Design of IJkdijk All-in-One/Sensor Validation Test

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Title
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Summary
In August and September 2012, new failure tests will be carried out on purpose-built levees at Booneschans, Netherlands, as part of the research and development program of the IJkdijk foundation. These tests comprise the All-In-One/Sensor Validation Test. Two levees on sand and one levee on clay and peat will be constructed and brought to failure. As opposed to previous tests, this time the failure mode is not known in advance. Sensor techniques and monitoring systems will be validated by these experiments to prove their value for flood safety management.

References
IJkdijk AIO/SVT

Version	Date	Author	Initials	Review	Initials	Approval	Initials
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1 Introduction

1.1 IJkdijk - research on levees

The IJkdijk ('calibration levee') is a Dutch research program with the two-fold aim to test any kind of sensors for the monitoring of levees under field conditions and to increase the knowledge on levee failure mechanisms. Since 2007, several purpose-built levees have been brought to failure at the IJkdijk test site at Booneschans, in the North-East of the Netherlands. Meanwhile, several regular levees have been instrumented or put under advanced surveillance by validated sensor equipment under the name of Livedijk ('application levee').

1.2 New field test program

In 2011 the Dutch Department of Economic Affairs, Agriculture and Innovation has granted a three million euro subsidy to the IJkdijk foundation for a liquefaction test and a test including several different failure mechanisms together, the so-called 'all-in-one' test or Sensor Validation Test (SVT). The SVT will be carried out in 2012 and the liquefaction test in 2013.

The main purpose of the new experiment in 2012 is to test the predictive power of full-service levee sensor systems, i.e. sensors combined with data processing and an information system producing a timely, reliable warning in case failure may occur. The application of such systems into practice will be a major improvement to the current state-of-the-art of levee management. Another reason is to learn more on levee failure mechanisms, including failure prevention methods.

1.3 About this report

This report describes the design of the Sensor Validation Test, with an emphasis on the geotechnical aspects. Previous memoranda described the preliminary design, viz. a memorandum with reference 1205450-002-GEO-0002 dated 17 December 2011, which has been discussed on 20 December, and a memorandum with reference 1206242-001-GEO-0001 dated 14 February 2012, which has been discussed on 17 February. These discussions and later input have led to several important changes to the basic set-up of the test, without changing the goals of the test. A discussion of the draft version of this report has taken place on 5 March 2012, at the 'Waterschapshuis' in Amersfoort. After that occasion little needed to be changed to the design.

In Chapter 2 the aim of the test is described more in detail. Chapter 3 gives an overview of the test. In Chapter 4 the activities of the various parties involved in the technical part of the actual test are described. Criteria to evaluate various sensor systems are given in Chapter 5. Finally, the current planning is described in detail in Chapter 6.

2 Aim of the Sensor Validation Test

The main aim of the Sensor Validation Test is to prove the applicability of ‘full service’ early warning/early detection systems for a variety of levee failure mechanisms. Such systems comprise sensors (which can be inside the levee or the subsoil, at the surface or remote - either terrestrial, airborne or space-borne), data-communication, analysis of the data and an information service to (end-)users, enabling them to take countermeasures to avoid failure and to help decisions on evacuations of the endangered area.

Other aims of this test are to increase the knowledge on failure mechanisms and prevention measures (both short-term measures and measures with a longer lead-time), and the testing of smaller parts of early warning/early detection systems, probably even down to the level of an individual experimental sensor (cf. the Slope Stability Test in 2008 [Weijers et al., 2009]).

Note that the loading conditions at this site are somehow artificial, as the levees are not part of a real levee system. Yet, a connection to various ‘real world situations’ can be made at all times.

3 Overview of the test

3.1 Introduction

In the Sensor Validation Test, several levees will be loaded to failure in August/September 2012. Basically, two different types of levees are tested: one with a levee on a very soft soil layer (clay and peat) and one with a levee on a sand layer. With the first type, a failure mechanism with a deep sliding plane is possible. With the second type, piping (under seepage erosion) may lead to failure, as well as overtopping with subsequent erosion. For both types, internal instability of the levee body may also lead to failure.

Figure 3.1 shows an overview of the test site at Booneschans. In the front of the picture, two levees can be built on a 3 metre thick sand layer, while the other levee will be built on a soft soil deposit of about 4.5 metres of clay and peat.

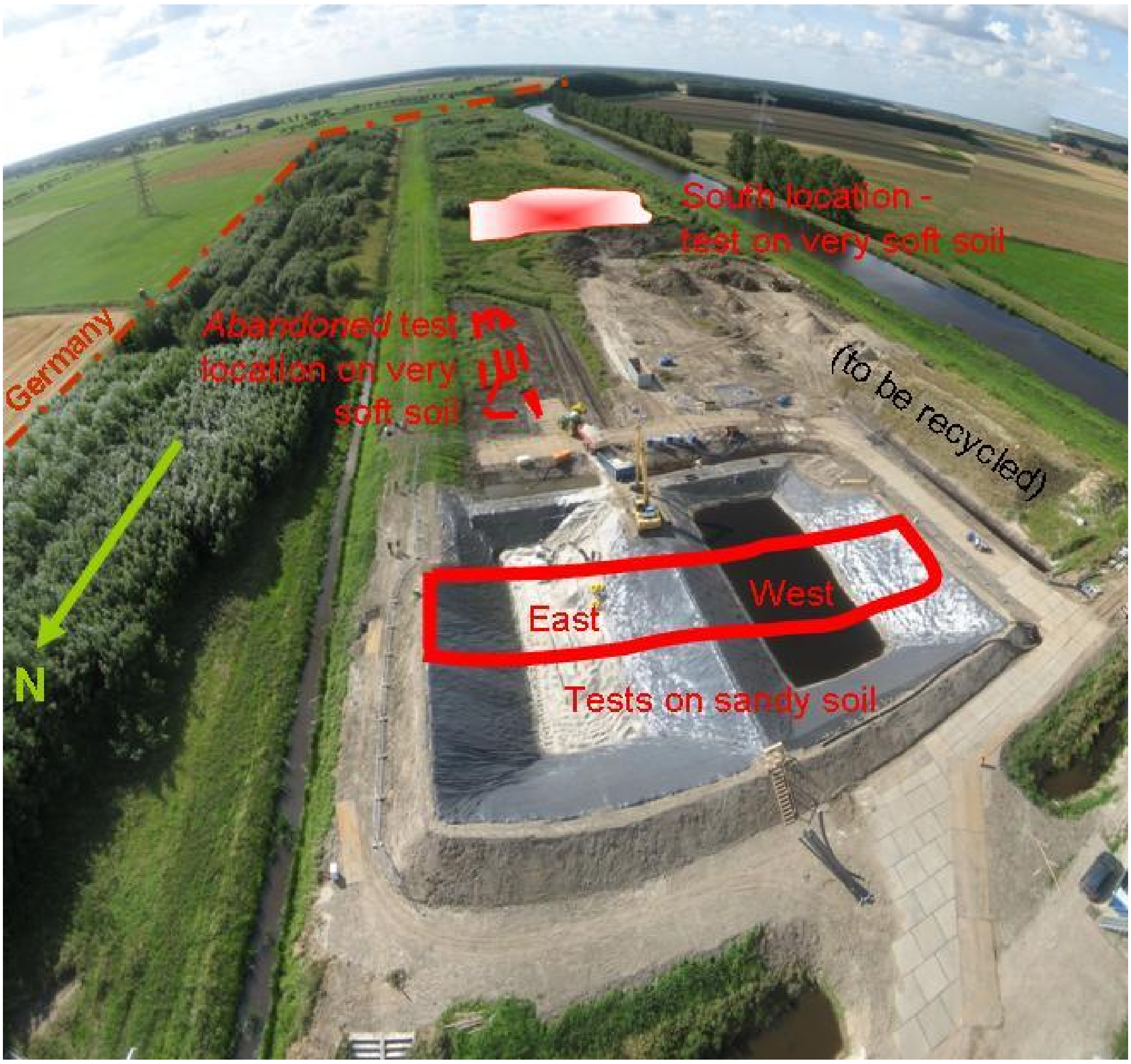

Figure 3.1 Bird's eye view of the test site with the proposed locations of the various test levees

3.2 Test levee on very soft soil

Initially, the design calculations for the test levee including the possibility of a deep sliding mechanism have been focused on the location close to the sand basins. However, the deep sliding mechanism would on this location, with soft soil layers of about 3 metres, only be possible if the test would be carried out rather quickly and directly after construction. With a few weeks between construction and testing, allowing for installation and calibration of the sensors and a limited time of obtaining measurements of a 'stable' levee, the deep sliding mechanism would become too unlikely to occur. Therefore, this location has been abandoned and an alternative location more to the South has been adopted to construct a test levee with a length of 50 metres at crest level. With a levee height around 5 metres, a levee length of 40 to 50 metres is required to avoid 3D effects regarding spreading of the load, resulting in a different failure mode and a higher ultimate load level.

A cross-section of the test levee on a clay and peat subsoil is shown in Figure 3.2. This figure is to scale. Apart from failure through a deep sliding plane, this levee may also fail due to rupture or uplift of the rather thin clay cover from high pore pressures inside the sand core of this levee. Failure from overtopping is however impossible at this location, because the water level in the reservoir on the 'waterside' of the levee cannot be raised high enough. Mainly for PR-reasons, a shallow reservoir shall be created on the South side of the levee. The reservoir is created by two small connecting levees at both ends of the test levee. Failure with a deep sliding surface will be encouraged on the North side.

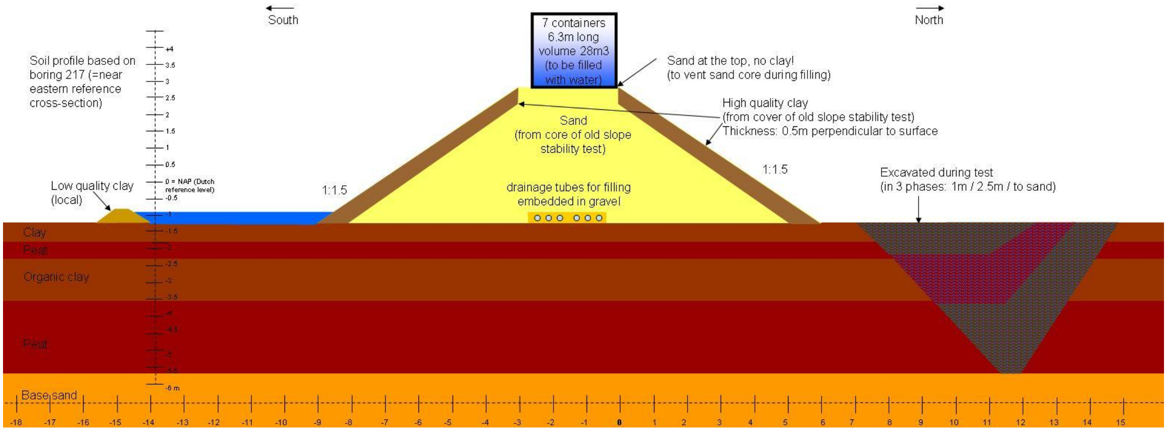

Figure 3.2 Cross-section of test levee with clay-dominated subsoil conditions (to scale)

Unlike the levee failure test in 2008, which was solely aimed at creating slope instability, in this test also the clay cover on the sand core may fail. General requirements, details on clay cover failure and details on the 2008 IJkdijk failure test, including properties of the various soil layers at the site, can be found in [VTV, 2007; Baggen & Snoek, 2008; Weijers et al., 2009; Koelewijn et al., 2008; Zwanenburg, 2008; van Beek & van Lottum, 2008, Zwanenburg & Koelewijn, 2008, Zwanenburg et al., 2009, Koelewijn et al., 2009ab].

This part of the test is therefore a 'two-in-one' test. Major differences with the 2008 levee are:

- A relatively thin clay cover – only 0.5 metre perpendicular to the slope.
- A height of 4 metres instead of 6 metres.
- A length at the crest of 50 metres instead of 100 metres.
- Construction well before the start of the test, thus the consolidation process is likely to be nearly finished.

With a clay cover of 0.5 metre there is a fair chance the levee will fail to this failure mechanism during the filling of the sand core. However, it may also fail from a deep sliding plane.

The following phasing is now foreseen *(details and order to be finalized after additional soil investigations have been completed)*:

1. Fill the sand core slowly up to a level of 1.0m (at this stage, a symmetric situation is still present).
2. Fill the reservoir on the South side.
3. Excavate the trench on the North side by 1m (steep slopes, bottom width 3 m).
4. Fill containers.
5. Empty containers, then excavate the trench further to 2.5 m depth.
6. Fill the sand core slowly up to a level of 2.5 m.
7. Fill containers.
8. Drain the trench (note that it will not actively be filled during/after excavation).
9. Fill the sand core completely.
10. Empty containers.
11. Excavate the trench down to the sand.
12. Fill containers.

Any next step is only taken once it seems clear that the current situation is not likely to fail soon. Emptying the containers before further excavation is for personal safety and to avoid failure during an ill-defined loading situation resulting from a partially excavated trench over the length of the levee.

At the end of step 9, with the two-dimensional Bishop model a stability factor of 0.82 is obtained for the deep sliding plane applying slightly conservative parameters for the pore pressures in the deep sand and assuming the excess pore pressures resulting from construction have dissipated completely. This gives sufficient hope that this failure mechanism may occur. Details are given in Annex A.

Experience has shown that for failure to occur a calculated value of 0.80 or less is desirable – otherwise, the failure process may be very slow or failure does not take place at all, because of 3D-effects and natural variations in the strength of the soil. Further excavation easily reduces the calculated stability factor by 0.2 to 0.3. For comparison: for the other (abandoned) location, only with more optimistic parameters a value of 0.93 could be obtained. This was not sufficient to have enough confidence that a failure would indeed be achieved at that other location, which was preferred from a logistics point of view.

To enable control of the construction process and the test itself, Deltares will provide a reference monitoring system that consists of 34 pressure metres, 2 settlement gauges, 2 inclinometers (SAAF), 3 cameras (two facing the North slope and only one facing the South slope, as failure of the North slope is most likely) taking 1 HD quality frame every 5 minutes, a terrestrial LiDAR system scanning the North slope, 7 simple floating devices and regular visual inspection. The locations of the pressure meters, the settlement gauges and the SAAFs are given in Figure 3.3.

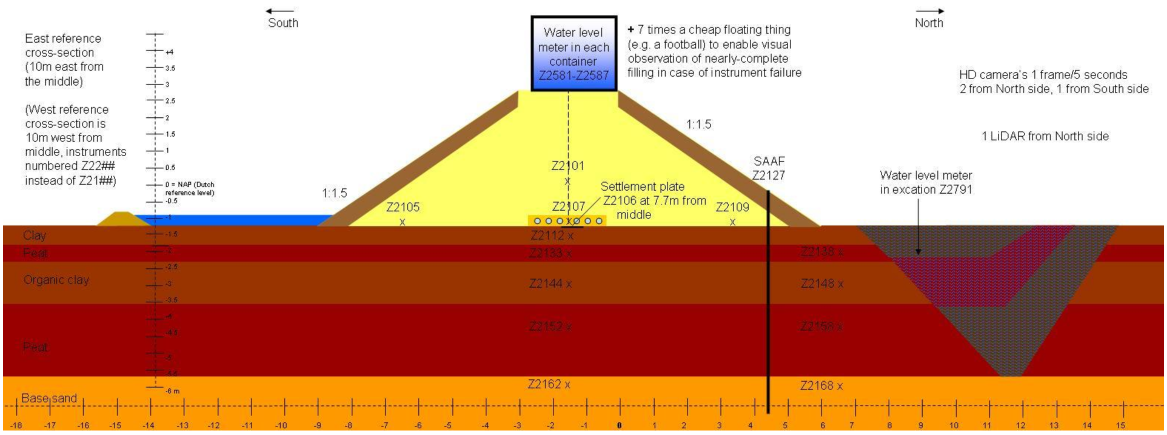

Figure 3.3   Reference monitoring at the South levee (to scale)

Based on the requests made by the participating sensor companies, some subsequent discussions and somewhat arbitrary, but marginal, decisions to resolve conflicting requests, all other instrumentation is shown in Figure 3.4.

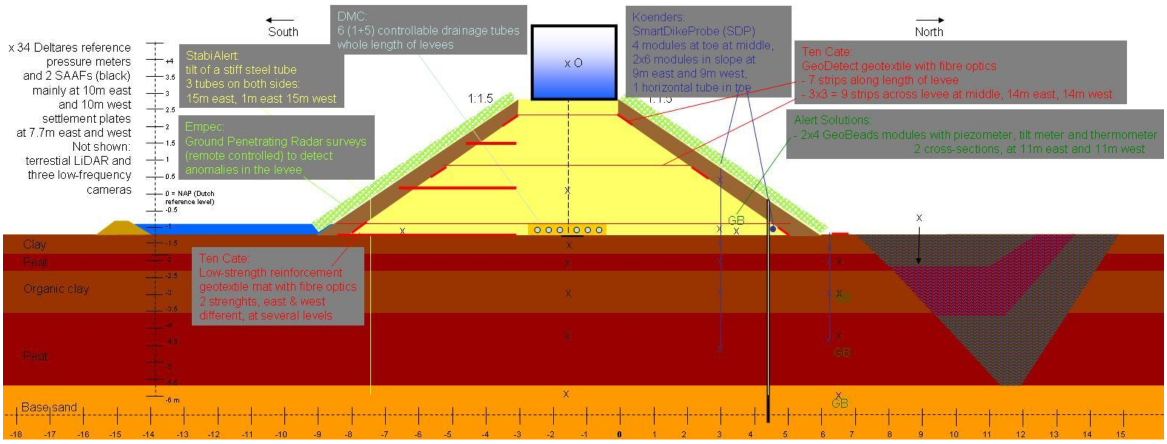

Figure 3.4   Cross-section of the South levee showing all in-situ monitoring

One feature which deserves special attention here is the geotextile at the base, under the South slope. This is meant as a (partial) measure against deep sliding planes. It is only a partial measure because it should be extended further towards the North – but then it would also work as a measure against a deep sliding plane towards the North, which is one of the desired failure mechanisms in this levee failure test. Still, some of the loading phases, especially the first one, will activate the tensile strength of the geotextile. This may be measured by e.g. the fibre optic system. Yet, the anchoring will be insufficient – but otherwise a failure in the other direction would be obstructed. Two different geotextiles will be applied, one under the East half of the test levee and one under the West half of the test levee, between the South toe and the South crest line.

Both ends of the levee, i.e. the West and East end beyond the test section with a length of 50 metres, will be constructed with a high quality (=watertight) clay volume first, supported by earth material at a 1:2 slope.

3.3 Test levees on sand

The test levees on sand will be situated in the facility which has been used for the piping tests in 2009, described by Koelewijn et al. [2010]. The original design drawings for these tests are repeated in Figure 3.5. However, the Sensor Validation Test, also called ‘All-in-One Test’, is not meant to be a repetition of the 2009 tests. Therefore also other failure mechanisms than piping will be made possible, viz. fluidization of the sand of which this levee will mainly be composed (after internal overtopping of a clay core) - see [den Adel, 2008] and [de Groot, 2008] and crest overtopping followed by erosion. Moreover, the effectiveness of piping prevention measures can be tested here.

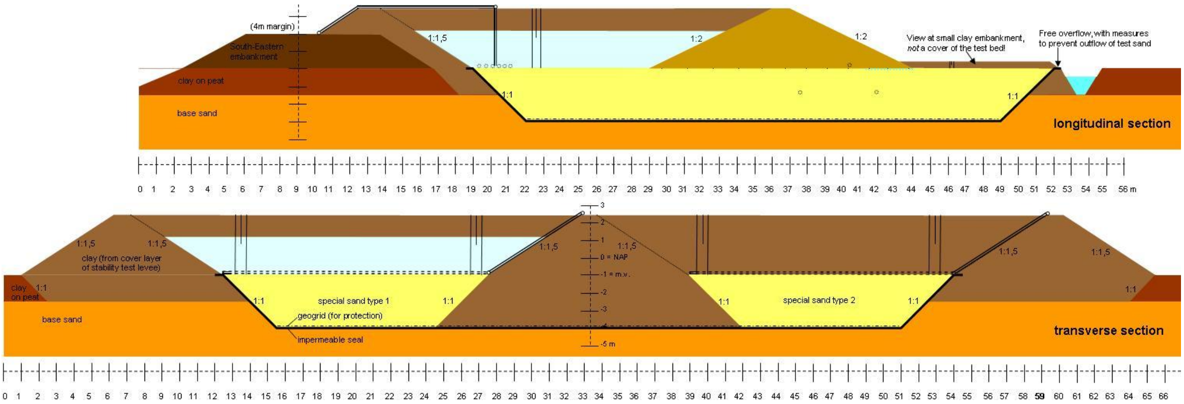

Figure 3.5   Longitudinal and transverse sections of the piping basins (to scale)

In Figure 3.6 the general cross-section is shown of the test levees in the piping facility. This replaces the all-clay test levees indicated by a light brown colour in the longitudinal section in Figure 3.5.

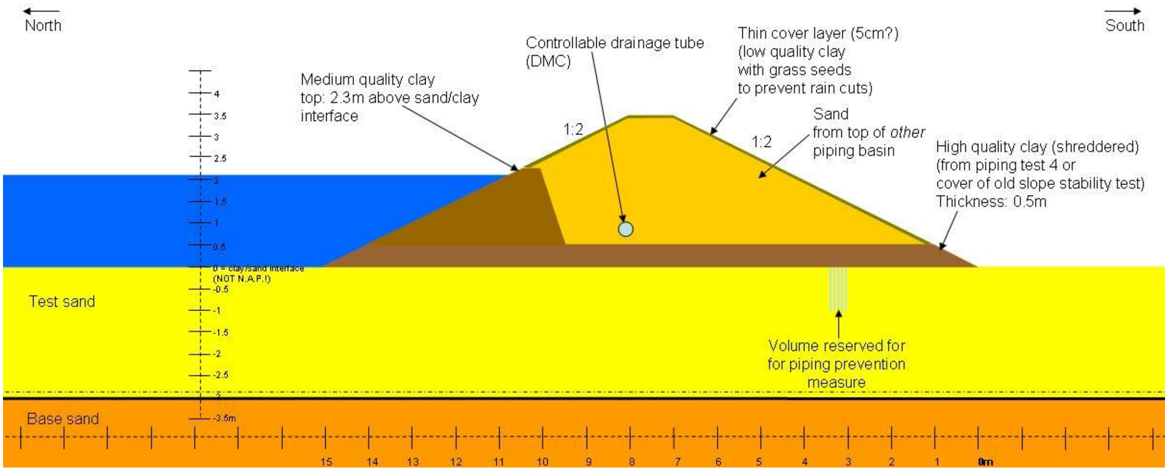

Figure 3.6   General cross-section of test levees on sand (to scale)

The test sand underneath the levee will be the same as in the 2009 piping experiments, although the upper 1 metre will be replaced by new sand of the same properties, to get rid of all organic matter. Sieve curves of the test sand are given in Figure 3.7 and Figure 3.8. Above the test sand, a 0.5m thick clay layer will be made. The thickness is in part required to reduce the risk of shortcut seepage paths after prolonged erosion. In each basin the same location is reserved for piping prevention measures: a virtual box of 0.5m width and a maximum depth of 1m (=1/3 of the total layer height).

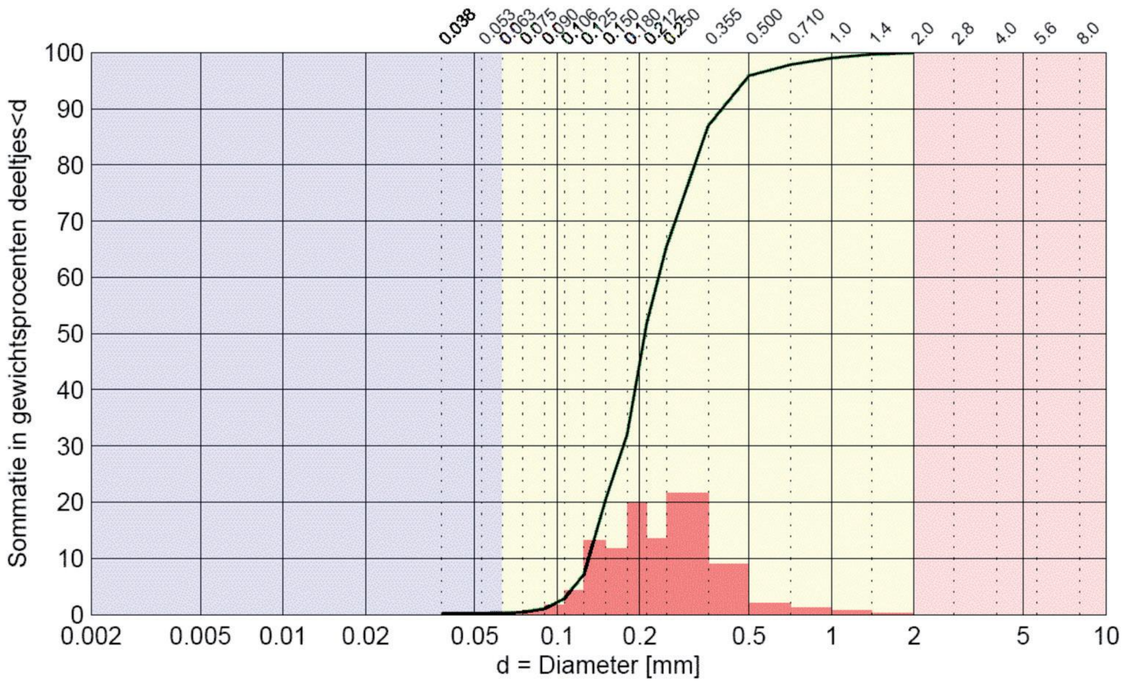

Figure 3.7 Sieve curve data of the test sand in the west basin

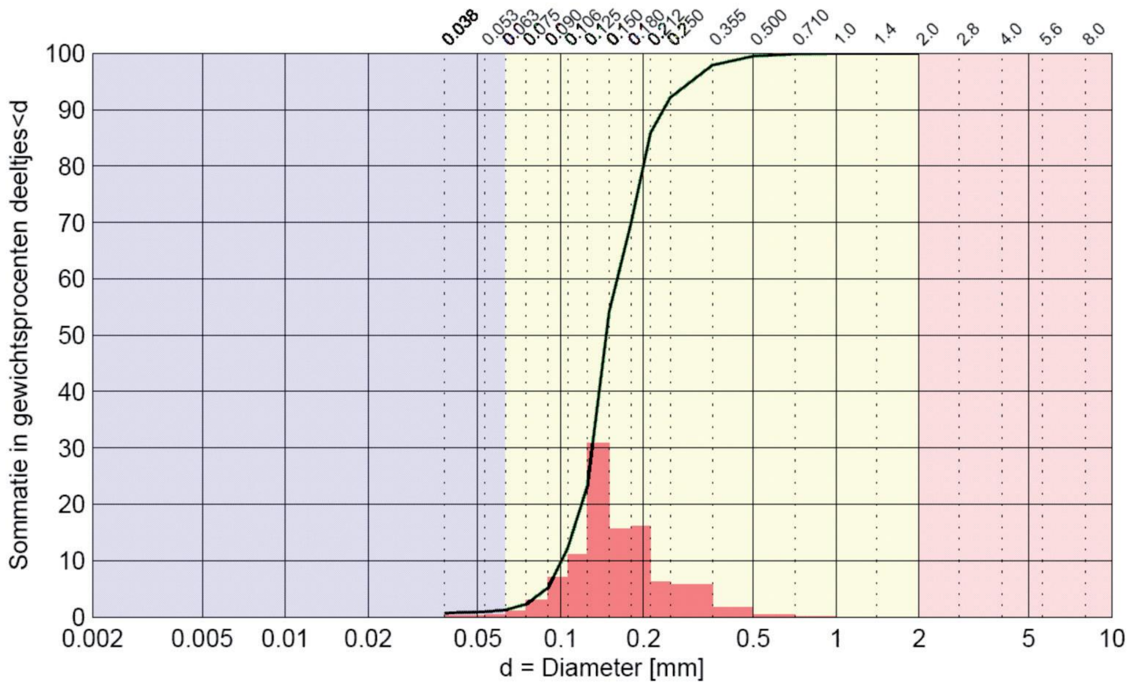

Figure 3.8 Sieve curve data of the test sand in the east basin

For the sand in each levee the excavated sand (upper 1 metre) from the *other* basin will be taken, to enable to distinguish between both failure mechanisms by the visual inspectors.

The reference monitoring mainly consists of reservoir level control (upstream and downstream) and four lines of pore pressure metres at the sand/clay-interface. Locations are indicated in Figure 3.9. All monitoring is shown in Figure 3.10 and Figure 3.11.

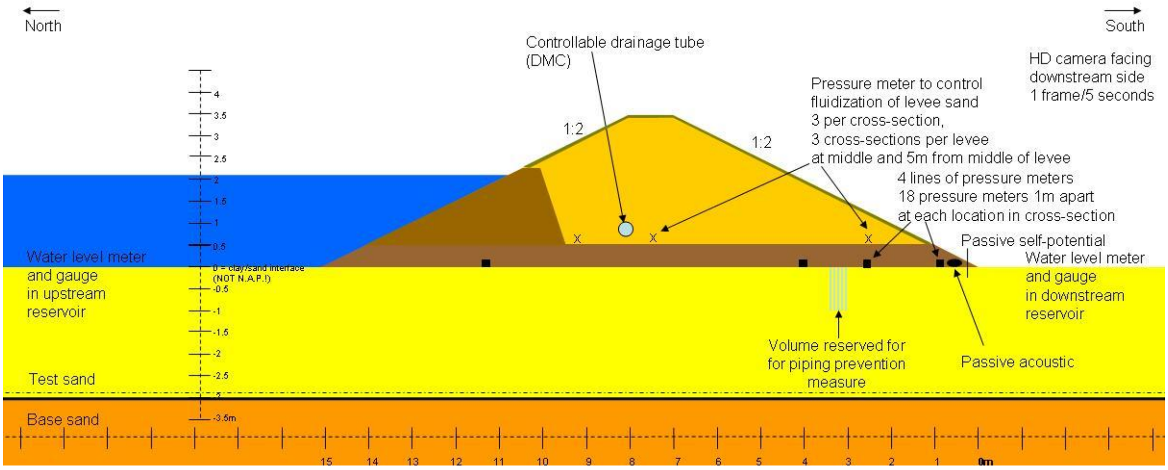

Figure 3.9 Reference monitoring for test levees on sand

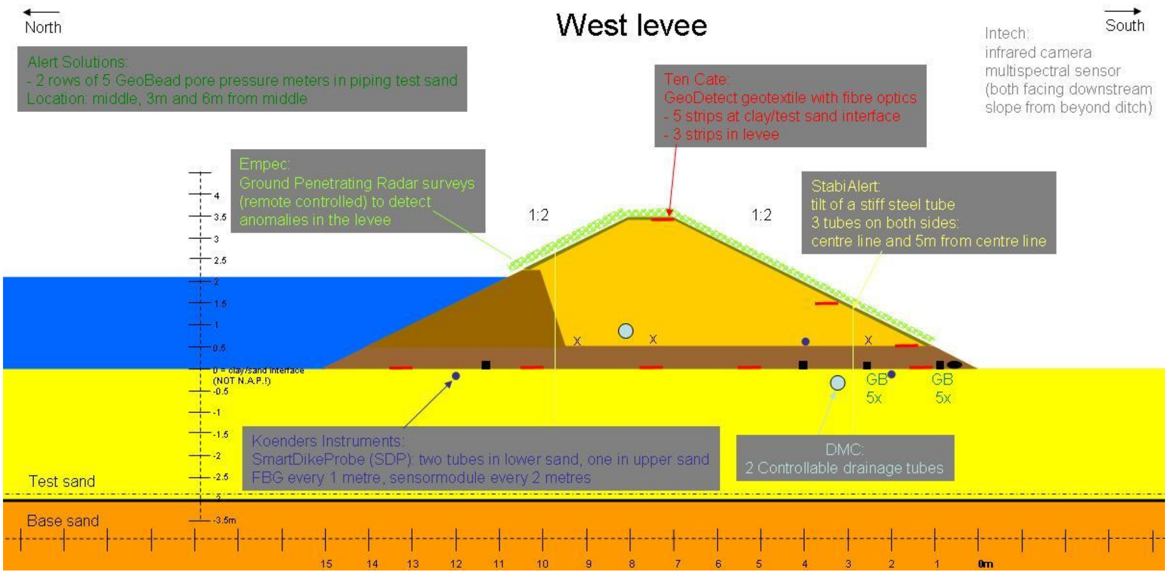

Figure 3.10 All monitoring for the West test levee

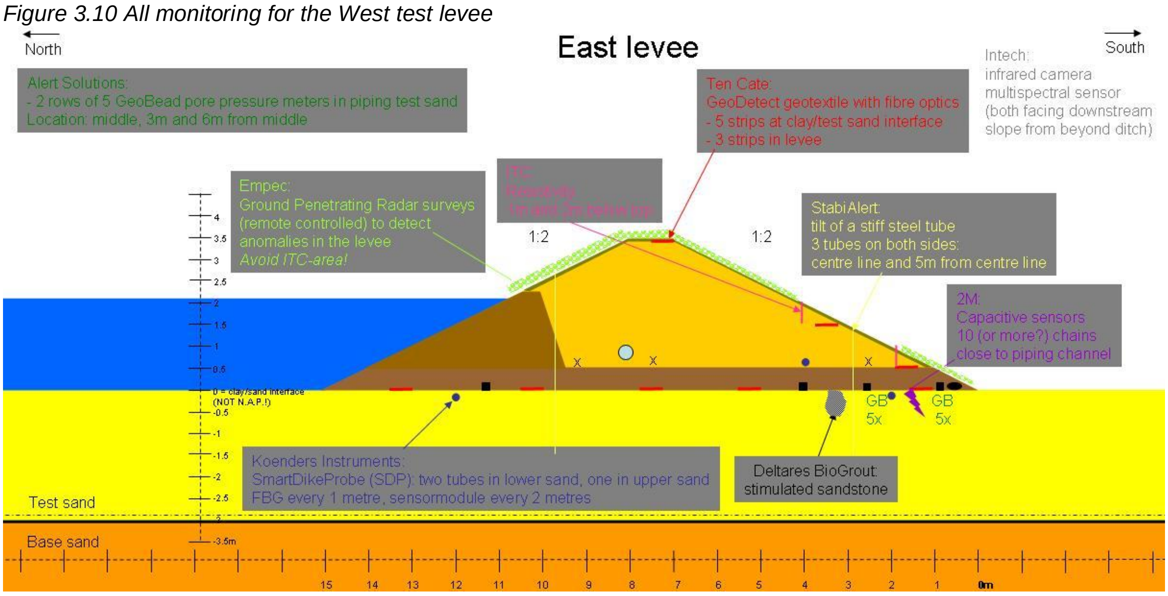

Figure 3.11 All monitoring for the East test levee

The interface between the lower test sand and the clay base of the levee is well-filled with instrumentation. To ensure a proper installation, the details of the locations of all instruments are repeated here (assuming a y-axis starting at the downstream side, positive towards upstream):

y=0.0m	downstream side
y=0.3-0.6m	passive acoustic
y=0.7m	GeoBeads1
y=0.9m	first line of reference monitoring - Deltares1
y=1.0-1.5m	GeoDetect1
y=1.6-1.9m	2M
y=2.2m	GeoBeads2
y=2.5m	Deltares2
y=3.0-3.5m	The Piping Prevention Measure (DMC/BioGrout/Geotextile)
y=4.0m	Deltares3
y=5.0-5.5m	GeoDetect2
y=7.25-7.75m	GeoDetect3 (right under the crest of the levee)
y=10.0-10.5m	GeoDetect4
y=11.25m	Deltares4 (at 3/4 of the seepage path)
y=13.0-13.5m	GeoDetect5
y=15.0m	upstream side

3.4 Planning

Initially, it was planned to test all three levees at the same time, in three test weeks separated by two weeks for rearrangements, necessary repairs and data evaluation. This would have enabled to repeatedly load the test levees and also to carry out a few additional tests focusing on the piping mechanism, by reconstructing a levee after failure in the two intermediate weeks. However, with the necessary change of the location of the levee on a very soft soil deposit to a more southern location, the logistics of executing three tests at the same time appeared to be too ambitious. The distance between the test levees has simply become too large and the parallel execution of three tests could be too complex to handle as well.

Moreover, such a set-up requires that all test levees be ‘neutralized’ by the end of a test week, unless failure has occurred already. For the tests on sand this can easily be achieved by emptying the upstream reservoir, but for the other levee this appears to be a narrow and dangerous path to follow: sufficient unloading to avoid failure in the intermediate period is difficult to achieve, especially because it is no option to refill the already excavated part of the trench, as that would take too much time.

Therefore it has been decided to uncouple the execution of the test on the South levee from the execution of the other tests. Given the overall constraints (tender process, construction time, time between construction and testing, test period and leaving the site in time) it has been decided that the levees on sand will be tested first, during one full week, then there will be one week to shift equipment to the South levee and then that levee will be brought to failure, preferably in seven days.

3.5 Possibility of additional tests on piping

As an alternative to the above basic scenario, the present opportunity to load levees prone to piping up to failure or at least to a significant load well above the usual critical head may be taken to test a few other alternatives for piping prevention, like a vertically placed geotextile in various configurations. This would mean a reconstruction of the levees on sand and additional tests after bringing the South levee to failure. Assuming that at least two of the piping prevention alternatives is very effective, failure as a result of internal overtopping followed by toe fluidization or as a result of crest overtopping will still be possible. Of course, the additional costs should be covered for then. These costs comprise at least the extra demolition of the test levees, removal of the top half-meter of sand and replacement of this sand, saturation under half-vacuum conditions and reconstruction of the test levees including the required instrumentation. As some of the materials will inevitably get mixed, this also means additional transport of sand and clay to the site.

3.6 General

The IJkdijk foundation will supply the required test environment, with input by Deltares for all issues related to geotechnics and input by TNO for the collection and distribution of all sensor data. A total of 16 companies have expressed their interest in this Sensor Validation Test, ranging from in-situ sensors to warning/alarm systems employing sensor data and artificial intelligence.

The total costs of this experiment are estimated at € 4.4 million, of which roughly € 3.0 million is meant for the experimental sensor systems and the remaining part for the design, construction and execution of the test. These costs are borne by the Dutch Ministry of Economic Affairs, Agriculture and Innovation, the Dutch Water Boards (including their research foundation STOWA) and the participating companies.

4 Participating parties

The flow chart below indicates the flow of information during and after the tests. The parties involved at each step are indicated in pink.

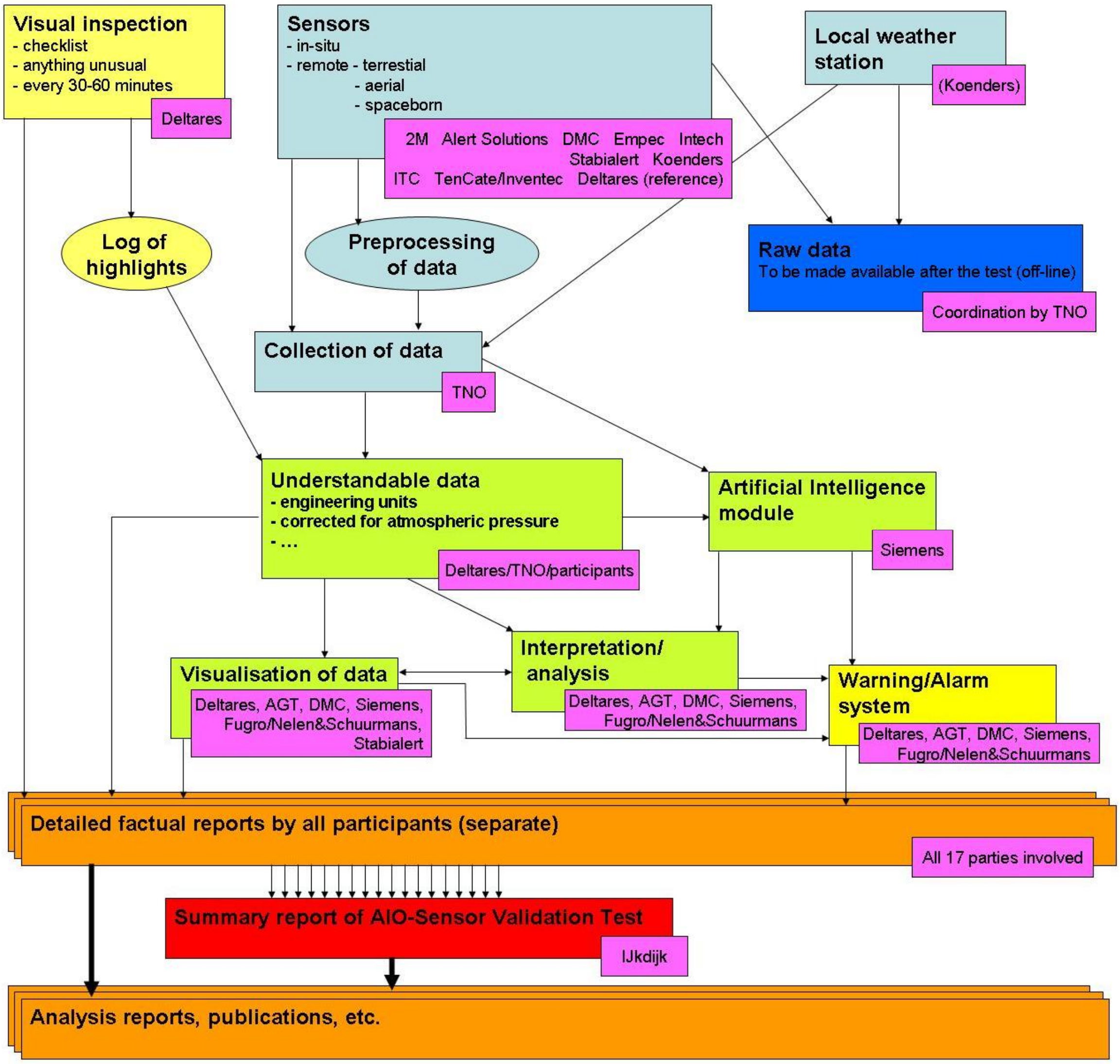

Figure 4.1 Flow chart of data in AIO-Sensor Validation Test

Based on existing agreements, the parties involved in this All-In-One/Sensor Validation Test mainly are those parties already involved in the IJkdijk at an earlier stage. Nevertheless, new parties may join if they can offer valuable knowledge or equipment not available to the parties already involved.

Although the test levees are rather big, yet some restrictions apply. Details are given on the next page.

For each participant (text with **bold** indicates limitations):
* 2M: sensors to measure erosion. Not relevant in the clay-dominated levee. Because of electrical current put into the ground, **only** in the east basin. If passive methods are hindered, then only intermittent measurements.
* TenCate/Inventec: small mats of GeoDetect can be placed in both piping basins as wanted. If only in one basin, then in the west basin. **No** vertical geotextile in the piping basin *unless* Rijkswaterstaat and Water Boards come with additional money, then this will be one of the five/six experiments. Microstability with thin clay cover: as requested, **but** on one side only. With instrumentation, still its functionality may be proven. The same holds for the geotextile to prevent a deep sliding surface: **only** on one side, moreover with a limited length to avoid non-failure - which would hinder the overall experiment too much.
* Intech: no problems, **some care** with the location of the LandRover.
* Koenders: no problems, the levees are large enough.
* Alert Solutions: no problems, the levees are large enough.
* Stabialert: how should the sensors be fixed to the levees? It is not a hard structure. Not a real problem, a hard plastic tube will do.
* Empec: no problems on the sand-based levees, although liability is an issue (walking the GPR on a failing levee may be considered unsafe by officials, although the test leaders are exposed to similar risks). *During* the tests on the clay-dominated levee, nobody should walk within short distance of the steel containers on top of that levee. This **limits the possibilities** on that levee.
* Nelen&Schuurmans/Fugro, Siemens, AGT, Synermediagroup: **data-transmission off the site** could be an issue because of the remote location in combination with an extreme effort to produce data (by all parties together). A solution might be to attend the test on-site.
* ITC: It is yet unclear whether the other measurements (including the reference monitoring *required* to control the test) will be hindered by the current. Therefore, application of these methods is **limited** to the east basin, where also 2M will use active methods. The ITC-equipment seems to use less electric current, therefore it may be used continously (also to be tested: does it influence the 2M measurements - therefore, at least for a short while it should be turned off).
- DMC: welcome to help Deltares to control the experiments! DMC mainly in the west piping basin and the clay-dominated levee, but also a tube in the east piping basin (in the levee sand) to help control the BioGrout-experiment together with the sand fluidization.
* TNO: provided that the data-acquisition and distribution system is stable, the proposed solution is good and no on-site personnel will be required.
* Deltares BioGrout: application of the BioGrout may need to be done at an **unfavourable time**, because otherwise too many participants would be hindered. Moreover, this depends on RWS & Water Boards (option with 4 tests on the sand-based levees).

Note that no instrument should obstruct the functioning of other instruments, including the reference monitoring required for the execution of the test (in some cases, instruments of the participants may be used in the execution of the test - e.g. observed strains in the GeoDetect-system).

Any extensions to the existing design are to be reviewed by the board of directors of the IJkdijk foundation.

5 Evaluation criteria

Validation experiment AIO-SVT: the test of techniques

The All-In-One/Sensor Validation Test is the penultimate validation experiment in the research and development program of the IJkdijk foundation. Like in the previous experiments, the AIO-SVT is meant to validate the monitoring techniques and the sensor- and data-acquisition systems, but in contrast to the earlier experiments the evaluation aspect is more pronounced. Systems and techniques will be judged in an objective manner with regards to the validity and area of application, as requested by the participating companies at the start-up meeting. Note the name of the Sensor Validation Test! The report with conclusions on the test will serve as a certificate for the companies to prove that techniques are valid for application in certain areas as levee monitoring systems.

This requires several issues to be clearly stated *on beforehand:*

- What framework is used and which criteria are applied?
- Which results are validated?
- Who performs the validation?
- How will the results be presented?
- How to ensure the objectiveness of the validation?

The participating companies should be aware of these matters.

Agreement on validation
In the mutual contract documents it should be clear that the participants accept a validation of their system or technique and allow communication on any conclusions drawn.

Framework and criteria
It is important to have clear before the experiment what the evaluation framework will be and by which criteria the systems and techniques will be judged. The following gradations will be used:

- System or technique is suitable for measurement of the following parameters.
- System or technique is suitable for measurement of the following failure mechanisms.
- System or technique is suitable for monitoring, for prediction and postdistion.
- Level of robustness of system or technique, installation procedure (with possibilities and limitations), influence of surrounding area, user-friendliness, durability.

Presentation of evaluation results
The outcome of the evaluation may be split in three categories as value judgments. This allows for a more subtle result than a more simple two-category-system. This is useful and even required, considering the potential damage for participants from unfavourable results.

One of the possible approaches leads to the following (explicit) categories:

1. In the AIO-SVT, the system or technique indicated the correct failure mechanism at the right location with the right actual strength and the right predictions within a small bandwidth (10-20%). The techniques and models used function as may be expected from fully operational techniques. The techniques and models are ready for application in daily practice and support the levee manager in a reliable manner. The time between measurement and model result (lead time) is short enough for levee manager to work with.
2. The validated technology and models are not sufficiently operational to apply in daily practice. At points to be specified, further development is required to improve them to enable application in daily practice. These improvements may be realised within a short term. Valid application in daily levee management practice can be achieved within the duration of the IJkdijk development program (ending in 2014).
3. The required development of technologies and models is still too large to expect that within a reasonable time span application in daily levee management practice can be achieved.

A more positive alternative is to assume a positive result, but to make clear in a different manner that a technique or system which is not yet adequate cannot be applied. For example, an approach may be followed as on websites designed for the selection of the best alternatives for a given situation, e.g. car insurance, a holiday trip, a computer, a sheetpile wall installation method (cf. www.geobrain.nl) or… a levee monitoring system. By making various selections it becomes clear which technique(s) can be applied.

As an example: a monitoring technique for a levee made of clay built on a sandy subsoil, with piping and overtopping as the failure mechanisms to be monitored. Influence to the surrounding area is not allowed, etc. The result will be a list of techniques with the one(s) at the top as the most suitable. In addition, it is indicated which combinations seem most adequate and which system fits the desires best. In this example no technique needs to be excluded, but on the basis of quality and specific application the best match is made.

Safeguarding the objectiveness of the evaluation
The framework and the criteria are set by the Dutch independent research institute for delta technology Deltares, with a check of the method applied and/or of the outcome may be carried out by the Dutch expert group on levees and other water retaining structure ENW and the levee managers. In accordance with the existing agreements, the results are supplied by the participants.

6 Planning

The planning of this test has been made in reverse order, because an important constraint is that the site has to be handed over to the owner, Staatsbosbeheer, by the end of October 2012. Before that, all signs indicating that experiments have been carried out there may need to be removed.

This means that the test program should finish by the end of September. Testing may take 1.5 months (mid-August - end of September), enabling all parties involved to obtain a good, not too short set of data and to have the ability to make necessary or desired adjustments in the course of the test period. All instrumentation should be installed before, including some time (half a month: early August) for the consolidation of excess pore pressures resulting from the installation of in-situ instruments and to test the ICT-environment. Installation of all equipment might take one month, i.e. the whole month of July. Construction of the various segments and auxiliary levees may take two months, i.e. start early May. Selection of a contractor may take one month and this detailed design therefore had to be ready before that process can start, i.e. at the end of March 2012. Before, several steps have been taken to arrive at a sound design. This process has started in the last quarter of 2011. The whole schedule is in accordance with experience from earlier experiments.

In chronological order:

- End of March 2012: detailed design ready
- April: contracting process
- May – June: construction of the levees (nine weeks):
  - Preparation of works (two weeks).
  - Sand-based levees:
    - Removal of old levee and upper 1 metre of sand (one week).
    - New sand and densification east side (one week).
    - Saturation east side, new sand and densification west side (one week).
    - Saturation wast side, placement of pre-installed instruments east side (one week).
    - Placement of pre-installed instruments west side, construction of east levee (one week).
    - Construction of west levee, installation of BioGrout under east levee - first week (one week).
    - Installation of BioGrout under east levee - final week (one week).
  - clay-dominated levee:
    - Removal of top layer etc. (one week).
    - Construction of four metre high levee, including DMC tube and GeoDetect (four weeks).
    - (Spare time on this levee: two weeks).
- July: installation of sensors (four weeks) - probably some delay from construction works at the beginning!
- Early August: consolidation of soil around in-situ sensors - not meant to be used to cover up delays!
- Wed 15 - Fri 17 August: test of ICT-systems at sand-based levees.
- **Mon 20 – Sun 26 August: first test week - sand-based levees (East and West).**
- Mon 27- Fri 31 August: move equipment to South levee.
- Wed 29 - Fri 31 August: test of ICT-systems at South levee.

- **Mon 3 September – Sun 9 September: second test week – South levee**
- Mon 10 - Sun 30 September: any additional tests
- October: removal and reshaping of the test site.
- October – later on: analysis and dissemination of results.

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A South Levee stability calculations

The design calculations for slope instability with a deep sliding plane have been based on similar calculations made before and after the September 2008 slope stability test at the IJkdijk. Some of the parameters, notably settlement parameters, have been fit to this large test and a preliminary test carried out at this site in January 2008 to retrieve bulk parameters for the peat layer.

As mentioned in Section 3.1, first calculations have been made for a location closer to the piping basins. These calculations have been made with Plaxis (finite element method), D-Geo Stability (Bishop and Van slope stability models) and MSettle (settlement calculations assuming lateral spreading using both Koppejan and Isotache methods). For the final location, the ‘South levee’, some of the D-Geo Stability and MSettle calculations have already been made. Further calculations are required for fine-tuning of the design, to determine the desired loading sequence and to get a feeling for the variations that may be expected (to be retrieved partly by making both Bishop/Van-calculations and Plaxis calculations.

Because of time constraints, at this point only a short report in Dutch on the design calculations of the South levee is given. In case a prediction competition will be organised, a report containing all necessary information will become available in English by the end of May 2012.

MSettle
Met MSettle is een berekening van de zetting van de dijk gemaakt inclusief een dissipatieberekening De doelen van de MSettle berekeningen zijn:

- Inzicht verkrijgen in de te verwachten zetting van de dijk.
- Berekenen van uitgangspunten voor de MStab berekeningen.
- Een vergelijkingspunt maken voor de later uit te voeren Plaxis berekeningen.

De berekening is uitgevoerd met het isotachen model. De gebruikte parameters zijn verkregen uit de rapportage van de vorige IJkdijk proef. Na het bezwijken van de macrostabiliteitsdijk zijn de verschillende parameters bepaald door het terugrekenen van de het bezwijkmechanisme. De bepaalde parameters zijn de parameters van de grond zoals aanwezig op locatie. Er zijn ook in het laboratorium bepaalde parameters maar omdat dit geen insitu meting is, en omdat dit zeer kleine monster zijn, zijn de paramaters waarschijnlijk minder betrouwbaar. De grondopbouw is bepaald aan de hand van 4 handboringen op de locatie van de nieuwe proefdijk. De gehanteerde grondopbouw en parameters zijn weergegeven in Tabel A.1.

b.k. laag [m t.o.v. NAP]	Materiaal [-]	γ_{droog} [kN/m³]	γ_{nat} [kN/m³]	φ [°]	c [kPa]	a [-]	b [-]	c [-]	OCR [kN/m²]	Cv [m²/s]
-1,1	Klei	15,93	15,93	31,92	6,3	0,007	0,07	0,002	2,3	6,7E-06
-1,8	Veen	10,09	10,09	33,87	0	0,0075	0,04	0,001	2,3	8,3E-06
-2,2	Klei	15,93	15,93	31,92	6,3	0,007	0,07	0,002	2,3	6,7E-06
-3,5	Veen	10,09	10,09	33,87	0	0,0075	0,04	0,001	2,3	8,3E-06
-5,9	Zand	18	20	35	0	-	-	-	-	Drained

Tabel A.1 Bodemopbouw en materiaalparameters van de MSettle berekening

De ophoging is in 5 slagen opgebouwd. Het ophoogmateriaal is hetzelfde zoals gebruikt voor de vorige proef. Het volumieke gewicht net als de overige parameters bepaald tijdens de vorige proef en is 15,11 kn/m³ droog en 19,41 kn/m³ nat. Het ophoogschema is weergegeven in Tabel A.2. In het schema is de start van de werkzaamheden aangenomen als dag 0. Omdat de eerste week waarschijnlijk alleen voorbereidende werkzaamheden uitgevoerd worden, wordt de eerste slag aangebracht op dag 7. Na het volledig aanbrengen van de dijk worden de lege containers die voor de proef gebruikt worden aangebracht. In de MSettle berekeningen is gerekend met een lege contianer op de kruin van de dijk vanaf dag 84.

De dijk heeft een hoogte van 4 m vanaf maaiveld. De kruin is 3 m breed. De taluds van de dijk hebben een helling van 1:1,5

Slag	Tijd	Hoogte
[-]	[dag]	[m t.o.v. nap]
1	7	-0.6
2	14	0.4
3	21	1.4
4	38	2.4
5	45	2.9

Tabel A.2 Ophoogschema

Uit de berekening volgt een maximale zetting onder het hart van de kruin van de dijk van 1,99m. Op het moment dat de proef begint op dag 105 zijn de wateroverspanningen voor circa 90% afgevloeid.

MStab
Om te bepalen of een 4 m hoge dijk op de zuidlocatie tot bezwijken komt is een conservatieve MStab berekening gemaakt. De geometrie van de dijk is afkomstig van de MSettle berekening. De gezette geometrie op T=105 dagen is gebruikt als MStab invoer. De gezette geometrie zal aanzienlijk stabieler zijn dan de ongezette geometrie. Verder zijn er de volgende conservatieve aannamen gedaan:

- 100% consolidatie, geen wateroverspanningen aanwezig.
- Geen wateroverspanning in het pleistocene zandpakket.

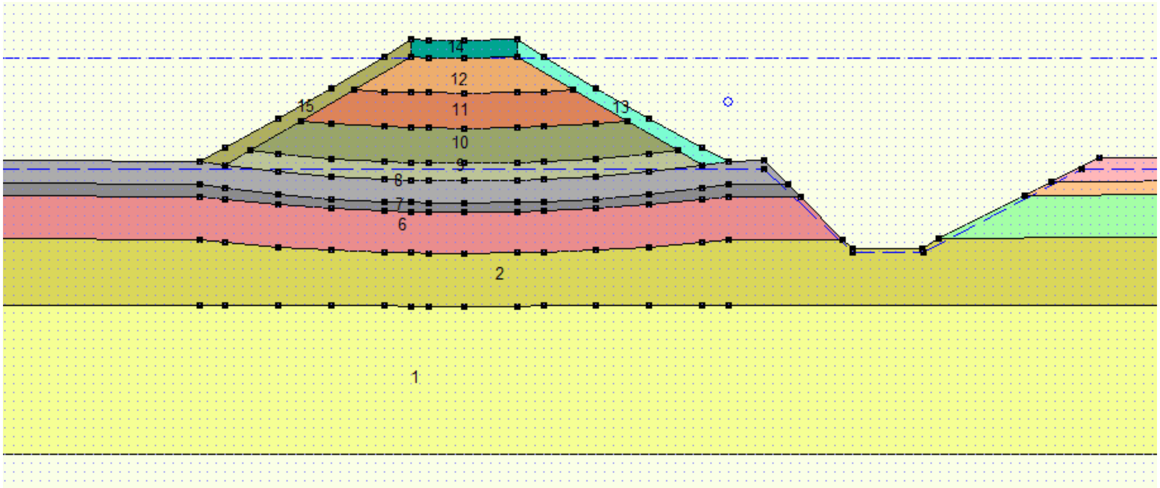
Vervolgens is de eindsituatie van de proef gemodelleerd. Hierbij zijn er volledig met water gevulde containers aanwezig op de kruin van de dijk. De inhoud van de containers is 28m³ bij een lengte van 6,1 m. Er is een sloot gegraven 1 m uit de teen van de dijk met een diepte van 2,5 m en een helling van 1:1 aan de dijkzijde en 1:2 aan de overzijde. Er is geen water aanwezig in de sloot. De zandkern van de dijk is volledig gevuld met water.

De berekening is uitgevoerd volgens de methode Bishop. De shuifspanning is uitgerekend met het C-φ model met uitzondering van de dekklei. Voor de dekklei is gerekend met het cu-measured model.

De geometrie van de MStab berekening is weergegeven in Figuur A.1 . De gehanteerde parameters zijn gegeven in Tabel A.3. In deze tabel is het zand in de kern van de dijk weergegeven als kernzand en de deklaag van klei op de dijk als dekklei.

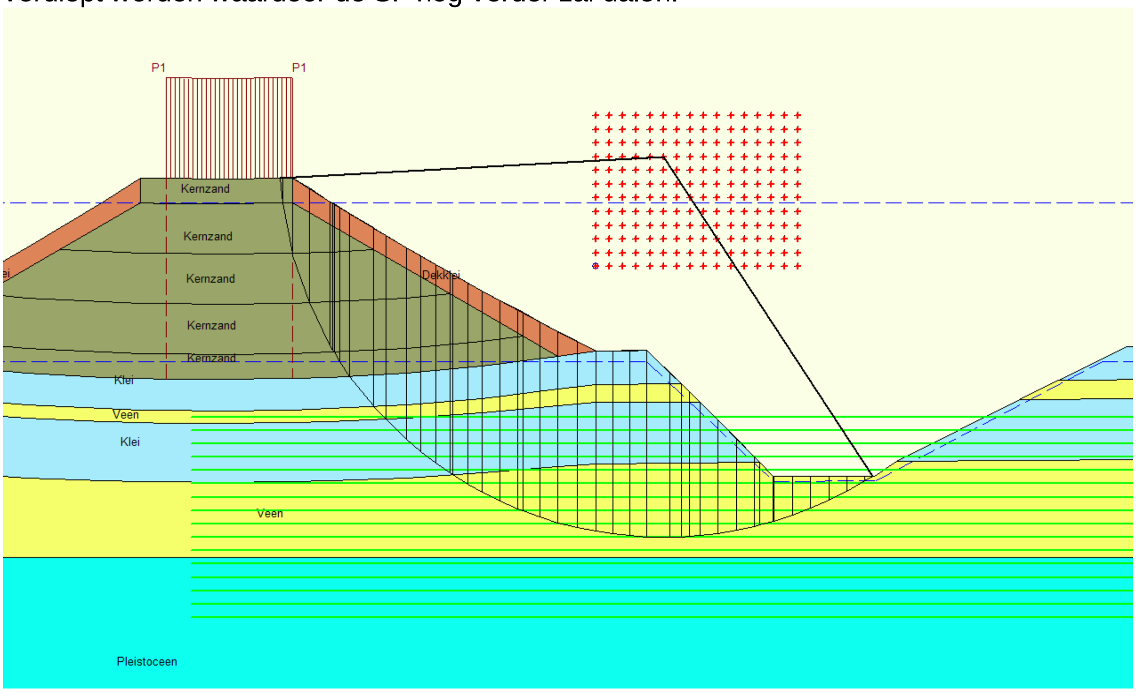
Materiaal [-]	**Gdroog [kN/m³]**	**γ_{droog} [kN/m³]**	**γ_{nat} [kN/m³]**	**φ [°]**	**cu_{top} [kn/m²]**	**cu_{bottom} [kn/m²]**
Klei	15,93	15,93	31,92	6,3	-	-
Veen	10,09	10,09	33,87	0	-	-
Zand	18	20	35	0	-	-
Kernzand	15,11	19,41	35	0	-	-
Dekklei	18	18	-	-	30	30

Tabel A.3 Materiaalparameters van de MStab berekening



Figuur A.1   Geometrie van de MStab berekening

De maatgevende glijcirkel is weergegeven in Figuur A2. De veiligheidsfactor (SF) is 0,82 op basis van de berekening die op meerdere punten conservatief is. Indien er een gedeeltelijke wateroverspanning in het pleistocene pakket en minder dan 100% consolidatie gehanteerd worden zal de SF nog verder dalen. Daarnaast kan de sloot aan de teen van de dijk verder verdiept worden waardoor de SF nog verder zal dalen.



Figuur A.2   Maatgevende glijcirkel. SF=0,82