Identification of Unmarked Graves Using Remote Sensing Technologies

By Dr. Abdul Raouf

Myths About Technology

- LiDAR is a magical tool to use for this purpose and if mounted on a Remotely Piloted Aerial Systems (RPAS) it can cover wide areas in a shorter period of time
- Ground Penetration Radar (GPR) will show the skeleton of a person buried in a grave just like it was shown in the movie "Jurassic Park"

The Technologies

- Light Detection and Ranging (LiDAR)
- Aerial Photographs
- Ground Penetration Radars

Light Detection and Ranging

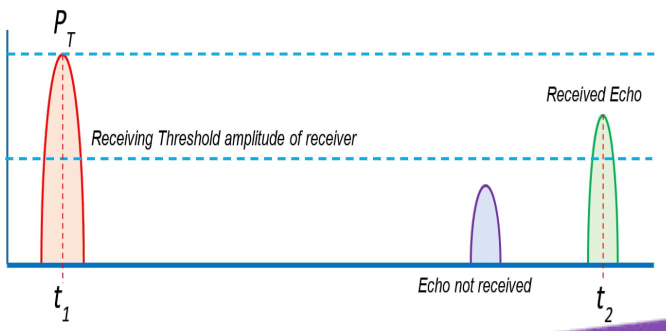
- An active remote sensing sensor
- Shoots laser pulses towards the target and receives reflected echoes
- Works on the time of flight principle
- More sensitive to elevation or height variation
- Vertical accuracy is within a few centimetres

LiDAR Characteristics

- **Pulse:** A clump of timestamped photons emitted by LiDAR Transmitter
- **Echo:** A portion of the pulse reflected from target. A pulse can have multiple echoes
- A LiDAR system is usually characterized by its:
  - ❖ $Pulse\ Density = \frac{Pulses\ Emitted}{m^2}$
  - ❖ $Echo\ or\ Return\ Density = \frac{Echeos\ Reveived}{m^2}$

Time of Flight (ToF) Principle

- $Time\ of\ Flight\ (ToF) = t_2 - t_1 = \Delta t$
- Where t_1 is the time when pulse was transmitted and t_2 is when it was received
- The range (distance of the target from the LiDAR) is given by:
- $Range\ (R) = \frac{c(\Delta t)}{2}$
- $c = 299{,}792{,}458 \frac{\mathrm{m}}{\mathrm{s}} \approx 2.99\ 10^8\ \frac{m}{s}$



SASKATCHEWAN POLYTECHNIC

Sequential Firing

- A LiDAR system fires LASER pulses towards the target which are reflected back after striking the target
- The nest pulse cannot be fired unless the previous pulse is received back by the receiver
- A sufficient time difference between the shooting pulses is required
- Firing LASER pulses at a frequency so that each pulse is received back after reflecting from the target before firing the next pulse is called sequential firing

Sequential Firing: Achieving Balance

- If a LiDAR system is firing (*N*) number of pulses in one second, the rate of average energy delivered at the target is given by:

$$E_R = P_T\,(FWHM)N$$

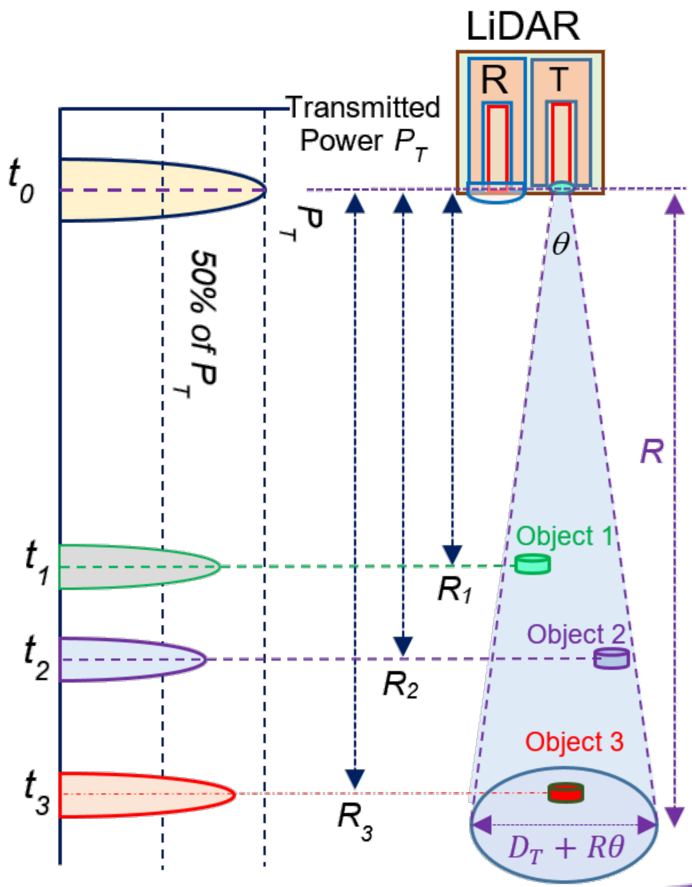
- The maximum power of each LASER pulse is P_T
- A pulse can travel a longer distance (range) by increasing its power P_T
- The pulse will take a longer time to return if it has to travel a longer distance
- It will reduce the pulses shooting frequency
- Increasing peak power P_T of pulses will also dissipate more heat. Thus, a better cooling system will be required to prevent overheating

Multiple Returns

- Assume a LiDAR system has a range of *R*. Its transmitter is shooting LASER pulses with divergence angle θ. Diameter of the LiDAR beam footprint on the ground is given by:

$$Footprint\ diameter = D_T + R\theta$$

- There could be several targeted within the LiDAR beam footprint and within its range

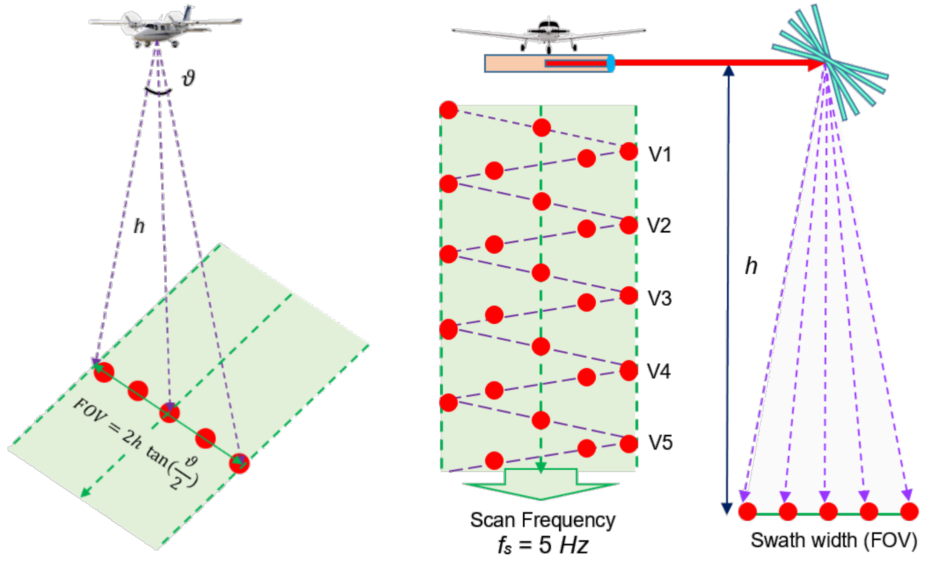


Multiple Returns

- Differentiation of multiple returns is possible because of sequential firing
- The range to each target is calculated by:
- $t_o - t_1 = \Delta t_1 \ R_1 = \frac{c\ (\Delta t_1)}{2}$
- $t_o - t_2 = \Delta t_2 \ R_2 = \frac{c\ (\Delta t_2)}{2}$
- $t_o - t_3 = \Delta t_3 \ R_3 = \frac{c\ (\Delta t_3)}{2}$

LiDAR Scanning Mechanism

- The transmitter optics of a LiDAR system include a scanning mechanism for the system
- It determines its FOV or swath width.
- Circular footprint of the system is its IFOV
- $FOV = 2h\ \tan(\frac{\vartheta}{2})$
- ϑ is scan angle, h is flying altitude



LiDAR Scanning Mechanism

- For a LiDAR system that has a fixed scan angle (ϑ), the ratio of its FOV to its height remains constant
- $\frac{FOV}{h} = constant$
- Similarly, the scan frequency (f_s) of the scanning mechanism is inversely proportional to its FOV
- $f_s \propto \frac{1}{FOV}$ or $f_s\,(FOV) = constant$

SASKATCHEWAN POLYTECHNIC

LiDAR Scanning Mechanism

- While scanning mechanism is scanning the swath width, the transmitter of the LiDAR system is shooting LASER pulses creating several circular LASER footprints across the swath width
- Sufficient separation between these footprints is required to distinguish return echoes from each footprint
- Sequential firing of pulses also imposes restrictions on the pulse frequency (f_p) of the LiDAR system
- Since echoes will take a longer time to return for longer ranges, the pulse frequency (f_p) is inversely proportional to the height of the aerial LiDAR systems
- $f_p \propto \frac{1}{h}$ or $f_p\,(h) = constant$

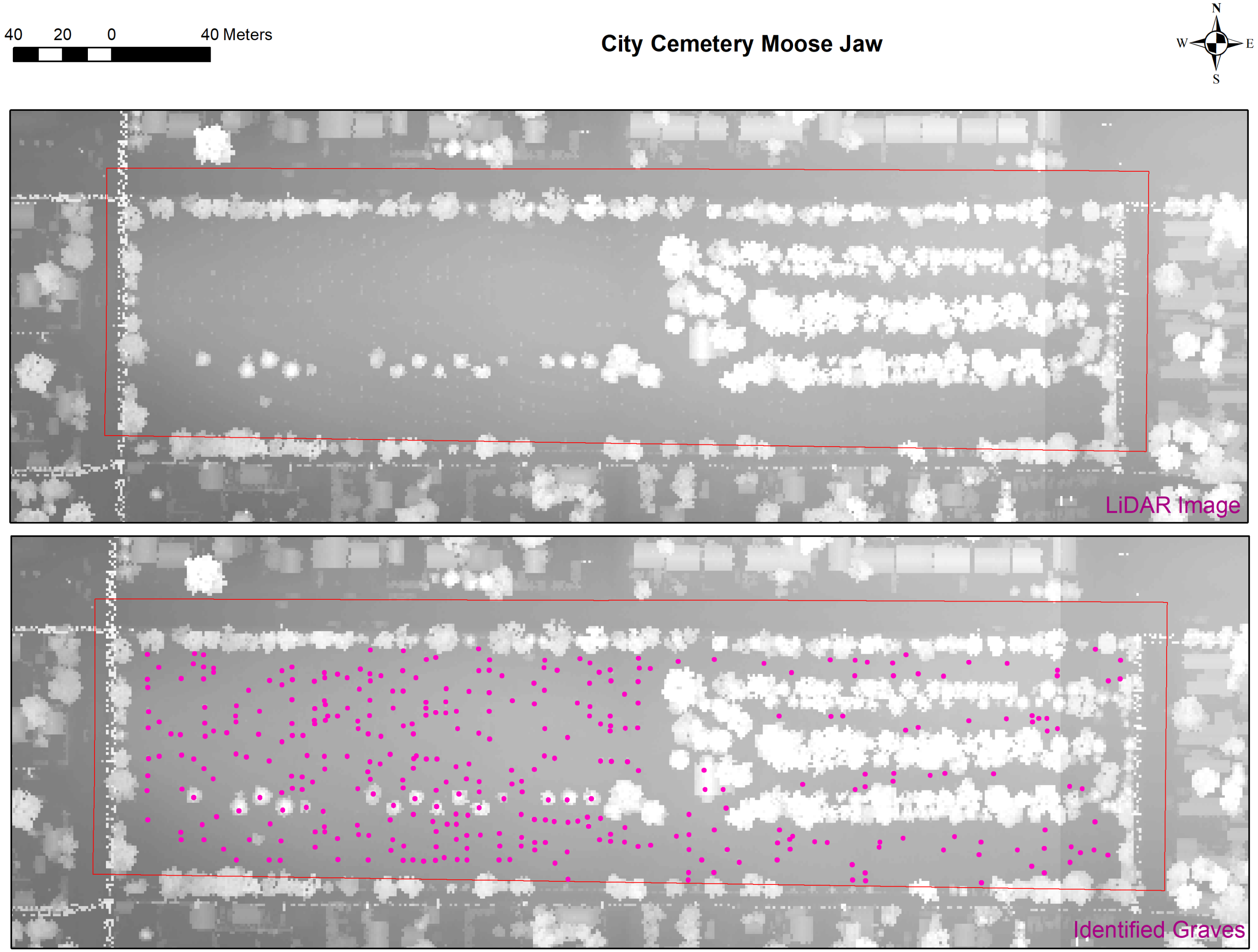
SASKATCHEWAN POLYTECHNIC

Typical LiDAR wavelengths

- A LiDAR system can be designed using ultraviolet, visible and infrared wavelength
- Some of these wavelengths are as given below:

Spectral Region	Wavelength	Application
Ultraviolet	250 nm	Meteorology
Blue – Green	500 – 600 nm	Bathymetry
Near Infrared	1040 – 1060 nm	Topography
Infrared	1500 – 2000 nm	Meteorology

LiDAR Image of City Cemetery, Moose Jaw



SASKATCHEWAN POLYTECHNIC

Passive Remote Sensing

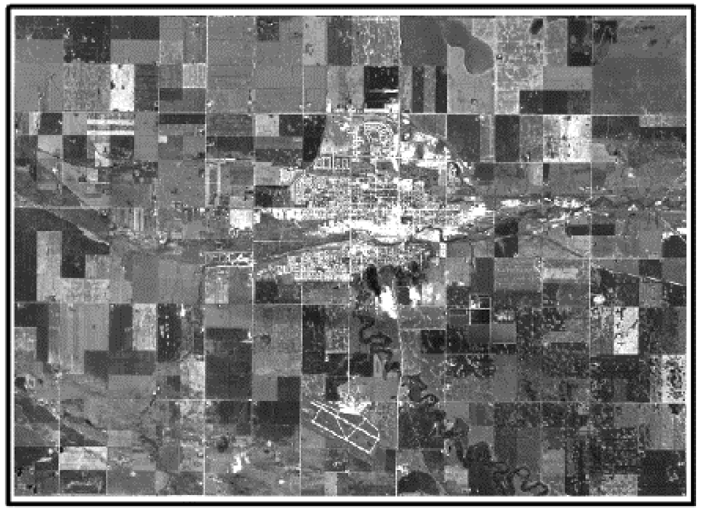
- An optical sensor (camera or scanner) mounted on a platform
- Data is acquired in digital form and downloaded for processing
- Sensor can acquire images in different wavelength region
- Can cover bigger area in shorter time
- Three resolutions to consider:
  - Spatial Resolution
  - Spectral Resolution
  - Radiometric Resolution

Spatial Resolution

- An ability of a sensor to record the smallest object which can be identified in the image
- It represents the details in the image
- An image having greater details also has a better spatial resolution. An image having smaller identifiable objects has better spatial resolution
- It can also be related with the pixel size in an image

Effect of Spatial Resolution on Image

Landsat-8, Band-8 (15m)



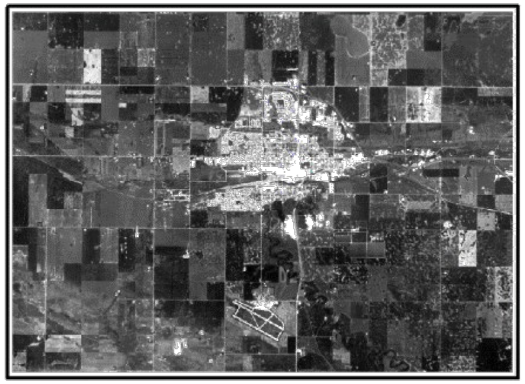
Landsat-8, Band-1 (30m)

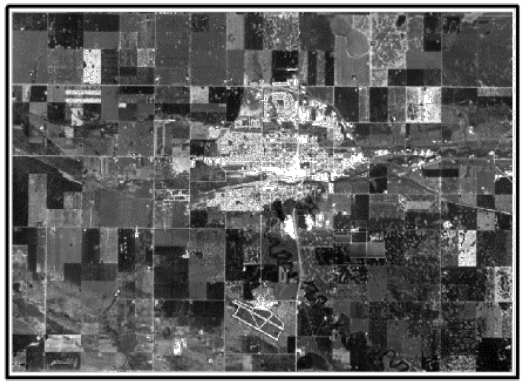
Landsat-8, Band-10 (100m)

Spectral Resolution

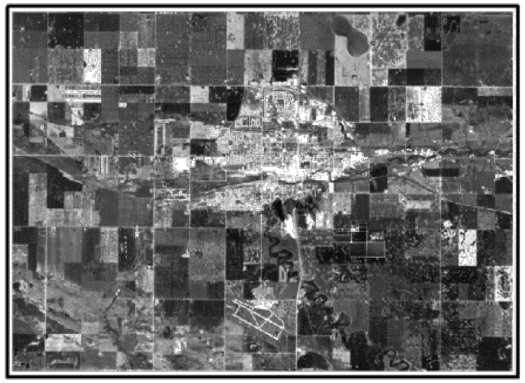
- Each wavelength region acts differently with the objects.
- Some wavelength regions reflect more than others
- A sensor capable of acquiring images in multiple wavelength bands will have a better spectral resolution
- The number of spectral bands and the spectral width of each band defines the spectral resolution of the sensor
- Greater number of bands or narrow spectral widths result in a better spectral resolution

Effect of Spectral Resolution on Images

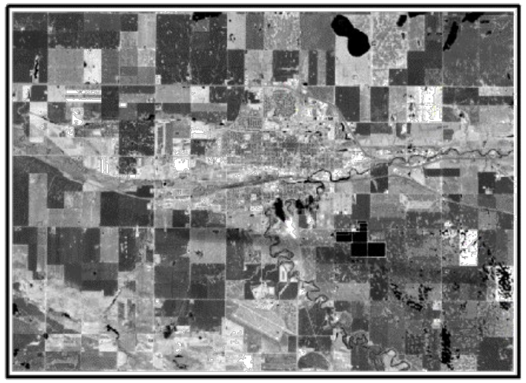

Landsat-8, Band-1


Landsat-8, Band-2


Landsat-8, Band-3


Landsat-8, Band-4


Landsat-8, Band-5

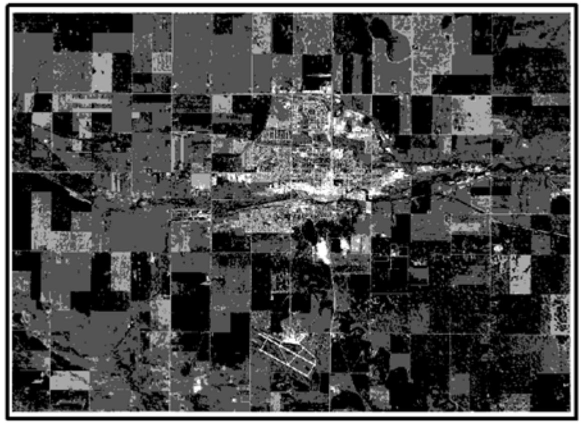

Landsat-8, Band-6

SASKATCHEWAN POLYTECHNIC

Radiometric Resolution

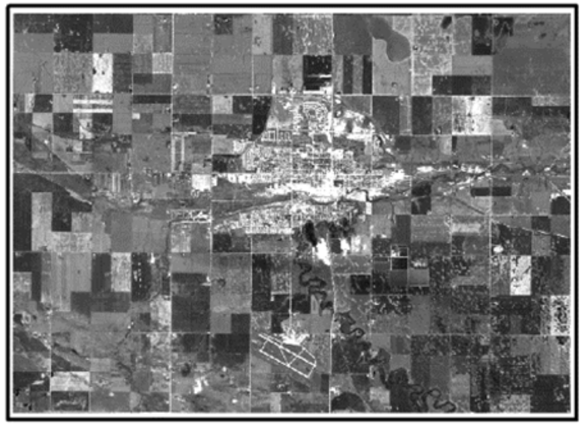
- Image pixel values can quantize depending on the sensors' capability to record the data in the form of bits
- These quantiles are sometimes also referred to as the number of gray levels
- The number of quantization will keep on increasing as the recording bit capacity of the sensors is increasing
- The file size will also increase with an increasing number of recordable bits in the data

Effect of Radiometric Resolution on Images



2 bit data (4 gray levels)

4 bit data (16 gray levels)

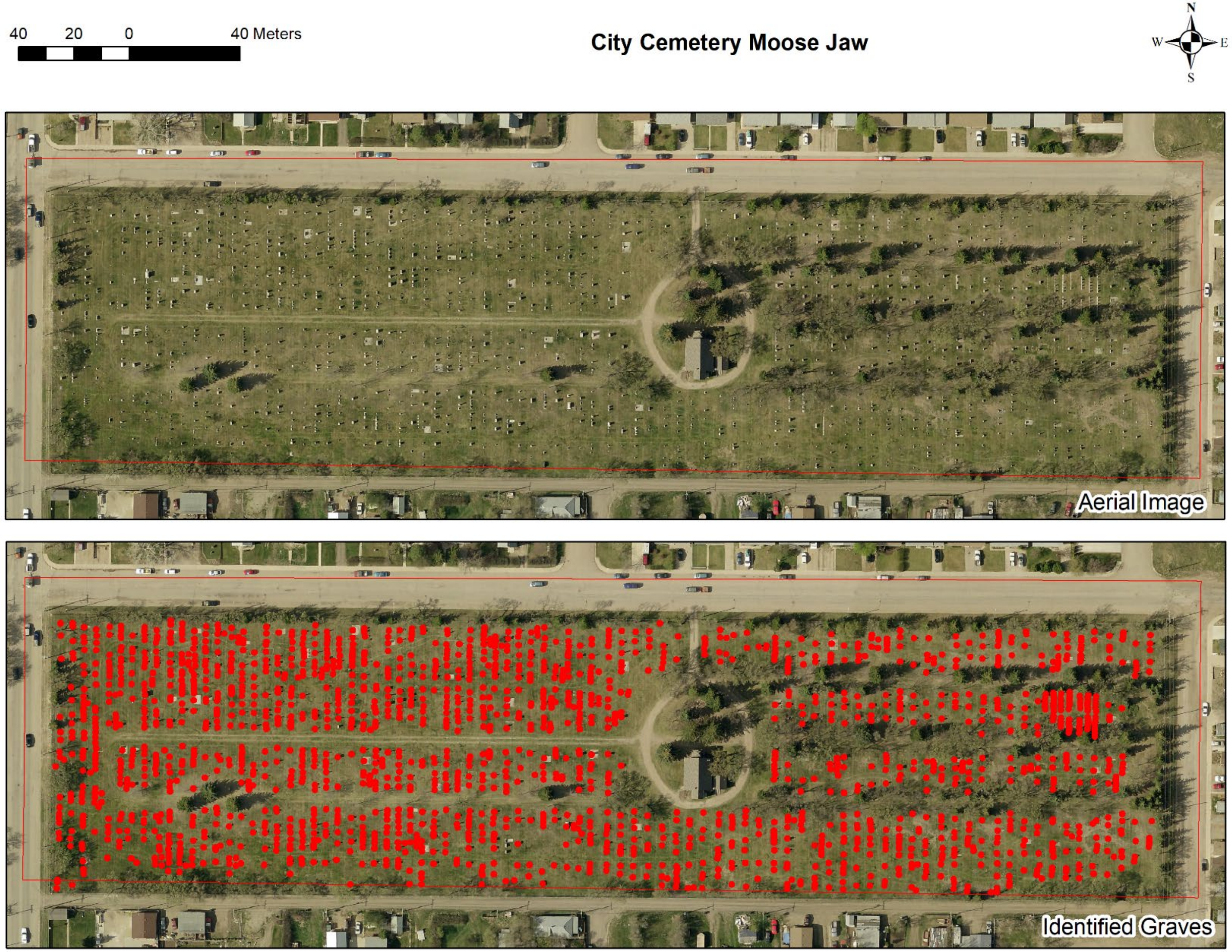


8 bit data (256 gray levels)

Bits	Calculations	Gray Levels	Min-Max Value
1	$2^1 = 2$	2	0 - 1
2	$2^2 = 4$	4	0 - 3
4	$2^4 = 16$	16	0 - 15
8	$2^8 = 256$	256	0 - 255
16	$2^{16} = 256$	65,536	0 - 65,535

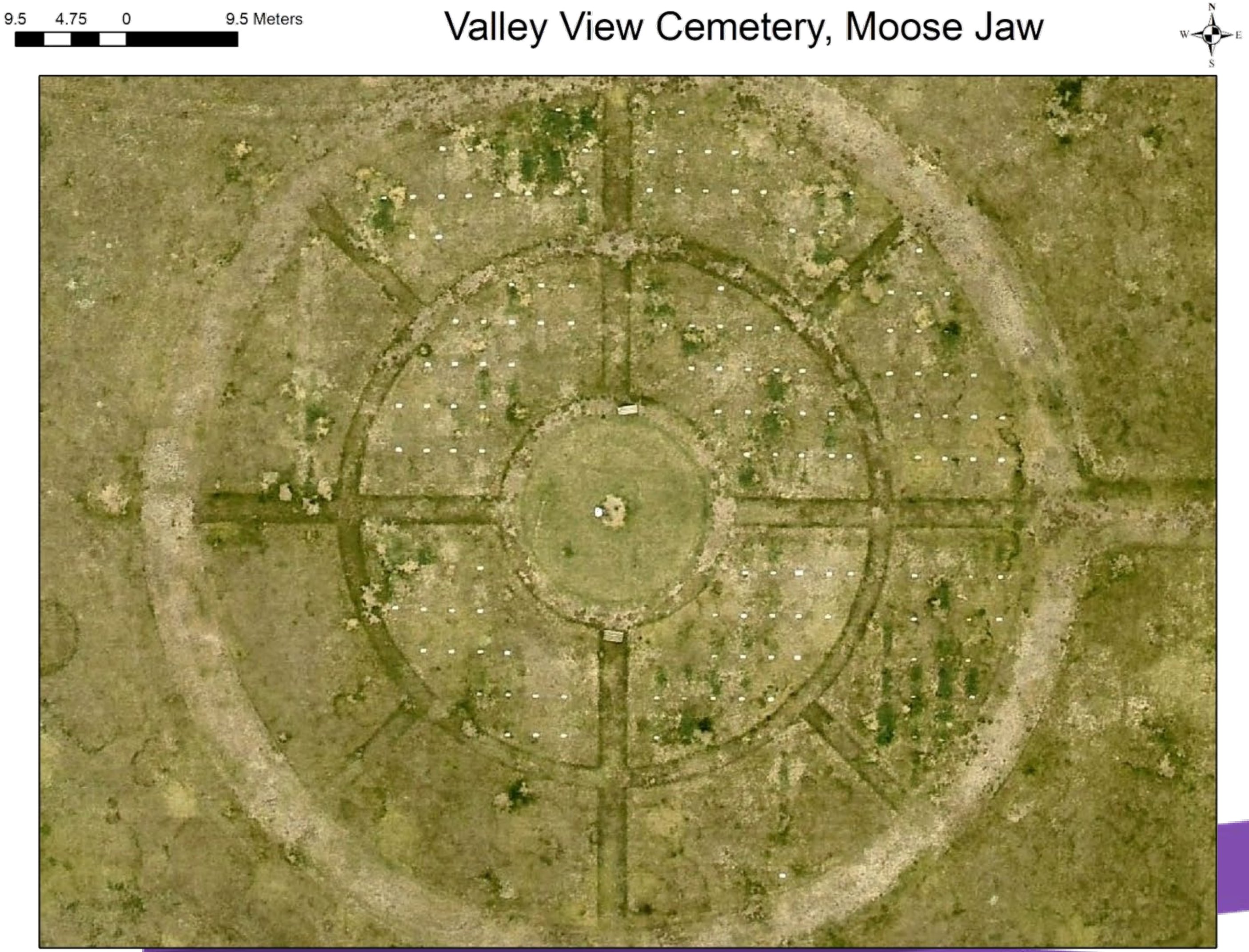
SASKATCHEWAN POLYTECHNIC

Cemetery Mapping Using Aerial Images



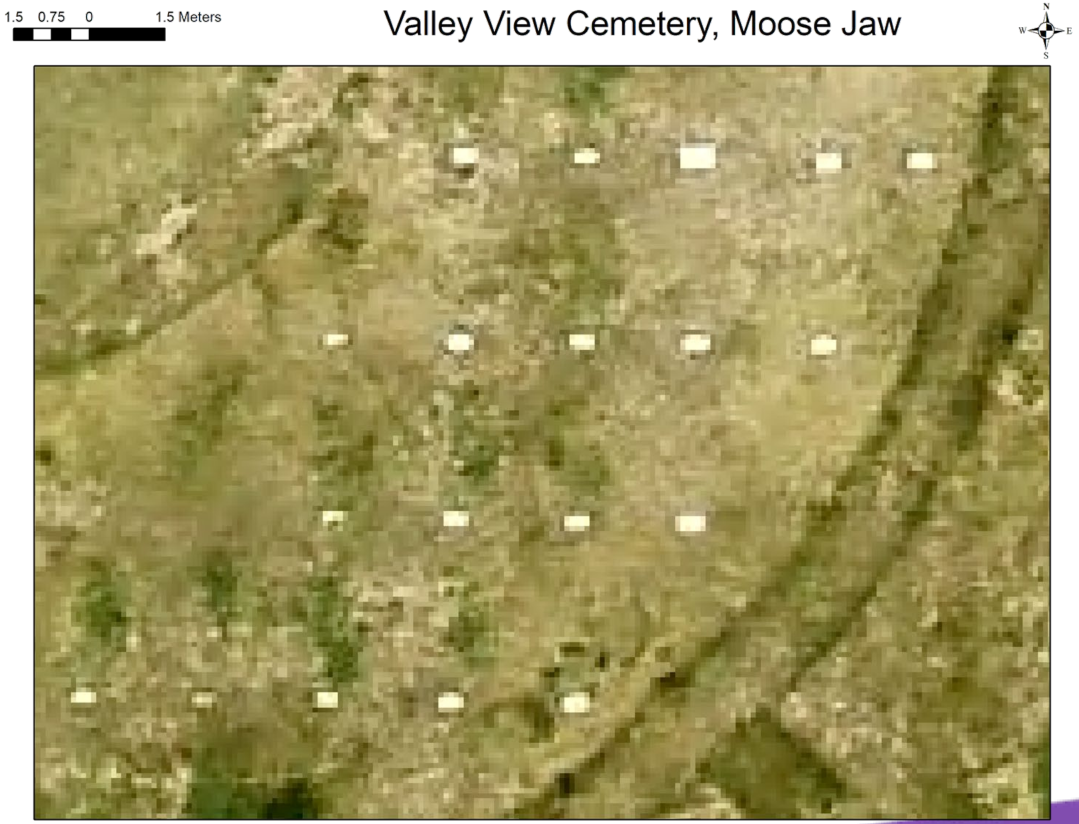
SASKATCHEWAN POLYTECHNIC

Valley View Cemetery



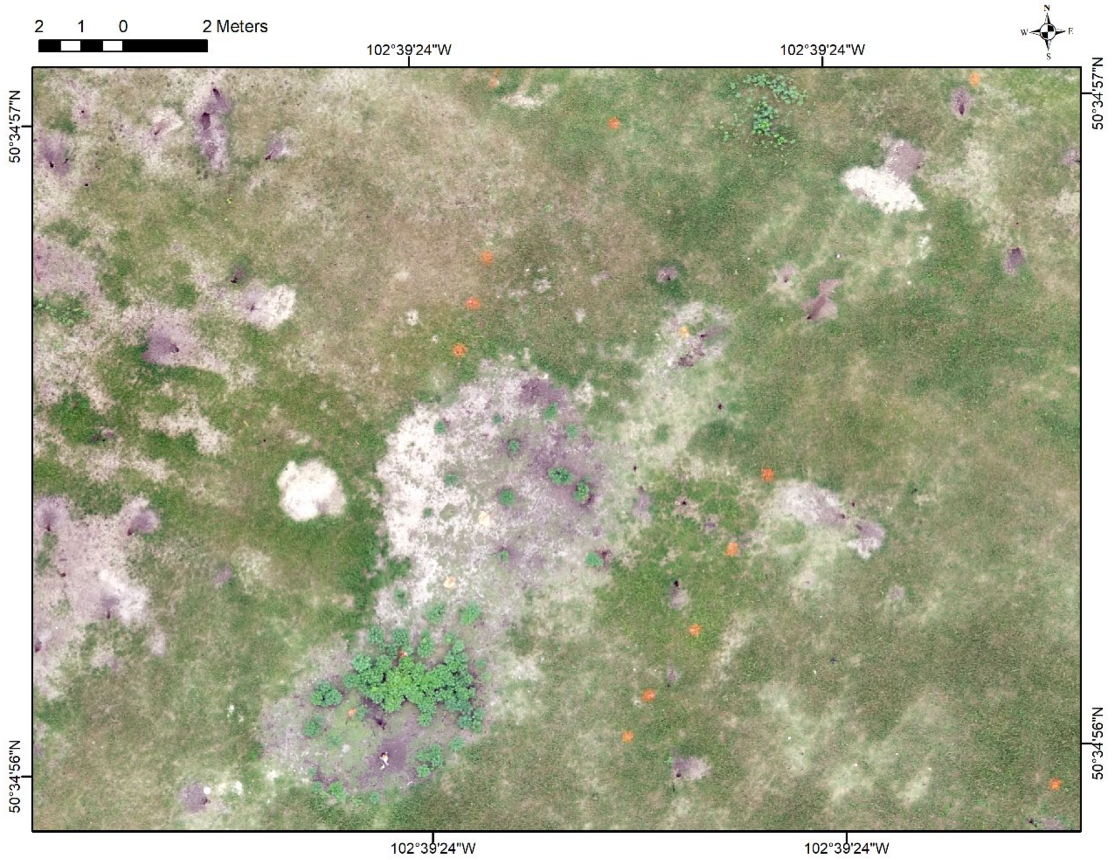
SASKATCHEWAN POLYTECHNIC

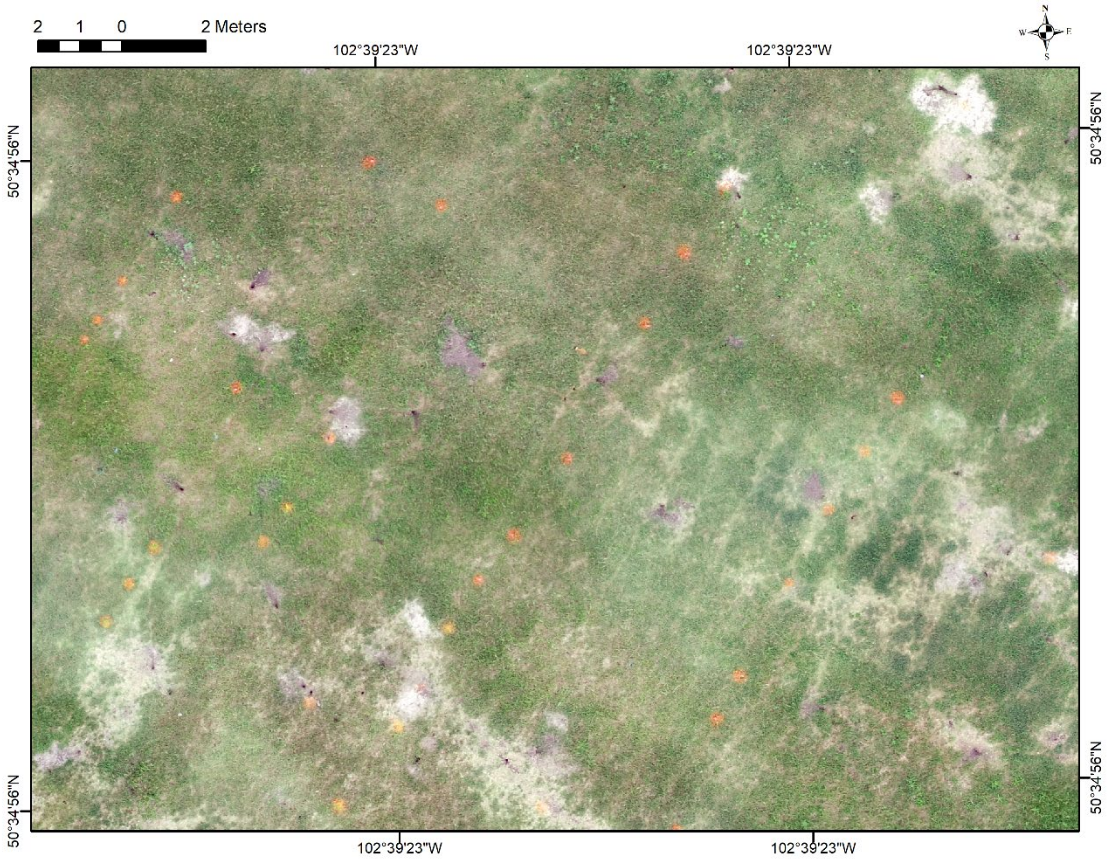
Valley View Cemetery



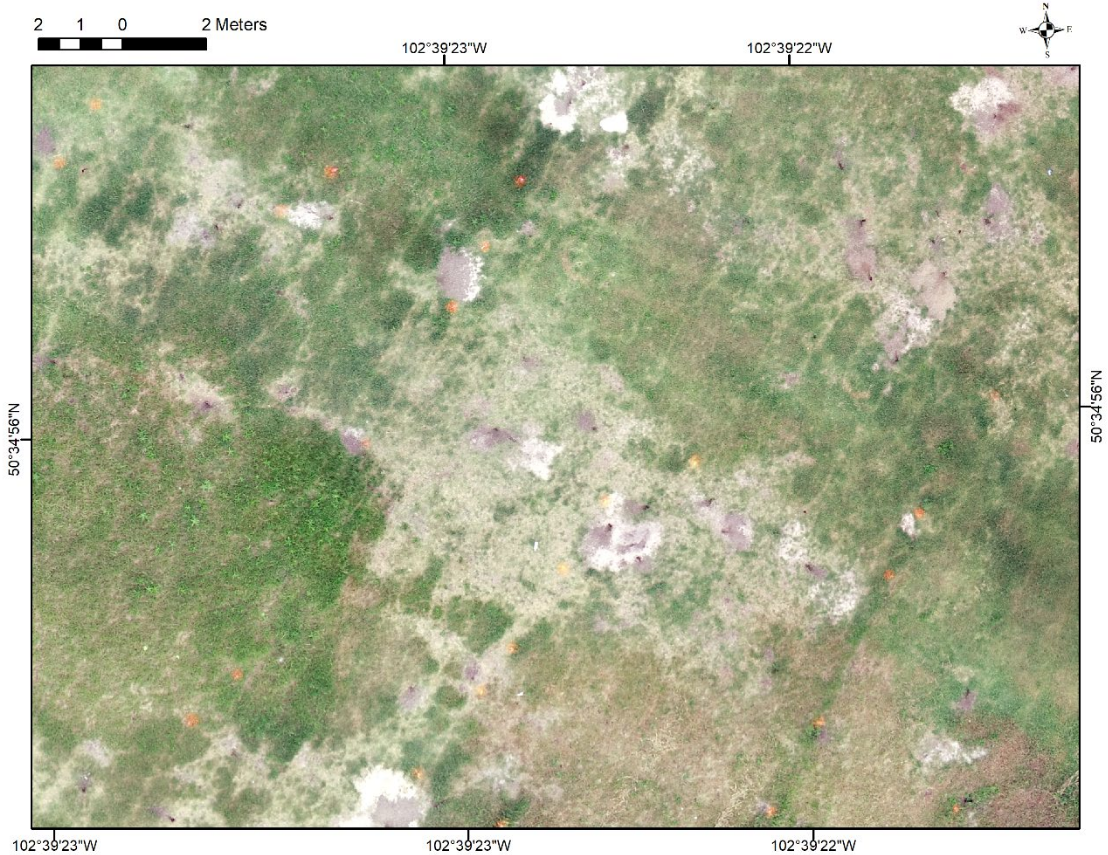
SASKATCHEWAN POLYTECHNIC

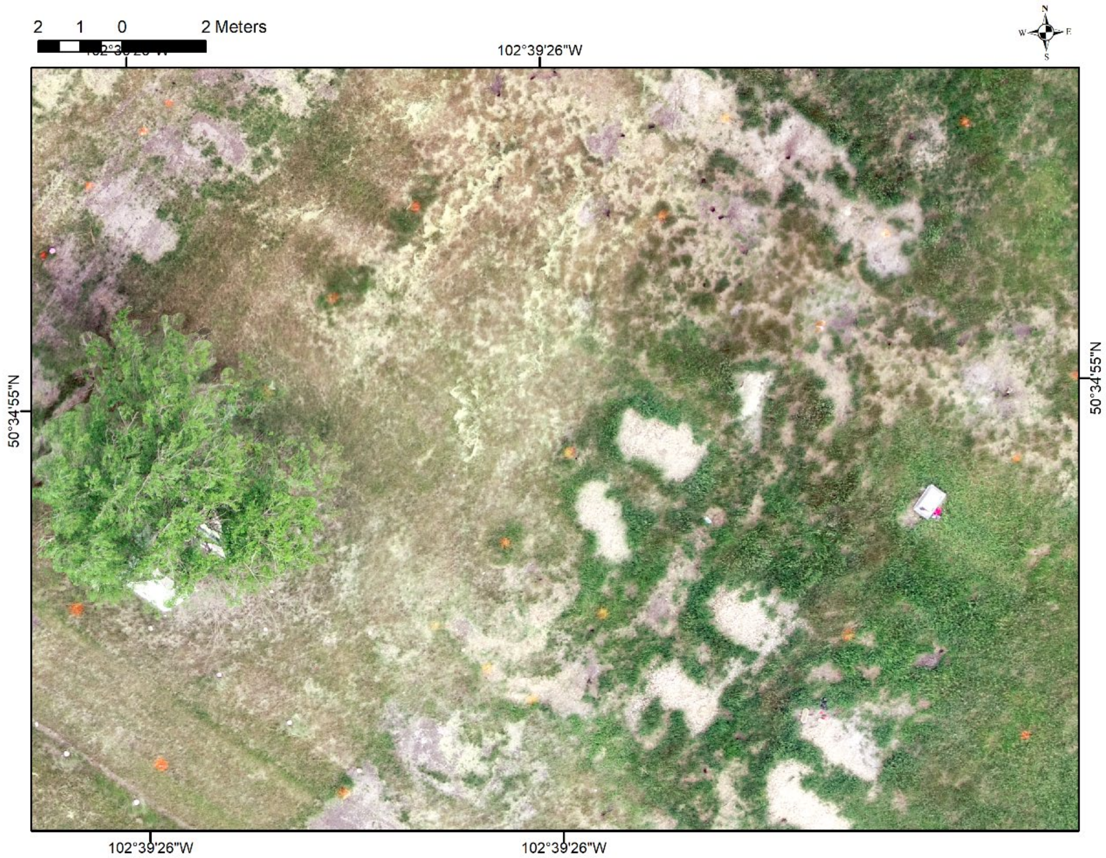
An Unknown Location





An Unknown Location



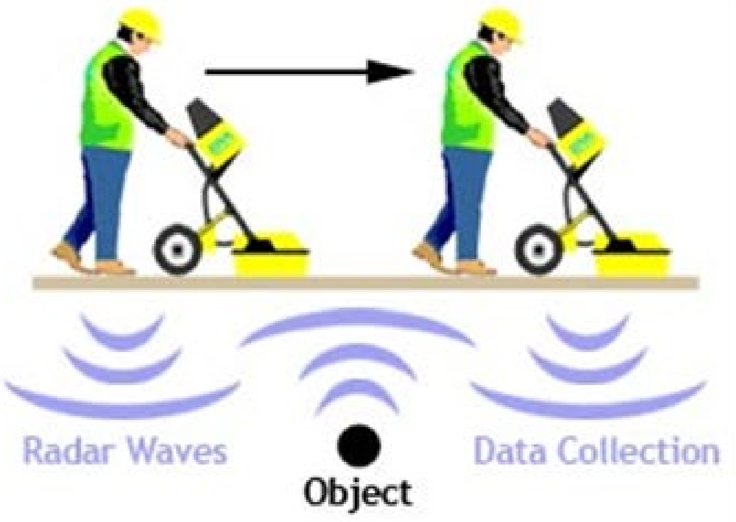


A Birds Eye View

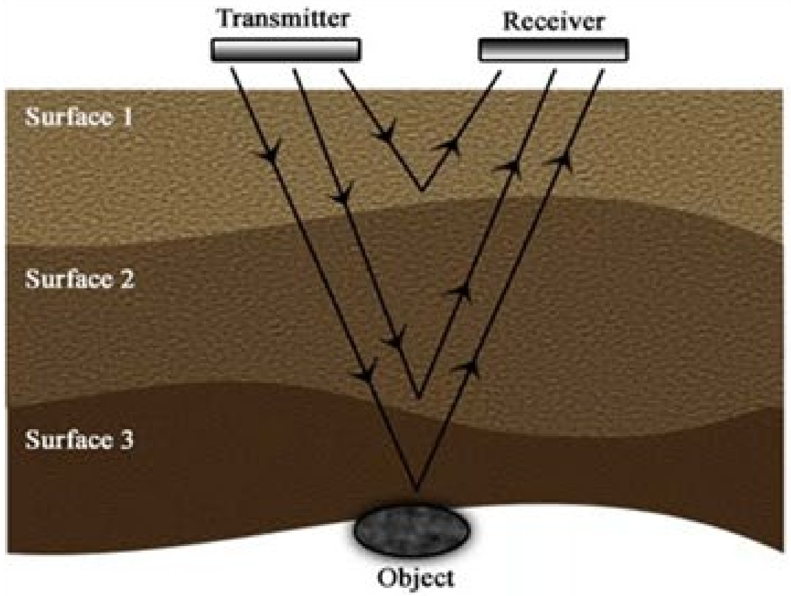
Ground Penetration Radar (GPR)

- It is a manually operated device having three components
- The transmitter transmits radio waves into the ground
- The radio waves travel deep into the ground and reflect back from an underground target indicating an anomaly
- The reflected signal is received by the receiver
- It is also displayed on a screen
- Can be post-processed for further analysis

GPR Working



Radar Waves
Object
Data Collection



Transmitter
Receiver
Surface 1
Surface 2
Surface 3
Object

GPR Frequencies and Applications

Frequency	Depth (Wet soil)	Depth (Dry soil)	Application
100 MHz	12 m	30 m	Geotechnical
250 MHz	4.5 m	9 m	Utility mapping
500 MHz	1.8 m	5 m	Archeology
1,000 MHz	0.6 m	1.8 m	Bridge deck
2,000 MHz	0.2 m	0.6 m	Concrete

GPR Survey Considerations

- Some soils may not allow deeper penetration
- Clay rich or wet soils may not be ideal for GPR surveys
- Deeper objects usually require lower frequencies
- Lower frequencies also have lower detection resolution
- Ideal depth to object size ratio is 24:1
- 1 cm object can be detected up to 24 cm depths

Size, Shape and Orientation of the Object

- An object will reflect more and will appear brighter if more surface area is exposed to the GPR signal
- Round spheres will appear as hyperbola
- A linear object will appear as a point if GPR survey lines are perpendicular to the object and will appear flat if survey lines are parallel to the object
- Objects beneath another object may not be seen

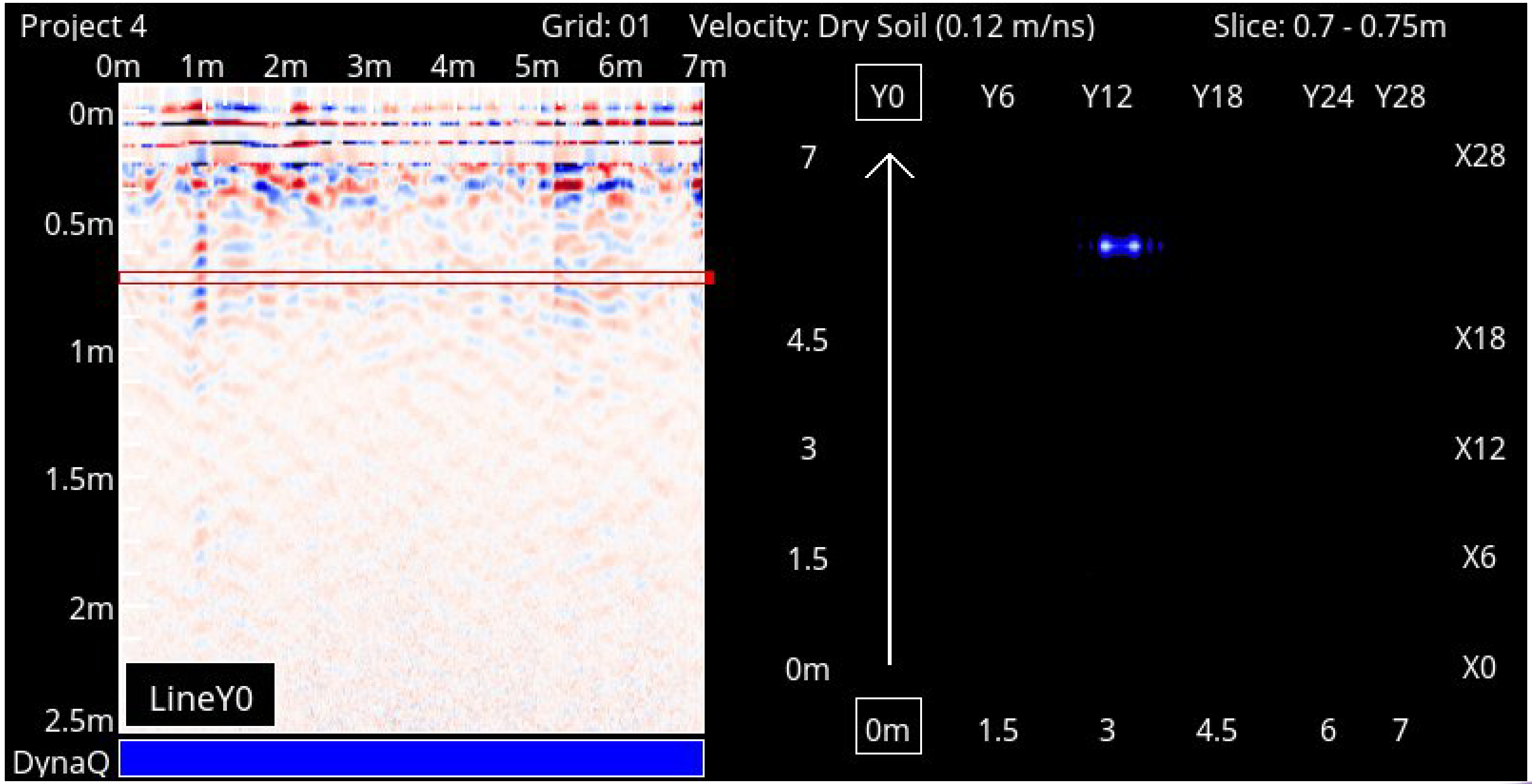
SASKATCHEWAN POLYTECHNIC

GPR Scan Setup

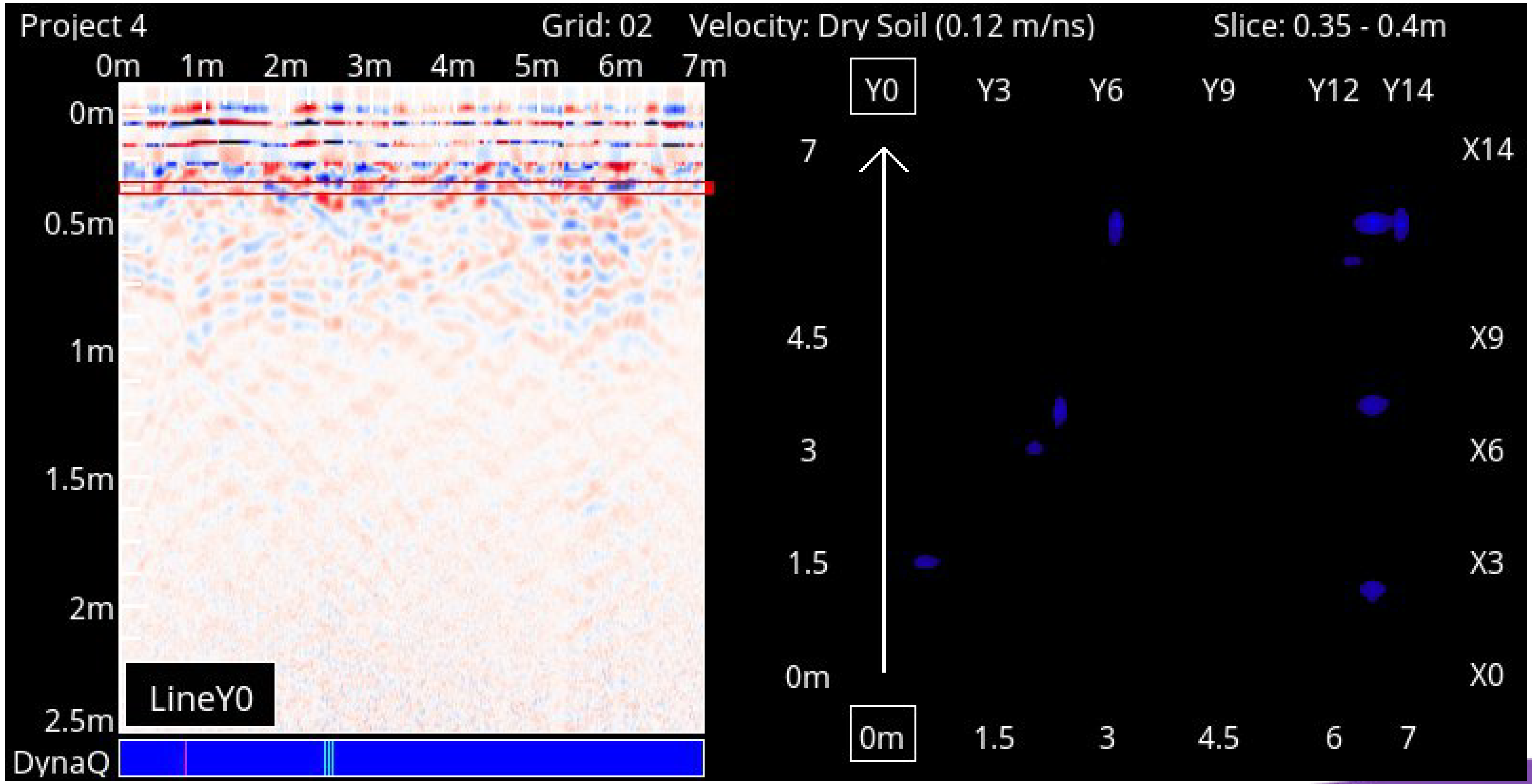
- Line spacing needed to setup for grid scan
- The grid has to be rectangular
- Grid scan is time consuming

Gird size	Area (hectares)	Area (acres)	Line Spacing	Total Distance	Time Required
10 m x 10 m	0.01	0.025	1.0 m	0.20 km	0.25 h
10 m x 10 m	0.01	0.025	0.5 m	0.40 km	0.5 h
10 m x 10 m	0.01	0.025	0.25 m	0.80 km	1.0 h
64 m x 64 m	≈ 0.4	≈ 1.0	1.0 m	8.00 km	10 h
64 m x 64 m	≈ 0.4	≈ 1.0	0.5 m	16.00 km	20 h
64 m x 64 m	≈ 0.4	≈ 1.0	0.25 m	32.00 km	40.0 h
100 m x 100 m	1	2.47	1.0 m	20.00 km	25.0 h
100 m x 100 m	1	2.47	0.5 m	40.00 km	50.0 h
100 m x 100 m	1	2.47	0.25 m	80.00 km	100.0 h

GPR Grid Scan (Line Spacing 0.25 m)

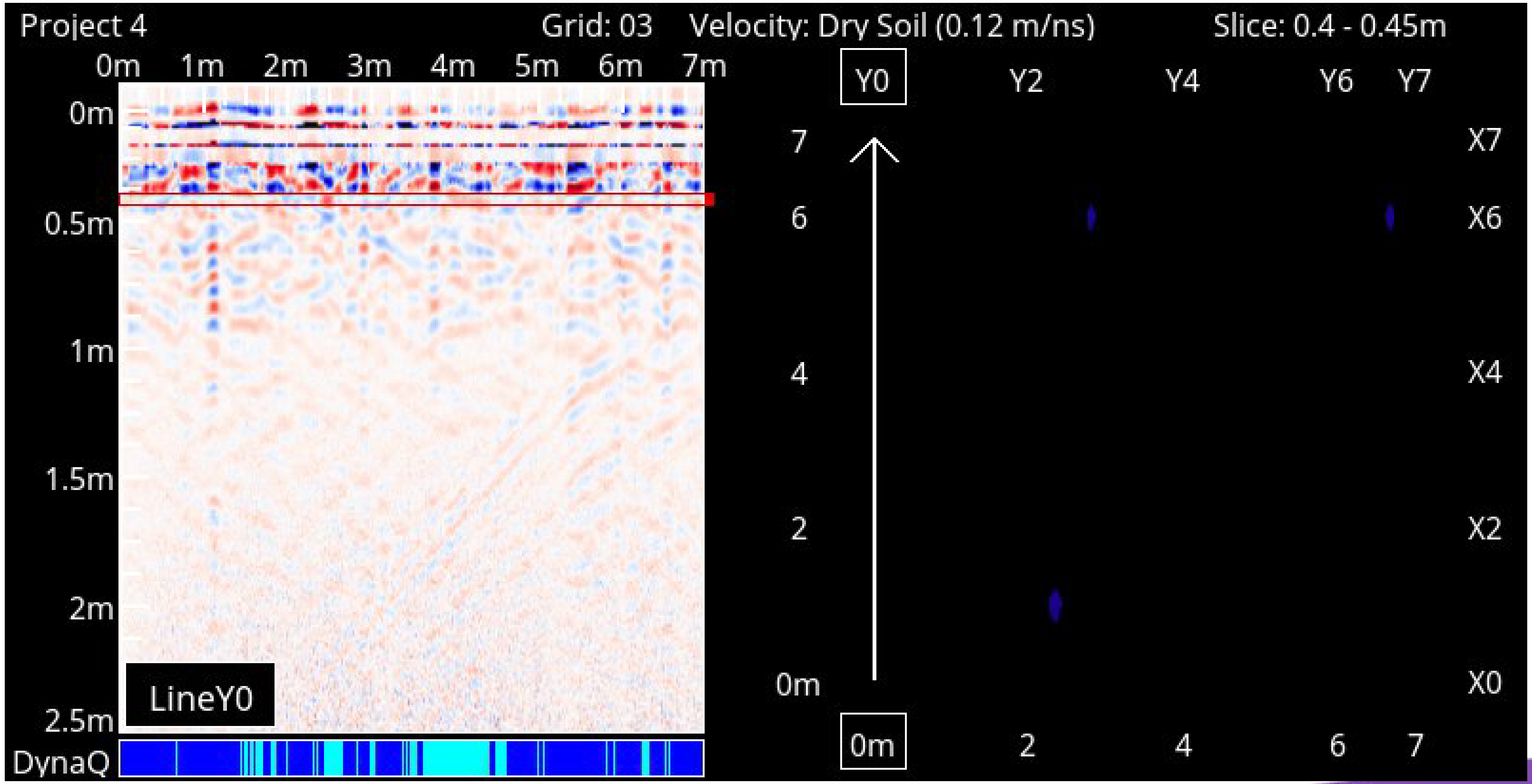


GPR Grid Scan (Line Spacing 0.5 m)



SASKATCHEWAN POLYTECHNIC

GPR Grid Scan (Line Spacing 1.0 m)



GPR Limitations

- The GPR data may not determine the age, sex or burial time
- GPR signal might go through multiple reflections when it is trapped in a hollow object. These multiple reflections are termed as airwaves and may be misleading
- Tunnels dug by small animals can also cause air waves
- The GPR signal is subject to external interferences such as external magnetic fields caused by powerlines
- The signal can reflect off tree branches and nearby buildings

Conclusion

- Using multiple technologies can enhance interpretation accuracies
- GRID scan can provide better images at different depths and is a laborious and a time-consuming procedure
- Line scans can be performed in a relatively short time but require expertise for data interpretation

SASKATCHEWAN POLYTECHNIC