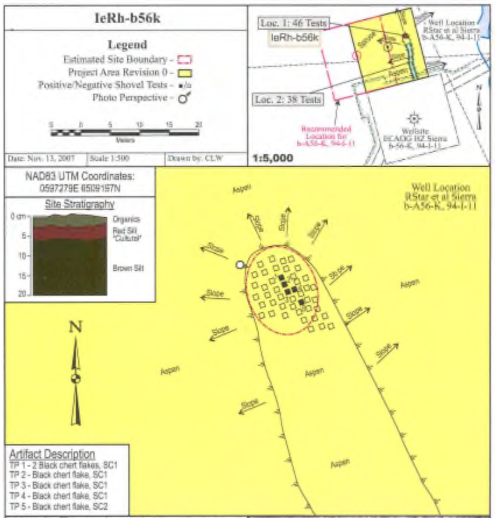
IeRh-5

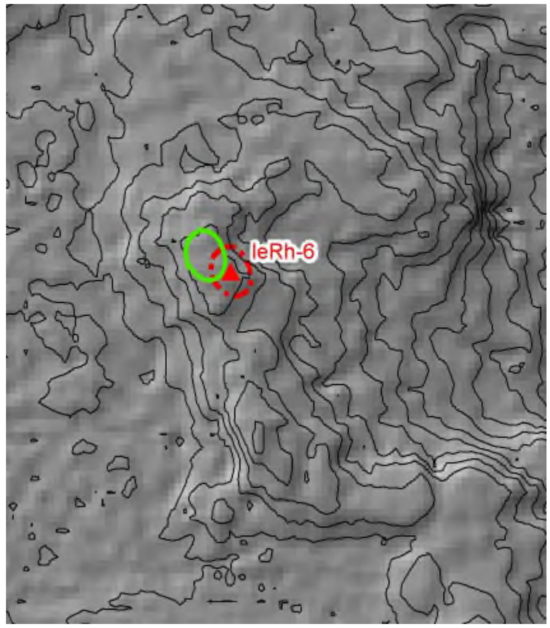

Revised Southern Boundary
of Borrow Pit B314
Western Boundary of Borrow Pit B214
ST 2
ST 6
ST 4
UTM NAD 83
0599318 E
6513202 N
SW Corner
of B314
Original Southern Boundary
of Borrow Pit B314
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Development Boundary
Tree
Crest of Slope
N
True North
Feb. 19/08
0
4 m

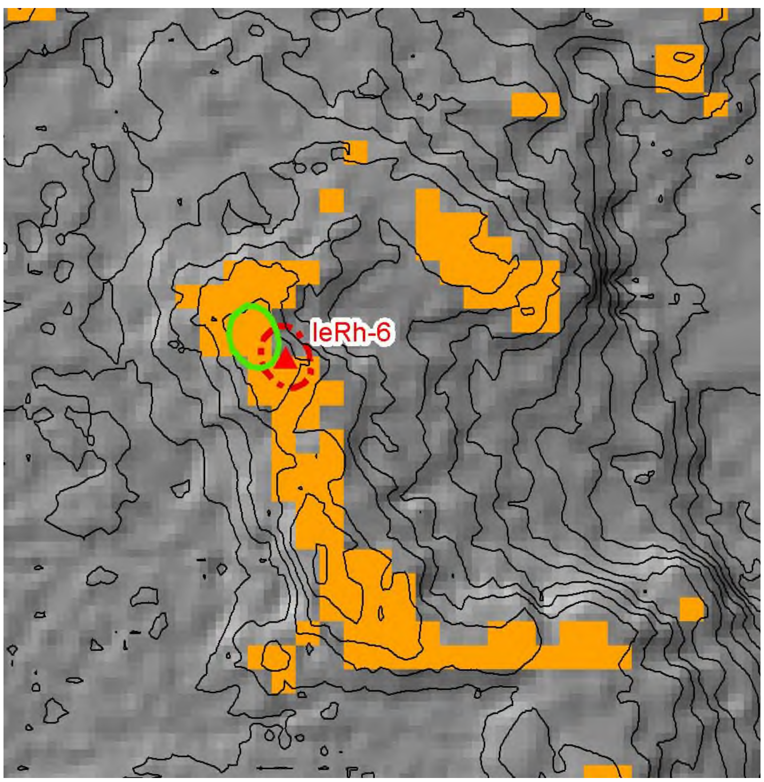

IeRh-5


IeRh-5

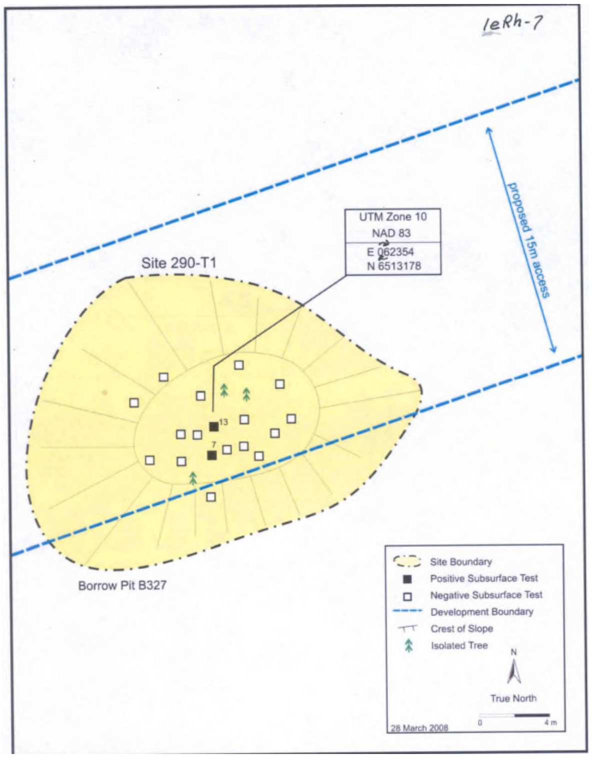
IeRh-6


IeRh-b56k
Legend
Estimated Site Boundary -
Project Area Revision 0 -
Positive/Negative Shovel Tests -
Photo Perspective -
Meters
Date: Nov. 13, 2007
Scale 1:500
Drawn by: CLW
Loc. 1: 46 Tests
IeRh-b56k
Loc. 2: 38 Tests
Well Location RStar et al Sierra b-A56-K, 94-I-11
Wellsite ECADG HZ Sierra b-56-K, 94-I-11
1:5,000
NAD83 UTM Coordinates:
0597279E 6509197N
Site Stratigraphy
Organics
Red Silt "Cultural"
Brown Silt
Well Location RStar et al Sierra b-A56-K, 94-I-11
N
Artifact Description
TP 1 - 2 Black chert flakes, SC1
TP 2 - Black chert flake, SC1
TP 3 - Black chert flake, SC1
TP 4 - Black chert flake, SC1
TP 5 - Black chert flake, SC2

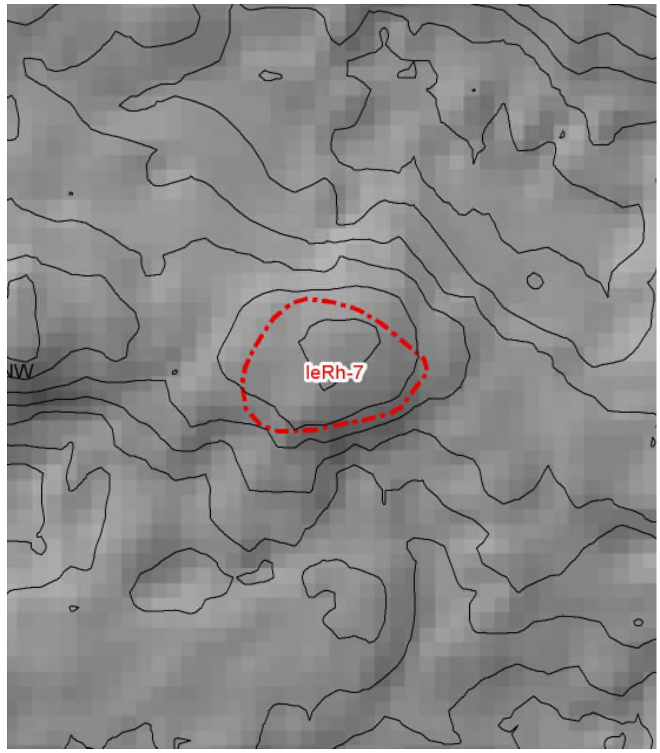

IeRh-6


IeRh-6

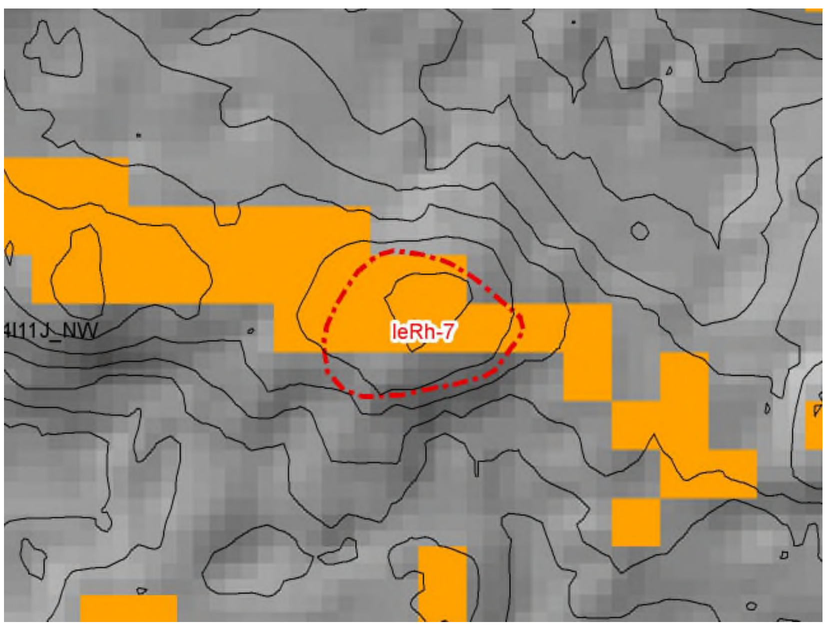
IeRh-7



IeRh-7
UTM Zone 10
NAD 83
E 062354
N 6513178
proposed 15m access
Site 290-T1
13
7
Borrow Pit B327
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Development Boundary
Crest of Slope
Isolated Tree
N
True North
0
4 m
28 March 2008

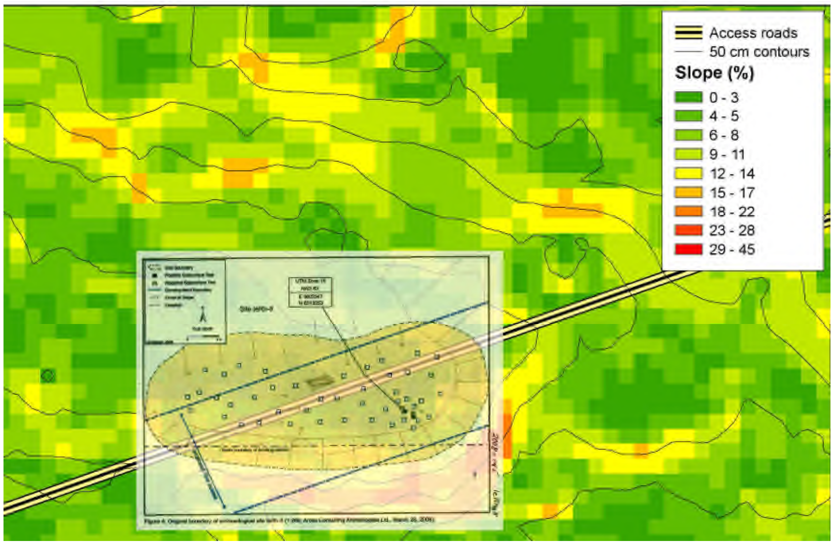


IeRh-7

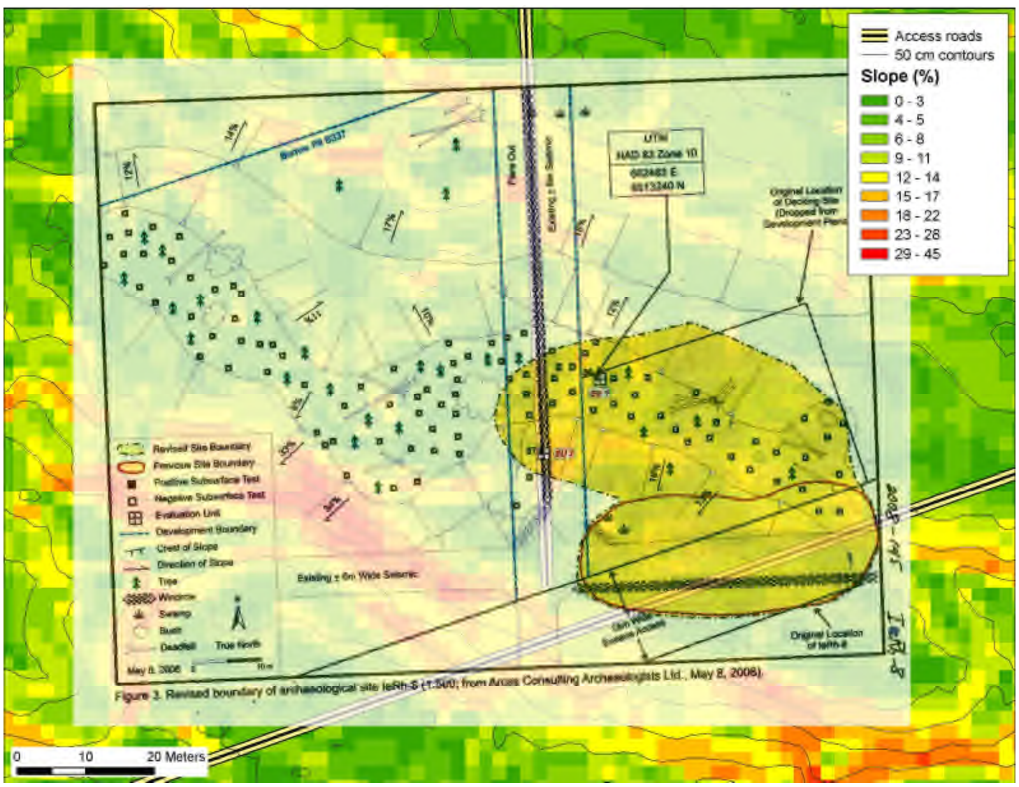


4I11J_NW
IeRh-7

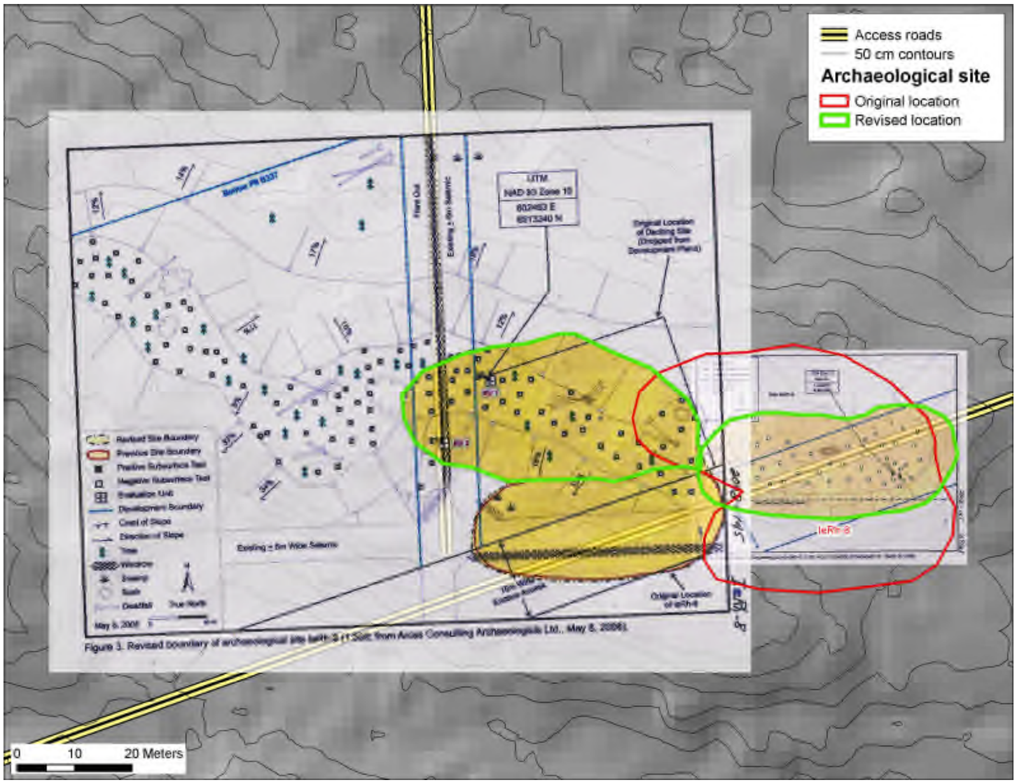
IeRh-8

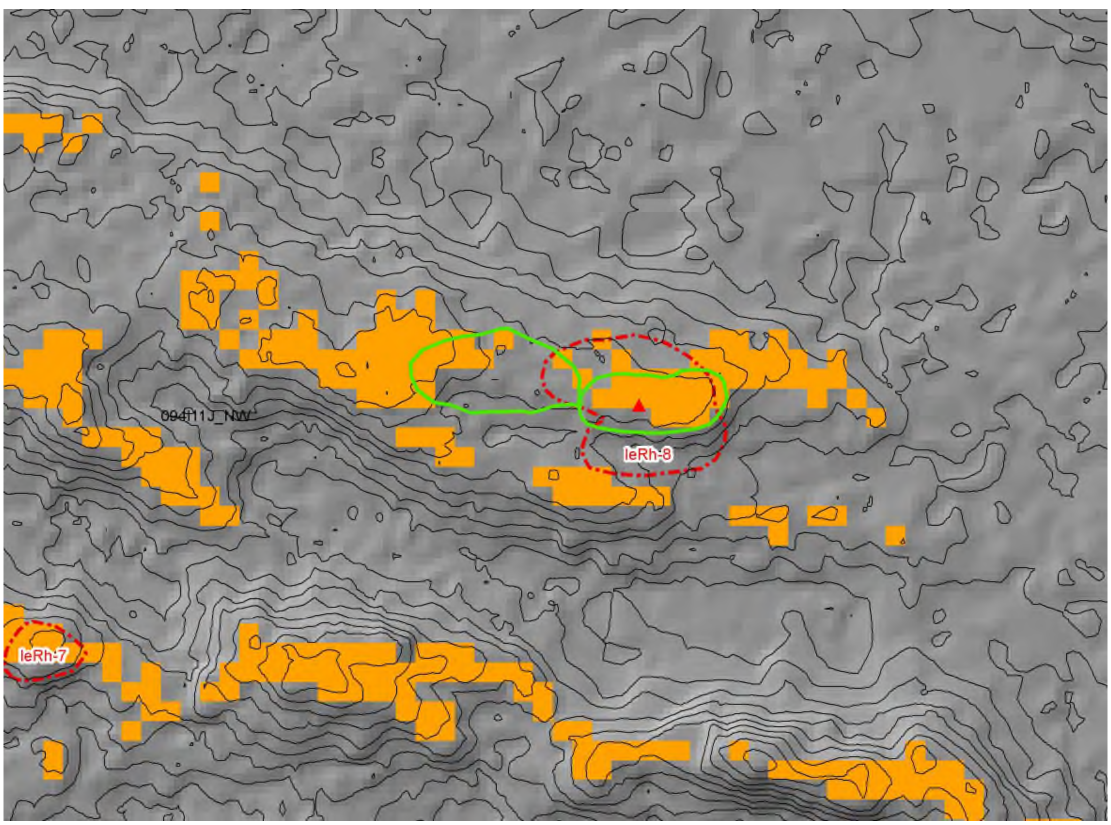


Access roads
50 cm contours
Slope (%)
0 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 17
18 - 22
23 - 28
29 - 45

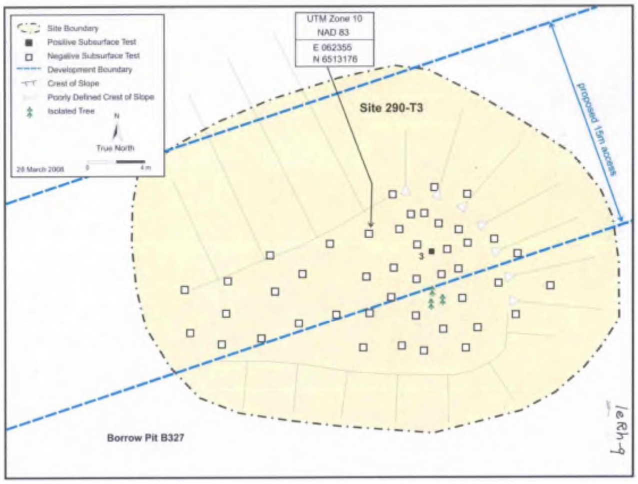


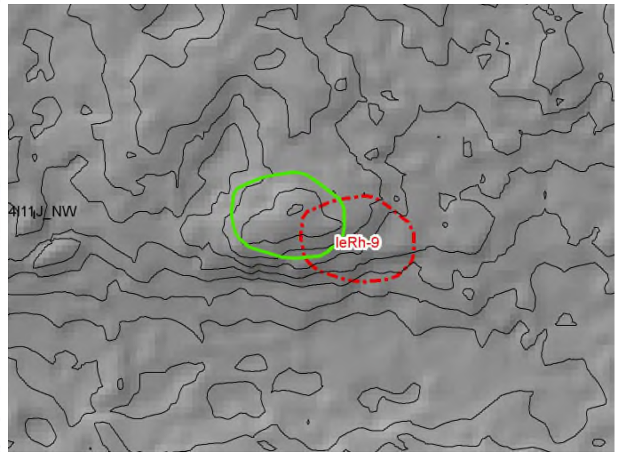
Access roads
50 cm contours
Slope (%)
0 - 3
4 - 5
6 - 8
9 - 11
12 - 14
15 - 17
18 - 22
23 - 28
29 - 45
0
10
20 Meters

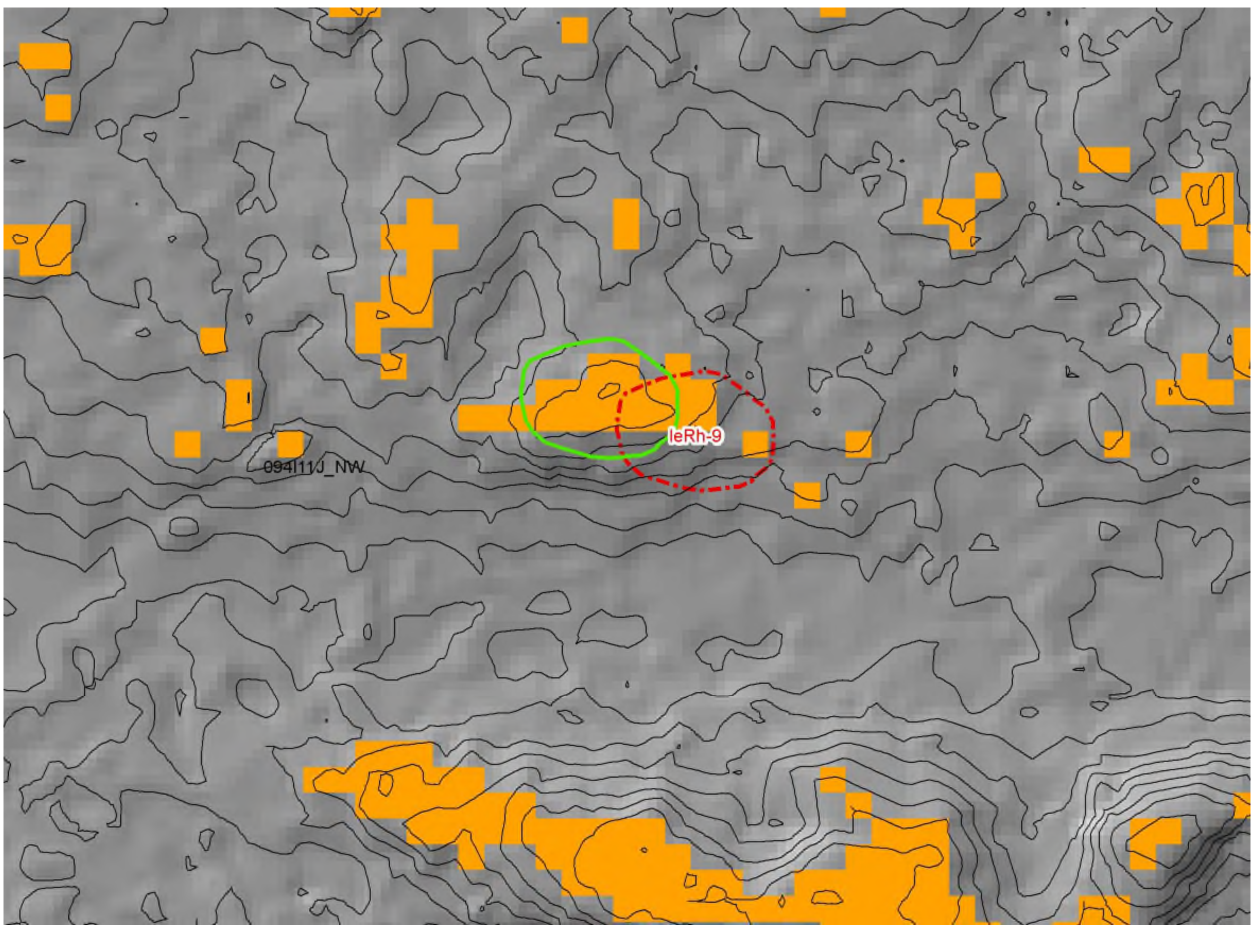

Access roads
50 cm contours
Archaeological site
Original location
Revised location
0
10
20 Meters


094I11J_NW
IeRh-8
IeRh-7

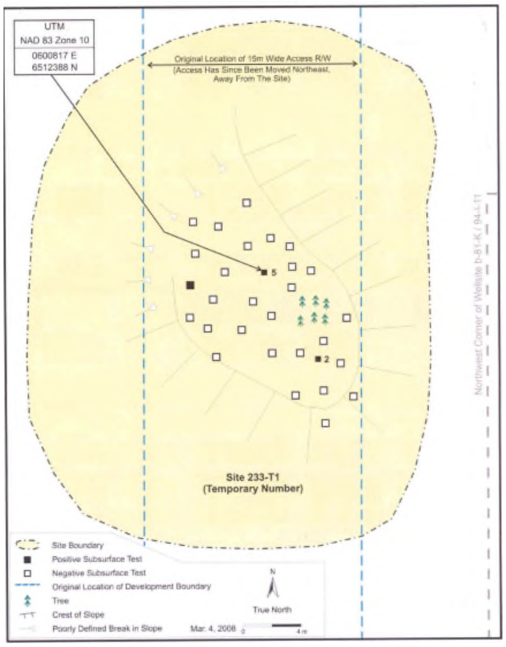
IeRh-9

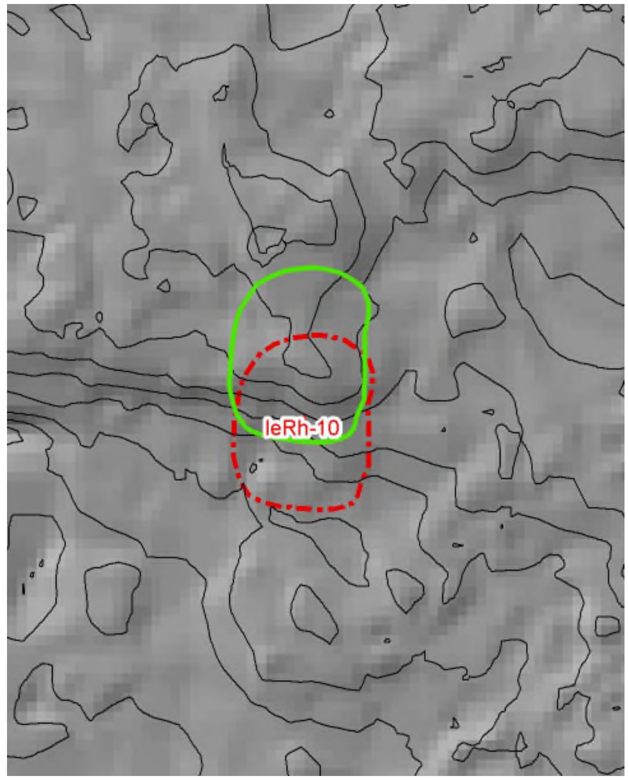

Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Development Boundary
Crest of Slope
Poorly Defined Crest of Slope
Isolated Tree
N
True North
28 March 2008
0
4 m
UTM Zone 10
NAD 83
E 062355
N 6513176
Site 290-T3
proposed 15m access
Borrow Pit B327
IeRh-9

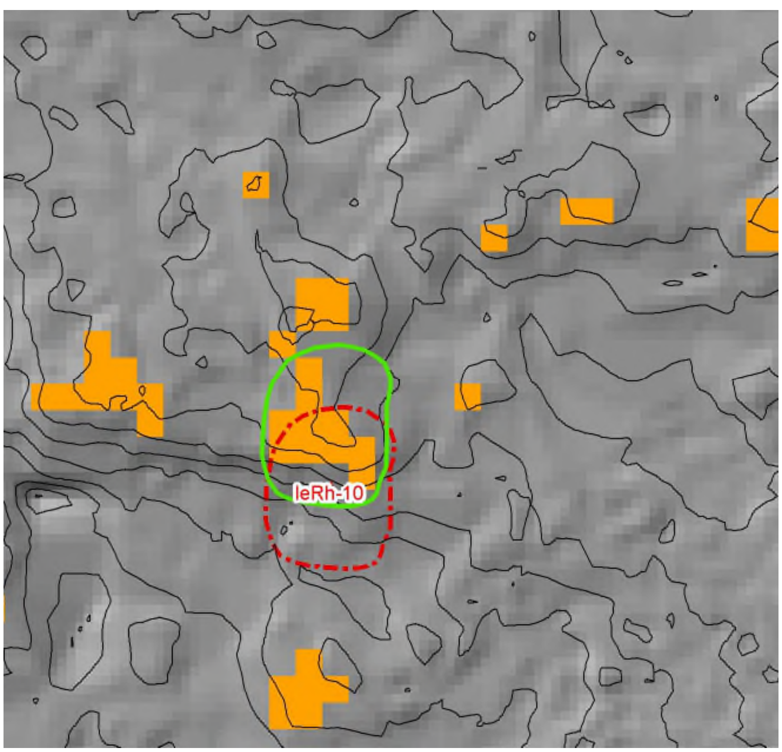

IeRh-9


IeRh-9
094I11J_NW

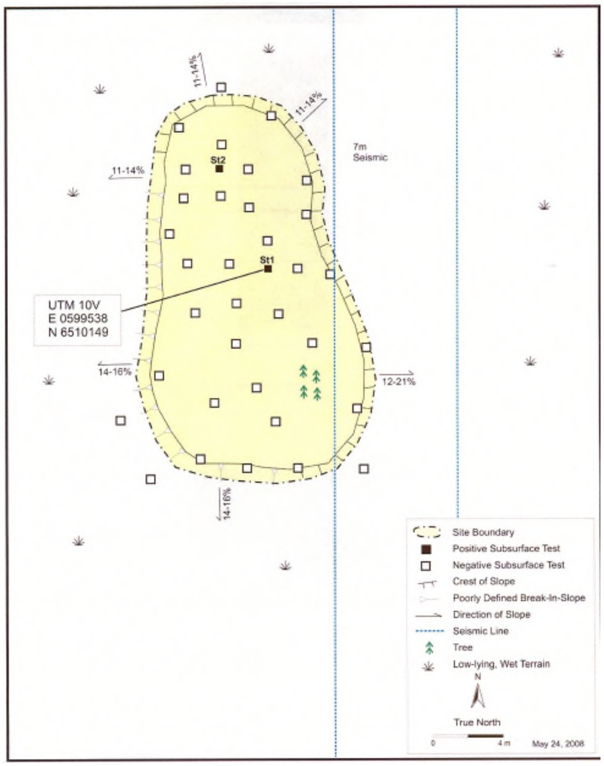
IeRh-10

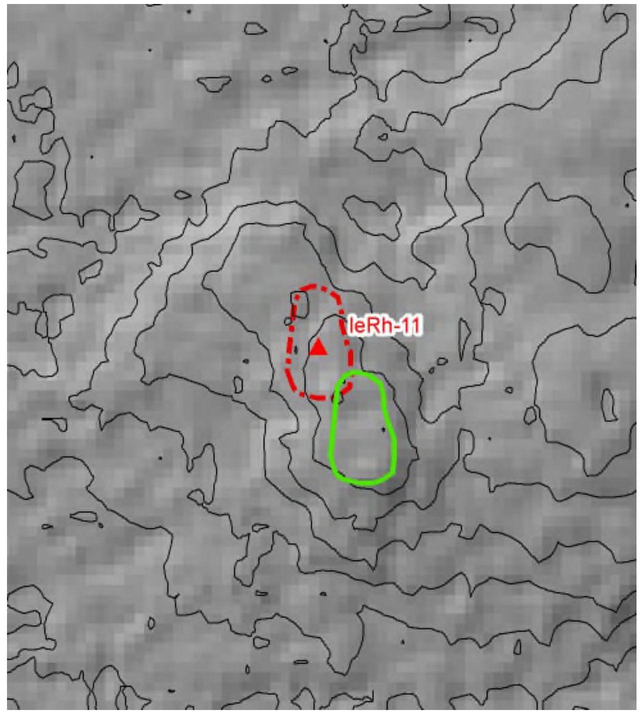

UTM
NAD 83 Zone 10
0600817 E
6512388 N
Original Location of 15m Wide Access R/W
(Access Has Since Been Moved Northeast, Away From The Site)
5
2
Site 233-T1
(Temporary Number)
Northwest Corner of Wellsite b-81-K / 94-I-11
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Original Location of Development Boundary
Tree
Crest of Slope
Poorly Defined Break in Slope
N
True North
Mar. 4, 2008
0
4 m

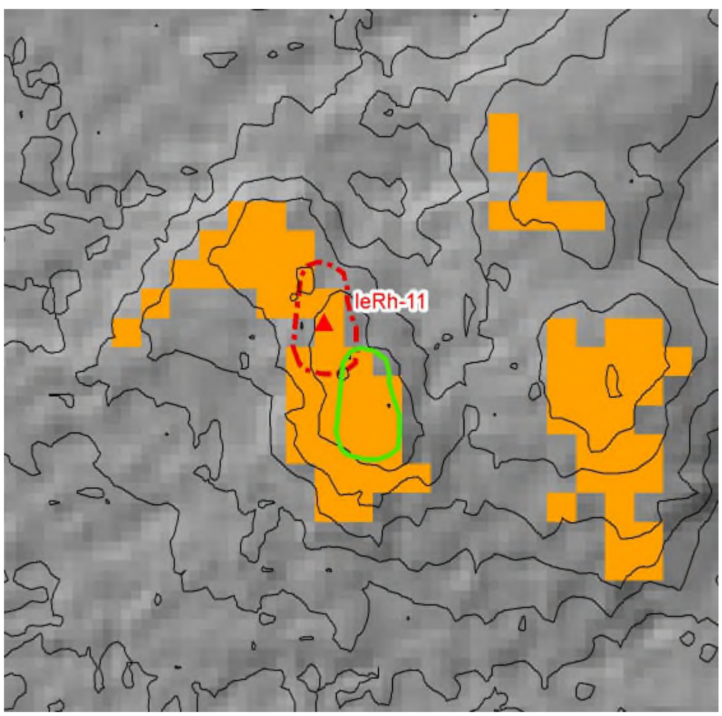

IeRh-10


IeRh-10

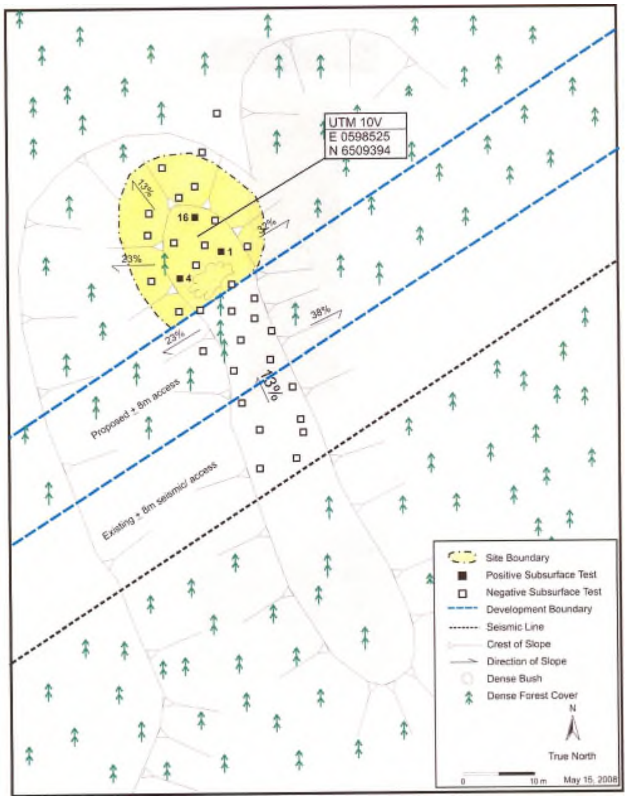
IeRh-11

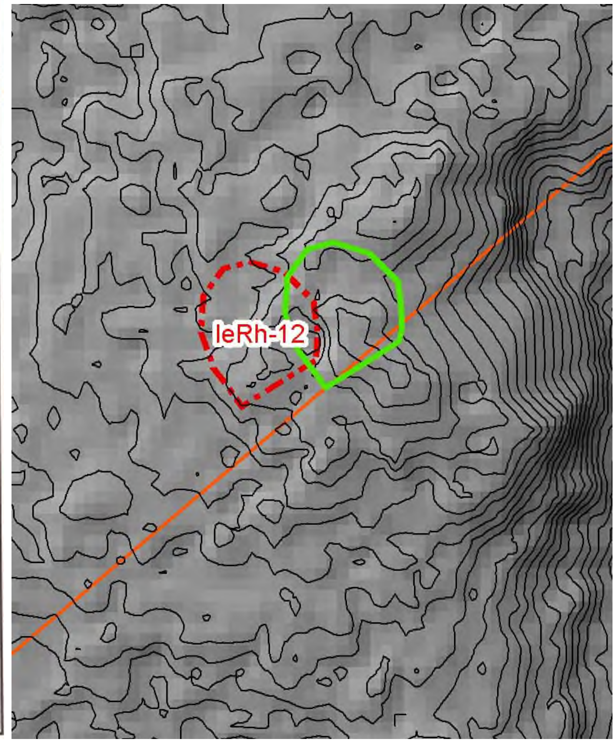

11-14%
11-14%
11-14%
7m
Seismic
St2
St1
UTM 10V
E 0599538
N 6510149
14-16%
12-21%
14-16%
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Crest of Slope
Poorly Defined Break-In-Slope
Direction of Slope
Seismic Line
Tree
Low-lying, Wet Terrain
N
True North
0
4 m
May 24, 2008

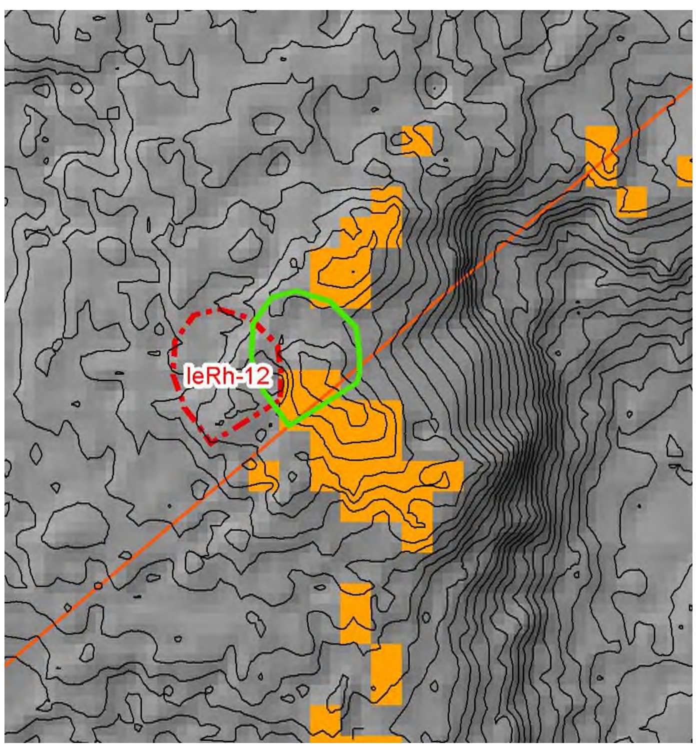

IeRh-11


IeRh-11

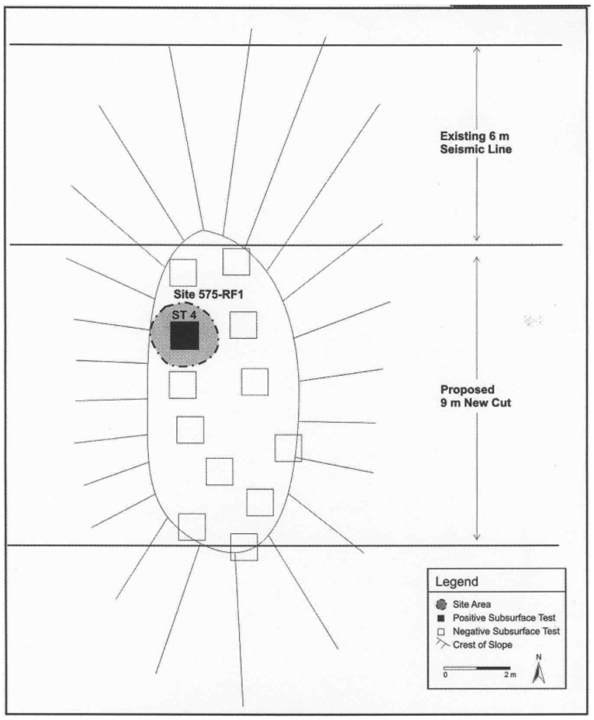
IeRh-12

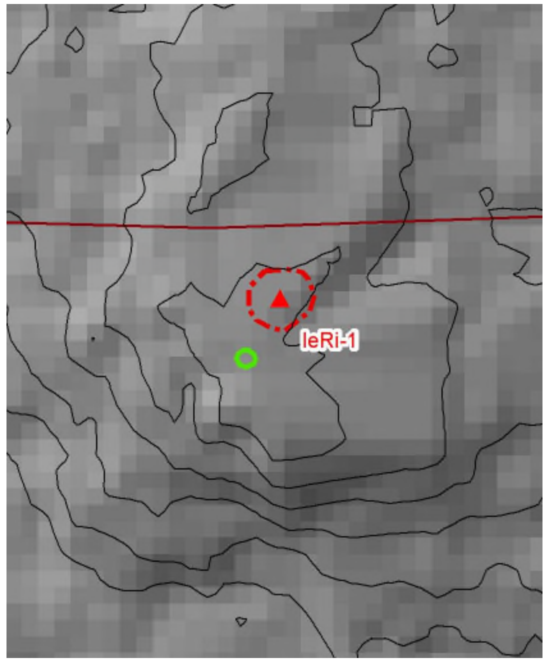

UTM 10V
E 0598525
N 6509394
16
1
4
13%
32%
23%
23%
38%
13%
Proposed ± 8m access
Existing ± 8m seismic/ access
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Development Boundary
Seismic Line
Crest of Slope
Direction of Slope
Dense Bush
Dense Forest Cover
N
True North
0
10 m
May 15, 2008

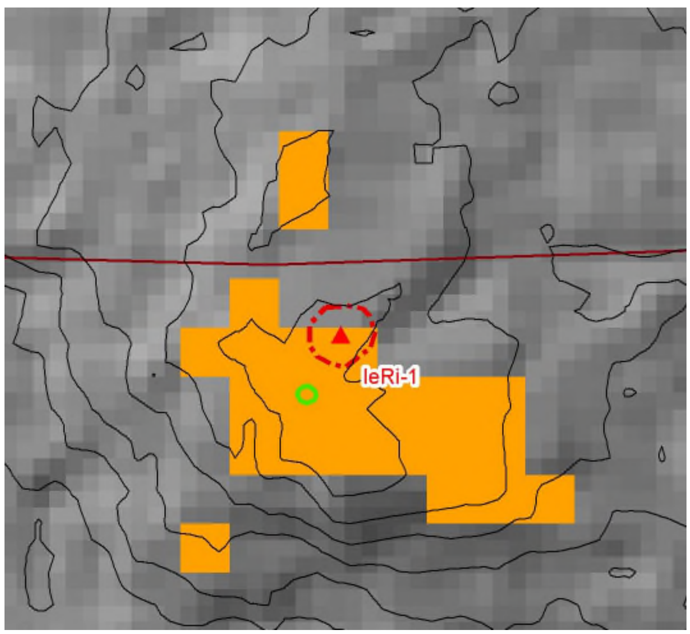

IeRh-12


IeRh-12

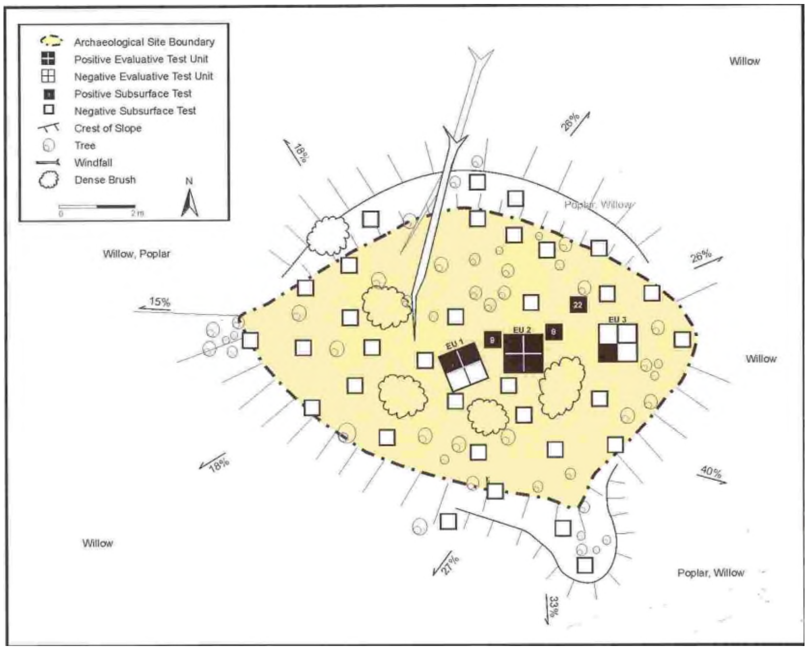
IeRi-1


Existing 6 m
Seismic Line
Site 575-RF1
ST 4
Proposed
9 m New Cut
Legend
Site Area
Positive Subsurface Test
Negative Subsurface Test
Crest of Slope
0
2 m
N

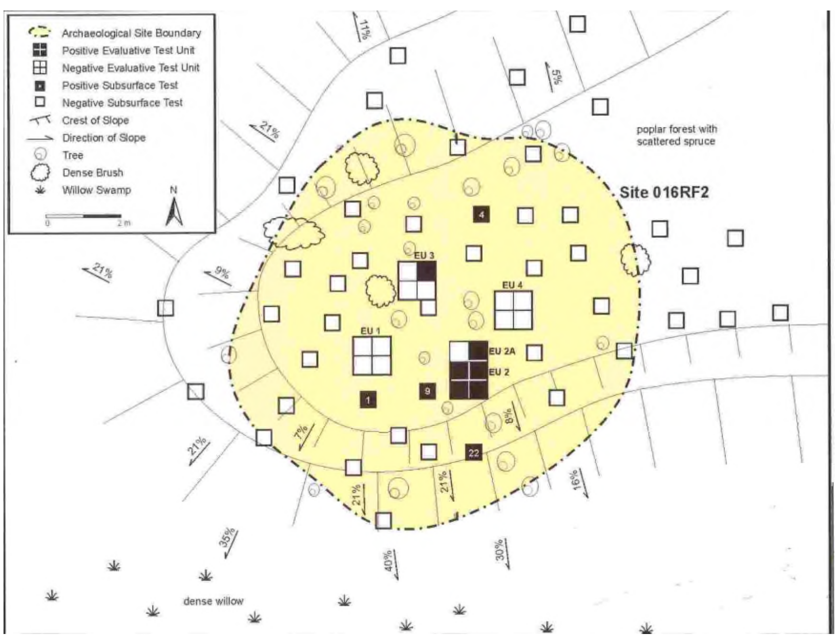

IeRi-1


IeRi-1

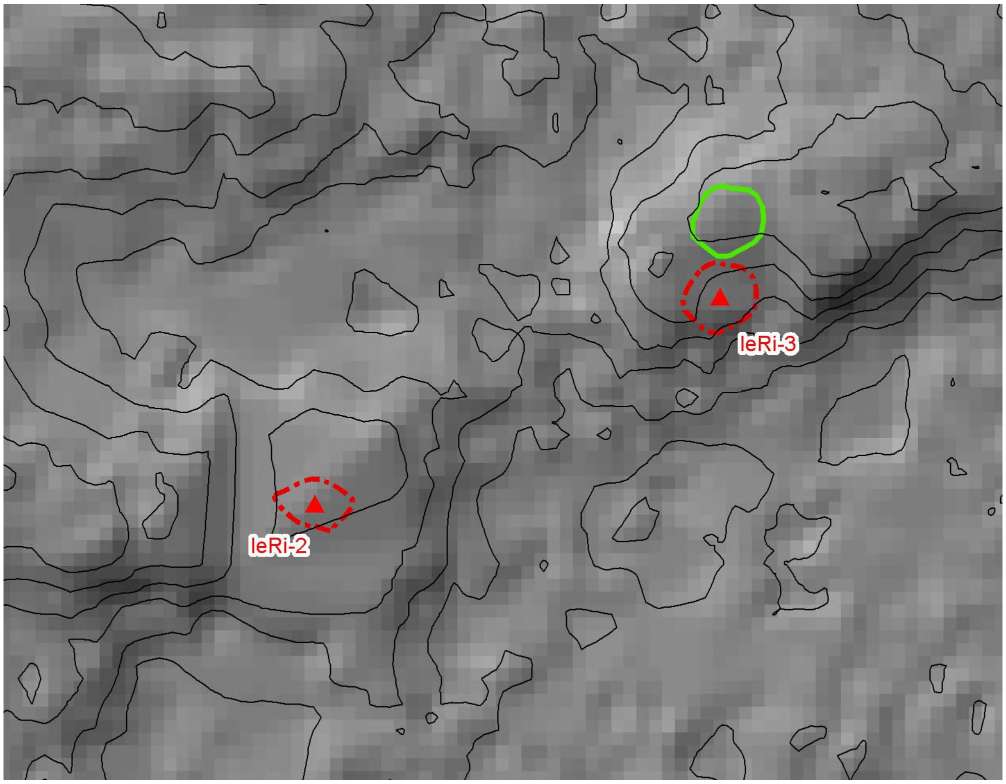
IeRi-2 and IeRi-3

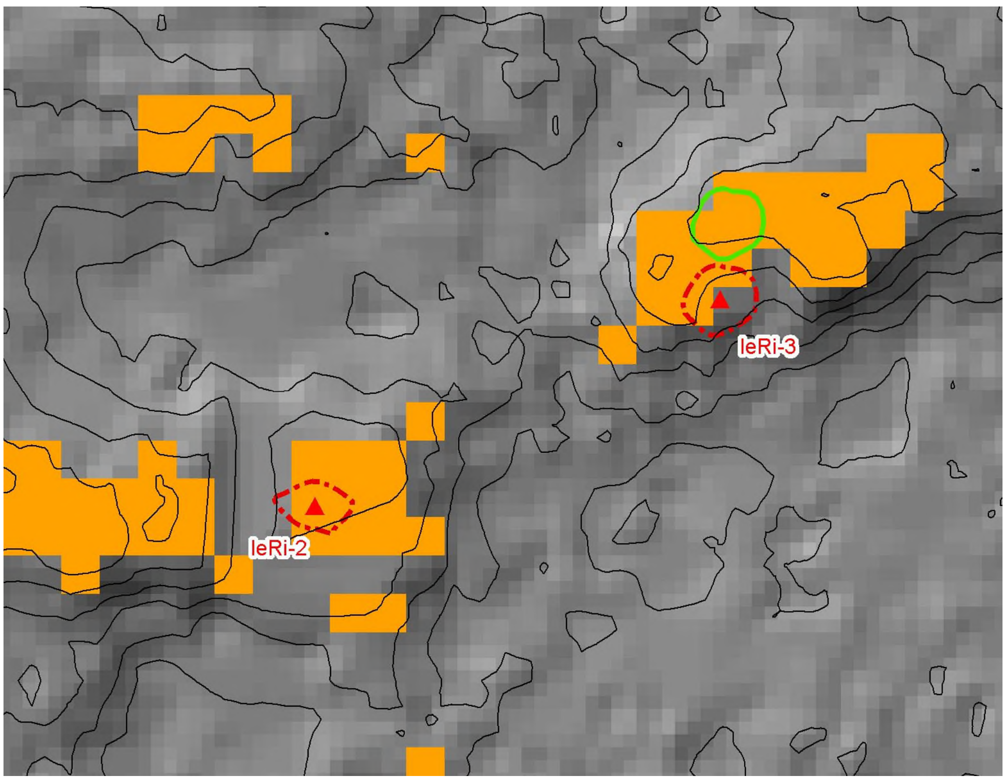


IeRi-2

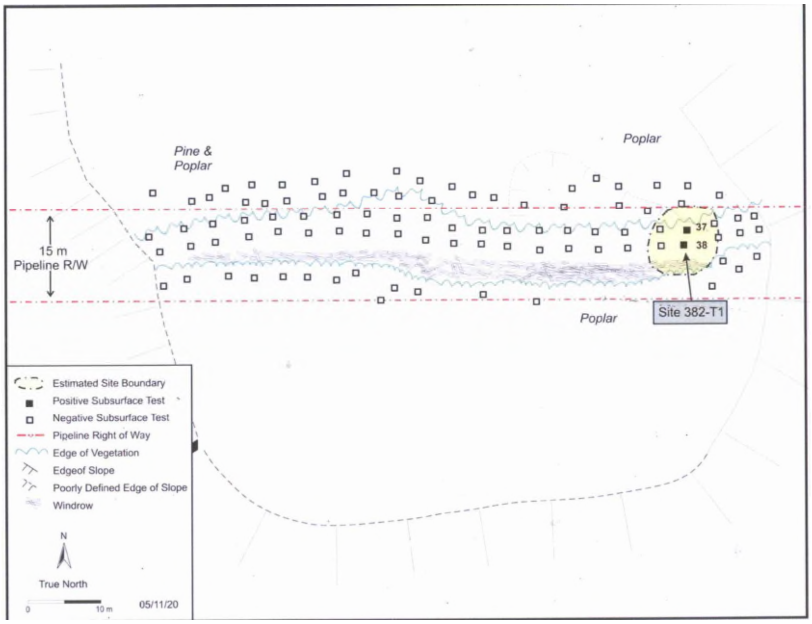


IeRi-3

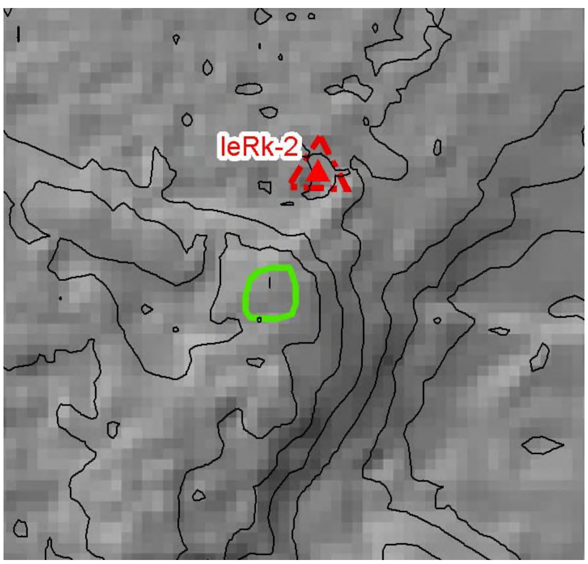

IeRi-3
IeRi-2


IeRi-3
IeRi-2

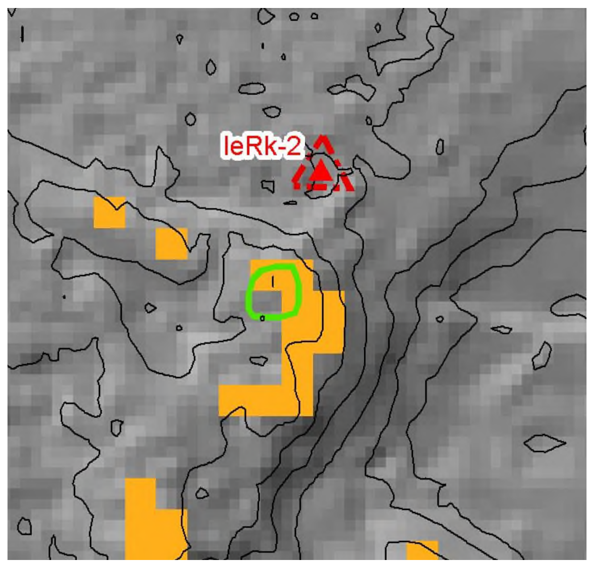
IeRk-2



Pine &
Poplar
Poplar
15 m
Pipeline R/W
37
38
Site 382-T1
Poplar
Estimated Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Pipeline Right of Way
Edge of Vegetation
Edgeof Slope
Poorly Defined Edge of Slope
Windrow
N
True North
0
10 m
05/11/20

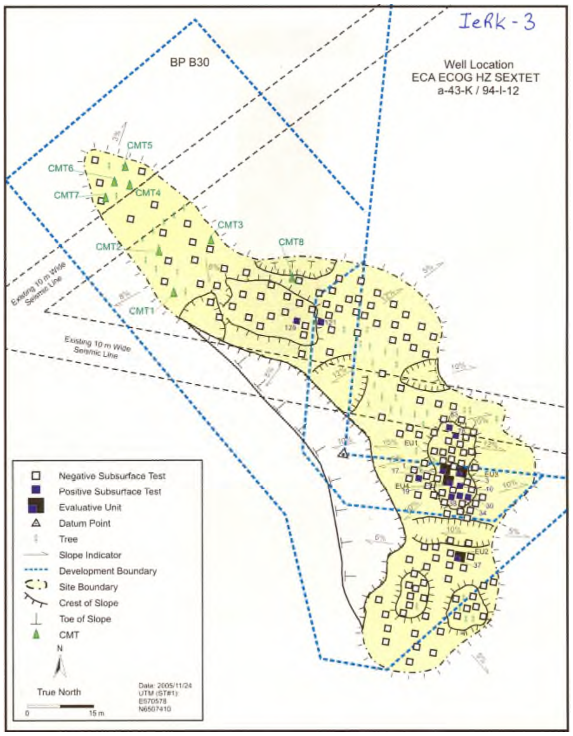


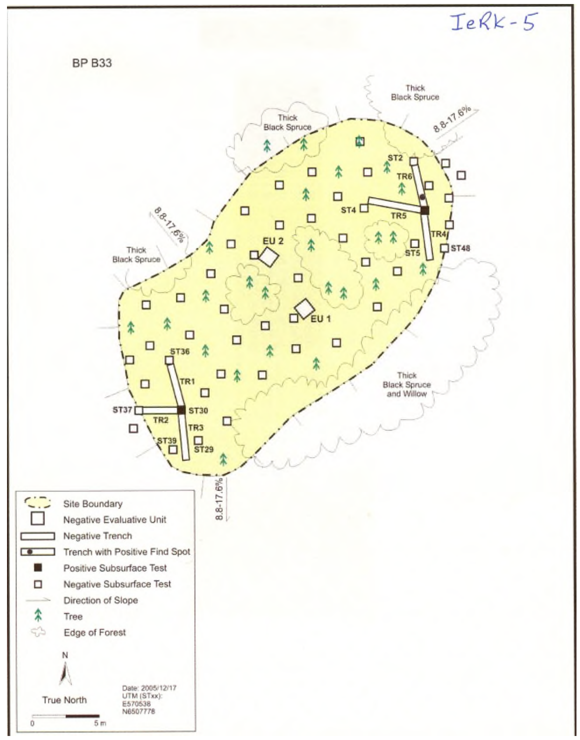
IeRk-2

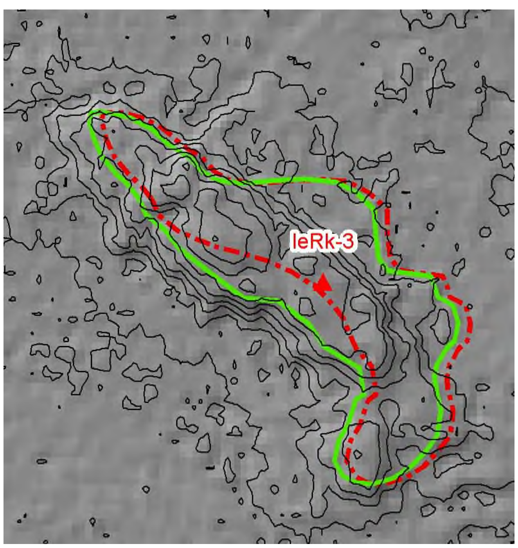


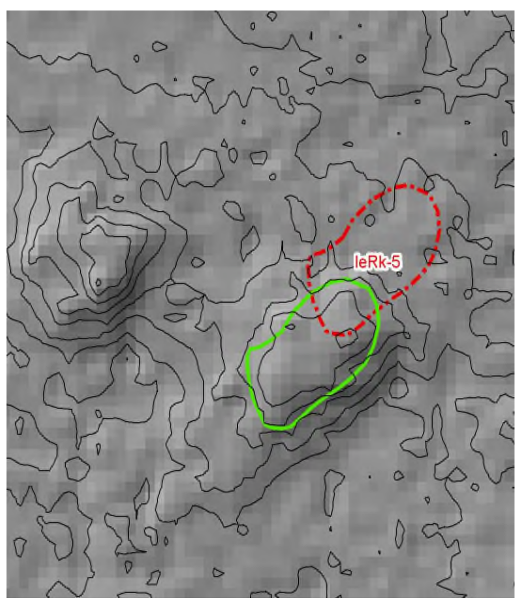
IeRk-2

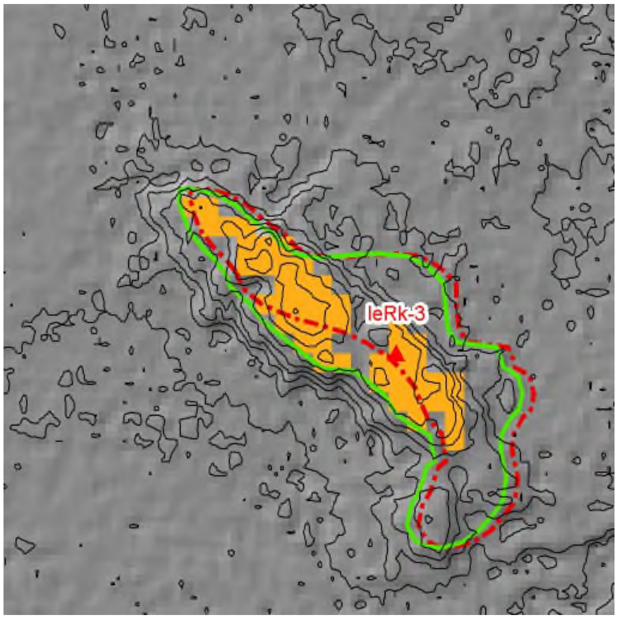
IeRk-3 and IeRk-5

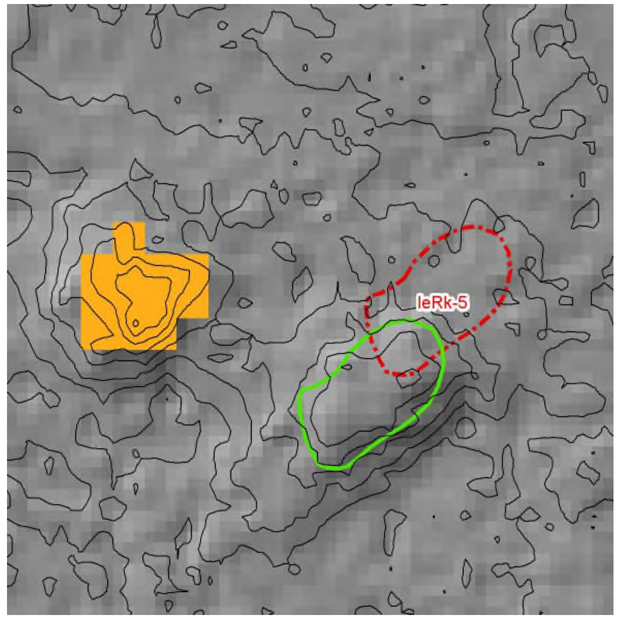




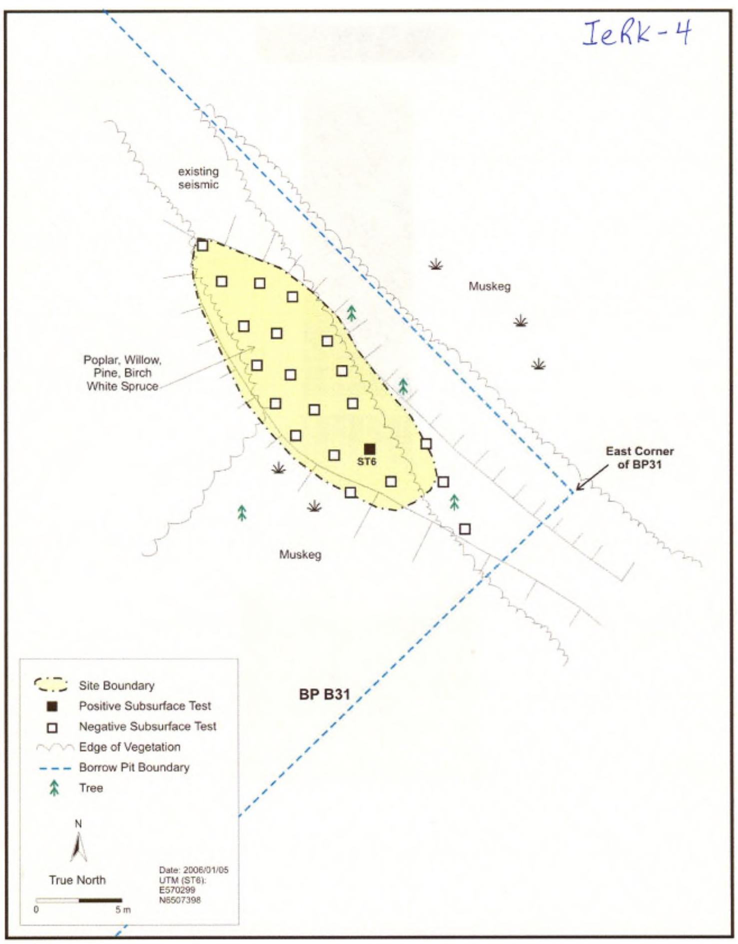




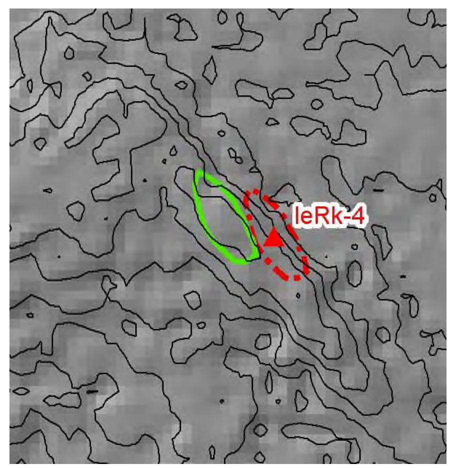


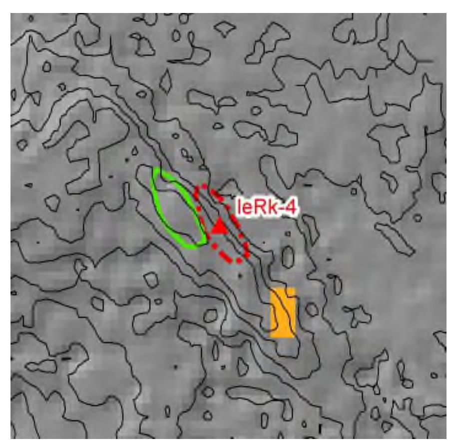


IeRk-4



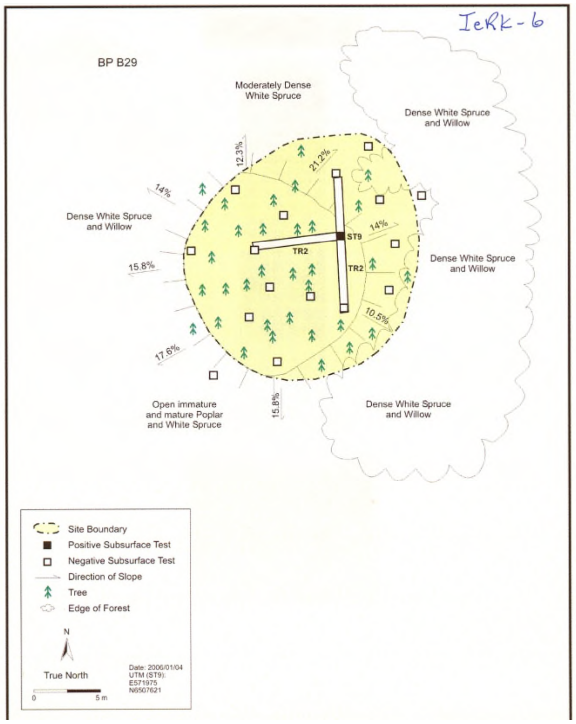
25 cm contours

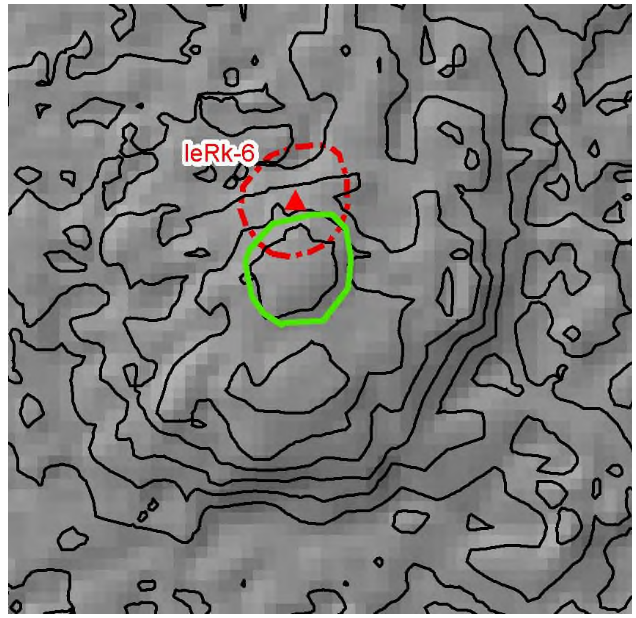


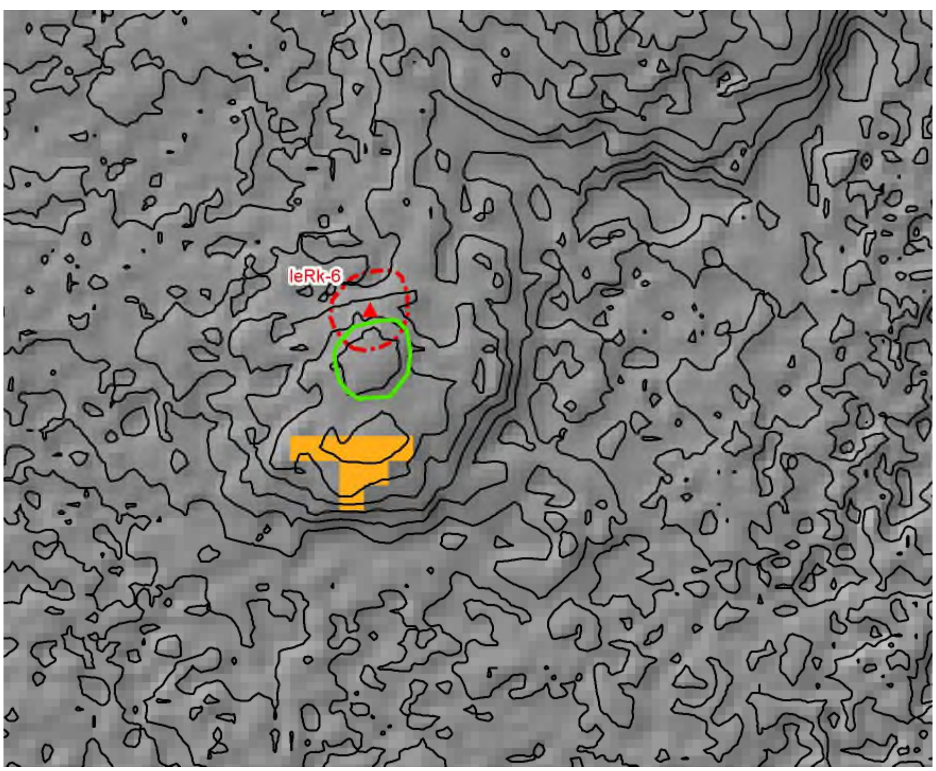


IeRk-6

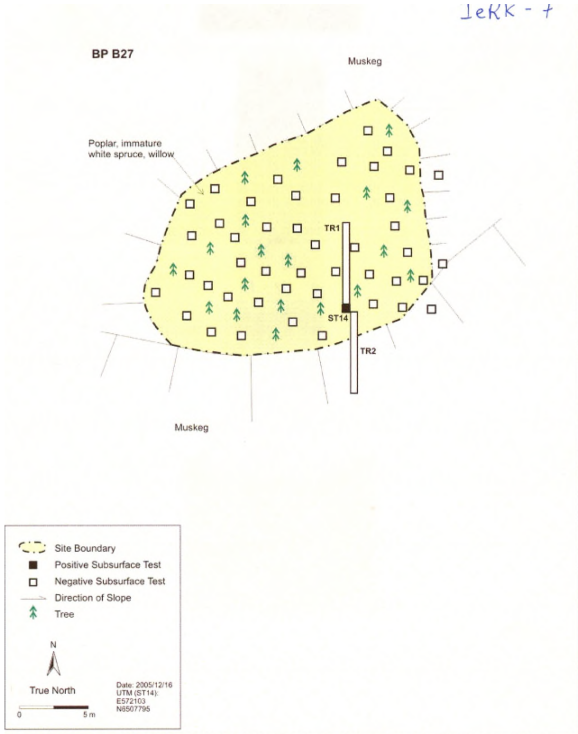
(25 cm contours)

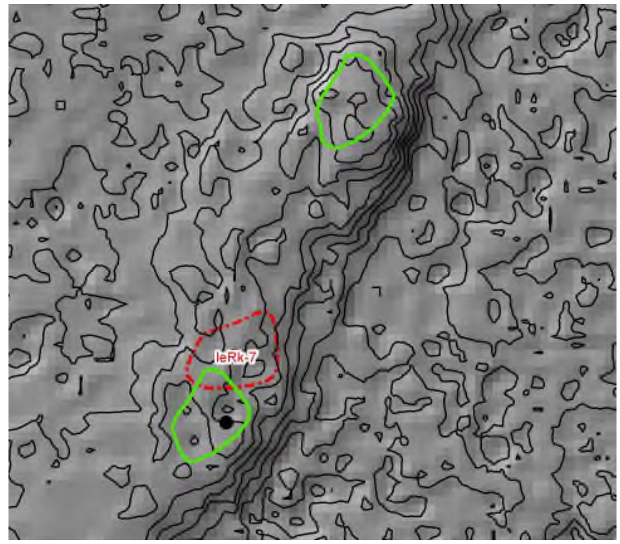






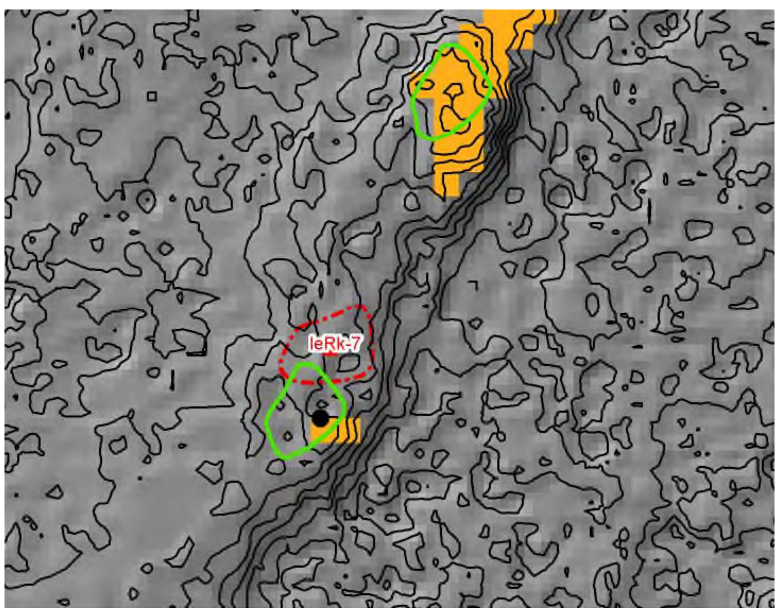
IeRk-7





25 cm contours

Two options presented. The southern option is closer to the GPS location (black dot) but the northern location matches the landform better. Both locations are captured in the model.



IeRk-8

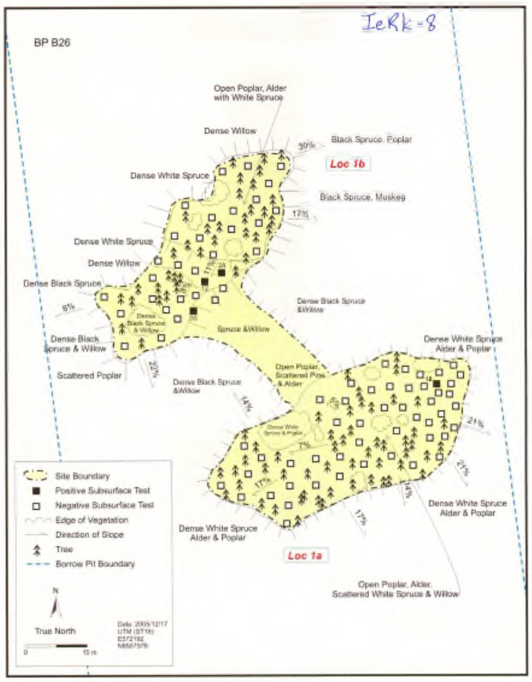
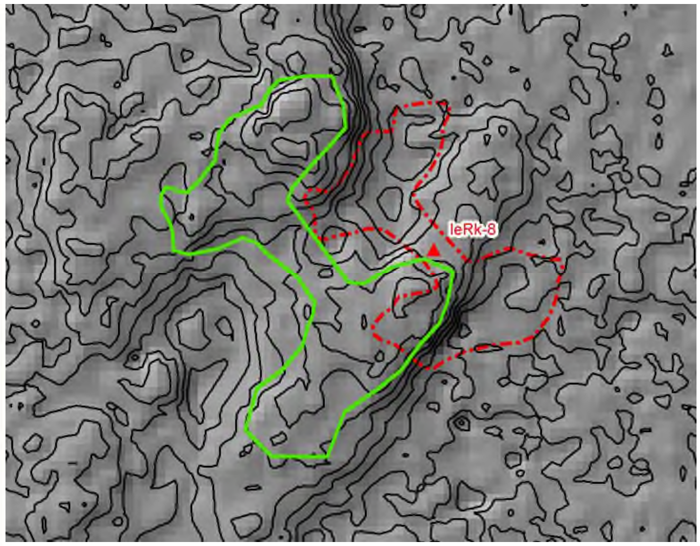
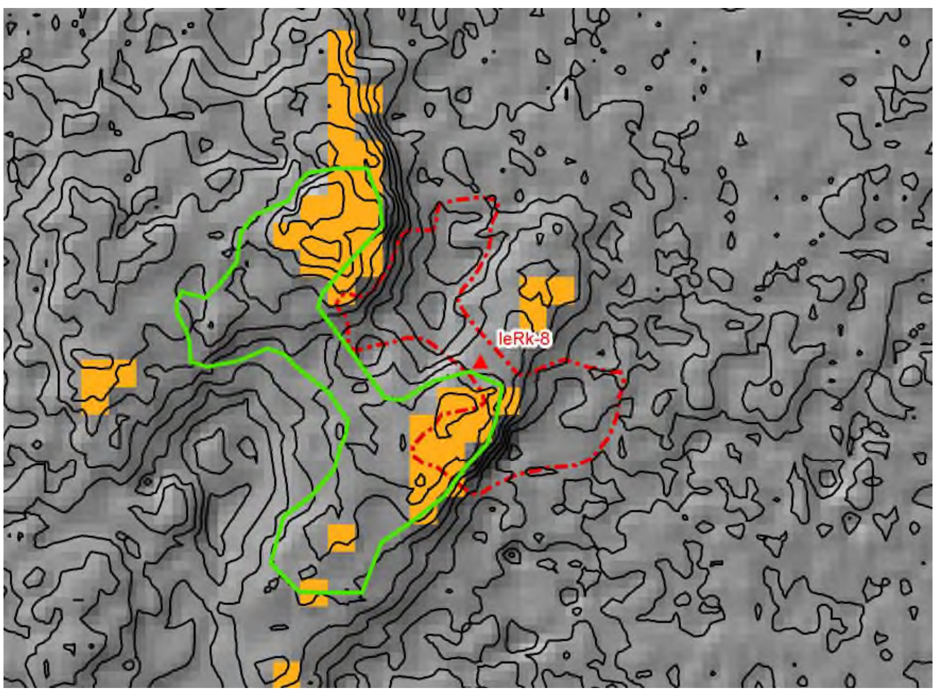
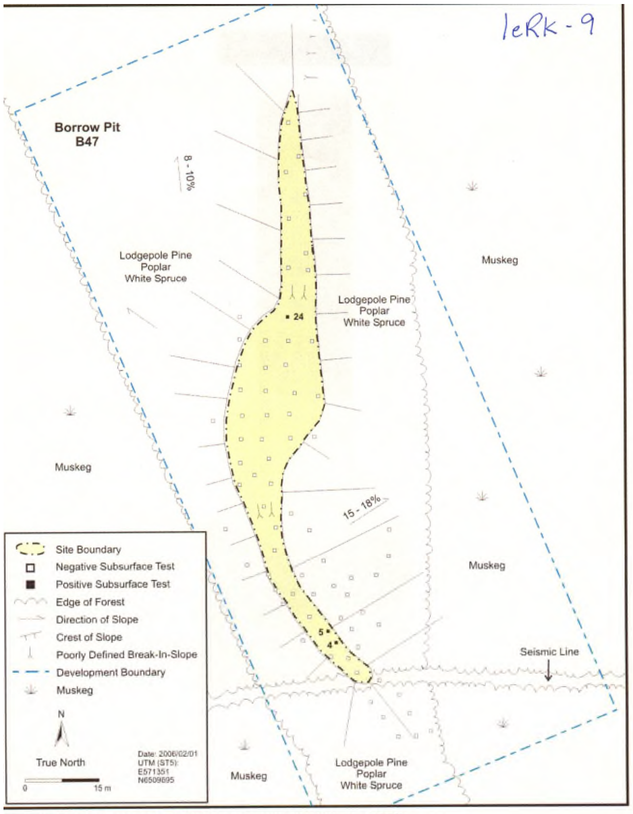


Figure 2. Archaeological Site 337-T6 in Borrow Pit B26 (1:500).

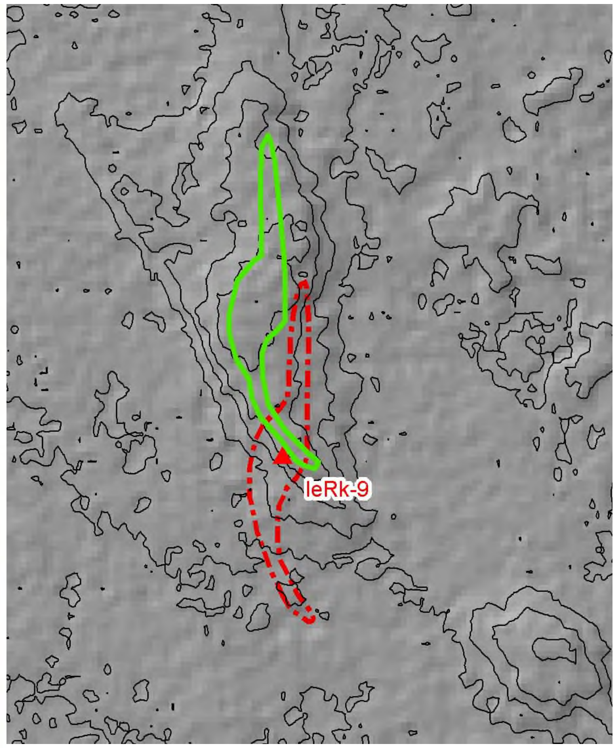


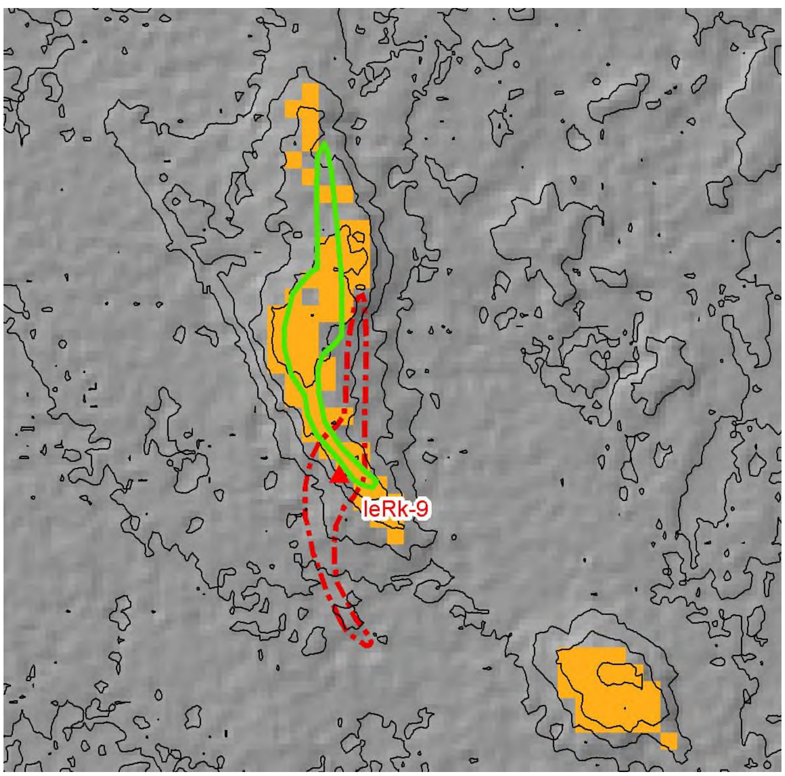


IeRk-9

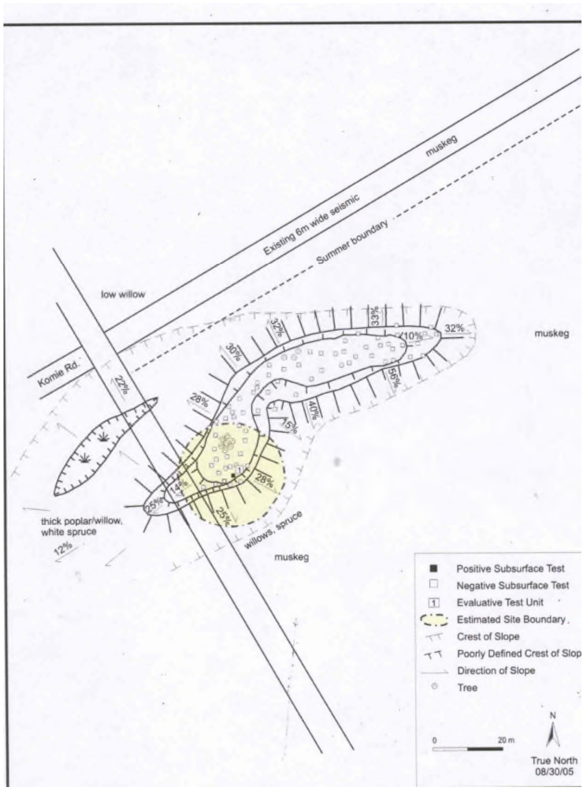


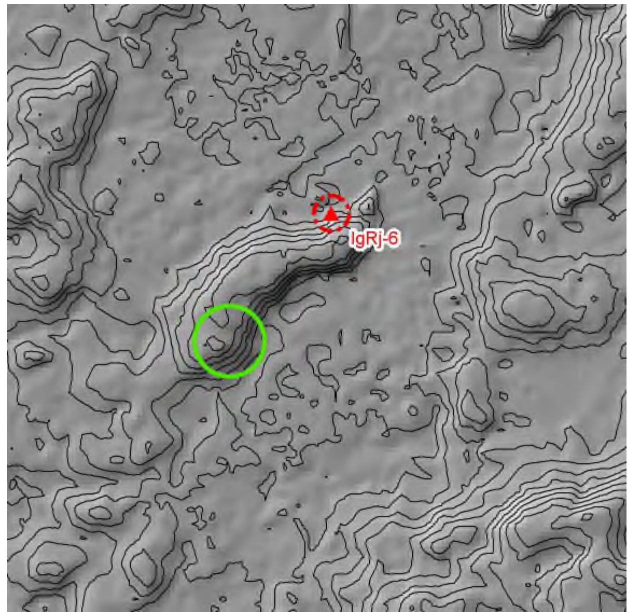
igure 2. Archaeological site 338-CD1 in Borrow Pit B47 (scale 1:750).





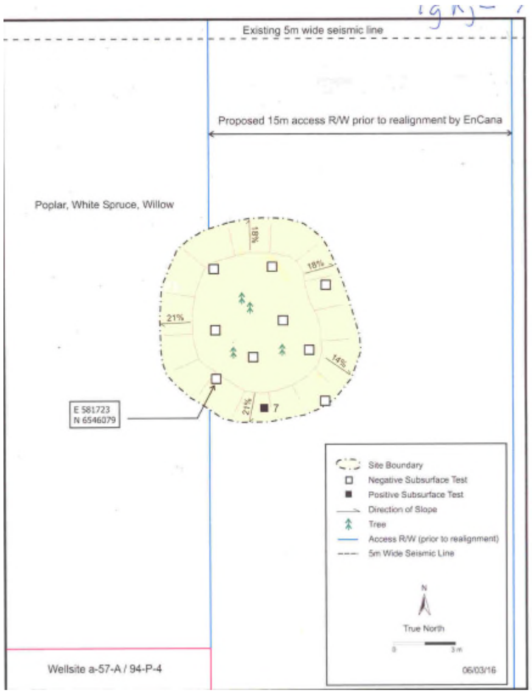
IgRj-6


Existing 6m wide seismic
Summer boundary
muskeg
low willow
Komie Rd.
thick poplar/willow, white spruce
willows, spruce
muskeg
muskeg
Positive Subsurface Test
Negative Subsurface Test
Evaluative Test Unit
Estimated Site Boundary
Crest of Slope
Poorly Defined Crest of Slop
Direction of Slope
Tree
0
20 m
N
True North
08/30/05

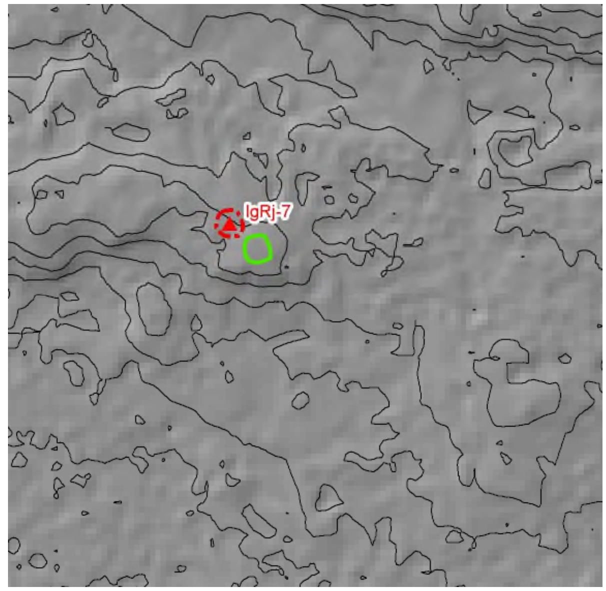

IgRj-6


IgRj-6

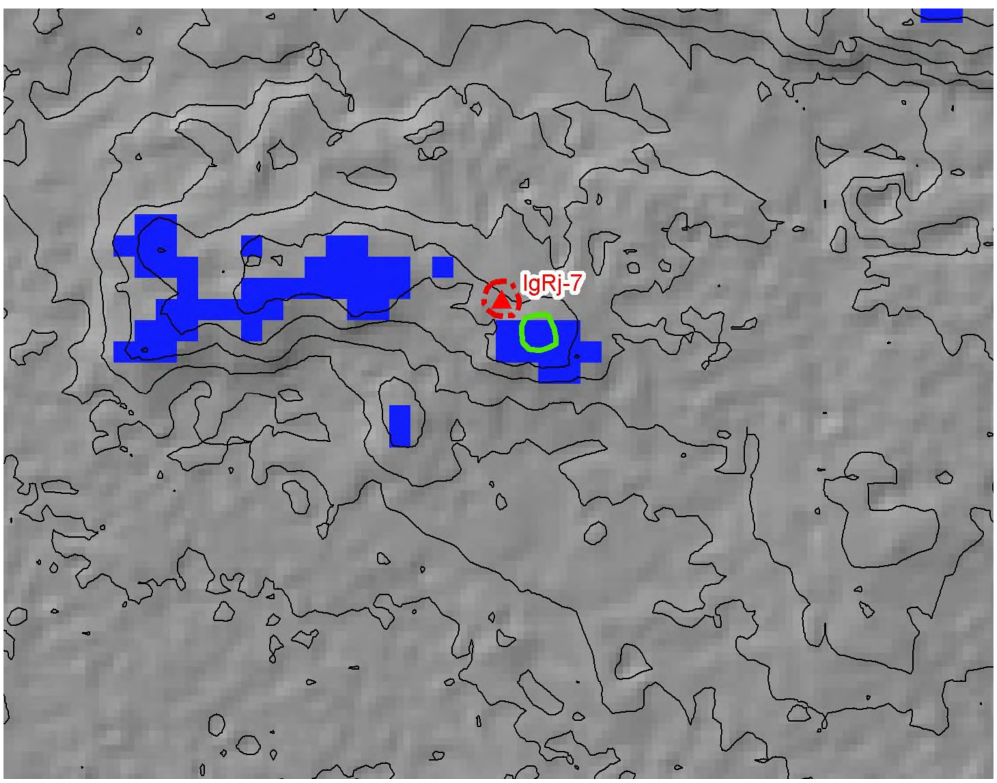
IgRj-7



Existing 5m wide seismic line
Proposed 15m access R/W prior to realignment by EnCana
Poplar, White Spruce, Willow
18%
18%
21%
14%
21%
7
E 581723
N 6546079
Site Boundary
Negative Subsurface Test
Positive Subsurface Test
Direction of Slope
Tree
Access R/W (prior to realignment)
5m Wide Seismic Line
N
True North
0
3 m
Wellsite a-57-A / 94-P-4
06/03/16

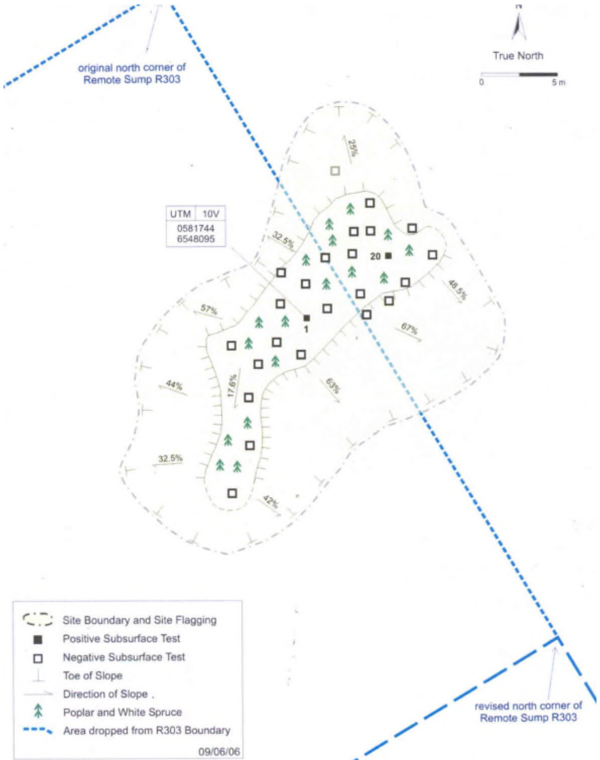


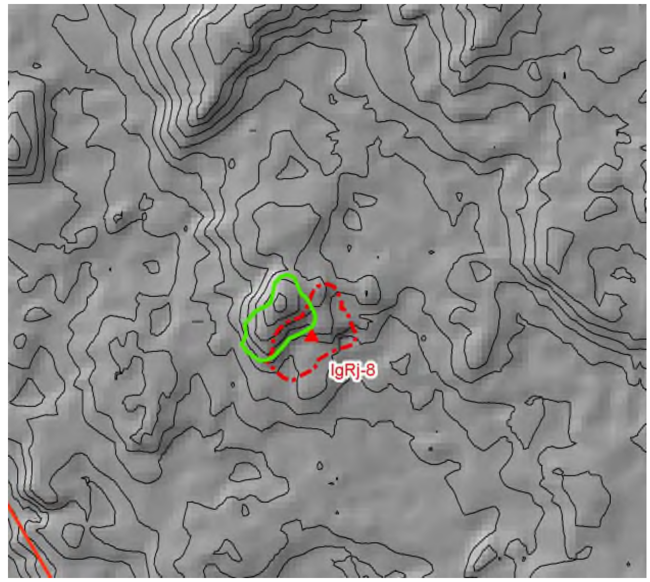
IgRj-7

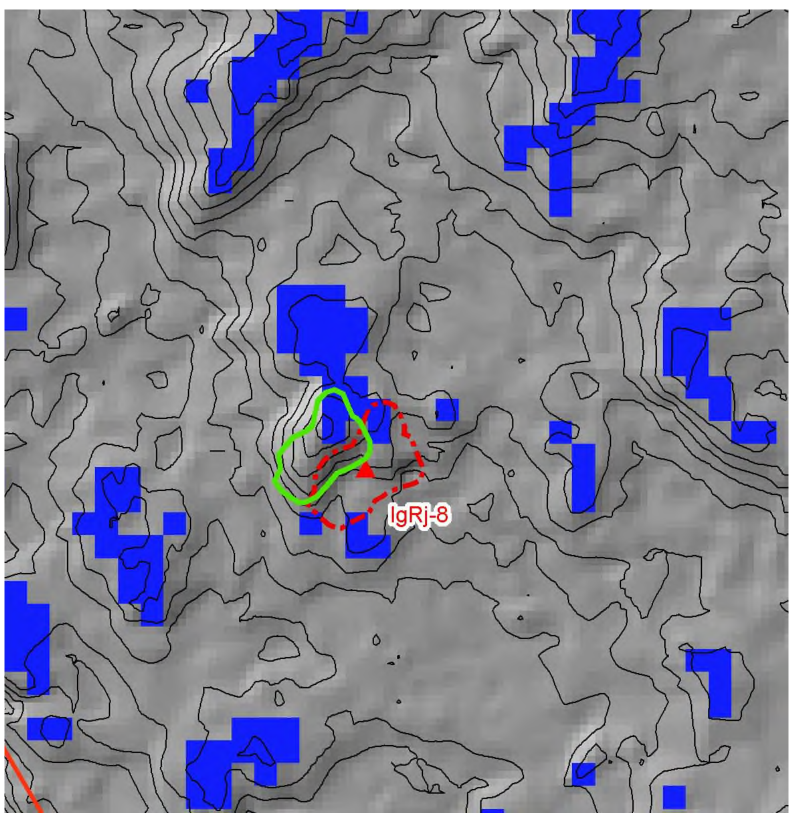


IgRj-7

IgRj-8


original north corner of
Remote Sump R303
True North
0
5 m
UTM 10V
0581744
6548095
20
1
revised north corner of
Remote Sump R303
Site Boundary and Site Flagging
Positive Subsurface Test
Negative Subsurface Test
Toe of Slope
Direction of Slope
Poplar and White Spruce
Area dropped from R303 Boundary
09/06/06


IgRj-8


IgRj-8

IgRk-2

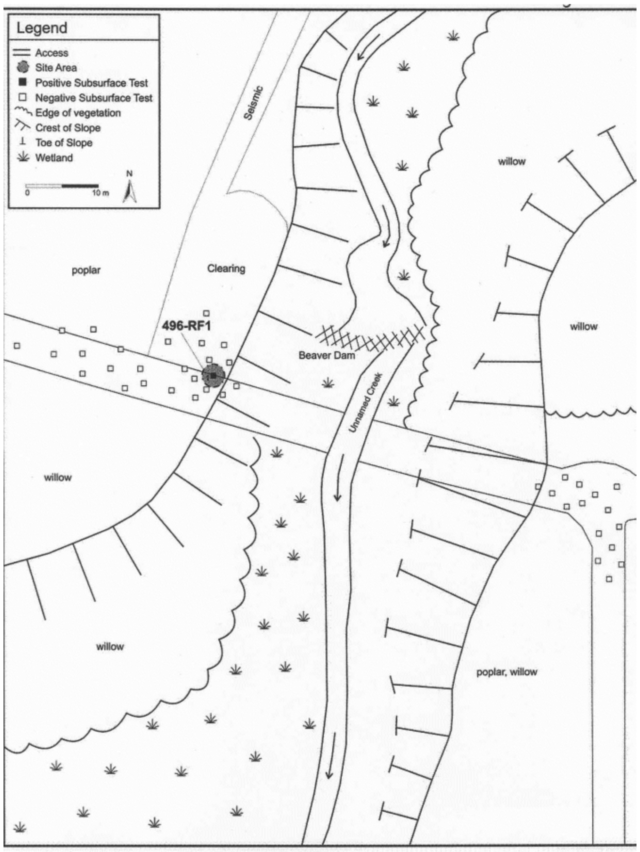
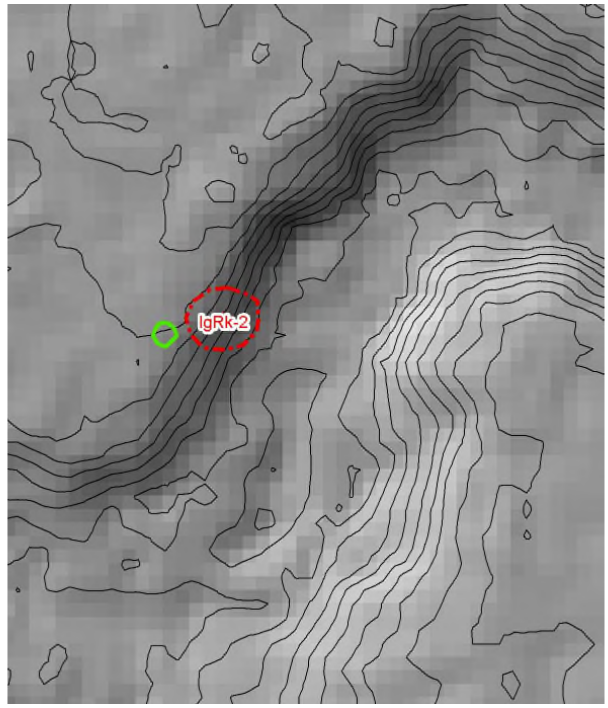
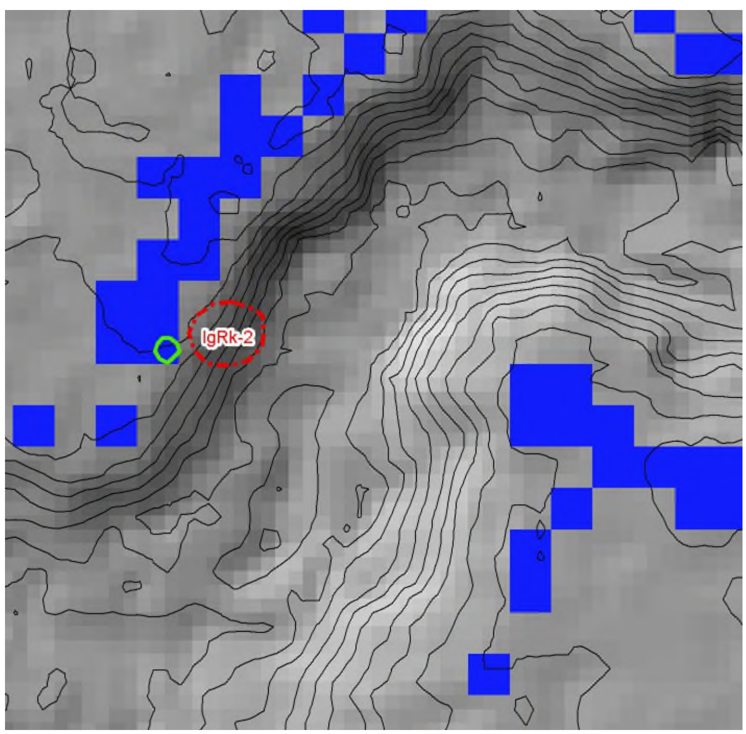
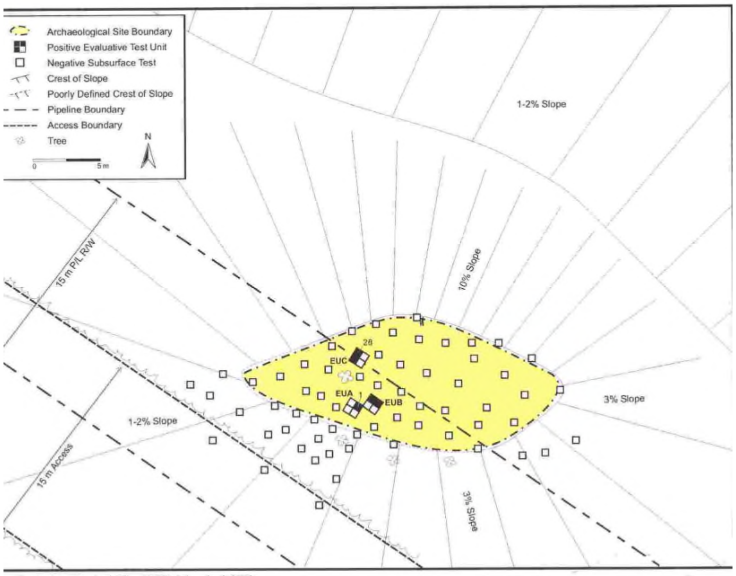


Figure 3. Site 496-RF1: location of subsurface tests (1:500).

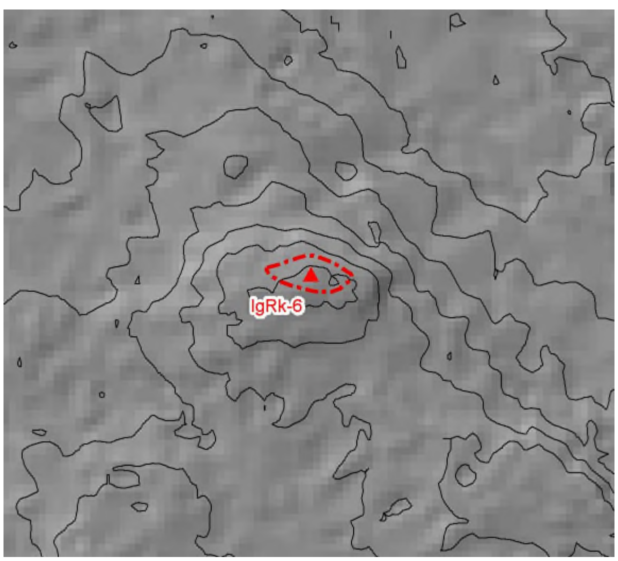




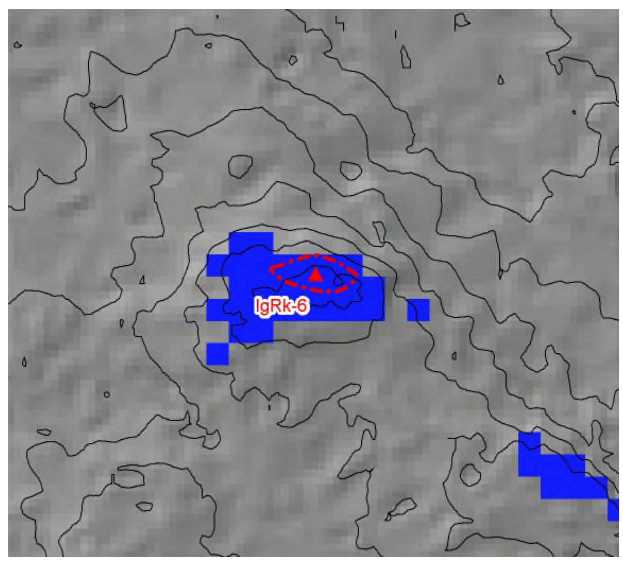
IgRk-6



Archaeological Site Boundary
Positive Evaluative Test Unit
Negative Subsurface Test
Crest of Slope
Poorly Defined Crest of Slope
Pipeline Boundary
Access Boundary
Tree
N
1-2% Slope
10% Slope
15 m P/L R/W
28
EUC
EUA
EUB
3% Slope
1-2% Slope
15 m Access
3% Slope

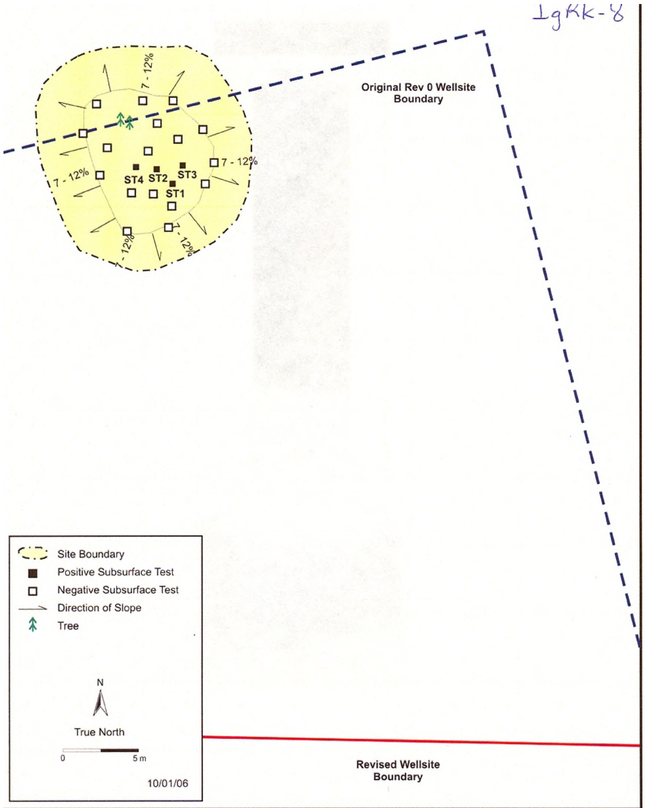


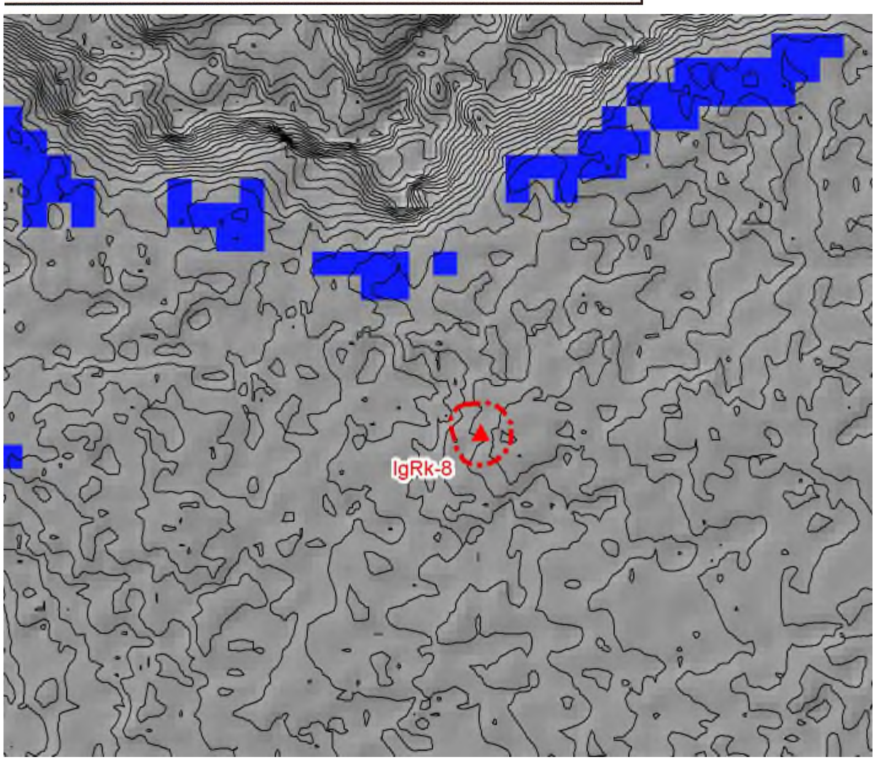
IgRk-6



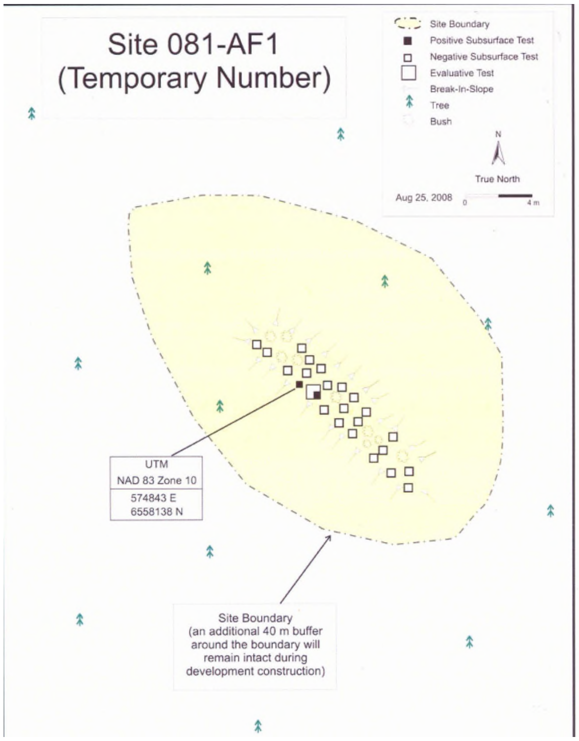
IgRk-6

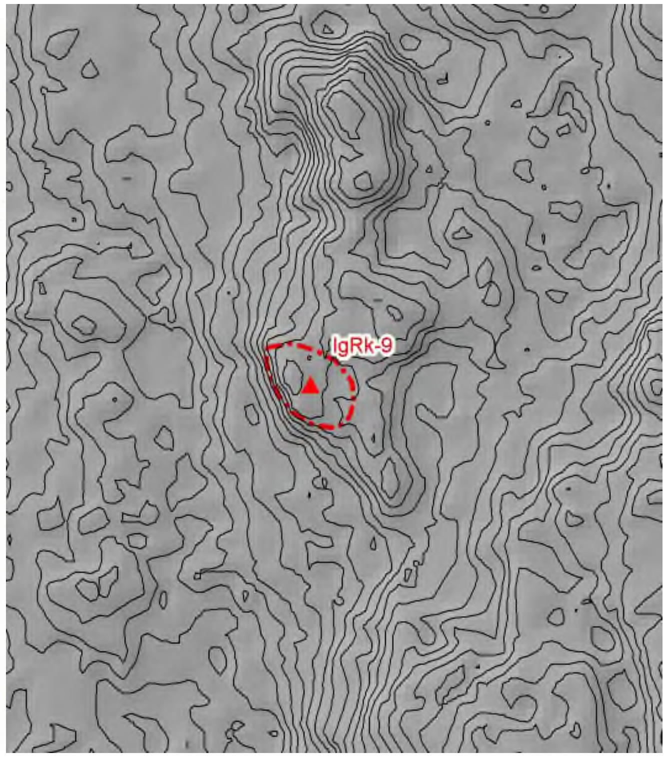
IgRk-8

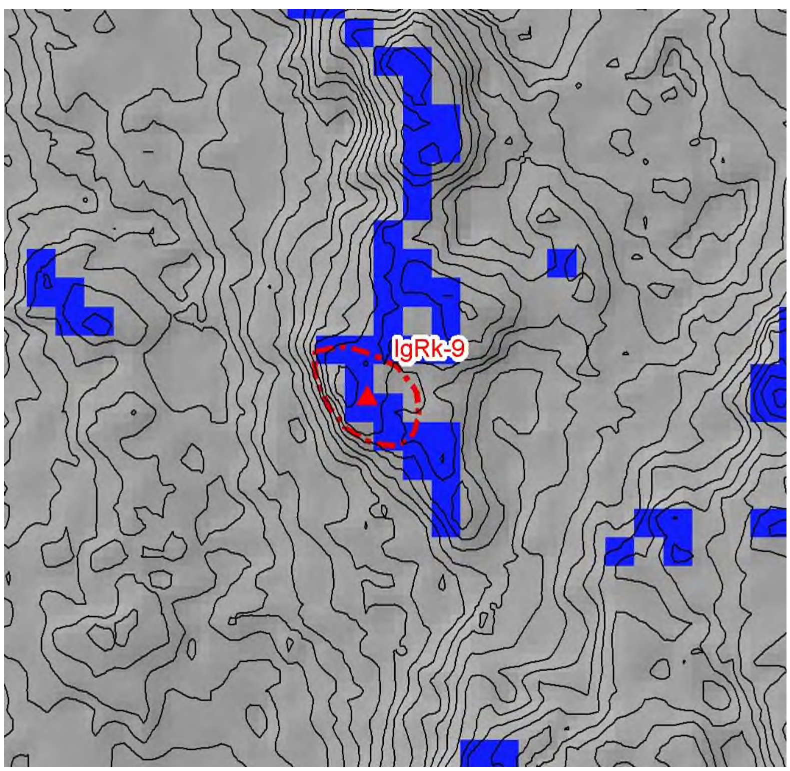

IgRk-8
Original Rev 0 Wellsite Boundary
7 - 12%
ST4 ST2 ST3
ST1
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Direction of Slope
Tree
N
True North
0
5 m
10/01/06
Revised Wellsite Boundary


IgRk-8

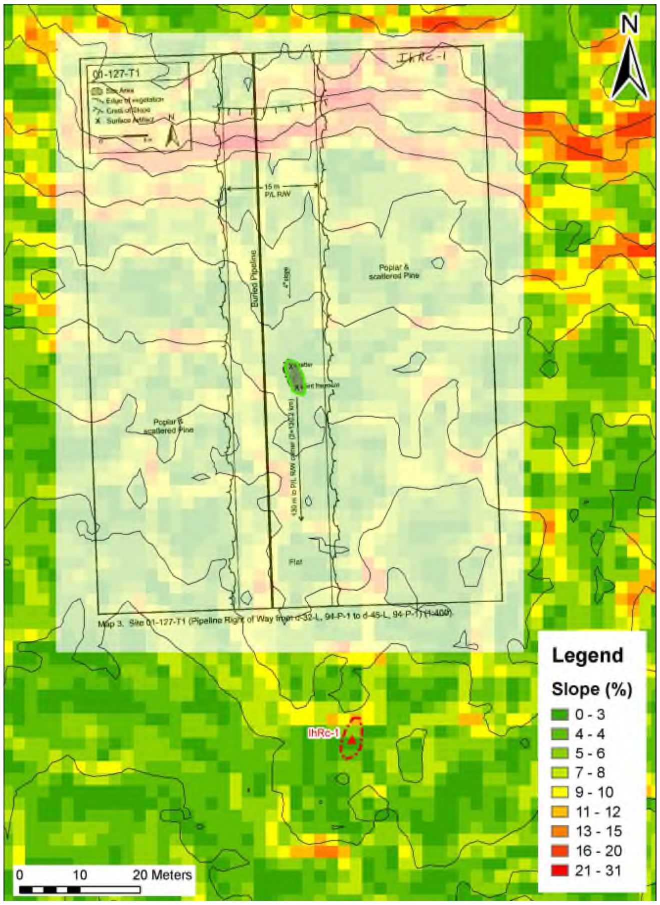
IgRk-9

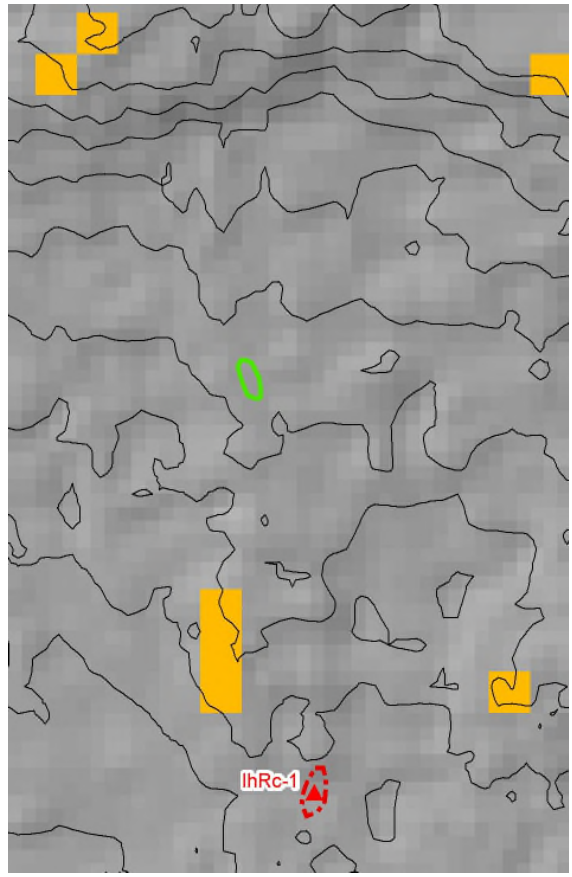

Site 081-AF1
(Temporary Number)
Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Evaluative Test
Break-In-Slope
Tree
Bush
True North
Aug 25, 2008
UTM
NAD 83 Zone 10
574843 E
6558138 N
Site Boundary
(an additional 40 m buffer
around the boundary will
remain intact during
development construction)


IgRk-9

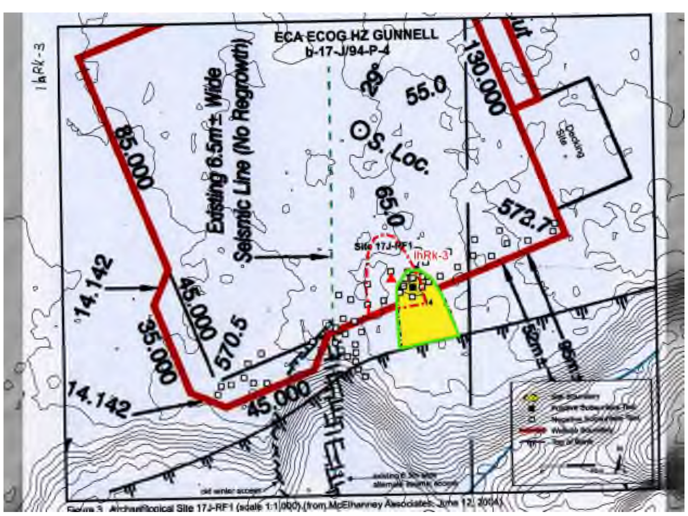

IgRk-9

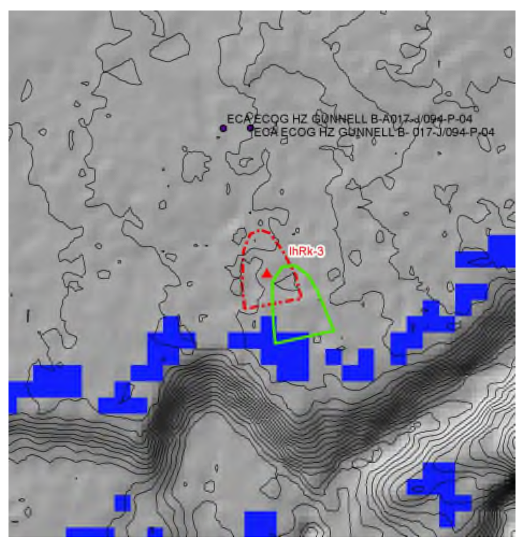
IhRc-1


N
Map 3. Site 01-127-T1 (Pipeline Right of Way from c-32-L, 94-P-1 to d-45-L, 94-P-1) (1:400)
Buried Pipeline
Poplar & scattered Pine
Flat
IhRc-1
Legend
Slope (%)
0 - 3
4 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13 - 15
16 - 20
21 - 31
0 10 20 Meters

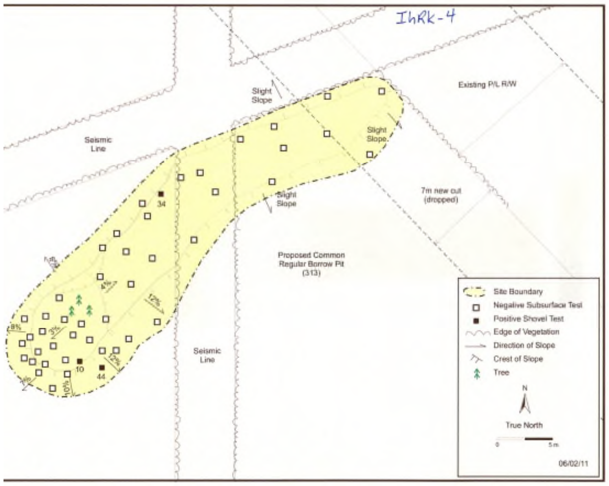

IhRc-1

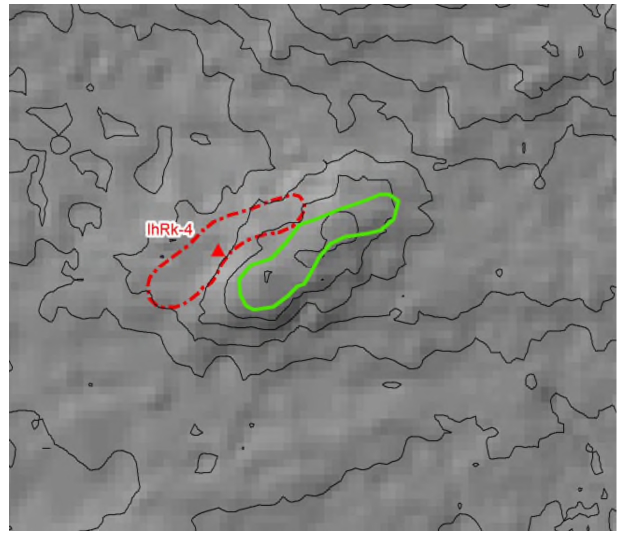
IhRk-3

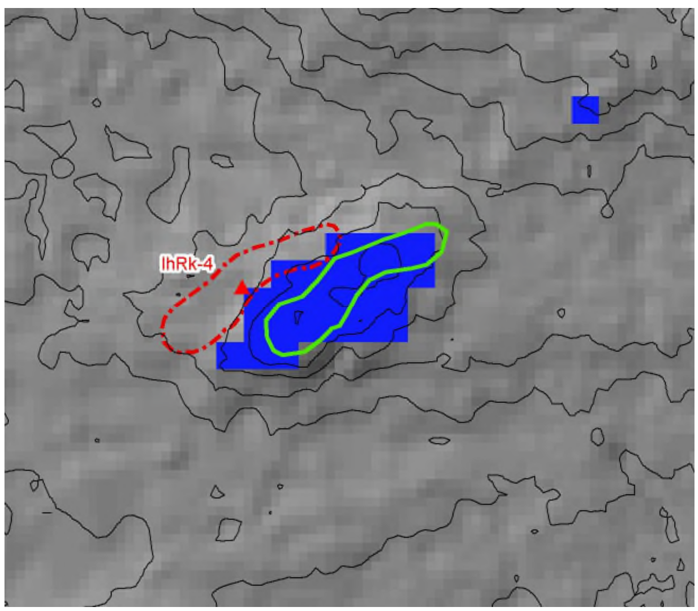

IhRk-3
ECA ECOG HZ GUNNELL
b-17-J/94-P-4
Existing 6.5m± Wide
Seismic Line (No Regrowth)
85.000
29°
55.0
O.S. Loc.
130.000
65.0
573.7
Site 17J-RF1
IhRk-3
14.142
45.000
35.000
570.5
14.142
45.000
Decking Site
Figure 3. Archaeological Site 17J-RF1 (scale 1:1,000) (from McElhanney Associates, June 12, 2004)


ECA ECOG HZ GUNNELL B-A017-J/094-P-04
ECA ECOG HZ GUNNELL B- 017-J/094-P-04
IhRk-3

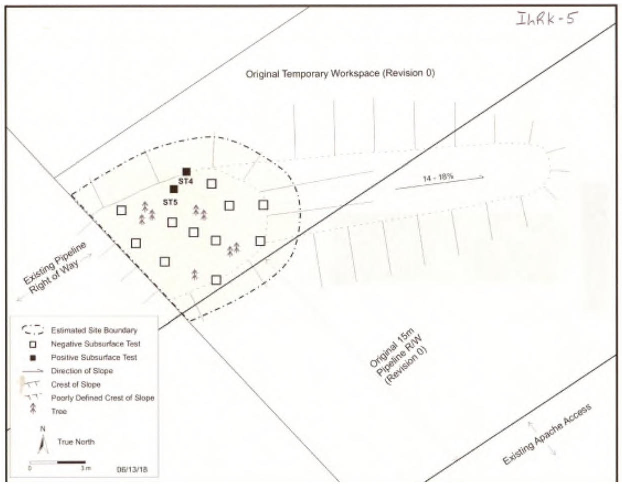
IhRk-4

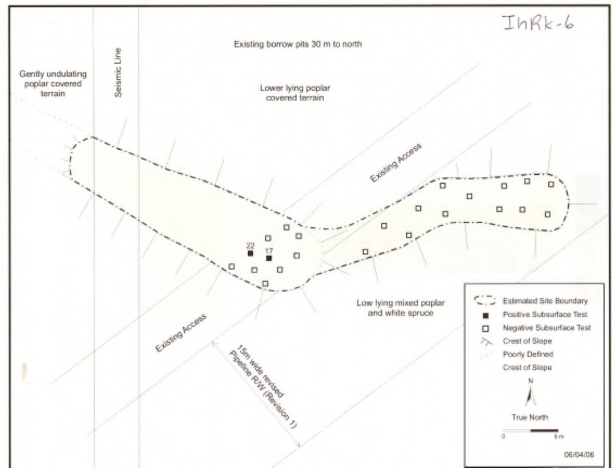

IhRk-4
Existing P/L R/W
Slight Slope
Seismic Line
Slight Slope
7m new cut (dropped)
Slight Slope
34
Proposed Common Regular Borrow Pit (313)
12%
8%
12%
10%
10
44
Seismic Line
Site Boundary
Negative Subsurface Test
Positive Shovel Test
Edge of Vegetation
Direction of Slope
Crest of Slope
Tree
N
True North
0
5 m
06/02/11

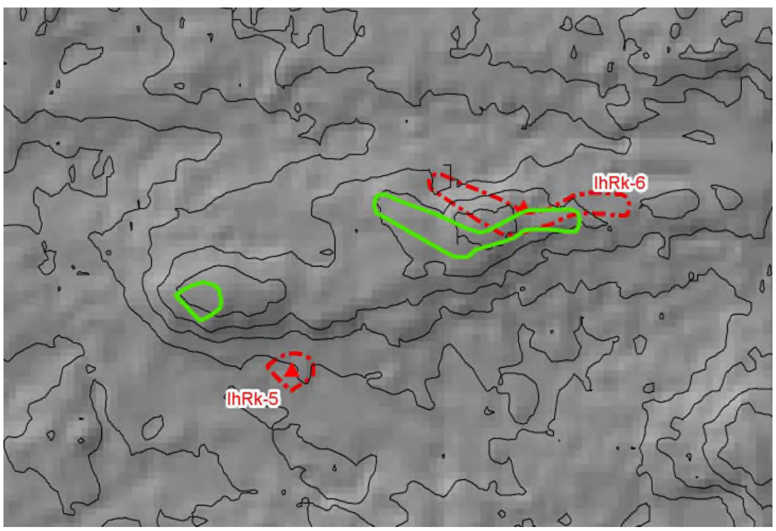

IhRk-4

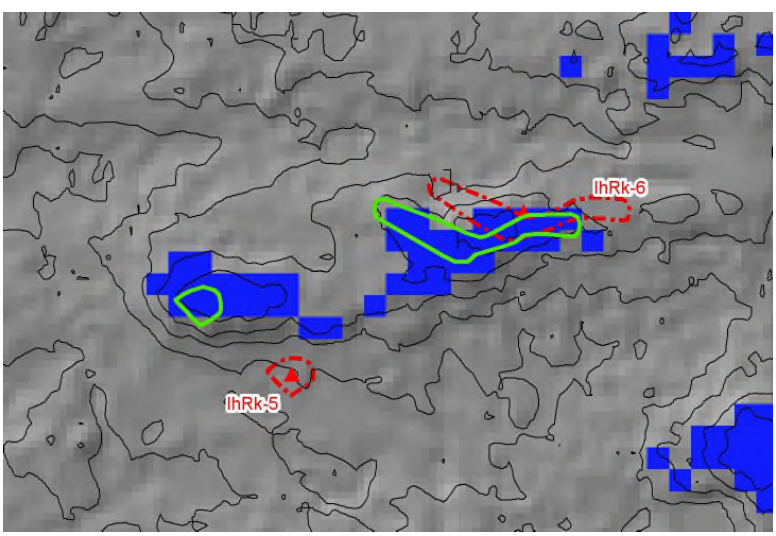

IhRk-4

IhRk-5 & IhRk-6

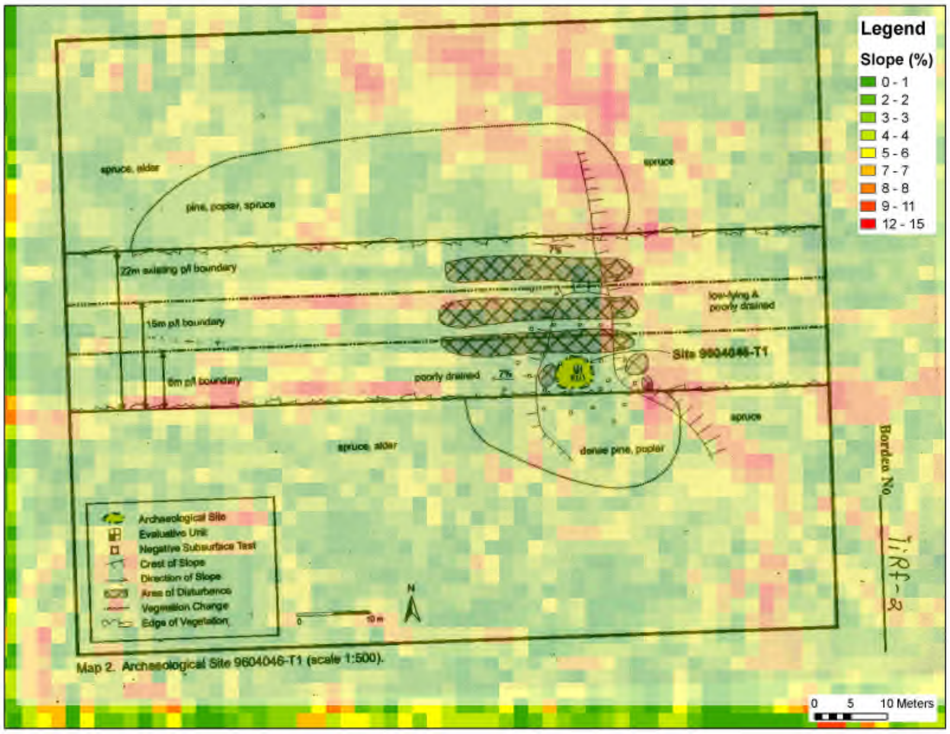

IhRk-5
Original Temporary Workspace (Revision 0)
ST4
ST5
14 - 18%
Existing Pipeline Right of Way
Original 15m Pipeline R/W (Revision 0)
Existing Apache Access
Estimated Site Boundary
Negative Subsurface Test
Positive Subsurface Test
Direction of Slope
Crest of Slope
Poorly Defined Crest of Slope
Tree
N
True North
0
3m
06/13/18


IhRk-6
Existing borrow pits 30 m to north
Gently undulating poplar covered terrain
Seismic Line
Lower lying poplar covered terrain
Existing Access
22
17
Low lying mixed poplar and white spruce
Existing Access
15m wide revised Pipeline R/W (Revision 1)
Estimated Site Boundary
Positive Subsurface Test
Negative Subsurface Test
Crest of Slope
Poorly Defined Crest of Slope
N
True North
0
6m
06/04/06

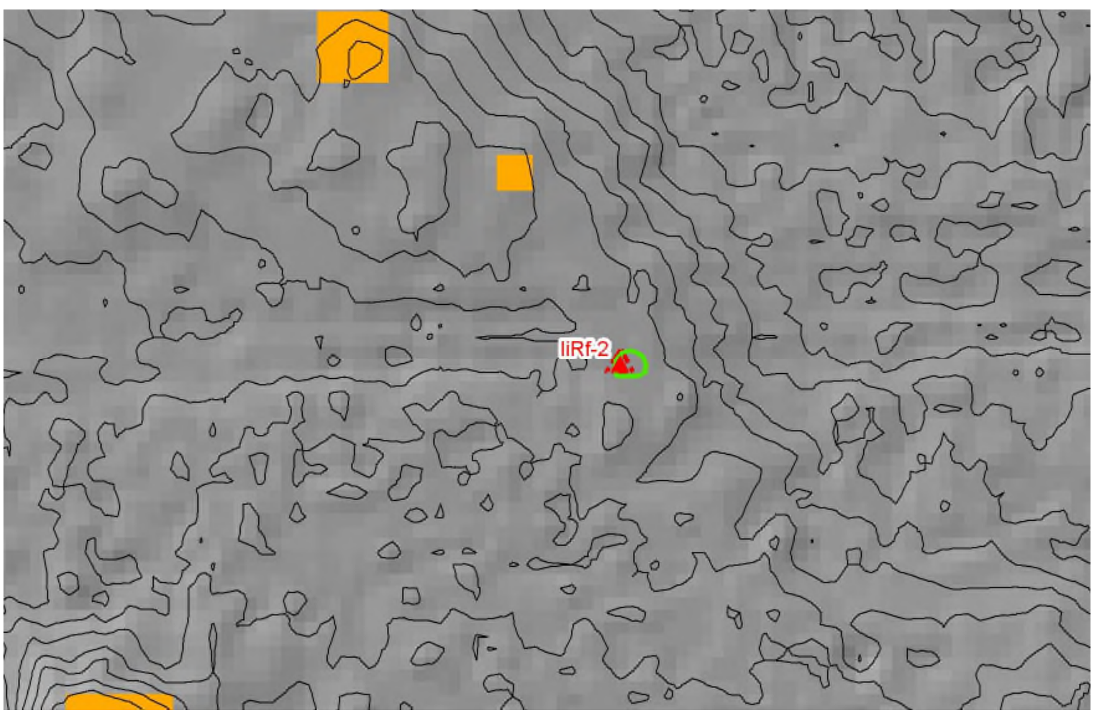

IhRk-6
IhRk-5


IhRk-6
IhRk-5

IiRf-2

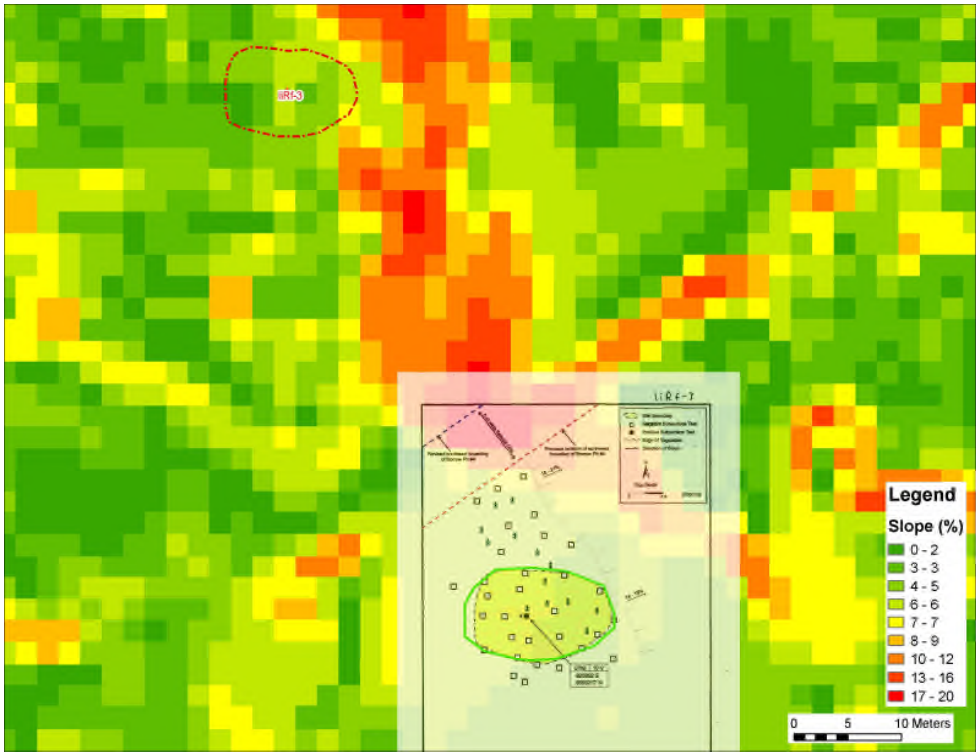


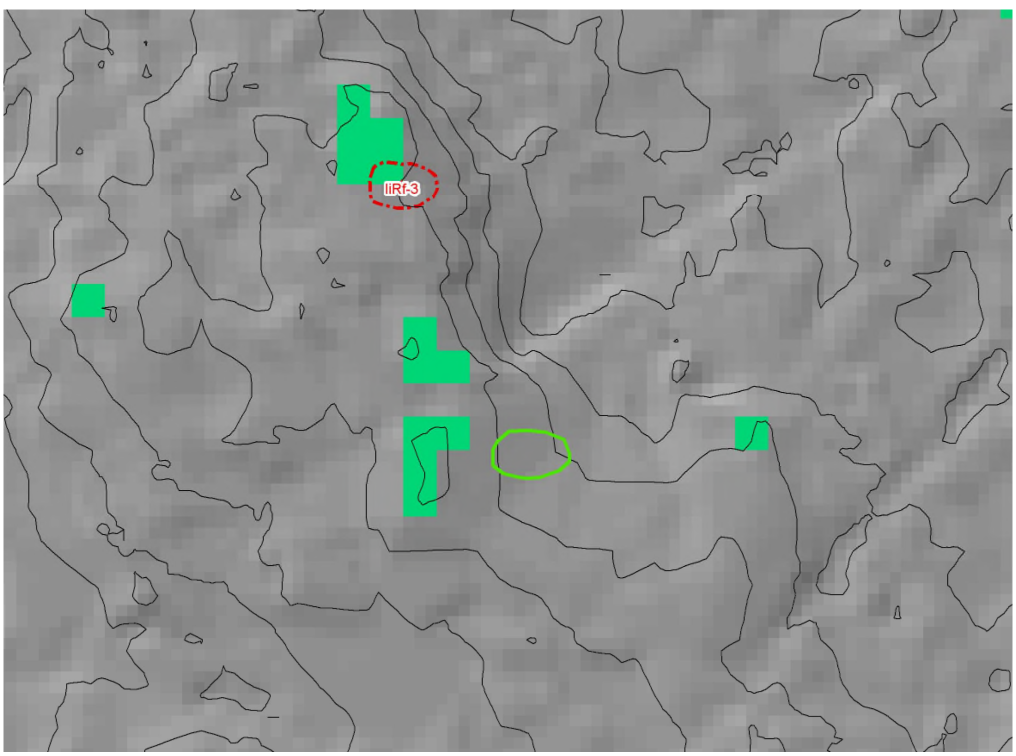
Legend
Slope (%)
0 - 1
2 - 2
3 - 3
4 - 4
5 - 6
7 - 7
8 - 8
9 - 11
12 - 15
spruce, alder
pine, poplar, spruce
spruce
22m existing p/l boundary
15m p/l boundary
6m p/l boundary
low-lying & poorly drained
Site 9604046-T1
poorly drained
spruce
spruce, alder
dense pine, poplar
Archaeological Site
Evaluative Unit
Negative Subsurface Test
Crest of Slope
Direction of Slope
Area of Disturbance
Vegetation Change
Edge of Vegetation
Borden No.
Map 2. Archaeological Site 9604046-T1 (scale 1:500).
0 5 10 Meters



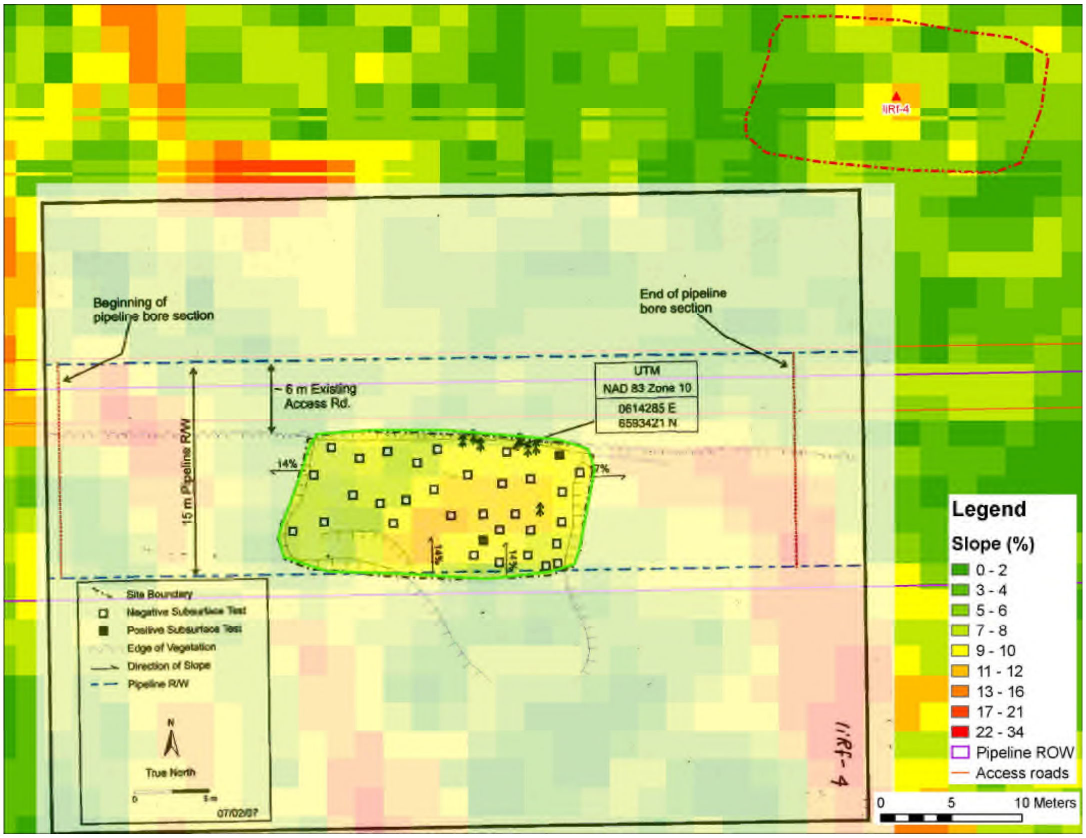
IiRf-2

<u>IiRf-3</u>

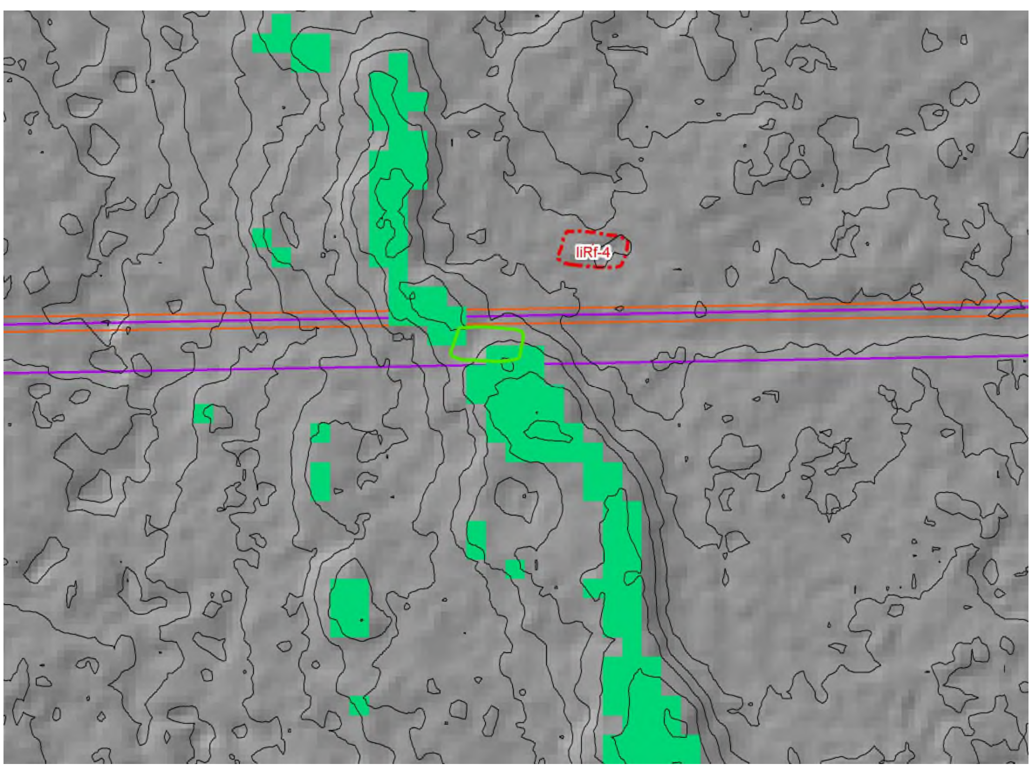

IiRf-3
Legend
Slope (%)
0 - 2
3 - 3
4 - 5
6 - 6
7 - 7
8 - 9
10 - 12
13 - 16
17 - 20
0
5
10 Meters


IiRf-3

IiRf-4

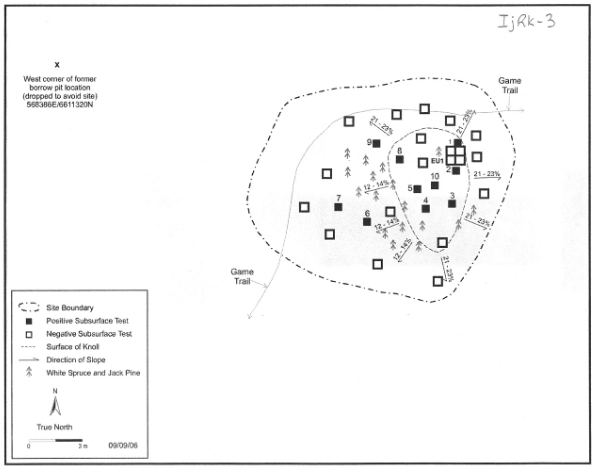


IiRf-4
Beginning of pipeline bore section
End of pipeline bore section
UTM
NAD 83 Zone 10
0614285 E
6593421 N
6 m Existing Access Rd.
15 m Pipeline R/W
14%
7%
Site Boundary
Negative Subsurface Test
Positive Subsurface Test
Edge of Vegetation
Direction of Slope
Pipeline R/W
N
True North
07/02/07
IiRf-4
Legend
Slope (%)
0 - 2
3 - 4
5 - 6
7 - 8
9 - 10
11 - 12
13 - 16
17 - 21
22 - 34
Pipeline ROW
Access roads
0
5
10 Meters

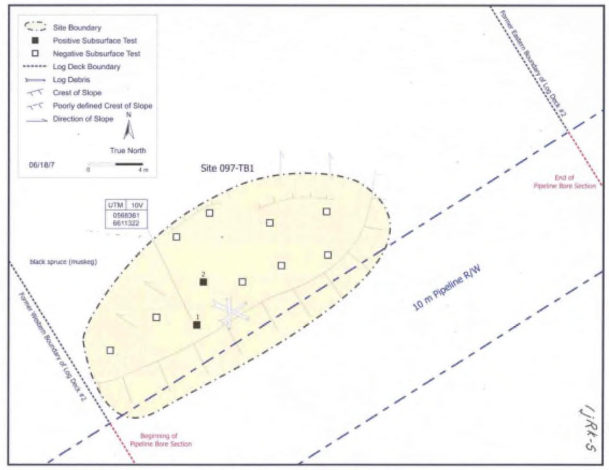


IiRf-4

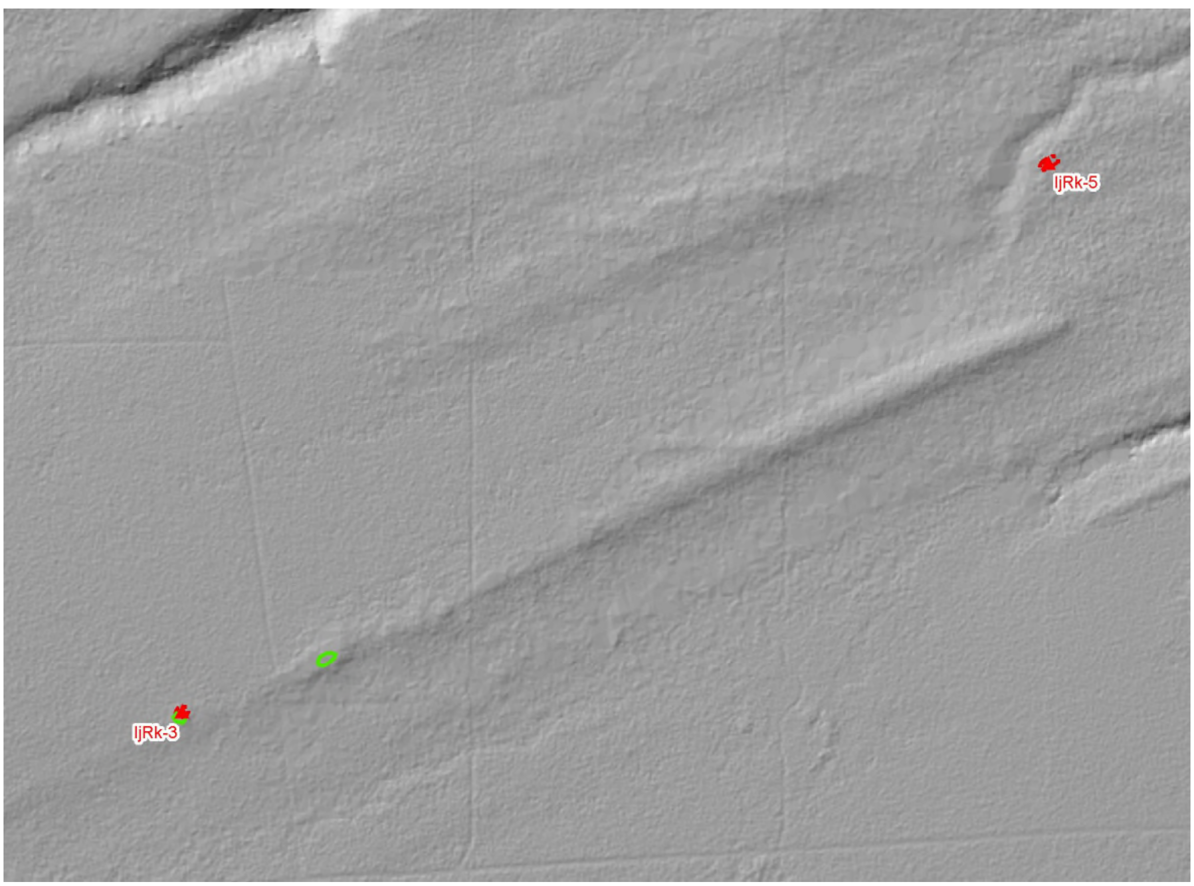
IjRk-3 & IjRk-5

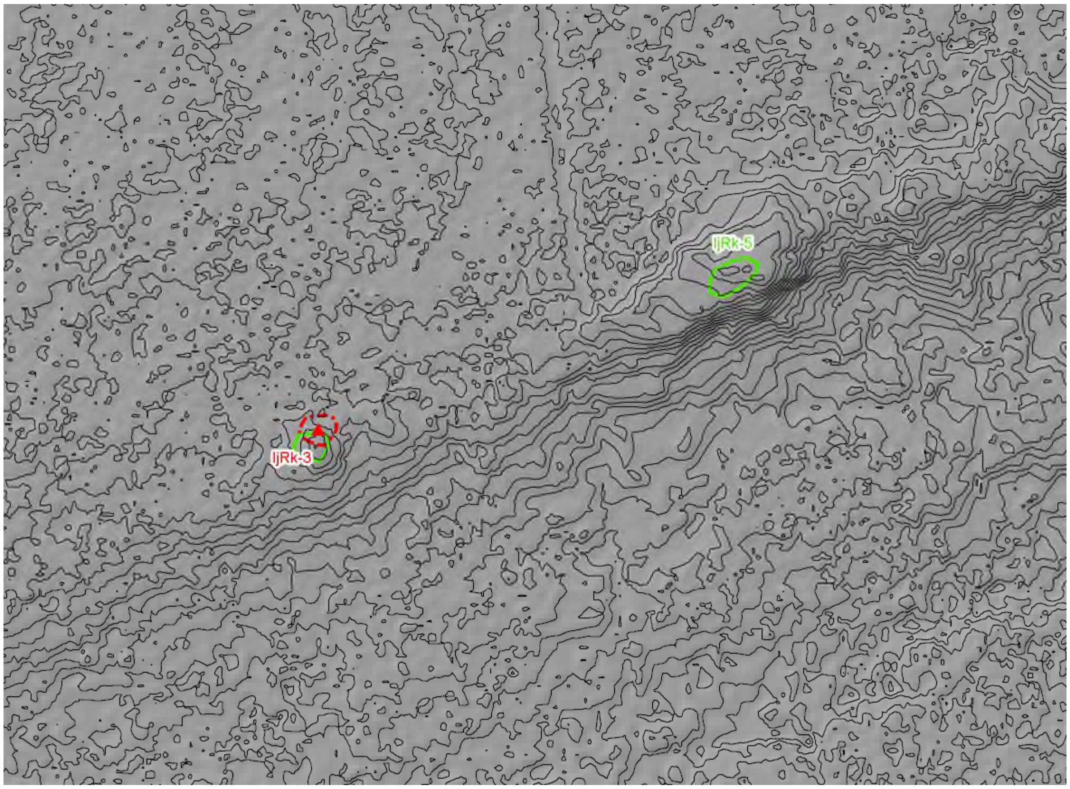


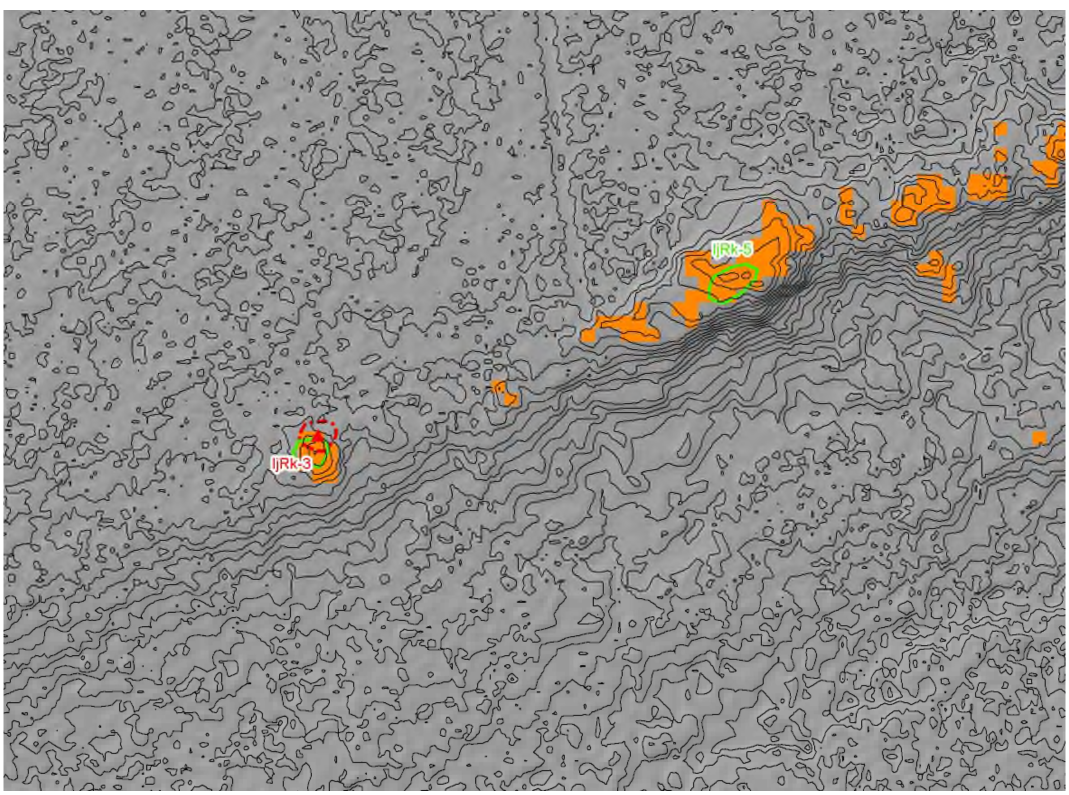
Map 2. Archaeological site 088-PJ1 (1:150; Arcas Consulting Archaeologists, August 9, 2006).



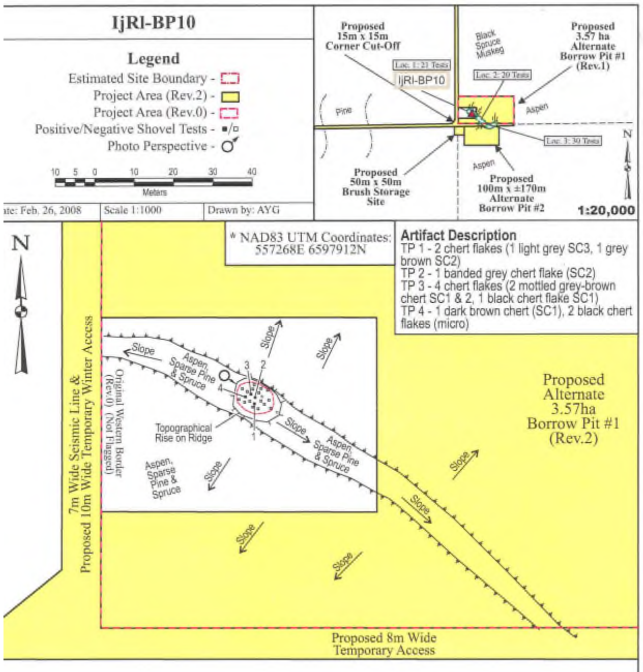
Map 2. Archaeological site 097-TB1 (1:200; from Arcas Consulting Archaeologists, Dec. 7, 2006).



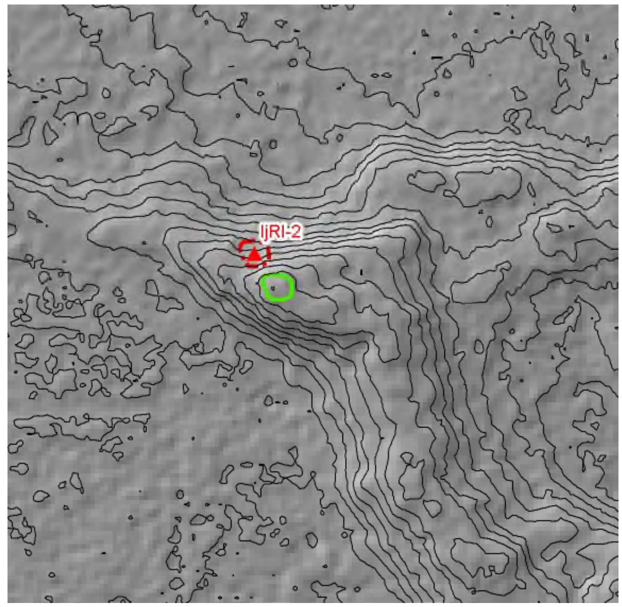

IjRk-5
IjRk-3


IjRk-5
IjRk-3

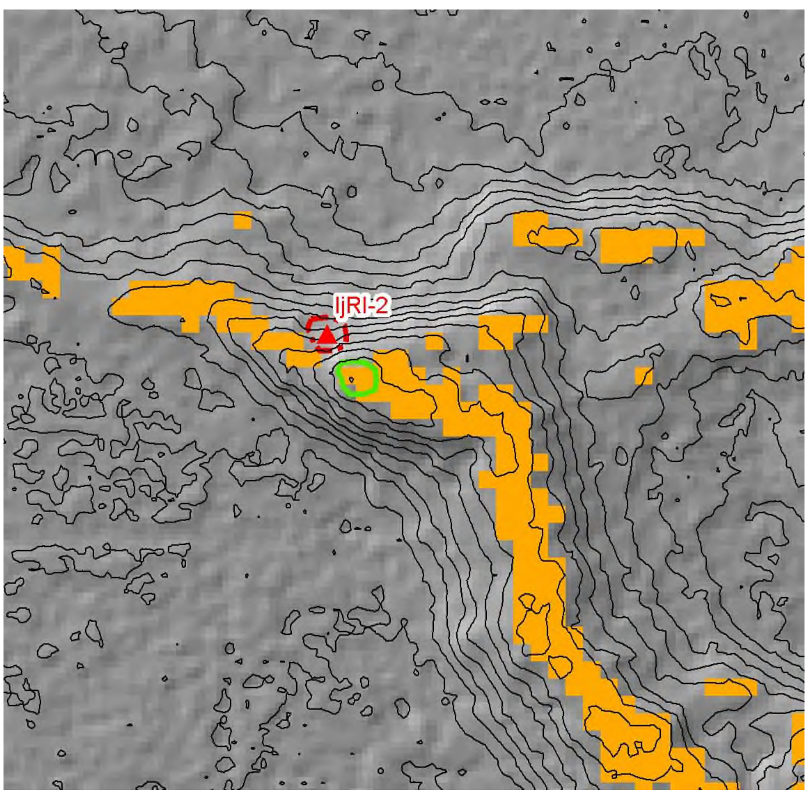
IjRl-2



IjRl-BP10
Legend
Estimated Site Boundary -
Project Area (Rev.2) -
Project Area (Rev.0) -
Positive/Negative Shovel Tests -
Photo Perspective -
Meters
ate: Feb. 26, 2008
Scale 1:1000
Drawn by: AYG
Proposed 15m x 15m Corner Cut-Off
Loc. 1: 21 Tests
IjRl-BP10
Black Spruce Muskeg
Loc. 2: 20 Tests
Proposed 3.57 ha Alternate Borrow Pit #1 (Rev.1)
Pine
Aspen
Loc. 3: 30 Tests
Proposed 50m x 50m Brush Storage Site
Proposed 100m x ±170m Alternate Borrow Pit #2
1:20,000
* NAD83 UTM Coordinates: 557268E 6597912N
Artifact Description
TP 1 - 2 chert flakes (1 light grey SC3, 1 grey brown SC2)
TP 2 - 1 banded grey chert flake (SC2)
TP 3 - 4 chert flakes (2 mottled grey-brown chert SC1 & 2, 1 black chert flake SC1)
TP 4 - 1 dark brown chert (SC1), 2 black chert flakes (micro)
7m Wide Seismic Line & Proposed 10m Wide Temporary Winter Access
Original Western Border (Rev.0) (Not Flagged)
Slope
Aspen, Sparse Pine & Spruce
Topographical Rise on Ridge
Proposed Alternate 3.57ha Borrow Pit #1 (Rev.2)
Proposed 8m Wide Temporary Access

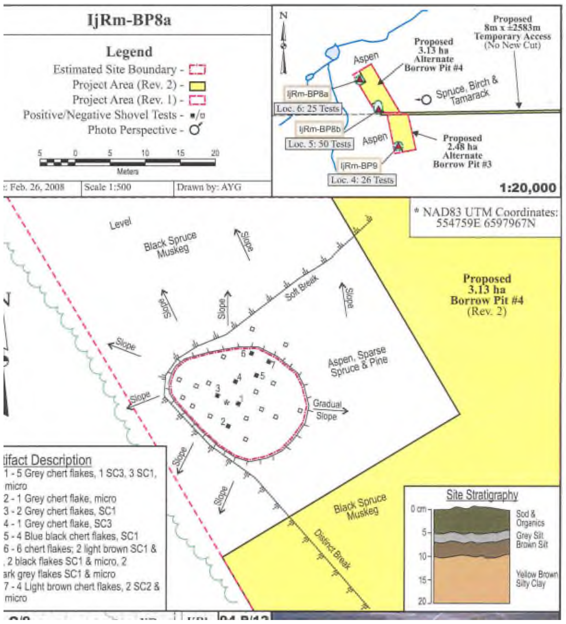


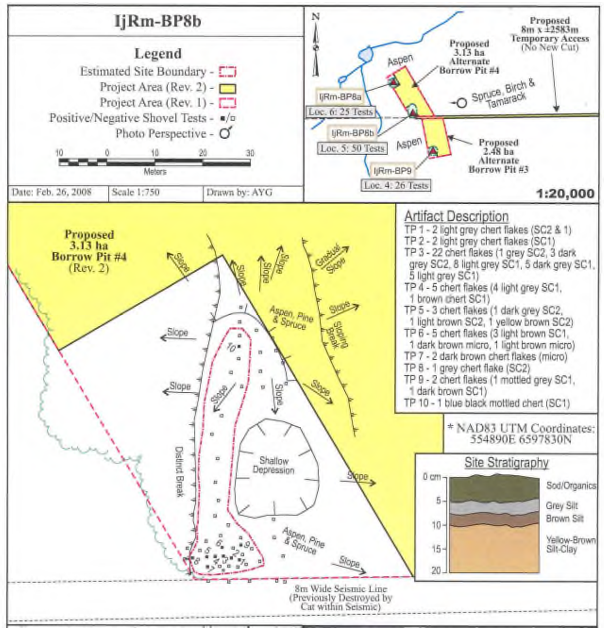
IjRl-2



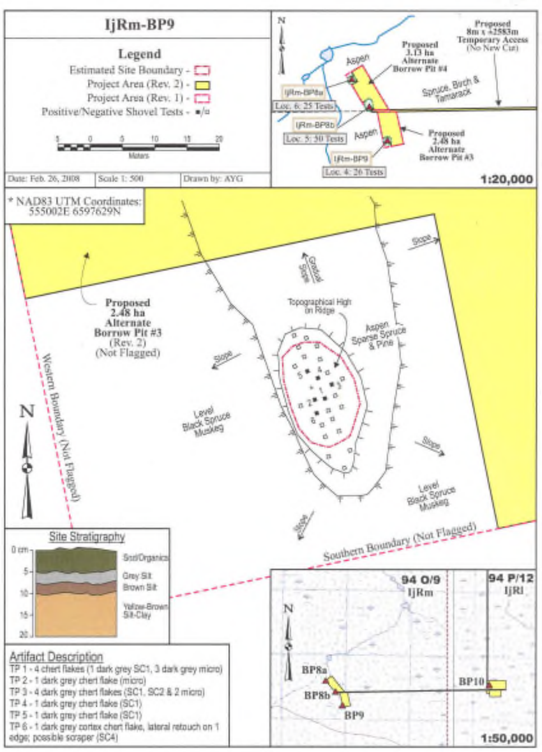
IjRl-2

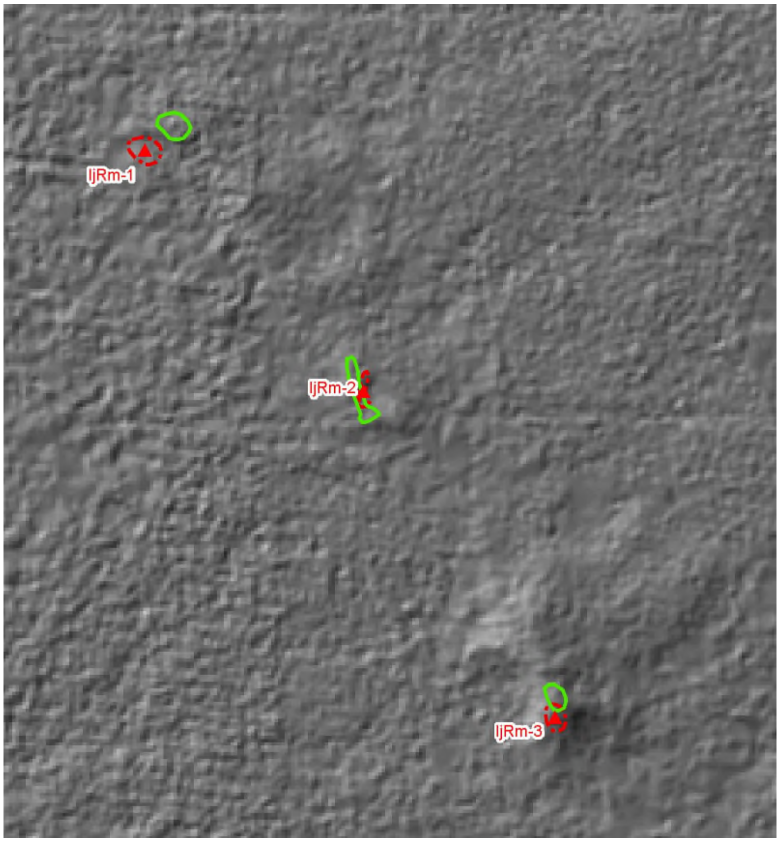
IjRm-1 & IjRm-2 & IjRm-3

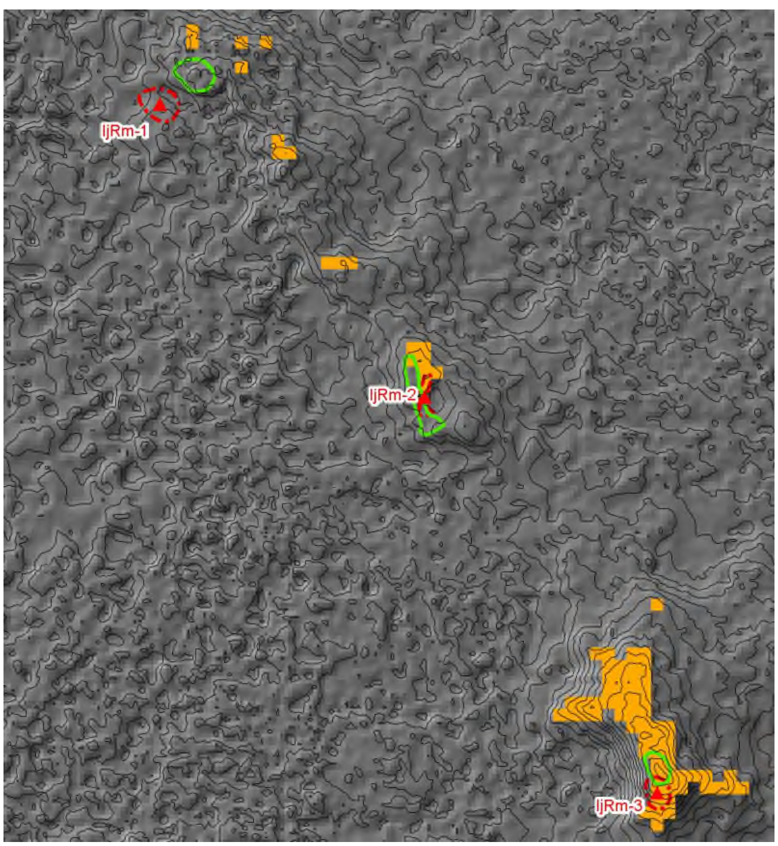




IjRm-3




IjRm-1
IjRm-2
IjRm-3


IjRm-1
IjRm-2
IjRm-3

Appendix B: Phase 2 Interim Report

Fort Nelson Archaeological Overview Assessment Revision Phase 2: LiDAR Modelling and Ground-Truthing Interim Report

Prepared for:
Forsite Consultants Ltd.

By:
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Morley Eldridge, MA, RPCA
Vashti Thiesson, BA

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March 25, 2010
Project #MR0905

Credits

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Authors	Morley Eldridge Alyssa Parker, BSc Vashti Thiesson, BA
Field Director	Morley Eldridge
Supervising Field Archaeologist	Vashti Thiesson
Field Crew	James Wolf, Prophet River First Nation Larry Bertrand, Acho Dene Koe First Nation Vashti Thiesson Alyssa Parker Morley Eldridge
Mapping and GIS	Alyssa Parker Ashley Dittmer, BSc

Management Summary

Phase 2 of the Ft Nelson Forest District Archaeological Overview, using LiDAR data, included expansion of the model to the entire data area, ground truthing, and analysis of data.

The model in its expanded form captures less land area as a percentage than did the Phase 1 test blocks; only 1.6% of the land is modelled as high potential.

The model appears to capture fewer sites; only 68% of the known sites are captured, but an examination of a sample of the missed sites suggests that most of the misses are as a result of mis-mapped site locations.

The Kv Gain, even without the site corrections, stands at 0.98, an extraordinarily precise model performance.

Recommendations for Phase 3 are to complete the correction of site locations to obtain an accurate measure of site capture and Kv gain, and to revise the model to account for missed sites and ground truthed high (in reality, 'moderate') potential areas, if this can be done without reducing the precision to any great degree. A further recommendation is to produce the model as several layers, to allow archaeologists in the field to discriminate between 'obvious' and 'marginal' potential locations on their GPS.

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Introduction

Millennia Research (Millennia) was contracted by Forsite Consultants Ltd. (Forsite) to create a model of archaeological potential for a portion of the Fort Nelson Forest District based on LiDAR data (Figure 1). A model known as the "Millennia model", based primarily on TRIM and forest cover data (Eldridge and Anaya 2005), is presently being used in the District. The current project follows from a Gap Analysis of the Millennia model that recommended the use of LiDAR data to improve performance (Eldridge and Pawlowski 2007). Phase 1 of the current project consisted of creating a preliminary model using LiDAR data for several test areas within the overall study area and the comparing of this model with the currently used AOA model. Initial model results were very promising, with exceptional accuracy and precision resulting in Kvamme's Gains of 0.97. Phase 2 objectives consisted of applying the model to the entire study area and implementing revisions recommended during Phase 1, as well as any additional revisions springing from the ground-truthing; the ground-truthing being another objective of Phase 2. Ground truthing of the model was conducted over the course of 10 days in February of 2010 by Millennia's field crew with the assistance of James Wolf of Prophet River First Nation and Larry Bertrand of Acho Dene Koe First Nation.

The following report details the results of Phase 2 of the project; ground truthing and comparing the revised LiDAR model's results to that of current and past models that have been used in the northeast.

The primary data source for this project was 2 m LiDAR data provided by Encana Corporation. A roads layer was provided by Canfor, and additional roads and well site data was obtained from the OGC (Oil and Gas Commission) website for GIS data (http://www.ogc.gov.bc.ca/gis.asp). This data was used to help check the mapped location of previously recorded archaeological sites.

Figure 1. Study area – Fort Nelson Forest District.

Study Area

The study area is comprised of the eastern portion of the Fort Nelson Forest District, for which LiDAR data has become available. This area is bordered to the north by the District of Mackenzie, Northwest Territories, to the east by Alberta and to the south by a portion of the Peace River Forest District. The area is comprised of a single biogeoclimactic zone, Boreal White and Black Spruce (BWBS) and five ecosections (Ministry of Sustainable Resource Management 2003). The ecosections are (north to south) the Trout Lake Plain, the Petitot Plain, the Etsho Plateau, the Fort Nelson Lowlands and the Sikanni Chief Uplands. The field reconnaissance was within the Fort Nelson Lowlands, the Etsho Plateau and the Petitot Plain. Forest cover in the BWBS zone is typically comprised of large tracts of black spruce, diamond willow, and paper birch in low lying and wet areas. Where drainage is better, poplar, aspen, white spruce and lodgepole pine are all present.

For a discussion of archaeological site types and the typical landforms they are found in association with, please see the Archaeological Overview of Northeastern British Columbia: Year Two Report (Eldridge, et al. 2002), which provides detailed descriptions of a variety of sites and the landforms with which they are associated. Further discussion can be found in the years 4 and 5 report (Eldridge and Anaya 2005). Essentially, sites are found most often on landforms described by Keary Walde (Walde 1997; Walde n.d.): knolls, small ridges, rises, slope breaks, terraces and linear summit terrain.

Potential Activities within the Study Area

The study area is currently one of the most rapidly expanding areas for oil and gas exploration in Canada; the expected activities include forestry and forest management, seismic exploration, oil and gas extraction, pipeline and road construction. All these activities have the potential to impact archaeological sites that are located within development areas and the development of this model will assist archaeological consultants and industry alike in supporting the intention of the *Heritage Conservation Act,* as it will enable more accurately estimations of archaeological potential and the likely costs of assessing developments.

Methods

Phase 1 of this project involved creation of a preliminary model based on a subsample of 40 of the available LiDAR datasheets. For the current project phase, the preliminary model was applied to the entire study area. Revisions to the model proposed in Phase 1 were tested and, if found to be effective, applied.

One of these revisions involved expanding the model to include smaller landforms where there were no larger landforms in the vicinity. This was done by using an elevation range over a 200 m window as a limiting layer – where this elevation range was less than 3 m (i.e. there are no landforms 3 m or higher within 200 m) the original model was performed but the 9 by 9 range of elevation was set to 1 m rather than 1.5 as in the original model. This captured several additional sites that were missed by the original preliminary model.

Another revision proposed was to include the clipping out of road features. Road lines were buffered then used to clip out potential since the potential was almost all anthropogenic errors.

Field Methods

Ground-truthing of the revised LiDAR model was conducted from February 3rd to 13th 2010. The field crew consisted of Vashti Thiesson, Alyssa Parker, Morley Eldridge (Millennia), James Wolf (Prophet River First Nation) and Larry Bertrand (Acho Dene Koe First Nation). Given the short timelines available for this project, the model was not available for the entirety of the study area, and field survey was focused on the test areas selected in Phase 1 where the model had been applied. A total of seven test areas were selected for ground-truthing based upon the terrain and number of previously recorded sites present in the vicinity (Figure 2). These areas were surveyed by the field crew and data points assessing archaeological potential were collected both in areas with model available, as well as in adjacent areas where the model had not yet been applied. Access was better in some areas than others, and the amount of data gathered in each area was dependent on the quality of access for the field crew.

Access was via truck, snowshoe and snowmobile, with each method providing advantages and disadvantages. Truck access allowed the field crew to survey large areas rapidly and collect data from widely dispersed and varied terrain. However, most of the data was collected from the road and landforms were either assessed visually from several tens of metres away or had been modified by road construction or other developments. Snowshoe access allowed field crews to take collect data while standing on the landforms being assessed. This produced a high level of confidence but snowshoe travel is slow and a limited amount of ground could be surveyed, generally without much variability. Snowmobile access via seismic lines, pipelines, etc combined with short walks when the landform was a short distance offset from the line resulted in rapid collection of high quality data over an extended area. This was particularly effective in reviewing areas of recent 3-D seismic programs. Survey was judgemental, with quick changes made to the general direction of the survey when obstructions such as fallen trees were encountered, but also with a view to the general coverage of the LiDAR mapped blocks. No attempt was made to conduct winter testing, except when viewing an area being tested under an investigation permit by another consulting company.

Data points were collected using a handheld GPS unit and a standardized recording form. GPS units were loaded with the model, previously recorded sites, roads, and the boundaries of the LiDAR data. This enabled the field crew to gather two types of data; 1) points where the model was available on the GPS and crews were able to examine landforms the model was identifying and 2) “blind” points, in areas where LiDAR was available, but the model had not yet been applied (Figure 2). The standardized recording form allowed field crews to rapidly record salient information about both high and low potential locations. The recording form was a single-line checklist that contained information on a landform’s potential, distance to water feature, water feature type, as well as landform description, size and height (Appendix 1: Ground-truthing notes).

Previously recorded sites were revisited whenever convenient to the ground truthing traverses. In almost all cases, flagging tape indicating archaeological site boundaries was associated with site locations.

Upon return to the office, the data points collected were downloaded and entered into the GIS for comparison with the expanded model. The recording forms and notes were transcribed into the attribute table of the GIS file, and where necessary, the points were shifted to reflect the actual feature targeted. In particular this was required when points were taken from the vehicle, as they commonly referred to a feature at some offset from the actual point location. The notes about the feature were used to shift the data point to the appropriate location prior to comparison with the modelled potential. The points were then intersected with the model to obtain the model potential rating, which was compared to the observed potential rating. Mis-matches between the observed and modelled potential ratings were then examined to identify if the model could be improved.

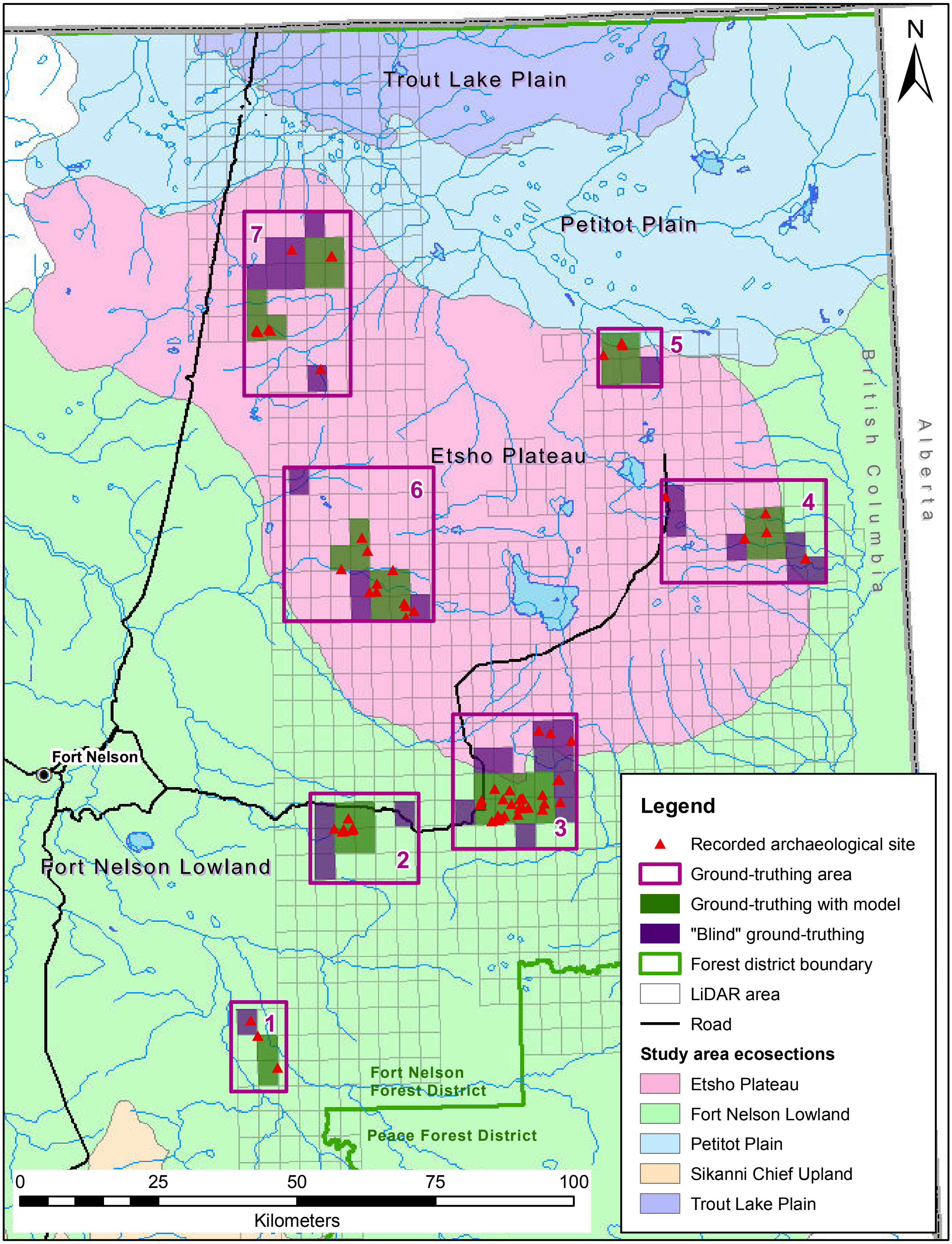

Figure 2. Locations of ground-truthing areas and recorded archaeological sites within ground-truthing areas.

Site location checking

A sample of sites was checked for mapping accuracy when a check of previously recorded sites outside the Phase 1 test areas showed a large percentage not captured by the model. The protocols followed those used for Phase 1 and other Millennia projects; the site form and detailed site maps were downloaded from RAAD; the 2 m DEM for the area was loaded; hillshades and 20 or 50 cm contours were created based on the DEM; an orthophoto of the area was loaded; and GIS layers for road, pipelines, etc were included. A visual assessment was then made of the mapped location; and the site moved if necessary. Sometimes the site location remained unclear; if the detailed site map showed slope angles, a slope map with classes matching the percent slopes was created from the DEM. Sites that still could not be resolved were removed from further consideration

Results

Documentary Research and Consultation Results

There are number of previous attempts to model for archaeological potential in the Fort Nelson Forest District. The two most recent are the Mackie model (1998) and the Millennia Model (2005), which is currently still in use.

The Mackie model was constructed based upon a combination of environmental variables, such as aspect, slope, proximity to waster and geological features which were extrapolated from data available at the time which included Ministry of Forests FC1 (vegetation) data and TRIM Digital Elevation Model (DEM) data for the area (Mackie 1998). For further details on the Mackie model and its construction, use and limitations, please see his 1998 final report on Archaeological Potential Modelling in the Fort Nelson Forest District (Mackie 1998).

The Millennia model, developed over the course of five years, from 2001 to 2005 was based on identifying topographic features from a TRIM DEM, water bodies, and forest cover.

Ground Truthing Results

The test areas examined during the ground truthing portion for this project were chosen for the variation of terrain and the number of sites present in each. Test areas 1, 2 and 3 were surveyed by Alyssa Parker, Vashti Thiesson (Millennia) and James Wolf (Prophet River First Nation) from February 4th – 8th 2010. Test areas 4 and 5 were surveyed by Morley Eldridge, Vashti Thiesson (Millennia) and James Wolf (Prophet River First Nation) on February 9th and 10th. Test areas 6 and 7 were surveyed by Vashti Thiesson, Morley Eldridge, James Wolf and Larry Bertrand (Acho Dene Koe) on February 11th and 12th. The weather throughout the survey was clear, providing excellent visibility for landform viewing. Snowpack depths varied from place to place but were generally 50 cm or less.

Test areas 1 and 2 are within the Fort Nelson Lowlands ecosection in the southernmost portion of the LiDAR area, which is characterized by very low relief and poor drainage. The typical landforms with archaeological potential observed in these areas consisted of small isolated areas of high ground located in the muskeg (terrestrial islands) or terraces associated with incised river drainages. The terrain here is very flat and the landforms observed had minimal relief. Only three known sites are located in test area 1 and the field crew was unable to access any of them. Known sites observed in test area 2 (IeRk-3 – 9) consisted of well-defined terrestrial islands with good relief and topped with pine. The areas in which these sites are located consist of large tracts of black spruce muskeg, in which the terrestrial islands present are the only areas of high ground visible for a great distance. The other landforms observed with archaeological potential in these two test areas were typically associated with established drainages that were well-incised with level terraces adjacent to them. The terraces present with these water features were typically level with well defined margins on the water side and a forest cover dominated by aspen and poplar with a relatively open understory.

Test area 3 is the largest of the seven test areas, and is mostly located in the Fort Nelson Lowlands ecosection, though the northern section falls within the Etsho Plateau ecosection and so test area 3 could be considered the transitional area between the two ecosections. Terrain in this area consisted of gently undulating poplar and aspen with some areas of muskeg. The rolling terrain had generally better drainage than the first two test areas, with poplar and aspen present where there is some relief and willow and black spruce in the lower, poorly drained regions. Archaeological potential in these areas is somewhat subjective as there is generally more relief and potential is not confined to the only dry ground as it tends to be in the flatter muskeg. Archaeological potential observed by the field crew in this area typically consisted of level spots with well-defined margins within the stretches of rolling poplar; ridges, knolls, hilltops and terraces were all observed and the primary indicator of potential in this area would likely be the margins of these landforms. Test area 3 also contained more known archaeological sites than any of the other test areas, but whether this is due to the amount of development activity in the block, which is bisected by the Sierra Highgrade, or the terrain itself, is currently unknown. The previously recorded sites observed by the field crew (IeRh-7, 8 and 9) in this area were on prominent, well-defined knolls on short ridges with forest cover dominated by poplar and aspen and an open understory, typically overlooking a drainage. Other landforms with potential observed included microtopographic landforms, such as knolls and short ridges, located on larger landforms with good drainage, as well as terrestrial islands in areas of muskeg and terraces adjacent to incised waterways.

Test area 4 is located in the northeastern portion of the LiDAR area, in the Etsho Plateau ecosection. This was the easternmost area surveyed, with only three previously recorded archaeological sites documented. This area exhibited more variety in forest cover than previous test areas. In well-drained soils, mixed mature white spruce, aspen and poplar with a willow understory was the predominant forest cover, and in low lying and wet areas, forest cover is dominated by black spruce muskeg, mature paper birch and diamond willow. Terrain in this region is characterized by plateaus of muskeg and sloping areas characterized by mature timber and incised drainages. Archaeological potential observed by the field crew typically consisted of microtopographic features located on larger landforms with well-defined margins and the terraces of incised drainages. Other landforms with potential observed included microtopographic landforms, such as knolls and short ridges, located in the large tracts of muskeg on the flat plateau.

Test area 5 is the northernmost test area in the eastern portion of the LiDAR area. It is located in the northern portion of the Etsho Plateau ecosection and consists of mostly black spruce muskeg, punctuated by terrestrial islands and ridges that are topped with pine and range in elevation above the surrounding terrain from 1 to 3 m. Archaeological potential as observed by the field crew in this area is limited to these islands and ridges as the remainder of the area is very low lying and wet.

Test areas 6 and 7 are also located in the Etsho Plateau ecosection in the north western portion of the LiDAR area. These test areas consisted mainly of very flat low-lying and poorly drained black spruce muskeg. Landforms with archaeological potential in this area consist of terrestrial islands and ridges topped with pine and elevated 1 to 3 m above the surrounding muskeg. Other landforms with potential observed included microtopographic landforms, such as knolls and short ridges, located in the large tracts of muskeg on the flat plateau.

Modelling Results: ground-truthing data

Table 1 presents the summarized results of the comparison between the observed (ground-truthed) potential and the model potential. Where the column indicates a mis-match, the column title gives the ground observation first (High-Low indicates high ground potential and low model potential). It became apparent that there was some inter-observer variability, so the results are divided by observer. Note that Observer 2 is the most experienced surveyor, and observer 3 the least experienced. Observers 1 and 3 were working together, whereas observers 1 and 2 were often working in different areas, so the variability may be due to the terrain in different areas. Note also that few 'low-low' points were recorded in the field, so as not to skew the overall result.

Table 1. Ground truthing results: model to ground observations.

Observer	Ground-truthed Potential to Model Potential:				Total # ground-truthing points
	High-High	Low-Low	High-Low	Low-High	
1	134	40	38	12	224
	60%	18%	17%	5%	
	78%		***22%***		
2	130	15	7	4	156
	83%	10%	4%	3%	
	93%		***7%***		
3	137	37	8	2	184
	74%	20%	4%	1%	
	95%		***5%***		
All	401	92	53	18	564
	71%	16%	9%	3%	
	87%		***13%***		
	Matching		***Non-Matching***		

The ground truthing showed that the model was, in most cases, performing extremely well. Several of the mismatching observations were found to be the result of development activities since the LiDAR was flown; landforms once present were now vanished. These data points were removed from the sample. Many of the Low-High values were due to anthropogenic features (road berms or flat-topped mounds beside borrow pits). Of the ground high potential locations that were missed, the great majority were very subtle small landforms that many archaeologists would not typically test; however, the fact that some of the missed known sites (see below) also occur on such features suggests additional examination should be made of this during Phase 3.

Modelling Results: previously recorded sites

Phase 1 had outstanding results. Out of the 52 sites in the test areas, a total of 42 (81%) were captured by the LiDAR model. The model captured a total of 2.3 % of the modelled land area. By comparison, the expanded model appears at first to not perform as well. Of the 169 sites currently recorded in the study area, 62 are not at present captured by the model (only a 63% capture rate). It quickly became clear that, like the Phase 1 area sites, the misses were mostly a result of mismapping. Twelve “missed" sites were checked: 8 would be captured if mapped correctly; 4 would not. This indicates that the model is performing much better than the 63% rate; but the missed sites came from diverse locations. Three of the four sites were found in existing exposures, during post-impact assessments, or in previously disturbed areas. Two are associated with tiny rises (6x10 m) and one was noted as ‘featureless terrain’. These locations are unlikely to have been tested if the lithics were not exposed in the surface. However, two of the sites can be seen to be at the margins of larger, very subdued topographic rises (Figure 3, Figure 4); it is likely that the model could be revised to include such locations. Because the model performed more poorly in the expanded area than in the Phase 1 area, it is recommended that the remainder of the sites be replotted for Phase 3.

The Kv gain for the total area, including the 12 checked sites from Phase 2, is now Kv Gain =0.98, with 68% of the known sites, and 1.6% of the land captured. The known site percentage is bound to rise substantially with remapping.

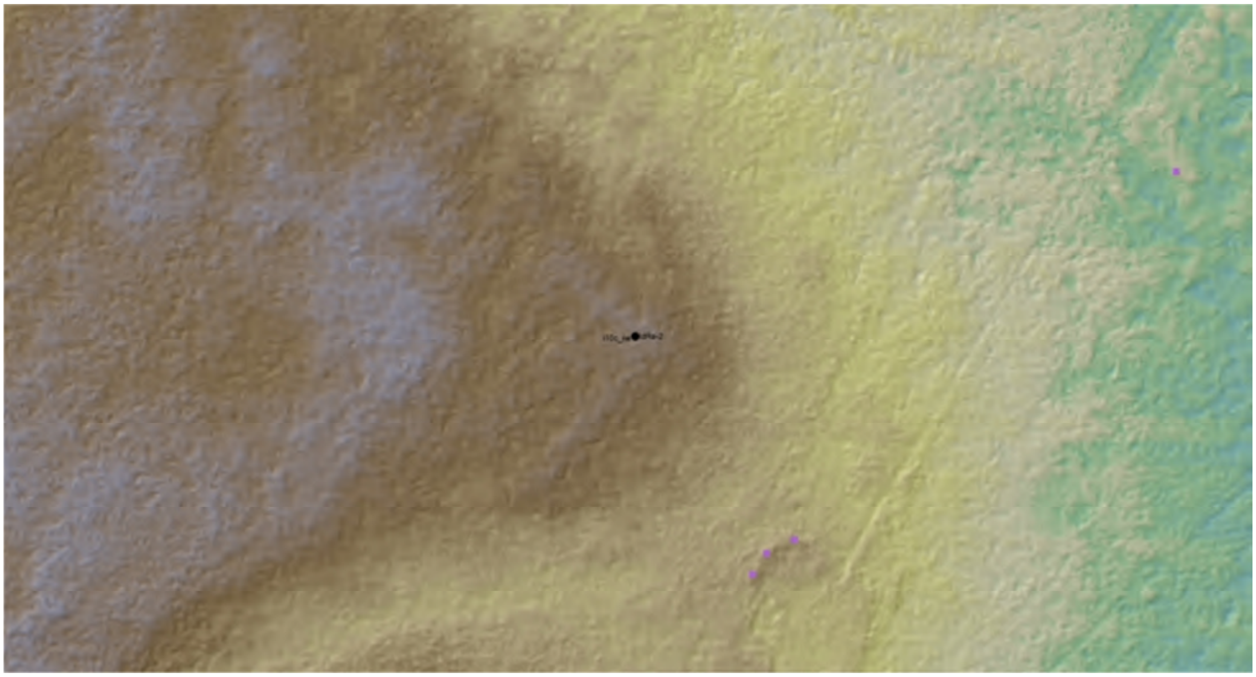

Figure 3. IdRe-2 showing location on the margin of a subtle, ca 1 m high feature.

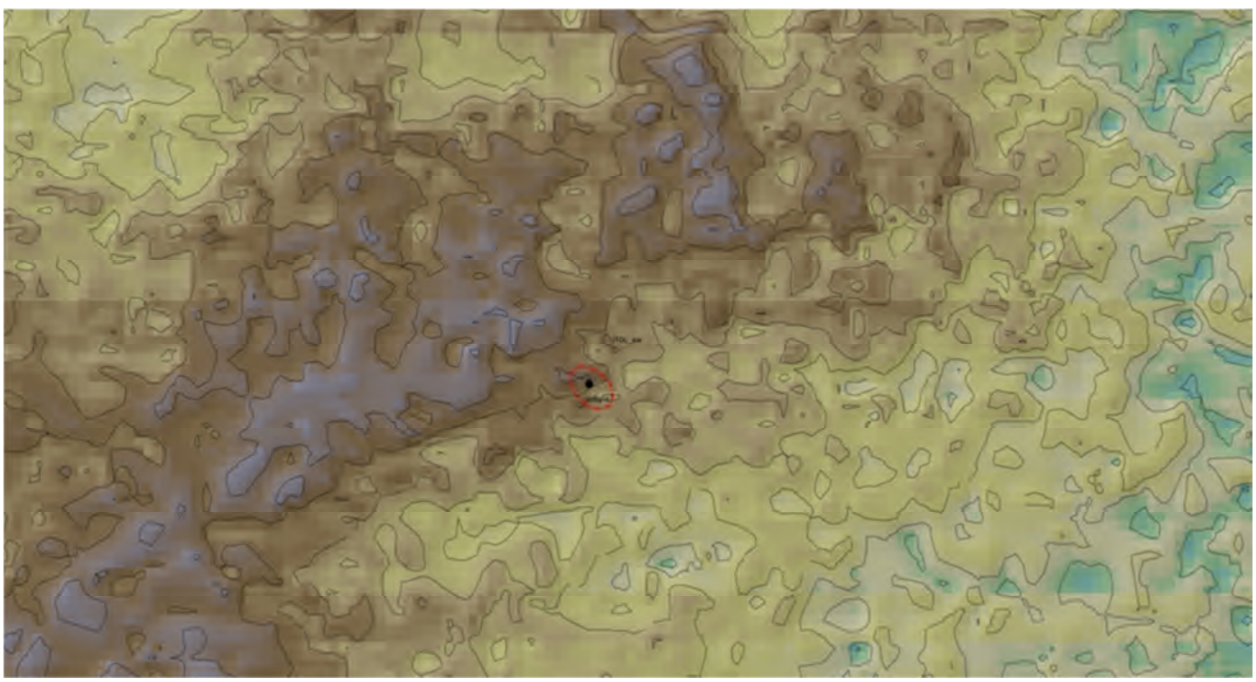

Figure 4. IdRe-1 showing location of an ephemeral large rise. Contour interval 20 cm. Pixels 2 m size.

Recommendations

1. Complete known site location accuracy checking and move sites to allow an accurate Kv gain to be calculated for the whole study area. This is particularly important since most of the misses were found in the last few sites to be checked.

2. Revise the model to capture the margins of large, low landforms (if site location checking suggests that this will substantially increase the model performance).

3. Produce the model as several layers, to allow archaeologists in the field to discriminate between 'obvious' and 'marginal' potential locations.

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Appendix 1: Ground-truthing notes

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WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
Observer 1											
005	High	<25m	Ck				x	cont	3-4m AST	nice terrace on fairly large drainage, level	L
006	High	<25m	Ck				x	cont	3-4m AST	other side	H
007	High				x			cont	1m AST	small discontinuous ridge 1m or less AST close to a small drainage	L
008	High			x				20x20m	1m AST	nice well defined level knoll good margins on E side	H
009	High	20m	willow swamp	x				cont	1-2m AST	See notes. nice knoll above drainage looks discontinuous. N margins more well defined than S ones. Feature runs E-W.	H
010	High									See notes. Model has ID'd a cell of potential on the east side of road. This is the toe of the feature identified in wpt9.	H
011	Low									No disc LF but model is picking up	H
012	High			x				30-40m long	1-2m AST	LF is 1/2 destroyed by pipeline but east 1/2 is good	H
013	Low									Rolling piece of ground not well defined, no nice margins, maybe 0.5m of relief, model identifying as high	L
014	Low									no disernable features, just rolling poplar and aspen	L
015	High				x			cont, 2m wide	1-2m AST	nice well defined discontinuous ridge level top trending E/W	H
016	High			x				20x30m	1-2m AST	nice well def knoll. N. margin looks great	H
017	High				x			cont	3-4m AST	Nice ridge, some part taken out by road	H
018	High				x			cont	1m AST	small ridge that is good, road has taken west 1/2 but is good	H
019	High			x				20x30m	1m AST	small knoll level top, looks ok	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
020	High				x			cont	1-2m AST	wide flat topped ridge above willow swamp to N, pretty good	H
021	High			x					1m or < AST	nice pine topped knoll, bisected by the road overlooking blackspruce muskeg	H
022	Low									BSM	L
023	High			x						small ill defined ridge, higher ground than BSM	L
024	High			x					1-2m AST	better defined discontinuous Ridge. Looks better than 23	H
025	High				x			8m cont	1m AST	small relief pine topped ridge at edge of BSM. See photo with Alyssa	L
026	High			x				30x50	1-2m AST	nice level knoll, poplar and aspen, f/c, open u/s	H
027	Low									BSM	L
028	High			x	x			40l x 20w	1-2m AST	small ridge elongated knoll with margins is nicest	H
029	High			x	x			40l x 20w	1-2m AST	really nice elevated short ridge With good margins to E and W	H
030	High			x	knoll or			10x10	2-3m AST	nice knoll with great N margins on an exisitng ridge	H
031	High				x			cont	1-2 m AST	nice cont ridge with live pine overlooking BSM	H
032	High					x		large	4-3m AST	hilltop taken out by development, really nice Alyssa has Photos	H
033	Low									BSM	L
034	High				x			small	1m AST	pine topped short ridge bisected by road	H
036	High				x						H
037	High						x	cont	1-2m AST	pine w/s terrace above drainage, model has it.	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
038	High	<100m	w/s drainage		x			sm cont	1m AST	15m visible pine topped ridge model is working	H
039	High				x			small discont	1-2m AST	nice long discontinuous ridge 10m wide	H
040	High				x			small discont	1-2m AST	a continuation of wpt 39, same as above	H
041	Low									LiDAR picking up road embankment	H
042	High				x					cont of morley's 35	H
043	Low									Basin of terrace recorded in Morley 32-35	L
044	Low									mismatch, maybe lidar has deadfall, nice terrace close by, model has a small tile here, open clearing with deadfall	H
045	High			x				large	1m AST	nice open knoll with level top, and ok margins	H
046	High	50m	WL				x	cont	2-3m AST	terrace margins above wetland, great margins	H
047	Low									BSM	L
048	High				x				1-2m	model has it sm discont ridge	H
049	Low									BSM	L
050	High	20m	ck				x	cont	1-2m AST	Pine topped terrace above drainage	H
051	High							cont	1.5m wide	1m AST nice ? Ridge in BSM, model has it	H
052	High	<50m	ck		x			cont 10mW	1-2m AST	nice ridge	H
053	Low									BSM	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
054	High				x			cont 10mW	1-2m AST	see notes	H
055	Low									BSM	L
056	High				x			cont 30m wide	1-2m AST	nice ridge along creek large good margin not on creek side	H
057	Low									BSM	L
058	High				x			cont low	1-2m AST	long ridge feature v similar to wpt 56	H
059	Low									BSM	L
060	High	<100m	ck	x					1-2m AST	isolated knoll good	H
061	High	<50m	ck				x	cont	1-2m AST	terrace along drainage	H
062	High				x			cont	2-3m AST	long ridge good margins well defined	H
063	High				x			cont	2-3m AST	cont ridge same as above	H
064	High				x			cont	2-3m AST	cont ridge same as above	H
065	High			x				10x20	2-3m AST	nice knoll pine top well defined	H
066	Low									BSM	L
067	High			x						nice short ridge	H
068	Low									low-lying and wet willow swamp	L
069	High									IiRf-4 Great ridge	H
070	High				x			cont	1m AST	same type of ridge feature as earlier, disturbed	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
071	High				x		x			above great drainage	H
072	High						x			above BSM	H
073	High				x					wpt is on Road, landform Is 72m at 228 degrees	H
074	High						x	cont	6-8m AST	nice cont remnant terrace good margin, good relief	H
075	High				x			cont	1-2m AST	m-85 is the other end of this cont ridge, nice	H
076	Low									too sloping	L
077	High				x				1-2m AST	knoll above drainage good margins	H
078	Low									featureless rolling poplar	L
079	High			x					1-2m AST	knoll above drainage , good margins	H
080	Low									f+f	L
081	High				x			cont	1-2m AST	small continuous ridge	H
082	High				x			8m cont	1m AST	Pine ridge in skeg	H
083	High	<50m	Cr/Dr		x		x	cont	3-4m AST	see notes	H
084	Low									Thought this looked like it should be high alpine terrace above muskeg but it was flat	L
085	Low									BSM, low and wet	L
086	High			x						See notes. There is potential on both sides, terrestrial is. Is muskeg, model is picking them up well, one is 145m @85 degrees.	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
087	Low									BSM (notes), skeg	L
088	High			x						Pine knoll 125m @ 342 degrees, no model here?	L
089	Low									Flat BSM	L
090	High			x				8m	<1m	115m @ 296 degrees	H
091	High									IjRk-3, nice bump, see notes. knoll on larger terrestrial island that has very low elev, AST but is higher and drier than everywhere else	H
092	Unknown**			x						model is picking up a small knoll here, but the ground is so obscured can't assess	L
093	High				x					model has it	H
094	High			x				small	1m AST	Bisected by rd, nice knoll	H
095	High						x	cont	1m AST	nice terrace, poplar and aspen above skeg	H
096	High									Part of IjRk-5? Check site form. See notes. Taken from rd, looking at an area 35m SW from the SW boundary of IjRk-5. . .	H
097	High			x	x				1-2m AST	nice ridge on W side of Rd, See notes. Good potential on W side of Rd here, on R it has been taken out by a borrow pit	H
098	High			x					<1m AST	poorly defined knoll, but on edge of nice slope break, ok test.	H
099	High						x	cont	2-3m AST	terrace edge above nice level drainage, margins are good	H
100	High									same as above	H
101	High			x				30x20m	<1m AST	v small pine knoll bisected rd ok, shoulder shoul be ID'd	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
102	Low									taken out by borrow pit potential 20m @ 42 degrees	H
103	Low									BSM	L
104	High			x	x			20x30m	1m AST	Pine-topped bisected by road	L
105	High						x	cont	2-3m AST	see photos and notes. Very small bit of potential ID'd but appears to be a longer pine terrace that has been bisected by the borrow pit. There are a few mismatches here . . .	L
106	Low										L
107	High			x						See notes. Site here? No model, pine knoll w/flaggin. See photos of possi CMT? Or nat scar.	L
108	High						x	cont	1-2m AST	long pine ridge, no ID be model	L
109	High			x	x					Pine knoll on a pine ridge, looks good, no model	L
110	Low									Borrow pit	H
111	High				x			cont	1-2m AST	nice ridge v similar to 109 only less relief	H
112	High				x			cont	1-2m AST	cont pine ridge, No Model	L
113	High				x			cont		model has this one	H
114	High						x	cont	2-3m above	drainage	H
115	High						x	cont	lots of R	See notes. Super nice slope break	H
116	High									See notes. Same ridge as 113 with better definition in that spot	H
117	High				x					margin of big ridge Petitot Ridge	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
118	High									nice margin going down N side of ridge	H
119	Unknown**									False P, road berm, however along this contour is a nice slope break w/ good P but no model	H
120	High				x				1-2m AST	Nice N-S poplar covered ridge (short), with good margins, looks like above drainage on E side	H
121	High						x			nice terrace above willow swamp	H
122	High									see notes. Nice knoll/ridge w/good margins about 30m E of 122 has been bisected by road	H
123	Low									BSM	L
124	High				x				1-2m AST	Long pine ridge trending NW/SE 10m wide here	L
125	High				x					Another like 124	H
126	High									slight rise on rd, pine ridge <1m AST maybe 15m wide	L
127	High									very approximate location of a good looking terrestrial island, see photo 145	L
128	High				x					another small continuous ridge looks ok, margins above skeg at least 1m approx AST	L
129	High				x					same as above	L
130	High									break in slope above drainage, pine topped, could be cont, can't really tell. . .	L
131	High								1m AST	nice margins, see photos (147) approx 1m AST, lots of pine overlooking skeg	L
132	High				x					ridge, very nice on little terrace or raised feature described in 131	H
133	High				x					see notes. Nice little ridge as described in 132, good definition, very close to IjRt-1	H
134	High				x					nice pine ridge, same as others in this area	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
135	High				x					same as above	L
136	High				x					same as above	L
137	High				x					more continuous, same as above	L
138	High				x					nice cont pine ridge overlooking skeg, pretty well defined, nice margins	H
139	Low									nothing but BSM from 138 to here, some visible terrestrial islands to west, but that's all	L
140	High				x					pine ridge, terrestrial island, ok	L
141	High									multiple terrestrial islands visible from here to south	H
142	High				x					pine ridge, definition ok, medium on the whole on a bit of a larger terrestrial island,	L
143	High				x					same as 142, on the same terrestrial island, different ridge	H
144	High				x					nice well defined ridge covered in pine trending N/S	L
146	High			x						beautiful knoll on E side of rd, great margins, bisected by road	H
147	High			x				large	1-2m AST	Beautiful pine topped, great margins	H
148	High			x	x			cont/5m	1-2m AST	From 148, 2 HP LF's are visible, on left, on right, see notes	H
149	High				x			cont	1-2m AST	photo 159 pine topped ridge visible in seismic	H
150	Unknown**									model has as high, looks good, but couldn't assess ground as to much deadfall	L
151	High			x				8m 10x10	1-2m AST	2 nice knolls with good margins on either side of rd look good	H
152	High						x	cont	3-4m AST	beautiful terrace above drainage, really nice	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
153	High				x			large	2-3m AST	nice pine ridge, good margins	H
154	High			x				8m 10x10	1-2m AST	nice knoll, well defined	H
155	High			x				30x15w	1-2m AST	good margins, well defined	H
156	High			x						this LF is just like 155, only with less relief, just want to see if revised model will pick it up	L
157	High									see notes. There is a larger drainage feature to the North about 200-300m and the model is picking up its upper terraces really well, these are visible from 157. Working really well	H
158	High			x				15x20m	1m AST	No model here, but there should be. Really nice knoll with good defn, will revised model pick it up?	L
159	High				x					no model here, elongated knoll, see notes. Knoll not that great, but model should have picked it up. Is there a data gap here?	L
160	High						x	large	2-3m AST	good sized LF here, no model? Only 1 tiny spot.	L
161	Low									BSM	L
162	High			x				15x10	1-2m AST	nice well defined knoll	H
163	High	<100m	ck				x	cont	1-2m AST	nice terrace margins visible from here	H
164	High	<50m	ck	x				small	1-2m AST	knoll in poplar close to creek	H
165	Low									potential to E of Rd id borrow pit	H
166	Low									BSM	L
167	High			x				large	1m AST	No model? Nice terrestrial island in skeg, pine topped margins would be good	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
168	High				x				1-2m AST	No model? Nice pine ridge	L
169	Low									Very flat!	L
170	High							cont		looks good from here, skeg too thick to walk, can see prominent vegetation change 70m to the south	H
171	High			x					1m or less	Its ok, hard to see margins in snow, they are very subtle	H
172	High						x			slope break	H
173	High				x				1m	nice break in slope model here	H
174	High				x				1-2m AST	nice pine knoll visible from rd	H
175	High				x			cont	1-2m AST	see notes. On a really nice small ridge. There are some really nice features visible to N from here, prominent ridges with veg changes and decent relief	H
176	Low*									line of Potential to W of this WPT is borrow pit - LiDAR pre-dates borrow pit	H
177	High									photo 166-168. Borrow pit, push used to be really nice. . .	H
178	High			x					1-2m	pine knoll visible to L	H
179	Low									model is showing potential on both sides here but is very skeggy	H
180	High				x			cont	1-2m	see notes. Model is picking up an area 90m @285 degrees from here and should be gabbing the whole ridge. It looks better where I took the wpt. A large pine ridge but no model here or to either side of the road	L
181	Low									very flat! BSM	L

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
182	High						x			great terraces on this creek	H
183	High			x					1-2m	See notes. nice knoll E side of mainline	H
185	Low									model picking up road	H
186	High									nice knoll N of rd	H
187	High			x				8m	2-3m AST	nice knoll with good margins bisected by road	H
188	Low									giant borrow pit to south	L
189	High									good potential her but bisected by road and borrow pit to N only S side is left	H
190	High									again, nice ridge but taken out by rd to south and seismic to N, see photo 179	H
191	High			x						very small knoll, model has it. Is working very well.	H
192	High						x	cont	1m AST	terrace edge overlooking skeg	H
193	High									See notes. The model has a bit of Rd, but also the margins of a 'terrace' or 'hip' above BSM	H
194	High			x						nice pine knoll/ridge to S of rd	H
195	Low									borrow pit	H
196	High				x			cont	1-2m AST	very nice ridge bisected by road, photos 180-184	H
197	Low									very obviously by the road	L
198	Low									road again, probably G.C, it's the highest point around	H
199	Low									borrow pit	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
200	Low									road	H
201	High			x				Medium	1-2m AST	pine terrestrial island, looks good	H
202	Low									borrow pit all around this one	L
203	High			x				5m 10x10	<1m AST	model has nice knoll w of road	H
204	High			x				5m 10x10	<1m AST	same as 203, nice knoll	H
205	Low									borrow pit and road	L
206	Low									road still	L
207	High	<10m	WL				x	cont		small terrace above WL, 1/2 taken out by road	L
208	Low									Flat	L
209	High				x			cont	1-2m AST	Ridge feature only high for long way	L
210	High							cont	1-2m AST	slope break, nice margin in otherwise flat area	H
211	High				x			cont	1-2m AST	nice ridge, bisected by seismic on W side of Rd	H
212	Low									borrow pit on S side of road	L
213	High							cont	1-2m AST	nice ridge, maybe part of 211?	L
214	Low									Flat, BSM	L
215	Low									Borrow pit	L
216	High			x				15x10	1m AST	nice small knoll with good margins	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
217	High				x			cont	2-3m AST	nice discontinuous ridge with good margins	H
218	High			x				20x30	3-4m AST	nice knoll, so nice there is already a site here. Site not yet on GPS. See photos 186-189	H
219	High			x				10x15	2-3m AST	nice well defined knoll with decent margins, photo 190	H
220	High						x	?	1-2m AST	A nice terrace or slope break above a small drainage. See photo 191	H
221	High							cont	1-2m	Road bisects a nice ridge here	H
222	High			x						nice little knoll at side of rd. photo 192	H
223	High			x				8m	1-2m AST	v nice knoll with good margins	H
224	High				x			cont	1m AST	skinny ridge (2) running N/S, look ok	H
225	Low									low-lying and wet willow swamp	L
226	High				x			cont	1m AST	ridge trending NW/SE looks ok	L
227	High	Terrace or lip above drainage					x	cont	1m AST	nice margin	H
228	High			x				?	3-4	nice knoll bisected by road	H
229	High									See notes. There are a lot of nice LF's at the side of the road here but the Komie is very busy so hard to go slow. . .	H
230	High				x			cont	1-2m AST	nice cont ridge bisected by road	H
Park	High			x						terrestrial island Pine top overlooking skeg	H
Park 1	High	<20m	ck				x	cont	2-3m AST	nice level terrace above creek that is incised	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
Park 2	Low									Borrow pit now, see photos	H
Park 3	High									Landform disturbed by old borrow pit	H
Park 4	High				x					nice pine rise at side of road	H
Park 5	Low*									Borrow pit	L
Observer 2											
020	High				x				~1m	NW/SE trend	H
023	High			x							H
026	High				x					Another 30m to SSW slope down to E/W	H
027	High				x			100m?	am	N/s trending small ridge, good potential, level top	H
028	High	?		x	x			30+ x 10	2.5-3		H
029	High	?		x	x			30+ x 10	2.5-3	S end of feature at WPT 28	H
030	High	?		x				10 x 5		isolated knoll	L
031	High			x				15 x 15 top	1.5m	miss - low flat rise, not bad, not great, better to EAST	L
032	High	?		x	x			15 x ?	1 to S 2.5 to N	E end	H
033	High			x	x			30 x 15		W end saddle to W	L
034	High				x		x	100 x 20	3 m to N	slope break to N	H
035	High				x		x			old glacial	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
036	High	?		x					3m N, 2m W	.50 S and E	H
037	High*	?		x	x			15 x 5	4-5m to N	nice bump not captured, good drop to N	L
038	High	?		x				10 x 15	1m	small feature, definite though	H
039	High	?				x			?	not very well defined	H
040	High			x		x		20 x 10	1m	See notes. not as well defined as slope break to N; Almost all WPTS to 68 High Pot 'obvious' except as in Vashti's notes	H
041	High										H
042	High										H
043	High										H
044	High					x			4-5m AST	20m to S or R, great margins, bisected by road	H
045	High			x						45m @ 322 degrees from wpt, knoll, pine top overlooking skeg	H
047	High										H
053	High										H
055	High										L
056	High										H
057	High										H
058	High										H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
059	High										H
060	High										H
061	High										H
062	High										H
063	High										H
064	High										H
065	High										H
068	High										H
069	High			x					0.7m	very subdued pine knoll	H
070	High			x						30 m N - 70 m S good ridge	H
072	High									some not high, pit [something I can't read}	H
074	High		creek				x			awesome creek with great terraced banks both sides, low in between	H
075	Low										L
076	High	100m	creek	x						nice knolls	H
077	Low									shows line on W - road cut? To E ??	L
078	Low									slope break is a bit gradual esp on W; actually, having driven down to well site, it looks much better from below - still not much actual slope break though	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
079	High									nice group of small hillock features	H
080	High			x						very subdued	H
081	High									may be too subdued for high potential	H
082	High									High at S is very subdued nice; 60m to N	H
083	High										H
084	Low	50?					x			intermediate terrace but sloping block failure	L
085	High									WPT 85-89 all high potential beside road	H
086	High										H
087	High										H
088	High										H
089	High										H
090	Low*									artificial mound beside borrow pit	H
092	High										H
093	High										H
094	High										H
095	High										H
096	High										H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
097	Low							10x10	1.5m	single hummock 20m N of road ;20m ridge behind N	L
098	High			x				10x10	1m	30m N isolated MTL	H
099	High			x				25 x15	1m	subdued isolated rise; Very few HP zones through here	H
100	High			x						50m back, N side 20m off; HP 1st bump	H
101	High			x				10x10	1m		H
102	High			x				10x10	1m		H
103	High							10x15	1m (+/-)	slight break down to N and E	H
104	Low									Black spruce muskeg	L
105	Low										L
106	High			x						Double feature at ??	H
107	Low						x			wet ground with slide MTL, big trees	H
109	High										H
110	High										H
111	High										H
112	High									nice knoll to E, model excellent through here	H
113	High										H
114	High				x			8m cont	1m AST	Pine ridge in skeg	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
115	High										H
116	High										H
117	High										H
118	High										H
119	High										H
125	High										H
126	High										H
128	High										H
129	High				x					Ridge 20m S (Gote Road)	H
130	Low									Looks all low muskeg behind and to S (SE)	L
131	High								0.5-1m	low hummocks	H
132	High									High potential to S too.	H
133	Low									borrow pit can't tell ridge (?) SW	H
134	Low										L
135	High		creek		x				3-4m	pine low ridge 3-4m above creek	H
136	Low								3m	50m to S, anthropogenic borrow pit, might cut into original hummock SW cnr 3m high	H
137	High		creek						3m	3m above creek, nice bank SP & LP	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
138	Low	Low	creek							low bank on creek	L
139	High									SW H Pine	H
140	High									SEE NOTES. Black spruce muskeg - marginal higher ground - trees higher	H
141	High			x	x					knoll, 1-1.5m ridge above ground to S	H
142	High									Pine ridge to E	H
143	High								0.5m	50 cm ? Rise but only one around, black spruce 5m tall	H
144	High				x					very subdued pine ridge	H
145	High									low hummock	H
146	High				x					low ridge	H
147	High			x					1.5m	1.5m hummock E	H
148	High									little bit better defined ridge to W	H
149	High								1m	well defined low 1m bump	H
150	Low									Flatt t t ttt tttt!!!!	L
151	Low									lake shore no topo	L
152	High										H
153	Low									some higher in vicinity	L
154	High									154-158 all HP	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
155	High									154-158 all HP	H
156	High									154-158 all HP	H
157	High									154-158 all HP	H
158	High									154-158 all HP	H
159	High									very subdued rise - very minimal feature, high??	H
160	High										H
161	High										H
162	High				x					on pine ridge, wolverine, lynx and cariboo tracks	H
163	High									high spot, well drained byt poorly defined, no breaks (1m+snow)	H
164	High				x				2-3m	nice toe of ridge	H
165	High								1m	hummock 1m high, coulndn't see this at first, Larry spotted it in the bush	H
166	High				x				1-2m	pine ridge somewhat subdued 1-2m high	H
167	High									very subdued minor MTL only one for 100s of meters though; masked by snow?	H
168	High										H
169	High				x					pine ridge	H
170	Low				x				0.5m	subdued pine ridge - L - 50cm high?	L
171	High*									low subdued hummock top. Pine, white/black spruce	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
172	High				x				0.5-1m	minor ridge, 0.5-1m high, surprised model didn't p/u but marginal for HP	H
173	High									marginal MTL	H
174	High				x				1m	1m ridge, well defined	H
175	High				x				1.5m	good ridge 1.5m	H
176	High				x				2m+	ridge, beauty, 2+m drop, well defined	H
177	High				x			20x20m		20x20m high spot on pine ridge - no sharp slope breaks	H
182	High				x			5-6m	2-3m	very nicely defined pine ridge 5-6m across top, nice ridge a little further S, not as good	H
183	High				x					flat on pine ridge better spot 50m W	H
184	High				x			20m	5m	large ridge 5m high, 20m across top	H
185	High									Heritage North site IjRl-2	H
186	High									SEE NOTES: Pine ridge to E. We have been converging w feature on either seismic line, turn S to cross, just miss	H
187	High				x			10x20	2-3m	nice ridge ad to E further from track	H
188	Unknown**				x				1-2m	low pine ridge	H
189	High			x				20x20	3m?	Site IjRm - knoll 3m? High, no labelled flagging	H
190	High				x				2m	SEE NOTES: IsRm-2 Heritage N low ridge 2m max looks less; white spruce poplar, looks like nat trail N-S	L
191	High									IsRm-2 Heritage N low ridge, 2m max looks less. Wh spruce, poplar, natural (?) trail N-S	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
192	High*				x					ca. 40m W of site - can see ridge where trees are taller. Too tired to walk in.	H
194	High									Winter testing with AMEC	H
195	High			x						off road to S	H
196	High			x	x					long N-S flat, high	H
197	High	50m	creek?	x						little potential, flat above creek or draw	H
198	High			x				12x6	0.5m	See NOTES: small landform, not all that well defined, Melissa and ___ both said they would want to see it on model would test if any features but even where lots potential around close by they would still want to see this prob 1 test in summer, ...	H
199	Unknown**									50m N - slight rise, better defined on N?? Model 2 capture this?	L
200	High						x			Now appears to be anthropogenic terrace edge - disturbed by well pad (well pad post-dates LiDAR)	H
201	High				x					top of ridge	H
202	High				x					slope break	H
203	High	20m	beaver pond	x				30x20	1.5m poplar	very nice minor hummock - only thing in area	H
204	High			x				10x10	0.5m	pine/poplar, very small size poor definition	H
205	High	10m	creek					70?x20	2-3m	slightly raised bank above creek	H
206	High	50m	beaver swamp/creek					30x20	0.5m	slight ridge on trail 'nose' to N beaver swamp	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
207	High										H
208	Low	5m	creek					10x10	1m	nose' that creek meanders about. Willow	L
209	Low									all these seem to be creek meanders	H
210	High	8m	creek							slight rise beside creek	L
211	High	20m	creek	x						slightly better defined, nice!	H
212	High	15m	creek	x						nice, white spruce, rise, moose shelter	H
213	High	15m	creek	x						Larry found 2 burnt sticks - camp?	H
214	High									slope - black pine	H
Observer 3											
015	Low									BSM both sides of road	L
016	High			x						Road cuts through	H
021	High				x				~1m	Pine, blk sprc. E-W trend	L
022	High							15-20 wide	~1-2m	Pine, blk sprc. E-W trend	L
023	High							15-20 wide	~1-2m	second lip to 022	H
024	Low									Muskeg - BSM	L
027	Low									BSM - looks f+f all around - no landforms in sight	L
028	Low									Dist, well site	L

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
029	High*				x					To NNW - ridge of diff veg	L
030	High	~10-15m	Crk				x			Terrace above sm drng	H
031	High				x				~1m	low rise with blk spruce	L
032	Low	drainage									L
033	Low									slight rise, probably low because of the other higher landforms nearby	L
034	High			x						To NNE/N of wpt, small rise	H
035	High			x	x					To NNE/N of wpt, small rise	H
037	High			x						Pine knoll	L
038	High			x						small rise above surrounding terrain	H
039	High						x			Terrace above drainage, road on high potential?	L
040	High				x					Long, discontinuous N/S good at margins	H
041	High	wetland overlook s			x					Good ridge, cut by road	H
042	High			x						To NW, good knoll, beavers	H
043	High*			x						To NW	H
044	Low									BSM	L
045	High			x						Good to NW beyond well	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
046	Low		Lake								L
047	Low*									Model shows potential, looks flat	H
048	Low										L
049	High				x					Best feature in area, S margin less well defined	H
050	Low*									Model shows potential, looks same as low (feat obscured by snow?)	H
051	Low									Looks not very nice but small bump	H
052	High			x					0.5-1m		H
053	Unknown**			x	x					To W, fairly well defined landform	L
054	High				x		x			To N, good landform	H
055	High									Pine stand	H
056	High			x	x						H
057	High			x							H
058	High				x					Next to borrow pit	H
059	High				x					Margin of ridge	H
060	Low									Borrow pit	L
061	High			x						Several hundred m to E, good vegetation	H
062	High			x						small well defined next to road	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
063	Unknown**				x					to E ~300m?	H
064	High			x						Lots of high potential landforms in area in addition to ones with sites, one to N/NW of IeRk-5	H
065	High			x						some dist to NW	H
067	Unknown**									to S, high landforms	L
068	High				x					Borrow pit interrupts feature	H
069	High*			x							L
070	High				x					Interrupted by borrow pit	H
072	Low										L
073	High			x						High to W of road, low, wet to E, landform to E past wet area	H
074	High			x						To E, well defined, to W, poorly defined	H
076	Low									Willow, swamp, no landforms visible	L
077	Low									To E, looks sloping and wet, willow	L
079	High			x						Ground not very nice, but well defined, better ground to E but less defined	H
080	High	~20m	drainage							High spot overlooking well defined drainage	H
081	High	~20m	drainage							Other side of drainage landform cut by road	H
082	Unknown**									well site to SE with higher banks surrounding	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
083	High		drainage				x			Terrace above drainage	H
084	High		drainage				x			Terrace above drainage	H
085	High									Nice relief on NE side of road	H
086	High				x					To SW side of road (both sides actually)	H
087	High				x						H
088	High				x		x				H
089	High	overlook	muskeg		x					Disturbed by borrow pit	H
090	High										H
091	High										H
092	High		drainage							Lip above drainage	H
093	High	overlook	willow/ swamp		x						H
094	High	overlook	willow/ swamp		x						H
095	Low										L
096	High				x					Arcas site (?) yellow NWZ flagging tape, same site as wpt 97	H
097	High				x					Arcas site (?) yellow NWZ flagging tape, same site as wpt 96	H
098	High	overlook	drainage				x				H
099	High	overlook	Drainage				x				H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
100	High		drainage				x			well incised	H
101	High		Drainage				x			well incised	H
102	High				x					Nice ridge overlooking muskeg	H
103	Low									False landform to N of road (well site bank)	L
104	High		drainage				x			To N especially	H
105	Unknown**		drainage							small rise, heavy tree cover	L
106	Low									BSM	L
107	High*				x?					High? Slightly raised landform	L
108	Unknown**									slightly raised, maybe still wet, not much other relief in area	L
109	High				x					overlooking muskeg	L
110	High				x					Nice ridge, NE/SW trending	H
111	High			x	x						H
112	Low										L
113	High			x	x					small rise	H
114	High			x						Nice terrace, island	H
115	Low										L
116	High										H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
117	Unknown**			x	x					to SW of road perpendicular to road, high site IFRd-1?	H
118	High			x						To NW, perpendicular to road	H
119	High			x							H
120	Unknown**									Good rise, but f/c not very nice	L
121	Low									Wetland	L
122	High		drainage				x				H
123	High		drainage				x				H
124	High	overlook	drainage				x				H
125	High				x					cut by road	L
126	High				x					cut by road	H
127	High				x					cut by road	H
128	High				x					cut by road	H
129	High			x	x					To N of road	H
130	High			x	x					cut by road	H
131	High			x	x					to E of road behind swale	H
132	Low									willow swamp, some paper birch, wet	L
133	High				x					to S of road	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
134	High				x					to S of road	H
135	High				x					to S of road	H
136	High				x					to W of road	H
137	High			x						200m to N on edge of mapped water body	H
138	High				x					Bisected by road	H
139	Low									BSM	L
140	High				x					overlook muskeg	H
141	High			x	x					To W of Rd, 2 knolls, ridge?	H
142	High			x						Bisected by road	H
143	High				x						H
144	Low									low lying and wet, willow, swamp	L
145	Low									low lying and wet, willow, swamp	L
146	High				x					Bisected by road	H
147	Low									Low lying and wet, both sides of road	L
148	Low									To S of road, false landform - borrow	L
149	Unknown**									Slightly higher than surrounding terrain	H
150	High			x	x					To W of road	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
151	High				x					Ridge interrupted by road	H
152	High				x					to N of road	H
153	High				x					to E of road, borrow pit to N	H
154	High	overlooking	drainage		x					cut by road	H
155	High	overlooking	drainage		x					cut by road	H
156	High	overlooking	drainage		x					Nice, well defined landform	H
157	High				x		x				H
158	High			x	x					Road cut out nicest part	H
159	High			x		x				to NNW of road, good knolls	H
160	High				x					IeRh-7, great landform	H
161	High				x					To S of road, nice ridge	H
162	High			x						IeRh-9, good knoll	H
163	High			x						To N of road	H
164	High				x					To W of road	H
165	High				x					Good ridges off to both sides of road	H
166	High				x					Cut in half by road	H
167	High				x					cut by road	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
168	High				x					Good to E, cut by borrow pit to W	H
169	High						x			Terrace to SE beyond well site	H
170	Low									Low-lying, wet	L
171	High			x						To W of road	H
172	High			x	x					Both sides of road	H
173	High				x					Drops down into low, willow	H
174	Low									Poplar, aspen, paper birch, with willow under story	L
175	High				x					Both sides of road	H
176	High				x					To N of road	H
177	High				x					Ridge to N, parallel to road	H
178	High			x						Pine on top	H
179	Unknown**									Poorly defined rolling terrain, very low	H
180	Low									BSM	L
181	High				x						H
182	High				x						H
183	High									Low discontinuous ridge	H
184	High			x							H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
185	Low			x						Muskeg	L
186	High				x					Well defined to E	H
187	High						x			Overlooking muskeg to South	H
188	High			x						To N of road	H
189	Low									low-lying willow/muskeg	L
190	High				x					Nice landform ~100m to N of road	H
191	High			x						can see flagging of IeRh-11 site	H
192	High*			x						To N, parallel to road, flagged site? See Vashti notes	L
193	High									To N of road	H
194	High	close to water			x					N of road, low-lying to S of road	H
195	High			x						IeRh-12, can see flagging	H
196	High				x					Timber change, good features to S of road	H
197	High				x					To N of road	H
198	Low									Borrow pit to N	L
199	High	overlook	drainage wetland				x			To E, but disturbed by well pad	H
200	High						x			overlooks low-lying area to SE of road	H
201	High				x					Best edge to S of landform	H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
202	High			x	x					cut by road	H
203	Low									low-lying and wet	L
204	High				x					N of road	H
205	High				x						H
206	Low									Model captures road	H
207	High	Above	Drainage		x					cut by pipeline	H
208	Low									Flat, muskeg	L
209	High			x						off to W/NW ~1-200m	H
210	High						x			Nice margin to E of road	H
211	High				x		x			very nice, two sites along landform, IeRi-2 and 3	H
212	High	Above	wetland				x			Nice terrace margin to SE of road	H
213	Low									Borrow pit to N, wet land to S	L
214	High			x						To E good, borrow pit to W	H
215	Low									False landform	L
216	High						x			Best to E of Road	H
217	High						x			Good to W of road	H
218	High				x						H

Appendix 1: Ground-truthing notes

WPT	Observed Potential	Distance to water	Water type	Knoll	Ridge	Hilltop	Terrace	Landform size	Landform height	Comments	Model Potential
219	High				x					off to E	H
220	High			x							H
221	Low									Low-lying, wet	L
222	High*				x					Small rise overlooking muskeg with pine - LiDAR pre-dates wellsite, landscape changed	L
223	High			x						Nice small rise above muskeg	H
224	Low									slight rise, not very well defined	L
225	High			x						~10m in to W, good small knoll	L
226	High			x				40mx~60 m		Good sized fairly high knoll	H
227	High				x					NW/SE trend, low ridge	H

Notes: * indicates where the notation of potential in the field could not be matched to the LiDAR (in some cases this is due to the fact that the LiDAR pre-dates many of the developments in the field; in other cases, a waypoint taken on the road could not be moved to the appropriate feature as the feature was not clear in the LiDAR

** the potential of a feature could not be determined in the field

AST = above surrounding terrain