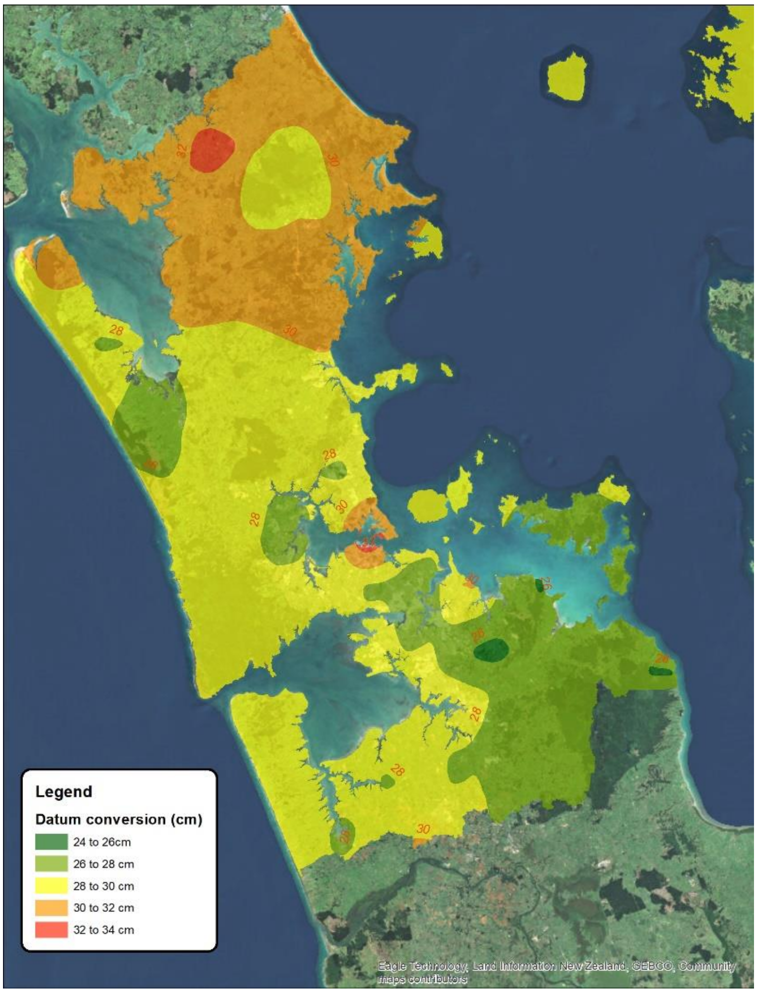
NZVD2016 Datum Change Impact Assessment Technical Report for Auckland Council



7 Nov 2022

CITE REPORT AS:

Auckland Council NZVD2016 Datum Change Impact Assessment – Technical Report

Submitted by Lynker Analytics for Auckland Council, November 2022

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Executive Summary

A new vertical datum, NZ Vertical Datum 2016 (NZVD2016) has been established as a nationwide standard for measuring elevation. In the Auckland Region, this will replace the existing vertical datum, Auckland 1946 (AUK1946). The Surveyor-General is encouraging surveyors to migrate to using elevation data based on NZVD2016. Toitū Te Whenua Land Information New Zealand (LINZ) also encourages local government agencies to migrate their geospatial data to use NZVD2016.

Through an evaluation of more than fifty data sets, this report provides an assessment of the impacts of adopting the NZVD2016 vertical datum. For this analysis geospatial data maintained by Auckland Council has been grouped into 7 domains including elevation, assets, freshwater, coastal and marine, survey and other.

Most of the geospatial datasets that hold elevation attributes or are derived from elevation data sources can be converted to NZVD2016 using standard GIS tools. This can be done in bulk, converting all attributes in a single operation per layer, using the LINZ datum correction surface. A scheduled "brown-out" or no access period for map services will be required while attribute fields can be duplicated to provide elevation values to both datums. There are no appreciable effects on data utility.

Key findings include:

- Overland Flow Paths (OLFP) show sensitivity to datum changes for lower order (smaller) watercourses. It is recommended that existing OLFP data is retained as-is for the time being, as it is fit for purpose.

- Survey data submissions should migrate to the new datum immediately after Auckland Council's GIS data are converted. Auckland council should require all as-built plans to clearly express the datum being used

- GIS metadata for elevation-related themes should be revised to clarify the vertical datum used for levels. Attributes for level data should be expressed in both AUK1946 and NZVD2016 datums for the foreseeable future.

1. Purpose

In June 2022 Lynker Analytics Ltd entered a contract with Auckland Council, to perform a project assessing the impacts of adopting the NZVD2016 vertical datum. The New Zealand Vertical Datum 2016 (NZVD2016) was introduced in June 2016, to replace the various height surfaces used across the country. It allows for the consistent collection and seamless exchange of heights across New Zealand. All Councils are progressively migrating their geospatial data assets to the new datum.

This project provides an assessment of the impact of this transformation for Auckland Council. The deliverables include:

1. Transformed sample data
2. Technical report outlining the conversion impacts and the work programme required to undertake an Auckland-wide change.
3. Briefing of results and implications to Client

This report explains the methodology, analysis and assessment of the potential impacts associated with this project.

Specific objectives included:

- Analysis of the LiDAR datasets in the AUK1946 and NZVD2016: DEM, DSM, Contours
- Identification of several test areas based on variation across the area. We included coastal, lowland residential, elevated rural, high relief zones and areas with significant flood or overland flow path risk.
- Identification of the datasets where there could be an impact of change. Target data included: catchment and hydrology, underground services, roading/kerblines, unitary plan, marine moorings, coastal inundation/tsunami layers, building outlines
- Evaluation of the impact of the new datum on all the reference datasets outlined above (final list agreed with Auckland Council)
- Evaluation of the impacts of the change from AUK1946 to NZVD2016 – including positional and vertical change, topology and data utility e,g. impacts on flow direction, pipe gradients, as-builts.

Background to NZVD2016 Adoption

Over the past 25 years or so, New Zealand has been changing its official projection systems which underpin mapping and surveying activities. This brings projection systems into alignment with modern GNSS-based survey systems & international standards. As part of these updates, a new vertical datum, NZ Vertical Datum 2016 (NZVD2016) has been established as a nationwide standard for measuring elevation.

Orthometric heights

Elevation data (Z value) is commonly expressed in terms of *orthometric height* (often the vertical height above sea level). For over 70 years, survey data in the Auckland Region has measured orthometric heights in metres above the Auckland Vertical Datum 1946 (AUK1946). This was established based on mean sea level in Auckland Harbour up to 1946. The datum was extended by levelling surveys along major roads to establish a network of official geodetic marks.

Airborne gravity surveys made by LINZ in 2013-2014 have been used to establish a new geoid surface across New Zealand. This geoid represents an equipotential surface, so is like a water surface such as mean sea level. This forms the basis for the new NZVD2016. It replaces the older local datums, such as AUK1946, and provides a unified nationwide datum.

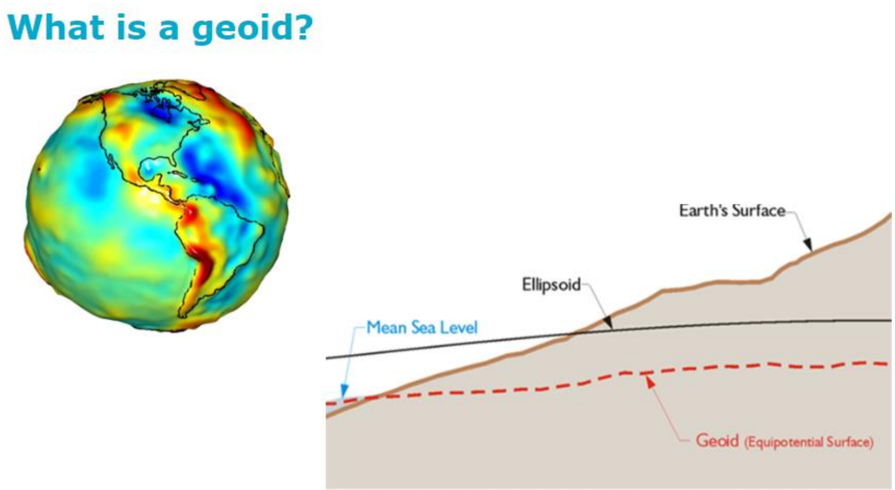


Figure 1 Concept of the geoid. (Copyright : LINZ)

Official recommendations from LINZ are now to move to the new NZVD2016 vertical datum for all orthometric height data. The change in datum level from AUK1946 to NZVD2016 is about +30cm in the Auckland Region. AUK1946 heights can be converted to NZVD2016 heights by subtracting 30cm (+/- 5cm according to the local area). The NZVD2016 datum approximates sea level – note that sea level has risen about 20cm globally since 1946, accounting for most of the datum differences.

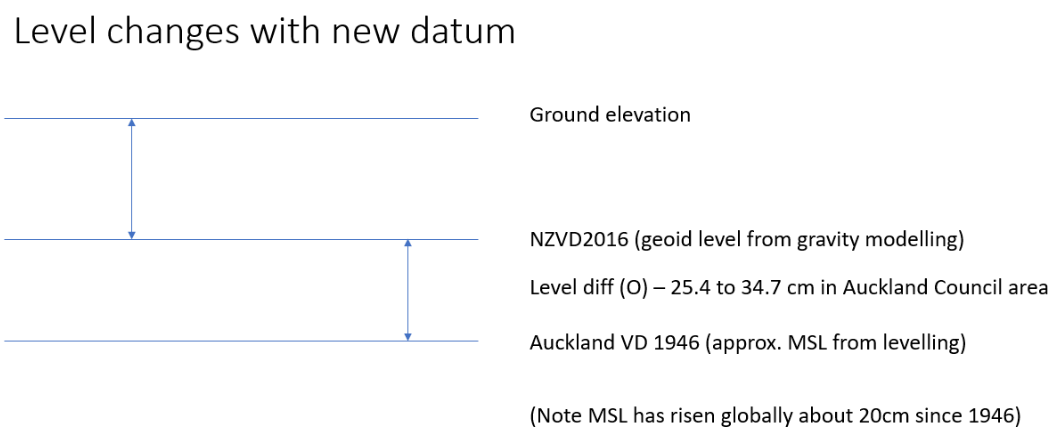


Figure 2 Level changes with the new datum

Conversion of data between datums

LINZ provides official conversion grids between the vertical datums, both as a mesh of points at 2 arc-second intervals (approx. 3.6 km apart) as well as a raster conversion surface. Minor irregularities or "hot-spots" occur in the conversion surface from AUK1946 to NZVD2016. These occur due to inaccuracies in earlier levelling for the AUK1946 datum.

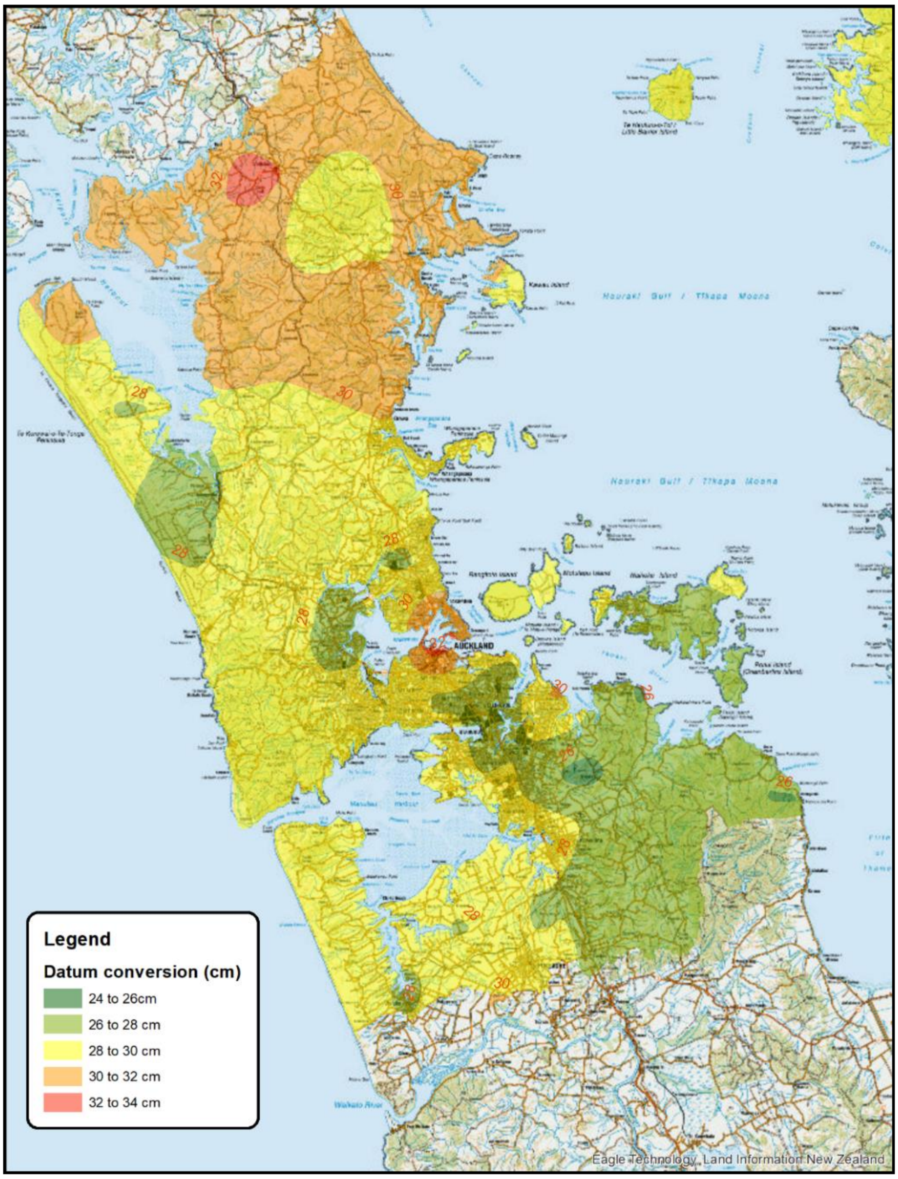


Figure 3 Auckland Council area – height of NZVD2016 datum surface above the AUK1946 datum.

Relationship of new datum to projection systems

Modern NZ map projections are based on the adoption of the NZGD2000 datum as a standard basis for NZ map projections. It describes location in terms of latitude, longitude, and ellipsoidal height. This is the basis for the national projection system (NZTM) as well as local circuit projection systems (Meridional Circuits). The Meridional Circuit system in the Auckland Region is Mount Eden 2000.

Note that ground elevations expressed as ellipsoidal heights in NZGD2000 differ considerably from the height above sea level in most places. In the Auckland Region the difference is over 30 metres. Hence the ellipsoidal height is inappropriate for common height measurements. The NZVD2016 datum is compatible with the NZGD2000 reference ellipsoid.

Why change?

New Zealand Vertical Datum 2016 (NZVD2016) provides a consistent height surface, it allows us to make better informed decisions about our heighted datasets:

- It is a transparent and reliable height system, which will result in 'the same answer' if independently checked. Auckland 1946 heights are less well defined, and heights may vary based on which reference mark values are used.
- NZVD2016 heights can be determined anywhere in the country, to the same level of accuracy. Thus, allowing accurate height points for large scale corridor projects (such as roading, rail and utilities). Auckland 1946 heights are only well defined along State Highways and in the city.
- NZVD2016 is a gravity-based height system (can be used for fluid flow) and can be used in the same way as Auckland 1946 heights. This means that current processes and technologies can continue to be used.
- NZVD2016 is based on a static reference surface, which enables us to better understand how the earth and sea level changes overtime. Auckland 1946 is based on a sequence of marks, if one mark moves over time, it will have flow on effects to other marks in sequence.
- Because of NZVD2016's static reference frame, the movement of marks can be easily measured. After natural events such as earthquakes, volcanoes, and flooding NZVD2016 can be used immediately to repair utilities and infrastructure (such as the three waters). Re-establishing Auckland 1946 heights would require extensive surveying and the re-observation of the sequence of marks across the affected area before recovery work can begin.
- As NZVD2016 is the national standard, it will be the minimum requirement for many national projects such as LiDAR, National Planning Standards, and utilities contracts. Currently there are more than 13 local datums used in New Zealand (such as Auckland 1946), the use of multiple height references does not support the access or exchange of information for decision making.

* *This section "Why Change?" adapted from original notes by Gisborne DC*

2. Study Area and Data

For the detailed study of geospatial data samples, a set of 9 x 1:1,000 tile areas were used. The rationale for selection was as follows:

- Include varied landforms, geology and land cover.
- Sample areas to be representative of variation across the entire Auckland Region.
- Include areas with different population densities : Central Business District (CBD), urban, suburban, and rural.
- Representative samples from local government areas which existed prior to the Unitary Authority.
- Areas with the greatest gradient of change within the datum conversion grid.
- Include coastal, lowland residential, elevated rural, high relief zones and areas with significant flood or overland flow path risk.
- Include a stable geological area of volcanic rock within the Central Business District (CBD).
- Include a coastal site with extensive flat and low-lying terrain subject to runoff from surrounding hills and coastal erosion.
- Include a high-density housing development.

Sites selected are as follows :

- Silverdale
- Helensville
- Kumeu
- Freemans Bay
- Mt Albert
- Kakamatua (Waitakere Ranges)
- Hingaia Bridge (Karaka)
- Browns Bay (N Shore)
- Wairoa Reservoir, Hunua Ranges

The study area was across the Auckland Council region, with nine specific areas of detailed investigation as defined in the figure below.

Figure 4 Auckland Council - areas of detailed investigation in red.

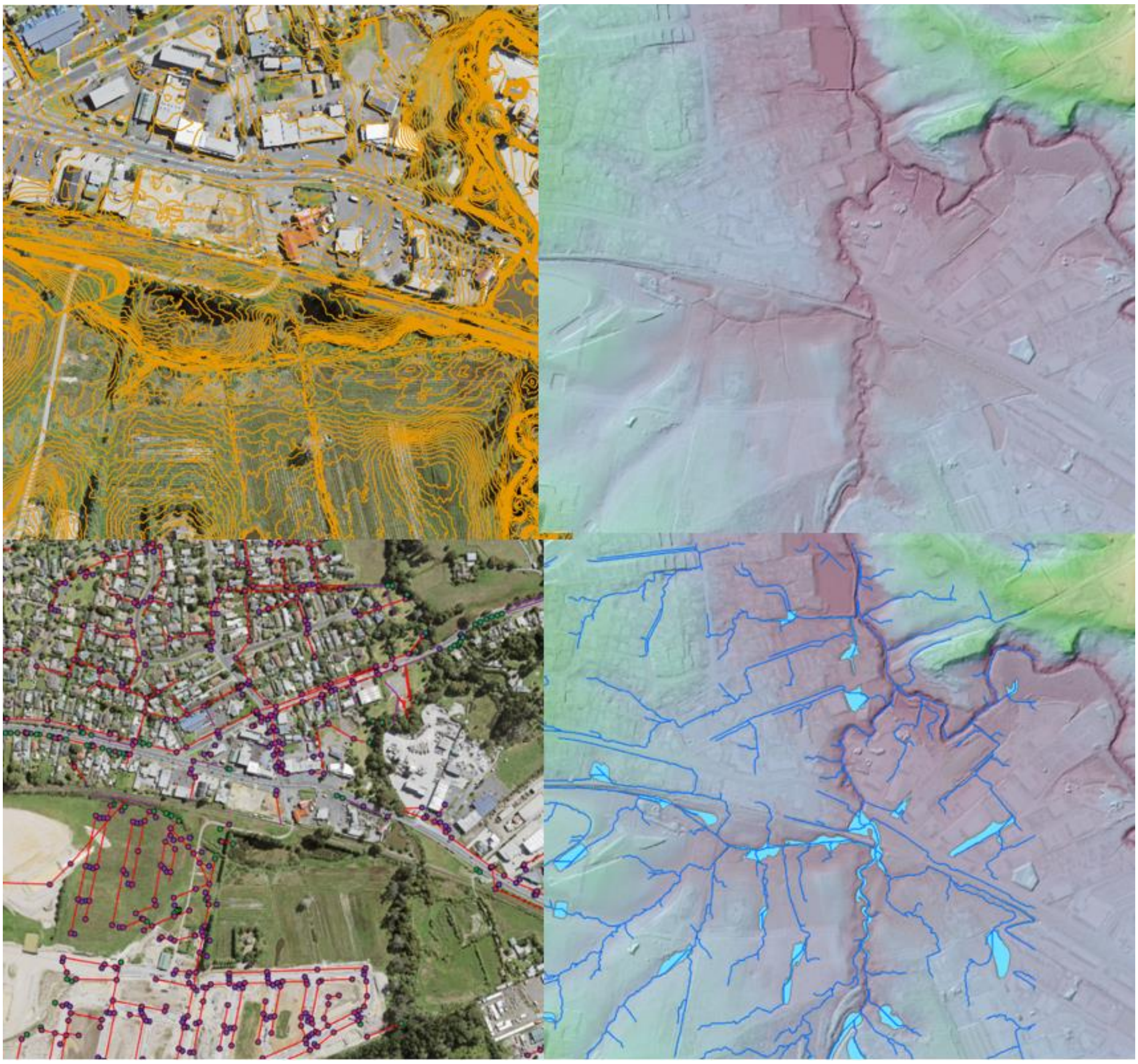


Figure 5 : Example study area – Kumeu.

Sample data layers acquired from Auckland Council Open Data and Geomaps shown. 25cm topographic contours (top left), DEM (top right), Overland flow and flood areas (bottom right), Asset data (bottom left). Up to 66 individual layers were acquired for each sample area where they exist.

3. Methodology

This project was completed by GIS analysis of geospatial datasets for each sample area. The main data sources were from Auckland Council Geomaps, Auckland Council Open Data, Watercare Open Data, AT Open Data, LINZ Data Service, and directly from Auckland Council. Data was analysed mainly in ArcGIS Desktop.

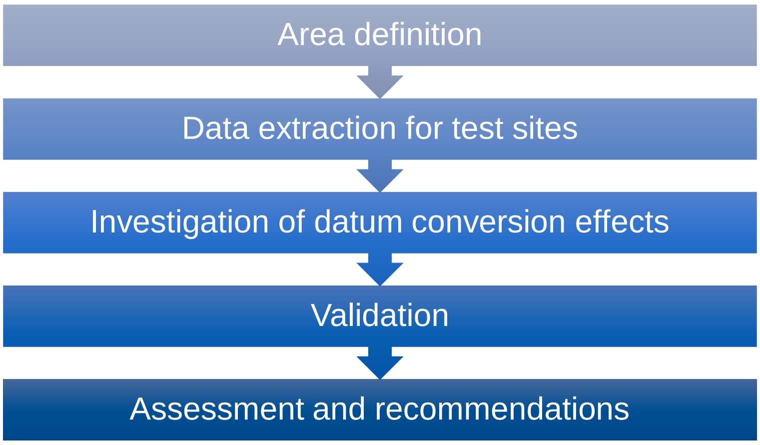


Figure 6 : Overview of analysis process used in the project.

3.1 Elevation Base Datasets

Introduction

Elevation base datasets comprise elevation surface datasets (DEM & DSM), geodetic marks, and contours, as listed in the table below.

Dataset	Origin	Vertical Datum	Data Supply
Digital Elevation Model (DEM) as 1m grid	Created from LIDAR survey data, captured in 2016-2018 for Auckland Region	AUK1946 for internal use in Auckland Council; NZVD2016 on LINZ Data Service	Auckland Council and LINZ Data Service
Digital Surface Model (DSM) as 1m grid	As for DEM	NZVD2016 on LINZ Data Service	LINZ Data Service
Geodetic marks (LINZ)	LINZ geodetic database	Both AUK1946 (historical) and NZVD2016	LINZ geodetic database
Topographic contours, 25cm interval	Auckland Council Open Data	AUK1946	Auckland Council Geomaps

Background

Prior to about 2010, most elevation data in the region was based around LINZ geodetic marks expressed mainly in AUK1946, plus elevation data derived from the 20m contours prepared for the LINZ 1:50,000 scale topographic map series. LiDAR coverage was limited.

An initial regional LiDAR elevation survey covering about 50% of the region was made in 2013. This was superseded by 2 further LIDAR elevation surveys (North and South) covering the whole region made in 2016-2018. The LIDAR survey results were processed to create 2 DEMs and DSMs in accordance with LINZ standards for LIDAR.

The two DEMs for North and South areas can be seamlessly merged at the junction in the Te Atatū peninsula. The quality of the LIDAR-derived data has been independently assessed & rigorously quality controlled (see *Auckland Council LIDAR lessons learned document, 2016*).

The DEM data was provided to Auckland Council in terms of both AUK1946 and NZVD2016 datums, with the AUK1946 datum made standard for internal use. It was provided in NZVD2016 for hosting on the LINZ Data Service.
25cm bare-earth topographic contours were provided to Auckland Council with the other LIDAR survey outputs.

The 2016-2018 LIDAR DEM and 25cm contours represent a dramatic improvement in the availability of elevation data for the region. Many other datasets are derived from the LIDAR DEM such as overland flow paths and modelled coastal inundation areas.

LINZ geodetic marks represent the fundamental reference dataset for elevation values (orthometric heights). The DEM and contour data has been checked by cross-referencing to these geodetic marks.

Data Sources

A copy of the 2016-2018 DEM and DSM in AUK46 Datum was supplied by Auckland Council for use in this investigation. Extracts of the DEM were taken for each of the study areas and converted to the NZVD2016 datum.
A copy of the 2016-2018 DEM and DSM is also available for download from the LINZ Data Service. This copy is in NZVD2016. Extracts of the LINZ DEM were taken for each of the study areas.
Samples of contours were taken from Auckland Geomaps for each of the 9 sites for checking.
All geodetic marks were downloaded (see https://data.linz.govt.nz/layer/50787-nz-geodetic-marks/) for the region.

Investigation

DEM comparison with LINZ geodetic marks

A sample of selected LINZ geodetic marks which use NZVD2016 was made for Auckland CBD, omitting marks at depth under covers, broken marks etc. The elevation was then interpolated from the 2016-2018 DEM (in NZVD2016) at the mark locations.
Comparison with 2016 LIDAR DEM values :

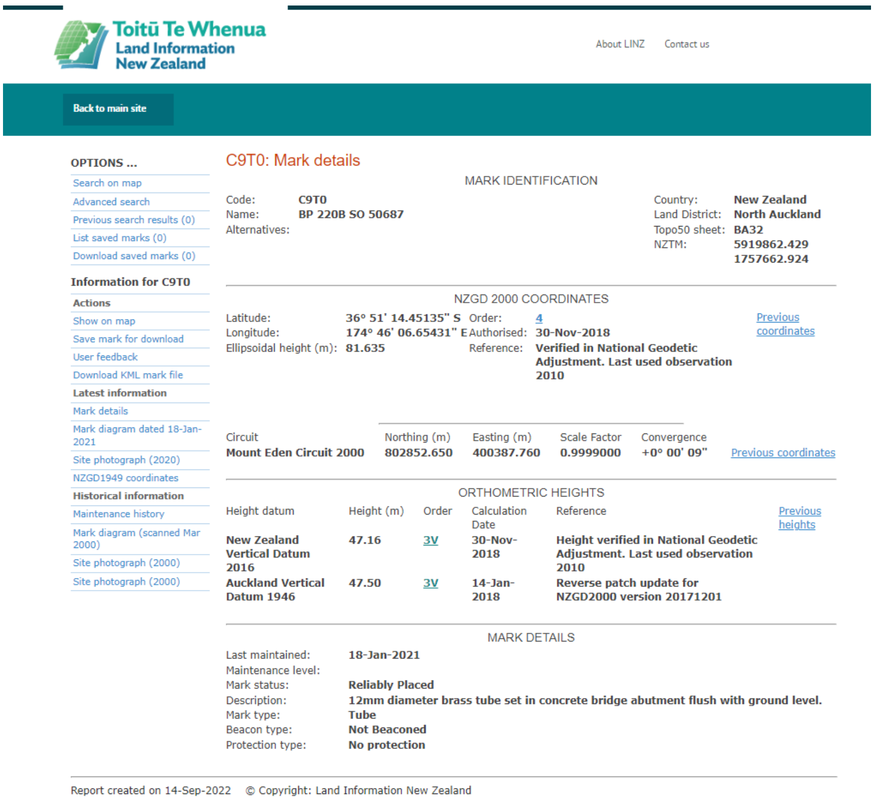
- Mean error 2.9 cm,
- Standard Deviation 6cm

LIDAR DEMs have quoted accuracies against survey control points used by the LIDAR contractors :

- Mean error 3 to 5 mm
- Standard Deviation 4 to 6cm

See vendor metadata reports for 2016-2018 LIDAR for more details :
https://cloud.sdsc.edu/v1/AUTH_opentopography/www/metadata/NZ16_NAuckland_metadata.pdf
https://cloud.sdsc.edu/v1/AUTH_opentopography/www/metadata/NZ16_SAuckland_metadata.pdf

Figure 7 : LINZ Geodetic Marks in Auckland CBD – marks used for DEM checks



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OPTIONS ...
- Search on map
- Advanced search
- Previous search results (0)
- List saved marks (0)
- Download saved marks (0)

Information for C9T0

Actions
- Show on map
- Save mark for download
- User feedback
- Download KML mark file

Latest information
- Mark details
- Mark diagram dated 18-Jan-2021
- Site photograph (2020)
- NZGD1949 coordinates

Historical information
- Maintenance history
- Mark diagram (scanned Mar 2000)
- Site photograph (2000)
- Site photograph (2000)

C9T0: Mark details

MARK IDENTIFICATION

Code: **C9T0**
Name: **BP 220B SO 50687**
Alternatives:

Country: **New Zealand**
Land District: **North Auckland**
Topo50 sheet: **BA32**
NZTM: **5919862.429 1757662.924**

NZGD 2000 COORDINATES

Latitude: **36° 51' 14.45135" S**
Longitude: **174° 46' 06.65431" E**
Ellipsoidal height (m): **81.635**

Order: **4**
Authorised: **30-Nov-2018**
Reference: **Verified in National Geodetic Adjustment. Last used observation 2010**

Previous coordinates

Circuit	Northing (m)	Easting (m)	Scale Factor	Convergence	
Mount Eden Circuit 2000	**802852.650**	**400387.760**	**0.9999000**	**+0° 00' 09"**	Previous coordinates

ORTHOMETRIC HEIGHTS

Height datum	Height (m)	Order	Calculation Date	Reference	Previous heights
New Zealand Vertical Datum 2016	**47.16**	3V	**30-Nov-2018**	**Height verified in National Geodetic Adjustment. Last used observation 2010**	
Auckland Vertical Datum 1946	**47.50**	3V	**14-Jan-2018**	**Reverse patch update for NZGD2000 version 20171201**	

MARK DETAILS

Last maintained: **18-Jan-2021**
Maintenance level:
Mark status: **Reliably Placed**
Description: **12mm diameter brass tube set in concrete bridge abutment flush with ground level.**
Mark type: **Tube**
Beacon type: **Not Beaconed**
Protection type: **No protection**

Report created on 14-Sep-2022 © Copyright: Land Information New Zealand

Figure 8 : Typical LINZ Geodetic Mark record in Auckland CBD (Symonds St).

Reliable higher-order geodetic marks as in the figure above were used for DEM checks. Note orthometric heights for this mark expressed in both AUK1946 and NZVD2016.

Comparing the Auckland Council DEM with the LINZ DEM

To check the consistency of available DEM data from the 2016-2018 Auckland LIDAR, samples were taken from the DEM available via the LINZ Data service. The LINZ LDS DEM (supplied in NZVD2016) was converted to AUK1946 datum using the LINZ transformation grid. The Auckland Council DEM was subtracted from the LINZ DEM using the ArcGIS minus tool to give difference grids as summarized below.

Sample site	Tile	Mean	Std Deviation	Comment
Freemans Bay / CBD	BA32_3503	0.008m	0.004m	No significant difference
Karaka / Hingaia Br	BB32_2329	0.0002m	0.0029	No significant difference
Silverdale / Pine Valley	BA31_0231	-0.001m	0.005m	No significant difference
Mt Albert	BA31_4245	0.00006m	0.003m	No significant difference
Kumeu	BA31_2413	-0.0028m	0.003m	No significant difference
Hunuas	BB33_2221	0.001m	0.003m	No significant difference
Kakamatua	BB31_1020	-0.025m	0.335m	Note significant differences
Helensville	BA30_0945	-0.097m	0.288	Note significant differences
Browns Bay	BA32_1501	-0.020m	0.215	Note significant differences
Bethells Beach	BA30_4244	-0.043m	0.348	Note significant differences

As expected, most sample areas showed no significant differences in elevation. However, some more rural sites showed significant differences in the DEM. These differences are summarized below.

Kakamatua

- The forested areas in the Kakamatua DEM sample are noticeably better smoothed in the Auckland Council copy of the data. This is likely to be due to better removal of non-ground LIDAR strikes in this dataset.

Helensville

- Building footprint removal results in a significantly smoother surface without "gable-end" effects in the Auckland Council copy of the data.
- Hydroflattening is better in the LINZ copy of the data. The river in the sample is about 30m wide.
- The DEM surface under scrub and woody vegetation differs between the 2 datasets.
- Re-contouring of the data shows that the contours derived from the Auckland Council copy of the DEM are closest to the original 25cm topographic contours, except for contours over the water surface for Helensville.

In general, the tests show that transformation of DEM data between AUK 1946 and NZVD2016 datums is a straightforward process, and that much of the DEM data is effectively identical. However there are differences in DEMs in some more rural areas between the 2 copies of the data (AC & LINZ). If recreation of contours is required at NZVD2016, the Auckland Council DEM would be preferred (except for some hydroflattened areas as noted).

See Appendix D for more information.

Topographic contours

25cm topographic contours derived from 2016-2018 LIDAR DEMs were supplied by contractors for the whole Auckland region. The datum is Auckland VD 1946. 25cm contours are currently not available in NZVD2016.
Points along contour lines were sampled & compared with elevations interpolated from the 2016-2018 LIDAR DEMs. There is a good fit to 2016 LIDAR DEM converted to Auckland VD 1946 (+/- 2 cm in Z). Visually the contours are attractive and vertex density has been optimized to reduce storage and aid rapid display.
See also the Auckland Council report *2016 LiDAR close out–Lessons learnt* for notes on contour standards.

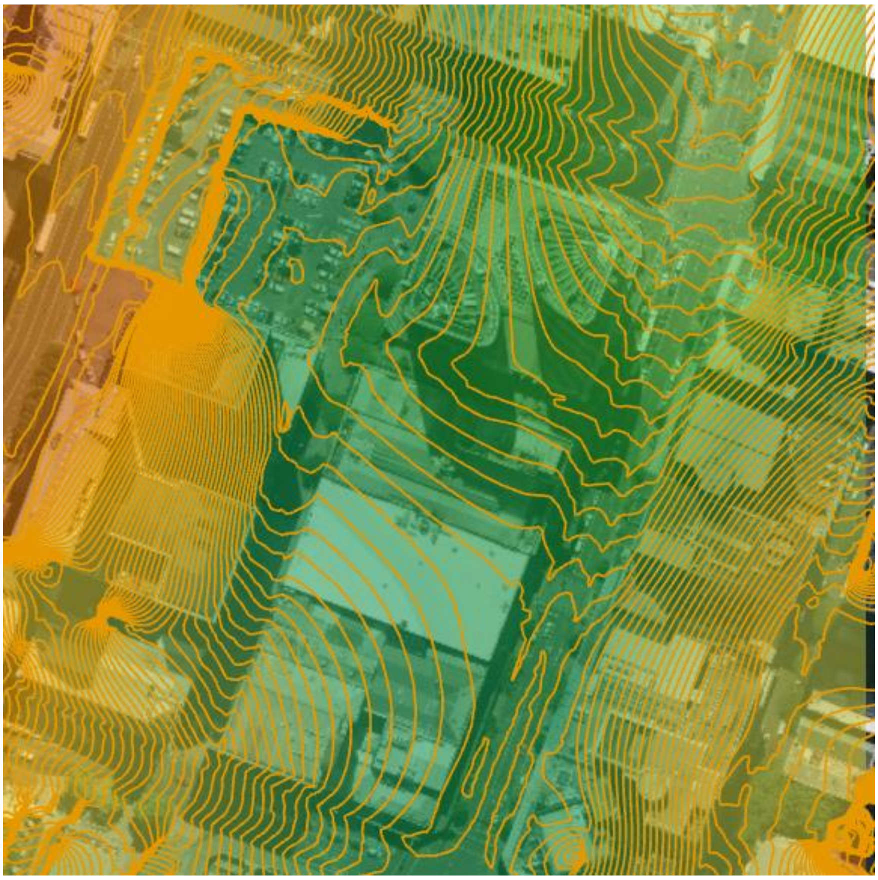

Figure 9 : 25cm topographic contours in Auckland CBD, AUK46, from Auckland Geomaps.

Note smooth interpolation under building footprints in the figure above (part of tile BA32_3603)

Recreation of topographic contours to the NZVD2016 datum

Contours are usually used as a visual guide to the landform surface. If absolute elevation values are required, it is usually best to refer to the LIDAR DEM or survey mark data. Nevertheless, the 25cm topographic contours should be migrated to the NZVD2016 at some point, for consistency and avoidance of confusion. Contouring of the NZVD2016 LIDAR DEM was tested, to confirm that contours can be recreated at a suitable quality to match the existing contour data.

Auckland CBD

Images below show contour data recreated off DEM data in both AUK1946 and NZVD2016 datums for Auckland CBD. In this case, the basic Contour tool was used in ArcGIS Desktop. The contour lines can be subsequently simplified to reduce disk storage requirements.

In these examples, it is straightforward to reproduce contours in NZVD2016 based off the Auckland Council DEM after datum conversion. The contours closely resemble the existing contour data used in Geomaps.

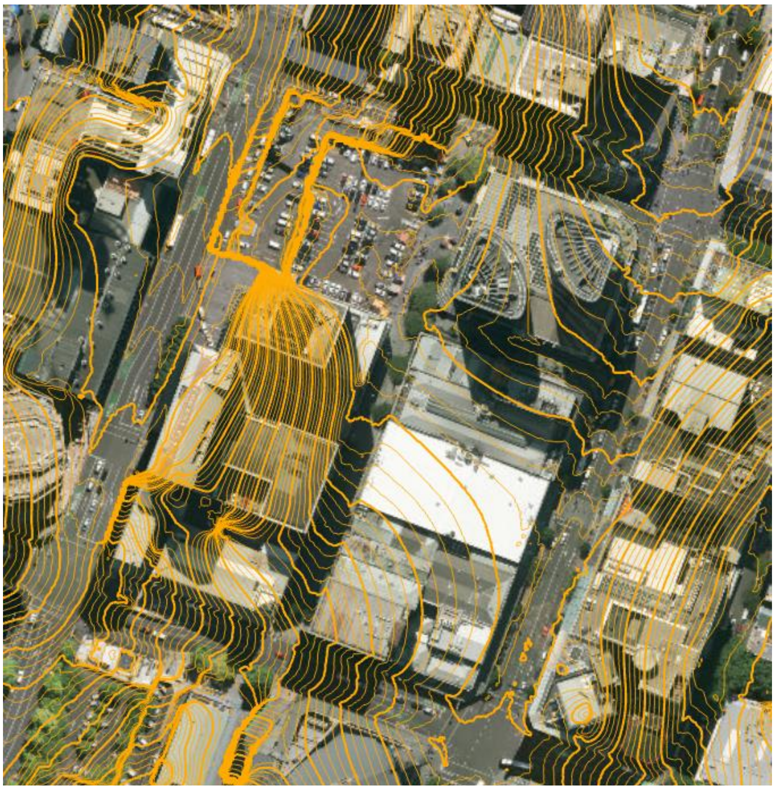
Figure 10: 25cm contours recreated from LINZ DEM (NZVD2016)

The figure above shows recontouring off the LINZ 2016-2018 DEM in NZVD2016, using ArcGIS Contour tool. Part of tile BA32_3603. (1m contours emphasised).

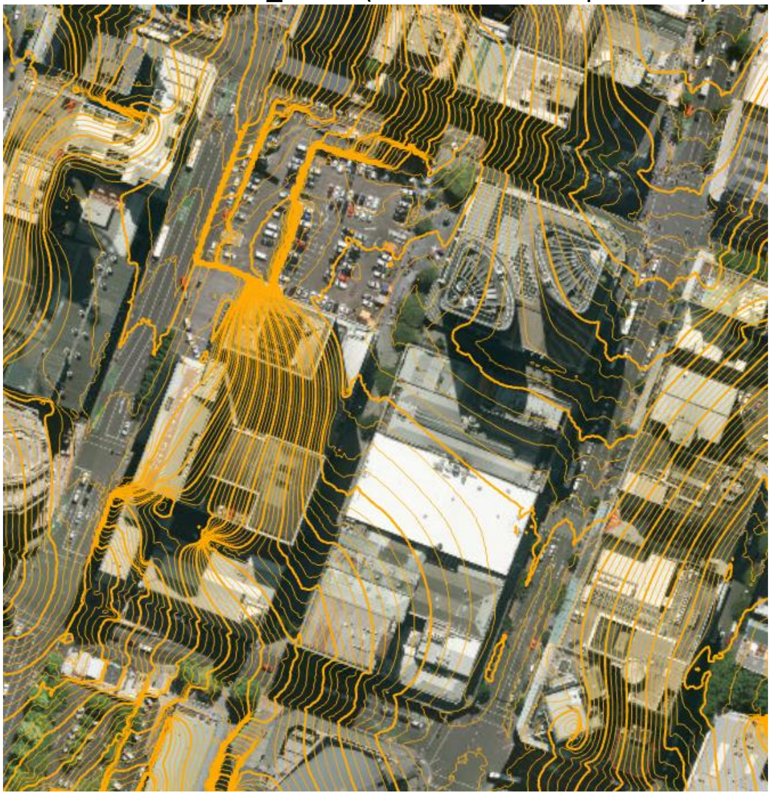
Figure 11: 25cm contours recreated from LINZ DEM (AUK1946)

The figure above shows recontouring off the LINZ 2016-2018 DEM in AUK1946, using ArcGIS Contour tool. Part of tile BA32_3603. (1m contours emphasised).

Kakamatua

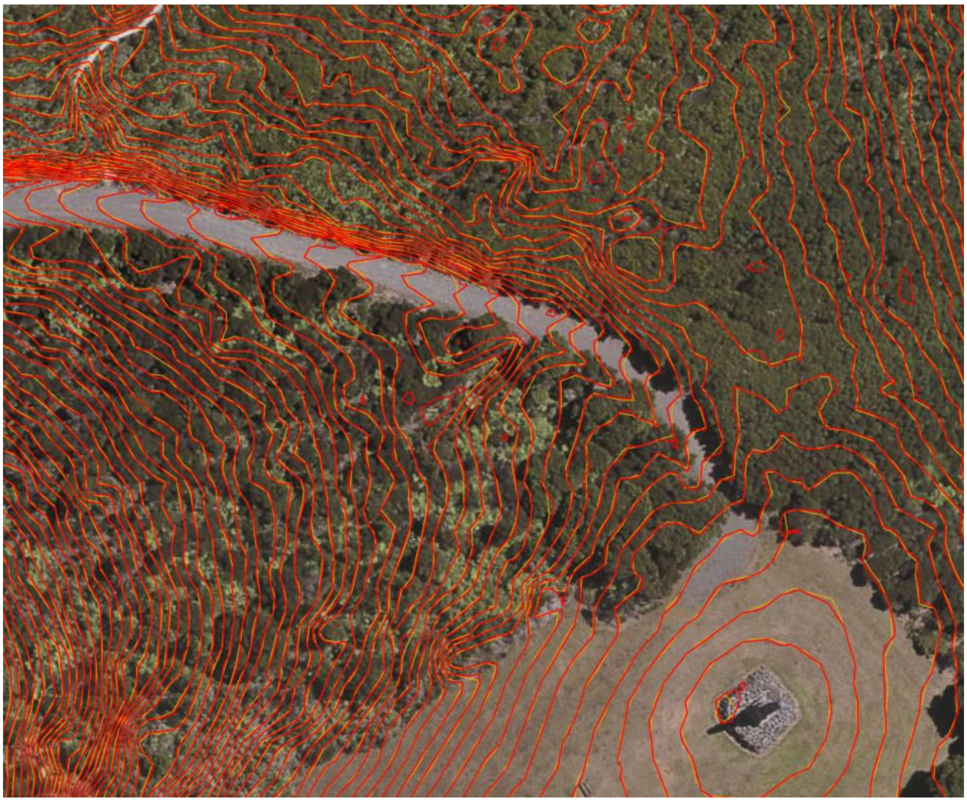

Figure 12: Spragg Monument, Kakamatua – contour comparison

The figure above shows Geomaps contours (orange) and contours from 2016-2018 DEM (red). Note vertex positions are apparent in the Geomaps data. Map view 100m across. Contours from DEM used ArcGIS "Contour" tool followed by "Simplify Line"

Both the QGIS and ArcGIS Desktop Contour tools give good results for contour recreation. Optionally Focal Statistics can be used for local smoothing of the DEM, e.g. *Focal Statistics, circle, radius 2m*.

Contours should be simplified after creation, to reduce storage requirements. Some useable options in ArcGIS are listed below.

ArcGIS Tool	Algorithm	Tolerance
Simplify Line	Douglas-Peucker	0.2m
Simplify Line	Wang-Muller	1.5m
Simplify Line	Zhou-Jones	1m
Simplify Line	Visvalingam-Whyatt	0.75m

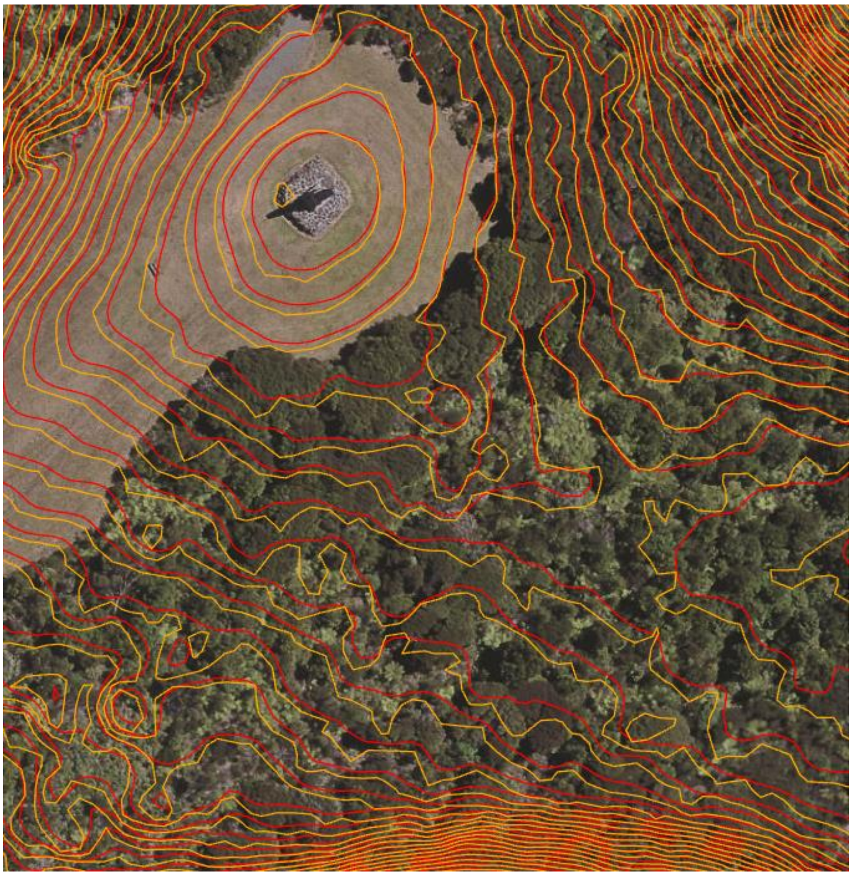

Figure 13: Kakamatua – effects of smoothing the DEM before recontouring.

The figure above shows Geomaps contours (orange) and recontouring from smoothed NZVD2016 DEM (red – Focal Statistics, Circle, 2). Map view 40m across.

Impact of change

The impact of change on Auckland Council geospatial users should be minimal. Both the DEM for internal use and contours in Geomaps should be swapped out. Suitable metadata & advisory messages will be required.

Conclusion

Overall the Auckland Council 2016-2018 DEM and topographic contour products are of excellent quality. The 1m DEM in AUK46 Datum being used by Auckland Council can readily be converted to NZVD2016 using the LINZ datum conversion data. The DEM should not be swapped out for the 1m DEM in NZVD2016 sourced from LINZ Data Service (e.g. https://data.linz.govt.nz/layer/106410-auckland-north-lidar-1m-dem-2016-2018/) due to differences in LIDAR data interpretation noted above. The Auckland Council DEM has been enhanced in some areas compared to the equivalent LINZ dataset.

The 25cm contour products can be readily recreated based off the Auckland Council LIDAR DEM when transformed to NZVD2016 using commonly available GIS tools. This can be done either using Terrasolid Terrascan (as detailed in the Auckland Council "Lessons Learned" notes) or using ArcGIS tools. There may be minor issues with contouring some water areas as noted for the Helensville sample area, but this appears to be a problem in a limited area & most hydroflattening of the Auckland Council DEM is of high quality.

Recreation of contours is not a high priority but should be done in conjunction with other datum conversion work to avoid potential confusion for users of Auckland Council Open Data and of the Unitary Plan. All DEM and contour products made available via Open Data should carry appropriate metadata on the vertical datum being used.

3.2 Auckland Unitary Plan (Operative in Part)

Introduction

The Auckland Unitary Plan (Operative in Part), herein referred to the Plan, takes into account height related matters from the Resource Management Act 1991 (RMA), National Policy Standards (NPS), and decisions of the High and Environment Courts for Council's action. The Plan contains approximately 400 references to datum requirements across Council's roles, including resource consents, stormwater, and transport. Council has been preparing for the change to NZVD2016 and this is apparent throughout the Plan. In general the required elevation corrections for NZVD2016 to meet the requirements of NPS have been thoroughly and correctly applied across restrictions on heights, relative levels, and planning. All elevation descriptions should be relative to NZVD2016.

Additionally, the proactive amendment to the Plan with heights in NZVD2016 where applicable by Council shows a positive step in data governance and long-term assurance of digital data. See https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/unitary-plan/auckland-unitary-plan-modifications/other-plan-updates/1452021/memo-section58i-new-zealand-vertical-datum-2016.pdf describing updates in 2021 which changed all elevation values using reduced levels (RL) in AUK1946 to NZVD2016.

The following are several examples of where elevation information in the Plan should be reviewed.

Use of Expressing Height Values

Policy 3 of the National Policy Statement on Urban Development requires Council to identify building heights, and specifically "in all cases building heights of a least 6 stories". This would now be in height above ground, expressed in NZVD2016. Other height measures with reference to ground level would thus also now be expressed in values of NZVD2016.

Measuring height with Reduced Levels

Reduced Levels are the predominant means of defining a height Rule, but the Plan also refers to measuring an average height across an area by means of "mean street level" or the horizontal plane above that level [Plan H8.6.8.2]. Such terms are relatively similar to infer heights above a series of other points, but terms such as "mean street level" would be a common term understandable, which could be further clarified in an interpretation. Providing guidance on Relative Levels within Definitions (Plan Chapter J10) would ensure the avoidance of doubt to the definition of height and where this was to apply.

Spatially defined height rules

Additional Rules within the Plan allow for practical applications of height-related matters. An area where this may require further explanation is the conversion from Mean Sea Level (MSL) to NZVD2016 with a direct equivalent using a Reduced Level of 1.7m for discharge in stormwater management areas (Table E10.4.1 (A1)). The value of 1.7m is possibly an approximation to the Mean High Water Springs (MHWS) level used to define the CMA boundary. However, in practice MSL differs from AUK46 0m due to sea-level rise since 1946 and to regional variations in MSL.

Spatially-defined Rules would also allow for sensitivities of stormwater models along the coastline. However, the implications appear to be very minor but guidance may sought from NIWA to ensure levels are adequately defined in localised areas. The Plan also notes that coastal areas are defined by the MHWS datum, with use of rules to determine the Coastal Protection Yard (Chapter M Appendix 6).

Use of existing Mean Sea Level for Aerodromes

Regarding transport matters of aerodromes, the Plan has references to Civil Aviation Authority (CAA) in the use of aerodrome requirements. We assess the impact on the Council would need to be in time with consultation with CAA to ensure Regulations are met.

Covenants on LINZ Titles

While not directly within the Plan, restrictive covenants registered on titles relating to heights may be impacted, including limits to the building height or minimum floor levels used to minimise flood risk, or for viewsheds. Historically this would have been in terms of AUK46, but without any clear indication of what vertical datum is in terms of either a distance relative to the ground, or the datum value of 0. A procedure to address this may be required, with management through a transition period when titles are lodged with LINZ

3.3 Asset Datasets

Introduction

Asset samples from all available asset classes were downloaded from Auckland Council GeoMaps and Auckland Council and AT Open Data Sites for the 9 test areas. The data was examined for attributes that would be affected by datum changes. Asset class groups are listed below.

Asset Class Group	Asset Classes	Comment	Action Required
Kerblines	Kerblines	Auckland Council from aerials 2008. No Z values.	No
Building Footprints	Building Footprints	Auckland Council from aerials 2008. No Z values.	No
Impervious surfaces	Impervious surfaces	Auckland Council from aerials 2008. No Z values.	No
Bridges	AT Bridges	AT Open Data, no Z values	No
Stormwater	13 stormwater asset classes	Several stormwater asset classes have elevation data	Yes
Wastewater	Various *	Wastewater assets accessible via Auckland Council Open Data	No
Water Supply	Various *	Some water supply assets accessible via Auckland Council Open Data	No

* *see https://data-watercare.opendata.arcgis.com/ and https://watercare.maps.arcgis.com/apps/webappviewer/index.html?id=3944a60cbf864b9494087cd39094e114 for Watercare GIS data. Out of scope for this report.*

Background

AC GIS asset data is derived from SAP asset systems and made available for download via FME automation (GeoMaps) or as ESRI Open Data layers.

36 asset feature classes were discovered and samples were downloaded. Only stormwater feature classes were found to have elevation values and be in-scope. Wastewater and potable water supply assets are managed by Watercare and are out of scope for this report. The wastewater and water supply asset data in Auckland Council GeoMaps appears to be identical to the data in Watercare's websites and is presumably replicated across from Watercare.

Stormwater asset data classes combine data with a wide range of ages, from about 1928 through to the present. In general, older data was often of poor elevation accuracy and attribute completeness, whilst more modern data (e.g. from recent as-builts) often has much more accurate elevations and higher attribute completeness. For example, in older data, connected pipes can show major variations in invert elevations where they join to a stormwater chamber, and sometimes the upstream pipe exit is apparently lower than the downstream pipe inlet point.

Some data had been topologically cleansed for network connectivity, and notably stormwater manhole data has a high accuracy when compared with the 2016-2018 LIDAR DEM in AUK46 datum. This suggests that manhole elevations may have been corrected based off DEM elevations.

Data Sources

A full list of data sources is given below.

Asset Class	Asset Layer	Comment	Action Required
Kerblines	Kerblines	Auckland Council from aerials 2008. No Z values.	No
Building Footprints	Building Footprints	Auckland Council from aerials 2008. No Z values.	No
Impervious surfaces	Impervious surfaces	Auckland Council from aerials 2008. No Z values.	No
Bridges	AT Bridges	AT Open Data, no Z values	No
Stormwater	Stormwater_Catchpit_point		Yes
	Stormwater_Connection_line		Yes
	Stormwater_Manhole_And_Chamber_point		Yes
	Stormwater_Pipe_line		Yes
	Stormwater_Inlet_And_Outlet_point		Yes
	Stormwater_Treatment_Device_Point	Has elevation level fields, rarely populated	Yes
	Stormwater_Channel_line	Has invert level fields, rarely populated	Yes
	Stormwater_Soakage_System_point	n.b. newly submitted asbuilt of a SWS chamber would show an LL and invert	No
	Stormwater_Watercourse_line	Has invert level fields, rarely populated	Yes
	Stormwater_Abandoned_Pipe_line	Has invert level fields, rarely populated	Yes
	StormwaterCatchment_polygon		No
	Stormwater Septic Tank	Source : Auckland Council Open Data site	No
	Stormwater Treatment Device	Source : Auckland Council Open Data site	No
Wastewater	Wastewater_Manhole_Local_point	LID_LEV often populated. Often show inv depth and inv level.	Yes

	Wastewater_Fitting_Local_point	No elevation values in attributes.	No
	Wastewater_Pipe_Local_line	No elevation values in attributes.	No
	Wastewater_Fitting_Transmission_point	No elevation values in attributes.	No
	Wastewater_Manhole_Transmission_point	No elevation values in attributes.	No
	Wastewater_Pipe_Transmission_line	No elevation values in attributes.	No
	Wastewater_Other_Structure_Local_polygon	No elevation values in attributes.	No
	Wastewater_Pump_Station_Local_polygon	No elevation values in attributes.	No
	Wastewater_Pump_Station_Transmission_polygon	No elevation values in attributes.	No
Water Supply	Water_Chamber_Transmission_polygon	No elevation values in attributes.	No
	Water_Hydrant_Local_point	LID_LEV is null	No
	Water_Other_Fitting_Local_point	No elevation values in attributes.	No
	Water_Other_Fitting_Transmission_point	No elevation values in attributes.	No
	Water_Pipe_Local_line	No elevation values in attributes.	No
	Water_Pipe_Transmission_line	No elevation values in attributes.	No
	Water_Pump_Station_Transmission_polygon	No elevation values in attributes.	No
	Water_Reservoir_Transmission_polygon	No elevation values in attributes.	No
	Water_Valve_Local_point	LID_LEV is null	No
	Water_Valve_Transmission_point		No

Investigation

Investigation of asset data had 2 main aims :

1. Whether any significant pipe gradient changes would occur as a result of the datum change to NZVD2016;
2. To determine which data classes and the amount of data that will need to be updated for the datum change to NZVD2016;

Impacts of datum change on asset data gradients

Some slight irregularities (or “hot spots”) in the datum change surface raised concerns that these might have impacts on gradients of linear features, such as stormwater pipes. These irregularities are created by the greater accuracy of the new datum revealing errors in the earlier datum, which was established by levelling before GNSS survey was available. Note that the maximum gradients of change to the topographic land surface are still very low (about 1cm per 1Km).

Tests were performed on asset data samples to check if the datum change would create any significant difference in gradients along pipes.

91 stormwater pipes with complete attribution for invert levels and ground elevations were extracted from asset data in the Freemans Bay area of Auckland. This is an area in one of the “hot spots” for datum change gradients.

Pipe gradients were calculated for pipe inverts in AUK1946 datum, and also when transformed to NZVD2016. The sample pipes are shown in the map below, with upstream (yellow) and downstream (magenta) end points.

Figure 14: Stormwater pipes used in pipe gradient tests. Freemans Bay area.

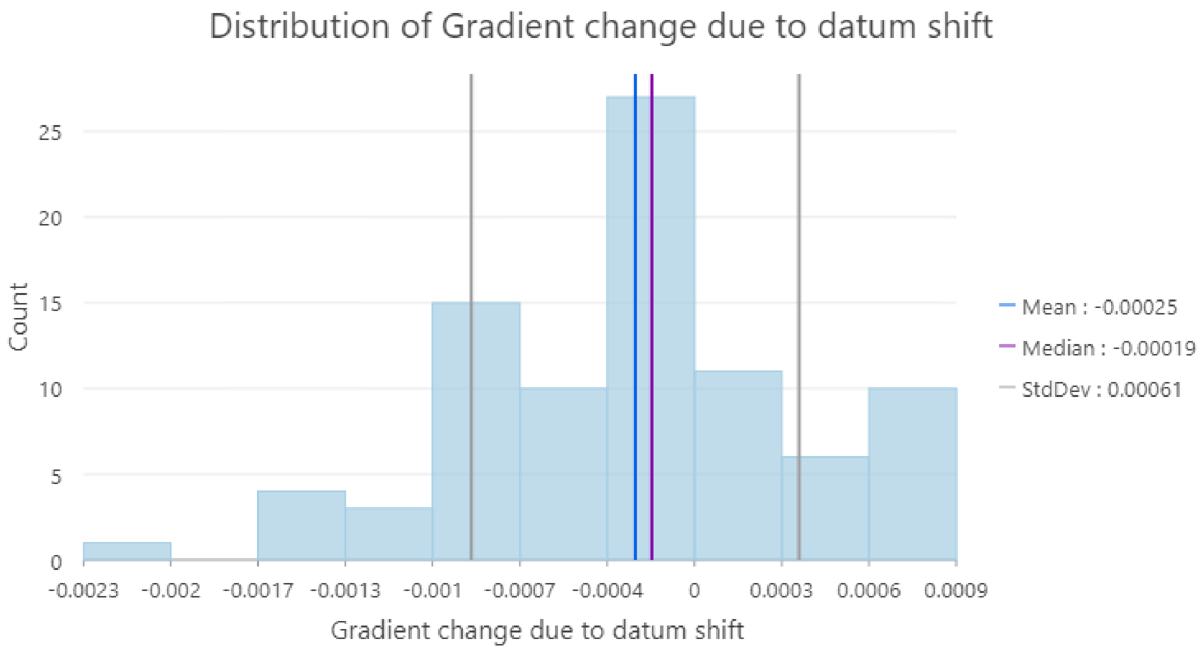

Figure 15: Summary graph of gradient changes (in degrees) due to datum change to NZVD2016.

In conclusion, the gradient changes due to datum shift are insignificant for sampled assets. See also Appendix E for tests on slope angle changes due to datum changes.

Impact of change

Overall, 16 attribute fields for 9 stormwater asset feature classes were identified as needing to be updated to convert elevation values to NZVD2016. These fields are listed below. The suggested methodology is given in **Section 6** (GIS Update Methodology).

Asset Class	Asset Layer	Feature count	Attribute Quality	Approx Completeness	Fields
Stormwater	Stormwater_Catchpit_point	128,235	Good for recent data, absent in older data	30	SW_GRATE_LEVEL_M
				30	SW_COVER_LEVEL_M
	Stormwater_Connection_line	218,462		10	SW_INVERT_LEVEL_DOWNSTREAM_M
				10	SW_INVERT_LEVEL_UPSTREAM_M
	Stormwater_Manhole_And_Chamber_point	181,441	Good elevation accuracy	70	SW_COVER_LEVEL_M
				70	SW_INVERT_LEVEL_M
	Stormwater_Soakage_System_point	3,953		10	SW_LID_LEVEL_M
				10	SW_INVERT_LEVEL_M

	Stormwater_Pipe_line	294,162	Variable elevation accuracy	60	SW_INVERT_LEVEL_DOWNSTREAM_M
				60	SW_INVERT_LEVEL_UPSTREAM_M
	Stormwater_Abandoned_Pipe_line			20	SW_DEPTH_DOWNSTREAM_M
				20	SW_DEPTH_UPSTREAM_M
	Stormwater_Inlet_And_Outlet_point	35,906		10	SW_INVERT_LEVEL_M
	Stormwater_Treatment_Device_Point	6,326	Has elevation level fields, rarely populated	15	SW_LID_LEVEL_M
	Stormwater_Channel_line	6,163	Has invert level fields, rarely populated	10	SW_INVERT_LEVEL_DOWNSTREAM_M
				10	SW_INVERT_LEVEL_UPSTREAM_M

Conclusion

For asset data, the updating of elevation data should be straightforward. There are no appreciable effects on pipe gradients. Overall the Auckland Council asset data can be fairly easily updated using standard GIS tools. This can be done in bulk, converting all attributes in a feature class in a single operation, using the LINZ datum correction surface. This might be done during a scheduled “brown-out” of access to map services. Attribute fields might be duplicated to provide elevation values to both datums, if this is suitable for current systems and workflows.

3.4 Freshwater Data

Introduction

AC GIS datasets related to freshwater data were downloaded and checked to see if they hold elevation values, and whether these would need updating for the new datum. In addition, there was concern that datum changes might affect underlying definitions of data, so the derivation of some freshwater datasets was checked.

Data Sources

The table below shows GIS datasets related to freshwater, and whether they hold attribute data for elevations. Only the Flood Prone Areas dataset were found to hold elevation attributes.

Marine dataset	Elev data	Comments	Source
OverlandFlowPaths_line	No	Has CatchmentAreaGroup attribute for each watercourse	AC Open Data
FloodProneAreas_polygon	Yes	Potential ponding areas that have no natural outlet and may flood frequently.	AC Open Data
FloodPlains_polygon	No	Modelled 100-year flood areas including max development and climate change factors	AC Open Data
Flood Sensitive Areas	No	Areas adjacent to the 100yr ARI floodplain that are within 0.5m of the predicted 100yr ARI flood level.	AC Open Data
StormwaterCatchment_polygon	No	Stormwater catchments with name of receiving environment.	AC Open Data

Investigation

Overland flowpaths

The Overland flowpaths line layer shows the predicted natural flow path of water over the ground when the stormwater network is overloaded. This layer is a dissolved version of the OverlandFlowPaths layer where each segment is classified by its upstream catchment area, which is categorized into 4 ranges.

The layer is an update of an existing layer and was created by WSP Opus in 2019. The layer was generated using the D8 flow model algorithm in ArcGIS.
As this data is modelled based off DEM data, the layer was recreated using DEMs in both AUK1946 and NZVD2016 datums to assess the effects of the datum change. This was done for these test areas :

- Helensville
- Pine Valley / Silverdale

- Freemans Bay

In each case, an identical conventional ArcGIS workflow was used, as follows :

1) **DEM** = clip extract from 2016-2018 LIDAR DEM, in appropriate vertical datum
2) **Fill** to fill any pits in the DEM
3) **Flow Dir** with D8 to create a flow direction grid
4) **Flow Accumulation** with D8 to create a flow accumulation grid
5) **Con** using a threshold of 2000 for flow accumulation
6) **SetNull** for Value=0 to set cells with zero values to null
7) **StreamOrder** tool to define stream order using the Strahler method
8) **Stream to Feature** to create stream vectors from the grid (with no simplification)

Note that the exact details of the original modelling workflow are unknown, such as flow accumulation thresholds, so this comparison is only an approximation.

Figure 16: A comparison of overland flowpaths.

The figure above shows recalculated watercourse lines in red, and original Auckland Council watercourses in blue (AUK1946 datum DEM used for calculation of new lines). Size of map image is about 800 metres across

It is unclear which datum was used for the DEM from which watercourses were modelled. All modelled datasets from DEM samples in both datums differ slightly but inconsistently from the original watercourse data. Differences are almost all in lower-order (the smallest) watercourses.
The watercourse modelling appears to be highly sensitive to very minor DEM differences for low-order streams. It was noted that some example stormwater engineering reports (e.g. https://www.aucklandcouncil.govt.nz/ResourceConsentDocuments/BUN60313600-Stormwater-Report.pdf) also report some differences when remodelling flow paths from the 2016-2018 DEM. The reason for these differences is not clear.

Figure 17: A comparison of datum effects on watercourses.

The figure above shows recalculated watercourses using 2 different vertical datums for the base DEM. Watercourses for NZVD2016 DEM in yellow, from AUK46 DEM in red. Area is Herne Bay / Ponsonby.

Figure 18: Detail area from previous figure.

The figure above shows more detail. 0.25m contours in orange. Note the NZVD2016-derived data matches the original Auckland Council watercourse data best.

The DEM used for Auckland Council watercourse modelling has clearly been hydrologically conditioned from the original DEM data, for example where culverts and bridges appear as obstructions to flow in the DEM. In these cases, the appropriate watercourse channel has

probably been “burnt-in” to the DEM. The figure below illustrates the great impact this can have in correcting flow paths.
The hydrological conditioning of the DEM would account for some but not all differences observed between the Auckland Council watercourse data and remodelled sample datasets. The hydrological conditioning is usually a labour-intensive part of this type of modelling.

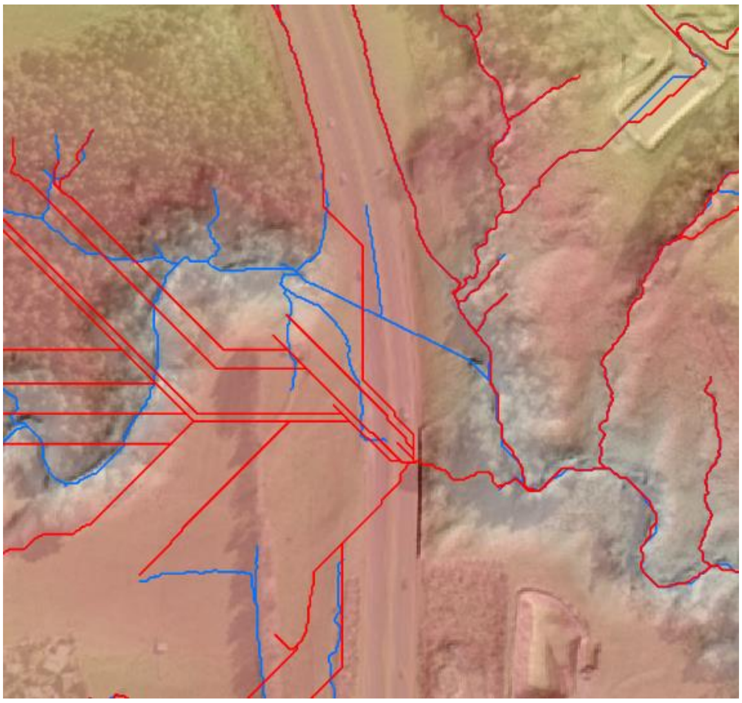

Figure 19: Watercourse running through culvert under expressway in Silverdale.

In the figure above, the correct culvert position under expressway earthworks is shown in Auckland Council watercourses data (blue). Calculated watercourses from AUK46 DEM (red) interpret this as an obstacle. Location is in Silverdale.

Figure 20: Helensville – watercourses example.

In the figure above, only minor differences exist in open terrain with low relief (when stream courses falling in the river are ignored). Calculated watercourses from NZVD2016 (yellow). Calculated watercourses from AUK46 DEM (red) show minor differences.

The hydrological conditioning work performed on the original DEM to correct errors would have been a major investment in time and effort.

It has been observed in the report section on asset gradients that gradient changes over a bare-earth DEM due to the datum changes are very minor (maximum 1cm in Z over 1 Km distance). Observed changes to modelled flow paths due to datum changes are fairly minor (e.g. see figure above for Herne Bay).

It is important to retain the value added to the modelling by the hydrological conditioning of the DEM by WSP Opus. It is suggested that the existing Overland Flowpath data is retained as-is for the time being, as it is fit for purpose. Lower-order streams will be affected by datum change but overall the impact is low. This has been discussed with Healthy Waters staff who are aware of the effects of datum change.

Flood Prone Areas

A layer is present in GeoMaps and through Auckland Council Open Data which shows Flood prone areas. (FPA) are potential ponding areas that have no natural outlet and may flood frequently. FPA are topographical depressions. Attributes of FPAs include the Spill Elevation, which is in metres to AUK1946 datum. A topographic contour created from the DEM at the spill elevation of any FPA closely follows the FPA polygon perimeter.

Examples of FPA polygons were checked to see if changing the datum has any effect on the FPA area, based on the assumption that contouring can define the perimeter.

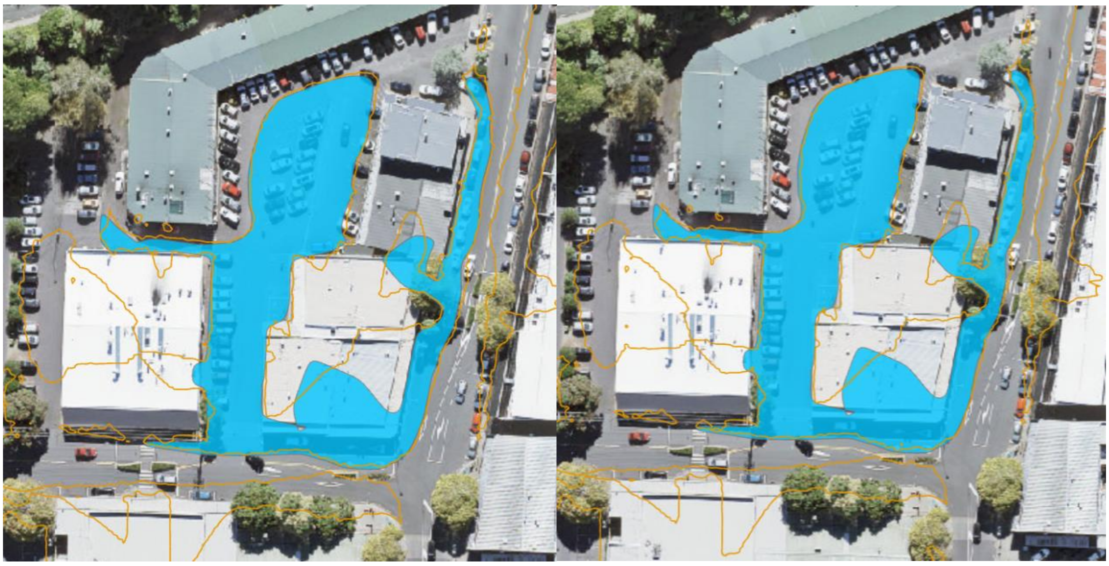

Figure 21: A typical Flood Prone Area (FPA)

The figure above shows FPAs in blue, with equivalent perimeter contours at the spill elevation in AUK1946 (4.25m, left) and NZVD2016 (3.96m, right). Browns Bay, North Shore

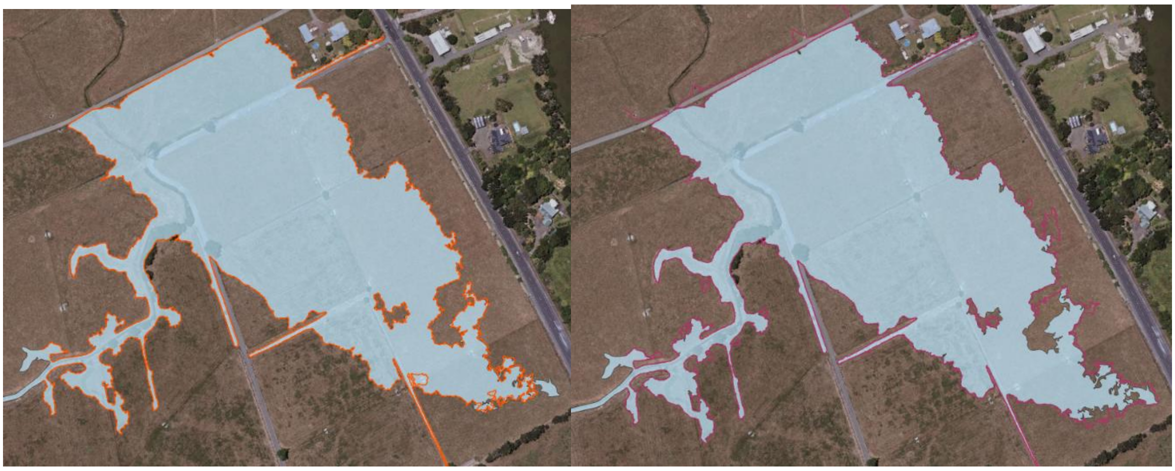

Figure 22: A typical FPA, Helensville area.

The figure above shows an FPA in Helensville, with equivalent perimeter contours at the spill elevation in AUK1946 (2.31m, left) and NZVD2016 (2.05m, right).

Whilst the exact derivation of the FPA is unknown to the author, the examples appear to show that any changes to FPA areas due to the datum change will be negligible. The Spill Elevation attribute will need to be updated to NZVD2016, other attributes such as depth will remain unchanged.

Flood Plains polygons

The Flood Plains dataset published in Auckland Council Open Data contains 2D polygon extents for over 100 flood plain areas, from a number of studies. The flood plains indicate the area of land inundated by runoff in a storm event that has a 1 percent or greater probability of occurring in any given year (1% AEP), assuming maximum probable development (MPD) and future climate change.

The Flood Plain polygons were created from a series of 3D flood modelling projects using tools such as DHI MIKE 21 and are of various dates from 2008 onwards. They depend upon digital terrain models (DTMs) that will be affected by the datum conversion. Remodelling any data is beyond the capabilities & brief of this report, however some comments can be made based off the available data.

The largest single flood plain feature in the dataset is the Hoteo River floodplain polygon from a 2008 study. The Hoteo River drains into the Kaipara Harbour in the NW of the region. It has a 55 Km2 modelled flood plain area within a catchment of about 420 Km2.

The catchment outline is shown in the figure below, superimposed on a layer showing the variation in the datum conversion surface, AUK1946 to NZVD2016. The datum conversion value varies from approx 28.5cm to 32.5cm across the catchment, with an approx mean of 30.5cm. The datum conversion can be thought of as a mathematical translation of the terrain model (DTM) along the Z-axis of 30.5cm, with a local variation of +/- 2cm across the catchment.

This local variation (+/- 2cm) is the only part of the datum conversion that will impact the flood model; the rest is just a shift of the reference frame. Given that the DTM used in the flood model was created before the Auckland Council 2016-2018 LIDAR DEM & most likely much less accurate, and the model grid size was 20x20m, the 2cm local variation is unlikely to have an impact on the modelled floodplain extent.

It is concluded that the datum change to NZVD2016 will not make any significant changes to modelled floodplain extents.

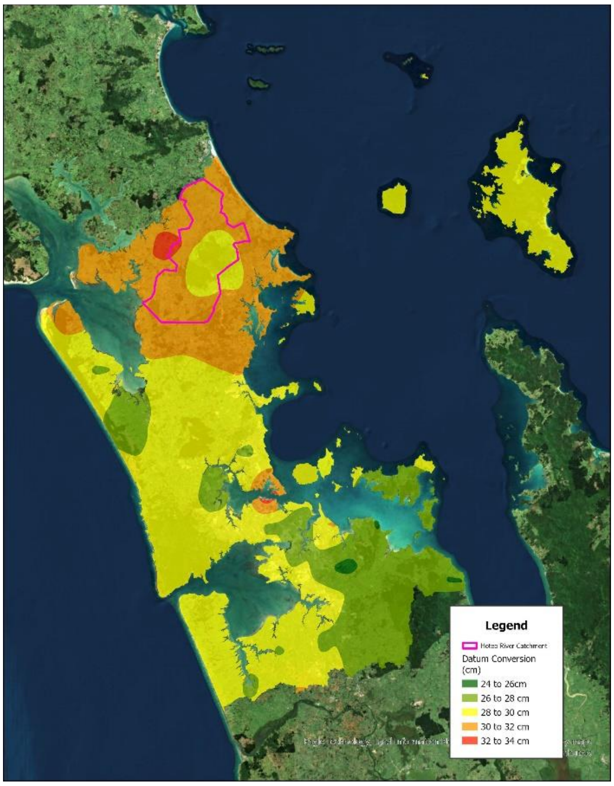

Figure 23: Extent of the Hoteo River catchment.

The figure above shows the extent of the Hoteo River catchment (outline in pink, top of map), superimposed on a map of the datum conversion surface model for Auckland Region.

Stormwater Catchment polygons

A polygon feature class for Stormwater Catchment polygons is available in GeoMaps. It has no elevation attributes. Its derivation appears to be manual, to separate existing parts of the stormwater network. It appears to have been adjusted away from catchment boundaries that would be derived from the 2016-2018 LIDAR DEM. It is assumed that datum changes will have no impact on this dataset.

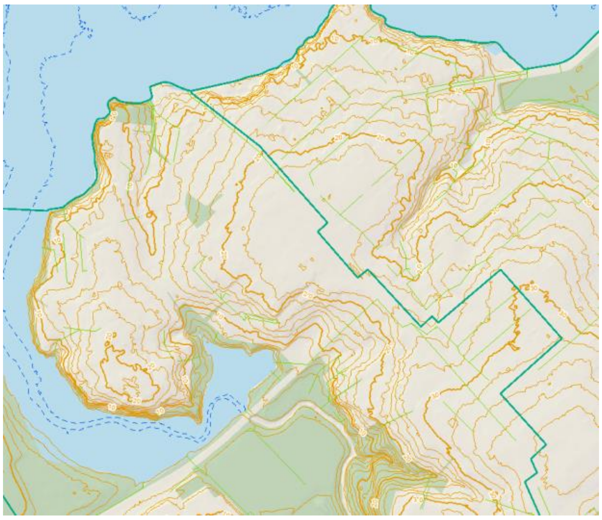

Figure 24: Stormwater catchment boundary example (green)

The figure above shows stormwater catchment boundaries in Western Springs. Faint green lines show stormwater pipes. The boundary is defined relative to as-built stormwater networks, so will not be affected by any datum change. Source : Auckland Council Geomaps.

Impact of change

The only digital dataset in the Freshwater class that needs attention for datum conversion is the Flood Prone Areas dataset. The Spill Elevation attribute for this dataset will require adjusting to NZVD2016.

Conclusion

The impacts of change on data in the Freshwater datasets appear to be low and easily addressed with updates to one polygon theme as above. Healthy Waters are aware of the implications of change for the Overland Flowpaths dataset & this has been discussed. The Flood Plain polygons dataset is assessed as not requiring change.

3.5 Coastal and Marine Datasets

Introduction

AC GIS datasets related to coastal and marine data were downloaded and checked to see if they hold elevation values, and whether these would need updating for the new datum. In addition, there was concern that datum changes might affect underlying definitions of data, so the derivation of some coastal inundation datasets was checked.

Data Sources

The table below shows GIS datasets related to coastal and marine topics, and whether they hold attribute data for elevations. Only the Moorings and Coastal Inundation High Water Levels datasets were found to hold elevation attributes.

Marine dataset	Elev data	Comments	Source
Tsunami_Evacuation_Zone	No	No datum effects	AC Open Data
50yr inundation	No	Derived from analysis carried out by Stantec in 2020	AC Open Data
CoastalInundationHazard ("current" data includes 2020 recalcs)	No	Aggregation of current and superceded data layers for inundation; includes latest 2020 updates	AC Open Data
Coastal_Inundation_5_yr_return_1m_sea_level_rise	No	The new data published replaces the 2018 inundation extent and has been derived from analysis carried out by Stantec in 2020.	AC Open Data
Coastal_Inundation_20_yr_return_1m_sea_level_rise	No	The new data published replaces the 2018 inundation extent and has been derived from analysis carried out by Stantec in 2020.	AC Open Data
Coastal_Inundation_50_yr_return_1m_sea_level_rise	No	The new data published replaces the 2018 inundation extent and has been derived from analysis carried out by Stantec in 2020.	AC Open Data
Coastal_Inundation_100_yr_return_1m_sea_level_rise	No	The new data published replaces the 2018 inundation extent and has been derived from analysis carried out by Stantec in 2020.	AC Open Data
Coastal Inundation High Water Levels	Yes	Points for high water levels as in Table 4-3 of TR2020/24 etc, in AUK46	AC Open Data
Coastal_Inundation_annual_exceedance_probability	No	100yr ARI with 0.0, 0.5, 1, and 2m SLR layers	AC Open Data
Susceptible Areas ASCIE 2080 RCP85 Regional	No	Area Susceptible to Coastal Instability and Erosion (ASCIE)	AC Open Data
Moorings	Yes	Mooring points with depth of mooring - M_DEPTH field	AC Open Data

Investigation

Moorings

A feature class of boat mooring points with a depth of mooring attribute is available through Auckland Council Open Data. The [M_DEPTH] field appears to be the depth below water of the mooring buoy, for swing moorings. No metadata is defined in GeoMaps but it is assumed that this is related to a tidal datum and no change is required. The data appears to be primarily owned by AT *(https://at.govt.nz/boating-marine/moorings/#zones)*

Coastal Inundation Data

Several layers are present in GeoMaps and through Auckland Council Open Data which show modelled extents of various coastal inundation hazards. They model the effects of extreme marine water levels due to tide effects plus storm surge, and optionally sea level rise, for a variety of scenarios.

The coastal inundation hazard layers are based on tables of data in a set of commissioned reports aggregated as a single document in 2020 (*Carpenter, N., R Roberts and P Klinac (2020). Auckland's exposure to coastal inundation by storm-tides and waves. Auckland Council technical report, TR2020/24).* The layers were all recreated in 2020 to take advantage of the improved elevation data in the 2016-2018 LIDAR DEM.
All of the coastal inundation layers have been derived in a similar manner based off data in the report TR2020/24. However one layer is particularly important as it is used in a rule in the Auckland Unitary Plan (Section E36.9). This layer is the *Coastal Inundation 100 yr return 1m sea level rise* polygon feature class.
This rule is also referred to in the Design Manual :
https://content.aucklanddesignmanual.co.nz/regulations/codes-of-practice/Documents/SW-CoP-v3-January-2022.pdf (Table 5, p.31)

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Extreme water levels and habitable floor calculations

For properties located within the 1% Annual Exceedance Probability (100-year ARI) Coastal Inundation Zone plus 1 m of sea-level rise, the Auckland Unitary Plan specifies that habitable floor levels must be above the 1% AEP plus 1 m sea level rise. A freeboard allowance is added to the calculated flood level to result in a minimum ground and/or floor level to account for any uncertainties associated with historical data and hydraulic assessments. To calculate habitable floor levels, freeboard plus 1 m (representing sea level rise) is added to the nearest high sea level value. High sea level values vary by area, with the open coast values including wave-set up heights, and are split across the 2013, 2016, and 2019 reports as detailed in Section 2 and Table 1.
Freeboard : 500 mm for dwellings and habitable rooms which are subject to wave action from the sea, 150 mm for all other cases

Source : Section E36.9 of the AUP

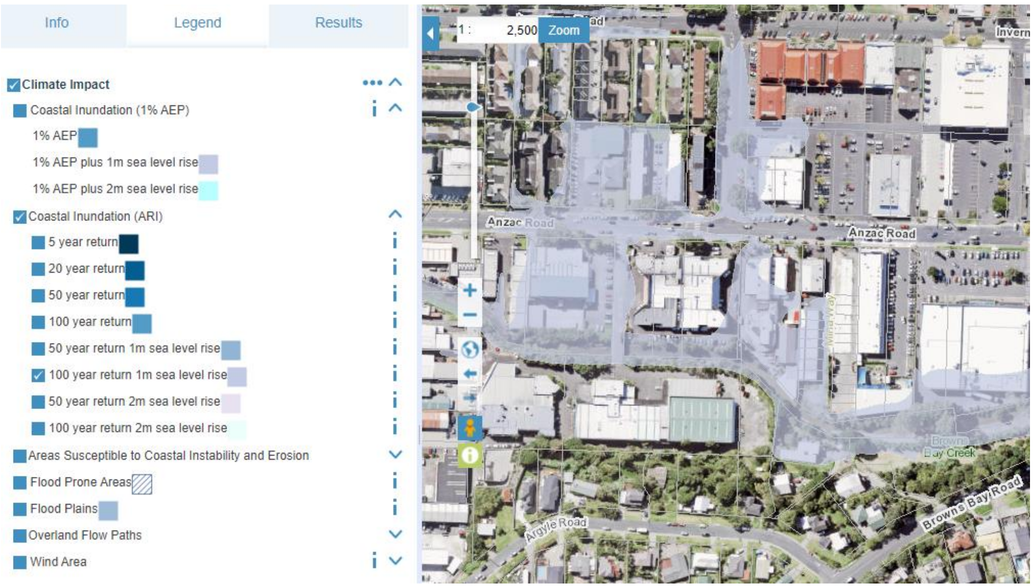


Figure 25: Example of properties affected by ARI 100 indundation zone with 1m SLR (GeoMaps - Browns Bay, North Shore)

Appendix F lists some worked examples of the derivation of the modelled coastal inundation areas. The vertical datum change will have no effect on these datasets.

Tsunami Evacuation Zone

A polygon feature class for the Tsunami Evacuation Zone is available in GeoMaps. It has no elevation attributes. Its derivation is assumed to follow similar logic to the coastal inundation zones, so no updates should be required for the datum change.

Impact of change

The only digital dataset in the coastal and marine group that will require update is the point layer *Coastal Inundation High Water Levels* which is derived from the tables in TR2020/24. These values are all expressed as elevations relative to AUK1946. This layer can easily be updated in bulk using standard GIS tools (see Section 5 for conversion methods).
The tables in TR2020/24 may also require updating to convert values to NZVD2016 at some point. This will not be urgent as the existing datum is clearly referenced in the report.

Conclusion

The impacts of change on data in the Marine and Coastal are minimal and easily addressed with updates to one point theme as above.

3.6 Other Non-Public Datasets

Introduction

Some Auckland Council GIS datasets related to stormwater, environmental monitoring, the Unitary Plan, and bathymetry have been received directly from Auckland Council, as they are not shared via Open Data. These datasets have elevation attributes.

Feature Class Group	Feature Classes	Comment	Action Required
Stormwater	Stormwater Survey Structures	Auckland Council from field survey. Z values.	Yes
	Stormwater Survey points	Auckland Council from field survey. Z values.	Yes
	SW Erosion and Control areas	No elevation values populated	No
	SW Embankments	Elevation values but rarely populated	Yes (minor)
Environmental Monitoring	Environmental Monitoring Points	Auckland Council for field sites. Z values.	Yes
Unitary Plan	Viewshaft Contours	Contours above ground level	No
Bathymetry	Bathymetry	Bathymetry polygons	No

Storm water survey structure points

352 Storm water survey structure points features in Browns Bay were sampled and checked. 100% of features are populated with non-null [RLMeters] attribute values.

Majority of features are not well represented in the DEM or DSM, such as SW Soakpit Centres (usually under cover). Some features such as SW Manhole Lids can be clearly compared with the DEM when not under tree canopy.

1. SW SOAKPIT CENTRE, 2.94m RL, 4.02m DEM AUK1946 (757 Beach Rd, Browns Bay) 1755656,5935103

2. SW SOAKPIT CENTRE, 4.02m RL, 3.95m DEM AUK1946,

   1755669,5935103
3. SW MH LID, 4.11m RL, 4.09m DEM AUK1946, 1755672,5935102

4. SW MH LID, 3.36m RL, 2.49m DEM AUK1946, 1755580,5935114 (under tree canopy by stream)
5. SW MH LID, 4.17m RL, 4.18m DEM AUK1946, 1755595,5935126 (on kerb)
6. SW MH LID, 3.86m RL, 3.88m DEM AUK1946, 1755642,5935125 (on kerb)

7. SW MH LID, 3.87m RL, 3.89m DEM AUK1946, 1755649,5935123 (on kerb)

Conclusion

Storm water survey structure points match well with DEM elevations when they are surface features and not under tree canopy. Many features are either subsurface such as SW drain inverts, or not “bare-earth” features, e.g wall tops. Some features are too small to be properly represented in a 1m DEM or DSM, e.g. exposed stormwater pipes, fence tops.
These features cannot readily be converted to use NZVD2016 by interpolation from the DEM. However they can be easily converted to NZVD2016 elevations, using the same processes as for point asset features using the LINZ conversion grid data.

Storm water survey points

1,970 Storm water survey points features in Browns Bay were sampled and checked. 100% of features are populated with non-null [RLMeters] attribute values. These features represent surveyed spot heights, bank tops, road centreline points etc.; many sites have bare-earth site locations.

Compared to the Auckland Council DEM (AUK1946), [RLMeters] - <DEM value> gives :
Mean 0.32m, Median 0.009m, SD 0.83m. Note points on bridges etc. give large differences.
Compared to the Auckland Council DSM (AUK1946), [RLMeters] - <DSM value> gives :
Mean -1.4m, Median -0.105m, SD 2.63m
Neither the DEM or DSM provides a very good fit to all RL values. This is due to some points being on bridges, or under tree canopy, etc. Where the RL locations are on bare earth & not under canopy, fit to the DSM is good :
Mean 0.012m, Median 0.011m, SD 0.02m

The RL values for the bare earth points are of high accuracy when checked against the DEM & DSM. These features cannot readily be converted to use NZVD2016 by interpolation from the DEM or DSM.

However, they can be easily converted to NZVD2016 elevations, using the same processes as for point asset features using the LINZ conversion grid data.

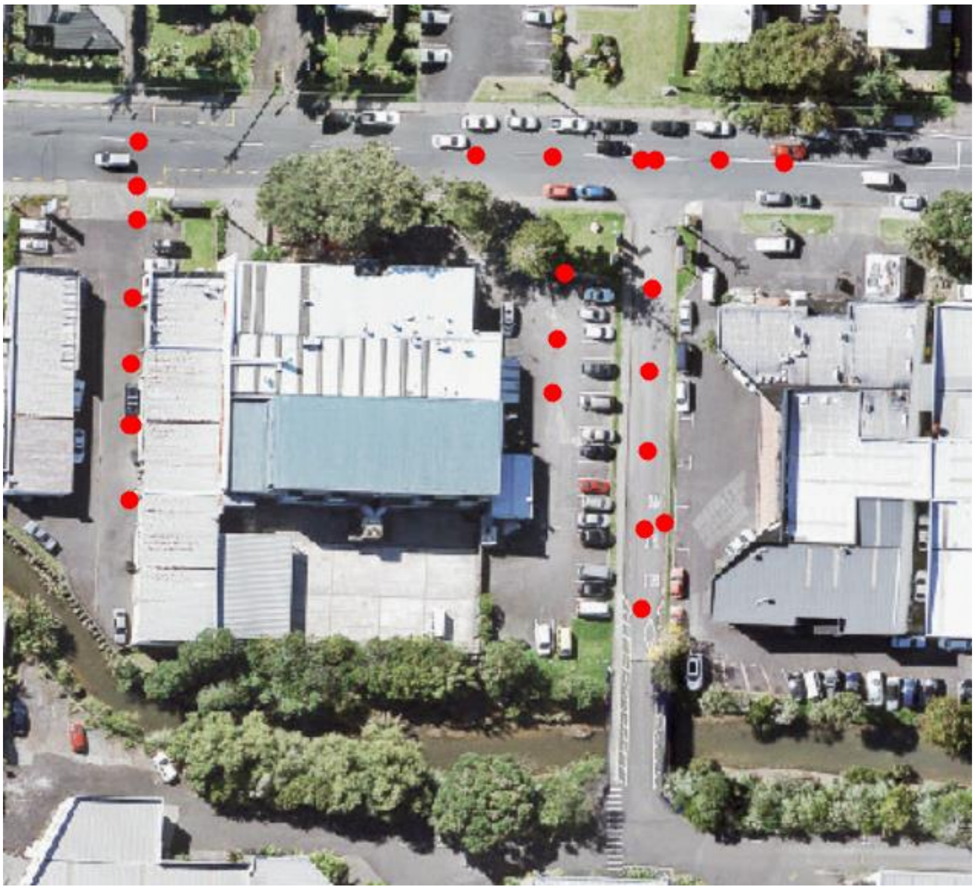


Figure 26 : Selected stormwater survey points.

The figure above shows stormwater survey points near the Taiaotea Stream, Browns Bay, on bare earth sites. These points have RL values with a mean difference of 1.2cm from the DSM values.

Storm water embankment polygons

123 Storm water embankment polygon features across the region were sampled and checked. 6 of 123 features are populated with non-null [SW_Crest_Level_m] attribute values, and 1 with a non-null [SW_height_pond_bed_m] attribute value. These features represent as-built stormwater control and detention features etc. Many are not currently visible on aerial photos and may be temporary features during site works, or possibly submerged in stormwater ponds. Where visible, the features have accurate ground levels to AUK1946 datum, these should be converted to NZVD2016.

Environmental Monitoring Data points

26 environmental monitoring points were examined. They cover sites for air quality, groundwater quality, freshwater quality sampling etc. 23 of 26 sites have elevation values. Sites are usually streamside locations, or in parks or public open spaces. The RL elevations are quite inaccurate compared to the DEM elevations (Mean difference 1.5m, SD 6.0m). This is probably not important – the elevations will be a general guide to the site environment, and values are probably based off handheld GPS or similar measurements. There is little value in converting the datum values from AUK1946 to NZVD2016.

If required, new and more accurate elevation values could be calculated from the DEM (e.g. ArcGIS Extract Values to Table tool).

Cliff Survey Data points

250 cliff survey points were examined for sites near Takapuna Head. All points have elevation attributes. The sample data is tightly clustered around one site on the beach, slightly below the visible tide mark. 200 of the points lie within a 5m2 area.

Point coordinates are expressed in Mt Eden circuit coordinates and the [Z] field has elevations. These are high-precision values and are likely to have been acquired using survey-grade GNSS equipment. These values can easily be converted to NZVD2016. If the high precision is needed to be retained, the values can be cross-checked using the LINZ online coordinate converter (https://www.geodesy.linz.govt.nz/concord/index.cgi?Advanced=2).

The points show a mean 0.38m difference from the AUK1946 DEM (point Z values are above the DEM values) suggesting that the Z values may already be in the NZVD2016 datum. As the dense points may represent heights on irregular rocky cliff-foot surfaces, further metadata on the data source should be gathered before deciding whether to adjust this data for the vertical datum.

Suggestion: If ongoing monitoring of the same points is required it is recommended that the next set of measurements is carried out in terms of the same datum, immediately prior to any adjustment to the data.

Viewshaft contours

The Auckland Unitary Plan identifies volcanic viewshafts and height sensitive areas as set out in the policy framework of D14 Volcanic Viewshafts and Height Sensitive Areas Overlay, D15 Ridgeline Protection Overlay and D16 Local Public Views Overlay and Schedules 9 and 11 of the Plan.
It is noted in https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/unitary-plan/declaration-proceedings/Documents/exhibit-b-application-for-declaration-by-tupuna-maunga-authority.PDF that viewshaft contours show height of the viewshaft above ground level and are indicative only.
As the relative elevation of these contours are to ground level, these contours will not be affected by the datum change to NZVD2016.

Figure 27: Viewshaft contours (red) and topographic contours (brown) near Mt Eden

Bathymetry

Samples of bathymetry data were provided from the Auckland Council geodatabase. Metadata is limited but it appears to be a regional bathymetry layer with a GRID_CODE attribute, probably depths in metres. Bathymetric data is usually referenced to Chart Datum, which is independent of the AUK1946 and NZVD2016 datums (which are usually only used for terrestrial data). It is most likely that this layer will be unaffected by the datum change to NZVD2016.

3.7 Survey Data

Introduction

None of the Open Data used in Geomaps or made available by Auckland Council directly involves survey data. LINZ geodetic mark data used by surveyors is referred to in the section on *Elevation Base Datasets*. Nevertheless, the interactions between Auckland Council and the survey industry, as well as interactions with LINZ, will be impacted by the datum change to NZVD2016. This is discussed further in this section.

The transition to the NZVD2016 vertical datum affects the survey industry in several ways. The main impact from surveyors for Auckland Council is in the submission of as-built plans. These plans are submitted to Auckland Council for engineering sign-off as part of an RMA s224c certification. Currently as-builts are submitted using the Auckland Vertical Datum 1946 (AUK1946) vertical datum.

The as-built submission process will need to transition to use the NZVD2016 vertical datum. There are opportunities in this transition to streamline processes and reduce the risk of error around elevation values. This can benefit the surveying industry, Auckland Council, and LINZ. Downstream use of as-built data will include asset data updates, e.g. stormwater assets, and their associated elevation attributes.

Background

The LINZ geodetic marks forming the reference framework for surveys are moving towards use of NZVD2016. New & updated marks are now more commonly recorded with NZVD2016 elevations. Older marks in the region using AUK46 are being phased out. This means that surveyors increasingly find it easier to take levels off marks which use NZVD2016.

Figure 28: A comparison : LINZ geodetic marks in the Albany area.

The figure above shows locations of LINZ geodetic marks in the Albany area. NZVD2016 marks are in red, AUK1946 marks in yellow. There is a much higher and more even density of NZVD2016 marks in this area of rapid development, allowing better survey vertical control.

Initial subdivision surveys are lodged with LINZ. They are mainly 2D surveys expressed in local circuit coordinates (Projection Mount Eden circuit 2000). In specific cases elevations may be required*, and LINZ allow elevations to be expressed in either AUK1946 or NZVD2016. This has no direct impact for Auckland Council.
Typically initial site topographic surveys, engineering designs and then as-built surveys will be in terms of Mount Eden 2000 Horizontally and AUK1946 vertically.

When as-builts are submitted to Auckland Council for engineering sign-off which forms part of an RMA s224c certification (meeting all conditions of a resource consent) they must be in terms of NZTM and AUK1946 for engineering sign-off and upload into their GIS system.
As AUK1946 Benchmarks become harder to find, initial site topographic surveys will need to be completed in terms of NZVD2016 heights. This then follows through to the design and the as-built. The as-built data will then need to be converted to AUK1946 heights by surveyors to submit to Council.

Typically accuracy specifications are +/- 50mm in XY & +/- 25mm in Z.

Error propagation will affect the accuracy of asset survey data - e.g. survey accuracy may be +/- 25mm from GPS, & it is necessary to add errors from laser levelling to pipe inverts etc.

Use of Auckland Council Open Data by the survey industry

GIS data held by Auckland Council is partially attributed with level data in AUK1946. This data would often be used by surveyors at the feasibility stage, but would be re-surveyed for confirmation of levels at design stage. Auckland City 25cm contours (AUK1946) are generally not used by surveyors, but are widely used in environmental and consulting reports. The 2016-2018 LIDAR point cloud is sometimes used by surveyors (e.g. for inaccessible areas, or survey area context data).

Current issues and risks

- The current transition of survey benchmarks to NZVD2016 requires surveyors to do extra work to back-calculate surveyed elevation data from NZVD2016 to AUK1946 for submission of data to council.
- It is increasingly inconsistent with national direction from LINZ for council to require survey elevations in AUK1946 datum.
- There is only about 30cm difference between elevations in AUK46 and NZVD2016. There is a risk of error by confusing data recorded in the 2 datums. This can be mitigated by moving to a single standard (NZVD2016) and also clearly expressing the datum used on all plans and in GIS metadata. (In contrast, the difference between values in accepted horizontal coordinate systems is usually obvious).
- It would ease processing if all council offices could standardise the required accuracy in Z, taking into account common surveying techniques and technology when setting the tolerance.

Recommendations

- Auckland Council should plan to transition to the acceptance of as-builts using NZVD2016.
- Consult with Auckland Council design team and the surveying industry to transition the datum. (This transition could have an independent timeline from Auckland Council asset updating for NZVD2016, etc)
- Enhance GIS metadata for all Auckland Council data products to clarify the vertical datum used for levels. Attributes for level data should be expressed in both AUK1946 and NZVD2016 datums for the foreseeable future.
- Require all as-built plans to clearly express the datum being used.

Footnotes

** Typical Land Transfer subdivisions are 2 dimensional only. This is where your title has no vertical limit. However, there are some instances where a height component is required, and titles are limited by height i.e. a 3D stratum boundary where you own a 3D box below another 3D box or a height limited easement where you rights may stop at a certain reduced level (RL) i.e. a right of way may stop vertically at the underside of a house eave etc.*

Cadastral Survey Rules 2021

These rules are made by the Surveyor-General under section 49 of the Cadastral Survey Act 2002.

The height of sea level at any location along the coastline as expressed in NZVD2016 allows for a relationship with the wider national-scale of sea level. The definition of the maritime boundary [AUP(OP)] by point features is a useful means

Errors in measurements. During the transition from AUK46 to NZVD2016 there will be changes made to the elevation, which may be subject to quality assurance methodology. Conversions should be used with either an approved methodology or the LINZ Coordinate Converter. In the case of the LINZ Coordinate Converter, all details relating to the conversion should be initially presented in the metadata, including the time of height capture, to ensure correct procedures are used and all data is correctly entered. In addition, it should be acknowledged that for many of the surveys conducted within Auckland Council there may be minor differences between results of datum conversion, but these are likely to be within any acknowledged margin of error in the measurement of features and therefore small. Guidance on errors in measurements should be relative to the size and importance of survey projects and stated in any measurements provided to Auckland Council for future reference.

“Over the scale of most cadastral surveys, the effect of NZGeoid2016 transformation errors on height differences is likely to be small. The major source of error is likely to be from the surveyor's determination of heights.” Source: Surveyor-General - Section 7(1)(ga) of the Cadastral Survey Act 2002 dated 1 July 2019 https://www.linz.govt.nz/kb/735.

See also :
https://www.legislation.govt.nz/regulation/public/2021/0095/latest/whole.html

https://www.linz.govt.nz/system/files_force/media/regulatory-documents/65303-Ruling%20on%20vertical%20control%20marks%20-%20LINZR65303_4.pdf?download=1

4. Summary of Findings

The table below shows a summary of findings for all the data groups. This gives an overview of the risk and effort associated with datum conversion for each group.

Data group	Subgroup	Risk	Effort	Comments
Elevation Base Datasets	DEM	Low	Low	Simple transform.
	Topographic Contours	Low	Medium	Can recreate from DEM, mostly straightforward. Note some areas (e.g. Helensville river hydroflattening) may need attention.
Unitary Plan		Low	Low	
Assets	Stormwater	Low	Low	9 feature classes. Updating straightforward. May need to duplicate fields (data in both datums).
Freshwater data	Overland flowpaths	Medium	Medium	May decide to retain existing data.
	Flood Prone Areas	Low	TBC	Update spill elevation attribute only.
Coastal and Marine Data		Low	Low	Only Coastal Inundation High Water Levels needs elevation attributes adjusting. Otherwise no change.
Miscellaneous Data		Low	Low	
Survey Data		Medium	Medium-High	Will require extensive communication and business process updates.

5. Conversion Methods

GIS layers update methodology

This section describes the tools to use for data conversion to the new datum. They assume use of ArcGIS software for these processes.

The Process for Point Layers

Currently all point asset layers have level attributes expressed to the AUK1946 datum. It is probably best to retain these levels for future reference; one option is to rename the fields with the suffix "_AUK46", e.g. rename the field [SW_COVER_LEVEL_M] as [SW_COVER_LEVEL_M_AUK46].

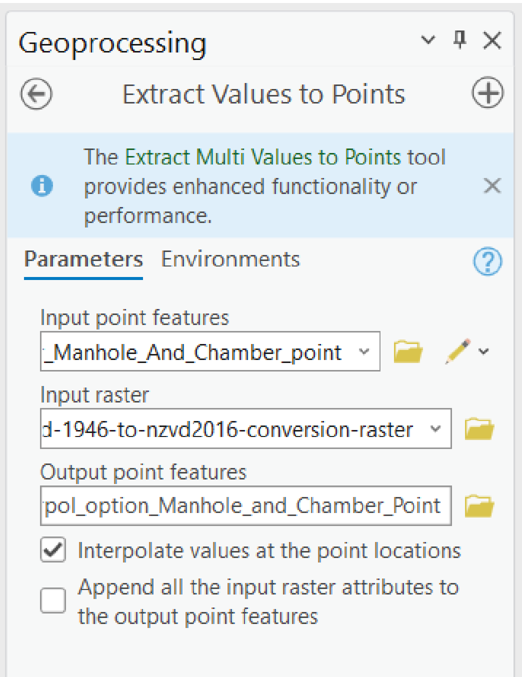
The process to convert Point Layers is as follows. It is important to note that we are simply adjusting existing elevation levels for the datum shift; any existing errors or discrepancies with data values will be carried forward to the new values.

Load the dataset you want to change into your desktop GIS (these notes assume that ArcGIS Pro is being used).

Load the base dataset that you will convert the data with (This is the one that will make the adjustment). This can be downloaded from https://data.linz.govt.nz/layer/103953-auckland-1946-to-nzvd2016-conversion-raster/ and saved as auckland-1946-to-nzvd2016-conversion-raster.tif

Under Analysis > Tools > Geoprocessing, go to Search for Tools

Type - ***Extract Values to Points***



This window will appear :

Input point features is the dataset you want to make the change with

Input raster is the base raster dataset that has the change values over the region

Output is where we save the dataset.

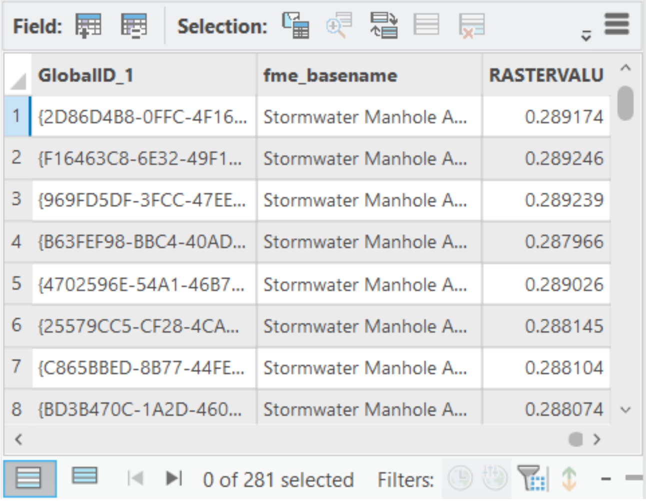
Tick the Interpolate option for maximum accuracy (if not, any loss of accuracy will be about 2cm in Z at most).

Then click *Run*

This will create a new feature class in the output Geodatabase

This will also be loaded into your table of contents

Right click on the layer to open the Attribute table to see the new values added

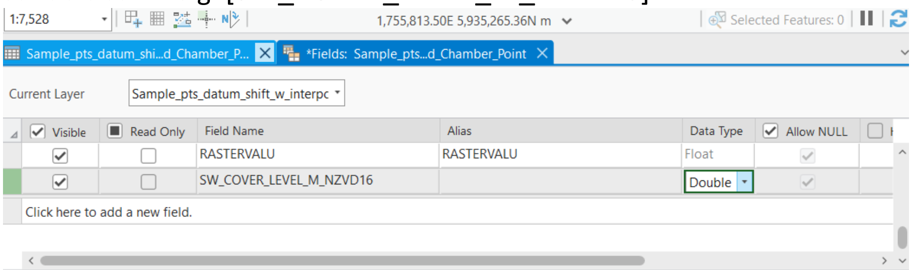


	GlobalID_1	fme_basename	RASTERVALU
1	{2D86D4B8-0FFC-4F16...	Stormwater Manhole A...	0.289174
2	{F16463C8-6E32-49F1...	Stormwater Manhole A...	0.289246
3	{969FD5DF-3FCC-47EE...	Stormwater Manhole A...	0.289239
4	{B63FEF98-BBC4-40AD...	Stormwater Manhole A...	0.287966
5	{4702596E-54A1-46B7...	Stormwater Manhole A...	0.289026
6	{25579CC5-CF28-4CA...	Stormwater Manhole A...	0.288145
7	{C865BBED-8B77-44FE...	Stormwater Manhole A...	0.288104
8	{BD3B470C-1A2D-460...	Stormwater Manhole A...	0.288074

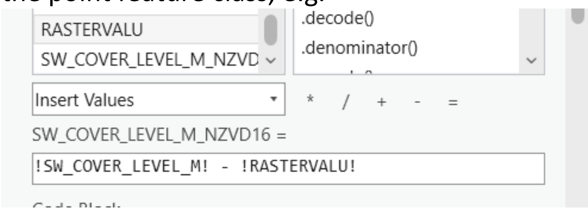
The new RASTERVALU Column is the adjustment that needs to be made to the existing level at that spatial location. This will be about 30cm (0.3m)

This is the Value to subtract from AUK46 elevation values to get to NZVD16 elevation.

Now add a new field (type double) for each level attribute field in the feature class, including a suitable suffix e.g. [SW_COVER_LEVEL_M_NZVD16].



Use the Calculate field option to overwrite numbers in existing level Field in the attribute table for the point feature class, e.g.



You may wish to set a selection first, to omit calculations where the target field is null or zero to avoid warnings during the Calculate Field operation.

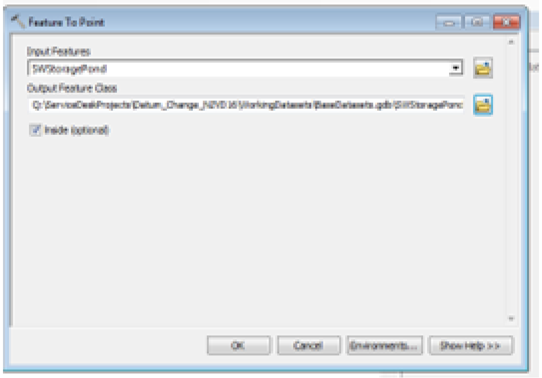
To populate the existing level field, in this case it will be the level in AUK46 minus **RasterValu**
Then delete the unwanted field **RasterValu** if required.

NOTE: Please remember we are only replacing levels, not depths, Depths in metres will always stay the same for any layer, e.g. [SW_DEPTH_TO_INVERT_M] remains unaltered.

The Process for Polygons

The process to convert Polygon Layers is as follows
First of all, if the current RL fields in the layer you are working with need to be kept, create a new field with the same name and add _AUK46 on to the end of it, e.g. LidLevel -> LidLevel_AUK46

Convert the Polygon to a point Layer
Get the **Feature to Point** layer from the toolbox



Fill in in as follows, choosing your polygon layer first, be sure to **tick** in **Inside** box
This will create a new file.
From here you will **follow the Process for a Point Layer**
Once you have done your conversions, do a table join back to the polygon layer based on the AssetID
Then with your Calculator, Repopulate the polygon layer with the new RL's

The Process for Polylines

The process to convert Polyline Layers is as follows
Note: Startpoint is Upstream, Endpoint is Downstream. These refer to the Upstream and downstream levels within the line layers. To obtain the correct datum correction values, we need to extract the start & end coordinates of each line feature, then process the new points as for point features in the previous section.

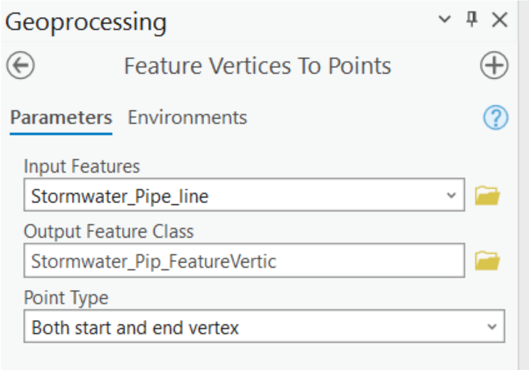
If the current RL field in the layer you are working with needs to be kept, create a new field with the same name and add AUK46 on to the end of it, e.g. SW_INVERT_LEVEL_DOWNSTREAM_M -> SW_INVERT_LEVEL_DOWNSTREAM_M_AUK46. Do this for all fields in the layer that require the height adjustment.

Step 1. Archive the old levels by creating the new fields as above

Step 2. Use the ArcGIS Field Calculator to transfer the existing levels from the existing fields to the new fields. These are Double 10,3 for field type

Step 3. You can now start populating the old field using the following process

Convert the Polyline to a point Layer using the *Feature Vertices to Points* tool with the Point Type option *Both start and end vertex.*



This will create a new layer, be sure the output is in the correct place
From here you will follow the Process for a Point Layer
Note: Once you have used this now layer to extract the heights, join it to the Line layer and use the calculator to populate the existing height layers.
The following calculation can only be done on field that have a known value in them. No Zeros or Null values
Calculation will be the [*AUK1946 RL elevation field* Minus *datum conversion value*] = existing RL field
As a quick check, the new NZVD2016 values should be about 0.3m less than the original AUK1946 values (+/- 0.05m).
Once you have done your conversions, do a table join back to the polyline layer based on the ObjectID or SAP_OBJECT_NUMBER field
Then with your Calculator, Repopulate the polyline layer with the new RL's.

* *This section "Conversion methods" adapted from original notes by Tim Watson of Tauranga CC*

6. Acknowledgments

Lynker Analytics would like to acknowledge the generous contributions made towards this report by the following people and organisations:

Dragos Bratasanu, Geospatial Data Lead, Auckland Council, for leadership of this project.
Rachelle Winefield, Senior Geodesist, LINZ, for advice from discussions.
Nathan Hogg, Senior Associate – Survey Manager, AR and Associates, for discussions and advice on impacts of datum change to the survey industry
Also, to the many Auckland Council staff who have contributed by way of informative discussions and data supply

The overall citation for the data supply is "Lynker Analytics Auckland Council Datum Change 2022". For additional details, refer to metadata.

7. ANZLIC Metadata Sheet

Reference: Australia and New Zealand Land Information Council (ANZLIC) Metadata Profile

Serial	ANZLIC Metadata	Statement
(a)	(b)	(c)
Project		
	Job No	C36P39
	Date	22 August 2022
	Source	Lynker Analytics Ltd, 2022
	Reference number	
Dataset		
	Title	Datum Change Impact Assessment
	Summary (Purpose)	
	Image filename	
	Topics and Keywords	
	Bands	
	Horizontal accuracies	
	Sensor	
	Medium of photo	
	Ortho Image Type	
	Pixel size	
	Positional Accuracy	
	Source	
	Resource Citation	Creative Commons Attribution 4.0 International CC BY 4.0
	Resource Citation Contacts	Contact - Custodian Name - Imagery Lead Organization – Lynker Analytics Ltd Role – Distributor
	Metadata Details	File Identifier
	Metadata Contacts	Imagery Lead, Lynker Analytics
	Metadata Constraint	Security Constraints - Unclassified
	Resource Details	Status - Completed Credit – Lynker Analytics Ltd, 2022. Supplemental Information – The source data has been compiled from photogrammetric dense photo matching, without ground control, and as such accuracy may vary throughout the dataset. This data is provided "as is" without warranty of any kind. While every effort has been made and best endeavours

		have been undertaken to achieve a high degree of confidence, Lynker Analytics Ltd recommends that you independently verify the accuracy, currency, and reliability of the detailed precision of any information upon which you intend to rely. This imagery made available may be amended and updated by us without notification.
	Extents	Extent Description – Auckland Council Temporal Instant Extent – 22 August 2022
	Maintenance	Resource Maintenance Update Frequency - As Needed
	Resource Constraints	Security Constraints - Unclassified Legal Constraints - Does not purport to define boundaries or other such representation. Legal Constraints - This work is licensed under a Creative Commons Attribution 4.0 International License CC BY 4.0.
	Lineage	Statement
	Distribution Format	Format Name – .tif, .shp

8. Appendices

Appendix A – Glossary of terms

Term	Explanation
ARI	Annual Recurrence Interval, e.g. ARI 100 is often referred to as a 1-in-100 year recurrence
AUK1946	Auckland 1946 vertical datum. An older datum for orthometric heights in Auckland Region, based off MSL in Auckland Harbour in 1946.
Datum	Datums define how coordinates, longitudes and latitudes or heights, relate to physical locations. In this report, the main reference is to vertical datums.
DEM	Digital Elevation Model. A model of the bare-earth land surface, representing its elevation. Usually presented in grid format.
DSM	Digital Surface Model. A model of the land surface, representing its elevation. It will include buildings, trees, and other objects on the earths surface.
ESL	Extreme Sea Level. This term is used in coastal inundation studies to refer to the highest possible sea level for particular conditions, e.g. a modelled ARI 100 storm surge on top of an extreme high tide.
Geodetic	Refers to geodesy, the science of accurately measuring and understanding Earth's geometric shape and size, orientation in space, and gravity. It implies the use of accurate 3D data in mapping and surveying.
Geodetic mark	An object placed to mark key survey points on the Earth's surface, including elevation.
Geoid	The geoid is the shape that the ocean surface would take under the influence of the gravity of Earth, including gravitational attraction and Earth's rotation, if other influences such as winds and tides were absent.
GNSS	Global navigation satellite system (GNSS) is a general term describing any satellite constellation that provides positioning, navigation, and timing (PNT) services on a global or regional basis. GPS is the best-known example.
Hydrodynamic modelling	Hydrodynamic modelling is the study of fluids in motion. For flood modelling, this can be used to account for the effects of interactions of water with the land surface, e.g in coastal plain areas
Hydroflattening	Hydro-flattening is the process of creating a lidar-derived DEM in which water surfaces appear and behave as they would in

	traditional topographic DEMs created from photogrammetric digital terrain models (DTMs).
LIDAR	Light Detection and Ranging. In this study, it refers to a technique for measuring landform elevation from an airborne sensor.
LINZ	Land Information New Zealand, the national lands and surveys department
Meridional Circuit	A local projection system used by land surveyors in NZ. Also sometimes called a local circuit. The LINZ Cadastral Survey Rules 2021 require surveyors to carry out surveys in terms of one of the NZGD2000 Transverse Mercator 2000 meridional circuit projections. In Auckland this is the Mt Eden 2000 projection.
MSL	Mean Sea Level
Mt Eden 2000	See Meridional Circuit. Mt Eden 2000 is the local meridional circuit for survey in the Auckland Region.
NZGD2000	NZ Geodetic Datum 2000. The ellipsoidal datum underpinning official NZ projections, e.g. NZTM and Mt Eden 2000
NZTM	NZ Transverse Mercator. The national standard mapping projection, covering the whole of the main islands of NZ.
NZVD2016	NZ Vertical Datum 2016. The official NZ vertical datum, based on a geoid model.
Orthometric Height	The orthometric height is the vertical distance H along the plumb line from a point of interest to a reference surface known as the geoid.
Reduced Level (RL)	A reduced level is the vertical distance between a survey point and the adopted level datum. (See *https://whycos.org/levelling-surveying/*)

Appendix B – References and further information

Title	URL
NZVD2016 background	
LINZ - NZVD2016 information for councils	https://www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/new-zealand-vertical-datum-2016-nzvd2016/nzvd2016-information-for-councils
Basis for NZVD2016 - accuracy etc	https://www.surveyspatialnz.org/Attachment?Action=Download&Attachment_id=2421
Standard for New Zealand Vertical Datum 2016	http://www.linz.govt.nz/regulatory/25009
New Zealand Vertical Datum 2016 - background notes	http://www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/new-zealand-vertical-datum-2016-nzvd2016
New Zealand Quasigeoid 2016 - background notes	http://www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/new-zealand-quasigeoid-2016-nzgeoid2016
Vertical Datum Relationship Grids	http://www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/vertical-datum-relationship-grids
Background notes - it's time to switch to modern datums	https://www.critchlow.co.nz/resources/blog/modern-datums
Background notes on NZ projection systems	http://www.ollivier.co.nz/projection/faq.shtm
LINZ presentation on geoids (2016)	https://www.fig.net/news/news_2016/2016_12_AP_CDN/Amos.pdf
Notes on basis for AUK1946 datum	https://www.linz.govt.nz/data/geodetic-system/datums-projections-and-heights/vertical-datums/local-mean-sea-level-datums
Coastal issues	
Auckland's Exposure to Sea Level Rise - Technical Report 2019/017	https://knowledgeauckland.org.nz/media/1085/tr2019-017-aucklands-exposure-to-sea-level-rise-part-1-regional-inventory-final.pdf
CMA boundary definition and MSL levels	https://knowledgeauckland.org.nz/media/2089/development-of-updated-coastal-marine-area-boundary-for-auckland-region-niwa-july-2012.pdf
Auckland's Exposure to Coastal Inundation by Storm-tides and Waves December 20 20 Technical Report 2020/024	https://www.aucklandcouncil.govt.nz/environment/what-we-do-to-help-environment/Documents/coastal-inundation-in-auckland.pdf
Coastal Hazard Assessment in the Auckland Region, Guideline document 2021/010	https://knowledgeauckland.org.nz/publications/coastal-hazard-assessment-in-the-auckland-region/
Planning issues	
Akl Unitary Plan notes	https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/unitary-plan/auckland-

	unitary-plan-modifications/other-plan-updates/1452021/memo-section58i-new-zealand-vertical-datum-2016.pdf
Plan Modification Memo : Section 58I update to the AUP to reference NZVD 2016.	https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/our-plans-strategies/unitary-plan/auckland-unitary-plan-modifications/other-plan-updates/1452021/memo-section58i-new-zealand-vertical-datum-2016.pdf
Auckland Unitary Plan Operative in part	https://unitaryplan.aucklandcouncil.govt.nz/pages/plan/Book.aspx?exhibit=AucklandUnitaryPlan_Print
The Auckland Code of Practice for Land Development and Subdivision Chapter 4: Stormwater	https://content.aucklanddesignmanual.co.nz/regulations/codes-of-practice/Documents/SW-CoP-v3-January-2022.pdf
Web Viewers and Open Data	
Auckland Council Geomaps	https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html
Planning maps viewer for the Auckland Unitary Plan (Operative in part)	https://unitaryplanmaps.aucklandcouncil.govt.nz/upviewer/
Watercare viewer	https://watercare.maps.arcgis.com/apps/webappviewer/index.html?id=3944a60cbf864b9494087cd39094e114
Watercare Open Data	https://data-watercare.opendata.arcgis.com/datasets/Watercare::wastewater-manhole/about
Auckland Transport Moorings	https://at.govt.nz/boating-marine/moorings/#zones
Auckland City Open Data Site	https://data-aucklandcouncil.opendata.arcgis.com
Auckland Transport Open Data Site	https://data-atgis.opendata.arcgis.com
Auckland City Hazard Viewer	https://aucklandcouncil.maps.arcgis.com/apps/MapSeries/index.html?appid=81aa3de13b114be9b529018ee3c649c8
LINZ Data Service - datum conversion grid	https://data.linz.govt.nz/layer/53417-auckland-1946-to-nzvd2016-conversion/
OpenTopography - Auckland LIDAR	https://portal.opentopography.org/datasetMetadata?otCollectionID=OT.072020.2193.2
Auckland LIDAR contractor metadata	https://cloud.sdsc.edu/v1/AUTH_opentopography/www/metadata/NZ16_NAuckland_metadata.pdf

Appendix C – Checking consistency of datum conversion methods

Objective

The objective of this section is to compare the consistency of datum conversion methods and assess their comparative accuracy. Samples of points from all 9 sample areas were tested using 3 methods. Also, the accuracy of interpolating asset elevations from the DEM was checked.

Brief Summary

To find the most appropriate method for datum conversion of vector GIS data to NZVD2016, 3 methods were tested, and results compared for some sample sites. Sample sites were spread across the whole region. 18 LINZ geodetic marks and 33 stormwater asset lid points were converted from AUK1946 to NZVD2016 using 3 methods. For all 51 sites, the 3 NZVD2016 values showed an average range of 2.4mm in Z. It is concluded that any of the 3 methods can be used without introducing any significant errors.

Method 2 (the ArcGIS "Values to point" method with interpolate option using the LINZ conversion raster) is recommended for vector data conversion in GIS. Either method 2 or method 3 (using the LINZ online conversion tool) are effective for converting text-based data from xyz values.

Method 1 (using a 1m interpolated grid based off LINZ mesh points) is appropriate for raster data datum conversions in GIS.

The 33 stormwater asset lid points were also checked against the 2016 DEM to interpolate Z values in AUK1946. These points had recent elevation attributes as the assets are recent (2018-2021). The mean difference in Z is 17.3cm. Some sites showed moderate amounts of recent ground disturbance from earthworks. It is concluded that interpolation of asset elevations from the DEM has low accuracy overall. It may have value for sites undisturbed since the date of LIDAR capture (2016-2018), and be suitable for assets for which no other elevation attributes are available.

Conversion methods

The datum conversion methods tested are as follows :

1. Method 1 - Using the LINZ Auckland 1946 to NZVD2016 Conversion Raster https://data.linz.govt.nz/layer/103953-auckland-1946-to-nzvd2016-conversion-raster/ The ArcGIS "Values to point" method was used with the *interpolate* option off this LINZ raster.

2. Method 2 - Using the LINZ Auckland 1946 to NZVD2016 Conversion, based off the LINZ point mesh at 2 arc-minute (~3.6Km) – 2cm accuracy. https://data.linz.govt.nz/layer/53417-auckland-1946-to-nzvd2016-conversion/ This point mesh was converted to a 1m grid using regularised spline interpolation in ArcGIS Desktop, and sample points then attributed with transform values using the "Values to point" tool in ArcGIS.

3. Using LINZ Online Conversions : https://www.linz.govt.nz/data/geodetic-services/coordinate-conversion/online-conversions/instructions-for-carrying-out-online-height-conversions. XYZ values for points were pasted into the online converter & the results copied back out.

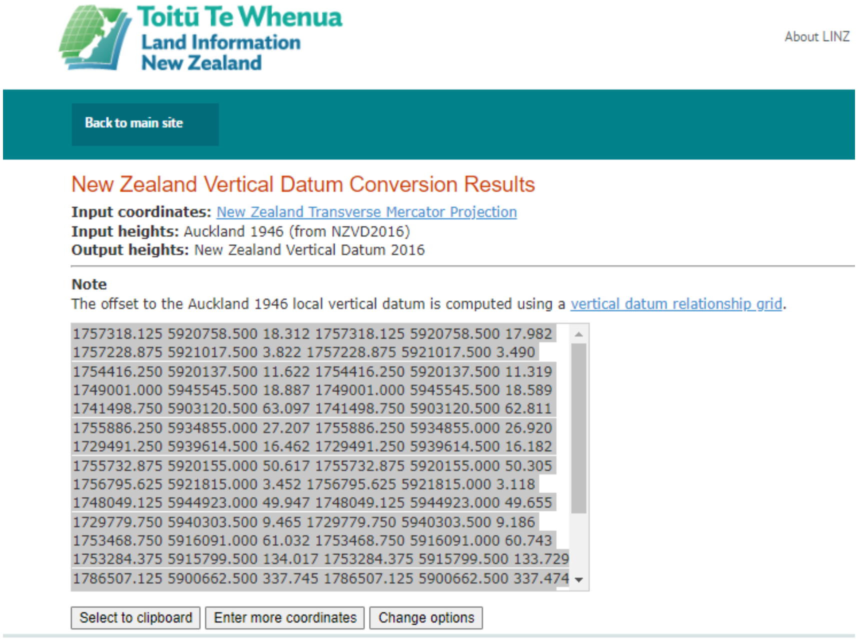


Figure 29 Example of datum conversion results using LINZ online tools

Converting LAS data is not covered here but details are at : https://medium.com/on-location/reprojecting-point-clouds-to-nzvd2016-b8724bbe1635, also https://community.esri.com/t5/arcgis-data-interoperability-blog/don-t-leave-las-behind/ba-p/883680

Conversion tests on Geodetic Mark samples

A set of 18 selected geodetic marks with known AUK1946 elevations were taken from the 9 sample areas & transformed from AUK1946 datum to NZVD2016. Note that these marks tend to be older than NZVD2016 marks.

The table below summarises the results of using the 3 methods to transform the point elevations.

LINZ Marks with AUK1946 elevations			**Location, NZTM**		**Calculated NZVD2016 elevations**			
Geodetic code	**Mark elevn AUK1946**	**Site**	**X**	**Y**	**Method1**	**Method2**	**LINZ website**	**Max difference, m**
CJKM	18.312	Freemans Bay	1757318.125	5920758.5	17.988	17.974	17.982	0.0144
CJKY	3.822	Freemans Bay	1757228.875	5921017.5	3.496	3.481	3.49	0.0144
CL5B	11.622	Freemans Bay	1754416.25	5920137.5	11.316	11.318	11.319	0.0026
CJHM	18.887	Silverdale	1749001	5945545.5	18.593	18.589	18.589	0.0037

CLTR	63.097	Kakamatua	1741498.75	5903120.5	62.811	62.811	62.811	0.0001
BCWU	27.207	Browns Bay	1755886.25	5934855	26.919	26.920	26.92	0.0011
ABQC	16.462	Helensville	1729491.25	5939614.5	16.182	16.182	16.182	0.0005
CKE0	50.617	Freemans Bay	1755732.875	5920155	50.302	50.300	50.305	0.0054
A5WL	3.452	Freemans Bay	1756795.625	5921815	3.117	3.110	3.118	0.0081
CL0T	49.947	Silverdale	1748049.125	5944923	49.657	49.655	49.655	0.0026
ABQF	9.465	Helensville	1729779.75	5940303.5	9.185	9.186	9.186	0.0012
CHC2	61.032	Mt Albert	1753468.75	5916091	60.743	60.742	60.743	0.0012
B1LE	134.017	Mt Albert	1753284.375	5915799.5	133.728	133.728	133.729	0.0012
A938	337.745	Hunuas	1786507.125	5900662.5	337.474	337.474	337.474	0.0004
B34V	21.376	Kumeu	1736289.375	5929718	21.087	21.086	21.087	0.0005
C63E	6.086	Karaka	1773083.25	5891893	5.807	5.807	5.807	0.0005
ADKG	5.667	Freemans Bay	1755365.5	5921936.5	5.343	5.346	5.349	0.0056
CLTT	40.897	Kakamatua	1742403.25	5903274	40.611	40.611	40.611	0.0003
							Average	**0.0036**

Table 1: Sample of 18 LINZ geodetic mark locations with AUK1946 elevations.

In the table above, the mark elevations were transformed to NZVD2016 using 3 methods as noted above. The mean difference across all methods is 3.6mm

The geodetic marks can be found in the LINZ website, e.g. mark CJKM can be found at https://www.geodesy.linz.govt.nz/gdb/?code=CJKM

Stormwater lid level tests

A set of 33 selected stormwater asset lid level points with known AUK1946 elevations were taken from the 9 sample areas & transformed from AUK1946 datum to NZVD2016.

The table below summarises the results of using the 3 methods to transform the point elevations.

Stormwater lids with AUK1946 elevations			Location, NZTM		Calculated NZVD2016 elevations			
REGISTER ID	**Cover elevn**	**Area**	**X**	**Y**	**Method 1**	**Method 2**	**LINZ website**	**Max Difference, m**

	AUK19 46							
VS1376 9	6.917	KAIPARA	1729313.625	593960 2	6.637 9	6.638 1	6.638	0.0002
VS1376 9	5.797	KAIPARA	1729299.75	593950 6	5.517 8	5.517 8	5.518	0.0002
VS1376 9	15.479	KAIPARA	1729389.75	593949 4	15.19 94	15.19 96	15.2	0.0006
VS1376 9	4.113	KAIPARA	1729293.5	593945 8.5	3.833 7	3.833 7	3.834	0.0003
VS1376 9	8.517	KAIPARA	1729314.375	593945 8	8.237 6	8.237 7	8.238	0.0004
VS1376 9	15.409	KAIPARA	1729384.5	593945 8	15.12 94	15.12 95	15.12 9	0.0005
VS1376 9	17.206	KAIPARA	1729406.25	593942 0	16.92 63	16.92 64	16.92 6	0.0004
VS1234 2	38.68	KAIPARA	1729966.25	593997 5	38.39 88	38.40 02	38.4	0.0014
VS1655 4	23.59	KAIPARA	1737879.625	592908 1.5	23.30 29	23.30 27	23.30 3	0.0003
VS1655 4	24.85	KAIPARA	1737748.75	592918 9	24.56 27	24.56 26	24.56 3	0.0004
VS1655 4	25.41	KAIPARA	1737731.875	592910 4	25.12 27	25.12 26	25.12 3	0.0004
VS1655 4	26.05	KAIPARA	1737713.125	592901 0	25.76 27	25.76 26	25.76 3	0.0004
VS1655 4	24.72	KAIPARA	1737814.125	592910 2	24.43 28	24.43 27	24.43 3	0.0003
VS1655 4	26.9	KAIPARA	1737641.375	592899 6	26.61 27	26.61 25	26.61 3	0.0005
VS8556	7.5	MANUKAU_HARB OUR	1769056.25	589436 7	7.214 3	7.213 7	7.214	0.0005
VS8556	8.95	MANUKAU_HARB OUR	1769100.5	589433 1.5	8.664 3	8.663 8	8.664	0.0005
VS8556	9.22	MANUKAU_HARB OUR	1769113	589434 8.5	8.934 3	8.933 8	8.934	0.0005
VS8556	9.47	MANUKAU_HARB OUR	1769119.375	589436 0	9.184 3	9.183 8	9.184	0.0005
VS8556	8.78	MANUKAU_HARB OUR	1769056	589426 2	8.494 4	8.493 9	8.494	0.0005
VS8556	8.42	MANUKAU_HARB OUR	1769061.375	589427 9.5	8.134 4	8.133 9	8.134	0.0005
VS1684 1	50.48	HIBISCUS_COAST	1748998.5	594688 4.5	50.18 39	50.18 15	50.18 2	0.0025
VS1684 1	51.9	HIBISCUS_COAST	1749006.5	594684 4	51.60 40	51.60 15	51.60 2	0.0025
VS1195 3	65.2	HIBISCUS_COAST	1749113	594643 3	64.90 41	64.90 13	64.90 2	0.0028
VS7120	61.43	HIBISCUS_COAST	1749427.875	594652 2	61.13 29	61.13 08	61.13 2	0.0021
13764	54.78	HIBISCUS_COAST	1749533.125	594717 6.5	54.48 22	54.48 08	54.48 2	0.0014
12900	31.96	HIBISCUS_COAST	1748630.375	594721 0	31.66 45	31.66 22	31.66 3	0.0023

12900	31.69	HIBISCUS_COAST	1748627	5947172	31.3946	31.3922	31.393	0.0023
12782	59.74	HIBISCUS_COAST	1749356.625	5947036.5	59.4428	59.4409	59.442	0.0019
VS16914	38.28	WAITEMATA	1754527.25	5920742.5	37.9712	37.9732	37.975	0.0038
CP14478	3.76	WAITEMATA	1755722.5	5921136	3.4383	3.4356	3.442	0.0064
CP14478	3.86	WAITEMATA	1755720.625	5921126	3.5384	3.5357	3.543	0.0073
CP14478	20.96	WAITEMATA	1755950.375	5921012.5	20.6371	20.6329	20.641	0.0081
CP14478	15.51	WAITEMATA	1755258.625	5921401.5	15.1911	15.1917	15.196	0.0049
						Average		**0.0017**

Table 30: Sample of 33 Auckland asset stormwater lid locations with AUK1946 elevations.

In the table above, the lid elevations were transformed to NZVD2016 using 3 methods as noted above. The mean difference across all methods is 1.7mm.

Stormwater lid level tests for DEM elevations

A set of 33 selected stormwater asset lid level points with known AUK1946 elevations were taken from the 9 sample areas & elevations were then interpolated from the Auckland City 2016-2018 DEM using the AUK1946 datum.

The table below summarises the results of interpolating the point elevations from the DEM and comparing with the original elevation attribute value.

Stormwater lids with AUK1946 elevations			**Location, NZTM**		**DEM elevations (AUK1946), m**	
REGISTER ID	**Cover**	**SW_CRE**	**X**	**Y**	**Elevation**	**DEM difference (m)**
VS13769	6.917	KAIPARA	1729313.625	5939602	3.1392	3.7778
VS13769	5.797	KAIPARA	1729299.75	5939506	3.3819	2.4151
VS13769	15.479	KAIPARA	1729389.75	5939494	15.4787	0.0003
VS13769	4.113	KAIPARA	1729293.5	5939458.5	2.8194	1.2936
VS13769	8.517	KAIPARA	1729314.375	5939458	7.4611	1.0559
VS13769	15.409	KAIPARA	1729384.5	5939458	16.3570	-0.9480
VS13769	17.206	KAIPARA	1729406.25	5939420	17.5177	-0.3117
VS12342	38.68	KAIPARA	1729966.25	5939975	38.7482	-0.0682
VS16554	23.59	KAIPARA	1737879.625	5929081.5	21.3229	2.2671
VS16554	24.85	KAIPARA	1737748.75	5929189	26.1413	-1.2913

VS16554	25.41	KAIPARA	1737731.875	5929104	27.0239	-1.6139
VS16554	26.05	KAIPARA	1737713.125	5929010	26.6200	-0.5700
VS16554	24.72	KAIPARA	1737814.125	5929102	23.7325	0.9875
VS16554	26.9	KAIPARA	1737641.375	5928996	28.9305	-2.0305
VS8556	7.5	MANUKAU_HARBOUR	1769056.25	5894367	7.3351	0.1649
VS8556	8.95	MANUKAU_HARBOUR	1769100.5	5894331.5	8.7207	0.2293
VS8556	9.22	MANUKAU_HARBOUR	1769113	5894348.5	8.9157	0.3043
VS8556	9.47	MANUKAU_HARBOUR	1769119.375	5894360	9.1348	0.3352
VS8556	8.78	MANUKAU_HARBOUR	1769056	5894262	8.9073	-0.1273
VS8556	8.42	MANUKAU_HARBOUR	1769061.375	5894279.5	8.2080	0.2120
VS16841	50.48	HIBISCUS_COAST	1748998.5	5946884.5	50.3240	0.1560
VS16841	51.9	HIBISCUS_COAST	1749006.5	5946844	51.8055	0.0945
VS11953	65.2	HIBISCUS_COAST	1749113	5946433	66.4300	-1.2300
VS7120	61.43	HIBISCUS_COAST	1749427.875	5946522	61.2196	0.2104
13764	54.78	HIBISCUS_COAST	1749533.125	5947176.5	54.7533	0.0267
12900	31.96	HIBISCUS_COAST	1748630.375	5947210	31.8654	0.0946
12900	31.69	HIBISCUS_COAST	1748627	5947172	31.7062	-0.0162
12782	59.74	HIBISCUS_COAST	1749356.625	5947036.5	59.7268	0.0132
VS16914	38.28	WAITEMATA	1754527.25	5920742.5	37.9911	0.2889
CP14478	3.76	WAITEMATA	1755722.5	5921136	3.6860	0.0740
CP14478	3.86	WAITEMATA	1755720.625	5921126	3.6891	0.1709
CP14478	20.96	WAITEMATA	1755950.375	5921012.5	21.2206	-0.2606
CP14478	15.51	WAITEMATA	1755258.625	5921401.5	15.4943	0.0157
				Average		**0.1733**

Table 3: Sample of 33 Auckland asset stormwater lid locations with AUK1946 elevations.

In the table above, the lid elevations were also interpolated from the 2016 DEM (AUK1946 datum). The mean difference between recorded asset elevation and the DEM height is 17.3cm

Appendix D – Details of DEM differences found in sample sites

This appendix provides further detail about differences found between the Auckland City and LINZ copies of the 2016-2018 LIDAR DEM, as in section 3.1 of the main report.

Helensville

The Auckland Council DEM (supplied in AUK1946) covering the Helensville area was converted to NZVD2016 datum using the LINZ transformation grid. The Auckland Council DEM was subtracted from the LINZ DEM to give a difference grid as below. For the sampled area (3.6 Km2) the mean difference is -0.097m with a SD of 0.288m. A small sample area is shown in the figures below.

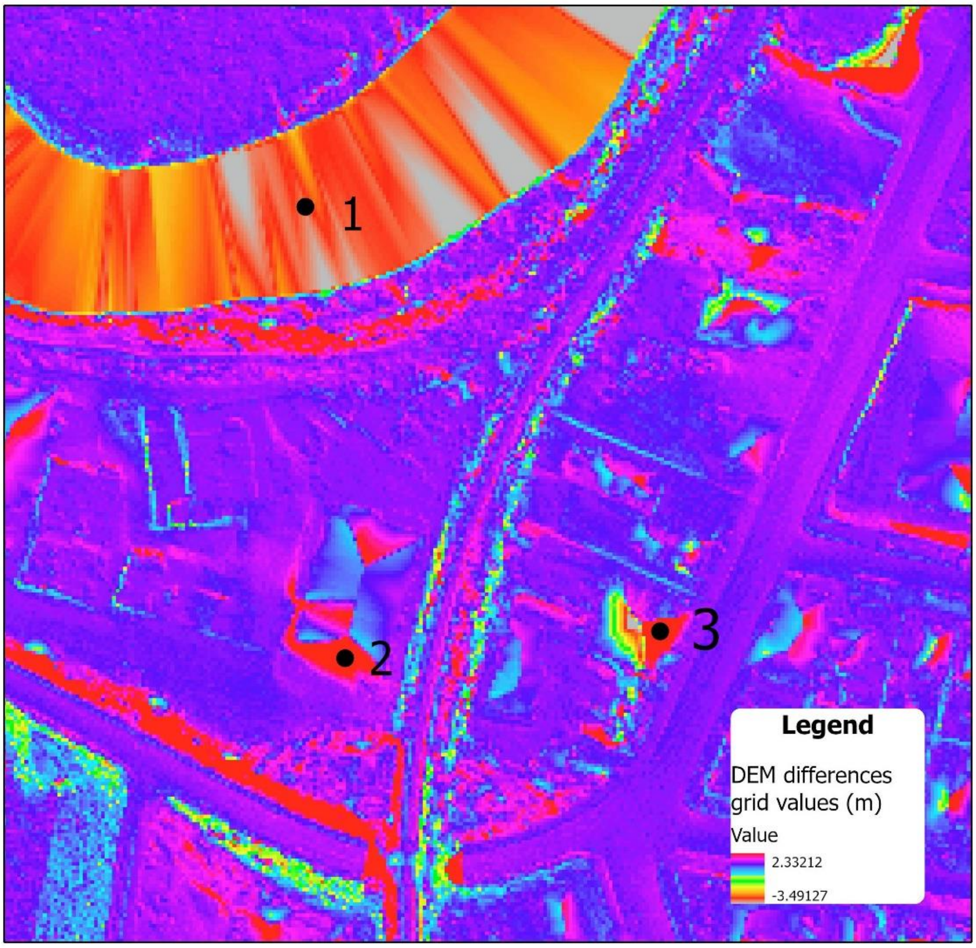


Figure 31 : differences of LINZ & Auckland Council DEMs in Helensville.

In the figure above, note major DEM differences in river. Also buildings and some slopes. Building removal & veg removal is an issue. Purple and magenta areas are all +/- 3cm. Significant differences are visible on rooflines, steep slopes, areas of trees and bushes, and in water surfaces.

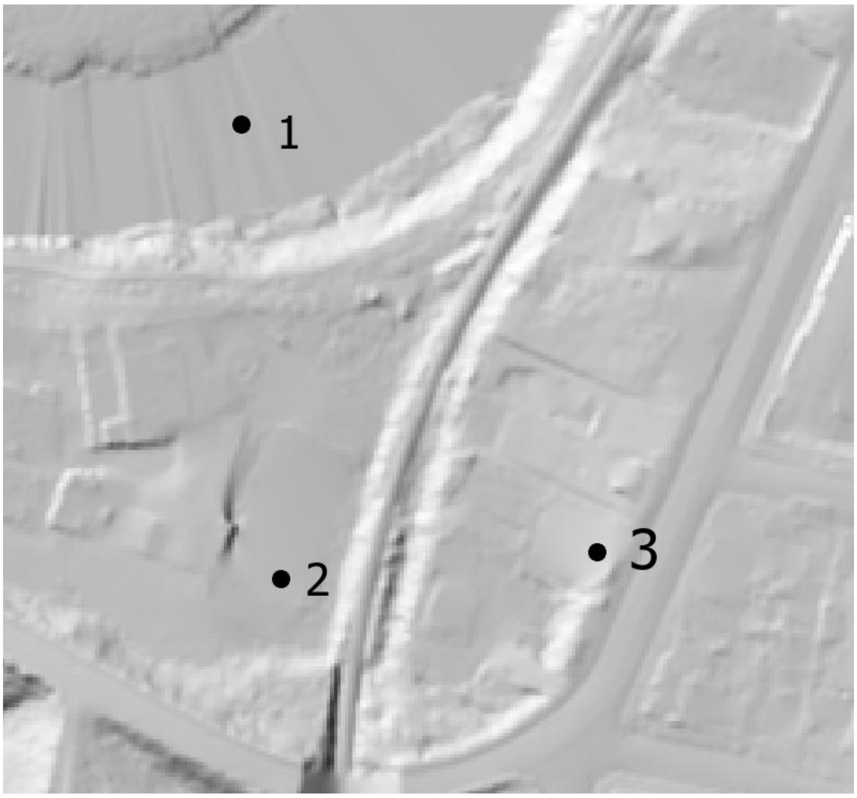


Figure 32: Hillshade from Auckland Council DEM, Helensville

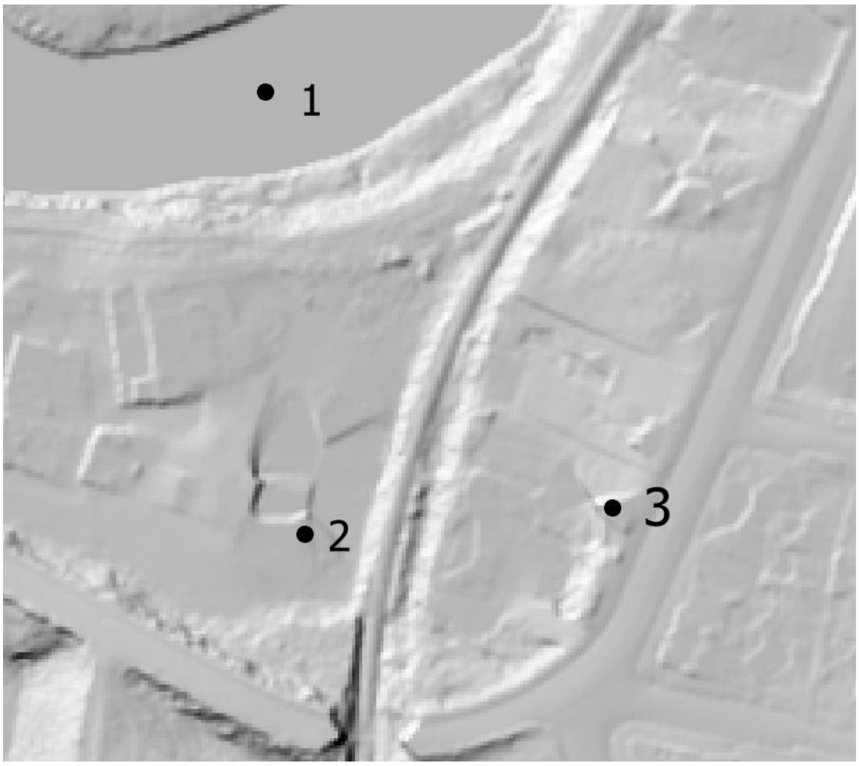


Figure 33 : Hillshade from LINZ DEM, Helensville

The figure above shows the original NZVD2016 DEM converted to AUK1946 datum. Note improved hydroflattening. At points 2 and 3, building roofline removal differ from the Auckland Council dataset. The LINZ DEM data (above) shows the “gable-end” effect of building footprint removal noted in Auckland Council LIDAR “Lessons Learned” notes.

Compare resulting contours

Contours defined using default ArcGIS Contour tool off DEMs without any smoothing.

Figure 34 : Helensville, 25cm contours of Auckland Council DEM

Figure 35 : Helensville, 25cm contours of LINZ DEM (converted to AUK1946 datum)

Figure 36 : Helensville, aerial photo of area shown in previous figures (2017).

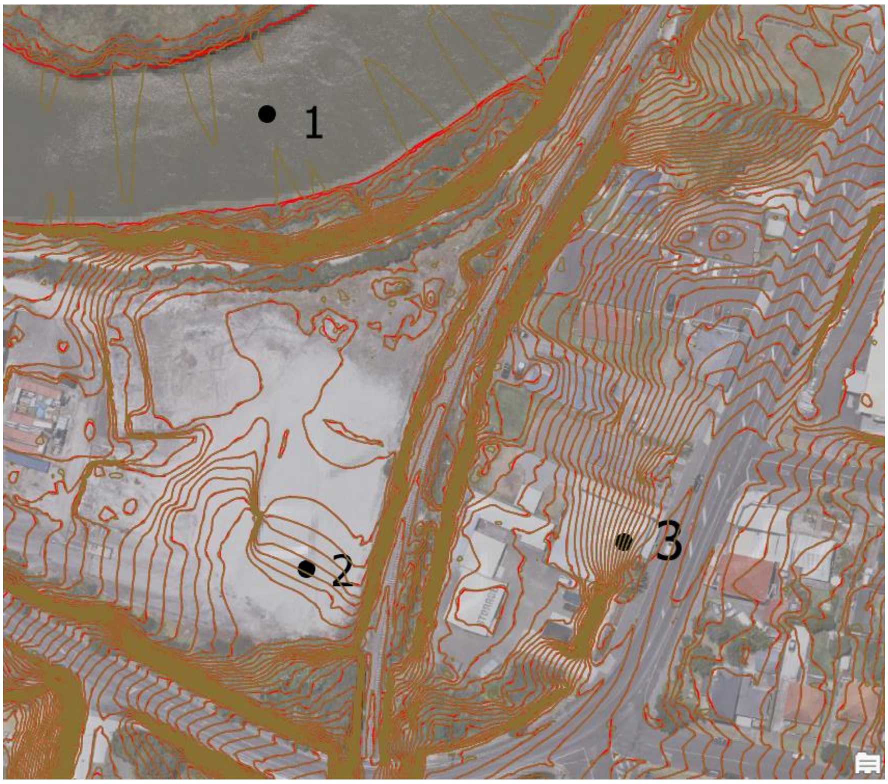


Figure 37 : Helensville, 25cm contours from Auckland Council DEM (brown) over Auckland Council 25cm Open Data contours (red).

In the figure above, contours recreated from the Auckland City DEM (AUK1946) are almost identical to existing contours in Geomaps, apart from the area alongside & across the river.

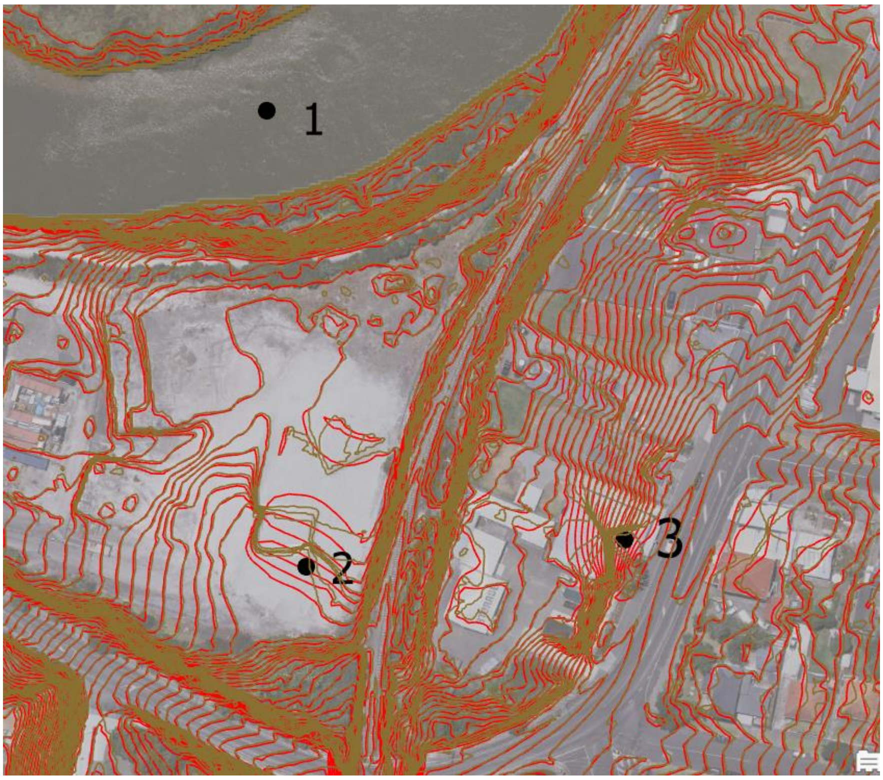


Figure 38: Helensville, 25cm contours of LINZ DEM (brown) over Auckland Council 25cm Open Data contours (red).

In the figure above, contours generated off the LINZ DEM (converted to AUK1946) are similar to existing Geomaps contours on open ground. They are significantly different under building footprints (e.g. points 2 and 3).

Kakamatua

The Kakamatua sample area shows significant differences in the 2 DEM datasets in forested areas.

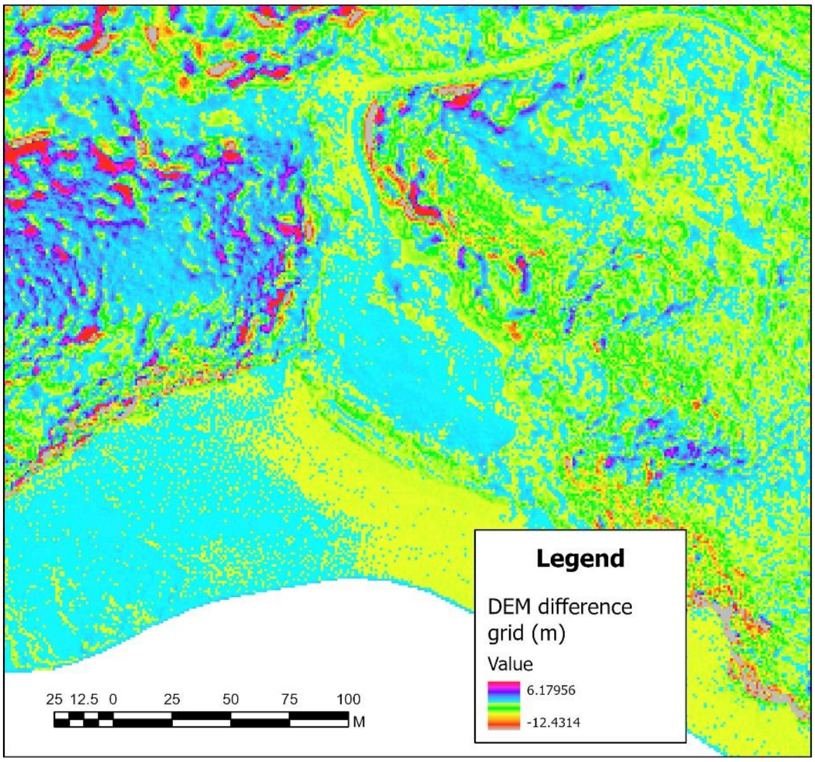


Figure 39 : Kakamatua, Kaitarakihi Bay, difference grid of DEMs

The figure above shows DEM differences : LINZ DEM values minus Auckland Council 2016-2018 DEM, after conversion to a common datum. Open areas have minor differences (+/- 5cm) whilst some forest areas have differences > 1m.

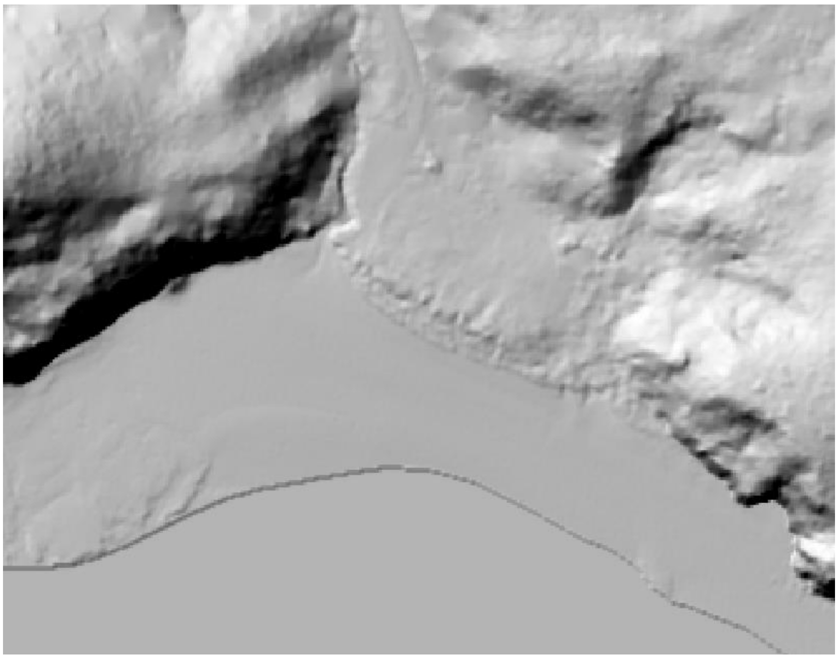


Figure 40 : Kakamatua, Kaitarakihi Bay, hillshade of Auckland Council 2016-2018 DEM.

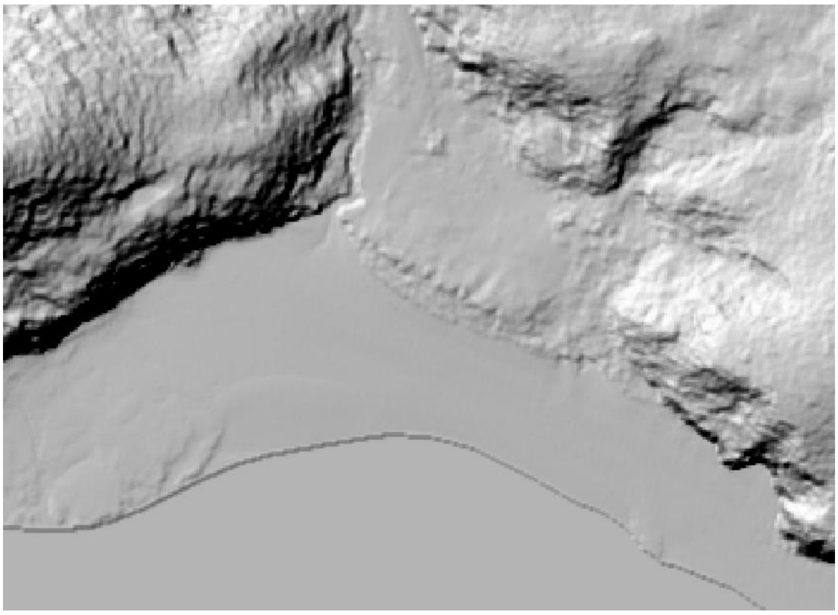


Figure 41 : Kakamatua, Kaitarakihi Bay, hillshade of LINZ 2016-2018 DEM.

Note forested areas show a much more irregular surface profile in the LINZ DEM at this site.

Browns Bay

The Browns Bay sample area shows significant differences in the 2 DEM datasets, in a similar style to the Helensville example.

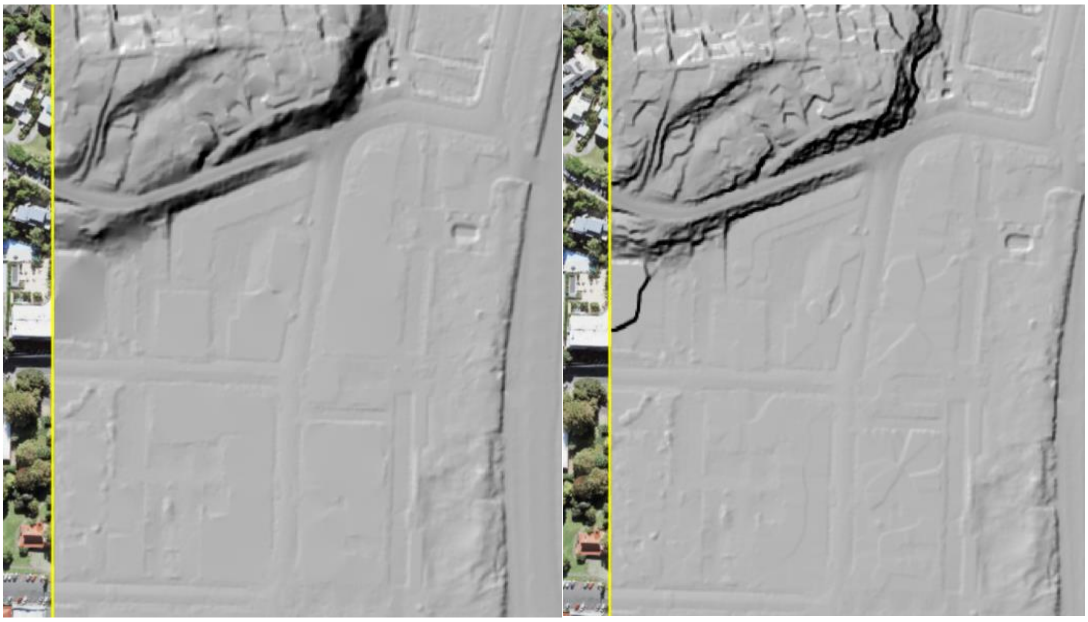


Figure 42 : Hillshades - Comparison of Auckland Council and LINZ DEMs.

The figure above shows a comparison of the hillshades from the Auckland Council 2016-2018 DEM (left) versus the LINZ 2016-2018 DEM (right). Location is Bayview Rd, Browns Bay, North Shore. Note greater smoothing of building footprints and vegetated slopes in Auckland Council dataset.

Extents of differences

10 comparison sites of single 1:1,000 tiles were used, as listed in the table in Section 3.1. The site locations are shown in the image below. Sites showing significant DEM differences are in red, those with no significant difference in green.

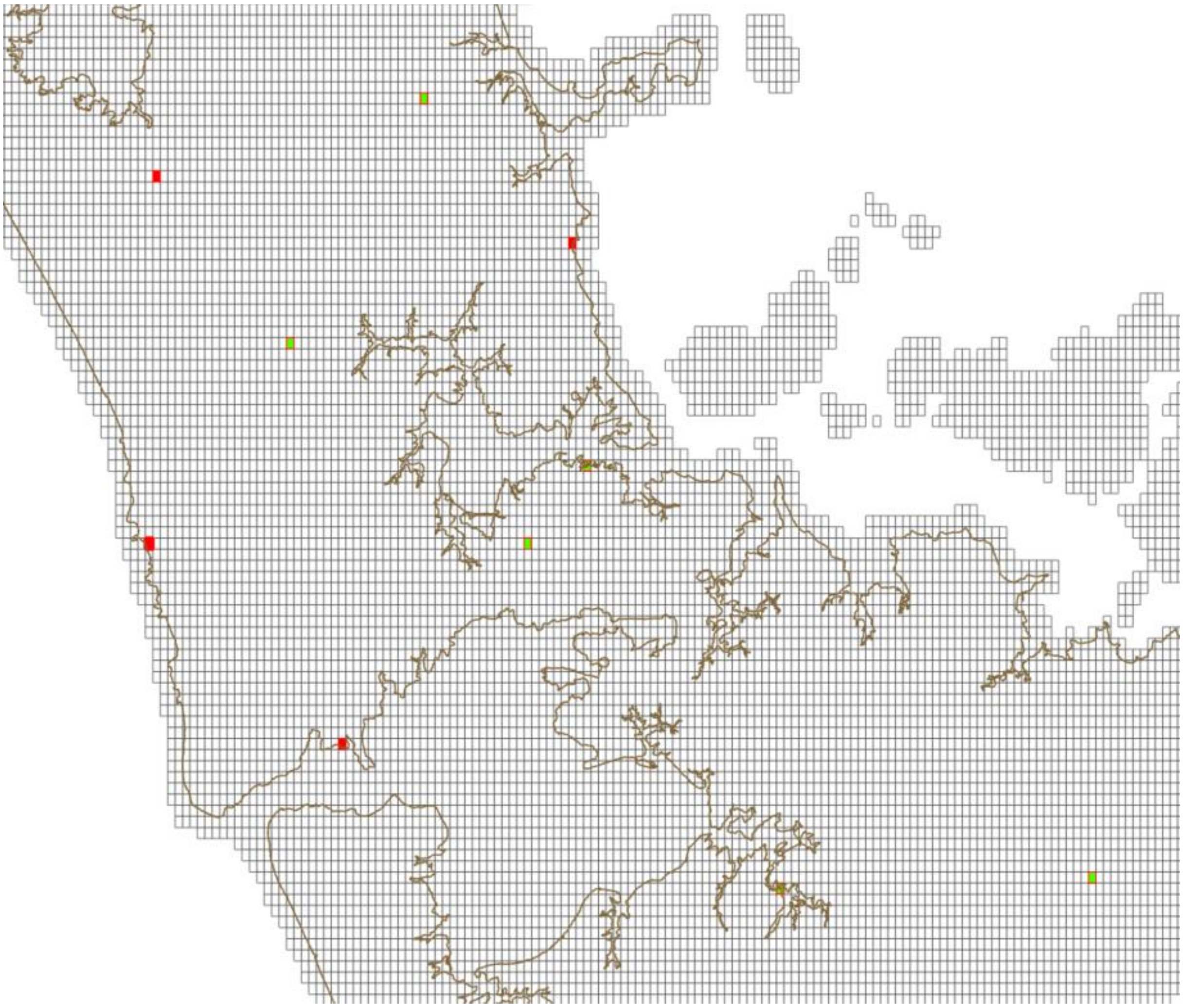


Figure 43 : Index of 1:1,000 tiles used for LIDAR DEM data for Auckland Region.

In the figure above, sites with significant differences between LINZ and the Auckland Council DEMs are in red (4 sites), those with no significant differences in green.

Appendix E – Impacts of change on slope angles due to datum changes

This appendix provides further detail about tests to determine if the datum change causes any significant change to slope angles in the DEM.

Impacts of change on slope angles

Further tests for this area were made by comparing slope angle rasters derived from the 2016 DEM, sampled at both 1m and 50m (downsampled) cell sizes.
A sample of the 2016 North Auckland LIDAR DEM in NZVD2016 (LINZ Data Service) was transformed to AUK1946. Slope angle rasters were derived from both DEMs, and the results compared using the ArcGIS Minus tool.

Figure 44: Slope angle raster from the 2016 LIDAR DEM, Freemans Bay, with original DEM using AVD1946 elevations.

Differences in the derived slope angles are extremely small at both resolutions, as summarised below for the 1m cellsize data (in degrees)

Band Name	Minimum	Maximum	Mean	Std. Deviation
Band_1	-0.000999927520751	0.00100028514862	0.00018081371289	0.00060039410783

In conclusion, the gradient changes due to datum shift are insignificant when applied to slope angle rasters. The only situation in which relative elevation changes (due to datum shifts) might become noticeable would be in very long linear features, e.g. major interceptor pipes. In these cases use of the new datum would improve accuracy & be more compatible with modern GNSS surveys. This situation is not applicable to the datasets examined for this report.

Appendix F – Derivation of Coastal Inundation data – checks of datum change effects

This appendix provides further detail about tests to determine if the datum change causes any significant change to the definition of coastal inundation areas, e.g. the 1%AEP 1m SLR coastal inundation zone polygons.

Derivation of coastal inundation data

The derivation of the layer *Coastal Inundation 100 yr return 1m sea level rise* was examined to check if the datum change would have any effect on the calculated extents.
This layer is derived from elevation values given in tables in TR2020/24. For example, Table 4-3, Site 13 shows the modelled 100-year extreme sea level (ESL) at Browns Bay as 2.52m to AUK1946 datum. Simply adding 1m for SLR gives the value 3.52m. The inundation polygon coastal boundary coincides with a DEM elevation of 3.54m to AUK1946 datum at this location (2cm margin of error). This confirms the derivation of the inundation data & shows how it could be recalculated if needed.
Translating the inundation elevation to NZVD2016 gives 3.246m at the same location. As expected, the NZVD2016 DEM has a value of 3.24m at this location. This confirms that no change is required to inundation zone layers for the changed datum.
The table below shows some sample locations at the upper boundary of the inundation zone polygon (100 year annual return interval (ARI), with 1m sea level rise (SLR)). Comparing the DEM values (AUK1946 Datum) with the extreme sea level values tabulated in TR2020/24, plus 1m SLR, confirms the consistency of DEM and inundation zone data.

Location on zone boundary (NZTM)	AUK1946 DEM	NZVD2016 DEM	Site	100-yr extreme sea level (ESL*)	ESL + 1m
1756374, 5935704	3.5359m	3.246m	Browns Bay - hard surface	2.52m to AUK1946 (Table 4-3, Site 13)	3.52m
1756267, 5935530	3.5153m	3.226m	Browns Bay - hard surface	2.52m to AUK1946 (Table 4-3, Site 13)	3.52m
1752242 5922737	3.4062m	3.09m	Freemans Bay - hard surface	2.40 to AUK1946 (Table 3-3, Site 5)	3.4m
1757214 5921134	3.356m	3.016m	Freemans Bay - hard surface	2.36 to AUK1946 (Table 3-3, Site 4)	3.36m

Table 1: Checks of upper boundaries of ARI 100, SLR 1m inundation zones against 2016 DEM

Tables of extreme sea level values in TR2020/24 can be used with NZVD2016 elevations by subtracting the appropriate conversion value from AUK1946 level values using the LINZ conversion data (typically about 30cm). In due course the tables could be republished with inundation levels referenced to NZVD2016.
An exception to these calculations is noted for the Kaipara Harbour and Helensville area. These areas have extensive flat coastal plains that require more detailed flood modelling. Here, ESL values have been used with hydrodynamic modelling to define the coastal inundation hazard area. The simple worked examples presented here for open coastal areas will not apply in these areas.

Worked example of using coastal inundation data

This example demonstrates derivation of the upper limit of the ARI 100, 1m SLR marine inundation polygon layer. The study area is Browns Bay, North Shore. It references tables in the report *TR2020/24.*

1. Pick the nearest site in Fig 4-1 to Browns Bay. This is site 13. Site data from the report will provide values of storm-tide and wave simulation output. This data is also available from Auckland Council Open Data as GIS dataset *Coastal_Inundation_High_Water_Levels*
2. Lookup site 13 in Table 4-3. This gives the 100-yr extreme sea level (ESL) as 2.52m relative to AUK-46 datum (Table 4-3, Site 13).
3. Add 1m sea level rise (SLR) to give 3.52m relative to AUK-46 datum. This assumes a "bathtub" model (no hydrodynamic effects) related to SLR.
4. In desktop GIS, create a contour on the DEM to AUK-46 at 3.52m elevation.
5. Overlay the resulting contour with the inundation area polygon. The line matches exactly.

Figure 45: Comparison of ARI 100 indundation zone with 1m SLR (blue) with 3.52m contour based off 2016-2018 DEM in AUK1946 datum (Browns Bay, North Shore)

6. Referring to the LINZ datum conversion grid, the datum conversion from AUK1946 to NZVD2016 at this point is 0.289m
7. The elevation for (ESL + 1m SLR) at this location becomes (3.52 – 0.289) = 3.231m relative to NZVD2016.
8. Take the LIDAR DEM using the NZVD2016 datum for contouring at 3.231m.
9. The resulting contour is identical, as expected.
10. This workflow shows that values in tables in report *TR2020/24* can be easily adjusted to be relative to NZVD2016, and give results compatible with published GIS inundation layers. This may be used for site-specific checks on building floor elevations etc.