Using LiDAR Digital Elevation Models in Archaeological Survey Design

Examples from the foothills of Alberta

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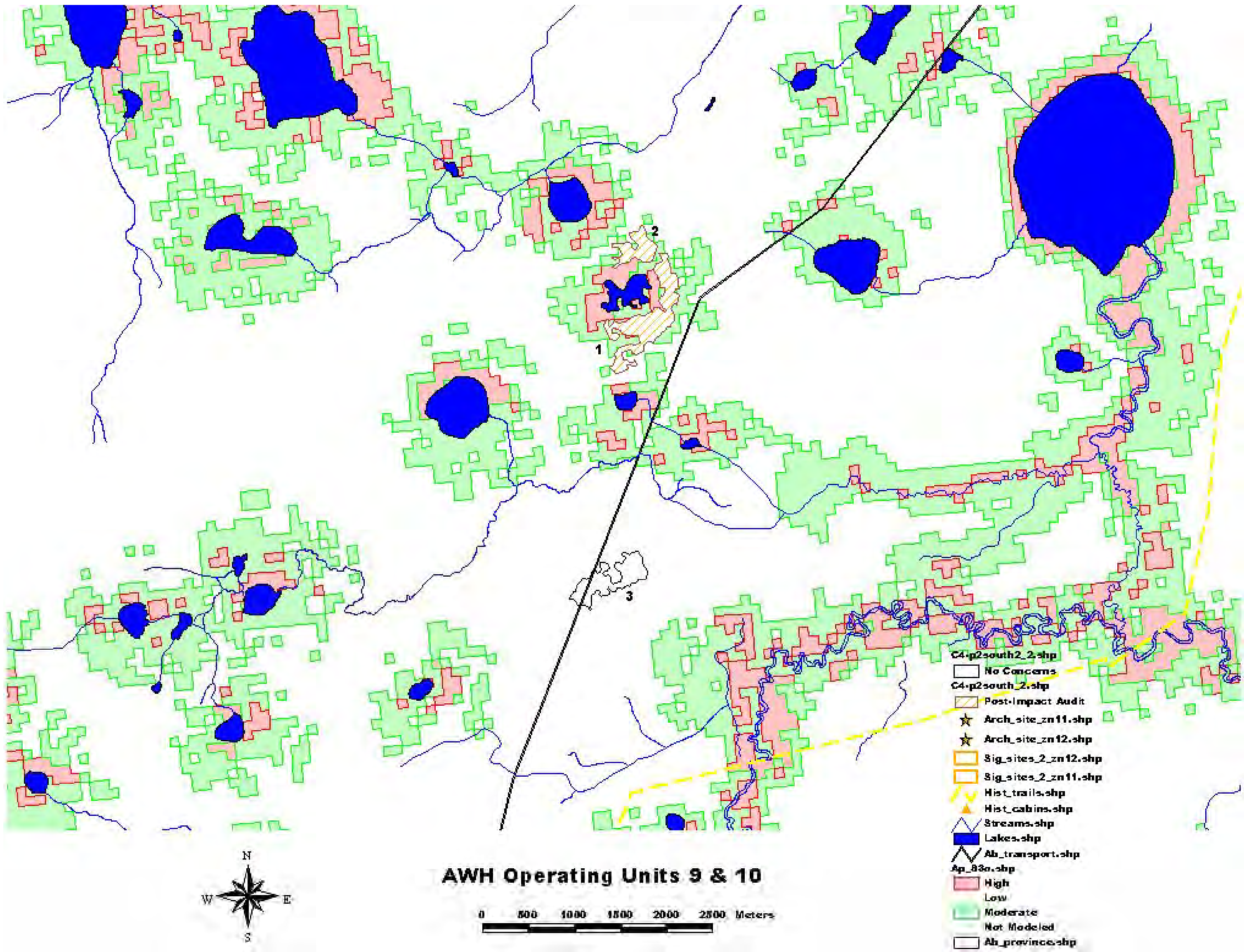
‘Predictive’ models in archaeology

- Identify areas likely to contain arch. sites
- Used as a project planning tools to help guide field survey and project component placement
- Usually use multi-criteria evaluation or regression to create low, moderate and high classes
- Most common variables are distance to water, slope, aspect, vegetation/soil
- Result in bands and patches around water sources and over heavily weighted soil/vegetation types



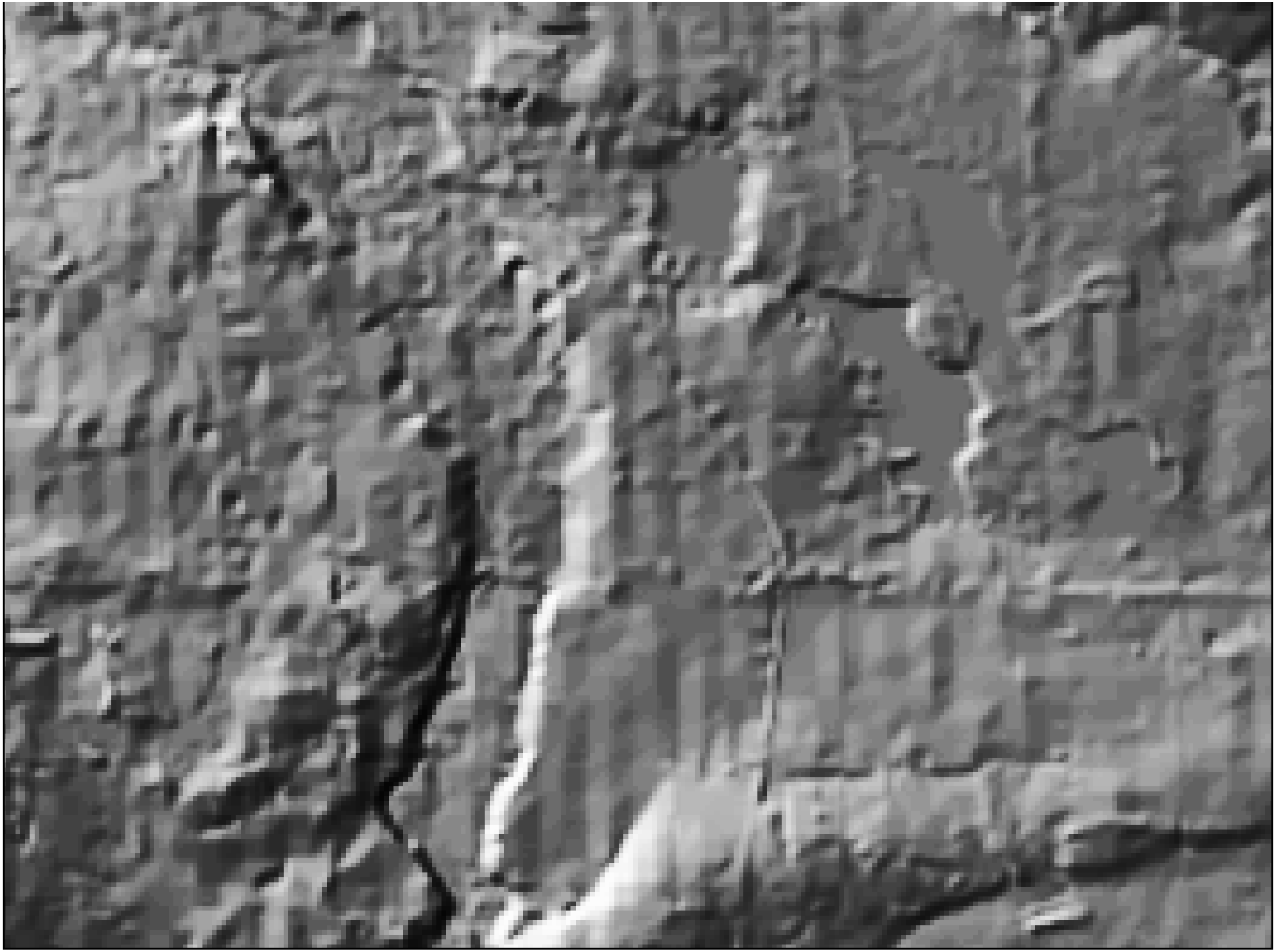
1
2
3
N
W
E
S
AWH Operating Units 9 & 10
0
500
1000
1500
2000
2500
Meters
C4-p2south2_2.shp
No Concerns
C4-p2south_2.shp
Post-Impact Audit
Arch_site_zn11.shp
Arch_site_zn12.shp
Sig_sites_2_zn12.shp
Sig_sites_2_zn11.shp
Hist_trails.shp
Hist_cabins.shp
Streams.shp
Lakes.shp
Ab_transport.shp
Ap_83o.shp
High
Low
Moderate
Not Modeled
Ab_province.shp

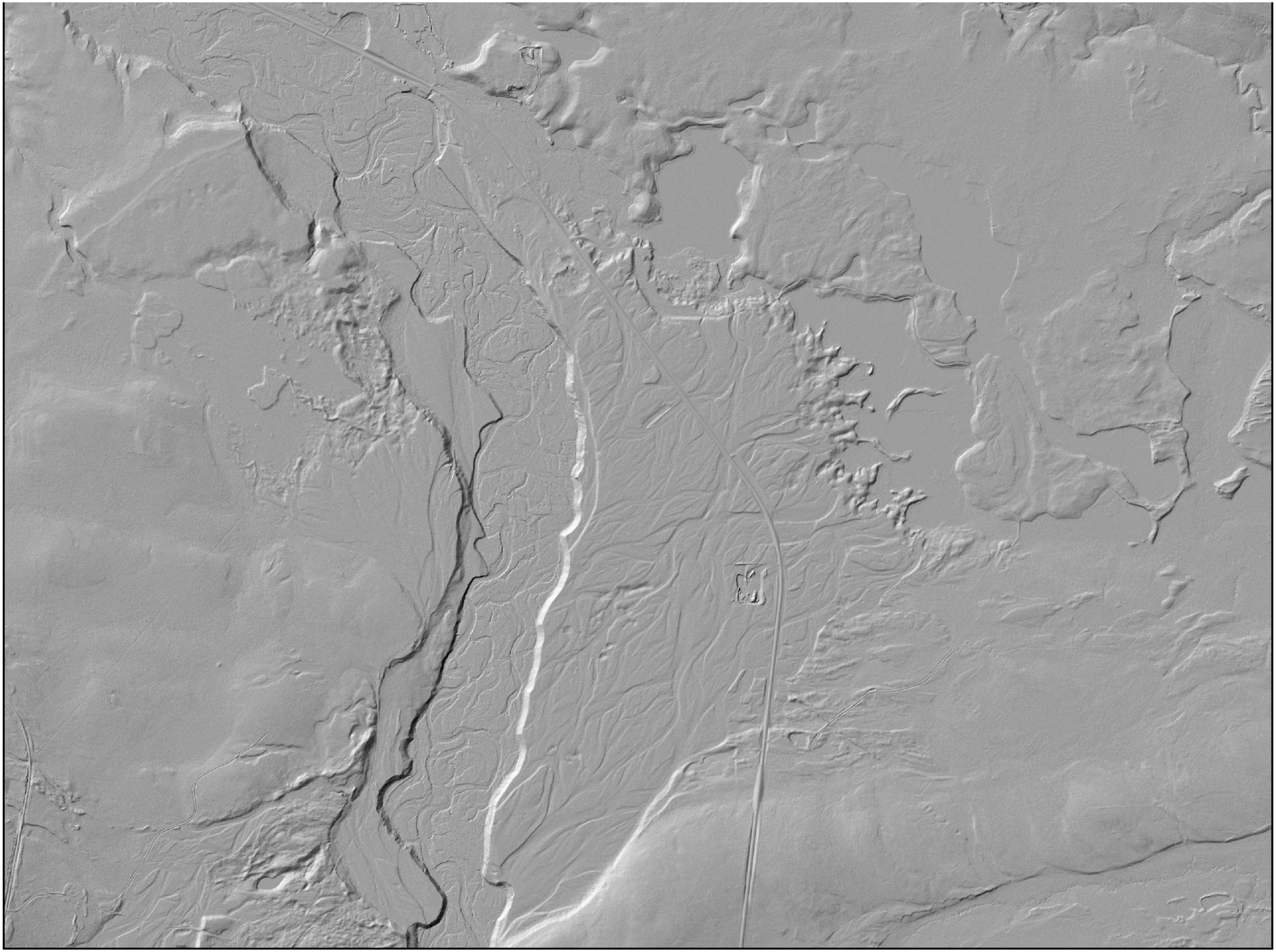
Landforms

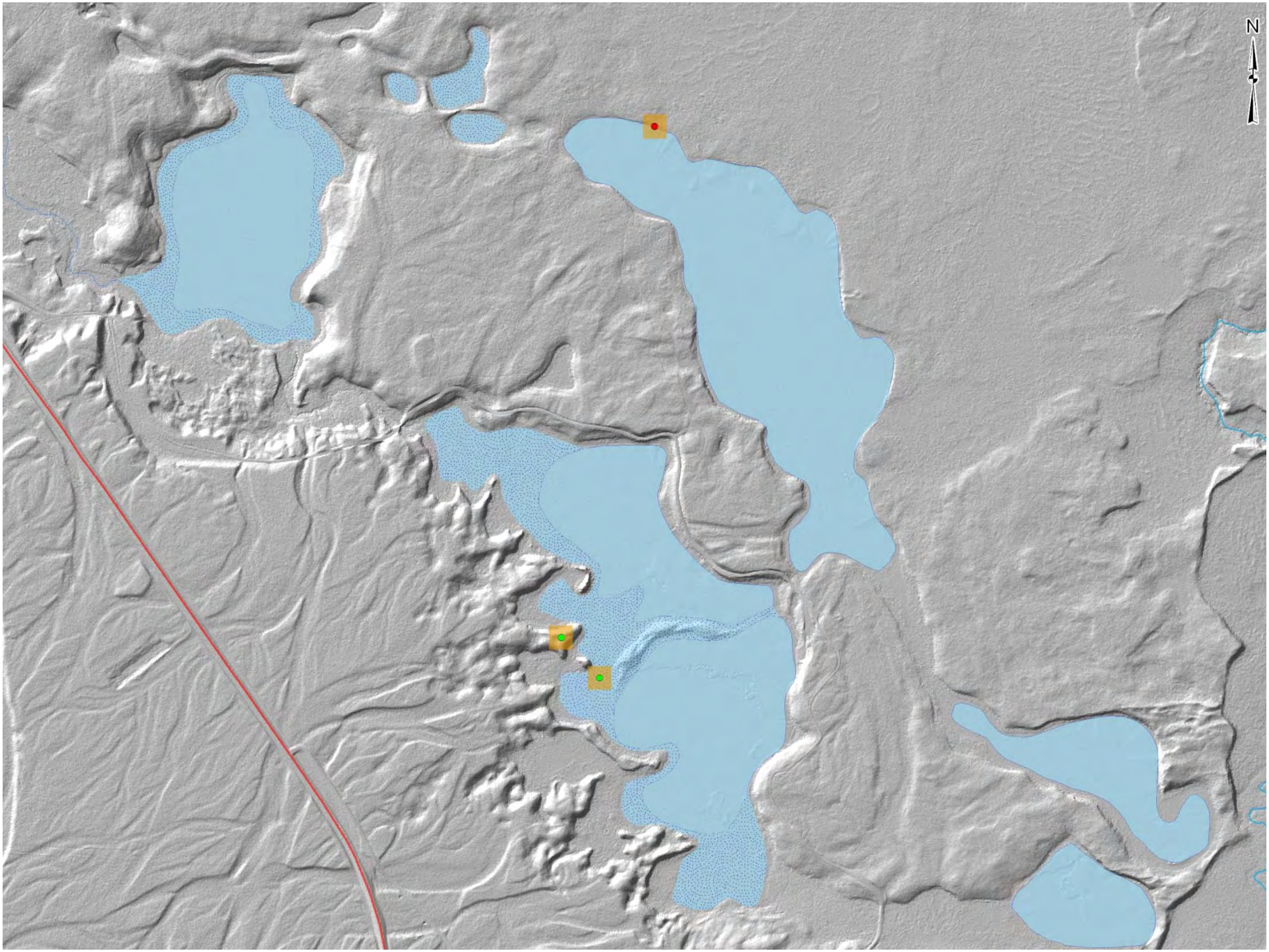
- Many of the landforms of interest to archaeologists in the forested regions of Alberta are small, discrete features that are higher than their surroundings (ridges, knolls)
- These features are difficult to resolve in coarse resolution DEMs and can be masked by vegetation in aerial photographs.
- Bare earth LiDAR models strip the vegetation and reveal "microtopography"
- Landforms of interest can be identified through manual examination of hillshade images and 3D perspective views or through some form of semi-automated landform classification
- Survey target areas are more accurately defined pre-field, leading to less time spent in the field
- Maintain representative samples and site returns

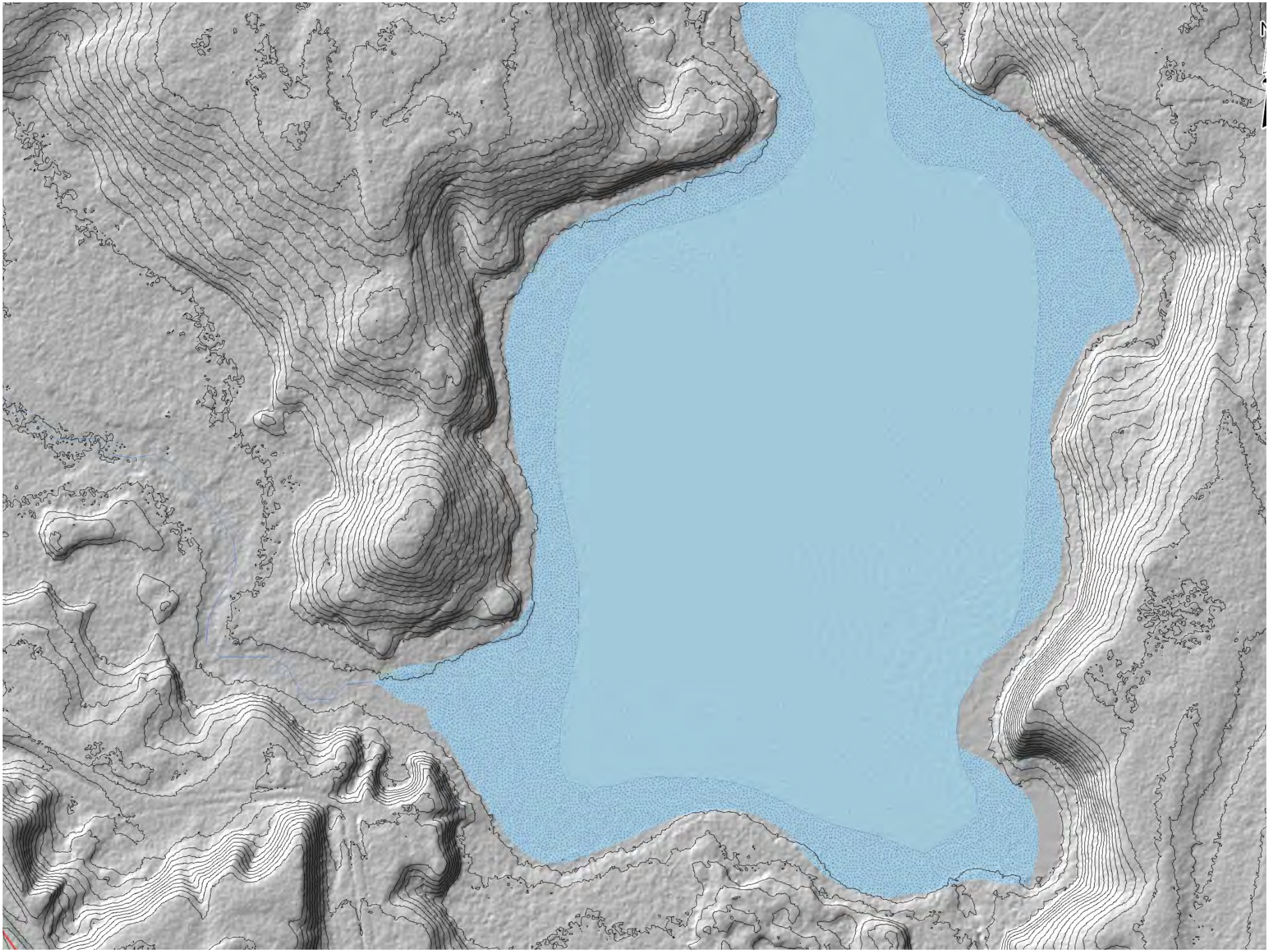
Landform Selection

- Desirable landform characteristics:
  - Flat, well drained
  - Near hydrological resource (modern or ancient)
  - Close to a terrain break (relief)
  - Viewshed
  - Some likelihood of sedimentation
- **Essentially a raised, flat, somewhat dry area located near a terrain break and a hydrological resource.**



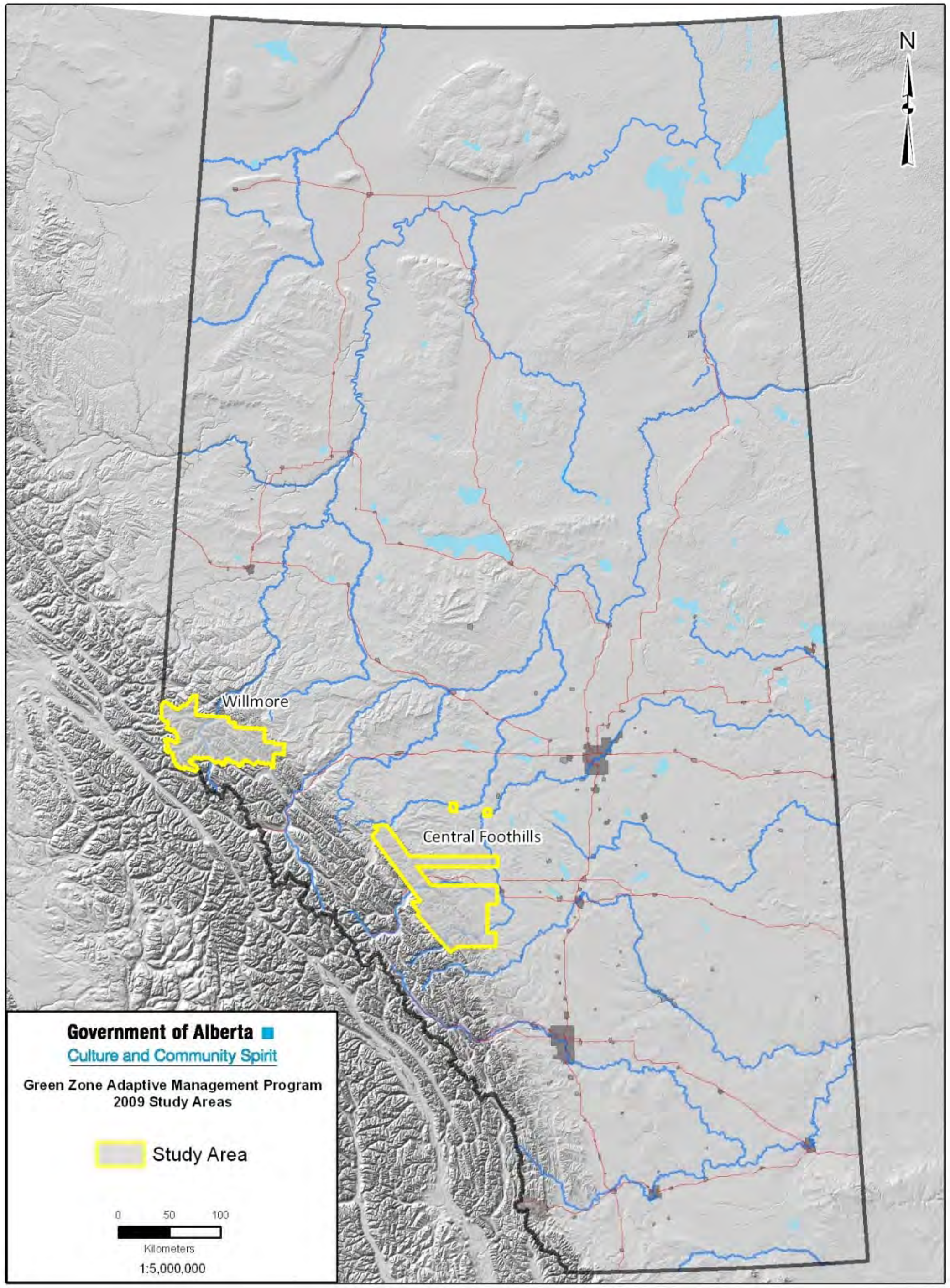



N



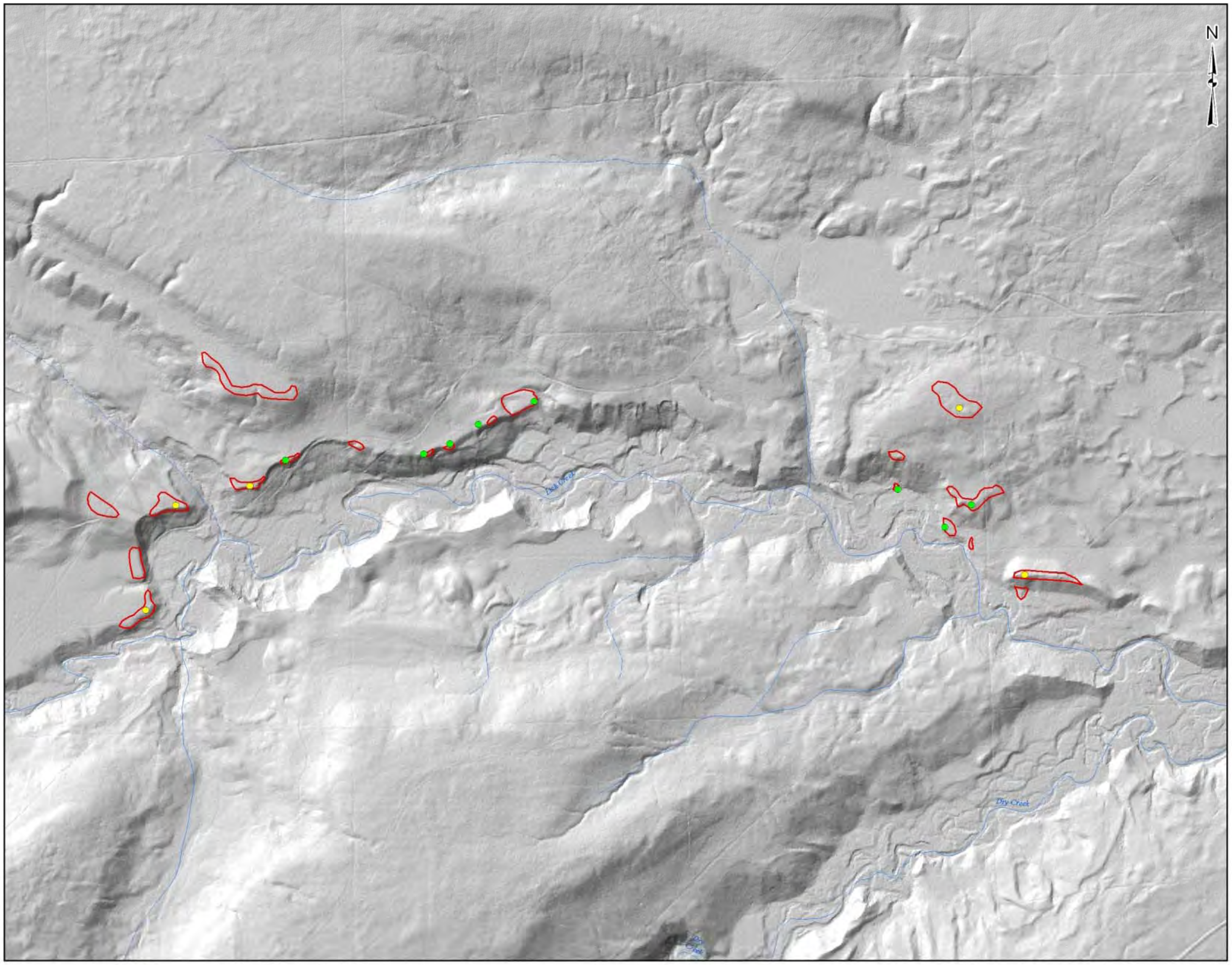
Expert Model Field Test – Alberta Foothills

- Two study areas – central foothills (Rocky Mountain House/Sundre Area) and Willmore Wilderness Park
- Central foothills survey concentrated on tributary valleys near proposed or existing cutblocks
- Willmore survey concentrated on major river valleys
- Target areas selected by manual analysis of hillshade images, aerial photographs, and topographic data
  - Called ‘expert landforms’


N
Willmore
Central Foothills
Government of Alberta
Culture and Community Spirit
Green Zone Adaptive Management Program
2009 Study Areas
Study Area
0 50 100
Kilometers
1:5,000,000

Field Survey

- All selected high potential landforms were assessed in the field
- Subjective determinations of ‘ground truth’ regarding potential were made



LEGEND

Arky Sites HRV

HRV

- <Null>
- HRV 0
- HRV 1
- HRV 2
- HRV 3
- HRV 4
- N/A

Target Landforms

Government of Alberta

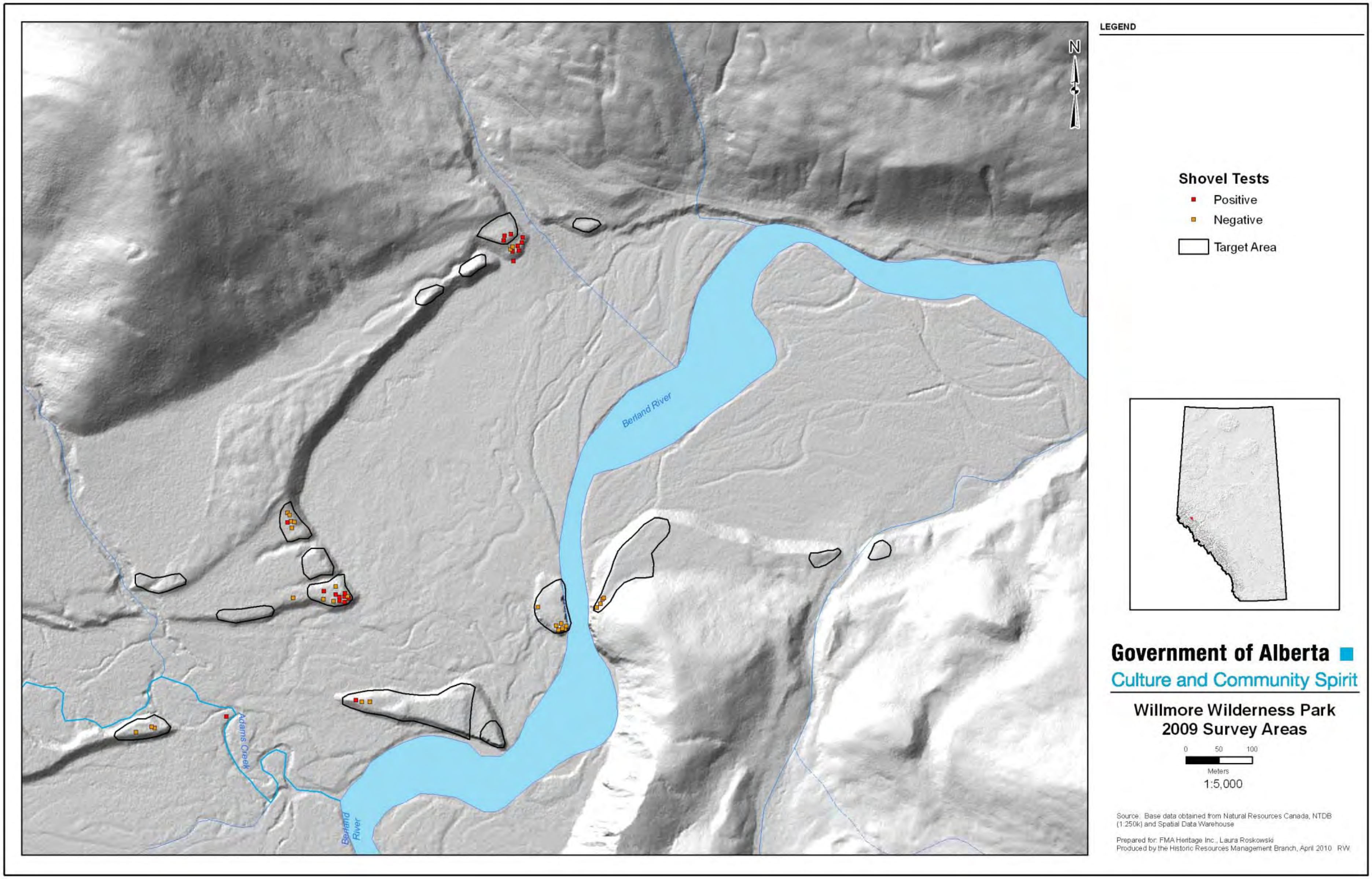
Culture and Community Spirit

Target Landforms
2009 Green Zone AMP

1:10,000

0 100 200
Meters

Source: Base data obtained from Spatial Data Warehouse
Produced by the Historic Resources Management Branch, April 2010. RW



N
Berland River
Adams Creek
Berland River
LEGEND
Shovel Tests
Positive
Negative
Target Area
Government of Alberta
Culture and Community Spirit
Willmore Wilderness Park
2009 Survey Areas
0 50 100
Meters
1:5,000
Source: Base data obtained from Natural Resources Canada, NTDB (1:250k) and Spatial Data Warehouse
Prepared for: FMA Heritage Inc., Laura Roskowski
Produced by the Historic Resources Management Branch, April 2010 RW

Results

- Successful. Found 27 sites in a week and a bit
- Site returns in CFH was 26%; 54% in Willmore
- For the most part, landforms selected were shovel test-worthy (70% CFH; 96% Willmore)
- Willmore more successful – combination of survey constraints, experience, time, environment, past land use (?)
- Field efficiency greatly improved
- Some areas have the right combinations of landform characteristics, but still did not yield archaeological sites or conform to our idea of mod/high potential
  - Scale?
  - Chance?
  - Other factors?
- Manual interpretation of images for large areas would be time consuming

Modeling

- Creating archaeological potential maps from high resolution sources is very time consuming for large areas
- Computer aided models assumed to reduce time
  - More standardized methods and documentation
  - Easier to alter
  - **No more accurate** than an experienced archaeologist
- Undertook a test model for a small portion of Lick Creek basin

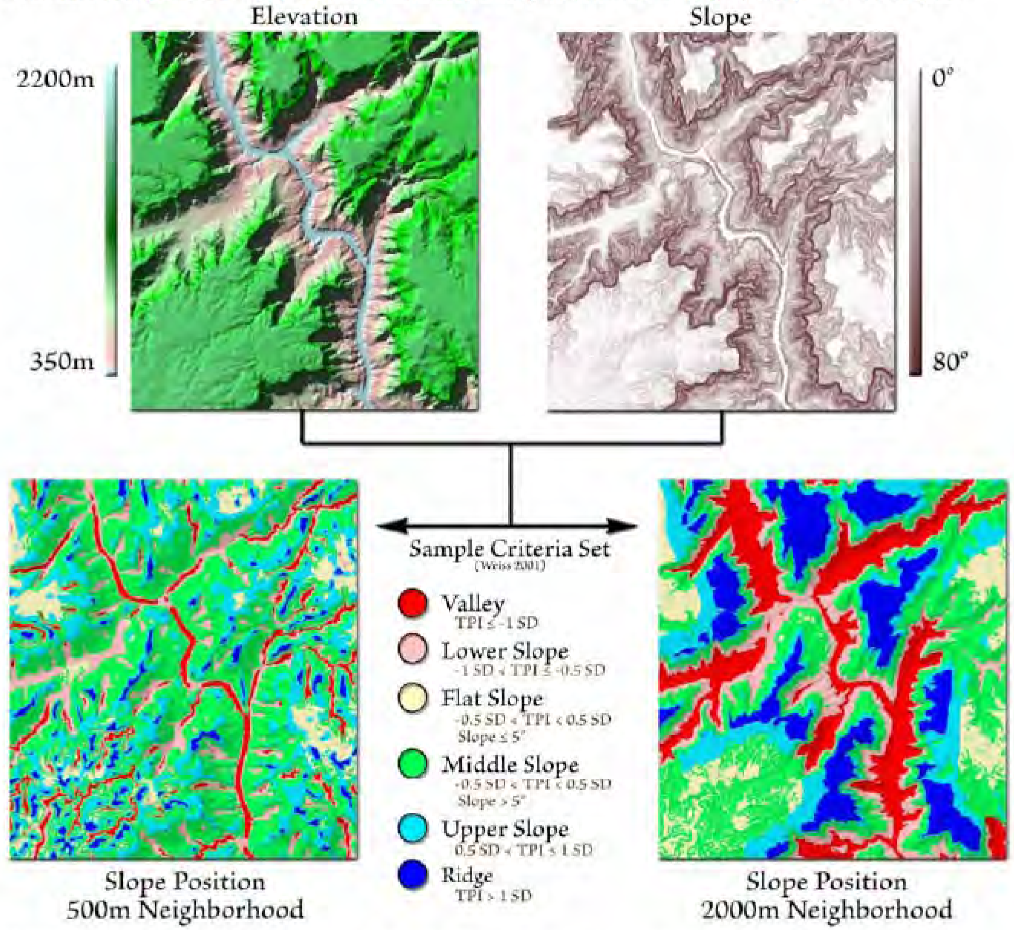
Modeling

- Goal is to create a digital model that more accurately reflects assumptions used by archaeologists (self fulfilling, for the moment)
- Basic assumption: Areas likely to contain archaeological sites occur on flat, well drained, **raised landforms** located near **water sources**
- Many other factors contribute to site location, but we begin with these two main variables
- Pilot model created for a portion of the Lick Creek basin, southwest of Rocky Mountain House – Sundre Forest Products

Raised Landform Detection

- Pre-processing – filtering and resampling.
- Digital terrain analysis:
  - Jenness' slope position index (SPI)
    - ArcGIS 9.3.1
    - Uses topographic position index (TPI) and slope values to classify landscape into ridges, flat areas, slopes and valleys
  - Pennock et al. (1987) landform classification
    - Uses curvatures and slope to classify landscape into convergent/divergent shoulders, backslopes, footslopes and level areas
    - Terrain Analysis System 2.0.9 (TAS)
    - Open source GIS created by John Lindsay (Guelph)

TPI values near 0 mean only that the elevation is close to the mean elevation of the neighborhood cells, and this could happen if that cell is in a flat area or if it is mid-slope somewhere. An easy way to distinguish between these 2 possibilities is to check the slope at that point. If the slope is near 0, then the point is probably on a flat area. A high slope value implies that the point is mid-slope somewhere. In his poster, Weiss demonstrates one possible classification process using both TPI and slope to generate a 6-category Slope Position grid.

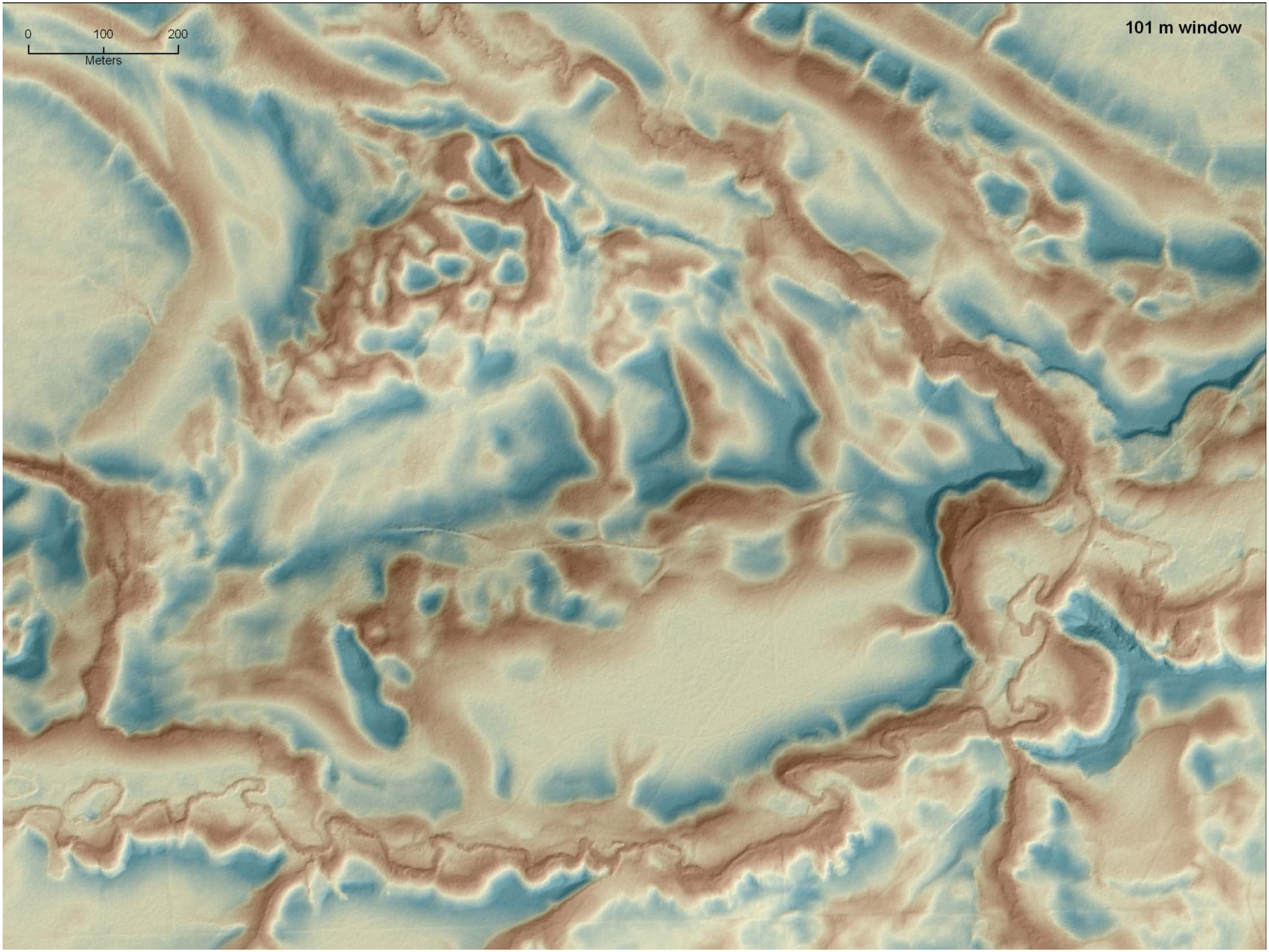


Classifying by Landform Category: Landform category can be determined by classifying the landscape using 2 TPI grids at different scales. The combination of TPI values from different scales suggest various landform types.

From Jeff Jenness 2006
TPI V1.0.2 guide

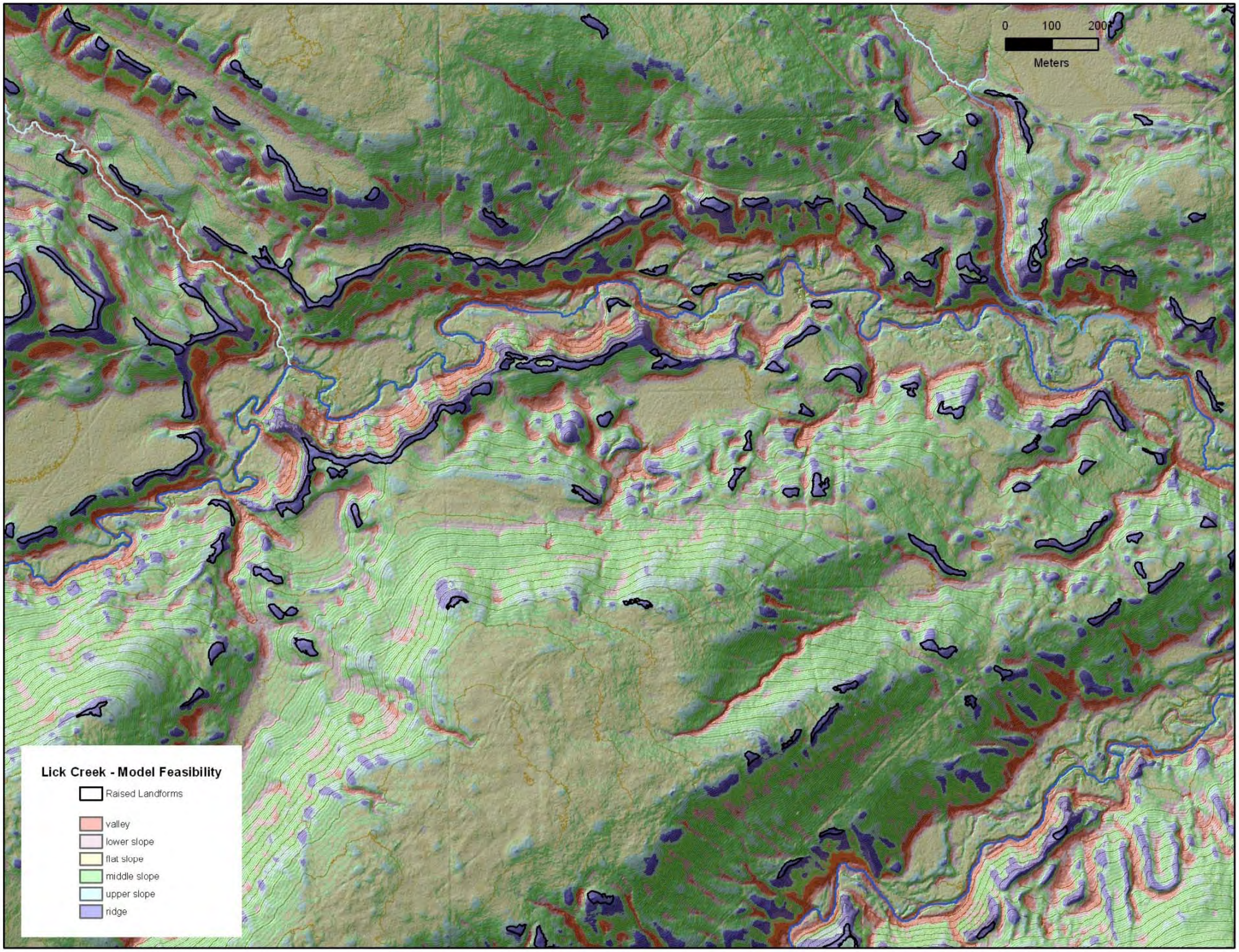
Noise reduction, scale

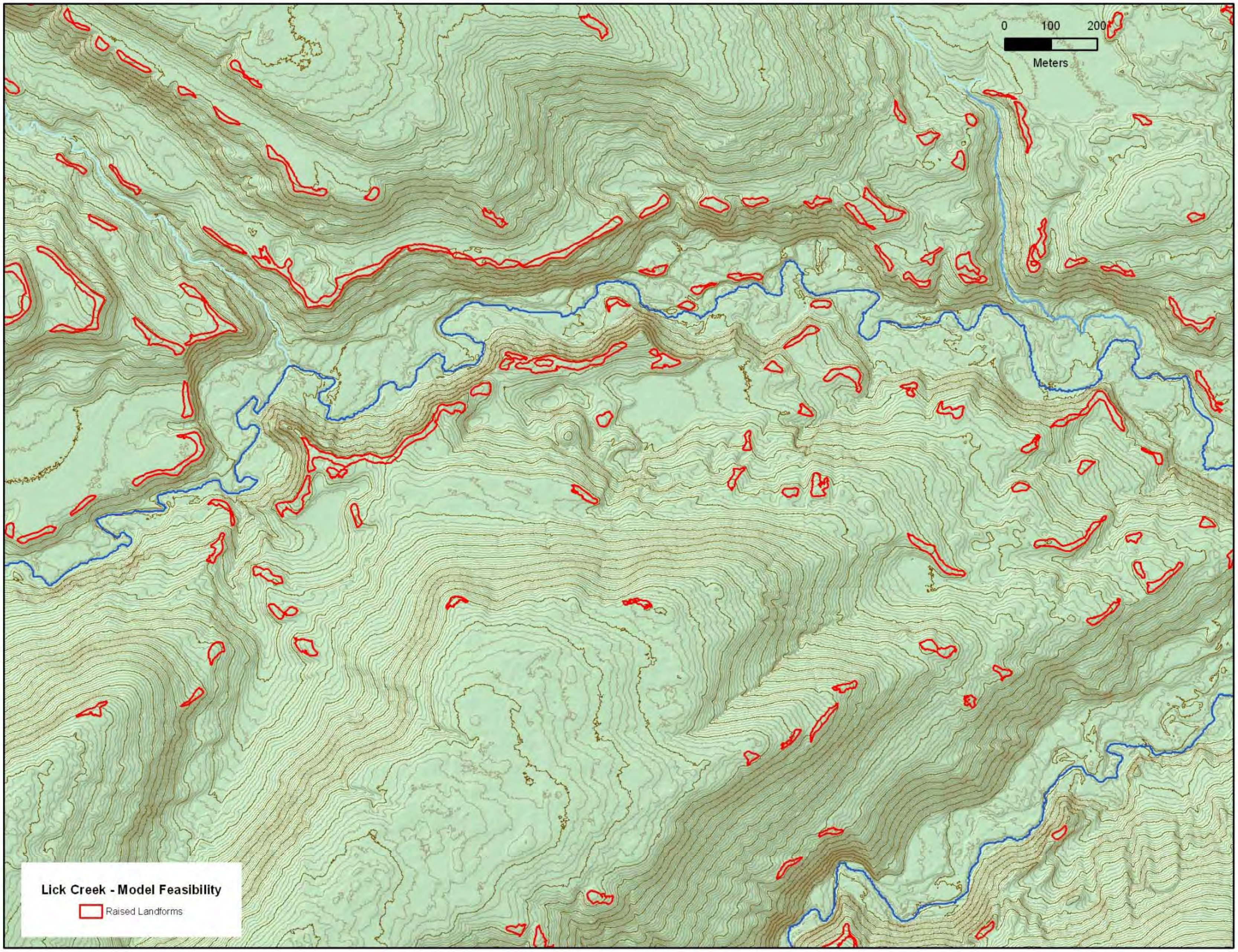
- For SPI, adjusted window size during analysis to control noise and scale of analysis


0
100
200
Meters
101 m window

Slope Position Index

- 31m x 31m neighbourhood
- Classifies landscape into ridges, valleys, middle slope, upper slope, flat slope. We're interested in ridges.
- Eliminated sloped ridges (>10°) and ridges smaller than 400 square metres, leaving flat areas that are perched above their surroundings at the selected scale


0 100 200
Meters
Lick Creek - Model Feasibility
Raised Landforms
valley
lower slope
flat slope
middle slope
upper slope
ridge



0
100
200
Meters
Lick Creek - Model Feasibility
Raised Landforms

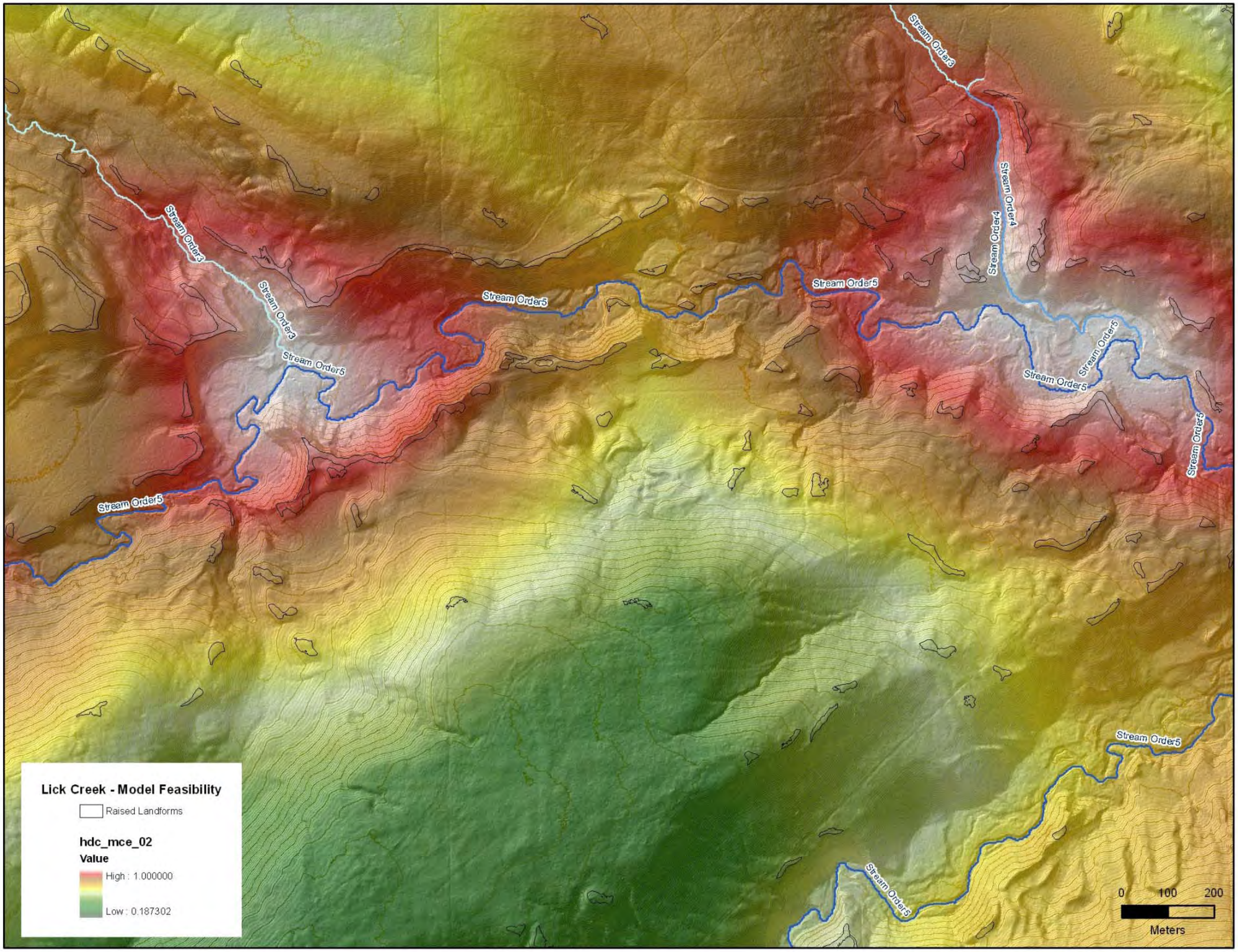
Raised Landform Detection

- Isolating discrete landforms reduces the 'ribbon' effect common in GIS models that use more conventional methods
- Low, saturated floodplain areas are not selected
- However, all raised landforms are not equally likely to contain sites.
- Need to be placed in environmental and cultural contexts

Relationship to Watercourses

Horizontal distance to channel (HDC)

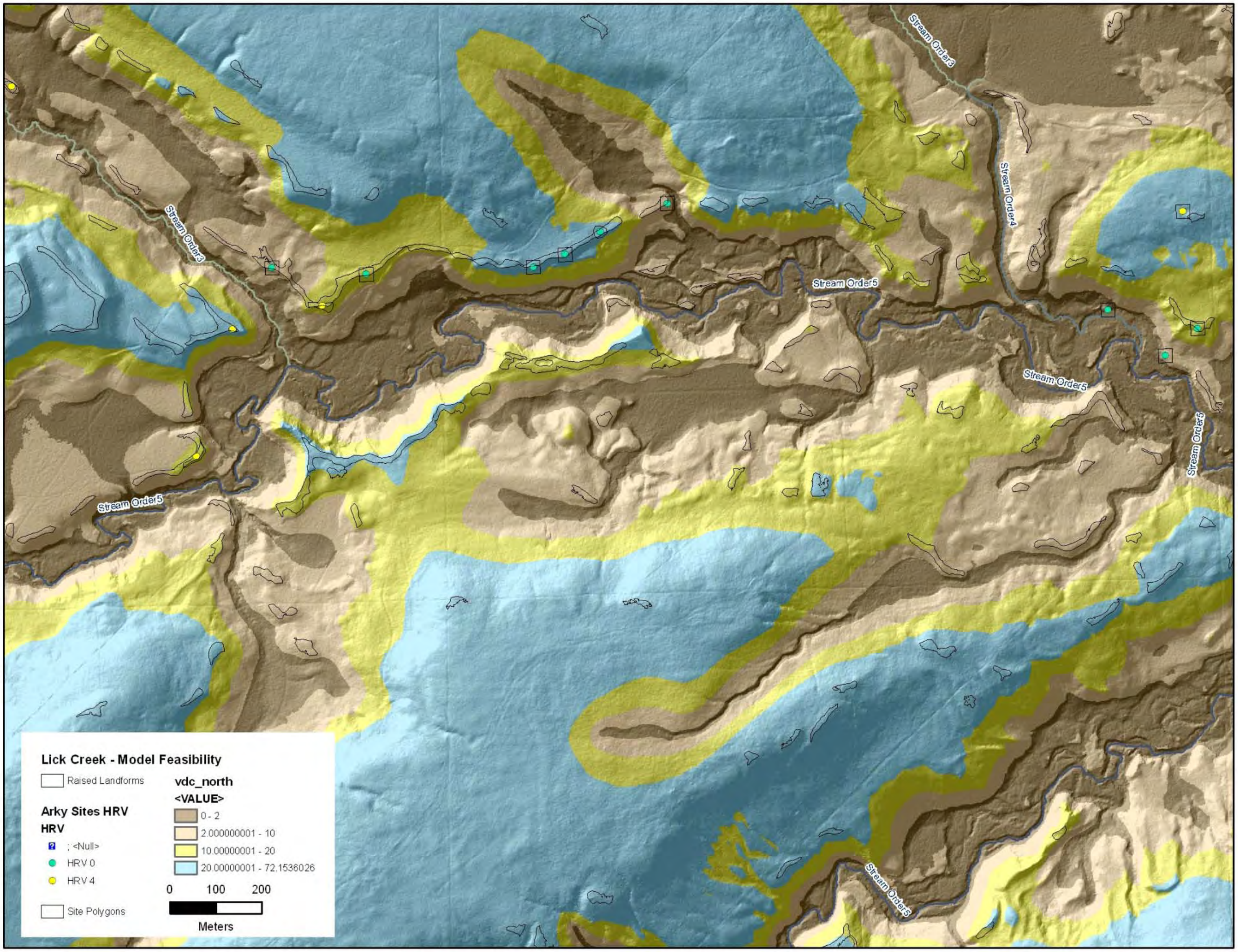
- Areas likely to contain archaeological sites are commonly associated with stream courses
- Stream size and may be correlated with site location
- Strahler stream order is one measure of stream size
- Created a layer that classifies the landscape according to horizontal proximity to channels of selected Strahler rankings
- If an area is close to a high order stream, or at the intersection of several streams, it receives a high horizontal distance to channel (HDC) score


Lick Creek - Model Feasibility
Raised Landforms
hdc_mce_02
Value
High : 1.000000
Low : 0.187302
Stream Order3
Stream Order4
Stream Order5
0
100
200
Meters

Relationship to Watercourses

Vertical distance to channel (VDC)

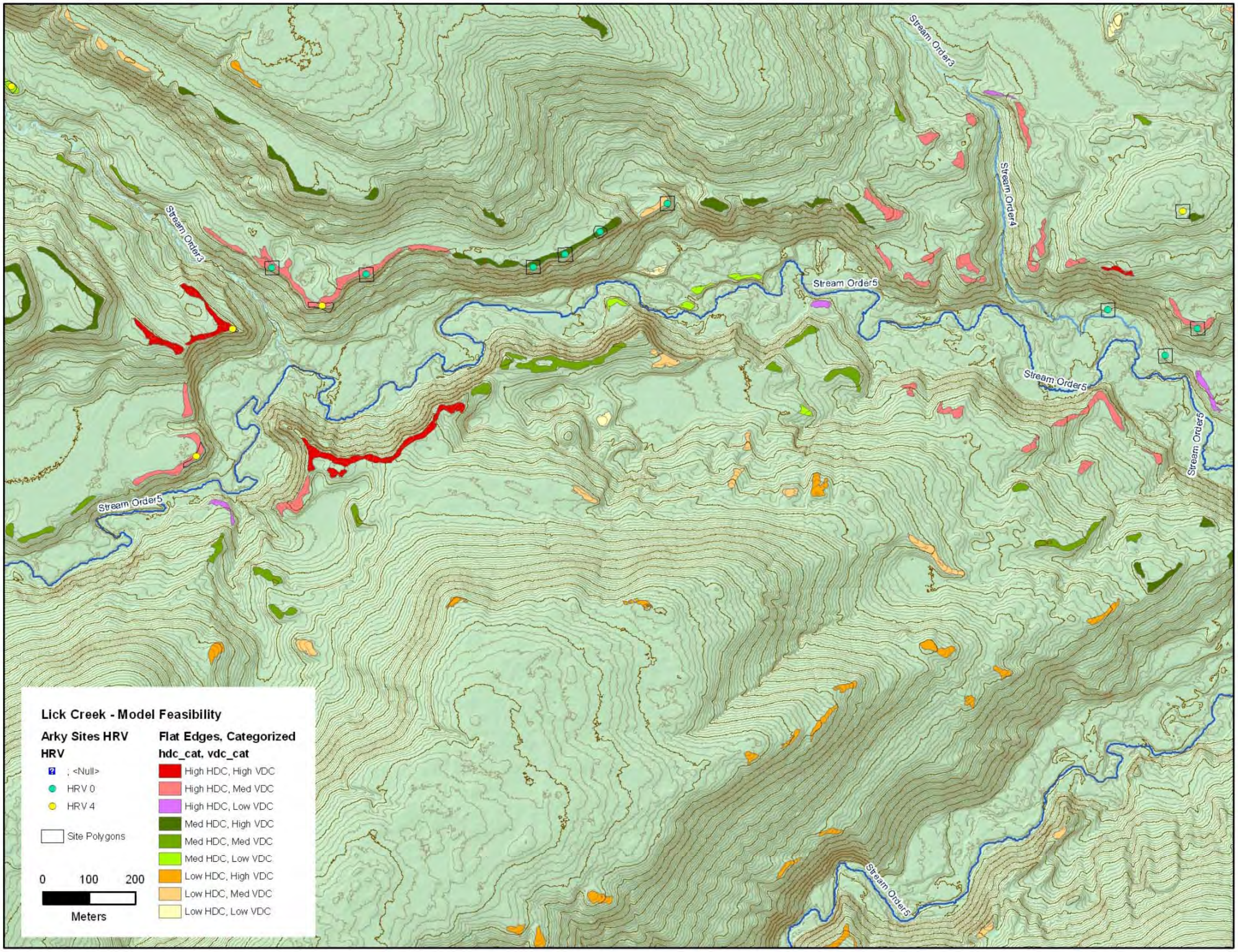
- Some landforms may be close to water sources in the x,y, but not in the z
- Calculated VDC to provide additional context for the raised landforms
- VDC may help identify areas likely to contain different site types or sites of particular ages



Lick Creek - Model Feasibility
Raised Landforms
Arky Sites HRV
HRV
; <Null>
HRV 0
HRV 4
Site Polygons
vdc_north
<VALUE>
0 - 2
2.000000001 - 10
10.00000001 - 20
20.00000001 - 72.1536026
0
100
200
Meters
Stream Order3
Stream Order4
Stream Order5

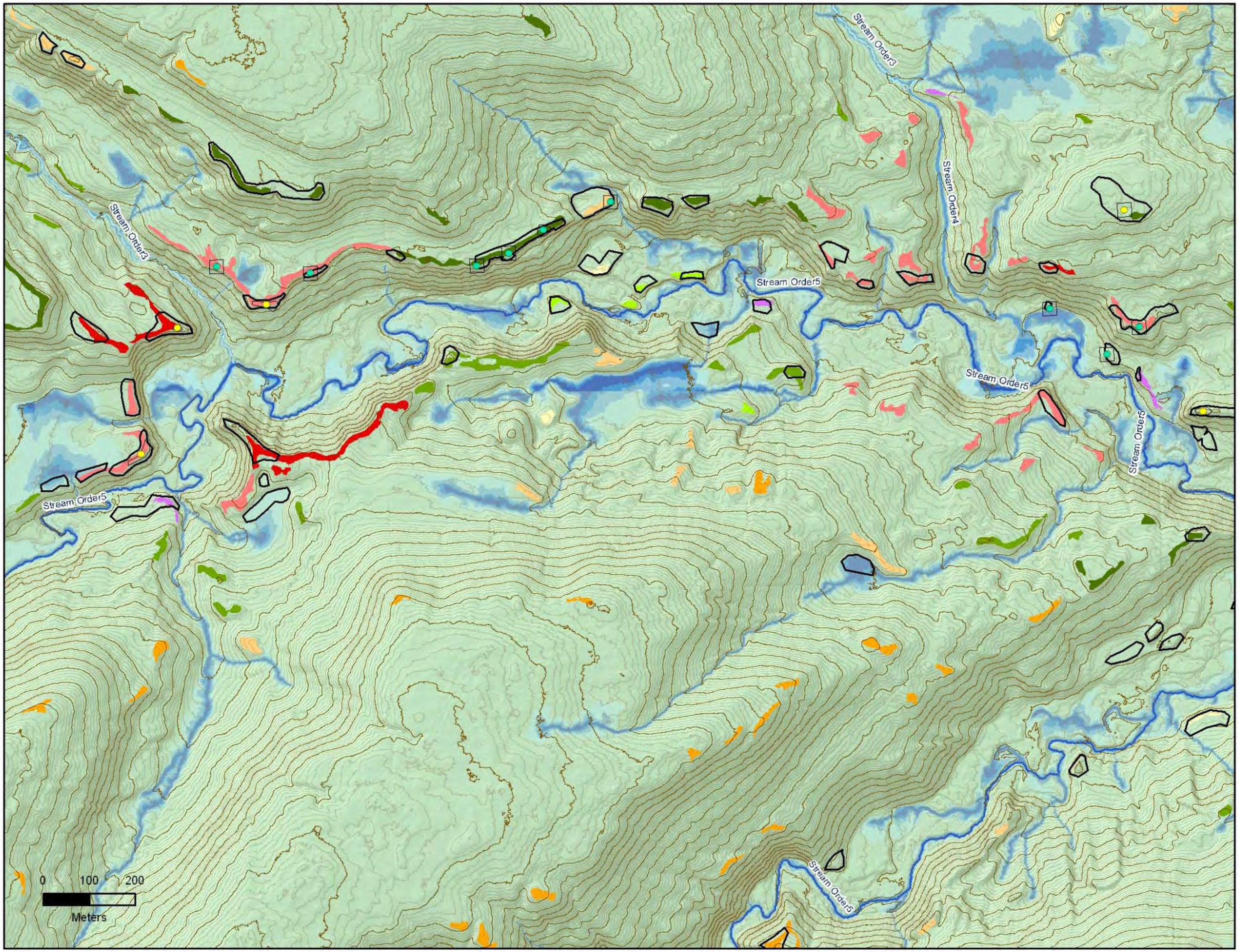
Results

- Raised landforms with high HDC scores may be considered to have higher potential
- VDC categorization provides additional context


Lick Creek - Model Feasibility
Arky Sites HRV
HRV
; <Null>
HRV 0
HRV 4
Site Polygons
Flat Edges, Categorized
hdc_cat, vdc_cat
High HDC, High VDC
High HDC, Med VDC
High HDC, Low VDC
Med HDC, High VDC
Med HDC, Med VDC
Med HDC, Low VDC
Low HDC, High VDC
Low HDC, Med VDC
Low HDC, Low VDC
0
100
200
Meters
Stream Order3
Stream Order4
Stream Order5

Expert Model vs. Digital Terrain Model

- Expert model identified 158 landforms with high potential (0.33 km^2). This represents (0.7%) of the model area
- Digital Terrain Model identifies:
  - High HDC: 251 (0.25 km^2; 0.6% of model area)
  - Moderate HDC: 280 (0.26 km^2; 0.6% of model area)
  - Low HDC: 708 (0.64 km^2 ; 1.4% of model area)
- The model and field programs are not yet at the stage where reliable accuracy assessments can be made


Stream Order3
Stream Order3
Stream Order4
Stream Order5
Stream Order5
Stream Order5
Stream Order5
Stream Order5
0 100 200
Meters

Conclusions

- LiDAR has great potential to increase the efficiency and efficacy of archaeological field survey
- Digital terrain analysis is key to effective computer based models
  - Effective at mimicking expert knowledge
- This approach is feasible, but requires further investigation

Future Work

- Assess other landform classification schemes
- Complete analysis of 2011 fieldwork (expanded to areas near Smoky River, Wapiti River, Athabasca River)
- Incorporate other variables: hydrological network connections, drainage basin characteristics, solar insolation
- Look at other site types, more rigorous field testing
- Assessment of how models can be used in regulatory environment: Green Zone Adaptive Management Program
  - Also address resources involved in creating models for large areas
- Collaboration with other Ministries, universities and industry
  - Can help pose and answer both research and regulatory questions