

LiDAR Training Series: Module 1

Acquiring and Visualizing LiDAR-Derived
Digital Elevation Models for Your Community



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Introduction

Francis Heron described the flood of 1826 by saying, “the forts now stand like a castle of romance in the midst of an ocean of deep contending currents, the water extending for at least a mile behind, and they are thereby only approachable by boats and canoes”. Today we would not think of it as a romance but understand the wording of “midst of an ocean”. This century has seen numerous floods which are still embedded in the minds of many.

The headlines of 1997 flood stated, “Grand Forks on fire” as the Red River in Grand Forks crested at 53.99 feet. The damage of flooding and fire scarred the city and efforts were on the way to never allow it to happen again. In Manitoba, damages exceeded 500 million dollars and it was the worst flood on record since the flood of 1852. The flood of ‘97 became known as the “Flood of the Century”.

Fast track ourselves to present day 2021 and we now are seeing drought, water restrictions and rivers at their lowest levels in 100 years. Add the effects of climate change, which this may be a part of, and you learn quickly that resilient and proactive thinking must happen. Gone are the days that you deal with it as it comes along, as it is now time to be proactively thinking of what is yet to come as it relates to weather and the changes occurring in our weather.

The answer to being proactive is far more affordable than being reactive and the use of LiDAR by Governments, First Nations, and businesses is one of the greater tools in the toolbox for planning. The data that LiDAR brings and the software that the data can be used with is the key for future planning, risk reduction and climate change adaptation.

It is the desire of the Red River Basin Commission, and its partners, to share, to assist and to support all those who wish for their communities to better prepare for the next century and what that century may bring as it relates to the changes and needs coming from climate change.

Steve Strang

Managing Director

Red River Basin Commission

The Red River Basin

The Red River is one of the few rivers that flows north. It meanders for over 800 kilometres, mostly through a flat plain of rich soil deposits which are some of the best agricultural lands in the world. The channel of the Red River forms the boundary between North Dakota and Minnesota and flows north into Manitoba and through City of Winnipeg before it reaches Lake Winnipeg. The drainage area for the Red River Basin is about 100,000 square kilometers and encompasses parts of eastern North Dakota, northwestern Minnesota, and northeastern South Dakota in the United States and southern Manitoba in Canada. It is also part of the larger Lake Winnipeg Basin.

The Red River being about 885 kilometres long, of which about 635 kilometres are in the United States and about 255 kilometres are in Manitoba, Canada. Over the course of the river, it falls 70 metres on its journey to Lake Winnipeg, where it first enters the largest coastal wetlands in North America called the Netley Marsh.

In 2007, the Government of Canada declared the Red River as a Canadian Heritage River as the historical role it played for First Nations, Metis, and the development of Western Canada.

For the last 40 years the Red River Basin Commission is proud to work along side its partners, in Canada and the United States, to maintain water quality and management of such a historical part of Manitoba, Minnesota, and North Dakota.

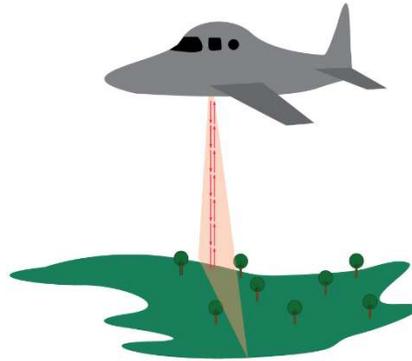
What is LiDAR?

LiDAR stands for *Light Detection And Ranging*. LiDAR originated as a technology for military targeting with key advances made by Canadian Allan Carswell at York University, and later became available for academic and commercial uses. The central goal of LiDAR is to measure the elevation of the earth's surface at a high resolution while maintaining high spatial accuracy.

The word LiDAR is a portmanteau of "light" and "radar" and conveys the essence of how it works.

Collection of LiDAR

LiDAR acquisition is usually done with low-flying specially equipped aircraft that travels along a predetermined path, with sensors affixed to them. From the sensor, beams of infrared light are rapidly shot at the ground en-masse, over 150,000 times each second as the plane heads down a pre-defined path. Each pulse of light bounces off the earth's surface (or an object such as a building or vegetation) and heads back toward the sensor, where the angle and time delay are captured. The time it takes for the pulse to travel determines the distance to the spot on the ground, since it travels at the speed of light. Since the plane's elevation is known, the distance is subtracted to get the ground elevation.

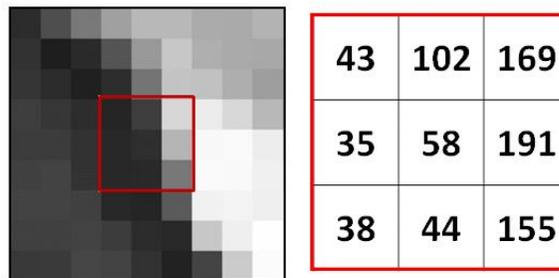


Two corrections have to be done at this point - distance has to be corrected using trigonometry since the pulses are almost never vertical, and secondly, the plane's elevation will have to be adjusted from its Internal Measurement Unit and GPS since the height will be minorly inconsistent due to turbulence. Spring and fall are the best times to fly as the leaves and vegetation are minimal, but the snow isn't on the ground either – in which either act to distort accuracy.

The product of this LiDAR collection is a densely spaced network of geo-referenced points, called a 'point-cloud' that can be used as an input to generate a 3D representation of the earth's surface. Using specialized geospatial software, such as QGIS, the point-cloud can be converted to a gridded dataset of the area that was captured, which is called a Digital Elevation Model (DEM).

The raw DEM at this point is never a perfect representation of the landscape, and this is due to the nature of LiDAR acquisition being overhead. Certain features, mainly those that are hidden from above, will not be accurate and survey data will need to be used to adjust them. One example is a bridge over a channel – the channel exists and has a definition to it, but since the bridge blocks the lidar signal from reaching it, the result just shows the deck of the bridge.

DEMs are gridded and are pixelated, and fall under a class of data called *rasters* – like most digital imagery. Each square cell within the raster is called a pixel. Each pixel is a uniform size and holds a value (*digital number*) for the area that it occupies - from a range of allowable values. For DEM's the value is from elevation, which in Manitoba is published as above sea level.



Raster data can come in a single *band* (channel) or in three bands. LiDAR derived DEMs only use 1 band, while most satellite imagery uses 3.

Use Cases for LiDAR

LiDAR as a remote sensing technique has several advantages. High accuracy, large coverage areas and a high amount of data collection points, allow for the ability to produce large-scale inexpensive and efficient datasets. 2021 LiDAR acquisition prices have been below \$30/km² and continue to decline as sensor sensitivity and signal processing power improve.

Some use cases for LiDAR include:

- Creating flood insurance risk maps. This is likely a strong driver of demand for more LiDAR capture.
- The planning of smaller scale civil engineering projects, that are related to surface water management.
- Wetland conservation strategies, along with flood and drought mitigation.
- Developing surface water retention strategies, and creating value from your assets.
- Developing an inventory of assets, such as culverts, bridges and other existing infrastructure, with important information about them such as dollar value.

LiDAR provides the critical backbone of computational analytical operations that can be done to determine watershed boundaries, flow pathing and surface depressions in minute detail – much more refined than traditional survey data.

LiDAR-based mapping also helps you identify sensible areas for water retention, which are integral to climate adaptation plans. LiDAR-based risk mapping also helps you target the areas of your community that may be vulnerable to flooding and the benefit of flood protection projects.

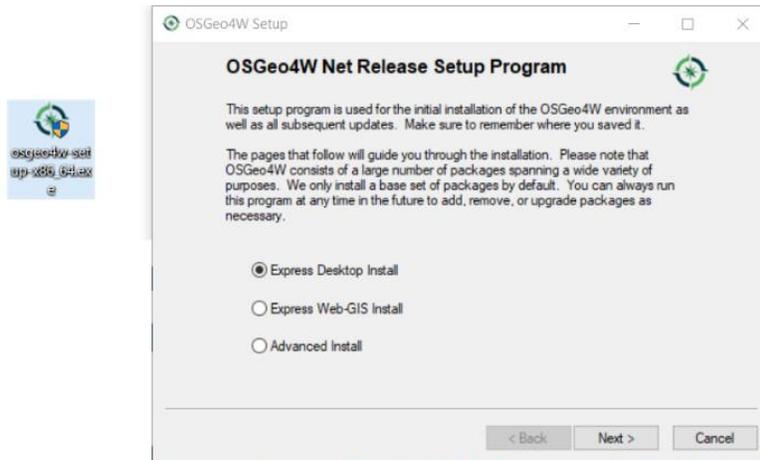
Installing QGIS

QGIS is free open source Geographic Information System (GIS) software, available for Windows, MacOS, and Linux operating systems. QGIS comes within a larger basket of apps – they are all part of what is called the OsGeo4W project. QGIS provides the capability to import and process DEMs derived from LiDAR.

Navigate to the downloads page on www.osgeo.org and select the network installer. If your operating system is 32 bit, you will need to use the 32 bit installer. If your operating system is 64 bit you have the option to choose both, but using the 64 bit version is a better option as it offers more computational power to you. If you're unsure, the packaging and installation disk or flash drive that came with your computer will have what bit system your computer has.



An installer icon should appear on the desktop. Click on it to bring the setup dialog box up and choose *Express Desktop Install*.



Next, from the list of download sites, choose *download.osgeo.org*

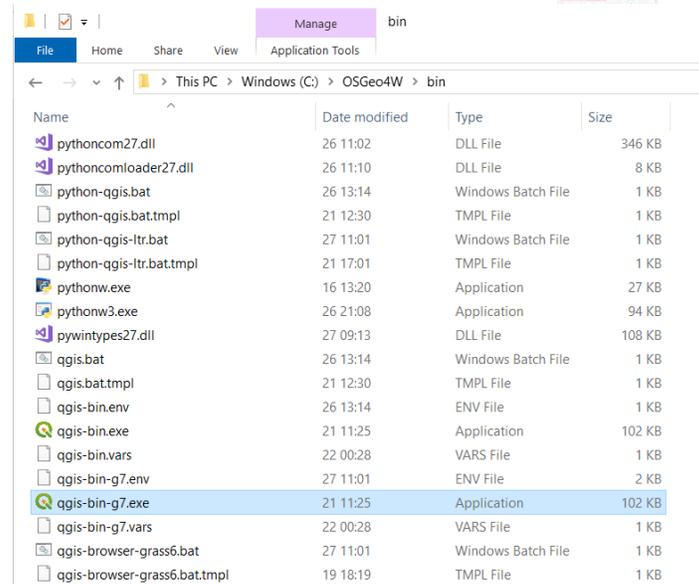
Next, a list of packages will appear – select all of them... and make sure that *QGIS*, *GDAL* and *GRASS GIS* are definitely checked off.

Now a warning should pop up informing that some dependencies are not met. Don't worry, this is fine...but make sure the check mark at the bottom is on to allow the installer to add packages that will patch everything up.

The last steps here are to fully integrate the QGIS environment into Windows Explorer so the file associations are set and everything runs smoothly.

Navigate to `C » OSGeo4W` and place any remaining shortcuts inside this folder. Now click on the `bin` folder and scroll down until you see *qgis-bin-g7.exe* and right click it. Make a shortcut and pin it on the start menu or taskbar.

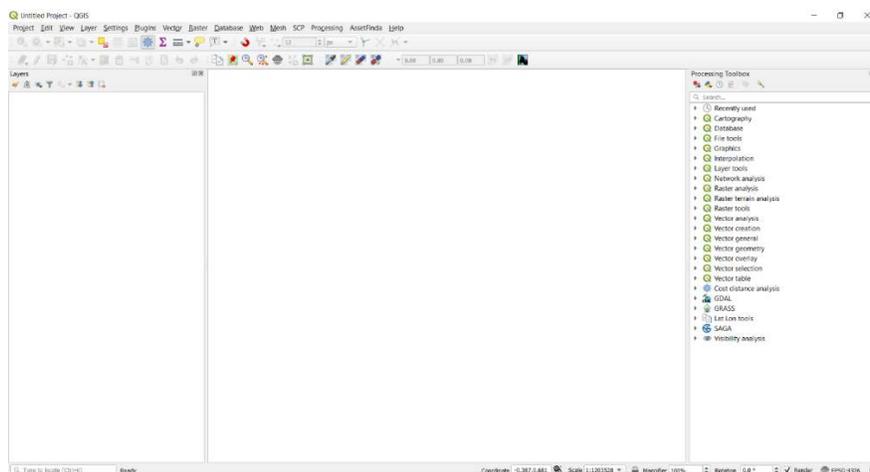
If there is an existing shortcut icon on the start menu, remove it and replace it with this new one to make things simple!



! Make sure you select the correct QGIS program, as there are two versions here. The standard *qgis-bin.exe* will have some tools missing (by design) and it is a simple quirk that is not super obvious later on when figuring out why some algorithms won't run.

It is critically important when working with GIS data that the filenames, and the entire file path has no spaces. The single best option to avoid this is using underscores_as_spaces and joinwordstogether as needed when creating files and folders in either Windows Explorer or in QGIS itself.

QGIS Interface and Basic Functions

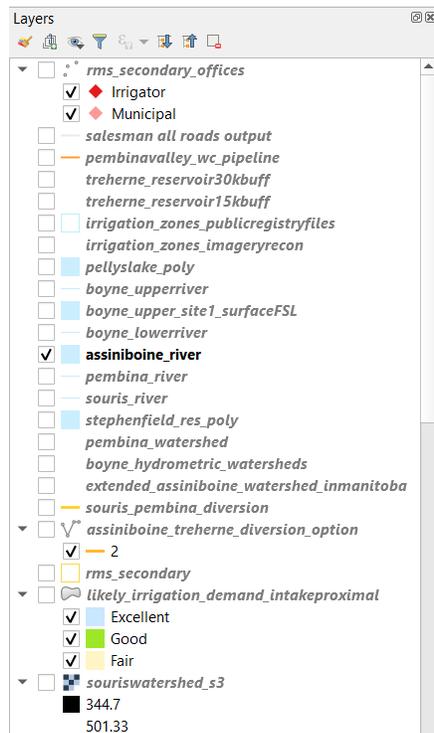


Pictured above is the QGIS interface when opening a new project. You'll see an array of panes and windows which hold information, tools and files. Let's go through each section here:

Layers list (left pane)

In the Layers list, you can see a collection of all the layers that you have connected into QGIS - this is similar to the list of layers you see in Photoshop. The drawing order moves from the topmost layer in the list to the bottom, so if you can't see a layer, move it upwards. You can toggle the layers on and off.

Expanding collapsed items will provide you with more information on the layer's current appearance. Right-clicking on a layer will give you a menu with lots of extra options such as opening the layer's properties or zooming to the layer.



Toolbars (top)

Similar to Microsoft Word and Excel, commonly used tools can be placed on a quick access toolbar. You can easily customize the toolbar to see only the tools you use most often via right clicking an area of empty space

Even if they are not visible on the toolbar, all of your tools will remain accessible via the menus.



Map Canvas (centre)

This is where the map itself is displayed, in the large centre area. All the layers that are visible will be drawn here depending on what location you've viewing and what your zoom level is.



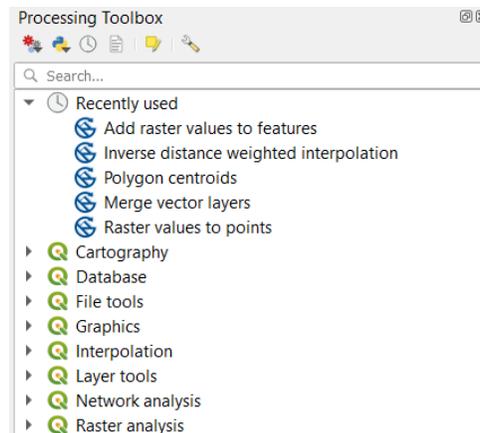
Status Bar (bottom)

This area allows you to adjust the map scale manually, verify georeferencing information and see the mouse's current geographic coordinates on screen.



Processing Toolbox (right pane)

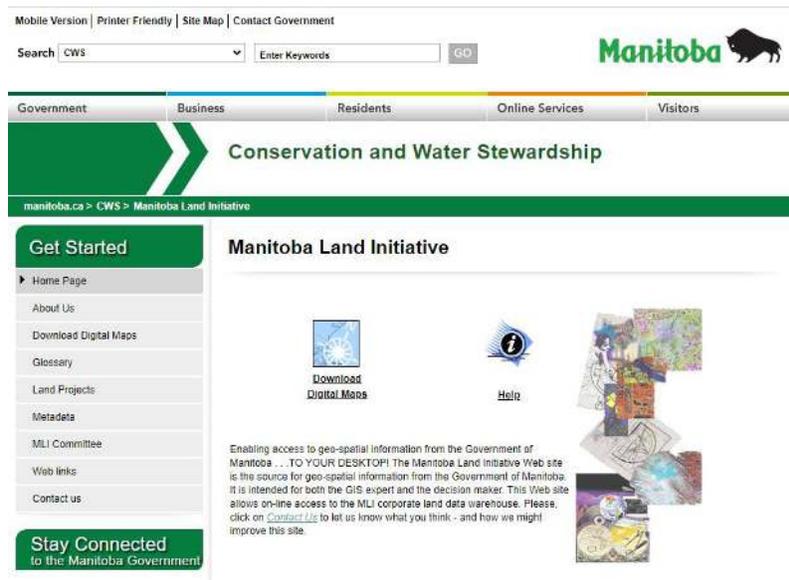
This area allows you to access a host of algorithms (computational operations) that process geospatial data. These will be discussed later.



Sourcing LiDAR for Manitoba

With support from the US Federal Emergency Management Agency, LiDAR was acquired for the US portion of the Red River Basin as a federal contribution to regional emergency preparedness in North Dakota and Minnesota in the aftermath of the 1997 Red River flood. Manitoba acquired some LiDAR at 5m resolution between 1999 and 2002 primarily along the main stem of the Red River, and utilized it for floodplain protection purposes. Since 2006, Manitoba has acquired LiDAR for much of southern Manitoba, generally at 1m resolution. The portion that is the Red River Basin was completed with the partnership of the Red River Basin Commission in 2020.

This LiDAR has been added to a valuable tax-funded public resource called the Manitoba Land Initiative, which is part of the Agriculture and Resource Development branch of the Manitoba Government. The site is easily searchable from Google, and the current website URL is: <https://mli2.gov.mb.ca>

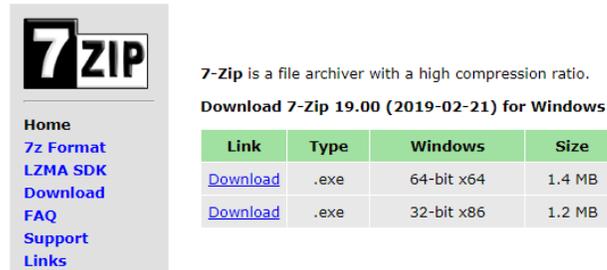


LiDAR datasets can be found under the Digital Elevation Models tab on the left side, which appear after clicking the ‘Download Maps’ button and accepting the disclaimer. At the bottom of the page that appears, there is a link called ‘LiDAR Various’ that points to a library of LiDAR datasets that are published as they become available. Shown below is an example piece.

Cooks Creek			
Cooks Creek LiDAR Raster	.GIF	metadata	DEM

For each publication, a graphic showing it’s extent on a sample map, a document showing technical specs and a link to the DEM are provided. In order to download any or all documents, click on the blue links.

Each Digital Elevation Model (DEM) file comes in a .zip folder, which are used to save space and reduce download time. The caveat is that it has to be unpacked, in order to be useable in QGIS. Several programs can do this but the one Strategic recommends is called 7-Zip.



7-ZIP

Home
 7z Format
 LZMA SDK
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 Links

7-Zip is a file archiver with a high compression ratio.

Download 7-Zip 19.00 (2019-02-21) for Windows:

Link	Type	Windows	Size
Download	.exe	64-bit x64	1.4 MB
Download	.exe	32-bit x86	1.2 MB

Inside the zip archive is the DEM, which will come in the form of a .tif file. TIF files are image files, similar to .jpg and .png, which can handle a large range of pixel values, deal with transparency easily and not be affected by modifications due to it being a lossless format.

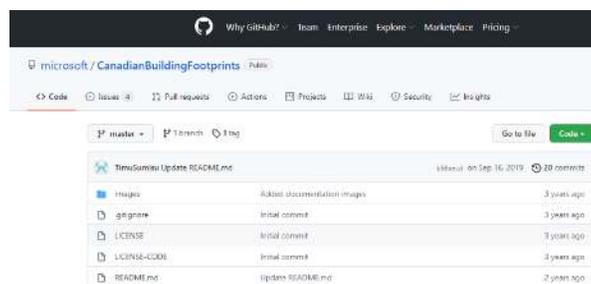
When unpacking files put them in a convenient location on your PC. Note that the file path can't contain spaces.

Once a .tif file is ready, it can be dragged and dropped into QGIS on-the-fly, just direct it to the 'layers' pane, which is on the left side by default. If all goes well, it will display and start loading.

Sourcing Building Data for Manitoba

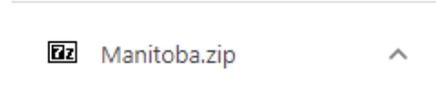
As part of an initiative to build a comprehensive geospatial inventory of building assets, Microsoft and Statistics Canada used satellite imagery and Artificial Intelligence (AI) techniques to derive building footprints across Canada, including Manitoba.

This can all be found on a code repository site called GitHub. The data can be found by searching "Canada Building Footprints Microsoft AI" and the URL is <https://github.com/Microsoft/CanadianBuildingFootprints>



In order to obtain the data, click on the link for Manitoba and a .zip file will begin downloading

Province/Territory	Number of Buildings	Unzipped MB
Alberta	1,777,439	389
British Columbia	1,359,628	301
Manitoba	632,982	135
New Brunswick	350,989	71
Newfoundland and Labrador	255,568	51



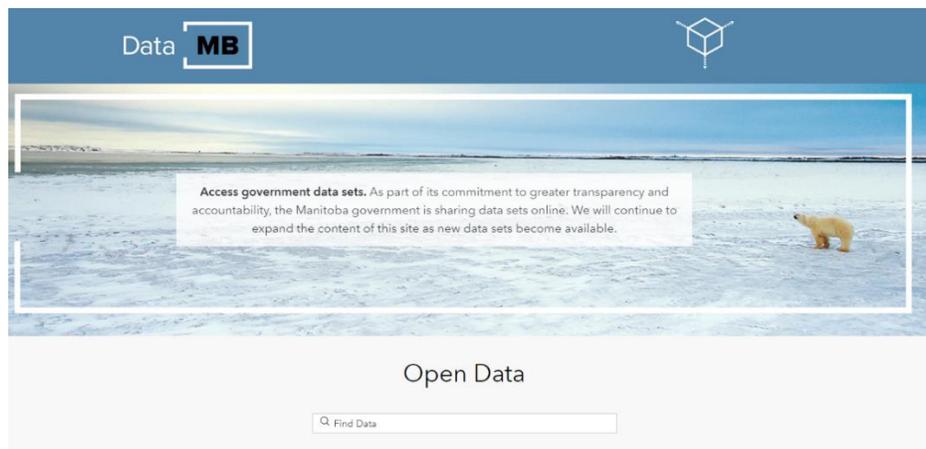
As before with the LiDAR data, the files inside the zip folder need to be extracted, so place them in a convenient location on your PC.

Instead of a gridded .tif file, inside this package is something called a geojson file. This essentially consists of a group of polygons - most of which being rectangles or whatever shape the buildings are located, which have ID's associated with them.

As with the .tif, the geojson can be dragged and dropped into QGIS on-the-fly, just direct it to the 'layers' pane, which is on the left side by default. If all goes well, it will display and start loading.

Sourcing Roll / Parcel Data for Manitoba

The Manitoba Government keeps records of the legal land parcel fabric, along with property values throughout the province (excluding Winnipeg, which has it's own survey records). The data is available on the province's GeoPortal, in which the URL is <https://geoportal.gov.mb.ca/datasets/manitoba-property-assessment-information/explore>



In order to use the data, click the ‘view full details’ button on the left pane. Then click on the ‘download’ button, and finally select ‘shapefile’ on the left.

As before, the data comes in the form of a .zip file, which the files inside will need to be extracted. Place all files in a convenient location on your PC. The Shapefile is officially the file with the .shp extension, but the others are needed to fully use and render the data in QGIS. Pictured below is an example shapefile of land parcels in a neighborhood (pink borders and transparent fill).



Due to the large number of features, it may take a while to render them all when dragged into QGIS. When doing any detailed examination, it’s better to zoom way in, so less need to be loaded.

Both jeojson and shapefiles fall under a second data class called *vector* data. Data of this type is derived from equations, has a pen-stroke appearance and always has a corresponding relational database associated with it for each feature. There are three subtypes of vector data which influence the type of data that can be collected and analyzed.

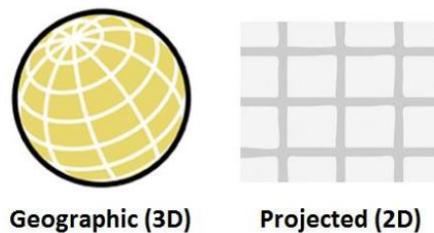
- Point – Commonly used for trees, stations, towers, markers
- Line – Commonly used for roads, waterways, utilities
- Polygon – Commonly used for buildings, land parcels, soil survey areas, forests, waterbodies



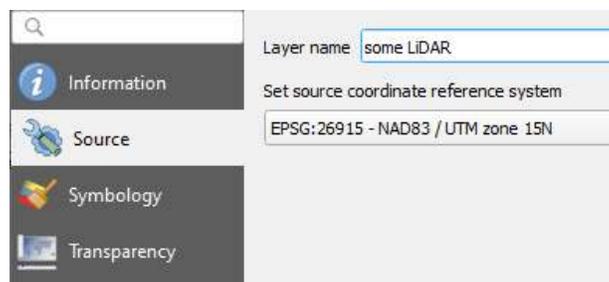
Importing LiDAR into QGIS

In order to work with the LiDAR downloaded in previous steps, it needs to be imported first. A crucial concept with spatial data is the spatial element of it, which is referred to as georeferencing.

The mathematics behind geographics are complex, but it essentially involves representing real-world locations on surface of the earth, which is approximately a sphere – an *oblate spheroid* to be precise – to locations on a flat map. To deal with this conversion, which is never perfect, a large number of map projections exist, which attempt to georeference data with most accuracy possible.

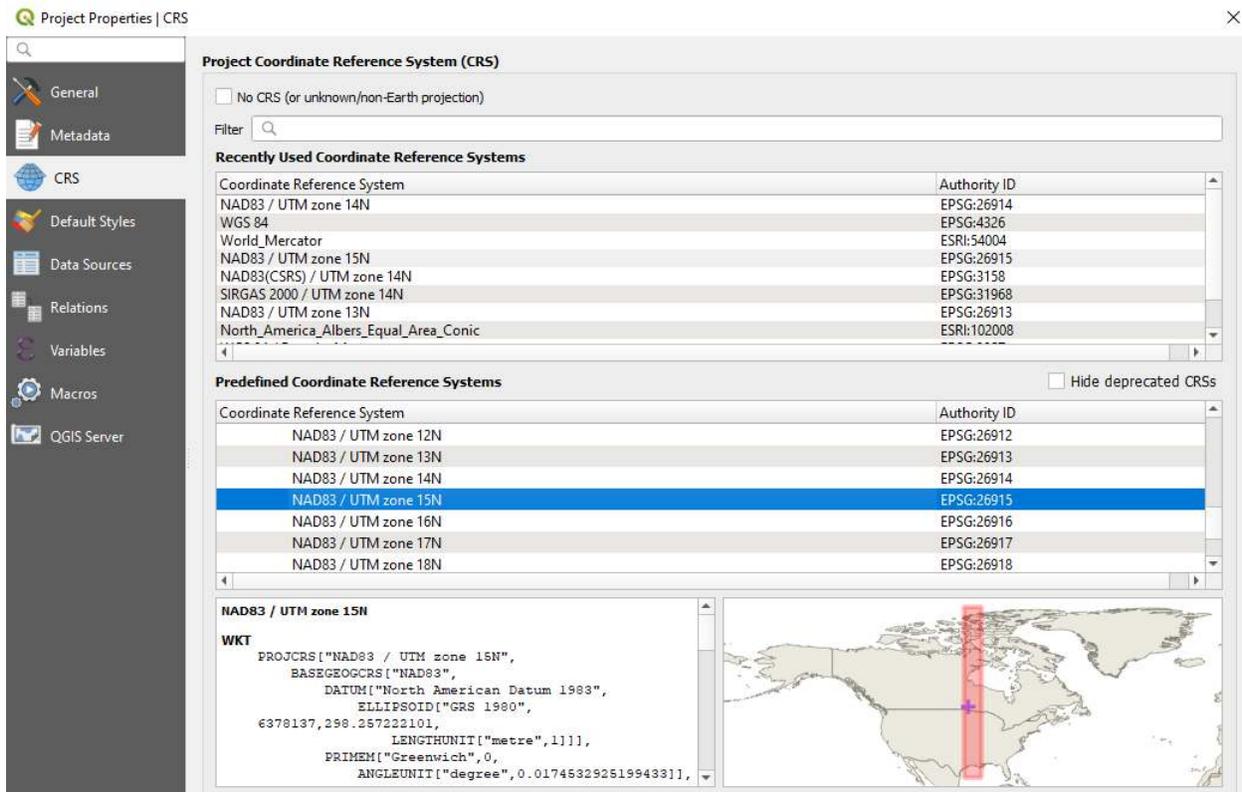


Importing a dataset is as easy as dragging and dropping the .tif file into the layers list on the left pane, where it will load and then display when done. If nothing displays on screen or data appears in the wrong location, that means there is some kind of issue with the data. Most often, the error is a georeferencing one, in which the math is incorrect. Many LiDAR pieces from the MLI and from elsewhere are able to be shown without issue, but the first thing to do is to check the georeferencing. To do this, right click on the layer on the left pane and select ‘properties’.



Under the source tab, select the reference system that the LiDAR was acquired in. Each dataset on the MLI has a metadata document which will specify this. The easiest way to determine the proper reference system is to look at what numerical id is used, which is called the EPSG code.

Secondly, on the bottom bar of QGIS on the right hand side lies the QGIS project spatial reference system, which is beside the  CRS icon. This controls which 2D projection is displayed on screen, since there can only be one at a given time. It should match that of the LiDAR piece that already has been imported. Note that QGIS usually sets these automatically when dragging a LiDAR dataset onto a blank project.



The LiDAR by default looks like a greyscale image, having darker and lighter areas which represent lower and higher elevations respectively.



Inspecting LiDAR for Quality Assurance

The next step is to confirm that the data itself makes sense and passes the ‘sniff test’. The approximate elevation of the area should be known beforehand, so the min and max values of the dataset area are reasonable. The pixel size should match the metadata, which in most cases from the MLI, is 1m by 1m.

These figures can be found through the information tab in the layer’s properties.

Layer Properties - some LiDAR | Information

Information from provider

Name	some LiDAR
Path	D:\Dropbox\
CRS	EPSG:26915 - NAD83 / UTM zone 15N - Projected
Extent	331475.2555048230569810,5390391.5148407900705934 : 789030.9925982932327315,5712438.7394551374018192
Unit	meters
Width	15198
Height	10697
Data type	Float32 - Thirty two bit floating point
GDAL Driver Description	GTiff
GDAL Driver Metadata	GeoTIFF
Dataset Description	D:/Dropbox/StrategicGIS/
Compression	
Band 1	<ul style="list-style-type: none"> • STATISTICS_APPROXIMATE=YES • STATISTICS_MAXIMUM=572.33544921875 • STATISTICS_MEAN=394.95346531718 • STATISTICS_MINIMUM=254.28910827637 • STATISTICS_STDDEV=45.195926348207 • STATISTICS_VALID_PERCENT=99.94
More information	<ul style="list-style-type: none"> • AREA_OR_POINT=Area
Dimensions	X: 15198 Y: 10697 Bands: 1
Origin	331475,5,71244e+06
Pixel Size	30.10631248147586447,-30.10631248147586447

Another figure to check is the *nodata* value for the dataset. Nodata is a special flag assigned to a single value in gridded data, which tells QGIS (or other programs) to effectively ignore pixels with that value and draw it as transparent on the map. This is usually a large negative number such as $-3.40282e+38$ or -9999 , which guarantees it won’t interfere with analysis. If the nodata value is not what it should be, a perimeter of pixels in the grid will be counted in the min to max range and will be for all intents and purposes, useless – it will have to be fixed using geoprocessing tools before moving on.

The nodata value can be checked under the ‘transparency’ tab on the left in the properties.



Lastly, a visual inspection can be done by zooming in and examining features to see if they make sense. The  identify tool can be used to tell the exact values upon clicking on a pixel to cross reference an area.

A basic water resources planning tool that be used in everyday analysis is the virtual application of a water plane, which can show which areas will likely be above and below the water line, whether the location is along a river or in a field depression. This isn't a perfect method but shows general risk.

Using the QGIS Raster Calculator

A very powerful tool in itself, the  *raster calculator* lets you manipulate data by performing mathematical operations on each LiDAR pixels value. Calculations are quite quick, with millions of cells being able to be processed in a short amount of time! Open the raster calculator from the **Raster** menu. All rasters that are currently in the layer list will appear here in the space on the left, and the number after the 'at' symbol refers to the band number.

The way the calculator works is that an *expression* has to be supplied, where it will go over each pixel in the grid one by one applying it as it goes. Expressions can be simple or complex, but they have to follow what is called *syntax* – 'grammatical' rules of code in order to be carried out correctly.

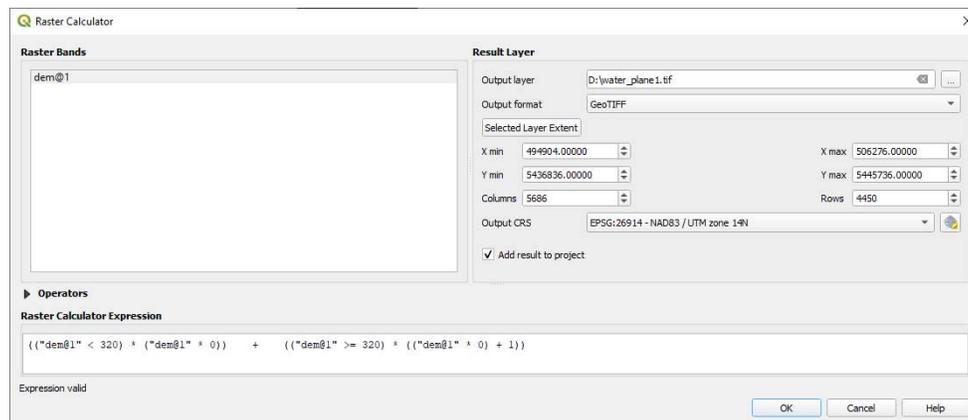
A simple way of calculating flood risk is using a flat plane representing the water's surface during a flooding event. The calculator can be used to create what's called a mask – this mask will show areas underneath the plane elevation and those above it.

The operation to do this is to assign two values to the output mask – 0 and 1 representing below and above the plane respectively. Using an example, the calculator expression would be done as follows:

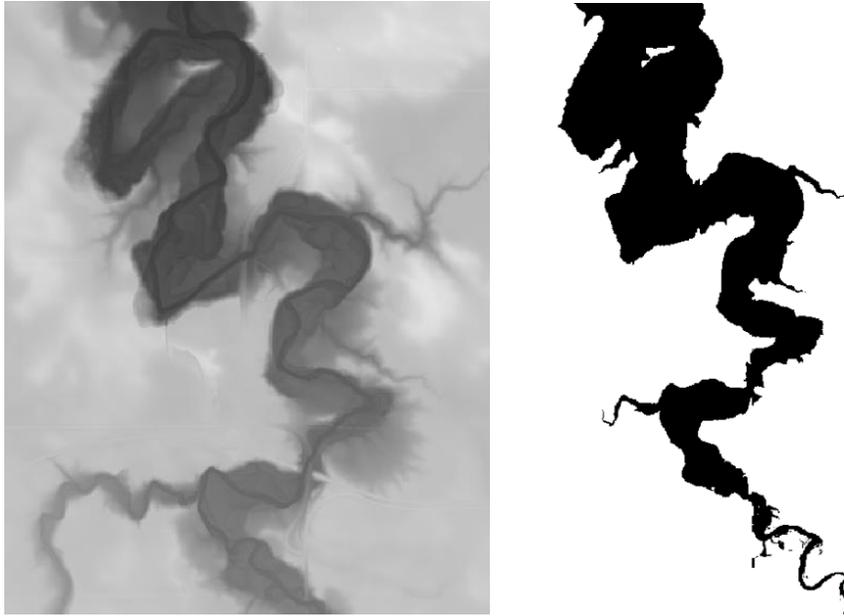
$$(("dem@1" <= 320) * ("dem@1" * 0)) + (("dem@1" > 320) * (("dem@1" * 0) + 1))$$

Targeting values in the dem that are below 320, and multiply them by 0

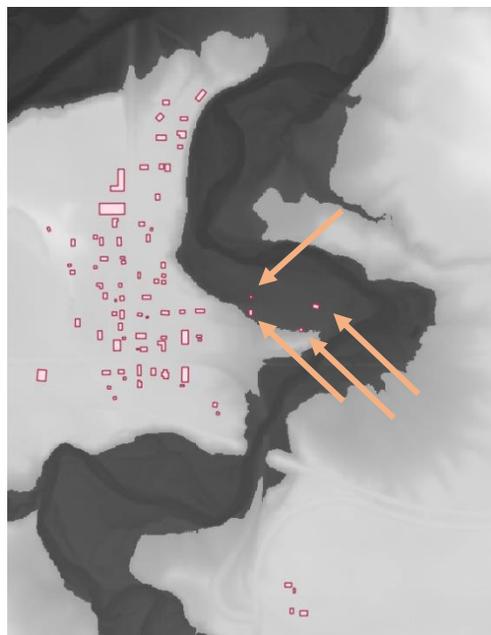
Additionally: targeting values above 320 in the dem, turn those pixels to equal 1



The output, by default, is displayed as a purely black and white grid. Using styling options, this can be changed to more accurately depict visual features such as water and green terrain.



Pictured above is a river valley with surrounding farmland – the left being the DEM and the right being the newly made mask. The DEM on the left has lightness corresponding to elevation – higher is lighter, and the mask on the right shows black as below the elevation cut-off (320 in this example) and white as above it.



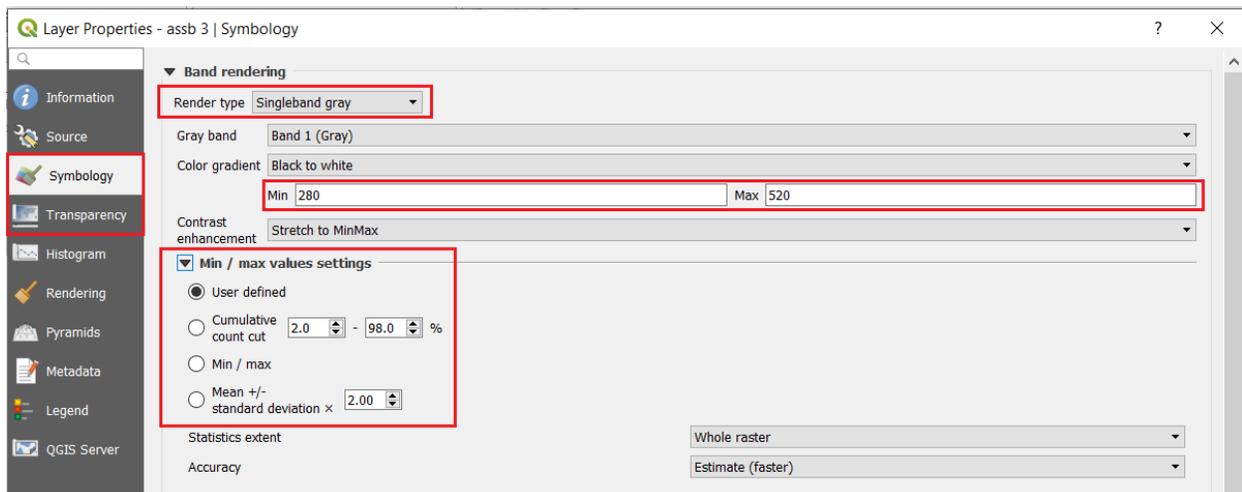
Here is the sample area with the flood masking applied to it by being overlain (semi-transparent at 50%) on top of the DEM, with buildings placed on it. What this significantly darker area here represents is the area of higher risk from flood inundation if the water level reached the elevation of the mask. The four buildings here would fall under this high risk zone.

Symbolizing Layers

QGIS maps and visuals would look bland and be completely uninformative without applying a sensible color and labeling scheme. Often the default randomly assigned symbology can be cumbersome to visually deal with not only for presentation purposes, but also for simply working with the data - especially with complex polygons!

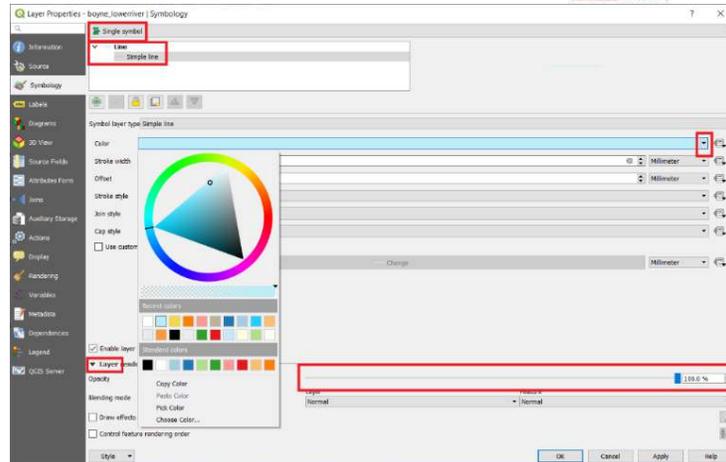
LiDAR and other gridded data

Raster data can be rendered in different coloured palettes. Greyscales can be shifted, and bands can be coloured differently. To change your raster, open its *properties* and hit  *symbology* on the left tab. The  *transparency* control is on a separate tab below it here, unlike for a vector layer.



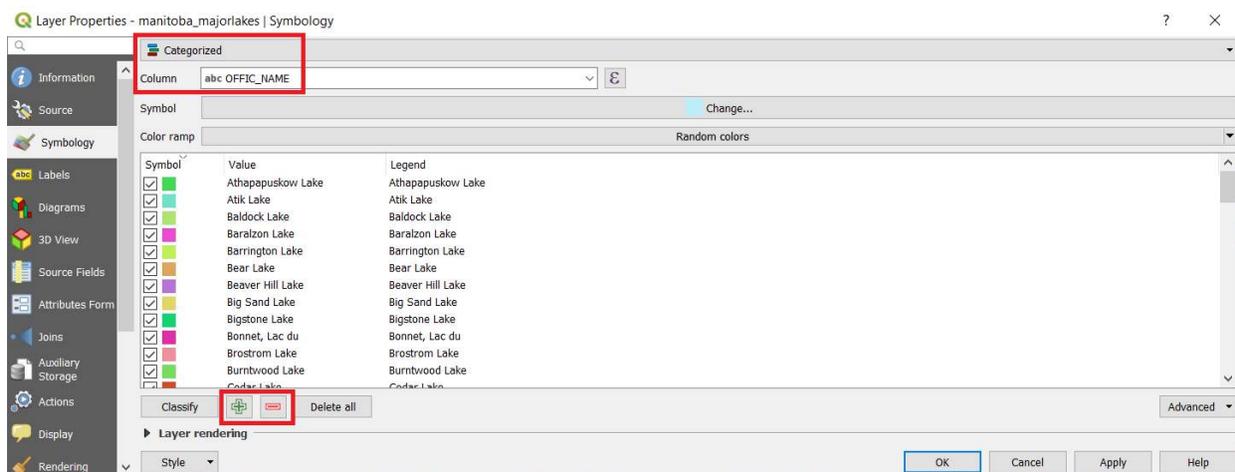
Vector based data such as the buildings

Select the file you want to re-colour and open its properties. Do this via right clicking the layer in the left layers menu and hitting *properties*. On the left tab select  *symbology* to see the colour palette and display options.



Most often, simple quick tweaks can be done in this menu. The visual can be done either as a single colour or on a gradient based on a text or numeric value from the layer's attribute data. In using gradients, you can use any colour and outlines for fields and their values.

When you have a field selected, and a colour ramp chosen, hit *classify* to populate the table. You can leave the entries as is or change individual entries. When customizing an entry, click the colour bar for the *ramp* or *swatch* and click the arrow for the wheel. As with other image, spreadsheet and document programs, you can *pick* colours and save custom ones for later use.

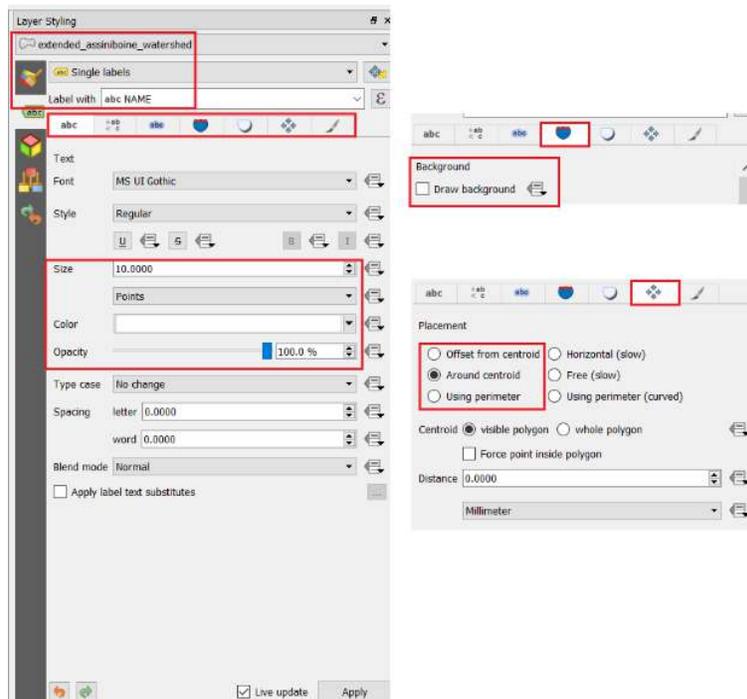


You can **+** *add* and **-** *remove* entries too, so you can show only the values you want to display. The *value* is the value in the attribute table to represent – the *legend* is the text that shows up on the left in the layers list, which can be whatever text you want. If a value isn't represented in the symbol list, it's shown as completely transparent.

Labelling Layers

Simple labels can also be added for easy identification of features during and after making a map. Labels are applicable to vector files only.

To label your layer, pull up the labelling toolbar by right-clicking on the top area. Now hit the  *label* button to pull up a separate window with labelling tools. Alternatively, you can click this tab in the layer properties.



Here you will be able to tell QGIS which field you want to symbolize, and its colour + location on the map. Alternatively for simple labelling work after publishing a map, other programs such as Photoshop, Gimp and MS Paint can be used. In any case, play around and see which placement option works the best for you.

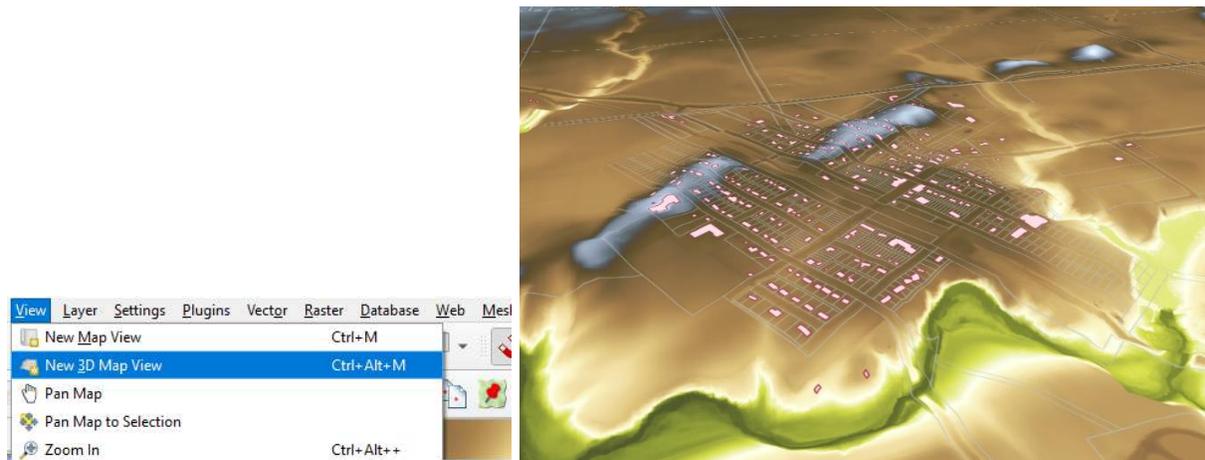


Here is an illustration of a town, with buildings, land parcels and DEM data showing how symbology can drastically change the visuals on a map. When vector layers are added they are given a random colour and are opaque - or in the case of raster data, they are greyscale. Note that the DEM is hidden in the before picture on the left.

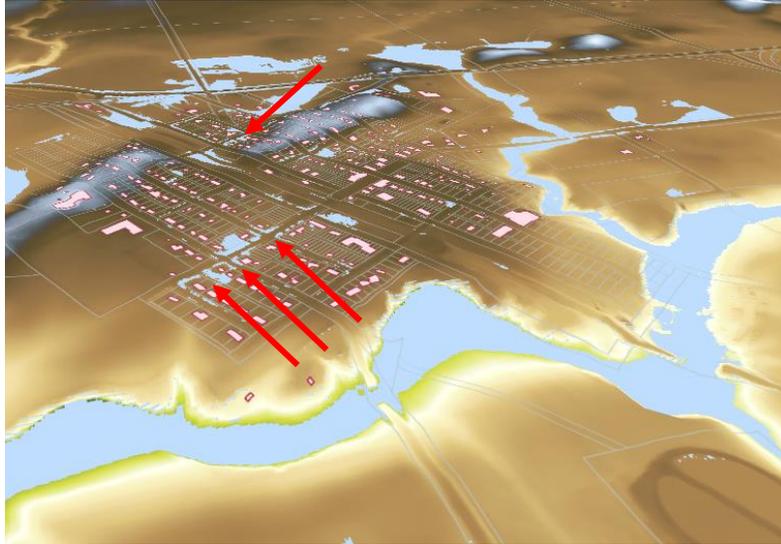
Using the 3D Viewer

QGIS has a built in 3D viewer, which works well in showcasing elevation differences for a given area from an aerial view. To access it, click the **View** menu item and then hit *New 3D Map View*. The layers that you see on the regular map, will appear in the 3D viewport as well. You can resize and move the viewport to a more convenient location if you wish.

Under the settings, which shows at the top as a wrench icon, you can tell QGIS to use the DEM as the elevation, and set a vertical exaggeration factor (use between 1 and 14) to use. If the screen appears blank, you can use the mouse wheel to zoom out until your layers appear. You can rotate the camera by holding down the shift button while dragging the mouse around. To take a screenshot, click the picture icon.



Shown here is the graphic from above in the 3D viewer, with a small vertical exaggeration applied.



Here is the same 3D scene with a blue mask layer added, where several buildings appear in the flood risk zone.

Publishing A Map

After labelling and symbolizing are completed to your satisfaction, a mapping product can be created. First zoom and pan over to the extent you wish to show. Then once everything is in frame, hit the [Project](#) menu item, then *Import / Export > Export Map to Image* options. A menu will pop up with some settings – leave them as they are, with the exception of DPI, which can be increased to 300 if you want a hi-res image.

A ‘Save As’ window will appear where you can save the file. Once done the map product will be published.

Conclusion

LiDAR is an incredibly useful and affordable way to obtain elevation details on the landscape which was not feasible or even possible in the past. LiDAR is a game changer for being able to model fluvial and pluvial flood risk across vast domains, and the increased computational availability will make this easier as the years go on.

This section discussed basic operations with LiDAR, however in future publications, more in depth techniques and tools will be shown in order to more accurately provide estimations for:

- benefits, costs and risks of flood inundation and drought for every area of each land parcel
- detailed water retention storage and flow pathing from algorithms
- more detailed estimations of hydrological balance, given soil, temperature and vegetation cover

LiDAR will undoubtedly be ever more useful in the years ahead, and the increasing availability of it will help drive more jurisdictions to be able to use it in order to make sensible, informed decisions on how to mitigate risk and make climate-focused preparations.

This combined video series and manual was developed by the Red River Basin Commission and completed with the help of Strategic Systems Engineering. The focus is to assist and help develop user-friendly resources so that First Nations/Indigenous communities, Municipalities, and Counties can operate more efficiently and better adapt themselves for future weather events, whether that be flood, drought, or other climate adaptation needs.

It is our hope that this is the beginning of a series of manuals which will guide the user from the beginning stages to an advanced user level.

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