How the Up-to-date Height Model of the Netherlands (AHN) became a massive point data cloud

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Abstract

The Up-to-date Height Model of the Netherlands (Actueel Hoogtebestand Nederland, AHN) is a digital terrain model of the Netherlands, owned by the 26 water boards and Rijkswaterstaat. The first generation was completed in 2003. In 2006 the steering committee decided for a second generation AHN with upgraded specifications to comply with the increasing requirements of the water boards. Pilot data was assessed on its suitability for the most demanding application: dike management. In this paper the development to the second generation AHN and its specifications are described. Also the available products and the assessment are described. The massive amount of data and limitations of hard- and software cause the point data to be much fewer used than the grid data.

1. Introduction

Rijkswaterstaat (the executive Directorate General for Public Works and Water Management of the Dutch Government) and the 26 regional water boards are in charge of water management in the Netherlands. They construct, manage and maintain the waterways, dikes, flood defences and structures in order to protect the Netherlands against flooding, they ensure a proper discharge of excess water and an adequate supply of good quality water for all users. For these tasks they need detailed information on the height of the terrain and dikes.

As soon as this seemed technologically viable, laser altimetry was used to produce a country-wide height model. The history of this first generation AHN, completed in 2003, is described in section 2. Meanwhile, technological development of the LiDar technique made it possible to obtain a height model with much higher density. These digital terrain models, for which some water boards undertook separate corridor laser mapping, were good enough to be used for the legally obliged assessment of dike height and stability. In 2006 a pilot was organised to acquire a next generation AHN. The upgraded specifications of this AHN-2 would make it possible to unify the acquisition of height data for both water management and dike management. It was decided that the AHN-2 would be acquired for the whole of the Netherlands during 2008 – 2012. This development is described in section 3.

Meanwhile, dike experts wanted to check whether the specifications of AHN-2 would indeed suffice to fulfil the legal obligations on dike management. Therefore an assessment of the pilot data for dike management was done. It is described in section 4. The upgraded specifications of AHN-2 cause the amount of data to increase dramatically. In section 5 the products and their usage by water boards are described. Special attention is paid to the point cloud data. Section 6 lists some concluding remarks.

2. History of the AHN

In 1996, the new remote sensing technique of laser altimetry promised to have reached the level of development necessary to be used in business processes. Rijkswaterstaat, the water boards and the provinces started an initiative to cooperate in obtaining a country-wide height model primarily suitable for water management: the *Up-to-date Height Model of the Netherlands* or *Actueel Hoogtebestand Nederland* (AHN). The availability of a high-density height model seemed promising compared to the old height information TOPhoogteMD, consisting of 20 to

50 year old terrestrial levelling data with a density of no more than one measurement per hectare.

However, the LiDar technique (in the Netherlands known as laser altimetry) turned out to be on a lower level of technological readiness than expected. In close cooperation with airborne laser scanning companies, the former Survey Department (Meetkundige Dienst) of Rijkswaterstaat developed a high level of scientific and executive expertise in acquiring and processing the data. Issues covered were GPS and the artefacts it could cause in the data, the influence of the behaviour of the inertial navigation systems (INS), the adjustment of overlapping scanning strips and an extensive treatment of the four error components leading to a detailed description of the error structure of the resulting height model (Brand et al., 2003).

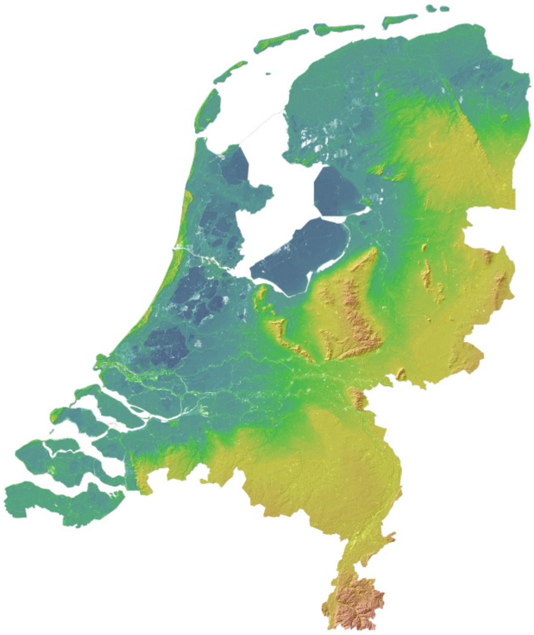
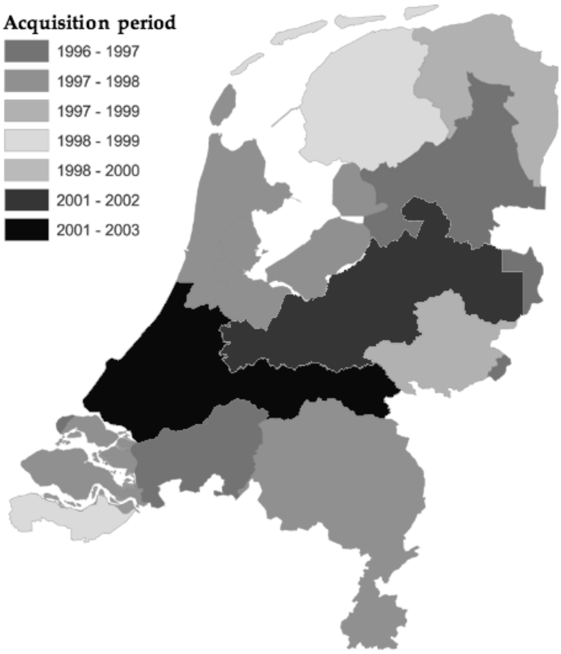


Figure 1. Overview of the first generation of the AHN, completed in 2003.

In 2003 the first generation of the Dutch height model, now denoted AHN-1, was complete, covering the Netherlands with a density of one height measurement per 1 to 16 square metre. As Figures 2 and 3 show, the increasing density is primarily a consequence of technological development and viability and hence almost only depending on the date of acquisition. In a simplification beyond the error structure mentioned above, the height error can be summarized to be at most 5 cm systematic plus 15 cm standard deviation for the stochastic component, for areas not covered with vegetation (Van Heerd et al., 2000).

For many applications, these specifications suffice. Even with the advent of the upgraded second generation of the AHN, the AHN-1 can be of use. Although it is not very up-to-date (cf. Figure 2), it is the only dataset covering the whole of the Netherlands. For large-area, low-detail applications its specifications can be sufficient, e.g. for some water management applications and the study of the topographic features, as the trivial example in Figure 4 illustrates. For some users the much smaller data files and low cost can also be an advantage.



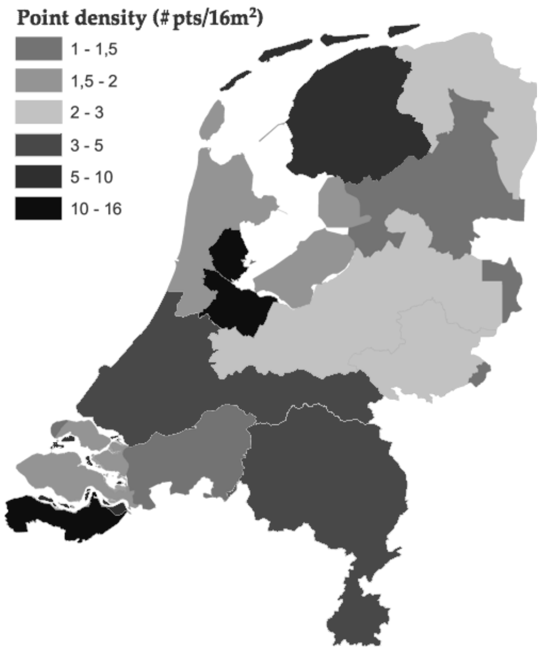


Figure 2. Year of acquisition of AHN-1.

Figure 3. Point density of AHN-1.

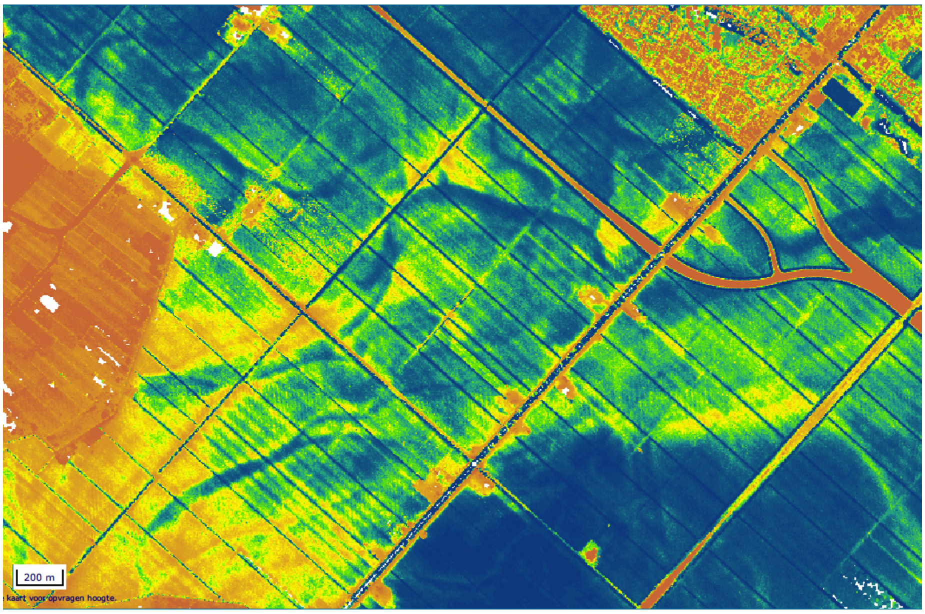


Figure 4. For many applications, the point density and accuracy of the AHN-1 suffices. With the AHN viewer at ahn.nl, any user can explore height data in sufficient detail to discover unexpected features in the landscape himself. Just by adapting the legend of the viewer at the world wide web, the author 'discovered' that the 180 sq km Haarlemmermeer polder he lives in is not as flat as it seems. The 1997 1pt/8m^2 data is sufficient to uncover old streams.

3. Need for a next generation: AHN-2

3.1. Need for higher specifications: dike management

Water boards and Rijkswaterstaat need detailed and precise height data of their dikes. The Flood Defences Act oblige them to assess their dikes and flood defences once per five year in accordance with the very detailed *Directions for the legal assessment of dikes* (*Voorschrift Toetsen op Veiligheid*, VTV) (Van den Berg et al., 2004). In these directions, the height of the top of the dike is important (because of water overflow and wave overtopping), but also its profile, because in combination with the composition of the dike body, this determines the strength of the dike and its resistance against sliding. Furthermore, apart from these primary dikes, also detailed geometrical information of the regional dikes and embankments is needed, because they are considered more and more to be important with respect to flood risk management. Geometrical information is also needed to draw up the obligatory public register of dikes, waterways and flood defences (legger en beheerregister).

Until recently, geometrical data of dikes was mainly acquired by terrestric surveying. The technological development in laser altimetry made it, however, possible to acquire digital terrain models of dikes by means of laser altimetry. As of 1999, some water boards in the large river area had their dikes acquired with LiDar from helicopters. These acquisitions were quite different from the AHN: the point density was much higher, the precision slightly better, simultaneous aerial photography and sometimes videos were available and the mapping was done in strips following the bends of the dikes (‘corridor mapping’).

3.2. A next generation AHN: pilot with upgraded specifications

Some water boards, experienced in using corridor LiDar mapping with high specifications for dike assessment, considered acquiring a full-area LiDar height model that also could serve their needs on dike management. Private companies were, in the mean time, offering such a high-precision high-density LiDar height model and even had plans to cover the whole of the Netherlands with such a commercially available height model.

In 2006, the AHN steering committee decided to organise a pilot with Waterschap Zeeuwse Eilanden (water board WZE) to acquire a next generation AHN. Its higher specification would make it suitable for dike management, so that separate corridor LiDar mapping with high specifications would no longer be necessary. Meanwhile, a new way of specification and tendering could be tested, leaving more initiative to the market. Also new was the tendering of the quality control to a separate contractor. All contractors had to prove the quality themselves.

The requirements were defined in terms of user needs instead of by detailed technical specifications. Therefore an inventory of current specifications and user requirements was executed and the results were assessed geodetically. An example of specification in terms of user needs is that the requirement on planimetric accuracy was that it should be possible to map objects of 2 x 2 meter with an error of at most 50 cm. The contractor is free to choose a combination of point density, point distribution and systematic and stochastic planimetric accuracy that leads to fulfilling this requirement (the relation between them was treated by Vosselman, 2008b). Also the operational procedures are fully left to the contractor.

Apart from the planimetric requirement mentioned above, the height model should have an accuracy in height of at most 5 cm standard deviation and 5 cm systematic error. Due to the new specification in terms of final qualifications, the point density is not specified, but in practice it will be between about 8 to 20 points per sq m. Apart from the laser point cloud itself, also grids must be delivered with grid sizes of 0.5 and 5 meter (see section 5.2).

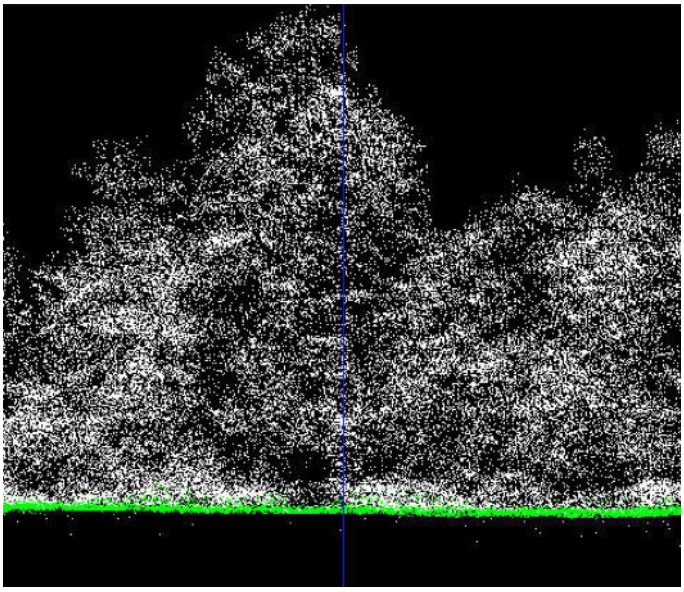


Figure 5. Classification of terrain (green) in the point cloud of an area with dense vegetation. Because of this vegetation, the AHN requires the acquisition to be in the winter (image Fugro Aerial Mapping).

Hydrologic modelling for water management, an other main task of water boards, imposes tight requirements on the accurate description of the terrain surface of the height model. Because of this, the data not representing the real terrain (‘maaiveld’) must be filtered out and delivered as a separate dataset (cf. Figure 5). Because leafs intercept the laser beam, the AHN requires acquisition of the data in the winter period, from December to April. The criteria for this classification process have been described elaborately and the data set is checked on this to the full extent by the quality control contractor because of its importance.

3.3. Realisation of AHN-2 from 2008 to 2012

After the pilot, done in 2007, the organisation and process were evaluated and it was decided that the next generation AHN would be viable. In 2008 the first part of this new AHN-2 was acquired for seven water boards. In a cycle of five years, the whole of the Netherlands will be covered. In 2012 the data acquisition will be completed, leading to an up-to-date high-precision high-density AHN-2 available for the whole of the Netherlands in 2013 (cf. Figure 6).

4. Assessing the potential of AHN-2 data for dike management

4.1. Workgroup to improve practical application of laser altimetry

In 2005, after the sliding of the peat dike of Wilnis and other calamities, an inventory for the Foundation for Applied Water Research (STOWA) showed that laser altimetry was the most promising technique in acquiring data that could improve dike management fast and effectively. STOWA installed a workgroup to improve the practical application of laser altimetry by water boards. This Workgroup Large-scale Laser altimetry (Werkgroep Grootschalige Laseraltimetrie, WGL) consisted of water board employees experienced in the application of laser altimetry and external experts.

The workgroup investigated the technological developments in laser altimetry and set up requirements to laser altimetry products, based on an analysis of existing tendering documents, a geometrical analysis of the directions for the legal assessment of dikes (VTV) and the experience of dike managers. This indicated that the AHN-2 specifications would indeed suffice to a large extent for dike monitoring.

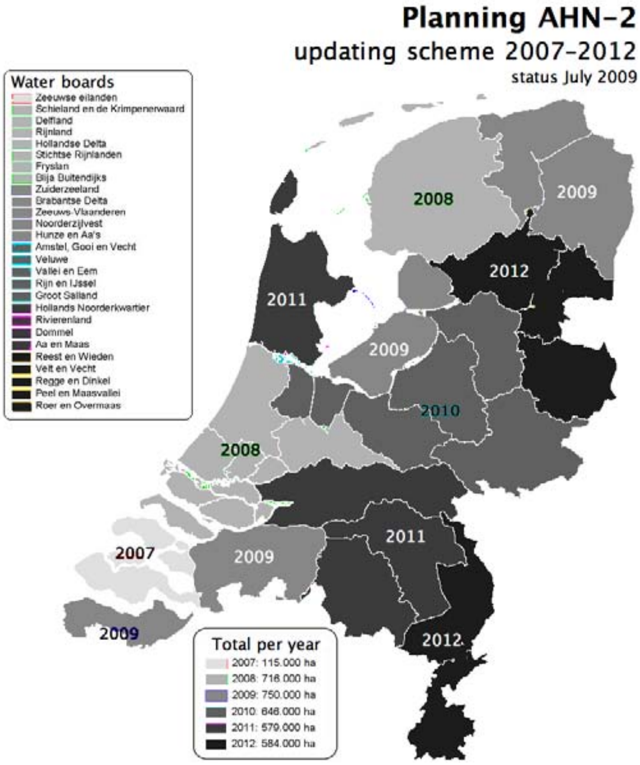


Figure 6. Planning of the next generation AHN (the AHN-2) per water board.

However, dike managers required one extra product: aerial photography of the scene during the laser acquisition. They need this to be able to identify and interpret objects or artefacts that seem to exist in the laser data. Because dike safety can depend on tiny details and is so important for the Netherlands, these detailed requirements must be set. This can pose severe limitations to the laserscanning contractor, because it makes laserscanning by night impossible, when atmospheric and weather conditions are often best. Therefore it was agreed upon that the requirement on aerial photography in AHN-2 will be that aerial photography must be acquired within one week from the laser acquisition. To limit costs, no requirements were set on mosaicing, colour correction and smoothing: the photographs must only be geo-referened.

4.2. Comparison of profiles from AHN and terrestrial data

The AHN steering committee supplied laser data of the pilot with WZE to the WGL, while water board WZE supplied terrestrial profiles of dikes. These data were analyzed by the WGL (Figure 7) (Swart et al., 2007 and Swart et al., 2009). The laser data complies to the requirements mentioned before.

A bilinear interpolation of height data from the laser grid of 50 cm was compared to the terrestrial profiles. Figure 8 illustrates that, although it is known that the terrestrial point measurements are more accurate, they give a coarser description of the topography of the dike. The surveyor makes a decision at which characteristic locations he makes a measurement, but his decision cannot be judged from the laser data only. Although the individual laser measurements have a lower accuracy, they provide a better description of the actual topography of the dike.

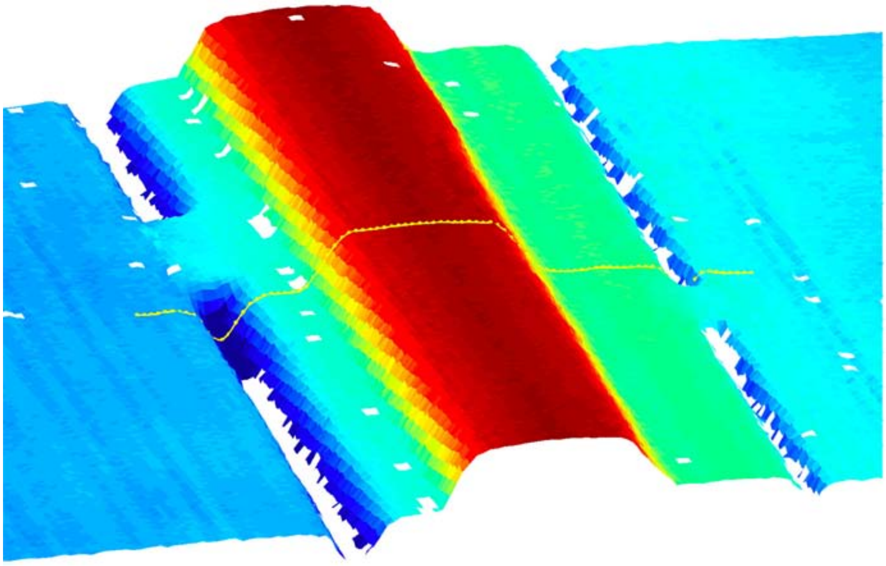


Figure 7. Height model (height exaggerated 2 times) of a 100 meter section of a dike about 2 m high. The 0.5 m laser raster is clearly visible. The yellow dots indicate the location of the terrestrial profile, used for the analysis (data AHN and WZE; analysis Swartvast/STOWA-WGL).

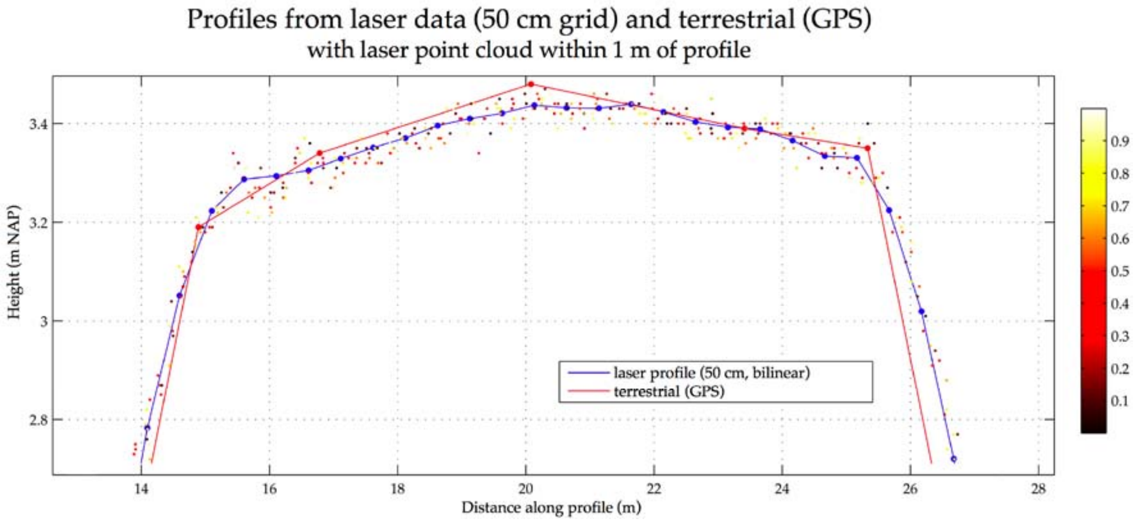


Figure 8. Height profile (exaggerated 6 times) of the top of a dike. The height data, bilinearly calculated from the 50 cm laser grid (blue dots), give a more detailed description of the topography than the terrestrial measurements (red dots). To be able to judge the variations in the individual laser point cloud and their relation with the laser grid, the individual laser measurements are also plotted. The point colour reflects the distance of the point ($0 \leq d \leq 1$ meter) to the profile (see Figure 13), as the legend shows (data AHN and WZE; analysis Swartvast/STOWA-WGL).

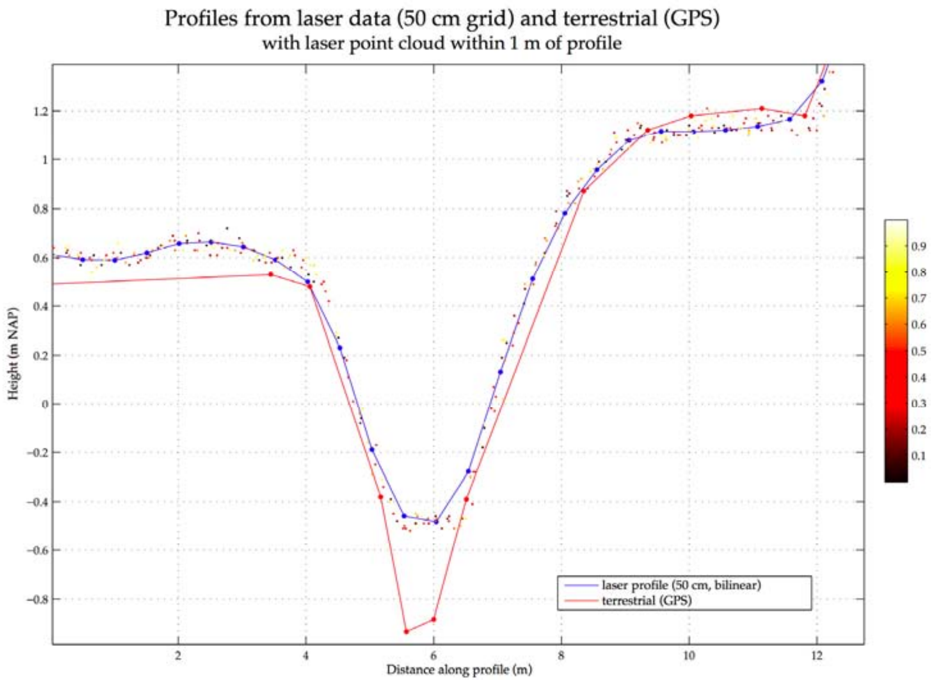


Figure 9. The profile near the ditch at the toe of the dike, plotted as described in Figure 8. The laser data reflect the topography with more detail than the terrestrial profile, although the height makes a significant excursion that cannot be judged without further knowledge. The depth of the ditch can only be measured with a terrestrial technique.

Sometimes significant discrepancies occur between laser and terrestrial data (Figure 9), but it cannot be judged without further knowledge what the reason is. It cannot be stated that in all cases the terrestrial data should be preferred. There is one exception, also illustrated in Figure 9. For the dike stability calculations, the water level in the ditch at the toe of the dike and the depth of the ditch itself is crucial. Both types of measurements cannot be derived from the laser data. The water level can be measured with more accuracy in height as well as location with a terrestrial technique. The ditch bottom cannot be observed with laser at all.

It is considered common sense with water boards that terrestrial data is superior to laser data because of its higher point accuracy, but the practice to use terrestrial profiles to do the quality control of laser data must be advised against. The decision where to do the measurement results in a height variation much larger than the intrinsic accuracy of the terrestrial measurement (this phenomenon is known in geodesy as the ‘idealisation accuracy’). The much denser description of the terrain by the laser data makes the lower accuracy acceptable.

4.3. Comparison of stability calculations based on AHN and terrestrial data

For the legally obliged assessment of dikes, also the stability of the dike must be calculated. This is done by calculating the resistance against sliding, based on the best assumption on composition of the dike body, maximum probable water level at both sides of the dike and the profile of its surface. Deltares compared the stability number using both the terrestrial and laser profile. In general, no significant differences were found, except were the ditch geometry was not defined well, as in Figure 9. In Figure 10, the sliding circle with the highest probability is shown. It was concluded that the AHN-derived profiles are suitable for stability calculations.

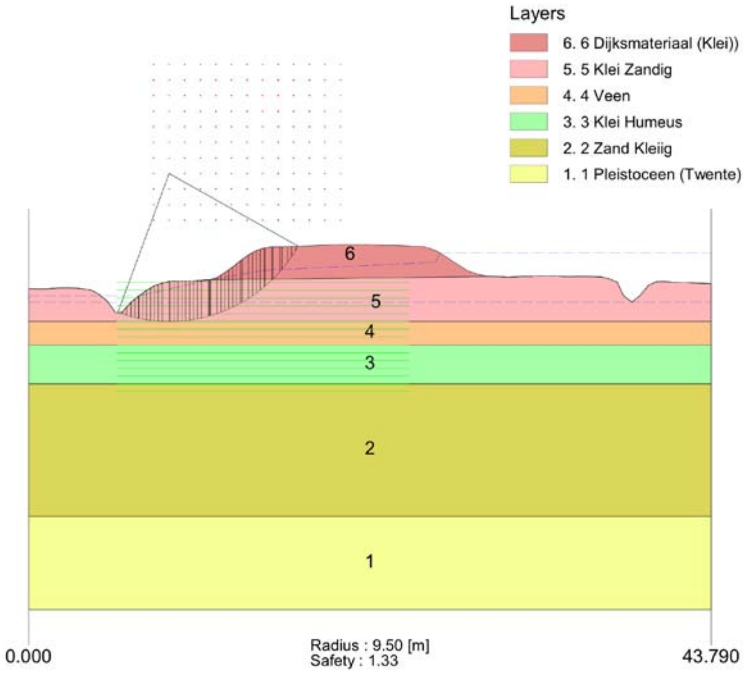


Figure 10. The dike stability calculations reveal the most probable sliding circle, based on the laser profile of the terrain and assumptions on dike body composition and maximum water level. Note that ditch geometry is, in this case, of large importance (Deltares for STOWA).

4.4. Suitability of AHN data for mapping

An important application of laser data for water boards is the establishment of the public register of dikes, waterways and flood defences (legger en beheerregister). Laser height data combined with aerial photography is used to map important lines like middle top line ('middenkruinlijn'), inner and outer toe lines ('binnen- en buitenteenlijnen') and the jurisdictional area of the water board (core zone plus protection zone). Because of the high density of the data and the extension of these lines, the planimetric accuracy of the location of those lines (sometimes bend lines) is much better than the planimetric accuracy of individual laser points. So, also for mapping purposes, the AHN-data suffices.

4.5. Conclusions

It can be concluded that the grid size of 50 cm yields a sufficiently dense data set to reflect the three-dimensional characteristics of dikes to the extent necessary for dike and water management. About 20% of the 17.600 km of dikes in the Netherlands has a height of less than 1 meter and can be almost invisible in the landscape. Only for these dikes, which are of importance to water management despite their small size, the resolution of 50 cm will possibly not suffice; this needs further investigation.

5. AHN-2 products and their usage by water boards

The requirements of water management and dike management lead to a massive dataset (section 5.1). The AHN data products can be divided into three availability levels (section 5.2). Experience and interviews give an interesting picture of the use of AHN products within water boards and, although this picture will not be representative, it will be described in sections 5.3 (grids), 5.4 (point could data) and 5.5 (aerial photography).

5.1. Result of the user requirements: a massive dataset

The requirements of water management and dike management lead to the specification of the second generation of the AHN as described above. Because of the requirements on planimetric object location accuracy and the 50 cm grid size, AHN-2 becomes a massive point data cloud. The aerial photography adds to that. The total number of laser points of the completed AHN-2 point data cloud will be about 400 billion (4×10^{11}); the 50 cm grid will consist of 135 billion grid cells.

5.2. Products and availability levels

The AHN comprises several products, which in combination will serve almost all height model needs of the water boards and Rijkswaterstaat and potentially many other users. The products are based on the user requirements and actual use and usability of the products. For example, because most users consider a grid to be far easier to handle than a point cloud, both point cloud and grid data are produced and offered. Furthermore, because for many applications a 5 meter grid contains sufficient detail and because it is, due to its smaller file size, easier to handle than the 0.5 meter grid files, both a 0.5 and 5 meter grid are offered.

In this section the AHN-2 products are described. The products can be divided into three classes or levels. Each product level has its own availability and pricing.

The lowest level of products is generally available to 'the rest of the world' and can be ordered from the data service desk of Rijkswaterstaat via the ahn.nl website. It can be divided into laser points and grids. The laser point data cloud is separated into two products: points representing the terrain according to the extensive and strict definitions described in the product specification, and all other, non-terrain points like buildings, vegetation and other objects. Both products are delivered as ascii xyz for compatibility reasons. For a typical 130,000 hectare water board, this is 0.4 TB of data in total.

The 'rest of world' grid data consists of four data sets. The first data set contains the terrain-filtered data, resampled to a grid with cell size of 50 cm. The second data set is almost the same, but the occasional gaps caused by an irregular point distribution should be filled in. An example is shown in Figure 11. Even if the average point density complies to the requirements, the irregular spacing of scan lines can lead to grid cells that do not contain a single laser point. In these cases the gap must be interpolated. In all other cases, the AHN does not allow interpolation because this can be regarded as creation of non-genuine height data.

The third 50 cm grid is calculated by resampling all laser points, terrain as well as non-terrain. This data set will, apart from water, cover almost the whole surface and contain buildings, objects and dense vegetation. Finally, the fourth grid is a resampling of the terrain-classified laser points to a grid with a cell size of 5 meter. The grids are delivered as ascii grid. For a typical water board of 130,000 ha, the four grids total to about 100 GB. As of 2010, the grids will be delivered in the ESRI .adf binary format and hence take up less space.

The intermediate availability level of AHN products consists of products only delivered to the owners of the AHN: the water boards and Rijkswaterstaat. This category actually consists of only one product: the aerial photography, intended to identify and interpret objects or artefacts in the laser data. The aerial photography cannot be ordered by other customers and will in general only be delivered to the target water board. For a typical water board, this data set will take up about 0.5 terabyte, depending on the way the contractor delivers and compresses it.

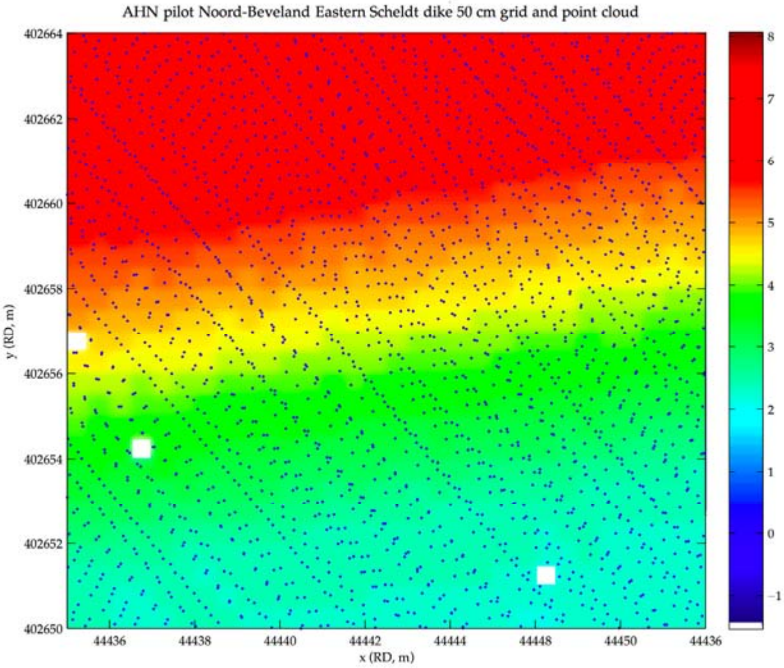


Figure 11. Example of grid cells containing not a single laser point, although the average point density is sufficient. This effect is caused by the irregular point distribution, in this case by irregularly spaced scan lines. This particular example was discovered by the WGL and led to the definition of an additional AHN-product (data AHN, analysis Swartvast/STOWA-WGL).

The most extensive product level comprises of products for quality control of the data acquisition. As acquisition and quality control is performed by separate contractors (although of course the acquiring contractor has its own quality control procedures and reports on these in his own quality report), the quality control products must be explicitly defined. After the data is accepted, the quality control products are archived. They are not distributed and cannot be ordered.

This product level consists of three additional laser data point products, delivered in flight strips. This data is used to check filtering, strip adjustment and accuracy in height and planimetry. The first product is the full laser data set. The second product consists of the terrain-filtered laser points and the third product contains the points filtered out. Also several grid data sets are delivered. For each strip overlap, a 50 cm grid of both laser strips and the difference grid is delivered by the contractor. Point density is checked using a point density grid with 1 meter cell size. The quality control contractor can check the tight filtering requirements on a hill shade grid with 0.5 m grid cell size, delivered by the acquisition contractor, although both contractors in general use additional methods to check the filtering. For a typical water board, all control products take up about 1 terabyte.

5.3. Usage of AHN grids by water boards

For almost all tasks, the AHN grids are used. For hydrologic modelling, the full 0.5 m resolution of the AHN-2 is welcome. The true representation of the terrain, and hence the correct filtering or classification of the terrain to the highest level of detail, is crucial. For hydrologic modelling the grids based on filtered data is postprocessed, because no gaps are allowed and, as water can run under an object, the terrain model should reflect this. The last requirement is reflected in the AHN specifications as precise as is possible for a product covering thousands of square kilometers, but the first requirement is not always met. As a product for general use, the AHN is required not to contain height data where there is no information, to prevent pseudoinformation from entering into the height model. Topological issues, like the existence of gaps, are left to the end users.

For water area plans, water boards prefer a lack of detail of the height model. This is not only because the small-scale information is not necessary and takes unnecessary processing time, but also because a high level of detail gives rise to questions of civilians that do not make sense for the goal of a water area plan. In fact, the first generation AHN often suffices.

Polder water level decisions (‘peilbesluiten’) always give rise to much discussion. For farmers a low level is important because only then they can use heavy machinery to work on the fields, but for the typical Dutch peat meadow-land, a ground water table too low causes oxidation of the peat and hence soil subsidence. Lowering the water table since the Middle Ages is actually the reason that water and dike management is such an important issue in the Netherlands (see for a concise overview in English of water management in past and present days: Arnold et al., 2009). Although the AHN is considered to give a representation of the terrain height as good as possible by extensive processing, water boards apply postprocessing to calculate the best mean soil height. This is done by removing all water ways and even slopes from soil top to ditches and any other non-soil objects that might still be present.

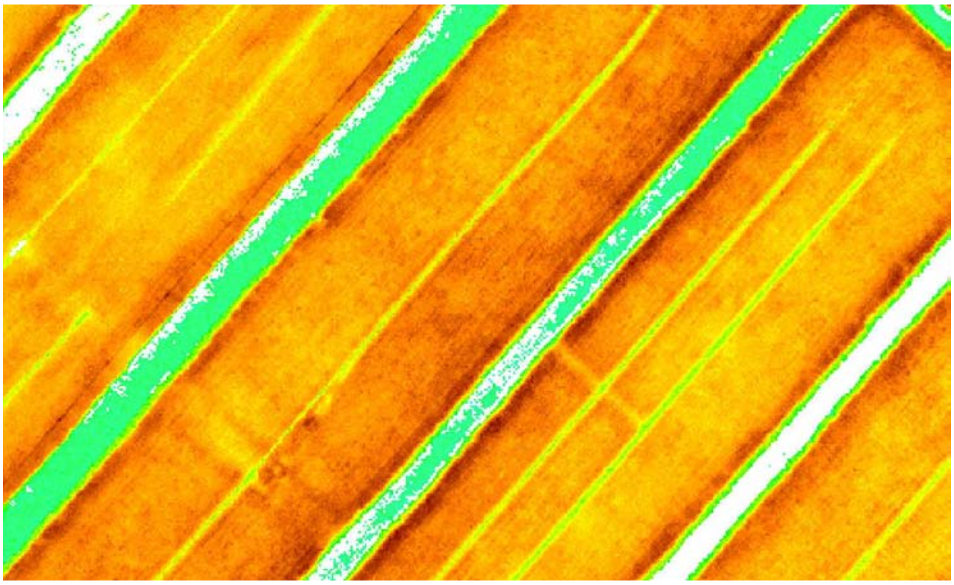


Figure 12. With a suitable legenda, the 50 cm AHN-2 grid shows ditches, drains and other topography of interest to water management with a high level of detail (Hoogheemraadschap De Stichtse Rijnlanden (HDSR)).

For dike management, the AHN data is used to its limits, as shown in section 4 when describing the requirements and assessment by the WGL.

For the public register of dikes, waterways and flood defences, the water boards map several key topography elements, like the middle of the top of the dike (‘middenkruinlijn’), and the inner and outer toe lines, using the AHN. This topography is not only used to assess the dike geometry and stability, it also determines the legal zone of jurisdiction of a water board, of importance to managing works that could deteriorate the stability and water resistance of the dike. Sometimes the water boards use the grid to map this topography. As described in the next section, automatic algorithms processing the point cloud data are better suited for mapping. Water boards leave this often to external contractors. An example of mapping dike topography features is shown in Figure 14.

Apart from the applications mentioned before, the AHN is also used for tenders for large-scale maintenance and mowing, for assessing and issuing permits and for enforcing regulations.

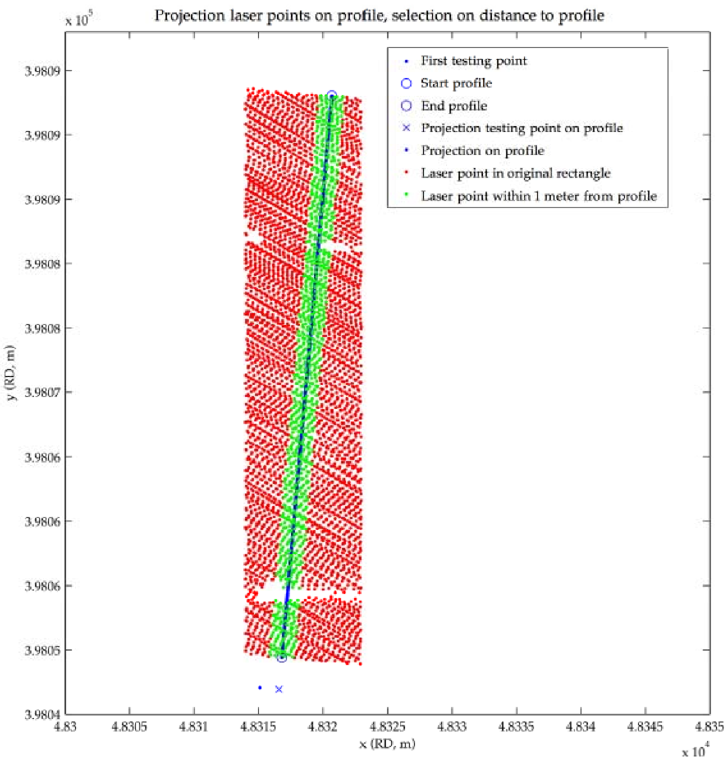
5.4. Usage of AHN point clouds by water boards

Although the requirement for planimetric accuracy of the AHN was deduced analytically from the relation between point planimetric accuracy, point density and point distribution (Vosselman, 2008b), the AHN point cloud products are not used as frequently by water boards as one would expect. Those data is sometimes even kept in the safe deposit and never used.

The main reason for not using of what is actually the original data, is that most data users are far more familiar with grids and the way grids are loaded, presented and analyzed in common GIS software. A second reason is that many standard installations of geo-information systems do not contain modules for handling point cloud data. Another reason is that, in particular because of distribution in ascii format, the sheer size of the point cloud data sets poses an obstacle to users or system administrators to load the data. This however also holds, to a lesser extent, for the grid data. Apart from that, not all storage and networking implementations are suitable to handle these large files and not all workstations and software can handle them in a convenient way.

Furthermore it cannot be denied that also a lack of knowledge, communication and documentation hampers the potential use of point cloud data.

Even the analysis of the suitability of the AHN for dike management by the author for the WGL, described in section 4, was based on the 50 cm AHN grid instead of on the point cloud. This was mainly because the analysis intended to supply support for the discussion whether a 50 cm grid size would suffice. The usage of a grid instead of a point cloud was more or less a pre-



Figuur 13. Although the analysis by WGL was focussed on the grids, the point cloud data was used to be able to judge the variations in the individual laser points compared to the laser grid, as shown by the colour-coded dots in Figures 8 and 9. Laser points were selected in a strip within 1 meter on both sides of the profile.

mise, because without doubt this would be used by water boards. Nevertheless, also the point cloud was used, as shown in Figure 8, 9 and 10 above, but mainly to illustrate the representativity of the 50 cm grid and the excursions the individual points make from the grid. WGL's conclusion that AHN describes dike topography better than terrestrial measurements seems valid even for the grid. The 50 cm cell size of the grid is often detailed enough; it is sometimes even too detailed, as mentioned in section 5.3.

An interesting development in the relation between the finest AHN grid and the point cloud it is calculated from, is that a decade ago the calculation of the AHN-1-grid was sometimes used to improve the height precision of a grid size by averaging several height points, at least when the density increased to several points per standard 5 x 5 m grid cell. For this Inverse Squared Distance Weighting (ISDW) was used (Van Heerd et al., 2000). Nowadays most contractors use the Triangular Irregular Network (TIN) algorithm, that does not average and hence does not improve precision but give a better description of the small-scale topography variations.

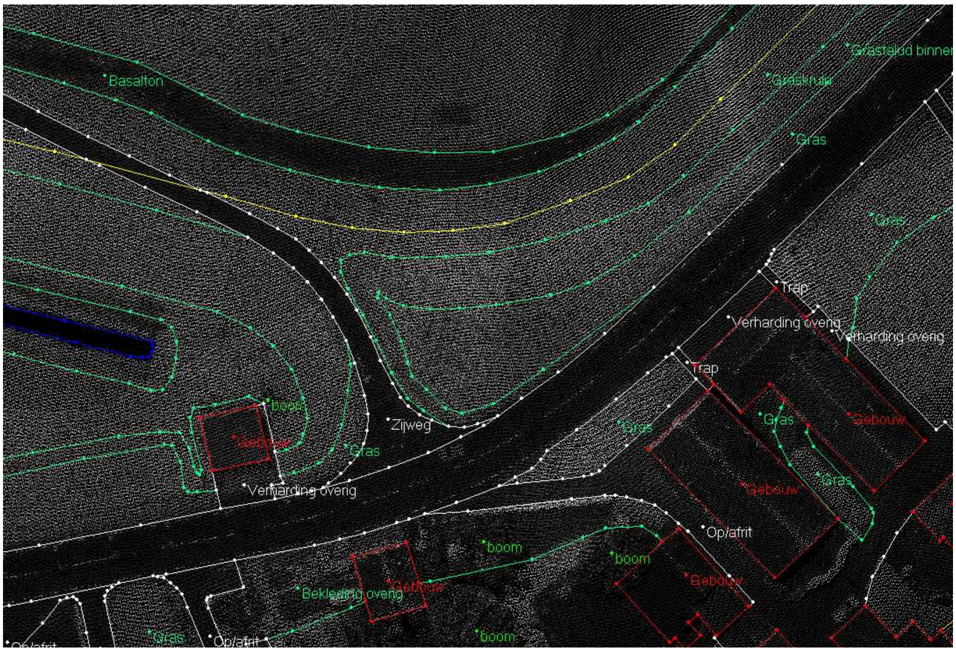


Figure 14. Mapping topography and bend lines using the laser intensity point cloud data and classified height point cloud data (image Fugro Aerial Mapping).

As described in the previous section, an accurate register of key topographic elements for water and dike management is crucial to water boards. For mapping of topography like bend lines it is best to use the point data (see also Brügelmann, 2001). Because of the high density of the data and the extension of these lines compared to the point distance, the planimetric accuracy of the location of those lines is better than the planimetric accuracy of the individual laser points. Because this mapping requires special software, at least if the software automatically determines bend lines from the topography and laser intensity data (as in Figure 14), water boards mainly leave this to specialised engineering agencies.

5.5. Usage of AHN aerial photography by water boards

Although the AHN aerial photography complies to strict requirements which result from the application of the photography as mentioned before, not all water boards use the aerial photography. Some find the photographs difficult to use if they are not mosaiced. Mosaicing and smoothing was not required to limit costs and because it did not seem necessary for dike management. On the other hand, some contractors make mosaics during the quality control process but these are not delivered because they are not required.

Some water boards, together with provinces and municipalities, have a contract for a yearly mosaic. Although this photography is of much higher image quality than the AHN aerial photography and hence is prefered by some water boards, it does not comply to the strict AHN-requirements regarding time of the year and interval between its acquisition and the laser acquisition. A lack of knowledge, communication and documentation seems to lead to fewer use of the aerial photography than would be justified.

6. Conclusions

For large-area, low-detail applications the first generation of the AHN, completed in 2003, can be sufficient. However, the second generation AHN with its upgraded specifications serves the needs of all kinds of applications within the water boards, Rijkswaterstaat and external users. The product requirements were defined in terms of user needs instead of by detailed technical specifications. In 2012 the data acquisition will be completed, leading to an up-to-date high-precision high-density AHN-2 available for the whole of the Netherlands in 2013. The detailed requirements on the exact representation of the terrain leads to products that are suitable for water management, e.g. hydrologic modelling. Meanwhile, an assessment of the pilot data showed that the grid size of 50 cm yields a sufficiently dense and accurate data set to reflect the three-dimensional characteristics of dikes, although maybe not for dikes lower than 1 meter. Hence it was concluded that the AHN-2 can be used to fulfil the legal obligations on the assessment of dike height and stability. The laser measurements provide a better description of the actual topography of the dike than terrestrial profiles do. In this way, the upgraded specifications of the AHN-2 make it possible to unify the acquisition of height data for both water management and dike management.

The AHN product family consists of four grid data sets with a cell size of 0.5 and 5 meter and two point cloud data sets. For the target water board and quality control additional products are available, like aerial imagery. For almost all water management tasks, the AHN grids are used. In general the full 0.5 m resolution is needed. For some applications, this is processed further. The aerial imagery, intended for interpretation of the laser data, is not always used, sometimes because it is not mosaiced.

Most water boards do not use the point cloud data, mainly because most users are far more familiar with working with grids and the software and hardware environment does not always accommodate the convenient use of the point data. But also a lack of knowledge, communication and documentation hampers the potential use of point cloud data. Nevertheless, the 50 cm grid data is in general sufficient to fulfill the user requirements. Only for mapping purposes the point cloud data is used and this is mainly left to external contractors.

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