Bijlage 1

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Supplementary information to the "Technical Addendum of the Winningsplan Groningen 2013"

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Contents

Executive Summary

Following the submission of the Groningen Winningsplan 2013 on 29th November 2013, a request was made by the Ministry of Economic Affairs to evaluate additional production scenarios. The objective of this supplement is to discuss these additional production scenarios.

In addition to the production scenarios described in the "Technical Addendum to the Winningsplan, Groningen 2013" another two scenarios have been evaluated, one to test a different compaction model in combination with a different aquifer model (Depletion Scenario 1) and another one to test a different way of depletion aiming to reduce seismicity in the core area (at least temporarily) by changing the offtake pattern (Depletion Scenario 2):

1. A Market Demand scenario with the isotach compaction model and with a weak aquifer in the north of the field (G2). For the isotach model, a compaction coefficient was taken that is in line with the compaction coefficient used for the time-decay compaction model.
2. A 30 Bcm/year production scenario with the isotach compaction model and with a weak aquifer in the north of the field (G2), with 5 production clusters (LRM, OVS, PAU, POS and ZND) around Loppersum closed in.

The second scenario is for the initial years (2014 – 2017) similar to the Alternative Production Philosophy presented in the "Technical Addendum to the Winningsplan Groningen 2013" (scenario option A2 in table 3.2 of the Technical Addendum, page 50). In this scenario the same 5 production clusters around Loppersum are closed in until 2017.

The maximum PGA (Peak Ground Acceleration) values for the 2 additional scenarios are shown in the table below:

Scenario 1	**Period**	**Maximum PGA**		
		P_{50}	P_{10}	P_2
	2013 - 2016	0.02g	0.16g	0.39g
	2013 - 2018	0.04g	0.23g	0.52g
	2013 - 2023	0.08g	0.40g	0.79g

Scenario 2	**Period**	**Maximum PGA**		
		P_{50}	P_{10}	P_2
	2013 - 2016	0.02g	0.13g	0.33g
	2013 - 2018	0.03g	0.19g	0.43g
	2013 - 2023	0.05g	0.30g	0.65g

Scenario 1

The fit between measured subsidence and modelled subsidence is worse for the weak aquifer model (G2) than for the moderate aquifer model (G1).

The seismic hazard (expressed as maximum PGA) for the subsurface realisation with a weak aquifer (G2) is higher than the seismic hazard predicted on the basis of the subsurface realisation with a moderate aquifer (G1). This is related to overprediction of subsidence in particularly the north-western part of the Groningen field (the G2 model shows a poor match with observed subsidence data in particularly that part of the field).

Seismic hazard maps indicate that the area with the highest PGA value has moved to the north-west for the the subsurface realisation with a weak aquifer (G2) compared to the subsurface realisation with a moderate aquifer (G1). This has moved the area with the highest PGA value away from the area with highest observed seismicity.

Scenario 2

The following observations can be made for this scenario:

- This alternative production scenario temporarily reduces compaction and consequently the seismic hazard in the area with the highest level of seismicity.
- A pressure differential builds up over the field, leading to an increased pressure differential across faults (NAM's current production philosophy aims at minimising pressure differentials across the field). These higher pressure differentials may increase stresses across faults and may consequently increase seismicity. The combined impact on the seismic hazard of reduced compaction with increased pressure differentials cannot be determined with the current model. A 3D geomechanical model including faults offers the possibility to assess the combined effect. Such model allowing effective subsurface stress management is under development.
- Production is stable at 30 Bcm/yr for 4 years and thereafter rapidly declines further.

Based on these results, we conclude that:

- The weak aquifer model provides a poor match with observed subsidence data, especially in the north-western part of the field, and consequently overestimates the seismic hazard
- The close-in of 5 clusters around Loppersum provides a temporary 15-18% reduction of the maximum PGA in the area with the highest level of seismicity, but
  - The associated increase in pressure differentials across the field may in turn increase seismicity. The combined effect of reduced compaction and increased pressure differentials can only be assessed by means of a 3D geomechanical model. Such model is currently under development
  - After a short plateau of 4 years the production level rapidly declines.

1 Introduction

Following the submission of the Groningen Winningsplan 2013 on 1st December 2013, a request was made by the Ministry of Economic Affairs to evaluate additional production scenarios. The objective of this supplement is to discuss these additional production scenarios.

2 Groningen Model Realisations

As part of the Groningen field review (2012), a set of subsurface realisations of the Groningen field has been developed, capturing the full subsurface uncertainty range. This set is based on a single structural and static model, while reservoir properties (e.g. transmissibility of major faults and the strength of critical aquifers) differ between the different realisations in this set. Different combinations of these reservoir properties led to different qualities of match between the modelled reservoir pressure and water encroachment and the observed reservoir pressure and water encroachment in the field.

The recent review of the static and dynamic models of the Groningen field by SGS Horizon focussed on the best matched model, but also addressed whether the set of selected subsurface realisation models (based on the quality of the history match) reflected the full reservoir uncertainty. In their Opinion Letter, SGS Horizon states *"The (computer assisted) history matching methodology, which employs Shell proprietary software, is clearly documented and is thorough. This has resulted in a suite of acceptable history matched reservoir realisations."* The suite of acceptable history matched models included models with different transmissibility of major faults and the strength of critical aquifers (including the northern aquifers).

Two of these subsurface realisations of the Groningen field were used in the "Technical Addendum to the Winningsplan Groningen 2013"; these are labelled G1 and G2. The G2 model is the best matched model from the history matching process, based on reservoir pressure and water encroachment from the aquifers in the north of the field. For this reason, it is used as the base case for development planning in the Groningen field. However, compaction modelling based on this reservoir realisation model showed some discrepancies with the measured subsidence at surface in the north of the field and adjacent aquifers. It has been suggested that this might be attributed to a lower actual reservoir porosity in this area than the average modelled porosity. A possible explanation for such a discrepancy could be the limited well and therefore data density in this peripheral part of the field. Some of the models in the set of realisations showed a better match between the modelled and the observed subsidence.

A subsurface realisation with a stronger aquifer north of the field resulted in an improved match between the modelled and the observed subsidence. Note that this realisation still overpredicts the subsidence in this peripheral area. While the match for reservoir pressure was still acceptable, the modelled water encroachment in the north of the field was slightly larger than seen in the observation wells. This suggests that a further improved match can possibly be achieved with a model based on a lower local porosity. In the coming year, such a model will be constructed and history matched to investigate this hypothesis. In the technical studies in support of the winningsplan, the model with the larger aquifer and closer correspondence between the modelled and observed subsidence in the north of the field was labelled G1. As compaction plays a crucial role for induced earthquakes, this G1 model was preferred and used for the seismic hazard assessment.

In section 3.6 (pg 49) of the "Technical Addendum to the Winningsplan Groningen 2013", the labels for these two models have erroneously been switched in the following sentence:

"Two geological models were used, i.e. the best history matched model based on reservoir pressure (G1) and a model with additional changes in the porosity and aquifer strength in the northwest of the field to improve the match of the modelled subsidence with the measured subsidence data (G2)"

3 Additional Depletion Scenarios

In addition to the production scenarios described in the "Technical Addendum to the Winningsplan, Groningen 2013" another two scenarios have been evaluated:

1. A Market Demand scenario with the isotach compaction model and with a weak aquifer in the north of the field (G2). For the isotach model, a compaction coefficient was taken that is in line with the compaction coefficient used for the time-decay compaction model.
2. A 30 Bcm/yr production scenario with the isotach compaction model and with a weak aquifer in the north of the field (G2), with 5 production clusters (LRM, OVS, PAU, POS and ZND) around Loppersum closed in.

In the "Technical Addendum to the Winningsplan Groningen 2013", an alternative production philosophy aimed at reducing production in the Loppersum area has been evaluated (labelled A2, see table 3.1 on page 50). In this philosophy, the clusters located at a larger distance from the seismically more active Loppersum area are produced preferentially, while production from the clusters located closer to this area is reduced. Sensitivities associated with the implementation of this philosophy were presented in the "Technical Addendum to the Winningsplan Groningen 2013" with curtailment to 30 Bcm/year and 40 Bcm/year.

When this alternative production philosophy is implemented for subsurface realisation model G1 (stronger aquifer) with a curtailment to 30 Bcm/year, the clusters near Loppersum (ZND, OVS, PAU, POS and LRM) are producing only minimal volumes (<1 Bcm/year) for the period 2014 to 2017. These 5 clusters are in this scenario effectively closed-in for this four-year period, refer figure 3.1a and 3.1b.

The production philosophy where 5 clusters are closed-in (as in the additional scenario 2) is for the period 2014 to 2017 very similar to the scenario presented in the "Technical Addendum to the Winningsplan Groningen 2013", based on the G1 model where the alternative depletion scenario was implemented with curtailment to 30 Bcm/year.

The production forecast for the additional scenario with a 30 Bcm/yr curtailment, where 5 clusters in the north of the field are closed-in, is shown in figures 3.2a and figure 3.2b. In this scenario, the production decline starts in 2018, consistent with the start of the ramp up of the northern clusters in case of the alternative production strategy.

The Ministry of Economic Affairs also requested to evaluate a Market Demand scenario with the 5 northern clusters closed-in. This is effectively a scenario with 40 Bcm/yr in 2014 (the maximum production level with 5 clusters closed-in) and steadily declining production levels down to 30 Bcm/yr around 2019 and further down in later years (see Figure 3.3a and 3.3b). In this scenario, there is already in the near-term no excess capacity available as all clusters are produced full out. The Norg underground gas storage is in this case the only supplier of flexible capacity. This facility is currently being expanded to a working volume of 7 Bcm in 2017. The resulting seismic hazard for this scenario was not assessed in detail, but will be between the values for the end-member scenarios 1 and 2.

Closing-in of 5 clusters also affects the recovery from the field. At the current base case abandonment date of 2080, the difference in recovery at this date between production from all clusters and production with 5 clusters closed-in is some 36 Bcm (based on subsurface realisation model G2).

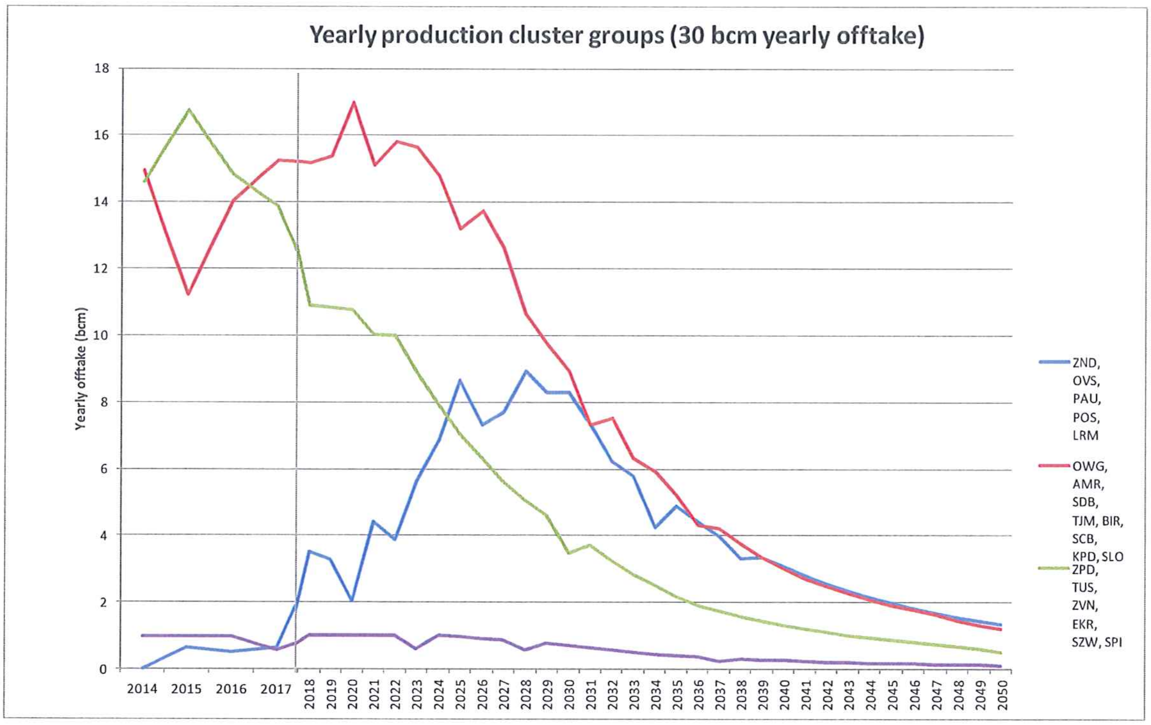


Figure 3.1a *Production forecast using the G1 model for the alternative production philosophy with production curtailment to 30 Bcm/year. The contributions to the gas production of the northern clusters (blue), the central clusters (red), the southern clusters (green) and Eemskanaal cluster (purple) is shown. The time-axis has been split to highlight the period 2014 to 2017.*

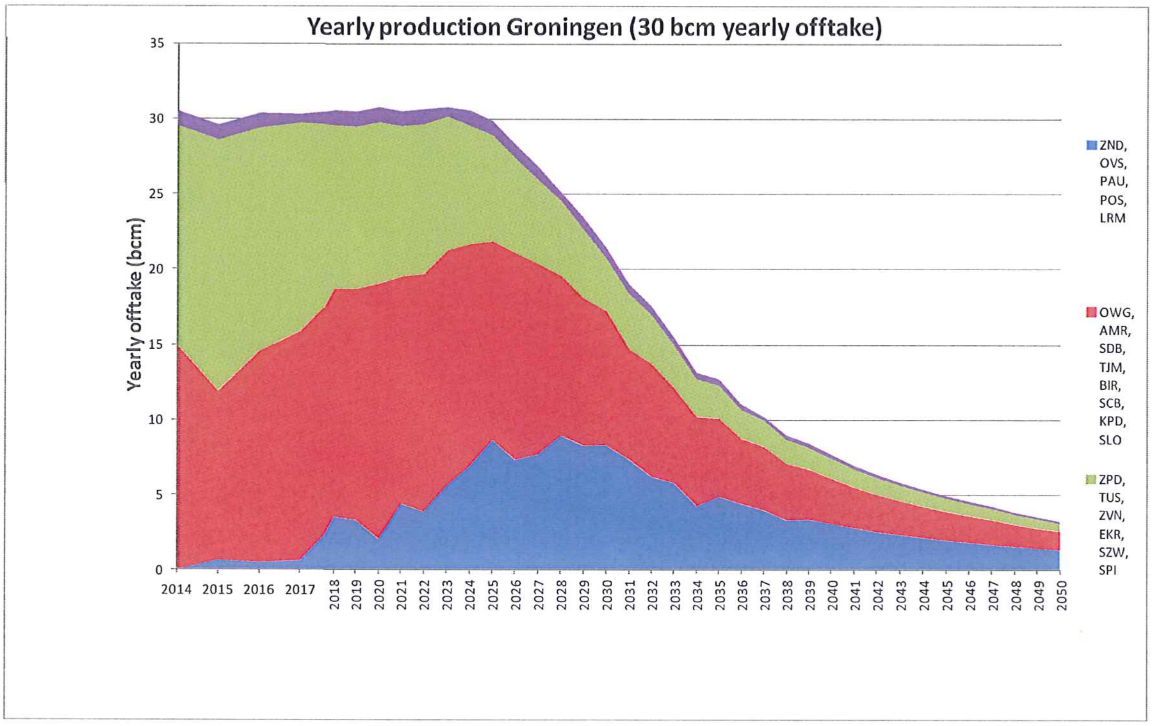


Figure 3.1b *Production forecast using the G1 model for the alternative production philosophy with production curtailment to 30 Bcm/year. The stacked contributions to the gas production of the northern clusters (blue), the central clusters (red), the southern clusters (green) and Eemskanaal cluster (purple) is shown. The time-axis has been split to highlight the period 2014 to 2017.*

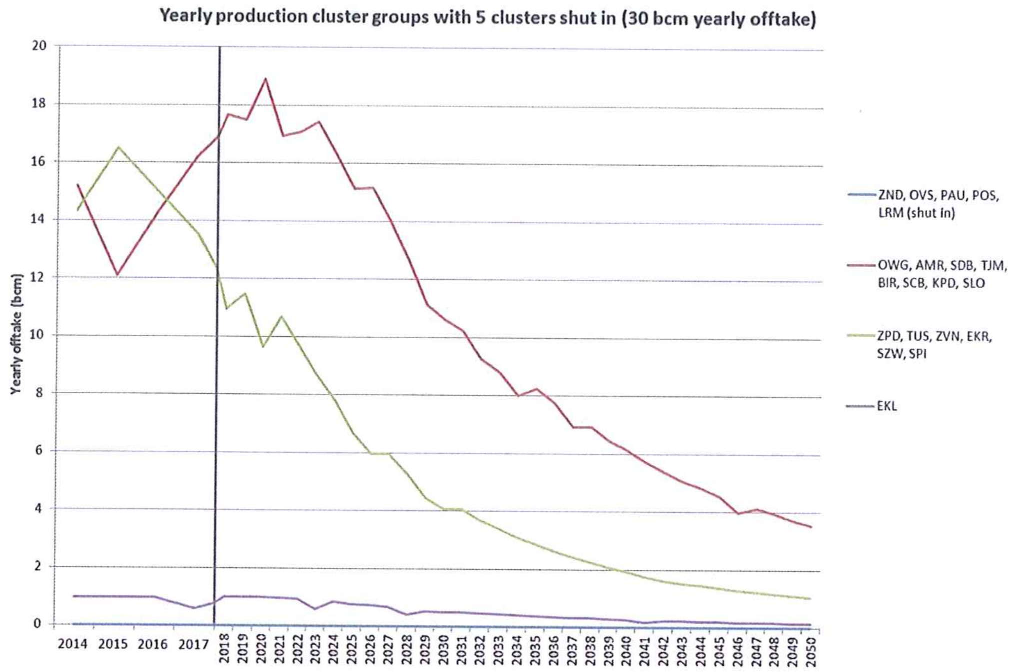


Figure 3.2a *Production forecast using the G2 model with the 5 northern clusters closed-in with production curtailment to 30 Bcm/year. The contributions to the gas production of the northern clusters (blue), the central clusters (red), the southern clusters (green) and Eemskanaal cluster (purple) is shown. The time-axis has been split to highlight the period 2014 to 2017.*

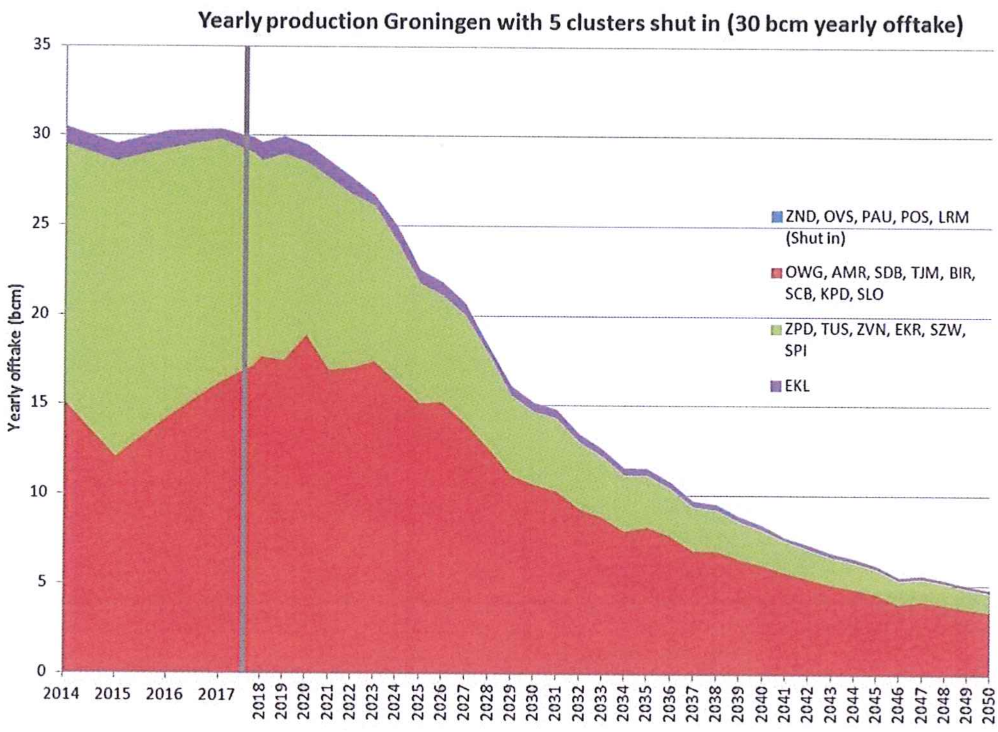


Figure 3.2b *Production forecast using the G2 model with the 5 northern clusters closed-in with production curtailment to 30 Bcm/year. The stacked contributions to the gas production of the northern clusters (blue; not shown), the central clusters (red), the southern clusters (green) and Eemskanaal cluster (purple) is shown. The time-axis has been split to highlight the period 2014 to 2017.*

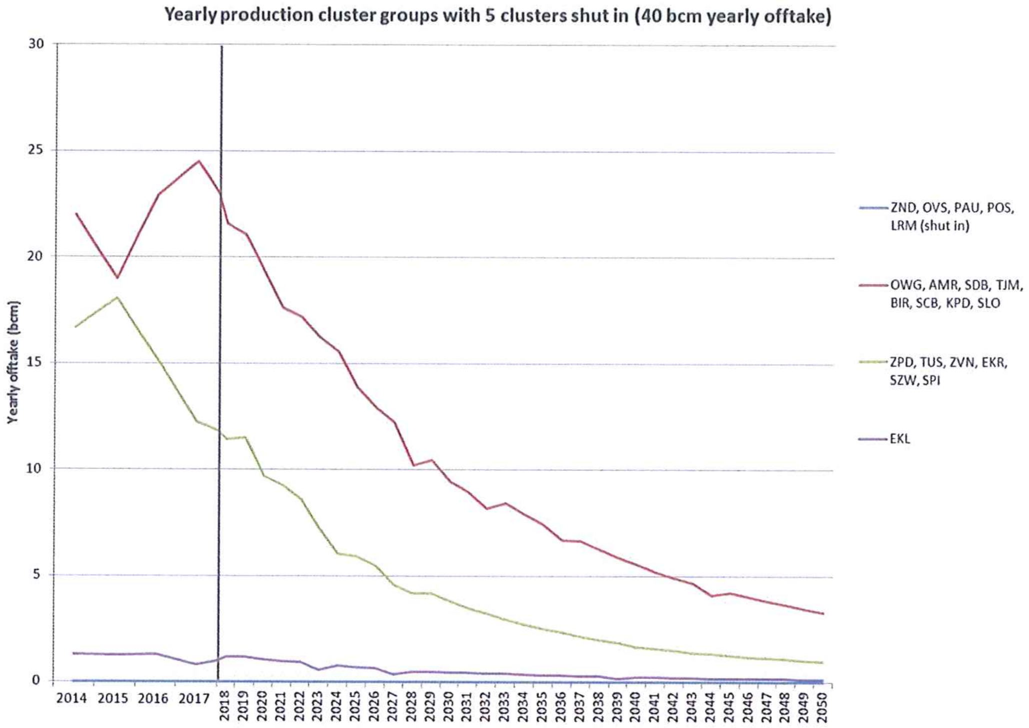


Figure 3.3a *Production forecast using the G2 model with the 5 northern clusters closed-in with production curtailment to 40 Bcm/year (as the field id not able to produce at higher levels, this is also the market demand scenario). The contributions to the gas production of the northern clusters (blue), the central clusters (red), the southern clusters (green) and Eemskanaal cluster (purple) is shown. The time-axis has been split to highlight the period 2014 to 2017.*

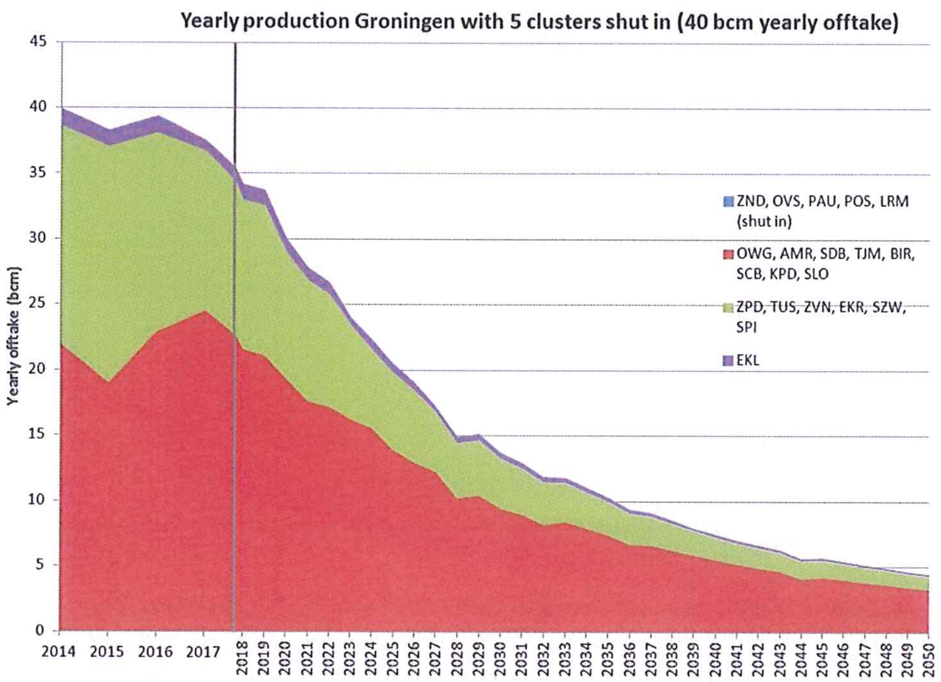


Figure 3.3b *Production forecast using the G2 model with the 5 northern clusters closed-in with production curtailment to 40 Bcm/year (as the field id not able to produce at higher levels, this is also the market demand scenario). The stacked contributions to the gas production of the northern clusters (blue; not shown), the central clusters (red), the southern clusters (green) and Eemskanaal cluster (purple) is shown. The time-axis has been split to highlight the period 2014 to 2017.*

4 Compaction Modelling

This section first describes the aquifer model and the compaction model used for the additional scenarios and subsequently discusses the predicted subsidence and seismic hazard for the two scenarios.

4.1 *Aquifer Model*

In general, with stronger aquifer support of the gas reservoir, the pressure decline in the aquifer will be less, but felt in a larger area of the aquifer. This will impact the compaction of the aquifer rock. The uncertainty in aquifer behaviour therefore impacts compaction and subsidence predictions and consequently also the seismic hazard.

In the history matching process the reservoir model is conditioned to reproduce the measured pressure data throughout the production history. A very extensive data set of more than 1700 pressure measurements in the gas column is available. The history matching process results in a well-conditioned model, which can serve to predict future reservoir pressure with confidence.

A good pressure match with historical pressure data can be obtained with different levels of pressure support from the aquifer. The geological model used for the evaluation of different production scenarios, as described in the "Technical Addendum to the Winningsplan Groningen 2013", was based on a moderate strength aquifer in the north of the field (G1). With this aquifer both observed pressures and observed subsidence can be matched well, but the rise of the water level in the north is overpredicted. An alternative geological model is one with a weak aquifer (G2). With this model a good match can be obtained with both observed pressures and the rising water level in the north. This weak aquifer model does however overpredict subsidence in the north of the field.

Given that compaction is the driver behind seismicity in NAM's seismic hazard model, a good match of measured subsidence data was deemed more important than a good match of rising water levels. This has led to a preference for the moderate aquifer model for the seismic hazard study (G1).

The additional depletion scenarios evaluated in this supplement (to the "Technical Addendum to the Winningsplan Groningen 2013") are based on a weak aquifer (G2).

4.2 *Compaction Model*

For the modelling of compaction and subsidence for the Winningsplan three compaction models were used: the time-decay model, the linear isotach model and the bi-linear model. These models are described in detail in Chapter 4 of the "Technical Addendum to the Winningsplan Groningen 2013".

A good fit with measured subsidence can be obtained for each of these three models. For the time-decay and bi-linear models the compaction coefficient needs to be adjusted from core measured values to obtain a good fit with measured subsidence levels. The isotach model is the only model that allows a good fit to measured subsidence levels without applying a correction to the core measured compaction coefficient. A good fit to observed subsidence data can however also be obtained for the isotach model with a compaction coefficient that is in line with the coefficient used for the time-decay model.

The additional depletion scenarios discussed in this supplement are based on an isotach compaction model with a compaction coefficient that is in line with the coefficient used for the time-decay model as described in Section 4.6.5 of the "Technical Addendum to the Winningsplan Groningen 2013".

Using this compaction model in combination with the weak aquifer reservoir model, the fit between the measured and modelled subsidence is less good, as shown below in figures 4.1 and 4.2. From comparing this figure with figure 4.29 in the "Technical Addendum to the Winningsplan Groningen 2013", it can be concluded that using the weak aquifer model does not improve the fit between modelled and measured subsidence data.

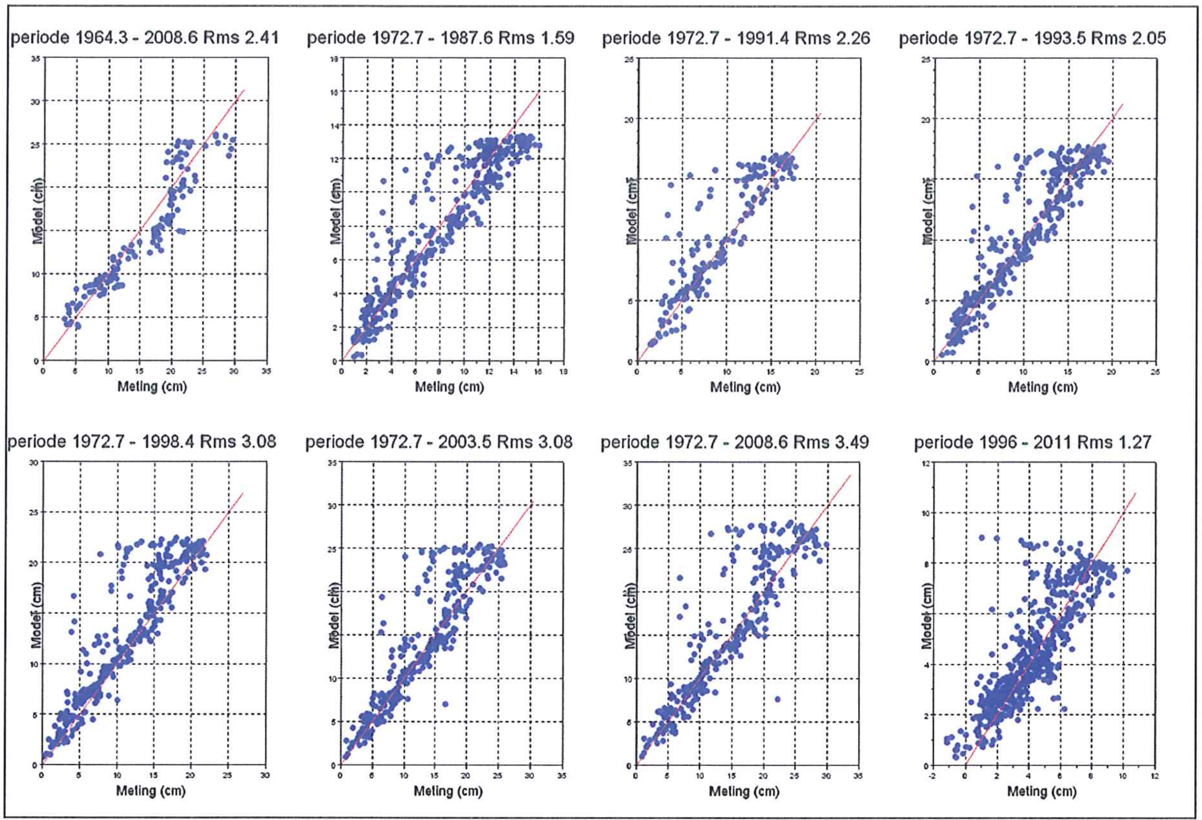


Figure 4.1 Measured vs. modeled subsidence for the full levelling and insar surveys (1996-2011)

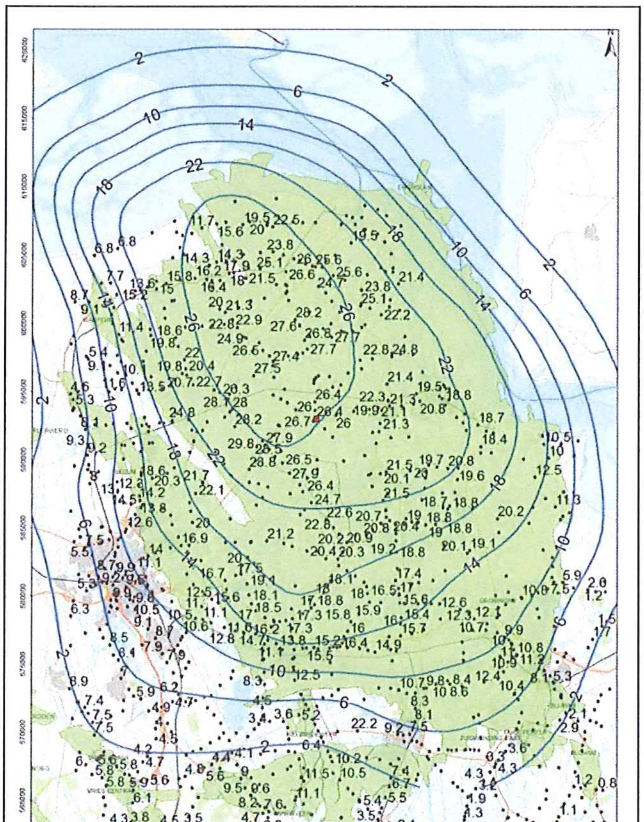


Figure 4.2

Subsidence measured in 2008 (since 1972) shown at the benchmarks with contours of the modelled subsidence in cm (1964 – 2008). Modelled contours indicate subsidence as a result from gas production exclusively from the Groningen field (G2). The red dot indicates the 7E00333 benchmark.

Figure 4.2 shows the poor match between modeled and measured subsidence for the G2 model especially in the north-western part of the field (difference of a factor 2 to 3 can be observed around the 18 and 22 cm contours).

Figure 4.3 shows the forecast of the subsidence at the end of the field life using the compaction model described above, again in combination with the weak aquifer reservoir model.

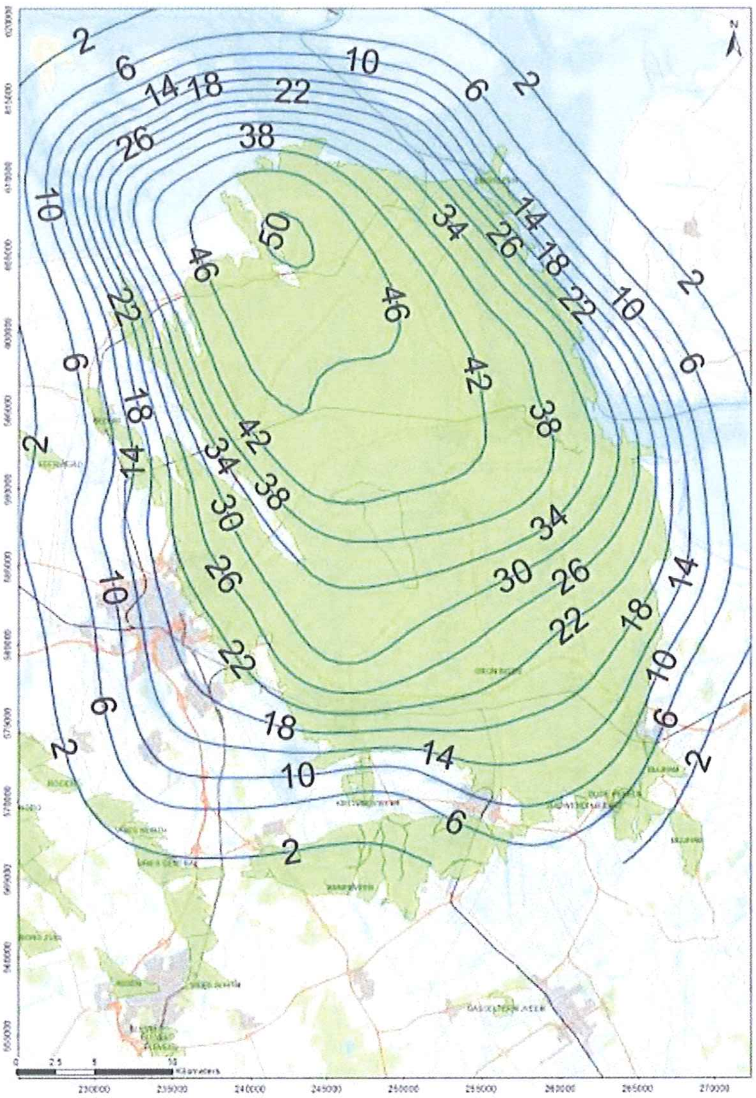


Figure 4.3 *Subsidence prognosis (in cm) at the end of field life, based on the isotach model using the C_m values determined by calibration with the time decay model, in combination with a weak aquifer model.*

5 Hazard Assessment

5.1 *Depletion Scenario 1*

Hazard maps (Peak Ground Acceleration – PGA) for this depletion scenario are shown in figures 5.1-5.3 for 3, 5 and 10 years, respectively.

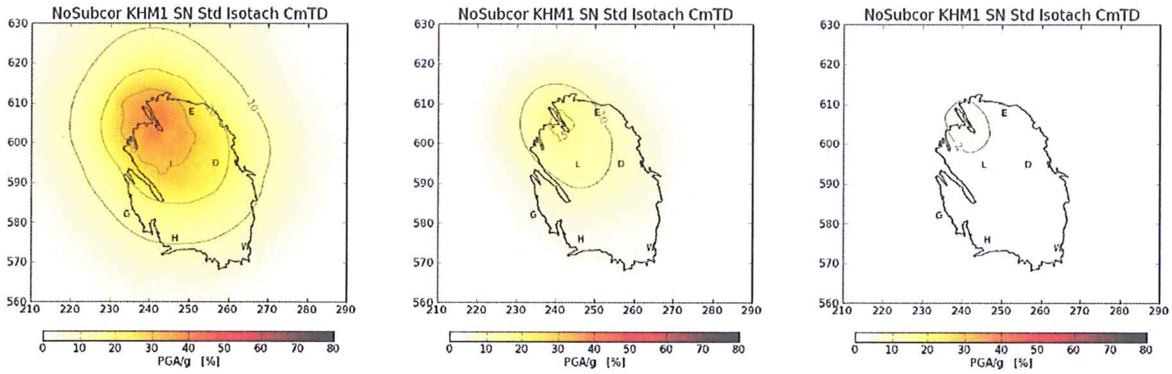


Figure 5.1 *PGA hazard maps for the 3 years from 2013 to 2016 with a (a) 2%, (b) 10% and (c) 50% chance of exceedance. The maximum PGA in each case is (a) 0.39g, (b) 0.16g, and (c) 0.02g.*

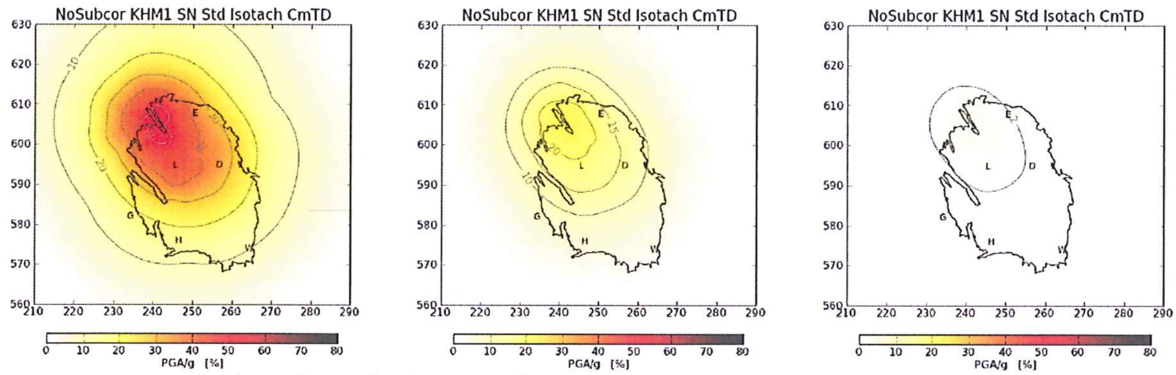


Figure 5.2 *PGA hazard maps for the 5 years from 2013 to 2018 with a (a) 2%, (b) 10% and (c) 50% chance of exceedance. The maximum PGA in each case is (a) 0.52g, (b) 0.23g, and (c) 0.04g.*

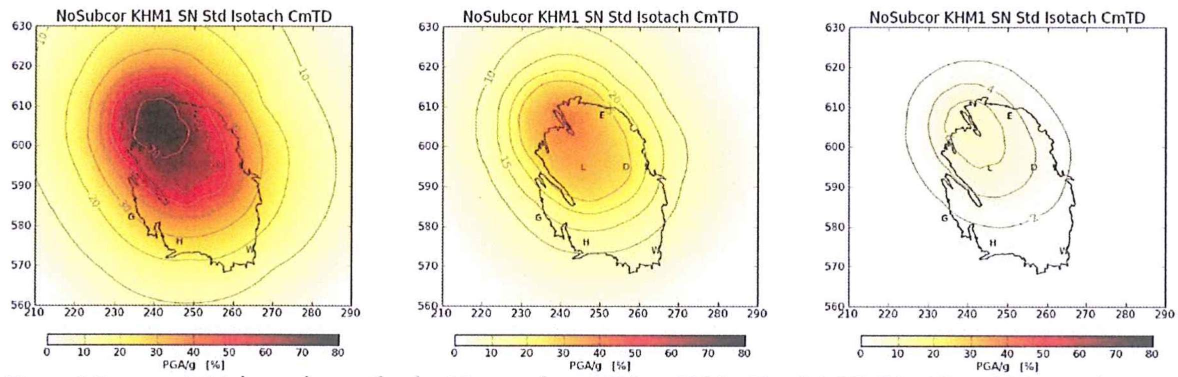


Figure 5.3 *PGA hazard maps for the 10 years from 2013 to 2023 with a (a) 2%, (b) 10% and (c) 50% chance of exceedance. The maximum PGA in each case is (a) 0.79g, (b) 0.40g, and (c) 0.08g.*

Figure 5.4 compares the probabilities of PGA exceedance for the 10-, 5- and 3-year assessments at the location of maximum PGA.

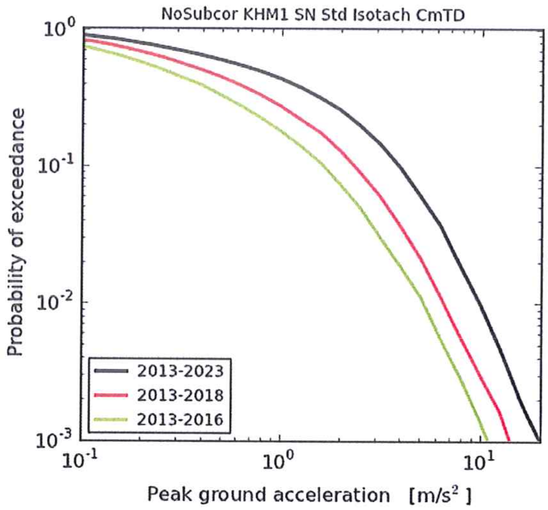


Figure 5.4 *The probability of exceedance for the maximum peak ground acceleration within the Groningen Field for three different assessment intervals: 3, 5, and 10 years.*

A table comparing maximum PGA's for the different depletion scenarios, including the scenarios discussed in the "Technical Addendum to the Winningsplan Groningen 2013", is provided in Appendix A. Plots with the resulting subsidence for this scenario are provided in Appendix B.

5.2 *Depletion Scenario 2*

Hazard maps (Peak Ground Acceleration – PGA-maps) for this depletion scenario are shown in figures 5.5-5.7 for 3, 5 and 10 years, respectively.

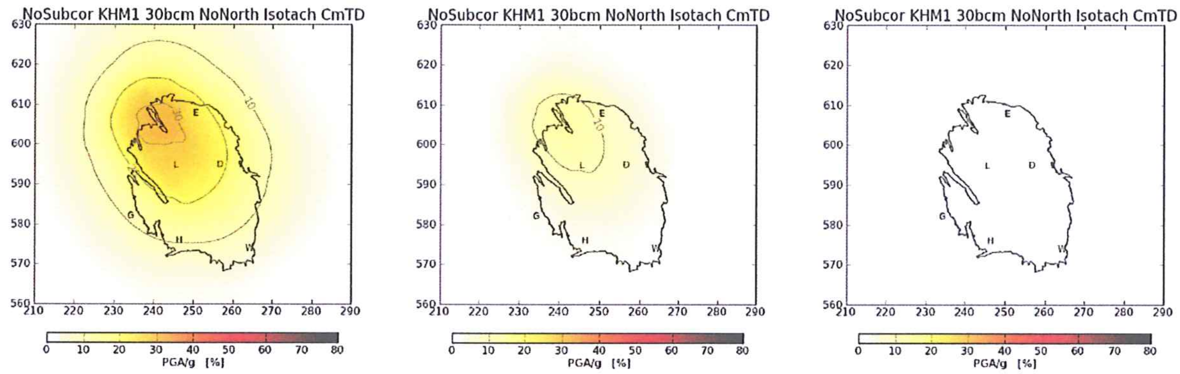


Figure 5.5 *PGA hazard maps for the 3 years from 2013 to 2016 with a (a) 2%, (b) 10% and (c) 50% chance of exceedance. The maximum PGA in each case is (a) 0.33g, (b) 0.13g, and (c) 0.02g.*

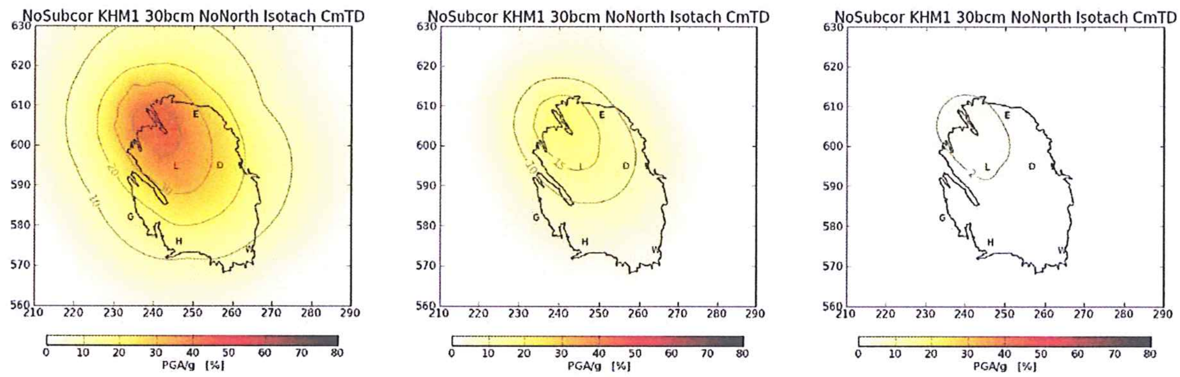


Figure 5.6 *PGA hazard maps for the 5 years from 2013 to 2018 with a (a) 2%, (b) 10% and (c) 50% chance of exceedance. The maximum PGA in each case is (a) 0.43g, (b) 0.19g, and (c) 0.03g.*

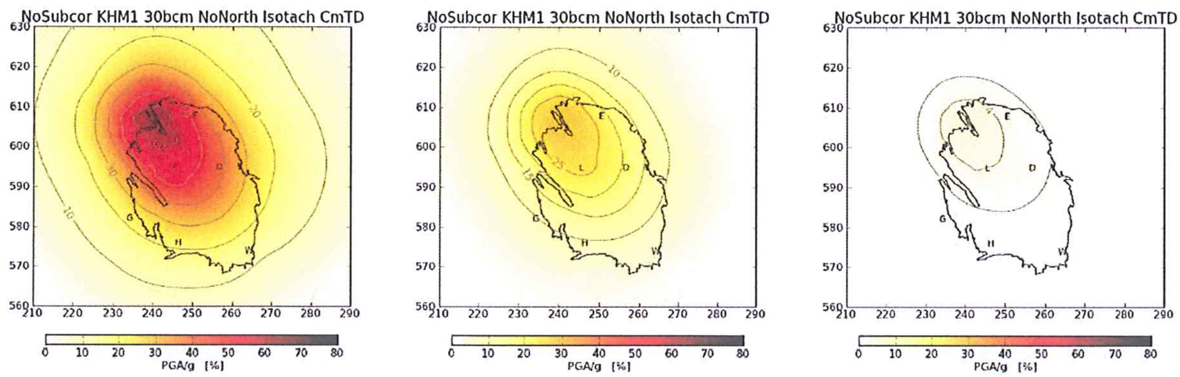


Figure 5.7 *PGA hazard maps for the 10 years from 2013 to 2023 with a (a) 2%, (b) 10% and (c) 50% chance of exceedance. The maximum PGA in each case is (a) 0.65g, (b) 0.30g, and (c) 0.05g.*

Figure 5.8 compares the probabilities of PGA exceedance for the 10-, 5- and 3-year assessments at the location of maximum PGA. The results of figure 5.8 and 5.4 are very similar.

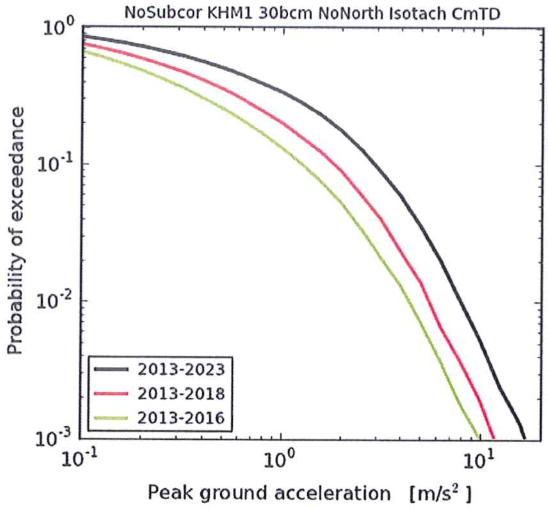


Figure 5.8 *The probability of exceedance for the maximum peak ground acceleration within the Groningen Field for three different assessment intervals: 3, 5, and 10 years.*

A table comparing maximum PGA's for the different depletion scenarios is provided in Appendix A. Plots with the resulting subsidence for this scenario are provided in Appendix C.

6 Discussion and Conclusions

In the case of the G1 model the inflow of water from the aquifers to the north of the field is larger. This improves the subsidence match in this part of the field. In the case of the G2 model, this inflow is smaller and as a result, the area north of the field shows a larger pressure depletion in the aquifer region. This will also result in a larger compaction in this very northern area. However, this area of larger compaction in the G2 model is an area of lower exposure reaching into the Waddenzee. In has to be noted that a small section of this compacting aquifer area (Waddenzee) is not captured within the sub-surface models.

The match of the subsidence prediction based on the G2 model is worse than that based on the G1 model. When using the G2 model the subsidence is overpredicted. The deepest point of the subsidence predicted with this model is shifted further towards the north, compared to the G1 aquifer model. This is also reflected in the corresponding hazard analysis, where the area of highest predicted seismicity (based on PGA exceedance) is not conform the observed area of highest seismicity.

The hazard predicted using the G2 reservoir model with the weaker aquifer, is higher than that predicted based on the G1 model. However, this is mainly a result of the higher modelled compaction and subsidence which is an overprediction of the observed subsidence in the field.

An additional scenario was evaluated, where 5 clusters in the north of the field are closed-in. In the "Technical Addendum to the Winningsplan Groningen 2013" a scenario was presented with an alternative production philosophy, which favoured production from the clusters in the south of the field. In this scenario, for a curtailment of production to 30 Bcm/yr, the same 5 clusters in the north of the field are also closed in until 2017. In effect these scenarios are very similar for the first 4 years.

Whereas the current production philosophy aims at minimizing pressure differentials across the field, the alternative production philosophy aims at a reduction of the annual depletion in areas where earthquakes occur more frequently and could be implemented by preferentially producing the clusters in areas with no or only infrequent earthquakes. In periods with increased demand, also clusters in the area with occasional earthquakes are taken into production. The clusters in the area with frequent earthquakes are only taken into production during periods with high demand – see also scenario A2, refer table 3.2 of the "Technical Addendum to the Winningsplan Groningen 2013".

The alternative production philosophy temporarily reduces compaction in the areas with the highest level of seismicity. As a negative consequence, the pressure differential between the northern and southern part of the field will increase. These higher pressure differentials may increase stresses across faults and may consequently increase seismicity. The combined impact on the seismic hazard of reduced compaction with increased pressure differentials cannot be confidently determined with the current model, used to generate PGA hazard maps. This model does not contain faults explicitly. A 3D geomechanical model including faults offers the possibility to assess the combined effect. Such model allowing effective subsurface stress management is under development.

7 Appendix A – PGA comparison for the additional depletion scenarios

Scenario 1	Period	Maximum PGA		
		P_{50}	P_{10}	P_2
	2013 - 2016	0.02g	0.16g	0.39g
	2013 - 2018	0.04g	0.23g	0.52g
	2013 - 2023	0.08g	0.40g	0.79g

Scenario 2	Period	Maximum PGA		
		P_{50}	P_{10}	P_2
	2013 - 2016	0.02g	0.13g	0.33g
	2013 - 2018	0.03g	0.19g	0.43g
	2013 - 2023	0.05g	0.30g	0.65g

Table A.1 *Variability in the maximum PGA for the two additional depletion scenarios presented in this supplement. P50, P10, P2 denote 50%, 10% and 2% chances of exceedance respectively over the 3, 5 and 10-year interval from 2013 .*

For ease of comparison the PGA values in the table below have been copied from the conclusions of section 8.11 of the "Technical Addendum to the Winnigsplan Groningen 2013".

Period	Maximum PGA		
	P_{50}	P_{10}	P_2
2013 - 2016	0.02g	0.12g	0.30g
2013 - 2018	0.03g	0.18g	0.42g
2013 - 2023	0.06g	0.33g	0.67g

These values are for the Market Demand scenario with the G1 Subsurface realisation model with the time-decay compaction model.

For comparison the full Table 8.4 of the "Technical Addendum to the Winningsplan" is also copied below. This table compares the maximum PGA for the different scenarios evaluated in the Technical Addendum.

Scenario	Maximum PGA [g]			Maximum PGV [cm/s]		
	P_{50}	P_{10}	P_2	P_{50}	P_{10}	P_2
SN STD Linear	0.05	0.27	0.56	1.8	10.2	22.4
KHM1 C40 STD Timedecay	0.06	0.34	0.69	2.3	13.1	28.4
NWPSWP SN STD Timedecay	0.06	0.34	0.68	2.4	13.2	27.9
NWP SN STD Timedecay	0.06	0.34	0.68	2.3	12.9	28.0
SN STD Timedecay	0.06	0.33	0.66	2.2	12.5	27.2
KHM1 SN Tremor Timedecay	0.05	0.31	0.64	2.1	11.9	26.2
KHM1 C40 Tremor Timedecay	0.05	0.30	0.64	2.0	11.2	25.9
C30 STD Timedecay	0.05	0.31	0.64	2.1	11.9	26.5
KHM1 C30 Tremor Timedecay	0.05	0.27	0.58	1.8	10.4	23.5
KHM1 SN Emergencystop Timedecay	0.03	0.17	0.41	0.9	6.5	15.8
NWP SN STD Isotach	0.07	0.41	0.82	2.8	16.3	36.8
KHM1 C40 STD Isotach	0.07	0.41	0.82	2.7	16.0	36.0
NWPSWP SN STD Isotach	0.07	0.40	0.81	2.8	16.1	36.5
SN STD Isotach	0.07	0.41	0.81	2.8	16.0	35.9
KHM1 SN Tremor Isotach	0.07	0.40	0.79	2.6	15.9	34.7
KHM1 C40 Tremor Isotach	0.06	0.37	0.78	2.5	14.4	33.5
C30 STD Isotach	0.06	0.37	0.76	2.4	14.6	33.8
KHM1 C30 Tremor Isotach	0.05	0.31	0.67	1.9	11.8	28.1
KHM1 SN Emergencystop Isotach	0.02	0.14	0.36	0.8	5.4	14.1

Table A.2 *Table 8.4 of the "Technical Addendum to the Winningsplan Groningen 2013". Variability in the maximum PGA and PGV with different reservoir compaction models and production scenarios. P50, P10, P2 denote 50%, 10% and 2% chances of exceedance respectively over the 10-year interval from 2013 to 2023. These results are listed in descending order of the P2 maximum PGA for each compaction model.*

8 Appendix B – Subsidence data for depletion scenario 1

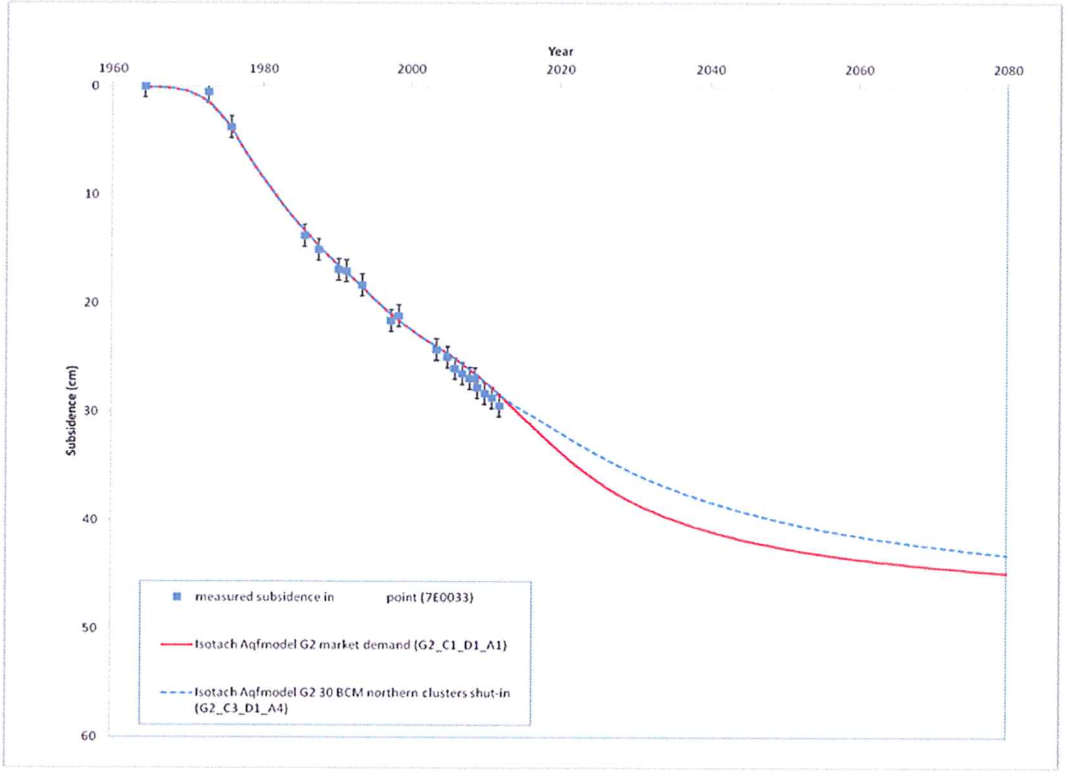


Figure B.1 *Comparison of subsidence forecast at the location of benchmark 7E0033 according to the two different production scenarios. For ease of comparison with figure 4.30 in the "Technical Addendum to the Winningsplan Groningen 2013" the same benchmark location was chosen.*

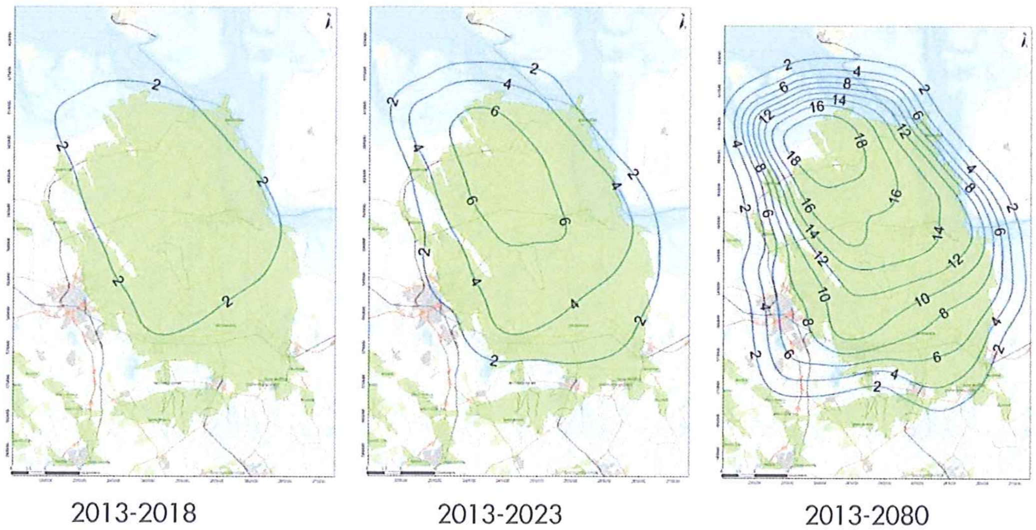


Figure B.2 *Development through time of the prognosed subsidence based on the isotach compaction model, and using the Cm values determined by calibration with the time decay model.*

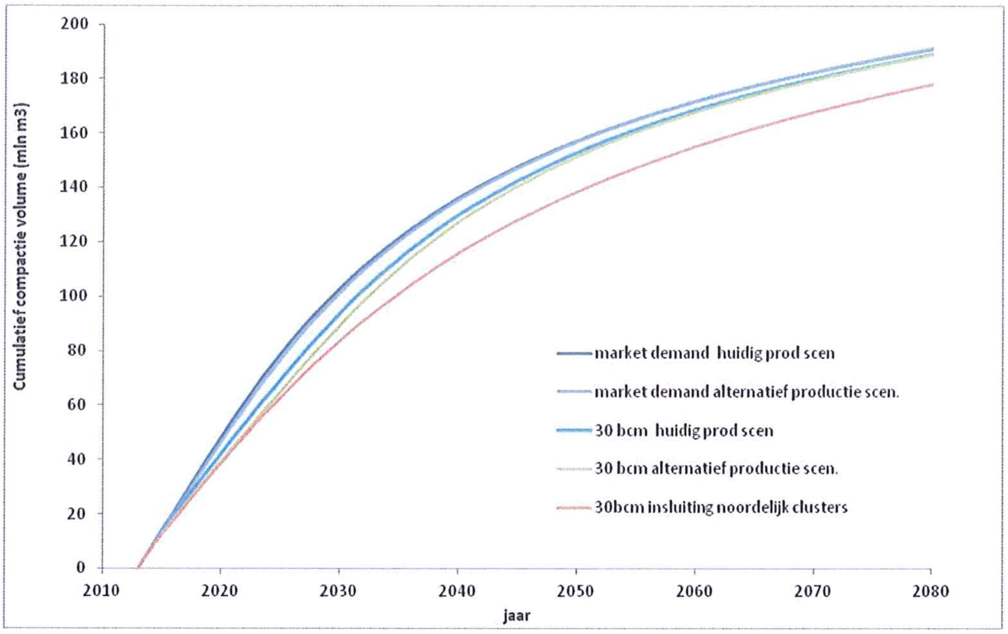


Figure B.3 *Development through time (2013 – 2080) of the compaction volumes based on the isotach compaction model, and using the Cm values determined by calibration with the time decay model.*

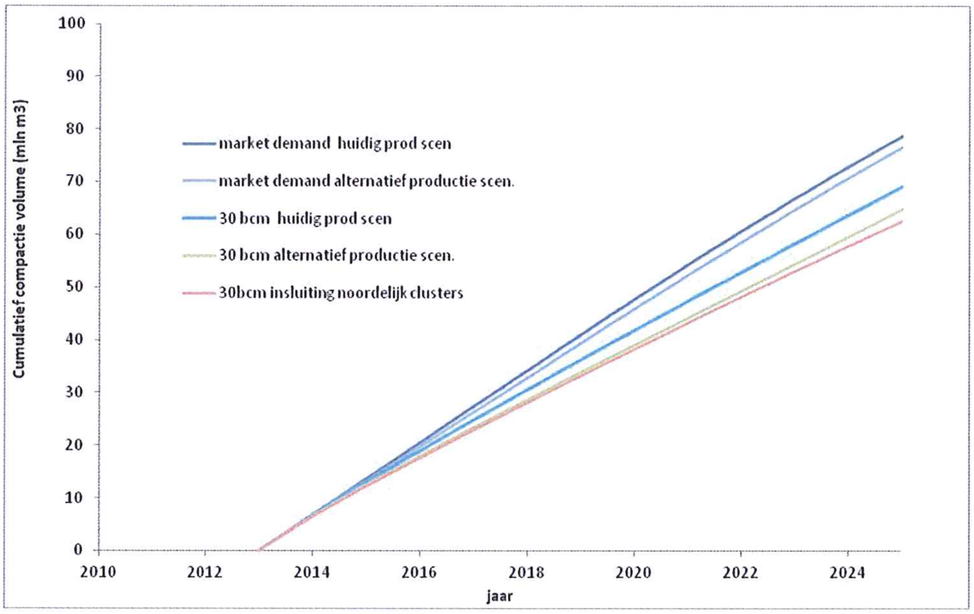


Figure B.4 *Development through time (2013 – 2025) of the compaction volumes based on the isotach compaction model, and using the Cm values determined by calibration with the time decay model.*

9 Appendix C – Subsidence data for depletion scenario 2

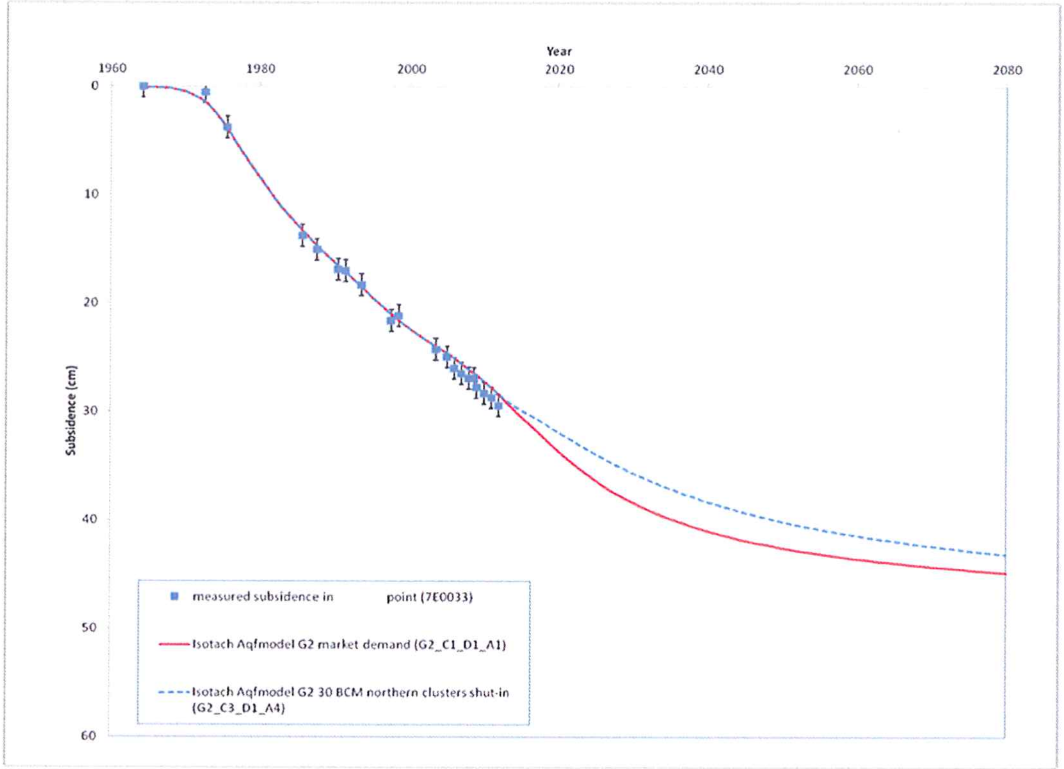
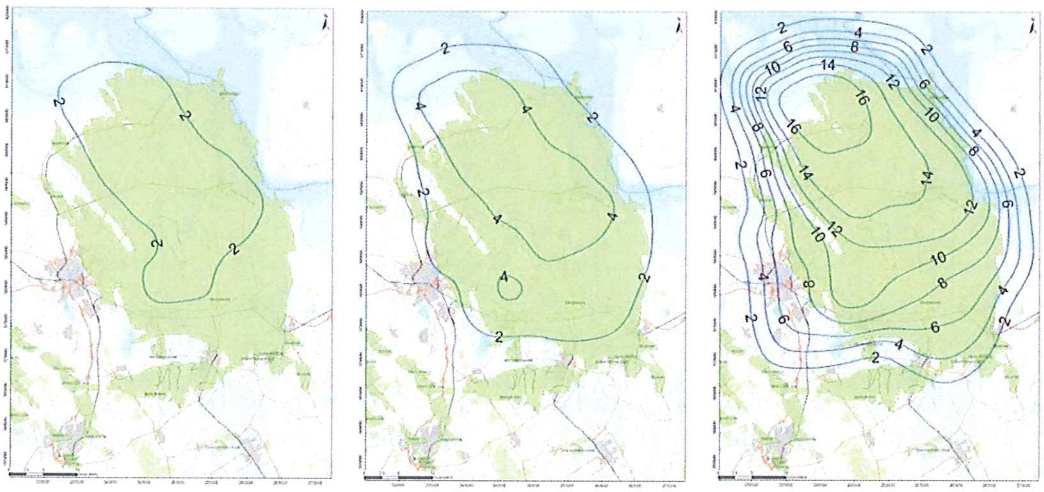


Figure C.1 *Comparison of subsidence forecast at the location of benchmark 7E0033 according to the two different production scenarios. For ease of comparison with figure 4.30 in the "Technical Addendum to the Winningsplan Groningen 2013" the same benchmark location was chosen.*



2013-2018 2013-2023 2013-2080

Figure C.2 *Development through time of the prognosed subsidence based on the isotach compaction model, and using the Cm values determined by calibration with the time decay model.*

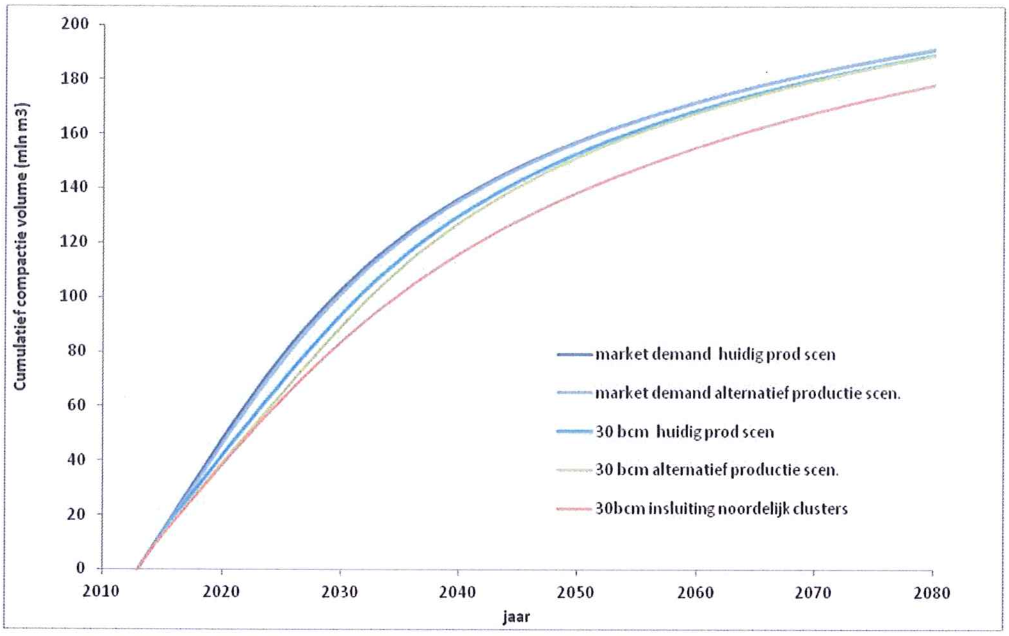


Figure C.3 *Development through time (2013 – 2080) of the compaction volumes based on the isotach compaction model, and using the Cm values determined by calibration with the time decay model.*

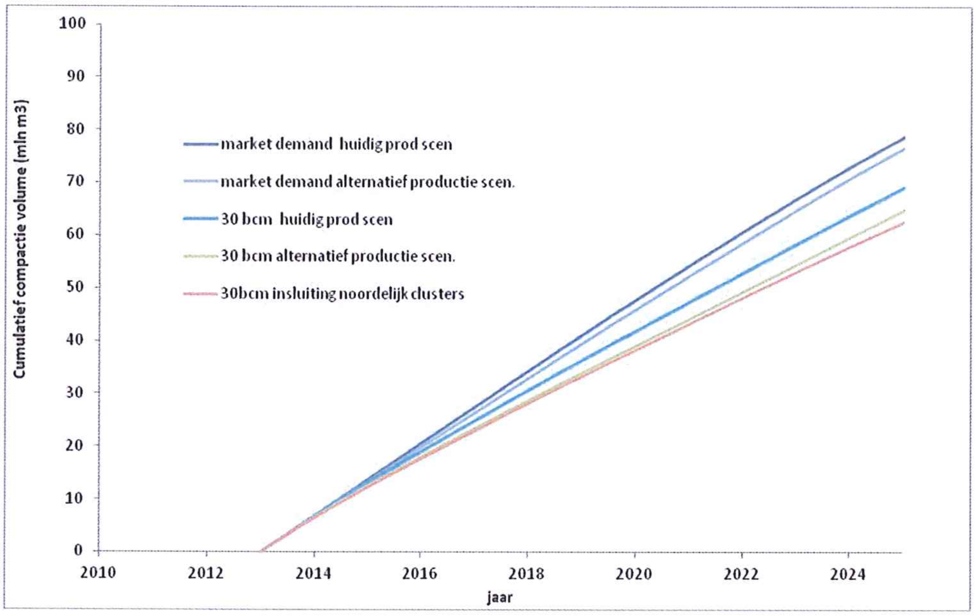


Figure C.4 *Development through time (2013 – 2025) of the compaction volumes based on the isotach compaction model, and using the Cm values determined by calibration with the time decay model.*