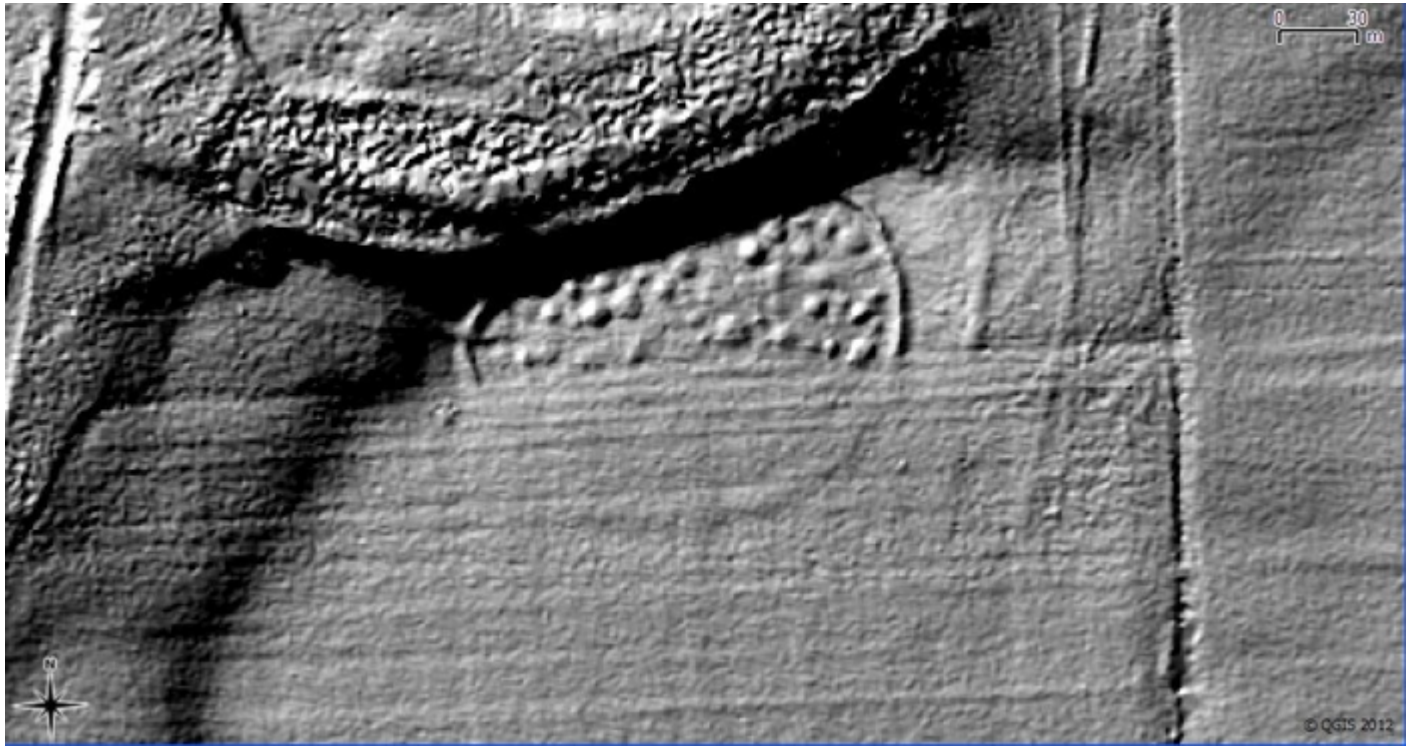
Non-Invasive Archaeological Site Assessment: A Combined Approach Using LiDAR and Sub-Surface Geophysical Survey

David Maki
Archaeo-Physics, LLC

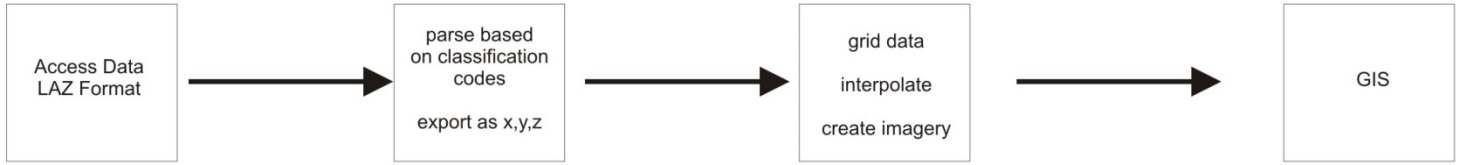


- Briefly examine data processing and imaging methods

- Discuss several case studies using LiDAR in an archaeological context
  - LiDAR for large-scale reconnaissance
  - LiDAR for geo-referencing historic maps
  - LiDAR using to target features for sub-surface geophysical survey

WORK FLOW

Data Processing



USGS
science for a changing world

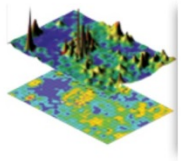
Minnesota
Department of Natural Resources

LAStools
by rapidlasso

rapidlasso

SAGA
System for Automated Geoscientific Analyses

Surfer® 12

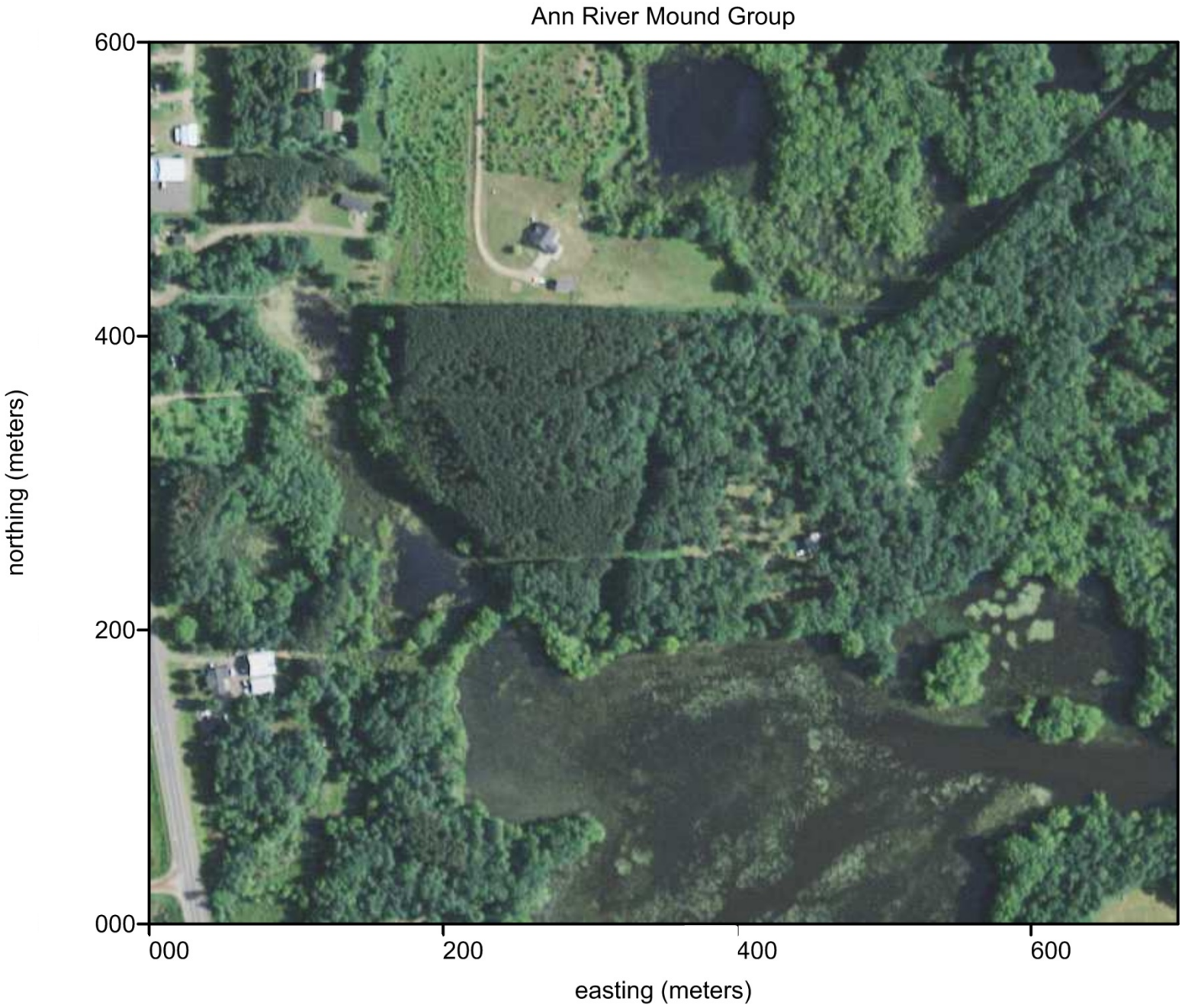


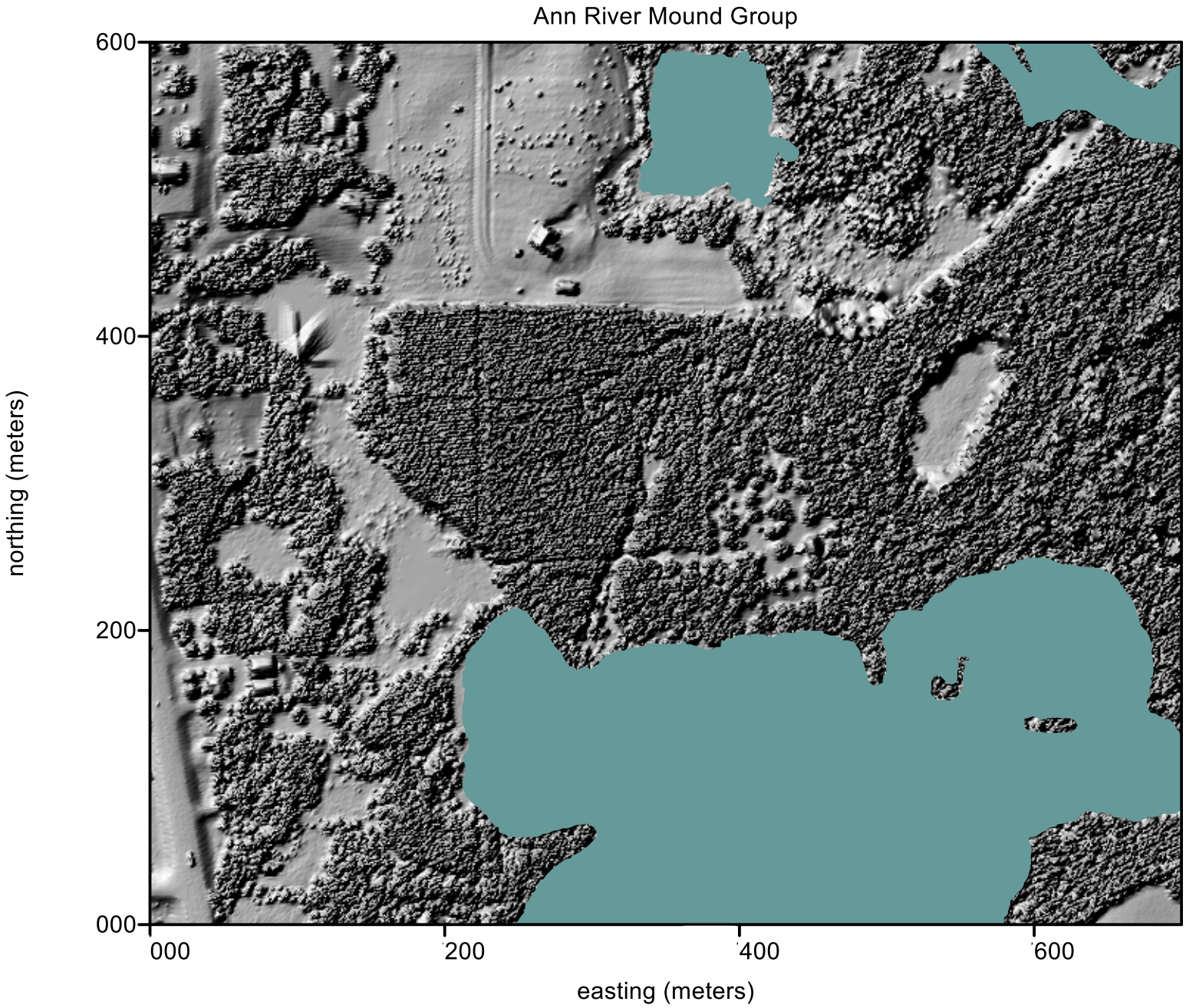
QGIS
Trademark

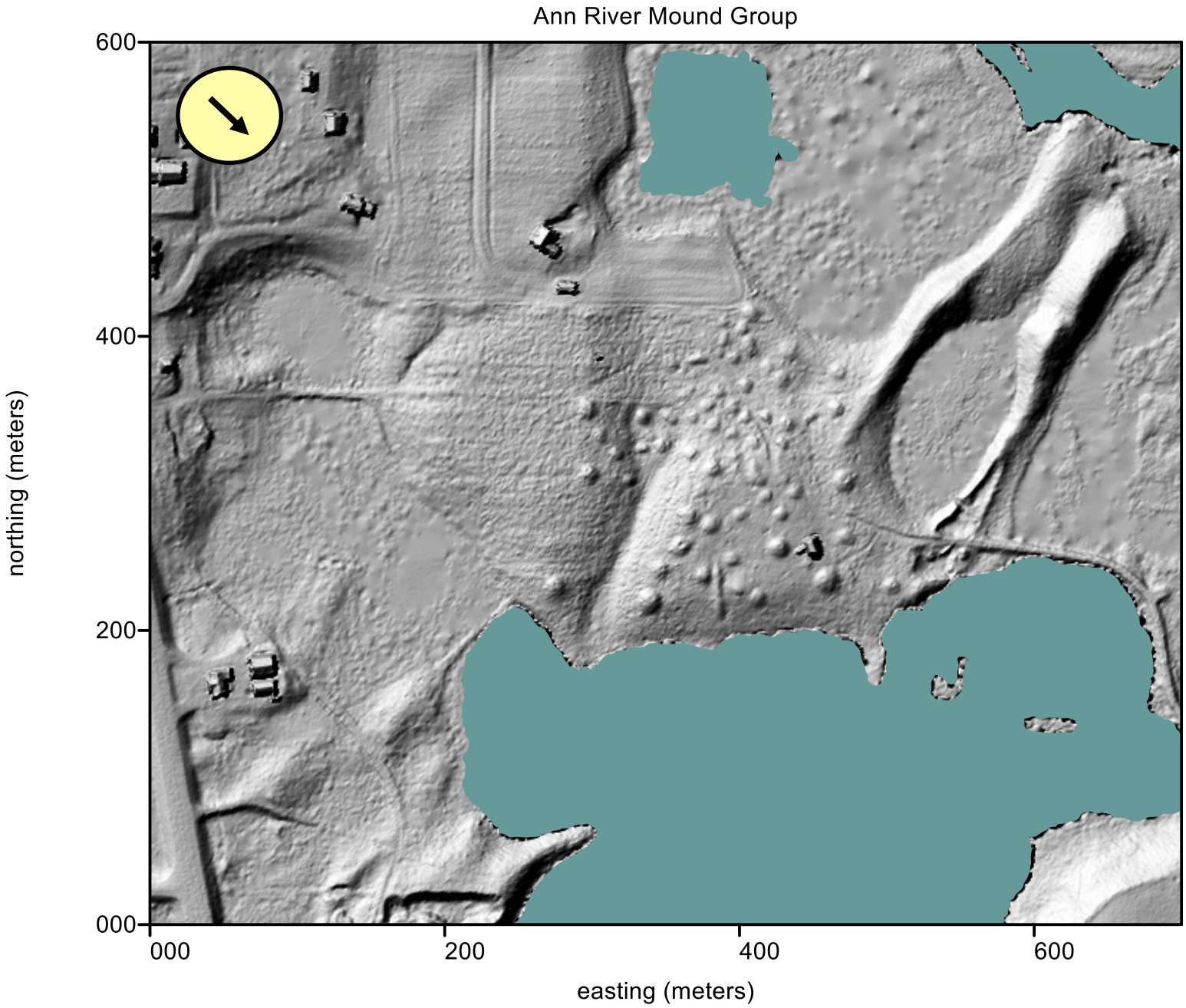
Common LiDAR Visualization Methods for Archaeological Prospection

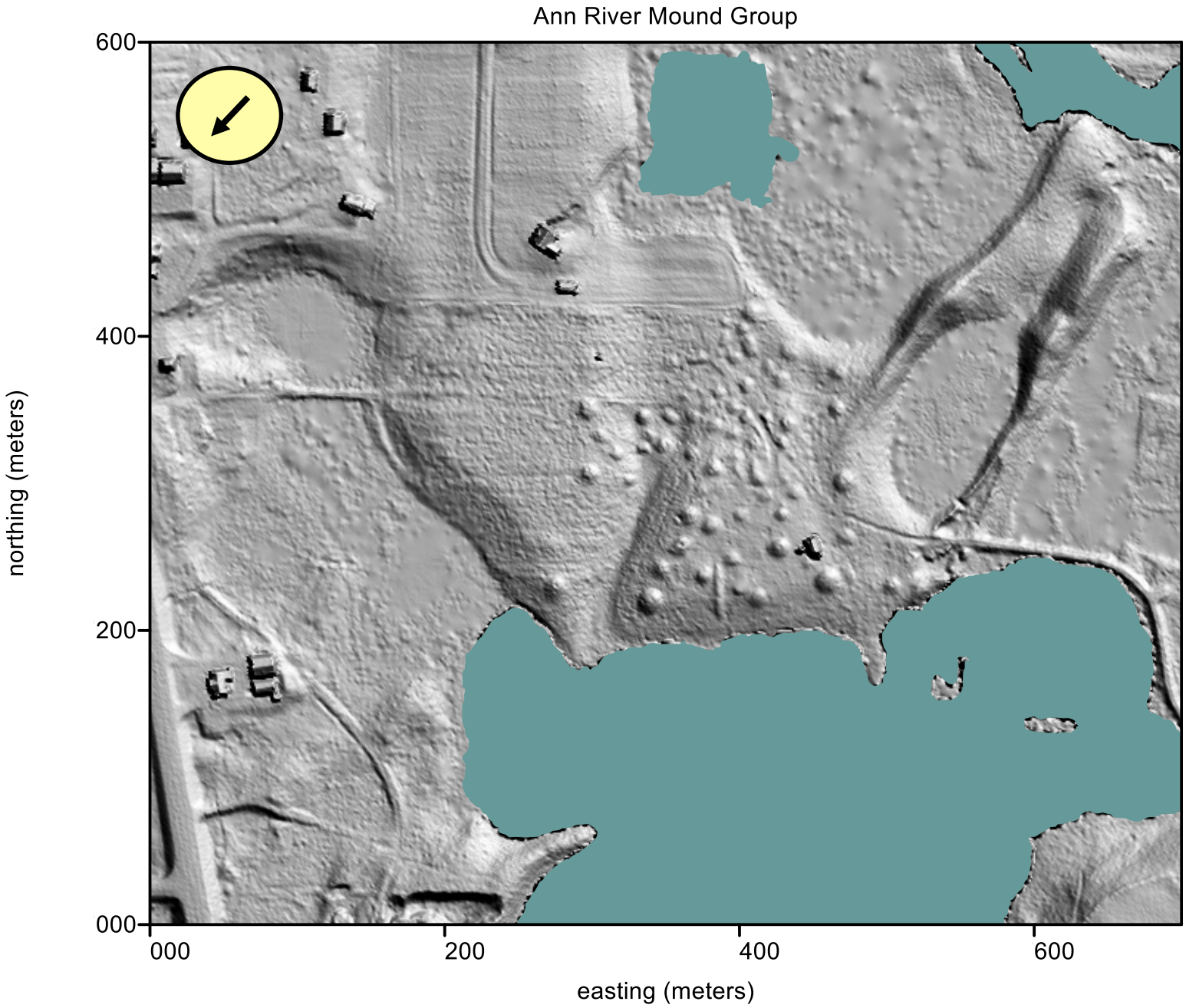
- **Shaded-Relief**
- **Constrained Shading**
- **Local Relief Models**
- **Terrain Slope**
- **Visible Sky and Sky View Factor**
- **Solar Insolation**

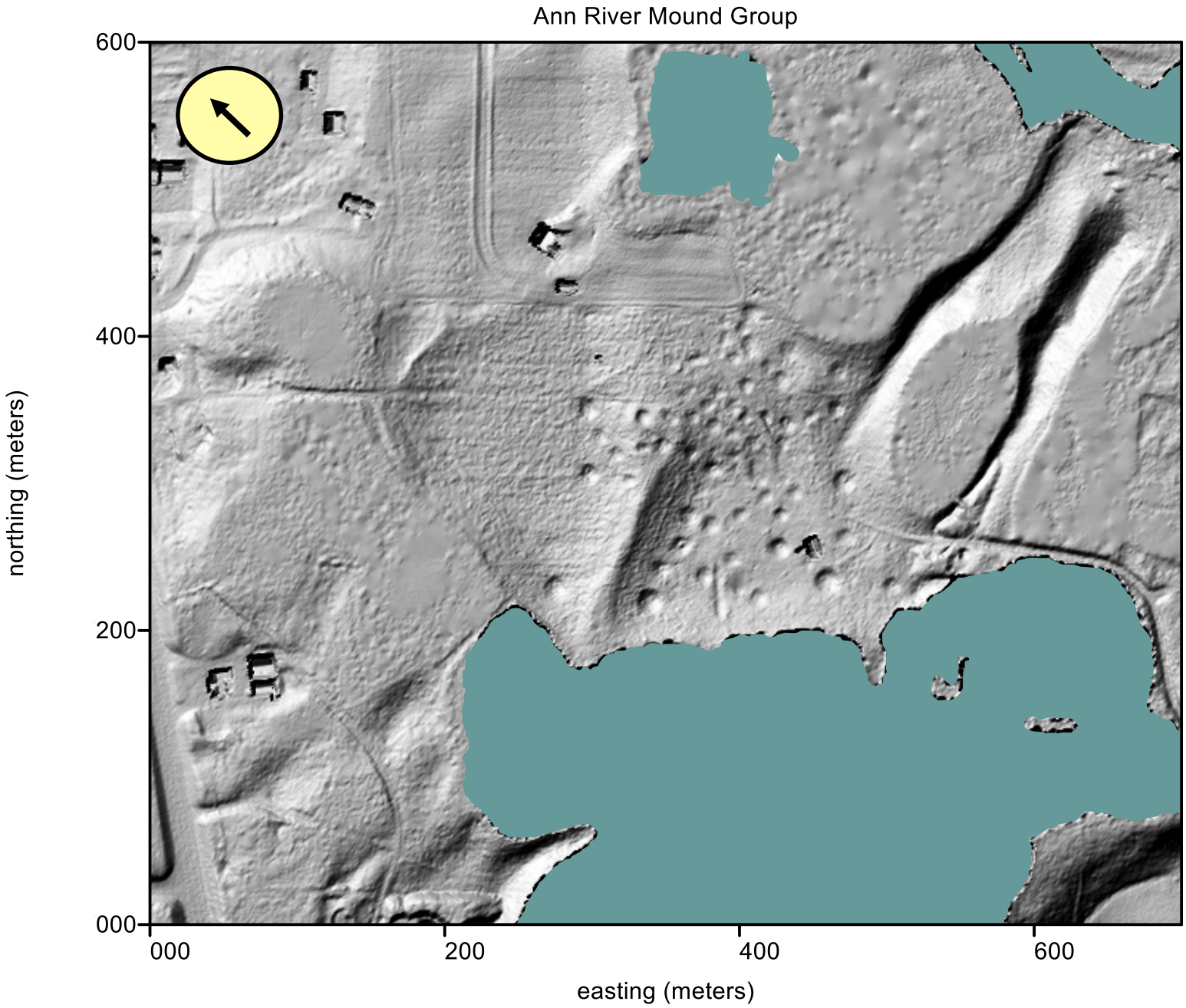
- **Shaded-Relief**: Artificial illumination of a DEM. Most common and intuitive, but care must be taken with lighting direction.

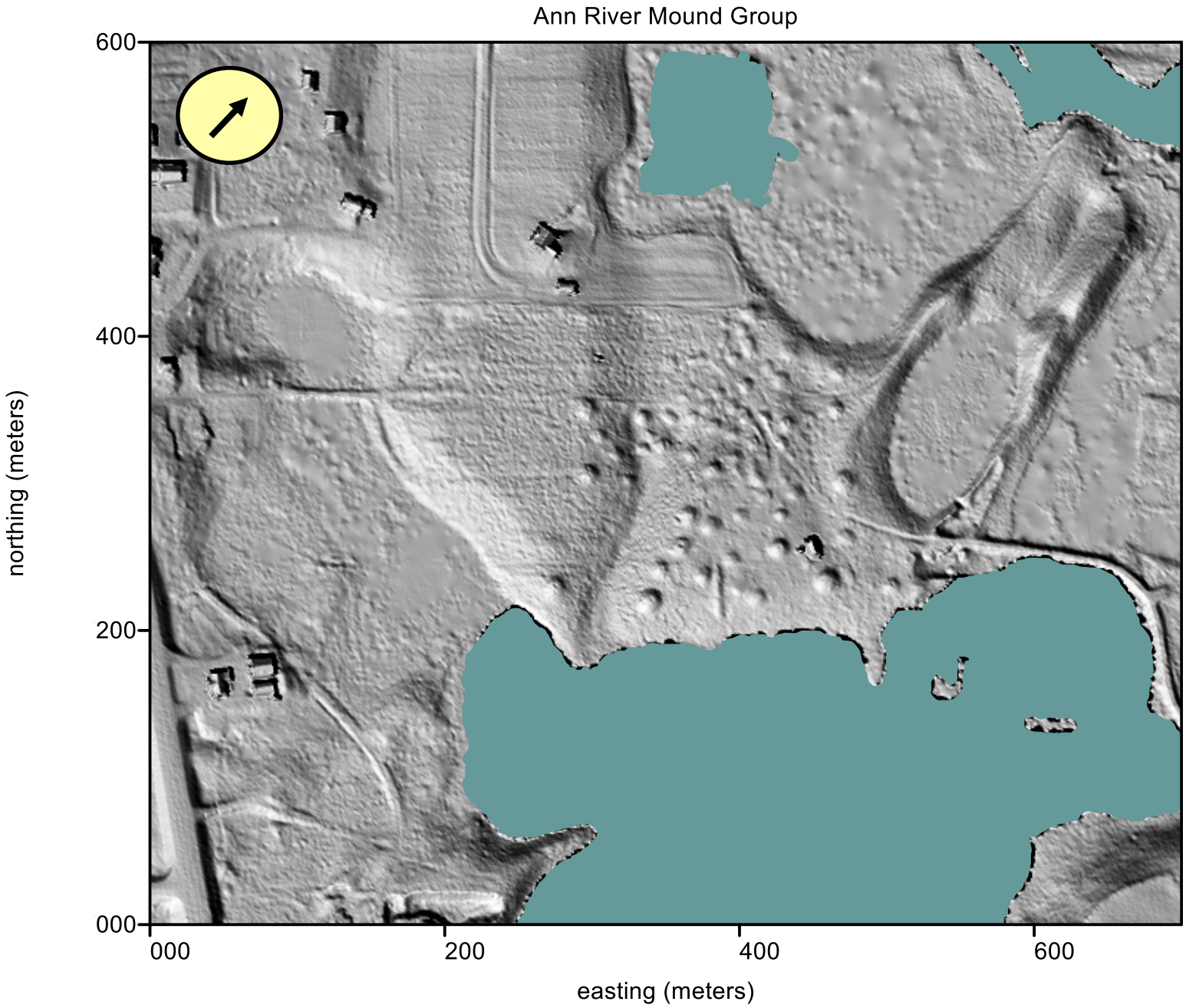

Ann River Mound Group
600
400
200
000
northing (meters)
000
200
400
600
easting (meters)

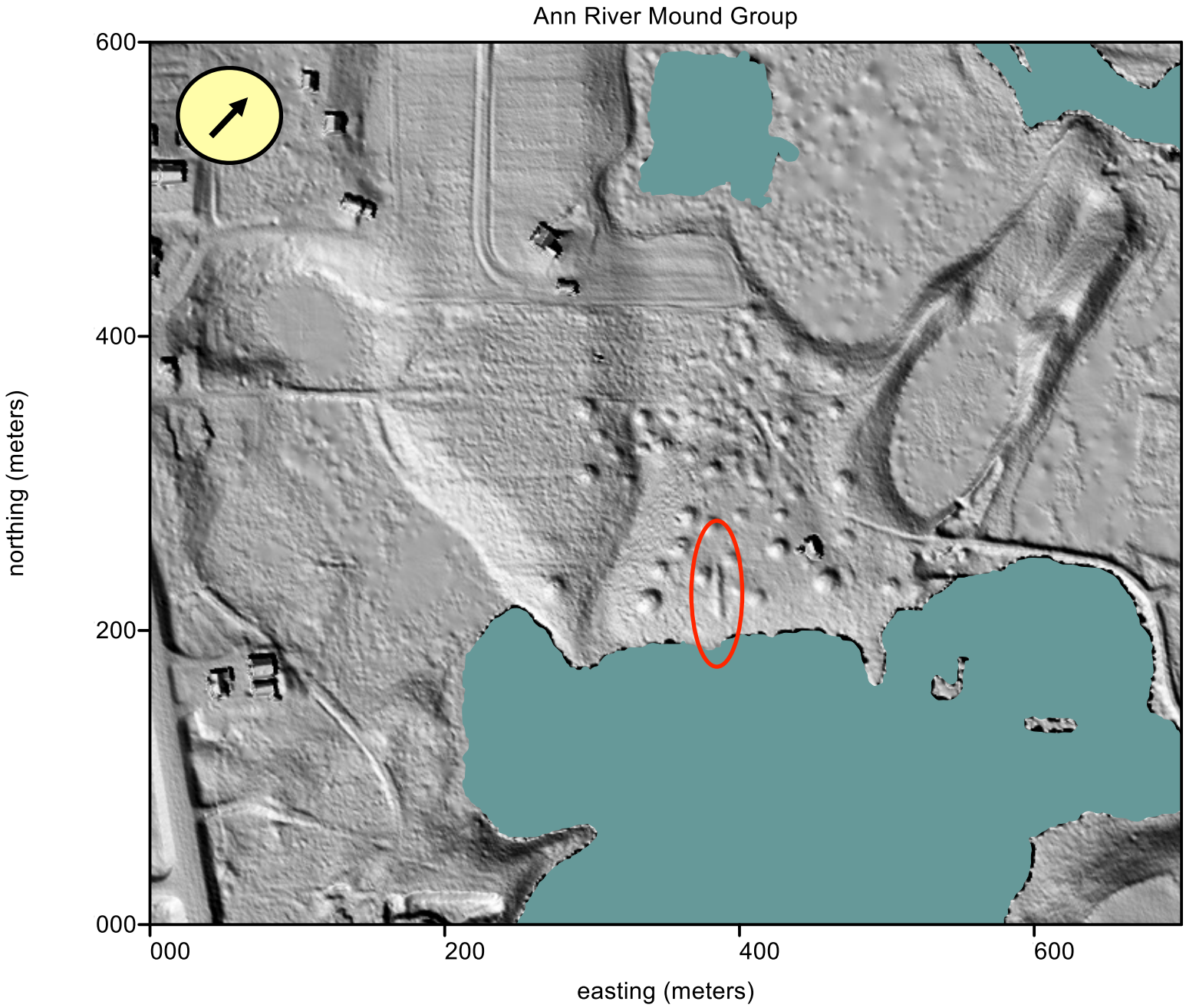

Ann River Mound Group
600
400
200
000
northing (meters)
000
200
400
600
easting (meters)

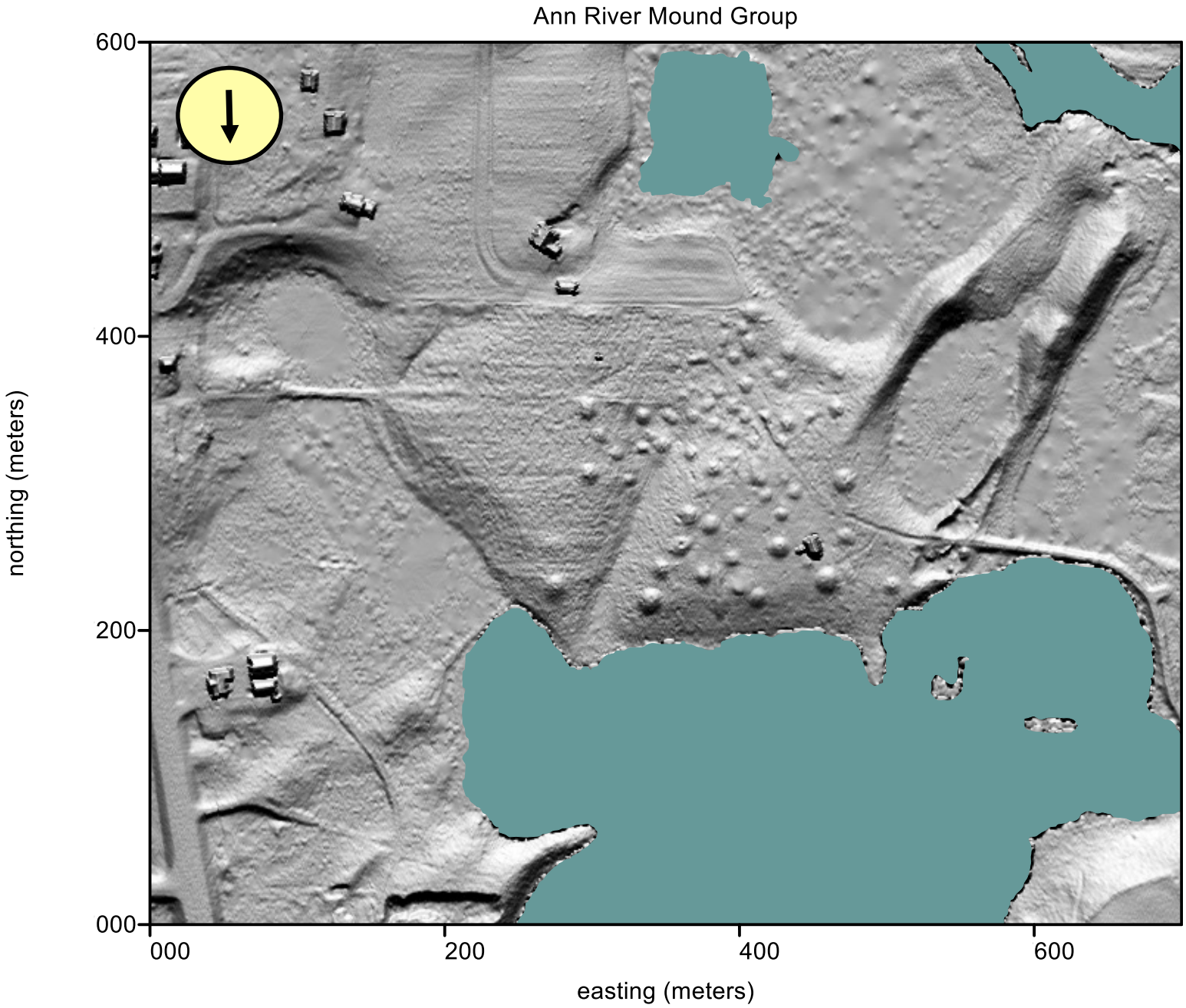

Ann River Mound Group
600
400
200
000
000
200
400
600
northing (meters)
easting (meters)


Ann River Mound Group
600
400
200
000
000
200
400
600
northing (meters)
easting (meters)


Ann River Mound Group
600
400
200
000
000
200
400
600
northing (meters)
easting (meters)

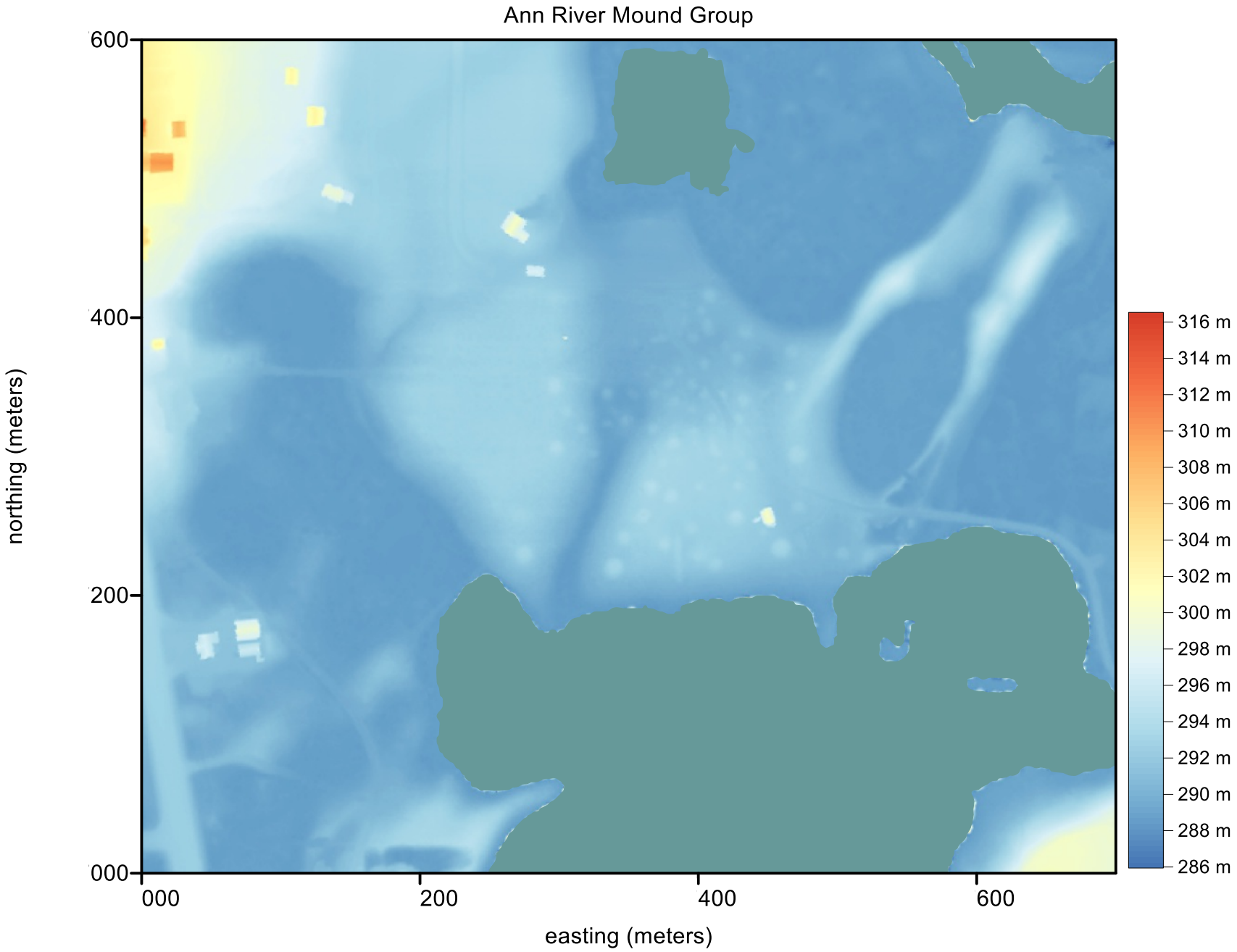

Ann River Mound Group
600
400
200
000
000
200
400
600
northing (meters)
easting (meters)

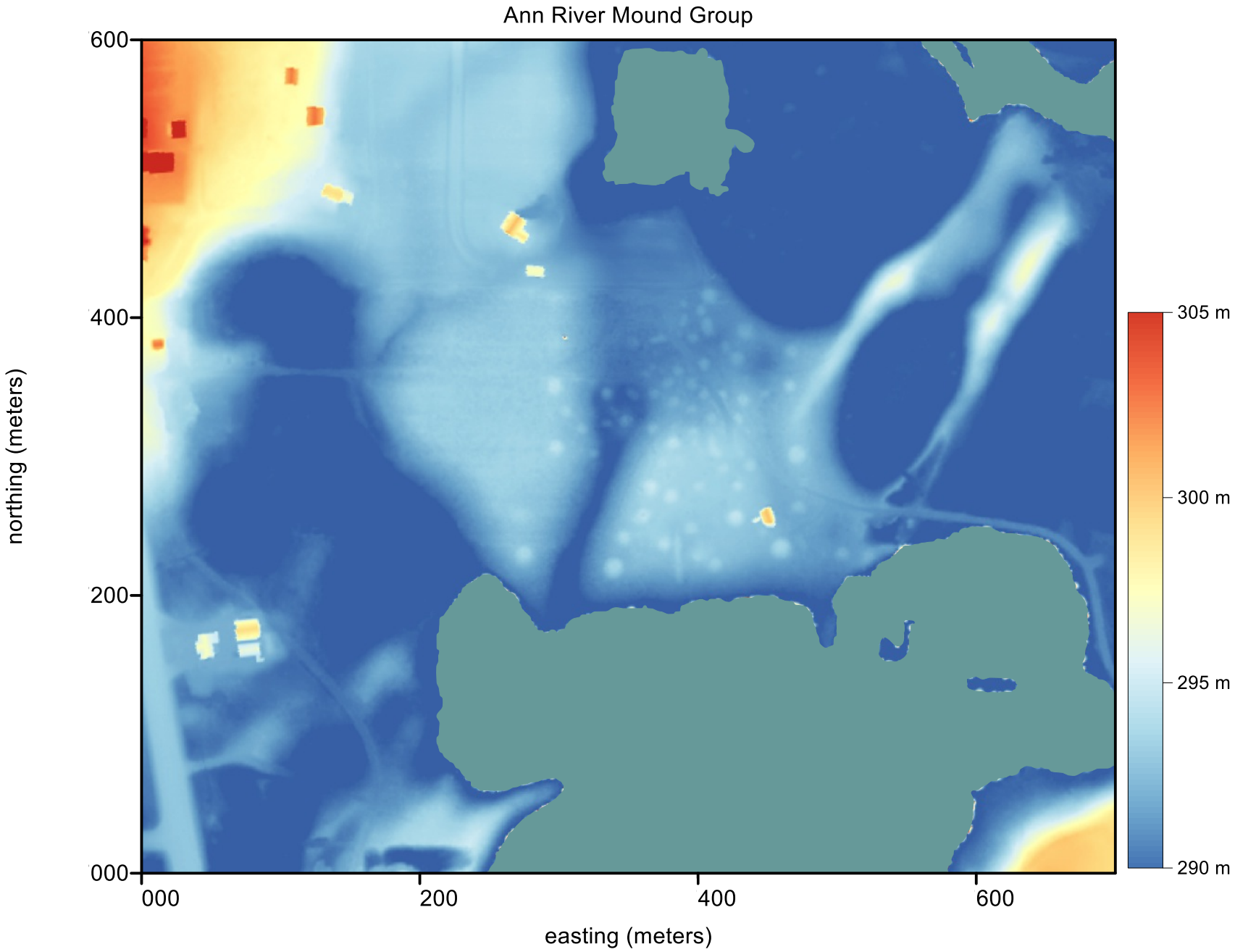

Ann River Mound Group
600
400
200
000
000
200
400
600
northing (meters)
easting (meters)

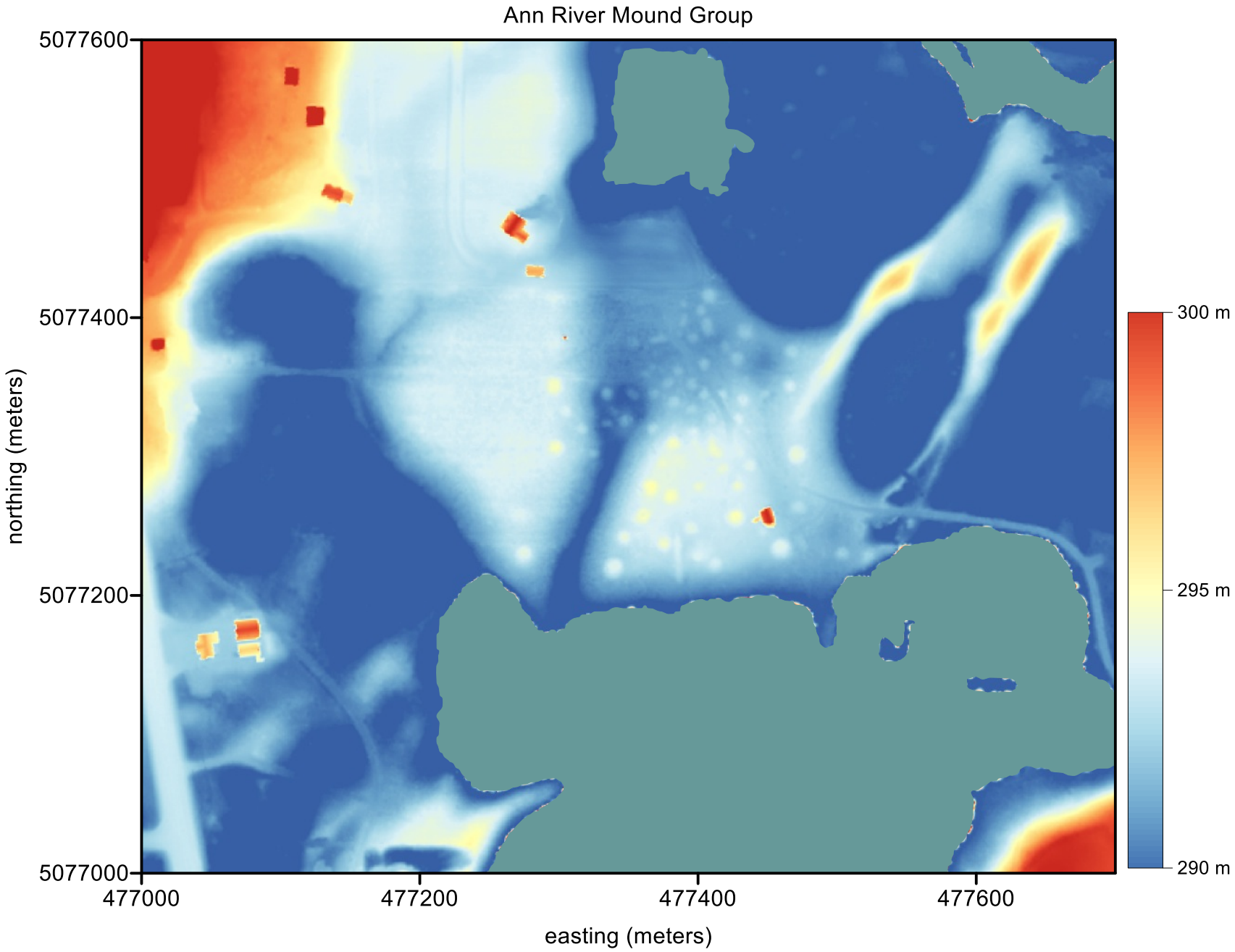

Ann River Mound Group
600
400
200
000
000
200
400
600
northing (meters)
easting (meters)

- **Constrained Shading**: Displays relative elevations as a shaded images (grey-scale or color). Data range may be constrained to show detail in desired areas.

- *Easy to understand relative elevation*

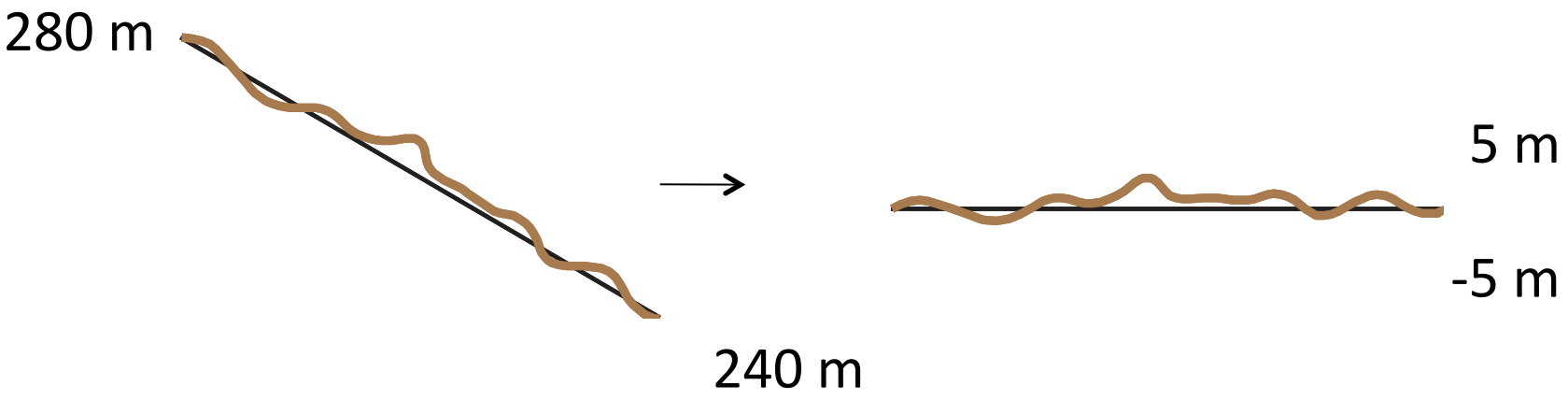

Ann River Mound Group
600
400
200
000
northing (meters)
000
200
400
600
easting (meters)
316 m
314 m
312 m
310 m
308 m
306 m
304 m
302 m
300 m
298 m
296 m
294 m
292 m
290 m
288 m
286 m

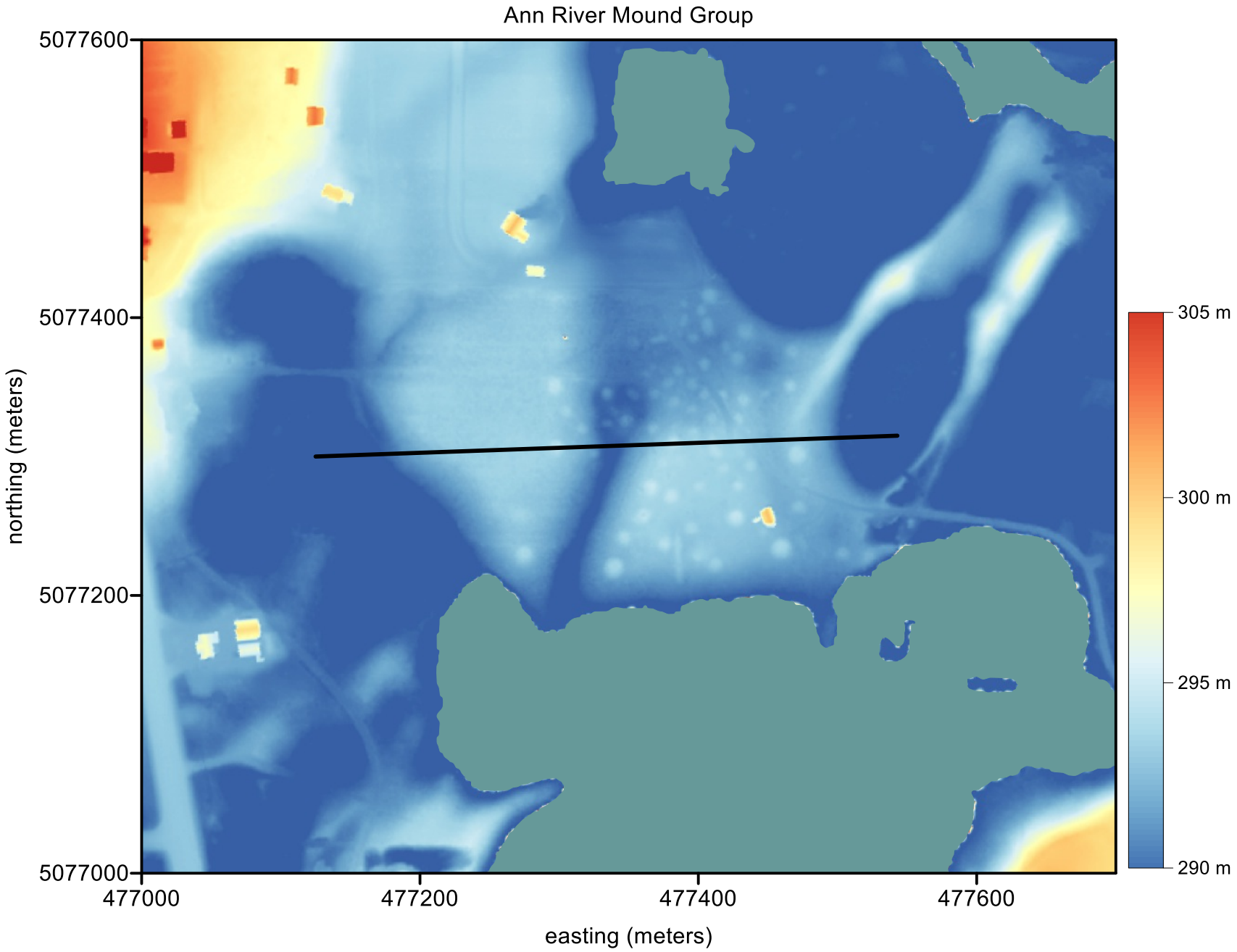

Ann River Mound Group
600
400
200
000
northing (meters)
000
200
400
600
easting (meters)
305 m
300 m
295 m
290 m

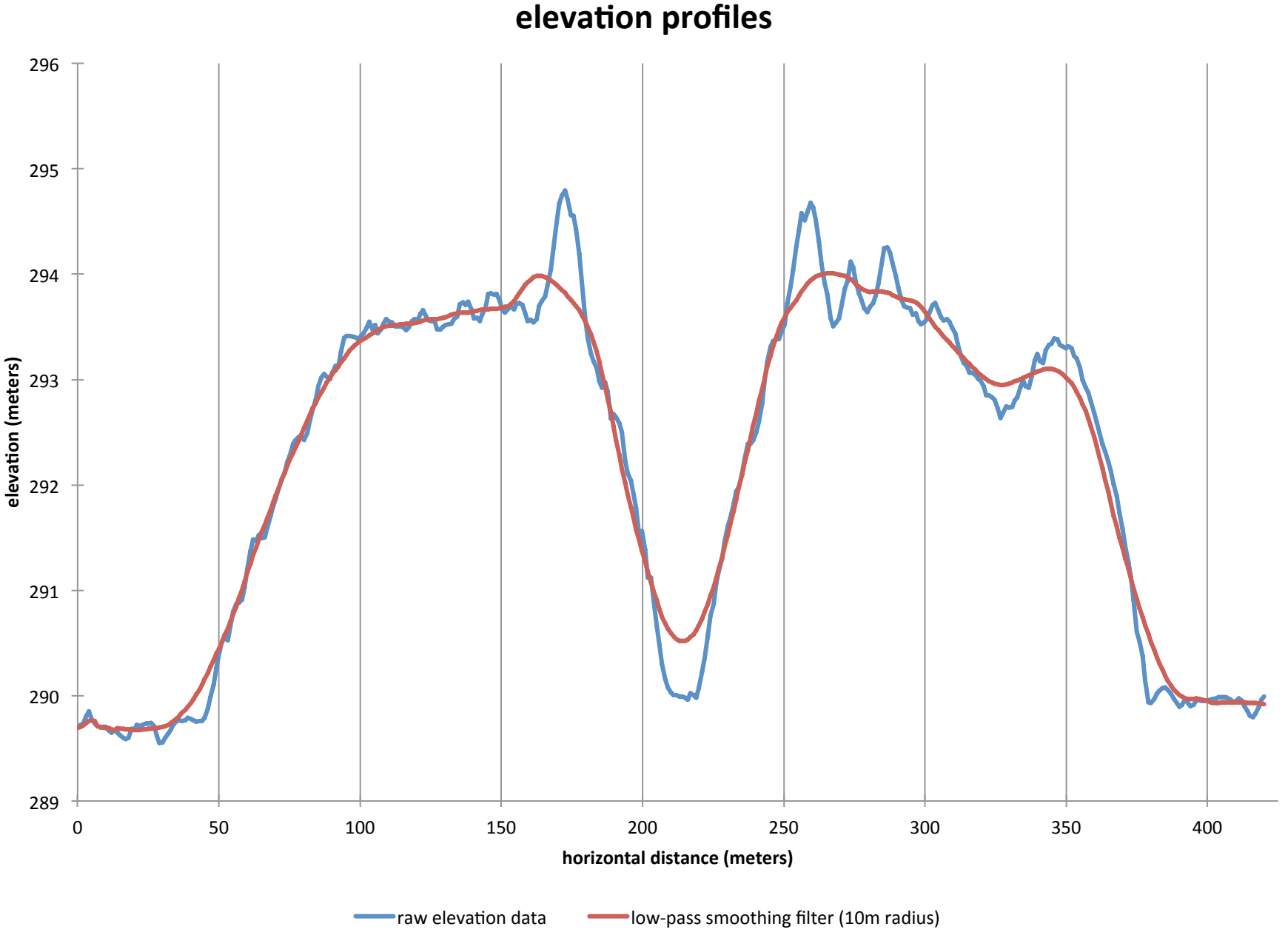

Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)
300 m
295 m
290 m

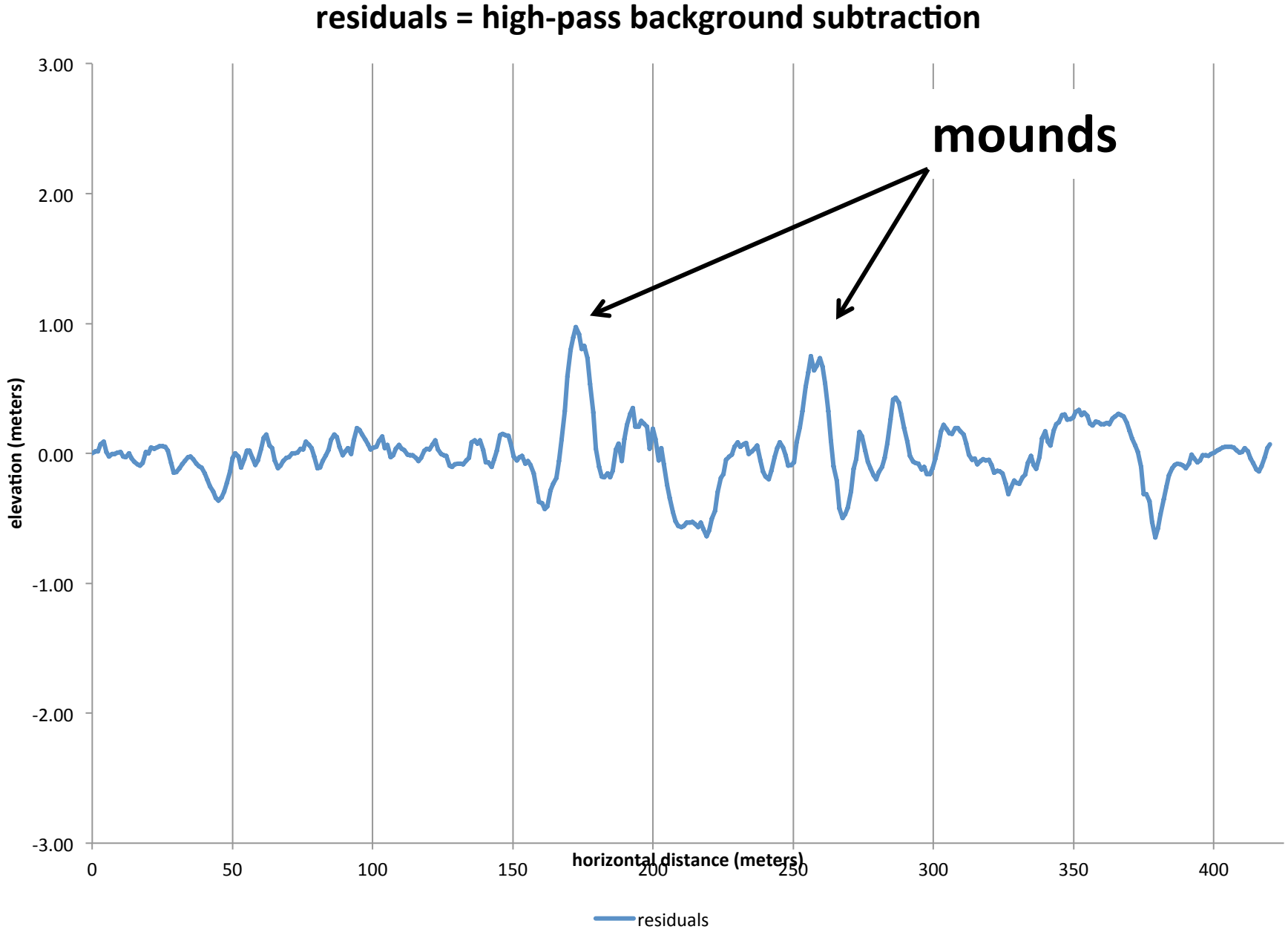
Local Relief Models

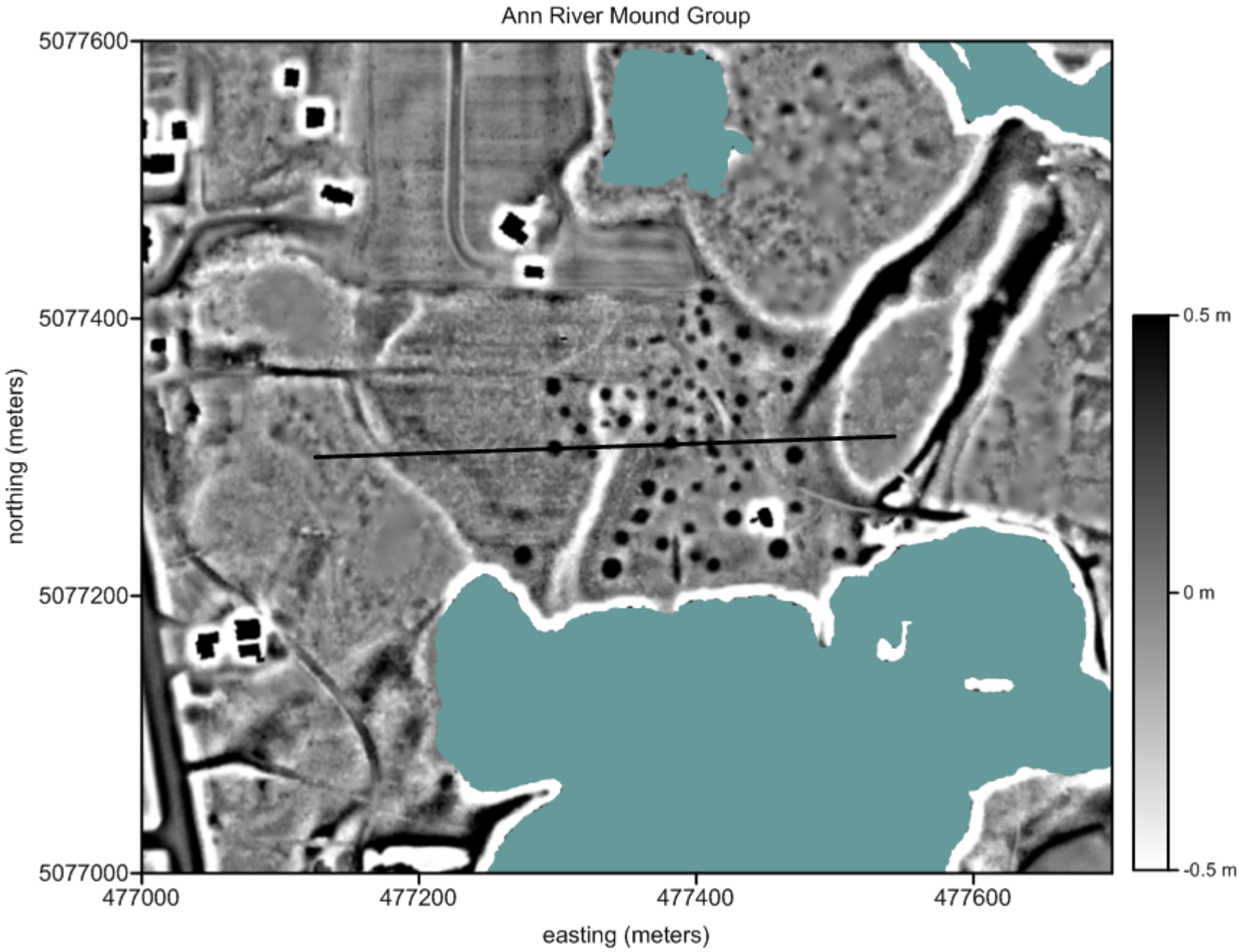
- remove the large scale “background” in data so only small scale features remain
- Allows detection of subtle low-amplitude features
- Can create processing induced artifacts

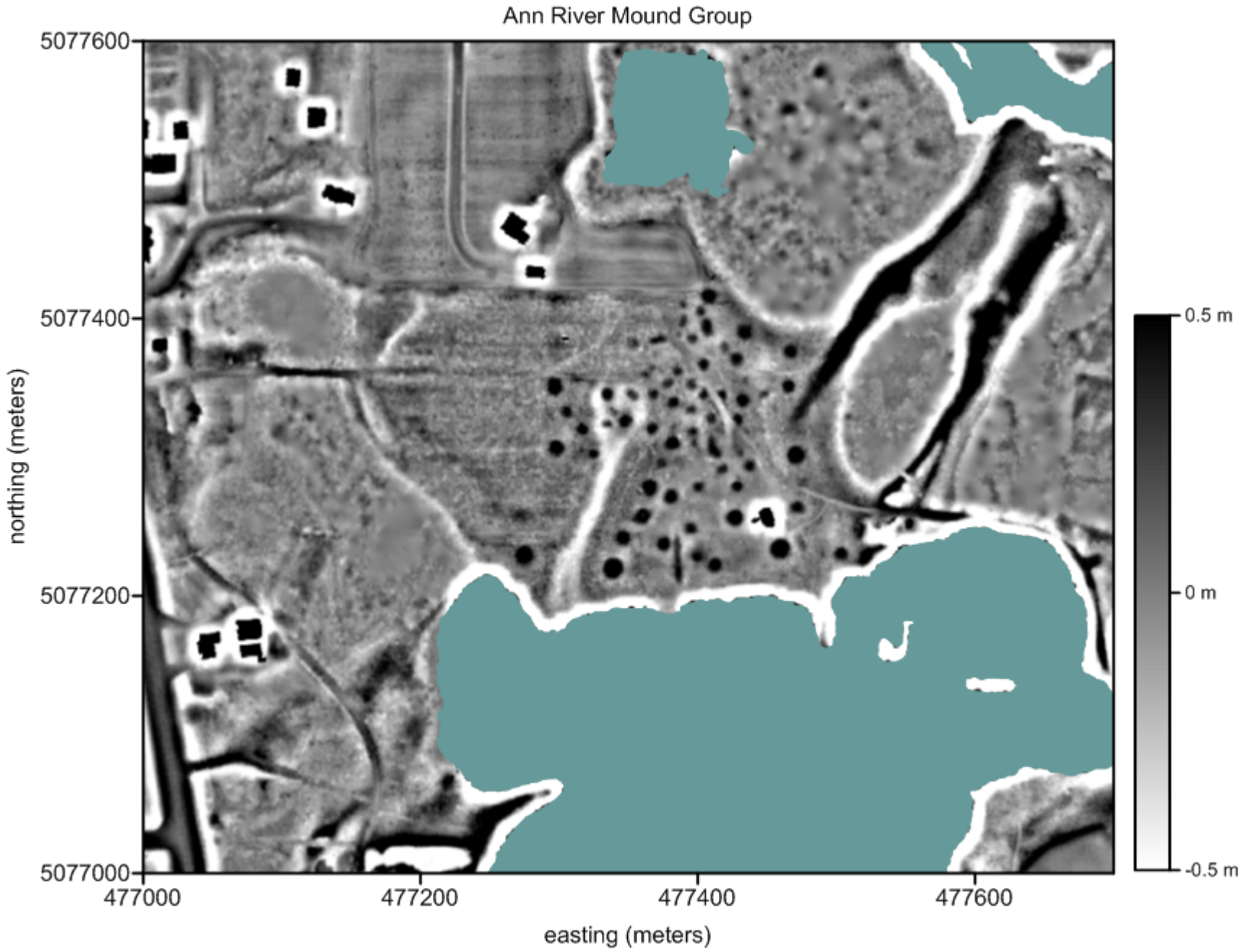



Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)
305 m
300 m
295 m
290 m


elevation profiles
296
295
294
293
292
291
290
289
elevation (meters)
0
50
100
150
200
250
300
350
400
horizontal distance (meters)
raw elevation data
low-pass smoothing filter (10m radius)


residuals = high-pass background subtraction
mounds
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
elevation (meters)
0
50
100
150
200
250
300
350
400
horizontal distance (meters)
residuals

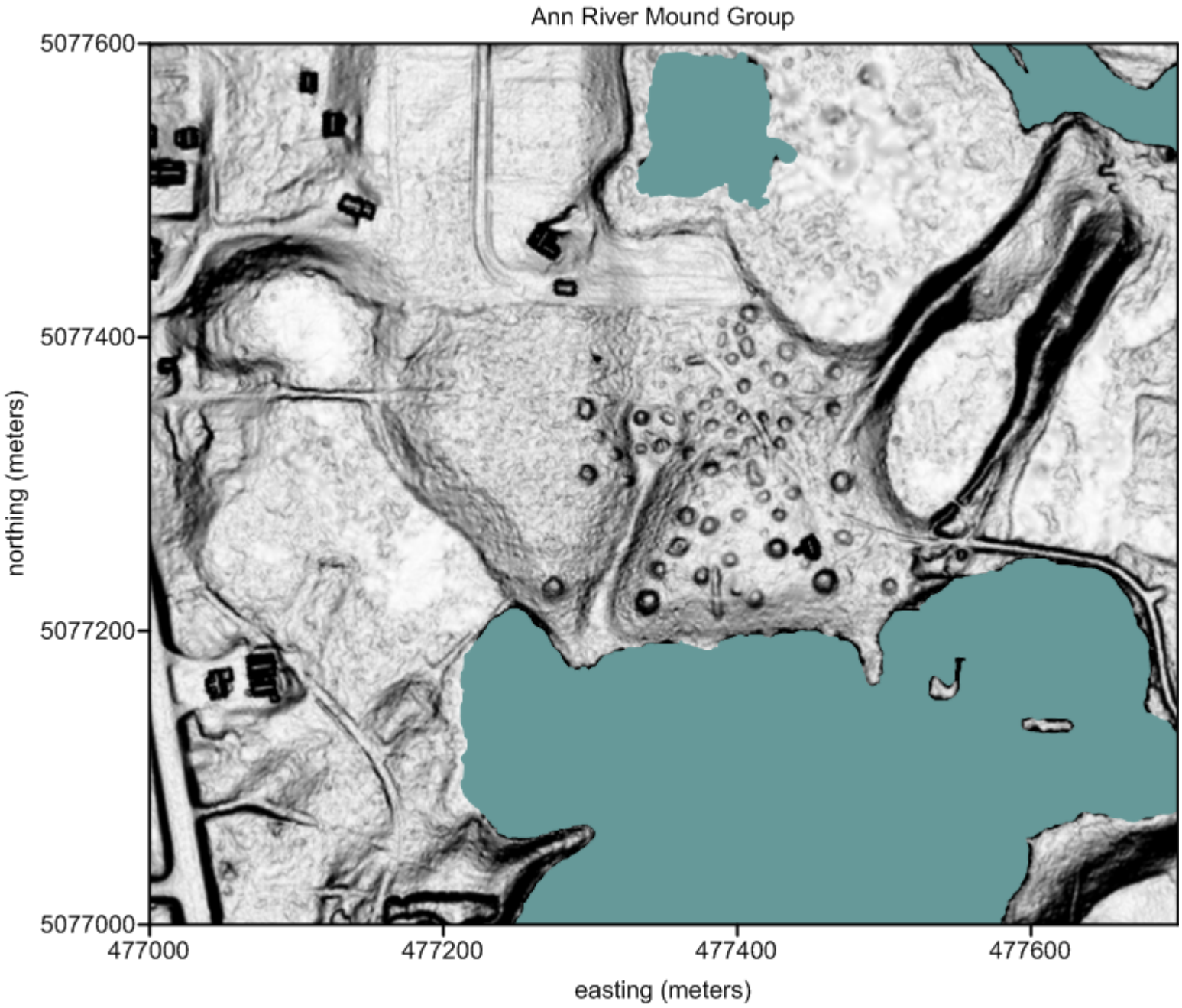

Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)
0.5 m
0 m
-0.5 m


Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)
0.5 m
0 m
-0.5 m

Terrain Slope is the magnitude of the gradient at that point - the first derivative of a DEM.

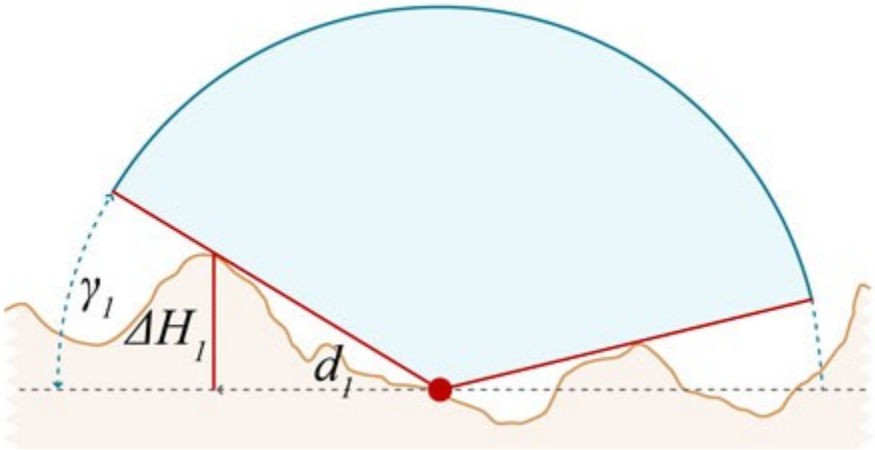
Not dependent on light direction!

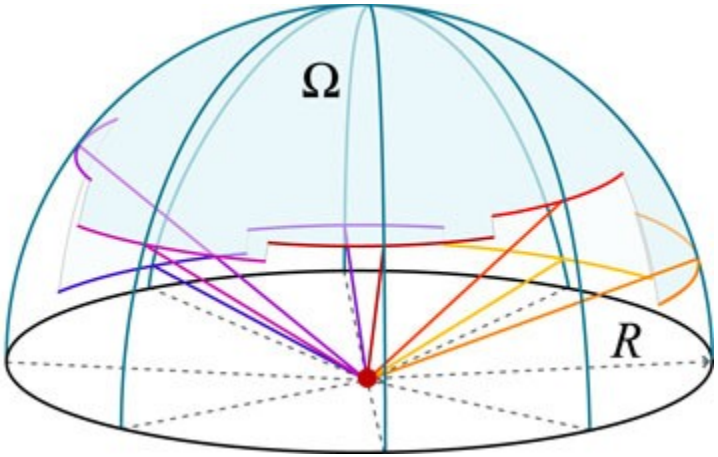
$$S = \sqrt{\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2}$$

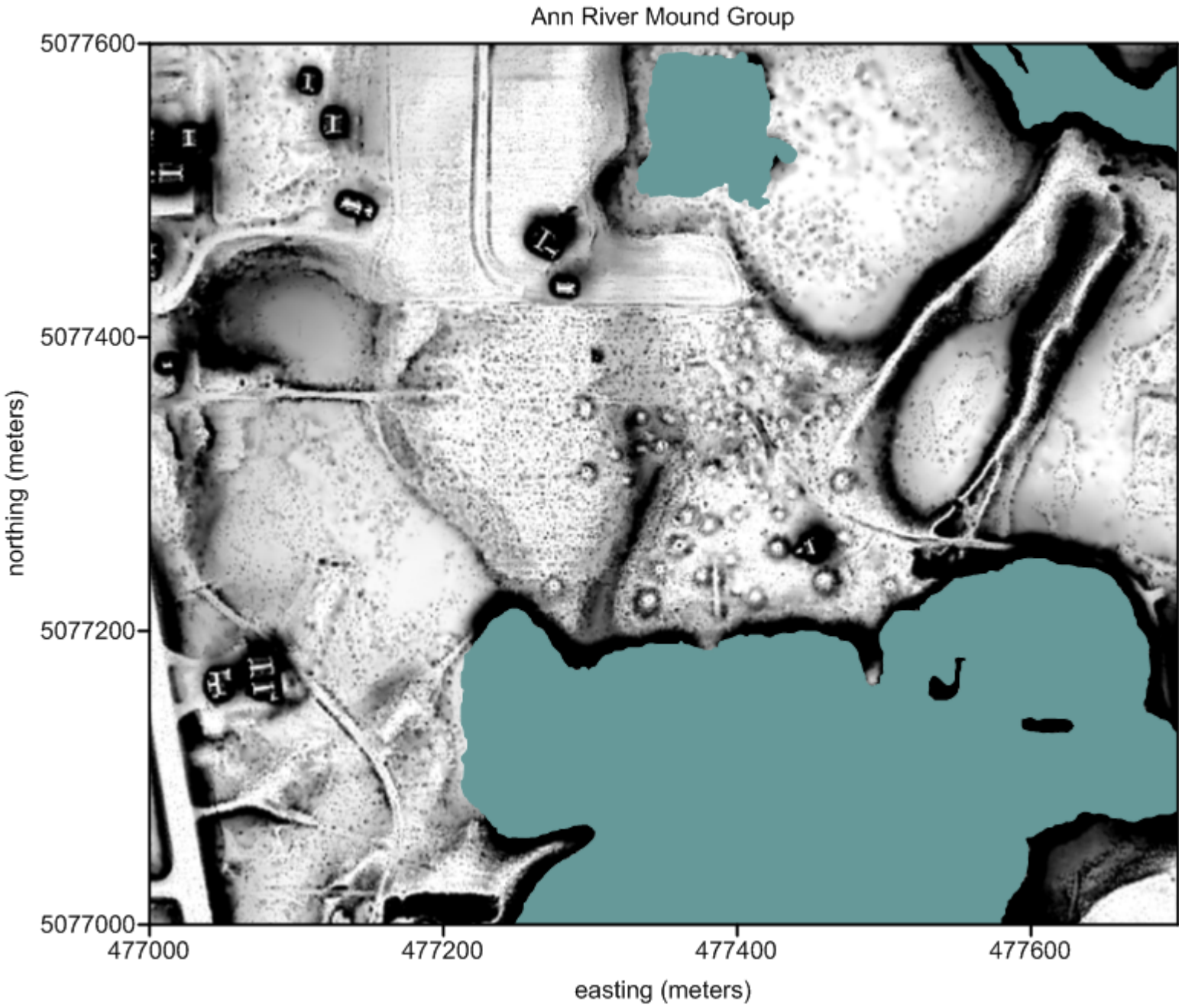

Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)

Visual Sky and Sky View Factor: Replaces elevation data with the percentage of sky visible from each point.

Not dependent on light direction!

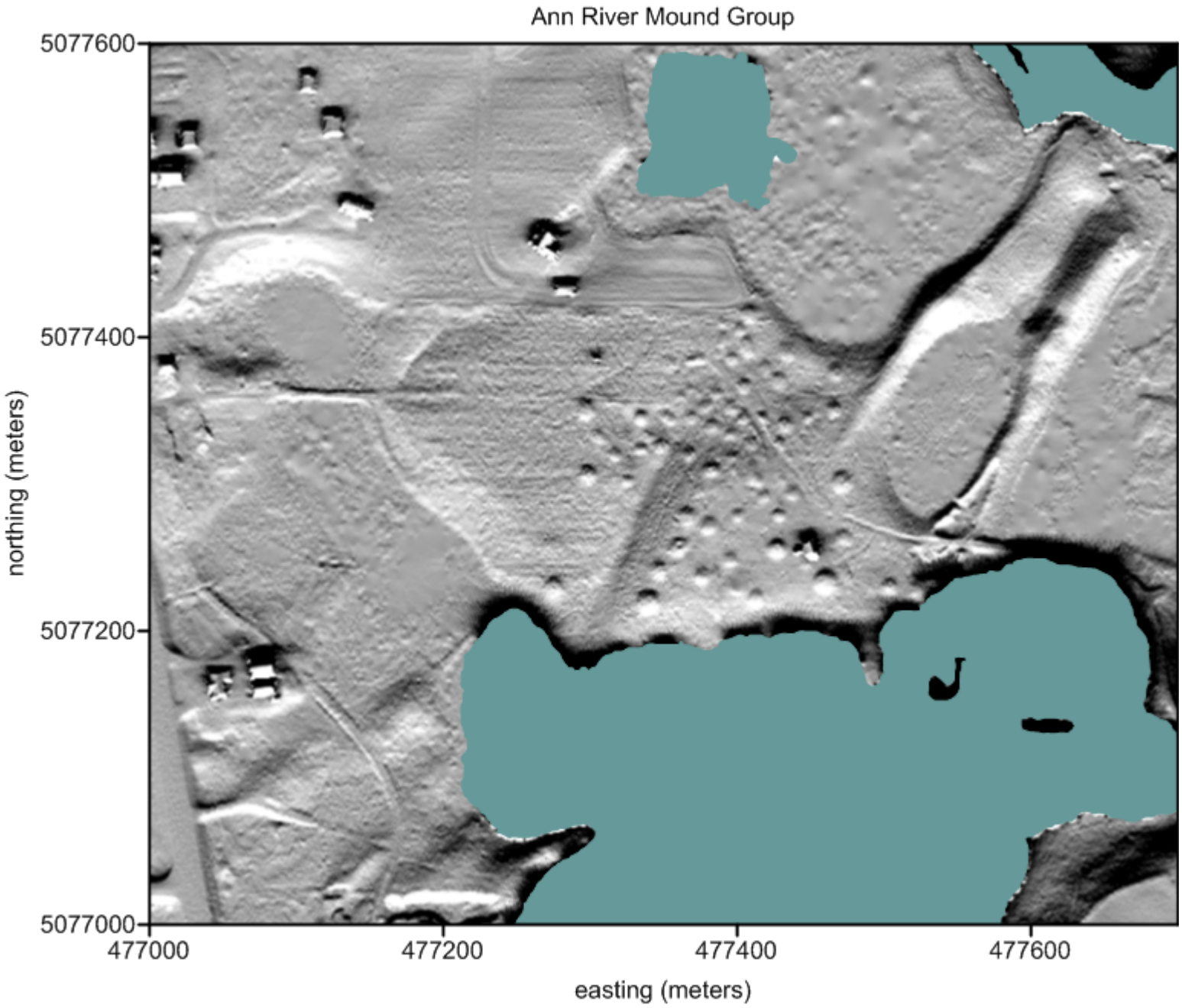





Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)

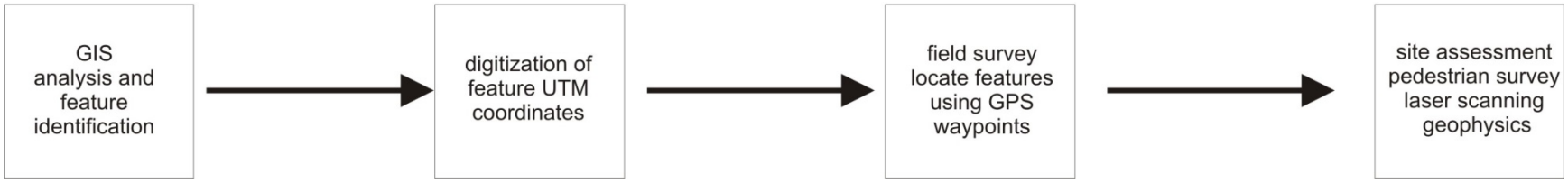
Solar Insolation: The amount of the solar energy received at each point on a surface.

- Direct insolation
- Diffuse insolation
- Total insolation = (Direct + Diffuse)


Ann River Mound Group
5077600
5077400
5077200
5077000
northing (meters)
477000
477200
477400
477600
easting (meters)

WORK FLOW

Analysis and Field Survey



Evaluating Minnesota's
HISTORIC DAMS
A Framework for Management

Prepared by Principal Investigators:
Sigrid Arnott, Douglas A. Birk, and David Maki

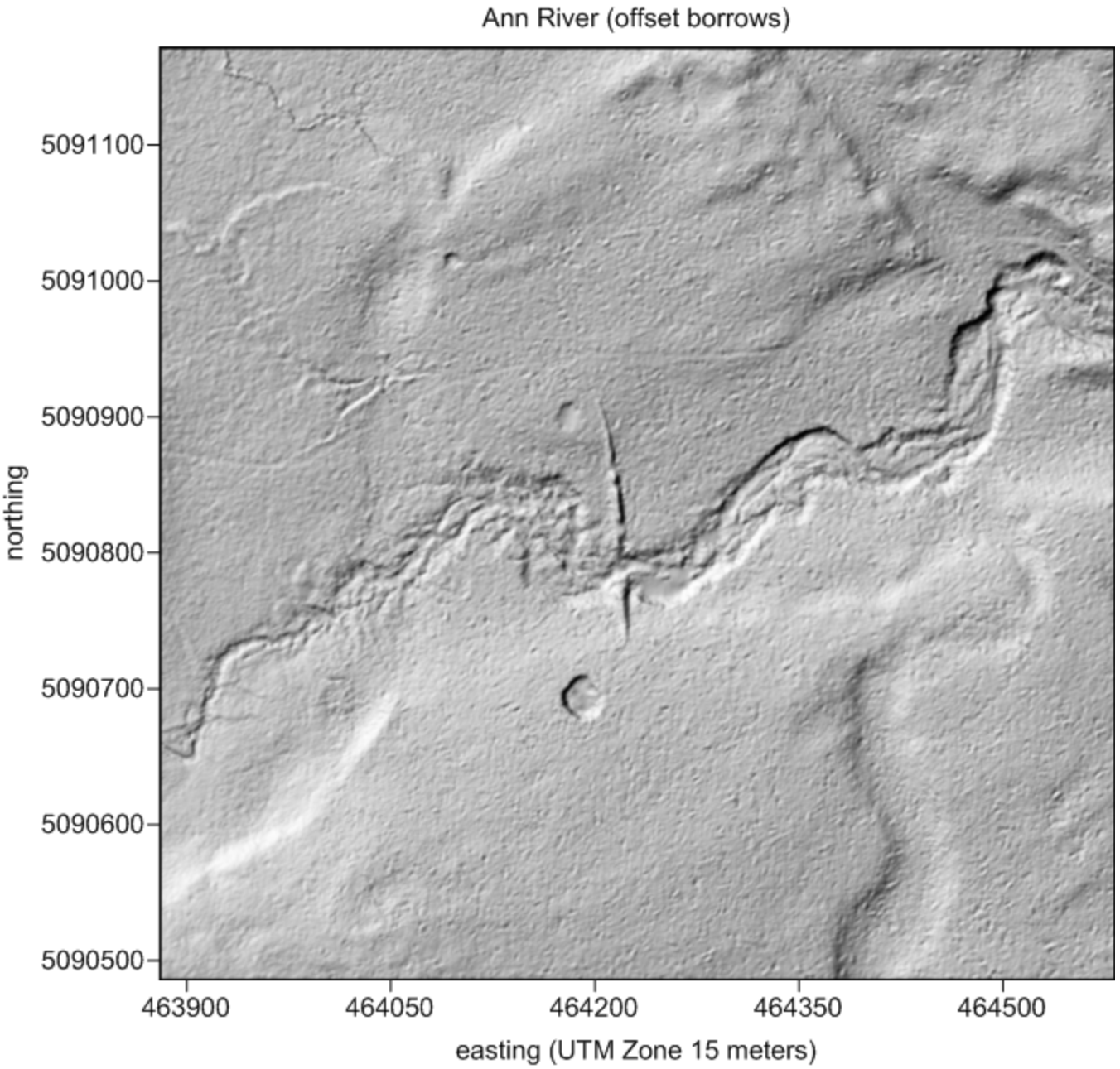
with contributions by Geoffrey Jones

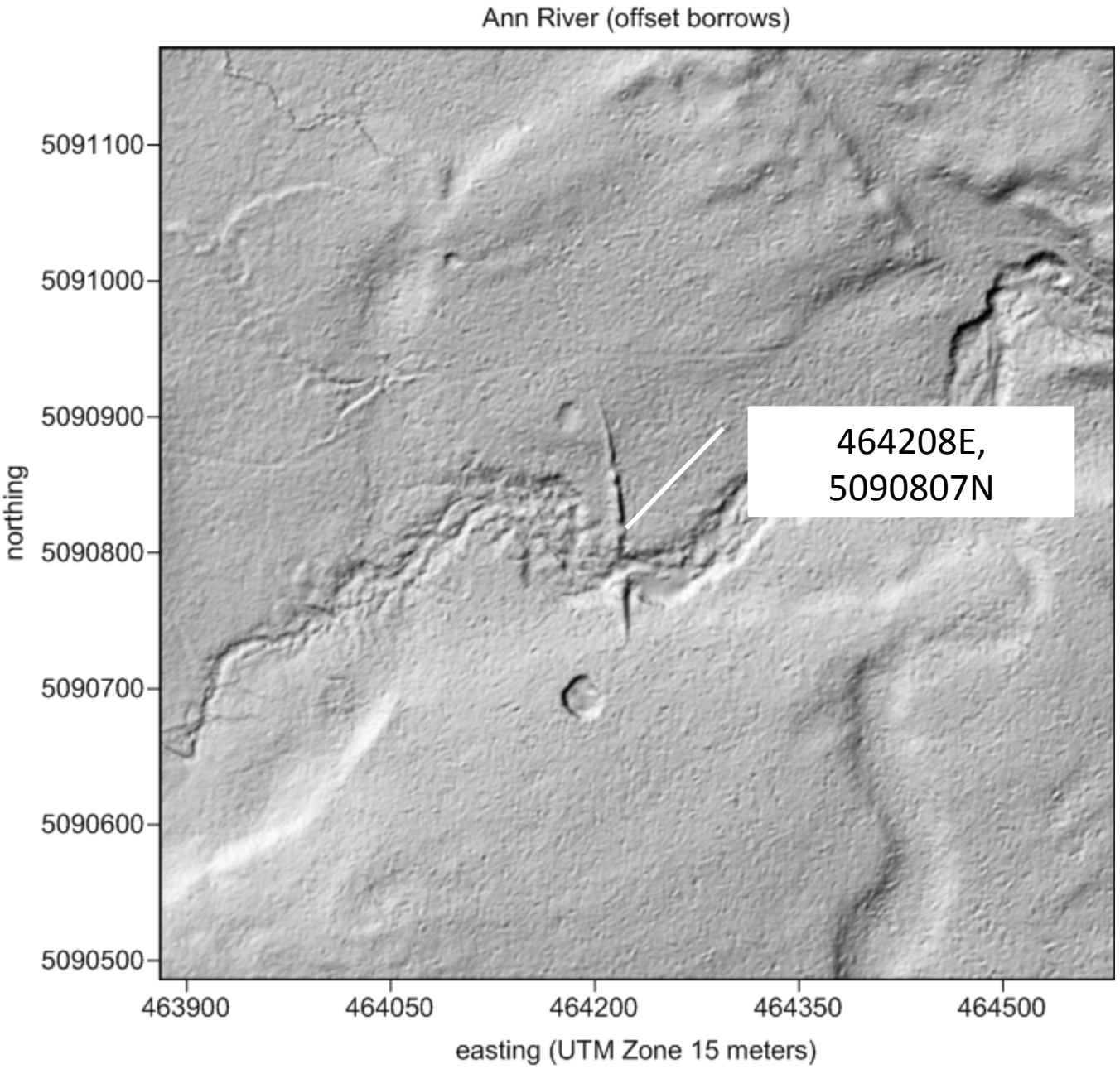
DECEMBER, 2013

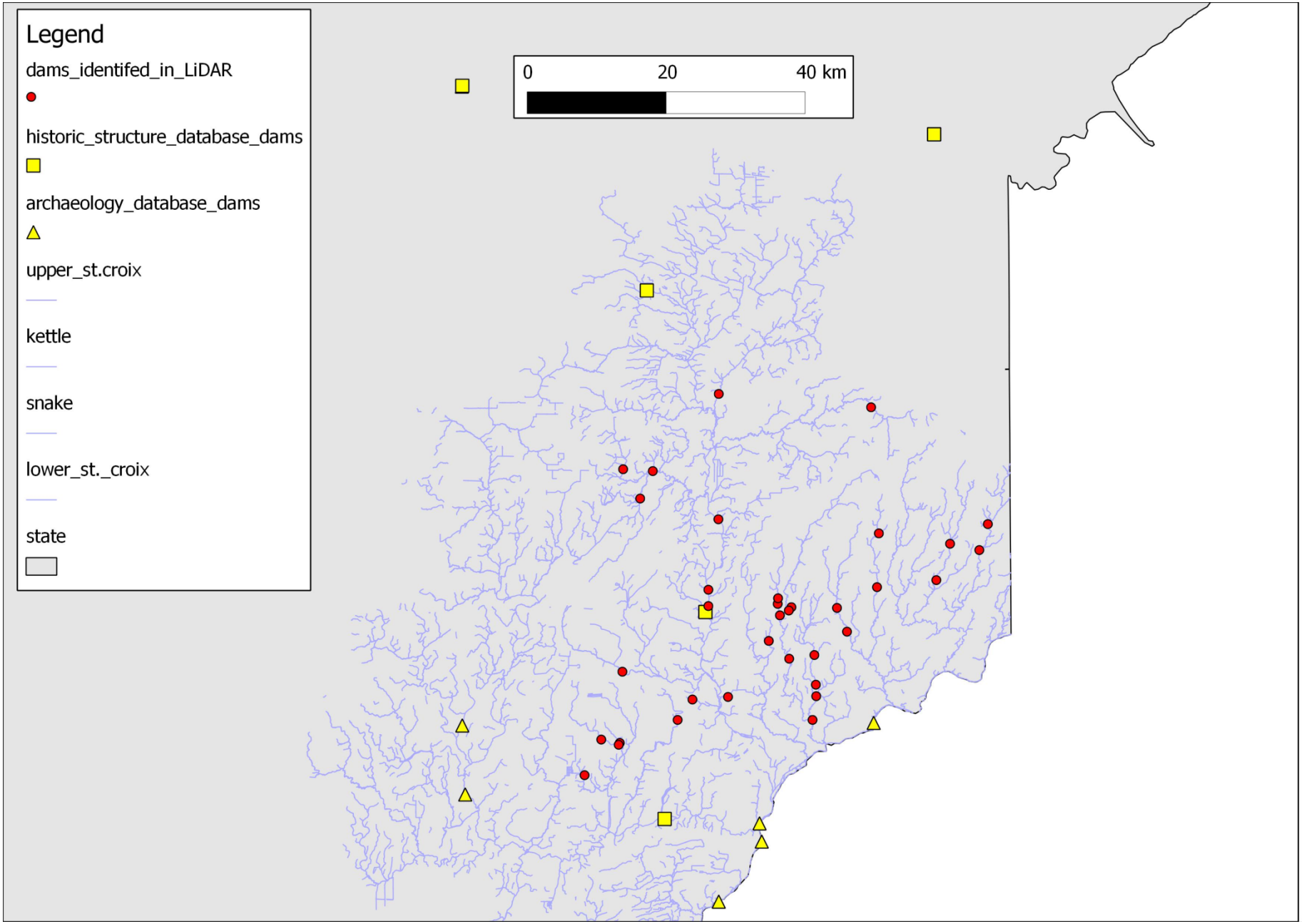
This project was funded by the Arts and Cultural Heritage Fund of the Minnesota Clean Water, Land, and Legacy Amendment as part of the Statewide Survey of Historical and Archaeological Sites

ARCHAEO-PHYSICS
SHALLOW SUBSURFACE GEOPHYSICAL SURVEY

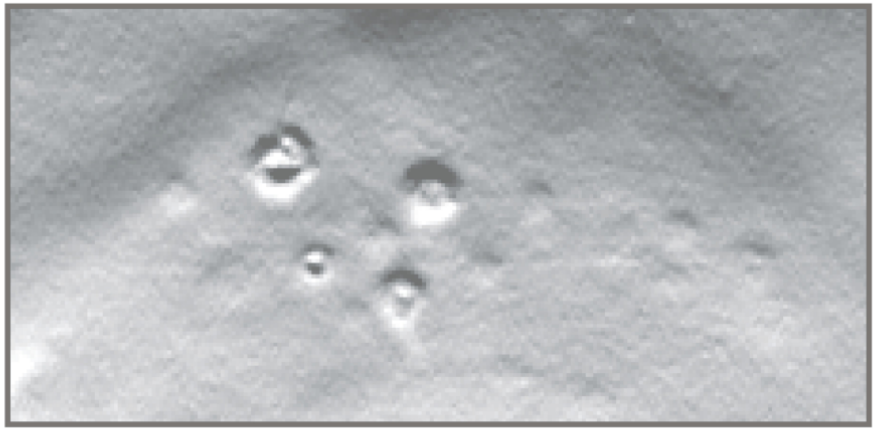
Report of Investigation Number 198
Archaeo-Physics, LLC
4150 Dight Avenue South #110
Minneapolis, MN 55406
(612) 379-0094 info@archaeophysics.com


Ann River (offset borrows)
5091100
5091000
5090900
5090800
5090700
5090600
5090500
northing
463900
464050
464200
464350
464500
easting (UTM Zone 15 meters)


Ann River (offset borrows)
5091100
5091000
5090900
5090800
5090700
5090600
5090500
northing
464208E,
5090807N
463900
464050
464200
464350
464500
easting (UTM Zone 15 meters)


Legend
dams_identifed_in_LiDAR
historic_structure_database_dams
archaeology_database_dams
upper_st.croix
kettle
snake
lower_st._croix
state
0
20
40 km

An Archaeological Survey of Prehistoric Mortuary Sites in Marshall and Day Counties, South Dakota



PREPARED FOR:

State of South Dakota State Historic Preservation Office
Pierre, South Dakota

By:

David Maki, Sigrid Arnott, and Geoffrey Jones
Archaeo-Physics, LLC
Minneapolis, Minnesota

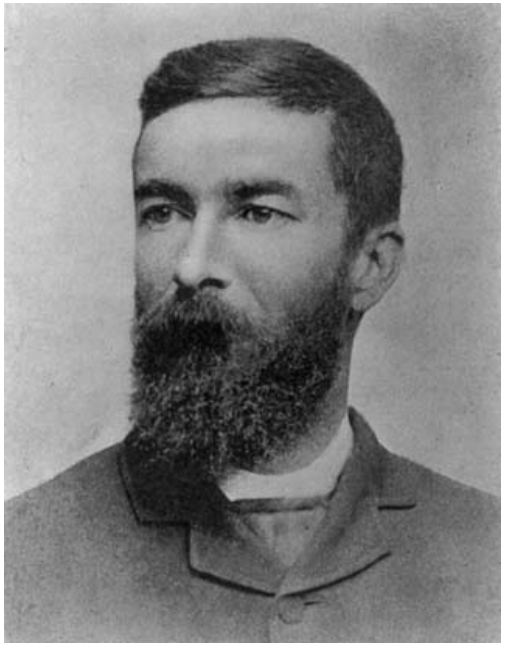
DRAFT REPORT
March, 2013

ARCHAEO-PHYSICS

SHALLOW SUBSURFACE GEOPHYSICAL SURVEY

Report of Investigation Number 215
Archaeo-Physics, LLC
4150 Dight Avenue South #110
Minneapolis, MN 55406
(612) 379-0094 info@archaeophysics.com

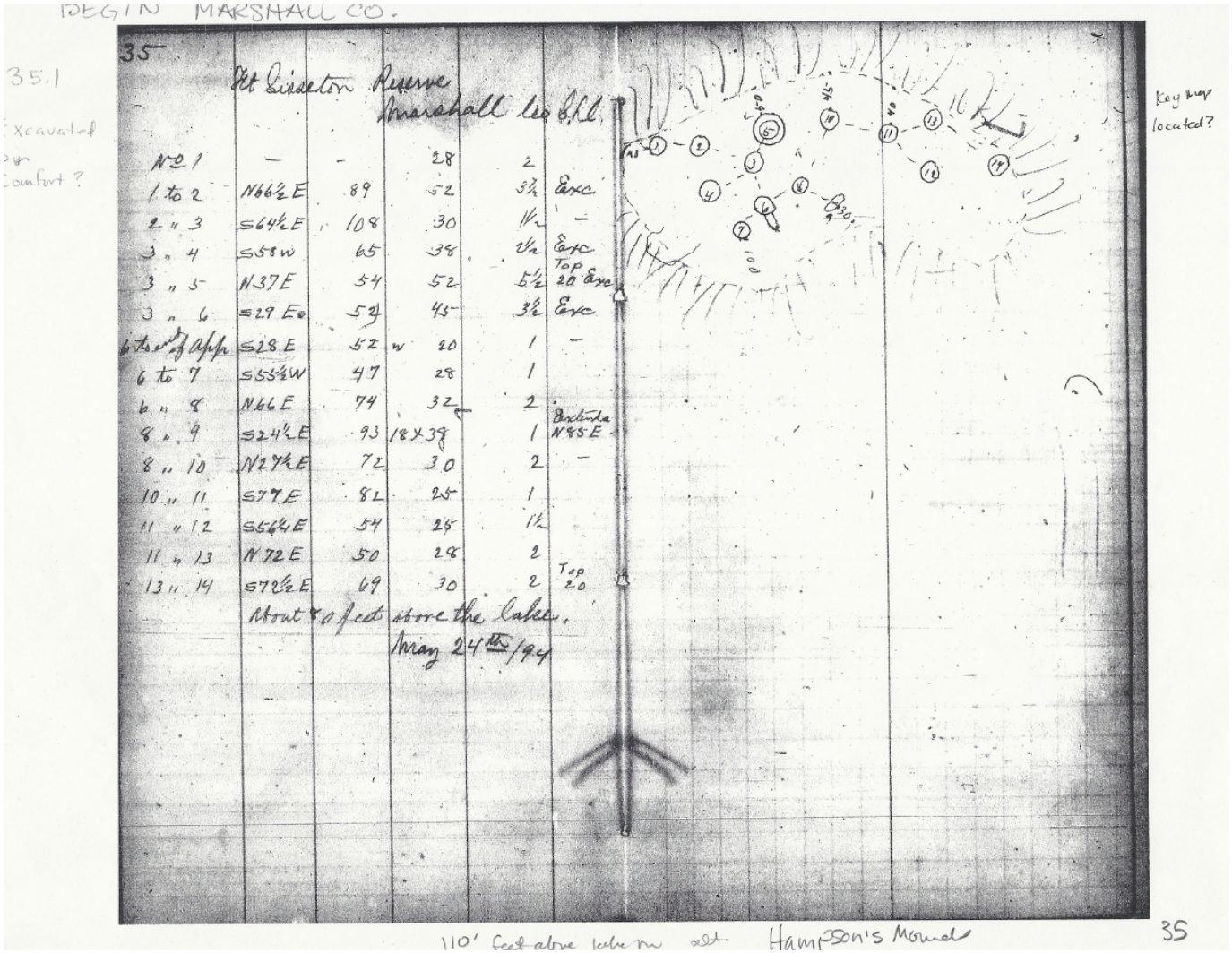
Using LiDAR to Geo-reference Historic Maps



Theodore Lewis (1856 -1909)
Between 1883 and 1895 Lewis surveyed more than 12,000 mounds in Minnesota, Canada. and surrounding states, including many sites with Marshall and Day Counties.

Map quality = excellent
Map locations in space = very poor

Lewis's notebooks were composed of angles, distances, heights and diameters, sometimes with a rough sketch



BEGIN MARSHALL CO.

35

Ft Lisdeton Reserve
Marshall Co Ill.

№ 1	—	—	28	2	
1 to 2	N66½E	89	52	3½	Exc
2 " 3	S64½E	108	30	1½	—
3 " 4	S58W	65	38	2½	Exc
3 " 5	N37E	54	52	5½	Top 20 Exc
3 " 6	S29E	52	45	3½	Exc
6 to end of App	S28E	52	20	1	—
6 to 7	S55½W	47	28	1	
6 " 8	N66E	74	32	2	Extends N85E
8 " 9	S24½E	93	18X38	1	
8 " 10	N27½E	72	30	2	—
10 " 11	S77E	82	25	1	
11 " 12	S56½E	54	25	1½	
11 " 13	N72E	50	28	2	
13 " 14	S72½E	69	30	2	Top 20

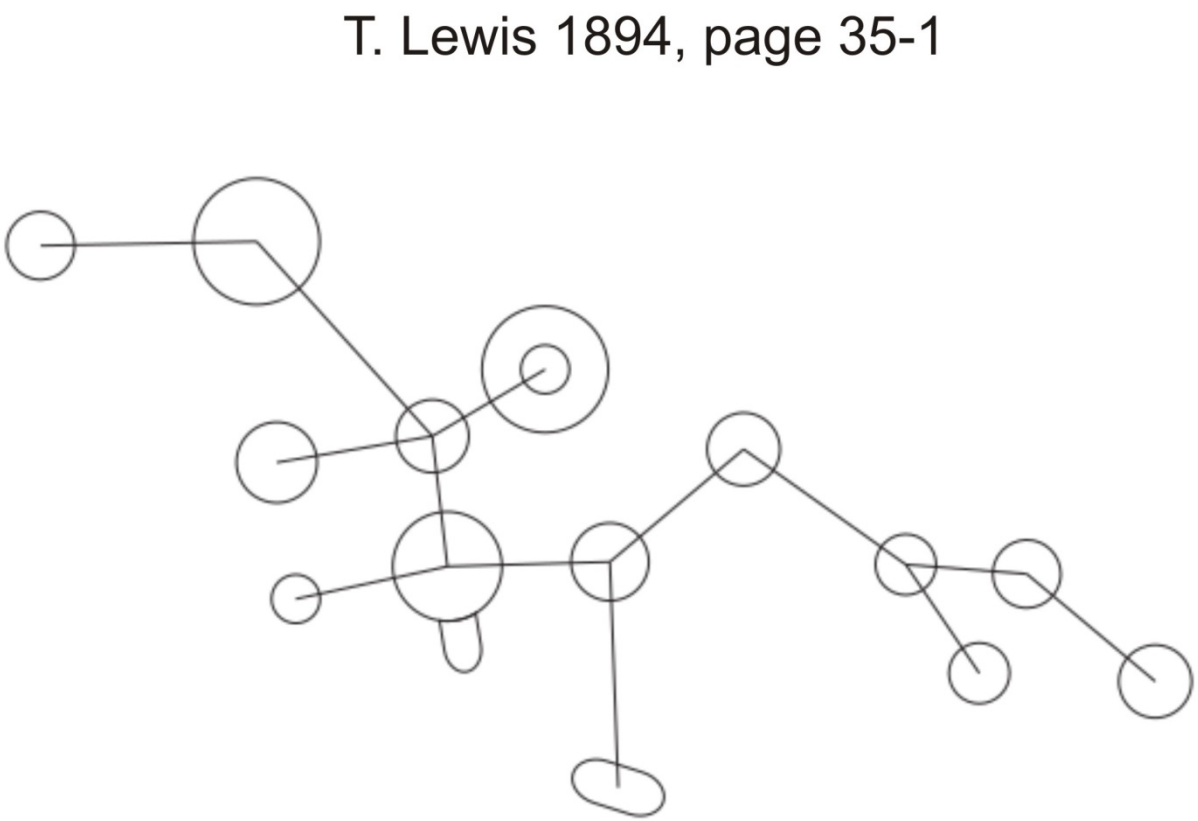
About 80 feet above the lake.
May 24th/94

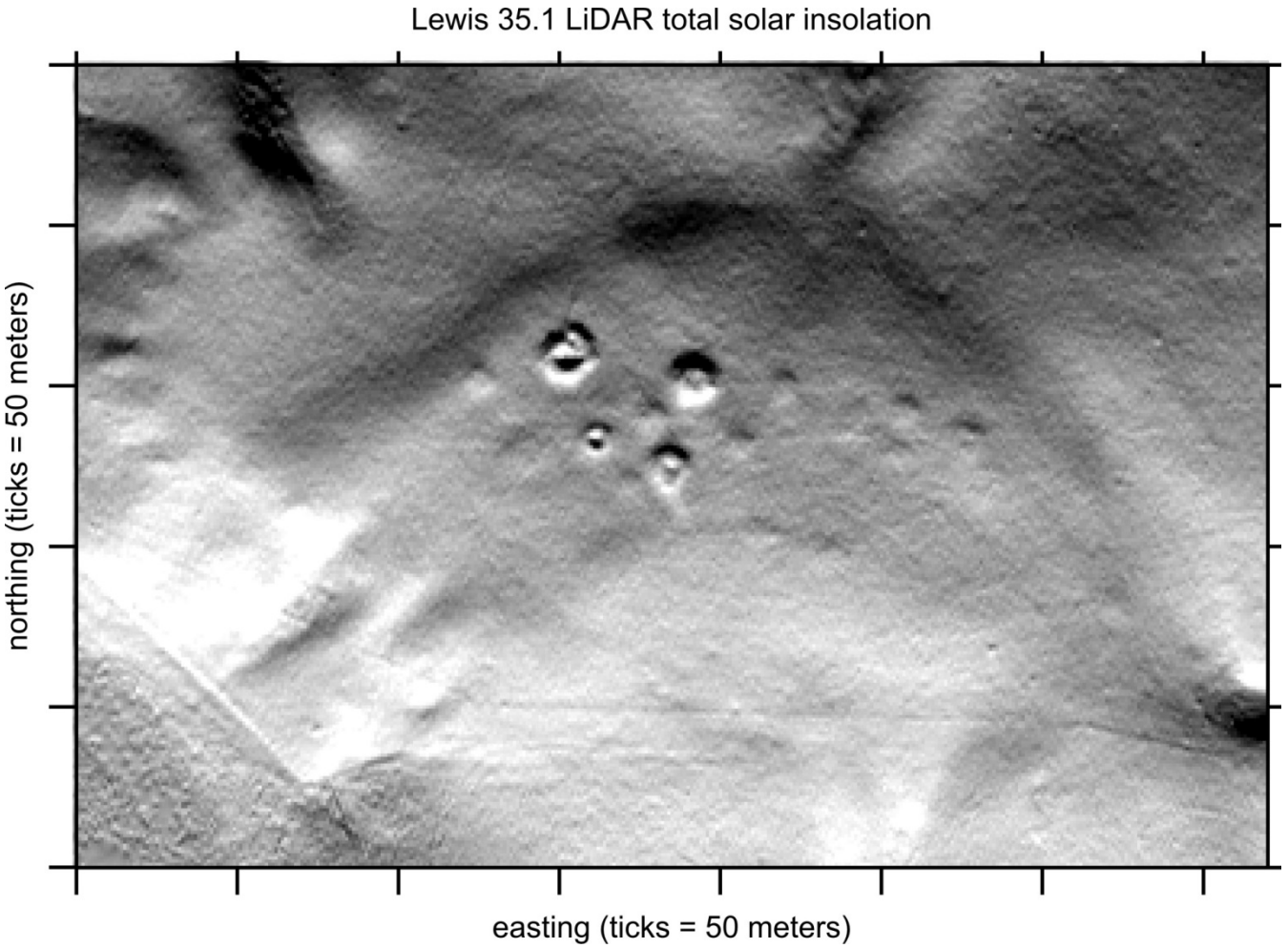
Key map located?

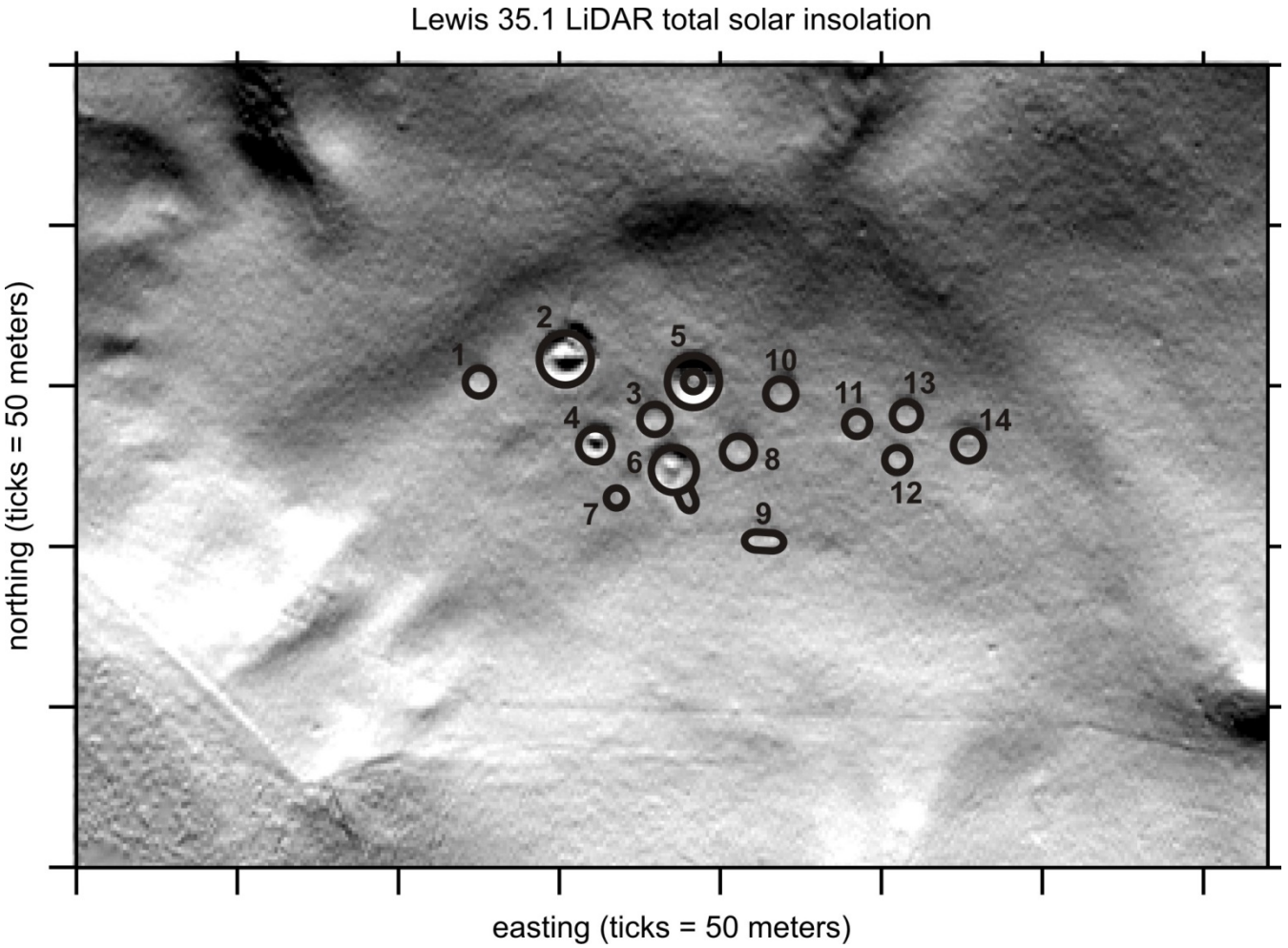
110' feet above lake mw at Hampson's Mound

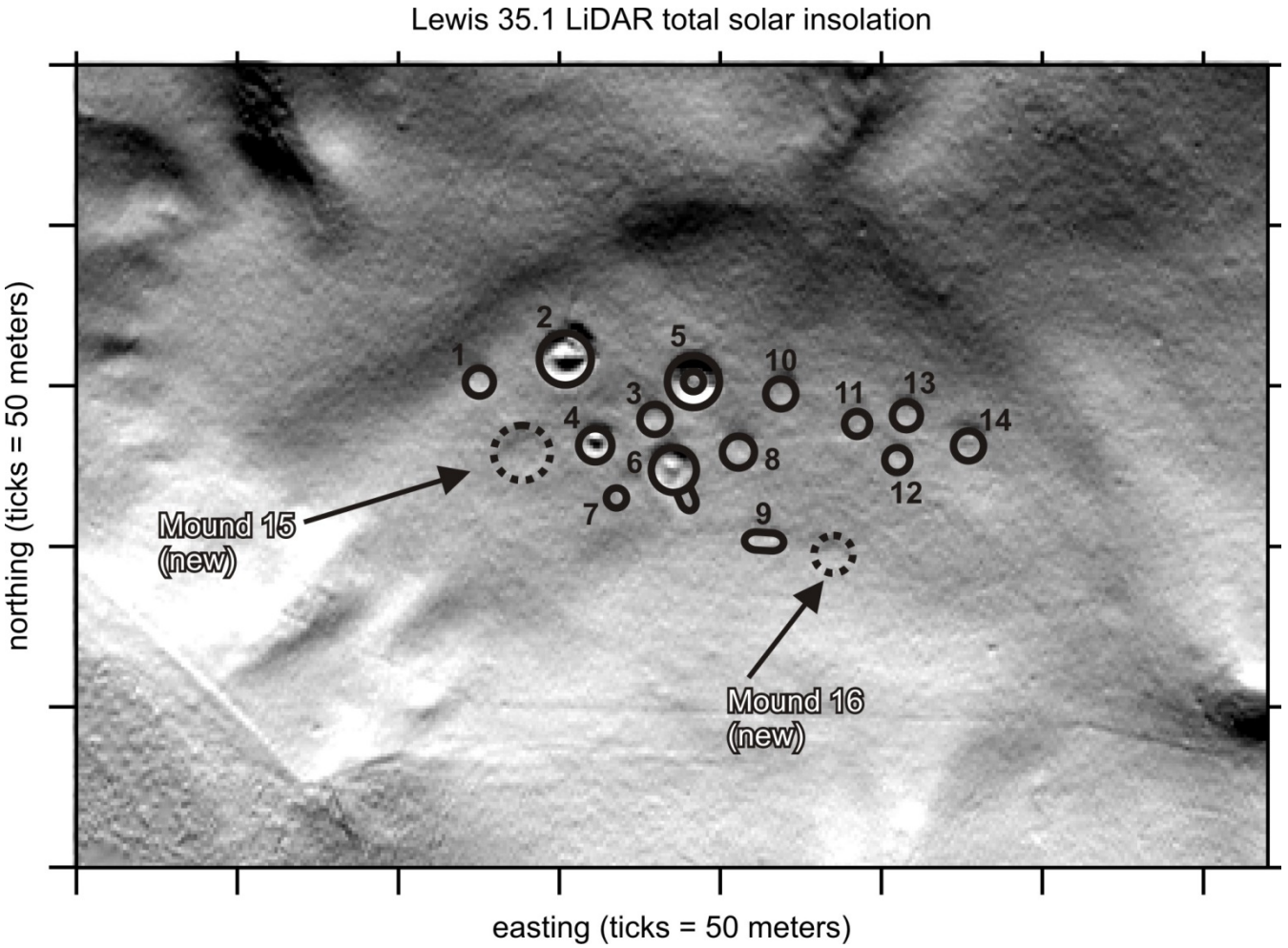
35

Map reconstructed from Lewis's notebook using modern cartographic software.

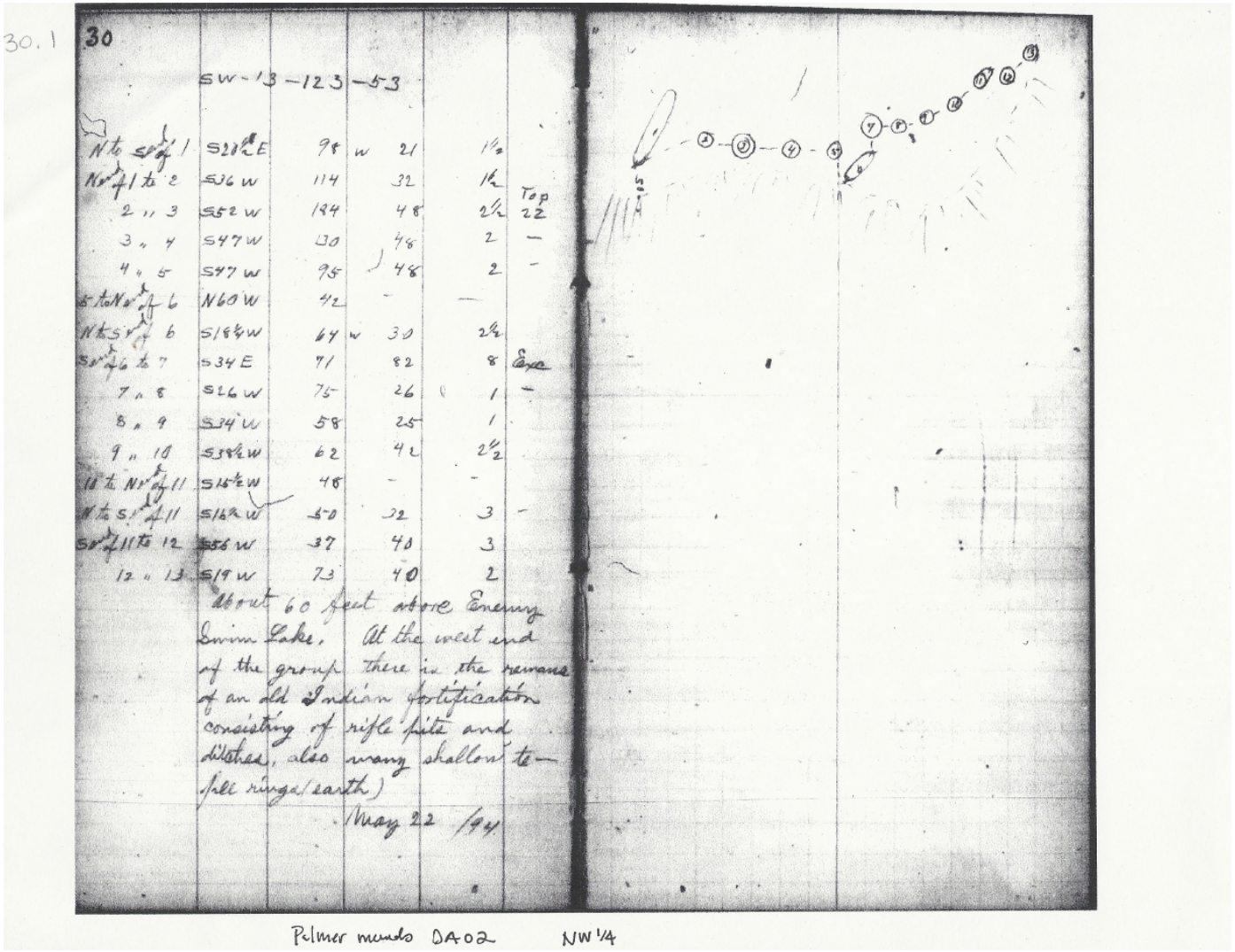



Lewis 35.1 LiDAR total solar insolation
northing (ticks = 50 meters)
easting (ticks = 50 meters)


Lewis 35.1 LiDAR total solar insolation
northing (ticks = 50 meters)
easting (ticks = 50 meters)
1
2
3
4
5
6
7
8
9
10
11
12
13
14


Lewis 35.1 LiDAR total solar insolation
northing (ticks = 50 meters)
easting (ticks = 50 meters)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Mound 15
(new)
Mound 16
(new)

Lewis's notebook entry from Enemy Swim Lake



30.1

30

SW-13-123-53

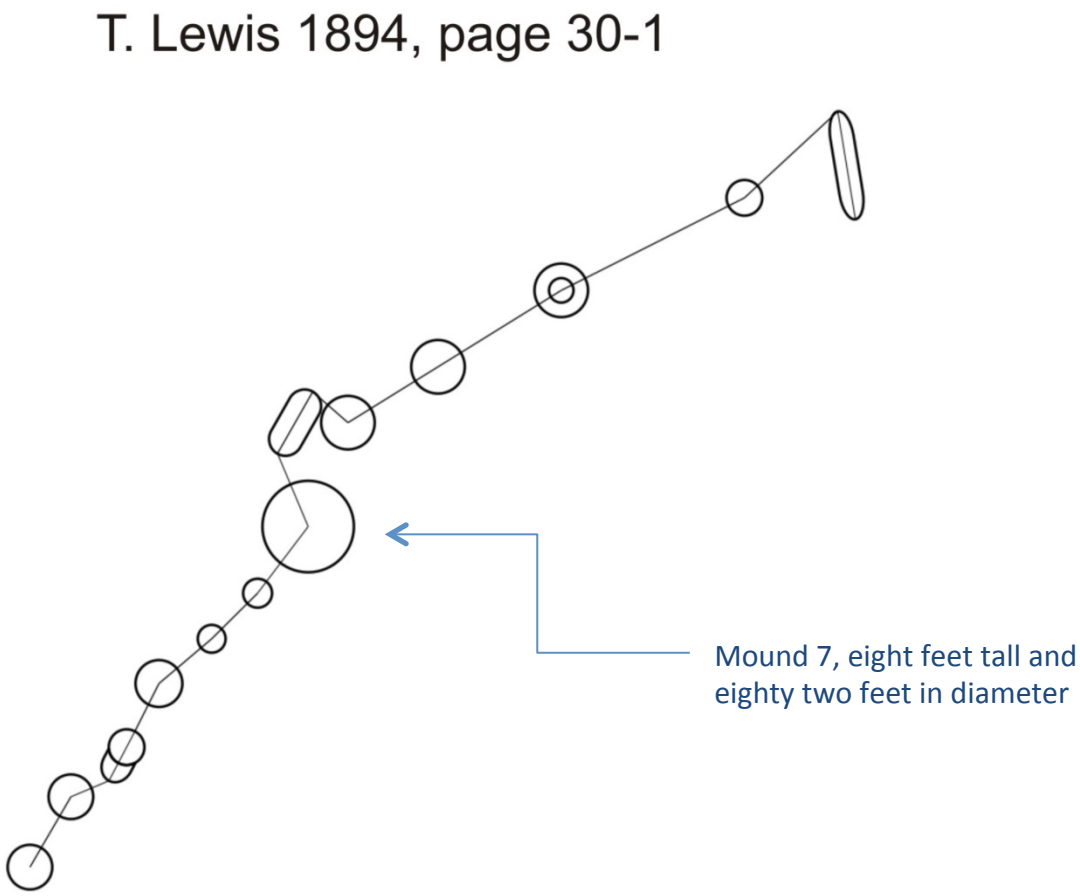
N to S of 1	S20½E	98	W 21	1½	
N of 1 to 2	S36W	114	32	1½	Top 22
2 " 3	S52W	134	48	2½	
3 " 4	S47W	130	48	2	—
4 " 5	S47W	95	48	2	—
5 to N of 6	N60W	42	—	—	
N to S of 6	S18¼W	64	W 30	2½	
S of 6 to 7	S34E	71	82	8	Cave
7 " 8	S26W	75	26	1	—
8 " 9	S34W	58	25	1	
9 " 10	S38½W	62	42	2½	
10 to N of 11	S45½W	48	—	—	
N to S of 11	S16½W	50	32	3	—
S of 11 to 12	S56W	37	40	3	
12 " 13	S19W	73	40	2	

About 60 feet above Enemy Swim Lake. At the west end of the group there is the remains of an old Indian fortification consisting of rifle pits and ditches, also many shallow te— pee rings (earth)

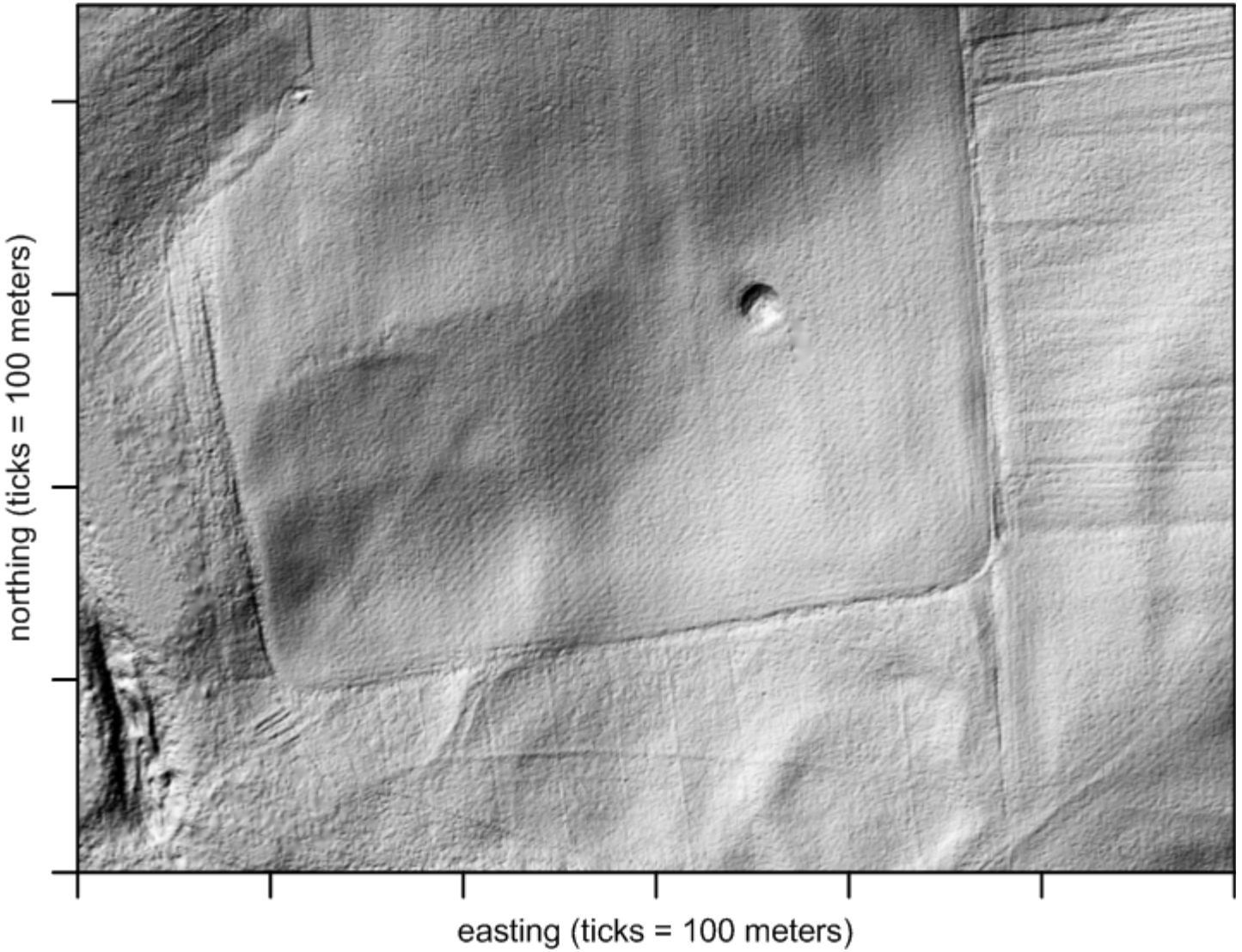
May 22 /94

Palmer mendo DA02 NW 1/4

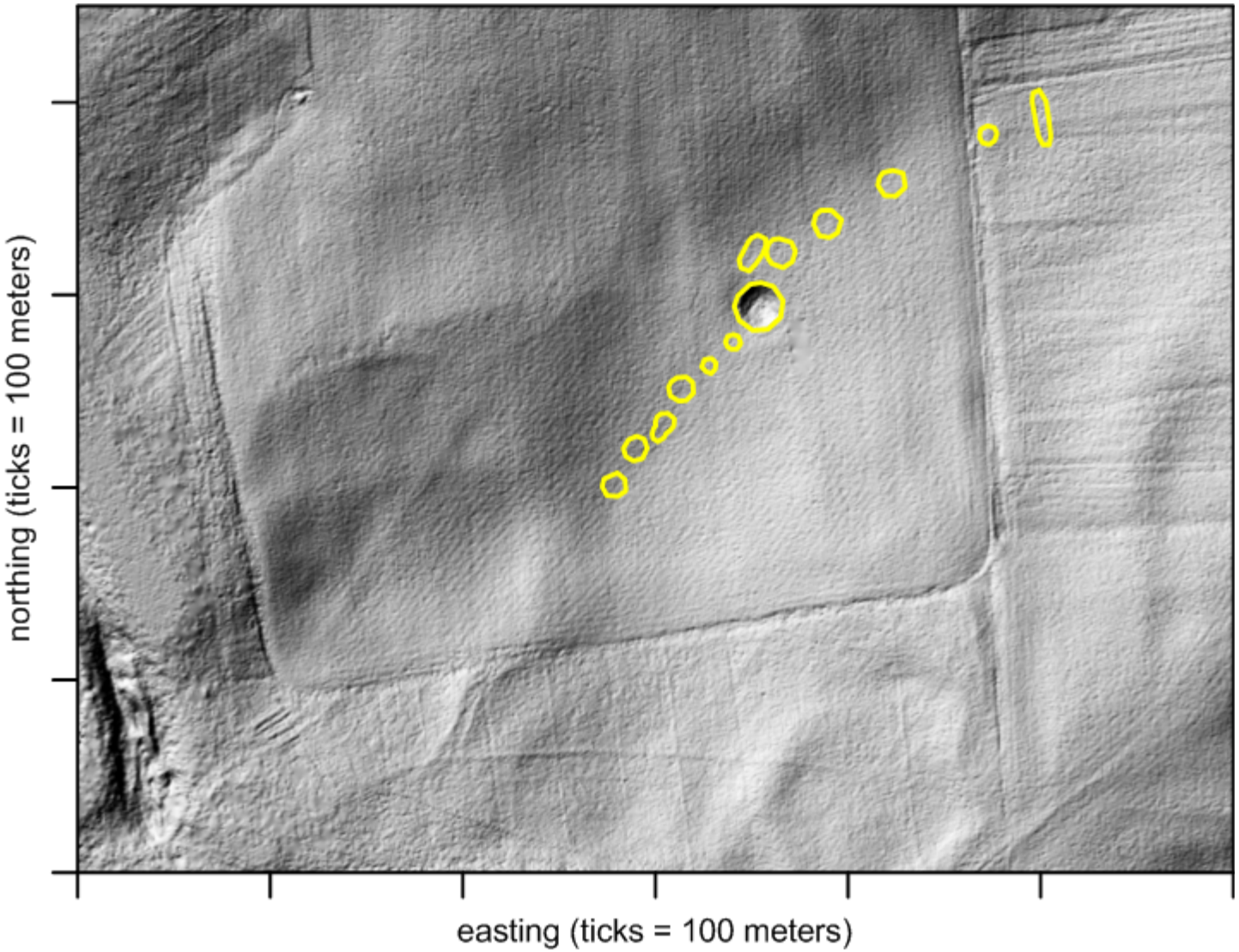
Enemy Swim Group reconstructed from Lewis's notes



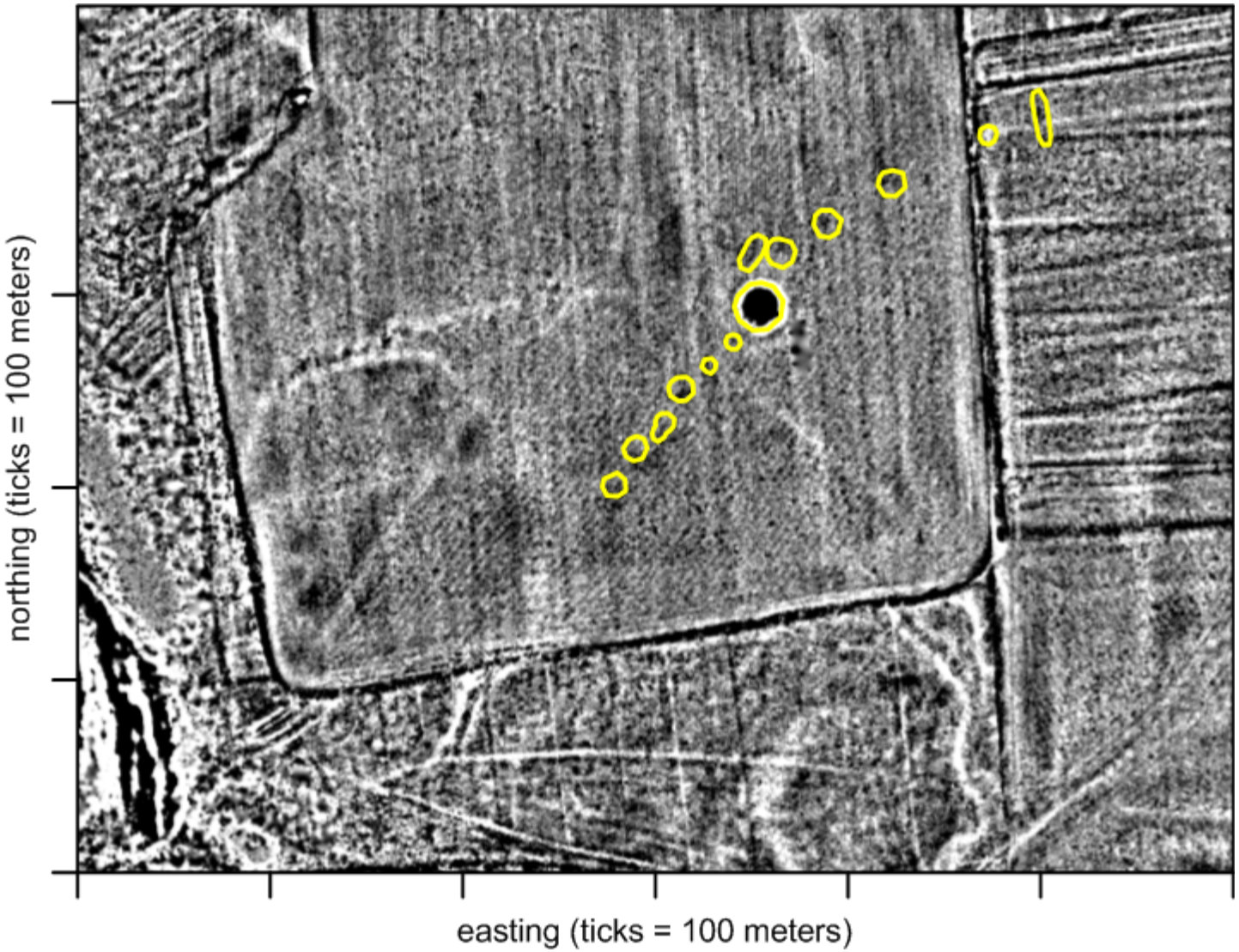
LiDAR shows one large mound remaining, remainder assumed destroyed by agricultural plowing



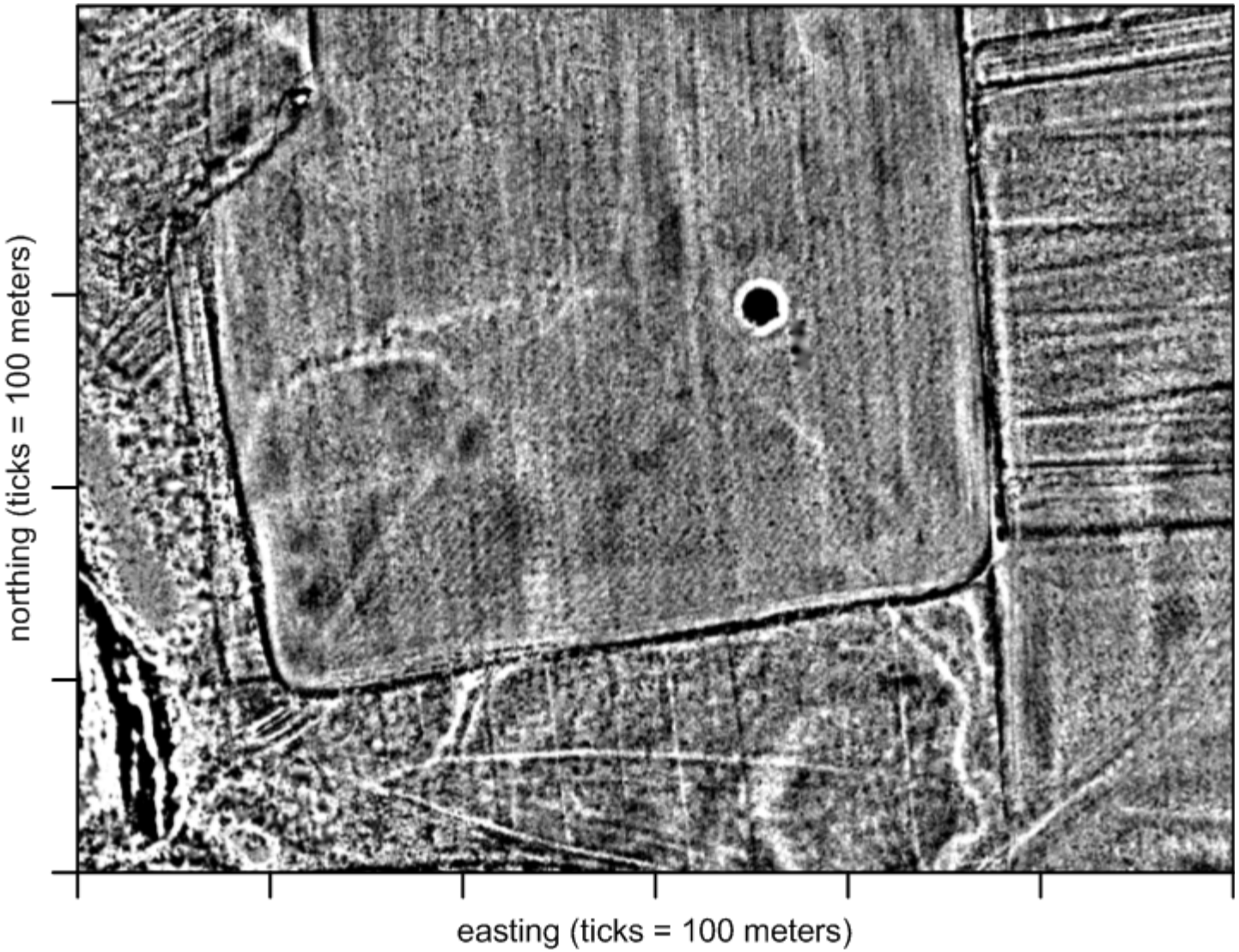
Lewis map overlay after scaling appropriately and accounting for changes in magnetic declination between 1894 and present



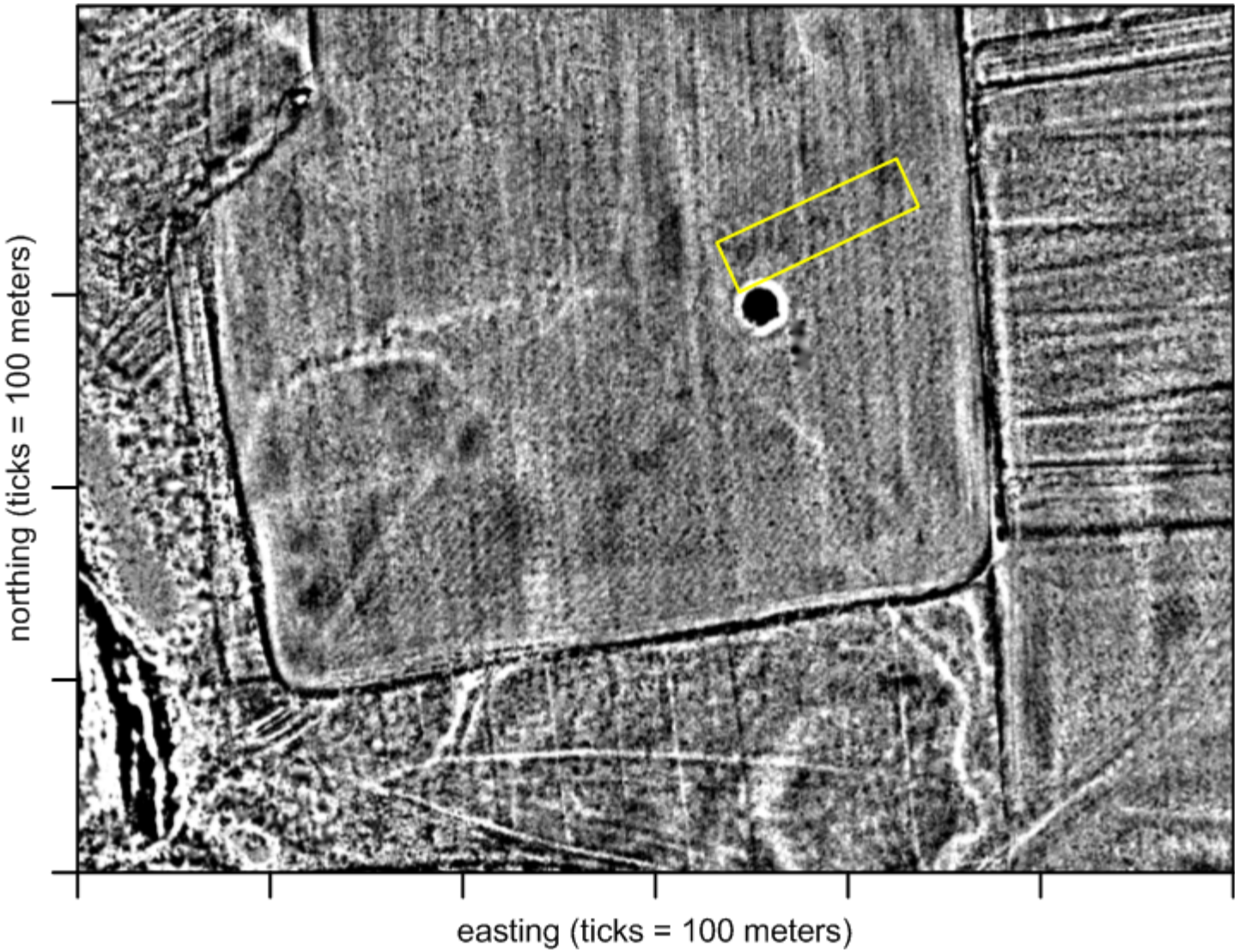
LiDAR Local Relief Model with Lewis Overlay



LiDAR Local Relief Model

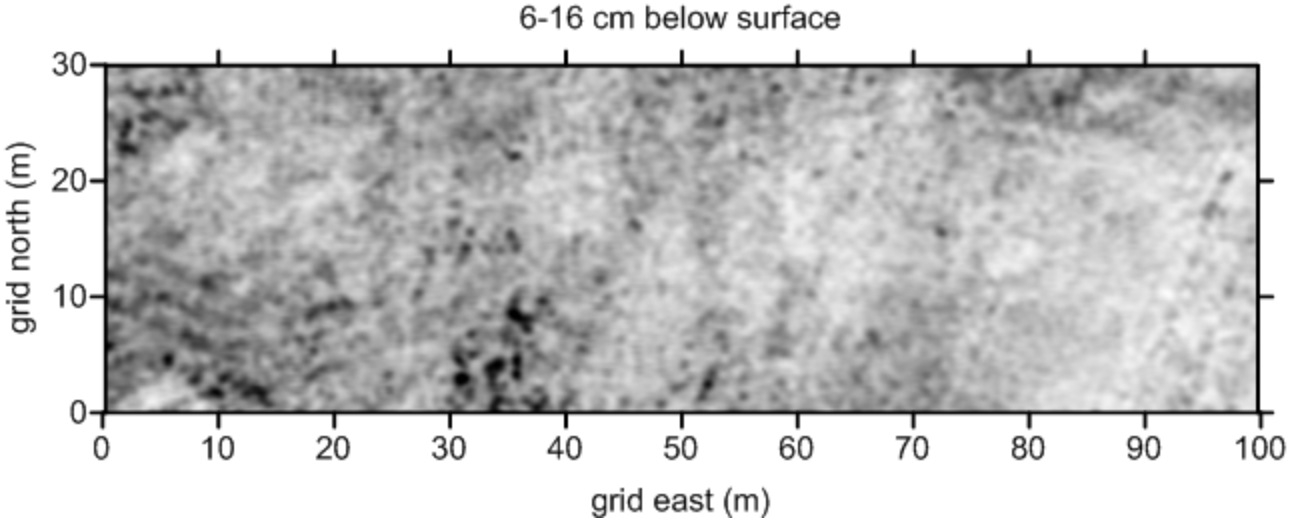


GPR Survey Area Targeting “Plowed” Mounds

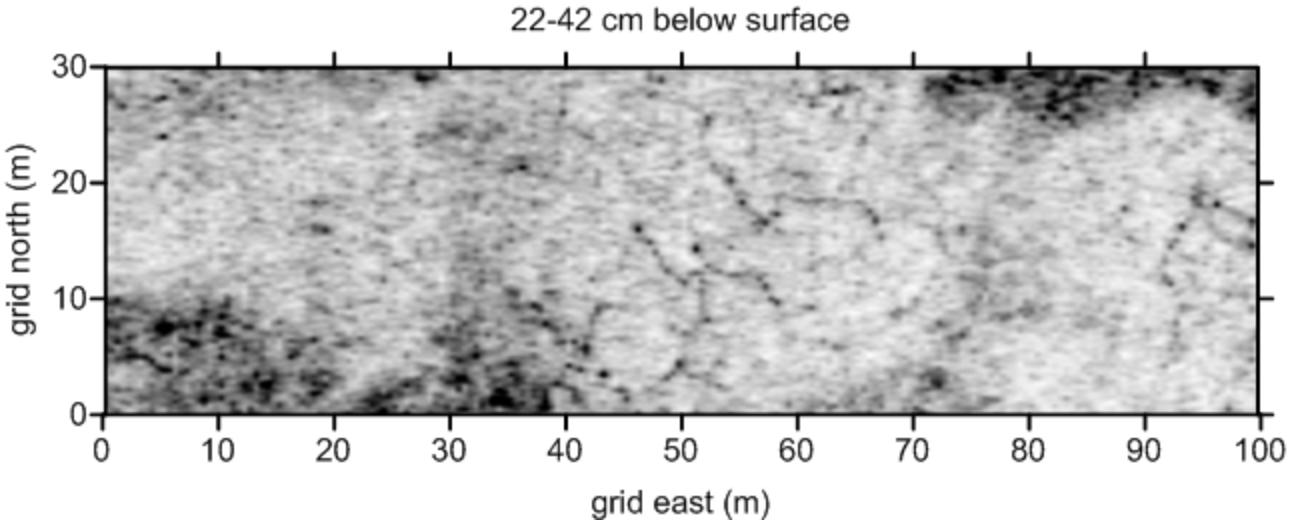


GPR survey in progress

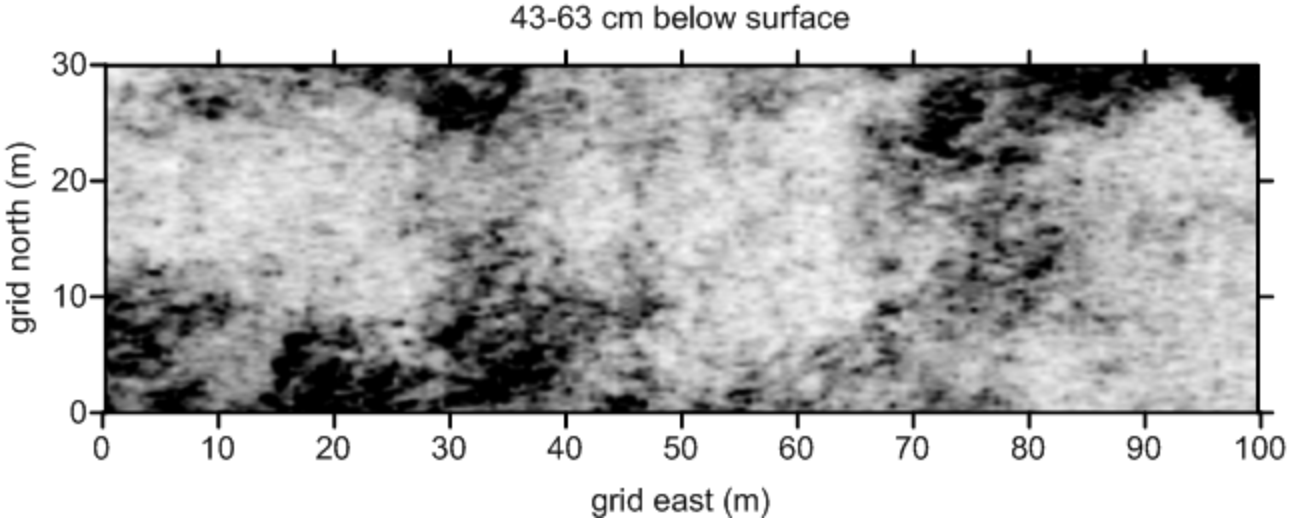
GPR results showing plow scarring



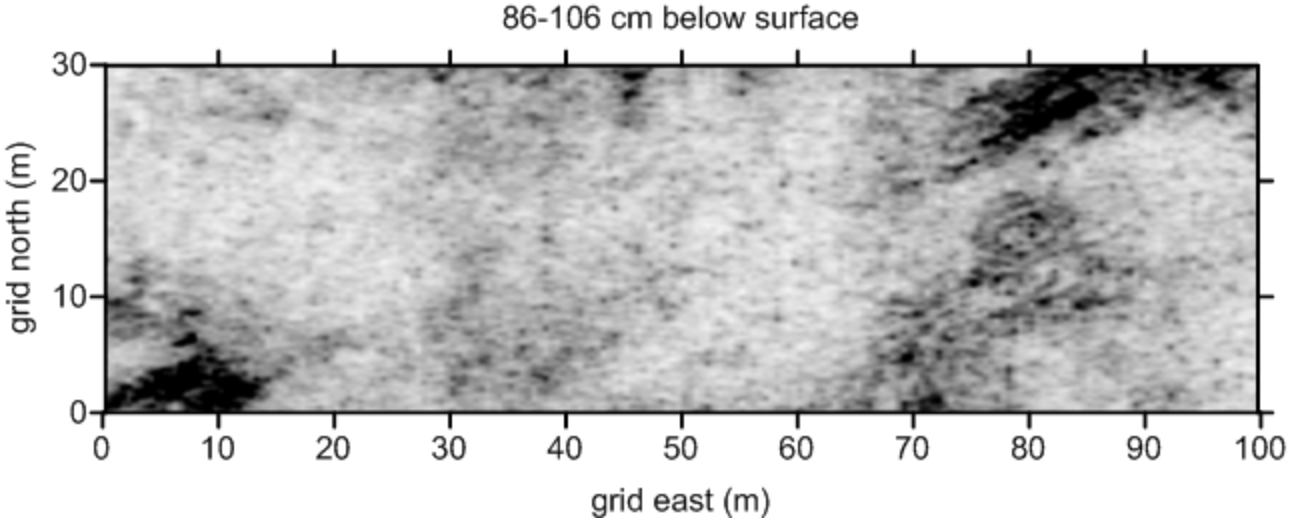
GPR results showing rodent burrows



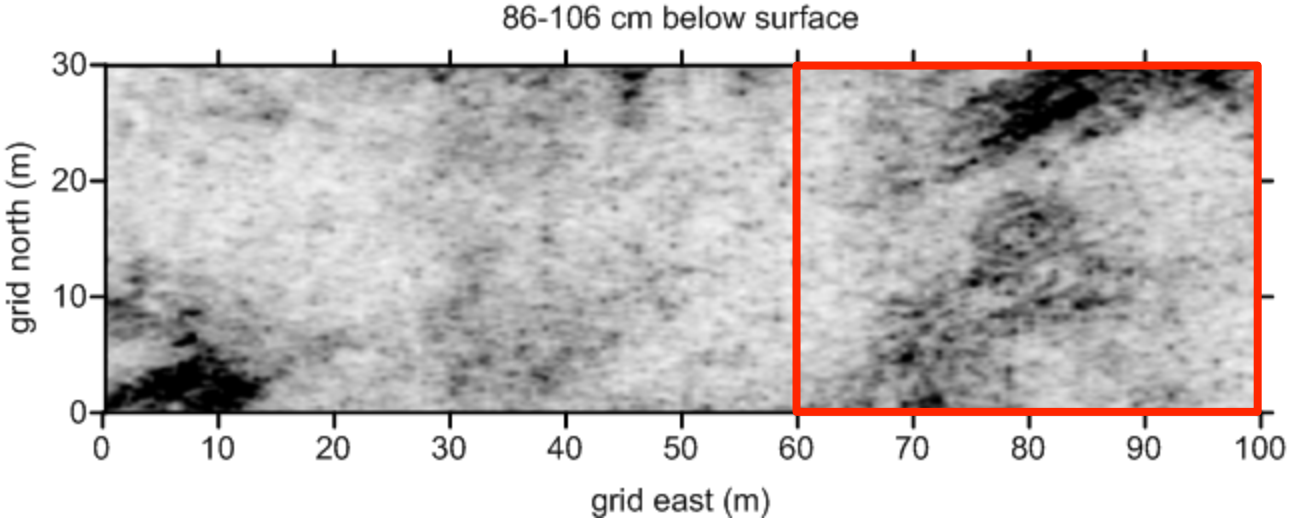
GPR results showing rough mound outlines

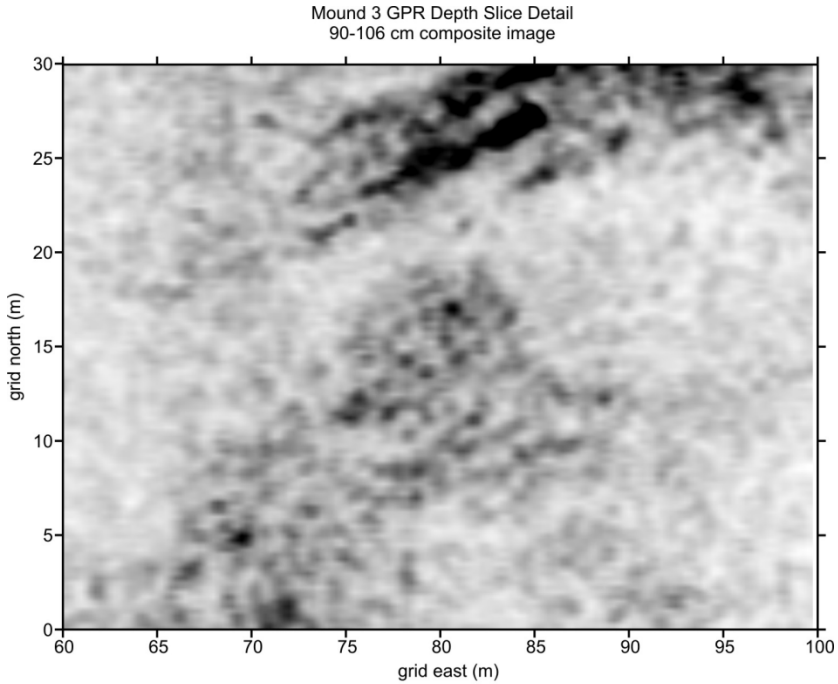


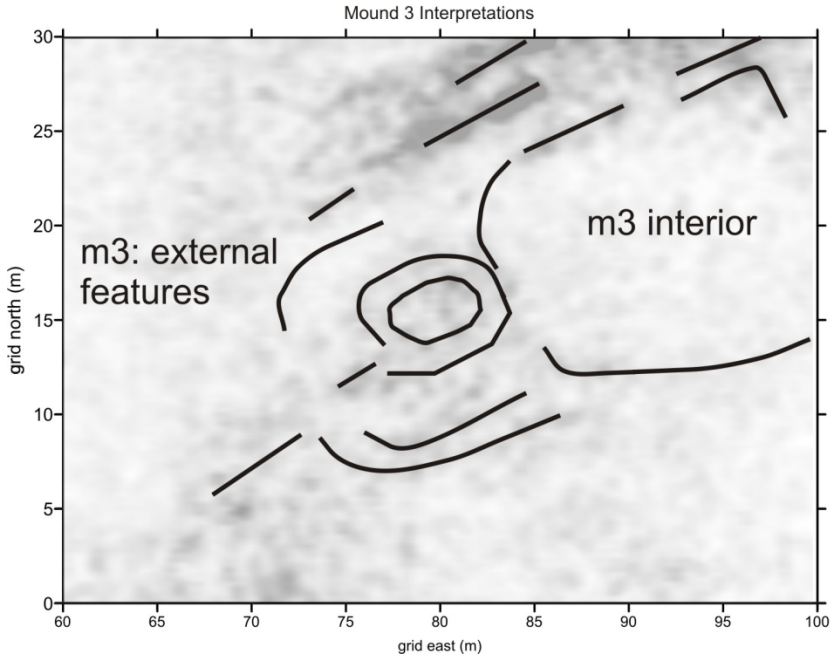
GPR results showing intact sub-plow zone feature

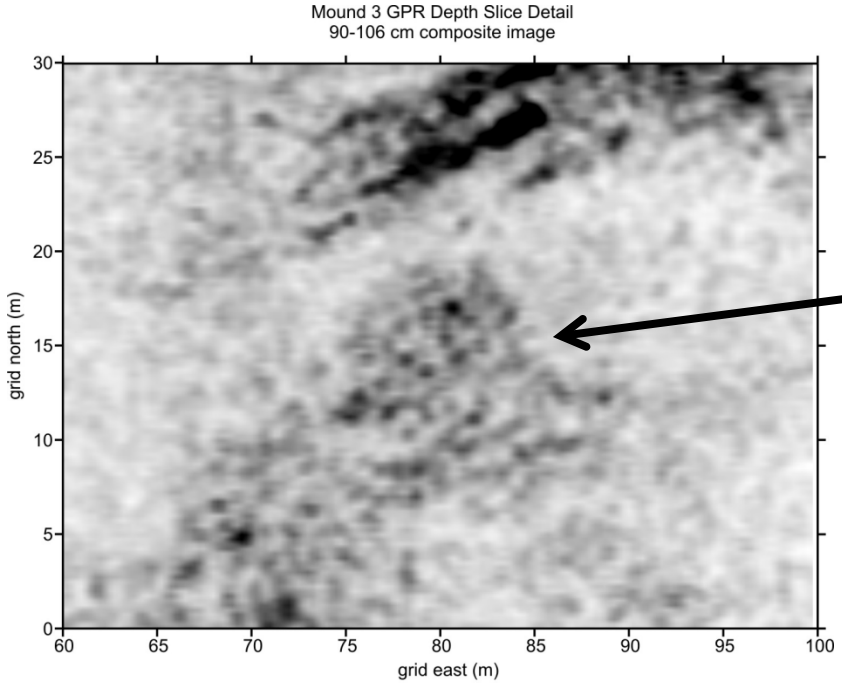


GPR results showing intact sub-plow zone feature
detail

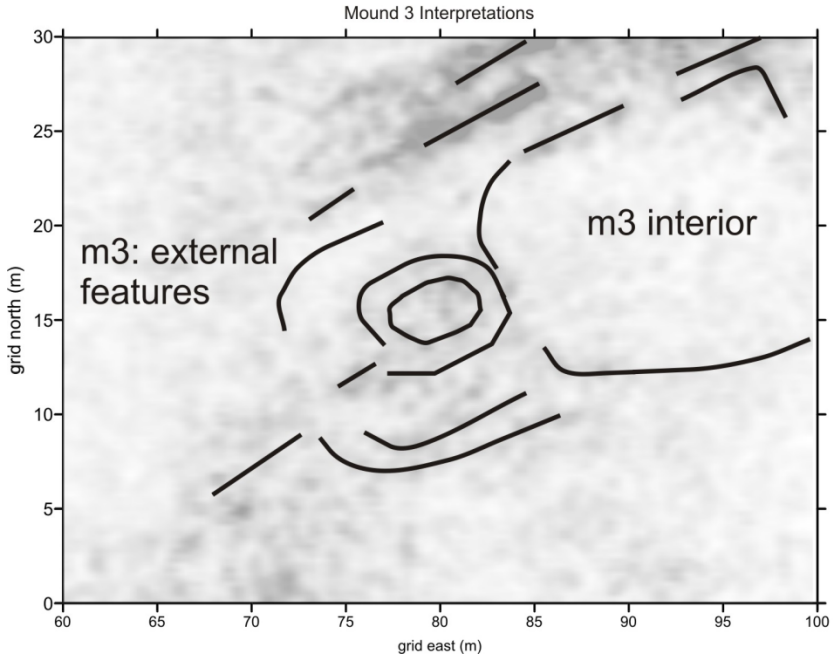



Mound 3 GPR Depth Slice Detail
90-106 cm composite image
grid north (m)
grid east (m)
0
5
10
15
20
25
30
60
65
70
75
80
85
90
95
100


Mound 3 Interpretations
m3: external features
m3 interior
grid north (m)
grid east (m)
0
5
10
15
20
25
30
60
65
70
75
80
85
90
95
100

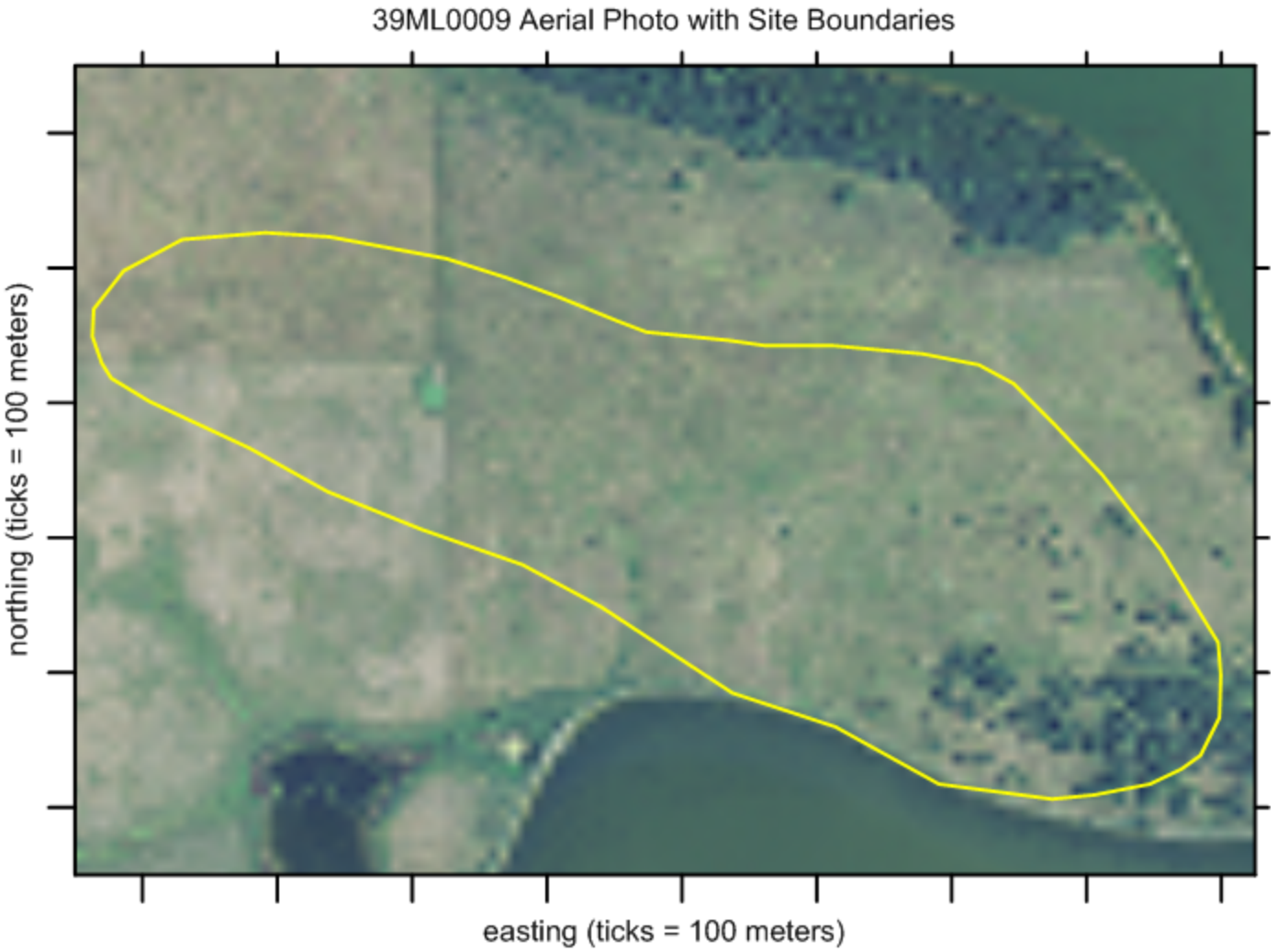


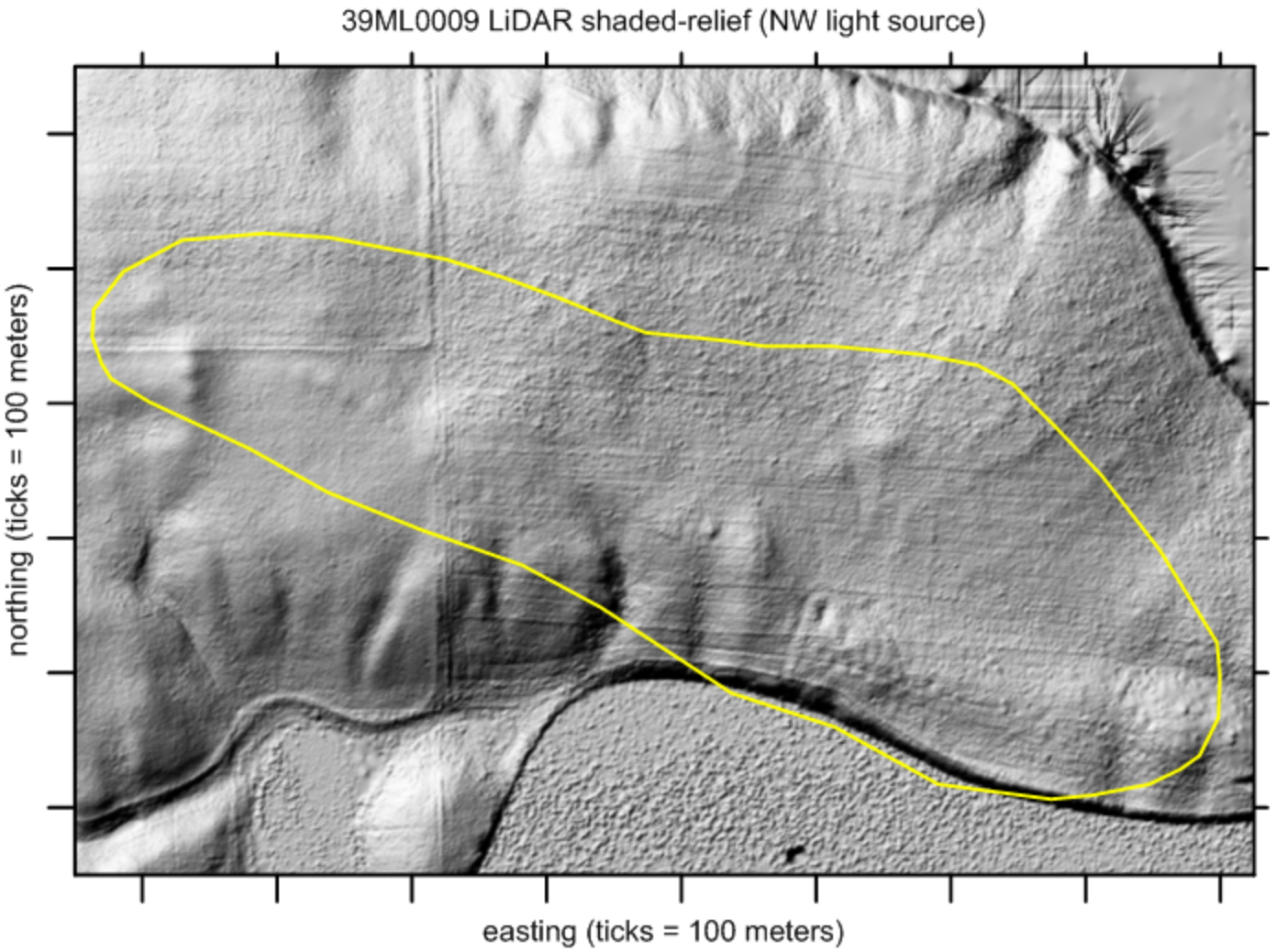
Sub-surface integrity of mounds presumed destroyed

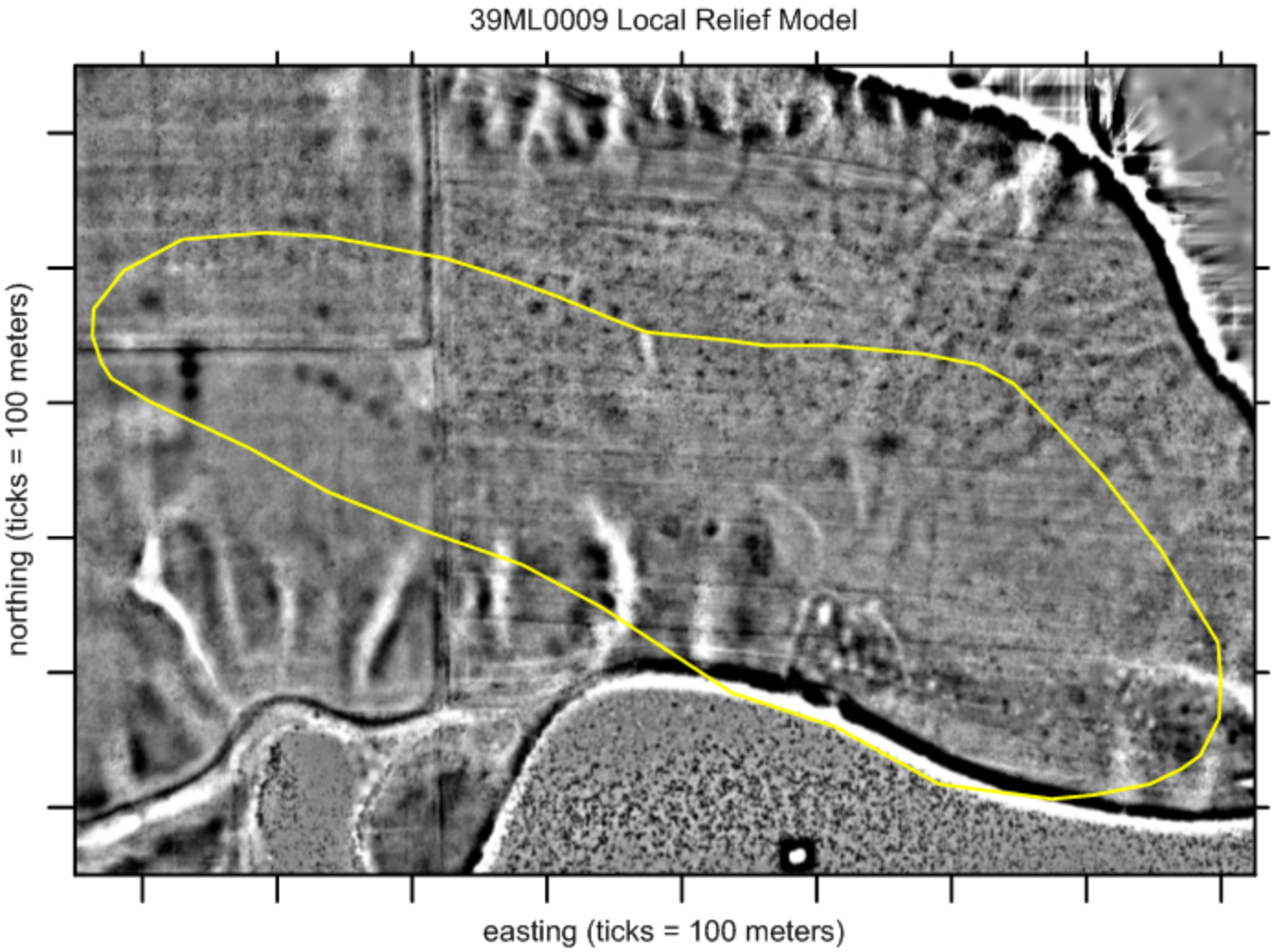


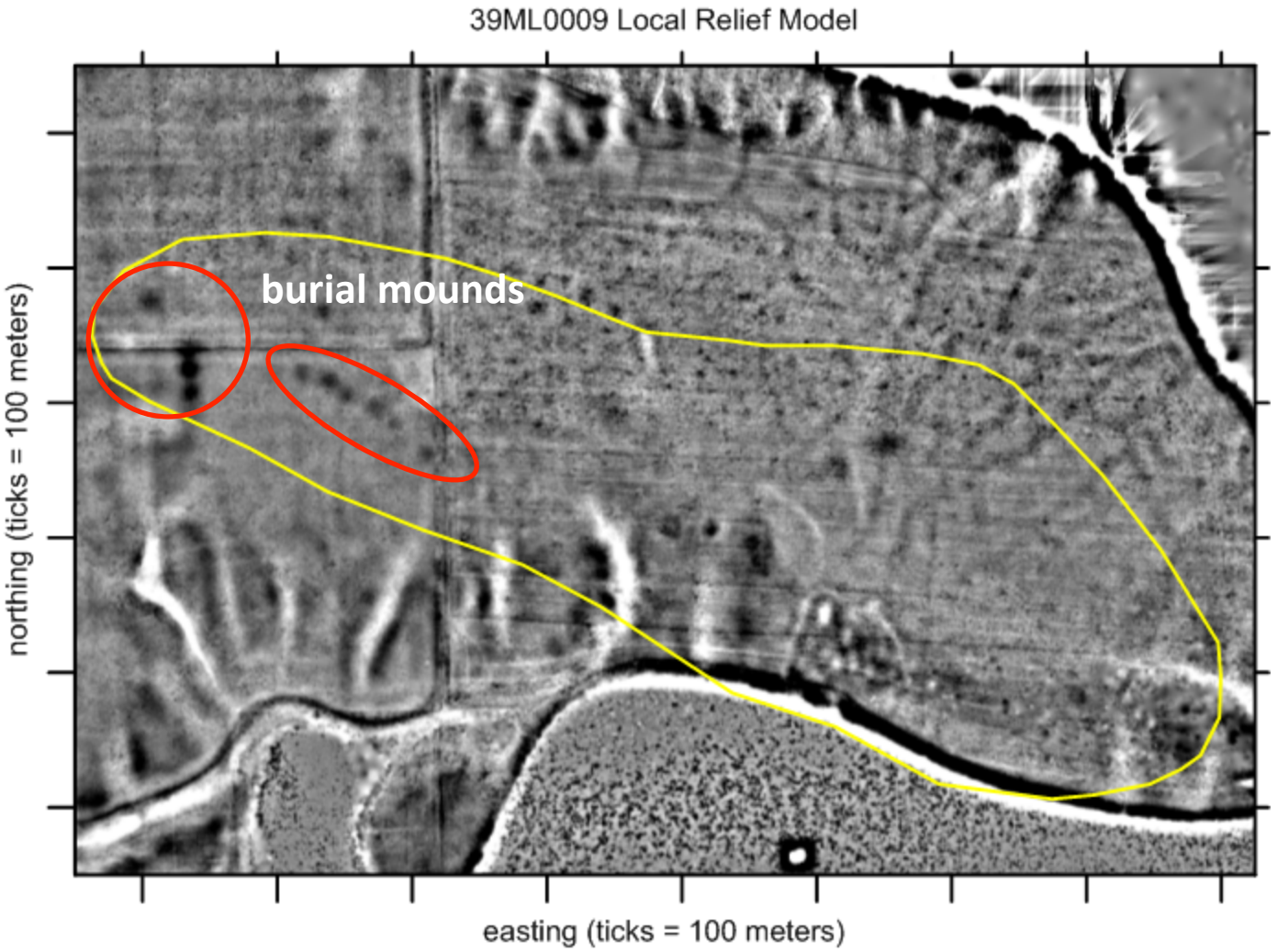
Accidental Discoveries

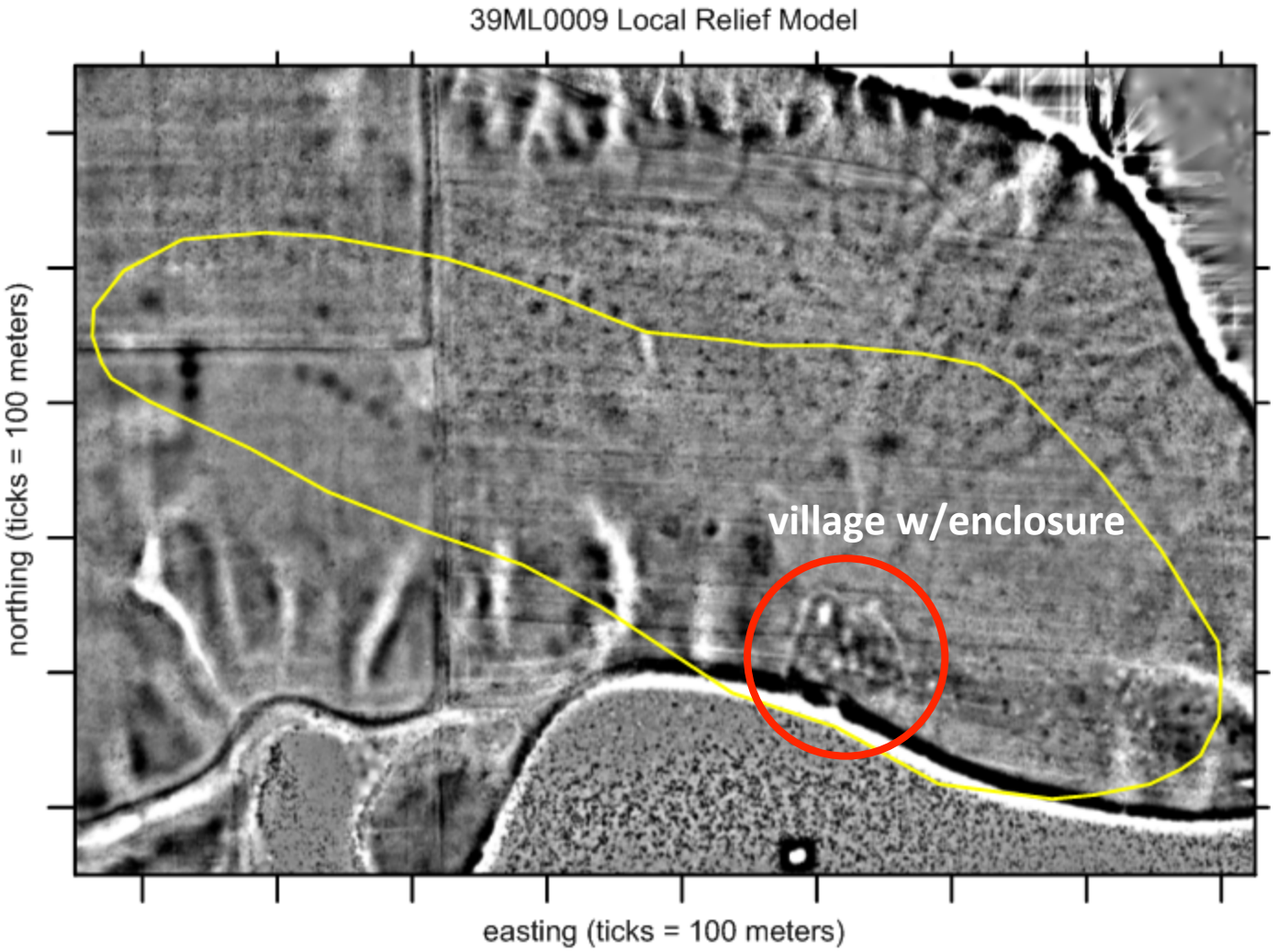
archaeological site defined by a ceramic sherd scatter

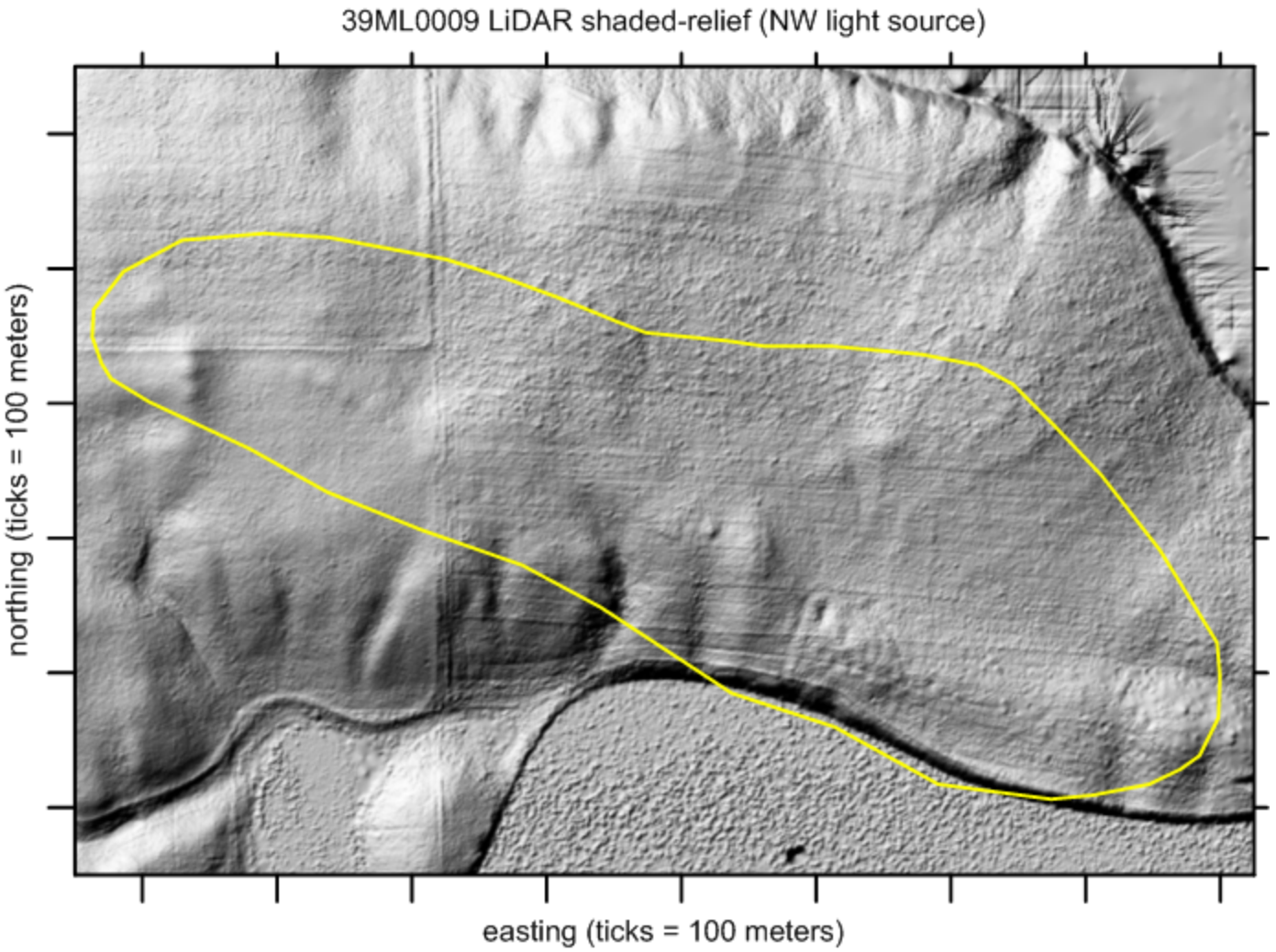



39ML0009 LiDAR shaded-relief (NW light source)
northing (ticks = 100 meters)
easting (ticks = 100 meters)


39ML0009 Local Relief Model
northing (ticks = 100 meters)
easting (ticks = 100 meters)


39ML0009 Local Relief Model
burial mounds
northing (ticks = 100 meters)
easting (ticks = 100 meters)


39ML0009 Local Relief Model
northing (ticks = 100 meters)
easting (ticks = 100 meters)
village w/enclosure


39ML0009 LiDAR shaded-relief (NW light source)
northing (ticks = 100 meters)
easting (ticks = 100 meters)

A Geophysical and Archaeological Assessment of the Buffalo Slough Mound Site (21GD74)

A precontact burial mound group located in Goodhue County, Minnesota

Prepared For:

The Prairie Island Indian Community
Welsh, MN

By:

David Maki, Sigrid Arnott, and Michael Bergervoet
Minneapolis, Minnesota

December, 2014

This project was funded by a grant from the Minnesota Historical and Cultural Grants Program, made possible by the Arts and Cultural Heritage Fund through the Legacy Amendment vote of Minnesotans on November 4, 2008

ARCHAEO-PHYSICS

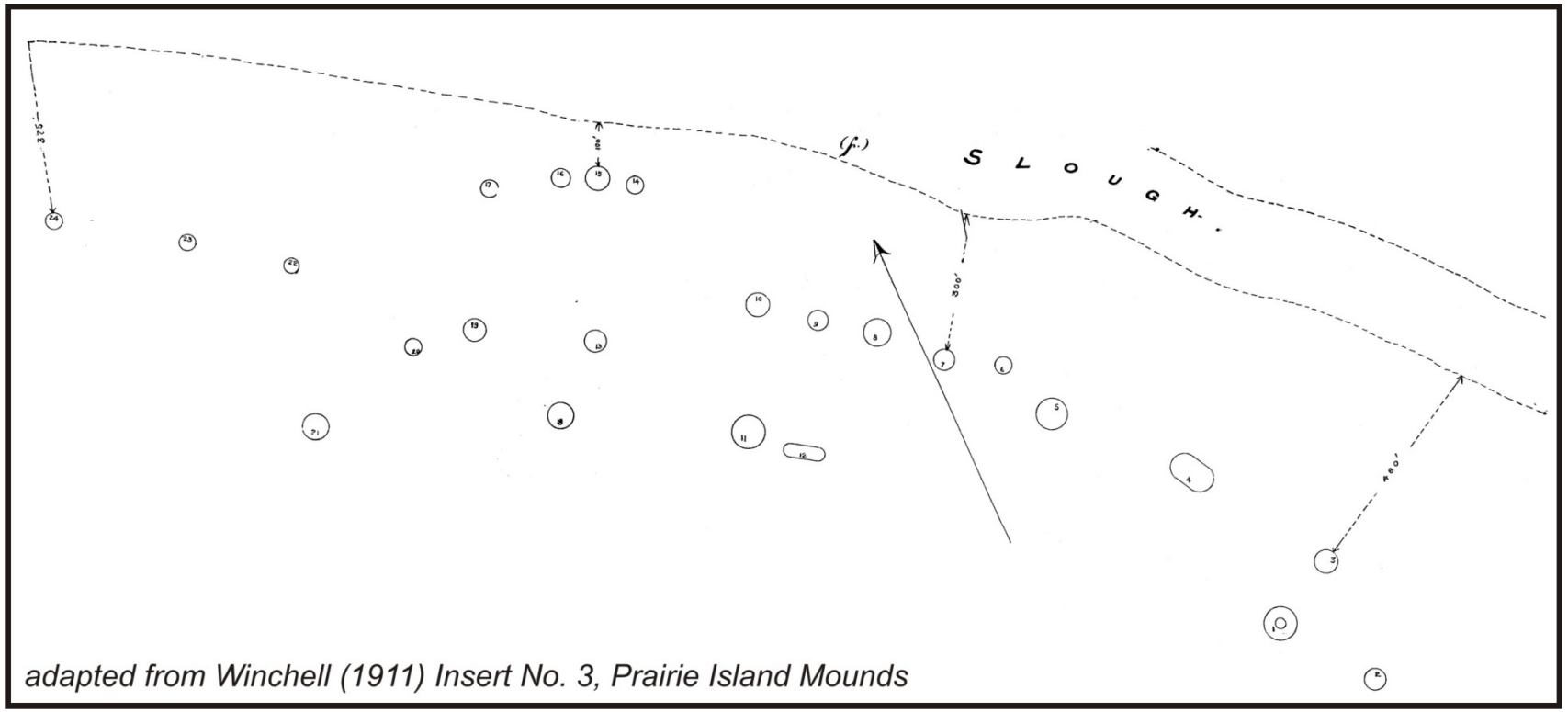
SHALLOW SUBSURFACE GEOPHYSICAL SURVEY

Report of Investigation Number 214
Archaeo-Physics, LLC
4150 Dight Avenue South #110
Minneapolis, MN 55406
(612) 379-0094 info@archaeophysics.com

Buffalo Slough Mound Group – Prairie Island Mdewahketon Dakota Reservation

Mapped by Lewis in 1884

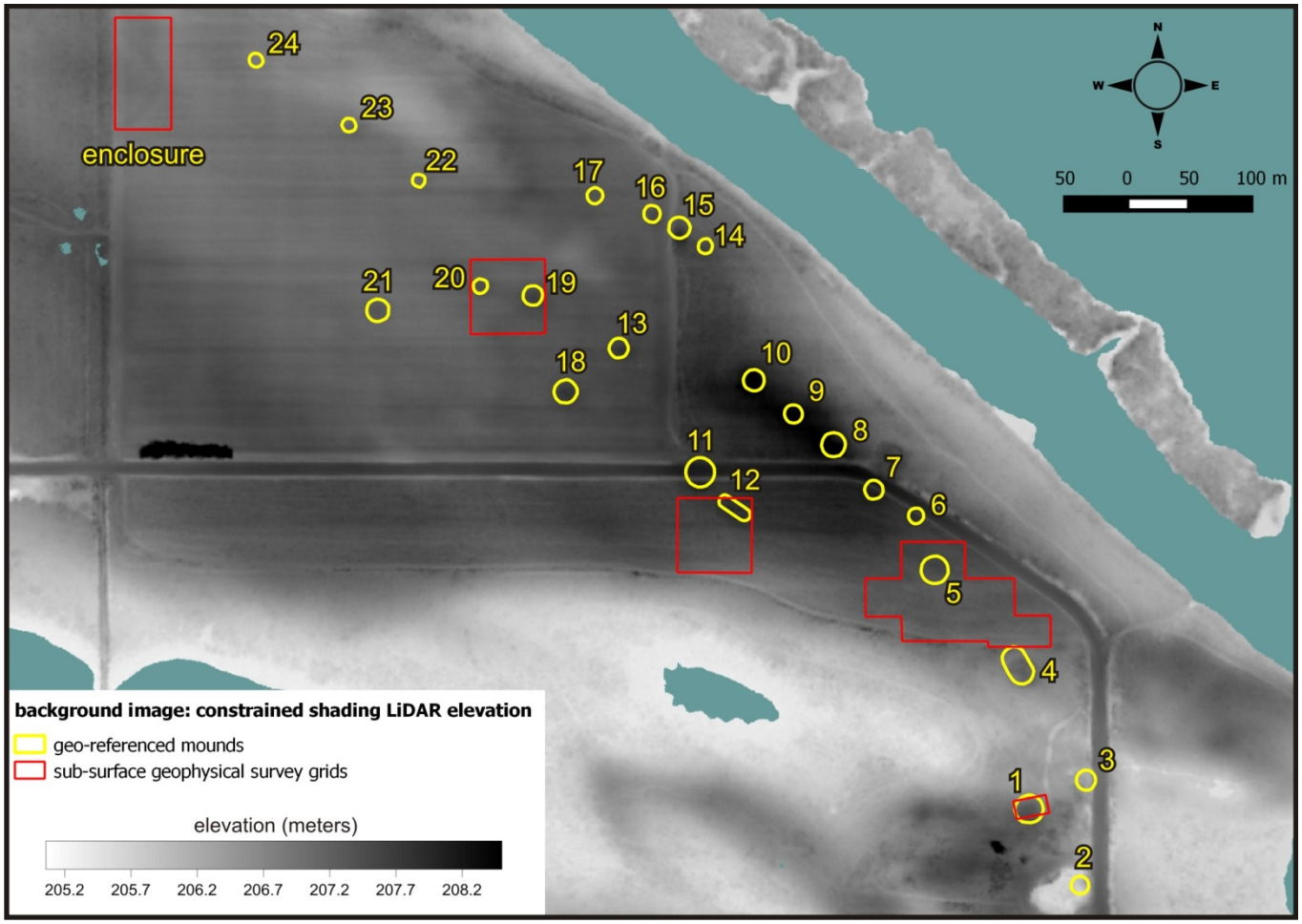
Majority of mounds assumed destroyed by agriculture



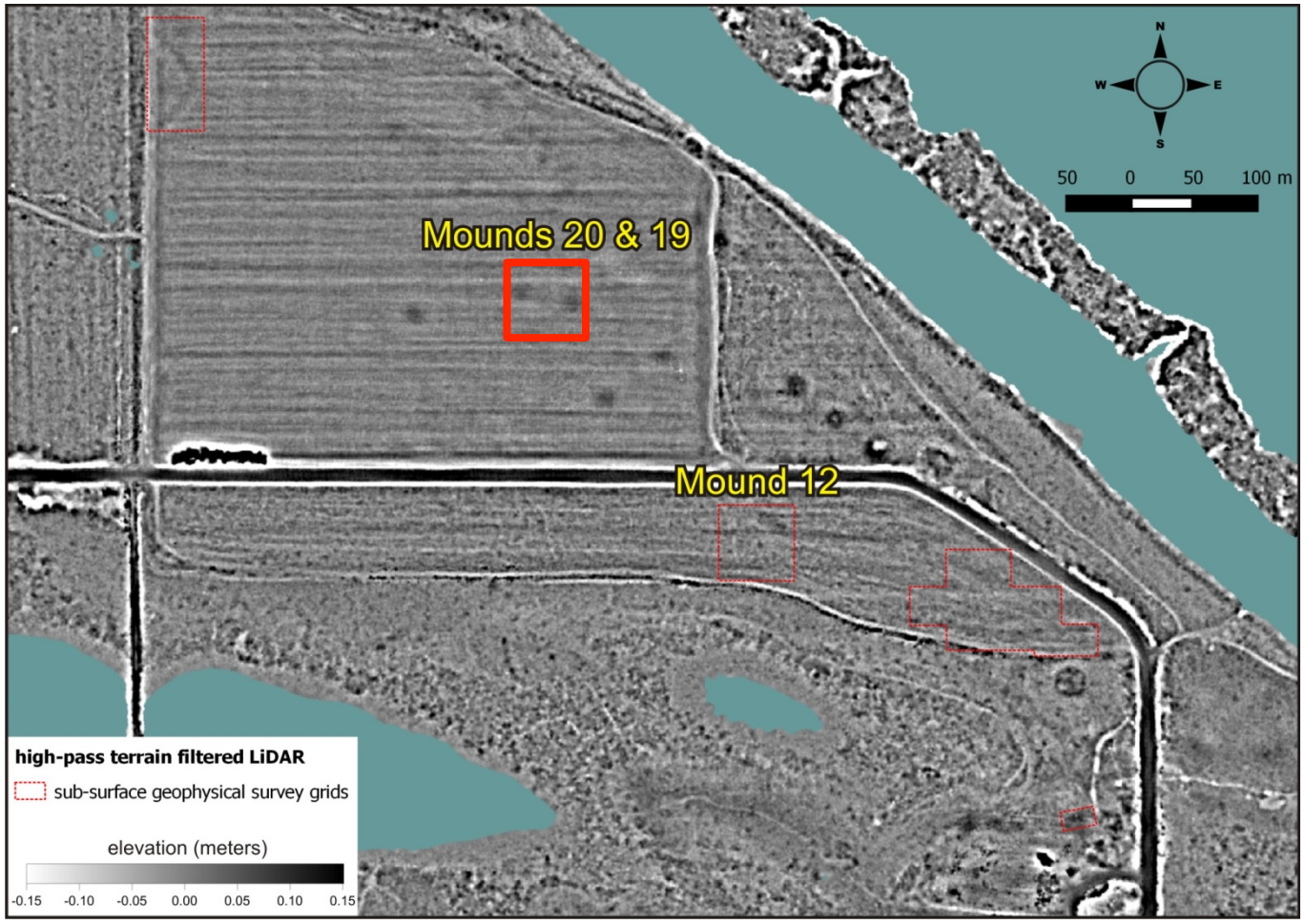
adapted from Winchell (1911) Insert No. 3, Prairie Island Mounds

Buffalo Slough Mound Group

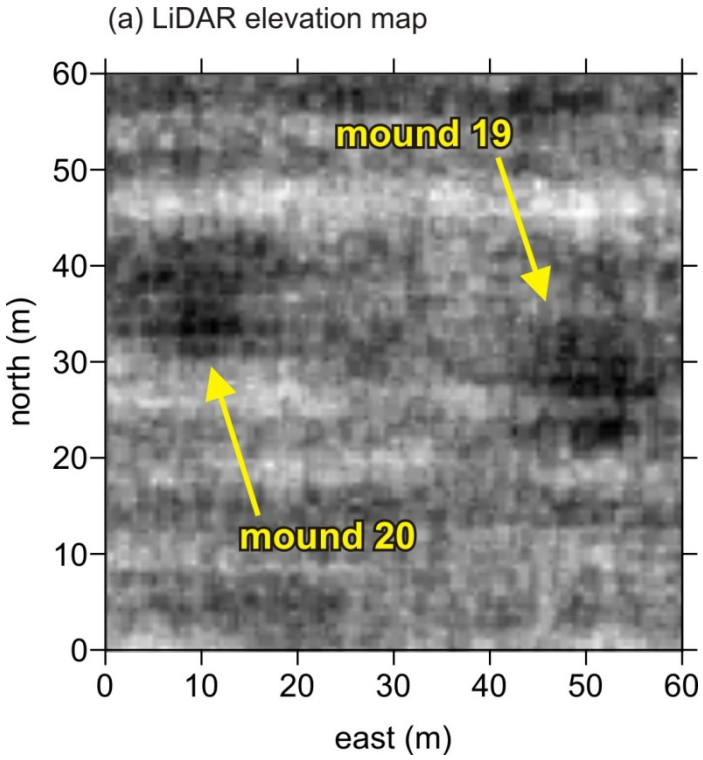
Geo-referenced Lewis Map



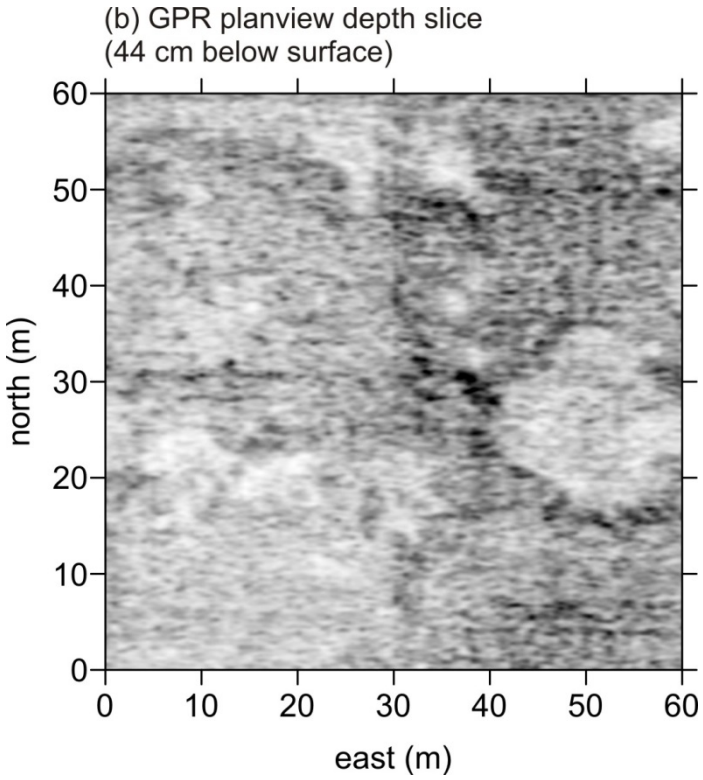
LiDAR local relief model



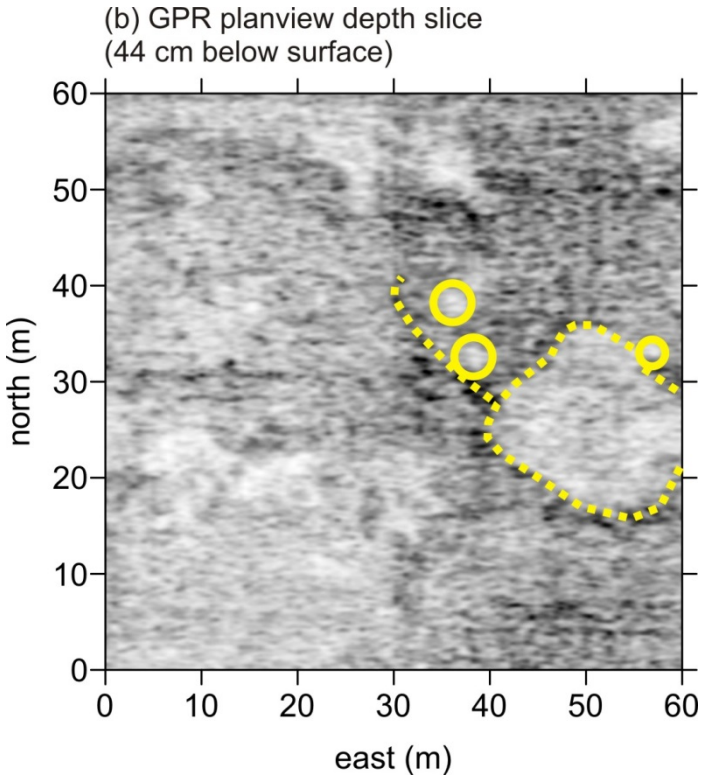
Mounds 19 & 20 Detail



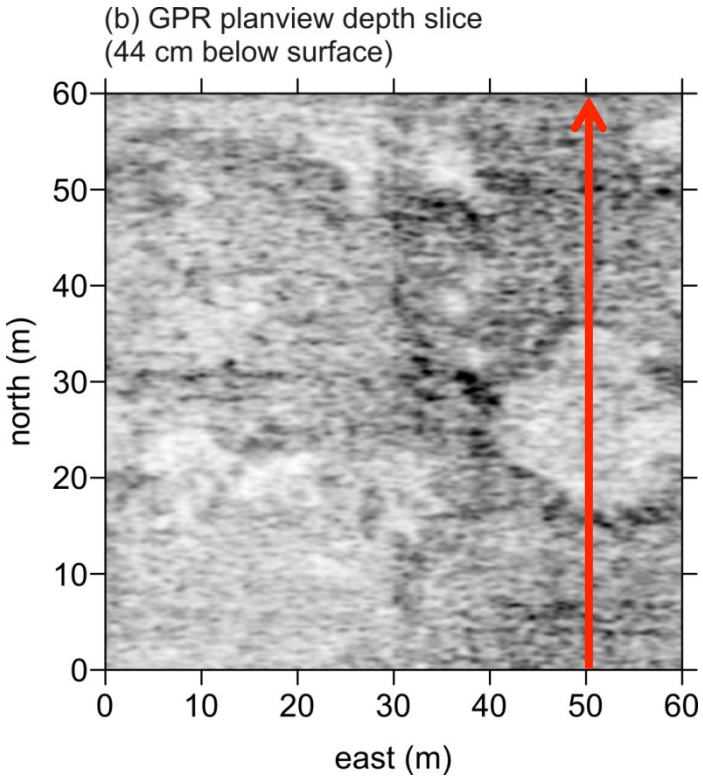
Mounds 19 & 20 GPR Plan Map



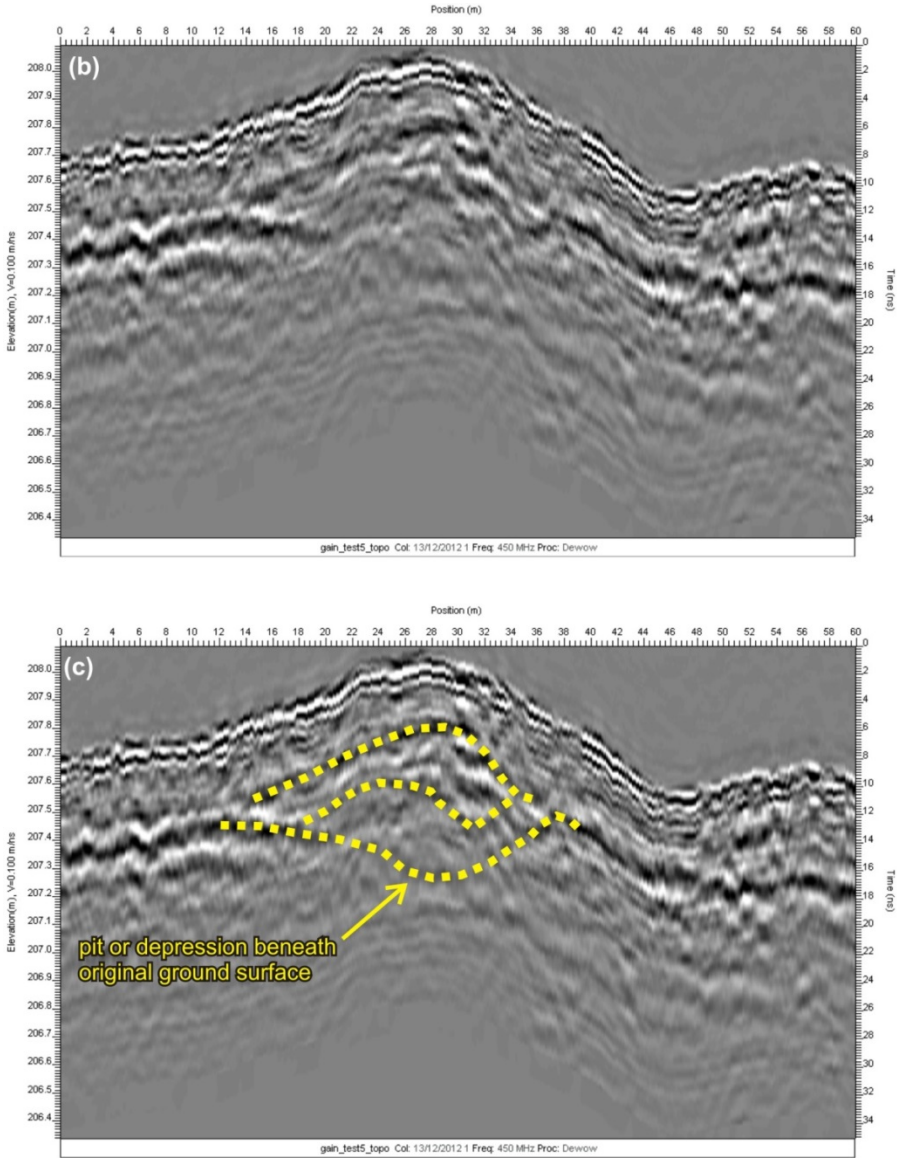
Mounds 19 & 20 GPR Plan Map



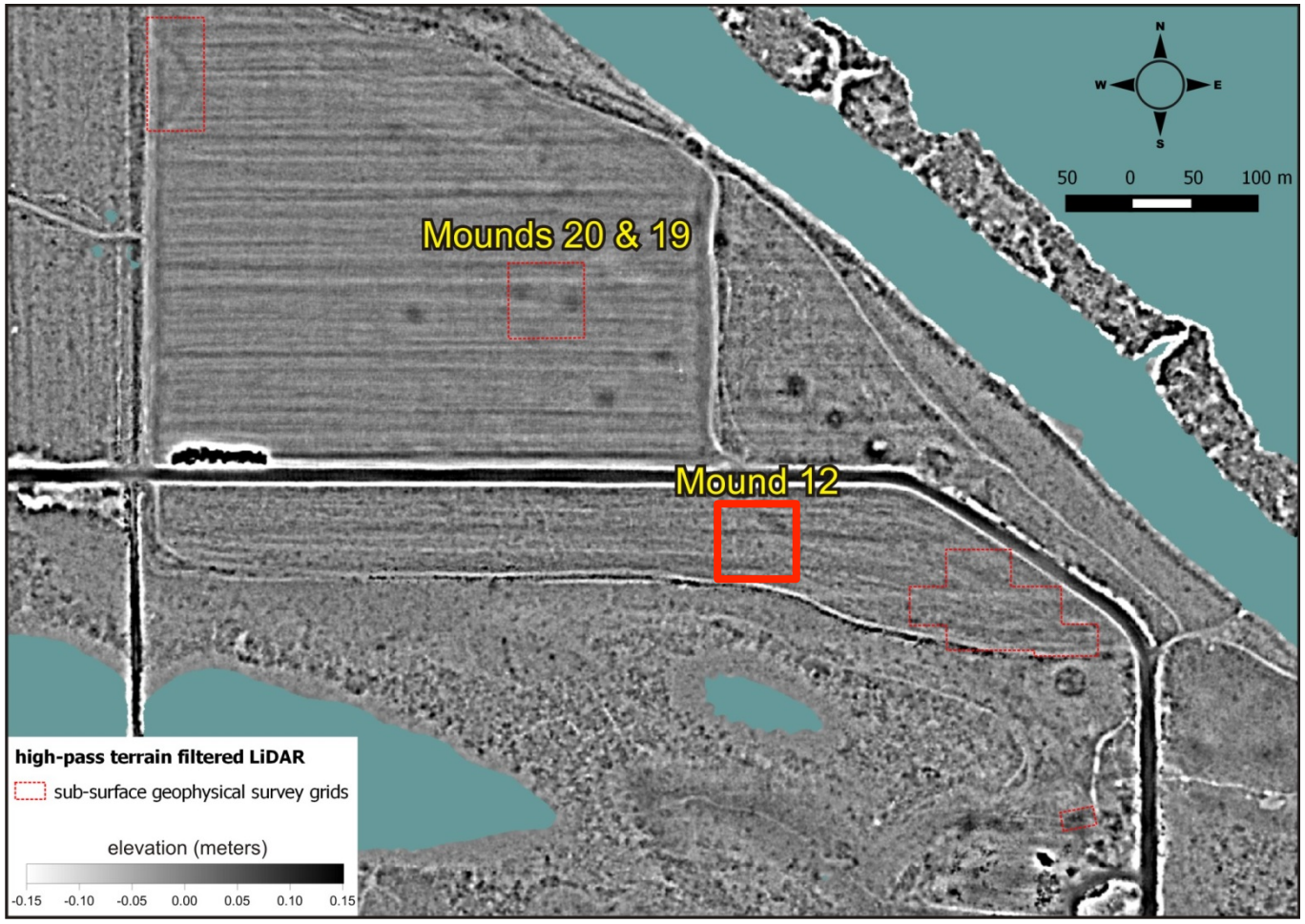
Mounds 19 & 20 Plan Map
Location of GPR Profile



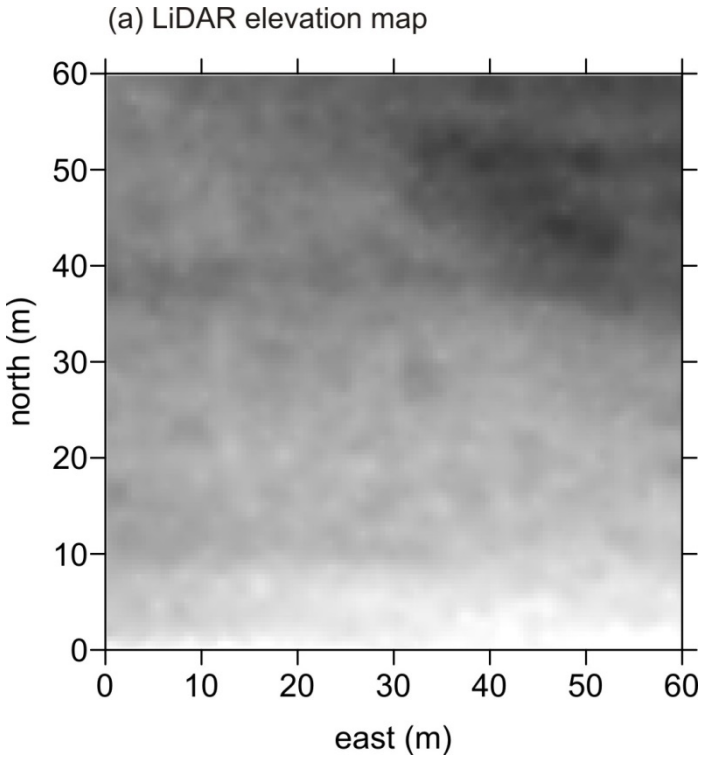
GPR profile corrected using LiDAR elevations



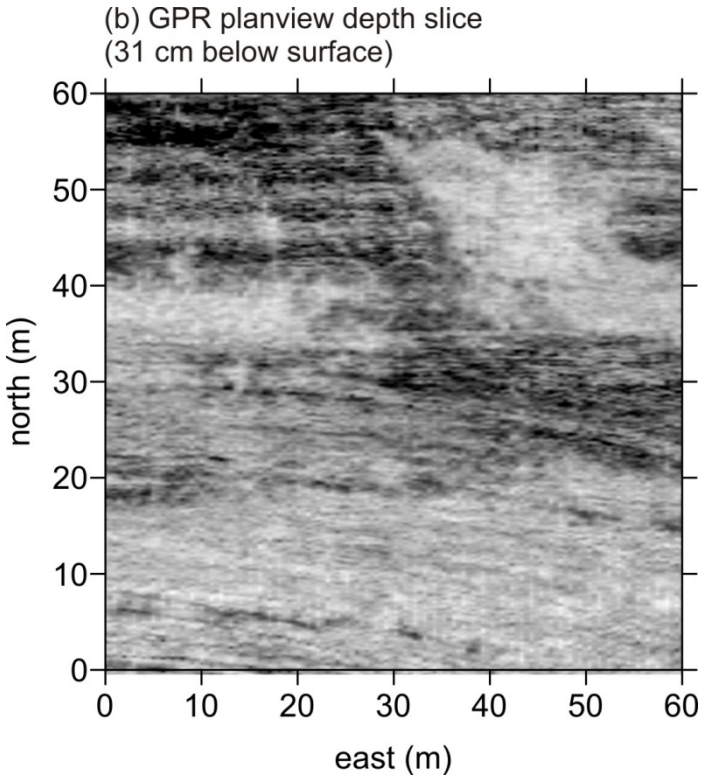
LiDAR local relief model



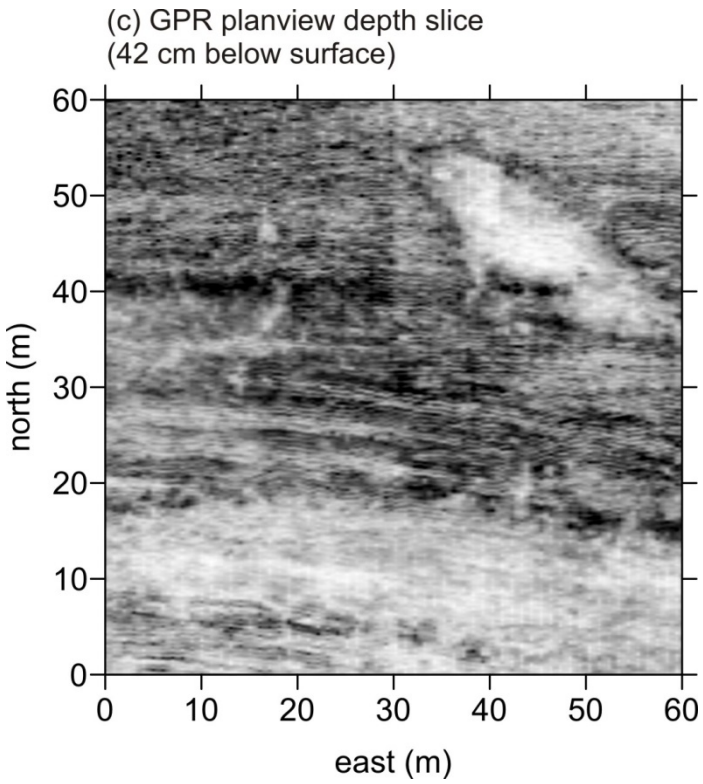
Mound 12 Detail



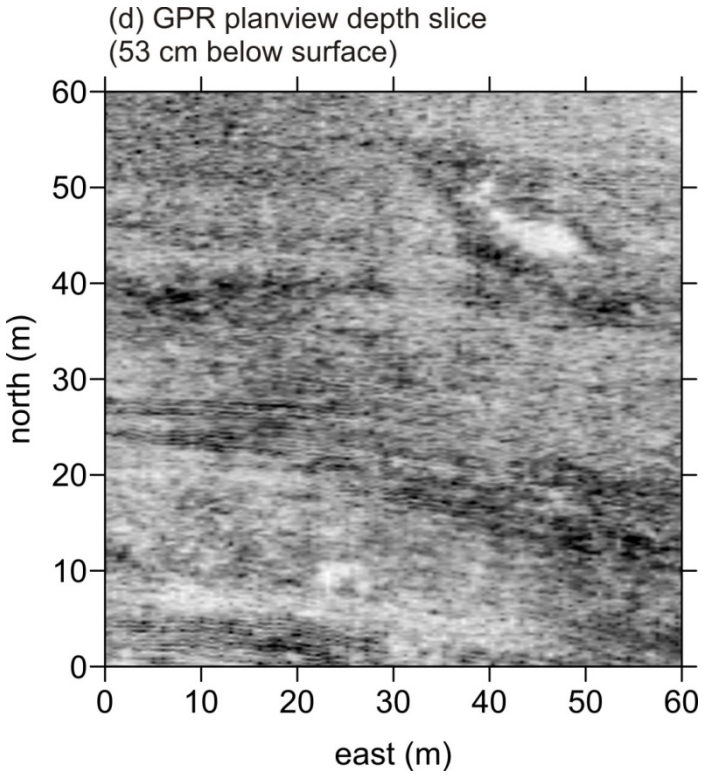
Mound 12 GPR Plan Map



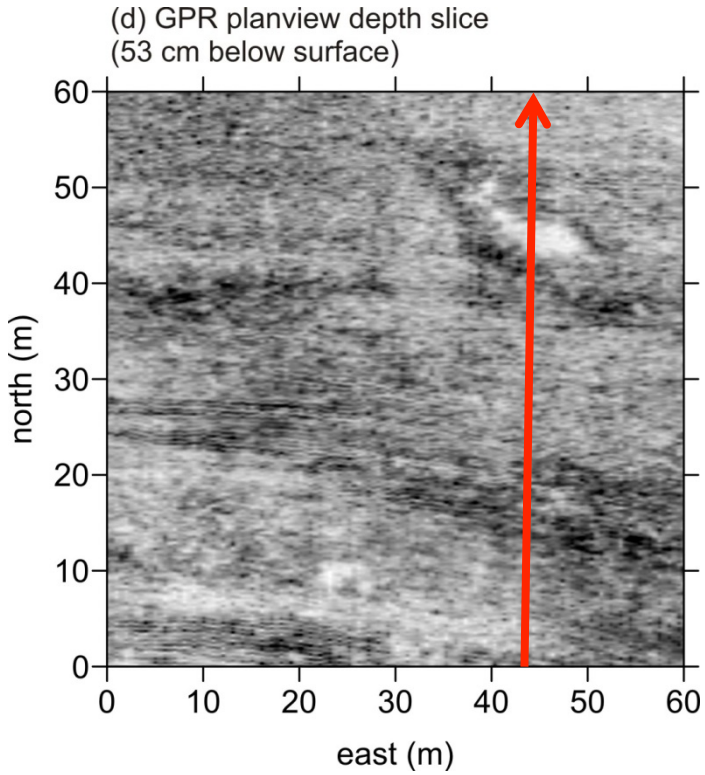
Mound 12 GPR Plan Map



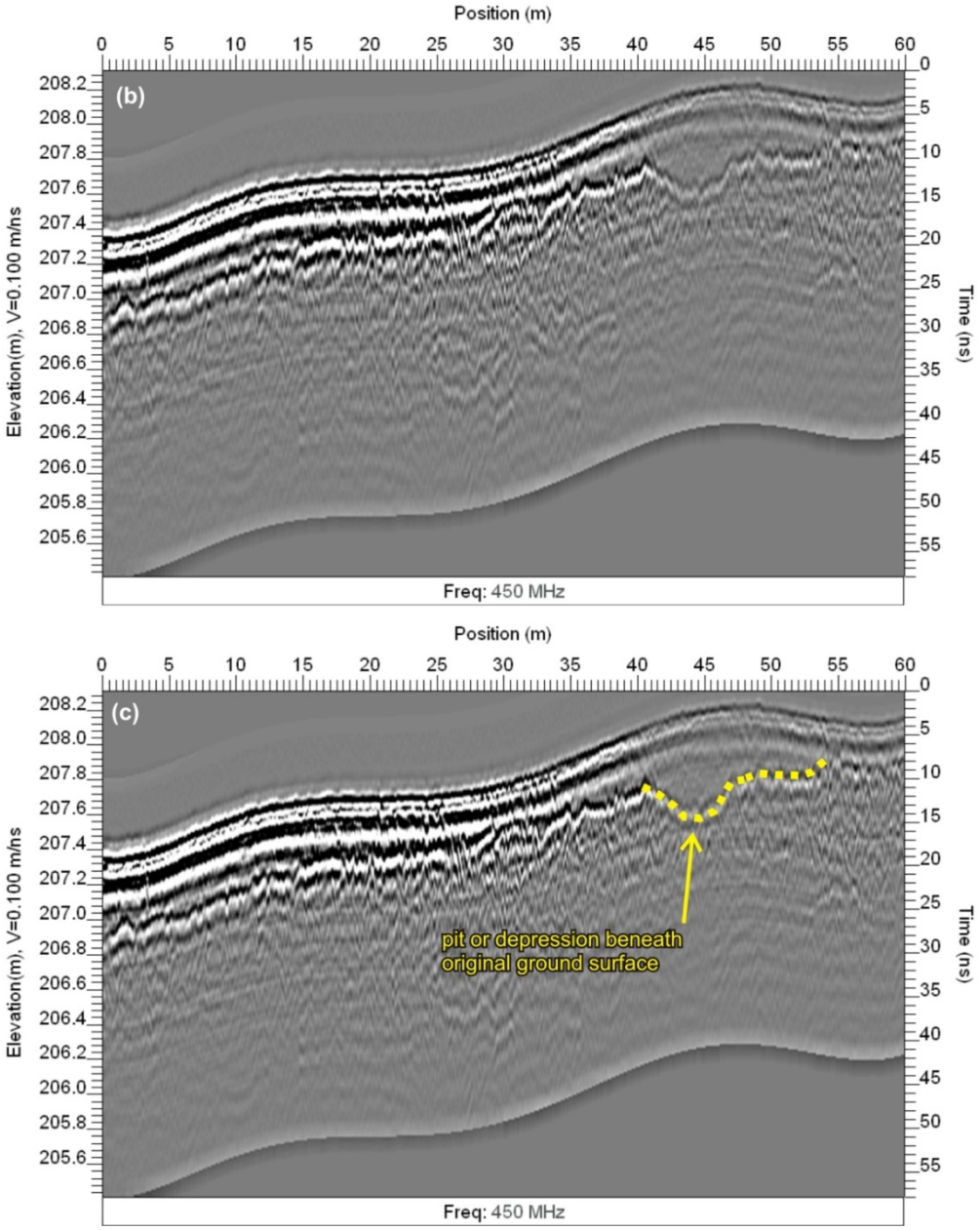
Mound 12 GPR Plan Map



Mound 12 Plan Map
Location of GPR Profile



GPR profile corrected using LiDAR elevations



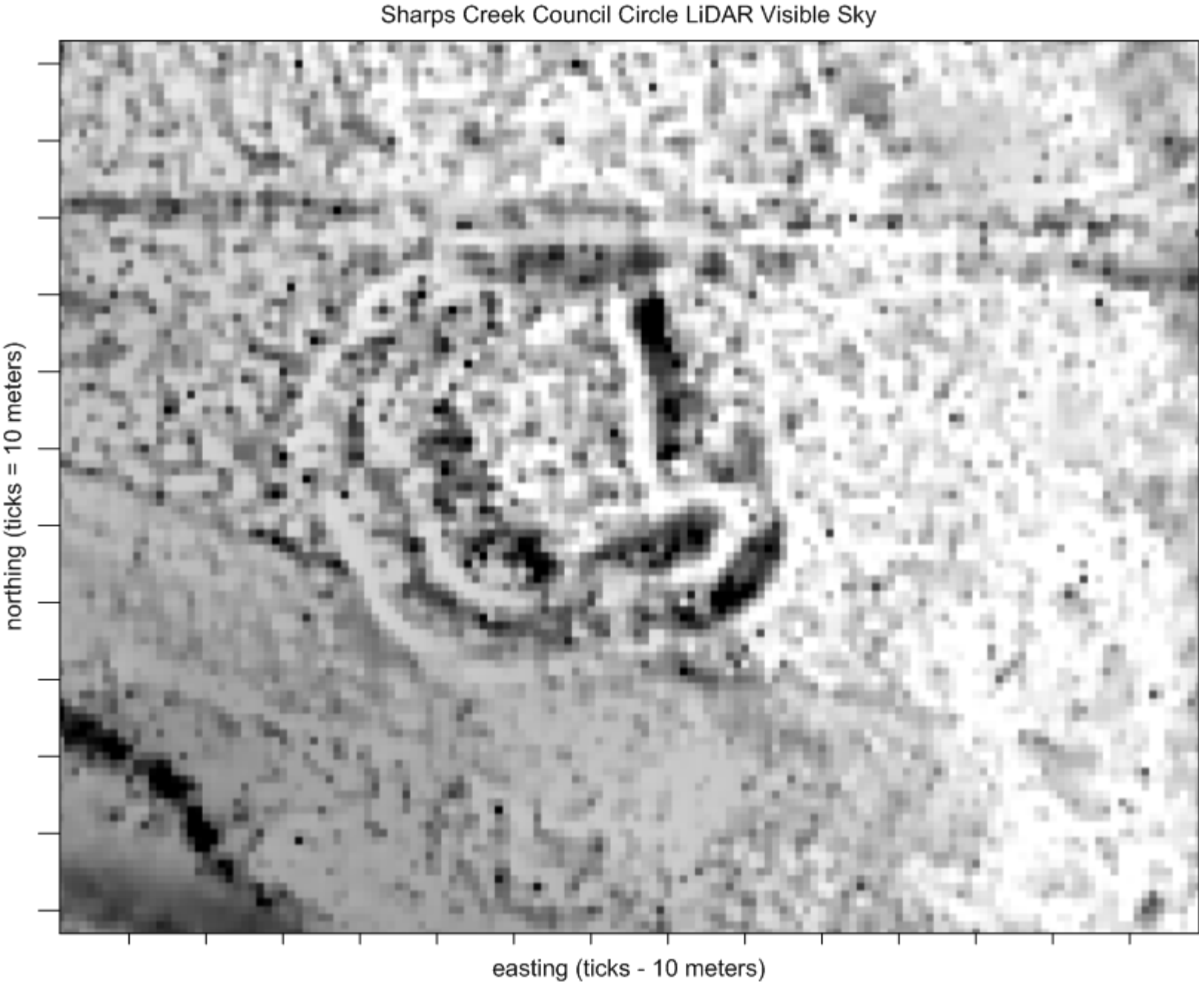
Central Kansas

Sharps Creek – A Tobias-Thompson Complex Site (ca. 16th century)

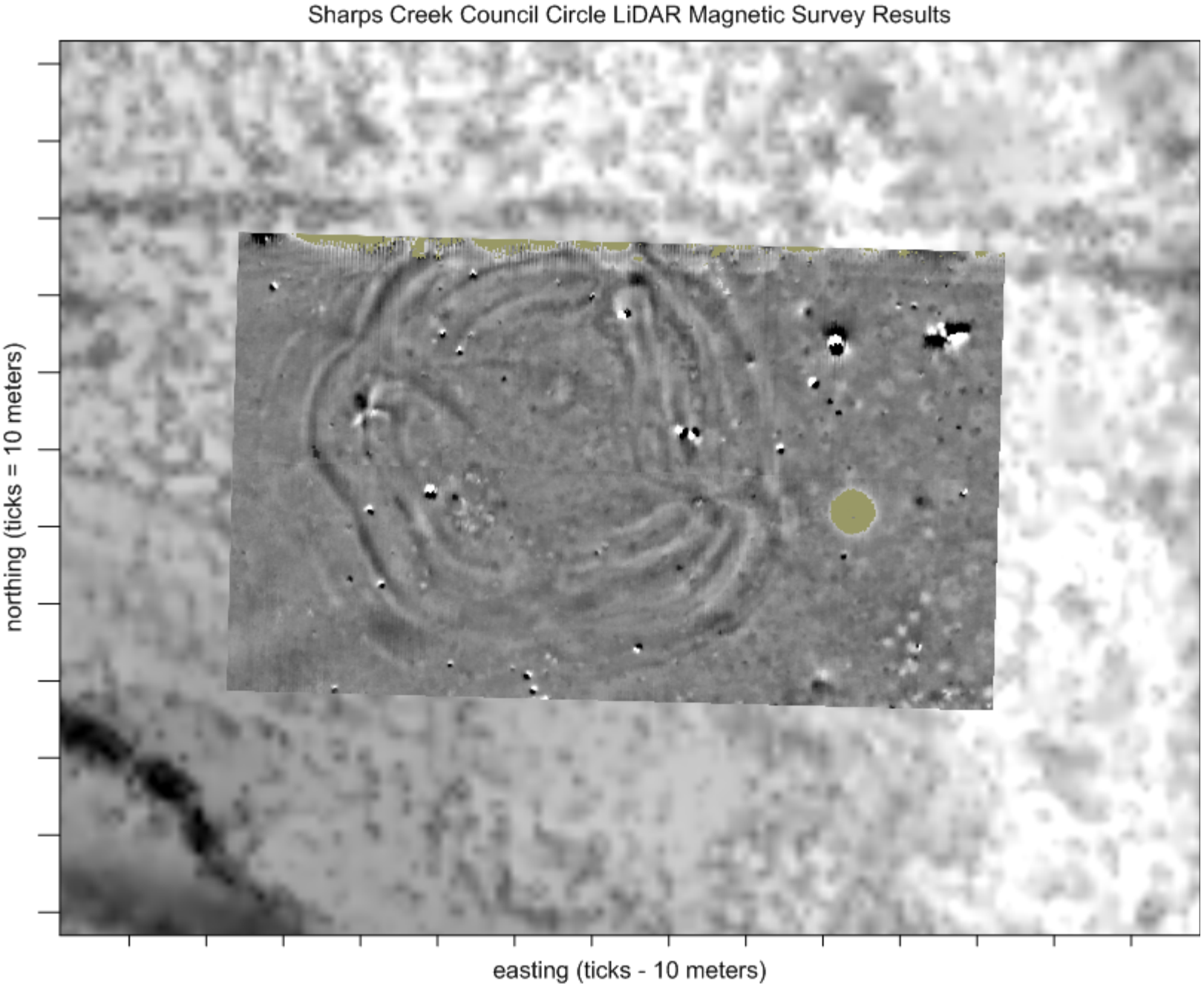
Central Kansas

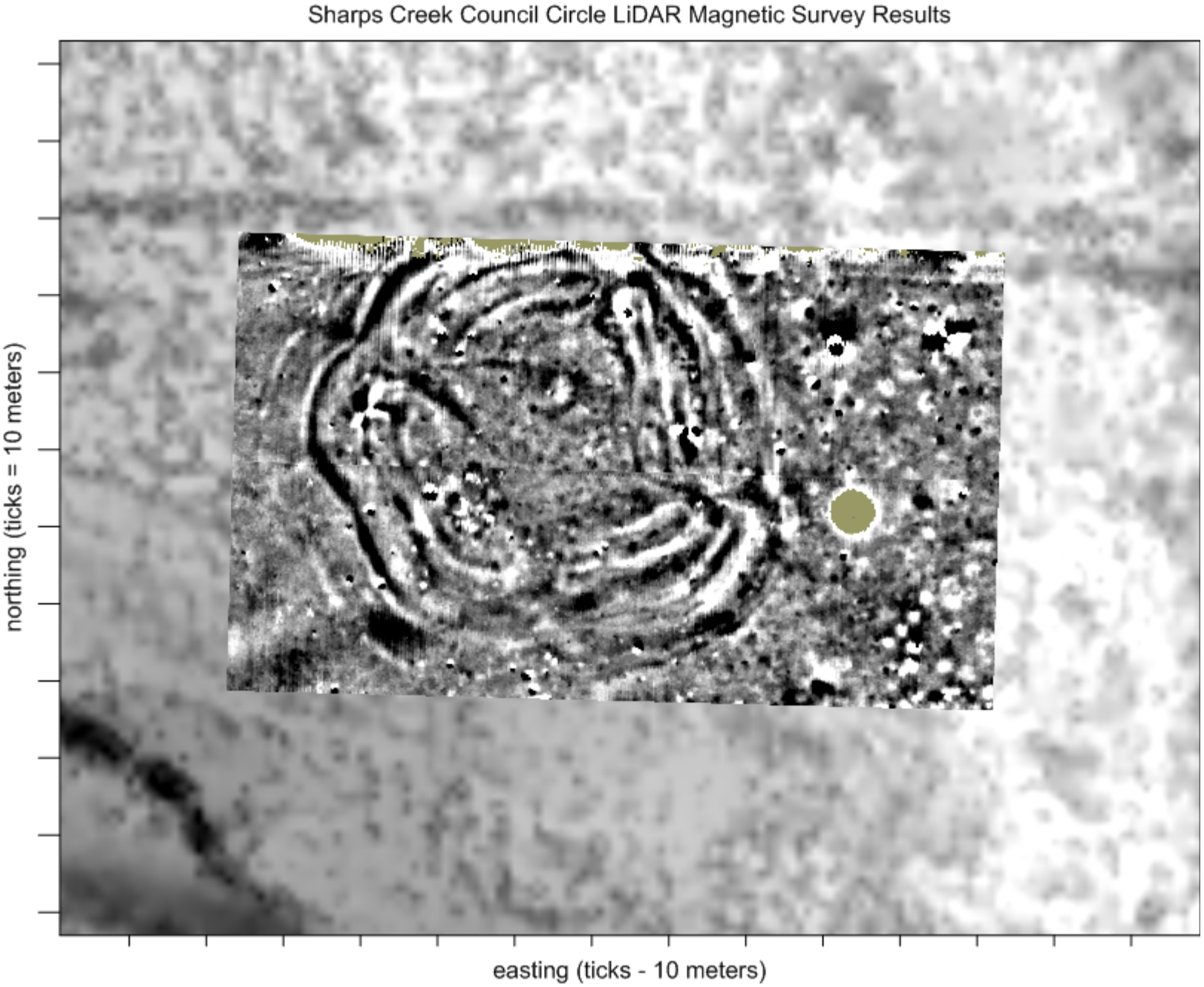
Sharps Creek – A Tobias-Thompson Complex Site (ca. 16th century)

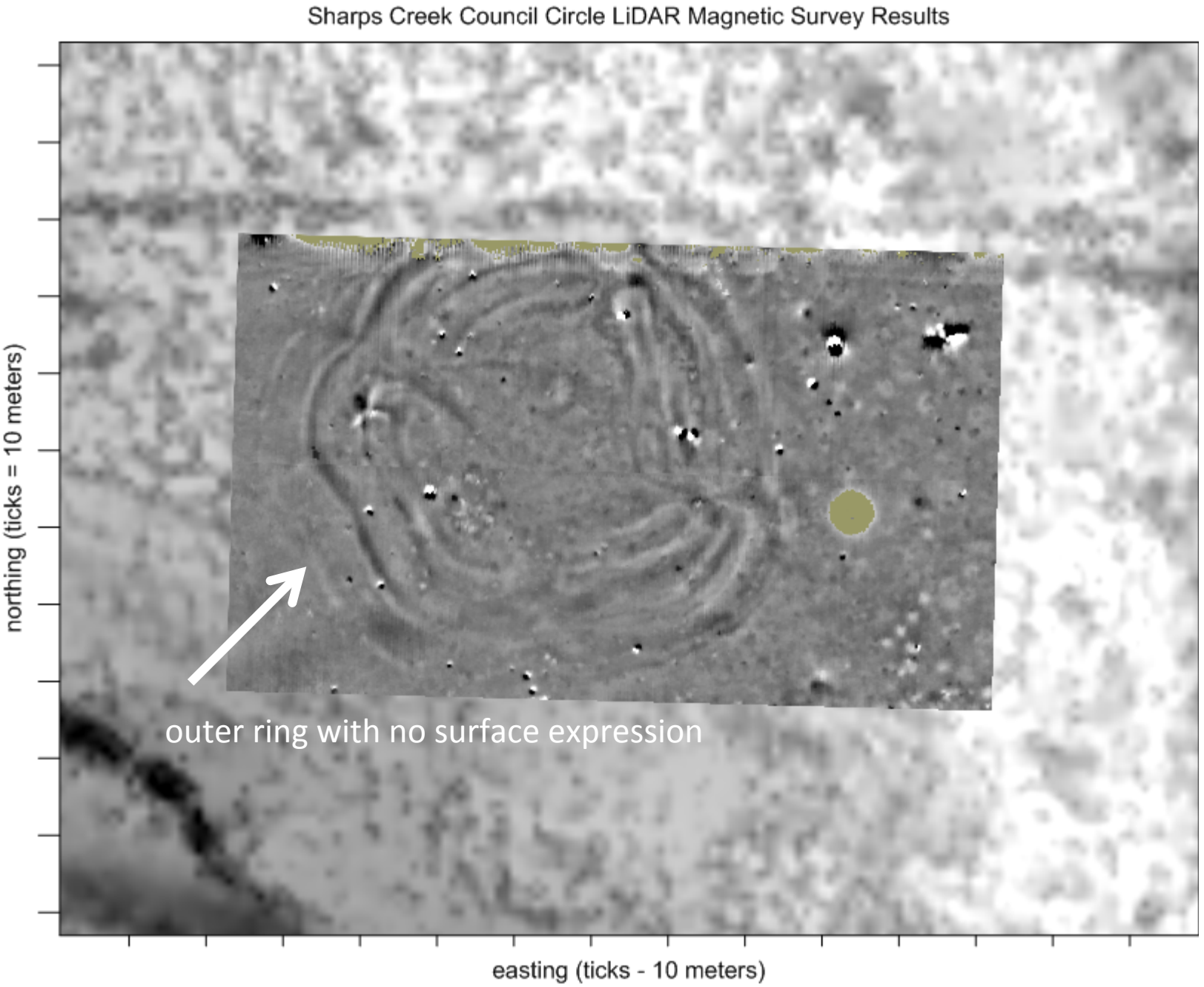

Sharps Creek Council Circle LiDAR Shaded-Relief (NW light source)
northing (ticks = 10 meters)
easting (ticks - 10 meters)


Sharps Creek Council Circle LiDAR Visible Sky
northing (ticks = 10 meters)
easting (ticks - 10 meters)


Sharps Creek Council Circle LiDAR Visible Sky (after threshold despike)
northing (ticks = 10 meters)
easting (ticks - 10 meters)


Sharps Creek Council Circle LiDAR Magnetic Survey Results
northing (ticks = 10 meters)
easting (ticks - 10 meters)


Sharps Creek Council Circle LiDAR Magnetic Survey Results
northing (ticks = 10 meters)
easting (ticks - 10 meters)


Sharps Creek Council Circle LiDAR Magnetic Survey Results
northing (ticks = 10 meters)
easting (ticks - 10 meters)
outer ring with no surface expression


Sharps Creek Council Circle LiDAR Magnetic Survey Results
northing (ticks = 10 meters)
easting (ticks - 10 meters)
4 circular features
in linear alignment

Conclusions

- Much can be learned using non-invasive methods such as LiDAR and sub-surface geophysical survey.

- Non-invasive methods will not replace excavation, but will allow us to ask more sophisticated research questions that may be addressed through archaeological invasive explorations.