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1. Introduction

Proton Ventures has requested the help of Antea Group in setting up a QRA for a new ammonia plant in Walvisbaai, Namibia. The plant will have an annual throughput of 250 kTon of ammonia (import) or 1000 kTon (export) . Both import and export of ammonia will take place at the plant through one jetty in the bay. An indicative QRA has been prepared integrating known design parameters as much as possible, some parameters remain to be determined and some assumptions have been made. This renders the status of this QRA indicative.

This memo gives an overview of the design parameters and the results. The calculations have been performed in Safeti 8.8 according to the *Reference Manual Bevi Risk Assessments* v3.2. This was until recently the official approach applied in the Netherlands and was also used in this study for Namibia as Namibia has no formal legislation in place concerning risk calculations for external safety. Recommendations are given at the end of the memo.

2. Legal Framework and external safety concepts

This QRA has been carried out according to Dutch legislation, the following applies:

- In the Netherlands facilities with large quantities of hazardous substances fall under the Dutch implementation of the Seveso-directive - Brzo (Besluit risico's zware ongevallen) act. With respect to external safety the decree Bevi (Besluit externe veiligheid inrichtingen) is applicable. Bevi imposes requirements with respect to the individual risk contours:
 - within the 10^{-6} /year individual risk contour no **vulnerable objects** (houses, hospitals, schools etc.) are allowed (norm value);
 - Vulnerable objects:
 - a. Houses, houseboats and caravans;
 - b. Buildings intended for the residence, whether or not for part of the day, of minors, elderly, sick or disabled persons, such as:
 - hospitals, retirement homes and nursing homes;
 - schools, or
 - buildings or parts thereof intended for day care for minors;
 - c. Buildings in which large numbers of people are usually present during a large part of the day, which in any case include:
 - office buildings and hotels with a gross floor area of more than 1500 m² per object, or
 - complexes in which more than 5 shops are located and of which the combined gross floor area is more than 1000 m² and shops with a total gross floor area of more than 2000 m² per shop, insofar as those complexes or shops contain a supermarket, hypermarket or department store is located, and
 - d. camping and other recreational areas intended for the stay of more than 50 people for several consecutive days;
 - within the 10^{-6} /year individual risk contour preferably no **limited vulnerable objects** are allowed (target value).
 - This includes all that does not fall in the above categories for instance industrial objects.

Within the policy framework for external safety, two key concepts are central: individual risk and societal risk. Although both concepts are interrelated, there are important differences. Both concepts are further elaborated below.

2.1 Individual Risk (IR)

The individual risk presents the probability of death for a person as contours on a map in the neighbourhood of the considered activity. The individual risk is determined assuming that a person is permanently (365/24/7) and unprotected present at that location. Risk contours on a map indicate where boundaries of risk levels are located. The magnitude of individual risk contours is independent of the real environment and gives no information about the number of persons that can be affected in an accident. The individual risk contours can be seen as an altitude map of death probability. For the determined individual risk, in the decree Bevi an allowed reference limit is established.

The societal risk (SR) is a measure of the chance that a group of victims of a certain size will die in an accident. The SR is therefore a measure of social disruption in the event of a calamity. The SR is determined within the area of maximum effect zone of an activity. This maximum effect zone is limited by the 1% lethality limit (unless specified otherwise): the distance at which 1% of the exposed people in the area will still die in the event of a disaster involving hazardous substances. The SR cannot be displayed 'on the map', but is shown in a graph, where the probability (f) is plotted against the number of casualties (N): the fN curve.

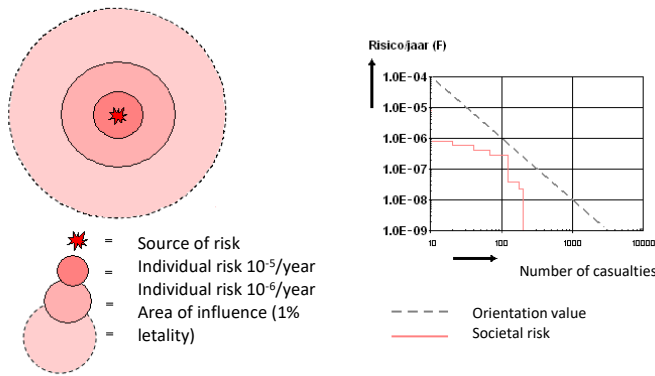


Figure 2.1 Individual risk, maximum effect zones and societal risk (with orientation value)

2.2 Area of influence

The area in which persons are to be included in the calculation of societal risk, by virtue of rules to be established by Ministerial Order. The boundary of the area of influence is the same as the boundary of the effect area, unless the area of influence for a specific substance is defined differently in the implementation orders forming part of the Decree.

In accordance with the Decree and Ministerial Order on external safety of installations, the effect distance for the determination of societal risk is the 1% fatality boundary, the distance at which 1% of the population will die. The effect distance in the recommendation on physical safety may extend much further. The alarm boundary value may be adopted.

2.3 Method

The Bevi decree states that external safety risks need to be calculated according to the document *Reference manual Bevi* using the software SAFETI-NL. Both the reference manual as well as SAFETI-NL are the result of years of development in the field of risk analysis and calculations. The latest version of the English reference manual is version 3.2, the Dutch version is 4.3 and SAFETI-NL version 8. The latest updates in the reference manual are mostly made to accommodate the latest version of Safeti¹.

The by law prescribed software program to calculate the external safety in the Netherlands is Safety-NL 8. For abroad located facilities it is forbidden to use Safety-NL 8. Instead the international version of this software: Safeti 8 has to be used. This program was used for this QRA.

The parameter file used in the version Safeti-NL 8 has also been used in Safeti 8, except the meteo-files, average temperature, average humidity and average air pressure. These values have been altered to reflect the situation in Namibia.

The above mentioned assumptions assure that the QRA has the same degree of validity and robustness as a QRA performed for a facility located in the Netherlands.

¹ Per 1-1-2024 the legal framework of environment and spatial planning laws has been altered to the so-called 'Omgevingswet'. For simplicity we adhere to the former legal frame work, as this is only slightly adjusted per 1-1-2024.

3. Selection of installations

The plant will have an annual throughput of 250 kTon (import) or 1000 kTon (export). Both import and export will take place via ships loading and unloading at the jetty in the bay, but not simultaneously. For the first five years operation the plant will only import ammonia. After this 5 years of import, the mode of the factory is altered: then only export will take place. Therefore, we have modelled and presented risk results reflecting these to modes of operation.

There will be one 40kT storage tank, piping towards the jetty and two loading/unloading arms, these have been included in the calculations. Due to the limited capacity of the BOG²-system it was deemed irrelevant.

3.1 Storage tank

The parameters used for the modelling of the storage tank are given in table 3.1 below.

Table 3.1: Overview of storage tank parameters

Type	Capacity [kT]	Pressure [atm]	Temperature [°C]	Height [m]	Diameter [m]	Bund
Double containment atmospheric storage tank	40	1	-34	32,12	58	None

The tank used in this project has one roof system, but consists out of three containment systems. The first one (inner part) being the primary container, the second one is the double steel wall. The roof spans the inner and outer steel tank wall. The outer wall is concrete and would function as a tertiary containment system, but this system is primarily designed as a blast wall and not as a secondary containment system, although it would function as one.

To model this tank, there are several tank types available in the *Reference manual Bevi* to choose from: mentioned are:

- Full containment tank;
- Double containment tank.

We have chosen to model the double containment tank type (and not the safer full containment tank) in this project because the failure of the inner containment will lead to ammonia vapour release.

The modelling of the tank in this QRA assumes that a leak, due to a failure of the primary container, would create an ammonia release. Practically this would only be possible when there is a release within the concrete outer wall, the tertiary container. For all intends and purposes, the current modelling in this QRA is a worst-case approach which is mandatory when following the reference manual.

Definition of a full containment tank in accordance to the reference manual Bevi

A full containment atmospheric tank consists of a primary container for the liquid and a secondary container. The latter is designed to collect both the liquid and the vapour in the event of a failure of the primary container and can withstand all possible stresses, such as explosions (static compression stress of 0.3 bar for 300 ms), fragments and cold thermal stress. The outer roof is supported by the second containment housing and is able to withstand stresses, such as explosions.

The applied scenarios for a double containment tank and corresponding frequencies for failure are listed in table 3.2 below.

² Bioled Off Gas

Table 3.2: Scenarios for double containment storage tank

Scenario	Frequency of failure [/year]
1: Instant failure of primary container and secondary container; release of total contents	$1,25 \times 10^{-8}$
2: Instant failure of primary container; full contents released into secondary container	$5,00 \times 10^{-8}$
3: Failure of primary and secondary container; full contents released within 10 minutes	$1,25 \times 10^{-8}$
4: Failure of primary container; release of full contents within 10 minutes into the secondary container	$5,00 \times 10^{-8}$
5: Failure of primary container; continuous release from a hole with an effective diameter of 10 mm into the intact secondary container	$1,00 \times 10^{-4}$

Explanation:

Ad 1: The volume of the specified tank has been set to 58.610 m³ (40.000 ton). Safeti spreads out the volume to an unrealistic 1 mm or 0,5 mm. This has been countered by imposing a bund with a specified area (3.860.000 m²) which leads to a pool depth of 1 cm. It is safe to assume that also this pool depth of 1 cm is worst-case. Bund floor has been set to dry soil.

Ad 2: Full contents of the primary container is released in the secondary container: but the gasses above the secondary containment are free to flow to the environment. This leads to a pool with a diameter of the secondary containment (diameter 58 m).

Ad 3: Idem Ad 1.

Ad 4: In this scenario the space between the primary and secondary containment is now a pool, which can generate evaporated ammonia that spreads to the environment. Used is a pool with an area of 628 m².

3.2 Ship loading/unloading

Ship loading (export) and unloading (import) will take place at the jetty via two 12" (un-)loading arms. The loading and the unloading rate is the combined loading rate of the two arms, so each arm operates at half the loading rate. The supply line consists of 2 x 16" pipes. Ship loading and unloading is done via 25 kT barges. With an annual throughput of 250 kT (import) this accounts for 10 ships per year. After 5 years, when the mode of the plant has shifted to export, the annual throughput will be 1000 kTon. This accounts for 40 ships for export.

The parameters for ship loading are presented in table 3.3.

Table 3.3: Overview of ship(un)loading parameters

Parameter	Import	Export
Annual throughput [tonnes]	250.000	1.000.000
Diameter loading arm	2 x 12"	2 x 12"
Length loading arm [m]	10	10
Volume loading arm [m ³]	0,73	0,73
Pressure [barg]	10,00	10,00
(un)loading rate [ton/hr]	545 Per arm: 273	1800 Per arm: 900
(un)loading time [hrs] per ship	46	14
Handling time [hrs]	6	6
(un)loading time [hrs] total per year	460	556
ESD intervention time [s]	120	120
ESD fail frequency	1/1000	1/1000

The basic scenarios that apply for loading and unloading of atmospheric barges are listed in table 3.4 below

Table 3.4: Scenarios for ship loading (semi-gas tanker, cooled)

Scenario	Frequency	
Break loading arm	$3,00 \times 10^{-8}$	per hr
Leak loading arm	$3,00 \times 10^{-7}$	per hr

Collision 126 m ³	1,20 x 10 ⁻⁴	x f ₀
Collision 32 m ³	2,50 x 10 ⁻²	x f ₀

The scenarios for breaking and leaking of the loading arm need to be corrected for the time the loading arm is in operation (hrs/year). The collisions scenarios need to be corrected for the time the ships are present at the jetty and can pose a risk for a collision scenario. This takes into account the number of passing ships. A standard number of 2.000 passing ships a year was assumed, according to the *Reference Manual Bevi Risk Assessments* v3.2. The corrected frequencies are given in table 3.5. Outflow of the scenarios are supposed to take place on the ocean.

Table 3.5: Applied scenarios for ship unloading (import: first 5 years) and export (after 5 years)

Scenario	Frequency [/year] Import	Frequency [/year] Export
Break loading arm – ESD	2,75 x 10 ⁻⁵	3,33 x 10 ⁻⁵
Break loading arm – No ESD	2,75 x 10 ⁻⁸	3,33 x 10 ⁻⁸
Leak loading arm – ESD	2,75 x 10 ⁻⁴	3,33 x 10 ⁻⁴
Leak loading arm – No ESD	2,75 x 10 ⁻⁷	3,33 x 10 ⁻⁷
Collision 126 m ³	1,81 x 10 ⁻⁴	1,94 x 10 ⁻⁴
Collision 32 m ³	2,51 x 10 ⁻²	2,51 x 10 ⁻²

3.3 Piping

The modelling includes two pipelines;

1. Import line from the loading arm to the tank (first 5 years);
2. Export line from the tank to the loading arm (after 5 years, after a mode switch of the plant);

Two pipes are present for import and export. Import and export do not occur simultaneously so the same set of pipes is used in both situations. Most likely the import of ammonia will happen in the earlier years of the terminal (est. 5 year) and the export of ammonia will happen in the later years. The total loading rate is split between the two pipes. Moreover, based on the amount of time in the year unloading (approx. 460 hrs/year: import) or loading (approx. 556 hrs/year export), separate scenarios have been defined for the situation the pumps are active and are not active. In other words, the calculations are based on two situations:

- Situation 1: the pipes having a specific flowrate because the pumps are working: roughly 10% percent of a year.
- Situation 2: the pipes not having a specific flowrate: the pumps are idle: the pipes are filled but stagnant, roughly 90% of the time of a year.

An overview of the parameters of the pipes is given in table 3.6.

Table 3.6: Overview parameters of piping

Parameter	Export line Tank -> Loading arm	Import line Loading arm -> Tank
Diameter	16" (2 lines)	16" (2 lines)
Pressure (barg)	10	10
Length (m)	3.770	3.770
Sectioning (m)	800	800
ESD intervention time (s)	30	30
Flow rate (ton/hr)	900 Per pipe	273 per pipe
Hours active	556 (fraction: 0,063)	460 (fraction: 0,052)

The pipes are modelled as a pipebay. The basic scenarios and corresponding frequencies for pipes in a piping bridge are displayed in table 3.7.

Table 3.7a: Scenarios Import (loading arm-> tank) with standard frequencies for piping

Scenario import (first 5 years)	Frequency	Number of lines	ESD	Time fraction	Frequency for QRA
<i>Pipe bay during Pumping</i>					
Nr. 1: Pipe break – ESD works	$7,0 \times 10^{-9}/\text{m.y}$	2	0,999	0,052	$7,27 \times 10^{-10}/\text{m.y}$
Nr 2: Pipe break – ESD fails	$7,0 \times 10^{-9}/\text{m.y}$	2	0,001	0,052	$7,28 \times 10^{-13}/\text{m.y}$
Nr 3: Pipe leak 20 mm	$6,3 \times 10^{-8}/\text{m.y}$	2	1	0,052	$6,55 \times 10^{-9}/\text{m.y}$
<i>Pipe bay during No Pumping</i>					
Nr 7: Pipe break – ESD works	$7,0 \times 10^{-9}/\text{m.y}$	2	0,999	0,947	$1,32 \times 10^{-8}/\text{m.y}$
Nr 8: Pipe break – ESD fails	$7,0 \times 10^{-9}/\text{m.y}$	2	0,001	0,947	$1,32 \times 10^{-11}/\text{m.y}$
Nr 9: Pipe leak 20 mm	$6,3 \times 10^{-8}/\text{m.y}$	2	1	0,947	$1,19 \times 10^{-7}/\text{m.y}$

Table 3.7b: Scenarios export (tank-loading arm) with standard frequencies for piping

Scenario export (after 5 years)	Frequency	Number of lines	ESD	Time fraction	Frequency for QRA
<i>Pipe bay during Pumping</i>					
Nr 4: Pipe break – ESD works	$7,0 \times 10^{-9}/\text{m.y}$	2	0,999	0,063	$8,82 \times 10^{-10}/\text{m.y}$
Nr 5: Pipe break – ESD fails	$7,0 \times 10^{-9}/\text{m.y}$	2	0,001	0,063	$8,82 \times 10^{-13}/\text{m.y}$
Nr 6: Pipe leak 20 mm	$6,3 \times 10^{-8}/\text{m.y}$	2	1	0,063	$7,94 \times 10^{-9}/\text{m.y}$
<i>Scenario no pumping</i>					
<i>Pipe bay during No Pumping</i>					
Nr 7: Pipe break – ESD works	$7,0 \times 10^{-9}/\text{m.y}$	2	0,999	0,937	$1,31 \times 10^{-8}/\text{m.y}$
Nr 8: Pipe break – ESD fails	$7,0 \times 10^{-9}/\text{m.y}$	2	0,001	0,937	$1,31 \times 10^{-11}/\text{m.y}$
Nr 9: Pipe leak 20 mm	$6,3 \times 10^{-8}/\text{m.y}$	2	1	0,937	$1,18 \times 10^{-7}/\text{m.y}$

Explanation:

The long pipeline model has been used: this model has been adjusted to reflect the following situation:

- Used is the long pipeline model. In this model valves have been introduced with 800 m segments. Failure on demand is 0,001, closing time 30 s.
- A part of the pipeline has been modelled above ocean (without bund) and another part above land with a bund (300 m²);
- The above shown scenarios are generated by Safety: Safety calculates the corresponding frequencies and outflow at the site of the breach).
- Used are the fail frequencies of a pipebay: this are in general frequencies applicable to underground pipelines, but here the pipeline is above ground. When specific requirements are met, these frequencies also can be used for above ground pipelines. These requirements are:
 - external damage has been ruled out (for example, when the pipelines are high above ground, and transport vehicles are not able to damage the pipelines);
 - the pipeline has been welded, and has few to no flanges and appendages.
 - the pipeline has been clearly marked.

3.4 Heat exchanging

The following scenarios have been modelled:

Scenario Heat exchanger	Frequency [1/y]	Amount of Heat exchangers	ESD	Time fraction	Frequency for QRA
<i>Pipe bay during No Pumping</i>					
Nr 1: Break 10 pipes	$1,0 \times 10^{-5}/\text{m.y}$	1	No ESD	1	$1,0 \times 10^{-5}/\text{m.y}$
Nr 2: Break 1 pipe	$1,0 \times 10^{-3}/\text{m.y}$	1	No ESD	1	$1,0 \times 10^{-3}/\text{m.y}$
Nr 3: Leak 10%, max 50 mm	$1,0 \times 10^{-2}/\text{m.y}$	1	No ESD	1	$1,0 \times 10^{-2}/\text{m.y}$

4. Results

In figure 4.1 and 4.2 the calculated risk contours are displayed.

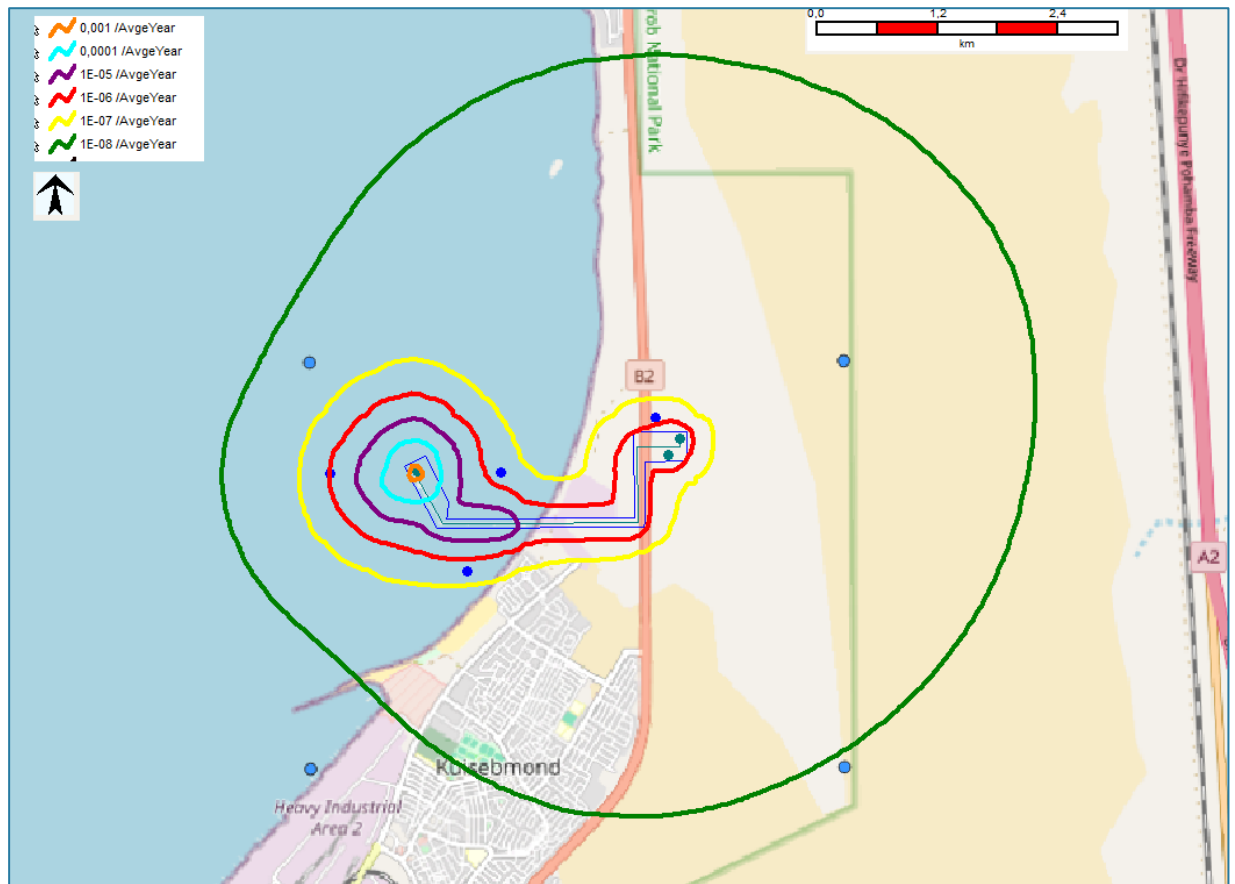


Figure 4.1: Risk contours double containment with import (first 5 years).

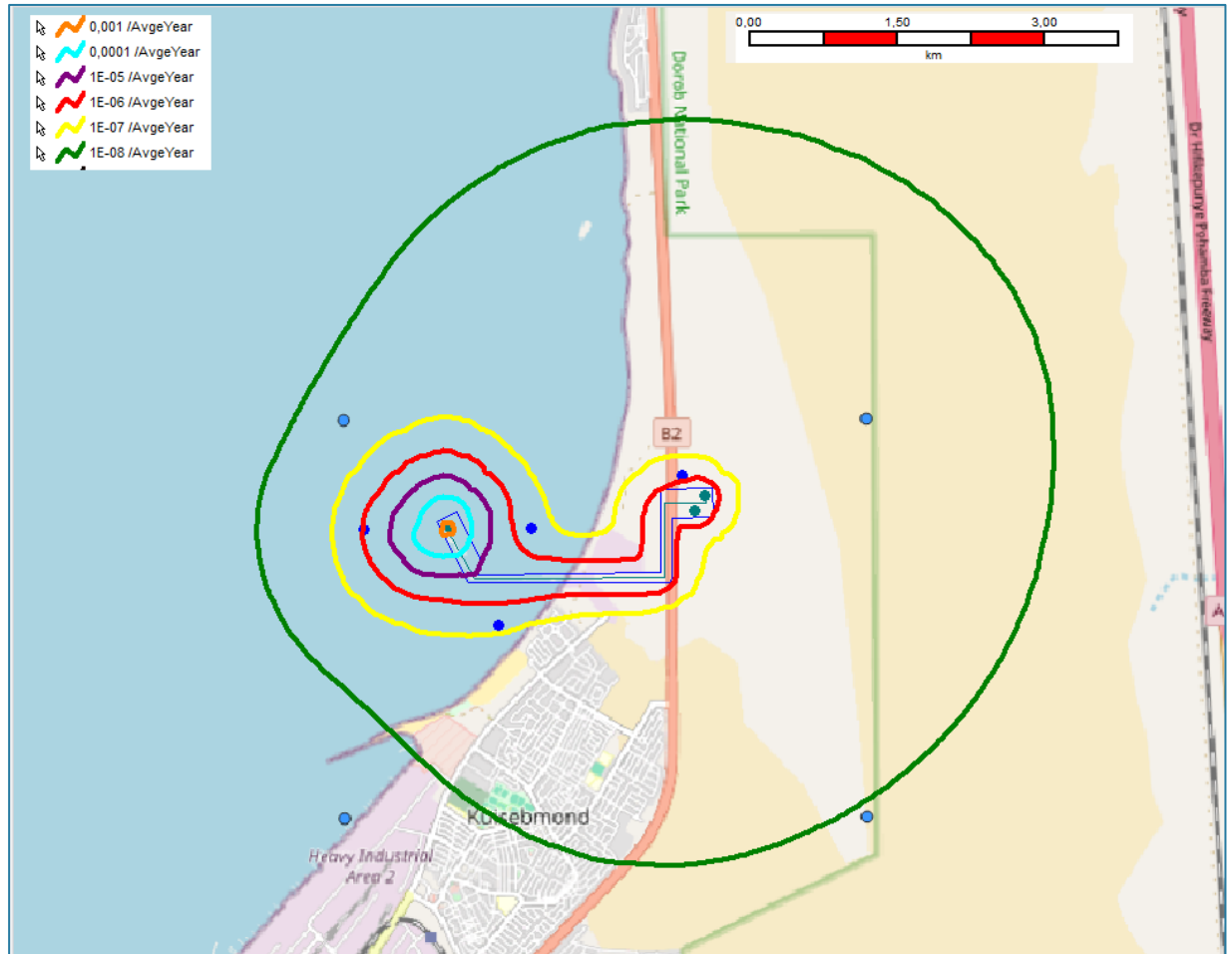


Figure 4.2: Risk contours double containment with export (after 5 years).

The $10^{-6}/\text{yr}$ contour is used to evaluate the external safety situation: is this situation acceptable or not. The $10^{-6}/\text{yr}$ is situated at 170 m to 180 m from the pipelines. This extends outside the current fencing of the facility. No houses or buildings are situated within this contour. We therefore can conclude that this situation is acceptable.

5. Conclusion

The indicative calculations of this ammonia export, import and storage facility have produced a 10^{-6} /yr contour that does not include any vulnerable objects (housing, office buildings and care facilities e.g. schools, hospitals etc.). Therefore this situation is acceptable according to Dutch law.