FRONTIER SI

NEXT GENERATION HEIGHT REFERENCE FRAME

PART 2/3: USER REQUIREMENTS

Nicholas Brown, Geoscience Australia

Nicholas Bollard, RMIT University

Jack McCubbine, Geoscience Australia

Will Featherstone, Curtin University

Document Control

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Contents

1. Purpose and Scope

The purpose of this study was to assess both the **User Requirements (Part 2/3)** for height determination and the **Technical Options (Part 3/3)** which could be implemented to meet the user requirements.

The only other user requirements study of physical heights in Australia was undertaken in 1988 (Kearsley, 1988) which predates the widespread use of GNSS. Given the technological advances of the past two decades and the modern methods some now use to access physical heights, we felt it necessary to reach out to the user community to assess their needs for physical heights now and into the future.

The results of the user requirements study should be reviewed in conjunction with the technical options report which reviews the height system and height datum options which could be implemented in Australia based on current and future data holdings.

The objective is to identify what requirements users have for height datums in Australia and what can technically be developed to provide users with what they need. The **Executive Summary (Part 1/3)** brings the recommendations of both reports together to describe the preferred option to satisfy the needs of users for physical heights in Australia.

2. Introduction

2.1 Changing world of geospatial

Within five years users will have the capacity to position themselves at the sub-decimetre level using mobile Global Navigation Satellite Systems (GNSS) technology, providing efficient and accurate positioning for industrial, environmental and scientific applications.

The Geocentric Datum of Australia 2020 (GDA2020) was introduced in 2017 in recognition of the increasing reliance on and accuracy of positioning from GNSS. The new geocentric datum enables precise positioning relative to the ellipsoid, that is, coordinates computed in terms of geocentric Cartesian coordinates (XYZ) that are then converted to latitude, longitude and ellipsoidal height in terms of the Geodetic Reference System 1980 (GRS80) reference ellipsoid. Nonetheless, ellipsoidal heights do not take into account changes in gravitational potential and therefore cannot be used to predict the direction of fluid flow.

For this reason we have a physical datum, known as the Australian Height Datum (AHD) and a model to convert ellipsoidal heights to AHD heights known as AUSGeoid.

2.2 Introduction to the AHD

The Australian Height Datum (Roelse et al., 1971; AHD) is Australia's first and only national height reference system. It was adopted by the National Mapping Council in 1971 based on a (staged) least squares adjustment of 97,320 km of 'primary' levelling (used in the original adjustment) and approximately 80,000 km of 'supplementary' levelling (included in a subsequent adjustment). Levelling observations ran between junction points (see Figure 1; Filmer et al., 2010) in the Australian National Levelling Network (ANLN), and were known as level sections. These level sections were created by combining levelling observations along level runs (usually following major roads). The interconnected network of level sections and junction points was fixed to mean sea level (MSL) observed for 1966-1968 at 30 mainland tide gauges, with MSL assigned a value of zero AHD at each gauge. The staged least squares adjustment propagated heights above 1966-1968 MSL (or defined AHD zero reference), across the ANLN. The ANLN contains systematic, gross and random errors which have propagated into the AHD as local and regional biases (e.g. Morgan 1992).

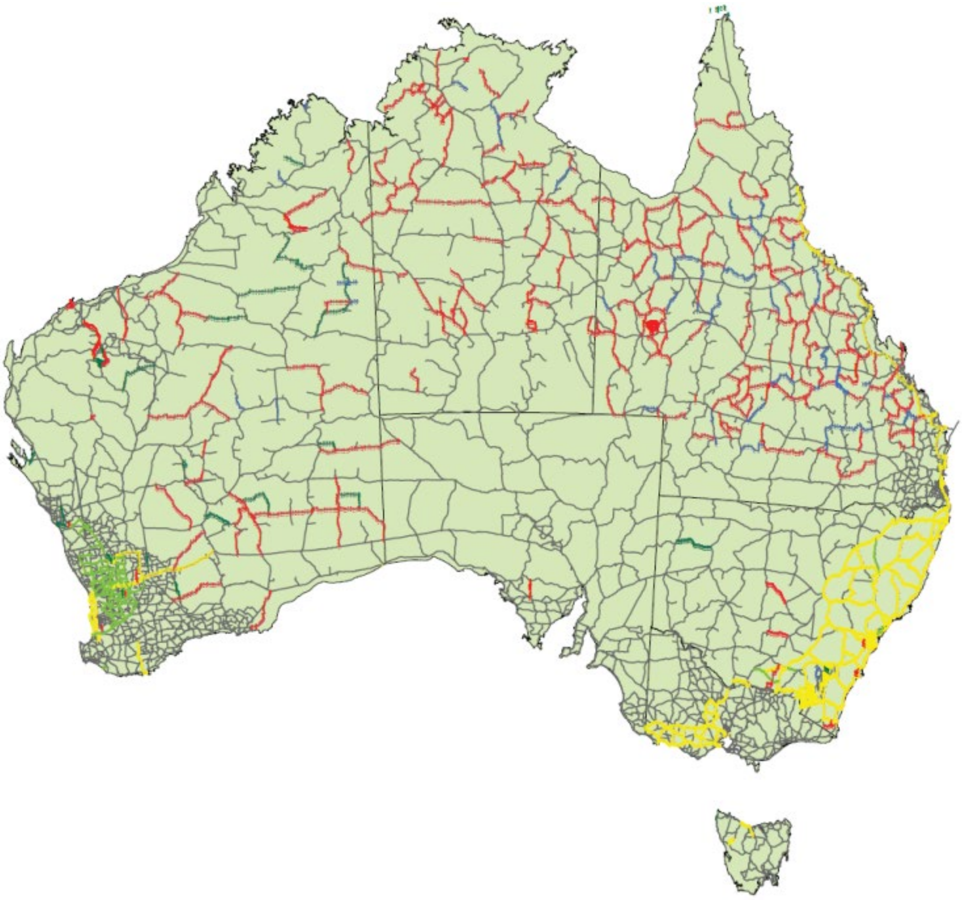

Figure 1: The Australian National Levelling Network (ANLN). First order levelling sections are in yellow, second order sections in light green, third order in fine grey, fourth order in dark green, one way (third order) in red and two-way (order undefined; Steed 2006, pers. comm.) in blue. The junction points are the intersection points of the levelling loops. Lambert projection (figure and description from Filmer et al., 2010).

The Australian Height Datum (Tasmania) 1983 (AHD–TAS83) zero reference is fixed to MSL observed for 1972 only at tides gauges in Hobart and Burnie. It was propagated throughout Tasmania using mostly third order differential levelling over 72 sections between 57 junction points and computed via least-squares adjustment on 17 October 1983. Because AHD (mainland) and AHD (Tas) are referenced to MSL observed at different times and locations, there is a vertical offset between the two datums, which has been estimated (from various methodologies and data) to be ~10 cm (Rizos et al. 1991), between 12 cm and 26 cm (Featherstone, 2000), and ~1 cm (Filmer and Featherstone, 2012). For the purposes of this document, AHD is used to refer to both the Australian Height Datum 1971 (AHD71; Australian mainland) and Australian Height Datum (Tasmania) 1983 (AHD–TAS83).

2.3 Problems with the AHD

The AHD is known to have a number of biases and distortions. The primary bias is due to the manner in which AHD was realised. In the adjustment of the levelling data, the measured mean sea level of tide gauges around Australian coastline was fixed to zero AHD. Due to the effect of the ocean's time-mean dynamic topography (MDT), AHD is about 0.5 m above the gravimetric geoid in north-east Australia and about 0.5 m below the gravimetric geoid in south-west Australia (e.g. Featherstone, 2004, 2006; Featherstone and Filmer, 2008). Secondary effects are uncorrected gross, random and systematic levelling errors in the ANLN (e.g., Roelse et al., 1975; Morgan, 1992; Filmer and Featherstone, 2009) and the use of the (truncated) Rapp (1961) normal-orthometric corrections applied to levelling data based on the GRS67 ellipsoid (Holloway, 1988).

Ignoring the primary bias from MDT, the secondary effects reveal the mean standard deviation of AHD heights used in the development of AUSGeoid2020 is ±0.038 m (Featherstone et al., 2017). Uncertainty in the national vertical datum of this magnitude may make AHD inappropriate for some users of the datum who require more accurate heighting capability because the data will be more accurate than the datum. It is therefore an appropriate time to engage with stakeholders and investigate their current and future requirements for physical heighting in Australia.

3. Stakeholder survey

The user feedback was captured via a Google Form survey sent out by Geoscience Australia on June 6, 2018 and closed on July 6, 2018. Over 300 stakeholders were contacted (organisation representatives and individuals) based on recommendations from state, territory and Commonwealth spatial representatives. The invitation to participate in the survey was distributed via:

- email by Geoscience Australia,
- publicised on Geoscience Australia’s LinkedIn and Twitter social media accounts
- shared by various surveying and spatial institutions

Broadly speaking, the survey was based around a person’s role within the spatial industry, the activities they required height for, how well AHD suited their activities and what they would like to see in a height reference frame in the future. Appendix A: Stakeholder Survey contains the specific questions asked in the survey.

3.1 Analysis methodology

The quantitative answers (1 – Low; 5 – Very High) could then be further explored or understood by reading the responses to the relevant qualitative (long answer) questions.

3.2 Overview of respondents

The survey received 172 responses with the respondents primarily being in more senior positions within industry or government. Analysis of the respondents suggests there are broadly two groups of respondents:

- **Group A**: cadastral, civil engineering, construction and mining, and
- **Group B**: environmental studies (e.g. flood, storm modelling), geodesy, hydrography or other research.

3.3 User satisfaction with AHD

Users were asked to list three activities they undertake using AHD. For each example, they were asked to provide a response on how ‘satisfied’ they were using AHD for this activity. User satisfaction for AHD was broken up into three categories, **high** (rating of 4/5), **medium** (3) and **low** (1/2).

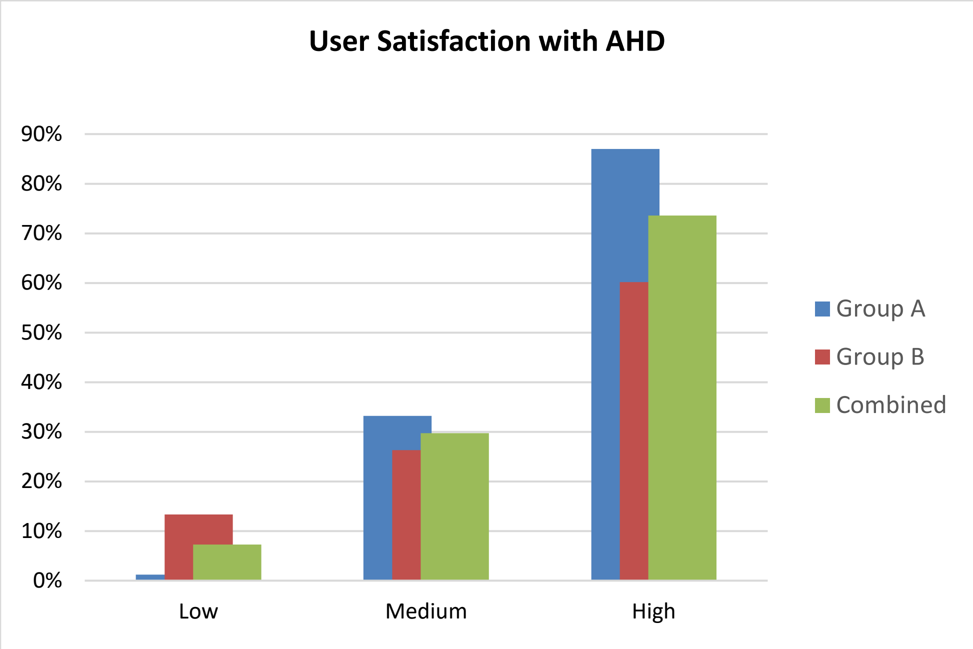

Figure 2.1 Summary of user satisfaction with AHD to perform height tasks.

- **74%** of the respondents record a **high** satisfaction rating with AHD across all tasks.
- **Group A** respondents made up **56%** of respondents and had a satisfaction rate of **87%**.
- The tasks undertaken **Group A** respondents are predominantly over short distances (<10 km) and the users are generally more concerned with the relative accuracy of AHD. This is demonstrated by the fact **77%** of this user group claim to only use levelling to access / work with AHD (i.e. levelling directly from local bench marks).
- **Group A** are less likely to be affected by the AHD's biases and distortions that generally occur over longer distances.
- **Group B** respondents made up the remaining **44%** of respondents and had a satisfaction rate of **61%**.
- **26%** of the respondents provided a **medium or low** satisfaction rating with AHD across all tasks. Common issues / problems identified by these respondents were:
  - Reliability
    - Regional biases or distortions in AHD over a large areas which make it difficult to determine if errors are in the users data, or in the datum. For example, this is an issue for respondents doing flood modelling.
    - Unstable / unknown ground motion of benchmarks which results in unknown / uncorrected movement over time (e.g. Gippsland Basin).
    - Unreliable height difference between ground marks over short and long distances.
    - Inconsistencies between published heights in jurisdictional databases and actual benchmark heights, especially in mountainous regions.
    - Sometimes published heights do not accurately describe which way water will flow.
    - Errors inherent in the datum mean that newer / more accurate data is inconsistent (e.g. digital elevation models (DEMs)).
    - AHD doesn't provide sufficient integrity over large areas (>10 km).
  - Access

- The national vertical datum cannot be accessed / realised offshore; this makes connecting onshore and offshore datasets difficult.
- Benchmarks are often a large distance from where you are working; particularly in remote / regional Australia.
- GNSS enables users to compute high precision coordinates, however, the benefits are diminished when AUSGeoid is applied which has uncertainty an order of magnitude greater than GNSS uncertainty.
- Offsets between the AHD and MSL (from 1966-68), MSL (today), chart datum, Lowest Astronomical Tide (LAT).
- Limitations is being able to align spatial data sets.

3.4 Access and efficiency of AHD

- The growing use of high accuracy GNSS within the spatial industry to either supplement traditional procedures such as levelling, or replace them all together, is improving a user's ability to efficiently connect to AHD.
- Using GNSS as part of a solution to obtain/transfer heights is now as common as levelling only.
- As shown in Figure 2.2, the most popular method (**44%**) used to observe / transfer height is a combination of GNSS with AUSGeoid and levelling.
- The top three next responses were levelling only (**29%**), GNSS with AUSGeoid only (**13%**), and DEMs (**6%**).
- This demonstrates that AUSGeoid is used for **57%** of activities described.

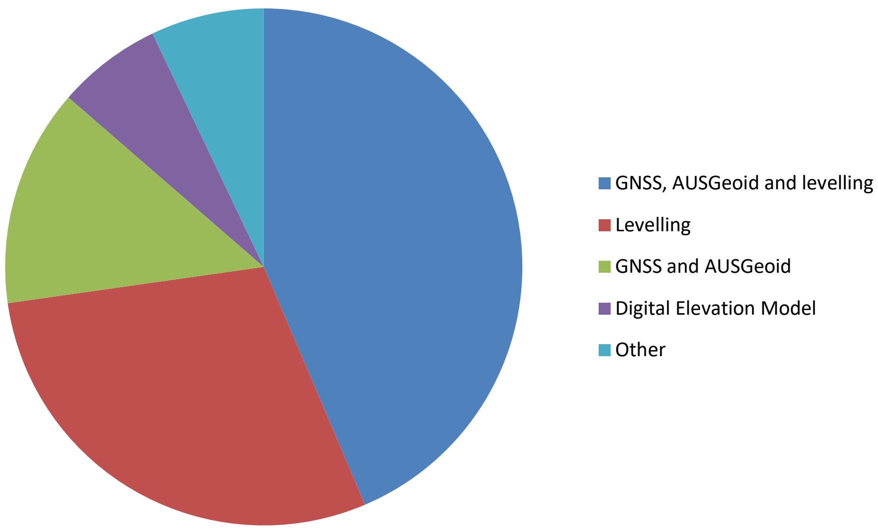

Figure 2.2 Summary of the methods used to compute / transfer AHD heights

- **78%** of **Group A** respondents remarked that AHD is efficient to observe and transfer height.
- **53%** of **Group B** respondents remarked that AHD is efficient to observe and transfer height.
- Combined results of satisfaction with AHD and efficiency of AHD indicate that AHD is fit for purpose for tasks over short distances (<10 km) while users are less satisfied and find it less efficient when working on tasks over larger areas (>10 km).

3.5 Accuracy of AHD

- For each of the three tasks described by the respondents, they were asked to record what 'absolute' and 'relative' accuracy they require to undertake the tasks.
- Absolute accuracy was defined as "accuracy with respect to the zero point of the height reference frame".
- Relative accuracy was defined as "accuracy of heights within a project area".
- As shown in Figure 2.3, **75%** of respondents have tasks which require absolute accuracy better than ±5 cm, with **27%** requiring better than ±1 cm (Figure 2.3).
- **86%** of respondents have tasks which require relative accuracy better than ±5 cm, with **47%** requiring better than ±1 cm.

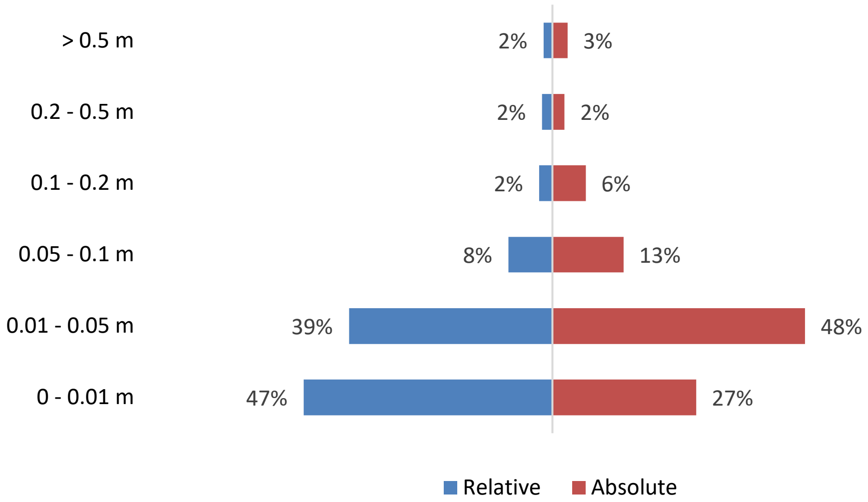

Figure 2.3 Summary of accuracy requirements of AHD for the tasks described by respondents.

- Featherstone et al. (2017) demonstrated that AHD has a one sigma accuracy of ±4 cm. This makes it very difficult to achieve the ±1 cm absolute accuracy **27%** of respondents claim they need.
- Furthermore, Brown et al. (2018) demonstrated that AUSGeoid2020 is only capable of computing absolute AHD heights with accuracy of ±5 - 13 cm. This effectively rules out the use of AUSGeoid2020 for absolute heighting for **75%** of tasks described by respondents.
- Given that **57%** of respondents use AUSGeoid to observe / transfer heights, this highlights a potential problem for the industry and demonstrates that further education on the use of AUSGeoid is required.
- It is important to note that the majority of users will be basing their answers on the use of AUSGeoid09 which claimed accuracy of better than ±5 cm across most of the country. The uncertainty estimates have increased in the recently released AUSGeoid2020 due to the inclusion of a more rigorous estimate of uncertainty including error sources from the gravity, levelling and GPS data (Brown et al., 2018).
- Respondents were also asked to describe their accuracy requirements of an alternative height reference frame (Figure 2.4).

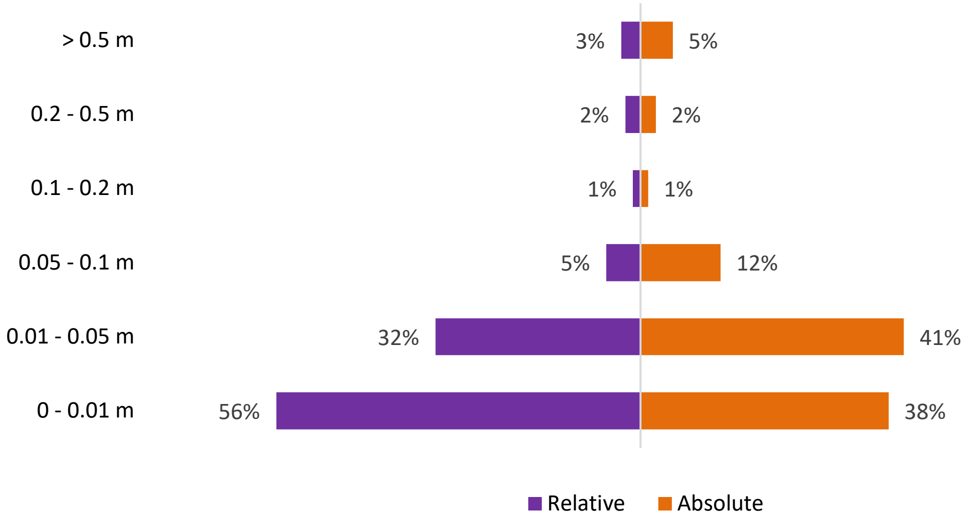

Figure 2.4 Summary of respondents desired accuracy of an alternative height reference frame.

- Compared to their current accuracy requirements, there was not a great deal of change. The main point of difference is the slight shift towards the requirement of a higher accuracy reference surface (**+11%** for absolute accuracy at better than 1 cm and **+9%** for relative uncertainty at better than 1 cm).

3.6 Why respondents use AHD

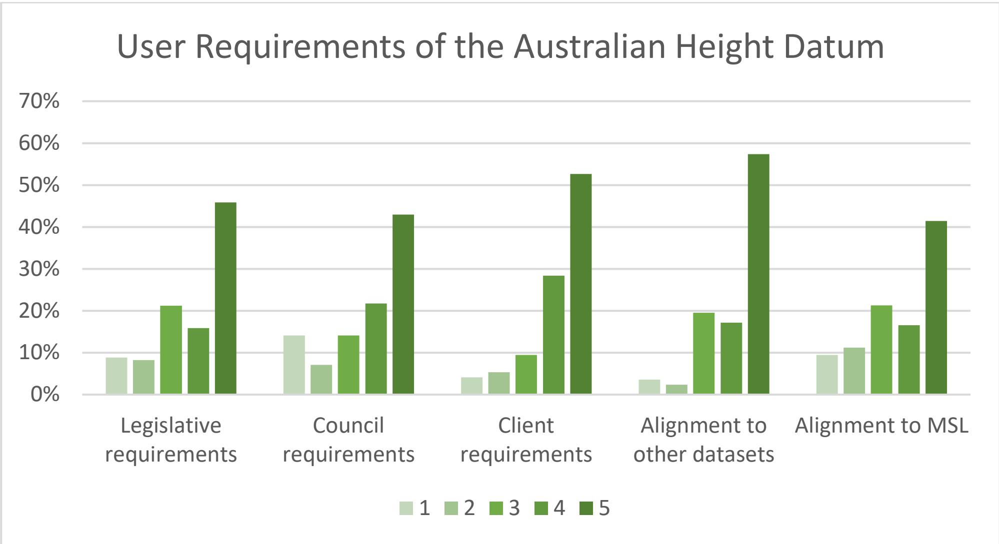

Figure 2.5 The drivers for respondents to use AHD (1 – Low; 5 – High).

- Many of the drivers for the use of AHD appear to be interconnected. It would seem that client and council requirements are linked to legislative requirements. This was particularly prevalent for the **Group A** respondents who rated legislative requirements **19%** more important than those from **Group B.**
- **70%** of respondents from **Group A** and **85%** from **Group B** rated their need to align spatial datasets as high. This indicates there is a slightly greater need for spatial alignment from **Group B** users who tend to undertake tasks that cover larger areas and use "big data".

- **63%** of respondents expressed a high requirement to have heights aligned to MSL, while **50%** of respondents expressed a high requirement to have heights aligned to a truly level surface. This indicates there may be a need for further information / education on this topic including advice on conversion between the gravimetric quasigeoid, AHD, MSL, other tidal datums and the uncertainties associated with the conversions.
- **100%** of those performing flood modelling rate alignment to MSL as high. Furthermore, hydrography (**77%**), research (**71%**) and mapping (**67%**) also consider the importance of alignment to MSL as high.
- **47%** of respondents indicated that alignment to MSL was of high importance and that they are satisfied with AHD. Given that they likely diverge by over 10 cm, this indicates either a misunderstanding of how closely AHD and MSL are aligned or a 10 cm requirement for alignment is generally adequate.
- **56%** of users who are likely to adopt an alternative height reference frame rated alignment to MSL as high. This indicates that if the alternative height reference frame is not directly aligned to MSL, a conversion surface should be supplied along with education material to explain the difference.

3.7 Using an alternative height reference frame

- When asked "given AHD is the national vertical datum, how likely is it your organisation would use an alternative height reference frame", **30%** of users said they were likely to adopt it.
- This is closely aligned to the percentage of respondents who indicated a low or medium satisfaction rating with AHD (**26%**).
- The reasons respondents gave for opting to move to an alternative height reference frame can be broadly described under the same headings as to why they were not satisfied with AHD, that is, reliability and access.
- Respondents remarked that an alternative height reference frame based on a gravity model only would provide:
    - improved access;
    - higher accuracy;
    - Increased efficiency;
    - surface without the known errors of the levelling network;
    - better alignment with GNSS; and
    - national consistency (including seamless onshore – offshore).

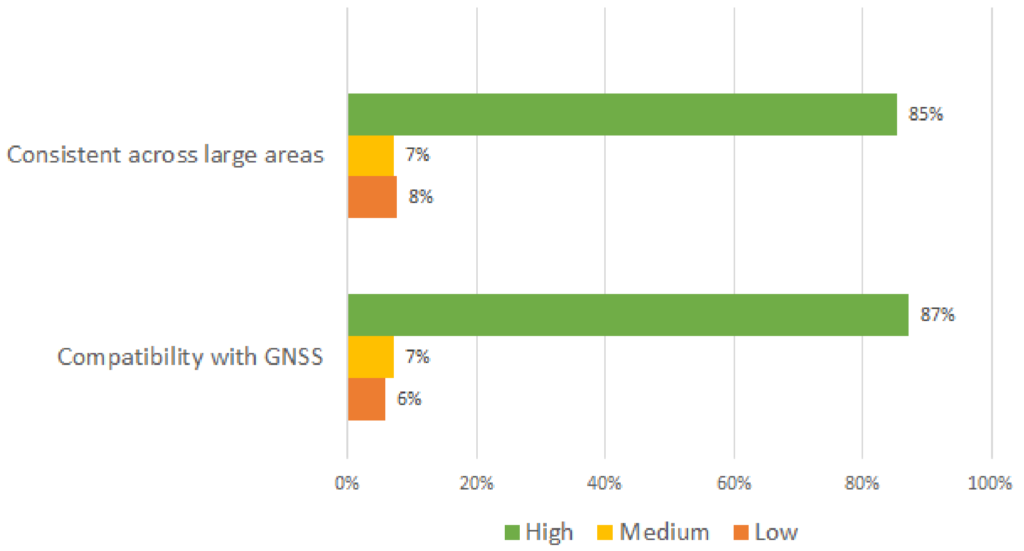

Figure 2.6 Summary of respondent statistics on how important consistency across large areas and compatibility with GNSS are to their organisation adopting an alternative height reference frame.

- It is clear from Figure 2.6 that respondents believe consistency across large areas (**85%**) and compatibility with GNSS (**87%**) is very important for adoption of the alternative height reference frame.

3.8 Monuments or model

- Respondents were asked whether or not they would be happy to compute height from a model as opposed to physical benchmarks.
- Results were mixed with:
  - **33%** of users indicated that deriving height from a geoid model is preferable over heights from ground marks;
  - **24%** indicated they may be able to use it depending on the task being performed, and
  - **27%** preferred using ground marks.
  - **16%** of responses were unclear from the descriptive responses provided.
- This is an interesting result given that **Group A** respondents had an AHD satisfaction rate of **87%**.
- This indicates that some from the more traditional AHD user group can see the benefits of moving towards a model to compute physical heights.
- It also highlights a reasonable demand from the user community to retain AHD in its current form.

3.9 Summary

- Analysis of the results suggests there are two distinct groups of respondents:
  - **Group A**: cadastral, civil engineering, construction and mining, and
  - **Group B**: environmental studies (e.g. flood, storm modelling), geodesy, hydrography or other research.

Table 2.1 Summary of responses from Group A and Group B. Green indicates satisfaction with AHD, yellow indicates issues / problems with AHD and red indicates more serious issues / problems.

	Group A	Group B
Respondents	56%	44%
Satisfaction	87%	61%
Access and efficiency	78%	53%
Accuracy	Absolute: 72% better than 5 cm; Relative: 85% better than 5 cm	
Why use AHD?	High need to align spatial data: 70%	High need to align spatial data: 85%

- The common problems with AHD identified by respondents AHD were to do with reliability of published height information and physical accessibility of the datum.
- Combined results of satisfaction with AHD and efficiency of AHD indicate that AHD is fit for purpose for tasks over short distances while users are less satisfied and find it less efficient when working on tasks over larger areas.
- **75%** of respondents have tasks which require absolute accuracy better than ±5 cm, with **27%** requiring better than ±1 cm (Figure 2.3).
- **86%** of respondents have tasks which require relative accuracy better than ±5 cm, with **47%** requiring better than ±1 cm.
- AHD internally propagated leveling errors have a one sigma accuracy of ±4 cm, although the accuracy maybe worse (up 0.5 m) in regional areas where leveling observations are more sparse. This makes it very difficult to achieve the ±1 cm absolute accuracy requirement **27%** of respondents claim they need. Furthermore, AUSGeoid2020 is only capable of computing absolute AHD heights with accuracy of ±5 - 13 cm. This effectively eliminates the use of AUSGeoid2020 for absolute heighting for **75%** of tasks described by respondents. Given that more than **50%** of respondents use AUSGeoid to observe / transfer heights, this highlights a potential problem for the industry and demonstrates that further education on the use of AUSGeoid is required.
- **63%** of respondents expressed a high requirement to have heights aligned to MSL, while **50%** of respondents expressed a high requirement to have heights aligned to a truly level surface. There seems to be a need for further information / education on this topic including advice on conversion between the gravimetric quasigeoid, AHD, tidal datums and the uncertainties associated with the conversions.
- **Group B (70%)** have a slightly greater requirement than **Group A (85%)** to align spatial data. **Group B**, who generally has tasks which cover larger areas and use "big data", have more problems with AHD.
- **56%** of users who are likely to adopt an alternative height reference frame rated the need for alignment to MSL as high. This indicates that if the alternative height reference frame is not directly aligned to MSL, a conversion surface should be supplied along with education material to explain the difference.

- Respondents remarked that an alternative height reference frame based on a gravity model only would provide:
    - improved access;
    - higher accuracy;
    - Increased efficiency;
    - surface without the known errors of the levelling network;
    - compatibility with GNSS; and
    - national consistency (including seamless onshore – offshore).
- Respondents were asked whether or not they would be happy to compute height from a model as opposed from bench marks.
    - **33%** of users indicated that deriving height from a geoid model is preferable to using ground marks;
    - **24%** indicated they may be able to use it depending on the task being performed, and
    - **27%** preferred using ground marks.

4. Recommendations

4.1 Choice of reference frame

1. Adopt a two frame approach for height in Australia. AHD remains as the national height datum, and an alternative height reference frame is developed and implemented based on a gravimetric geoid/quasigeoid model.
2. The alternative height reference frame should be:
   a. cost-effective to develop and implement;
   b. nationally consistent;
   c. reliable and robust in its ability to transform heights from GNSS ellipsoidal heights to physical heights over large regions (10s-100s km);
   d. compatible with GDA2020, GDA94, International Terrestrial Reference Frame (ITRF) realisations and Australian Terrestrial Reference Frame (ATRF);
   e. easily used to connect onshore and offshore heights.
3. The proposed alternative height reference frame should be chosen by combining the users requirements summarised in this report, along with the CRCSI Report *Project 1.29 Next Generation Height Reference Frame – Technical Requirements*.
   a. The alternative height reference frame should be based only on the gravimetric geoid.
   b. The gravimetric geoid/quasigeoid is a better model for onshore-offshore connection as a reference surface (minimum uncertainty). Other conversions can be done to get user to AHD, LAT, MSL, MSS etc.

4.2 Name of reference frame

4. The name of the alternative height reference frame should be decided as part of a specifically designed communications strategy.

4.3 Communication and Education

5. The release of the alternative height reference frame should be clearly communicated to users based on a defined strategy and stakeholder management plan.
6. Education material demonstrating the benefits of the alternative height reference frame should be released with the reference frame to allow users to make informed decisions and maximise the number of users likely to adopt the alternative height reference frame.
7. Education is required on the uncertainties associated with AHD and AUSGeoid. The statistics reported in the user requirements study suggest there are a large number of users who believe AHD and AUSGeoid are more accurate than they are.

4.4 Tools / Products

8. To make the alternative height reference frame as user friendly as possible, a conversion model between AHD and the alternative height reference frame the should be made available to users.
9. The alternative height reference frame should be periodically refined and improved with time as new data and development techniques are available.

4.5 Future Work

10. A follow up user survey should be completed to assess changes in user requirements and opinions regarding the alternative height reference frame a couple of years after it has been made public.

Appendix A: Stakeholder Survey

User requirements for height reference frames in Australia

The Australian Height Datum (AHD) is Australia's first and only national height datum. Since its implementation a number of biases and distortions have been identified with AHD which limit its ability to support some applications. Furthermore, a number of technological developments have occurred which make height observation / transfer using modern technology more efficient than the techniques used in the 1970's and 1980's.

In recognition of this, a Cooperative Research Centre for Spatial Information project has been established to investigate the height datum / reference frame requirements of Australian users. As part of this project, Geoscience Australia is undertaking an assessment of user requirements, and will lead the technical development of an alternative height reference frame which will be made publicly available.

This project is not attempting to replace AHD as the national datum for heights, but instead to develop an alternative height reference frame that meets the requirements of those users who do not have their requirements met by AHD. To help us understand your requirements and guide the technical development of an alternative height reference frame, we would appreciate your input on the following survey.

Please feel free to circulate this link to others who you think may be able to provide input.

The survey end date has been extended and will now close on Friday 6 July 2018.

Definitions:

** Height reference frame: a reference point / surface to which heights can be referred.*

** Relative (or local) accuracy: Relative accuracy is the degree to which the height of a point is accurate relative to other heights of points within the area.*

** Absolute (or global) accuracy: Absolute accuracy, is the degree to which the height of a point corresponds to the height reference frame.*

** AUSGeoid: A model used to convert ellipsoidal heights to AHD heights and vice versa.*

Email address *

Valid email address

This form is collecting email addresses. Change settings

Name: *

Short answer text

Organisation: *

Short answer text

Role within organisation: *

Short answer text

Section 2 of 3

Your use of the Australian Height Datum (AHD)

This section is intended to shape our understanding of your current use of the Australian Height Datum (AHD)

1. Overall, how important are the following factors to the use of AHD in your organisation?

Description (optional)

Legislative requirements *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very important

Council requirements *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very important

Client requirements *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very important

Alignment to other datasets *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very important

Alignment to mean sea level *

	1	2	3	4	5	
Not at all	○	○	○	○	○	Very important

1b. Are there any other important factors which require you to use AHD in your organisation? *

Long answer text

2. How do you currently use the Australian Height Datum? (Please provide between one and three examples)

Description (optional)

Example 1

Description (optional)

Type of task? *

- ○ cadastral
- ○ construction
- ○ mining
- ○ environmental studies
- ○ civil engineering
- ○ mapping
- ○ research
- ○ geodetic
- ○ Other...

Please provide a description of the task

Long answer text

Absolute accuracy (i.e. accuracy with respect to the zero point of AHD) *

- 0 - 0.01 m
- 0.01 - 0.05 m
- 0.05 - 0.1 m
- 0.1 - 0.2 m
- 0.2 - 0.5 m
- > 0.5 m
- Not Applicable

Relative accuracy (i.e. accuracy of heights within a project area) *

- 0 - 0.01 m
- 0.01 - 0.05 m
- 0.05 - 0.1 m
- 0.1 - 0.2 m
- 0.2 - 0.5 m
- > 0.5 m
- Not Applicable

What technique do you use to observe / transfer to AHD height for this activity? *

- Levelling
- GNSS with AUSGeoid
- Digital Elevation Model
- Combination of GNSS with AUSGeoid and levelling
- Other...

How well does AHD satisfy your requirements for this activity? *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very well

How efficient is it for you to obtain AHD heights for this activity? *

	1	2	3	4	5	
Very inefficient	◯	◯	◯	◯	◯	Very efficient

Does the use of AHD cause problems for this activity? If so, how? (e.g. reliability, ability to align data sets)

Long answer text

Section 3 of 3

Your height reference frame requirements

This section is intended to shape our understanding of your requirements of an alternative height reference frame recognising that they may be different to what AHD can provide.

3a. How important would the following factors be to your organisation using an alternative height reference frame?

Description (optional)

Compatibility with GNSS *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very important

Consistent across large areas *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very important

Have a known connection to the state / territory survey control mark network *

	1	2	3	4	5	

A truly level surface (i.e. surface of equal gravitational potential) *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very important

Alignment to mean sea level *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very important

Research clearly demonstrating the benefits *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very important

Alignment of spatial data? *

	1	2	3	4	5	
Not at all	◯	◯	◯	◯	◯	Very important

Absolute accuracy required? (i.e. accuracy with respect to the zero point of the height reference frame)

- 0 - 0.01 m
- 0.01 - 0.05 m
- 0.05 - 0.1 m
- 0.1 - 0.2 m
- 0.2 - 0.5 m
- > 0.5 m
- Not Applicable

Relative accuracy required? (i.e. accuracy of heights within a project area) *

- 0 - 0.01 m
- 0.01 - 0.05 m
- 0.05 - 0.1 m
- 0.1 - 0.2 m
- 0.2 - 0.5 m
- > 0.5 m
- Not Applicable

4. Given that AHD is Australia's national height datum, how likely would it be for your organisation to use an alternative height reference frame? *

	1	2	3	4	5	
Highly unlikely	○	○	○	○	○	Highly likely

4b. Why did you choose this rating?

Long answer text

5. One option for the alternative height reference frame is a geoid model (like AUSGeoid2020). Would generating / accessing heights from a combination of GNSS ellipsoidal heights and a geoid model be a useful option for your organisation as opposed to generating / accessing heights from survey bench marks? Why? (NOTE: An implication of this approach may be that the absolute accuracy of heights is not as good as AHD) *

Long answer text

6. Is there anything else you would like to tell us?

Long answer text

Thank you very much for your time and feedback. Your response is greatly appreciated.

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