

# Long-term subsidence study in the Wadden Sea Region

## Bestuur

Prof. dr. Pavel Kabat (voorzitter)  
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**To:** NAM/Shell, Steering Committee (SC), State Supervision of Mines (SSM), Advisory Group for Economic Affairs (AGE), Wadden Academy (WA)

**From:** B. Orlic

**Date:** 16 May 2014

**Subject:** Minutes of the 3rd Steering Committee meeting held on 3 and 4 April 2014 at TU Delft

**Filename:** [01-Minutes-3-SC-meeting-3-4April2014-public.docx](#)

**Legend:** => Action points NAM

## Distribution list:

### **NAM/Shell:**

Antony Mossop, Pieter van de Water, Dirk Doornhof, Ruud van Boom, Hermann Bähr, Harry Piening, Wim van der Veen, Sander Hol, Arjan van der Linden, Fons Marcelis, Pedro Zuiderwijk

### **SC:**

Hessel Speelman, Ramon Hanssen, Patrick Baud, Robert Zimmerman, Ryszard Hejmanowski, Rune Holt, Adriaan Houtenbos, Bogdan Orlic

### **SSM:**

Hans de Waal, Annemarie Muntendam-Bos, Rob van Lieshout

### **AGE:**

Jaap Breunese

### **WA:**

Klaas Deen

## Attendance:

**NAM/Shell:** T. Mossop, D. Doornhof, R. van Boom, H. Bähr, S. Hol, A. v/d Linden, F. Marcelis, P. Zuiderwijk

**UU (Utrecht University;** 4 April afternoon) R. Govers, G. Marketos

**SC:** H. Speelman, R. Hanssen, A. Houtenbos, P. Baud, R. Zimmerman, R. Hejmanowski, R. Holt, B. Orlic

**SSM:** A. Muntendam-Bos, H. de Waal

**Advisory Group Economic Affairs (AGE;** meeting invitation sent late): -

## Absent:

All members of the Steering Committee attended the meeting.

## Technical documents prepared by NAM and distributed to SC/SSM/AGE before the meeting:

*Update on the overall project progress by NAM*

*Update on the experimental test program by Shell*

*Update on the salt mechanics modelling by Utrecht University*

*Update on the micro-mechanical modelling by NAM*

*Update on the geodetic research plan by NAM*

## Response by SC/SSM/AGE to the technical documents prepared by NAM received after the meeting:

*Written comments by two SC-members on the project updates presented by NAM*

*A document summarizing experimental work by SINTEF possibly relevant for the project*

**Action points from the previous meeting (the 2<sup>nd</sup> SC meeting held in October 2013 in Leeuwarden) and open points from previous meetings:**

=> Rock mechanics test program

NAM is requested to prepare the test program proposal for the first part of the rock mechanics tests and make it available to the SC members and the SSM before the telecom scheduled for the 2nd December 2013.

The test program proposal was updated and distributed before the Teleconference held in December 2013. This action point is closed.

=> Progress report

NAM is requested to prepare a progress report and make it available to the SC and SSM by the 14th of March 2014 (about 3 weeks before the 3rd SC meeting).

A set of technical documents prepared by NAM was timely distributed before the meeting. This action point is closed.

=> NAM is requested to provide information package with the existing key technical documents to the Steering Committee, to familiarize themselves with the problem. This information will be made accessible through a sharepoint arranged by the Wadden Academy.

This action point can be closed. The relevant documents have been sent or made available via the sharepoint. The documents comprise two special issues of Journals mentioned below and a short summary of experimental results prepared by one SC-member.

In order to facilitate preparation and distribution of information package to the SC members, the Wadden Academy acquired and sent the relevant documents listed below to the SC members and the stakeholders.

**Documents sent by WA to the SC-members after the meeting:**

*A copy of the special issue of the Netherlands Journal of Geosciences on the Geoscientific research in the Wadden sea region (91-3, 2012). The papers in this issue provide background information relevant for the Long-term subsidence study in the Wadden Sea region. The last paper in this issue by de Waal et al. explains the concept of the effective subsidence capacity and the Hand on tap principle used to manage the subsidence in the Wadden Sea region.*

**Documents sent by WA to the stakeholders:**

*A copy of the special issue of the Netherlands Journal of Geosciences on the Geoscientific research in the Wadden sea region (91-3, 2012) (as above).*

*A copy of the special issue of Ocean Coastal Management on the Wadden Sea region (68, 2012).*

In addition, several relevant publications and theses were uploaded to the SharePoint accessible to the project participants and the SC members. A document was prepared summarizing experimental work done by SINTEF, which is possibly relevant for this project.

## Meeting objective

- **Day 1: 3 April 2014**

1) **The research progress meeting** was held to receive an update from NAM on

the research activities undertaken in the past 6 months, to review the results and to give NAM feedback on the activities planned for the next 6-8 months.

- **Day 2: 4 April 2014**

2) **The stakeholder meeting** was held with the objective to inform the stakeholders on project progress.

3) **A visit to the rock mechanics lab at Shell Rijswijk** was organized with the objective to explain and review the experimental work carried out within this study.

## Agenda

### Day 1: 3 April 2014

Location: CiTG, instructiezaal 2.99

- 10:00-10:30 Arrival and coffee
- 10:30-10:45 Introduction and announcements (Hessel Speelman)
- 10:45-12:15 Project progress overview (Tony Mossop)
  
- 12:15-13:00 Lunch
  
- 13:00-14:30 Rock mechanics testing (Sander Hol)
- 14:30-15:30 Salt mechanics (Rob Govers, UU)
  
- 15:30-15:45 Break, refreshments
  
- 15:45-17:15 Geodetic research (Hermann Bähr)
- 17:15-on Any other business

### Day 2: 4 April 2014

Location: CiTG, colloquiumzaal 02.110

- 10:00-12:30 Stakeholders meeting

Agenda:

10:00-10:20 Background on Subsidence study (NAM/R.van Boom)

10:20- 10:40 Study progress summary based on the outcome of 3<sup>rd</sup> St.Com. Technical meeting on 3/4 (WA/B. Orlic)

10:40-11:00 Proposal to address the Questions by Waddenvereniging (NAM/R.van Boom; WA/H.Speelman)

11:00-12:30 Time for questions related to the Subsidence study, discussion, any other business (Stakeholders)

- 12:30-13:30 Joint lunch with the stakeholders
- 13:30-14:00 Transfer by car/taxi to Shell Rijswijk
- 14:00-16:00 Visit to the rock mechanics lab at Shell Rijswijk (for the Steering Committee members)

## Announcements

- The chairman announced that R. Hanssen shall serve further on the Steering Committee. To recall, R. Hanssen offered his resignation at the 2<sup>nd</sup> SC meeting due to the potential conflict of interests. The possible conflict has been resolved in such a way that the postdoc at TUD, working on a geodetic research project funded by NAM, shall be supervised directly by NAM, department of Geomatics. NAM has confirmed this in a letter sent to the WA.

## Meeting highlights

- **Overview of project progress**  
T. Mossop gave an overview of the current status of research.  
The research addresses the topics listed in the terms of reference as defined by SSM.
- **Discrete Element Modelling (DEM; research proposal)**  
NAM will address the topic of Discrete Element Modelling (DEM) with a study possibly sourced out to an academic institution and a company specialized in DEM modelling.  
The motivation for using DEM is to understand better deformation behaviour of compacting reservoir rocks.

One member of the SC expressed his dissatisfaction with expanding the project scope with yet another hypothesis such as the DEM modelling, which will not lead to better understanding of anomalous time-dependent subsidence in the Wadden Sea region. Instead of using scarce resources on this hypothesis, the project needs to focus on the core of the problem.

Other members of the SC supported the use of DEM approach, but pointed out current limitations of the method. DEM can provide better understanding of lab tests, but it is not suitable for field-scale application. This is based on many years of modelling experience with DEM at SINTEF, which has a leading research group in this area. The shortcomings of DEM approach are many input parameters not possible to measure experimentally, inability to match the compressive and the tensile strength of rock material with one set of input parameters, etc. It was unanimously concluded that DEM models and other geomechanical models for subsidence calculation do not have to include geological faults, as there is no indication of fault control on subsidence.

### The SC's recommendations:

A DEM modelling approach has been a part of the scope of the project as requested by SSM. This topic needs to be explored by NAM to a limited extent, as it might provide useful insights into the mechanisms behind the time-dependent behaviour of the compacting sandstone reservoir rock.

- **Flow and compaction in heterogeneous permeable media (research proposal)**  
This study will most likely be outsourced to a company with the required level of expertise in similar studies.

One member of the SC expressed his dissatisfaction with expanding the project

scope with another hypothesis. He advised to perform a problem analysis first and commit to this study only if this hypothesis appears worthwhile.

One member of the SC advised to study a 1D problem first before doing computationally intensive 3D stochastic simulations. Realistic pore-throat dimensions need to be considered in simulations.

SSM suggested to consider doing experimental work. It was noticed that the effect of slower pressure equilibration of even a small fraction of permeable rock could retard rock compaction and temporarily strengthen the rock.

NAM responded that they were planning to run tests to determine bound water content.

The SC's recommendations:

A 1D problem can be studied first instead of many stochastic simulations on a 3D simulation grid.

Simulations need to consider flow over larger distances (corresponding to the thickness of Ten Boer) through the material with the pore-throat dimensions in the nano-meter size range.

- **Rock mechanics testing (preliminary results from on-going experiments)**

Rock mechanics tests are conducted at the Shell Rijswijk lab. Large part of the capacity of the lab is currently in use for this project. Samples are obtained from the well "Moddergat-3". Stand-alone triaxial cells and quadruple systems are fully operational; testing of Ten Boer samples is in the final stage; long-term creep tests on Rotliegendes samples are ongoing; failure tests on Rotliegendes samples are in the final stage.

The following advices and suggestions were given by the SC-members during discussion:

- To measure sample permeability as this parameter is important for delayed compaction.
- To examine whether the creep behaviour is associated with cracking. This can be done by post-mortem testing of velocity, permeability and other properties on thin sections.
- To run short-term experiments first and then decide on how to extend the testing program.
- To run at least one long-term creep test beyond 3-4 weeks.
- To investigate the role of shale / sandy shale within the depleting reservoir on delayed compaction.
- To investigate whether the observed time-dependence can be related to reduced stress arching by increased depletion areas with time.
- To investigate the role of accelerating plastic strain on delayed compaction and subsidence.
- To check internal archives for useful information from the past.

The SC's recommendation:

The ongoing testing program should be continued as planned. The results obtained in the next 3 months will be discussed and reviewed by the rock mechanics experts serving on the SC at a meeting in June. Based on the outcome of this meeting, recommendations will be issued on whether and how to proceed with the long-term creep tests.

It is recommended to consider measuring sample permeability and other properties indicating cracking of loaded samples, in line with the suggestions given above.

- **Salt mechanics (first results)**

The presentation was given by a researcher from Utrecht University

The work will mostly be done by a postdoc from Oct.2013 - Oct.2016.

Preliminary finite element simulation results were shown for a synthetic reservoir overlain by a Zechstein salt caprock. The numerical model was validated against an analytical solution. The modelling results show that the presence of viscous salt in the overburden of compacting reservoirs can lead to larger subsidence (compared to the elastic case) and to a change in subsidence profile over time in the post-depletion period.

The SC's recommendations:

Future work needs to consider more realistic structural settings, variation of material parameters, the influence of loading by gravity, etc.

Literature search is needed to find examples of geomechanical models matched against measured field data for the geological settings with viscous salt layers.

**Geodetic research (research proposal)**

The geodetic research plan has been revised following the comments by the SC members given at and after the Geodetic meeting held on 21 January 2014.

The revised plan comprises two parts: research on geodetic data processing and hypothesis testing. The use of levelling and InSAR data is envisaged.

One member of the SC made several comments during the meeting, and also in writing after the meeting regarding the presented geodetic plan. He suggested to drop a part of the research related to geodetic data processing, to use leveling data only (instead of both leveling and InSAR data) and to use real data test cases, which provide the only true reference for detecting errors in geomechanical models for subsidence prediction.

One member of the SC commented that testing hypothesis on synthetic data sets, as proposed by NAM, is still valuable to do and has not been seen in the literature. The SSM explained that validation of various hypothesis against actual field data, enabling discrimination between hypothesis that do and do not adequately describe the observations, falls within the scope of this study.

One member of the SC advised to have more discussion between the geodesists and the geomechanics researchers in order to resolve the problem of comparison of the measured and modelled subsidence. He also suggested to make use of Discussion area on the Sharepoint for communication and discussions.

The SC's recommendations:

NAM should consider reducing the amount of research related to geodetic data processing and proceed with hypothesis testing on synthetic and real data sets.

NAM should consider the comments made by the SC members when working out details of the research plan and conducting the research.

## Stakeholders meeting

- One stakeholder attended the meeting from the Wadden Association (Waddenvereniging). She gave a short introduction about the Wadden Sea Region, which is a unique natural site.

- The Wadden Association compiled a list of questions in Dutch and sent it to NAM and WA two weeks before this meeting. The list comprises a few groups of questions related to:
  - 0) the effectivity and reliability of the Hand on tap principle, which is the technical framework put in place to manage the subsidence in the Wadden Sea Region;
  - A) the main features of all existing geomechanical models and those used for subsidence prediction in the Wadden Sea Region;
  - A1) the geodetic monitoring in the Wadden Sea Region;
  - A2) the use of various simulation models of gas production and subsidence prediction over time in the Wadden Sea Region;
  - B) measurements of sand plates in the Wadden Sea Region;
  - C) sedimentation rate and sediment composition in the Wadden Sea Region.
- The representative from the SSM explained the history behind the subsidence study. The study was ordered by the Minister and the terms of reference prescribed by SSM.

NAM is required under the regulations governing the Moddergat, Lauwersoog, Vierhuizen, Anjum and Ameland extraction plans to carry out a detailed study prior to 1 July 2015, to the satisfaction of the Inspector General of Mines, to improve knowledge of the physical background of measured time-dependent effects of subsidence behavior and its possible influence on expected subsidence in the long term. The study should lead to a better understanding of the physical processes that explain the subsidence which has already occurred, with the aim of improving the forecasting of future subsidence.

After the study scope had been defined, an open debate was held when the Wadden Association raised additional questions. These questions, however, could not be included into the subsidence study as its scope had been already defined.
- NAM presented a proposal on how to address the different groups of questions posed by the WV. Many of the questions have to be answered regularly and reported to SSM through the *Meet- en regelprotocol* (M&R). NAM suggested organizing a separate meeting with the stakeholders, SSM and WA in order to answer the questions of Wadden Association which fall under M&R.
- The questions, which remain unanswered by M&R and fall within the scope of the subsidence study, will be translated into English and sent to the members of the Steering Committee. The outcome will be communicated back to the stakeholders.
- One member of the SC noted that the SC lacks a common perspective on the problem, which is an unreliable prediction. There is no effective steer from the SC and the direction that study takes is effectively decided by NAM.

In reaction to this comment, the chairman asked each of the remaining five SC members whether their advices have been taken up and sufficiently followed by NAM. Each of the five members of the SC responded positively that this was indeed the case: the input/advice was taken by the NAM researches and followed up.

Another remark was given over the lack of information package with gray literature from the past to familiarize with the problem.

One SC-member offered his help in making a short summary of experimental results obtained by SINTEF in other projects that can be relevant for the Subsidence study.

One SC-member made a remark that SSM should restrain from over-steering.

## Requests and Action points NAM

- ⇒ **Reports on subsidence modelling (internal NAM gray literature)**  
Selected reports and case histories on subsidence modelling in the Wadden Sea Region should be made available to the SC members via the SharePoint.
- ⇒ **Geodetic meeting in May/June 2014**
- ⇒ **Rock mechanics meeting in June 2014**  
NAM is requested to consider the recommendations given by the SC and present results from the on-going research at the Geodetic meeting and the Rock mechanics meeting to be held separately in June 2014 (see the section on Next meetings).  
The technical documents to be discussed at these meetings need to be prepared and sent to the meeting participants not later than **1 week** before the meetings.
- ⇒ **4<sup>th</sup> Steering Committee meeting on 1 and 2 December 2014**  
NAM is requested to prepare a progress report and make it available to SC by **14 November 2014** (2 weeks before the meeting).

## Next meetings

### **The Geodetic meeting will be held in May or June 2014.**

⇒ NAM will take the initiative to find a suitable date for this meeting. The presence of the geodetic experts serving on the SC is expected.

### **The Rock mechanics meeting will be held in June 2014.**

The rock mechanics experts serving on the SC prefer to have a meeting with the NAM researchers involved in rock mechanics testing at the scientific conferences, which they will attend in June.

The first meeting will be held sometime during the ARMA2014 symposium in the U.S.

The second meeting will be held sometime during the EAGE conference in Amsterdam.

### **The 4<sup>th</sup> Steering Committee meeting will be held on 1 and 2 December 2014**

in the Netherlands. The presence of all members of the SC is expected. Further details about this meeting will be given later.