User's Guide

to the Greater South Dunedin Geodatabase

Leigh McKenzie, Janet Stephenson, and Caroline Orchiston
Centre for Sustainability
University of Otago
April 2017

Table of Contents

Introduction

The geodatabase is a compilation of 141 layers of data which can be used by agencies and researchers for future studies into the impacts of sea level rise and other hazards in greater south Dunedin.

A changing climate is causing the sea level to rise (IPCC, 2013). Sea level along New Zealand's coast has already risen 17 cm over the past 100 years, with another 30 cm 'virtually guaranteed' before the end of this century, and possibly more than a metre over that time depending on the trajectory of greenhouse gas emissions (RSNZ, 2016). Sea level rise has serious implications for coastal areas and low lying land, and even more so when coupled with other climate change impacts such as more frequent extreme weather events (RSNZ, 2016; PCE, 2015). The Parliamentary Commissioner for the Environment has identified greater south Dunedin as one of the most at-risk urban areas in New Zealand, due to its low lying nature, proximity to the coast, its geological past, and high groundwater levels (PCE, 2015).

This vulnerability was recently highlighted when a severe flooding event affected the South Dunedin area from the 3rd – 5th of June in 2015. This event was a result of heavy rainfall coinciding with a high tide, which together have the effect of raising the height of ground water. The compounding effect of the heavy rain, raised groundwater and infrastructure problems led to surface ponding. Estimates suggest that between 100 and 800 households were flooded (Telfer, 2015). While this event cannot be directly linked to climate change, it is an example of the kind of impacts that are expected to occur more frequently as a result of climate change because of the combination of more frequent extreme weather events and higher sea levels.

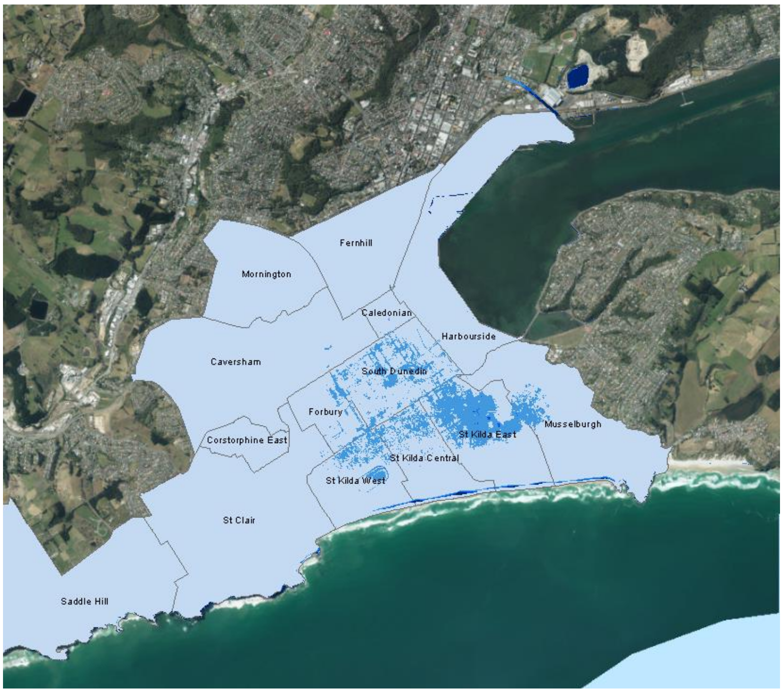


Figure 1: An overlay created from the geodatabase. Areas <1 m above mean sea level (in blue) are mapped over the named area units from the 2013 census. This map uses database layers: 'Areas_under1m_MSL' and 'SDunedin_Area_Units'

Work undertaken by the Otago Regional Council (ORC) and GNS Science identifies a significant area of greater south Dunedin that is currently within 1 metre of sea level, including parts of the suburbs of St Kilda, Forbury, South Dunedin, Musselburgh, Caversham, and St Clair (Otago Regional Council, 2012; 2014, 2016) (Figure 1).

The purpose of this report and its associated spatial data is to assist future research on the potential impacts of sea level rise on this area. The GIS database brings together publicly available information from a variety of sources, with a focus on mapping the characteristics of the people, social assets, and the physical attributes of the area. It was created in the first instance to assist future researchers at the University of Otago, but is also open for use by Otago Regional Council, Dunedin City Council, and other bona fide researchers.

Potential users should note that many of the layers in this database include the whole Otago Region, not just the greater south Dunedin area. The database has been purposefully built for the south Dunedin area, but it could also be useful to those researching other areas of Otago.

Part 1 of this report outlines the content of the GIS database. **Part 2** shows and describes some overlays created from the data as an example of how it can be used. **Part 3** details the sources of the data. **Part 4** describes how specific layers have been manipulated to create the geodatabase.

For permission to access the GIS geodatabase, please contact Assoc Prof Tony Moore (tony.moore@otago.ac.nz) at the School of Surveying, University of Otago, or Dr Caroline Orchiston (caroline.orchiston@otago.ac.nz) at the Centre for Sustainability, University of Otago.

A Webmap (which does not require GIS expertise and software) has also been created using ArcGIS Online to make a sample of the data available to the public. This can be accessed via http://www.arcgis.com/home/webmap/viewer.html?webmap=2e3bcdc97d7147318a363677e104a831&extent=170.4514,-45.9247,170.6134,-45.85

PART 1: CONTENT OF THE GEODATABASE

1.1 Overview of Structure

The geodatabase is grouped into seven categories: coastal, land and flood hazards; human landscape; sea level rise ponding; seismic hazards; storm surge inundation; terrain; urban landscape.

Figure 2 shows how the geodatabase is structured, the data categories, and what types of data have been collated. Not all layers have been included in Figure 2 due to size of the lists. Greater detail on the nature of the data is provided in section 1.2.

1.2 Database structure

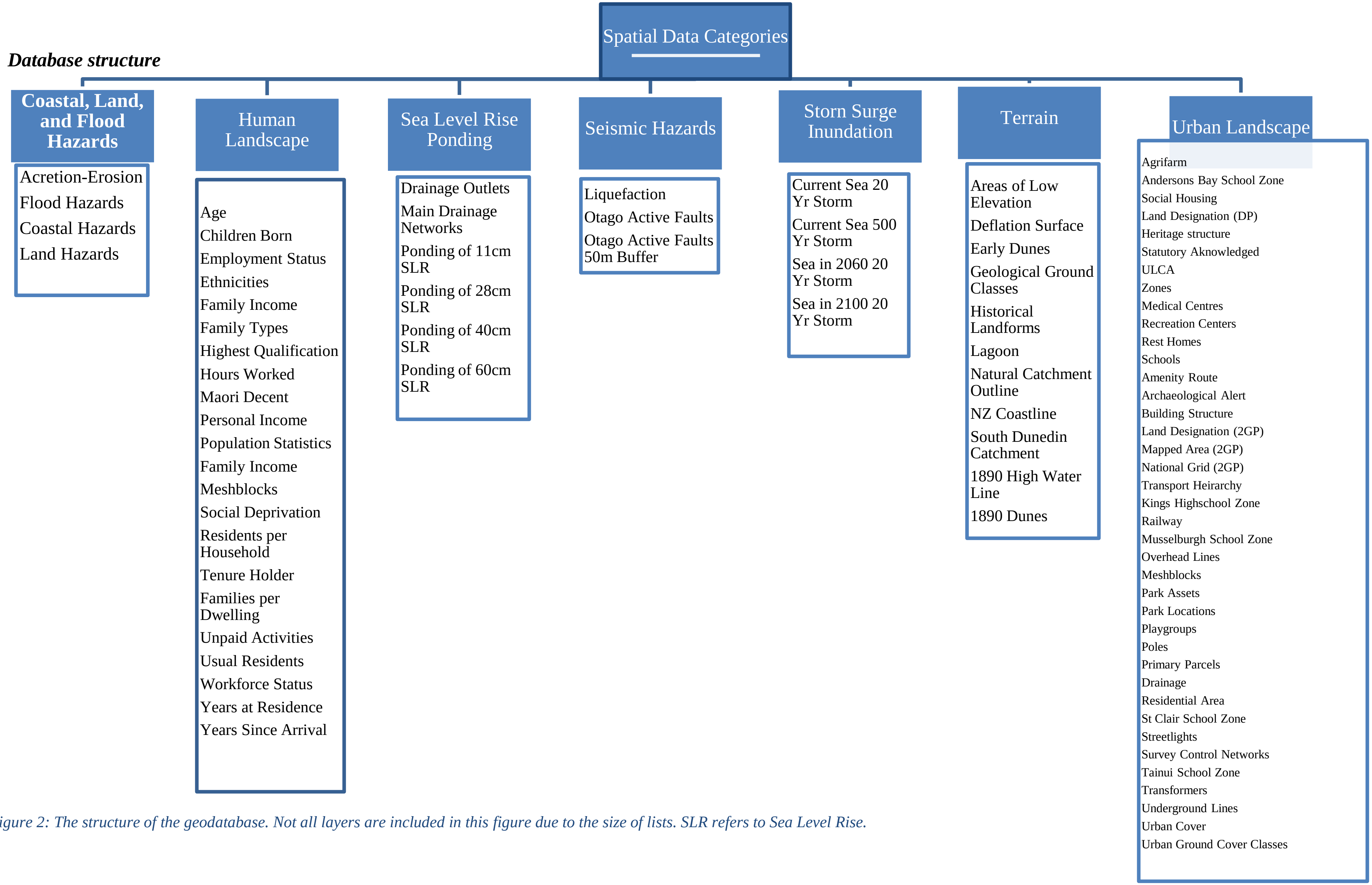


Figure 2: The structure of the geodatabase. Not all layers are included in this figure due to the size of lists. SLR refers to Sea Level Rise.

The database comprises four data formats - polygons, polylines, points and raster data. These are detailed by data format in Tables 1-4 below. Note that the data in the geodatabase has been categorised according to the structure in Figure 2 rather than by data format.

Polygons

Table 1: A summary of the polygon data kept in this geodatabase.

Coastal, Land, and Flood Hazards	Human Landscape	Sea Level Rise Ponding	Seismic Hazards	Inundated by Storm Surge	Terrain	Urban Landscape
Acretion-Erosion	Age	Modelled Ponding 11cm	Liquefaction	Current Sea Level in a 500 year Storm	All Elevation Polygons	Agribase Farm 2012 (Commercially sensitive – requires permission for use, check with DCC – who provided it to the Surveying School)
Flood Hazards (2GP)	Number of Children Born		Otago Active Faults with 50m Buffer	Storm of 1:20 Years with Current Sea Level	Areas of Low Elevation (<1m above Current Sea Level)	Andersons Bay School Zone
Coastal Hazards (2GP)	Employment Status	Modelled Ponding 28cm	Susceptible to Liquefaction	Storm of 1:20 Years with 60cm Sea Level Rise	Coastal Landscape (2GP)	DCC Social Housing
Land Hazards (2GP)	Ethnicity Groups	Modelled Ponding 40cm		Storm of 1:20 Years with 100cm Sea Level Rise	NZ Coastline	District Plan Land Use Designation
	Family Income	Modelled Ponding 60cm			Historic Landforms from Hilton (2010) - Deflation Surface - Early Dunes - Lagoon - 1890 Dunes	District Plan Statutory Acknowledged Land
	Family Types				Otago Region Clipped to NZ Coastline	District Plan Urban Landscape Classification Areas (ULCA)
	Highest Qualifications				Geological Ground Classes	District Plan Zones
	Hours Worked per Week				Historic Landforms (ORC)	Polygons of Elevation
	Maori Descent				NZ Coastline	Schools
	Median Personal Income				South Dunedin Catchment	Second Generation Plan Archaeology Alert

	Meshblock Population Statistics				Dune System (2GP)	Second Generation Plan Archaeology Sites
	Social Deprivation Index					Second Generation Plan Coastal Hazards
	Grouped Personal Income					Second Generation Plan Coastal Landscapes
	Residents per Household					Second Generation Plan Land Designation
	Tenure Holders					Second Generation Plan
	Total Families per Dwelling					Second Generation Plan Flood Hazards
	Hours in Unpaid Activities					Second Generation Plan Flood Minimum Floor Level
	Usual Residents					Second Generation Plan Land Hazards
	Workforce Status					Second Generation Plan Mapped Areas
	Years at Usual Residence					Second Generation Plan National grid
	Otago Meshblocks					Second Generation Plan Wahi Tupuna (Acknowledges ancestral connections and values)
	Residents per Household					Second Generation Plan Zones
	Tenure Holder for Usual Residents					House Age
	Years since arrival in NZ					Liquefaction Hazards
						Rate Assessment
						Updated Schools Layer from the DCC
						Otago Region Clipped to the New Zealand Coastline
						Park Assets
						Park Locations
						Primary Parcels
						Residential Areas
						South Dunedin Area Units
						Susceptible to Liquefaction
						Urban Cover (Imperviousness)

						Urban Ground Cover Classes (Imperviousness with renamed classes)
						DCC Social Housing
						District Plan Land Use Designation
						District Plan Statutory Acknowledged Land
						District Plan Urban Landscape Classification Areas
						District Plan Zones
						Kings High school Zone
						Musselburgh School Zone
						Saint Clair School Zone
						Tainui School Zone
						Otago Meshblocks
						Minimum Floor Rule for South Dunedin (Crown of the Road)

Polylines

Table 2: A summary of the polyline data kept in this geodatabase.

Coastal, Land, and Flood Hazards	**Human Landscape**	**Sea Level Rise Ponding**	**Seismic Hazards**	**Storm Surge Inundation**	**Terrain**	**Urban Landscape**
		Drainage Outlets	Otago Active Faults		Historic Landforms from Hilton (2010) - Marlow St to Forbury Road - 1890 High Water Coastline	GP2 Amenity Route
		Main Drainage Networks	Historic Landforms from ORC		Natural Catchment	Over Head Lines
			Natural Catchment Outline			Under Ground Lines
						GP2 Amenity Route
						GP2 Transportation Hierarchy
						Railway
						Road CC (Classification)

Points

Table 3: A summary of the point data held in this geodatabase.

Coastal, Land, and Flood Hazards	Human Landscape	Sea Level Rise Ponding	Seismic Hazards	Storm Surge Inundation	Terrain	Urban Landscape
						District Plan Heritage structures
						Medical Centres
						Recreation and Community Facilities
						Rest Homes
						Second Generation Plan Building Structures
						Playgroups
						Poles (Power)
						Road Drainage
						Streetlights
						Survey Control Networks
						Transformers

Raster data

Table 4: A summary of the raster datasets held in the geodatabase. Unlike the vector datasets detailed above, raster datasets are listed in the database, not categorised.

Aerial Photos from 1947 (Individuals)	Others
Q49-55	Imagery Basemap
R47-57	1947 Aerial Photography (mosaicked)
S47-59	LiDAR of Dunedin 2009 Clipped to Coast (Connect to the Survey school's database)
T26-30	South Dunedin Elevation
U33-35	Hillshading (Connect to the Survey School's database)

Note: The hillshading and LiDAR data could not be copied into the geodatabase due to maintenance being undertaken to the database at the time of developing this database. For these data layers, ask for permission to connect from Dr Tony Moore, at the School of Surveying, University of Otago.

1.3 Data Limitations

As with all data, this geodatabase has limitations. This section outlines the known limitations to the data.

Census data is intended to capture information from the entire country's population, and Statistics New Zealand estimates they captured 98% of the population in the 2013 census (Statistics New Zealand, 2013). This data is collected from individual households but is only reported to meshblock level, which is the smallest geographical unit for which this data is available – commonly all or part of a city block, for example. In order to prevent data from being linked with individuals or households, the meshblock data is only provided in an aggregated form.

The sea level rise scenarios used for the **storm surge inundation** data by the ORC do not account for changes in land surface or topography, and also does not take into account any changes in drainage networks (ORC, 2016). The model uses predictions made by the IPCC in 2013 (IPCC 2013). There were four predictions made by the IPCC, each based on a different trajectory of greenhouse gas emissions into the atmosphere (ORC, 2016; Church, *et al.*, 2013). The model includes sea level rise scenarios of up to 60cm. The ORC has used current sea level, 30 cm of sea level rise, and 60cm of sea level rise for the model. Adding to this, the ORC's scenarios use storm return periods which they considered were plausible within a person's lifetime (1:20 years) (ORC, 2016). It must be noted that return periods for natural events (such as the 1:20 year storm in this data) indicate that a storm of that magnitude is *likely* to occur at some point in that period of time. It is not certain when the event will occur.

Historic landforms were mapped by Dr Mike Hilton (Geography Dept, University of Otago) for his research on the Ocean Grove Domain (Hilton, 2010). The historic landforms were identified from a hand drawn map in 1890 (Hilton, 2010). The map showed Victoria Road and this was used for georeferencing the landforms onto a current day map. This limits the accuracy as the hand drawn map may not have the position of the past landforms precisely relative to Victoria Road. The ORC then copied the historic land forms that Dr Hilton had mapped, further simplifying and reducing certainty and accuracy. Both the shapefiles from Dr Hilton and the ORC are included in this geodatabase.

The **LiDAR** data used for the elevation mapping has a resolution of 1m, which is the finest resolution able to be accessed. The Lidar was taken in 2009. The land in the greater south Dunedin area is now known to be subsiding (ORC, 2016). Therefore, the Lidar from 2009 may not be perfectly representative of the elevations across the greater south Dunedin area today.

The shapefiles showing **earthquake hazards** and areas **susceptible to liquefaction** were originally created through an assessment by GNS Science which drew upon existing information on the substrate of the Dunedin region. This consisted of geological maps, soil maps, landform maps, groundwater level measurements, and borehole records. There were insufficient geotechnical records (such as observations of damage from other earthquakes) to assess lateral spreading hazards of the greater south Dunedin area, so GNS Science only assessed susceptibility to liquefaction. The liquefaction hazard assessment that was carried out differs from a full susceptibility assessment which requires detailed information on geotechnical properties of near surface sediments. Instead, this assessment focussed on identifying areas using geological and geomorphological considerations, which are likely to be underlain by types of sediment that are susceptible to liquefaction, and where groundwater levels are close enough to the surface to make liquefaction a possibility (Barrell, *et al.*, 2014; p19). Liquefaction susceptibility has been grouped into three domains to show the likelihood. These categories are described in more detail in the GNS Science report (Barrell, *et al.*, 2014). The shapefiles in this geodatabase are simplified versions of the originals produced by GNS Science. These simplified versions were produced by the ORC, discussed in 'The natural hazards of South Dunedin' report (ORC, 2016, p 39).

Aerial photographs were acquired from the Dunedin City Council (DCC) and georeferenced to enable their use in this project. The images were georeferenced with a Reduced Mean Square error of < 4.5m which is well under the recommended accuracy of 15m (Sounny-Slitine, 2012).

Delta provided this project with data on the **electrical network assets** in Dunedin (Delta Utility Services, 2017). The electrical network was created 60 years ago, and it began to be mapped in GIS in the 1990s. In terms of spatial accuracy, Delta has a range of accuracies depending on the dataset but generally achieves 95% ± 1m. As for temporal accuracy, as the network is extended a data management process is followed. The database is updated daily, audits and reviews are carried out monthly (Delta, 2017).

The data describing **ponding** which may occur from **sea level rise** was modelled by the ORC, and also modelled by Beca using a different approach which is not used in this project due to limitations in their assumptions and data used to create the model (ORC, 2016, p48). The ORC modelled the aquifer under the greater south Dunedin area using the best known estimate of recharge rate for the aquifer (ORC, 2016). The ORC's model used mean sea level as recorded at the White Island sea level recorder (Otago Regional Council, 2016). This level was progressively raised to simulate an increase in mean sea level. The influence of the DCC's stormwater network was taken into account in assessing ponding, but not the effect of other networks such as wastewater pipes and drains (ORC, 2016). Only 'mean' sea level rise scenarios have been mapped, and the above ground ponding will vary over time with changes in groundwater level from precipitation (ORC, 2016). The groundwater model is planned to be revisited with GNS Science in the next two years, using new data.

The **Dunedin City Council (DCC) data** does not have any metadata such as when it was created or how often it is updated, or any information regarding its accuracy (DCC, 2016). This limits the knowledge we can have about the data being used, such as how recently the assets in the greater south Dunedin area have been mapped. This may be a limitation in the accuracy of the data.

School zones have been transposed from the Ministry for Education's TKI (Te Kete Ipurangi) website (2017). The polygons were created in Google Earth, then converted from a KML file to a shapefile in ArcGIS. Following this, the projection was converted to NZ Transverse Mercator 2000. This means the zones are not precise, but are estimated to be accurate to the street block level.

Shapefiles of the **accretion and erosion** which has been occurring at St Clair and St Kilda beaches, was derived by the ORC from satellite imagery using the change in vegetated dune position from 2000-2013 (ORC, 2016). It must be kept in mind that coasts have natural accretion and erosive cycles so users must be aware that this data shows a snapshot of two points in time rather than representing the ongoing dynamic process.

The **flood hazard zones** layer was obtained from the Otago Regional Council, as used in the Natural Hazards of South Dunedin report (ORC, 2016). The Hazards report accounts for more variables in the physical environment than the Natural Hazards Database which is publically accessible online (ORC, 2012). For example, infrastructure and surface types are included in the calculation for the hazard areas in this layer, however, they are not taken into account in the Natural Hazards Database online. It should also be noted that the low-lying part of the greater south Dunedin area is not classed as a flood zone because of how flood has been defined. Floods are defined in the Hazards report as being from rivers and rain water, so flooding from groundwater and sea level rise are not included.

Future Data to Obtain

Geological studies of the **ground subsidence and tilting action** of the greater south Dunedin area is currently being worked on. At this point in time the data is expected to be ready in about a year's time. Contact Belinda Smith-Lyttle, senior technician at GNS Science, to find out how to get hold of this data for the geodatabase. This data will provide a more complete picture of the hazards of the greater south Dunedin area.

As mentioned in the limitations section, the **ground water ponding** predicted for the greater south Dunedin area will be remodelled by a consultancy firm for the Otago Regional Council, expected in 2018. This data would be a good addition to this geodatabase when it is available.

PART 2: USING THE DATA LAYERS

This section offers some snapshots created from overlays of selected data layers to introduce the reader to some basic applications of the geodatabase. **Note the overlays simply use existing data and do not necessarily identify areas of greater or lesser risk from sea level rise – this is a highly complex issue that requires further technical research.**

Figure 3 shows low-lying land (of less than 1m above mean sea level) in relation to the suburb boundaries (as defined by the NZ census area units 2013). By overlaying these data layers it can be seen that the St Kilda area units (particularly St Kilda East) have more low lying land than the South Dunedin area unit. Forbury and Musselburgh also have significant areas of low-lying land. For this reason, the report uses the term 'greater south Dunedin area' to make it clear that a number of suburbs are potentially facing risks from sea level rise and other hazards. **It should be noted that low-lying areas are not the same as areas of predicted ponding, which is a separate series of layers in the database.**

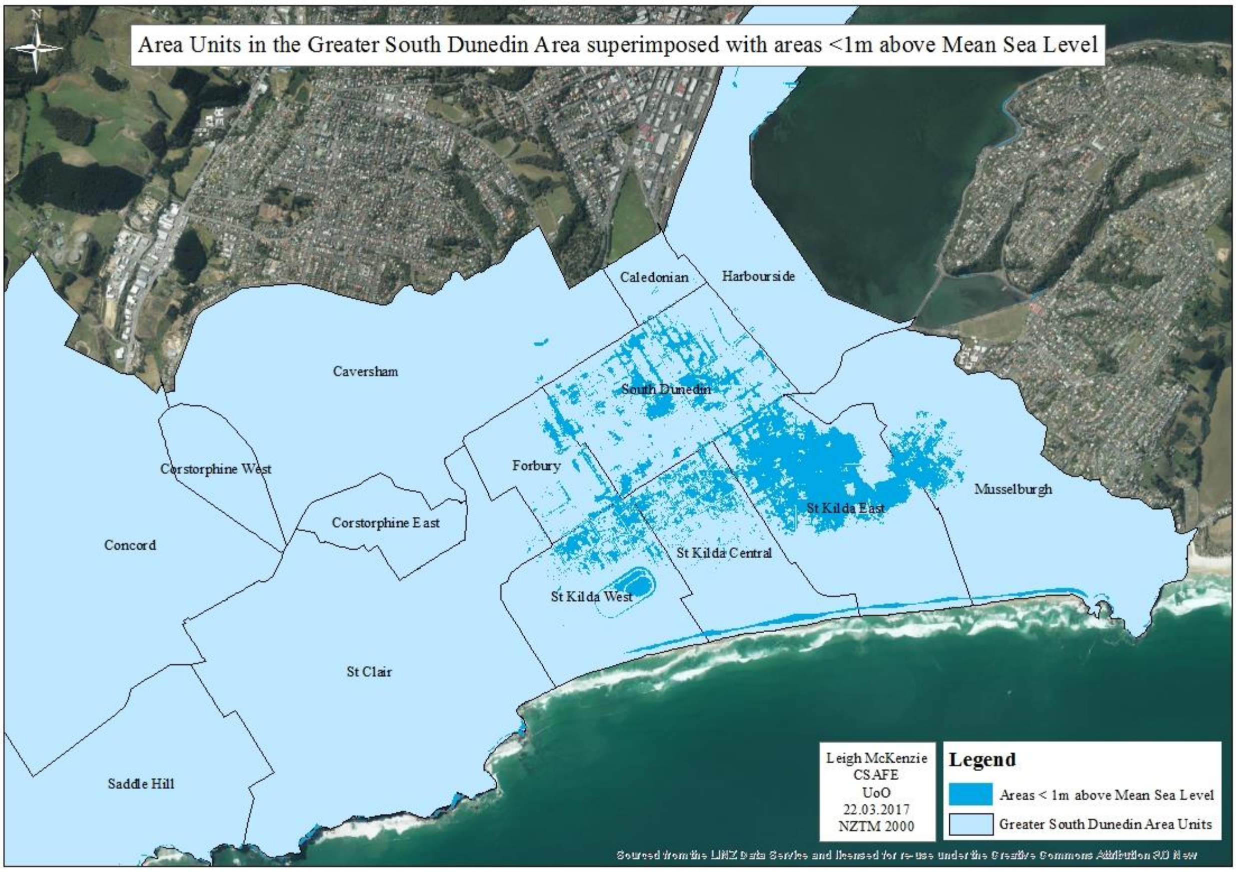


Figure 3: This map shows the area units of the greater south Dunedin area superimposed over land which is less than 1 m above mean sea level, using LiDAR data from 2009 with a resolution of 1m. Area units are used to define suburb boundaries. St Kilda East has more low lying land than South Dunedin. This map uses database layers: 'Areas_under1m_MSL' and 'SDunedin_Area_Units'

The land elevation can be seen in Figure 4, using LiDAR data from 2009 attained from the Surveying School database. Note the majority of low lying land is concentrated in St Kilda and Musselburgh, not as concentrated in South Dunedin.

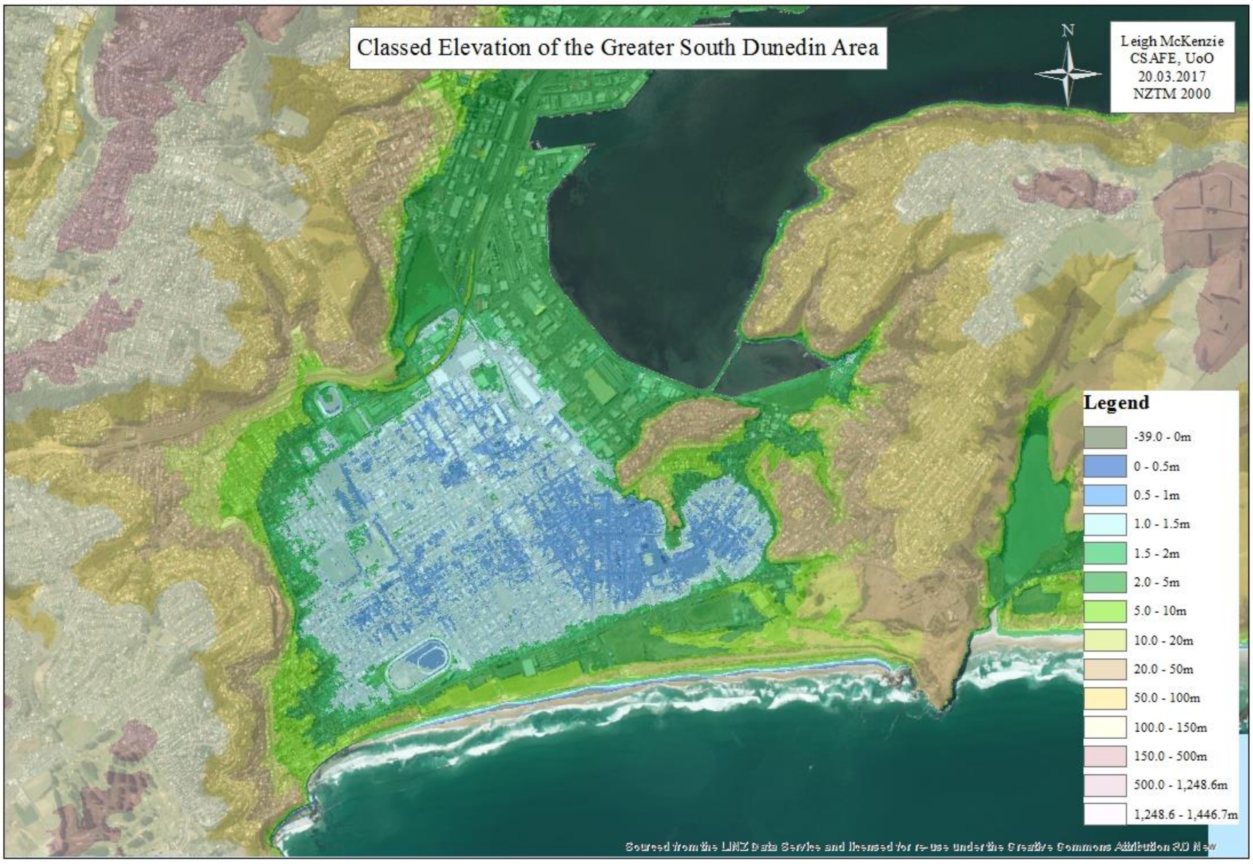


Figure 4: This map shows elevations of the greater south Dunedin area in more detail, using Lidar data from 2009, with 1m resolution. The data has been grouped to show the elevations more clearly. This map uses database layer: 'Reclass_Dunedin_LIDAR3'.

Collecting layers that showed demographics and other social-related features was a key focus for this project so the next few snapshots show the distribution of social attributes of the greater south Dunedin area in relation to the lowest lying areas.

Figure 5 shows median personal income at the meshblock level as collected by Statistics New Zealand for the 2013 Census. This is overlaid with the lowest lying parts of the greater south Dunedin area using 2009 LiDAR data with a resolution of 1m. This indicates that many of the meshblocks in the lowest lying areas are occupied by people in lower income brackets.

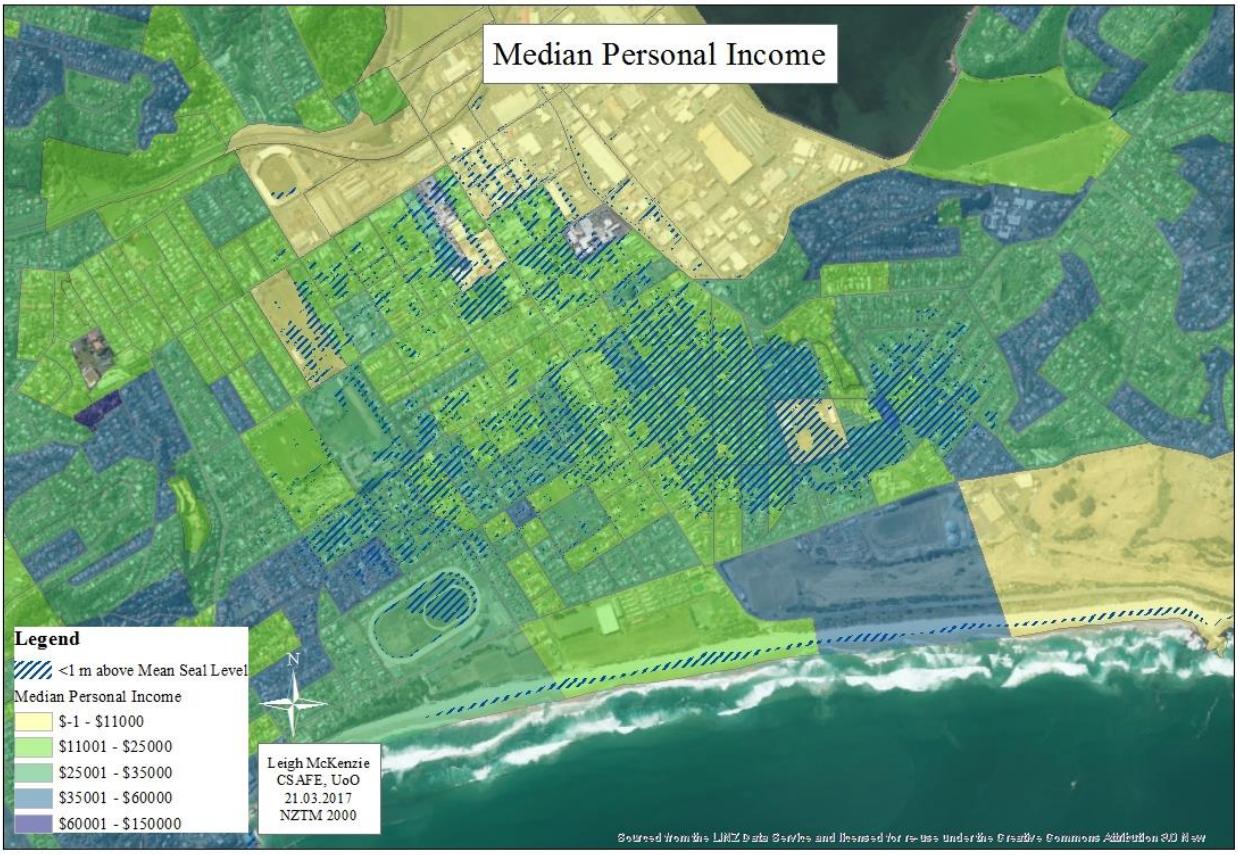


Figure 5: Median personal income overlaid with areas that are <1 m above mean sea level. This map uses database layers: 'Areas_under1m_MSL' and 'Median_Personal_Income_Meshblocks1'.

Figure 6 shows median age by meshblock, as collected by Statistics New Zealand for the Census in 2013. It is possible that low income in these areas could be related to a preponderance of retired people on superannuation. However median age in the lowest lying meshblocks ranges from 31-50 years.

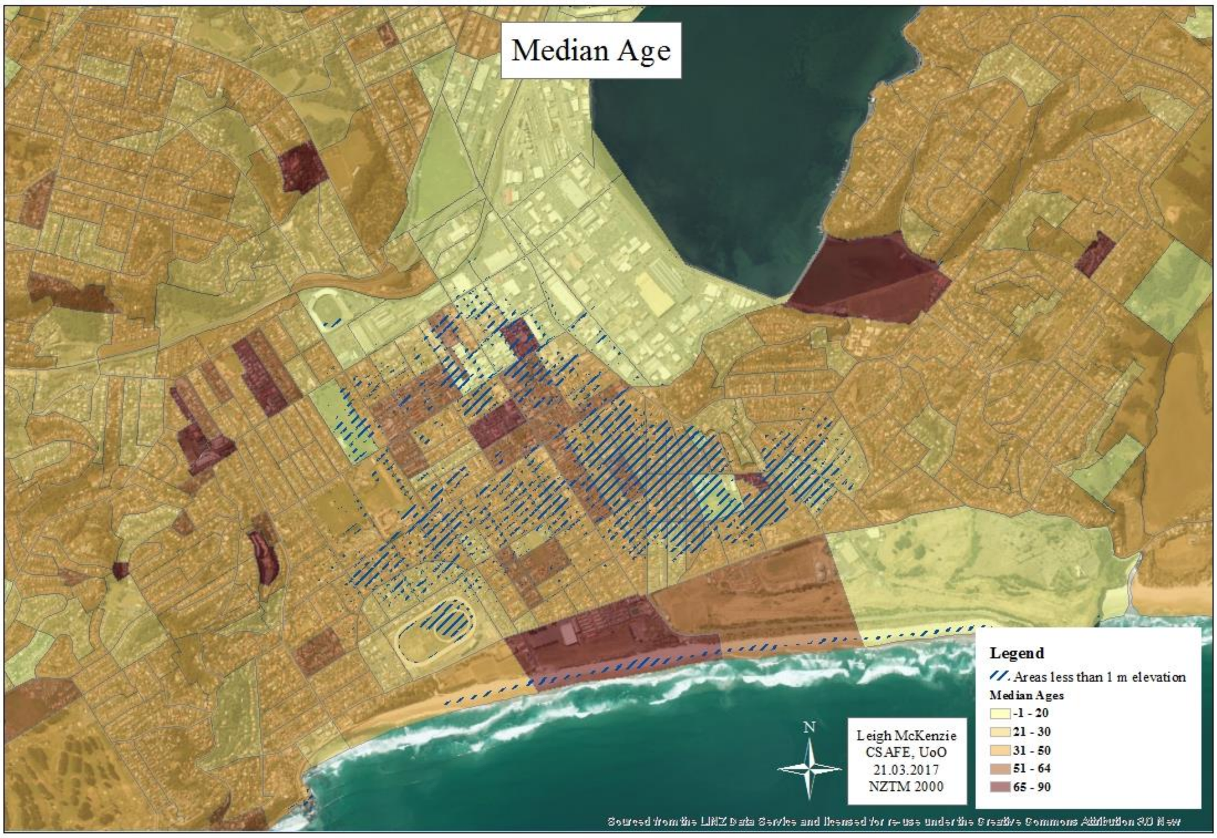


Figure 6: The lowest lying areas of the greater south Dunedin region has been overlaid with median age to see whether pensioners and the elderly live in the low lying areas with low income. This map uses database layers: 'Areas_under1m_MSL' and 'Ages_for_Otago_Meshblocks1'.

To examine this distribution of low income further, percentage of unemployed per meshblock has been mapped in Figure 7. There are pockets of relatively high unemployment is some of the lowest lying meshblocks, however generally employment levels in these areas are greater than 85%.

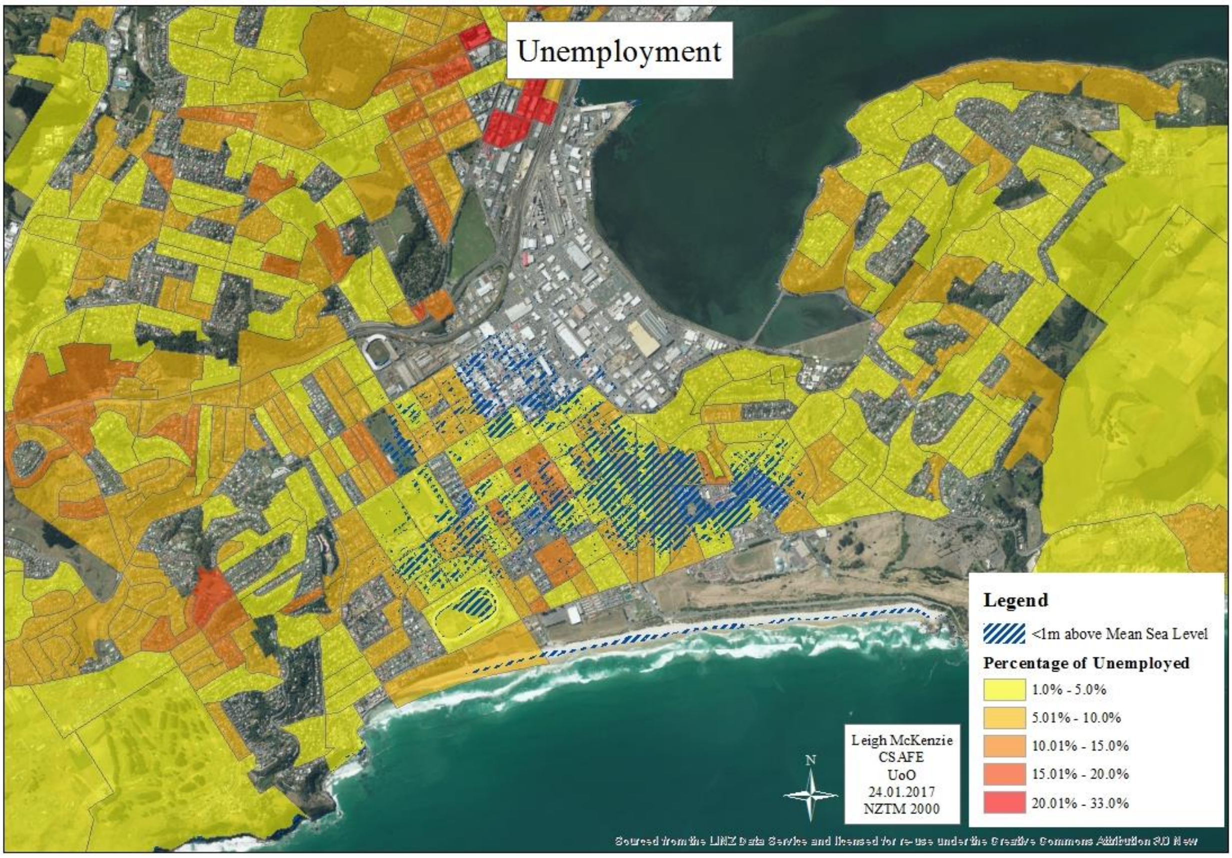


Figure 7: Percentage of unemployed people per meshblock has been overlaid with the lowest lying areas of the greater south Dunedin ares. This map uses database layers: 'Areas_under1m_MSL' and 'Workforce_Status_Meshblocks_Otago1'. The percentage of unemployed was calculated using the number of unemployed per 'total people stated' of each meshblock as recommended by Statistics New Zealand (2013). Please note the missing meshblocks are a result of some where the data was required to be confidential, and also some which had zero 'people stated', therefore could not be used as a denominator in the percentage calculation.

Whether people own or rent is also important for understanding vulnerability. People who are renting may be able to move away from the low lying areas more easily, whereas those who own their homes may not be able to as easily, particularly if their homes become depressed in value as sea level rise becomes a greater risk. Whether people own their own homes or not is also likely to affect the willingness of people to invest in maintaining or upgrading dwellings. This could be particularly problematic for the quality of rental accommodation if landlords start to see little point in making improvements to buildings that are losing value. It could influence building owners' motivations to spend money on mitigation measures, such as raising building floor heights to reduce the impacts of high ground water levels and ponding. Figure 8 shows the percentage of tenure holders in the greater south Dunedin area, overlaying the lowest lying areas.

It can be seen that in some of the lowest lying areas there is a high proportion of people who do not own their home.

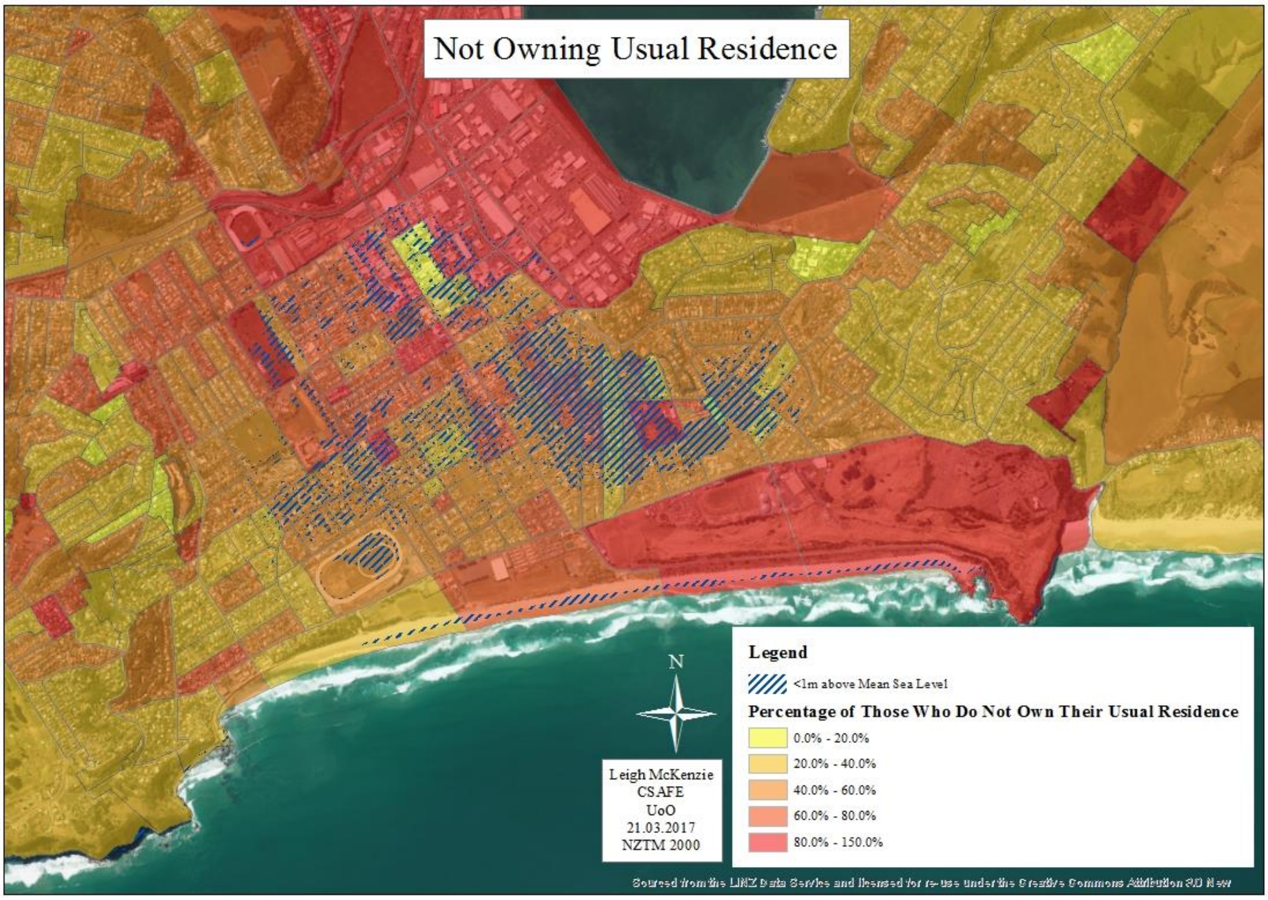


Figure 8: Those who do not own their own residence have been mapped with the lowest lying areas of the greater south Dunedin area. This map uses database layers: 'Areas_under1m_MSL' and 'Tenure Holder_Usual_Res_Otago_Meshblcks_1'. Percentage was calculated for each meshblock using those who 'do not own their usual residence' per 'total people stated' as recommended by Statistics New Zealand (2013). It is important to note that in published census data, categories which refer to 'total people stated' are usually rounded so are expected to add to more than 100%, as seen in this figure (Statistics New Zealand, 2013 pg 20).

So far it appears that at least some of the lowest lying areas, relative to the surrounding areas, are populated with people who have low incomes, and a larger proportion of people living in rented housing.

The social deprivation index captures communication, income, as well as income from benefits, employment, qualifications, home ownership, support, living space, and transport. Accounting for so many aspects of people's welfare means it is a useful aggregate measure of social vulnerability. A value of 1 on the scale is the least deprived, and 10 is the most deprived.

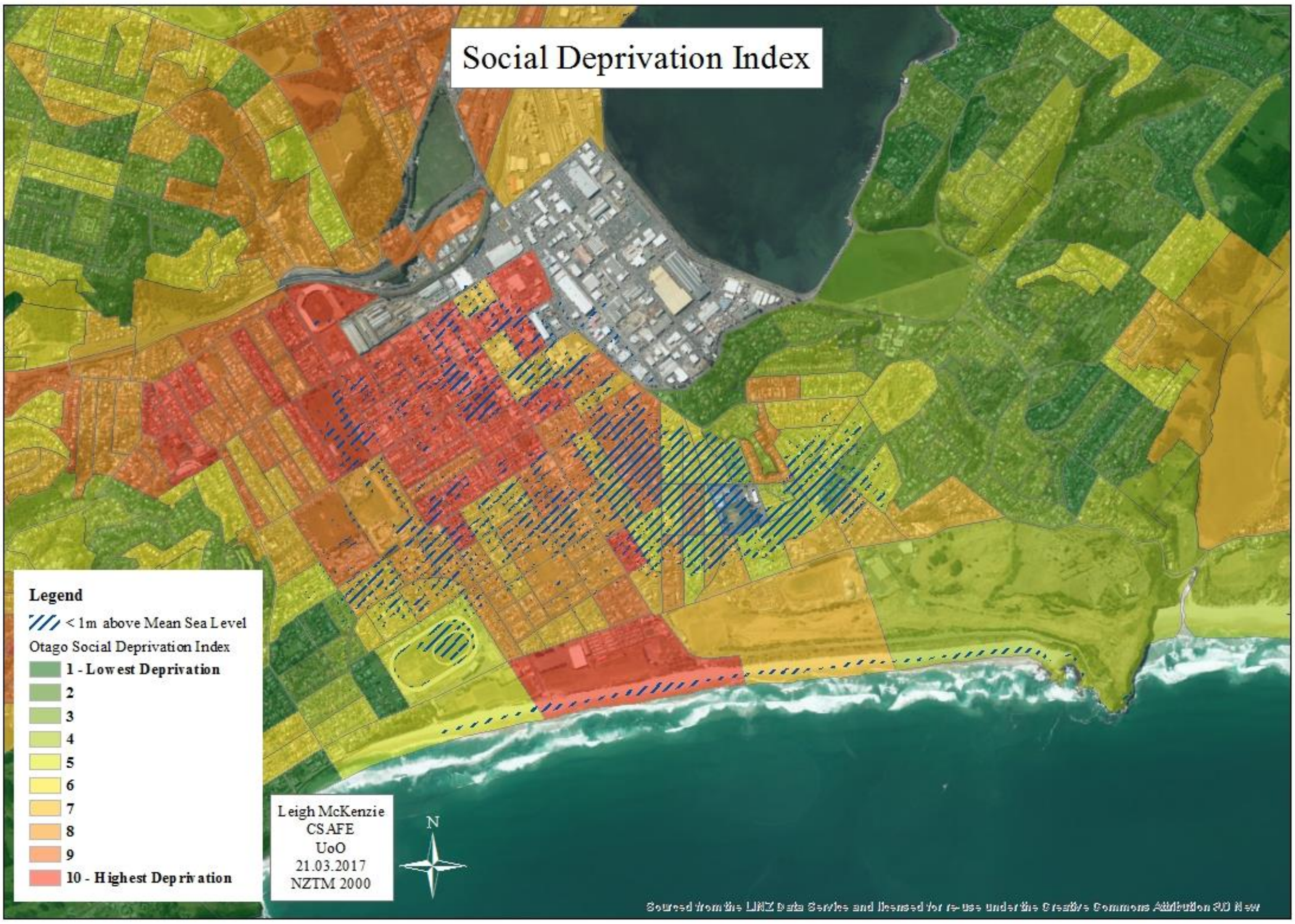


Figure 9: The social deprivation index, as created by the Public Health Department of the University of Otago has been mapped with the lowest lying areas of the greater south Dunedin area. This map uses database layers: ''Areas_under1m_MSL' and 'OtagoSocialDeprivIndex'.

Figure 9 indicates that some of the lowest lying areas are occupied by people who are in the range of mid- to high levels on the social deprivation index.

Apart from population qualities, social infrastructure is also important as it supports the community, and provides jobs and education. The next few snapshots look at social assets which may be at risk to sea level rise.

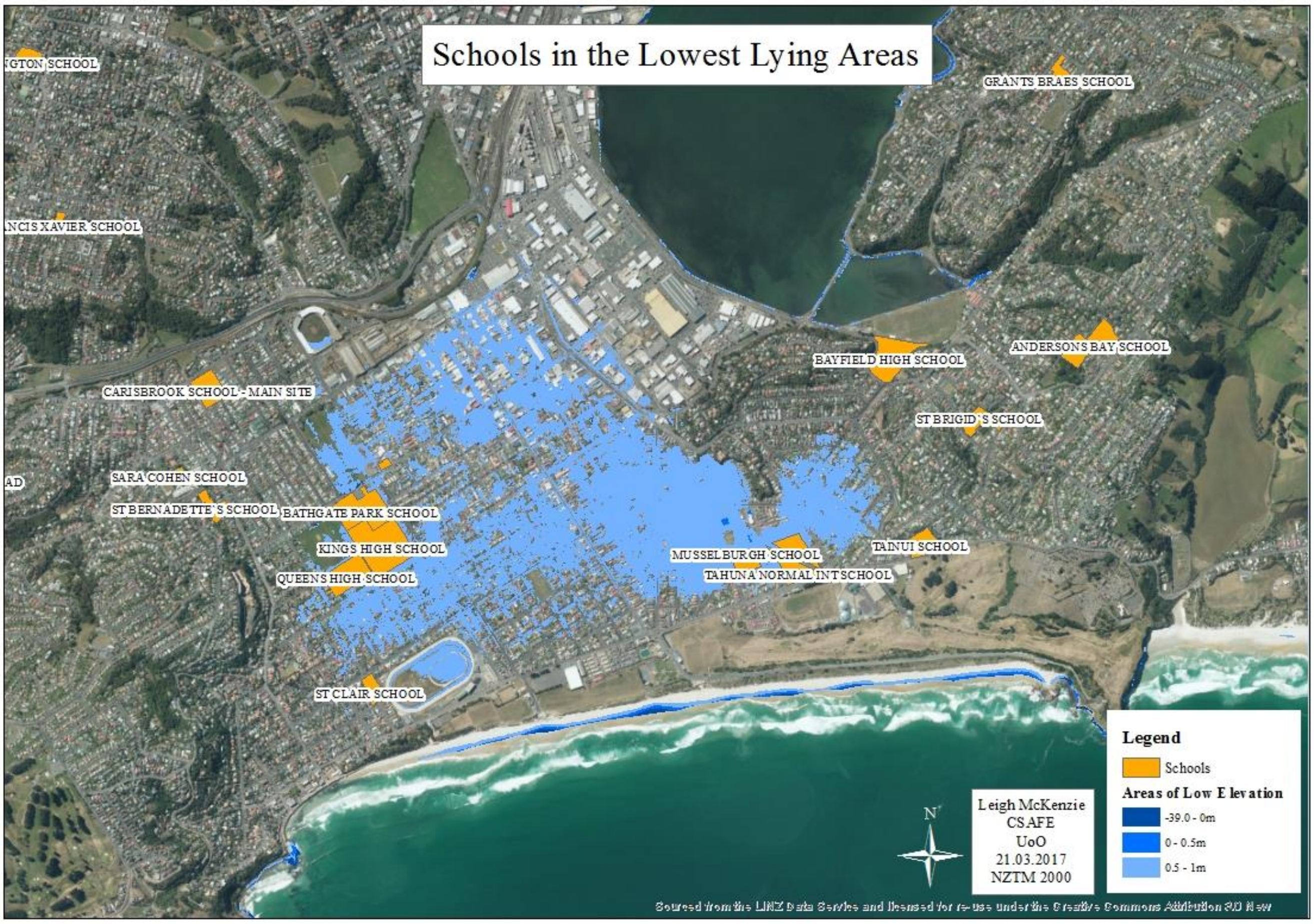


Figure 10: The schools in the greater south Dunedin area have been mapped with the lowest lying areas to find which ones are at most risk. This map uses database layers: 'Areas_under1m_MSL' and 'Schools_DCC' as it is the more up to date layer.

Schools are key to communities. Figure 10 shows the location of schools in the greater south Dunedin area. The schools which appear to be most at risk are Bathgate School, Kings High School, Queens High School, Musselburgh School, and Tahuna Intermediate.

The zones of the schools in the lowest lying areas (the area from which pupils are drawn) also influence the school's vulnerability to sea level rise. If their zones are limited to low lying areas, and people begin to move away or stop buying in these lower areas, the school's potential for students could decrease. Therefore, the schools with zoning have been mapped to find if the location of their zones make them even more vulnerable. Of the schools in low lying areas, only Kings and Musselburgh are zoned (Fig. 11).

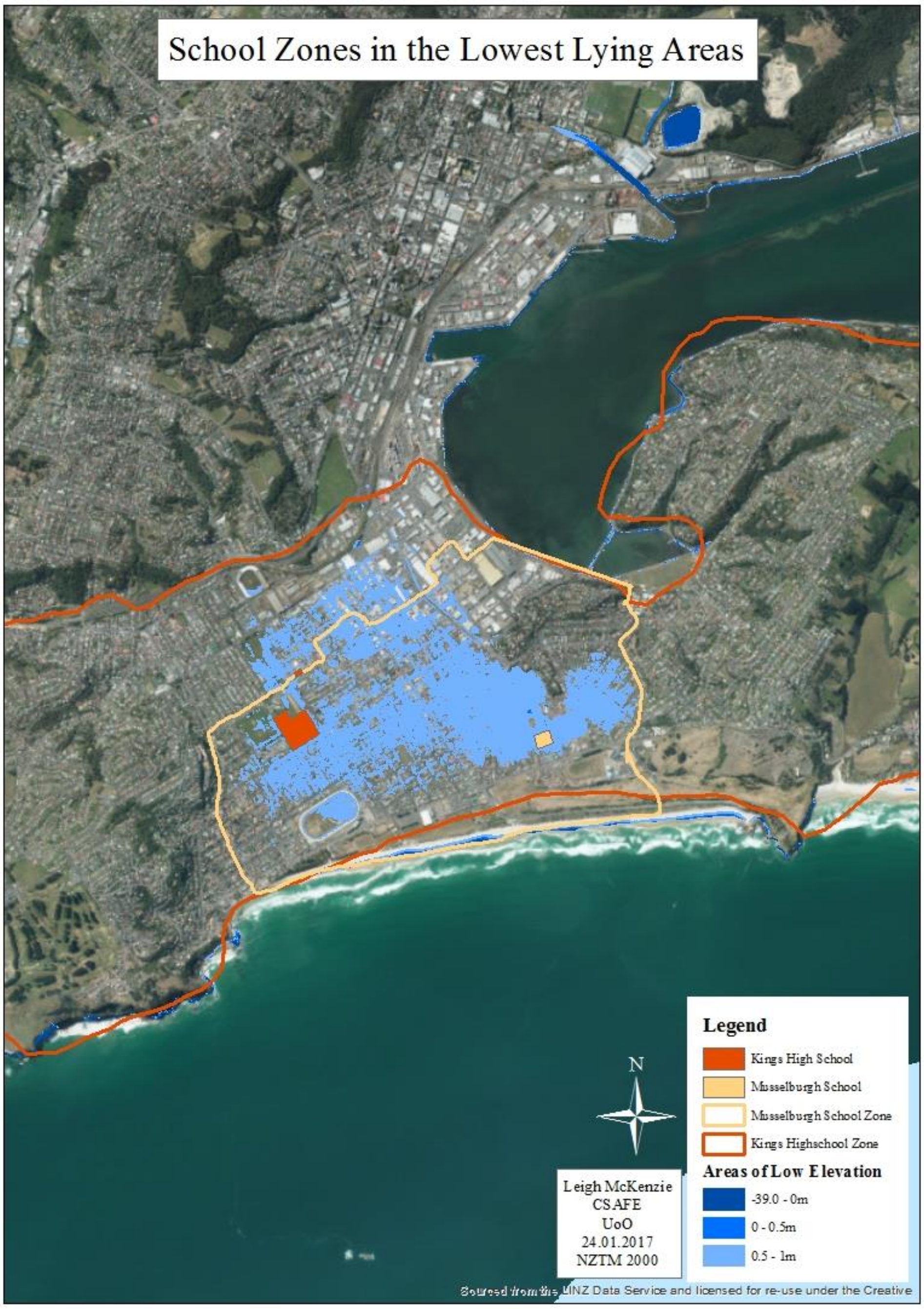


Figure 11: Kings High School and Musselburgh School are both in the lowest lying areas of the greater south Dunedin area. These schools are zoned, as shown in the map. These zones are approximations and should not be taken as accurate. This map uses database layers: 'Areas_under1m_MSL', 'Kings_Highschool_Zone', 'Musselburgh_School_Zone', and 'Schools_DCC'.

It can be seen in Figure 11 that Musselburgh School's zone is limited in extent and contains the majority of the lowest area, leaving it not only vulnerable due to its own position, but also vulnerable as the zone it can obtain students from is also mostly low lying. In comparison, Kings High School campus is very low lying, but its student roll is less vulnerable as its zone extends from Corstorphine to the end of the Otago Peninsula, and the majority of this area is elevated on hills.

Schools are not the only social asset in the greater south Dunedin area that may be at risk to sea level rise. In Figure 12, other community and recreation facilities in the area have been mapped, along with medical centres and rest homes.

Figure 12: A map showing community assets in low lying areas. This map uses database layers: 'Areas_under1m_MSL', 'fc_medical_1', 'fc_recreation_1', 'fc_rest_home_1'.

Figure 12 shows there are a number of facilities for community members, recreation, and rest homes located within the lowest lying parts of the greater south Dunedin area. At least 17 recreation and community facilities and three rest homes are within the low elevation area. Neither of the two medical centres located in the greater south Dunedin area are within the lowest elevation area (< 1m above Mean Sea Level).

These overlays provide some snapshots of the data, and invite more detailed study into questions of sensitivity and vulnerability. It should also be reinforced that low-lying areas are not the same as areas of predicted ponding.

PART 3 DATA SOURCES

In order to map the assets in the most vulnerable parts of the greater south Dunedin area, a data layer of the coastline and the lowest lying areas first needed to be created to determine the extent of the area of interest. All other data was then related to this area of interest.

The index below details the sources of all data used for creating the geodatabase (Table 5). All data uses NZTM 2000 as the map projection, or has been converted to use this one. Dunedin City Council data was originally sourced via the University of Otago School of Surveying database, but updated versions were subsequently obtained from the DCC (2016). The database contains both sets of data, with notes to clarify which layer is the updated one, for example, the Schools layer and 'New schools layer' that you can see in Table 5 below. Notes are also added to explain where 'updated' layers from the Dunedin City Council are the same as the layer obtained from the Surveying School.

Index of Data Sources

Table 5: A summary of the data layers, source, origin, date where known, and any important notes that should be associated.

Layer Name	Source	Link for the Data	Date	Notes
Liquefaction Hazard Area	By GNS Science for the Otago Regional Council	'Assessment of Liquefaction Hazards in the Dunedin City District' report by GNS Science, May 2014.	2005	This shapefile was provided by the ORC as a simplified shapefile of the work by GNS Science.
Park Asset Area	Surveying School Database	Connect to the School of Surveying GIS database.	Acquired 2016	
Storm Surge Inundation	Otago Regional Council	'The Natural Hazards of South Dunedin' report, August 2016.	Created from 2012 data	
DCC Ground Lidar	Dunedin City Council	Connect to the School of Surveying GIS database	2009	
Road Classifications	Dunedin City Council	Connect to the School of Surveying GIS database	Acquired 2016	
Railway	Dunedin City Council	Connect to the School of Surveying GIS database	Acquired 2016	
Survey Control Networks	LINZ	Connect to the School of Surveying GIS database	Acquired 2016	
Water Plant	Dunedin City Council	Connect to the School of Surveying GIS database	Acquired 2016	
DP Heritage Structure	Dunedin City Council	Connect to the School of Surveying GIS database	Acquired 2016	The updated layer from DCC is the same as the layer available through the Surveying School
Rest Homes	Dunedin City Council	Connect to the School of Surveying GIS database	Acquired 2016	

Medical Centres	Dunedin City Council	Connect to the School of Surveying GIS database	Acquired 2016	
River Centre Lines	LINZ	Connect to the School of Surveying GIS database		
Residential Area 50K	LINZ	Connect to the School of Surveying GIS database		
Primary Parcels	LINZ	Connect to the School of Surveying GIS database		
ULCA (Urban Landscape Classification Areas)	Dunedin City Council	Connect to the School of Surveying GIS database		The updated layer from DCC is the same as the layer available through the Surveying School. 2GP layer is the same.
Statutory Acknowledged Areas	Dunedin City Council	Connect to the School of Surveying GIS database		
AgriBase Farm	Dunedin City Council	Connect to the School of Surveying GIS database	June 2012	
Schools	Dunedin City Council	Connect to the School of Surveying GIS database		
Dunedin Zone Types	Dunedin City Council	Connect to the School of Surveying GIS database		The updated layer from DCC is the same as the layer available through the Surveying School.
Hillshade 25	LENZ	Connect to the School of Surveying GIS database	Acquired 2016	For topographical detail and display
New Zealand Coastline	LINZ	Connect to the School of Surveying GIS database		Polyline was transformed into a polygon to enable use in clipping
Otago Census Statistics	Statistics NZ	Statistics New Zealand Website: http://www.stats.govt.nz/Census/2013-census/data-tables/meshblock-dataset.aspx#excelfiles	2013	Extracted statistics for the Otago Region.
Otago Meshblocks	Statistics NZ	Statistics New Zealand Website: http://www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/digital-boundary-files.aspx	2013	Used for joining statistics with meshblocks to map (Statistics New Zealand, 2013b)
Area Units	Statistics NZ	Statistics New Zealand Website: http://www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/digital-boundary-files.aspx	2013	Area units have been used as suburb boundaries in this map because suburbs in Dunedin have not been officially defined. See the layer description in ArcGIS for more details on how these are created, as described by Statistics

				New Zealand (Statistics New Zealand, 2013a).
Social Deprivation Statistics	Socioeconomic Deprivation Index	University of Otago Wellington website: http://www.otago.ac.nz/wellington/departments/publichealth/research/hirp/otago020194.html	2013	See the 'NZDep2013 Index of Deprivation User's Manual' for details.
District Plan Land Designations	DCC	DCC Geodatabase	Acquired 2016	This is land designations by the DCC prior to 2GP
HNZ Social Housing	DCC	DCC Geodatabase	Acquired 2016	
Amenity Route	DCC	DCC Geodatabase	Acquired 2016	2GP
Archaeology Alert	DCC	DCC Geodatabase	Acquired 2016	2GP
Archaeological sites scheduled	DCC	DCC Geodatabase	Acquired 2016	2GP
Heritage and character contributing buildings	DCC	DCC Geodatabase	Acquired 2016	2GP
Coastal Hazard 2GP	DCC	DCC Geodatabase	Acquired 2016	2GP
Coastal Landscape	DCC	DCC Geodatabase	Acquired 2016	2GP
Designations 2GP	DCC	DCC Geodatabase	Acquired 2016	2GP
Dune System	DCC	DCC Geodatabase	Acquired 2016	2GP
New Schools Layer	DCC	DCC Geodatabase	Acquired 2016	This layer updates the previous schools layer which was sourced from the surveying school database. The difference is the presence of Carisbrooke School
Flood Hazard	ORC	Otago Regional Council	Acquired 2016	Flood hazard is defined by areas vulnerable to flooding by heavy rainfall and existing water ways, not ground water rising, hence South Dunedin is not included.
Minimum Floor Level	DCC	DCC Geodatabase	Acquired 2016	City Planning rules
Land Hazard 2GP	DCC	DCC Geodatabase	Acquired 2016	South Dunedin has not been identified as a land hazard by the DCC

Mapped Areas	DCC	DCC Geodatabase	Acquired 2016	South Dunedin, 2GP
National Grid	DCC	DCC Geodatabase	Acquired 2016	National electricity network – 2GP
Transport Hierarchy	DCC	DCC Geodatabase	Acquired 2016	Hierarchy of roads
2GP Zones	DCC	DCC Geodatabase	Acquired 2016	Zones of land use for 2GP (vs original district plan)
House Age	DCC	DCC Geodatabase	Acquired 2016	Derived from QV Ltd data, using 'effective year built' which accounts for significant modernisation. This is not perfectly accurate. See the layer description in ArcGIS for more details.
Rate Assessment	DCC	DCC Geodatabase	Acquired 2016	
Park Locations	DCC	DCC Geodatabase	Acquired 2016	Different to the layer available through the surveying school database.
Delta Electrical Assets	ThinkDelta	Contact Think Delta	Acquired Jan 2017	Access given to the University of Otago to use, and also permission for the DCC and ORC to use.
Historic Landforms ORC	ORC	Figure 5 in 'The Natural Hazards of South Dunedin' report by the ORC.	Acquired Jan 2017	These shapefiles are simplified forms of the historic landforms originally mapped by Mike Hilton in 'The geomorphology of the Ocean Beach Dune System – Implications for Future Management of Ocean Beach Domain' (2010)
Historic Landforms by Mike Hilton	Mike Hilton – Geography Department at UoO	Hilton, M. (2010) 'The geomorphology of the Ocean Beach Dune System – Implications for Future Management of Ocean Beach Domain', Fig. 6, Pg. 11.	2010	Mike Hilton mapped these historic landforms using a hand drawn map of the area from 1890.
1947 Aerial Photography	DCC	Imagery available at: https://apps.dunedin.govt.nz/arcgis/rest/services/Public/1947_AerialPhotography/ImageServer However, this will only provide a layer that links to the image server. A copy of the data itself is	Georeferenced in 2016	This data layer is a result of Leigh McKenzie georeferencing the imagery, and Andrew Dunn from the DCC joining it into a raster

		on a DVD disk provided by the DCC.		and removing the black borders. Andrew Dunn subsequently published it on a webmap here: http://dunedin.maps.arcgis.com/apps/webappviewer/index.html?id=9f355e06e2df4b6b949e9e313b913d97
Sea Level Rise Ponding ORC	Otago Regional Council	Contact the Otago Regional Council	Natural Hazards of South Dunedin report (ORC, 2016 p 49).	This is a layer of polygons created that approximates the raster model which was created to predict where ponding would arise in different sea level rise scenarios. Please note that the model was low resolution to begin with due to limitations by the detail of data on pipe networks which were accounted for in this model. Beca also made a model for this, however, it is not as representative and comprehensive so has not been included in this database.
Earthquake hazard shapefiles	Otago Regional Council	Contact the Otago Regional Council	Assessing the Seismic Hazards of the Dunedin City District report (Barrell, *et al.*, 2014, p 43).	Layers regarding the MMI index were not included due to a lack of certainty around the origins of the data.
Erosion-Acretion shapefiles	Otago Regional Council	Contact the Otago Regional Council	Natural Hazards of South Dunedin (ORC, 2016 p 43).	The change in position of dune vegetation at St Clair and St Kilda from 2000 - 2013.
Minimum Floor Level in the south Dunedin area	Approximated from the DCC website	Map of minimum floor level rules: http://www.dunedin.govt.nz/council-online/webmaps/minimum-floor-levels	Approximated in 2017, original from the DCC ~2014 (by	This layer should not be taken as exact as it was approximated by sight from the DCC website. A second layer of this was

			the Hazard report produced).	created to replace the first in order to improve the representation. Both are held on the database.

The social statistics and meshblock data used was from the 2013 census. Although a meshblocks layer exists for 2016, there are no census statistics for 2016. Therefore, to match the most recent census statistics (2013) with meshblocks, the meshblock pattern from 2013 was used so that the statistics could be mapped (Statistics New Zealand, 2013b). ‘MB’ has been used in file names to refer to Meshblocks.

The Social Deprivation Index was created by the Department of Public Health at the Wellington Campus of the University of Otago. It aggregates 9 variables from the 2013 census which reflect 8 dimensions of deprivation: access to the internet, income from benefits, income below an equivalised threshold, employment, qualifications, home ownership, family support, living space and access to transport (Atkinson, *et al.*, 2014). The NZDep2013 Index of Deprivation’s User Manual provides details around how the index was created, its limitations, and how to use it. This user’s manual is saved to the greater south Dunedin project folder but can also be accessed online (University of Otago, 2013).

PART 4: MAPPING METHOD

This section outlines how specific layers have been manipulated to create the geodatabase.

Census Statistics at the Meshblock Level

In order to link social statistics from the Census dataset with meshblock shapefiles, the census data was downloaded, and copied into a new excel file in order to format it so that ArcGIS could use the data. This involved ensuring the data was vertically formatted in columns, and that the first row contained column headings, as seen in Figure 13below.

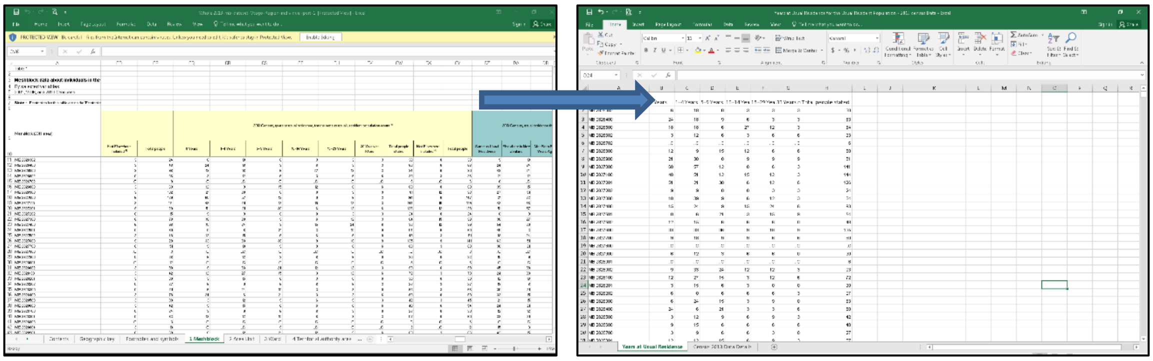
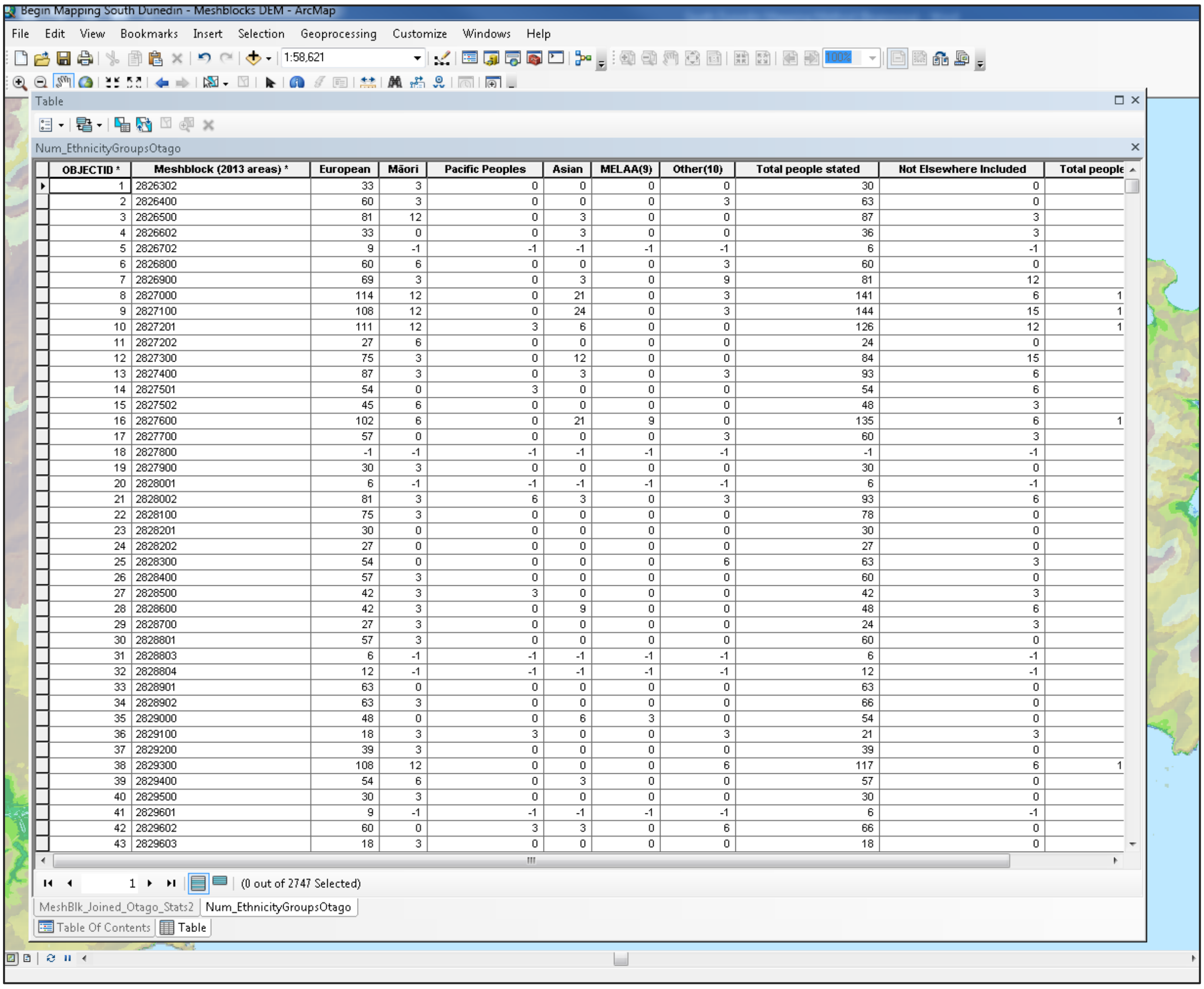


Figure 13: An example of how the Census data was reformatted for it to be suitable for use in ArcGIS.

The census uses '..C' values to represent confidential records, for cases where there are few cases in a single meshblock, such that someone could be identified due to infrequency in the meshblock area. Having '..C' values in the dataset meant that the data was in string format, but it needs to be in numerical format to be symbolised in a representative way in ArcGIS. Therefore, all '..C' values were replaced with '-1' values in excel, and then all cells were set to 'numerical' rather than text or string. Additionally, the Meshblock Id field in the census statistics data also needed to be edited in excel so that it would match the meshblock Id used in the meshblock shapefile table. The meshblock Id's did not match, which prevents the tables from being able to be joined in ArcGIS. To match the meshblock Id's, 'MB ' needed to be removed from the beginning of the meshblock Id values in the census datasheet. To do this, a formula was used to trim the beginning characters and only use the 7 characters from the right. The function used to trim the MB Id in excel was:

$$= RIGHT(A2, LEN(A2) - 3)$$

Once the document was correctly formatted for use with ArcGIS, the 'Excel to table' tool in ArcGIS was used. This created an ArcGIS table from the census data excel file shown in Figure 14 below.



OBJECTID *	Meshblock (2013 areas) *	European	Māori	Pacific Peoples	Asian	MELAA(9)	Other(10)	Total people stated	Not Elsewhere Included	Total people
1	2826302	33	3	0	0	0	0	30	0	
2	2826400	60	3	0	0	0	3	63	0	
3	2826500	81	12	0	3	0	0	87	3	
4	2826602	33	0	0	3	0	0	36	3	
5	2826702	9	-1	-1	-1	-1	-1	6	-1	
6	2826800	60	6	0	0	0	3	60	0	
7	2826900	69	3	0	3	0	9	81	12	
8	2827000	114	12	0	21	0	3	141	6	1
9	2827100	108	12	0	24	0	3	144	15	1
10	2827201	111	12	3	6	0	0	126	12	1
11	2827202	27	6	0	0	0	0	24	0	
12	2827300	75	3	0	12	0	0	84	15	
13	2827400	87	3	0	3	0	3	93	6	
14	2827501	54	0	3	0	0	0	54	6	
15	2827502	45	6	0	0	0	0	48	3	
16	2827600	102	6	0	21	9	0	135	6	1
17	2827700	57	0	0	0	0	3	60	3	
18	2827800	-1	-1	-1	-1	-1	-1	-1	-1	
19	2827900	30	3	0	0	0	0	30	0	
20	2828001	6	-1	-1	-1	-1	-1	6	-1	
21	2828002	81	3	6	3	0	3	93	6	
22	2828100	75	3	0	0	0	0	78	0	
23	2828201	30	0	0	0	0	0	30	0	
24	2828202	27	0	0	0	0	0	27	0	
25	2828300	54	0	0	0	0	6	63	3	
26	2828400	57	3	0	0	0	0	60	0	
27	2828500	42	3	3	0	0	0	42	3	
28	2828600	42	3	0	9	0	0	48	6	
29	2828700	27	3	0	0	0	0	24	3	
30	2828801	57	3	0	0	0	0	60	0	
31	2828803	6	-1	-1	-1	-1	-1	6	-1	
32	2828804	12	-1	-1	-1	-1	-1	12	-1	
33	2828901	63	0	0	0	0	0	63	0	
34	2828902	63	3	0	0	0	0	66	0	
35	2829000	48	0	0	6	3	0	54	0	
36	2829100	18	3	3	0	0	3	21	3	
37	2829200	39	3	0	0	0	0	39	0	
38	2829300	108	12	0	0	0	6	117	6	1
39	2829400	54	6	0	3	0	0	57	0	
40	2829500	30	3	0	0	0	0	30	0	
41	2829601	9	-1	-1	-1	-1	-1	6	-1	
42	2829602	60	0	3	3	0	6	66	0	
43	2829603	18	3	0	0	0	0	18	0	

Figure 14: An example of an Arc table resulting from using the 'excel to table' tool to create an ArcGIS table of census statistics to use.

Once all census data sheets had been reformatted, changed to numeric values, and had all meshblock Id's edited, the tables were joined with the meshblock shapefile in order to link all census data with each meshblock. An additional layer 'Population Statistics' was made to link all census data to one shapefile, so that symbology can be used to display more than one census attribute at once. For example, household income could be symbolised by colour, and number of family members could be represented by symbol size. The census statistics joined to the meshblock shapefile for this map are shown in Table 6 below.

Table 6: A list and description of the census data which has been included in this geodatabase.

Name of Census Statistics	***Description***
Otago Meshblocks	Shapefiles for the 2013 census meshblock pattern.
Number of Usual Residents	Number of residents who usually live in the meshblock.
Ages of Usual Residents	5 year age groups and median age.
Employment Status	Status in employment for the employed, usually resident population, aged 15 years and over.
Family Income	Total family income (grouped) for families in occupied private dwellings.
Family Type	Family type, for families in occupied private dwellings.
Highest Qualification	Highest qualification for the census usually resident population count, aged 15 years and over.
Hours Worked per Week	Hours worked in employment per week, for the employed usually resident population count, aged 15 years and over.
Maori Descendant	Maori descendant for the usually resident population count.
Median Personal Income	Total personal income (grouped and median) for the usually resident population count, aged 15 years and over.
Number of Children Born	Number of children born alive, for the female usually resident population count aged 15 years and over.
Social Deprivation Index	Calculated by the UoO Department of Public Health, Wellington campus. Accounts for: Communication, Income by benefit, Income below threshold, employment, qualifications, owned home, support, living space, and transport.
Tenure Holdings for Usual Residents	Tenure holder for the usually resident population count aged 15 years and over.
Total Families per Dwelling	Family type, for families in occupied private dwellings.
Hours of Unpaid Activities	Unpaid activities for the census resident population count aged 15 years and over.
Workforce Status	Work and labour force status for the usually resident population count aged 15 years and over.
Years since Arrival in New Zealand	Years since arrival in NZ, for the overseas born, usually resident population count.
Ethnicity Groups	Ethnic group (grouped total responses), for the usually resident population count.
Years at Usual Residence	Years at usual residence for the usually resident population count.

Lidar of the greater south Dunedin Area

The Lidar data was acquired from the Surveying School database and added to ArcGIS, along with a raster layer for detailing the hill shading of Dunedin's topography (University of Otago, 2016). However, parts of the greater south Dunedin area were expressed as the same elevation as the sea, leading them to both be expressed as green, an inaccurate representation of Dunedin (Figure 15). In order to exclude the sea from being displayed as green, and from future data analyses, the Lidar raster was clipped to the extent of the New Zealand coastal layer (Figure 16). The New Zealand coastline was originally formatted as a vector polyline, but has been transformed to a closed polygon so that it can be used in the raster clipping tool.

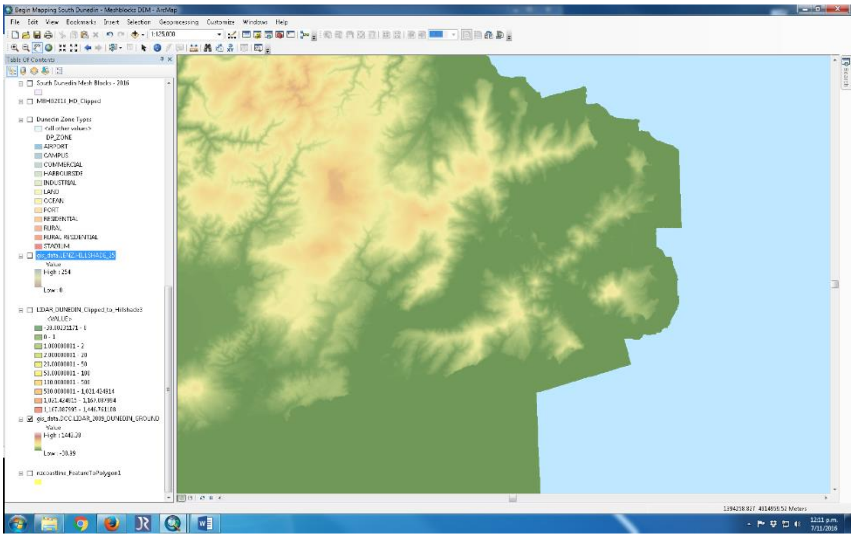


Figure 15: The Lidar raster of Dunedin shows areas of the sea as green because it is in the same elevation category as the low lying areas of land.

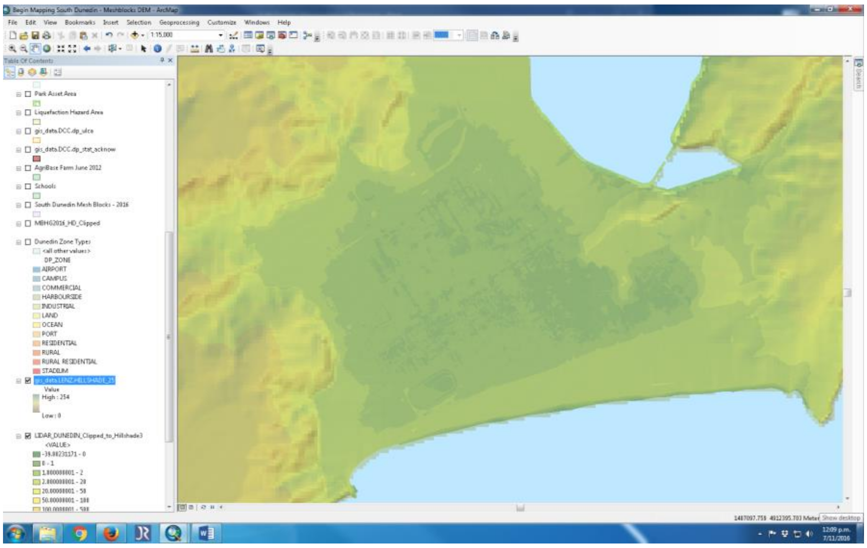


Figure 16: By clipping the Lidar raster to the extent of the New Zealand coastline, the land elevations are separated from sea so that they can be distinguished in colour and in future analysis.

The clipping tool used settings and extraction details as shown in Figure 17 below. These settings were selected to ensure the Lidar layer would maintain its original degree of resolution but still result in a new Lidar layer which was limited in extent to the coastline of New Zealand.

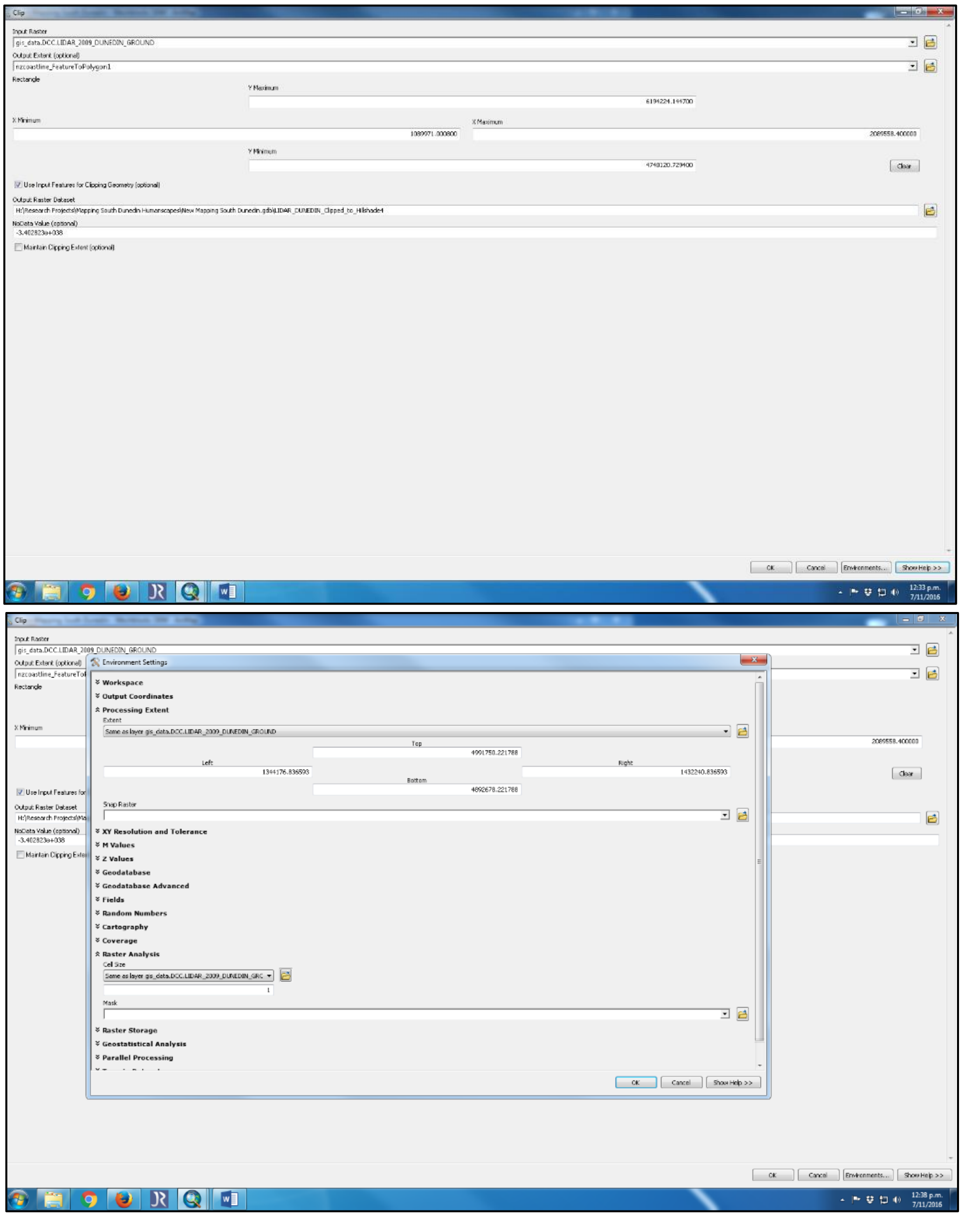


Figure 17: The clipping tool was used to trim the Lidar raster layer to the same extent as the New Zealand coastline. The settings for the clipping tool were selected as shown.

Once the Lidar data was clipped to exclude the sea, its elevations were classified using symbology settings in order to express detailed variations of the low-lying areas of Dunedin more clearly. The classes used are shown in Figure 18 below, and Table 7 for clearer display.

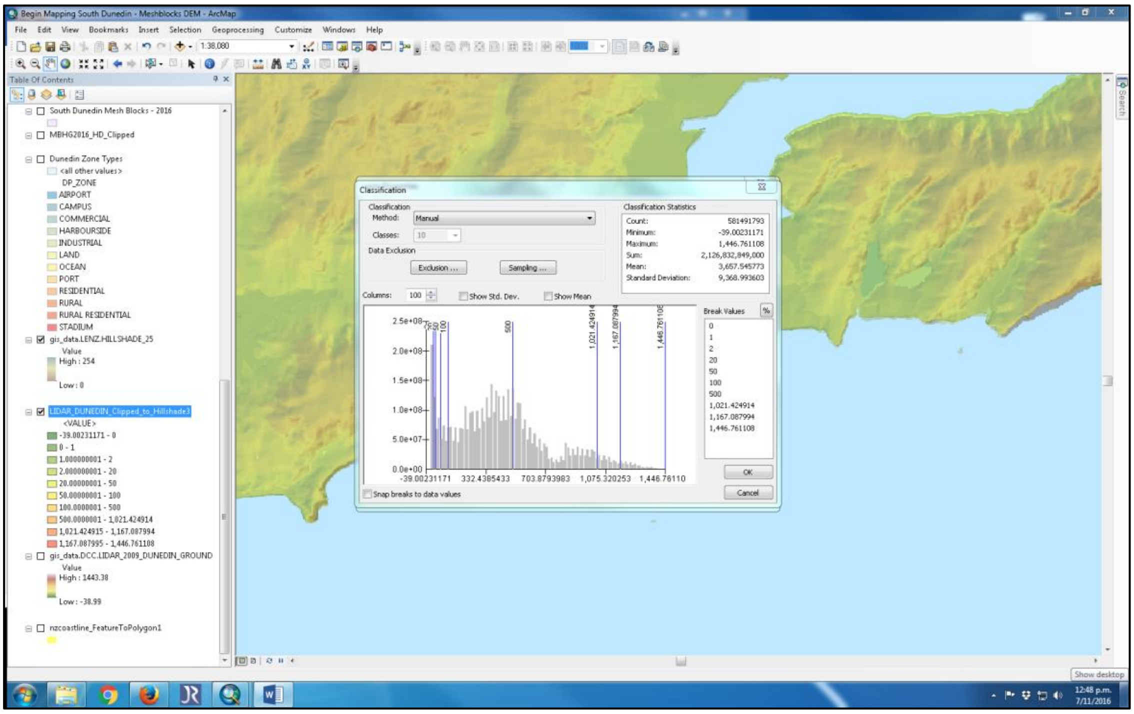


Figure 18: A screenshot of how the Lidar data was classed in order to show more detail in the topography of lower elevations. The final elevation classes used are shown in Table 6 below.

Table 7: The values of classes used to distinguish more detail of low lying areas of Dunedin.

Classes	Break Values (m)	Range (m) (1dp)
1	0	-39.0 - 0
2	0.5	0-0.5
3	1	0.5-1
4	1.5	1-1.5
5	2.0	1.5-2.0
6	5.0	2.0-5.0
7	10	5.0-10.0
8	20	10.0-20.0
9	50	20.0-50.0
10	100	50.0-100.0
11	150	100.0-150.0
12	500	150.0-500.0
13	1248.6	500-1248.6
14	1446761108	1248.6-1446761108

More detail of low-lying areas is expressed in Figure 19, compared to the low-lying areas in Figure 16, which are more consistent in colour, not expressing the detailed variation in elevation across the low lying land.

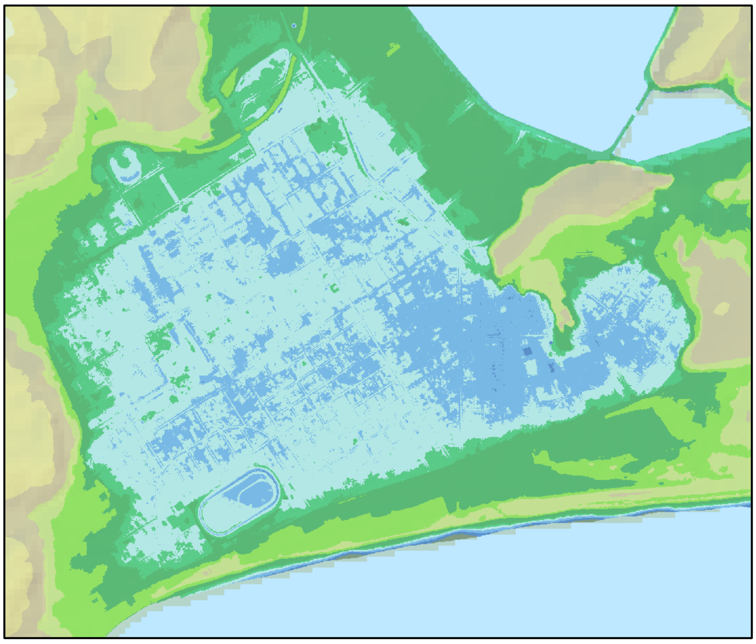


Figure 19: The resulting map after classifying elevations of lower lying areas to show more detail. LiDAR data from 2009 was used. The layer is titled 'Reclass_DunedinLiDA3' in the database.

The cells with an elevation of 1m or less were extracted from the raster to create a polygon of low-lying areas in the greater south Dunedin area. The polygon makes it easier to symbolise in conjunction with other data layers. An example of the low-lying areas displayed by polygon is shown in Figure 20.

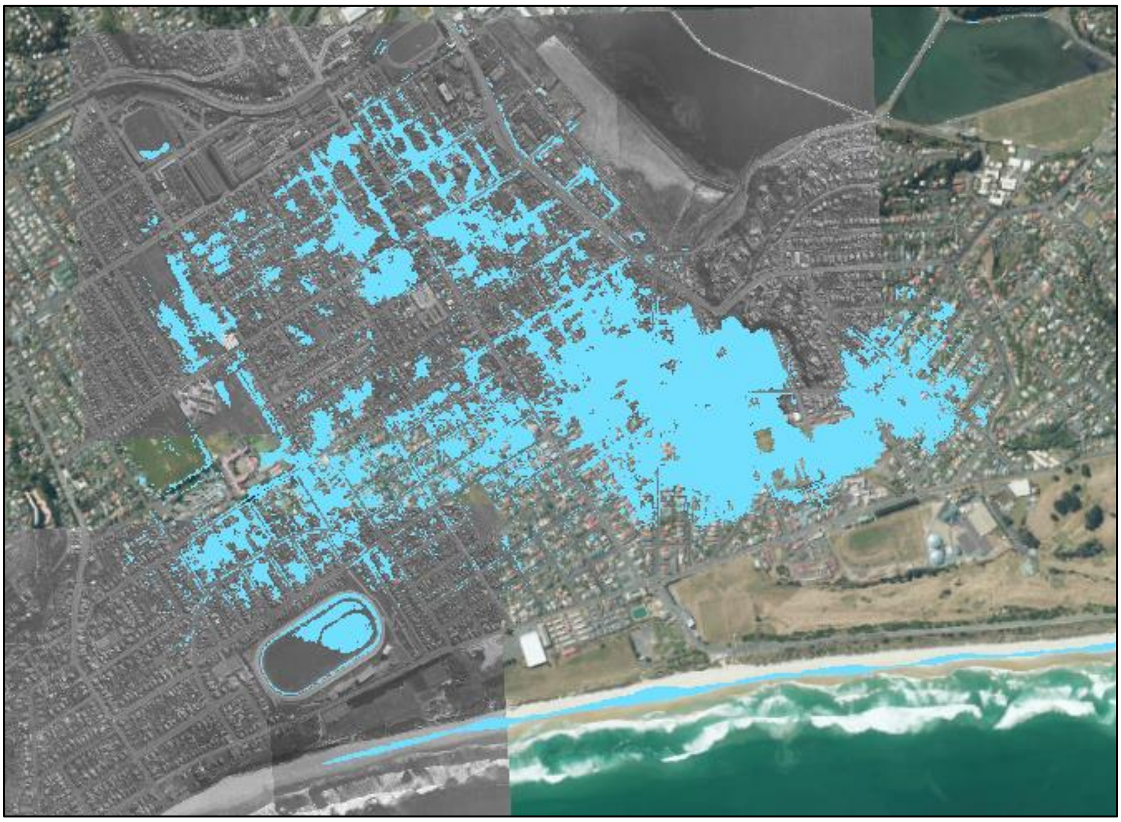


Figure 20: The low-lying areas of Dunedin were extracted to a polygon layer. The blue shows the filled in polygon of area <1m elevation above sea level. The 1947 aerial photography has also been included in this map, the layer is titled 'ph_1947_SouthDunedin'in the database.

Georeferencing Historic Aerial Photos

Historic Aerial Photos from 1947 were obtained from the DCC. Initially, these images had no spatial reference so could not be used in maps. To use these images in the geodatabase I gave the images of the south Dunedin area a coordinate system by georeferencing them using a recent ArcGIS imagery base map, which had a New Zealand Transverse Mercator 2000 projection. An example of the 1947 aerial photography is in Figure 21 below.

Figure 21: An example of the aerial photos taken in 1947. This aerial photo is 'S53' and shows part of the racecourse, which is still in the south Dunedin area today.

The images obtained included all of Dunedin, but only a subset of these were selected in order to focus on the south Dunedin area. The aerial photo path is shown in the index in Figure 22. The photos that were georeferenced from the whole set are listed in Table 7, along with their associated accuracy which is explained next.

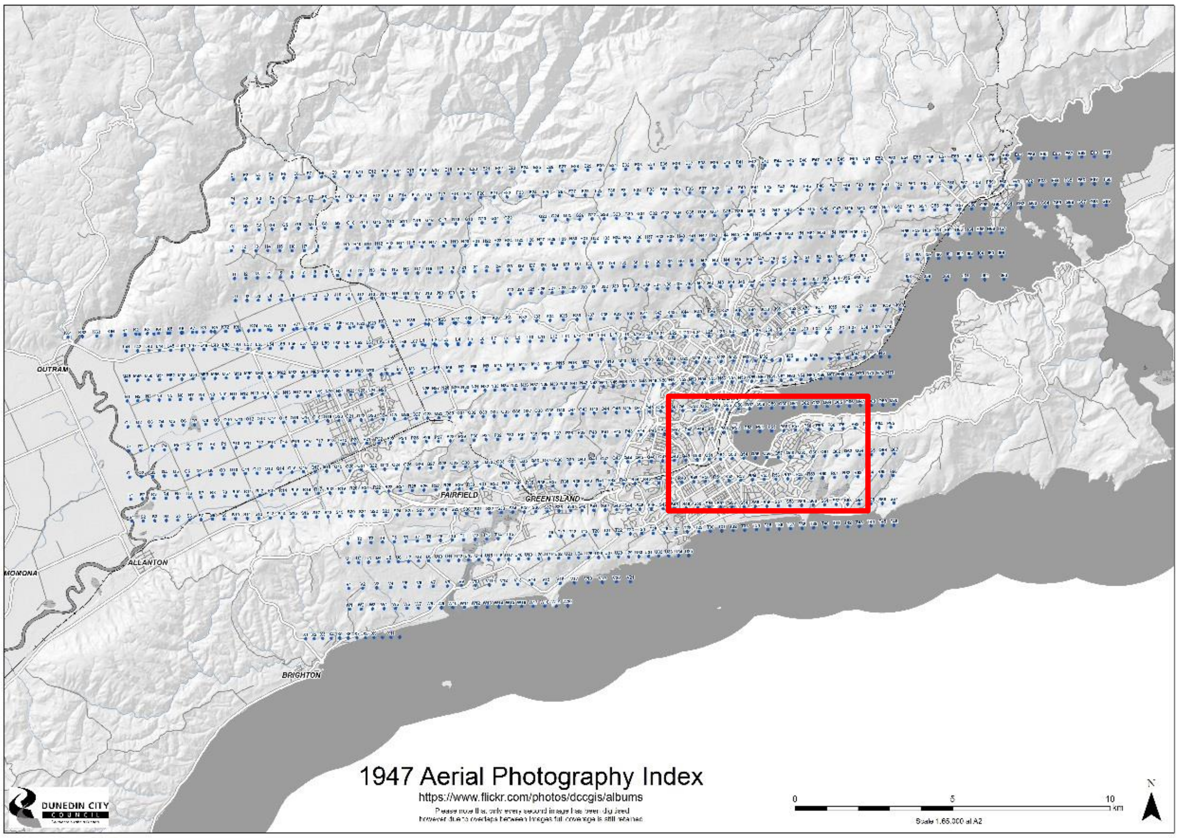


Figure 22: The aerial photo path shows all of the photos taken by plane in 1947. Only a subset of these were georeferenced in order to focus on the south Dunedin area. The area that was georeferenced is roughly indicated in red.

The georeferencing toolbar in ArcGIS was used to give the aerial photos a spatial reference system. The georeferencing toolbar is found under the Customize tab, Toolbars, then select the georeferencing option. The resulting tool bar is shown in Figure 23. The key part of the toolbar is the drop down menu in which you select the image to georeferenced. Note that the images offered in this drop down menu come from the table of contents, not ArcCatalogue, so the image you want to georeference must be in the table of contents to become an option in the drop down menu. The control point button was used to create points of common landmarks between the 1947 photos and recent imagery, and finally the link table button shows the points made and their associated error and accuracy.

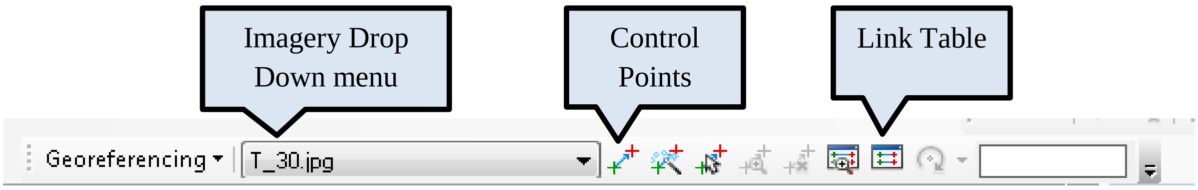


Figure 23: The georeferencing toolbar in ArcGIS. The main components used was the drop down bar where you select images to georeference, the control points, and the link table to view points made and associated error and accuracy.

Control points were created in the old image, using landmarks which could also be found in the more recent imagery. These landmarks were then matched by ArcGIS and the 1947 aerial photos were aligned to fit the newer imagery, calculating a spatial reference system for the aerial photos. Figure 25 shows aerial photo R51 being georeferenced. The image is laid over recent imagery, and control points are being made, indicated by small numbered crosses on the aerial image. At least 5 control points were created, spread across the images. The control points can be viewed with their associated accuracy in the link table, as shown in Figure 26.

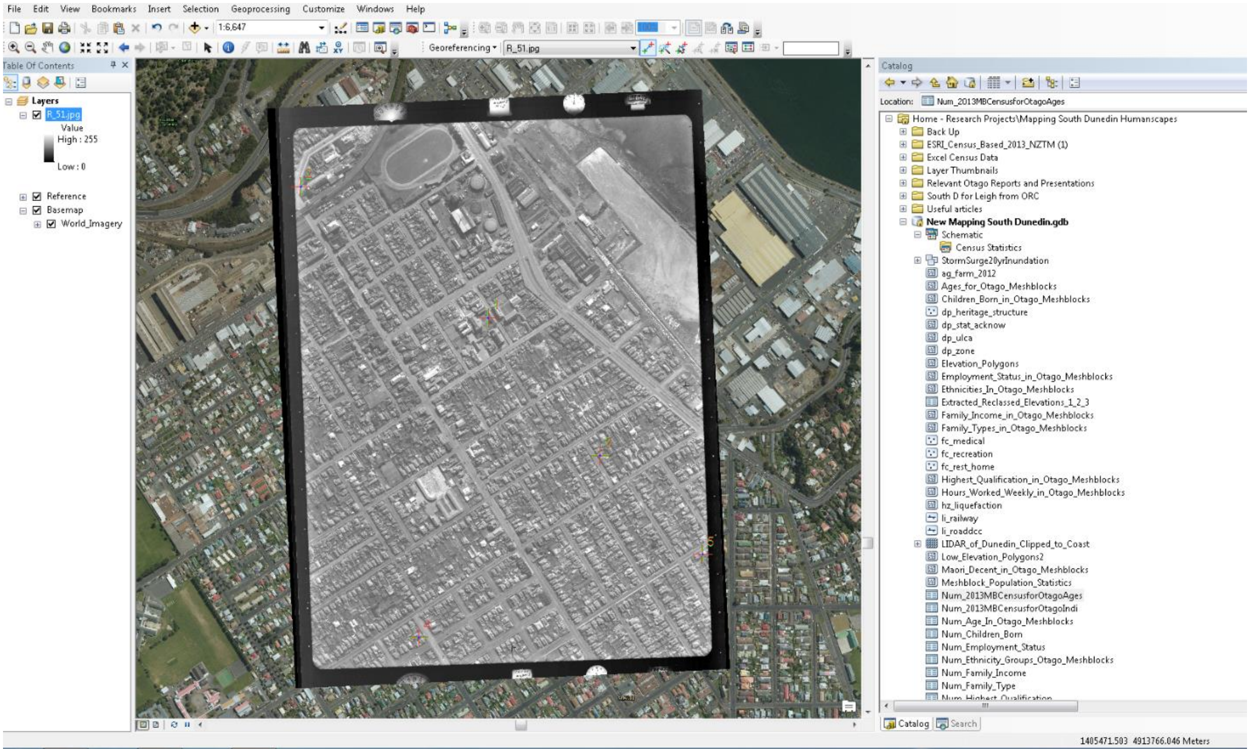


Figure 24: A screenshot of the georeferencing method. Aerial photo R51 is displayed and control points are being created.

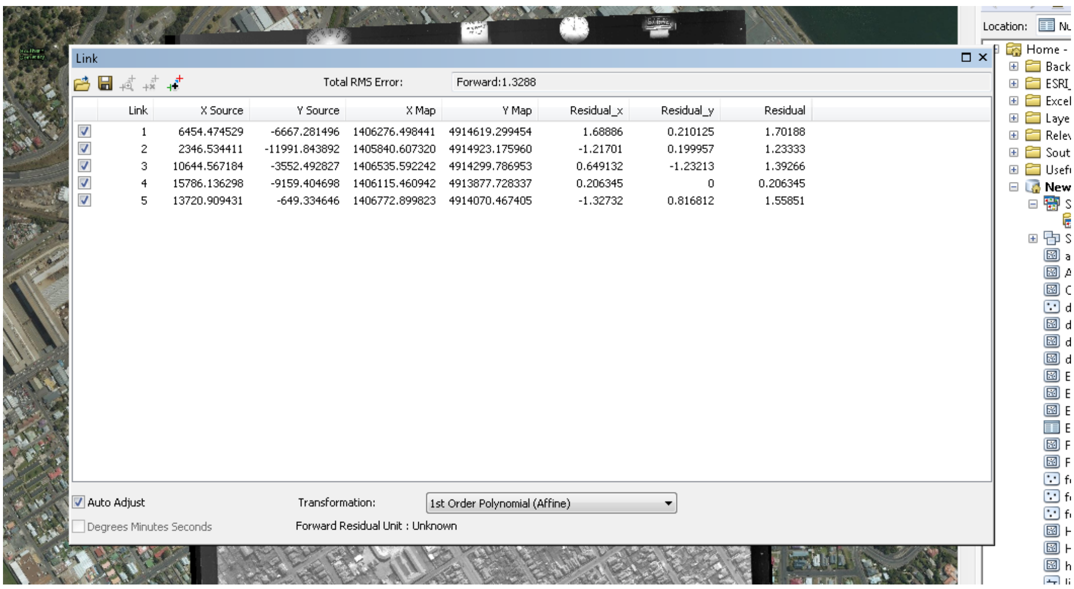


Figure 26: Link table for control points created for aerial photo R51.

The method used in this project for georeferencing the 1947 aerial photos can be found on Youtube, a clip called ‘Georeferencing historical aerial photography in ArcGIS 10.1’ (Sounny-Slitine, 2012). In this video a clear and simple step by step process is explained and demonstrated. Here, accuracy is recommended to have a root mean square of <15m. For this project each image was ensured to have an accuracy of <5m. The video suggests using the centre of road intersections for control points. Some of these points were used for these aerial photos. However, this project mostly used the pitches of house roofs. House roofs were found to provide a finer point making it more precise than estimating the centre of intersections, especially as roads change in width, and it is clear if a house has changed or not. The control points for each aerial photo and the overall root mean square for each image is summarised in Table 8 below.

Table 8: The aerial photo from 1947 with associated accuracy (root mean squared) and the number of points created to georeference the image with current day imagery.

Aerial Photo Name	Georeference Accuracy (Total Root Mean Squared)	Notes
Q49	2.0014	5 points used
Q51	0.988137	5 points used
Q53	2.83517	5 points used
Q55	1.85861	5 points used
R47	2.44566	5 points used
R49	0.915191	5 points used
R51	1.3288	5 points used
R53	1.62025	5 points used
R55	1.75138	9 points used
R57	4.43583	7 points used
S47	2.65251	5 points used
S49	3.22681	7 points used
S51	1.39858	6 points used
S53	1.31528	6 points used
S55	0.347387	5 points used
S57	2.48367	5 points used
S59	4.40516	5 points used
T26	4.30868	5 points used
T28	0.489583	6 points used
T30	0.792829	5 points used
U33	3.22125	5 points used
U35	3.76143	5 points used

Once the 1947 aerial photos had been georeferenced, the photos became rasters. However, they needed to be joined together as they were still individual images. To do this the mosaic tool in ArcGIS was used to join the raster aerial photos into a mosaic dataset. However, the black borders around the aerial photos were still present. The georeferenced aerial photos had the footprints adjusted to remove the borders (right click on the mosaic dataset and select ‘Build Footprints’) and finally the mosaic dataset was converted to a raster dataset, this work for removing the borders was completed by Andrew Dunn in the Dunedin City Council GIS department.

The layer showing the zones of schools in the south Dunedin area was created by copying the polygons provided by the Ministry for Education, as shown in Figure 27 below.

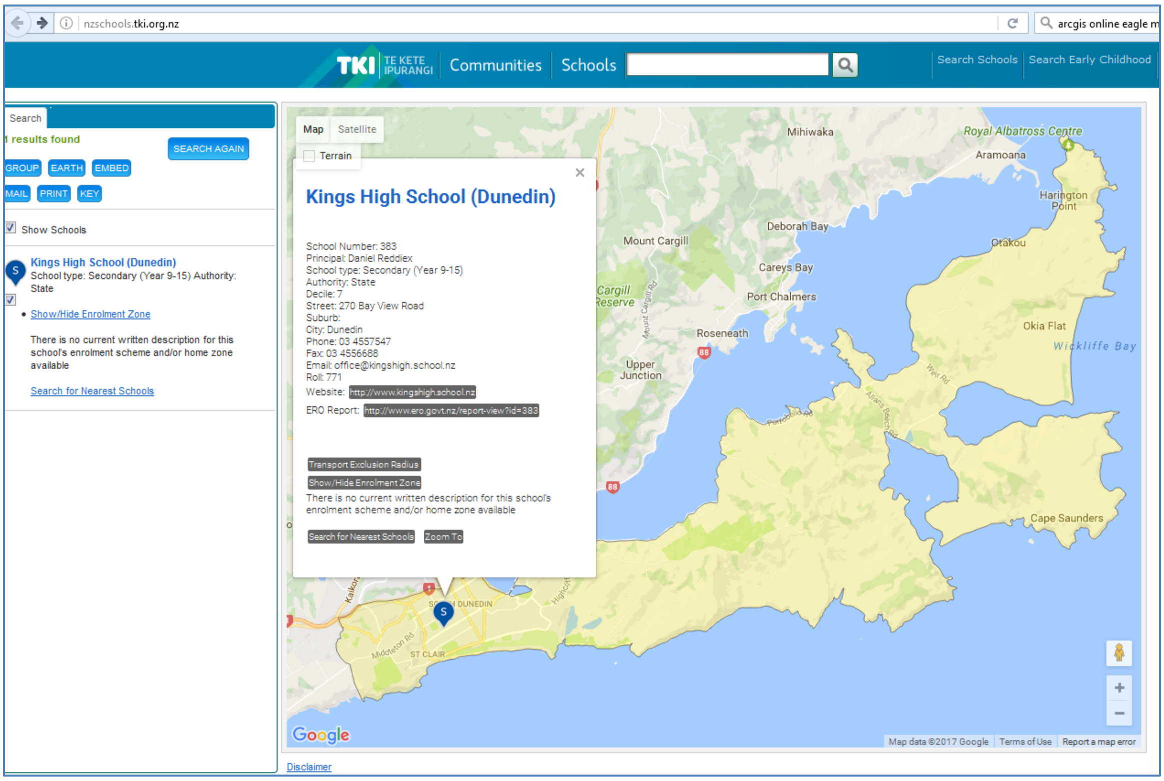


Figure 257: The Ministry for Education provides mapped polygons showing school zones. This figure shows King's High school as an example (Ministry for Education, 2017).

The polygons were approximated using the polygon tool in Google Earth, and saved as a KML file. These were subsequently converted into feature classes in ArcGIS using the KML to Layer tool. It must be noted that the polygons are approximations. For accurate representations of school zones see the Ministry for Education (2017).

CONCLUSION

The greater south Dunedin area has been identified by the Parliamentary Commissioner for the Environment as the largest urban area at risk from sea level rise in New Zealand. Its vulnerability is due to its low lying nature, proximity to the coast, geological past, groundwater distribution and dense population. The geodatabase project is a compilation of approximately 141 layers of existing data which can be used by agencies and researchers for future studies into the impacts of sea level rise and other hazards in greater south Dunedin.

For permission to access the GIS geodatabase, bona fide researchers should contact Assoc Prof Tony Moore (tony.moore@otago.ac.nz) at the School of Surveying, University of Otago, or Dr Caroline Orchiston (caroline.orchiston@otago.ac.nz) at the Centre for Sustainability, University of Otago.

References

Atkinson, J., Salmond, C. and Crampton, P. (2014) 'NZDep2013 Index of Deprivation User's Manual', *Department of Public Health, University of Otago,* Wellington.

Barrell, D., Glassey, P., Cox, S. and Smith Lyttle, B. (2014) 'Assessment of liquefaction hazards in the Dunedin city district', *GNS Science Consultancy, New Zealand*.

Church, J.A., Clark, P.U., Cazenave, A., Gregory, J.M., Jevrejeva, S., Levermann, A., Merrifield, M.A., Milne, G.A., Nerem, R.S., Nunn, P.D. and Payne, A.J. (2013) 'Sea level change', *PM Cambridge University Press.*

Delta Utility Services (2017) 'Electrical Network Assets Data', *Delta Utility Services*, accessed: January 2017.

Dunedin City Council (2014) 'Minimum Floor Levels', *Dunedin City Council*, URL: http://www.dunedin.govt.nz/council-online/webmaps/minimum-floor-levels, accessed: 05.01.2017.

Dunedin City Council (DCC) (2016) 'Dunedin City GIS Data Layers', *Dunedin City Council*, accessed: November 2017.

Hilton, M. (2010) 'The Geomorphology of the Ocean Beach Dune System – Implications for Future Management of Ocean Beach Domain', *Unpub., Report to the Dunedin City Council,* Dunedin.

Intergovernmental Panel on Climate Change (IPCC) (2013) 'Climate Change 2013: The Physical Science Basis', *Intergovernmental Panel on Climate Change*, Bern, Switzerland.

Ministry for Education (2017) 'TKI', *Te Kete Ipurangi*, URL: http://nzschools.tki.org.nz, accessed: 4.01.2017.

Otago Regional Council (ORC) (2012) 'Otago Natural Hazards Database', *Otago Regional Council*, Dunedin.

Otago Regional Council (ORC) (2014) 'Coastal Hazards of the Dunedin City District', *Otago Regional Council*, Dunedin.

Otago Regional Council (ORC) (2016) 'The Natural Hazards of South Dunedin', *Otago Regional Council*, Dunedin.

Parliamentary Commissioner for the Environment (2015) 'Preparing New Zealand for Rising Seas: Certainty and Uncertainty', *Parliamentary Commissioner for the Environment*, New Zealand.

Royal Society of New Zealand (2016) ‘Climate change implications for New Zealand’, *The Royal Society of New Zealand*, New Zealand.

Sounny-Slitine, M. (2012) ‘Georeferencing Historical Aerial Photography in ArcGIS 10’, *Youtube,* URL: https://www.youtube.com/watch?v=k6rY4SnrR3I.

Statistics New Zealand (2013) ‘2013 Census data user guide’, *Statistics New Zealand*, Wellington.

Statistics New Zealand (2013a) ‘Geographic boundary files’, *Statistics New Zealand*, URL: http://www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic-areas/digital-boundary-files.aspx, accessed 10.11.2016.

Statistics New Zealand (2013b) **‘**Census meshblock data 2013’, *Statistics New Zealand*, URL: http://www.stats.govt.nz/Census/2013-census/data-tables/meshblock-dataset.aspx#excelfiles, accessed: 10.11.2016.

Telfer, I. (2015) ‘South Dunedin considers sea level threat’, *Radio New Zealand*, URL: http://www.radionz.co.nz/news/regional/290122/south-dunedin-considers-sea-level-threat, accessed: 16.11.2016.

University of Otago (2013) ‘Socioeconomic Deprivation Indexes: NZDep and NZiDep, Department of Public Health’, *Department of Public Health*, URL: http://www.otago.ac.nz/wellington/departments/publichealth/research/hirp/otago020194.html, accessed: 15.11.2016.

University of Otago (2016) ‘School of Surveying geodatabase’, *University of Otago*, accessed: 31.10.2016.