QGIS and Open Data for Hydrological Applications – Exercise Manual



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1 Preface

A Geographic Information System (GIS) can be a useful tool for preparing the input of models and tools. Furthermore, in this era of Open Data ample open access data is available that can easily be retrieved from the internet and integrated in open source desktop GIS software, such as QGIS.

These exercises will guide you through different steps that are needed to preprocess data to be used in models and tools. In the first exercise you will learn how to register a scanned topographic map and use it as a backdrop for digitizing vector data. In the second exercise you will learn how to import data from spreadsheets into a GIS and to use it to join tables, manipulate the attribute table and interpolating the data to a continuous raster layer. In the third exercise you will download open access data from OpenStreetMap and use it for further analysis and conversion. The geodatabase will also be introduced in this exercise. In the fourth exercise you will use map algebra for spatial planning. Finally, you will learn how to delineate catchments and streams form digital elevation models and to present them in maps or in an interactive webpage.

The exercises have been developed for different MSc programmes at IHE Delft and tailor made trainings in Uganda, financed by the Vitens Evides International (VEI) fund. I would like to thank Jan Hoogendoorn and Jonne Kleijer, GIS experts from VEI, for their contribution to these exercises. The Adjumani dataset was developed by VEI and the National Water and Sewerage Corporation (NWSC) in Uganda. I'm thankful for their permission to use the dataset for educational purposes.

In the near future we will further update the exercises and distribute it as Open CourseWare so the whole community can use the course materials.

2 Introduction

2.1 Learning objectives

After following this step-by-step tutorial you will be able to:

- Use QGIS in its main functionalities, also in conjunction with plugins
- Digitize features from a scanned map or satellite image
- Import tabular data in a GIS
- Do simple vector analysis
- Interpolate point data
- Convert vector and raster data
- Reproject vector and raster data
- Use map algebra
- Use online data
- Perform catchment and stream delineation

2.2 Software requirements

During the next exercises we will make use of the following software:

- QGIS ver 3.4 (Madeira) or higher,
- Google Earth,
- Firefox Mozilla
- MS Excel or OpenOffice Calc

You need an internet connection to download plugins or to use the open access data.

2.3 **Preparation**

Please note that QGIS is already installed on the laptops of IHE Delft participants. Please do not change the version and skip this section. The exercises have been tested for QGIS 3.4.

- 1) Download QGIS from http://www.qgis.org/en/site/forusers/download.html
- 2) Install QGIS
- 3) Install the exercise data from http://ocw.unesco-ihe.org

2.4 Convention

Throughout this guide we have used three different fonts according to what kind of operation we wanted to point at:

- Calibri, is used for the main text
- Times New Roman, Italic, is used to identify software commands
- Courier New is used for text input, that is text that you have to write in the software, or for file names

3 Getting familiar with QGIS

3.1 Start QGIS 3

You can start QGIS 3 Desktop by looking for it in the Start menu or using the search function. Make sure you open the **QGIS Desktop with Grass** in order to have all functionality we need.



3.2 The screen

Like many commercial GIS also QGIS has a "traditional" GIS layout.

It is made of the <u>Standard System Menu</u> or <u>Main Menu</u> (we will refer to Main Menu in the following pages) which is always on the top of the software's window, of standard <u>toolbars</u> like the Zoom Tools, or others that can be activated clicking in the Main Menu *View* and then *Toolbars*.

On the left hand side there is the <u>Table of Content</u> (<u>Layers list</u>) area, where all the layers displayed are shown. To the left of this space there is a vertical toolbar, the <u>Manage Layers</u> toolbar.

In the centre of the window is the Map Canvas, where all maps will be displayed.

More information about the QGIS Graphical User Interface can be found here: <u>http://docs.qgis.org/2.18/en/docs/user_manual/introduction/qgis_gui.html</u>



Exercise 1: Digitizing from a scanned map

4 Digitizing from a scanned map

4.1 Introduction

In order to use hardcopy maps in a GIS, they need to be scanned and georeferenced. Georeferencing is also needed for raw remote sensing images, such as aerial photographs and satellite images.

For the best result, choose a map sheet that is clean and does not have too many folds. Use a scanner that is large enough to scan the whole map. The resolution of the scanner should be large enough (e.g. 1200 dpi) to have enough detail in the resulting raster maps.

For georeferencing we need to link locations on the scanned image to coordinates. There are two ways:

- 1. Collect ground control points (GCPs) at locations that are clearly visible in the image, such as bridges and junctions.
- 2. If the hardcopy map contains a coordinate grid, you can use the printed grid as a reference. Make sure that you know the projection of this grid, which usually is stated on the map.

In this exercise we will use a scanned map of Mount Marcy (USGS, 1979)

(Mount_Marcy_New_York_USGS_topo_map_1979.JPG), which we will georeference with the coordinate grid printed on the map. You can find the data (Data Exercise 1) on the OpenCourseWare website (<u>http://ocw.unesco-ihe.org/course/view.php?id=11</u>). Save the map on your hard drive (e.g.

D:\QGIS_Exercises\Exercise_1\Mount_Marcy_New_York_USGS_topo_map_1979
.JPG

4.2 Choosing the projection

Have a look at the scanned map and try to find the projection that has been used. You can use any image viewing software for this. Which projection was used? Look for the EPSG code in http://www.spatialreference.org and write it down.

4.3 Enable the Georeferencer GDAL plugin

The *Georeferencer GDAL plugin* is a core plugin, which means that it is already installed. In order to use it, you need to activate it. This works as follows:

- 1. In the main menu go to *Plugins* \rightarrow *Manage and install plugins*...
- 2. Search for *Georeferencer GDAL* and check the box
- 3. Click *Close* to close the dialogue

🔇 Plugins All (275)					?	×
al 👔	Q geor					
Installed	Another DXF Importer / DXF2Shape Converter	This is a core plug	in, s o you can't	uninstall it	t	
Not installed	Georeferencer GDAL	Georefer	encer G	DAL		
🞾 Upgradeable	QWeather RiverGIS	Georeferencing	g rasters usi	ng GDAL		
誉 New	s Video Uav Tracker	Category	Raster			
📕 Invalid		Installed version	Version 3.1.9			
🥼 Install from ZIP		4				F
🔅 Settings		Upgrade All	Uninstall Plugin	Reinsta	ll plugin	
				Close	He	elp

4.4 Importing the scanned map into the Georeference GDAL plugin

- 1. From the main menu choose *Raster* \rightarrow *Georeferencer*...
- 2. Click the Open Raster button
- 3. Browse to the Mount Marcy New York USGS topo map 1979.JPG file
- 4. A window will open where you have to specify the *Coordinate Reference System (CRS)* of this input map. It does not yet have a CRS, so you can click *Cancel*.

4.5 Setting the transformation parameters

First we have to set the transformation settings (see also screenshot on next page).

- 1. In the menu choose *Settings* \rightarrow *Transformation Settings*...
- 2. Here you can choose:
 - a. Different transformation types. A simple linear transformation can be used if the map is not much deformed. The other ones can be tried when more deformation exists. We will start with a linear transformation.
 - b. Resampling method: if you need the pixel values in further calculations, it is best to choose the nearest neighbour option. This resampling method will preserve as much as possible the original pixel values by choosing the nearest one. Visually, however, this method results in a "blocky" map. If the purpose is only for visual use, for example as a backdrop for digitization of vector layers, then it is better to choose another resampling method. Here we will use the cubic method, which uses the average of the 4 nearest pixels.
 - c. Target SRS: here choose the code that you have noted before; EPSG: 26718. You can choose it by clicking and using typing 26718 in the filter field.

Browse to the folder where you want to save the georeferenced map. The tool automatically adds _modified to the file name. So in our case the georeferenced file will be named D:\QGIS_Exercises\Exercise_1\Mount_Marcy_New_York_USGS_topo_map _1979_modified.tif

Keep the other settings on default and check the box *Load in QGIS when done*. The dialogue should look like the one below.

Q Transformation Settings		?	×
Transformation parameters			
Transformation type			•
Resampling method Cubic			•
Target SRS EPSG:26718 - NAD27 / UTM zone 18N	I	•	
Output settings			
Output raster D:/QGIS_Exercises/Exercise_1/Mount_Marc	y_New_York_USGS_topo_map_1979_modified.tif		
Compression None			•
Create world file only (linear transforms)			
Use 0 for transparency when needed			
Set target resolution			
Horizontal	0.00000	:	*
Vertical	-1.00000		*
Reports			
Generate PDF map			
Generate PDF report			
✓ Load in QGIS when done			
	OK Cancel	He	lp

4.6 Adding Ground Control Points (GCPs)

In order to link the file coordinates to real world coordinates, we need to indicate Ground Control Points (GCPs) with known coordinates. We can derive these coordinates in different ways:

- The easiest way is to use the coordinate grid on the scanned map if this is available and if it is in a known projection. We click on a node in the grid and type the corresponding X and Y coordinates in the dialogue.
- Using a reference map in the QGIS map canvas that has already been georeferenced. In this way we can obtain the right coordinates by clicking on the reference map.
- Using GCPs that were measured in the field using a GPS.

Here we will use the coordinate grid that is printed on the map.

- 1. Zoom in on the node with coordinate 581000 East and 4885000 North.
- 2. Click the Add Point button \ge to add a GCP.

3. Enter the map coordinates in the pop-up window:



If you have a reference map in the QGIS map canvas, you can use the From map canvas button to capture the coordinate and perform an image to image georeferencing. Here we will only type the coordinates form the map grid.

4. Press OK. Now your screen should look like this:



The red dot is the location that you have referenced. In the table below the map, you can see the Source X and Source Y coordinates. These are the unreferenced file coordinates. Their values depend on which pixel you clicked for placing the GCP, so it can differ from the screenshot above. Dest. X and Dest. Y show the real world coordinates that you have linked to this location. The other fields of the table have to do with estimated accuracy and will be filled in after adding more points.

5. Let's choose a second GCP in the upper right corner of the map and proceed in a similar way as with the first GCP. Your screen should look like this:



You can see that some error statistics have been calculated. With only two points this does not make much sense. The minimum amount of GCPs for a linear transformation should be 4.

6. Add in a similar way a GCP in the lower left and the lower right corner of the map. If you

made a mistake you can remove the GCP by using the *Delete point* button ^{SON}. Your screen should look like this:



At the bottom of the screen you can see the estimated mean error (40.2829 pixels in our case). The error is also visualized at the GCPs using a red line. Obviously your values will not be exactly the same.

There are two ways to reduce the error:

- a. Use the button (move GCP point) to place the GCPs really at the nodes where the grid lines cross. You need to zoom in to select the right pixel. Note that the mean error is not automatically updated. You need to change the transformation type to something else and then back.
- b. If option a. doesn't reduce the error, we can change the transformation type. If we change to another transformation type in the transformation settings, the error values will be recalculated.

We'll apply option b.

- 7. In the menu go again to Settings → Transformation Settings... and now let's select a 1st order polynomial (Polyniomial 1) instead of the linear transformation. Keep the rest as it was. Click OK to return to the GCP table. Now you can see that the mean error has been reduced to a fraction of a pixel, which is acceptable. If you don't see a mean error < 1 pixel, than you have to check the GCP locations and correct them.</p>
- 8. Now we can start georeferencing using the button. After some calculation time the georeferenced map appears in the QGIS map canvas. You can close the Georeferencing plugin. It will ask if you want to save your GCPs. You can click *Discard* if you don't want to use them. If you save them, you can load them again in the Georeferencing plugin.
- 9. In order to verify the result you can use the Coordinate Capture plugin. If it is not activated yet you can do it by choosing from the menu: *Plugins* → *Manage and Install Plugins*... . Then search for the *Coordinate Capture plugin* and check the box to activate and click *Close*:

🔇 Plugins All (275)		? ×
i All	Q coord	(a)
	 Azimuth and Distance Calculator CoordGuesser 	This is a core plugin, so you can't uninstall it
Not installed	Coordinate Capture	Coordinate Capture
😕 Upgradeable	Geo2Local SICSM NTv2 Transformer	Capture mouse coordinates in different CRS
Invalid	 Indicatrix mapper Lat Lon Tools RiverMetrics 	Category Vector
🥼 Install from ZIP	 zoomtopaste 	Installed version Version 0.1
🔆 Settings		4)
		Upgrade All Uninstall Plugin Reinstall plugin
		Close Help

10. A panel has appeared under the layers list. Here you click on *Start capture*. Click on a grid node in the map and the coordinates are displayed in the panel:

Coordin	nate Capture	8	×
\bigcirc	-73.98733,44.11572		
	581001.719,4885001	306	5
8	Copy to Clipboard		
	- Start capture		

The first field shows the coordinates in the Geographic Reference System (Lat/Lon coordinates), the second field shows the coordinates in the projection of the project. Read the coordinates from the side of the map and verify if they are correct.

Another way to verify the result is to use the web maps as a backdrop. The *QuickMapServices* plugin provides easy access to many web maps such as Google satellite and OpenStreetMap.

- 11. If not yet installed, install the *QuickMapServices* plugin: in the main menu choose *Plugins* → *Manage and Install Plugins*... and search for the *QuickMapServices* plugin and install.
- 12. After installing, choose from the main menu $Web \rightarrow QuickMapServices \ plugin \rightarrow Settings$
- 13. Now choose the *More services* tab and click *Get contributed pack*. Click Save when the <u>contributed pack is installed</u>. This will give you access to many more useful web maps.

Q QuickMapServices Settings		×
General Tiles Add\Edit\Remove Visibility More s	services	
Attention!		
Contributed services definitions are provided 'as is' and are validated by plugin authors. These are proof-of-concept ar testing only. Visit <u>https://github.com/nextgis/ guickmapservices_contrib</u> to add new services. Use at your risk!	r ovn	
Get contributed pack		
Save	Cance	3

- 14. Go back to the main menu and choose $Web \rightarrow QuickMapServices plugin$ and try some of the options.
- 15. This is a good moment to save your QGIS project (. qgz file). Choose from the main menu *Project* \rightarrow *Save as...* and save it as

D:\QGIS Exercises\Exercise 1\Exercise 1.qgz.

The project file contains references to all layers, styles, projections, extent and zoom level of the Map Canvas. Save your project regularly!

4.7 Digitizing vector layers from a georeferenced backdrop

Our georeferenced scanned map can now be used as a backdrop to digitize vector layers. Vectors can be points, (poly)lines or polygons. In this exercise we are going to digitize:

- Mountain tops as points
- Rivers as (poly)lines
- Lakes as polygons

We will create these vector layers in a GeoPackage spatial database. In that way we have all layers together in one file, instead of using separate shapefiles.

The following steps guide you through the process.

First we have to create an empty shapefile. In the main menu select Layer → Create Layer
 → New GeoPackage Layer...



2. In the *New GeoPackage Layer* dialogue we first select the Database filename by

- Create a new field with the Name Elevation, Type Decimal number (real) and click Add to fields list
- 4. Click OK.
- 5. The empty layer has now been added to your layers list.

	ige Layer			?	×
Database		ises\Evercise 1\Mo	upt Marcy apka	-63	-
	D. QOD_EXERC	Bes (Exercise_1 (Ho	апс_магсу.урку	····	
l'able name	Peaks				
Geometry type	° Point			•	
	🗆 Include Z din	nension 🗔 Includ	e M values		
	EPSG:26718 - 1	NAD27 / UTM zone	18N	- 🌚	
New field	,				
Name					
Туре	1.2 Decimal	number (real)		<u> </u>	
March 1997	ath				
Maximum leng	gui j				
Maximum ieng	yui j		🔚 Add to f	ields list	
Maximum ieng	yur j		🔚 Add to f	ields list	
- Fields list	yui j		Add to f	îelds list	
Fields list	Type	Length	Add to f	îelds list	
Fields list	Type real	Length	Add to f	ields list	
Fields list	Type real	Length	Add to f	îelds list	
Fields list	Type real	Length	Add to f	îelds list	
Fields list	Type real	Length	Add to f	ields list	
Fields list	Type real	Length	Add to f	ields list	
Fields list Name Elevation	Type real	Length	Add to f	ields list	



- 6. In order to start digitizing, you have to toggle to edit mode. Click on the Peaks layer so it is selected.
- 7. Click on 🖊 to toggle to editing mode. Now the other editing buttons become active and a pencil before the layer name shows that we are editing the layer.
- 8. In the topographical map navigate to a spot height of a mountain. They are indicated with x and an elevation value. If you have found one, zoom in and click the *Add Feature button* .
- 9. Move the mouse to the mountain top. The cursor changes in a crosshair. Click on the mountain top.
- 10. A dialogue with a form shows up. fid is the feature id that is automatically generated. It's a unique integer number for each feature. The other attribute that we have to fill in is Elevation. We type there 738 in this case.



11. Repeat this step for a few other peaks. If you made a mistake, you can use the vertex tool

***** to move the feature or use one of the select options to select the point feature



and click \square to delete the selected point feature. These buttons \square can be used to undo/redo something. Use \square to save the edits.

12. When done, click again on the 🖉 button to toggle editing. If you didn't save edits yet, it will ask you to *Save* or *Discard*. With *Discard* you can always undo your edits until the last time it was saved.

13. You can check the attribute table of your new point vector layer by right clicking on the layer name (Peaks) and selecting *Open Attribute Table*

Spatial.ite PostGIS MSSQL Cracle BB2 WMS/WMTS WMS/WMTS WS WS WS WS WS WS WS WS WS W	Zoom to Layer Zoom to Selection Show in Overview Show Feature Count Copy Layer Rename Layer Duplicate Layer										
ArcGisMapServ	La <u>R</u> emove Layer		6	Dooks # Footuros	Totalı 4. Filtaradı 4	Colocto	di O				
🕀 💥 GeoNode				Peaks reatures	rotal: 4, rittered: 4,	, Jelecte	u. v				
	// Toggle Editing		/	7 🖶 🔁 🛱	💼 🌱 🖻 🖻	<mark>ا ا</mark>		b 🕇	X 💐	• 🔎 🏗 🖪 .	🗰 🚍 🔍
	<u>F</u> ilter			fid	Elevation						
	Set Layer Scale Visibility		1	4	1.068						
	Set CRS		2	3	594,9						
1	Export •		3	2	697,8						
Layers	Styles 🕨	Ľ^	H		720						
≪ Щ ∞, ↑ ℃, ▼	Properties		4	1	/38						
Peaks	- -				1						
📔 🖳 💽 🚛 Mount_M	arcy_New_York_USGS_topo	_m		Show All Feature	s.						

Now you can see the attributes that you have added and their *fid* and elevation values.

14. Our next task is to digitize line features. The procedure is similar to creating a point layer. In the New GeoPackage Layer dialogue first browse to the existing Database D:\QGIS Exercises\Exercise 1\Mount Marcy.gpkg. Give a new Table name:

Rivers and Geometry type Line

15. As a new attribute we add Name with the type *Text data*. Check if the dialogue resembles the one below and click *OK*.

🔇 New GeoPackag	e Layer			?	×
Database	D:\QGIS_Exercise	es\Exercise_1\Mo	ount_Marcy.gpkg		
Table name	Rivers				
Geometry type	√° Line			•	í
I	Include Z dime	ension 🗏 Includ	le M values		
	EPSG:26718 - NA	AD27 / UTM zone	e 18N	- 🌚	
New field					
Name					
Туре	abc Text data	1		•	
Maximum lengt	th				
			🔚 Add to fi	ields list	
Fields list					
Name	Туре	Length			
Name	text				
			-		
			Remo	ve field	
Advanced of	ptions				
				1	<u> </u>
		ОК	Cancel	Help)

16. QGIS will tell you that the file already exists and if you want to overwrite the database or add the new layer. Obviously, we choose *Add new layer*.

🔍 New	GeoPackage Layer	×		
?	The File already exists. Do you want to overwrite the existing file with a new database or add a new layer to it?			
	Overwrite Add new layer Cancel			

- 17. Click on 😼 to add a new line feature. Zoom and pan on the map to find a stream to digitize.
- 18. Click on the starting point of the line (node) and click when necessary to make a vertex. You can use the zoom and pan buttons to trace the stream. You can also change the symbology to visualize clearer the line that you are digitizing. After you placed the end node of the line, click right. You can use the spacebar to pan during digitizing.
- 19. In the dialogue, fill in the name of the river.

Rivers - F	eature Attributes		×
<u>A</u> ctions			
fid	Autogenerate		
Name	Big Sally Brook		
		ОК	Cancel

- 20. Repeat these steps for a few streams and save your edits. Check the attribute table. <u>Extra:</u>
 - If you want to add tributaries that connect to streams, play around with the snapping settings (Click right on a toolbar and choose *Snapping Toolbar*).
 - Try to find out how to combine all tributaries into one river feature.
- 21. Finally we are going to create a polygon vector layer for some lakes. Try to find out yourself how to do this. It is very similar to the procedure for lines. The only difference is that the first node should be the same as the last node in order to close the polygon. **Extra:**
 - Try to find out how to deal with islands in the lakes

4.8 Image to image registration

Try to use the *Georeferencer* plugin to register the scanned map (JPG file) to a satellite image from the *QuickMapServices* Plugin. In this way you can perform an image to image registration. Please make sure you use the right projection. Does the image to image registration give better results?

This whole exercise can be viewed in a screencast at: https://youtu.be/m12ZXpGBoDc

Exercise 2: Importing tabular data into GIS and interpolation

5 Importing tabular data into a GIS

5.1 Introduction

After this exercise you are able to import tabular data into a GIS. In this example we are going to import a table with the daily average temperature on September 1st 2013 at several meteorological stations in the Netherlands. The data was downloaded from the KNMI Data Centre (KNMI, the Royal Netherlands Meteorological Institute, http://data.knmi.nl), but reformatted for the purpose of this exercise.

In this exercise we'll use the following data:

- KNMI_20130901_tday.xls: table with average daily temperatures for different stations
- KNMI_stations.xls: table with station number and coordinates of the location of the stations

This data can be downloaded from the OpenCourseWare website (<u>http://ocw.unesco-</u> <u>ihe.org/course/view.php?id=11</u>). You can find the data under Data Exercise 2. You can save the files under D:\QGIS Exercises\Exercise 2.

This exercise will guide you through the following steps:



5.2 Convert Excel table to GIS format

There are different ways in QGIS to import tabular data:



Add delimited text layer: this is the standard importer that requires a comma separated ASCII file.



Spreadsheet layers plugin. This tool can open spreadsheet files (*.ods, *.xls, *.xlsx) with some options (use header at first line, ignore some rows and optionally load geometry from x and y fields).

In this exercise we'll use the Spreadsheet layers plugin

- Open the files KNMI_20130901_tday.xls and KNMI_stations.xls in a spreadsheet program (e.g. MS Excel) and check the contents. Which file contains coordinates? Is there a way to link both files? How could we do that?
- 2. Start QGIS Desktop (make sure you start a new project and not continue the previous one).
- 3. In the menu go to Plugins → Manage and install plugins... and check if Spreadsheet layers plugin is installed. If not, you should install the plugin. Plugins are developed by the community to add extra functionality to QGIS. With the Spreadsheet layers plugin you can import from/export to Excel files for example.

🔇 Plugins All (275)	? ×
all 🔪	Q spre
Installed	Spreadsheet Layers Spreadsheet Layers
油 Not installed	Load layers from spreadsheet files (*.ods, *.xls, *.xlsx)
Invalid	This plugin adds a "Add spreadsheet layer" entry in "Layer" / "Add new Layer" menu and a corresponding button in the "Layers" toolbar.
🏇 Install from ZIP	These two links open the same dialog to load a layer from a spreadsheet file (*.ods, *.xls, *.xlsx) with some
🔆 Settings	options (use header at first line, ignore some rows and
	Upgrade All Uninstall Plugin Reinstall plugin
	Close Help

4. Now in the menu choose Layer \rightarrow Add Layer \rightarrow Add spreadsheet layer

Layer Settings Plugins Vector	<u>R</u> aster <u>D</u> ata	base <u>W</u> eb Processing <u>H</u> elp	
幌 <u>D</u> ata Source Manager	Ctrl+L		0 2 0
Create Layer	+		Ц
Add Layer	•	Va Add Vector Layer	Ctrl+Shift+V
Embed Layers and Groups		📲 Add Raster Layer	Ctrl+Shift+R
Add from Layer Definition File.		🔊 Add Delimited Text Layer	
Copy Style		🧠 Add PostGIS Layers	Ctrl+Shift+D
Paste Style		🎤 Add SpatiaLite Layer	Ctrl+Shift+L
a constance		- 🎠 Add MSSQL Spatial Layer	Ctrl+Shift+M
Copy Layer		Add DB2 Spatial Layer	Ctrl+Shift+2
Paste Layer/Group		Add Oracle Spatial Layer	Ctrl+Shift+O
🛅 Open <u>A</u> ttribute Table	F6	Add/Edit Virtual Layer	
🥖 Toggle Editing		Add WMS/WMTS Layer	Ctrl+Shift+W
📑 Save Layer Edits		Add ArcGIS MapServer Layer	
🖉 Current Edits	•	🍓 Add WCS Layer	
Save As		🕅 Add WFS Layer	
Save As Laver Definition File		🚱 Add ArcGIS FeatureServer Layer	
Remove Layer/Group	Ctrl+D	🔣 Add spreadsheet layer	

- 5. In the dialogue browse to the file with the locations of the meteorological stations (KNMI_stations.xls).
- 6. Fill in the dialogue as below. Make sure the right *Geometry Fields* and *Reference system* are chosen. Also indicate the data types correctly for the fields. E.g. STN are station numbers and should be imported as *Integer*, while ALT (m) should be imported as *Real* numbers.

Q C	reate a Layer from	a Spreadsheet File					? ×			
File N	Name D:/QGIS_	Exercises/Exercise	_2/KNMI_stations.:	xls			Browse			
Sheet Sheet1										
Laye	Laver name KNMI stations table									
Rows	s Number o	f lines to ignore 0	🕂 🗆 Header a	at first line		🔽 End of fi	e detection			
	Geometry									
Fie	lds X	field LON	▼ Y field	LAT	▼ □ Show fie	lds in attribute table				
Re	ference system	Project CRS: EPSG:	4326 - WGS 84				- 🌚			
	6 7 1			AL 7()						
	SIN	LON		ALI(m)	NAME		-			
	Integer	Keal	Real	Real	String					
1	210.0	4.419	52.165	-0.20	VALKENBURG					
2	225.0	4.575	52.463	4.40	IJMUIDEN					
3	235.0	4.785	52.924	0.50	DE KOOY					
4	240.0	4.774	52.301	-4.40	SCHIPHOL					
5	242.0	4.942	53.255	0.90	VLIELAND					
6	249.0	4.979	52.644	-2.50	BERKHOUT					
7	251.0	5.346	53.393	0.50	HOORN (TERSCHELLING)					
8	257.0	4.603	52.506	10.00	WIJK AAN ZEE					
9	260.0	5.177	52.101	2.00	DE BILT					
10	265.0	5.274	52.13	13.90	SOESTERBERG					
11	267.0	5.384	52.896	2.60	STAVOREN					
12	269.0	5.526	52.458	-4.00	LELYSTAD		•			
	Help					ОК	Cancel			

- 7. Now a map with the meteorological stations is displayed. If you don't see the map, you probably need to zoom to the extent of the map: click right on the layer name (KNMI_stations_table) and choose *Zoom to layer*.
- 8. Now add the table with the temperature data in the same way. Because there is no geometry (coordinates) in the table, we should uncheck the box:

Q (🔇 Create a Layer from a Spreadsheet File							
File I	File Name Dr/OCIC Exercises/Exercise 2///NML 20120001 tday via							
File I	Name ji	r/Quis_	Exercises/E	xercise_	_2/ KIN	41_2013090	1_tuay.xis	
She	et S	heet2						
Laye	er name 🖡	(NMI_ten	nperatures_	table				
Row	s N	umber of	f lines to igr	nore 0	-	🗌 Header a	t first line	
	Geometr	у						
Fie	elds	х	field			▼ Y field	YYYYMMDD	
Re	eference s	ystem ir	nvalid projec	tion				
						,		
	ST	'N	YYYYM	MDD	Т	(0.1C)		
	Integer	•	Integer	•	Real	•		
1		210.0	201	30901		162.0		
2	225.0		20130901			NULL		
3		235.0	201	30901		158.0		

- 9. The next step is to convert **KNMI_stations_table** to a GIS vector format, i.e. shapefile. Click right on **KNMI_stations_table** and choose *Export* → *Save Features as*...
- 10. In the dialogue use the _____ button to browse to the folder to save the file as ______ KNMI ______ stations.shp. In order to change the projection to the local Dutch projection

choose for CRS "Selected CRS" and Browse to Amersfoort / RD New by clicking on the button. Tip: use the *Filter* field to lookup EPSG code 28992:

Q Coordinate Reference System Selector				?	×
Select the coordinate reference system for the ve coordinate reference system.	ctor file. The data j	points will be t	ransformed from	n the lay	/er
Filter Q 28992					
Recently used coordinate reference systems					
Coordinate Reference System		Authority ID			
Amersfoort / RD New		EPSG:28992			
4					
Coordinate reference systems of the world			🗌 Hide dep	recated	d CRSs
Coordinate Reference System		Authority ID			
🖻 🏢 Projected Coordinate Systems					
Oblique Stereographic Alternative		5000-00000			
Amerstoort / RD New		EPSG:28992			
Selected CRS Amersfoort / RD New					
Extent: 3.20, 50.75, 7.22, 53.70 Proj4: +proj=sterea +lat_0=52.15616055555555 +lon_0=5.3876388888889 +k=0.9999079 +x_0=155000 +y_0=463000 +ellps=bessel			No.	_	
		ОК	Cancel	He	elp

Here you see the advantage of using EPSG codes: it standardizes the projection. So it is useful to determine the EPSG code of the projection you want to work within your project. Also note that all maps in your project need to be in the same projection if you want to combine them in a GIS analysis or modelling.

Click OK. Now the dialogue looks like the figure (also check the box Add saved file to map and make sure that ESRI Shapefile is chosen as the Format).

Click OK to proceed.

11. Remove the knmi_stations_table from the display by clicking right and selecting *Remove Layer*..... Click *OK* to confirm. Be sure to remove the right one. If you hover your mouse over the layer name it will show the file name. With *Remove* you only remove it from the display, the file will still be on your hard disk.

🔇 Save Vecto	r Layer as	?	×				
Format ESRI Shapefile File name D:\QGIS_Exercises\Exercise_2\KNMI_stations.shp Image:							
Encoding	UTF-8		•				
☐ Save on	ly selected features						
Add sav	ed file to map						
Select	fields to export and their export options						
▼ Geome	try						
Geometry	v type Automatic		-				
Force	multi-type						
☐ Includ	e z-dimension						
 Extension Layer (Custor 	ent (current: layer) Options n Options						
,	OK Cancel	Hel	p				

- 12. Although the knmi_stations.shp dataset is in the EPSG 28992 projection (Amersfoort / RD New), the QGIS Map Canvas still uses the EPSG 4326 projection (lat/lon WGS 84) and has reprojected knmi_stations.shp on the fly for visualisation. In order to visualise all layers in EPSG 28992 we have to change the QGIS Project properties. In the menu choose Project → Properties...
- 13. Choose the Coordinate Reference System (CRS) tab.
- 14. Choose from the recently used coordinate reference systems EPSG:28992 and click OK.

					~
Q		Project Coordinate Reference System (CF	RS)		
🔀 Gene	eral	□ No projection (or unknown/non-Earth proj	jection)		
📝 Meta	adata	Filter 🔍			
		Recently used coordinate reference systems			
CRS CRS		Coordinate Reference System		Authority ID	
💉 Defau	ault Styles	WGS 84 WGS 84 / UTM zone 195		EPSG:4326 EPSG:32719	
		WGS 84 / UTM zone 31N		EPSG:32631	
🔣 Ident	tify Layers	WGS 84 / UTM zone 32N WGS 84 / UTM zone 37S		EPSG:32632 EPSG:32737	
		NAD27 / UTM zone 18N		EPSG:26718	
Data	Sources	Amersfoort / RD New		EPSG:28992	
Delet					
Telati	tions				
S Varial	ables	Coordinate reference systems of the world		I Hide deprecated	CRSs
		Coordinate Reference System		Authority ID	_ _
🧟 Macro	ros	World_Hotine		EPSG:54025	
		Oblique Stereographic Alternative			
QGIS 💽	S Server	- ATS77 / New Brunswick Stereogr	aphic (ATS77)	EPSG:2200	_
		ATS77 / Prince Edward Isl. Stered	ographic (ATS77)	EPSG:2290	
		- Amersfoort / RD New		EPSG:28992	
		Amersfoort / RD New		EPSG:7415	
		Selected CRS Amersfoort / RD New			
		Extent: 3.20, 50.75, 7.22, 53.70 Proj4: +proj=sterea +lat_0=52.1561605555 +lon_0=5.3876388888889 +k=0.9999079 +x_0=155000 +y_0=463000 +ellps=bessel +towgs84=565.2369,50.0087,465.658,-0.4 50733,-1.87035,4.0812 +units=m +no_defs	5555 06857,0.3	+ 2	
		Datum transformations			
		☐ Ask for datum transformation if several are	available (defined in g	lobal setting)	
		æ 💻 🥖			
		Source CRS Source datum transform	Destination CRS	Destination datum transform	
			0	OK Cancel Apply	Help

Note that the projection of the project is indicated in the lower right of the screen

• EPSG:28992 . You can always check there if the EPSG code is okay. You can change the on-the-fly projection also by clicking on that EPSG code.

5.3 Join attribute tables

We still have the locations of the stations and the temperature data in separate tables. We have to combine them in one shape file. In GIS terms this is called a "join" operation. We can only join tables if they have a column in common.

After determining which column both tables have in common we can join the data of KNMI_temperatures_table to the attributes of our shapefile KNMI_stations.shp.

- 16. First close the attribute tables.
- 17. Next, click right on KNMI_stations and choose *Properties*.
- 18. In the dialogue choose the button Joins
- 19. Click the + sign and choose check if the dialogue looks like this one:

🔇 Add Vector Join		?	×
Join layer	KNMI_temperatu	ires_table	•
Join field	123 STN		•
Target field	123 STN		•
Cache join layer in virtua	al memory		
Create attribute index o	n join field		
Dynamic form			
▼ □ Edi <u>t</u> able join layer			
Upsert on edit			
🗖 Delete cascade			
▼ 🔽 Joined Fields			
STN YYYYMMDD T(0.1C)			
▼ ▼ Custom Field <u>N</u> ame	Prefix		
Temp			
	ОК	Cance	9

Note that the common field is STN (the station number), we join only the temperature field and we give the column the prefix $Temp_{-}$. Click *OK*.

20. Now the *Joins* dialogue looks like this:

0	Layer Properties - K	NM	_stations Joins									?	×
Q			Setting	Value									
i	Information	•	Doin layer Join field	KNMI_temperatu STN	ures	_tab	le						
3	Source		Cache join layer in virtual memory	✓ ×									
~	Symbology		Editable join layer Upsert on edit Delete cascade										
ab	c Labels		Custom field name prefix Joined fields	Temp_ 1									
9	Diagrams												
	3D View												
l	Source Fields												
19	Attributes Form												
••	Joins												
2	Auxiliary Storage												
<u>.</u>	Actions												
9	Display		£ _ /		_			-		_			
~	Rendering	-	Style -			O	<		Cancel		Apply	He	lp

Click *OK* to perform the Join operation.

- 21. Now check again the attribute table of KNMI_stations. What happened?
- 22. First we need to remove the missing values. Click on row numbers with NULL or no values for temperature, while keeping the Ctrl button pressed. Now the attribute table looks like this:

۹	KNMI_stations :: F	eatures Total: 36, Fi	iltered: 36, Selected	2	- 🗆	×
/	7 B C 🗄	<u>n</u> ≈ 0 0 0	ې 🚽 🖻 😼	7 🍱 🌺 🔎 🛙	. ii: 🗰 🗐	۹ 🔍
	STN	ALT(m)	NAME	Temp_T(0.1C)		
23	225	4.4000000000	IJMUIDEN			
24	275	50.00000000	DEELEN	135		
25	277	3.000000000	LAUWERSOOG	161		
26	380	114.00000000	MAASTRICHT	136		
27	270	1.500000000	LEEUWARDEN	152		
28	391	19.00000000	ARCEN	139		
29	273	-3.100000000	MARKNESSE	152		
30	375	21.100000000	VOLKEL	141		
31	267	2.6000000000	STAVOREN	158		
32	377	30.00000000	ELL	138		
33	269	-4.000000000	LELYSTAD	148		
34	260	2.000000000	DE BILT	143		
35	265	13.900000000	SOESTERBERG	NULL		-
7	Show All Features	i .				8

- 23. In the attribute table click on *logical above the table to toggle editing mode.*
- 24. Click the using icon (in the toolbar above the attribute table) to remove the 2 features with missing data and save the attribute table by clicking using tables are the attribute table by clicking tables are tables and save the attribute tables are tables are tables at the attribute table by clicking tables are tables at tables at
- 25. The only problem now is that the temperatures in the table are in 0.1 °C. We need to convert the values to °C.
- 26. Click the *New field* button to add a new column to the table. And fill in the dialogue according to this screenshot:

🔇 Add Field		?	×
N <u>a</u> me	T(C)		
Comment	Temperature in Celcius		
Туре	Decimal number (real)		•
Provider type	double		
Length	3		*
Precision	1		+
	ОК	Cance	I

Length is the amount of numbers, *Precision* is the amount of decimals. Click *OK* to proceed.

27. Now the attribute table shows an extra column with NULL values. In order to calculate the right values click above the table to open the *Field Calculator* dialogue.

Fill the dialogue like the screenshot below. To avoid typos the best practice is to double click on the field name in the middle of the dialogue screen and to click the * button. Then type 0.1. Click *OK* to proceed.

Q Expression Dialog		? ×
Expression Function Editor		
= + - / * ^ () \n "Temp_T(0.1C)" * 0.1	Q. Search Fields and Values	group field Double-click to add field name to expression string. Right-Click on field name to open context menu sample value loading options. Notes Loading field values from WFS layers isn't supported, before the layer is actually inserted, ie. when building queries.
Output preview: 16.2		
	ОК	Cancel Help

R	KNMI_stations :: F	eatures Total: 36, Fi	iltered: 34, Selected:	: 0	- 0	×			
/	🗾 🕞 🕄 📅	💼 🛰 🖻 🖪	ې 🚽 📔 😼	7 🔳 🏘 🔎 🛙	, ii, 🗰 🗐 🗃 🕯				
1.2	1.2 T(C) ▼ = E Temp_T(0.1C)" * 0.1 ▼ Update All Update Sele								
	STN	ALT(m)	NAME	Temp_T(0.1C)	T(C)	_			
1	210	-0.200000000	VALKENBURG	162	16.2				
2	235	0.500000000	DE KOOY	158	15.8				
3	240	- 4. 400000000	SCHIPHOL	154	15.4				
4	242	0.900000000	VLIELAND	161	16.1				
5	249	-2.500000000	BERKHOUT	147	14.7				
6	251	0.500000000	HOORN (TERSCHELLING)	153	15.3				
7	257	10.00000000	WIJK AAN ZEE	162	16.2				
8	260	2.000000000	DE BILT	143	14.3				
9	267	2.600000000	STAVOREN	158	15.8				
10	269	-4.000000000	LELYSTAD	148	14.8				
11	270	1.5000000000	LEEUWARDEN	152	15.2				
12	273	-3.100000000	MARKNESSE	152	15.2	•			
7	Show All Features	5 .				8			

28. Make sure the *Attribute table* window looks like below. **Please note that** T(C) **should be indicated as column to assign the calculation to!** Click *Update All*.

- 29. Now check the result in the attribute table.
- 30. Click again on the *Levents* to toggle back to non-editing mode. Click *Save* to save the changes when asked and close the attribute table. **If you made a mistake, don't save, but instead choose** *Discard* **to undo all changes since last save.**
- 31. Now remove the table KNMI_temperatures_table and check the attribute table of KNMI_stations. What columns do you see now? What can you conclude about the join function? You could have saved the entire attribute table by saving KNMI_stations to a new shapefile using the previously used *Export* → *Save as*... function.

5.4 Interpolate point features to raster

32. The final task is to interpolate the temperature values to a raster. In the menu choose Raster \rightarrow Analysis \rightarrow Grid (Nearest Neighbor).



33. In the dialogue specify the output file: tday_NN.tif by using the browse window and specifying the .tif format.

> Select T(C) as Z value from field. This is the field that we will interpolate to Thiessen polygons. Check the Open output file after running algorithm checkbox. For the rest of the dialogue keep the defaults. The dialogue should now look like the figure.

Note that the dialogue generates a GDAL command. Click *Run* to proceed. Click *Close* to close the dialogue.

- 34. The interpolated temperature map is now loaded into the display. It is visualised in greyscale, so you have to set the visualisation options. Click right on the map and select *Properties*.
- 35. Under the *Symbology* tab, play around with the different options and click *OK* to return to the display.

Parameters Log				
Point layer				
* KNMI_stations [EPSG:28992]				
r Selected features only				
The first radius of search ellipse				
0.000000				
The second radius of search ellipse				
0.000000				
Angle of search ellipse rotation in degrees (counter clockwise)				
0.000000				
NODATA marker to fill empty points				
0.000000				
▼ Advanced parameters				
Z value from field [optional]				
1.2 T(C)				
Additional creation options [optional]				
Profile Default				
Name Value				
Value				
🕀 📼 Validate Help				
Image: Second				
Image: Walidate Help Output data type Image: Walidate				
Image: Walidate Help Output data type Float32				
Image: Walidate Help Output data type Float32 Interpolated (Nearest neighbor)				
Image: Walidate Help Output data type Float32 Interpolated (Nearest neighbor) D:/QGIS_Exercises_/Exercise_2/T_NN.tif				
Interpolated (Nearest neighbor) D:/QGIS_Exercises/Exercise_2/T_NN.tif Open output file after running algorithm				
Image: Second system Validate Help Output data type Float32 Image: Second system Interpolated (Nearest neighbor) Image: Second system Image: Second system D:/QGIS_Exercises/Exercise_2/T_NN.tif Image: Second system Image: Second system Image: Open output file after running algorithm GDAL/OGR console call Image: Second system				
Image: Second system Walidate Help Output data type Float32 ✓ Interpolated (Nearest neighbor) ✓ ✓ D:/QGIS_Exercises/Exercise_2/T_NN.tif ✓ ✓ Open output file after running algorithm GDAL/OGR console call				
Image: Construct of the system of the sy				
Image: Construct of the system of the sys				

- 36. Now drag the knmi_stations file to the top in order to display the stations on top of the temperature grid.
- 37. Click right on the knmi_stations layer and select Properties.
- 38. Select the Labels icon and choose *Single labels*. Choose T(C) as the Field containing the label. Play around with the placement options (see screenshot below) to make a nice map. Click *Apply* to test and *OK* to visualise.

🔇 Layer Properties - KNM	11_stations Labels	?	×
<u>२</u>	📾 Single labels	•	
🧃 Information 🔶	Label with 1.2 T(C)		3
Source	▼ Text Sample -		
	Lorem Ipsum		
(abc Labels			-
Magrams	abc Text	9 1:1.248.584 💌 🔊	•
幹 3D View	^{+ab} _{< c} Formatting		-
Source Fields	Background	○ Cartographic ④ Around point ○ Offset from point	
🔡 Attributes Form	 Shadow Placement 		
• Joins	A Rendering	Distance 0,9000	
Auxiliary Storage		Millimeter	€.
Actions		Quadrant 📲	
🧭 Display			<u> </u>
🖌 Rendering 🗖	Style -	OK Cancel Apply	Help

39. Now repeat the interpolation using the Inverse distance to a power (IDW) algorithm (repeat from step 32). Call the result file tday_IDW.tif. Visualise the result. Which interpolation method is better? Why? Can you explain the temperature gradient in the map?



- 40. You can save your QGIS project at this point by choosing from the menu $Project \rightarrow Save as...$ Now you can close QGIS and load the project the next time you use QGIS.
- 41. We can also plot our newly created GIS data over a topographical map. For this purpose you have to install the QuickMapServices Plugin. In the menu go to Plugins → Manage and install plugins... and install the QuickMapServices plugin if it is not yet installed. You can also install the experimental additional services. You can do that under Web → QuickMapServices → Settings.
- 42. Choose from the menu $Web \rightarrow QuickMapServices \rightarrow OSM \rightarrow OSM$ Standard. Make sure your point vector layer is on top.

Extra:

Try to repeat the first part of the exercise with the default QGIS importer for comma separated files.

This whole exercise can be viewed in a screencast at: https://youtu.be/PxLufyvJ9jA

Exercise 3: Importing data from a GPS and conversion to vector layers

6 Importing data from a GPS and conversion to vector layers

6.1 Introduction

In this exercise you will learn how to collect data from a GPS, import the data into QGIS and create point, line and polygon vector layers.

6.2 **Preparing the survey**

Before going in the field it is important to be well prepared. Fieldwork is expensive and you want to prevent that you will have to go back. In the next sections there are some guidelines.

6.2.1 Preparation of maps

Use a GIS to prepare the following maps before going to the field:

- Use available maps to understand the study area
- Decide on the map projection that you want to use and look for the EPSG code (<u>http://www.spatialreference.org</u> or <u>http://epsg.io</u>:
 - Local projection: if your study area is in one country, you can choose to use a national projection system
 - Global projection: if your study area covers multiple countries, you can choose for a global projection, such as UTM
 - Unprojected: this is not preferred, but you can use latitude, longitude coordinates (EPSG:4326).
- Create detailed maps (1:10,000) with a coordinate grid
- Print several copies of the map for different purposes:
 - Field map, with numbered locations that you want to sample. Digitize the locations in a GIS based on your understanding of the area. It is better to digitize more locations than you can visit, because many will not be accessible in the field.
 - Field map, where you note where you make a field observation, based on the location you measured with the GPS and the grid printed around the map. Make enough of these maps, because they will get dirty in the field. Always use a pencil to write on the maps, because a ballpoint will not work with dust and humidity.
 - Neat map. This is a map with your observation point that you keep at home and that you update every time you come back from the field.

In this exercise we are going to survey de Markt in Delft, the Netherlands.

- > Open QGIS


- Note that the projection of the Map Canvas is EPSG: 3857. In this exercise we will use UTM Zone 31 North/WGS 84. Use <u>http://www.spatialreference.org</u> to find the EPSG code and write it down. You need this also for setting up the GPS.
- Change the on-the-fly projection to EPSG: 32631, by clicking on the EPSG code in the lower right of the Map Canvas.
- In the dialogue that follows, select the EPSG: 32631 projection from the list (tip: use Filter).

🔇 Project Properties CRS				? X				
Q	- Project Coordinate Reference System (C	RS)						
General	No projection (or unknown/non-Farth pro	iection)						
	Filter Q 32631	jectiony						
📝 Metadata	Recently used coordinate reference systems							
CRS CRS	Coordinate Reference System		Authority ID					
	WGS 84 / UTM zone 31N		EPSG:32631					
Vefault Styles								
Identify Layers								
Data Sources								
E Relations	•			•				
	Coordinate reference systems of the world		🗆 Hide	deprecated CRSs				
💍 Variables	Coordinate Reference System		Authority ID					
Diacros	Projected Coordinate Systems							
••••	Universal Transverse Mercator (UTM)	1						
QGIS Server	WGS 84 / UTM zone 31N		EPSG:32631					
	Selected CRS WGS 84 / UTM zone 31N							
	Extent: 0.00, 0.00, 6.00, 84.00			Car an				
	+units=m +no_defs	84						
				ST ST				
		1 and the second		F. Maril				
			. The subto	S.A.				
	- Datum transformations							
	Ask for datum transformation if several are	e available (defined in	global setting)					
	Source CPS Source datum transform	Destination CPS	Destination datum transform					
		Descination CKS	Descination datum cransionn					
			OK Cancel App	Dly Help				

Now the correct EPSG code should be displayed in the lower right of the screen. Zoom in well on the square using the magnifier.

Now from the *QuickMapServices plugin* choose the Google Satellite data to be displayed. From the main menu choose: *Web* \rightarrow *QuickMapServices* \rightarrow *Google* \rightarrow *Google Satellite*



If you don't see this option, you need to go to settings and install the contributed services pack.

Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help 🦊 🎕 Vi 🖉 🦏 | //. / 🗟 ·: k 🗵 🛍 🔸 🗈 🖺 5 @ | 🖷 🍕 🗃 🧠 🥵 🛯 🥠 🖉 | 🖉 🦛 🖉 HPX YYXY+ 👌 👫 📜 12 đΧ Browser 0 1 2 7 1 0 Favorites * * * Home C:\ D:\ Z:\ 🔮 GeoPackage ayers đΧ 🗸 🏨 🔍 ү 🖏 🛪 📮 Google Satellite
 Standard 1 leg Coordinate 593214.8,5763273.7 🛞 5cale 1:860 💌 🔒 Magnifiei 100% ÷ Rotation 0,0 ° 🕂 🔽 Render 🛛 💮 EPSG:32631 .

Make sure that the image is on top of the layers list or uncheck the OSM Standard layer.

> This image can be saved to a GeoTiff, so we can also use it offline. From the main menu choose: $Project \rightarrow Import/Export \rightarrow Export Map to Image...$



> Keep the Save Map as Image dialogue as default:

	North 57	763279.4260		
West 59318	36.8634	East 5	93367.7380	
	South 57	763132.9061		
c	alculate from layer 👻	Map view extent	Draw o	on canvas
Scale	1:860			•
Resolution	96 dpi			÷
Output width	795 px			÷.
Output height	644 px			· · ·
Draw active	decorations: none			
🗹 Draw annot	ations			
Save world	file			
			1 . (

- Markt Delft UTM31N.tif
- Start a new QGIS project and discard the current one by clicking and click *Discard* in the popup that will appear.
- > Now add the raster layer Markt_Delft_UTM31N.tif clicking the Open Data Source

Manager button and then the choose Raster Choose the right projection when the dialogue shows up. Note that this GeoTiff is georeferenced, but it does not contain the projection. It only has a world file (.tfw) that contains the coordinates. Therefore, the projection needs to be indicated.

Now we are going to prepare your survey by digitizing points on the satellite image that you want to visit in the field, e.g. buildings, statues, trees, etc. For now we only need to digitize Points and give them an observation number. You can use this:

- T01, T02, etc. for trees
- S01, S02, etc. for statues
- B01, B02, etc. for buildings
- R01, R02, etc. for streets

Follow the steps below to do this:

▶ From the main menu select Layer \rightarrow Create Layer \rightarrow New Shapefile Layer...

🔇 *Untitled Project - (QGIS									
Project Edit View	Layer	Settings	Plugins	Vect <u>o</u> r	<u>R</u> aster	Database	<u>W</u> eb	Processing Help		
🗅 👝 🗐 🖡	D	ata Source	Manager		Ctrl+L		\square		1 2 0.	Ć
	C	reate Layer				🔹 🕨 🏤	New	GeoPackage Layer	Ctrl+Shift+N	E
] 🖳 🎇 V ₀ 🖉	A	dd Layer				• V.	New	Shapefile Layer		abi (
A & 12	E	mbed Laye	rs and Gr	oups		P	New :	SpatiaLite Laver		Γ
	A	Add from Layer Definition File			New	Temporary Scratch Lay	er	F		
	2	con Chula						remperary berater bay		

> In the dialogue, choose for the File name

D:\QGIS_Exercises\Exercise_3\Planned_observations.shp, select the correct projection and create an attribute Obs_Code with *Text data* as data type.

🔇 New Shapefile La	yer				?	×
File name	Þ	:\QGIS_Exercise	s\Exercise_3\Pl	anned_observations.	shp 🖾	
File encoding	Ju	TF-8				•
Geometry type		° Point				•
	Γ	Include Z dime	ension	🗆 Include M value	s	
	E	PSG:32631 - W	GS 84 / UTM zo	one 31N	-	-
New field						
Name						-
Type abc Text	data					-
Length 80	Preci	sion				=
Langen joe		I Add to	fields list			
-Fields list						
Name	Туре	Length	Precision			
id Obs. code	Integer	10				
Obs_code	Sung	00				
				Re	emove fie	ld
			ОК	Cancel	Help	,

- Click Add to fields list
- Click OK

The new, empty, shapefile has now been added to your Layers panel.

- > Select the Planned_observations layer and click // to toggle editing
- Click the Add feature button to start digitizing the points that we want to survey. Fill in the attributes with the proper code.
- > After digitizing toggle off editing by pressing *f* again and chose *Save*.
- Now style and label the points in such a way that they are clearly visible in the map.



Use the *Print Composer* to make a map with the points and a coordinate grid around. Export the map to pdf and print the map on A3 format in colour and take it with you on the survey.



6.2.2 Observation forms

Depending on the purpose of your fieldwork, you need field observation forms. These can be forms to observe land use, geomorphology, geology, household surveys, etc. Whatever form you need, it always needs the following information:

- Observation number
- Name of the observer. This is important if you work in teams. Some observations are subjective (e.g. visual estimation of vegetation cover) and it might be useful to relate it back to the observer. This is also important if you need further information that is not covered with the field forms.

- Date/time. This is very useful to link the observation to other time coded data, such as digital photographs taken at the location, the GPS measurements or measurements from other devices.
- Coordinates (X, Y, Z). Always write down the coordinates that you measure with a GPS at the observation location. The reason is that the device can get damaged or lost. Also you might lose the data when you return the GPS to the laboratory where you borrowed it from.

You can print the field forms and make a strong booklet that you can take into the field or use a notebook. Always fill in the forms with a pencil. Ballpoints don't work with dust and humidity.

After each field day, copy your field form to a neat form or a database on your laptop. Always make a backup and store it in the cloud or on a USB stick that you don't take with you in the field.

> Make a field form in your notebook for the survey of de Markt in Delft.

6.2.3 Preparation of the GPS

Before going into the field, please make sure that:

- You have enough spare batteries to take with you
- The GPS is complete with a USB cable
- You have tested that the GPS works and connects to your laptop
- Check GPS settings in the setup page. Check the time zone. The map projection and map datum settings should correspond with the cartographic projection used on your field maps
- > Prepare the GPS with the guidelines above.

6.3 Surveying using a GPS

You are now ready to use the GPS for measuring your location in the field. Pay attention to the following guidelines:

- Wait marking your location into the GPS or writing down the coordinates until the handheld GPS is receiving sufficient satellites with reasonable strength.
- Apart from writing down in your field book the coordinates, write also down the EPE: Estimated Point Error. It indicates how accurate the GPS reading is horizontally in meters. Accurate GPS readings typically have EPE's around 3-5 m.
- Always use GPS and a together in the field. Always mark your position not only in the GPS or in GPS coordinates but also on your field map and verify that you know where you are.
- Be aware that satellite reception can sometimes be poor under a dense forest canopy, below escarpments and in dense urban areas and hence position computation becomes less accurate. Always check the EPE value.
- The vertical height information (Z coordinate) of the GPS unit can have significantly higher inaccuracy values and is therefore not trustworthy. For a detailed height measurement, more Differential GPS (DGPS) systems or barometric altimeters should be used.

For this exercise, choose an open area that you can use for practicing surveying, e.g. a park or a big square. Try to find 3 types of objects:

- Points (e.g. trees, statues, wells)
- Lines (e.g. paths)
- Polygons (e.g. footprint of a house, terrace of café)

With most handheld GPS it is only possible to mark locations as waypoints. With the waypoints we can store attributes. By default it has a Name and a Comment attribute. We will use the Name field to give a unique code to each feature with a follow-up number. We will use the Comment field to give a unique name to each specific object. This can then be used to convert the groups of waypoints to features in QGIS using the *Points to path* tool form the *Processing Toolbox*.

The table below shows how this works:

Name	Note	
T01	Tree1	
T02	Tree2	
T03	Tree3	_
B01	CityHall	
B02	CityHall	Those wayneints form one polygon
B03	CityHall	
B04	CityHall	
B05	House	
B06	House	These wayneints form one nelvgen
B07	House	- These waypoints form one polygon
B08	House	
R01	Street1	
R02	Street1	These waypoints form one line
R03	Street1	
R04	Street2	These waypoints form one line
R05	Street2	

- Mark the waypoints of the objects:
 - For points you only need 1 waypoint per feature. Give the waypoint a code for points, e.g. T01, S01. Also give the feature a unique code in Comments, e.g. Tree1, Statue1
 - For lines you need multiple waypoints per feature and the number needs to be ordered, e.g. R01, R02, R03 are 3 points on the line in that order. Also give the feature a unique code in Comments, e.g. Road1, Road2 or the name of the street.
 - For polygons you need multiple waypoints per feature and the number needs to be ordered, e.g. B01, B02, B03. Also give the feature a unique code in Comments, e.g. Cityhall, Church, etc.
- > Fill in your field form for each feature.

6.4 Importing the GPS data into QGIS

- > After getting back from the field, connect the GPS with a USB cable to the laptop.
- > When the drivers are correctly installed, the computer will see the GPS as a USB disk. To

access the files choose from the main menu $Vector \rightarrow GPS \rightarrow GPS$ Tools or use the button (make sure the *GPS Tools* plugin is installed and/or activated).



- > In the dialogue choose the tab Load GPX file
- > Browse to the GPS and choose the right GPX file from the GPX folder.

Select GPX file									
Comp	→ → Computer → Garmin GPSMAP 64 (F:) → Garmin → GPX →						X		P
Organize 👻 New fo	older								0
Documents	^ N	ame	Date modified	Туре	Size				
J Music	1	Waypoints_06-AUG-15.gpx	06/08/2015 9:15	OpenStreetMap d		3 KB			
Pictures		Waypoints_05-AUG-15.gpx	05/08/2015 16:18	OpenStreetMap d		3 KB			E
Videos		Waypoints_28-JUL-15.gpx	28/07/2015 13:10	OpenStreetMap d		4 KB			
Consider		Waypoints_15-JUL-15.gpx	15/07/2015 12:47	OpenStreetMap d		5 KB			
Windows (C)		Waypoints_14-JUL-15.gpx	14/07/2015 17:57	OpenStreetMap d		5 KB			
Windows (C:)		Waypoints_13-JUL-15.gpx	13/07/2015 17:46	OpenStreetMap d		6 KB			
	-	Waypoints_12-JUL-15.gpx	12/07/2015 18:13	OpenStreetMap d		6 KB			
SDHC (E:)	1	Waypoints_11-JUL-15.gpx	11/07/2015 17:30	OpenStreetMap d		4 KB			
		🕻 Track_2015-07-11 081900.gpx	11/07/2015 8:19	OpenStreetMap d		2 KB			
Jkw (\\vp-fileserv		Waypoints_02-JUN-15.gpx	02/06/2015 16:04	OpenStreetMap d		2 KB			
Software Library	T 1	Waynoints 31-MAV-15 any	31/05/2015 12:54	OnenStreetMan d		2 KR			Ŧ
Fil	File <u>n</u> ame:						nge forma	t (*.gpx)	-
						Open		Cancel	

🔏 GPS Tools	? <mark>×</mark>
Load GPX file Import other file Download from GPS Upload to GPS GPX Conversions	1
File F:/Garmin/GPX/Waypoints_06-AUG-15.gpx	Browse
Feature types 🔽 Waypoints	
Routes	
Tracks	
OK Cancel	Help

- > Only check the box before *Waypoints* and click *OK* to import the data to QGIS
- From the attribute table select the point features and export them as a separate shape file. Do the same for lines and polygons so you have 3 files, one for points, one for lines and one for polygons.
- > Open the *Processing Toolbox* panel from the menu: *Processing* \rightarrow *Toolbox*

Processing	<u>H</u> elp	
🕸 <u>T</u> oolbo	x	Ctrl+Alt+T
🤌 Graphic	al <u>M</u> odeler	Ctrl+Alt+M
() <u>H</u> istory.		Ctrl+Alt+H
Results	Viewer	Ctrl+Alt+R

> In the *Processing Toolbox* search *Points to Path*

Processing Toolbox	đΧ
🎋 🐔 🕓 📄 🔧	
Q points to path	
Recently used	
🔅 🏘 Points to path	
🗄 🔇 Vector creation	
👾 🜞 Points to path	

- In the Points to Path dialogue choose the shapefile containing the points that should be converted to lines. As Order field choose the observation number. For Group field you use the Comments.
- Repeat the same steps for the polygons
- > Evaluate the results.

7 Spatial planning using map algebra

7.1 Learning objectives

After this exercise you will be able to:

- apply map algebra for raster analysis
- distinguish Boolean, discrete and continuous rasters
- make legends for Boolean, discrete and continuous maps
- understand the use of Nodata
- use logical operators
- calculate distances

7.2 Introduction

The Department of Planning of the (imaginary) oasis Aïn Kju Dzjis is planning to build the National Institute for Oasis Management (NIOM) in their village. They came up with the following conditions for building the complex:

- 1 No industry, mine or landfill within 300 meters of the new complex;
- 2 Not on locations presently in use for buildings, water or roads;
- 3 The slope should be less than or equal to 3%;
- 4 The distance from an existing road should be less than 500 meters;
- 5 The area should be contiguous;
- 6 The area should be greater than, or equal to 2 hectares.

They hired you as a GIS consultant to find the most appropriate locations. You will use map algebra to perform the required multicriteria analysis.

7.3 **Preparation**

Download the data for Exercise 4 from the OpenCourseWare website (<u>http://ocw.unesco-ihe.org/course/view.php?id=11</u>) and store the files in a folder on your harddrive (e.g. D: \QGIS_Exercises\Exercise_4).

In this exercise you will use the following maps: buildg.tif, iswater.tif, isroad.tif, topo.tif, roads.tif and areamask.shp.

First we are going to add the exercise folder to the Favorites in the Browser Panel.

 \blacktriangleright Click right on *Favorites* \rightarrow *Add a Directory*...



- Click the + to collapse the contents of the folder.
- Preview the maps and metadata of these raster layers by clicking right on the layer file Properties.



The Layer properties window will open, showing the metadata of the layer:

nformation from pr	ovider	-
Name	builda tif	-
Path	7:\QGIS_Exercises\Exercise_4\builda tif	
CRS	EPSG:32630 - WGS 84 / UTM zone 30N - Projected	
Extent	288674.6709999999729916,3349810.1430000001564622 : 291674.6709999999729916,3352810.1430000001564622	
Unit	meters	-
Width	60	
Height	60	
Data type	Ulnt16 - Sixteen bit unsigned integer	
GDAL Driver Description	GTiff	
GDAL Driver Metadata	GeoTIFF	
Dataset Description	Z:/QGIS_Exercises/Exercise_4/buildg.tif	
Compression		
Band 1	STATISTICS_MAXIMUM=5 STATISTICS_MAXIMUM=5 STATISTICS_MEAN=0.199166666666667 STATISTICS_MINIMUM=0 STATISTICS_STDDEV=0.8638089905889	
More information	 AREA_OR_POINT=Area 	
Dimensions	X: 60 Y: 60 Bands: 1	
Origin	288675,3.35281e+06	
Pixel Size	50,-50	

➢ Fill in the table:

Layer	File type	Number of cells	Projection	Cell size	Minimum value	Maximum value
buildg						
isroad						
iswater						
roads						
topo						
Areamask						

Select buildg.tif, iswater.tif, isroad.tif, topo.tif, roads.tif and areamask.shp in the browser pannel. Keep the <ctrl> button pressed to select multiple files. Then click right and choose Add Selected Layer(s) to Canvas.

Browser	8	>
🖻 🛧 Favorites		4
Z:\QGIS_Exercises\Exercise_4		
Add Selected Layer(s) to Canvas buildg.t v isroad.ti v iswater. belete File "areamask.shp" v topo.tif v wells.tif		

> Go to the Layers panel and drag the areamask vector layer to the bottom.



Rasters normally only store values, so also in this case we need to assign a proper legend to the maps. Let's start with <code>buildg.tif</code>.

- > Click right on the name of the layer and choose *Properties*.
- Click on the Symbology icon on the left
- Under Render type choose: Paletted/Unique values
- ▶ Keep Random as color ramp type and click OK
- Click Classify
- Now use the screenshot below to add the labels to the class numbers. Double click on the label name to do this. Double click on the colour to make it more intuitive like the example.

🔇 Layer Properties - buildg Sy	ymbology				×
Q Information	Band Render Render type Pa	ing letted/Unio	que values 💌		_
🗞 Source	Band Ban	d 1 (Gray)			
Symbology	Color ramp		Random colors		_
Transparency	Value 0	Color	Label None		-
📐 Histogram	1		House		
🞸 Rendering	- 2		Public building		
🖄 Pyramids	- 3		Landfill		
📝 Metadata	- 4		Industry		
듣 Legend	5		Mine		
QGIS Server					
	C:	assify	문 Delete All] _ _ _
	Style 🝷		OK Cancel Apply	Н	elp

Click OK to close the dialogue and look at the result. Is buildg a Boolean, discrete or continuous map?

We have now learned that for **discrete rasters** we use the *Paletted/Unique values* render type.

7.4 Using the Processing Toolbox

Browser

The Processing Toolbox in QGIS provides a lot of tools for processing GIS data. Besides QGIS tools, it also has tools from GDAL, GRASS and SAGA that are very useful.

First activate the Processing toolbox by choosing from the menu Processing → Toolbox

 • Initial Project - QGIS

 • Project Edit View Layer Settings Plugins Vector Raster Database Web Processing Help

 • Initial Project - QGIS

 • Initial Project - QGIS

First we are going to change a default setting of QGIS. The processing toolbox by default doesn't use the file name of the output as a layer name, which can be confusing.

P Results Viewer

Ctrl+Alt+R

- > In the main menu choose *Settings* \rightarrow *Options* \rightarrow *Processing*.
- Collapse the General menu by clicking on the plus sign. Then check the box at Use filename as layer name:

Q Options Processing		? ×
۹	Setting	Value
General	🖶 🔆 General	·
	🗝 🌞 Default output raster layer extension	tif
🗞 System	🗁 🌞 Default output vector layer extension	gpkg
	🖙 🌞 Invalid features filtering	Stop algorithm execution when a geometry is invalid
💮 CRS	🛛 👾 🗰 Keep dialog open after running an algorithm	✓
	🗠 🜞 Output folder	$\label{eq:c:Usershansa} C: Users \ ansa \ AppData \ Roaming \ QGIS \ QGIS3 \ profiles \ default \ processing \ outputs$
Data Sources	Post-execution script	
💉 Rendering	Pre-execution script	
	Show layer CRS definition in selection boxes	
🔯 Canvas & Legend	Show tooltip when there are disabled providers	
<u>. </u>	Style for line layers	
🔣 Map Tools	Style for point layers	
E. Oslar	Style for polygon layers	
Colors	Style for raster layers	
📝 Diaitizina	Use filename as layer name	
	warn before executing if parameter CRS's do not match	
Layouts	H Henus	Reset to defaults
•_	🕀 🍢 Models	
GDAL	🕀 🌞 Providers	
	🕀 🥐 Scripts	
Authentication		
르토 Network		
Q Locator		
Advanced		
Acceleration		
Rrocessing		OK Cancel Help
N Oliali OKta alaan	the analysis and a second	

Click OK to close the dialogue.

7.5 Condition 1: No industry, mine or landfill within 300 meters of the new complex

For condition 1 we have to create a grid with only mines, industry and landfills. Then we have to calculate the Euclidean distance to these cells. Let's start with creating a Boolean grid with only mines, industry and landfills. The sections below will guide you through the steps.

7.5.1 Create a Boolean grid with True for industry, mine and landfill, and False for other buildings

Choose in the processing toolbox
SAGA → Raster tools → Reclassify values (simple).



> The *Reclassify values (simple)* dialogue appears. We are going to reclassify the buildg raster using a **lookup table**. Fill in the dialogue exactly as follows:

🔇 Reclassify Values (Simple)	?	×
Parameters Log		
Grid		
buildg [EPSG: 32630]	-	
Replace Condition		
[0] Grid value equals low value		•
Lookup Table		
Fixed table 3x3		
Changed Grid		
D:/QGIS_Exercises/Exercise_4/industry.sdat		
✓ Open output file after running algorithm		
0%	Cano	el
Run as Batch Process Run Close	Help	>

- Then go to Lookup table and click
- Fill it like the table below. Note that don't change the second column (*High Value*), because the *Replace Condition* is set to [0] *Grid value equals low value*. We can use the second column if we want to reclassify ranges of pixel values.

2	Fixed table			? ×
	Low Value	High Value	Replace with	Add row
1	0	0	0	Remove row(s)
2	1	0	0	Remove all
3	2	0	0	ОК
4	3	0	1	Cancel
5	4	0	1	
6	5	0	1	

- Click *OK* and *Run*. Close the dialogue.
- Check the result: 1 for mines, industry and landfills, 0 for the other classes. Use the *Identify tool*

and click on the map. On the panel down right you can find the identify results. It displays the value of the pixel of the selected layer in the *Layers panel*. You might have to resize the columns to see the pixel values.

Identify Results	 -	₽×
Feature	Value	
Ē- 0	buildg	
⊡ buildg	F	
(Derived)	5	
Mode Current layer	▼ [Auto open form
View Tree		Help

- > Is industry a Boolean, discrete or continuous raster?
- Is the legend that QGIS has assigned automatically correct? Give the industry layer a nice legend, similar as you did for the buildg layer.

7.5.2 Calculate the Euclidean distance to industry cells

▷ Select from the menu Raster \rightarrow Analysis \rightarrow Proximity (Raster Distance)....

🔇 *Exercise_4 - QGIS		
Project Edit View Layer Settings Plugins Vector	Raster Database Processi	essing Help
🗅 📛 🖶 昆 💽 🕄 📙 🖑 🍫 🌶	Raster Calculator	₽ £ £ ⊑ " 2
🦛 🎕 V. 🔏 🖏 🥢 🖉 😁 M	Analysis	🚡 Aspect
Brower □ C T T T 0 Travorites □ C T Travorites □ C T T Travorites □ C T T Travorites □ C T T T Travorites □ C T T T Travorites □ C T T T T Travorites □ C T T T T T T T T T T T T T T T T T T	Miscelaneous + Extraction + Conversion +	Image:
	6 7 6 7 6 6 7 6 7 6	Topographic Position Index (TPI) Terrain Ruggedness Index (TRI)
Layers ≪ ① ∞ ▼ € → I □ □ → I □ ∞ Industry → No industry Industry	8 ×	×

a 1 1 *1* a 1 a 1 a

- > Fill in the *Proximity (Raster distance)* dialogue as in the screenshot:
 - o Make sure the Input layer is industry
 - Because our raster layer consists of only one band we keep Band number as Band 1.
 - Choose for Distance units Georeferenced coordinates. In this way the distances are calculated in meters.
 - We don't choose a maximum distance. The default 0 means that there's no maximum.
 - By default the Nodata value to use for the destination proximity raster is set to 0. This means that the distances will be calculated from all zero cells to the nonzero cells.
 - Name the output
 Proximity map
 inddist.tif.
- Click *Run* and *Close*.
- Check the result. Is the inddist

layer a Boolean, discrete or continuous raster? Make a legend that is appropriate for this raster type using *Singleband pseudocolor* as render type. Use intuitive colours.

Parameters Log
Input layer 🔶
■ industry [EPSG:32630]
Band number
Band 1
A list of pixel values in the source image to be considered target pixels [optional]
Distance units
Georeferenced coordinates
The maximum distance to be generated [optional]
0.000000 🚳 🕯
Value to be applied to all pixels that are within the -maxdist of target pixels [optional]
0.000000 🚳 🕂
Nodata value to use for the destination proximity raster [optional]
0.000000 🚳 🕂
Output data type
Float32
 Advanced parameters
Additional creation options [optional]
Profile Default
Name Value
⊕ _ Validate _ Help_
Proximity map
D:/QGIS_Exercises/Exercise_4/inddist.tif
Open output file after running algorithm
GDAL/OGR console call
gdal_proximity.bat -srcband 1 -distunits GEO -nodata 0.0 -ot Float32 -of GTiff Z:/ QGIS_Exercises/Exercise_4/industry.sdat D:/QGIS_Exercises/Exercise_4/inddist.tif
0% Cancel
Run as Batch Process Run Close Help

~

7.5.3 Create a Boolean map with True for cells further than 300 meters from industry and False for other cells

Now we need a map with all the pixels further than 300 meters from mines, industry and landfills. In the Menu select *Raster* \rightarrow *Raster calculator*....



Double click on inddist@1 (@1 means first layer of a stack, but our maps are single layers so all have only @1), click on the >= button and type 300. Call the output layer noind.tif. The dialogue should resemble the figure below.

🔇 Raster Calculato	or						? ×
- Raster Bands -	- Result I	ayer					
buildg@1	Output	ayer	D:\QGIS_Exe	ercises\Exercise	_4\noind.tif		⊠
industry@1 isroad@1	Output	format	GeoTIFF				•
iswater@1 roads@1	Selecte	d Layer Extent					
topo@1	X min	288674.6710	00 🕂		X Max	291674.67	100 🛨
	Y min	3349810.143	300 ÷		Y max	3352810.1	4300 🛨
	Columns	60	÷		Rows	60	÷
	Output	CRS	EPSG:32630	- WGS 84 / UT	FM zone 30N		- 🌚
	🔽 Add	result to projec	t				
 Operators 							
+	*	sqrt	cos	sin	tan	log10	(
-	1	^	acos	asin	atan	In)
<	>	=	!=	<=	>=	AND	OR
- Raster Calculat	tor Expres	sion					
"inddist@1" >	= 300						
Expression valid							
					OK	Cancel	Help

Click OK and view the resulting grid for condition 1. Is the result of condition 1 (noind) Boolean, discrete or continuous? Give the right legend.

7.6 Condition 2: Not on locations presently in use for buildings, water or roads

For condition 2 we have to select pixels without buildings, water or roads.

- First we produce a Boolean grid with value 1 for locations without buildings. Use the Raster calculator to do this: "buildg@1" = 0. This results in Boolean true (1) for locations without building and false (0) for locations with buildings. Call this map nobuild.
- With the raster calculator we search for which pixels have no water and no roads. The pixels without water can be calculated by the following expression: "iswater@1" = 0 Call this map nowater.
- > Do the same for pixels without roads (use the isroad layer). Call it noroad. Check the results.
- Are nobuild, nowater and noroad Boolean, discrete or continuous rasters? Give the right legend to these layers.

7.7 Condition 3: The slope should be less than or equal to 3%

For condition 3 we have to calculate the slope from the topo grid, which contains elevation values.



▶ From the Menu choose: Raster \rightarrow Analysis \rightarrow Slope...

Fill in the dialogue like below. Don't forget to choose topo as the DEM Raster, check the box before Compute edges, choose for Mode Slope and choose Slope expressed as percent (instead of as degrees). Keep the algorithm as default, call the output slopemap.tif.
 Why do we need to compute the edges?
 Does this algorithm work with unprojected (lat/lon) coordinates?

						?
Parar	neters Log	g				
Input	layer					
🕨 top	o [EPSG:32	630]				•
Band ı	number					
Band	1 (Gray)					
Ratio	of vertical un	nits to ho	orizontal			
1.000	000					
🗷 Sloj	oe expressed	l as perc	ent instead o	of deg	rees	
Cor	npute edges					
🗆 Use	Zevenberge	en <u>T</u> horne	e formula ins	tead (of the H	lorn's d
▼ Ad	vanced para	meters -				
Addi	tional creation	on optior	ns [optional]			
Prof	le Default					
		Name			V	alue
÷	<u>Valic</u>	late	Help			
Slope						
	GIS_Exercise	s/Exercis	se_4/slopem	ap.tif		
D:/Q	_					
D:/Q	n output file	e after ru	nning algori	thm		
D:/Q ⊂ Ope GDAL	en output file 'OGR consol	e after ru e call	inning algori	thm		

- ➢ Click Run, Close
- > Check the result. Is slopemap a Boolean, discrete or continuous raster? Give the right legend.
- In order to select the slopes less than or equal to 3% use the Raster Calculator ("slopemap@1" <= 3). Call the output map nosteep. Is nosteep a Boolean, discrete or continuous raster? Give the right legend.

7.8 Condition 4: The distance from an existing road should be less than 500 meters

Let's first describe what we should do, before we perform the GIS analysis. The steps will follow. Like condition 1, this condition is met by applying the following steps:

- 1) Creation of a Boolean map with True for tarmac roads and False for other cells
- 2) Calculation of Euclidean distance from all cells to these roads by:
 - a. Calculating the Euclidean distance
 - b. Creating a Boolean map with True for cells < 500 m from these roads and False for cells ≥ 500 m from these roads.

First we have to select all the tarmac roads. The table below shows the legend of the roads map.
Make the legend in the same way as we did for buildg before. Use this table:



- In this case use the Raster calculator to assign Boolean True (1) for tarmac roads and False (0) for the rest of the map. Call the map tarmacroad. Check the result. Assign the right legend.
- Now calculate the distance to a tarmac road like you did before (*Raster* → *Analysis* → *Proximity* (*Raster Distance*)...). Call the resulting map tardist. Check the result. Assign the right colours to the legend
- To create a grid with only pixels within a distance of 500 meters from tarmac roads, use the *Raster Calculator*. The equation should be "tardist@1" < 500. Check the result. Name it tarzon. Assign the right colours to the legend.

7.9 Combine criteria 1 to 4

Now all the new maps should be combined to create a grid, which satisfies condition 1 to 4. So all pixels with value 1 (True) in noind, nobuild, nowater, noroad, nosteep and tarzon should be selected. Use the *Raster Calculator*. The dialogue should resemble the figure below.

🔇 Raster Calc	ulator							×
-Raster Ban	ds		-Result L	ayer				
industry@1			Output la	iyer	Exercises\Exer	cise_4\niomgo	.tif 🖾	
iswater@1		_	Output f	ormat	GeoTIFF			•
noind@1			Selecter	d Layer Extent				
nosteep@1			X min	288674.67100	÷ X Ma	x 291674.67	100	÷
roads@1			Y min	3349810.1430	0 🗄 Y m	ax 3352810.1	4300	÷
slopemap@ tardist@1	1		Columns	60	÷ Row	s 60		÷
tarmacroad tarzon@1	@1		Output C	RS	EPSG:32630 -	WGS 84 / UT	M zor 💌	
topo@1		-	🔽 Add r	esult to project				
 Operator 	s							
+	*	sqrt	COS	sin	tan	log10	(
-	1	^	acos	asin	atan	In)	
<	>	=	!=	<=	>=	AND	OR	
- Raster Calc	ulator Express	ion						
"noind@1"	AND "nobuild(]1" AND "nowate	er@1" AND	"noroad@1" /	AND "nosteep@	1" AND "tar	zon@1"	
Expression vali	d							
Expression vali	u				OK	Cancel	Hol	
						Cancer		P

Call the resulting map niomgo and click OK. Check the result carefully and give it the right legend.

7.10 Condition 5: The area should be contiguous

To satisfy condition 5 the groups of pixels must be clustered and then they will get a unique group number. Then the area must then be calculated for each group. Because Zero values also form a cluster we need to first change them to nodata.

We can use the clipper tool to change 0 values to nodata in niomgo. In the main menu choose Raster → Extraction → Clip Raster by Extent...



- At Clipping extent click on the button, choose Layer extent and choose niomgo. It will copy the extent of niomgo.
- > At Assign a specified nodata value to output bands type 0. In this way we make all zeros nodata.
- > Name the result isniomgo.

🔇 Clip Raster by Extent ? >
Parameters Log
Input layer
▼ niomgo [EPSG:32630]
Clipping extent (xmin, xmax, ymin, ymax)
288674.671,291674.671,3349810.143,3352810.143 [EPSG:32630]
Assign a specified nodata value to output bands [optional]
0.00000 🗠 🚊
Advanced parameters
Additional creation options [optional]
Profile Default
Name Value
🐵 😑 Validate Help
Output data type
Use input layer data type
Clipped (extent)
D:/QGIS_Exercises/Exercise_4/isniomgo.tif
✓ Open output file after running algorithm
GDAL/OGR console call
gdal_translate -projwin 288674.671 3352810.143 291674.671 3349810.143 -a_nodata 0.0 -of GTiff Z:/QGIS_Exercises/Exercise_4/niomgo.tif D:/QGIS_Exercises/Exercise_4/isniomgo.tif
0% Cancel
Run as Batch Process Run Close Help

Click Run and *Close* the dialogue after running.

The method in GIS to give unique values to each cluster of pixels is called **clump**.

> In the toolbox click on the *r.clump tool* (*Grass* \rightarrow *Raster* \rightarrow *r.clump*).

Processing Toolbox	8	×
🎋 👶 🕓 🖹 🔍 🔧		
Q Search		
🗈 Q Vector overlay		
🗉 Q Vector selection		
🗉 🝳 Vector table		
🖶 🚋 GDAL		
🛱 🖗 🚱 GRASS		
Imagery (i.*)		
Hiscellaneous (m.*)		
r.Dasins.till		
w w r.blend.combine		
🛛 💮 🛞 r.blend.rgb		
🖉 🦢 🎡 r.buffer		
🛛 🎡 r.buffer.lowmem		
🦳 🎡 r.carve		
🚽 🐨 🔬 r.category		
🚽 🖗 r.category.out		
- 👷 r.circle		
🚽 😡 r.clump		

Fill in the dialogue that opens as below. Choose isniomgo as Input layer, call the output layer niomgoclu.tif

Q r.clump	? X
Parameters Log Input layer Input layer Information in the second secon	 Recategorizes data in a raster map by grouping cells that form physically discrete areas into unique categories.
niomgoclu ✓ Advanced parameters ✓ Clump also diagonal cells Classic cuttors (units careau units careau) [rations]]	-
GRASS GIS / region extent (xmin, xmax, ymin, ymax) [optional] [Leave blank to use min covering extent] GRASS GIS 7 region cellsize (leave 0 for default) 0,000000 Output Rasters format options (createopt) [optional]	
Output Rasters format metadata options (metaopt) [optional]	-
Clumps D:/QGIS_Exercises/Exercise_4/niomgoclu.tif	
	0% Cancel
Run as Batch Process	Run Close Help

- Click *Run* and *Close* the dialogue when ready.
- Inspect the result? Is the automatically assigned legend okay? Is niomgoclu a Boolean, discrete or continuous layer? Assign the correct legend.

7.11 Condition 6: The area should be greater than, or equal to 2 hectares

Finally, areas greater than 2 hectares can be calculated to satisfy the last condition. For this last step we have to convert our raster to vector.

1. In the menu choose:



Fill in the dialogue as below. Call the output shapefile niompoly.shp. Note that the default vector format is GeoPackage, so make sure you choose shapefile!

🔇 Polygonize (Raster to Vector) ? X
Parameters Log
Input layer
niomgodu [EPSG:32630]
Band number
Band 1 (Palette)
Name of the field to create
dump
Use 8-connectedness
Vectorized
D:/QGIS_Exercises/Exercise_4/niompoly.shp
✓ Open output file after running algorithm
GDAL/OGR console call
gdal_polygonize.bat Z:/QGIS_Exercises/Exercise_4/niomgodu.tif D:/ QGIS_Exercises/Exercise_4/niompoly.shp -b 1 -f "ESRI Shapefile" None dump
0% Cancel
Run as Batch Process Run in Background Close Help

Click *Run* and *Close* to return to the map canvas where the vector layer is displayed.

> Change the vector style of the niompoly layer so it matches with its contents:

Q	Layer Properties - nion	npoly Symbo	ology						? ×
Q		📑 Catego	rized						•
i	Information	Column	123 clump						3 -
ગુજ	Source	Symbol				Change			
	Symbology	Color ramp			Rar	ndom colors			•
~	Symbology	Symbol	Value	Legend					_
abc	Labels								
			1	1					
	Diagrams		2	2					
\diamond	2D Viow		3	3					
	SD VIEW		5	5					
	Source Fields		6	6					
			7	7					
-8	Attributes Form		8	8					
			9	9					
•	Joins		10	10					
-			11	11					
	Auxiliary Storage		12	12					
	Actions		13	13					
÷	ACUOIIS		14	14					
	Display		16	16					
	,		17	17					
~	Rendering		18	18					
			19	19					
3	Variables		20	20					
			21	21					
1	Metadata		22	22					
			23	23					
Ŀ	Dependencies		24	24					
=	Legend			25					•
•-	Legend	Classify		Delete All					Advanced •
	QGIS Server	Ciddolly		Delece / III				-	
		Layer F	Rendering						
	Digitizing	Style	-			ОК	Cancel	Apply	Help

In order to visualise the polygons larger than 2 ha, we have to do a selection based on this criterion.

- Open the attribute layer of niompoly and click to open the dialogue for selection based on an expression.
- In the dialogue go to Geometry and double click on \$area. Fill in the dialogue as given below and click Select features.

Q Select by Expression - niompoly		? X
Expression Function Editor		
= + - / * ^ () '\n' \$area >= 20000	♀ Search ⊕ Aggregates ⊕ Arrays ⊕ Color ⊕ Conditionals ⊕ Conversions ⊕ Date and Time ⊕ Fields and Values ⊕ Fuzzy Matching ⊕ General ⊖ Geometry □ angle_at_vertex □ Sarea □ area □ aimuth □ boundary □ bounds_height □ builds_width □ buildsread	function \$area Returns the area of the current feature. The area calculated by this function respects both the current project's ellipsoid setting and area unit settings. For example, if an ellipsoid has been set for the project then the calculated area will be ellipsoidal, and if no ellipsoid is set then the calculated area will be planimetric.
Output preview: 0	buffer_by_m	\$area 🗾
Help		Select features Close

The attribute table now shows 6 selected features. They are also highlighted in the map canvas, giving the answer to the planning issue.

Export the selected polygons to a new shapefile:

- ➤ Click right on the niompoly layer name and choose Export → Save Selected Features As...
- In the dialogue, name the output file selectedlocations.shp and check the box before Save only selected features.

2
\sim
-

🕄 Save Vecto	r Layer as	?	×	
Format	ESRI Shapefile		•	
File name	D:\QGIS_Exercises\Exercise_4\selectedlocations.shp	р 🖾		
Layer name				
CRS	EPSG:32630 - WGS 84 / UTM zone 30N			
Encoding	UTF-8		•	
Save on	y selected features			
Add save	ed file to map			
Select	fields to export and their export options			
▼ Geome	try			
Geometry	r type Automatic		•	
Force	multi-type			
☐ Includ	e z-dimension			
Ext	ent (current: layer)			
Layer (Options			
Custor	n Options			
	OK Cancel	He	lp	

Click OK.

- > Now hide all layers and only show the selectedlocations layer. Give the layer the right legend so we can see each location.
- > Try by yourself to add a column to the attribute table of the selectedlocations layer and to calculate the areas of these locations.
- Visualise the end result with a Google satellite image in the background. Use the QuickMapServices plugin.

This whole exercise can be viewed in a screencast at: https://youtu.be/IfZSyBf6o84



8 Inaccessible wells

The Department of Planning of the Aïn Kju Dzjis oasis has consulted you again to report to them which wells in the oasis are inaccessible for the population. They consider wells that lie more than 150 meters from houses or roads as inaccessible. They provided you with a map with all the wells in the oasis (wells.tif).

Try to solve this assignment on your own, using the map algebra skills of the previous section. The result should be a raster layer with TRUE for the inaccessible wells and FALSE for the remaining area. Besides wells.tif you should also use buildg.tif and isroad.tif. Make a flowchart of the analysis.

Exercise 5: Catchment delineation

9 Catchment delineation

9.1 Introduction

In order to delineate a catchment from a DEM we need to follow these steps:

- 1) Download the DEM tiles of your study area. Make sure that the tiles cover at least the study area and that the catchment you want to derive is covered completely. Better to take it a bit larger to avoid boundary effects
- 2) If your study area is covered by multiple DEM tiles, you need to *mosaic* (merge) the tiles to create a single raster DEM layer
- 3) The DEM tiles might be in a different coordinate system then desired. In that case you have to reproject the DEM layer to the projection you want to use in the study area
- 4) In the case that the merged tiles are much larger than your study area, you can *subset* (clip) it to a smaller area to reduce calculation time
- 5) Make a hydrological correct DEM by filling sinks and removing spikes from the raw DEM
- 6) Calculate the flow direction for each cell
- 7) Calculate the flow accumulation for each cell: how many upstream cells contribute to the runoff in each downstream cell of the DEM
- 8) Derive the drainage network
- 9) Calculate the catchment for the outflow point of the catchment

When a map with the stream network already exists, the procedure can be improved by "burning" the river network into the DEM. In that way the DEM is always lower at rivers and runoff will follow the actual river network. This is out of the scope of this exercise.

This flowchart below summarizes the procedure:



9.2 Download the DEM tiles

For the Rur study area, we will use 4 tiles from the SRTM 1 Arc-Second global data set. The United States Government announced on September 23 2014 that the highest possible resolution of global topographic data derived from the SRTM mission will be released to public. Since the end of 2014 a 1-arc second global digital elevation model (30 meters) has been released. Most part of the world has been covered by this dataset ranging from 54 degrees south to 60 degrees north latitude except for the Middle East and North Africa area. A description of the SRTM data products can be found here: https://lta.cr.usgs.gov/SRTM1Arc.

For this exercise the tiles n50_e005_larc_v3.tif, n50_e006_larc_v3.tif, n51_e005_larc_v3.tif and n51_e006_larc_v3.tif were already downloaded and provided. Save the data in e.g. D:\QGIS_Exercises\Exercise_5.

If you want to download data yourself, you can use the USGS EarthExplorer (<u>http://earthexplorer.usgs.gov</u>).



Alternatively, you can use the SRTM Downloader plugin to download the tiles directly your map canvas.



9.3 Load the DEM tiles in QGIS

- 1) Start QGIS Desktop.
- 2) Use the Open Data Source Manager button
- 3) Choose Raster and browse up to the folder containing the SRTM tiles (e.g.

D:\QGIS_Exercises\Exercise_5). Hold the <Ctrl> button and select the 4 tiles
(n50_e005_larc_v3.tif, n50_e006_larc_v3.tif,

n51_e005_larc_v3.tif and n51_e006_larc_v3.tif) by left clicking on the tiles.

Click Open.



- 4) Click Add and Close.
- 5) You should be able to see this map in the *Map Canvas* (as shown below).



We see the four tiles in greyscale. We can distinguish the tiles, because QGIS automatically stretches the grey values per tile. That means that the grey values are distributed according to the minimum and maximum value of each tile. When we mosaic (merge) the tiles, QGIS will stretch the values for the whole area, using the minimum and maximum value of the merged raster layer. You'll see that in the next section.

9.4 Mosaic DEM tiles

Before we proceed, we have to merge the four DEM tiles, which in GIS terminology is called mosaic. There are two ways to mosaic the tiles:

- Merge the tiles into one physical file
- Merge the tiles into a virtual file

The first option is slower. If we have many tiles, we prefer to make a virtual file that virtually merges all the tiles. That will be done with the following steps:

1) In the menu choose *Raster* \rightarrow *Miscellaneous* \rightarrow *Build Virtual Raster*...



- 2) In the *Build Virtual Raster* dialogue you can choose each file individually or merge all files in a directory (folder). We can also merge the files that are visible in the *Map Canvas*. We use the last option:
 - At Input layers click _____
 - Use the Select all button to select the four tiles and click OK.

Q Multiple selection	? ×
 ✓ n50_e005_1arc_v3 [EPSG:4326] ✓ n50_e006_1arc_v3 [EPSG:4326] 	Select all
✓ n51_e005_1arc_v3 [EPSG:4326] ✓ n51_e006_1arc_v3 [EPSG:4326]	Clear selection
	Add file(s)
	ОК
	Cancel

- browse to the location where you want to save the output file (e.g.
 D:\QGIS_Exercises\Exercise_5) and give it the name dem_mosaic.vrt
- Resolution is default set to average. In our case the files all have the same resolution (1 Arc Second).
- Uncheck the box before *Place each input file into a separate band*. This needs to be checked only if you want to create a mapstack, i.e. with remote sensing bands.
- Keep the *Resampling algorithm* at the default: nearest. This also has no impact, because resampling is not needed.
The dialogue should now look like this:

🔇 Build Virtual Raster	? ×
Parameters Log	
Input layers	
4 elements selected	
Resolution	
average	•
\square Place each input file into a separate band	
□ Allow projection difference	
 Advanced parameters 	
Add alpha mask band to VRT when source raster has none	
Override projection for the output file [optional]	
	- 🌚
Resampling algorithm	
nearest	<u> </u>
Virtual	
D:/QGIS_Exercises/Exercise_5/dem_mosaic.vrt	
Open output file after running algorithm	
GDAL/OGR console call	
gdalbuildvrt -resolution average -r nearest -input_file_list C:/Users/hansa/AppDa Local/Temp/processing_3898e6f6a87c4341bea851eaa885db40\buildvrtInputFile D:/QGIS_Exercises/Exercise_5/dem_mosaic.vrt	ta/ s.txt
0%	Cancel
Run as Batch Process Run Close	Help

- 3) Click *Run* to run the algorithm. Click *Close* to get back to the main screen where you can see the merged DEM. You notice that in the Map Canvas the borders of the tiles are not visible anymore in the merged DEM, because QGIS stretches the greyscale using the minimum and maximum of the entire merged DEM. This is only for visualisation, the values in the tiles are the same as in the mosaic.
- 4) Click right on the layer and choose *Rename Layer*. Rename the layer to dem_mosaic.
 Renaming is not needed anymore if you have changed the setting as described in Section 7.4.
- 5) Now remove the individual tiles (not the dem_mosaic) from the layers list by selecting them while the *Ctrl* button is pressed. Then clicking right one of the tile names and select *Remove Layer*.... Click *OK* to confirm. This will remove the tiles from the screen, but not from the hard disk.



9.5 Reproject DEM

Before continuing, we need to know the projection of the DEM and reproject it to the projection of our project.

1) Right click on the layer's name, and select *Properties*....



- 2) In the new window select *Information* (the top tab on the left hand-side of the new window).
- 3) In the Information window check the CRS (Coordinate reference system).

Q Layer Properties - dem_mos	aic Information		?	×
Q	Information from pro	wider		•
🥡 Information				- 1
	Name	dem_mosaic		
Source	Path	Z:lugis Exercises/Exercise 5/dem mosaic.vn		
💉 Symbology	Extent	4.99972222222222222222222222222222222222		
-,		7.000277777777778,52.00013888888888840		
Transparency	Unit	degrees		
	Width	3601		
🗠 Histogram	Height	7201		
	Data type	Int16 - Sixteen bit signed integer		
≼ Rendering	GDAL Driver Description	VKI Virtual Raster		
	Dataset Description	Z:/OGIS Exercises/Exercise 5/dem mosaic.vrt		
Pyramids	Compression			
	Band 1	 STATISTICS_APPROXIMATE=YES 		
📑 Metadata		STATISTICS_MAXIMUM=708 STATISTICS_MEANL_100_0007157		
		STATISTICS_MEAN=108.0444390/15/ STATISTICS_MINIMUM=-131		
E- Legend		 STATISTICS_STDDEV=188.06635770914 		
OGIS Server	More information			
	Dimensions	X: 3601 Y: 7201 Bands: 1		
	Origin	4.99972,52.0001		
	Pixel Size	0.000555556,-0.0002////8		
				•
	Style 🔻	OK Cancel Apply	Н	elp

The DEM is in its original Lat/Lon Geographic Coordinate System with datum WGS 84 (EPSG: 4326). We need to convert it into the projection of our project. Because the project covers multiple countries, we will not use a local projection but a global projection: UTM Zone 32 North, with WGS-84 as datum.

We can find the EPSG codes at http://www.spatialreference.org

4) Use the website to search for UTM 32N. You can leave QGIS opened and open a browser:



5) The database returns:

Spatial Reference List Spatial × +								-				x
(i) spatialreference.org/ref/?search=u	C Q Search	☆ 自		Ŧ	⋒	ø	ABP 👻	٥	ра	÷.	-	≡
Spatial Reference	spatial referer	nce list	:									
Home Upload Your Own List user-co	ontributed references	List all r	efere	nces			utm 3	2N wg	s 84		Sea	arch
Search References: utm 32N wgs 84	Search											
 EPSG:2215: Manoca 1962 / UTM zone EPSG:3064: IGM95 / UTM zone 32N EPSG:3199: LGD2006 / UTM zone 32N SR-ORG:6860: UTM-WGS84 32N SR-ORG:7021: prova SR-ORG:7025: Dont know what it is SR-ORG:7325: ETRS89 Zone32 Germa EPSG:7416: ETRS89 / UTM zone 32N SR-ORG:7887: ETRS89 / UTM zone 32 SR-ORG:7911: test SR-ORG:8089: WGS_1984_UTM_Zone EPSG:32432: WGS 72BE / UTM zone 32N EPSG:32632: WGS 84 / UTM zone 32N 	e 32N N + DVR90 height 2N 2N (ZE-N) ≥_32N N											
About												

We have to look at the EPSG codes. We will use the EPSG: 32632 throughout this project. If you click on it you can see more details.

6) Now we are going to reproject the DEM from unprojected (Lat/Lon WGS 84 - EPSG: 4326) to UTM Zone 32 North / WGS 84 (EPSG: 32632). From the main menu choose Raster → Projections → Warp (Reproject)



- 7) In the *Warp* window, click 🗐 to choose the *Target CRS*
- 8) In the dialogue that opens type 32632 at Filter and select *WGS... EPSG: 32632* in the middle of the dialogue window and click *OK*.

- 9) Now complete the dialogue:
 - Resampling method to use: We choose Nearest Neighbour to preserve the elevation values of the original files.
 - Set the No data value for output bands to – 9999. Because the raster layer will be reprojected there will be "no data" at the borders. In this way we define that "no data" has a value –9999 and will not be visualised as "data".
 - Set the *Output file* resolution to 30 m.
 - Browse to your exercise folder and name the output file dem_reprojected

Note the *gdalwarp* command that will be executed in the background.

10) Click *Run* to run the algorithm. After running click *Close* to close the window.

S Coordinate Reference System Selector	?	×
	•	<u> </u>
Define this layer's coordinate reference syste This layer appears to have no projection specification. By default, of the project, but you may override this by selecting a different p	em: this layer will now have its projection set to t projection below.	that
Filter 🔍 32632		×
Recently used coordinate reference systems		
Coordinate Reference System	Authority ID	
WGS 84 / UTM zone 32N	EPSG:32632	
4		•
Coordinate reference systems of the world	🗌 Hide deprecated (CRS
Coordinate Reference System	Authority ID	
E Projected Coordinate Systems		_
- Universal Transverse Mercator (UTM)	EDS(0.22622	
W03 64 / UTW 2018 52N	EP 30:32032	
4		•
Selected CRS WGS 84 / UTM zone 32N		
Extent: 6.00, 0.00, 12.00, 84.00		
Proj4: +proj=utm +zone=32 +datum=WGS84 +units=m +no_defs	Reverse and	g.
	. The State Balan	
	OK Cancel Help)
🔇 Warp (Reproject)	?	×
Parameters Log		
Input layer		-
Mem_mosaic [EPSG:4326]	·	
Source CRS [optional]		
	- 🌏	
Target CRS		
EPSG:32632 - WGS 84 / UTM zone 32N	- <u>-</u>	
Resampling method to use		1
Nedata value for output bands [antional]		1
	- m	1
Output file resolution in target georeferenced units [/	ontional]	1
		1
Advanced parameters		
Additional creation options [optional]		
Profile Default	•	
,		
Name	Value	
🐵 드 Validate Help		
Output data type		
Use input layer data type	•	
Georeferenced extents of output file to be created (xmin, xmax, ymin, ymax) [optional]	
[Leave blank to use min covering extent]		
CRS of the target raster extent [optional]		
	• 🌏	
✓ Use multithreaded warping implementation		
Reprojected		1
D:/QGIS_Exercises/Exercise 5/dem reprojected.tif		1
- Onen autout file after running algorithm		
	0% Cance	el
Run as Batch Process	Run Close Help	2

Now you will see that the re-projected DEM will appear in the list of Layers. The DEM may seem distorted, as shown in the image below. This is due to the fact that the Map Canvas Projection is still in Lat/Lon, as testified by the coordinates in the lower part of the Map Canvas. And the EPSG code given in the lower right corner. This is due to the **on-the-fly projection**, which causes a difference between the projection in the file and the one that is visualised.

Coordinate 4.604,50.122 🎗	Scale 1:594378	-	Magnifier 100%	+ Rotation	0,0 ° ÷	🗹 Render	EPSG:4326	
---------------------------	----------------	---	----------------	------------	---------	----------	-----------	--

- 11) To complete this operation, and display properly the new dataset, we need to change the on-the-fly projection of the Project. To do so click on the EPSG: 4326 in the lower right of the screen.
- 12) In the new dialogue window select the *EPSG:32632 projection* that is already in the list of *Recently used coordinate reference systems*, as shown below, and click *OK*.

🔇 Project Properties CRS	? X
۹	Project Coordinate Reference System (CRS)
🔀 General	No projection (or unknown/non-Earth projection)
📝 Metadata	Filter Q 32632
	Recently used coordinate reference systems
CRS CRS	Coordinate Reference System Authority ID
ኛ Default Styles	WGS 84 / UTM zone 32N EPSG:32632
Data Sources	
	Coordinate reference systems of the world
💍 Variables	Coordinate Reference System Authority ID
😥 Macros	Projected Coordinate Systems Universal Transverse Mercator (UTM) WGS 84 / UTM zone 32N EPSG:32632
	Selected CRS WGS 84 / UTM zone 32N
	Extent: 6.00, 0.00, 12.00, 84.00 Proj4: +proj=utm +zone=32 +datum=WGS84 +units=m +no_defs
	Datum Transformations
	☐ Ask for datum transformation if several are available (defined in global setting)
	Source CKS Source datum transform Destination CKS Destination datum tra
	OK Cancel Apply Help

In the Map Canvas the DEM is now displayed in the correct position (with the North pointing up), as shown below. The coordinates of the new display are also in meters as we want.



13) You can now remove the file dem_mosaic

9.6 **Subset DEM**

In order to reduce the calculation time of the algorithms, we will subset (or clip) the raster layer.

An easy way to select the boundary of your study area (always make it a little bit bigger to prevent boundary effects) is to use OpenStreetMap. OpenStreetMap contains crowd sourced data (see http://www.openstreetmap.org for more info). If the QuickMapServices plugin is installed, you can add an OpenStreetMap to QGIS as follows:

1) In the menu choose $Web \rightarrow QuickMapServices \rightarrow OSM \rightarrow OSM$ Standard

🔇 *Untitled Project - QGIS			
Project Edit View Layer Settings Plugins Vector Raster Database Web Project	ro <u>c</u> essing <u>H</u> elp		
🗌 🗅 💳 🔜 🔂 😫 🔛 🖑 🌞 🗩 🗩 🕅 🔀 🔐	kMapServices 🔸 🔮	2gis	• 🦹 - 🔣 - 🚍 - 🌄 🗐 🔛
		AutoNavi	abc abc abc
		Bing	
Browser 🗠 🗙	est	ESRI	•
		GeoQ	•
	(Geofabrik	•
C:\QGI5_Exercises\Exercise_4 A areamask shn	G	Google	•
- The buildg.tif		Kosmosnimki.ru	• •
- Q Exercise_4	1	Portugal	•
- Mindustry.sdat		Landsat	•
isroad.tif	1	MapSurfer.NET	•
roads.tif	2	Mapbox	•
- 📝 topo.tif		NASA	•
wells.tif	+	Georgia	•
Home	•	CartoDB	•
₩ □ C:\ D:\	2	Rosreestr	•
₽ C E:\		OpenSeaMap	•
⊕ <u></u> [] Z:\	c	Sputnik	
GeoPackage		Stamen	•
Layers & X		strava	
		LISGS	
E State Constructed		TianDiTu	
-195	199	Genchtah	
···· /00	FS:RI	Ukraine Cadastre	
	<u>fu</u>	Ware	
		Vvaze	
	7	Yandex	
		Bergtex	
		eAtlas Mos	
		OSM	OSM Cycle map
	0	Search QMS	SM Humanitarian
	Q	Add to Search	OSM Standard
r r			OSM TF Landscape

- 2) Now an OpenStreetMap will be shown in the *Map Canvas*. Temporarily hide the DEM by unchecking the box or dragging the OSM layer to the top.
- 3) In order to know the approximate extent of the Rur catchment, the exercise data contains a shapefile with the sources and the mouth of the catchment. Open the vector layer source_mouth.shp
- A) Now, from the Main Menu select *Raster* → *Extraction* → *Clip Raster by Extent*... as shown below:



5) In the Clip Raster by Extent dialogue choose as Input layer dem_reprojected. For Clipping

extent, click on _____ and choose *Select extent on canvas*.

🔇 Clip Raster by Extent	?	×	
Parameters Log Input layer Input layer Imput layer Imput dem_reprojected [EPSG:32632] Clipping extent (xmin, xmax, ymin, ymax)			
1		<u></u> II	Use Canvas Extent
Assign a specified nodata value to output bands [optional]			Select Extent on Canvas
Not set		E	Use Layer Extent
 Advanced parameters 			Havener

6) Draw a box on the map around the points from the <code>source_mouth</code> layer.

	Rooma Region of	Clip Raster by Extent ? X
	Rigger vyckie with vychech Contractioner Dilles	Parameters Log
	Wareners Creeks Freezebart	dem reprojected [FPSG:32632]
		Clipping extent (xmin, xmax, ymin, ymax)
	Starson Sectory IL	65.07345154276,5570715.671823739,5683882.629037111 [EPSG:32632]
	Acertar Austr	Assign a specified nodata value to output bands [optional]
	Forwels - Dates	Not set
	Addrest Somery Brygen	 Advanced parameters
	Rawas Relayin Subert	Additional creation options [optional]
	Buren Strategen Perfueren	Profile Default
	Marzdia del Ball Minder	Name
	1. 1 - Pa () - P / S / S / S / S / S	· · · · · · · · · · · · · · · · · · ·
	Rest and a set	
	The second second	🛞 🧰 Validate Help
	⁵ after yrg Hilesbern	Output data type
7)	Give the ouput file the	Use input layer data type
	name	Clipped (extent)
	dem subset.tif. Use	D:/QGIS_Exercises/Exercise_5/dem_subset.tif
		Open output file after running algorithm
	the button to browse	GDAL/OGR console call
	to the right location (e.g.	gdal_translate -projwin 280321.8132797977 5683882.629037111
	D:\QGIS_Exercises\	341365.07345154276 5570715.671823739 -of GTiff Z:/QGIS_Exercises/ Exercise 5/dem reprojected.tif D:/QGIS Exercises/Exercise 5/dem subset.tif
	Exercise_5).	
8)	Click Run and Close the	0% Cancel
	dialogue when ready.	Run as Batch Process Run Close Help

9) Now you can remove dem_reprojected from the layers list as we have done before for other layers that are not longer needed.

9.7 Fill sinks / remove spikes

Raw, unprocessed DEMs have artefacts such as depressions and peaks. These artefacts are a result of the DEM acquisition process and need to be removed before a DEM can be used for hydrological analysis, like catchment and stream delineation or hydrological modelling. There are several algorithms for filling sinks. Here we will use the algorithm developed by Wang and Liu (2006), which is faster than other algorithms and therefore works better with high resolution datasets.

1) We will use the QGIS *Processing Toolbox*. If you don't see the *Processing Toolbox* at the right of your screen, you can enable it by choosing from the main menu *Processing* \rightarrow *Toolbox*



2) In the *Processing Toolbox* use the *Search...* field to search for fill sinks



3) Go to SAGA \rightarrow Terrain Analysis - Hydrology \rightarrow Fill sinks (wang & liu).

You see that there are more algorithms for filling sinks. Each has its own advantages and disadvantages in terms of calculation time, memory usage and accuracy. For your own research you need to make a decision based on the documentation of the algorithms or by analysing the results of several algorithms.

4) In the dialogue keep the defaults. Make sure to select dem_subset as the input and define dem fill.sdat as the *Filled*

DEM. Always use the **....** button and *Save to file...* to browse to the right location (e.g.

D:\QGIS_Course\Exercise_5). We only need the Filled DEM at this point, so you can uncheck the boxes for opening the output of *Flow Directions* and *Watershed Basins*.

- 5) Click *Run* and *Close* when done.
- Now remove dem_subset from the layers list, because it is no longer needed.

🔍 Fill Sinks (Wang & Liu)	?	×
Parameters Log		
DEM		
dem_subset [EPSG:32632]	-]
Minimum Slope [Degree]		
0.010000		÷
Filled DEM		
D:/QGIS_Exercises/Exercise_5/dem_fill.sdat		
Open output file after running algorithm		
Flow Directions		
[Save to temporary file]		
Open output file after running algorithm		
Watershed Basins		
[Save to temporary file]		
Open output file after running algorithm		
0%	Canc	el
Run as Batch Process Run Close	Help	,

9.8 Calculate Strahler order and determine threshold for streams

Before we can derive the streams from the DEM, we need to determine what we consider streams. For this purpose we use the Strahler order. The higher the order, the bigger the stream.

1) Search for Strahler in the Processing Toolbox and select $SAGA \rightarrow Terrain Analysis - Channels \rightarrow Strahler order$



2) In the dialogue select the Filled DEM for the elevation. And use strahler.sdat as the output filename and click *Run*. Click *Close* when the algorithm is done.

🔇 Strahler Order	?	×
Parameters Log Elevation		
Filled DEM [EPSG:32632]	•	
Strahler Order		
D:/QGIS_Exercises/Exercise_5/strahler.sdat		
✓ Open output file after running algorithm		
0%	Cano	el
Run as Batch Process Run Close	Hel	p

- 3) Check the result. What are the minimum and maximum values? Is the Strahler raster discreet or continuous? Make a nice legend, where the highest Strahler orders are more blue so you can clearer see what the rivers are.
- 4) Use the Raster
 Calculator to create a
 Boolean map with 1 for
 Strahler order >= 5 and
 0 for the other values.
 Call the output file
 strahler5.tif
- Make a nice legend where 1 is blue and 0 is transparent. Check the result with the rivers in OpenStreetMap.
- Repeat steps 4 and 5 with different threshold values and choose the best result.

	Result L	ayer						
dem_fill@1	Output l	ayer	D:\QGIS_E	kercises\Exercise	e_4\strahler5.	tif		
stranier@1	Output f	ormat	GeoTIFF					
	Selecte	d Layer Extent						
	X min	280311.32297	÷			X Max	341361.32	297
	Y min	5570732.0524	0 🗄			Y max	5683892.0	5240
	Columns	2035	÷			Rows	3772	
	Output (CRS	EPSG:3263	2 - WGS 84 / U	TM zone 32N			•
	🔽 Add r	esult to project						
▼ Operators -								
+	*	sqrt	COS	sin	tan		log10	(
	1	^	acos	asin	atan		In)
-				1	1	1	AND	OR
	>	=	!=	<=	>=		7445	
	> tor Express		!=	<=				
	> tor Express		!=	<=				
	> tor Express		!=	<=				
-	> tor Express		!=	<=				

9.9 Calculate flow direction, channel network and catchments

Now with our corrected DEM and the threshold value (Strahler order) we can proceed to calculate the flow direction, channel network and catchments in our area. We will use the D8 method for flow direction. The D8 method evaluates the slopes in 8 discrete directions around a pixel.

In the *Processing Toolbox* you can also find related tools that use different algorithms. Always check the documentation of the algorithm to find the right one or do a comparative analysis.

- 1) Search for Channel in the Processing Toolbox and select SAGA → Terrain Analysis - Channels → Channel network and drainage basins Processing Toolbox

 Processing Toolbox
 Image basins

 Image: Image of the second select
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- 2) In the dialogue select the dem_fill for the elevation and put the threshold at the value you found in step 6 of the previous section, e.g. 8. This means that streams with a Strahler order larger than or equal to this value will be considered as rivers. The algorithm will calculate flow direction and the Strahler order to determine the channels and drainage basins. Select the checkboxes for the following outputs:
 - *Flow direction* and save it as flowdir.sdat
 - *Channels* and save it as channels.shp.
 - Drainage basins and save it as basins.shp (the other one is for raster)

Always use the button and Save to file... to browse to the right location (e.g. D:\QGIS_Exercises\Exercise_5). If the dialogue is similar as below, click Run.

🔇 Channel Network and Drainage Basins ? X
Parameters Log
Elevation
Filled DEM [EPSG:32632]
Threshold
8
Flow Direction
D:/QGIS_Exercises/Exercise_5/flowdir.sdat
✓ Open output file after running algorithm
Flow Connectivity
[Save to temporary file]
Open output file after running algorithm
Strahler Order
[Save to temporary file]
Open output file after running algorithm
Drainage Basins
[Save to temporary file]
Open output file after running algorithm
Channels
D:/QGIS_Exercises/Exercise_5/channels.shp
✓ Open output file after running algorithm
Drainage Basins
D:/QGIS_Exercises/Exercise_5/basins.shp
Open output file after running algorithm
Junctions
[Save to temporary file]
Open output file after running algorithm
0% Cancel
Run as Batch Process Run Close Help

- 3) Inspect the results. Make legends for all these maps (are they discrete, continuous or Boolean?).
 - What does the Drainage Basins map show? Does it already give a good indication of the Rur catchment?
 - What does the Flow Direction map show? What does the legend mean? Make a nice legend using styling.
 - Does the stream delineation map (channels) reflect well the flowline of the Rur river? Drag it to the top of the layers list and give it an intuitive style. Overlay the Channels vector on OpenStreetMap to see if the derived streams fit with the rivers on the map (make them different than blue to see the difference with the map. What went well? What went wrong? Why?



9.10 **Define outflow point**

A catchment is an extent or an area of land where surface water from rain, melting snow, or ice converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean. In order to delineate a catchment we need to have two fundamental data:

- the coordinates of our outlet in the same coordinate system as the map we are using
- the channel network that matches the flow directions as calculated from a hydrological correct DEM

The outflow point of the Rur catchment is in Roermond an can be found in the given shapefile source mouth.shp. The channel network that has been derived is in channels.shp.

- 1) Make sure you have the channels.shp layer on top of the OpenStreetMap layer from the QuickMapServices plugin.
- 2) Check that the source_mouth.shp (1) has the same projection as channels.shp, and (2) that the outflow point is located exactly overlapping the delineated river in channels.shp. If the outflow point is not exactly over the delineated river, the catchment will not be delineated. In that case we need to look for a location over the delineated channels as in this example:



Note that there has been some distortion for 3 reasons:

- Incorrect automatic delineation of streams, which can be caused by errors in the DEM or areas that are too flat
- Distortion due to on-the-fly reprojection
- Human influence on the natural course of the channels
- 3) Now use the coordinate capture tool to get the coordinates of the outflowpoint in channels.shp. You can find the coordinate capture tool from the menu: Vector → Coordinate capture → Coordinate capture. Or look for this icon in the icon panel on the left

of the screen: . Note that the plugin needs to be installed and activated (check the box in the *Plugins Manager*). Another panel will show up:

	Coordinate Capture	
٢		
]
8	Copy to di	pboard
	-d-start c	apture

4) Click on *Start capture* and click on a point on the delineated river close to the mouth of the Rur as indicated in the figure. Make sure you capture it from the river in channels.shp, because the background map (OpenStreetMap) has not been derived from the DEM and will result in errors in the catchment delineation. What projection are we using? How do you know?

Coordin	ate Capture	₽×
\bigcirc	5.97702,51.19441	
▦	288787.394,5675788.683	
8	Copy to clipboard	
	-\$ Start capture	

9.11 Delineate catchment

Now we're going to use these coordinates to calculate the upstream area that produces discharge at this point.

 In the Processing Toolbox search for Upslope Area and choose SAGA → Terrain Analysis - Hydrology → Upslope Area



2) Fill in the dialogue as below. Use the coordinates that you captured near the outflow point. For elevation use your filled DEM. Use the default D8 method. Name the output Rur_catchment.sdat. Click Run. Click Close after the algorithm is done.

🔍 Upslope Area	?	×
Parameters Log		
Target Area [optional]		
	•	
Target X coordinate		
288786.396000	×	•
Target Y coordinate		
5675815.310000	×	•
Elevation		
em_fill [EPSG:32632]	•	
Sink Routes [optional]		
	•	
Method		
[0] Deterministic 8		•
Convergence		
1.100000		•
Upslope Area		
D:/QGIS_Exercises/Exercise_5/Rur_Catchment.sdat		
Open output file after running algorithm		
0%	Canc	el
Run as Batch Process Run Close	Help)

The result should look like the screenshot below.



3) In order to overlay the catchment boundary with other data, it is better to convert it from raster to vector (polygon). To convert the raster layer to vector, go to the menu and choose Raster → Conversion → Polygonize (Raster to vector). Make sure you choose the right input and call the output Rur_catchment.shp. Click Run. Click Close to get back to the main screen.



- 4) Look at the result. Also check the attribute table (Click right on layer name and choose Open attribute table). What value has the inside of the catchment polygon? What value has the outside area?
- 5) Of course we are only interested in the catchment area, so we have to remove the outside polygon. In the attribute table toggle to editing mode by using

Rester to Vector) ? X				
Parameters Log Input layer				
Rur_Catchment [EPSG:32632]				
Band number				
Band 1				
Name of the field to create				
DN				
Use 8-connectedness				
Vectorized				
D:/QGIS_Exercises/Exercise_5/Rur_Catchment.shp				
Open output file after running algorithm				
GDAL/OGR console call				
gdal_polygonize.bat Z:/QGIS_Exercises/Exercise_5/ Rur_Catchment.sdat D:/QGIS_Exercises/Exercise_5/ Rur_Catchment.shp -b 1 -f "ESRI Shapefile" None DN				
0% Cancel				
Run as Batch Process Run Close Help				

this button: \swarrow . Then select the record that you want to remove. The selection will be highlighted in yellow on the map. Then click m to delete the selected feature and toggle off the editing by clicking again m and save the changes.



6) Now remove all unnecessary layers from the layers list so that we have only Source_mouth, Channels, Rur_catchment, OSM Standard and Filled DEM (in that order).



7) We can clip the Channels vector layer to see only the streams that are inside the catchment. Go to the menu and select Vector → Geoprocessing Tools → Clip. Sometimes the topology of the catchment polygon has some problems. In that case you can try other clip functions from the Processing Toolbox.



8) Fill in the dialogue as below to use the catchment layer as a "cookie cutter" to clip the channels shape file to the catchment extent. Call the output channels_clip.shp. Click Run to run the tool. Click Close to return the main screen.

🔇 Clip	? ×
Parameters Log	Clip
V [°] channels_clip [EPSG:32632] ▼ ♀	This algorithm clips a vector layer using the features of an
Selected features only	additional polygon layer. Only the parts of the features in the
Werlay layer Rur_Catchment [EPSG:32632]	Input layer that fall within the polygons of the Overlay layer
☐ Selected features only	layer.
Clipped DGIS Exercises/Exercise 5/channels clip.shp	The attributes of the features are not modified, although
✓ Open output file after running algorithm	properties such as area or length of the features will be
	0% Cancel
Run as Batch Process	Run Close Help

- 9) Remove Channels from the layers list and drag channels_clip to the top of the list.
- 10) Give channels_clip an intuitive colour and make the Rur_catchment polygon hollow (no fill colour) and give it a thick red border. You can do this by clicking right on the layer name, selecting Properties... and go to the Symbology tab. You can also press <F7> to open the styling dock and set the styling options for different layers from there.

The result should be similar to this:



11) At this point save your project. Choose from the main menu Project \rightarrow Save as...



- 12) In the dialogue that follows, browse to D:\QGIS_Exercises\Exercise_5 and save your project as Exercise_5.qgz
- 13) Now try to calculate slope, aspect and hillshade using the functions in the menu Raster \rightarrow Analysis or the processing toolbox and make some nice maps with good legends.

This whole exercise can be viewed in a screencast at: https://youtu.be/Ro-RRzMMw-c

Exercise 6: Using Open Data

10 Using Open Access data

10.1 Introduction

Now that we have defined the boundaries of our study area, i.e. the Rur catchment, we can look for open access data that is available on the internet. In this exercise we will use

- Data from the European Environment Agency (EEA) public map services: <u>http://discomap.eea.europa.eu</u>
- Data from OpenStreetMap: <u>http://www.openstreetmap.org</u>

Instead of using a web browser, we will create a live link between the online data and our data in QGIS, using Web Map Services (WMS), which is an open standard for sharing maps through the internet and we will also download vector layers from OpenStreetMap through QGIS.

For this exercise you need the delineation of the Rur catchment and its streams from the previous exercise. You can also download them from the Open Courseware website (<u>http://ocw.unesco-ihe.org</u>).

Before we start, make sure that you have the following layers on your screen:

- Boundary of the Rur catchment
- Streams in the Rur catchment
- OSM Standard backdrop from the QuickMapServices

Your screen looks now like this:



10.2 Adding data from the European Environment Agency (EEA) public map services

The European Environment Agency (EEA) is the agency of the European Union (EU) that provides independent information on the environment, thereby helping those involved in developing, adopting, implementing and evaluating environmental policy, as well as informing the general public. The European Environment Agency provides maps on thematic areas such as air, water, climate change, biodiversity, land and noise. The map services are accessible through

<u>http://discomap.eea.europa.eu</u>. In this exercise we will add data from the EEA public map services to our QGIS project.

- 1) Go to the website <u>http://discomap.eea.europa.eu</u>. There you see a list of themes.
- 2) Click on Land under Land. Here you can see the EEA datasets related to land cover and their descriptions.
- 3) Look for the CLC2012 ETRS89 LAEA (MapServer) data and click on *More info* to see what data it contains.
- 4) Click on the picture of the map on the left to open an interactive map viewer
- 5) In the map viewer click on the Legend tab and zoom in at the study area.



6) Now we're going to add this land-cover data to our QGIS project. Go to your QGIS project.

From the main menu choose click the Open Data Source Manager button 🤽

7) In the *Data Source Manager* dialogue choose *WMS/WMTS*

🔇 Data Source Manager WM	IS/WMTS	? X
📂 Browser	Layers Layer Order Tilesets Server Search	
V- Vector	EEA Land	
Raster	Connect New Edit Remove Load Save Add	Default Servers
Mesh	ID Name Title Abstract	
7 , Delimited Text		
餐 GeoPackage		
🍂 SpatiaLite		
PostgreSQL		
MSSQL	∣ □ Image Encoding	
📮 Oracle		
DB2 DB2	Options-	
Virtual Layer	Tile size	
WMS/WMTS	Request step size	
ter wcs	Heature limit for GetHeatureInfo J10	
WFS	Use contextual WMS Legend	
ArcGIS Map Server		
ArcGIS Feature Server	Layer name Ready	
SeoNode	<u>Close</u> <u>A</u> dd	Help

- 8) In the dialogue that opens click the *New* button.
- 9) In the dialogue that follows type for Name: EEA Land
- 10) We can find the URL on the website: below the title of the CLC2012 ETRS89 LAEA (MapServer). Click right on WMS and choose *Copy link location*

CLC2012 ETRS89	LAEA (MapServer)	
REST JSON SOAP WWM	Open Link in New <u>T</u> ab Open Link in New <u>W</u> indow	EA
Author Subject	Open Link in New <u>P</u> rivate Window Bookmark This Link	ne of the datasets produc
Keywords Copyright Text	Save Lin <u>k</u> As Save Link t <u>o</u> Pocket	ip,satellite image interore vironment Agency (EEA)
Registered first time	Copy Link Loc <u>a</u> tion <u>S</u> earch Google for "WMS"	
Service Description Image: More info	Send Link to <u>D</u> evice Inspect Element (<u>Q</u>)	 tom-up) solutions has sli

11) Paste the link in the QGIS dialogue (see screenshot below), keep the defaults and click OK.

Create a New WMS/WMTS Connection		\times
Connection details		
Name EEA Land		-
URL http://land.discomap.eea.europa.eu/arcgis/services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities&services/Land/CLC2012_LAEA/MapServer/WMSServer?request=GetCapabilities	=WMS	_
Authentication		
Configurations Basic		
Choose or create an authentication configuration		
No authentication 🔽 🥢 🚍 🖶		
Configurations store encrypted credentials in the QGIS authentication database.		
		-
WMS/WMTS Options		
Referer		
DPI-Mode all	•	i
Ignore GetMap/GetTile URI reported in capabilities		
🗍 Ignore GetFeatureInfo URI reported in capabilities		
□ Ignore axis orientation (WMS 1.3/WMTS)		
Invert axis orientation		
Smooth pixmap transform		
OK Cancel	Help	

- 12) Back in the other dialogue window click *Connect*. The layers will now be retrieved from the WMS server
- 13) Click on *Wetlands* so that it is highlighted, choose PNG for the Image encoding format (this allows transparency) and check the box before *Use contextual WMS legend*. Then click *Add* and *Close* to return to the main screen. Note that WMS layers are georeferenced pictures, not vectors.

🔇 Data Source Manager WMS/WMT	s ? X
Figure Browser	Layers Layer Order Tilesets Server Search
V- Vector	EEA Land
Raster	Connect New Edit Remove Load Save Add Default Servers
Mesh	ID Name Title Abstract
▶ Delimited Text	E 21 Agricultural Areas Corine Land Cover Agricultural Areas include arable land, pe 16 Artificial surfaces Corine Land Cover Agricultural Areas include arable land, pe Corine Land Cover Agricultural Areas include arable land, pe Corine Land Cover Agricultural Areas include arable land, pe
🤗 GeoPackage	⊕ 1 Poles Selin Hadda Arleas Come Land Cover Agricultural Areas include arable land, pe ⊕ 1 Wetlands Come Land Cover Agricultural Areas include arable land, pe
🎢 SpatiaLite	
PostgreSQL	
MSSQL	Image Encoding
Oracle	● PNG ○ PNG8 ○ JPEG ○ GIF ○ TIFF ○ SVG
DB2 DB2	Options (0 coordinate reference systems available)
Virtual Layer	Tile size
WMS/WMTS	Request step size
t wcs	Feature limit for GetFeatureInfo 10
WFS	Use contextual WMS Legend
ArcGIS Map Server	
ArcGIS Feature Server	aver name j elect layer(s)
GeoNode	CloseAddHelp

- You can see that the source area of the Rur catchment is located in wetlands. What are the names of these wetlands?
- In which country/countries are these wetlands?

14) Now add in a similar way Artificial Surfaces.

- In the midstream part of the catchment there are some large purple areas. What are these?
- Add Google satellite from the QuickMapServices to have a closer look at these features. Describe what you see.
- What are the other Artificial Surface classes in the map? Can you describe the geographical distribution of population in the Rur catchment?
- What are the largest cities in the catchment?
- 15) Load the remaining classes.
 - Where are the forests and agricultural areas located?
- 16) Now rearrange the layers as such that you have a map with the catchment boundary, stream network and land cover classes.



17) Save the project before you continue.

If you have time, you can look for more EEA data in a similar way.

10.3 Adding vector data from OpenStreetMap

OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. OSM is considered a prominent example of volunteered geographic information (VGI) or crowdsourcing. There are several ways to use the data:

- Through the interactive map on the OpenStreetMap website (<u>http://www.openstreetmap.org</u>)
- In QGIS through the QuickMapServices Plugin
- In QGIS through the option to download OSM data directly from the internet. There are several ways to do this. In this exercise we'll use the QuickOSM plugin which uses the Overpass API (https://wiki.openstreetmap.org/wiki/Overpass_API).

In this exercise we are going to download OSM vector data directly in QGIS for the Rur Catchment. We continue from the previous results, but we only visualise the Rur_Catchment and Channels Clip layers. The other layers should be unchecked.

- Install the QuickOSM plugin through the main menu: *Plugins* → *Manage and Install Plugins*... Search for QuickOSM
- 2) Open the QuickOSM dialogue by choosing from the main menu: $Vector \rightarrow QuickOSM \rightarrow QuickOSM$



We're first going to download the rivers so we can compare them with the rivers that we have derived before. The OSM data attributes consist of keys and values. To learn more about it, click *Help with key/value*.

3) Choose waterway as *Key*, river as *Value*. Choose the Rur_catchment polygon as the extent. Click the arrow before *Advanced* and make sure only *Node*, *Way*, *Relation* and *Lines* are checked. The dialogue should now look like the screenshot below. Click *Run Query*.

QuickOSM		? ×
🖗 Quick query	Help with key/value	Reset
🥖 Query	Key waterway	•
CSM File	Value river	•
Parameters	Layer Extent 🔄 🖙 Rur_Catchment	•
	 Advanced 	
1 About	Node 🔽 Points	,
	Way 🔽 Lines	v
	Relation 🖻 Multil	inestrings 🗖
	Multip	olygons 🗖
	Timeout 25	<u>*</u>
	Directory Save to temporary file	
	File prefix	
	Show query	Run query
		0%

- 4) Adjust the style and compare the waterway_river from OSM with the Channels_Clip layer. What do you observe?
- 5) Let's add the mines in a similar way. The key=landuse, value=quarry. Don't forget to select *Multipolygons* instead of *Lines*.
- 6) Try to locate Jülich. You can also use the GeoCoding plugin to locate Jülich. You can install it through the menu: Plugins → Manage and Install Plugins... . Search for GeoCoding. The GeoCoding plugin uses web services (Nominatim and Google) to retrieve the coordinates of an address.
- 7) Now zoom in on the centre of Jülich (see figure below).



Southeast of Jülich is the Forschungszentrum Jülich, a large research institute. In the south and east we see a large surface mining of lignite. The one in the south is in the Rur catchment.

- 8) Now compare the OSM derived quarry with a Google Satellite and the EEA artificial surfaces map. What are the differences? Which one is more up-to-date? Google Satellite, EEA or OSM? How does the hydrography relate to the quarry (OSM vs GIS delineated)?
- 9) Save the quarry polygons as a shapefile: click right on the layer, choose Save as...In the dialogue, save the file as quarries.shp in the right folder using the Browse button.Click OK to save the shapefile.
- 10) Now add a few other interesting features (points, lines and polygons), e.g.:
 - Dams: Key=waterway, value=dam
 - Lakes: Key=natural, value=water
 - Springs: Key=natural, value=spring

11) Style the layers with intuitive colours.

11 Create 2D and 2.5D maps

11.1 Introduction

With the GIS data collected in the previous exercises, we are now ready to produce some maps to take with us in the field. In this exercise we will produce two types of maps:

- A PDF map with coordinate grid, north arrow, scale bar and legend (2D)
- An interactive 2.5D map to visualise the layers draped over the DEM

You can make maps through combination of layers that we have collected in the previous exercises.

11.2 Creating a PDF map

- First arrange the layers on the screen in such a way that all layers you want to have in the map are visible and at the right zoom level. Also verify that the on-the-fly projection is EPSG:32632.
- 2) Configure the right styling of the layers. Remember to use intuitive colours.
- Use the Print Composer (*Project* → *New Print Layout*) to create a map with all its properties (North arrow, scale bar, intuitive legend, etc.). Use the instruction video on eCampus.
- 4) When finished choose from the menu *Layout* \rightarrow *Export as PDF*...

🔇 *exercise_5 - QGIS					
Project	Edit	View	Layer	Settings	Plugi
🗋 New	1		C	Ctrl+N	4
New	/ from	Templ	ate		۱.
🛅 Ope	n		C	Ctrl+O	- P
Ope	n Fron	n			۰L
Ope	n Rec	ent			۰E
Clos	e				
🗟 Save	9		c	trl+S	
🔜 Save	As		C	trl+Shift+S	5
Save	е То				•
Reve	ert				
Prop	erties		C	trl+Shift+I	
Snap	oping	Options	5		
Imp	ort/Ex	port			•
🔂 New	ı Print	Layout	C	Ctrl+P	
📑 New	/ Repo	rt			
🔄 Layo	out Ma	nager			
Layo	outs				•
Exit	QGIS		C	trl+Q	



11.3 Creating a 2.5D interactive map

We can drape GIS layers over a DEM and create a 2.5D interactive map.

1) Open a new 3D map view by choosing from the main menu: $View \rightarrow New 3D Map View$



- 2) In the new 3D Map View (3D Map 1) click the configuration button
- 3) In the *3D Configuration* dialogue choose the Filled DEM as *Elevation* and choose 10 for the *Vertical scale* (the area is quite flat so we exaggerate 10 times). Keep the rest as default and click *OK*.

Q 3D Configuration			? ×
Terrain			
Elevation	🕅 dem_fill		
Vertical scale	10.00		
Tile resolution	n 16 px		
Skirt height	10.0 map units		×
Map tile resolution	n	512 px	· ·
Max. screen error		3.0 px	*
Max. ground error		1.0 map units	<u>*</u>
Zoom levels		0 - 10	
□ Show labels			
□ Show map tile info			
□ Show bounding boxes			
□ Show camera's view center			
			OK Cancel

4) Enlarge the window. Use the scroll button of your mouse to zoom in/out. Drag the with the scroll button clicked to create an oblique view. Navigate through the landscape with the mouse or the arrow buttons. With the shift button pressed you can rotate around a point.

With the 📠 button you can save the result to a TIFF file to include the 2.5D map in a report.



11.4 Export to Google Earth

- You can also export files to Google Earth. To export the catchment delineation to Google Earth do the following: click right on the Rur_catchment layer and select Export → Save features as...
- 2) In the dialogue select *Keyhole Markup Language [KML]* as the output format. Choose an output filename and click OK. The resulting file can be opened in Google Earth by double clicking on the filename in Windows Explorer.

🔇 Save Vector Layer as ?							
Format File name Layer name	Keyhole Markup Lang Dt\QGIS_Exercises\E Rur_catchment	uage [KML] xercise_5\Rur_catchment.kn	r 🖾 🛓	•			
CRS	EPSG:32632 - WGS 8	84 / UTM zone 32N	•				
Encoding Save on Add save Select	ly selected features ed file to map fields to export and	UTF-8	Ŧ				
Symbology	export	No symbology	•				
Scale		1:1000000	-				
▼ Geometry							
Geometry	y type	Automatic	-				
Force multi-type Include z-dimension							
Extent (current: layer)							
Datasource Options AltitudeMode relativeToGround DOCUMENT_ID root_doc OK Cased Hole							
			нер				

Note that the CRS does not matter. A KML file will always be saved in the projection that is supported by Google Earth.



12 Styling and map design

12.1 Introduction

After this exercise you will be able to:

- Create a GeoPackage with data and styles
- Style vector layers
- Copy, import and export styles
- Design a map

In this exercise we are going to add mainly vector data related to water supply. The exercise encloses the styling of various vector layers and designing of a map with various map item in the print composer.

In this exercise we'll use the following data:

- Area.shp (and associated files): polygon of the area of interest
- Endcap.shp (and associated files): points of the endcaps
- Household_connection.shp (and associated files): points of house hold connections
- Hydrants.shp (and associated files): points of the hydrants
- Pipeline.shp (and associated files): lines of the pipelines for the water supply
- Source.shp (and associated files): points of the sources of water
- Tanks.shp (and associated files): points of storage tanks for water

The dataset has been developed by Vitens Evides International and the National Water and Sewerage Corporation in Uganda.

You can download the data for Exercise 7 from the OpenCourseWare website (<u>http://ocw.unesco-ihe.org/course/view.php?id=11</u>) and store the files in a folder on your harddrive

(e.g. D:\QGIS Exercises\Exercise 7).

This exercise will guide you through the following steps:



12.2 Creating a Favorite in the Browser Panel

- 1. Start QGIS Desktop.
- 2. Add the folder with the data from this exercise to the *Favorites* in the *Browser Panel*: click right on Favorites and choose *Add a directory*.... Then browse to the Exercise_7 folder. The contents of the folder will now be listed under *Favorites* for easy access.



3. First we check the metadata. Click right on Area. shp and choose *Properties*.... What is the projection of this layer? Also check the projection of the other layers in the same way.

Q Layer Properties	?	×
Information f	rom provider	-
Name	Area.shp	
Path	Z:\QGIS Exercises\Exercise 7\Area.shp	
Storage	ESRI Shapefile	
Comment		
Encoding	UTF-8	
Geometry	Polygon (MultiPolygon)	
CRS	EPSG:21096 - Arc 1960 / UTM zone 36N - Projected	
Extent	362862.1131753329536878,369859.5358004590962082 : 368024.2126909086364321,375025.7825009398511611	
Unit	meters	
Feature count	1	-
	Cle	ose

4. Now select all the layers from this exercise with the shift button pressed and drag them to the *Map Canvas*.

12.3 Creating a GeoPackage

Before we start styling these layers we are going to save them all into a GeoPackage, so we have all the layers together in one file. Later we are also going to add the styles to the GeoPackage.

5. In the Processing Toolbox search for the Package layers tool



- 6. Double click on Package layers to open the *Package Layers* dialogue.
- 7. At Input layers click and select all vector layers
8. Choose Adjumani.gpkg as the Destination GeoPackage.

Q Package Layers	? ×
Parameters Log Input layers 7 elements selected Overwrite existing GeoPackage Destination GeoPackage D:/QGIS_Exercises/Exercise_7/Adjumani.gpkg	 Package layers This algorithm collects a number of existing layers and packages them together into a single GeoPackage database. ? ×
 ✓ [Area [EPSG:21096] ✓ Endcap [EPSG:21096] ✓ Household_connection [EPSG:21096] ✓ Hydrants [EPSG:21096] ✓ Pipeline [EPSG:21096] ✓ Source [EPSG:21096] ✓ Tanks [EPSG:21096] 	Select All Clear Selection Toggle Selection Add File(s) OK Cancel
Run as Batch Process	0% Cancel Run Close Help

- 9. Click Run.
- Now all the shapefiles have been stored in a GeoPackage you can remove all the shapefiles from the Layers Panel (right click → Remove layer...).
- To add the new GeoPackage layers first refresh your Browser panel by clicking 2
- 12. Click the plus sign before Adjumani.gpkg to see the layers in the GeoPackage.
- 13. Select all these layers and drag them to the Map Canvas.
- 14. Rearrange the layers so all data is visible.



12.4 Styling the vector layers

- 15. As a background, a satellite image can be used from the *QuickMapServices Plugin*. In the menu choose $Web \rightarrow QuickMapServices \rightarrow Google \rightarrow Google Satellite$.
- 16. Place the vector layers and the Google Satellite image in a useful order by dragging the items in the layers list. For example, background images are normally the lowest layers.

We now start with styling the vector layers. Each layer is appointed a random style when you open it. Styling covers the colours, shapes, sizes, text labels. The styling is done under the properties of each layer (right-click on layer) or by using the *Layer Styling* panel by pressing <F7>.

- 17. Now choose *Household_connection* \rightarrow *Properties* \rightarrow *Symbology*.
- 18. For the household connections a red cross will be the symbol to use. In order to do so select simple marker \rightarrow cross symbol. The Stroke colour should be red.
- 19. You can enter for the *size 20 map unit* and for the *Stroke width 3.0 map unit*. You can choose between mm and map units. For millimetres the zooming level does not matter and the symbol always stays the same size, even if you zoom in very closely. When selecting map units, the symbol becomes bigger when you zoom in.

Q	Layer Properties - Hous	ehold_connection	n Symbology	? X	
Q		Single symb	ol	•	-
i	Information	Marker	Die marker		
3	Source				
~	Symbology		X		
abc	Labels				
۹.	Diagrams				
\	3D View				
1	Source Fields	<u>+</u>			
-8	Attributes Form	Symbol layer typ	e Simple marker	•	
•	Joins	Size	20.000000 🚊 Map Units 💌 🔧		
đ	Auxiliary Storage	Fill color		E.	
٩	Actions	Stroke color			
,	Display	Stroke style	Solid Line	E.	
Ý	Rendering	Stroke width	3.000000 🕲 🕂 Map Units 💌 🔧		
3	Variables	loin style	Powel		
2	Metadata	Sour Scyle			
4	Dependencies	Rotation	10.00 °	¶⊒.	
	Legend	Offset	x 0.000000 v 0.000000 i Milimeter		
	QGIS Server		VCenter VI		- 1
170	Digitizing	Style 🝷	OK Cancel Apply	Help	

20. Click OK to close the dialogue and return to the map canvas.

21. Open the attribute table of the Pipeline layer. Do this by clicking right on the layer and choosing *Open Attribute Table*. Investigate the type of information that is there.



22. Now style the Pipeline vector layer by opening its properties. Instead of a *Single Symbol*, select the *Categorized*. In the map, there needs to be a distinction between the transmission lines and the distribution lines. In order to do so, which column do we need to select to categorize on?

🔇 Layer Properties - Adjumani Pipeline Symbology					
Q	Eategorized		-		
🥡 Information	Single symbol				
Source	Gategorized Graduated Rule-based				

- 23. After the selection of the correct column, click *Classify*. You will find two new symbols for 'Transmission' and 'Distribution'. By *double clicking on the lines* you can modify the style.
- 24. Choose an appropriate style according to your own insight. Just to remind you use the map unit for the width of the line. After finishing the styling of the two layers, click *Apply*.
- 25. The map should also indicate the type of material and the width of the pipeline by not using anymore colours. For that we use text label, which you can also find in the *Layer Properties* tab on the left side. Choose from the dropdown menu *Single labels*. Now you can *select* a column using the drop down list at Label with.
- 26. If you want multiple columns in the label, you can enter an expression, which is next to the

arrow. Click the ε button to enter the following expression:

```
"Material o" || ' - ' || "Diameter o" || ' mm'
```

- The text between double quotation marks (") indicate the column. The text between single apostrophe (') is a text of string.
- The double vertical bars (||) are necessary to have multiple strings next to each other.
- ▶ If the preview looks okay, click OK.

Q Expression Dialog		? ×
Expression Function Editor		
= + - / * ^ II () \n "Material o" ' - ' "Diameter o" ' mm'	Q Search symbol_color Value Aggregates Arrays Color Search Conditionals Conversions Date and Time Fields and Values Fields and Values General Geometry Map Layers Maps Record and Attributes String Variables Watibles Excord (generic)	group Aggregates Contains functions which aggregate values over layers and fields.
Output preview: 'HDPE - 90 mm'		
	ОК	Cancel Help

- 27. The default text is not yet appropriate. To change this you find a lot of options below the 'Lorem Ipsum', which shows an example of how the text will look.
 - > Under TEXT For font use Tahoma, for size use 10 points, for colour choose blue.
 - Under Buffer For Size use 1 mm
 - > Under Placement Choose curved, for position tick 'On line' and untick 'Above line'
 - > Press OK

🔇 Layer Properties - Adjum	nani Pipeline Labels			? ×
Q	🛲 Single labels			- 🐟
🥡 Information	Label with Materia	o" ' - ' "Diameter o" ' mm'		3 -
Source	▼ Text Sample -			
Symbology	Lorem Ipsum			<u> </u>
(abc Labels				-
Diagrams	Lorem Ipsum		544 💌 📖	
	+ab Correct	Placement		-
Y 3D View	abc Buffer			-
Source Fields	🖶 Background	C Parallel C Curved C Horizontal		
📰 Attributes Form	Shadow			
	Placement	Allowed positions 🗆 Above line 🔽 On line 🗖 Below line		
Joins	Kendening	\square Line orientation dependent position		
Auxiliary Storage		Distance 0,0000	×	1 @
S Actions		Milimeter	<u>_</u>	16
🇭 Display		Repeat No repeat	<u>*</u>	
🞸 Rendering		Milimeter		16
Variables		Maximum angle between curved characters		
📝 Metadata		inside 25,0 to utside 25,0	<u>.</u>	
Nependencies		▼ Data defined		
Legend		Coordinate X 🖶 Y 🖶		
QGIS Server		Alignment horizontal (vertical)		
		Rotation 🕞 🔽 Preserve data rotation values		
		▼ Priority		•
	Style +			Help
	Style •	OK Car	Apply	нер

For the Source and the Tanks layers, the following two symbols will be created:



These are basically two simple markers. Here the marker for the Source layer will be discussed.

- 28. Open *Properties*... \rightarrow *Symbology* and *Add a symbol layer* P. Both simple markers should be a circle. For the top circle:
 - Make *Stroke color* transparent
 - Set Fill color to red
 - Set size to 20 map units

For the lower circle:

- Make Stroke color transparent
- Set colour to white
- Set size to 30 map units

🔇 Layer Properties - Sc	ource Symbology				? >	×
Q	📑 Single symt	ool			-]_
🥡 Information	🖻 📒 Marke	r Hardan				
🇞 Source	Sim	iple marker iple marker		I		
Symbology						
(abc Labels						
ң Diagrams						
প 3D View						
Source Fields	<u>+</u>					_
🔡 Attributes Form	Symbol layer ty	pe Simple marker			•]
• 📢 Joins	Size	30.00000	<u>.</u> M	ap Units 💌 🔧		
auxiliary Storage	Fill color					
🔊 Actions	Stroke color			-		
🧭 Display	Stroke style	Solid Line		•		
🞸 Rendering	Stroke width	Hairline	<u>*</u>	Millimeter 💌		
8 Variables						
📝 Metadata	Join style	Benel			۹ <u>ط</u>	
Dependencies	Rotation	0.00 °		• •	¢,	
E Legend	Offset	x 0.000000		Millimeter	e.	
QGIS Server		VCasta				
Digitizing	Style -	Jvcenter	OK Cane	cel Apply	¶⊒↓ Help	-

29. Make a similar symbol for the Tanks layer as shown before step 25. We can easily do this by copying the style and modifying it. To copy the style of Source click right on the layer name and select *Styles* → *Copy Style* → *All Style Categories*.



- 30. Now click right on the Tanks layer name and select *Styles* \rightarrow *Paste Style* \rightarrow *All Style Categories*.
- 31. You can now modify the style of the Tanks layer in the Styles dialogue similar to step 25.
- 32. Design your own symbol for the ${\tt Endcap}$ layer with a label to identify the ID.
- 33. The background satellite image is too dominant. We can make it transparent. Click right on Google Satellite and choose *Properties*.... Set the Global opacity to 60%.

Q Layer Properties - Google S	Satellite QGIS Server Transparen	cy		? ×
Q Information	✓ Global opacity	J	40,0 %	
Source	▼ No data value			
ኛ Symbology	No data value not defin Additional no data value	ned		
Transparency	 Custom transparency or 	ptions		
≼ Rendering	Transparency band None			<u>~</u>
📝 Metadata	Transparent pixel list	То	Borcont Transparent	
E Legend	FIGH	10		
QGIS Server				
	Style -	OK Car	cel Apply	Help

- 34. Lastly the style of the Area polygon layer will be set. Open *Properties*... \rightarrow *Symbology tab* \rightarrow *add symbol layer* (the + sign). For the top symbol layer choose the following specifics:
 - Fill is transparent
 - Stroke color is grey
 - Stroke width is 2 mm

For the bottom symbol layer choose the following specifics:

- Symbol layer type is Shapeburst fill
- Change the gradient colours to grey and white with 50% opacity
- Shade to set a distance to 5mm.
- 35. Lastly *change from 'Single Symbol' to 'Inverted polygons'*. This actually means that you are styling everything outside the selected polygon and click *OK*

🔇 Layer Properties - Adjumani Area Symbology				
Q	Inverted polygons			
🥡 Information	Sub renderer 🔤 Single	e symbol 💌		
Nource	Merge polygons before rendering (slow)			
😻 Symbology	E Fill			
(abc Labels	Shapeburst fill			
Magrams				
🕎 3D View				
Source Fields	Unit Milimeter			
Attributes Form	Color			

The result now looks like this:



12.5 Saving layer styles

Layer styles are not stored in the GIS files (e.g. shapefile or GeoTiff). They can be stored in your project file (a .qgz file), together with the zoom level, on-the-fly projection, etc.

36. Save the project as Adjumani.qgz. In the menu choose: *Project* → *Save as...* and save the file to the correct folder.

If you don't want to share an entire QGIS project, but just a layer with its styling, you'll have to save the styling to a file. Similar to an ArcGIS Layer file (.lyr) QGIS has its own format, the Layer Definition File (.qlr). Please note that these are software specific xml files and not international standards that allow for interoperability among software. For interoperability, it is better to use the Styled Layer Descriptor (SLD) file. SLD's are also used to style online maps.

- 37. To save the style go back to the
 Symbology dialogue and select Style →
 Save Style...
- In the Save Layer Style dialogue you can choose one of the formats. Let's first save it as an SLD file.



Q Layer Properties - Ho	isehold_connection Symbology			? X	
Q	🔄 🔄 Single symbol				•
🥡 Information	Marker				
🗞 Source					
Symbology				_ ×	
abc Labels					
🛉 Diagrams				I	
🜳 3D View					
Source Fields		\square			
🔡 Attributes Form	Unit Millimeter Opacity				<u>▼</u> 0.0 % ÷
Joins	Color				
Auxiliary Storage	Size 20.00000				
Actions	Rotation 0.00 °				
🧭 Display	All Symbols				∞ - *
🞸 Rendering					-
Ovariables	Load Style			•	
📝 Metadata	Save Style	•	•	•	
Tependencies	Save as Default Restore Default	diamond green	diamond red	dot block	
Legend	Add	ulamonu green		UUL DIACK	-
QGIS Server	Rename Current			Save Symbol	Advanced -
Migitizing	✓ default Style →		ок	Cancel Apply	Help

If you would now start a new project and you add a layer, you can also load a saved style from the .sld file. Also if you would upload a shapefile to GeoServer, you can use the .sld file to style the online map.

A great advantage of a GeoPackage is that also styles can be saved in the GeoPackage, so we really keep everything together in one file that we can easily share with others.

- 39. Go back to the *Symbology* dialogue and select *Style* \rightarrow *Save Style*...
- 40. Now choose In database (GeoPackage)
- 41. In the *Save Style in Database* dialogue give for the *Style Name* the name of the layer and provide a *Description*. Check the box to *Use as default style for this layer* and click *OK*.

🔇 Save Layer St	Save Layer Style ? X					
Save style In database (GeoPackage)						
Style name	Style name Household					
Description	Style of household conne	ction				
UI						
	Use as default style for	this la	ayer			
	OK Cancel	He	р			

- 42. Repeat this for all vector layers
- 43. Check if this indeed works: close QGIS, reopen and load the layers from the GeoPackage again. Don't forget to also add the Google satellite, make it 60% global opacity and reorder the layers. The styles of the vector layers should be as you defined them before.

This exercise can be viewed in a screencast at: https://youtu.be/i95xHt51eqI

12.6 Make a map in the print composer

1. Create under *Project* → *New Print Layout* a new layout and give it an appropriate name, e.g. Adjumani.

-						
Q	*adju	mani -	QGIS			
Pro	oject	<u>E</u> dit	<u>V</u> iew	<u>L</u> ayer	<u>S</u> ettings	<u>P</u> lu
	<u>N</u> ew				Ctrl+N	
	New	from	Templ	ate		<u> </u>
	<u>O</u> per	ı			Ctrl+O	
	Oper	n Fron	n			->
	Oper	n <u>R</u> ec	ent			•
	Close					
	Save				Ctrl+S	_
	Save	Δc			Ctrl_Shift_	_c
e S	Save	<u>п</u> з			contonict	٦,
	Reve	rt				
	Drop	ortion			Ctdu Chiftu	_
	Snan	nina	 Ontions		CUI+SIIIIC+	r
	Impo	ort/Ex	port	2		•
	New	<u>P</u> rint	Layout	t	Ctrl+P	
	New	<u>R</u> epo	rt			
	Layo	ut Ma	nager			
	Layo	uts				->
	Exit	QGIS			Ctrl+Q	

2. Normally, you need to design a map layout before you start to make the map, this means that you already know the general set up of the map and the various items you want to show on the map.

Title MAIN MAP	Title MAIN MAP reference map 1 reference reference legend legend	Title Title Title Title Title Title Title Title Teference map MAIN MAP
		margin

- 3. To set up the print layout, you need to choose which paper size you want to use (A3/A4 etc.). Click right on the paper and choose *Page Properties*.... The export DPI (dots per inch) is important for the quality of the map. With more dots per inch, you will get a higher quality (and larger size) export product. A DPI of 300 is appropriate for now. You can also choose between 'Landscape' vs 'Portrait' according to your needs. Here we'll make an A3 landscape map.
- Click the Add a map button and click and drag to insert the map.
 Under *Item properties*, you can edit the position on the canvas and zoom in. Find an area of

interest to you. You can also use the *Move item content* button

5. As you are now zoomed in to a part of the city in the map, a small overview map makes it easier to orientate yourself. Again click the *Add a map* button and drag a smaller map. (If you hold shift, it will become perfectly rectangular). Zoom out until you have the whole area in the overview map.

6. To create an overview select the tab *Item properties*. Under Overviews click the + sign to add an overview. Select for *Map Frame* Map 1. You can edit the color, transparency and even make it inverse. Choose yourself.



- 7. Now you will see every layer in the overview map, but we can remove some detail to make it easier to understand. Go back to the *Map Canvas* of QGIS and untick every layer except the Area layer.
- 8. Go back to the *Print Layout* and Select the overview map. Under its *Item Properties* → *Tick Lock Layer for this Map.* Click *Update preview.* Now it will only use the Area layer to draw the map and it will be fixed if you *tick the layers back on* for the larger detailed map.
- Below you find an overview to add other items.
 NOTE: under properties you will find many options per item. The default is often **not** the one you want.
- 10. Do not forget to *save* **b** the project file (.QGZ) once in a while.
- 11. Now add north arrows logos scale bars legends (sub)titles to your choosing. Be creative!
- 12. After finishing the map with your satisfaction, export the map to a pdf E or an image E.



	Add new map from QGIS map canvas
	Add image to print composition (images such as logo, north arrow)
T	Add label to print composition (text such as (sub)titles or abstract)
E.	Add new legend to print composition
	Add new scalebar to print composition
\bigtriangleup	Add basic shape to print composition
P	Add arrow to print composition
	Move content within an item (move within a map to redefine the x, y and scale)
	Group items of print composition and Ungroup
	Raise/Lower selected items
_	Move selected items to top/bottom
╒╴╕╏╺═╺╹╸	Align selected items left / right center / center vertical / top / bottom

References

Wang, L. and Liu, H., 2006. An efficient method for identifying and filling surface depressions in digital elevation models for hydrologic analysis and modelling. International Journal of Geographical Information Science, 20(2).

Links

EPSG codes: <u>http://www.spatialreference.org</u>

European Environmental Agency Public Map Service: <u>http://discomap.eea.europa.eu</u>

OpenStreetMap: <u>http://www.openstreetmap.org</u>

QGIS: <u>http://www.qgis.org/</u>

SRTM data description: https://lta.cr.usgs.gov/SRTM1Arc

USGS EarthExplorer: <u>http://earthexplorer.usgs.gov</u>

Screencasts

Screencasts can be found in the following YouTube channel: http://www.youtube.com/c/HansvanderKwast

Please subscribe for updates.