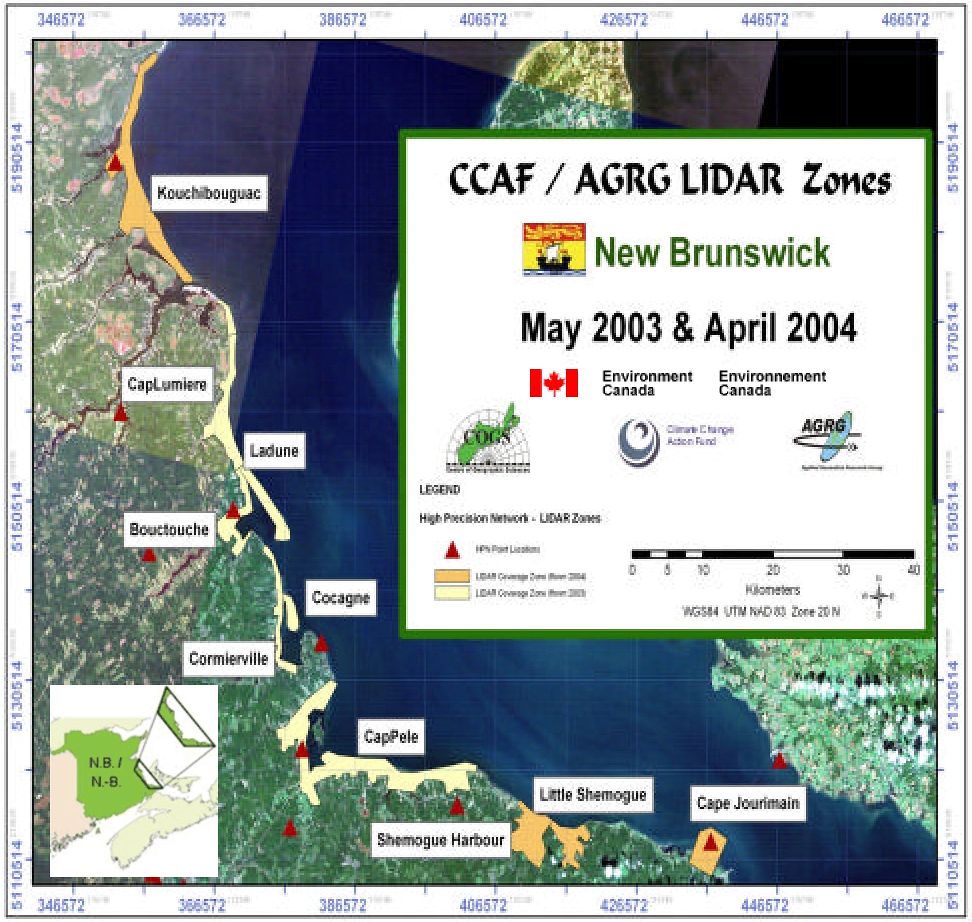
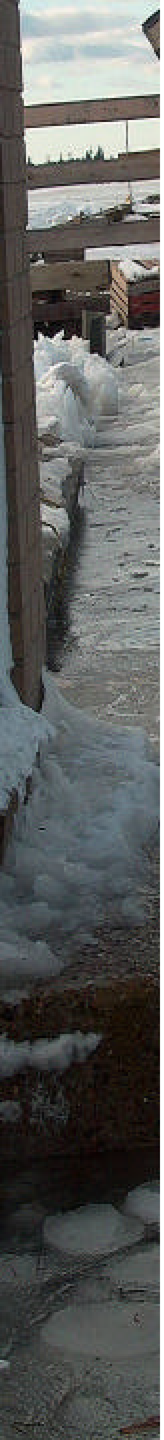
Flood Modeling with High Resolution LIDAR



Edward MacKinnon - http://tmackinnon.com

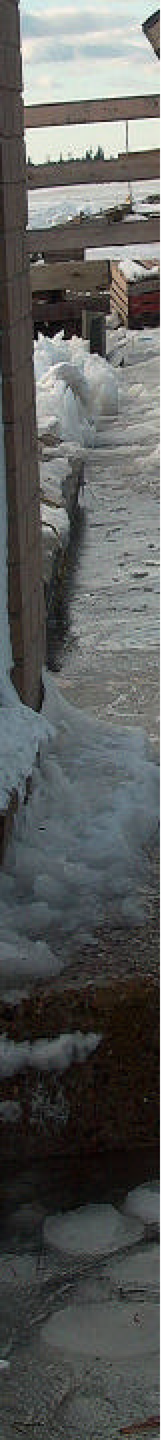
PCI Geomatics

Canadian Institute of Geomatics
2005 Conference



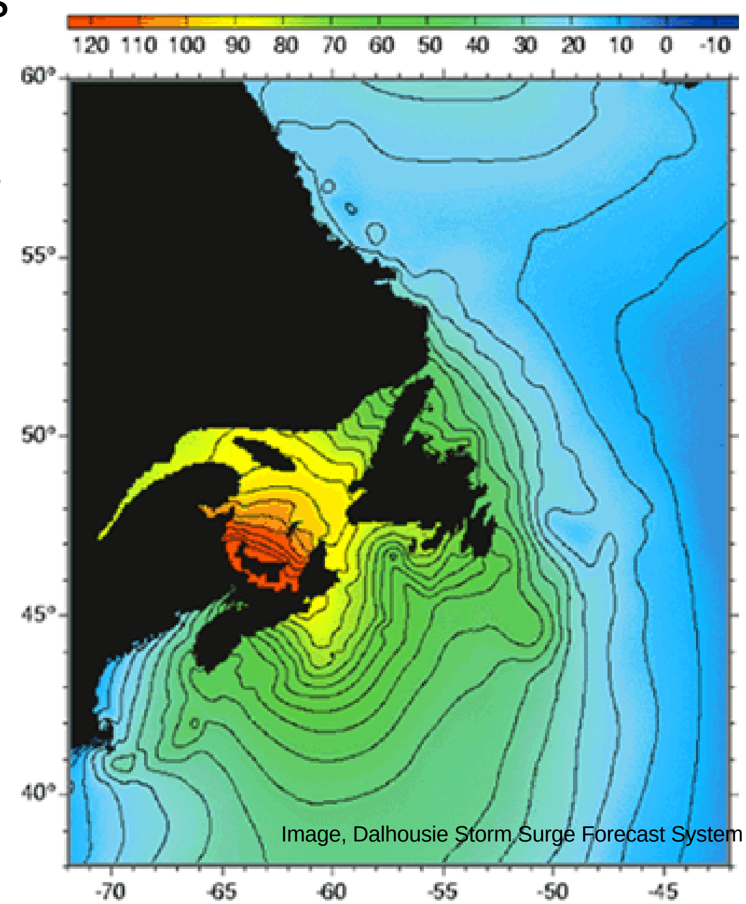
- This presentation covers flood modeling with EASI modeling; which was a major aspect of my extensive graduate work in LIDAR research that lead to the completion of the Applied Geomatics Research program at COGS / AGRG last year. Further papers, presentations, images, animation, examples and more on this project can be obtained from my website **http://tmackinnon.com** or by contacting me directly.

- More information on the current status of the CCAF project that my project was a major part of see http://atlantic-web1.ns.ec.gc.ca/slr/default.asp?lang=En&n=61BB75EF-1 or http://agrg.cogs.ns.ca/

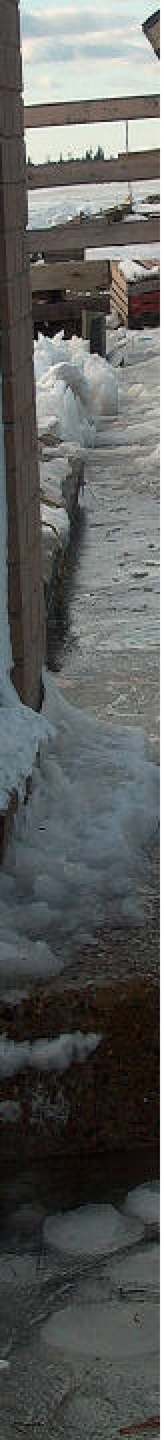


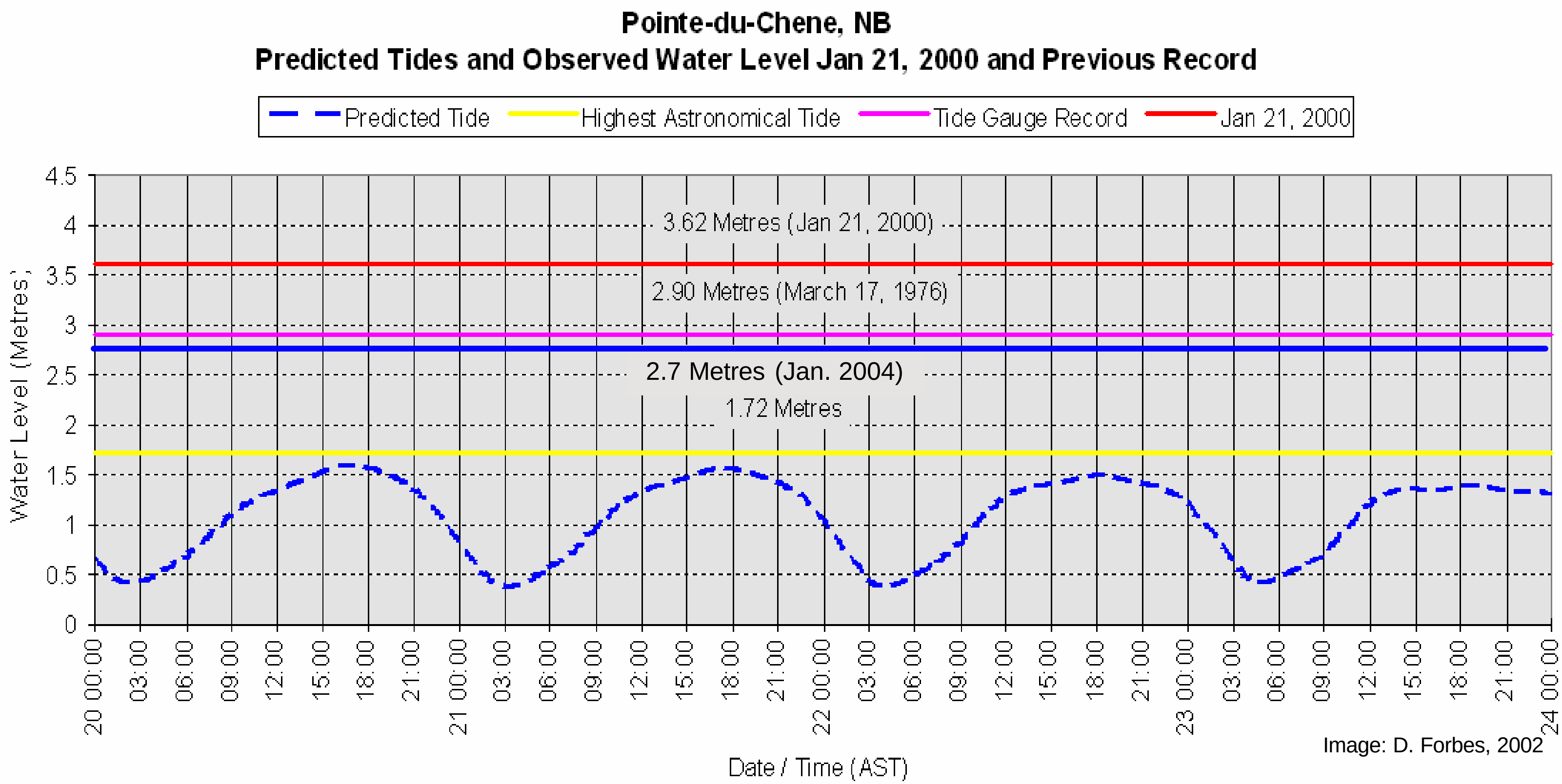
Storm Surges

- Storm surge are caused by changes in sea-level produced by strong winds and low atmospheric pressures that cause coastal waters to flood inland
- Are extremely powerful when they coincide during peaks of high tides and can cause extensive coastal flooding.
- Maritimes are really susceptible to these events and a January 2000, storm surge event was the largest on record for area and caused extensive damage to the area



Image, Dalhousie Storm Surge Forecast System





- The flooding of Jan. 2000 saw water levels rise to 3.62 m (CD) instead of the expected 1.72 m (CD)
- On Jan 17, 2004 another significant event occurred, not as dramatic but still caused extensive damage to some areas
- These events are not one time events, they continue to occur and SLR is expected to increase the problem

- Extensive flooding caused havoc in many coastal communities


Photo: ATV News, 2000


Photo: B. Belliveau - The Weather Network, 2000

- Water also flooded across roads making access to the area for rescue vehicles near impossible

- **Ice piled up high causing damage to homes and infrastructure**

Photo: Weather Channel, 2000

Photo: M. Campbell, 2000

Photo: R. Leblanc, 2000

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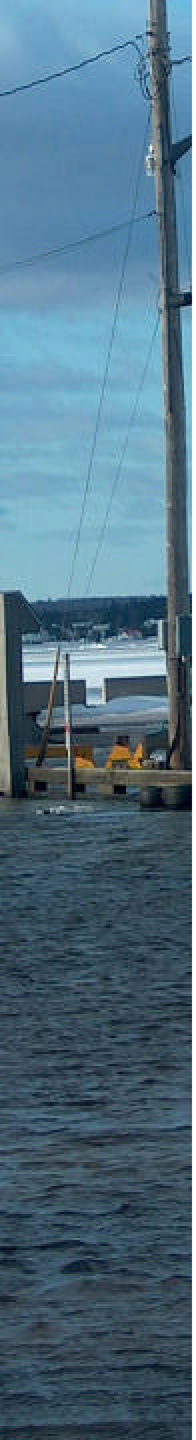
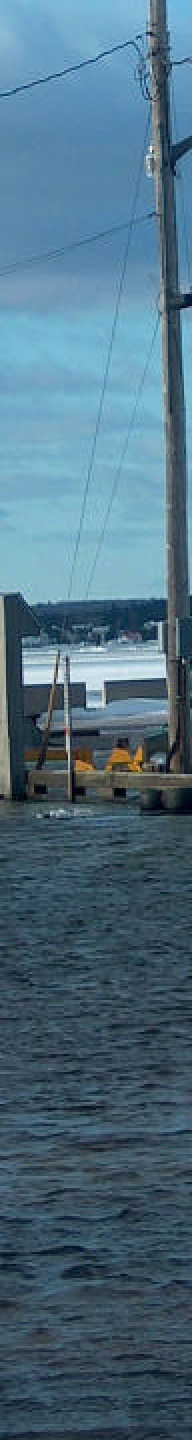


Flood Modeling

- A GIS model is a set of rules and procedures for representing a phenomenon or predicting an outcome.

  ”Dictionary of GIS terminology: ESRI Press 200”

- Used to derive new information that can be analyzed to aid in problem solving and planning
- Can include a combination of logical expressions, mathematical procedures, and other criteria, which are applied for the purpose of simulating or predicting an outcome or representing a situation
- Several Flood Simulation products can be modeled using high resolution digital elevation data (LIDAR), GIS and Remote Sensing tools.



- Flood models for this project were created to represent actual and predicted flood events
    - Flood extent modeling
    - Flood depth modeling
    - 3D modeling of flood
    - Flood animation

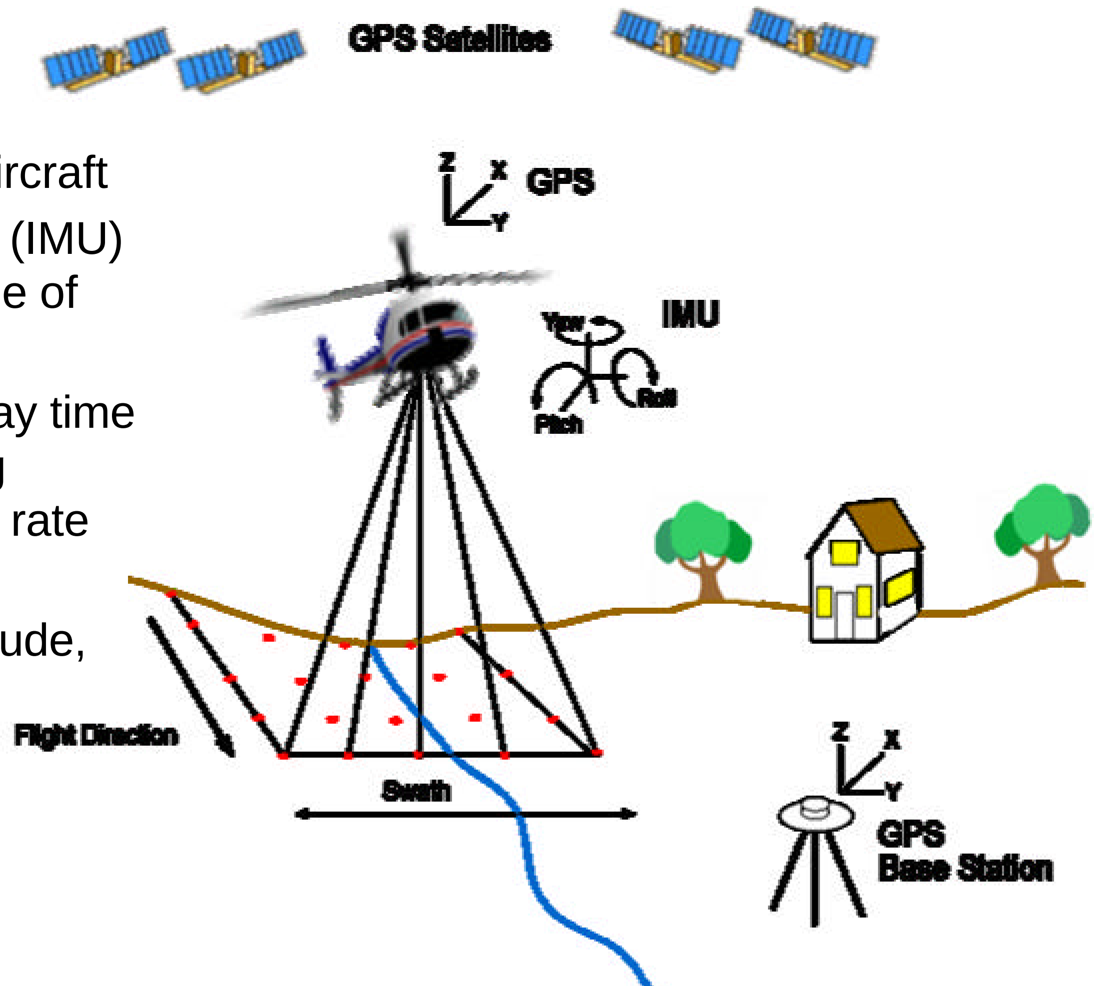
- The models were generated with sub meter (0.6 m cell and +/- 10 to 20 cm vertical accuracy)* LIDAR surfaces with ArcInfo and PCI Geomatica.
- These products now provide valuable information to CCAF partners for strategic planning to help prevent coastal flood damage.

* An standard deviation of 9.75 cm and an mean of 20.25 cm was calculated from 219727 LIDAR data points & RTK GPS points

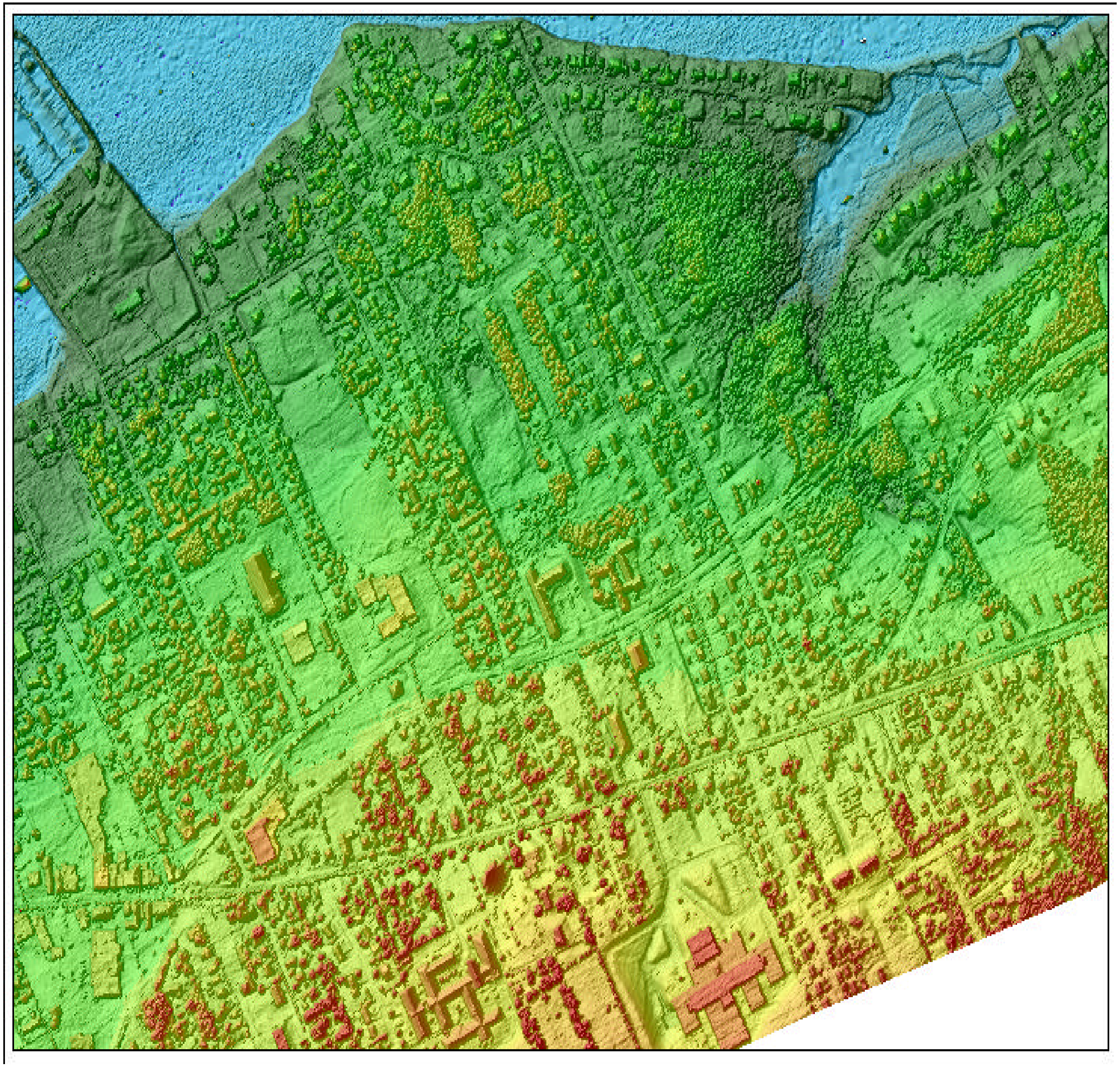
LIDAR

LIDAR uses laser pulses, fired from an airborne platform, to determine and record the elevation of the ground integrated

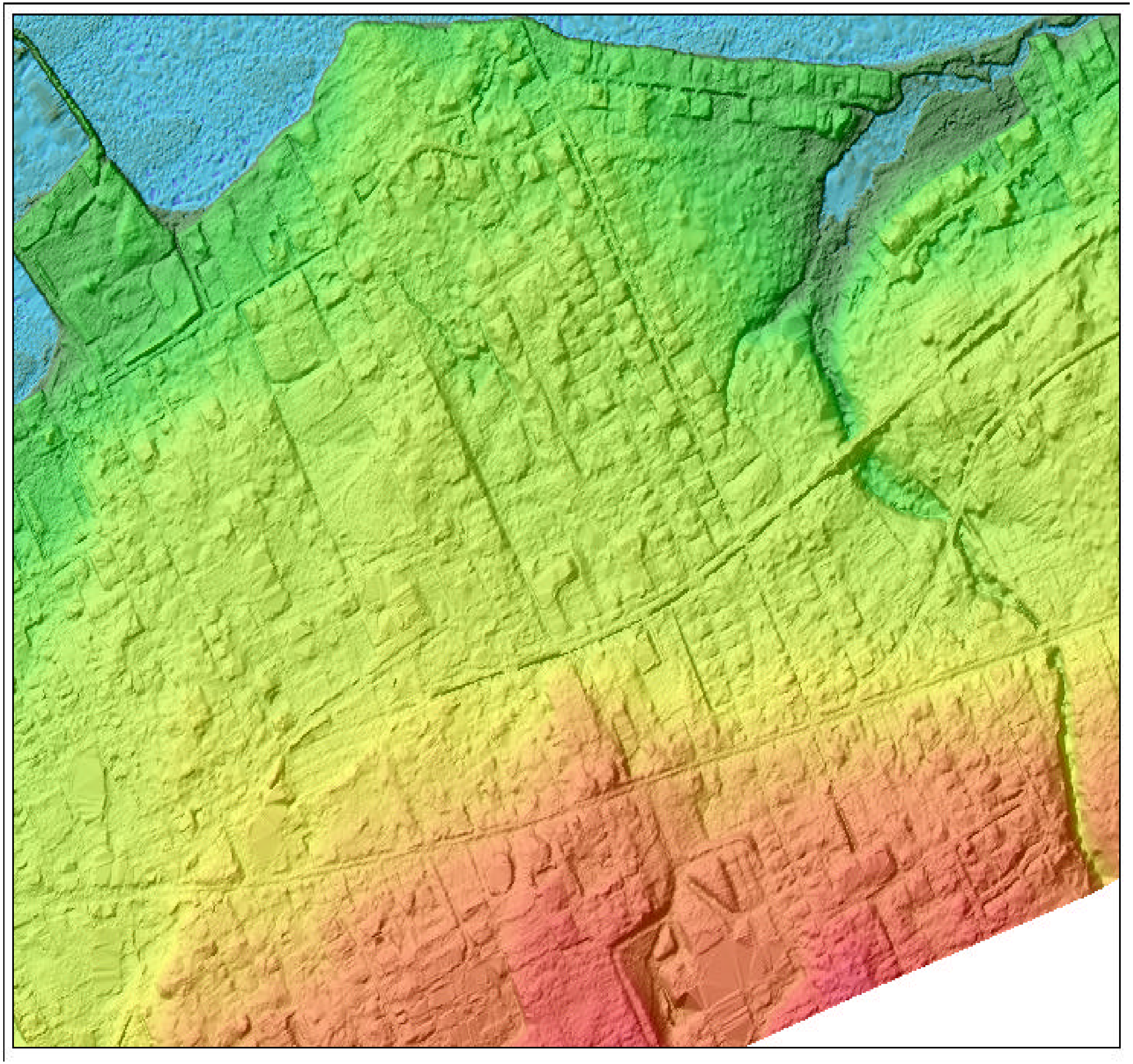
- GPS is used to position the aircraft
- Inertial Measurement System (IMU) is used to measure the attitude of the aircraft (pitch, yaw, roll).
- TIM used to record pulse 2 way time and scan angle (point spacing controlled by pulse rate, scan rate and forward speed).
- Target position latitude, longitude, ellipsoidal height

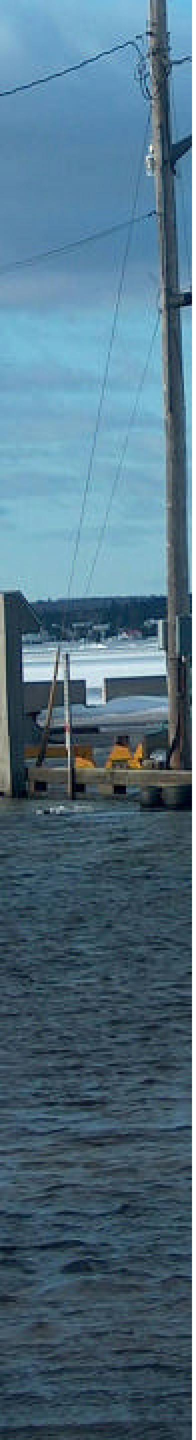


DSM (Digital Surface Model)



DEM (Digital Elevation Model)





Flood Data

- Data for the project was calculated from actual tide gauge readings and historic storm surge events and were converted from chart datum values to mean sea level

Flood Related Data

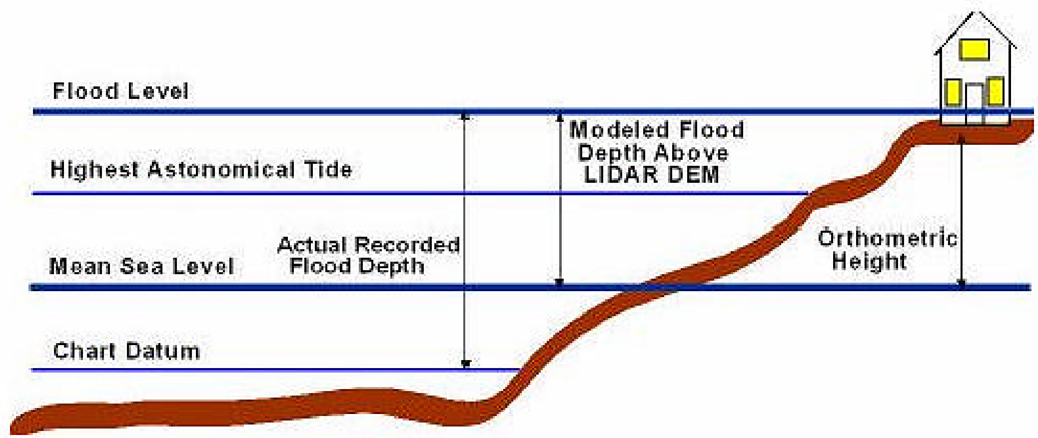
Ellipsoidal height values

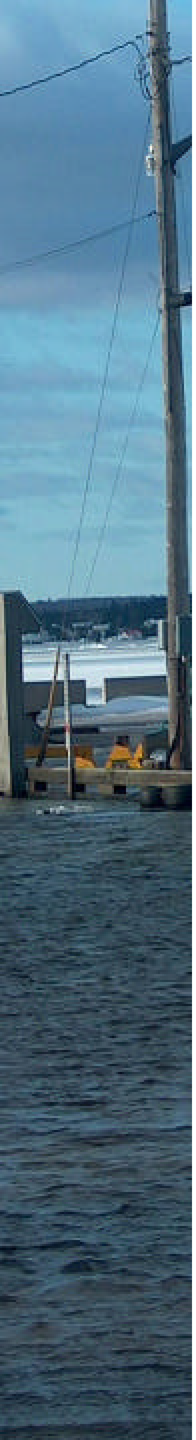
Station Number	Station Name	CD Above WGS84	MWL Above CD	MWL Above WGS84	DE Above CD	DE Above WGS84	Flood Level Jan-00	Flood Level extreme 100yr	Flood Level moderate 100yr	Mapped Flood Level
1817	Bouctouche	-19.833	0.7	-19.133	1.4	-18.433	3.6	4.3	4.1	2.9
1820	Richibucto Cape	-20.182	0.66	-19.522	1.4	-18.782	3.6	4.3	4.1	2.94
1818	Saint Edouard De Kent	-20.16	0.7	-19.46	1.4	-18.76	3.6	4.3	4.1	2.9
1805	Shediac	-19.879	1.05	-18.834	1.7	-18.179	3.6	4.3	4.1	2.55
1802	Robichaud	-19.966	0.7	-19.266	1.5	-18.466	3.6	4.3	4.1	2.9
1812	Cocagne	-19.78	0.74	-19.038	1.3	-18.48	3.6	4.3	4.1	2.86

Flood above Chart Datum (Tide gauge)

Orthometric height MSL of Jan 2000 event

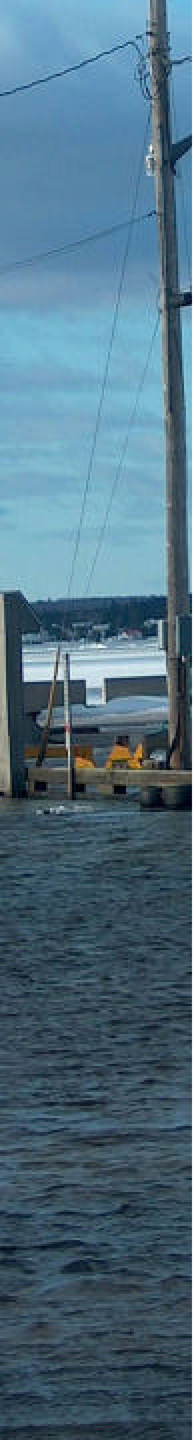
CD Chart Datum
DE Datum of Elevations
MWL Mean Water Level (Geodetic 0 CGVD2
WGS84 (Datum) Earth Centered Fixed Cartesia





Flood extent models

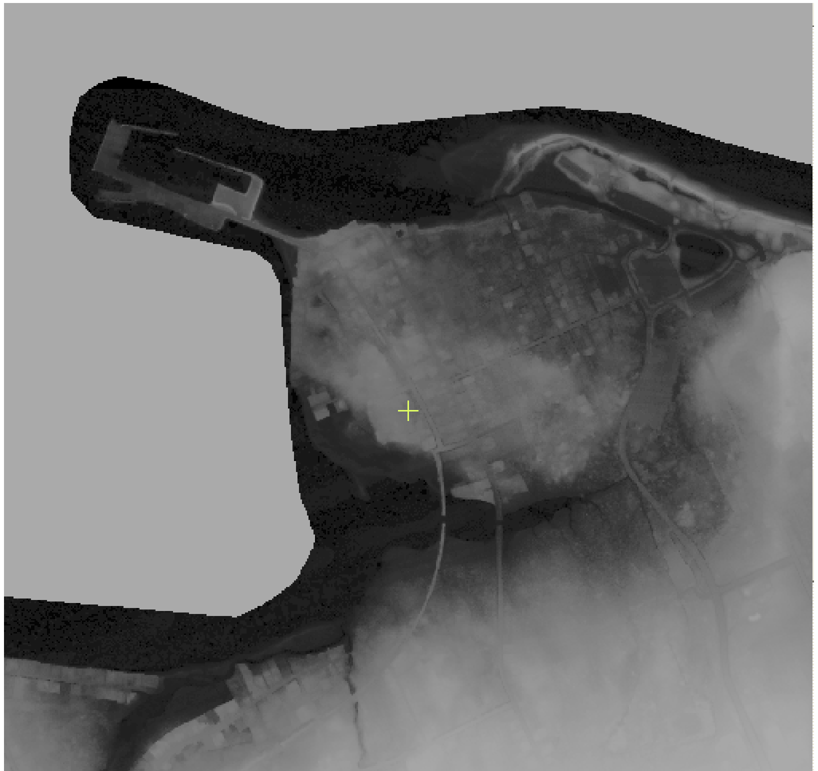
- Define the possible spatial extent that flood water could reach
- It is a binary mask defining flood level, (either water or no water)
- Can convert the flood extent models into data that can be integrated with other GIS and use it to create other models
- PCI Geomatica EASI modeling was used to derive flood models

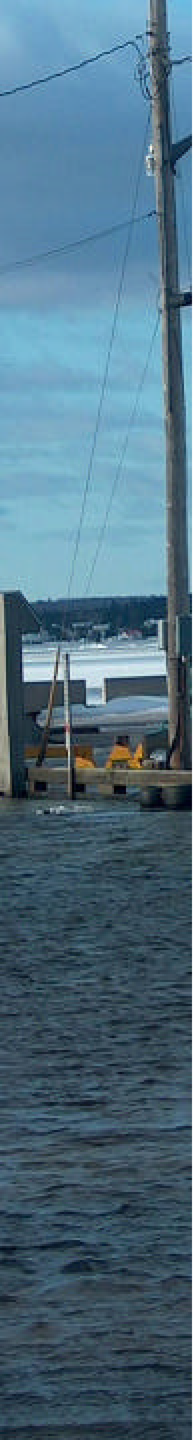


Flood extent models

- if DEM is less then or equal to flood depth
  then
  flood layer will equal 1(true or water)
  else flood layer will equal 0 (false or no water)

```
if %1 =< 2.55 then
  %2 = 1
else
  %2 = 0
endif;
```





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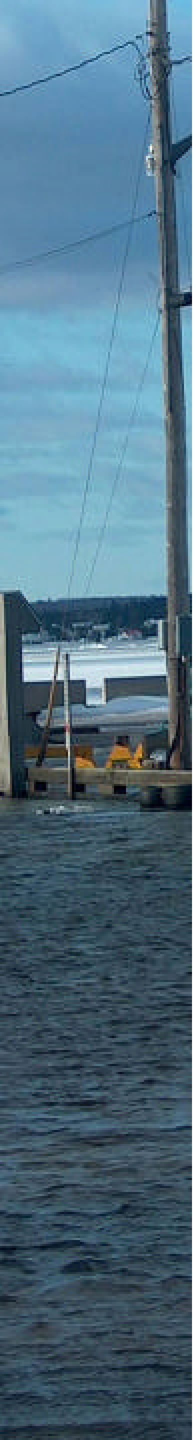


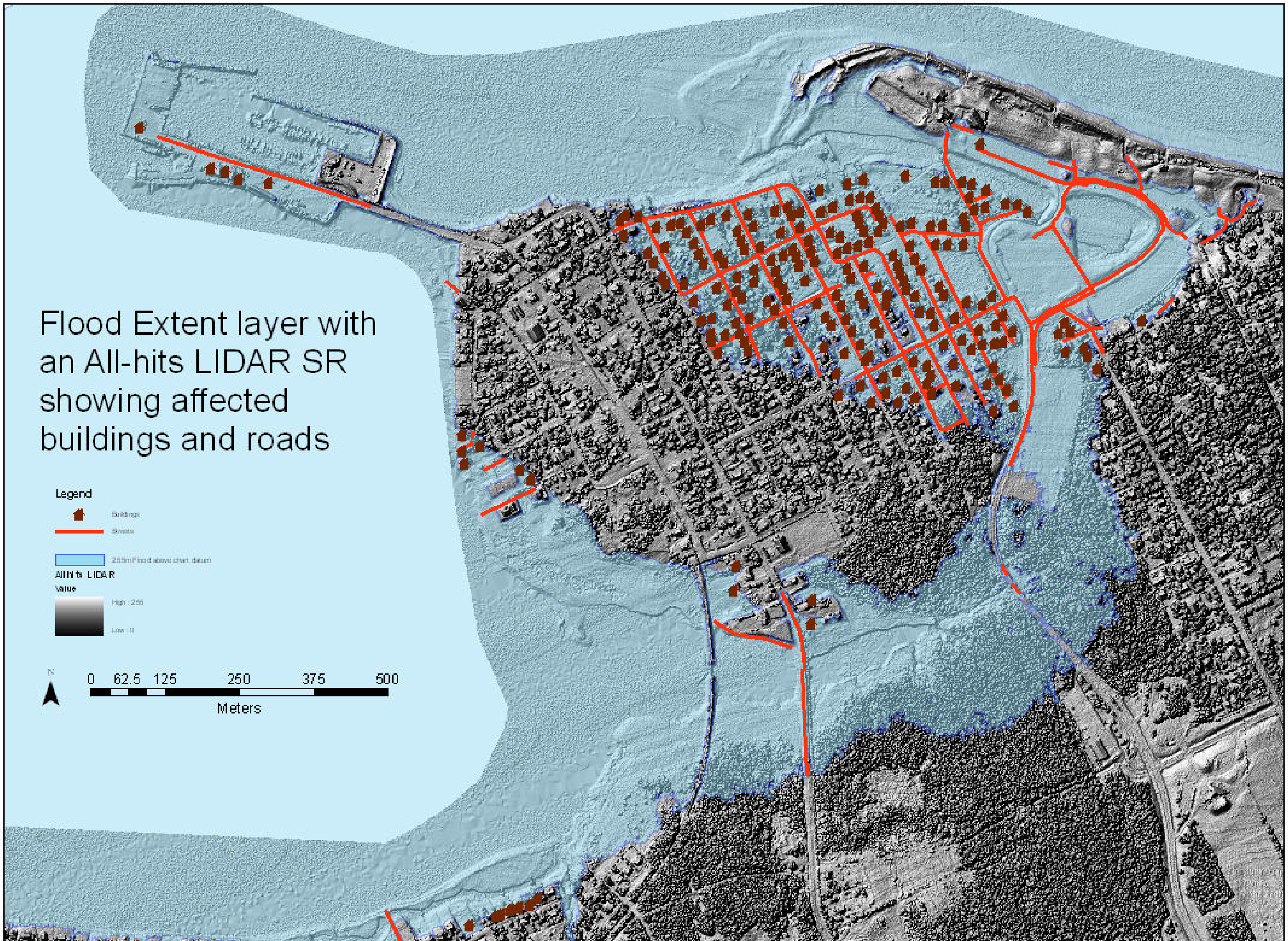
Flood extent models

- Benefits:
  - Can easily identify where the flood will reach to and what areas will be effected
  - Can be converted into polygons or thematic layers and combined with other data to perform statistical analysis with (e.g. building data, property etc)
  - Integrate with other data sets to help educate people and make them aware of the risks of storm surge flooding
  - Can be used to further derive other models

- Disadvantages
  - This method does not detail connectivity issues, further logic and data sets would be needed to make more accurate models (e.g. culvert data, building footprint, outward flow of fresh water etc)
  - An area beyond an obstruction such as a causeway that had no connection to water would be given flood values when in fact it may not be possible for the flood water to get there

Flood extent models

Flood extent models

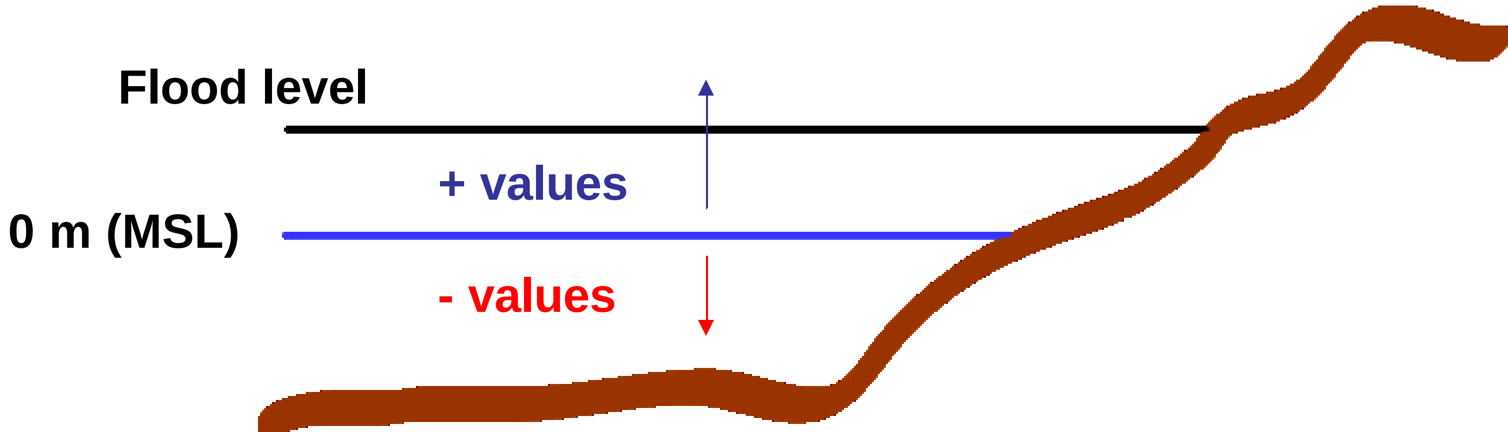


Flood depth models

- Define actual depths that the flood water would represent
- It is similar to a traditional DEM except the vertical (Z) values represent depth of water for each raster cell
- To derive use the ground only DEM less the measured flood depth and multiply by -1 to ensure the values are positive

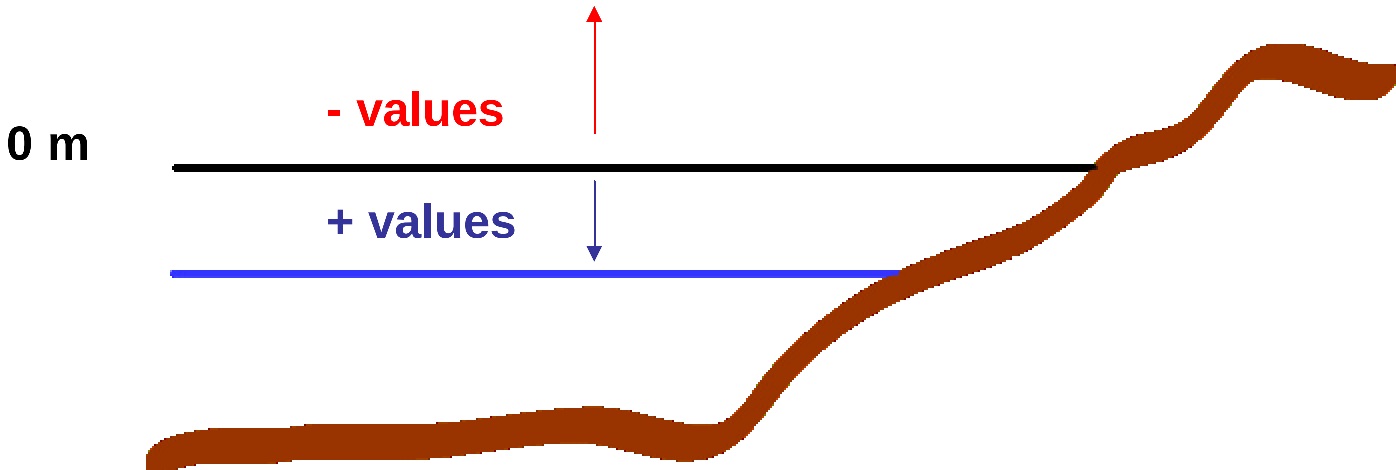
%3 = (%1 - 2.55) * -1

Cross section of a Traditional DEM



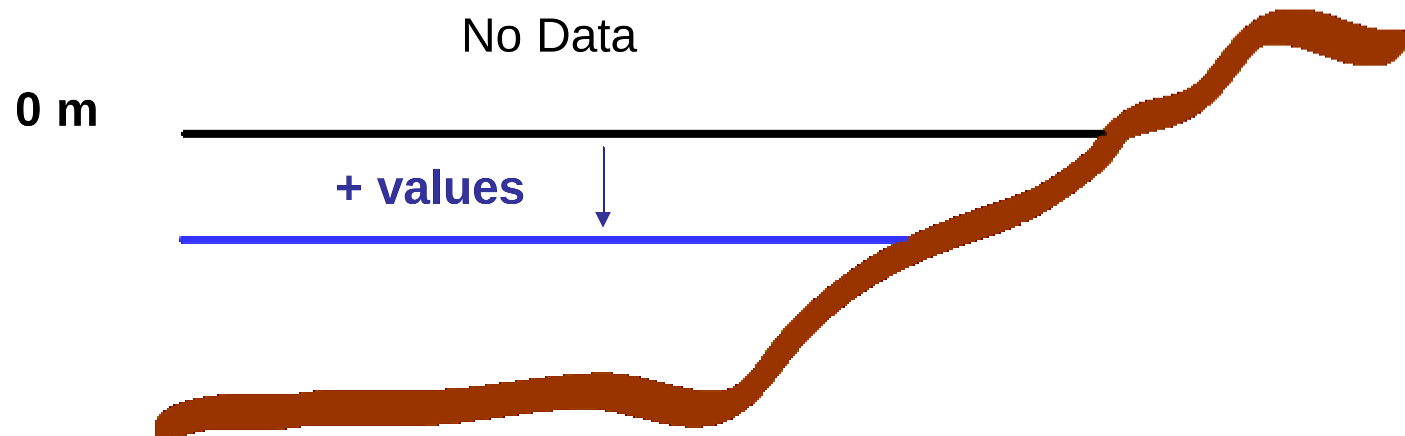
- Results in a raster depth surface that you can query and obtain actual depth of flood at for any point
- To avoid confusion with negative numbers it is a good idea to clip the flood depth raster with the associated flood extent layer

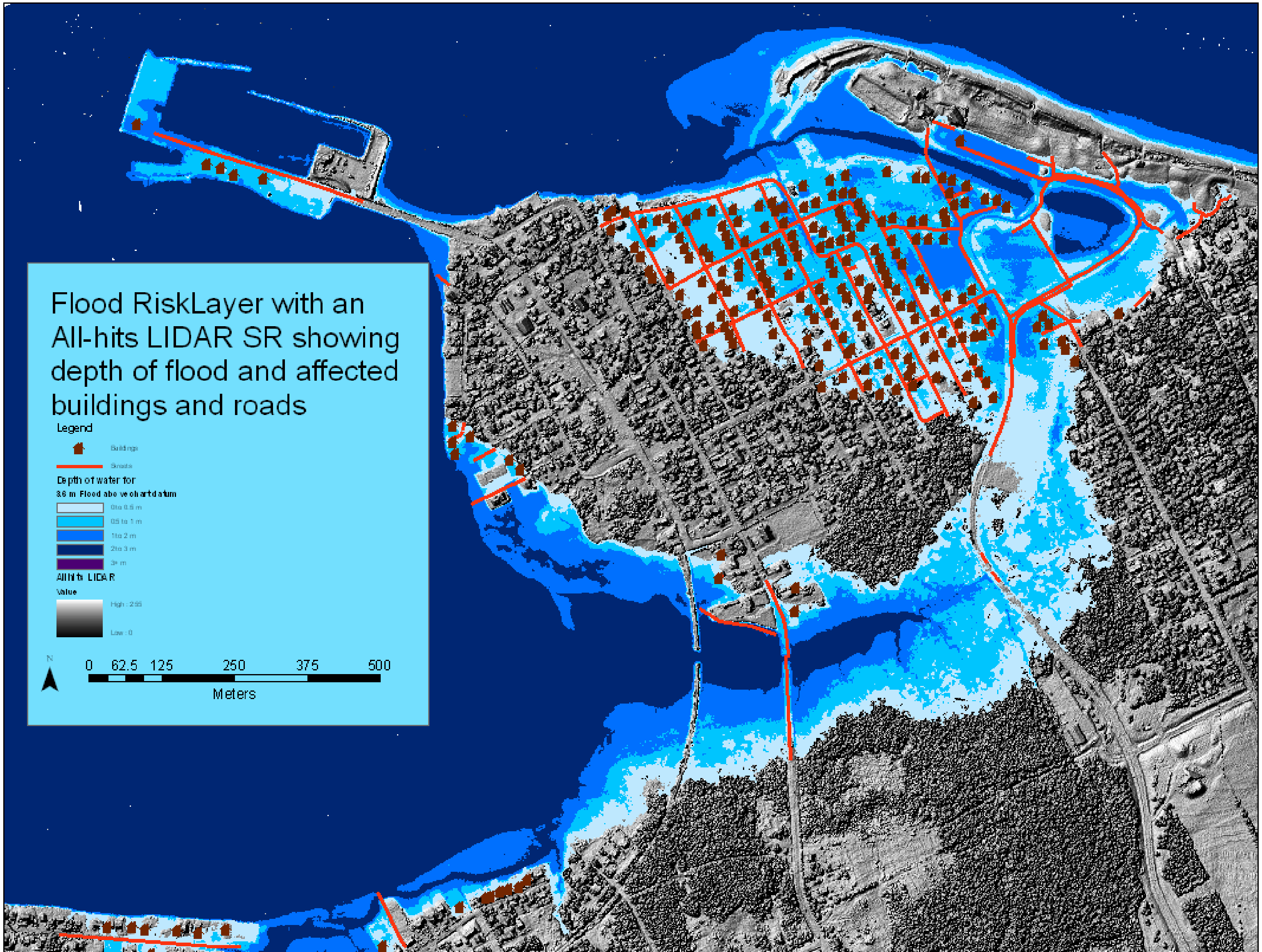
Cross section of a flood depth raster



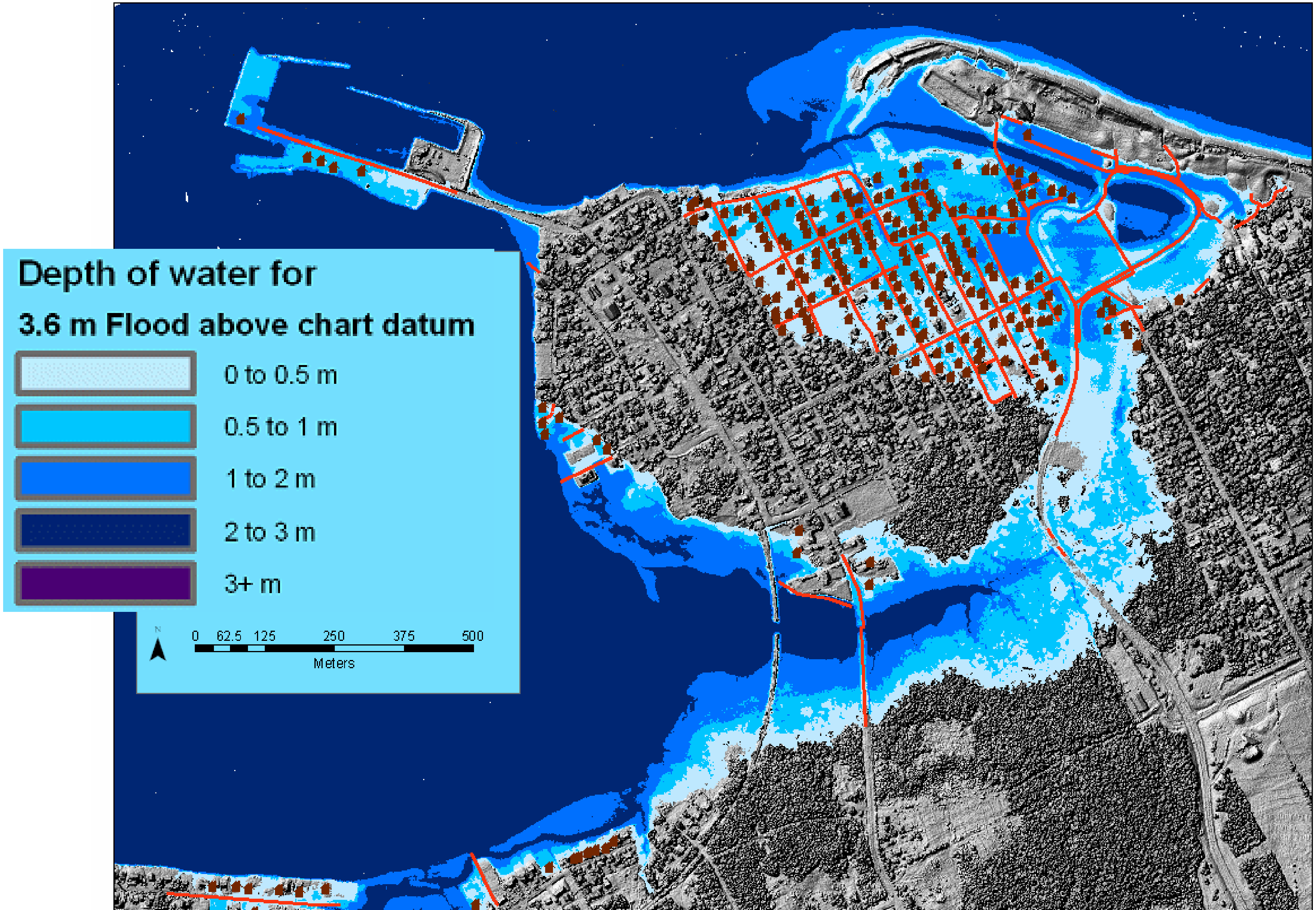
- All values will be either actual depth of flood or no data
- Can classify the results into classes to aid with quick assessment and easily determine flood risks

Cross section of a flood depth raster





Flood RiskLayer with an All-hits LIDAR SR showing depth of flood and affected buildings and roads
Legend
Buildings
Streets
Depth of water for
3.6 m Flood above chart datum
0 to 0.5 m
0.5 to 1 m
1 to 2 m
2 to 3 m
3+ m
All hits LIDAR
Value
High : 255
Low : 0
N
0 62.5 125 250 375 500
Meters



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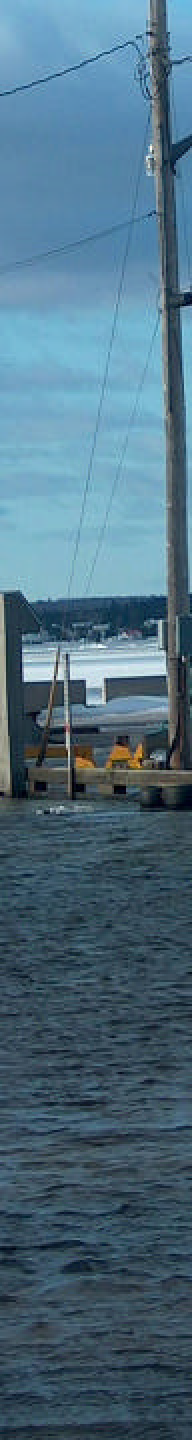


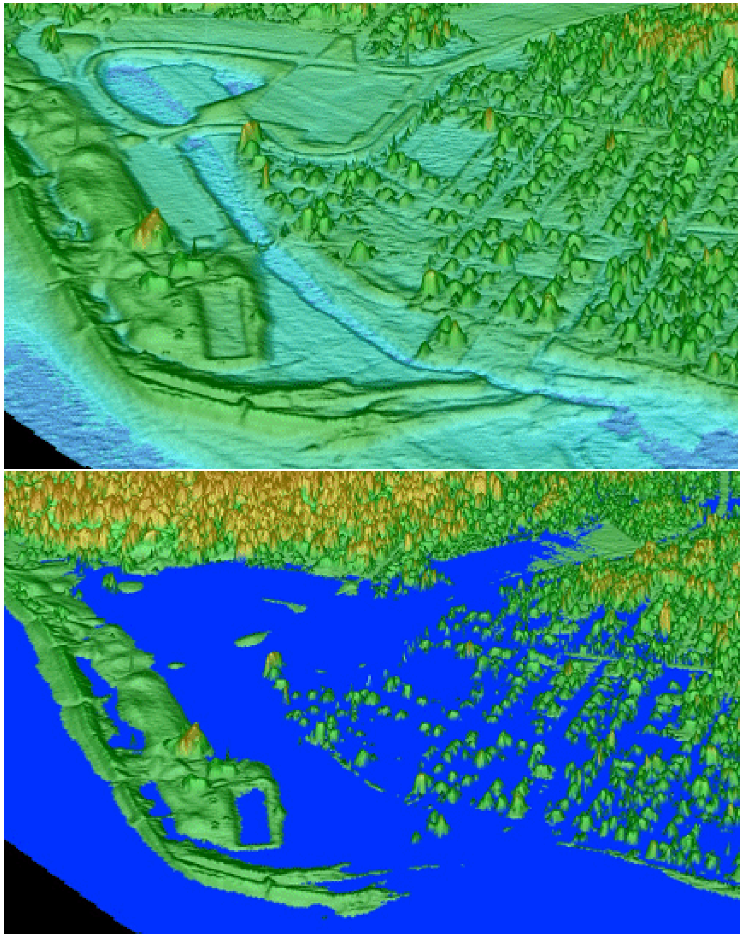
Flood depth models

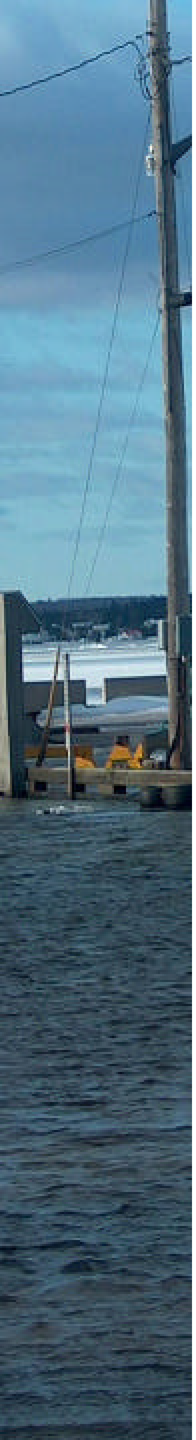
- Benefits:
  - Can easily identify where the flood will reach to and what areas will be effected and how deep the flood will be
  - Can be converted into polygons or thematic layers and combined with other data to perform statistical analysis with (e.g. building data, property etc)
  - Integrate with other data sets to help educate people and make them aware of the risks of storm surge flooding
  - When classified into sub classes, can be used to easily distinguish areas of higher risk
  - Can be used to further derive other models

- Disadvantages
  - This method does not detail connectivity issues (unless clipped by a flood extent layer that does address that issue)

3D Flood modeling

- Generate perspective view of flood scenarios to give a 3D simulation of the flooded area
- Determine a View Point (PSGIMAG)
- Use elevation data to model the z axis and simulate a terrain surface
- Use flood extent models to fuse it to the elevation data (or other data such as imagery) to see a 3D view of your flood





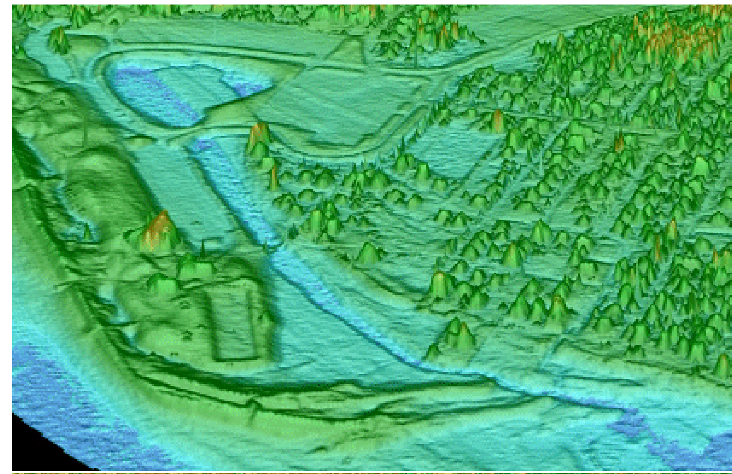
3D Flood models

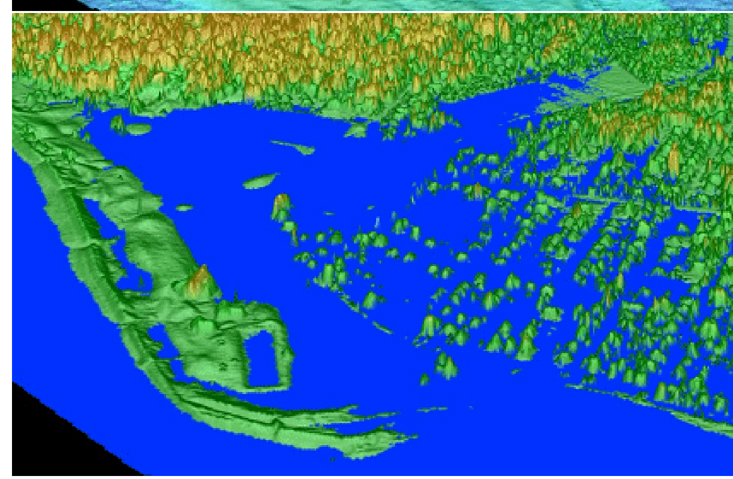
- Benefits:
  - Can easily identify where the flood will reach to and what areas will be effected and possibly what areas are of higher risk if the classified depth models are used
  - Integrate with other data sets to help educate people and make them aware of the risks of storm surge flooding
  - Can easily catch somebody’s attention

- Disadvantages
  - More of a visual tool and does not really provide any statistical analysis

Flood animation

- Simulate flood scenario from no flood to flood level and/or beyond that
- Will easily capture someone's attention
- Generate 3D flood views, fuse the flood layer with elevation model or imagery
- Used an EASI script to generate 52 images for flood increments of 5 cm (from 0m up till the flood layer or 2.6m)
- Use animation software (Jasc animation studio) to combine the frames (images) together into a compatible animation file

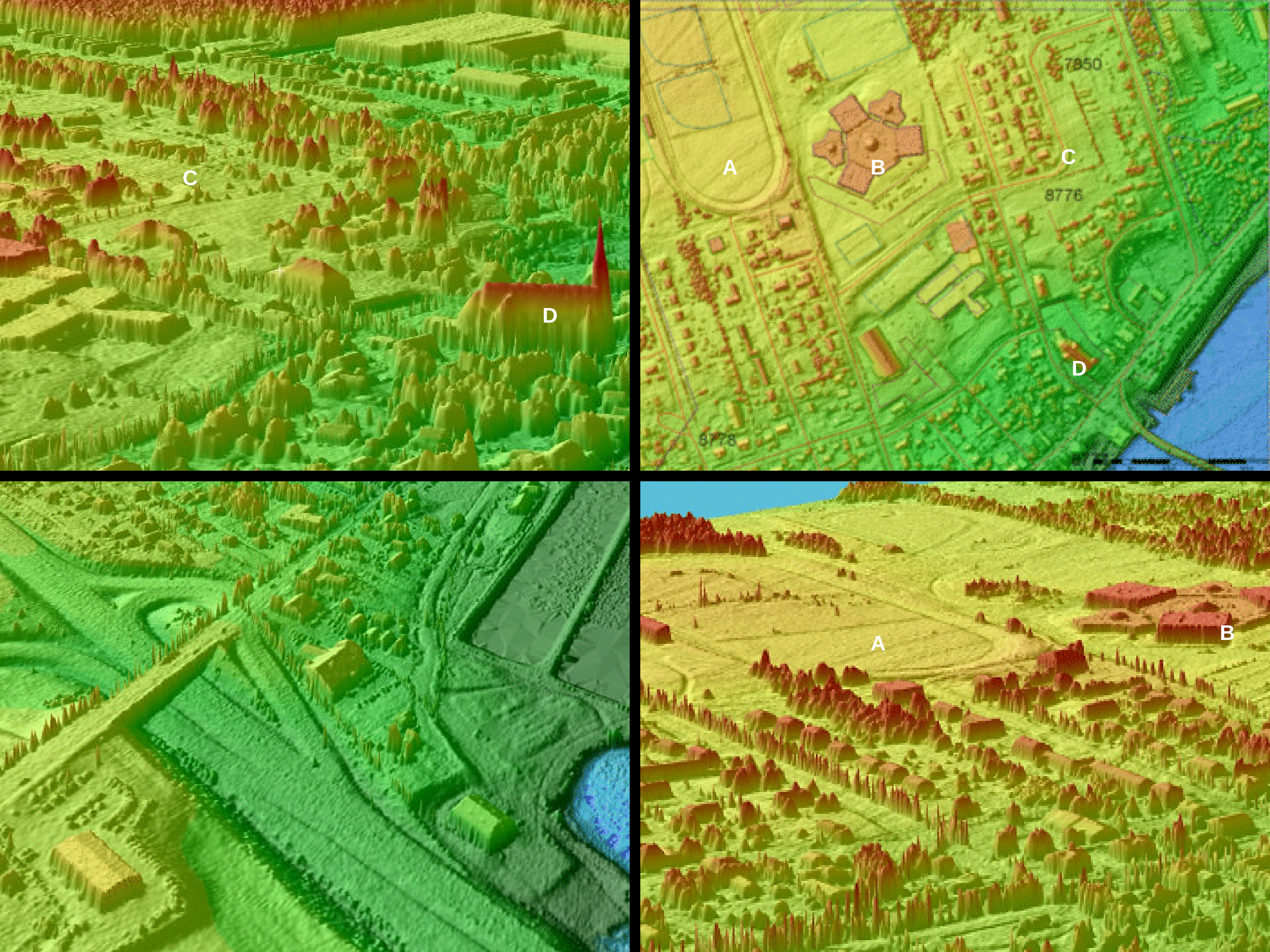




Conclusions

- Flood modeling is ideal for both simulating and depicting historic flood events and demonstrating water levels of predicted flood levels
- Requires an accurate source of elevation data and some further process sing to ensure that the connectivity issue is addressed
- LIDAR data is ideal because it is both high resolution spatially and vertically and has the ability to generate hydrological DEM surfaces (Bald earth DEMS)
- Can be integrated with other GIS data to perform both spatial and statistical analysis with
- More criteria could be implemented into these simple flood models along with thematic layers and other municipal data sets to further calculate more accurate results

Further information - **http://tmackinnon.com**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