Hands-on exercise

on

Generation of Tsunami Vulnerability Maps

Training Course on

'Coastal Vulnerability Mapping using QGIS

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I. Introduction

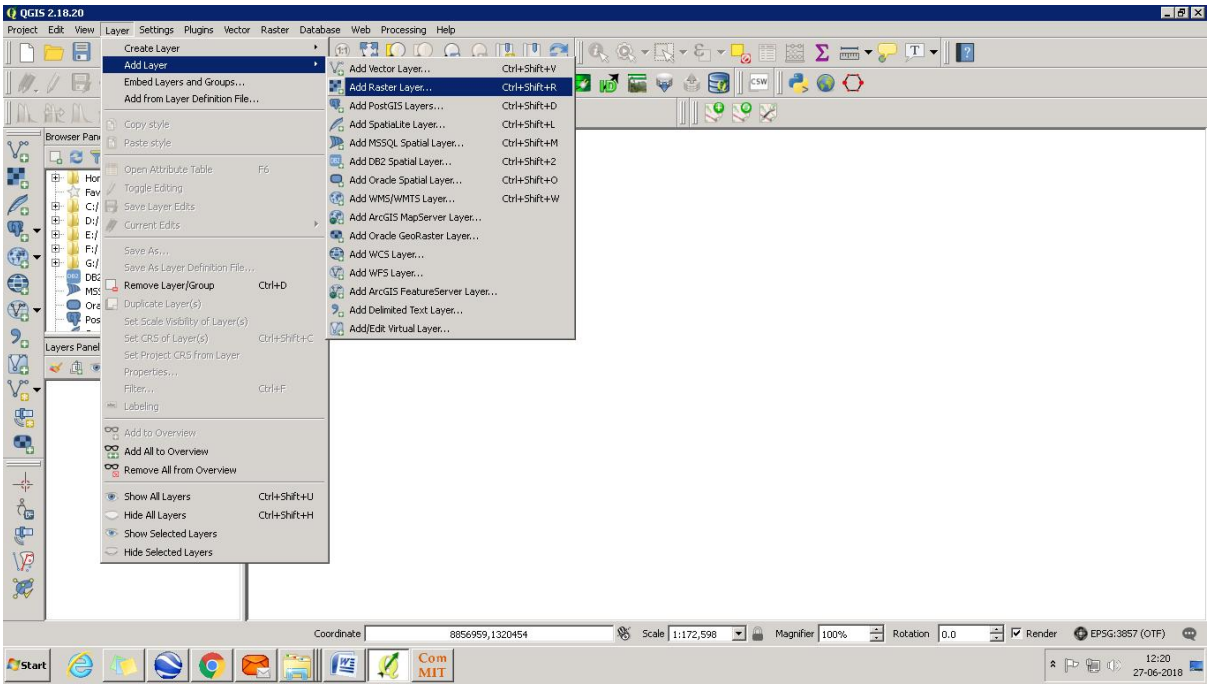
This exercise focus on the generation of tsunami vulnerability maps and evacuation maps using the inundation results obtained from tsunami inundation models. The entire exercise will be carried out using the QGIS software.

1.1 Generation of tsunami inundation map

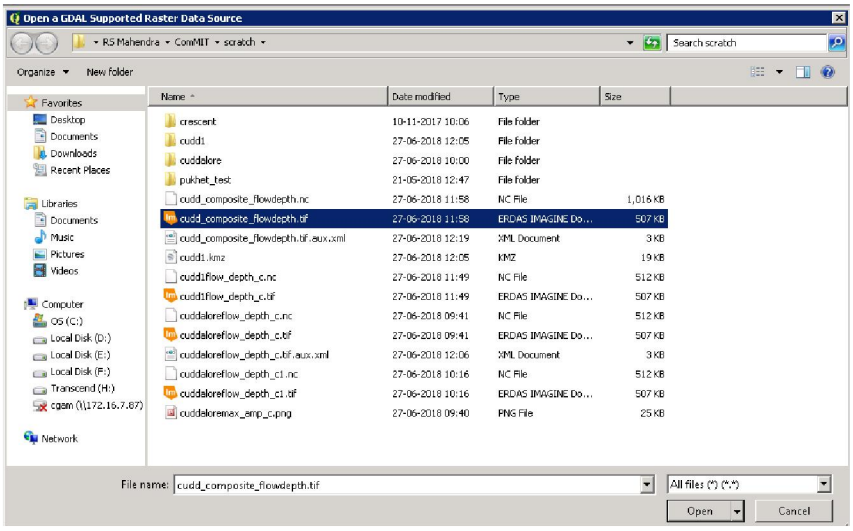
The tsunami inundation model run for the Cuddalore southeast coast of India and the maximum inundation (flow depth) on land was calculated. This file saved as "cudd_composite_flowdepth.tif" and available in example data will be used for this exercise. The following steps are performed to prepare tsunami vulnerability map.

Step1: Open QGIS Desktop with GRASS

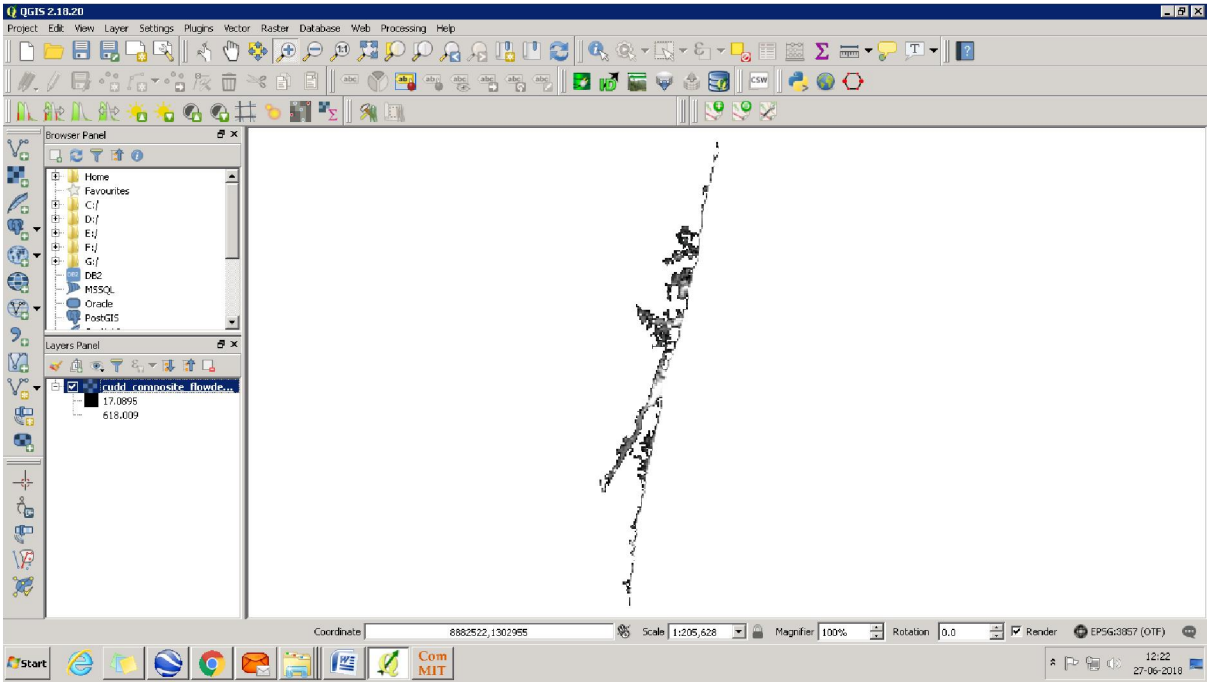
Step2: Choose the option "**Layer, Add Layer, Add Raster Layer**" data source data source manager for raster dialog will appear



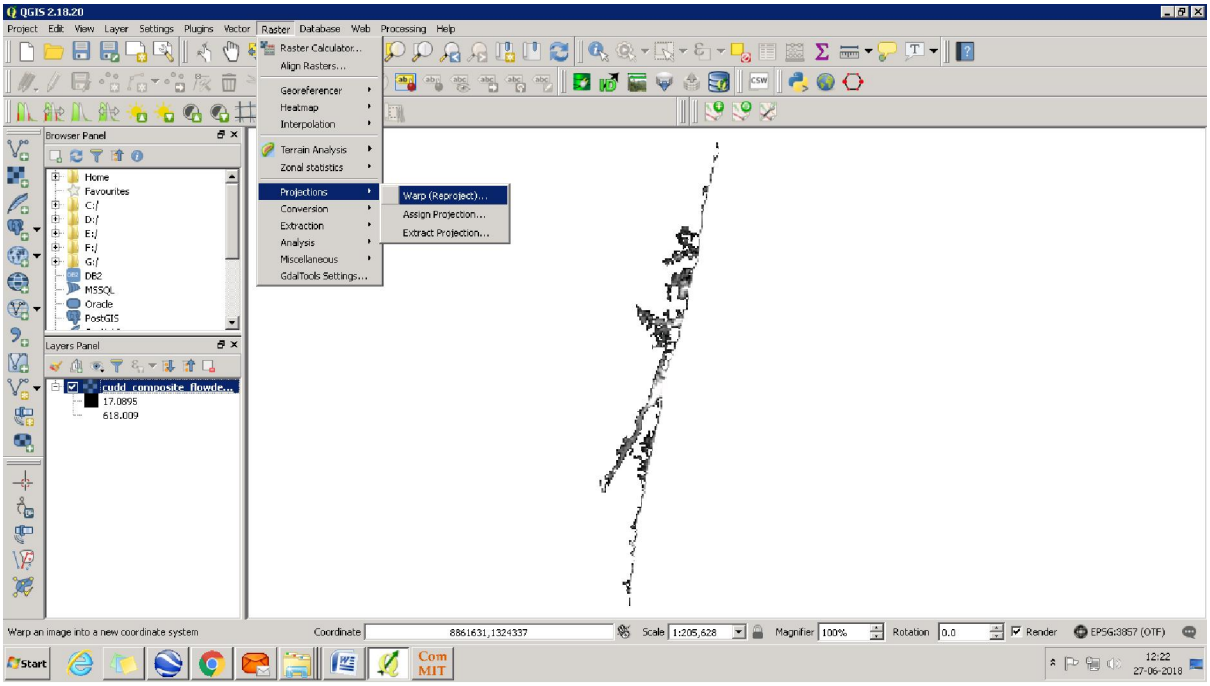
Step3: Navigate to your example data folder and choose **"cudd_composite_flowdepth.tif"** and click add in data source manager for raster dialog. This image is a flow depth of tsunami inundation recorded in centimetres, this is the water level above ground.



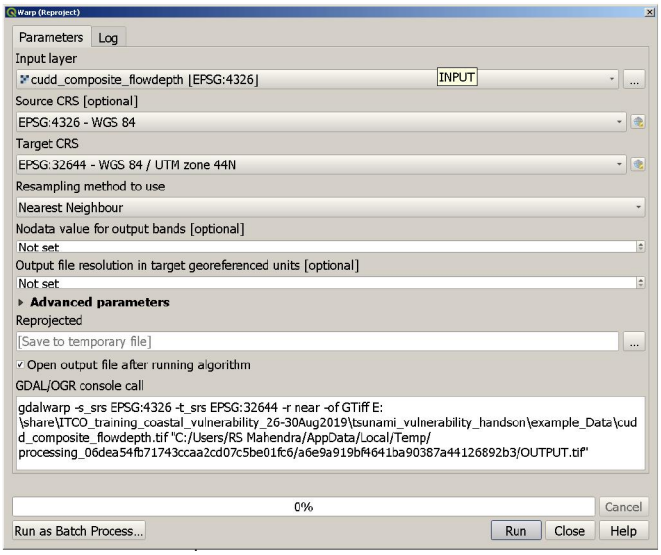
Step4: Tsunami flow-depth image showing inundated area in the viewer QGIS



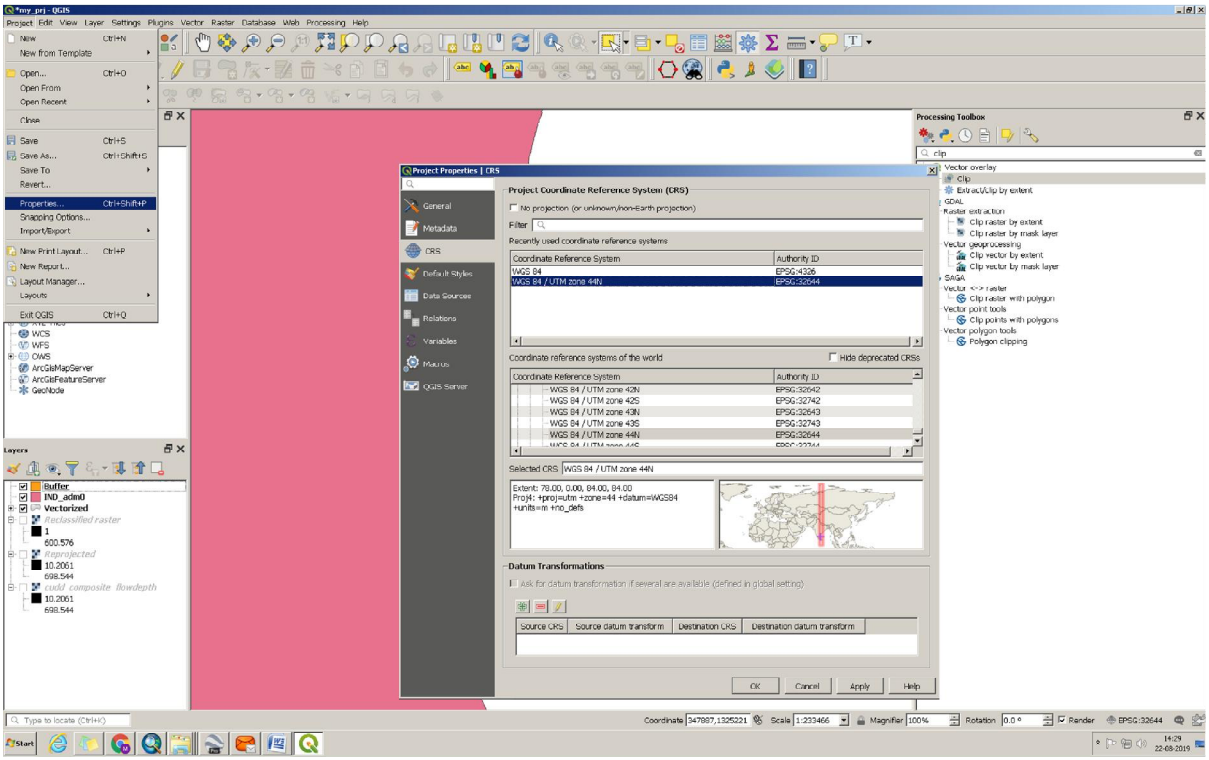
Step5: We re-project the image to the coordinate system in which the map is being developed and worked. This step is very important because tsunami modelling outputs might have in different projection or might not have defined. Select menu **Raster-Projections-Wrap,** a wrap (reproject) dialog will appear



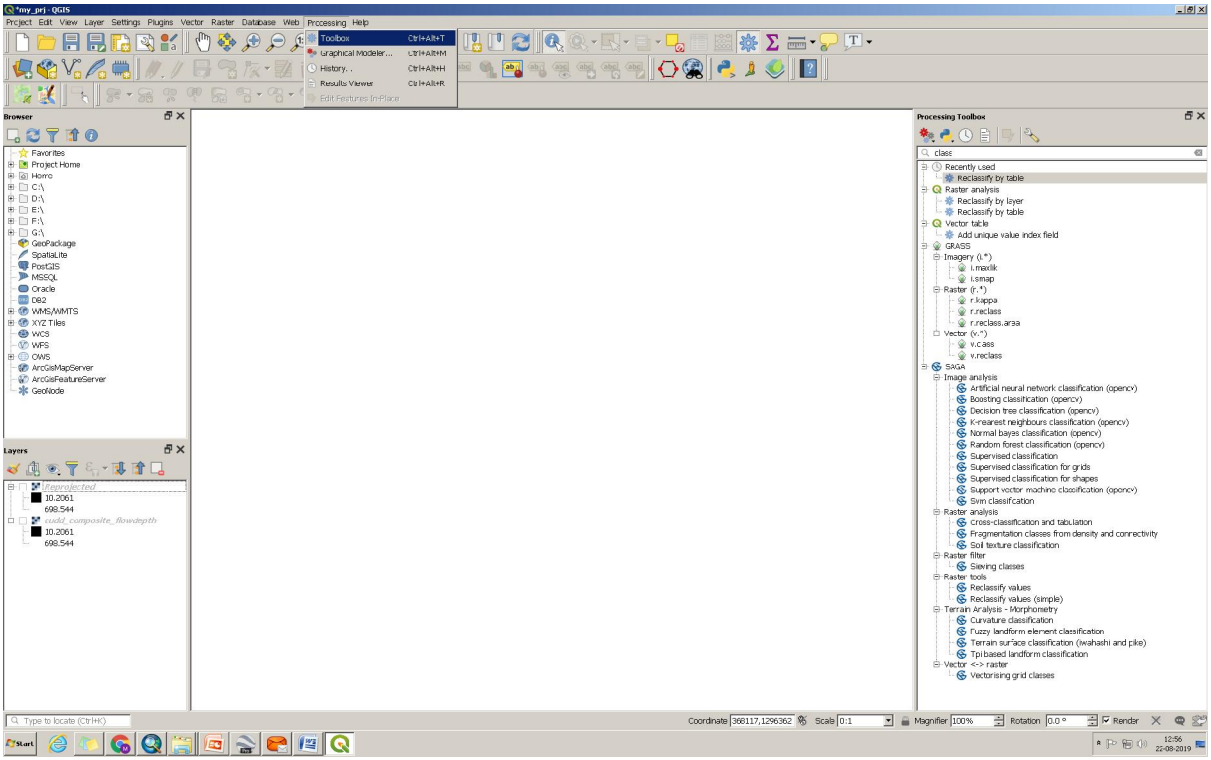
In wrap dialog select make sure that input file selected is **cudd_composite_flowdepth.tif**, give output file name "**reproject.tif**". Enter source Coordinate Reference System (CRS) as EPSG:4326 (CGS_WGS-84) and Target CRS as EPSG:32644 (UTM zone N44). Then **run** the process you will get re-projected image.



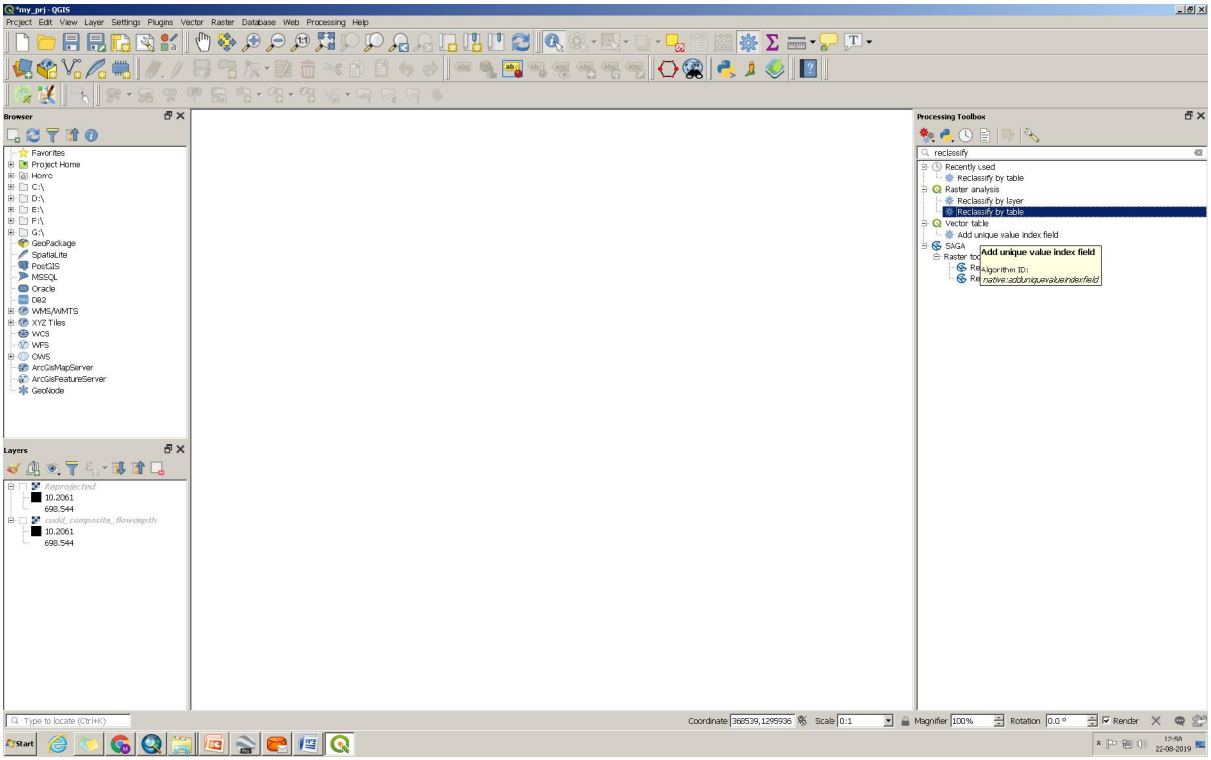
To assign projection to viewer go to Project menu select properties and project properties dialog will appear. Uncheck no projection and select WGS84/UTM... and click ok



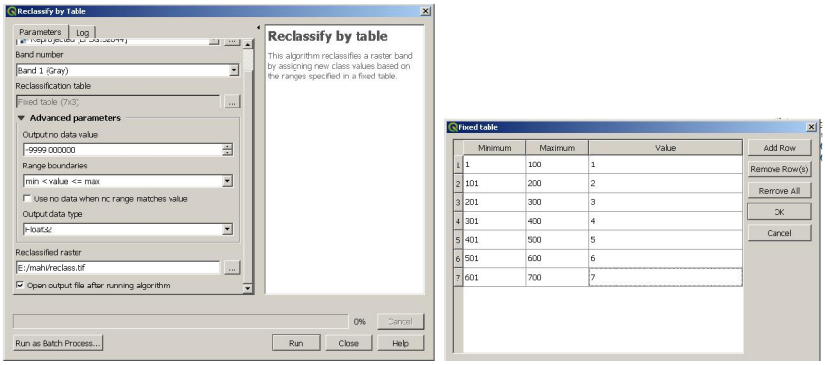
Step6: Select the image rerpoject.tif to start with the information development. Select **Processing - toolbox** from menu option, you will get processing toolbox right side.



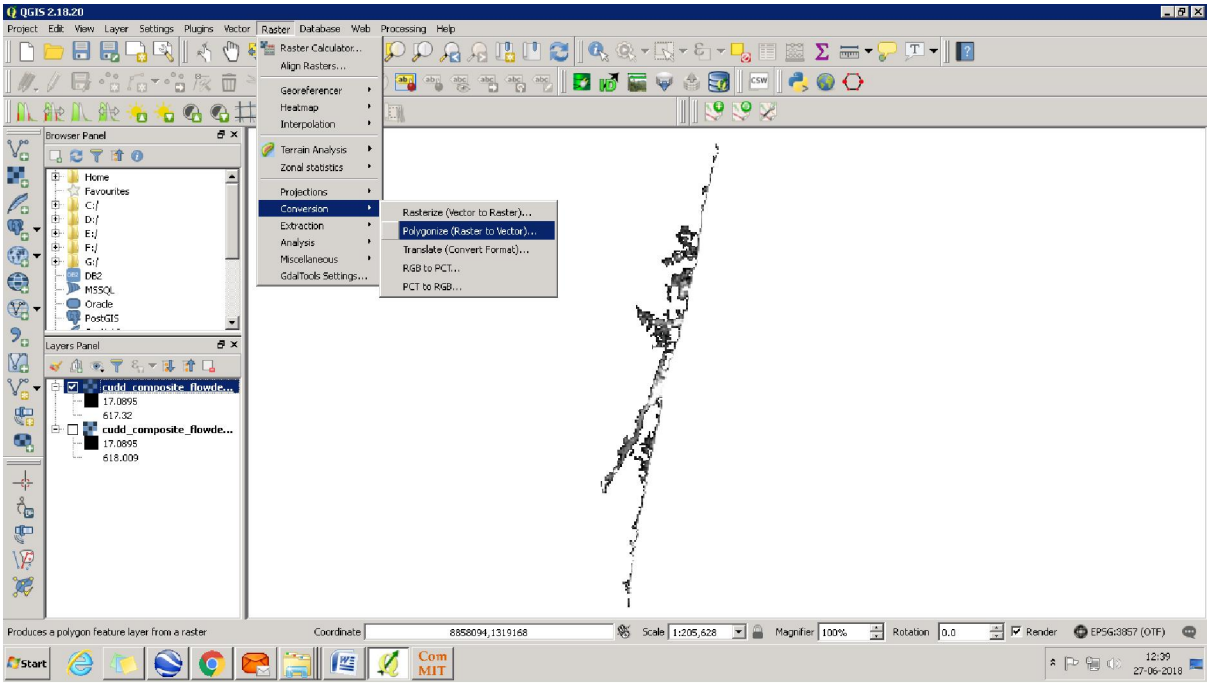
Type 'reclassify' in search bar and select **reclassify by table** under raster analysis, you will get reclassify by table dialog.



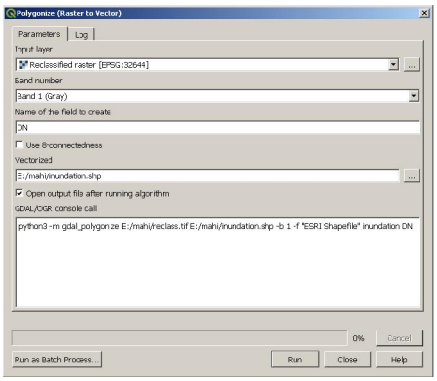
Provide input file name **reproject.tif** and output file name **reclass.tif**. Click on reclassification table you will get fixed table dialog, add 7 rows by clicking add rows button 7 times. Then enter the values as shown in the table below. It creates new image and rewrites the range of DN values (min max) in to new values. This means the DN values 1-100cm will write as 1. This means inundation up to one meter. The maximum inundation in this area is 699 cm hence 7 rows were added. After adding values in the table click ok. Then run this task.



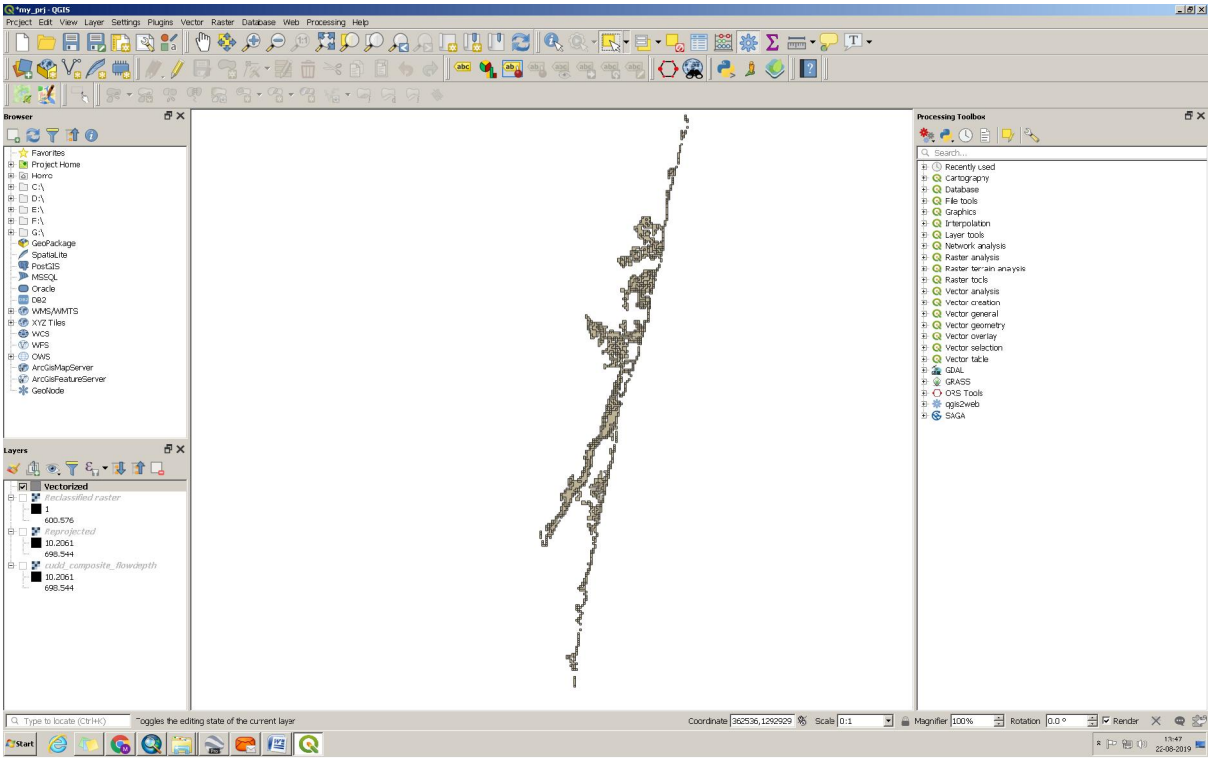
Select the option "Raster, Conversion, Polygonize (Raster to Vector)" to convert this reclass.tif raster into vector.



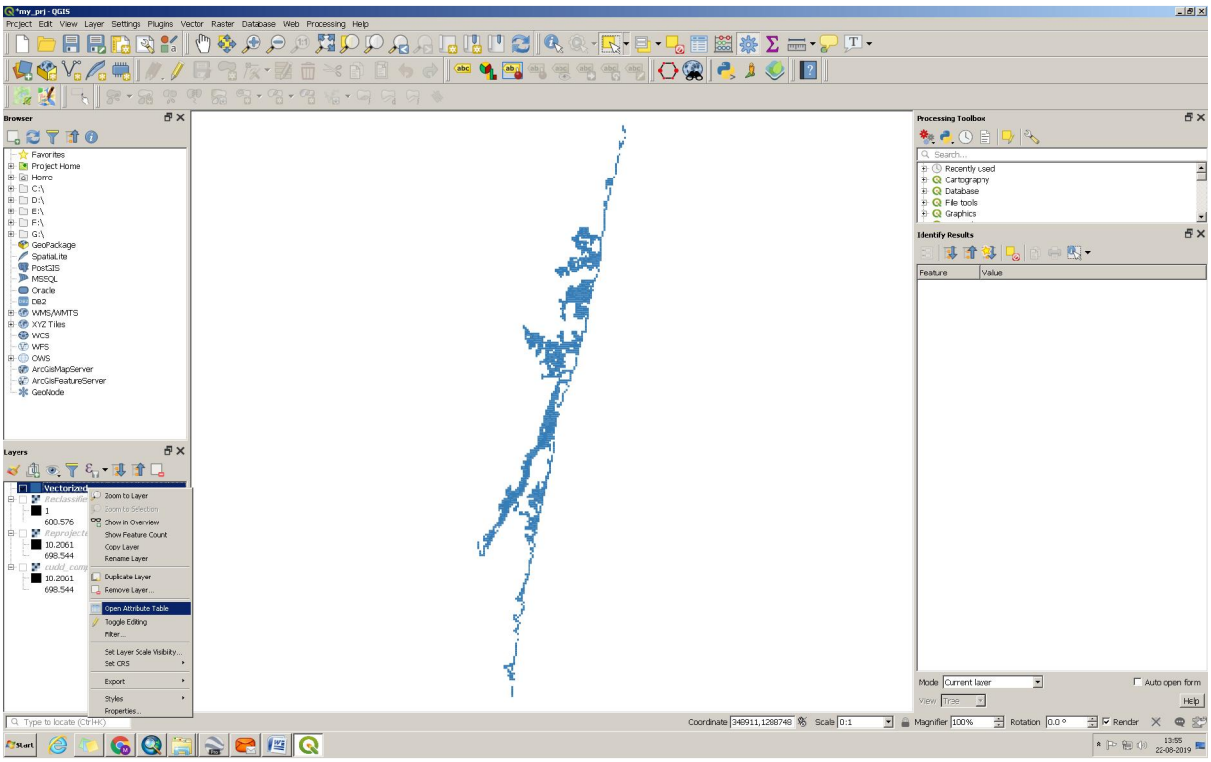
Step7: Save the file to the desired place, select file type as SHP files (*.shp), give output file name as "inundation.shp" then run.



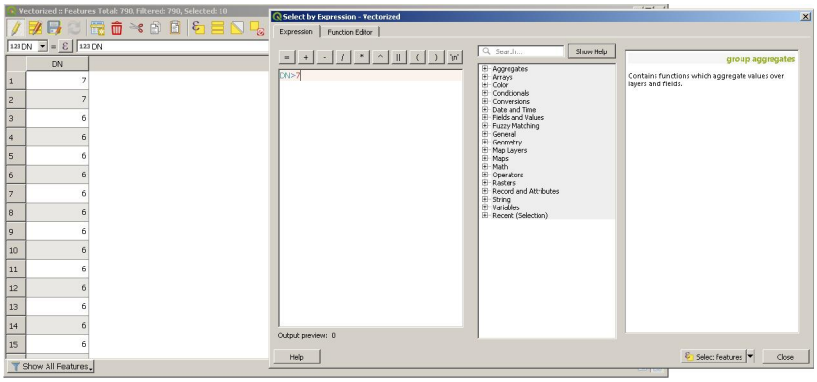
Step8: Then we open the vector file inundation.shp that is generated by the vectorization.



Step9: Open attribute table by right clicking on vector layer in layer panel

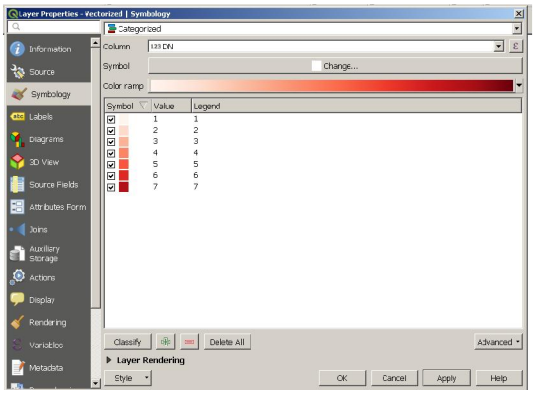


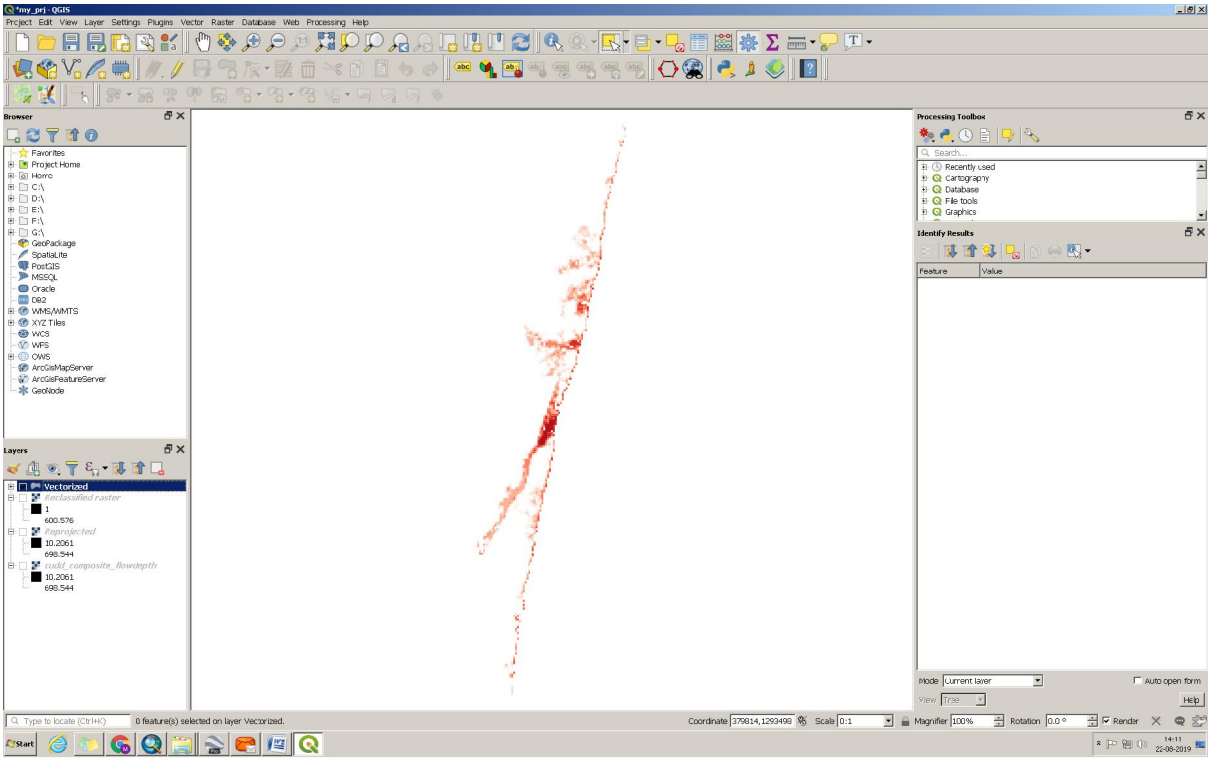
Click on toggle editing mode (pencil till of top left side of table), Select the tool "Select feature by expression"  and type DN > 7 and select



Then delete selected by selecting the delete tool, then click on toggle editing tool click save. Now this vector file is completed representing the inundation of tsunami on coastal areas with different water levels.

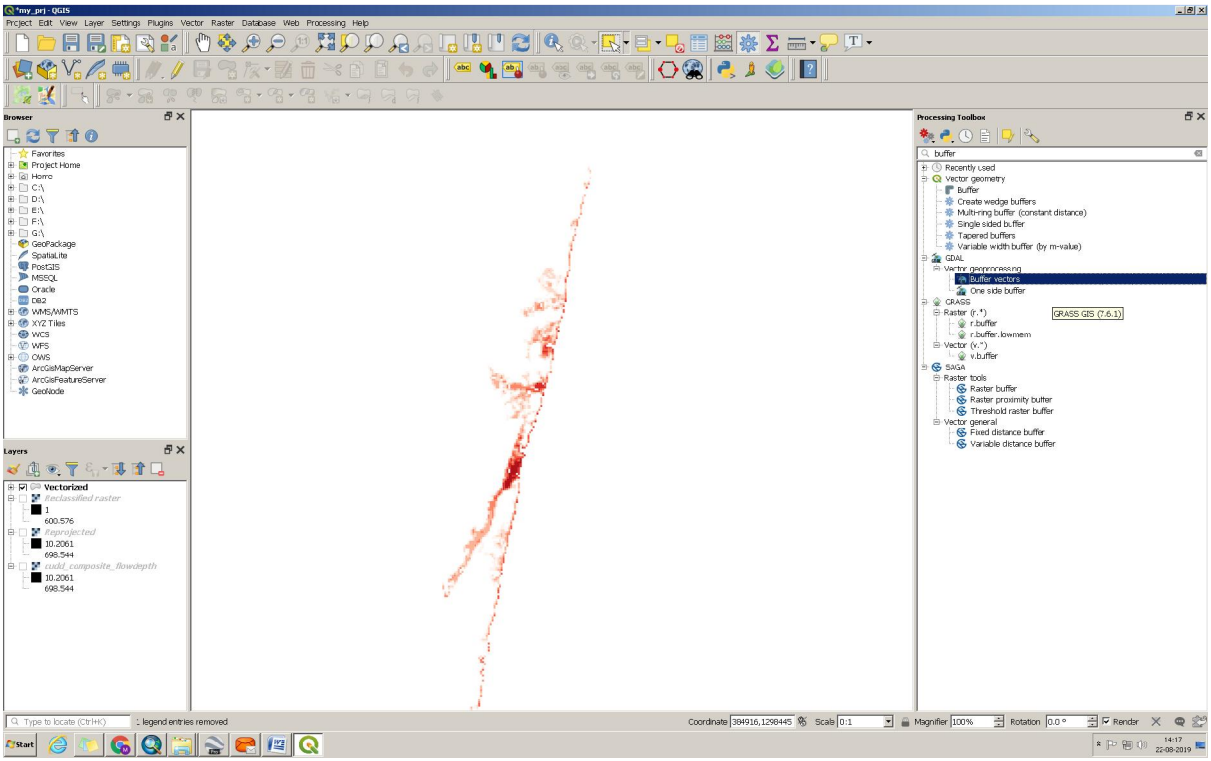
Step 10: Symbolizing vector file- Right click on vectorized file select properties. Select symbology in the left panel, select categorized based on column. Select DN in the column and select the colour ramp click on classify. Select the items with no values and remove and apply. Now vector file is assigned the values based on the inundation level.



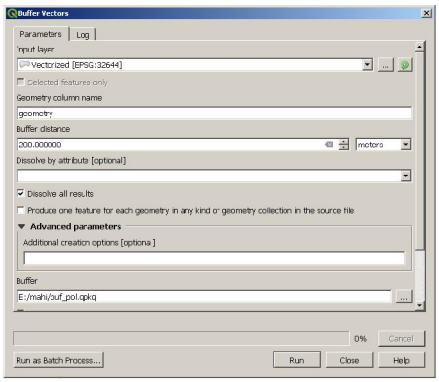


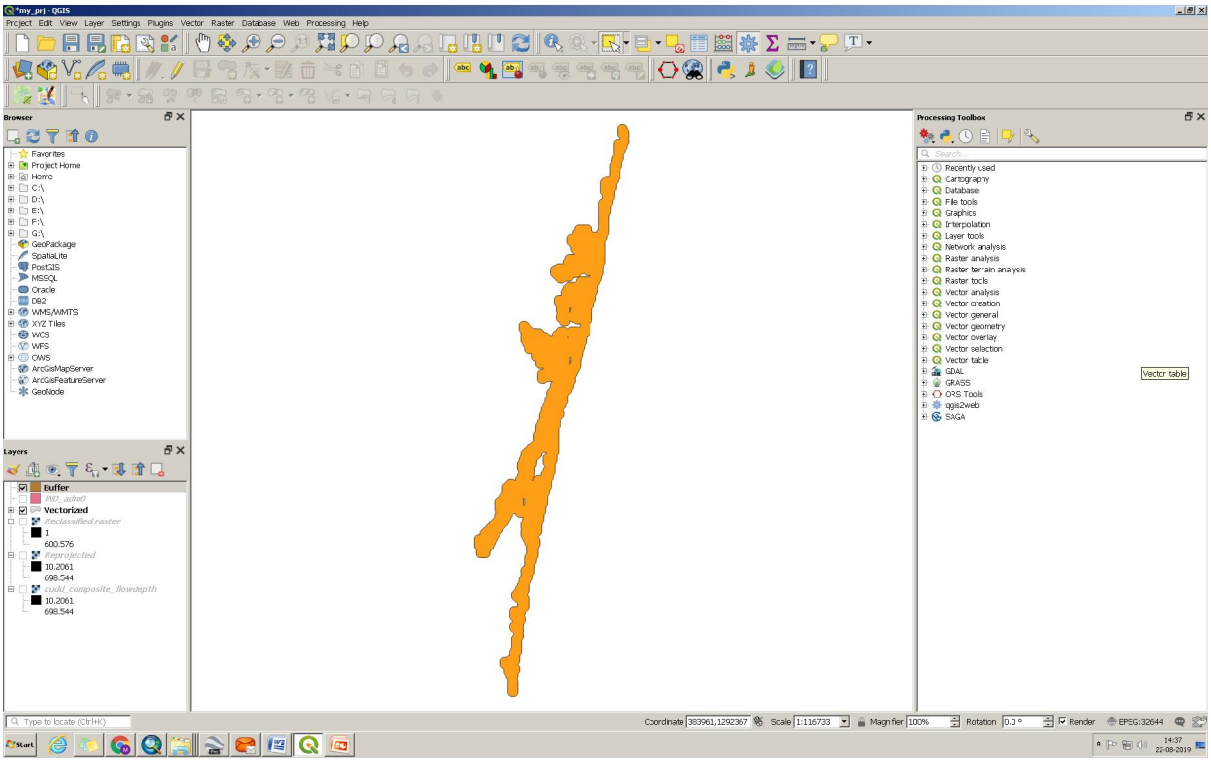
1.2 Creating Buffer to tsunami hazard zone

It is necessary to add buffer to the tsunami hazard zone as transition zone to consider the uncertainties of the tsunami modelling. Hence add 200 m buffer to tsunami hazard zone. Go to Processing menu select Toolbox and type buffer in processing tool box right side. Select "Buffer vectors" tools under "[OGR] Geoprocessing".

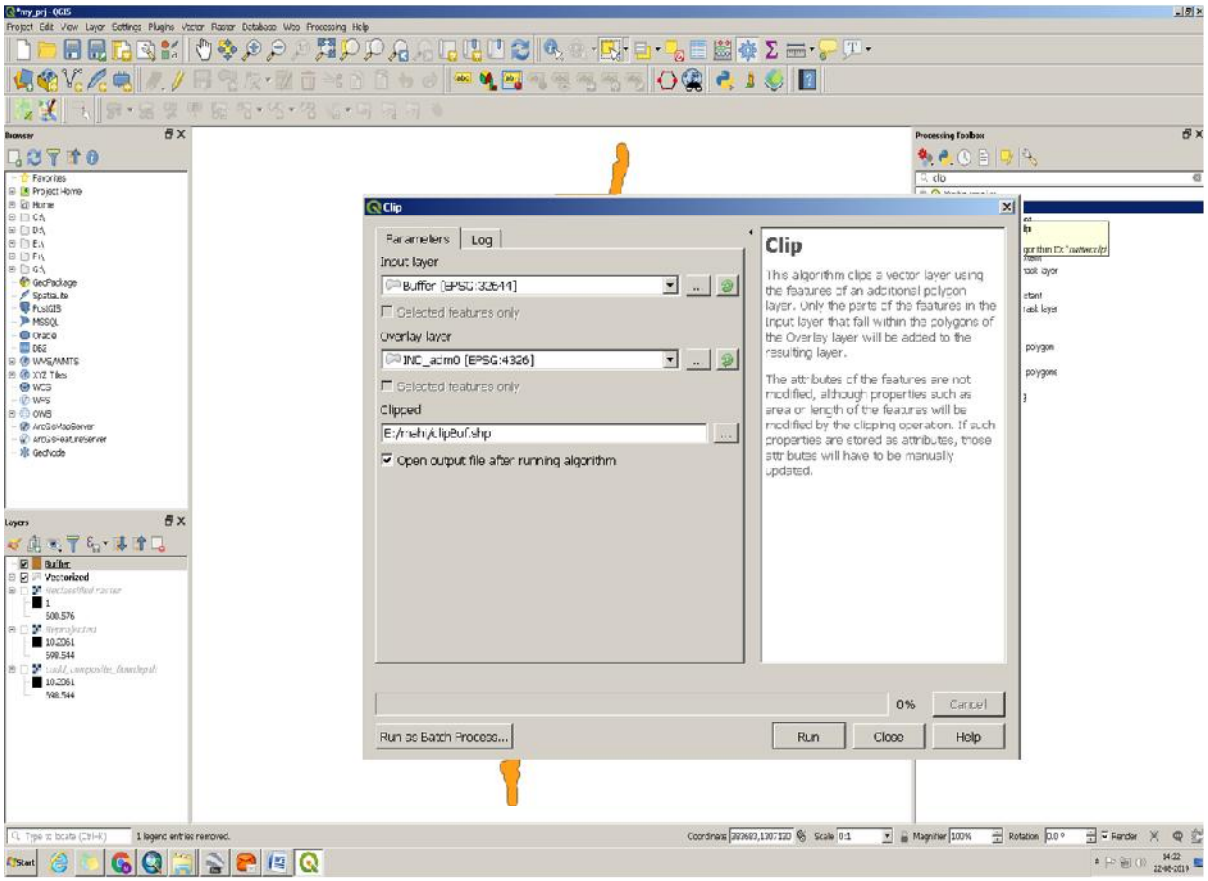


The following dialog will appear, Select the input layer to create buffer (vectorized/inundation.shp), enter buffer distance 200m, check "dissolve all results" and enter output file name (buf_pol.shp) and then run

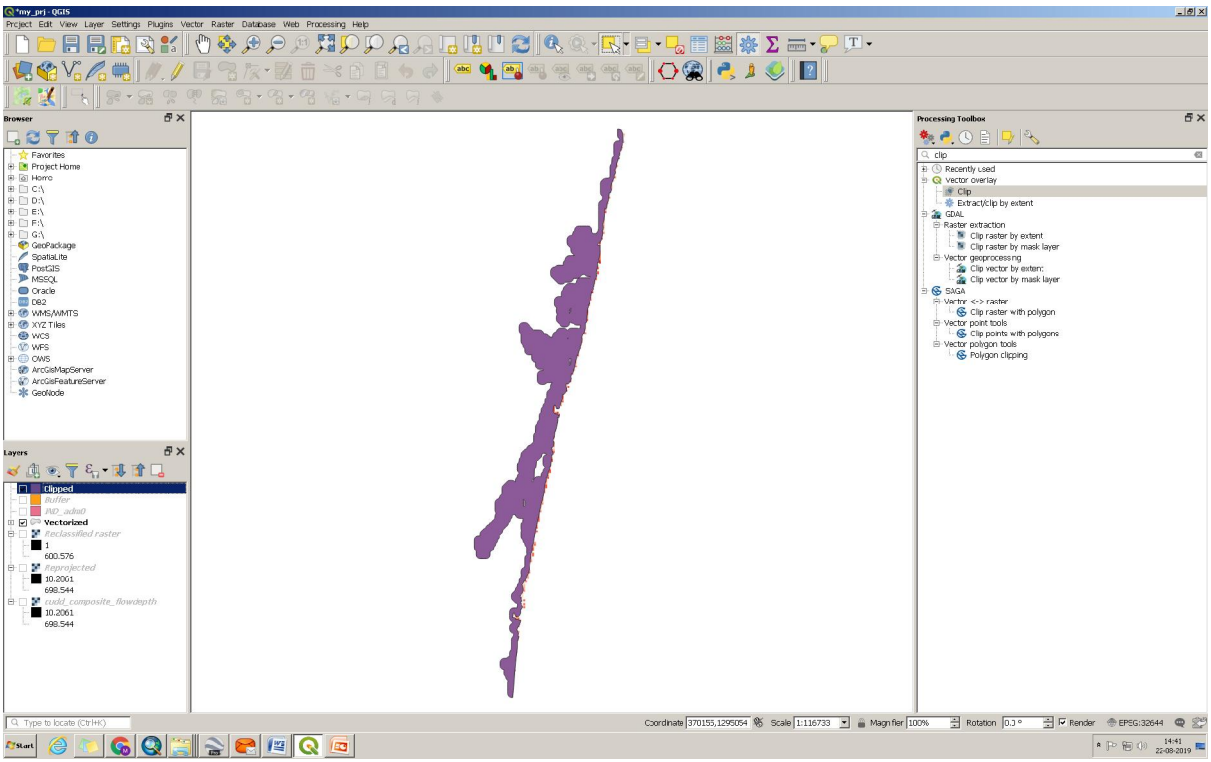




This function will buffer around the polygons and we need not require buffer in the sea part. Hence, need to clip this buffer using the administrative boundary to have buffer only on land. Add IND_adm0.shp file by **layer, add layer, add vector layer** by menu option. Select **clip** tool from toolbox under vector overlay tools. Select input buffer and overlay layer IND_sdm0.shp and give output file name clipbuf.shp and run



The following clipped buffer will be displayed



Then save project as "my_prj_mahi"

II. Installation of QGIS plug-ins and OCHA Icons

The following plug-ins needed to develop Tsunami Evacuation Maps:

Digitizing Tools - Allows utilities of CAD drawing as a system within the QGIS platform.

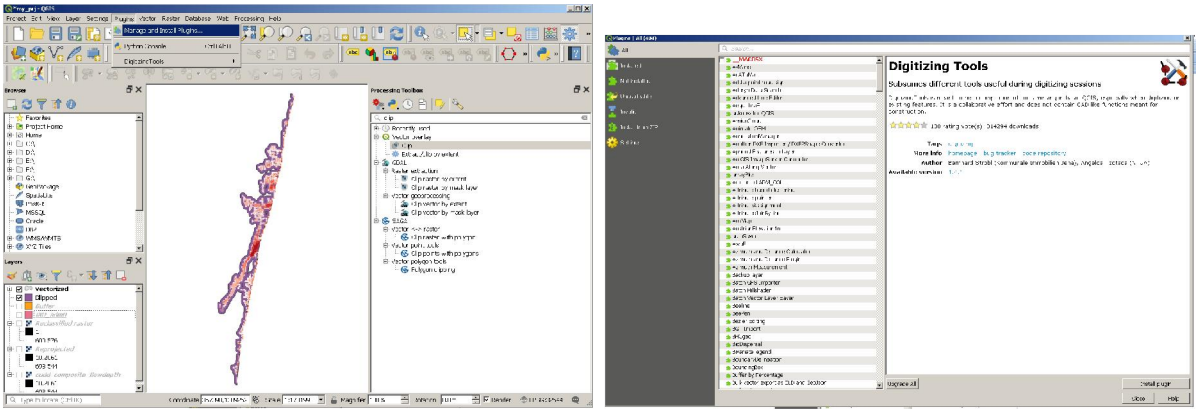
OpenLayers plug-in- Download the databases: Google Maps, Bing Maps, OpenStreetMap and others.

QuickMapServices: This facilitate users to add the web map services from OSM , NASA, etc.

QuickOSM - Executes QGIS specific queries for information from Open Street Maps (OSM Data).

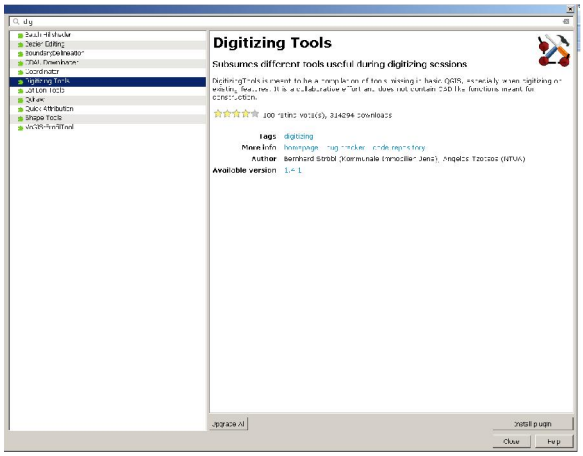
2.1 How do you install the QGIS Plug-ins?

Step1. After opening the QGIS application go to Plugins menu and select "Manage and Install Plug-in". A dialog will appear as shown below:



Window Showing the Plugins

Step2. Select the required plug-in to be installed for example select **Digitizing tools** and select the lower right button that says "Install Plug-in" as shown in the image below plug-in:



This Window Shows the Plug-in Options

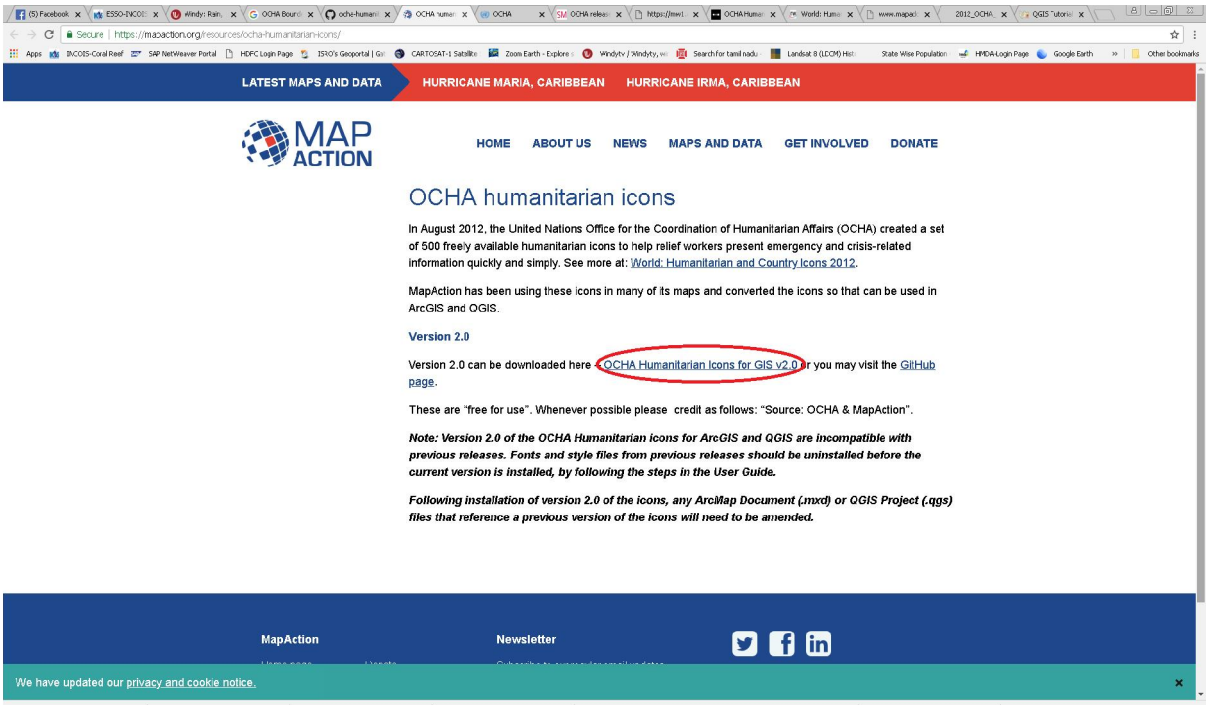
Similarly install other plugging **OpenLayers plug-in, QuickOSM and QuickMapServices**

2.2 Installation of Library Symbology QGIS

Step 1. Download the OCHA symbols library, at the following link https://mapaction.org/resources/ocha-humanitarian-icons/

Click on **"OCHA_Humanitarian_Icons_For_GIS_v2.0.zip"**

Save into your working folder

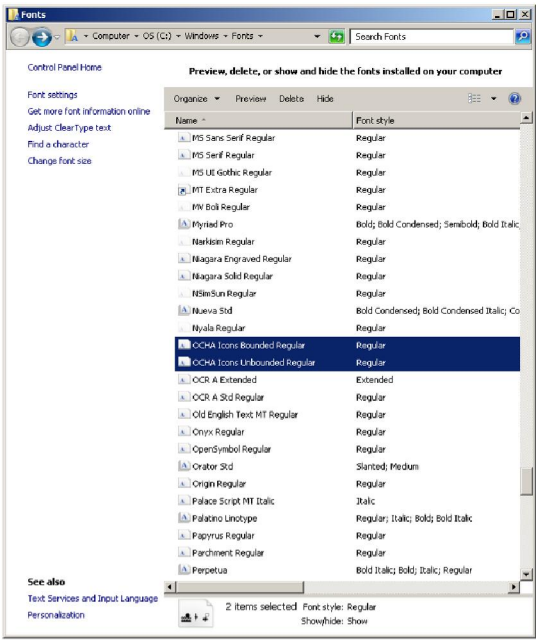


Web Page Showing OCHA Available Symbols

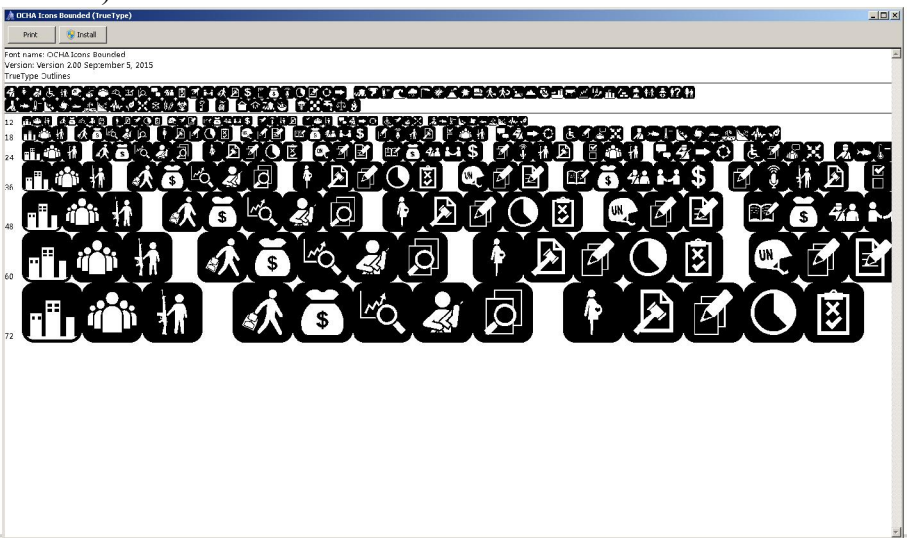
To establish a standard Evacuation or Tsunami Evacuation Maps symbology it must be unify a symbology which is simple and common in all maps. For this reason we use the symbols provided by OCHA (Office for the Coordination of Humanitarian Affairs) and then show the next step for installation:

Step2. We must remove all versions OCHA (if you're not going to point 2.)

- Access the disk *C:\Windows \ Fonts* and remove the Fonts *"OCHA Bounded Icons"* and *"OCHA Icons Unbounded"*

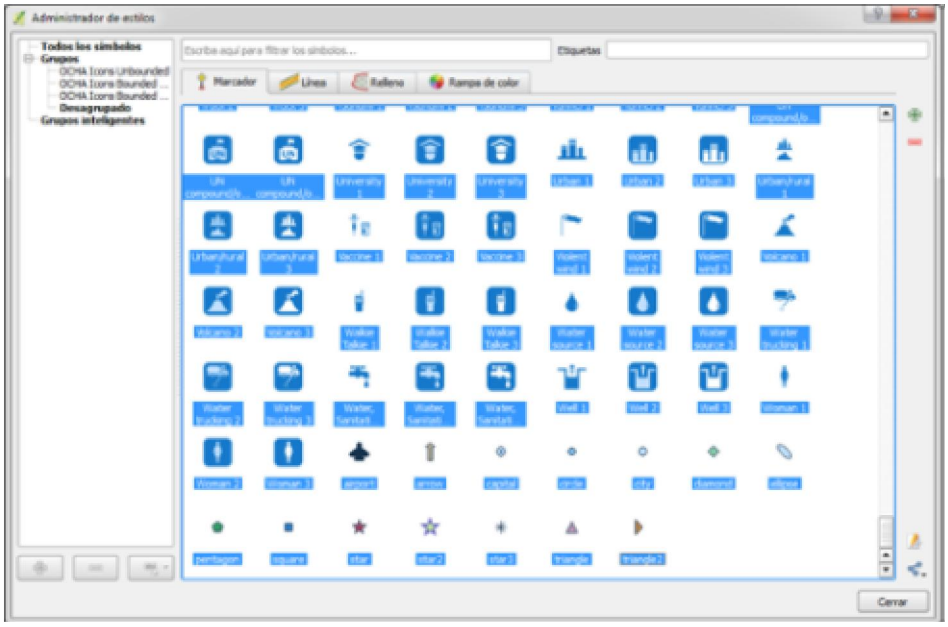


Step2. Install the current version of OCHA icons fonts: Copy the files "OCHA - Icons- Bounded.ttf" and "OCHA - Icons- Unbounded.ttf" in the Windows Fonts folder (C:/Windows/Fonts). Double click on these ttf file and click install



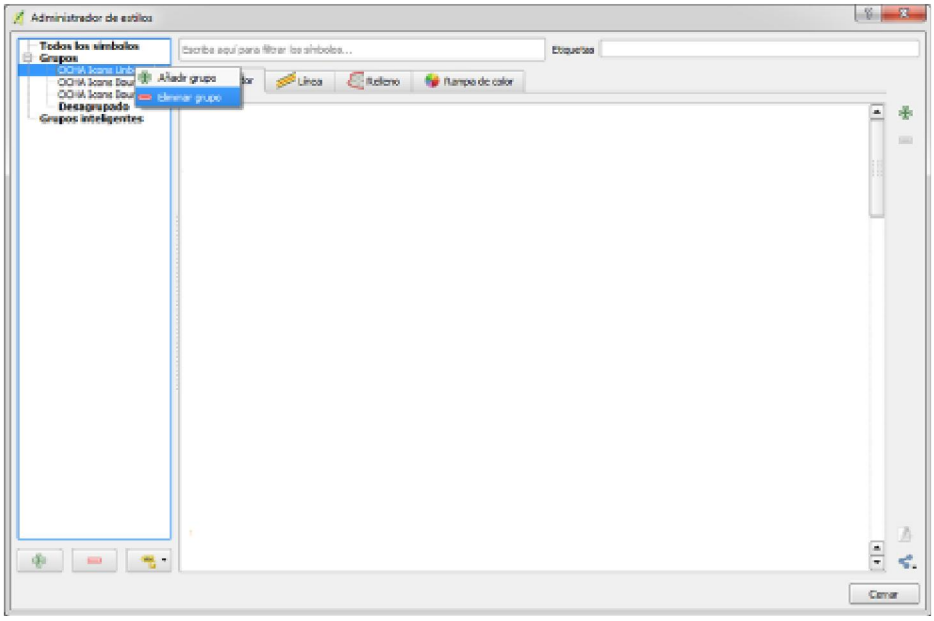
Step3. Installing files OCHA Humanitarian style for QGIS Icons:

1. Remove previous versions of the styles OCHA Humanitarian Icons (if it is not installed, go to step 4.)
2. Select QGIS.
3. Go to Settings---Style Manager and selections OCHA Unbounded which is on your left hand side.
4. Select the first icon and press Ctl+A and right click remove items.



Window showing the OCHA Symbols that are going to be replaced

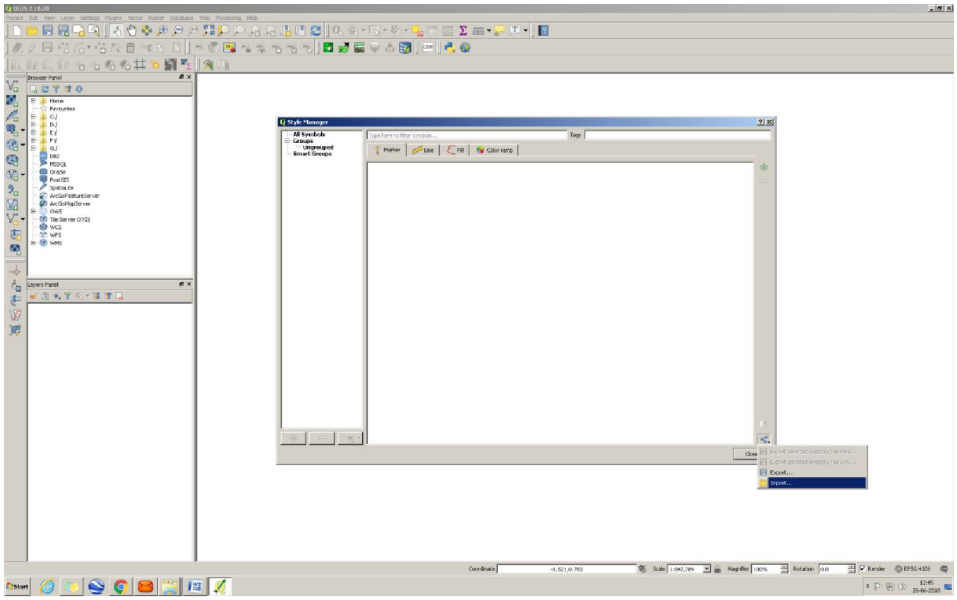
5. We select icon delete item(s)
6. Otherwise "Click" Unbounded right to OCHA Icons located on the left side and make "Click" Delete Group.
7. We do the same in OCHA Icons Bounded White and OCHA Icons Bounded Transparent.



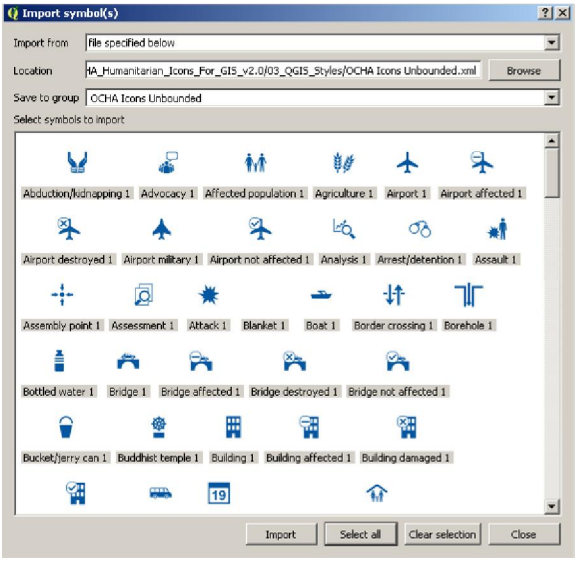
Window showing how the groups are managed

Step4. Install the current version of the stylesheet:

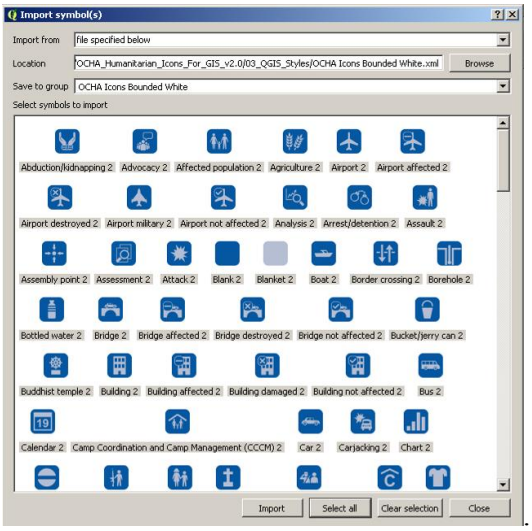
1. Select QGIS.
2. Let's Settings---Style Manager.
3. We click on Share --- Import.



4. In the Search window or "Browse" Select the location of OCHA Icons Unbounded.xml, give click Select All and then Import.



5. Repeat points Share and Import and Search to find OCHA Icons Bounded Transparent.xml and OCHA Icons Bounded White.xml. After this step the icons should appear in the Style Manager window.



III. Downloading opensource data using QGIS

3.1 Required Data Development Tsunami Evacuation Maps

The data needed to develop Tsunami Evacuation maps are different and will depend on the complexity of the coastal community development. Communities with greater coastal development have typically denser infrastructure and therefore results in many more dense mapping information. The density of information presents new challenges as they often have to decide what kind of crucial information is the most effective to be added in the development of a map. For the development of a Tsunami Evacuation map the following data layers or data are required:

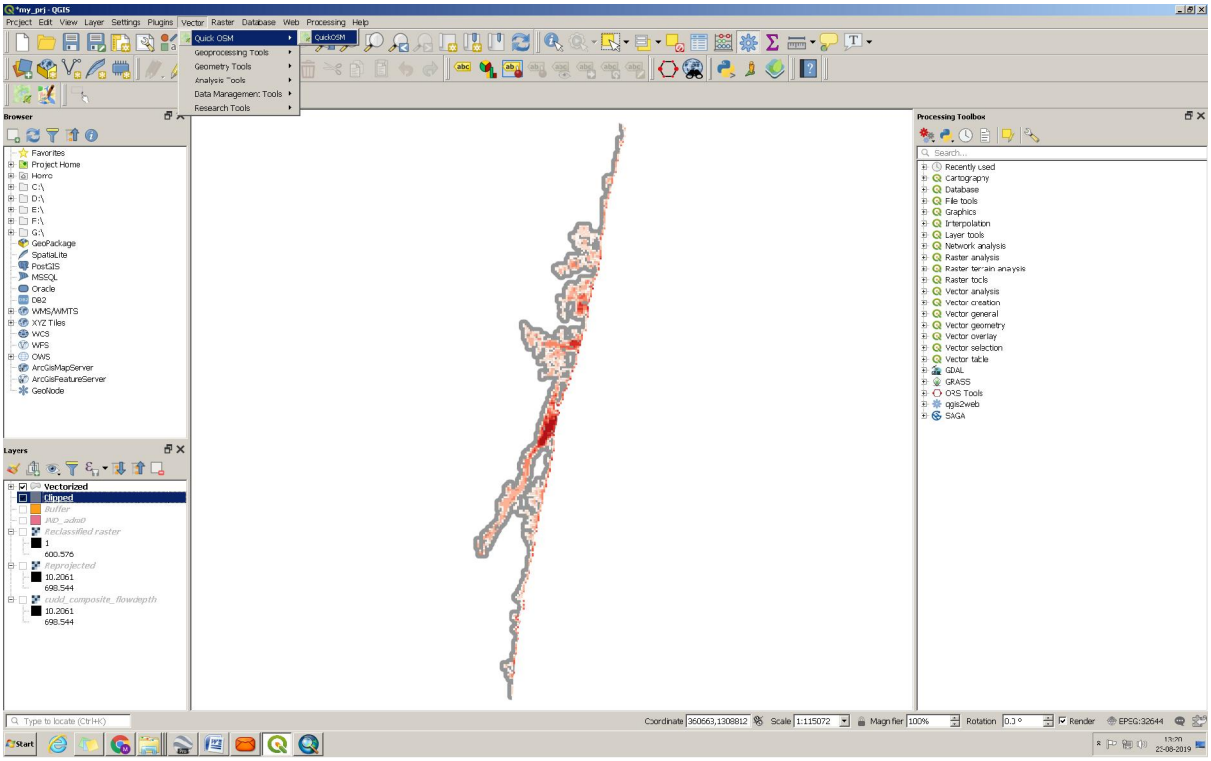
- **Aerial Images or satellite Area (Georeferenced)**
- **Digital Terrain Model**
- **Vector Layer Road Infrastructure (Streets, Roads, etc.)**
- **Tsunami Inundation Area Vector Layer (Polygon)**
- **Tsunami Evacuation Area Vector Layer (Polygon)**
- **Water Ponds affluent Vector layer attribute**
- **Infrastructure Detailed layer:** May contain but is not limited to airports, schools, University and Educational Centres, Hospitals - Primary Health Care Centres, Springs - Seaports - Marinas - Anchoring Areas , Beaches and Resorts, Bridges , Police and Fire department offices, Assembly points, Camping site, Tourist points of great interest, etc.
- **Entities Logos involved in development of the map**

The above data pertaining to each country may be obtained from their national agencies working on geospatial sciences and planning. In absence, we may use from the open source data available on the different websites. Some useful GIS data available on the web is given below.

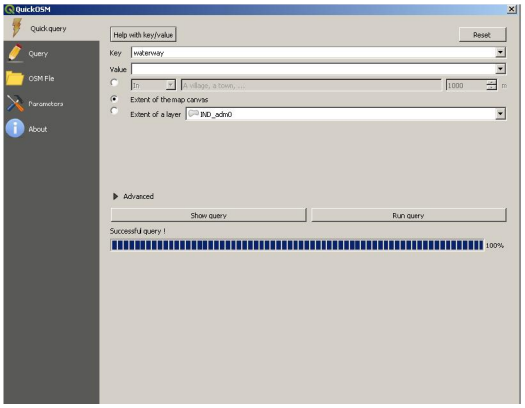
Source	Link	Datasets

Natural Earth Data	http://www.naturalearthdata.com/downloads/	Cultural, physical and raster (basemap) data.
ESRI Open Data	https://hub.arcgis.com/search	Download formats are in spreadsheet, KML, shapefile and API's are OGC WMS, GeoJSON and GeoService.
USGS Earth Explorer	https://earthexplorer.usgs.gov/	Remote sensing data
OpenStreetMap	https://www.openstreetmap.org/	High spatial resolution cultural vector data. (buildings, land use, railroads, roads, waterways
NASA's Socioeconomic Data and Applications Center (SEDAC)	https://sedac.ciesin.columbia.edu/	Socioeconomic data (agriculture, climate, conservation, governance, hazards, health, infrastructure, land use, marine and coastal, population, poverty, remote sensing, sustainability, urban and water)
UNEP Environmental Data Explorer	http://geodata.grid.unep.ch/	Freshwater, population, forests, emissions, climate, disasters, health and GDP spatial and non-spatial data.
Terra Populus	https://terra.ipums.org/	Area-level, micro-data & environmental data describing land cover, land use, and climate.
FAO GeoNetwork	http://www.fao.org/geonetwork/srv/en/main.home	Agriculture, fisheries, land resource GIS data.
ISCGM Global Map	https://globalmaps.github.io/	Boundaries, drainage, transportation, population centers, elevation, land cover, land use and vegetation.
NOAA, NGDC Data	https://ngdc.noaa.gov/products/	topography, disaster related

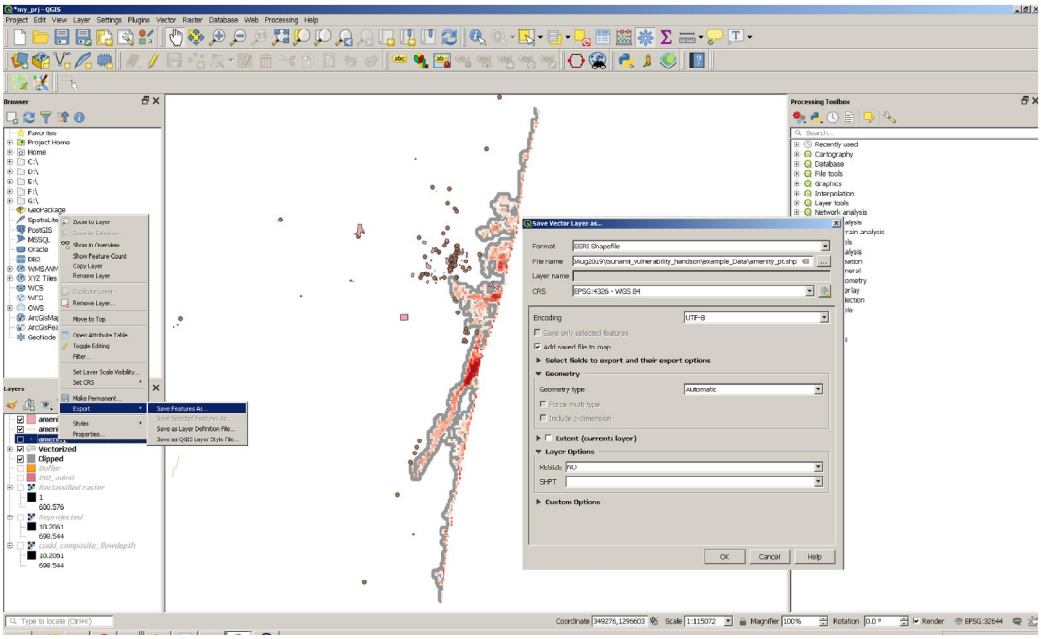
Step1: downloading data from Open Street Map (OSM) database. Go to **Vector, QuickOSM, QuickOSM.**



The following QuickOSM dialog will appear. Select amenity in the key field, keep the extent of the map canvas checked and run query. You will see the three amenity layers were loaded on to your viewer. These files are the amenities available in your area representing Point, polygon and line.

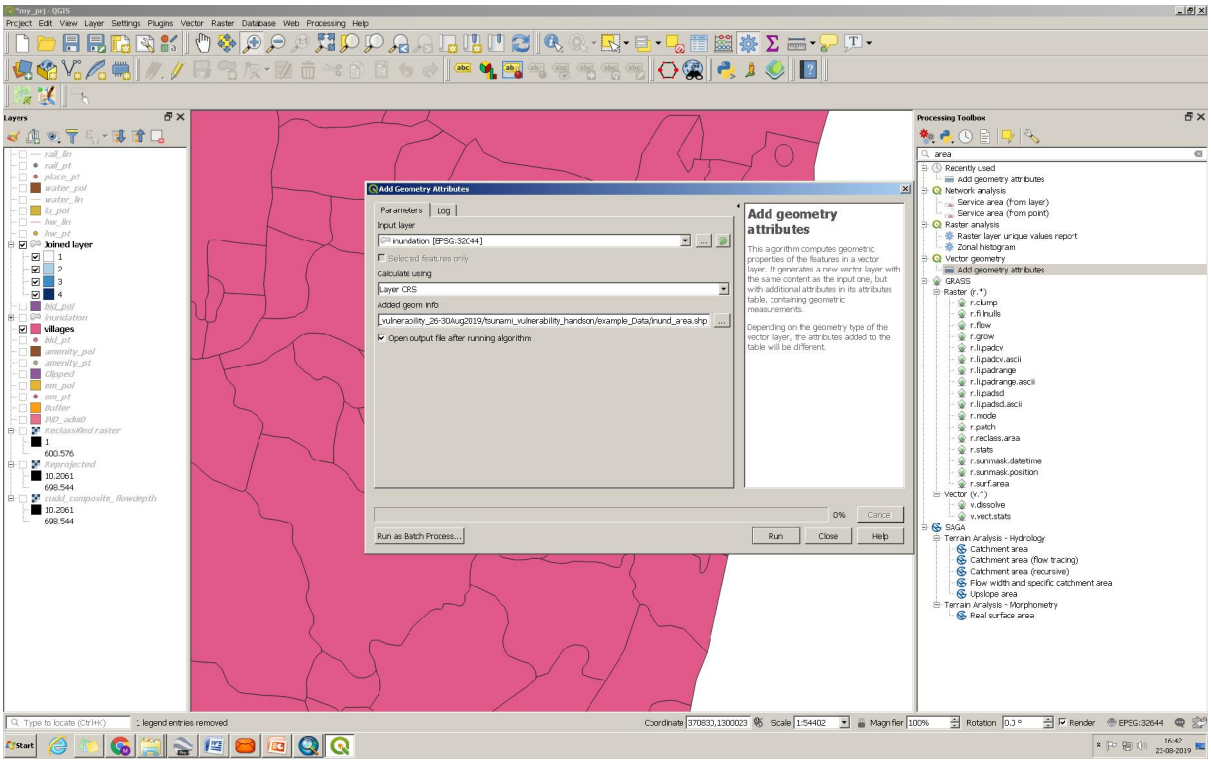


Step2: Right click on amenity point layer in the layers window select **export, save feature as** a dialog will appear to save the file. Select format ESRI Shapefile and enter output file name amenity_pt.shp and click ok. Similarly save the amenity polygon as well. Repeat this exercise for OSM data download for features building, emergency, evacuation centre, highway, landuse, place, railway and waterways. And save them all into your working folder.

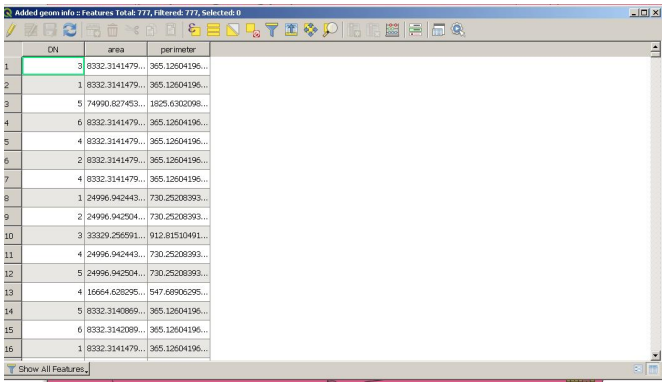


IV overlay analysis, socio-economic impact and statistics generation using own surveyed data

Step1: to calculate area of each feature select add geometry attribute under vector geometry category from toolbox and give output file name inund_area.shp

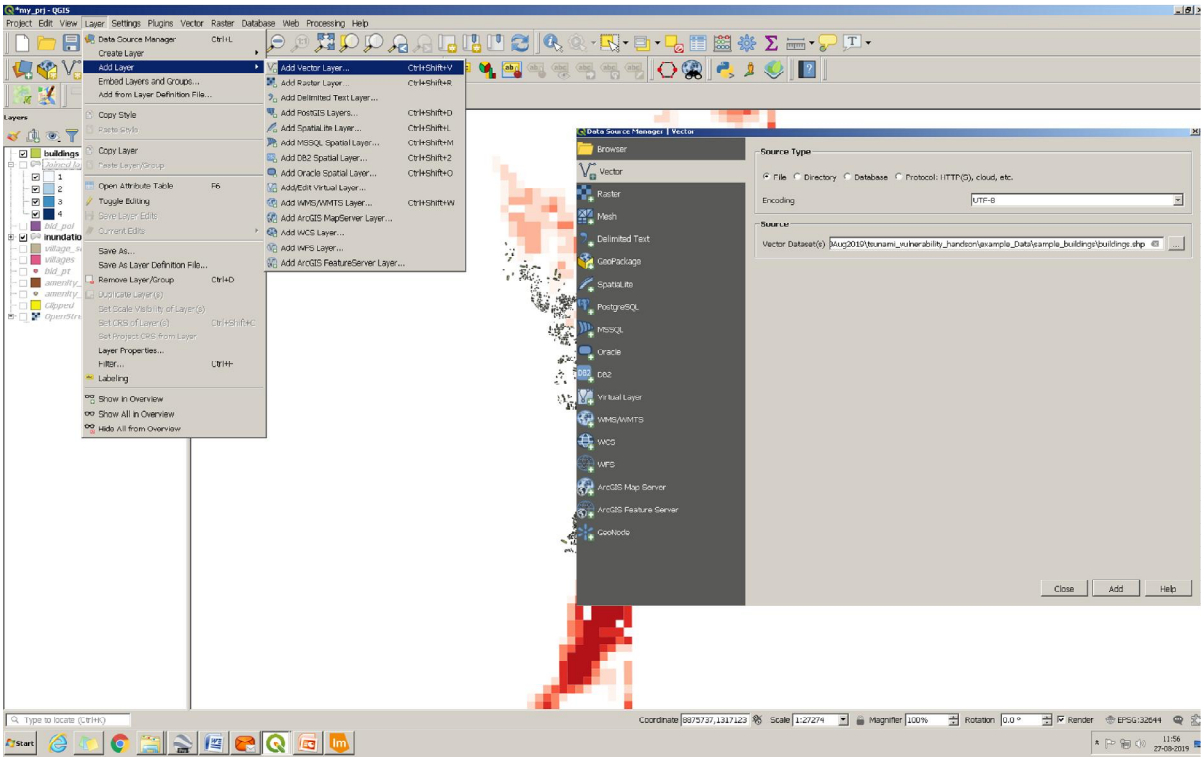


You can check the attribute table and see the area and perimeter calculated for each feature

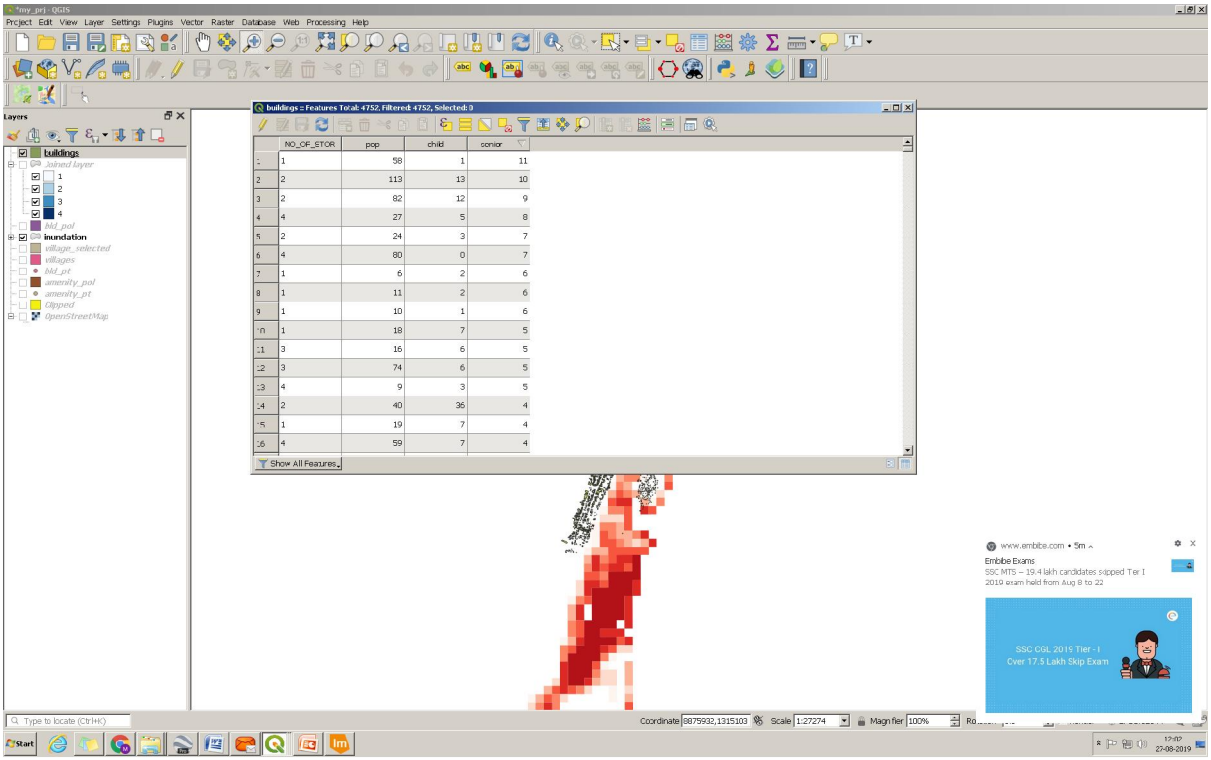


To obtain the statistics on area of inundation at different water level select statistics by categories from tool box. Give input file name inund_area.shp. select **area** field to calculate statistics, select **DN** under statistics by category. Give output file name flow-depth_area.csv (summarized statistics will be written in table format). Then you will get area of inundation at different water level. You can use this for reporting.

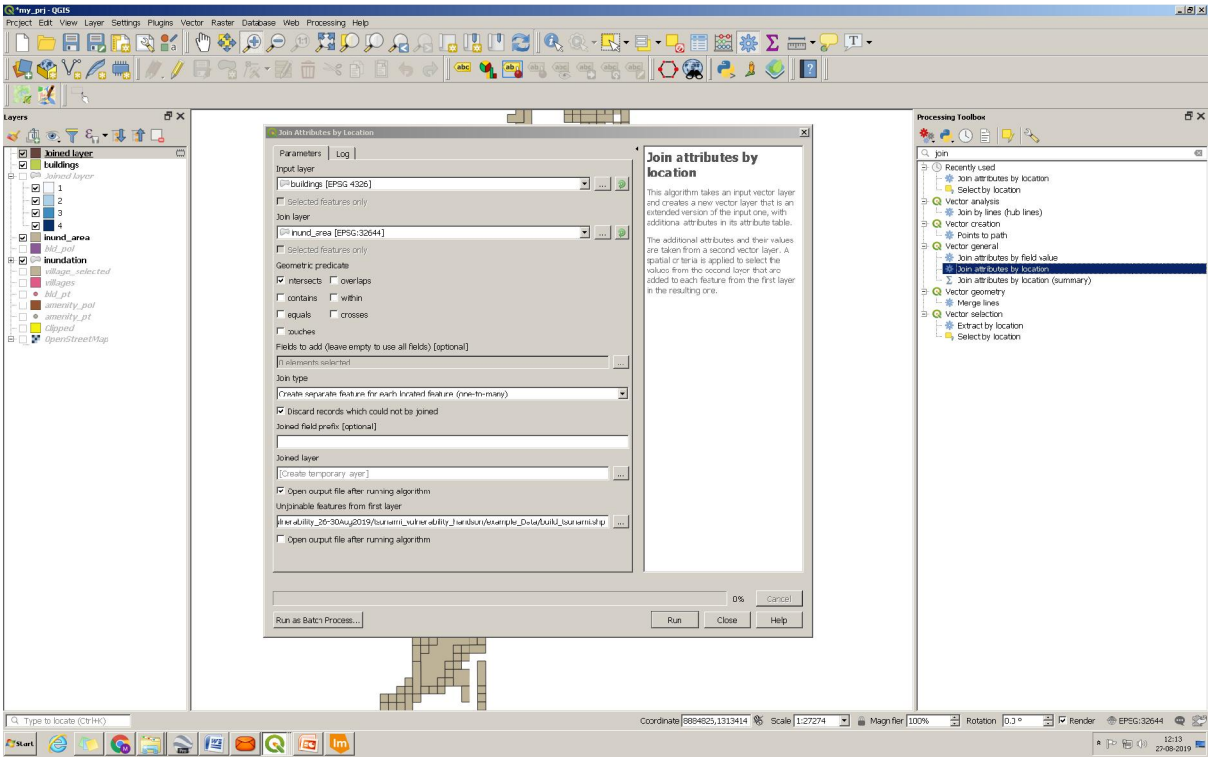
Step2: add **buildings.shp** from folder sample_buildings.



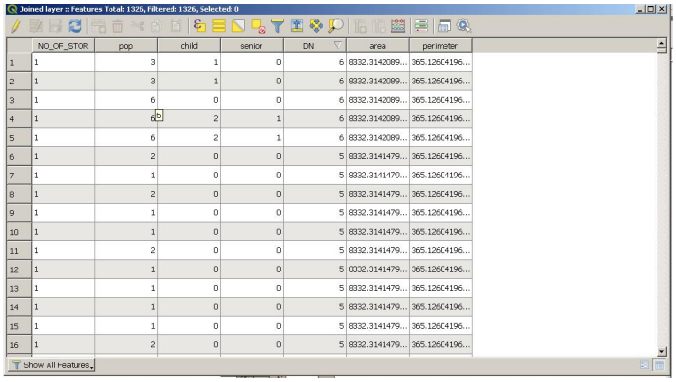
Right click on buildings layer in layer window and select open attribute table you will see the following table. This building base data generated from ground survey from our projects. It has got number of storeys, total population, children (age below 12y) and seniors (age above 60y).



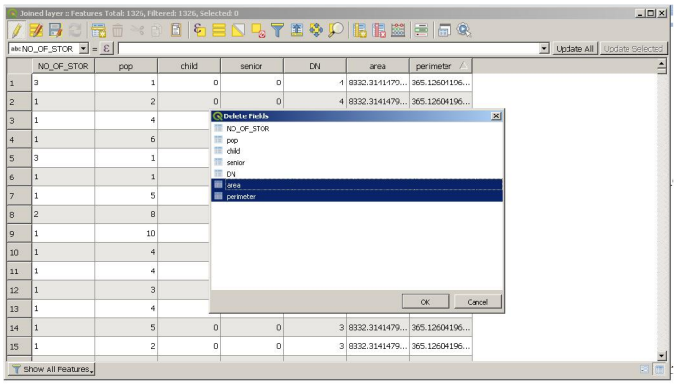
Step3: select **join attribute by location** from toolbox select input layer **buildings**, join layer **inund_area**. check **intersect, overlap and touches** options under geometric predicate, join type "**create separate feature for each located feature**", check **discard records which could not be joined**. Enter name of joined output layer file name **build_tsunami.shp**. This file will have inundation of tsunami at each building



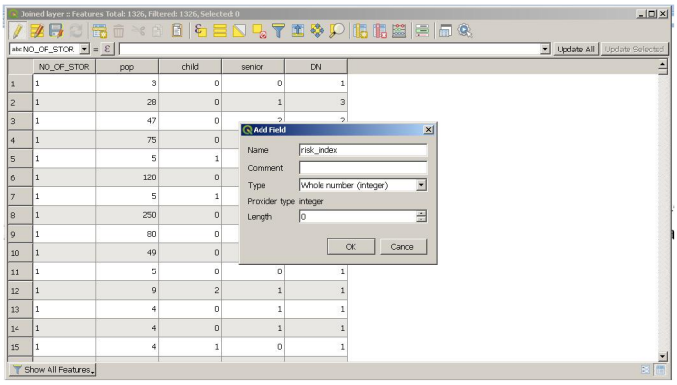
Joined layer will appear in the viewer and lists in the layers window. The attributes of the joined layer looks like below. It will contain the tsunami flow depth (DN) recorded at each building.



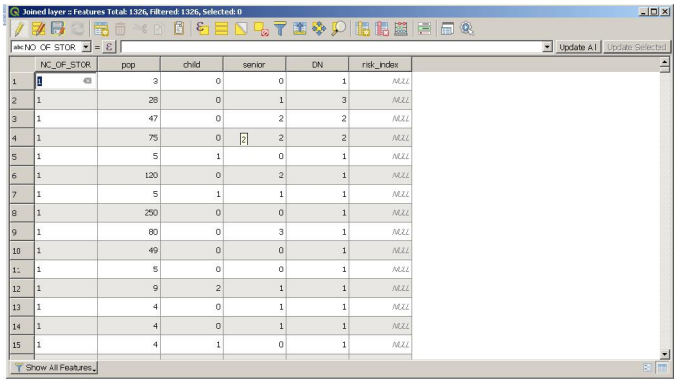
Step4: click on toggle editing mode (yellow pencil tool in top left) or ctl+e shortcut keys. Now table is in editing mode. Select delete filed (ctl+l) select 'area' and 'perimeter' by holding shift key and click ok



Click on new field till (ctl+w) and click **ok**

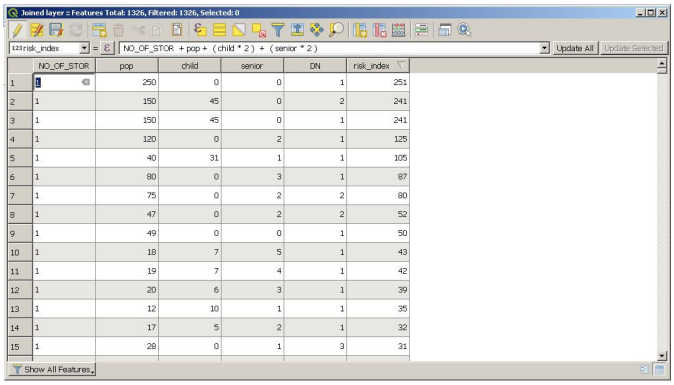


New field **risk_index** is added



Step5: calculate risk index use the following equation

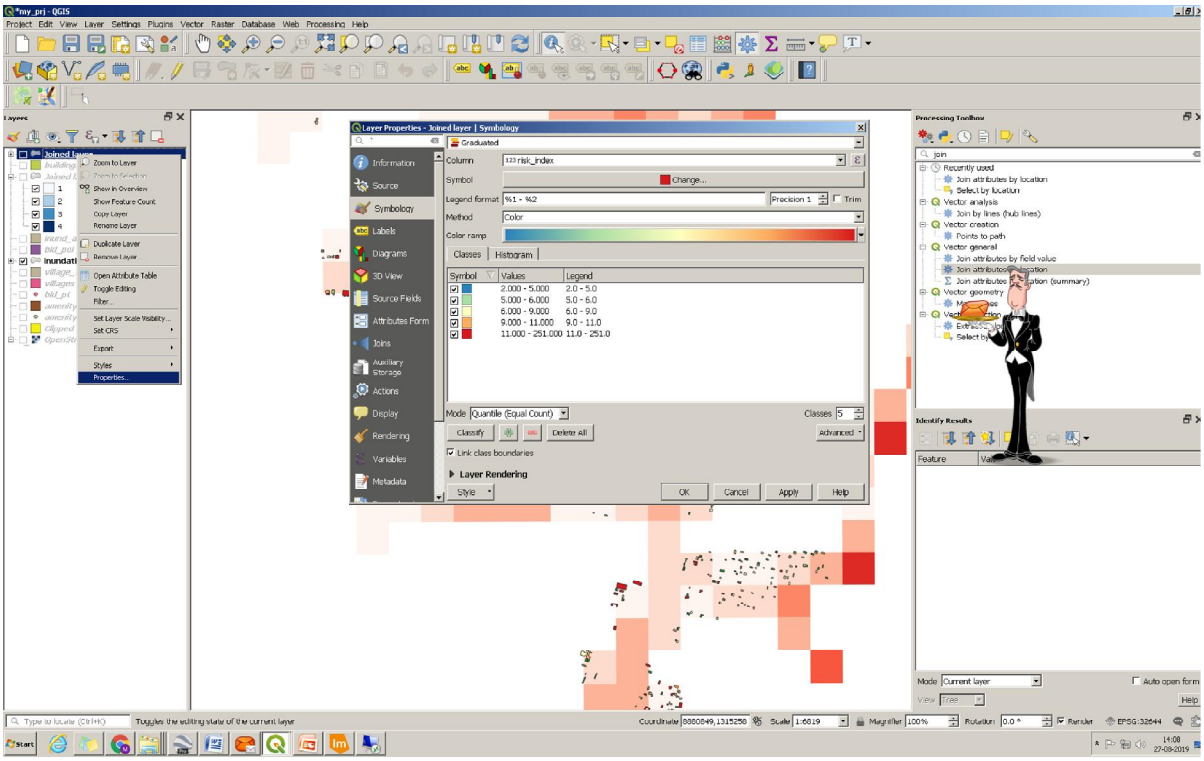
risk_index =(1/ NO_OF_STOR *4) + pop + (child * 2) + (senior * 2)



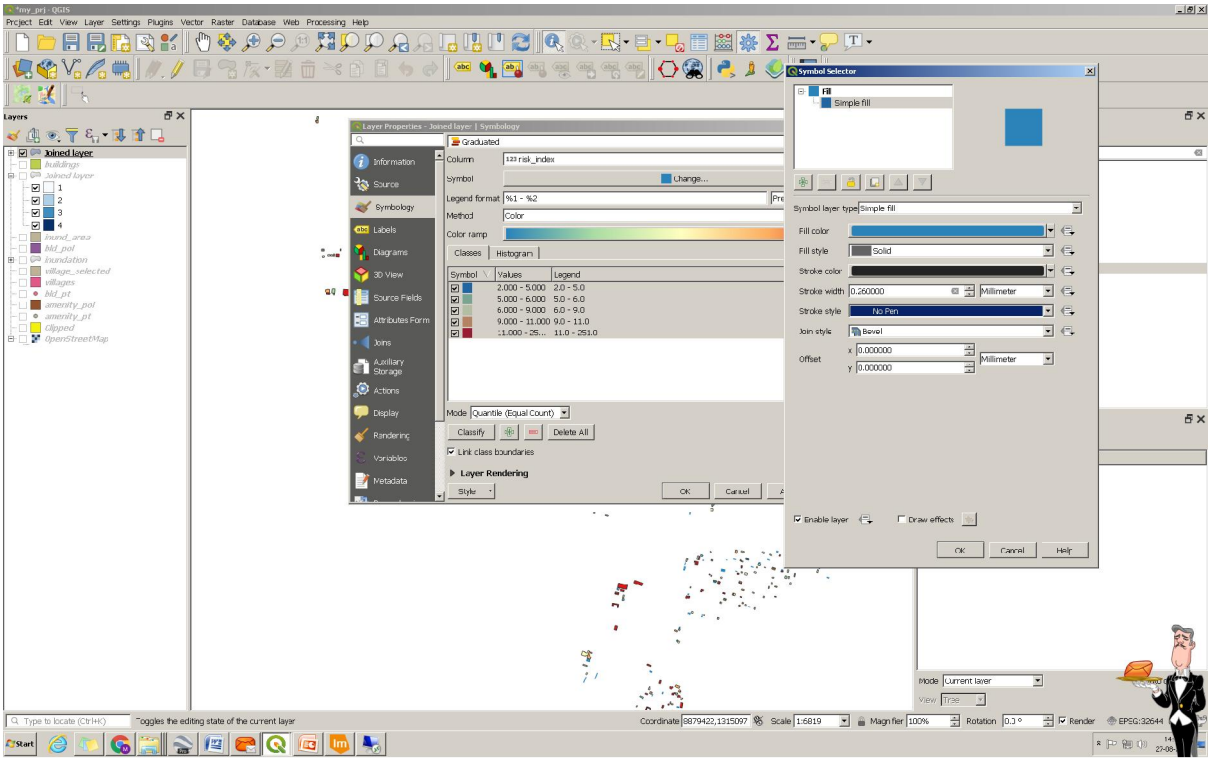
	NO_OF_STOR	pop	child	senior	DN	risk_index
1	1	250	0	0	1	251
2	1	150	45	0	2	241
3	1	150	45	0	1	241
4	1	120	0	2	1	125
5	1	40	31	1	1	105
6	1	80	0	3	1	87
7	1	75	0	2	2	80
8	1	47	0	2	2	52
9	1	49	0	0	1	50
10	1	18	7	5	1	43
11	1	19	7	4	1	42
12	1	20	6	3	1	39
13	1	12	10	1	1	35
14	1	17	5	2	1	32
15	1	28	0	1	3	31

Then click on toggle editing tool and click **save** close the table

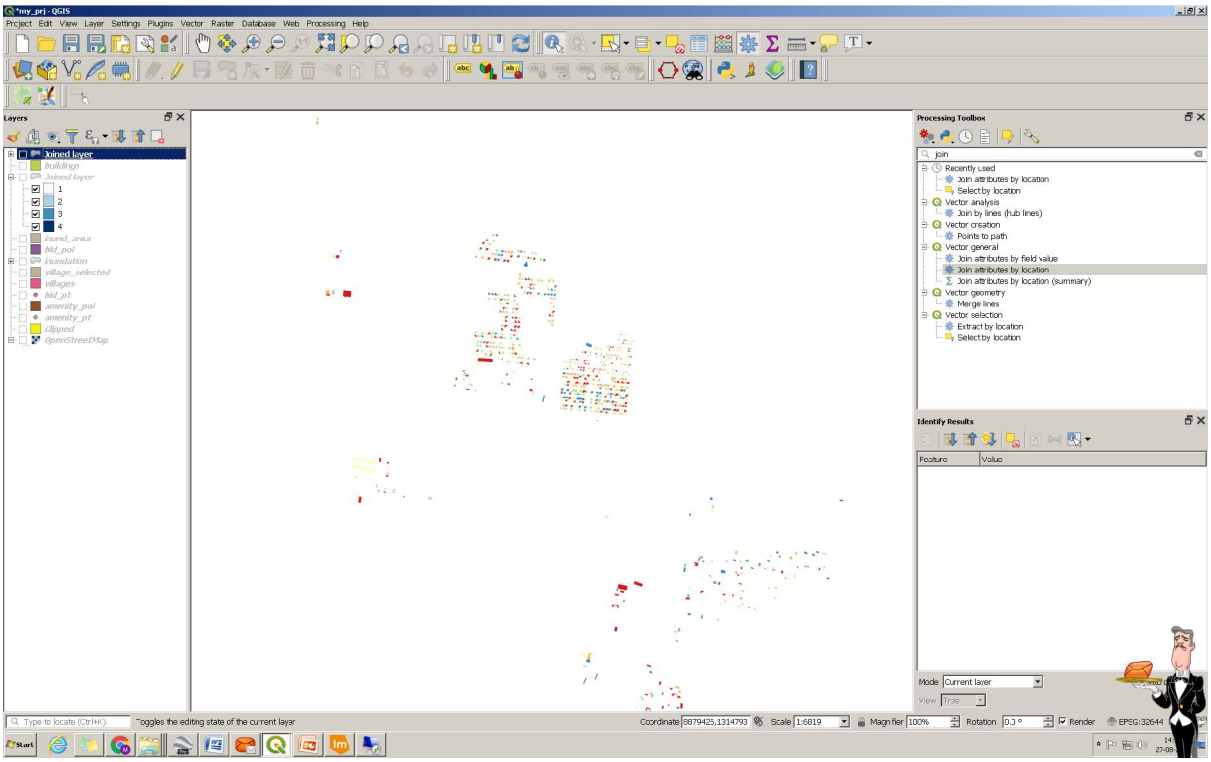
Step6: symbolize buildings based on the field risk_index which represents socio-economic risk index at building level. Right click on joined_layer. Select symbology, type is graduated, column risk_index and click classify. Select colour ramp spectral and invert ramp, select mode **quantile (equal count).**



The building polygon features are very small most of the colour shown by outline of the symbol. Hence select all the symbols, click on **colour** change symbol, symbol selector dialog will appear. Click on **simple fill**, change stoke style to **no pen**. Click ok and click **apply** and **ok** in layer properties dialog.

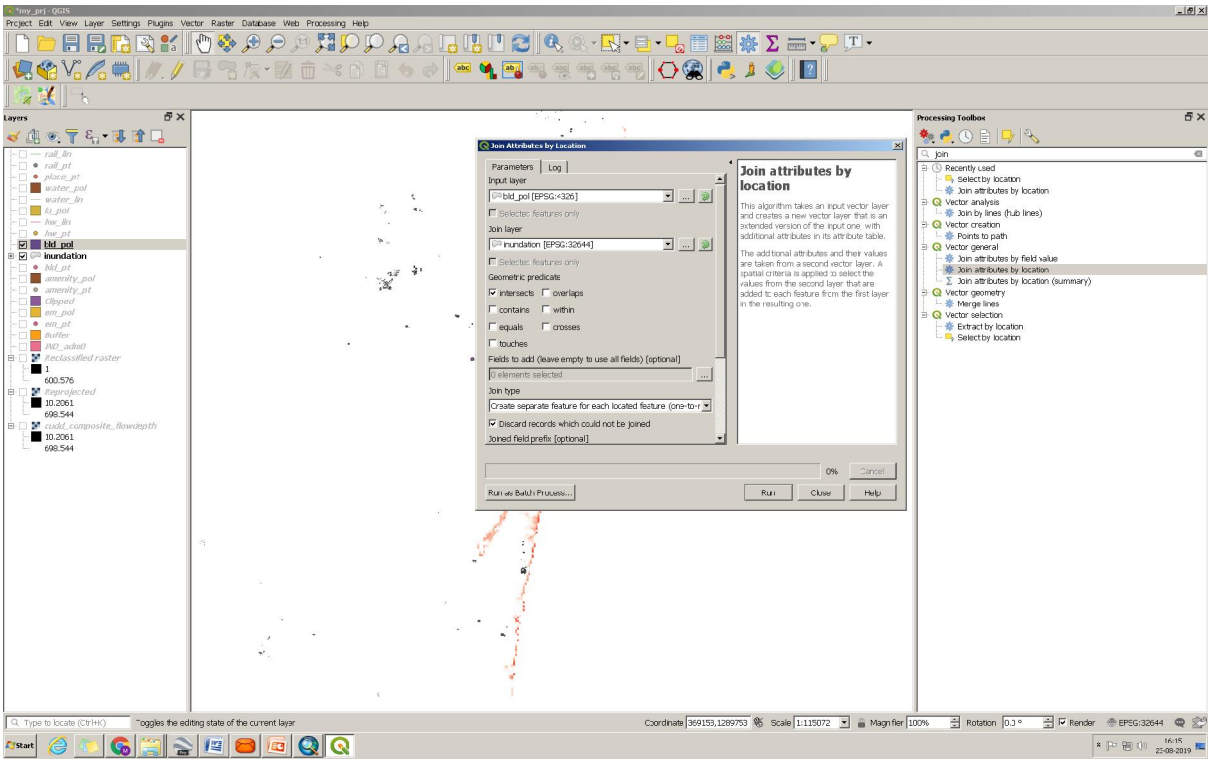


Building associated with risk will appear as below

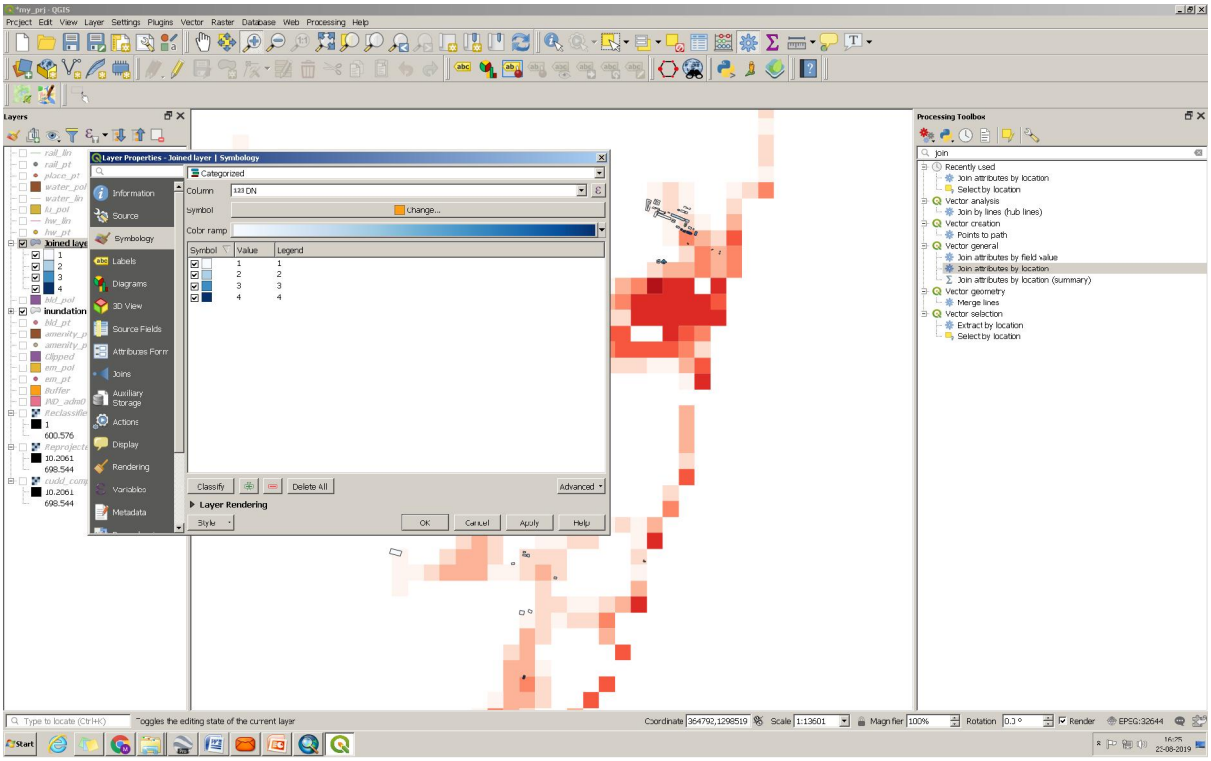


V overlay analysis, socio-economic impact and statistics generation using open source data

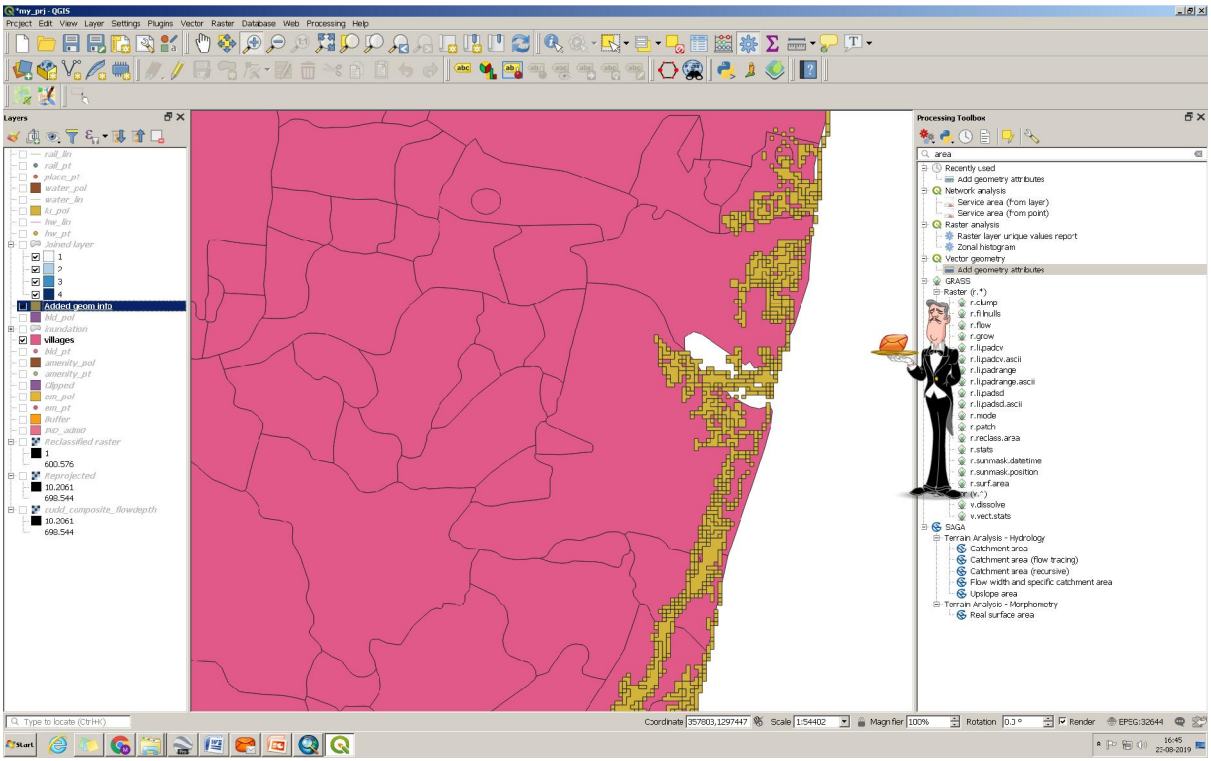
Step1: select join attribute by location from tool box select input layer bls_pol.shp, join layer inundation.shp. check intersect under geometric predicate, join type "**Take attributes of the first located feature only (one-to-one)**", check **discard records which could not be joined**. Enter name of joined output layer file name **bul_inund.shp**. This file will have inundation of tsunami at each building



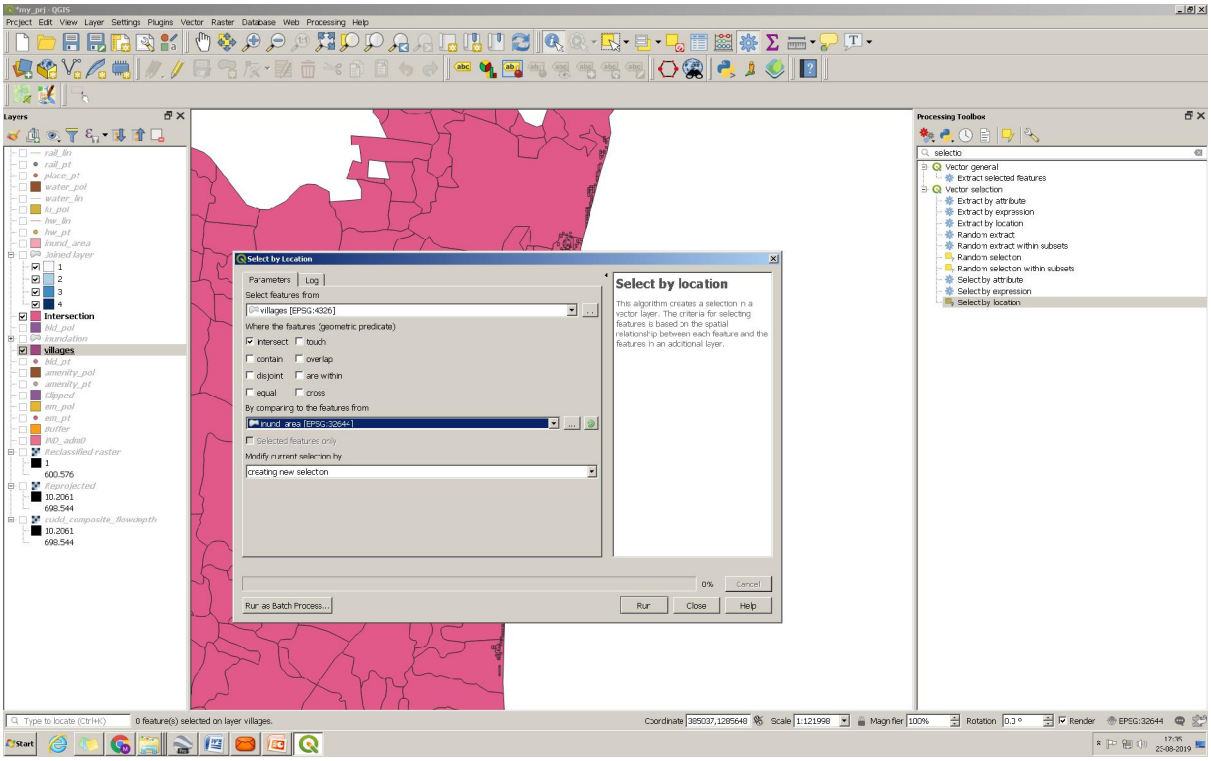
Step2: you can check the attribute for buildings experience maximum inundation. You can symbolize buildings based on the water level. Go to layer properties, symbology and assign symbology for the inundated buildings based on the category using the DN field. The data is inadequate to cover all the buildings in the area, hence only few buildings recorded.



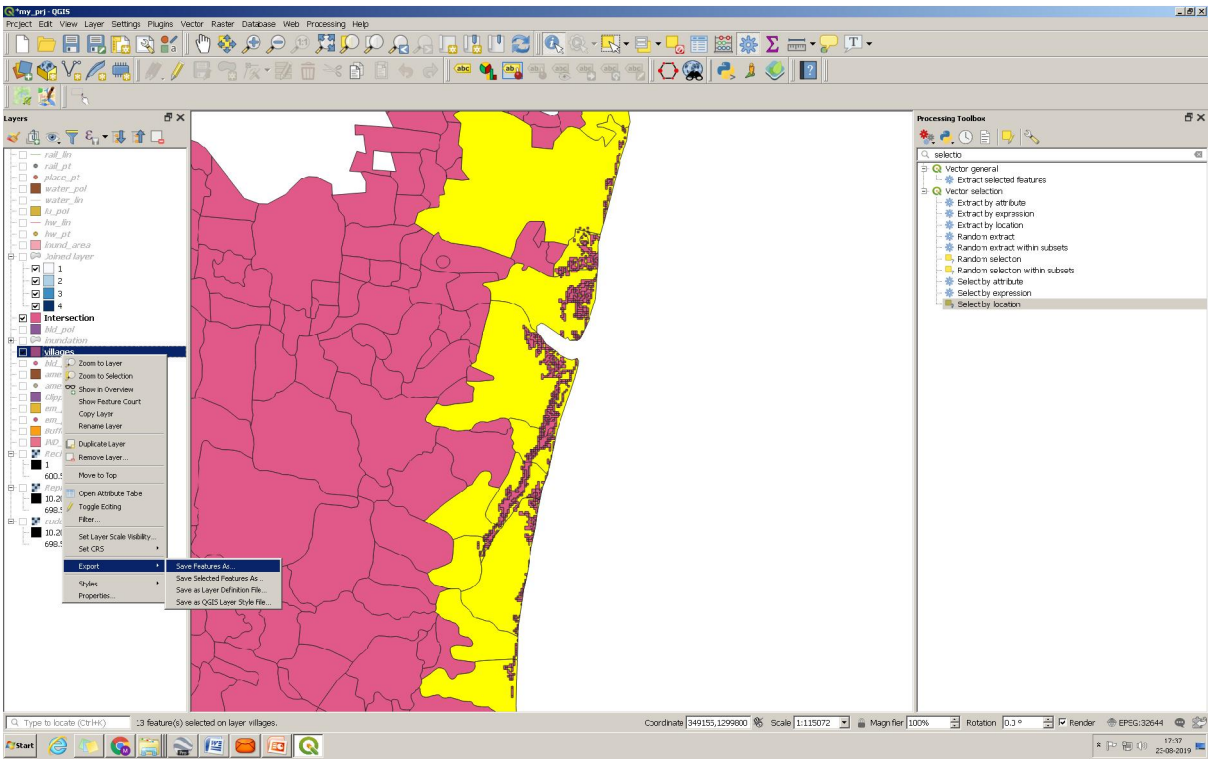
Step3: add the village boundary (smallest administrative unit) villages.shp file from example data folder.



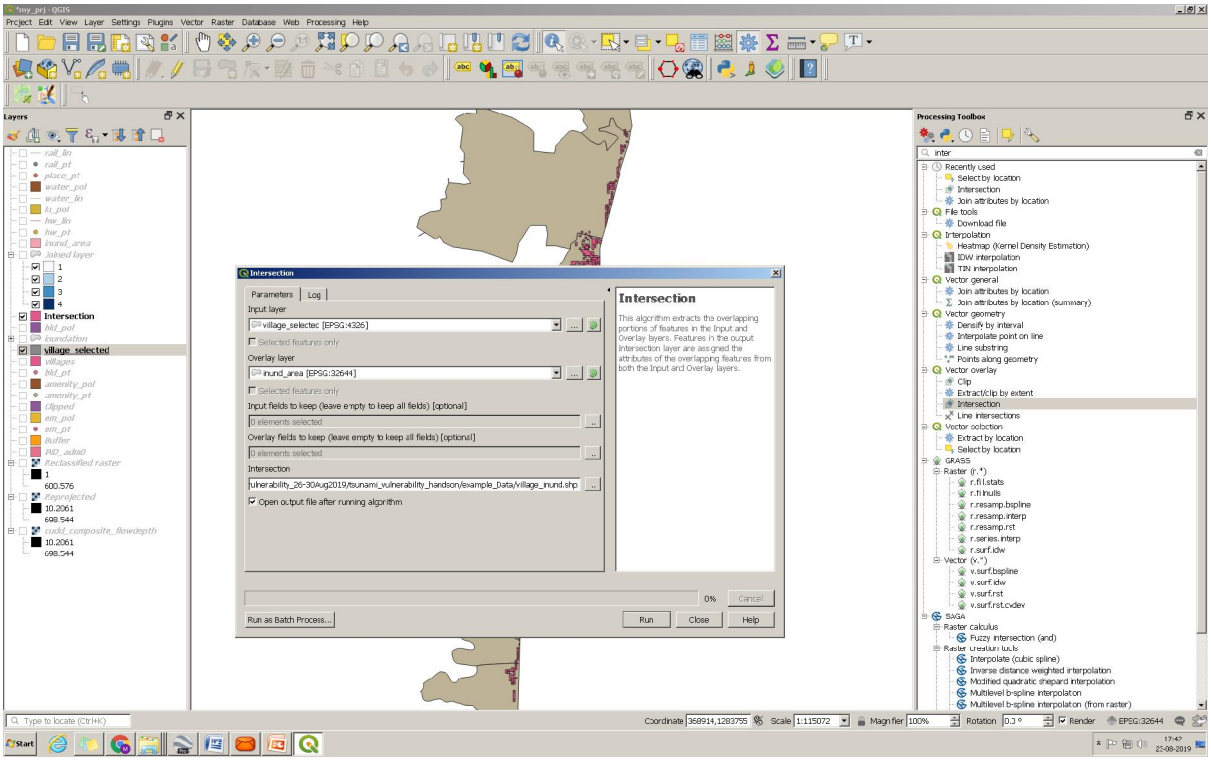
Step4: selecting the villages experiencing the inundation input villages.shp intersection inundation area as shown below



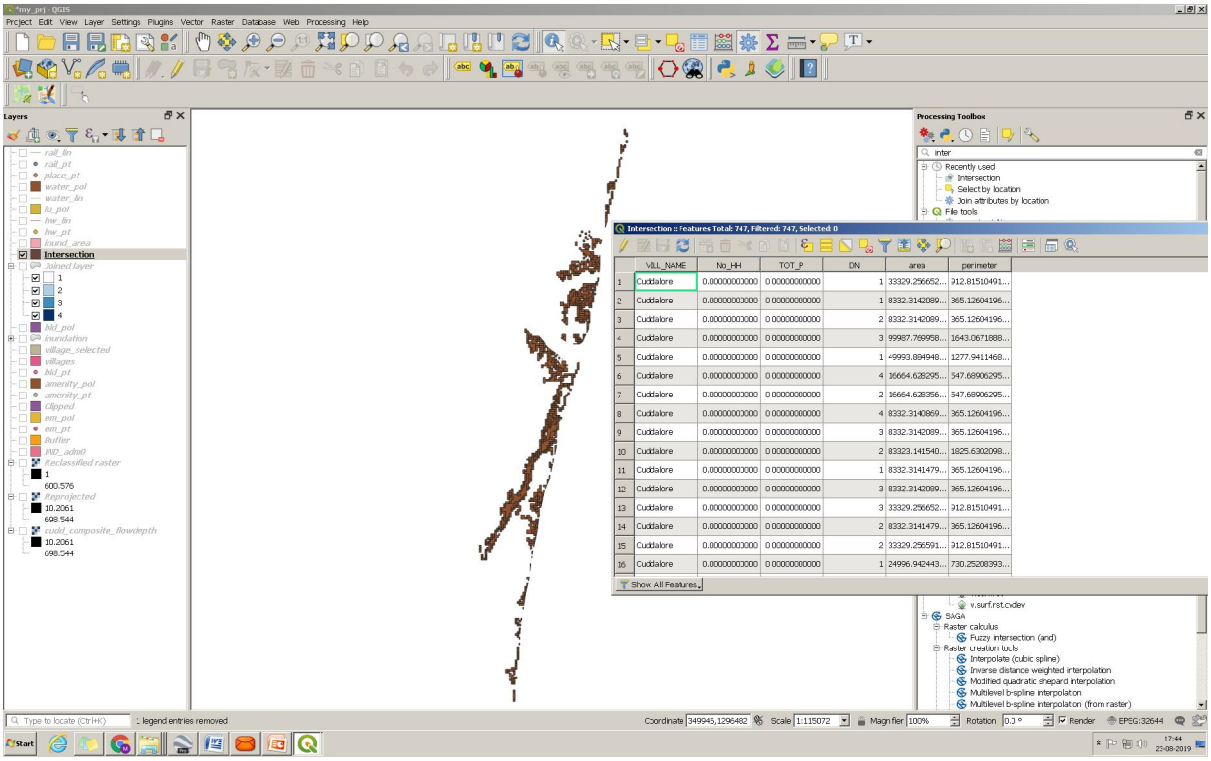
Save the selected features into new shape file village_selected.shp check selected features only.



Step5: select intersection tool from tool box provide input village_selected.shp and overlay layer inund_area.shp. Enter output file name village_inund.shp and run.



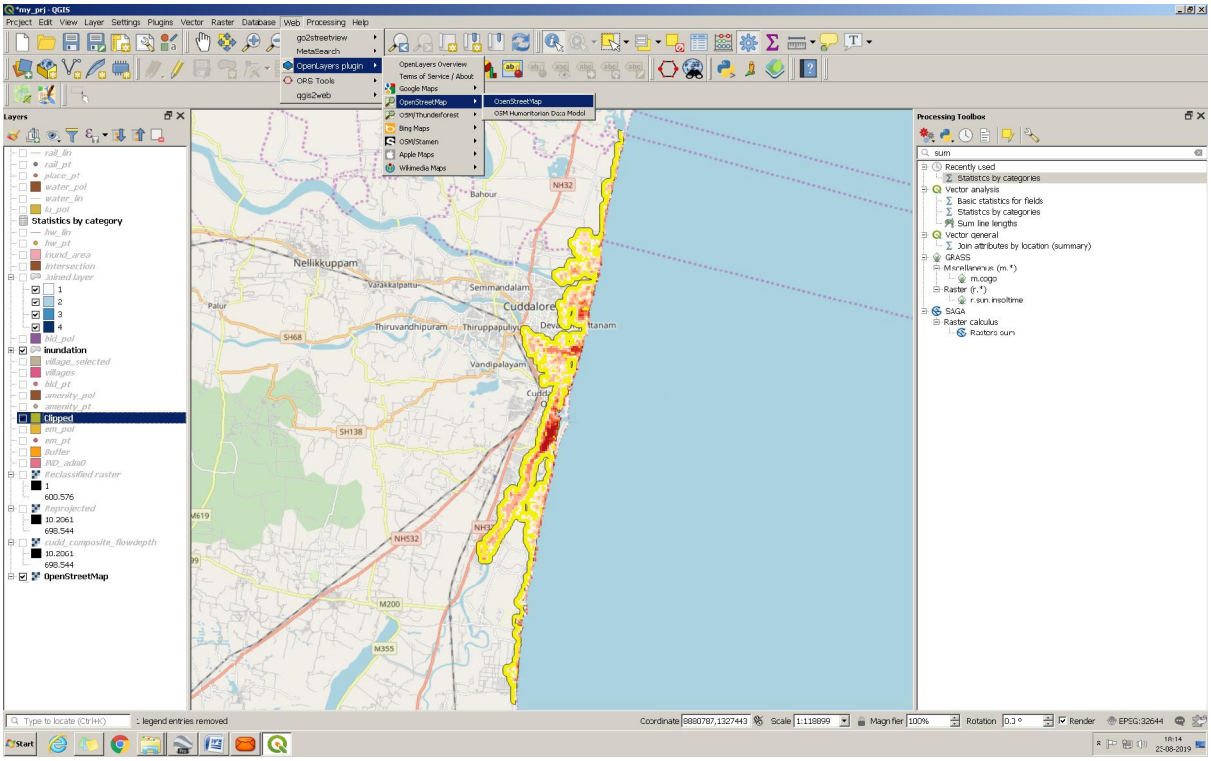
You will get the intersected layer associated with village names and inundation levels



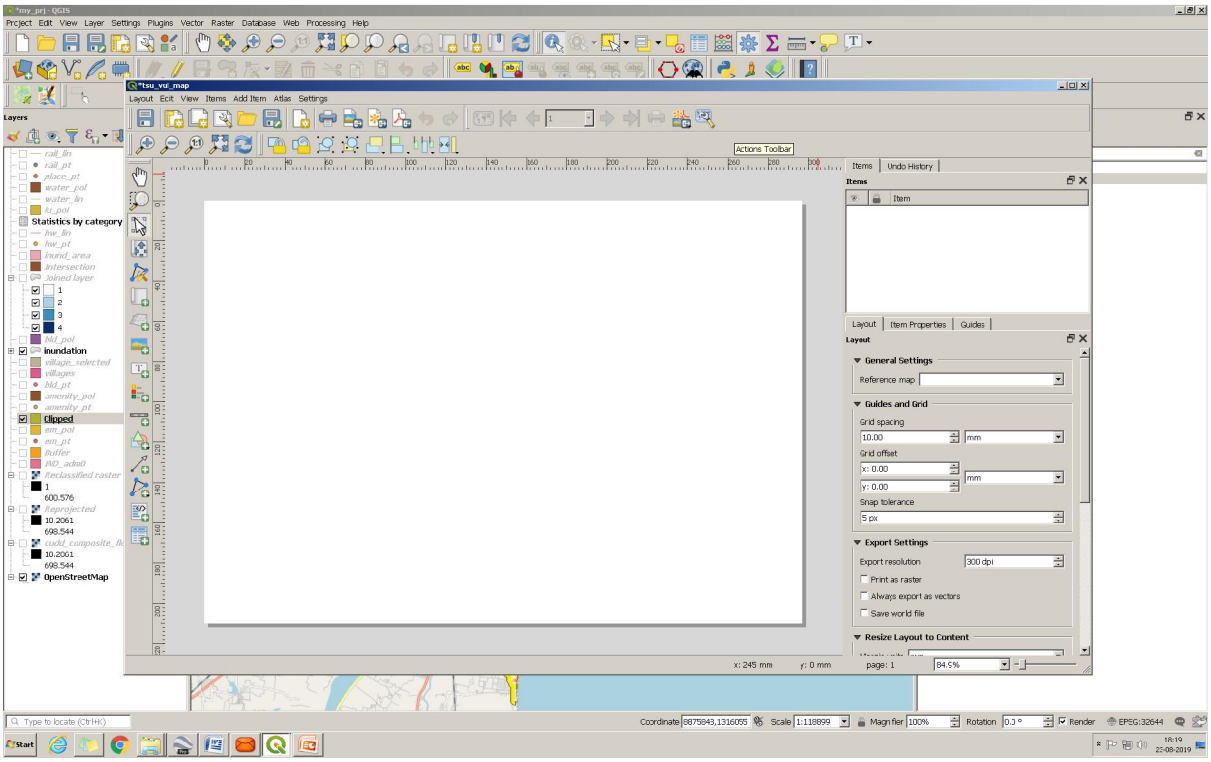
Step6: to obtain the statistics at village level select statistics by categories from tool box. Give input file name intersect file village_inund.shp. select **area** field to calculate statistics, select **VILL_NAME** under statistics by category. Give output file name vil_stat_area.csv (summarized statistics will be written in table format). Then you will get village wise inundation area statistics. You can use this for reporting. Similarly you can try on DN field to get statistics on inundation levels at each village.

VI Map Generation/Map Composition

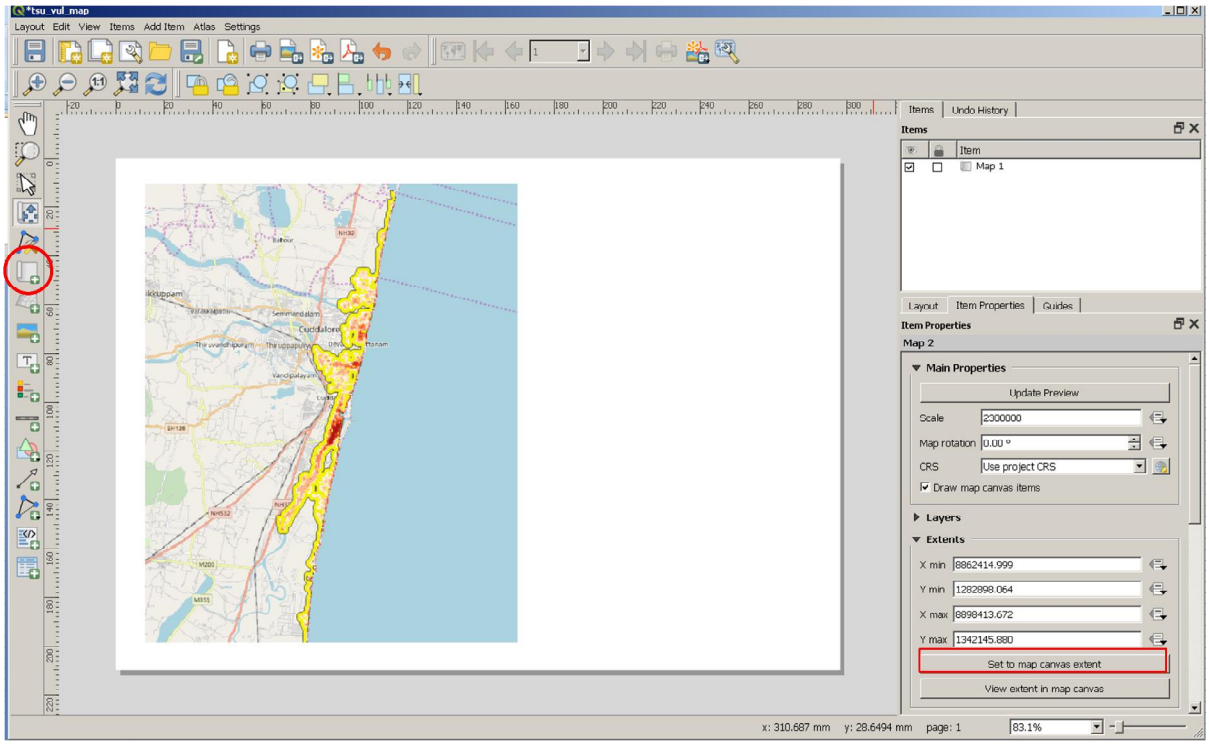
Step1: in order to finish map the base maps are necessary. We can open WMS services available online. Go to web menu, open layer plugin, open street map you will see the following layer opened in your viewer. Switch on the inundation.shp and clip_buf.shp in the viewer. Make sure all other layers are switched off.



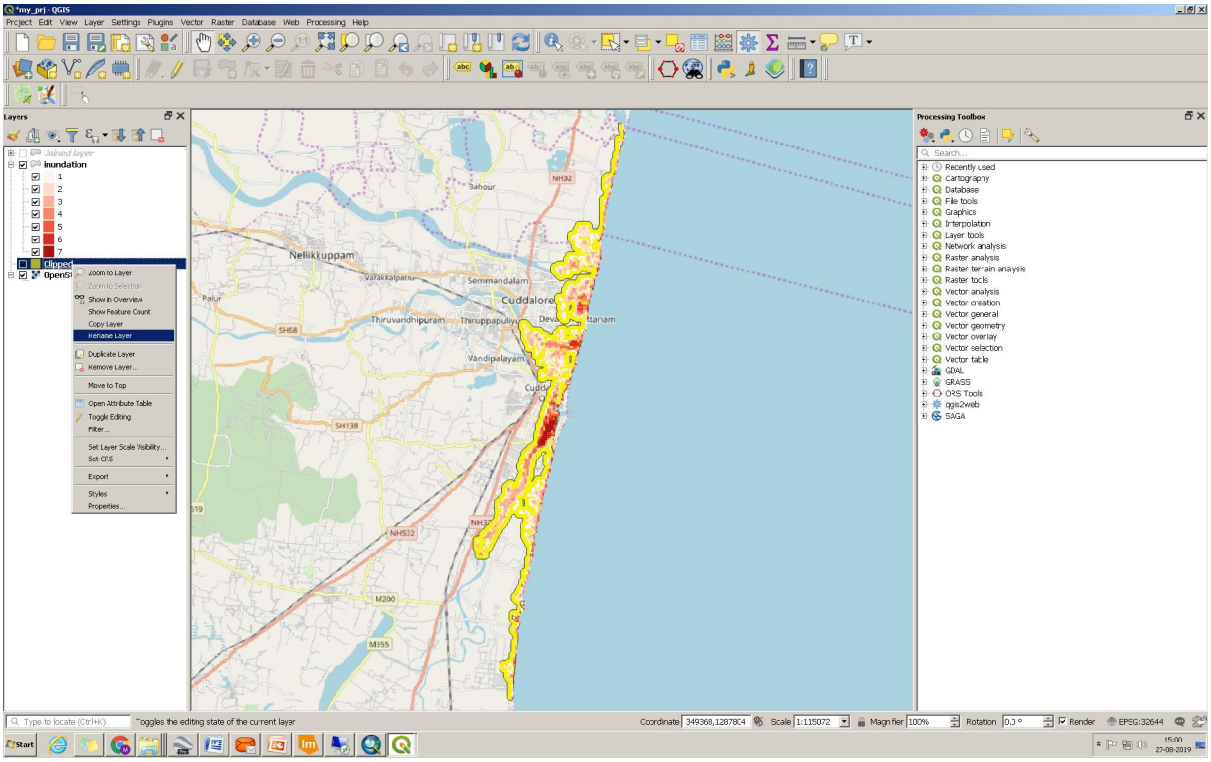
Step2: go to **project** select **new print layout** and enter print layout title "tsu_vul_map" and click ok. The print layout window will appear as shown below



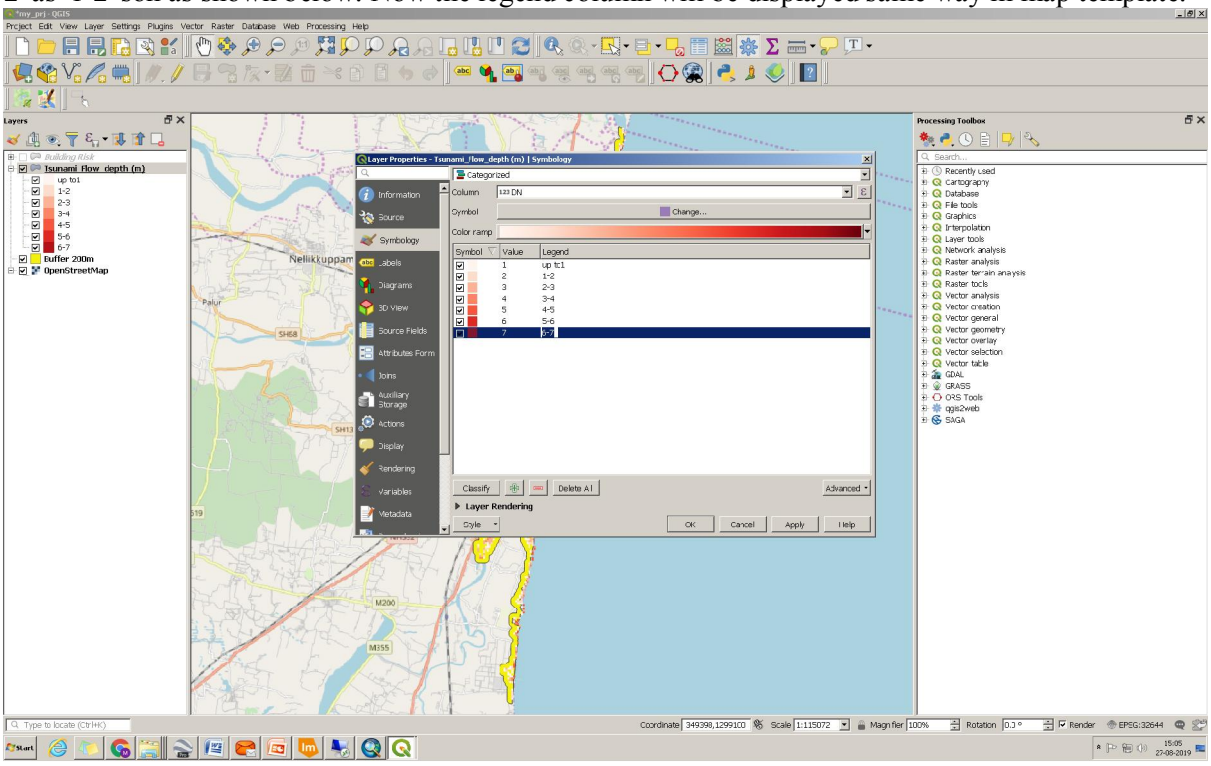
Step3: select **add map to layout** tool and draw frame on the template. The layers visible on QGIS viewer/canvas will appear on map template. If not go to item properties in the right side panel click set to map canvas extent. Map appear on map template.



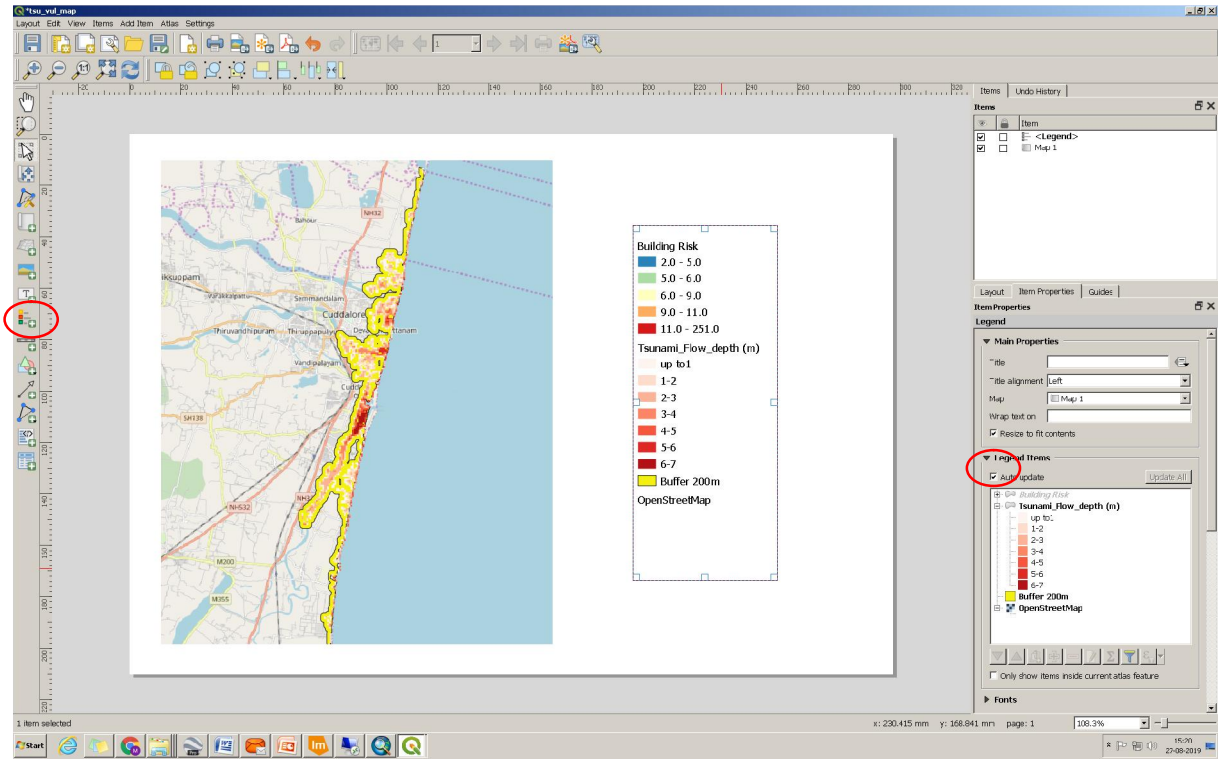
Step4: Map requires adding mandatory marginal details to make it to become self explanatory. Remove all the layers except Joined_layer, inundation, Clipped. Right click on clipped select and rename it for 'Buffer 200m' and rename Inundation as Tsunami Flow-depth (m) and joined_layer as 'Building Risk'



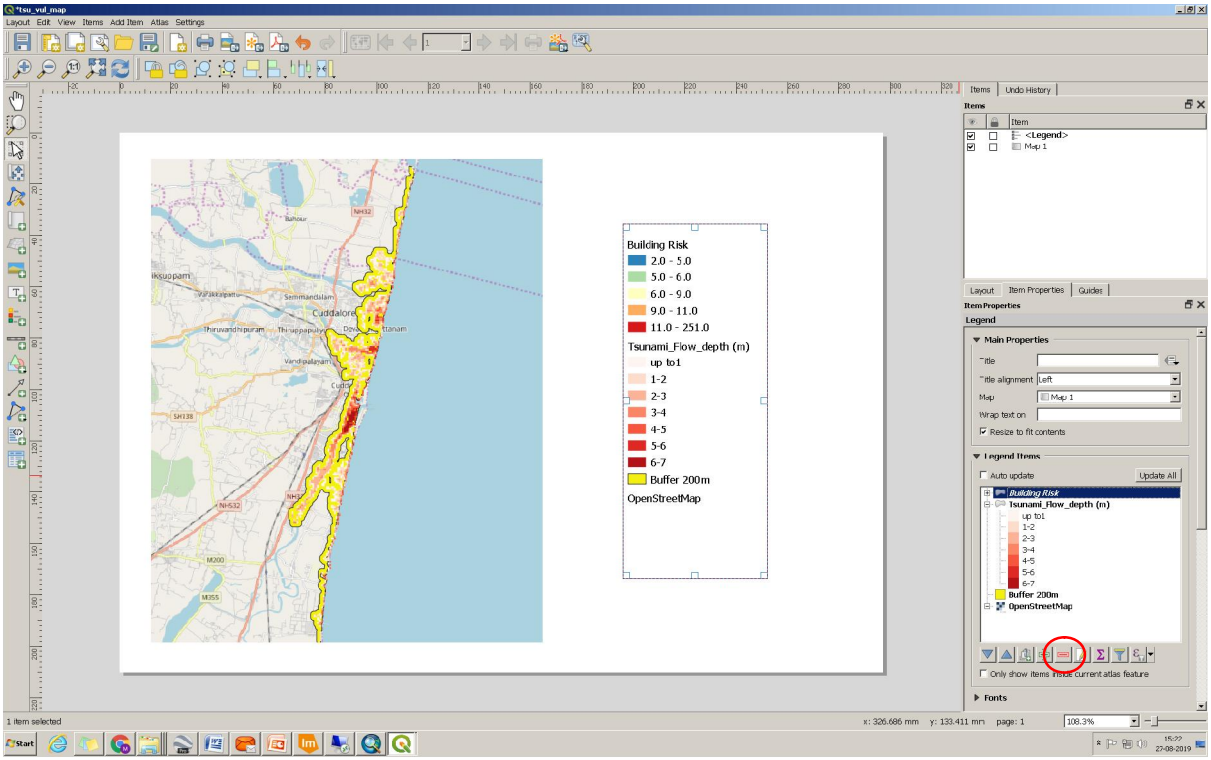
You can also change the legend entry displayed on the map the way you want. For eg. Select the tsunami flow-depth layer symbology double click on value '1' legend entry and change it to 'up to 1', '2' as '1-2' son as shown below. Now the legend column will be displayed same way in map template.



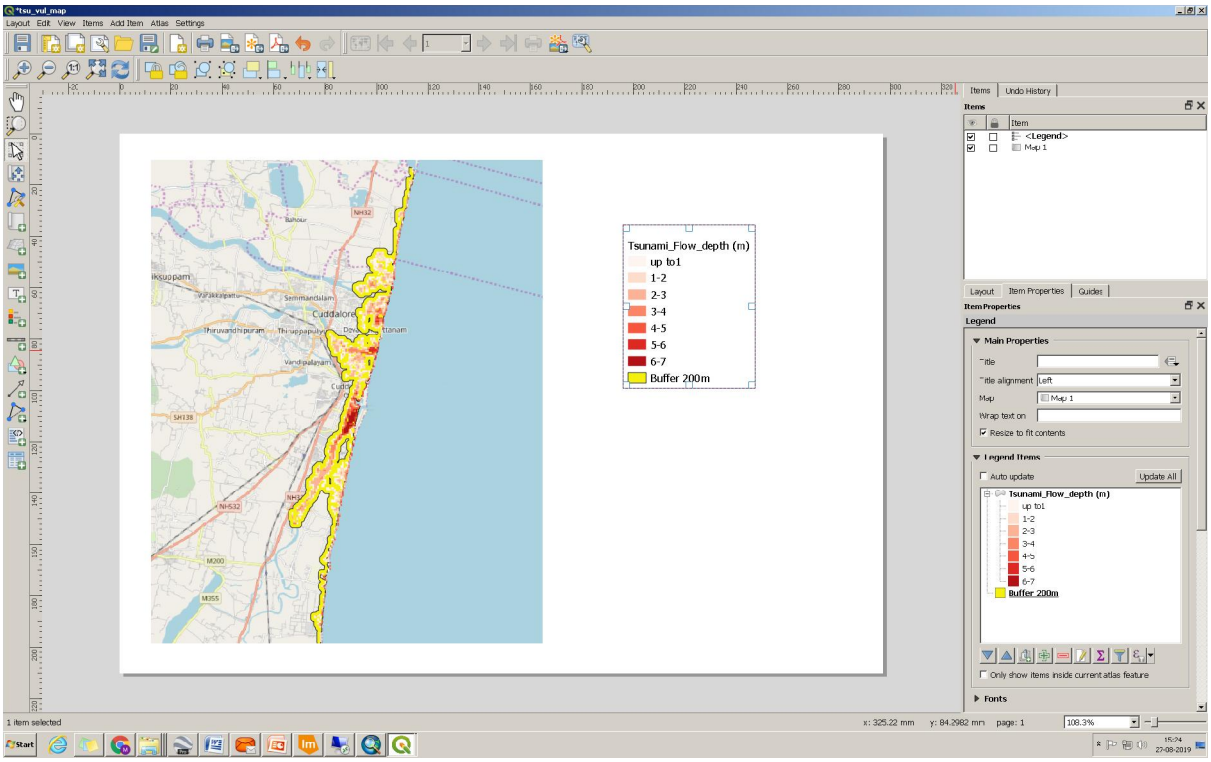
Step5: Add legend: select legend tool draw box on map template then map legend will appear.



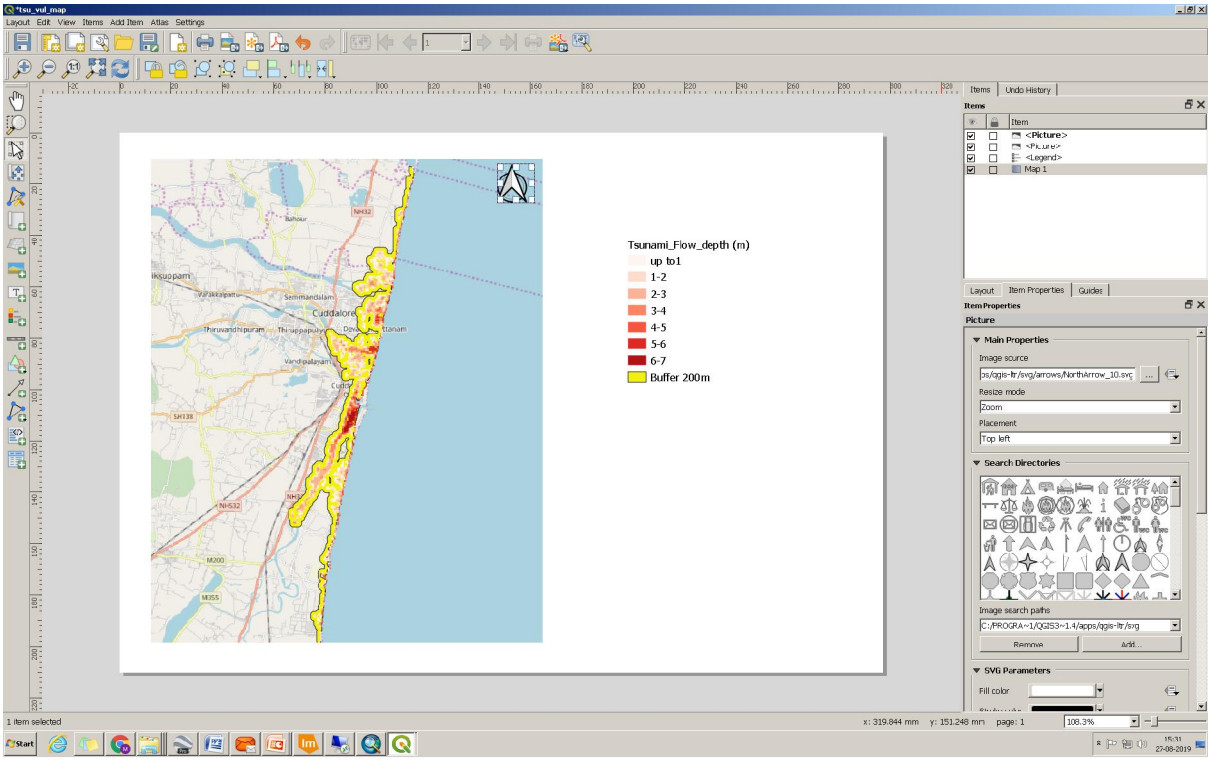
Right panel uncheck auto update select building risk and click remove tool (red colour minus symbol) similarly remove open street map as well



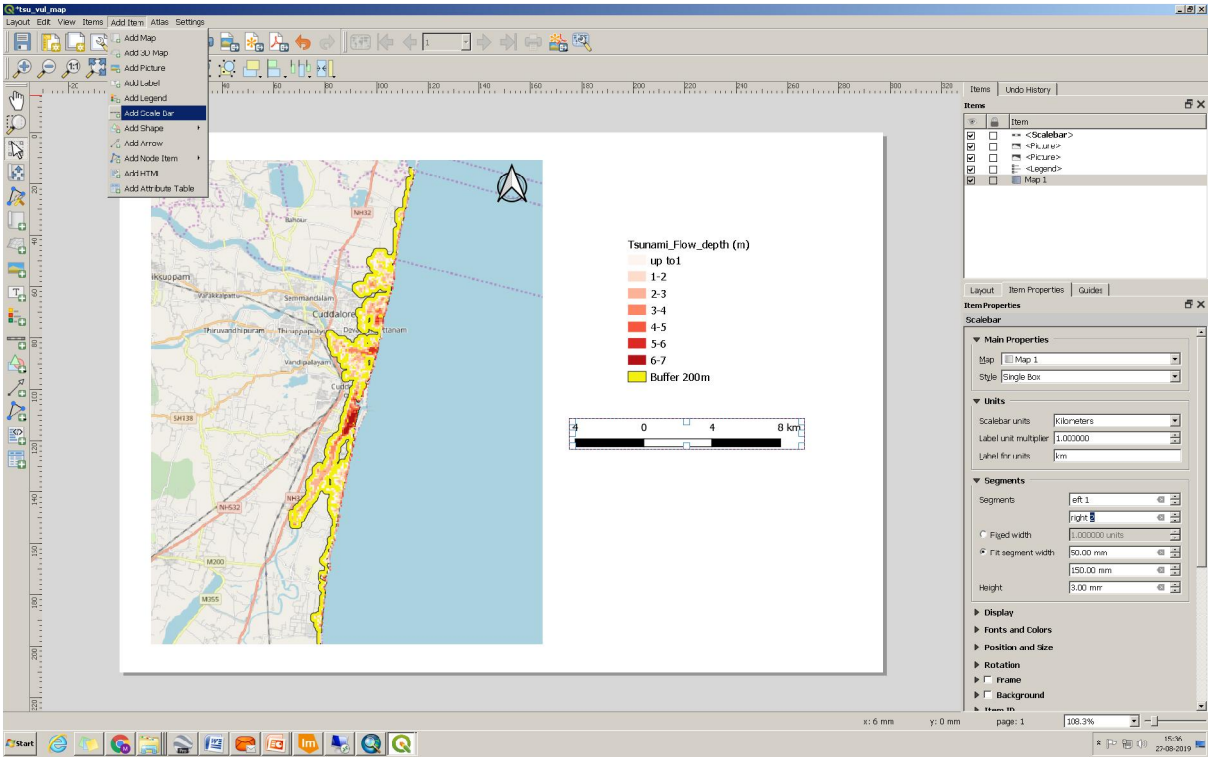
A map appear like below



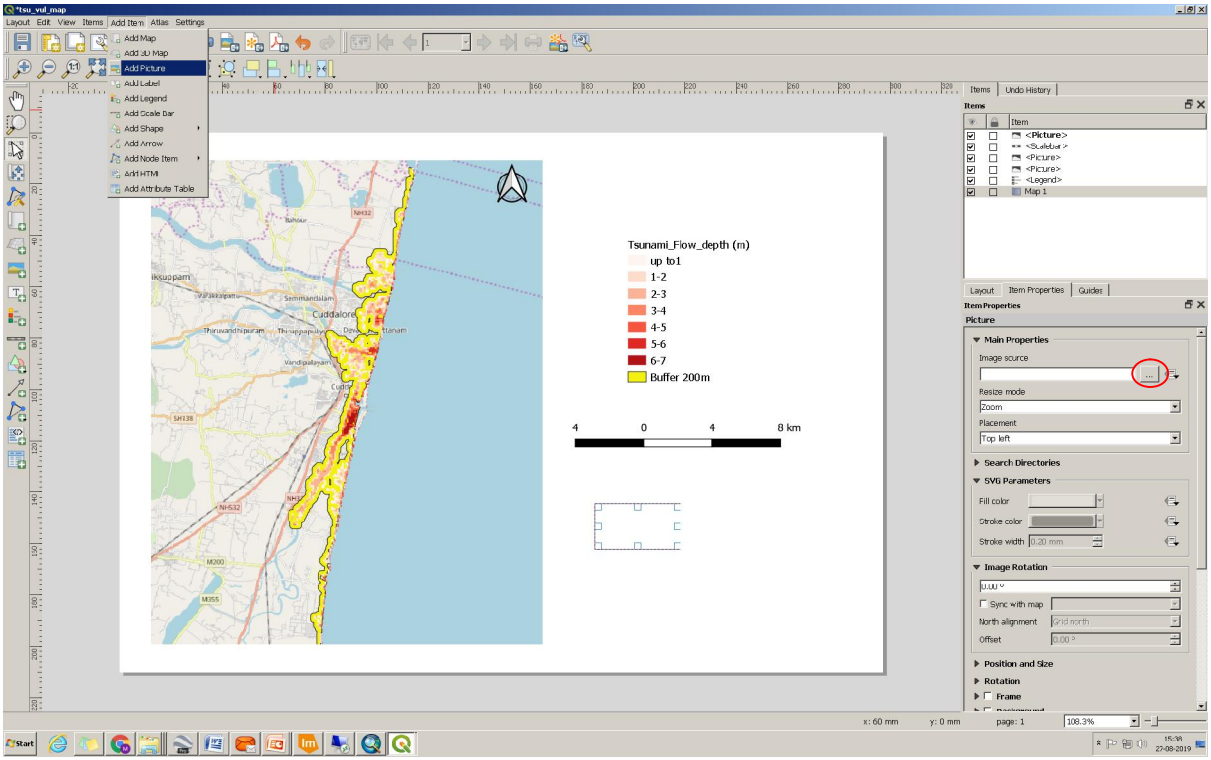
Add north arrow select add image tool draw box where place to north arrow click on search directory select north arrow



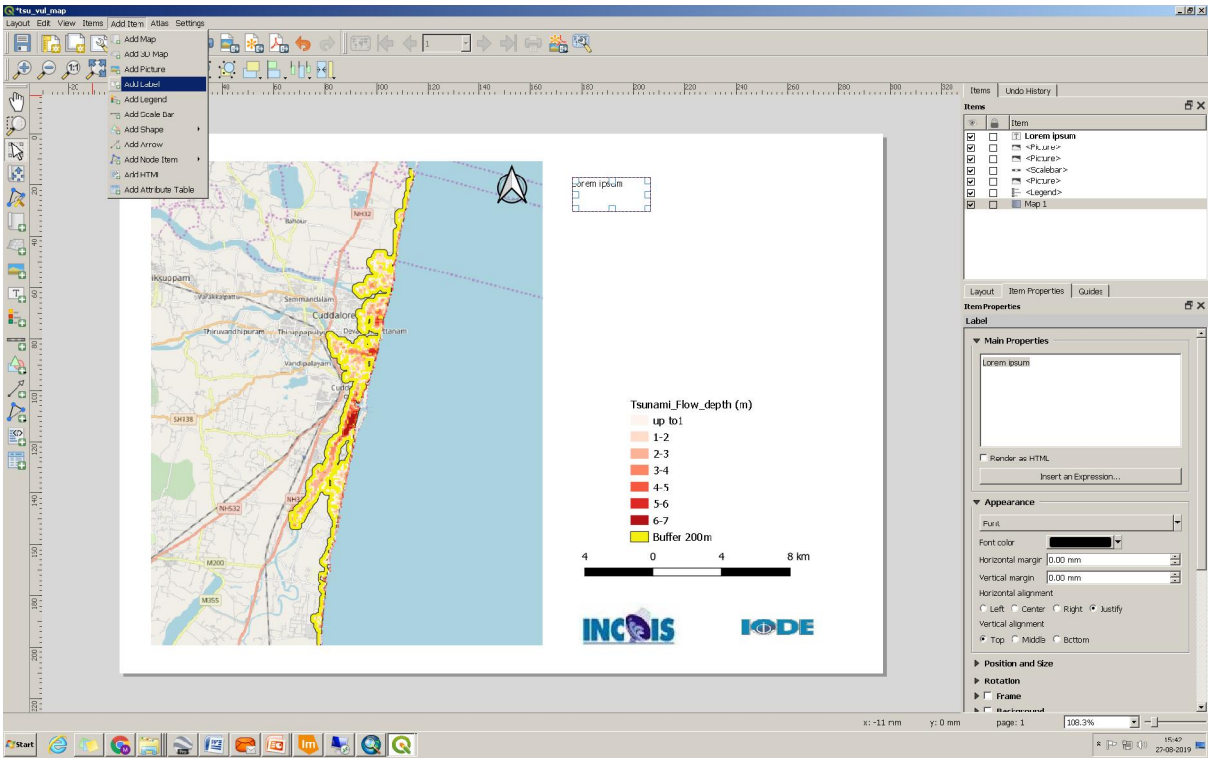
Step6: To add scale bar go to add item menu and select add scale bar draw box the place you want to add scale bar you can resize the length of scale by changing in segment in the right panel of the scale bat item properties window.



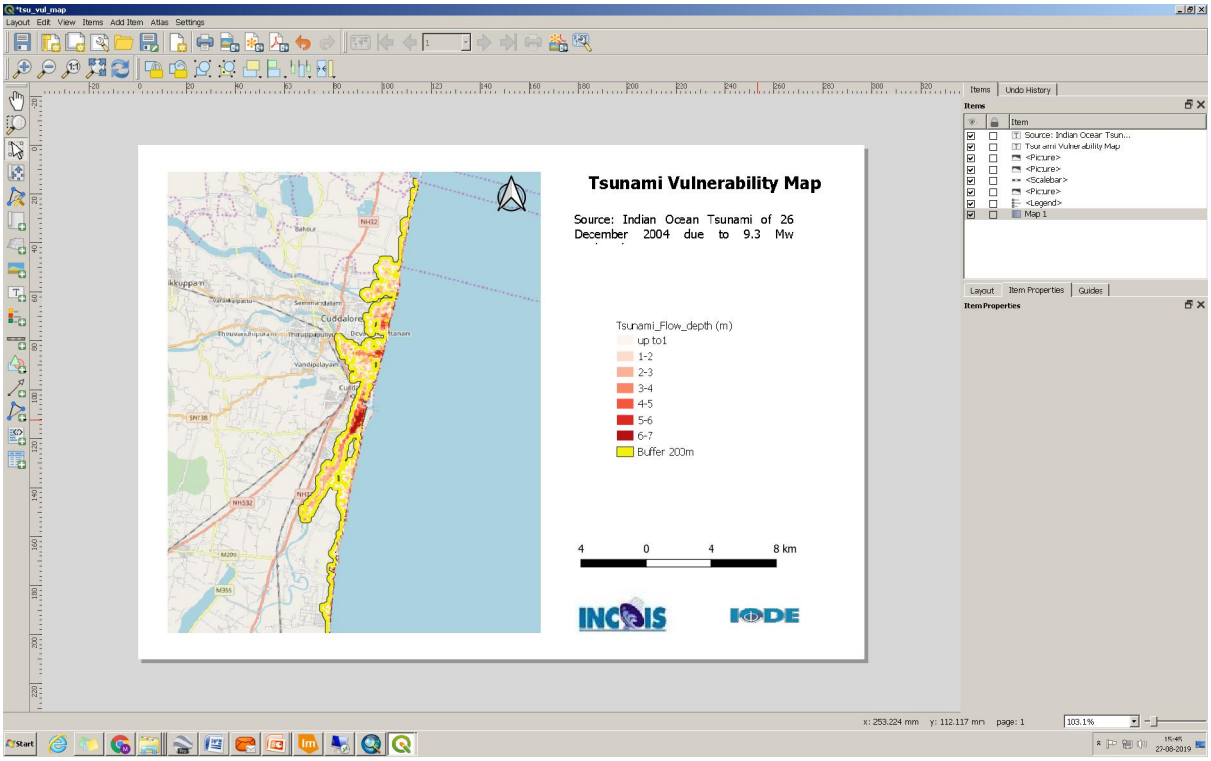
Add logo go to add items menu select add picture and navigate to the folder logos given in the example folder



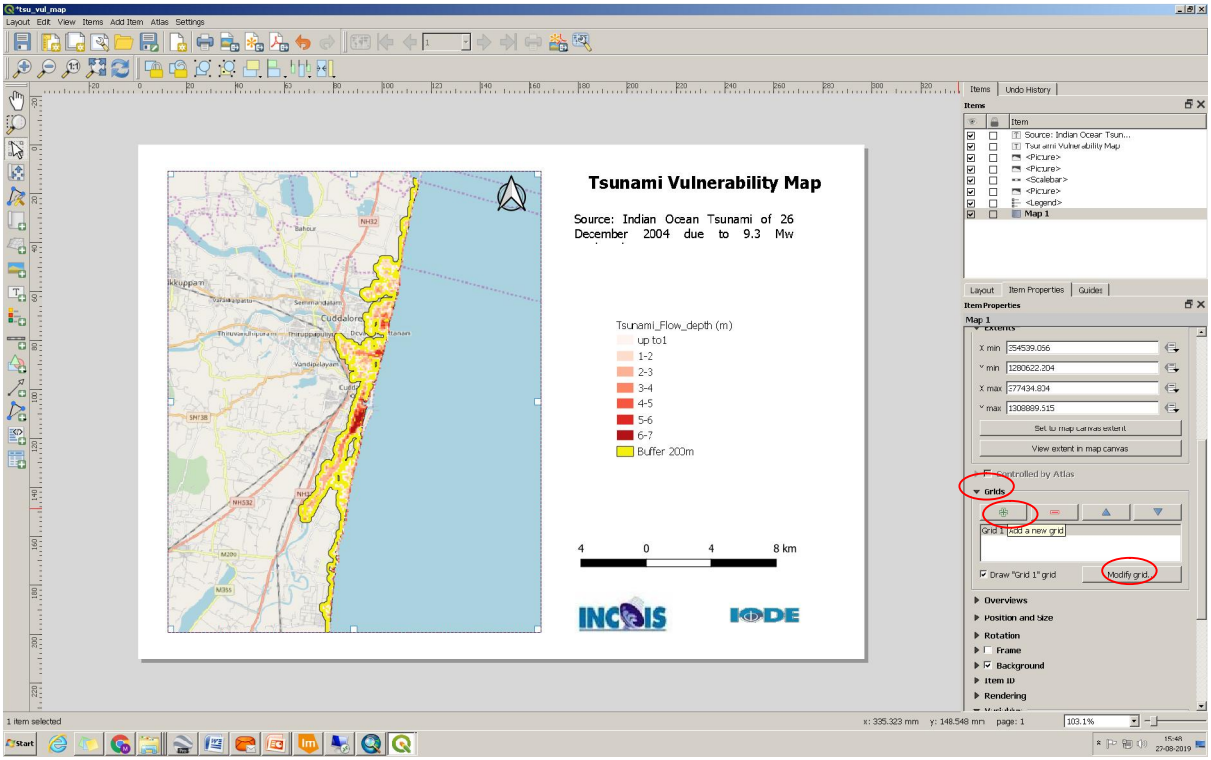
Add title go to add items menu select add label draw box type



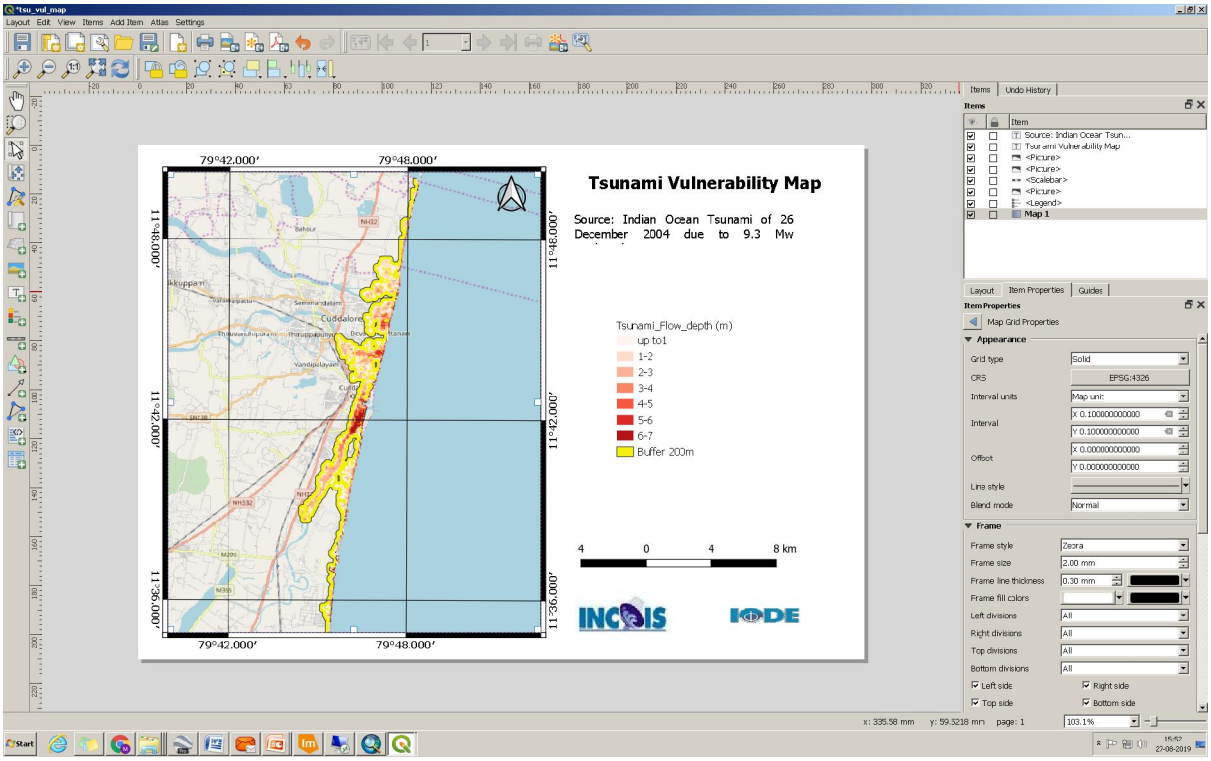
Add the title and sources of inundation and you can change font size and type by using the item properties panel.



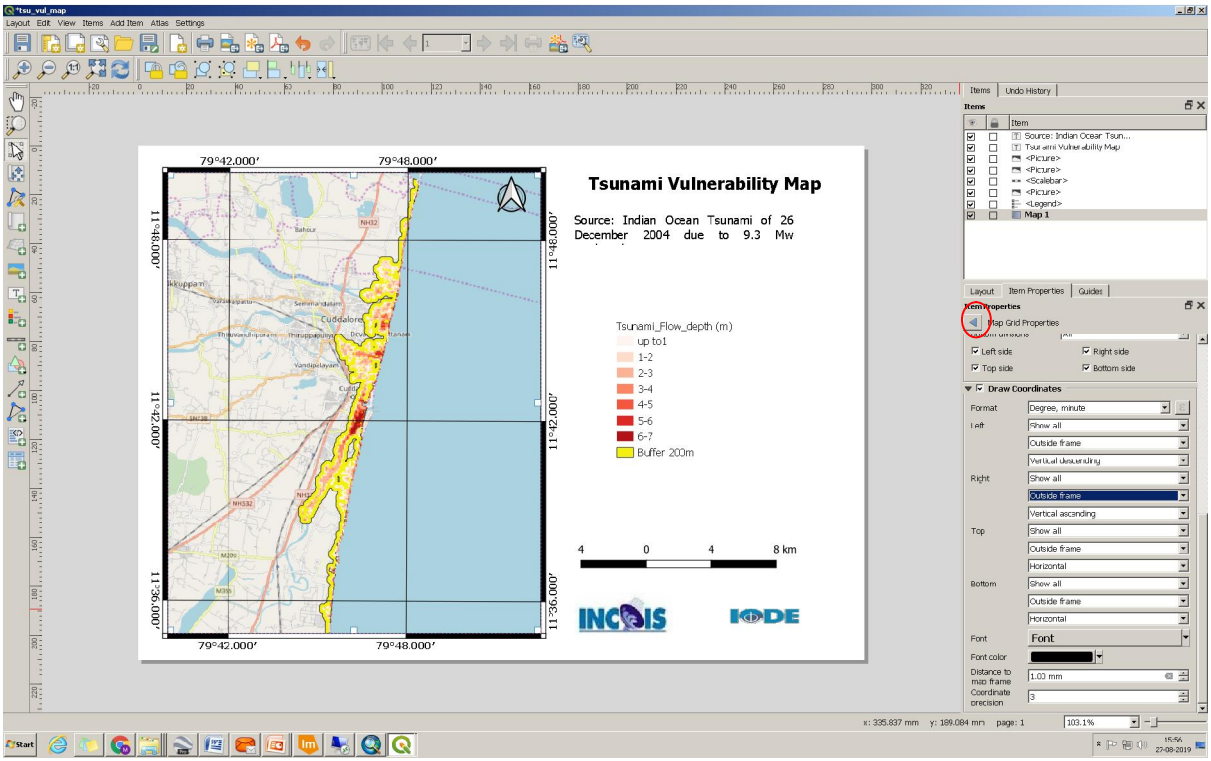
Adding coordinate grids on the map: select the map frame go to item properties select grids add (green plus symbol) select grid1 click modify



The map grid properties appear like below change CRS to EPSG:4326 (this is in order to get the grid labels in degree, minutes and seconds) interval 0.1 and 0.1 in x and y direction. add frame style zebra

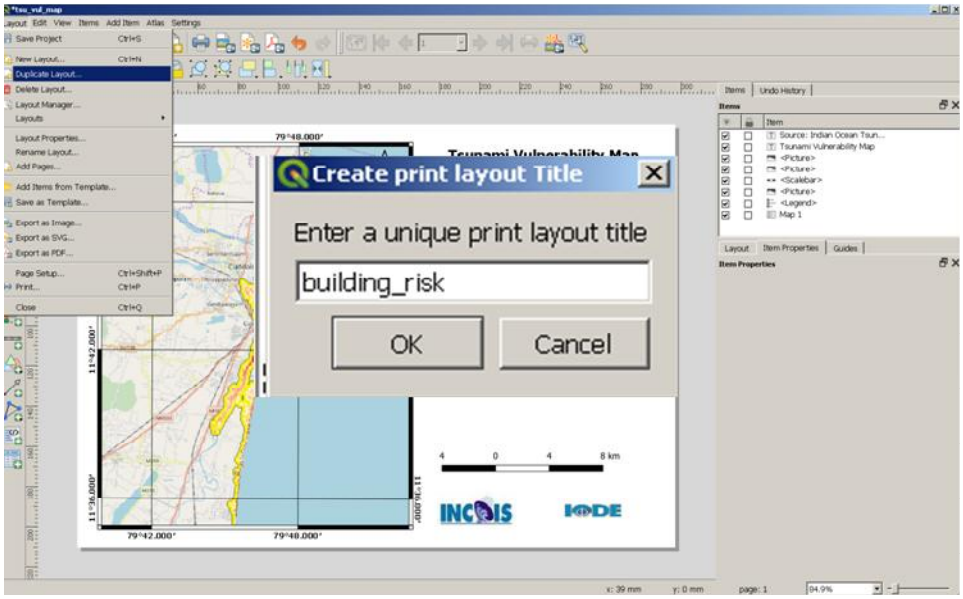


Pull down item properties panel in the right and check draw coordinates, format: degrees, minutes, make left 'vertical ascending and right label as vertical descending. After finishing click on go back arrow shown in the red circle. Save the map template and you can export o various output formats in the layout export menu options.

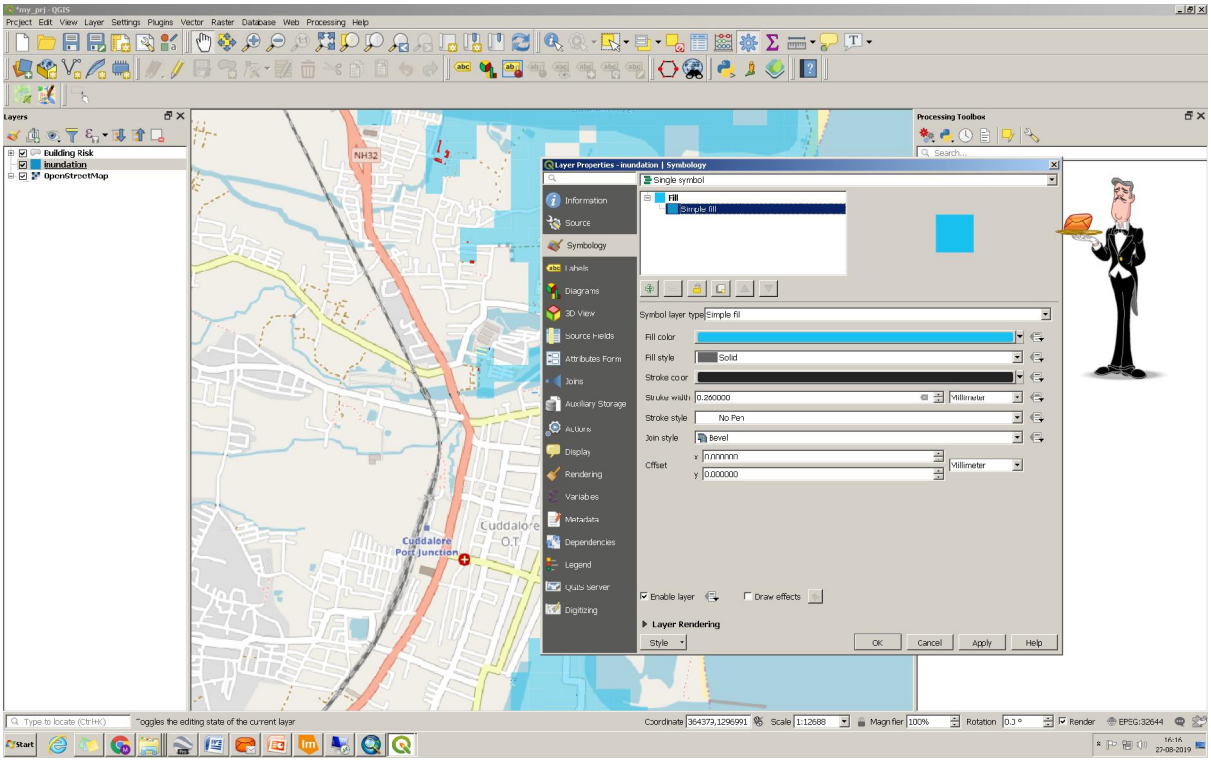


Preparation of building level risk map

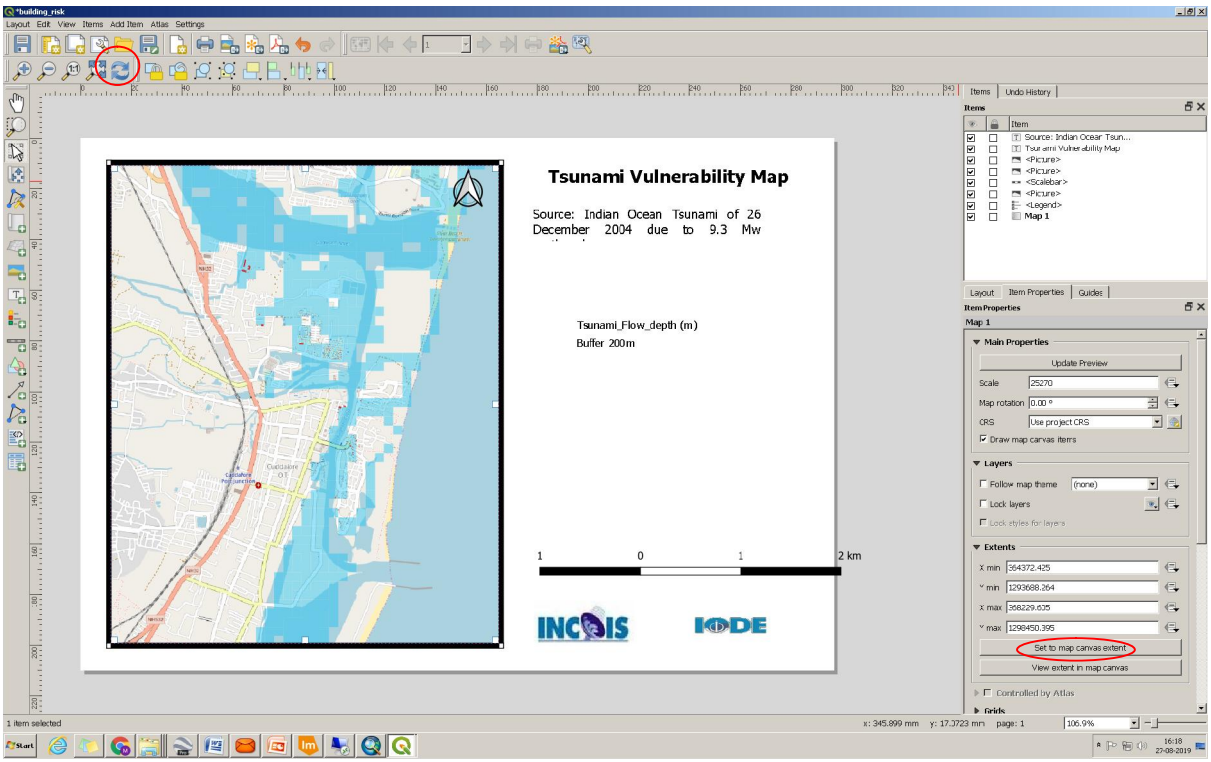
The finalized map template 'tsu_vul_map' can be duplicated as building_risk by selecting



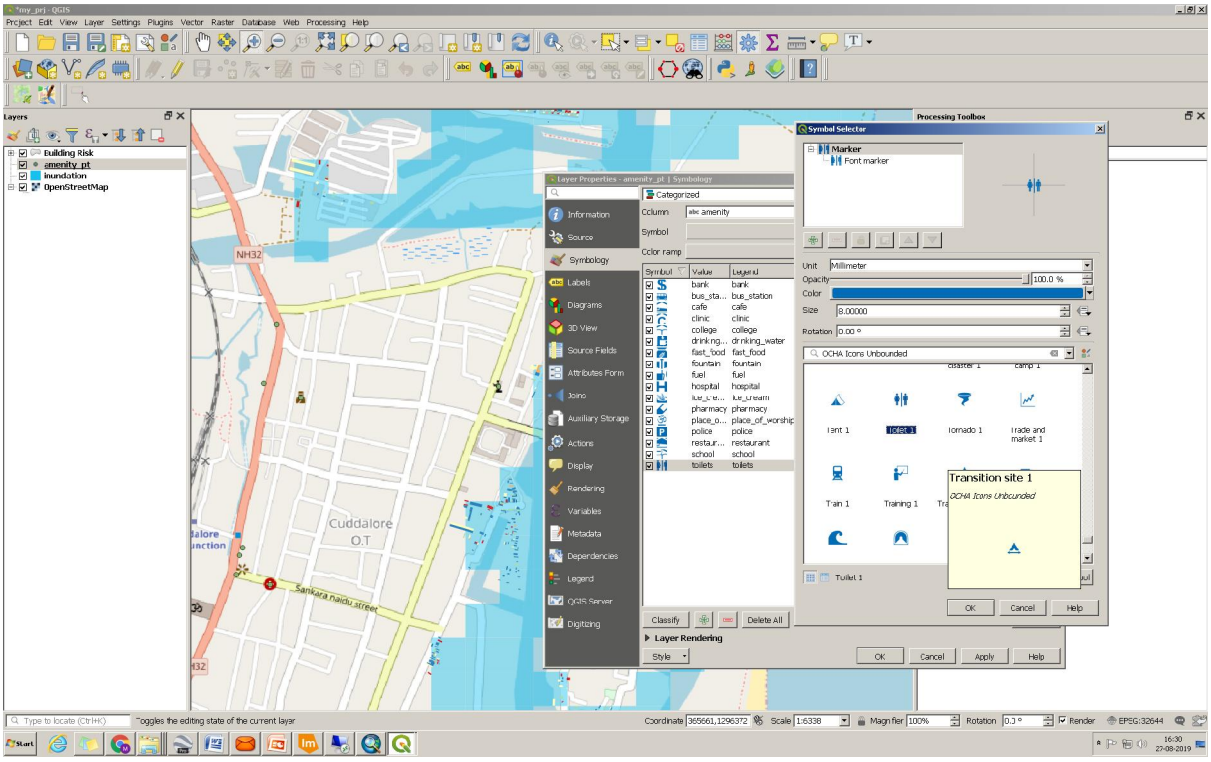
Then close tsu_vul_map template keep only building_risk map template. Go to viewer remove buffer and tsunami flow depth layers and switch on building risk layer. Right click on building risk layer and select zoom to layer option. Add inundation layer change its colour from symbology



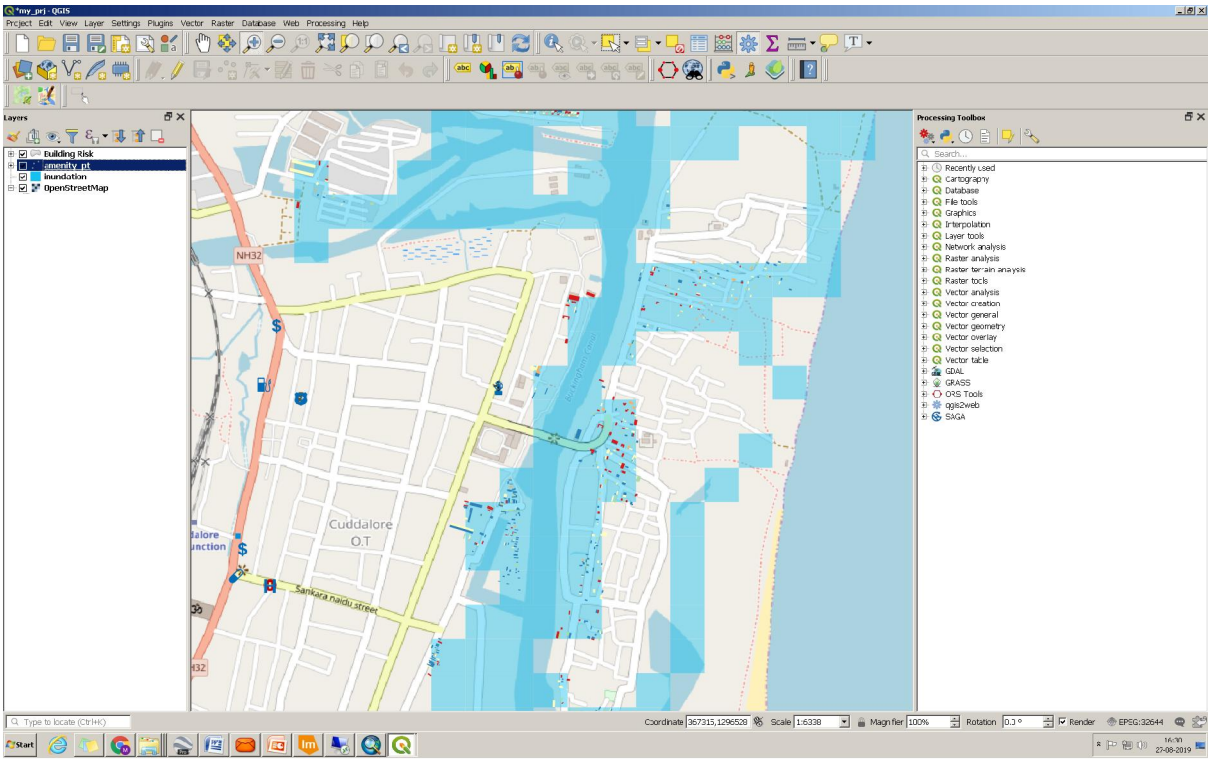
Go to map template and click refresh button and set to canvas extent



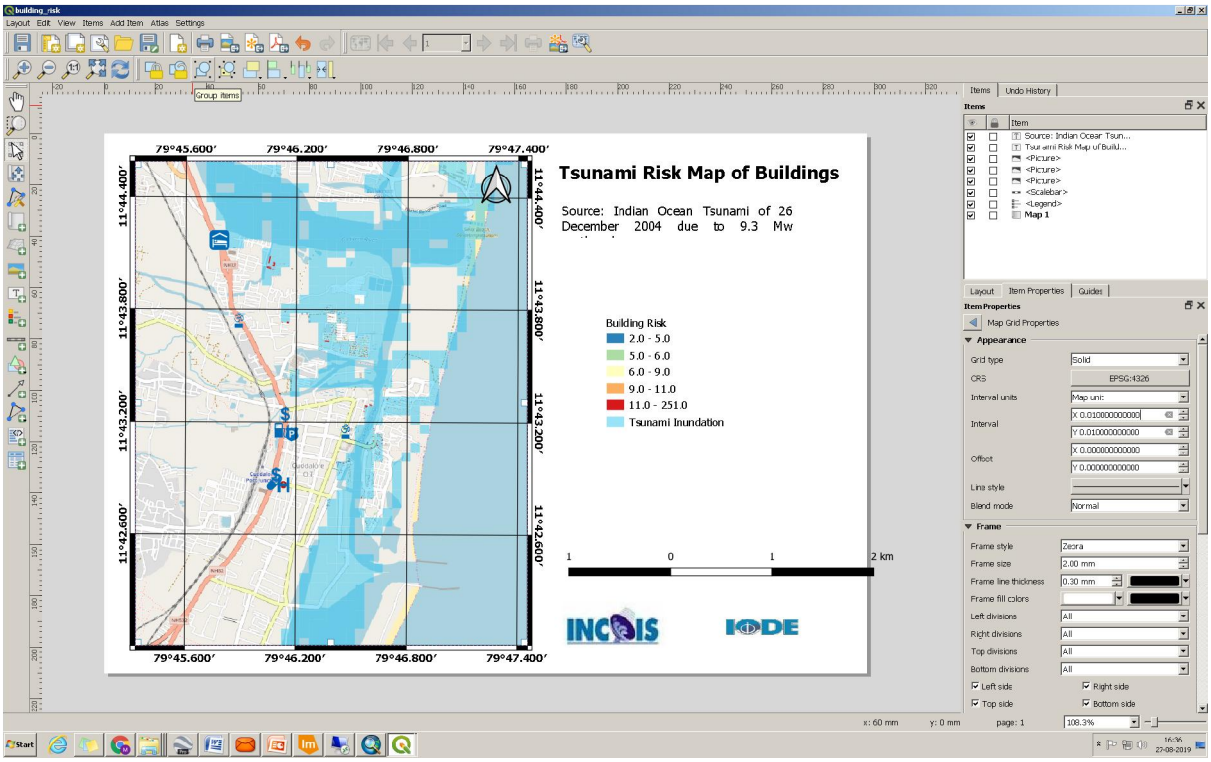
Add amenity_pt from OSM_data folder and symbolize the amenity points select categorized and classify. Assign symbol to individual category based on the OCHA symbology style already installed. And finish



It will appear in the map as below



Go to map template and refresh the symbols will appear in the map. Change the map title and reset the legend entries and save the template you cha change the grids interval to obtain map grids. Export the map to desired output format



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