Quantitative Risk Assessment (QRA)

Middenmeer [MDM-GT-10]

PREPARED FOR

ECW Geo Middenmeer BV
Agriport 109,
1775 TA Middenmeer
The Netherlands

Author: Toni Gospodnetic
Publication: 01/11/2022
Version: 2.0
Reviewed by: [redacted]
Approved by: [redacted]

PREPARED BY

Well Engineering Partners
Toldijk 17-19
7900 AP Hoogeveen (NL)
Tel: +31 (0) 528 227710
www.wellengineering.com

REVISION CHANGE NOTICE

Version	Date	Brief description of Change	Author
0.1	19-07-2022	Initial Version	TG
1.0	20-07-2022	First Version submitted to client	TG
2.0	01-11-2022	Changed surface location	PvdK

CONTENTS

1 INTRODUCTION

Operator ECW Geo Middenmeer BV intends to drill a new geothermal producer well MDM-GT-10. This well will replace well MDM-GT-06 which suffers production limitations due to sand production and corrosion. Target of this new well is in Slochteren formation with TVD 2439 m (base Slochteren). Predicted thickness of the aquifer is 212 m TVD (309 m AHD).

The Decree on general rules for the mining environment (BARMM, ref. 3), article 7.1.e describes the definition of the 10^{-6} per year safety contour resulting from the calculation of the site-specific risk analysis of carrying out work with mobile installations.
The site-specific contour is expressed as the set of points on which there is an equal probability for which applies: the probability per year that a person, who would stay continuously and unprotected in that place and who would die as a direct result of an unusual occurrence within that establishment.

The Decree on external safety establishments (ref.4)**,** paragraph 4, defines this with the mentioned 10^{-6} safety contour, within which no vulnerable objects may be located.

Two scenarios have been calculated for the site-specific risk analysis, according to the Interim Manual (ref. 2):

1. Catastrophic blow-out where gas with maximum outflow flows through installed casing
2. Leak outflow in the casing with a size of 10% of the internal diameter of the casing

2 METHOD

The Risk Calculations Manual (ref. 1) describes scenarios and associated frequencies for the risk calculations related to mining activities. However, scenarios for the drilling activity are missing**,** hence the Interim manual (ref. 2) was published in 2010. The 10^{-6} risk contour is calculated using the Safeti-NL (ref. 5) program. The calculated contour depends on activity-specific input, including the pumped inflow potential. The worst-case outflow potential is calculated with the properties of the formation with the highest gas-containing potential. Guidelines from the SPE have been applied for this (ref 6.) Using WEP's internal program, the gas outflow potential is calculated for the prescribed scenarios.

3 ENVIRONMENT

3.1 Distances to vulnerable objects

In the direct vicinity of the planned well, there are tool containers and greenhouse, see Figure 1: Planned locations of the wells and distances to objects. The shortest distance from the planned well to the greenhouse#1 is approximately 30 meters. The tool containers #1, #2 and #3 are likely to be removed for the duration of the drilling operations

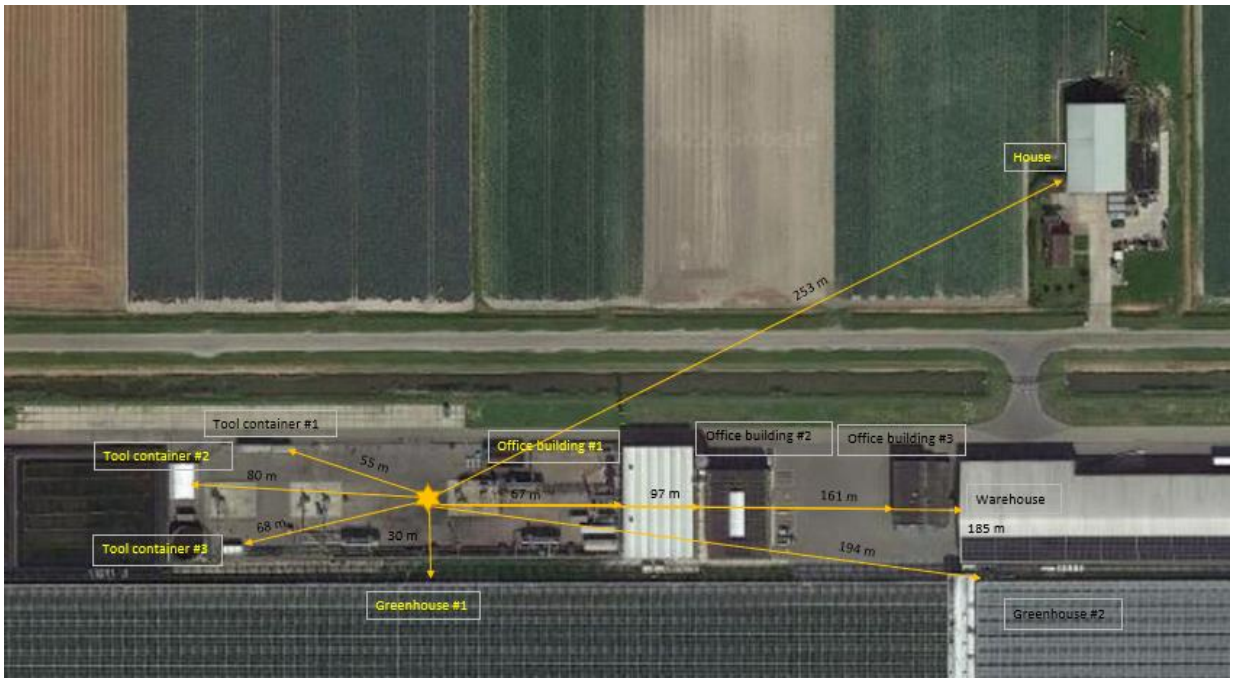


Figure 1: Planned locations of the wells and distances to objects

4 OUTFLOW POTENTIAL

4.1 Formation with the highest gas outflow potential

The formation with the highest possibility of the gas outflow is Breda. Formation characteristics are mentioned in table 1. The average values are extracted from the geological study (ref. 7) and with consultations with WEP geologist.

Table 1: Formation with the highest gas outflow potential and reservoir characteristics

Formation	Ave. porosity [%]	Ave. Permeability [mD]	Vertical thickness [m]
Breda	27	350	94

4.2 Worst-case scenario

The probability of encountering a producible hydrocarbon reservoir in any stratigraphic sequence of MDM-GT-10 is estimated to be very small, since offset wells in geological studies did not come across any free gas or large quantities of dissolved gasses. The probability of finding a structural trap is very low but the probability of finding a stratigraphic trap is considered high. The Breda Formation shows some minor folding, and no faults are visible in the available seismic lines but the seismic cross-section does show a potential bright spot along the trajectory which could indicate a gas filled trap. This trap is possible since the Breda Formation contains layers which can potentially trap hydrocarbons in the sandy sections.

As a worst-case scenario for this QRA, it is assumed that the top (20 meters) of the reservoir is gas-containing ("free gas"), so not the full thickness of the intended reservoir is considered gas-containing. This is a very conservative assumption, based on offset wells where no gas has been found. The worst-case scenario is determined in line with the guidelines, drawn up by the Society of Petroleum Engineers (ref. 6). This assumes that there is unexpected gas in the formation mentioned in Table 1. An average permeability of 350 mD (very conservative assumption) was taken according to discussion with WEP geologist. For this scenario, in section 4.3, the maximum gas outflow is determined, with which the site-related and group risk can be calculated.

4.3 Input for the calculation of gas outflow potential

According to the detailed design for the well MDM-GT-10, the formation indicated in table 1 will be drilled with a 20” bit while the 28” conductor is in place. This scenario is assumed to calculate the outflow potential in case a gas-containing Breda formation is drilled. Flow through the casing will lead to resistance and pressure losses, depending on the flow rate of the formation fluid. Other data that will influence the maximum outflow are shown in Table 2 and Figure 1.

Table 2: Formation with the highest gas outflow potential and reservoir characteristics

Maximum reservoir pressure **Assumed pressure gradient is 1,09 sg as per detailed design*	77 bar
Average porosity	27%
Average permeability	350 mD
Formation thickness	20 m

The parameters used for the calculation of the outflow potential, including the formation parameters are shown in Table 2 and in Figure 2. Figure 3 is the result of the calculation.

IPR Input: reservoir and gas properties:

OH diameter at reservoir	Ø	20	*[Inch]*	Pressure behaviour:
Eff. Thickness gas in reservoir	h	20	*[m]*	**Semi-steady-state**
Drainage radius	r_e	126	*[m]*	3/4
Gas permeability	k	350	*[mD]*	
Porosity	ϕ	0,27	*[-]*	
Skin factor	s	0,00	*[-]*	
Reservoir pressure	p	77	*[bar(a)]*	
Reservoir Temperature	T	35,0	*[°C]*	
Gas specific gravity	γ	0,636	*[s.g.]*	
Mole fraction of N_2		0,024	*[fraction]*	
Mole fraction of CO_2		0,017	*[fraction]*	
Mole fraction of H_2S		0,000	*[fraction]*	
Non-Darcy coefficient	D	0,00019	*[10^{-3} m^3/d] (calculated with Jones, 1987, empirical corr.)*	

TPC Input: Well schematic and conditions at surface:

Blow-out scenario

	ID	Depth from	Depth to	Depth to	eff. Incl.	Roughness
	[Inch]	*[m AH]*	*[m AH]*	*[m TVD]*	*[°]*	*[mm]*
Section 1:	26,170	0	96	96	0,0	0,2
Section 2:	20,000	96	781	706	27,1	0,2
Section 3:	0,000	0	0	0	0,0	0
Section 4:	0,000	0	0	0	0,0	0
Section 5:	0,000	0	0	0	0,0	0

WH pressure	p_{hf}	1,01325	*[bar(a)]*
WH temperature	T_{hf}	10	*[°C]*

Leak scenario

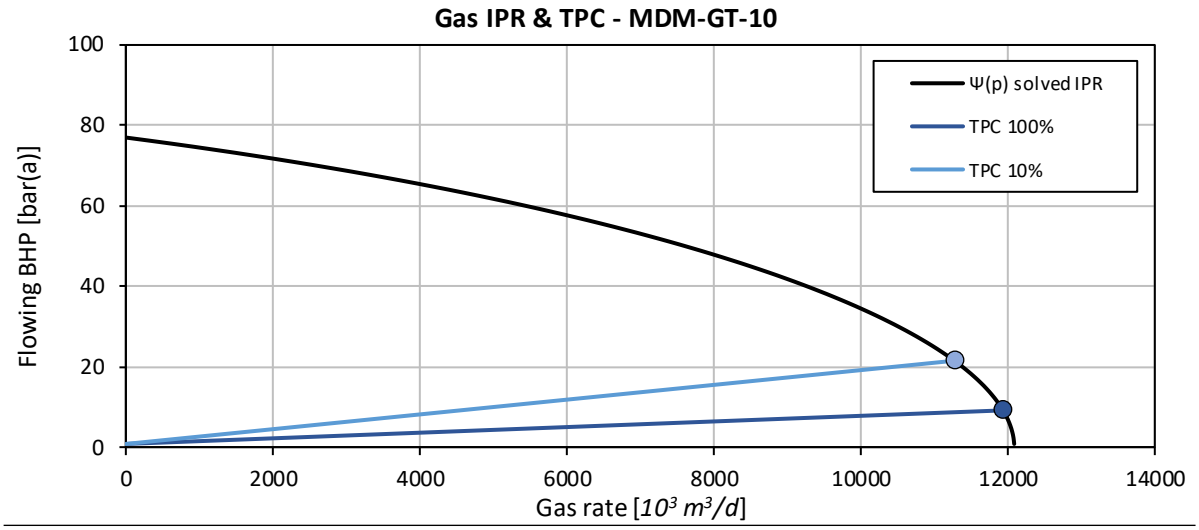
	ID	Depth from	Depth to	Depth to	eff. Incl.	Roughness
	[Inch]	*[m AH]*	*[m AH]*	*[m TVD]*	*[°]*	*[mm]*
Section 1:	26,170	0	96	96	0,0	0,2
Section 2:	20,000	96	781	706	27,1	0,2
Section 3:	0,000	0	0	0	0,0	0,2
Section 4:	0,000	0	0	0	0,0	0,2
Section 5:	0,000	0	0	0	0,0	0

ID of 10% leakpath at surface	ID	2,617	*[Inch] over a*	0,1 [m] length
WH pressure	p_{hf}	1,01325	*[bar(a)]*	
WH temperature	T_{hf}	10	*[°C]*	

Figure 2: Parameters for the gas outflow calculation

Results:

WellID: MDM-GT-10



Gas rate 100% leak path:	**11909**	*[10³ m³/d]*	**107,39**	*[kg/s]**
Gas rate 10% leak path:	**11233**	*[10³ m³/d]*	**101,29**	*[kg/s]**

**Density gas mixture: γ_g [s.g.] x 1.225 kg/Nm³ (density air at 15 °C and 1.01325 bar)*

Figure 3: Result of the gas outflow calculation

The results for the two scenarios, as described in Interim Manual (ref. 2) and summarized in Chapter 5, give an outflow rate of 11,909 x10³ m³/day (107,39 kg/s) for a catastrophic blowout (scenario 1) and 11,233 x10³ m³/day (101,29 kg/s) for outflow as a leak (scenario 2).

5 RESULTS

5.1 10^{-6} contour

The risk contours are calculated using the Safeti-NL programme and shown in Figure 4. The red contour shows the 10^{-6} contour.

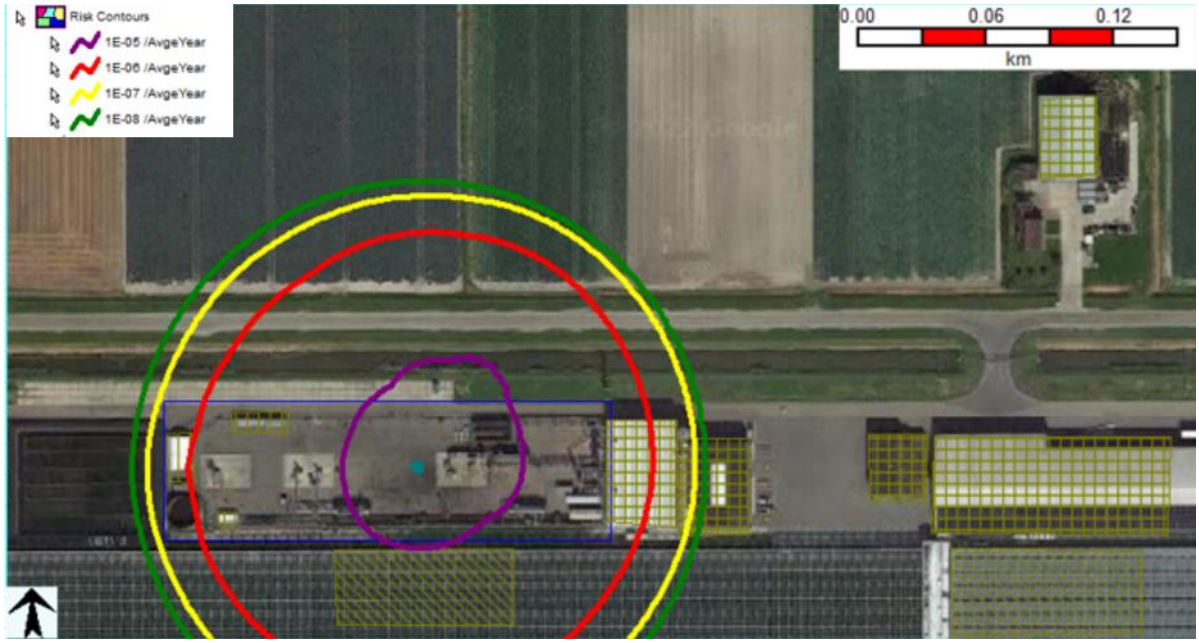


Figure 4: Risk contours MDM-GT-10

Within the red, 10^{-6} contour, there are no dwellings or other vulnerable objects (Decree on external safety establishments, Article 1, ref. 4). However, there are 3 tool containers, office building and a greenhouse within the contour which can possibly be considered as limited vulnerable objects. The tool containers are likely removed for the duration of the drilling operations. It should be mentioned that the existing wells on this location are shut-in during drilling and are therefore not identified as vulnerable.

5.2 Maximum effect distance

The maximum effect distance indicates the distance where the chance of death has dropped to 1%. This distance has been calculated by SAFETI-NL and it is 82 m for well MDM-GT-10 in weather condition D9 (light sunny weather with wind speed = 9m/sec) for the horizontal leak scenario. This distance is based on heat radiation from a burning blow-out with a 1% lethality criteria of 10 kW/m2.

5.3 Group risk

A conservative assumption is taken that during the day in each tool container and in affected part of the greenhouse 2 people are working, while there are 12 people in the office building. Occupancy rate during the night is negligible.

The maximum number of victims is 8. This means that there are fewer than 10 victims and therefore formally there is no group risk. In addition, the calculated group risk remains far below the orientation value (yellow) line, see figure 5.

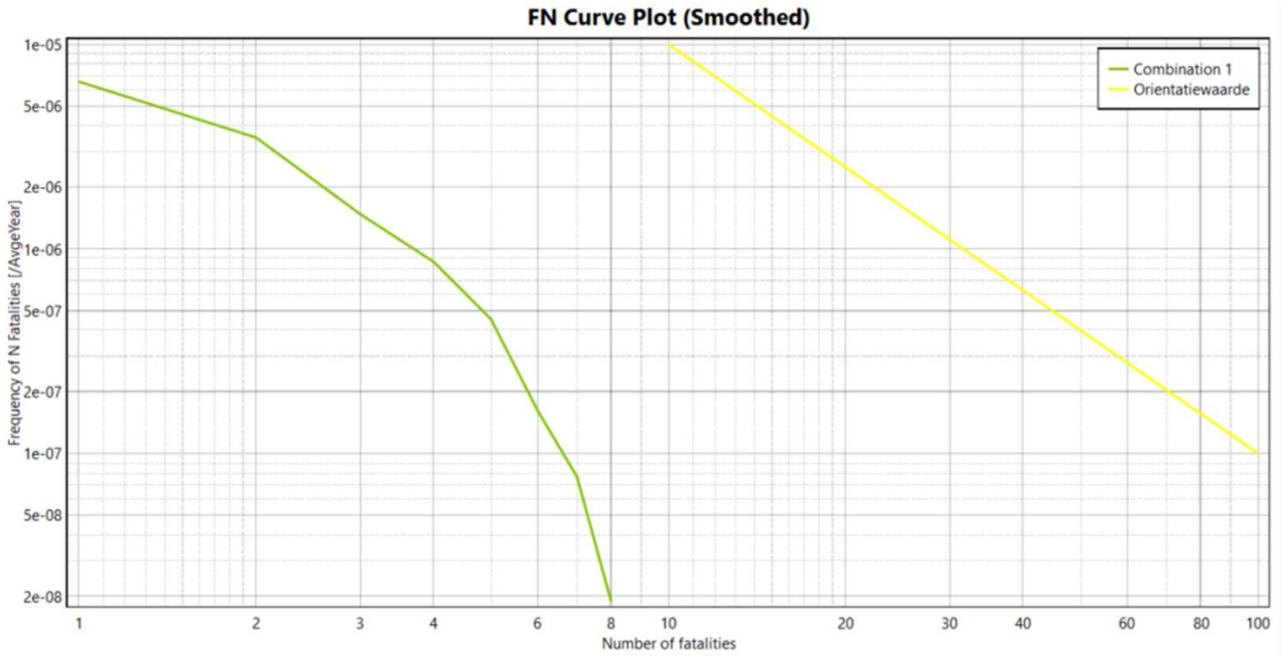


Figure 5: Group risk

6 CONCLUSION

This quantitative risk analysis (QRA) was carried out for operator ECW Geo Middenmeer B.V. for the planned drilling of the geothermal well MDM-GT-10 on a location at Oostlanderweg 15 in Middenmeer.

The calculated risk was based on a worst-case scenario with conservative assumptions:

Below conclusions can be taken from the analysis:

- Based on the data taken from the offset well MDM-GT-06, it can be concluded that the risk of finding gas in the reservoir is very small. This report indicates the worst case situation
- Within 10^{-6} contour there are no vulnerable objects
- As mentioned, tool containers, office building and greenhouse on the drilling location fall within 10^{-6} contour. However, the guideline value of The Risk Calculations Manual (ref. 1) is not met

The Risk Calculations Manual (ref. 1) version 3.3, 1 July 2015 describes following: "*The risks of drilling and completion of the well are not considered. They are one-off activities for which the assessment framework of the Decree is not suitable. When applying for the drilling permit, it is considered if the risks to the environment are acceptable*"

From above statement, it can be concluded that The Risk Calculations Manual (ref. 2) does not formally apply to drilling.

The activity may be authorised based on the following considerations:

- As mentioned, the Decree does not formally apply.
- Deviation from the guide values is permitted and can also be justified because of the temporary nature of drilling, which also enables permanent generation of sustainable energy afterwards

7 REFERENCES

1. RIVM; Handleiding Risicoberekeningen Bevi (*engl. Risk Calculations Manual*), version 3.3, 1 July 2015
2. Staatstoezicht op de Mijnen; Interim handleiding risicoberekeningen (*engl. State Supervision of Mines; Interim risk calculations manual*). Version 1.0. 2010. Letter from Mr. M. van Pinxteren (SodM) 2 July 2010. Attachment 10097961
3. Besluit algemene regels milieu mijnbouw (*engl. Decree on general rules for the mining environment*), Ministry of Economic Affairs, 1 May 2017
4. Besluit externe veiligheid inrichtingen (*engl. Decree on external safety establishments*), Ministry of Infrastructure and Environment, 1 January 2016
5. DHV; Safeti-NL, version 8.3 (software)
6. SPE; Guidance for complying with BOEM NTL No. 2010-N06 on Worst Case Discharge for Offshore Wells, September 22, 2010
7. J. Smulders (WEP), Evaluation of the hydrocarbon risk of the geothermal well MDM-GT-10, version 1.2, September 2022