

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: 23 January 2015
Subject: Minutes of the 4th St. Com. meeting held on 1 & 2 Dec. 2014 in Utrecht
Filename: [01-Minutes-4-SC-meeting-1-2Dec2014-public.docx](#)
Legend: => Action points NAM

Distribution list:

NAM/Shell:

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

SC (Steering Committee):

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

SSM (State Supervision of Mines):

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

AGE (Advisory Group Economic Affairs):

Jaap Breunese

WA (Wadden Academy):

Klaas Deen

Attendance:

NAM/Shell: T. Mossop, D. Doornhof, R. van Boom, H. Bähr, S. Hol (1st day), A. v/d Linden (1st day), P. Zuiderwijk (1st day), J. Jansen, S. Bierman (1st day), P. Kole (1st day), F. Seeberger (1st day)

UU (Utrecht University) R. Govers (1st day), G. Marketos (1st day)

SC: H. Speelman, R. Hanssen, A. Houtenbos, P. Baud, R. Zimmerman (1st day), R. Hejmanowski, R. Holt, B. Orlic

SSM: H. de Waal

AGE: J. Breunese (1st day)

Absent:

All members of the Steering Committee attended the meeting.

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

[Update on project progress, general presentation by NAM](#)
[Update on project progress, technical presentation by NAM](#)
[Update on aquifer modelling by NAM](#)
[Update on geodetic research by NAM](#)
[Update on salt modelling by UU](#)
[Update on in situ compaction by NAM](#)
[Update on rock mechanics testing by Shell](#)
[Update on diffusion modelling by NAM](#)
[Update on workflow applied statistics by Shell](#)

Presentation given by one member of the steering committee:

[Presentation on reliability of geodetic data by a committee member](#)

Response by the SC to the technical documents prepared by NAM, received before and after the meeting:

Written comments by four members of the steering committee

Response from NAM to the comments regarding the geodetic sub-project, received after the meeting:

Reply on questions related to geodetic research by NAM

Action points from the previous meeting (The 3rd SC meeting held in May 2014 in Delft) and open points from previous meetings:

=> Reports on subsidence modelling (internal NAM grey 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. This action point was only partially fulfilled by NAM at this meeting in presentations on particular topics (e.g. aquifers).

This action point is still open. A practical way to close this point is to address it in an appropriate way in final reports.

=> Geodetic meeting in May/June 2014

Geodetic meeting was held at NAM in Assen on 7 July 2014.

This action point is closed.

=> Rock mechanics meetings in June 2014

Rock mechanics meetings were held on 2 and 17 June 2014.

This action point is closed.

=> 4th Steering Committee meeting on 1 and 2 December 2014

NAM is requested to prepare a progress report and make it available to SC/SSM/AGE by 14 November 2014 (2 weeks before the meeting).

The technical documents were submitted on time and the meeting was held as planned.

This action point is closed.

Meeting objective

- **Day 1: 1 December 2014**

- 1) **Progress review meeting** was held to receive an update from NAM on the research progress over the past 6 months, to review the results and to give NAM feedback on the activities planned for the next 6 months, until 1 July 2015 when the project ends.

- **Day 2: 2 December 2014**

- 2) **Reflection on Progress review meeting, Next steps towards project finalization, Reporting issues**

Stakeholders meeting planned on Day 2 had to be postponed to early 2015 because of unavailability of many stakeholders to attend the Dec 2 meeting.

- 3) **A visit to the high pressure and temperature (HPT) lab at the Faculty of geosciences of Utrecht University, hosted by Prof. C. Spiers.**

Agenda

Day 1: 1 December 2014

Location: Grand Hotel Karel V, Utrecht, Anna van Oostenrijk zaal, 12:00-max.19:05

Arrival and lunch 12:00-13:00

St.Com. meeting 13:00 - max.19:05

Note that agenda items include the time allocated for presentation and discussion.

Opening	13:00	Opening (Hessel Speelman 10 min)
Introduction general	13:10	General (Ruud van Boom 15 min)
Introduction technical	13:25	Technical (Tony Mossop 35 min)
Aquifer	14:00	Impact and uncertainties (Fritz Seeberger 30 min)
Geodetic	14:30	Monitoring and Noise (Hermann Baehr 45 min)
Short break	15:15-15:30	(15 min)
Salt	15:30	Salt Modelling (George Marketos 30 min)
In situ compaction	16:00	In situ compaction (Pepijn Kole 15 min)
Rock Mechanics	16:15	Laboratory results & Constitutive Laws (Sander Hol 60 min)
Continuum Mechanics	17:15	Anomalous diffusion (Tony Mossop 15 min)
Short break	17:30-17:45	(15 min)
Statistics	17:45	Workflow applied statistics (Stijn Bierman 30 min)
Discussion & Conclusion	18:15	(Tony Mossop : 45 min)
Closing	19:00	(Hessel Speelman 5 min)
End	19:05	

Day 2: 2 December 2014

Location: Grand Hotel Karel V, Utrecht, Anna van Oostenrijk zaal, 09:00-12:30

St.Com. meeting 9:00-12:30

Discussion	9:00	All (90 min)
Break	10:30-10:45	(15 min)
Geodetic	10:45	Reliability of geodetic data (A. Houtenbos 30 min)
Discussion	11:15	All (15 min)
Project finalisation	11:30	Reporting (Ruud van Boom 15 min)
Next steps & wrap up	11:45	Hessel Speelman (max.30 min)
End	12:15	
Lunch	12:30-13:30	

Visit HPT-lab UU 13:30-15:00 **For the S.C. members, SSM, AGE**

Faculty of Geosciences, Utrecht University Budapestlaan 4, 3584 CD Utrecht

Transport to HPT-lab	13:30-14:00	on your own
Visit HPT-lab	14:00-15:00	

Meeting highlights

- **General, NAM's plans for finalization of the study**

NAM presented plans for finalization of this study.

The plan is to complete The long-term subsidence study and submit the reports in June 2015, before the deadline of 1 July 2015. The reports will address all the topics listed in the Terms of reference (TOR), but will not include hypothesis testing and implementation on a field case.

Hypothesis testing and implementation on Ameland gas field will be done in a follow-up study, which will be executed by NAM in the period between 1 July

2015 and Q1 2016. The follow-up study will result in a report submitted in Q1 2016. The mandate of the current Steering committee is ending on 1 July 2015. NAM wants to receive input from the meeting participants whether a Steering committee is needed for a follow-up study and, if yes, in which composition.

The SSM-representative stated that NAM has an obligation to inform SSM in a formal way about the plans for a follow-up study.

Steering committee recommendations:

Hypothesis testing and implementation on a field case is strongly supported and recommended. The hypotheses to be tested include: the impact of aquifer depletion, the impact of rock salt caprocks, the hypotheses developed in the geodetic sub-project, etc. The committee supports selection of Ameland gas field for hypotheses testing.

Making comments on project management issues such as project timeline is beyond the role of this steering committee (the committee was established to review, advice and provide guidance on technical issues).

- **Overview of project progress**

NAM gave status overview of the study program. Each of the topics described in the terms of reference (TOR) is addressed in more detail later during the meeting in different presentations.

NAM stated that the study program was charged with identifying, if possible, the causative physical process(es), to the observed anomalous time dependent behaviour.

Perhaps more importantly the program is meant to identify and recommend how an objective modelling, prediction and monitoring workflow should be structured, so that relevant data is included correctly and uncertainties properly determined. Based on this line of thought, preliminary recommendations have been formulated to improve the existing workflows. Discussion on preliminary recommendations was held later in a separate session (see the section ***Preliminary recommendations for improving workflows***).

- **Aquifer modelling**

NAM gave a presentation on impact and uncertainties related to aquifer depletion.

Steering committee recommendations:

Committee strongly recommends testing the impact and uncertainties related to aquifer depletion and depletion delays on a field case. Analyses need to consider also the effects related to depletion of Ten Boer aquifer.

- **Geodetic research**

NAM researcher gave presentations on stochastic modelling and output level study. The research goal of the geodetic sub-project is to review the stochastic properties of levelling and InSAR subsidence measurements, to get more insight in possible spatio-temporal variability of different noise components, and to propose a clear and coherent step-wise procedure to construct the required stochastic model.

Two members of the committee expressed their appreciation for the progress in geodetic research and made a number of technical comments and recommendations.

Another member of the steering committee provided several comments on the geodetic sub-project. He noticed that GPS data was not considered although this

was needed. Further, it was suggested to derive noise models for levelling, InSAR and GPS in the same way. It was also suggested to use the *Rijkswaterstaat* guidelines for design and checking of levelling surveys and to use integrated 3D spatio-temporal processing.

Steering committee recommendations:

Hypotheses testing on field cases is required by the Regulator and supported unanimously by the Steering committee. Committee recommends using the same geographic area for both levelling analysis and InSAR analysis. Technical questions posed by two members of the committee need to be considered and answered.

NAM replied in writing to comments regarding the geodetic sub-project.

- **Salt mechanics**

The presentation was given by a researcher from Utrecht University..

The goal of the research is to investigate time-dependent ground surface deformation above depleting reservoirs overlain by a viscous rock salt layer. Numerical simulations showed that the presence of viscous salt in the overburden of compacting reservoirs can lead to larger subsidence (compared to the elastic case) and to time-dependent subsidence profile, which changes over production- and post-production times. The results of this research will be published (two papers are currently in preparation).

Steering committee recommendations:

Future work needs to consider realistic structural settings. Literature on deep solution salt mining in the Netherlands should be checked as it may provide useful information on the salt creep processes and the values of material parameters applicable to field conditions. The salt research needs to provide constraints on the timescales on which stress relaxation in salt caprocks occurs and the related effects on time-dependent ground deformation during production- and post-production phase.

- **In situ compaction**

The presentation was given by NAM.

Monitoring of reservoir compaction is done in 3 key wells in the Groningen area, thus outside of the Wadden Sea region. Current research comprises development of new methods for data interpretation and the use of tools based on fiber optics.

Steering committee recommendations:

Monitoring of in situ compaction would be useful to do in the Wadden Sea gas fields on the long-term (i.e. over a period of several years, which is far beyond this project).

- **Rock mechanics testing**

The presentation was given by Shell.

An overview was given of the status of laboratory work and delivered data. More than 100m of core was retrieved from a well located in the Wadden Sea area. The tests executed so far comprise triaxial failure tests on two sets of samples and over 30 pore pressure depletion, i.e. creep tests. Further, rate-type compaction tests have started. The results show that most of the depletion-induced strain was measured during the depletion stage, and not during the creep stage.

Several suggestions were given by the committee members related to rock mechanics testing in the final phase of the project.

Steering committee recommendations:

NAM needs to take into account the recommendations received from the committee members and adjust future experiments in such a way to better characterize the constitutive behaviour of sandstone.

Rate-type compaction tests should be executed as planned.

The committee acknowledges that the recommendations given at the previous meetings were thoroughly addressed in the report and in the ongoing experimental program.

- **Anomalous diffusion**

The presentation was given by NAM.

Modelling of fluid flow in heterogeneous media has started at Heriot-Watt. High-resolution numerical methods are used to study how far diffusion in heterogeneous porous media differs from a diffusion front that has been predicted using averaged properties of the heterogeneous media.

Steering committee recommendations:

No particular recommendations were given here except that the research should proceed.

Workflow applied statistics

The presentation was given by Shell.

The research explores statistical methodology for comparing the performance of subsidence models. An outline of the workplan was presented.

One member of the steering committee expressed his reservations relating to the use of new statistical models.

Steering committee recommendations:

It is recommended to use the current state-of-the-art geodetic statistical practices for hypothesis testing. The committee recommends the use of alternative approaches only in addition to the current well-established common practices.

- **Preliminary recommendations for improving workflows**

The list of preliminary recommendations, which are following from the results of this ongoing study, was compiled and presented by NAM.

Preliminary recommendations were formulated for improving current workflows at NAM used for objective modelling, prediction and monitoring of subsidence. Recommendations for improving workflows are seen by NAM as an important outcome of the Long-term subsidence study, besides the goal of identifying the physical processes to the observed anomalous time dependent subsidence.

Steering committee recommendations:

It is recommended to revise the preliminary recommendations in line with the suggestions given by the committee members at the meeting and in writing. The revised version should be sent to the scientific secretary by the end of January 2015. The secretary will circulate the revised version among the steering committee members, the SSM- and the AGE-representatives, with request for further comments.

- **Reliability of geodetic data – presentation by a committee member**

One member of the committee gave a presentation related to the geodetic research. A solution was presented for spatio-temporal statistical testing for errors in geodetic and geomechanical measurements, covariance models and functional models. A workflow was presented for statistically pure hypothesis testing of

geodetic and geomechanical data, models and covariance. A review was given of the use of InSAR data in northern Netherlands.

- **Stakeholders engagement**

Stakeholders meeting planned on 2 December had to be postponed to early 2015 because of unavailability of many stakeholders to attend this meeting. The goal of this future meeting is to inform stakeholders about the results of the Long-term subsidence study achieved so far. On behalf of NAM, one researcher has regular contacts with the Wadden Sea Association (the largest stakeholder). The two parties are working together on documents that will be used to clearly communicate the main results of the subsidence study to the public in a common language.

- **Other business**

One member of the committee commented that problem analysis was not done upfront the study to make an inventory of all the possible causes for anomalous time dependent subsidence. Extensive comments on the NAM research program, which were given by the steering committee members at the beginning of the project, were not discussed at the meetings and answered in detail by NAM.

The answer to this recurring question was given earlier by the chairman of the steering committee and the SSM-representatives (see the minutes of the 3rd Steering committee meeting, [01-Minutes-3-SC--meeting-3-4April2014-public.pdf](#)). A short explanation is repeated here. The study was ordered by the Minister. The goal of the study is better understanding of the physical processes causing the observed time dependent subsidence. The topics and hypotheses that need to be investigated were identified and extensively discussed between NAM, SSM and AGE at several meetings prior to this study. These research topics were included in the project proposal (TOR) prepared by NAM and are currently investigated in the Long-term subsidence study. Nevertheless, the steering committee can, during the execution of the study program, recommend NAM to explore a new topic or hypothesis, which is not included in TOR. So far, no new topics or hypotheses have been put forward by the committee members; hence, there were no recommendations on extending the project scope.

Another member of the committee noticed that reflecting on the study could indeed be useful. The problem of anomalous time dependent subsidence was not sufficiently well described and documented. This should have been done at the start of the project, by showing the modelled subsidence versus observed subsidence over time for several gas fields. Starting from the same level of knowledge would have been beneficial for all the parties involved in the project.

- **Visit HPT-lab at Utrecht University**

We thank Prof. C. Spiers and his collaborators for organizing a visit to Experimental rock deformation / HPT-lab at Utrecht University.

Requests and Action points NAM

- ⇒ **Preliminary recommendations for improving workflows**

NAM is requested to revise the preliminary recommendations in line with the suggestions given at the meeting and suggestions received in writing. The revised version should be sent to the scientific secretary by **31 January 2015**. The secretary will circulate the revised version of recommendations

among the steering committee, the SSM- and the AGE-representatives, with request for approval or further comments.

⇒ **The 5th Steering Committee meeting on 11 and 12 May 2015**

NAM is requested to prepare progress report(s) and send it to the scientific secretary by **23 April 2015** (2.5 weeks before the 5th steering committee meeting).

Next meeting

The 5th Steering Committee meeting will be held on 11 and 12 May 2015 (Monday and Tuesday) in the Netherlands. All members of the Steering Committee are expected to attend the meeting. Further details will be given later.