



Challenges of using brackish water as a source for drinking water:

# Removal of As(III) using BWRO\*

\*: Brackish Water Reverse Osmosis

# Hello, nice to meet you!

Meet the Brabant Water team:



**Tim van Dijk**  
Senior process  
engineer



**Amir Haidari**  
Advisor water  
technology &  
researcher at  
TU Delft



**Teun de Zeeuw**  
Advisor water  
technology



**Jannes van Hove**  
Senior strategist



**Vincent de Laat**  
Business developer



**Yasmine Wiersema**  
Project manager

and your host for  
today 😊

# Who are you?



# Outline of today

**09:00** – Opening and introduction

**09:10** – Case introduction

**09:20** – Break-out session

**09:50** – Group presentations

**10:00** – Discussion & vote

**10:15** – Wrap-up (any other business)

**10:20** – Closing

# The future of Brabant Water

*Our ambition:* to deliver and keep delivering drinking water of excellent quality to our customers, 24/7/365

## Challenges

- Increase in demand
- Sources under pressure – lack of sources
- Quality of our sources decreases
- Reaching the limits of our capacity


## Solution (one of many)

- Develop additional, alternative sources: brackish water and sea water → brackish water plant due before 2030! (5 mil. m<sup>3</sup>/y)




# But Noord-Brabant is not located at sea...

Project location brackish groundwater



Project location seawater

...true. But we do have The Oosterschelde and Westerschelde!



The image features a blue map of the province of Noord-Brabant, Netherlands. Two orange arrows point to specific locations: one in the north-central region labeled 'Project location brackish groundwater' and one in the west labeled 'Project location seawater'. The map is populated with numerous white dots representing various municipalities, including Gendersen, Drongelen, Vlijmen, Helvoirt, Nuland, Loosbroek, Oosterhout, Waalwijk, Haaren, Schijndel, Veghel, Dorst, Ginneken, Tilburg, Oirschot, Son, Lieshout, Wouw, Kruisland, Seppe, Prinsenbosch, Gilze, Bergen op Zoom, Roosendaal, Schijf, Vessem, Welschap, Aalsterweg, Klotputten, Groote Heide, Someren, Luyksgestel, and Budel. To the left of the map, two blue wave icons are positioned above and below the text '...true. But we do have The Oosterschelde and Westerschelde!'. To the right, an inset photograph shows a close-up of a water filtration system with several white cylindrical filters connected by blue pipes.

# Today's case study

## In a nutshell

- *The Challenge:* our brackish groundwater contains arsenic. Quite a lot.
- *Proposed solution:* we thought of 2 ways of removing arsenic.
- *Workshop:* please discuss and reflect on our proposal. What are pros and cons? Do you have any better ideas? We share and vote.

## P.S.

Not a die-hard process engineer? Don't worry! You can think of any topic, like sustainability, costs, environmental impact, governance, ... to base your pros and cons on. Use your group members for discussion!

# Water Quality - Arsenic challenge

Brackish groundwater quality		Drongelen	Goal
pH	pH-units	7,93	7,8-8,3
Hydrogen bicarbonate	mg/l HCO <sub>3</sub>	288	>75
Sodium	mg/l Na	242	<75
Chloride	mg/l Cl	<b>384</b>	<b>&lt;75</b>
Iron	µg/l Fe	733	<10
Manganese	µg/l Mn	557	<10
Ammonia	mg/l NH <sub>4</sub>	1,8	<0,005
Arsenic	µg/l As	<b>49,2</b>	<b>&lt;1</b>
Calcium	mg/l Ca	27,0	Nr
Magnesium	mg/l Mg	41,3	Nr
Boron	µg/l B	473	<500
Osmotic pressure	bar	0,8	

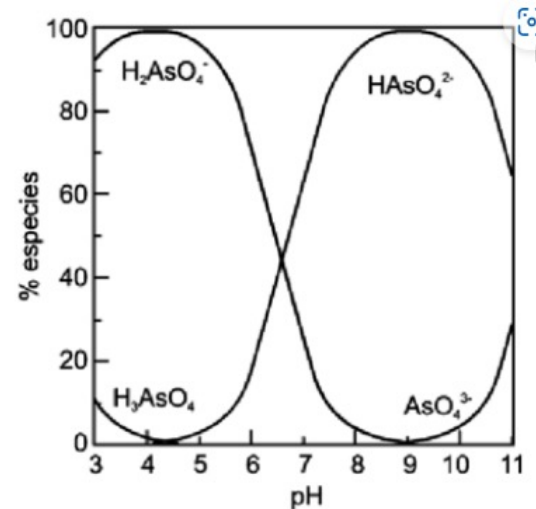
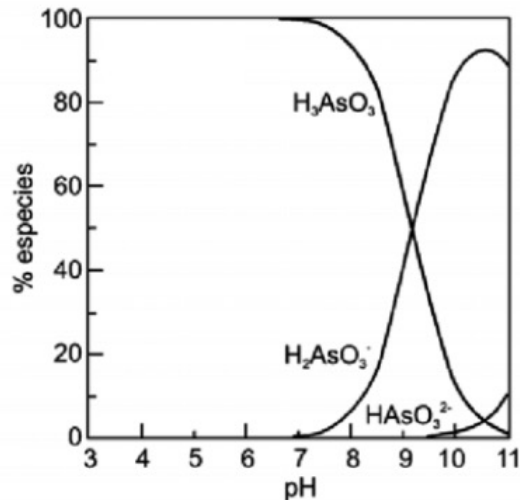
Tricky part: there are two types of arsenic: As(III) and As(V)



# Why is this a challenge?

- **As(III) removal in reverse osmosis is unknown**, relatively low (40-80%) depending different factors such as pH, ionic strength, other ions.

**As(III)** has no charge and is therefore poorly removed in RO membranes. It has to be oxidized or pH must be increased



**As(V)** always has a charge and is therefore removed in RO membranes

- Strict guidelines: our goal limit for drinking water is very low, 1  $\mu\text{g}/\text{l}$  (WHO=10 $\mu\text{g}/\text{l}$ )
  - Discharge limit (concentrate stream) is 10  $\mu\text{g}/\text{l}$
- Extra treatment step(s) required

# Our proposed solutions

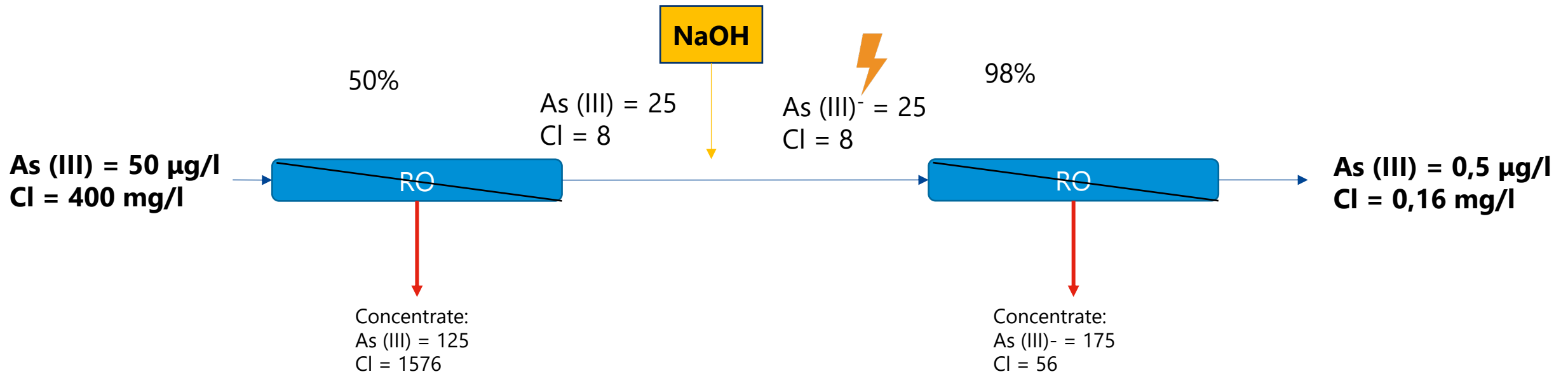
Our team came up with two possibilities to use RO for removing arsenic(III):

- Anaerobic RO treatment with double pass
- Aerobic RO treatment

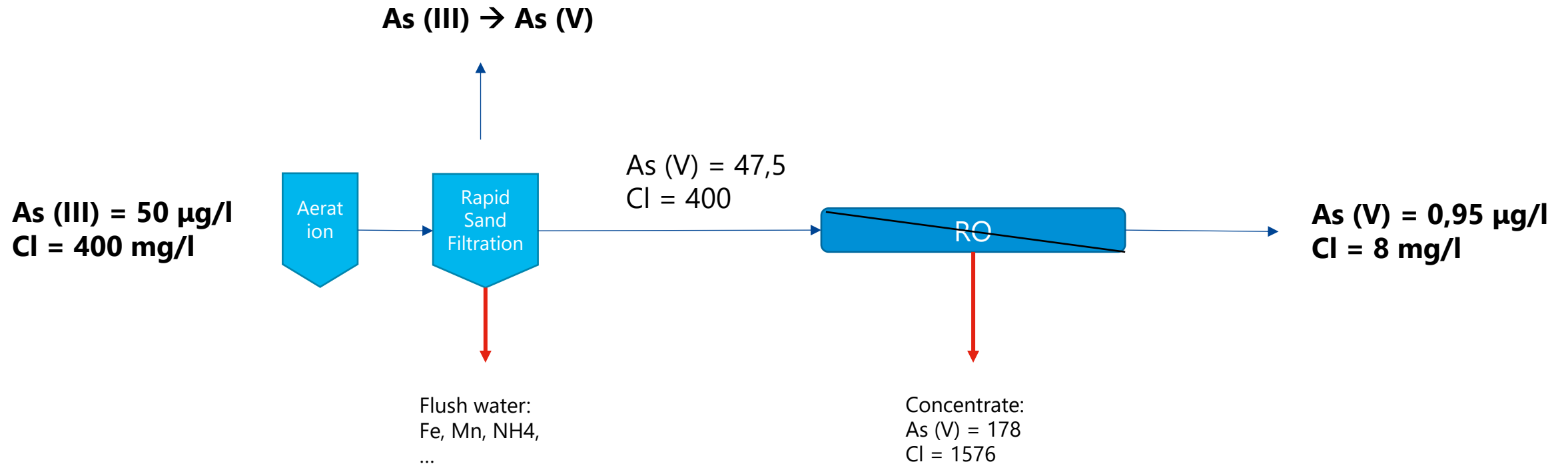
Other research themes (not for today's workshop):

- Remineralisation (necessary after RO)
- Treatment of concentrate


# Solution #1: Anaerobic RO – double pass



# Solution #2: Aerobic RO



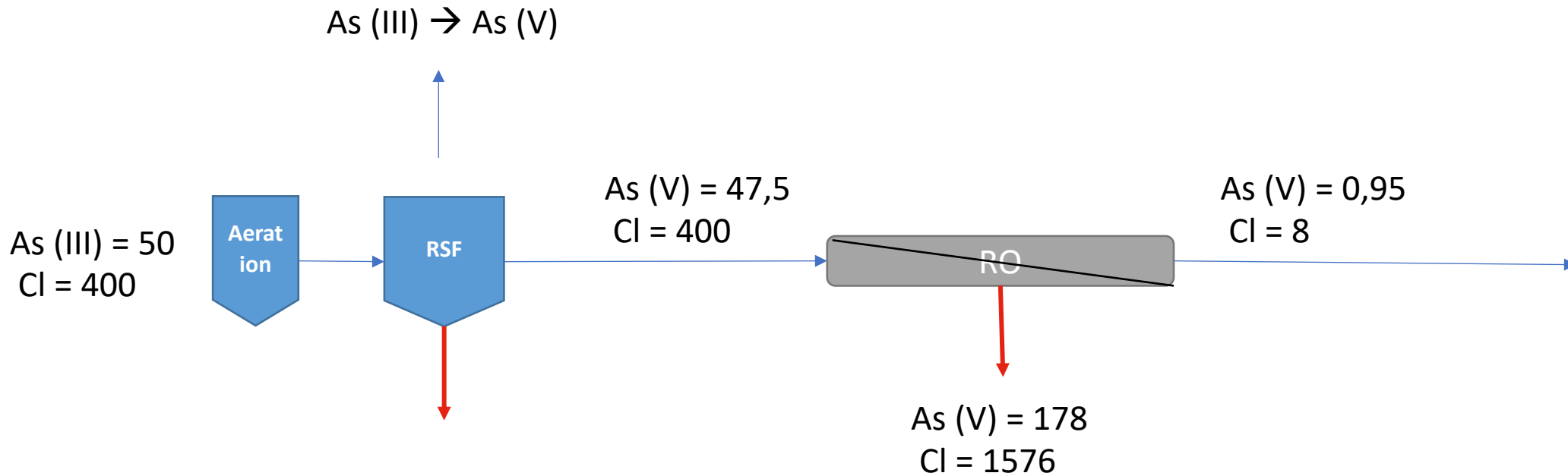
# Break-out session

- Forming groups
- Use sheet to brainstorm about the solutions
-  9:50 → One member of each group presents their findings in 1 minute

	Aerobic	Anaerobic	Other
<b>Pros</b> Advantages			
<b>Cons</b> Disadvantages			
Remarks			

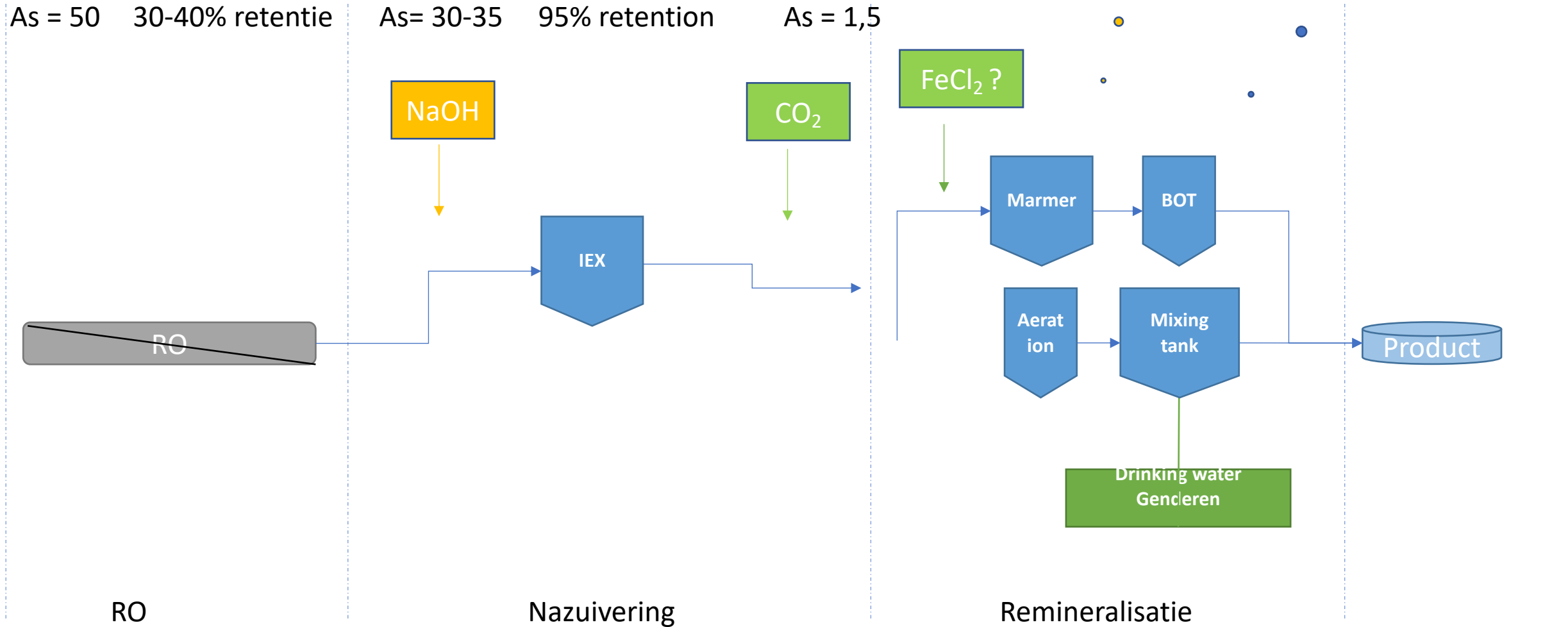
# Practical questions?

# Pilot Aerobic



Additional advantage: no Fe, Mn and  $\text{NH}_4$  in RO concentrate stream

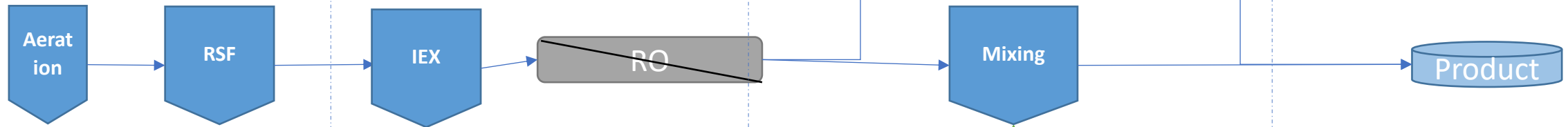
# Pilot Anaerobic - IEX



# Pilot Aerobic with IEX

As = 50    2,5-5ug/l removal    As= 45    95-99% retentie

As = 1



Voorzuivering

RO

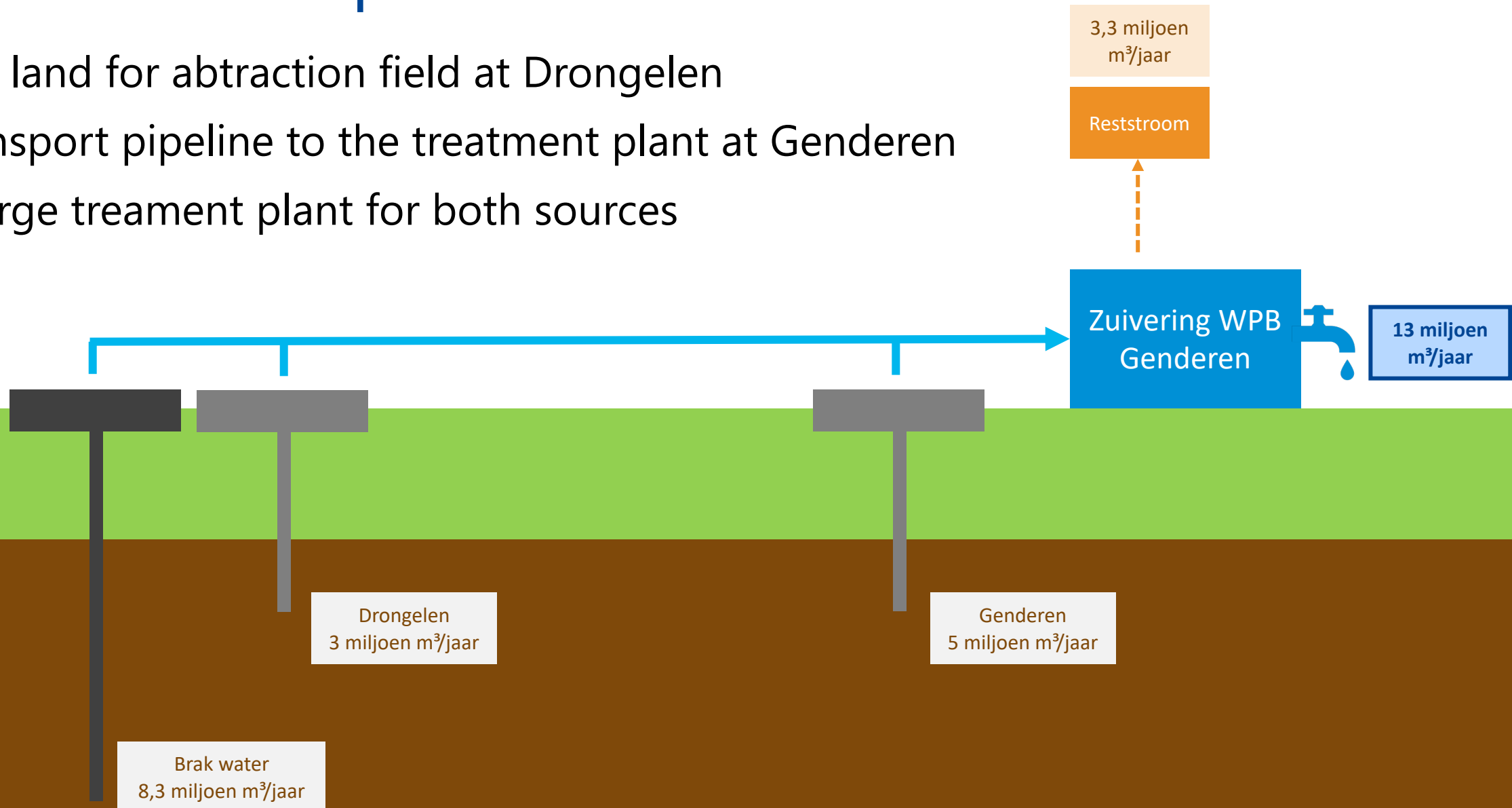
Remineralisatie

Location  
MgCl<sub>2</sub> dosing

NaOH/HCl  
conditioning

# Full-scale set-up

- Buy land for abstraction field at Drongelen
- Transport pipeline to the treatment plant at Genderen
- 1 large treatment plant for both sources

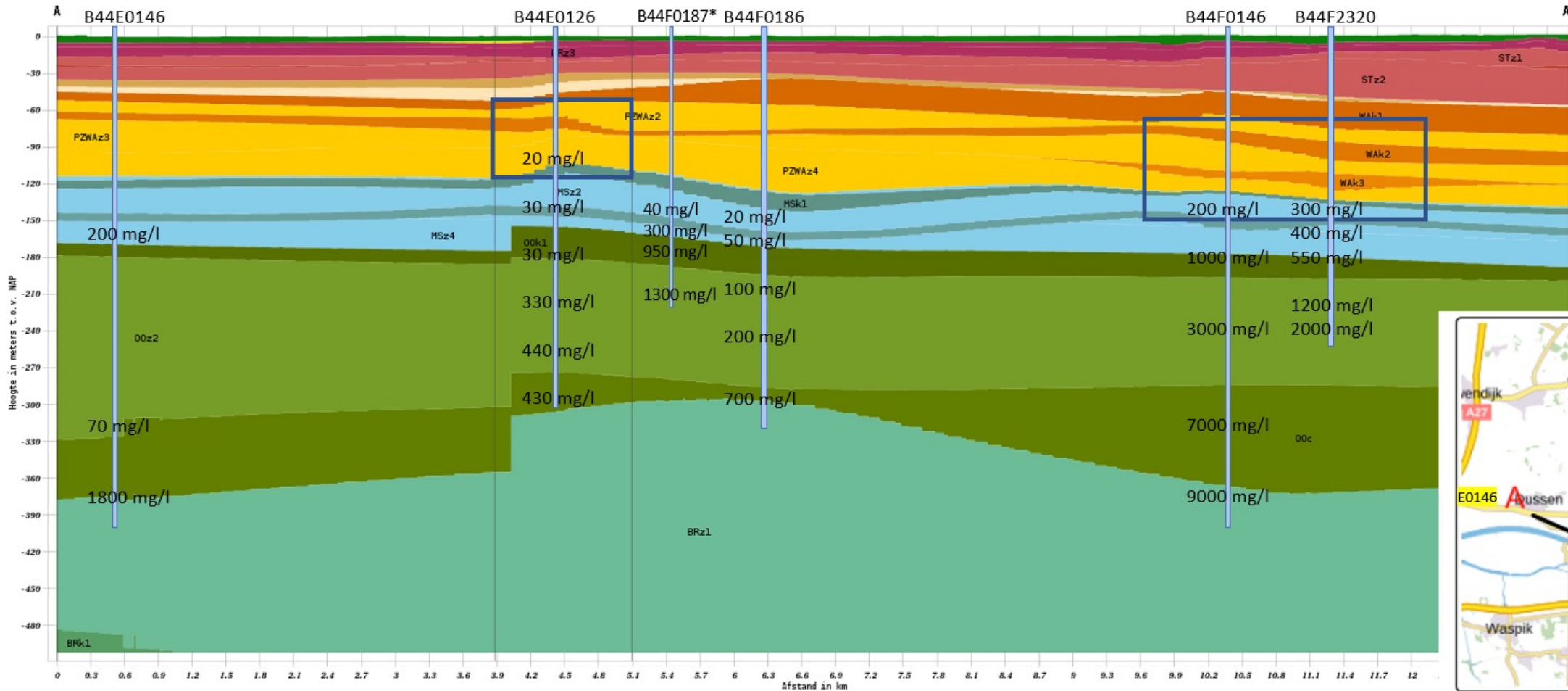


# Two locations

Verticale Doorsnede BRO REGIS II v2.2

Drongelen

Genderen



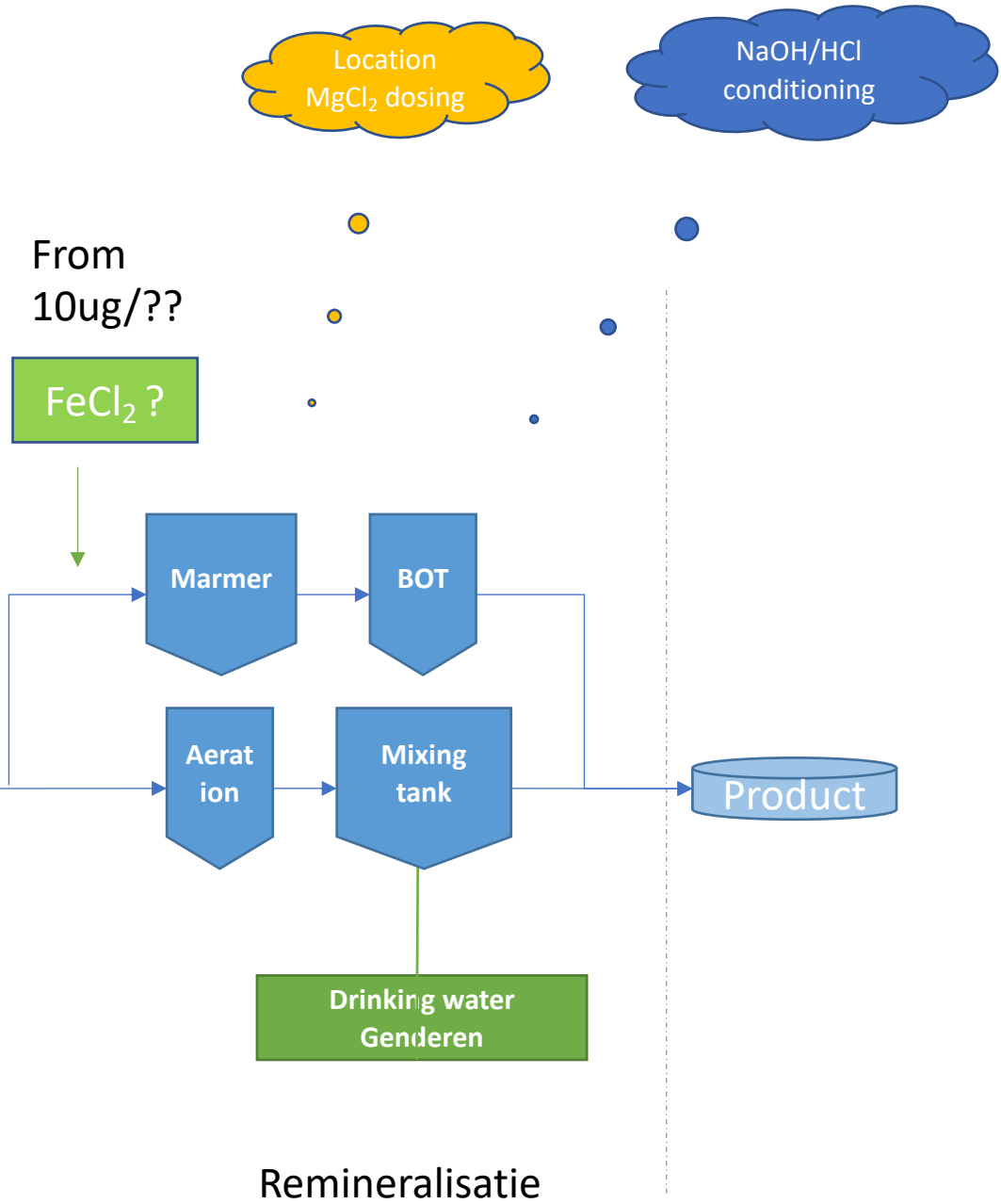
# Pilot Anaeroob

Average

As = 50    30-40% retention    As = 30-35  
As = 25    30-40% retention    As = 10-15

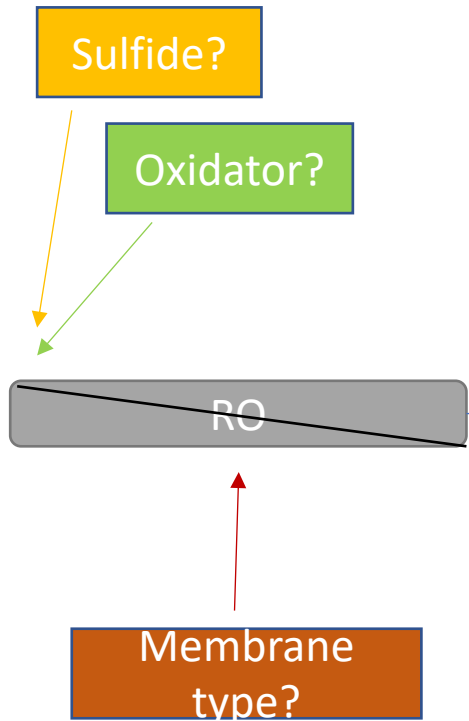


RO



# Pilot Anaerobic

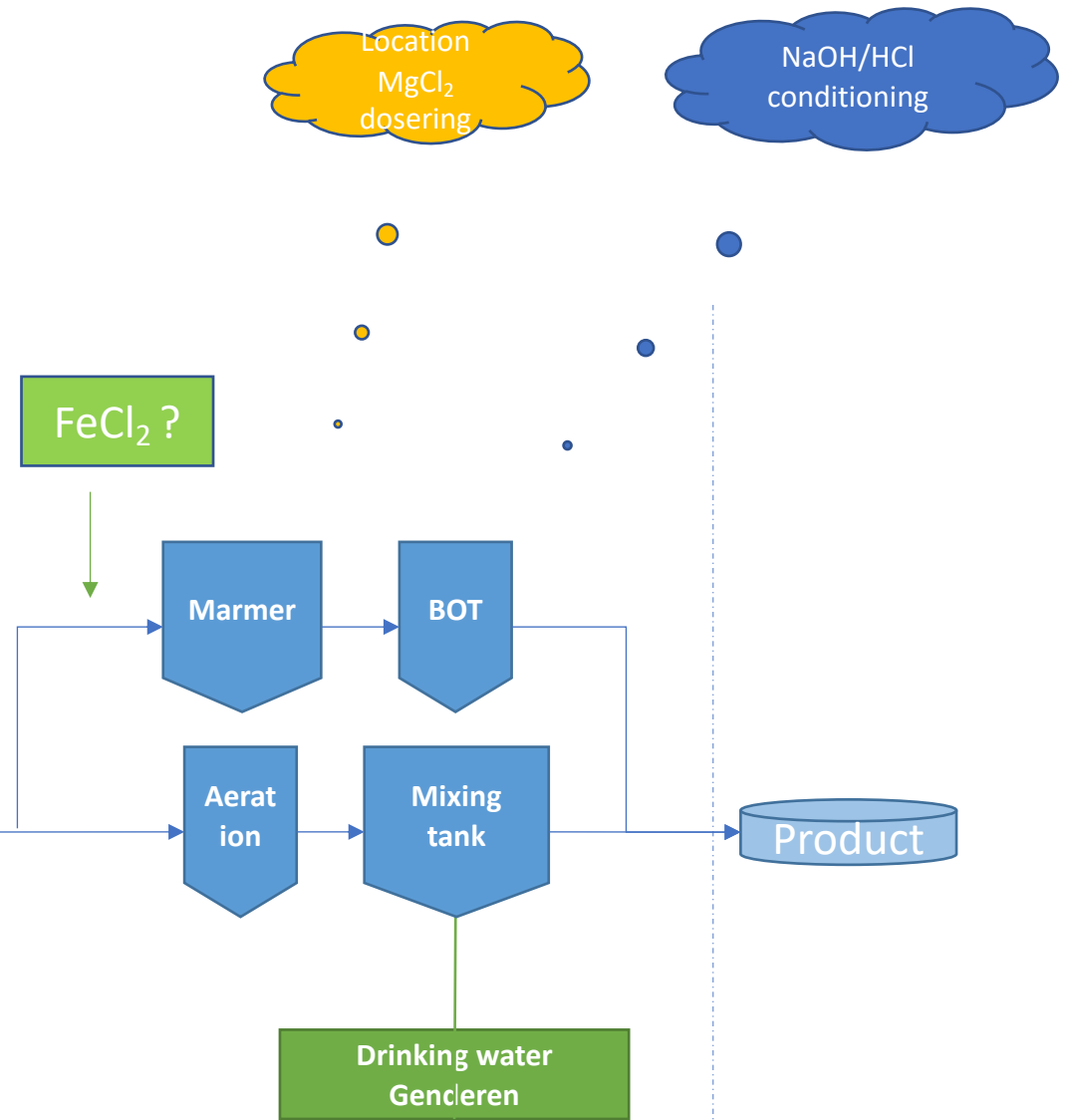
As = 50 80-95% retention As = 2,5-10



RO

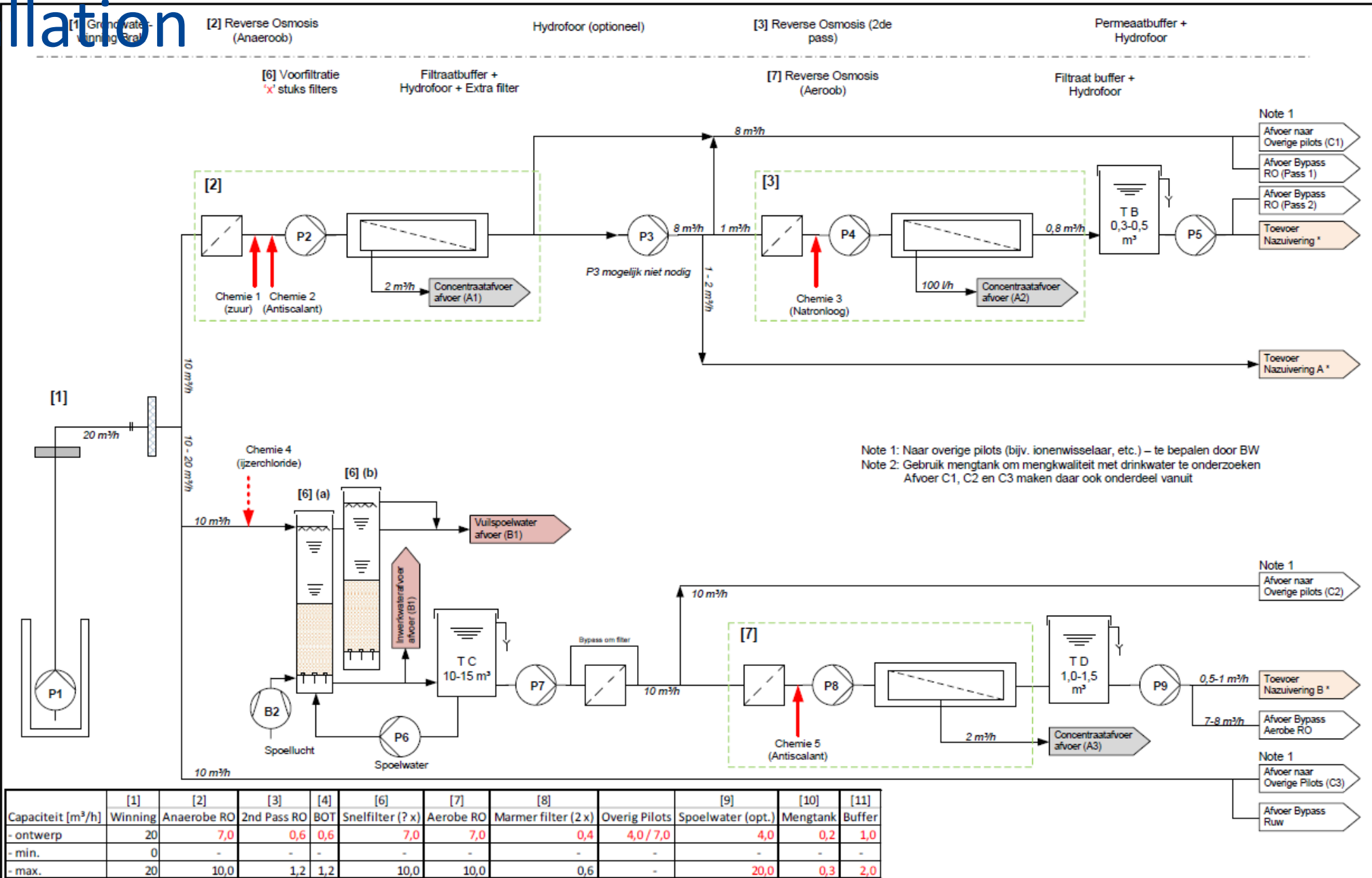
← Input from KWR

Nazuivering

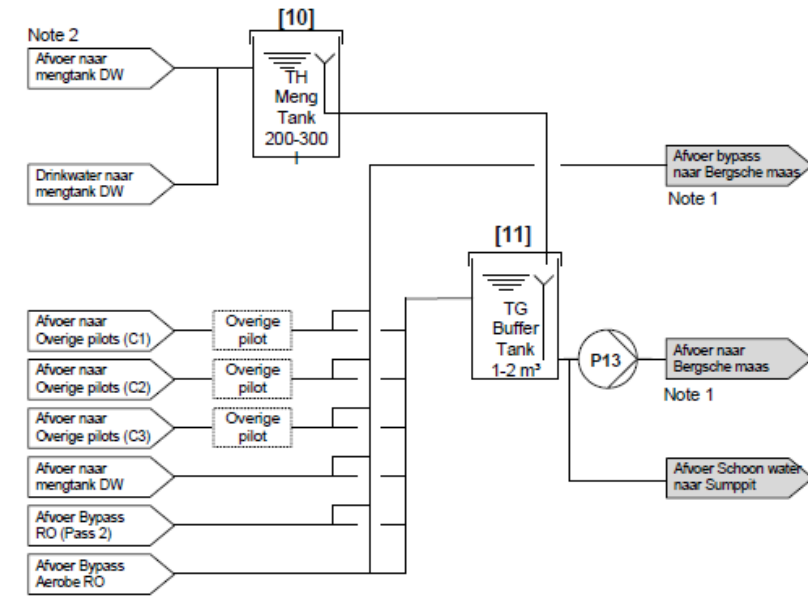
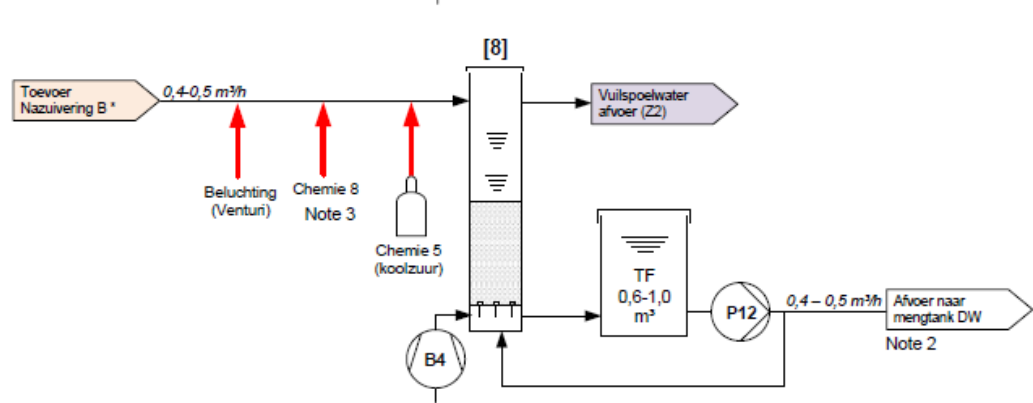
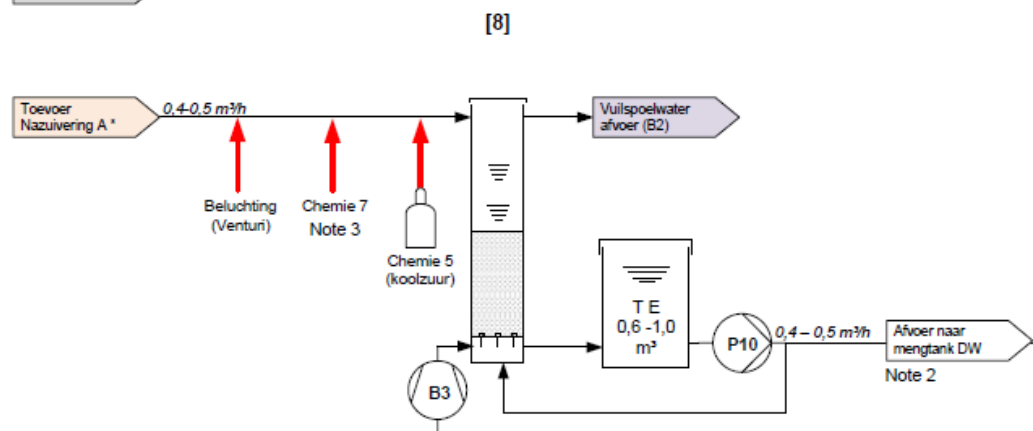
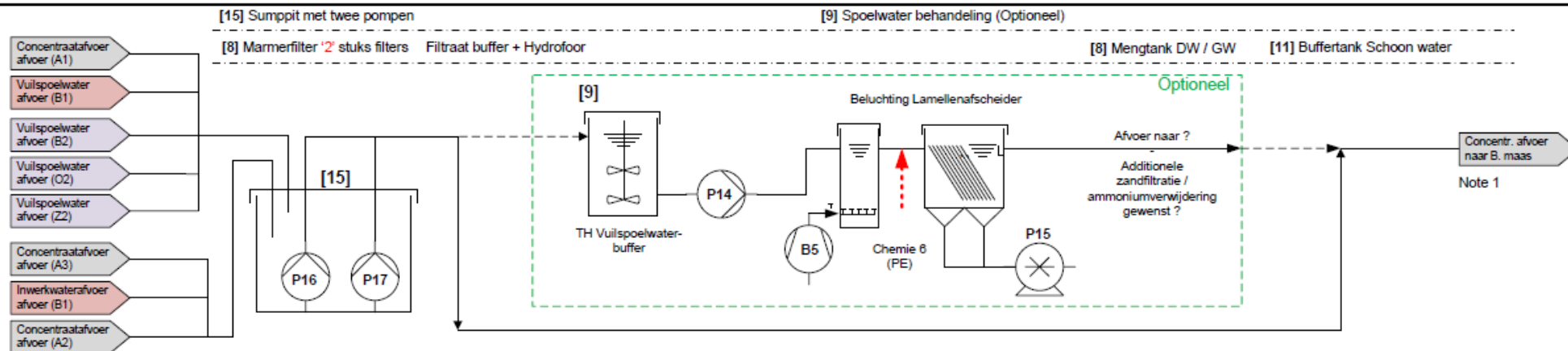


Remineralisatie

# Pilot installation



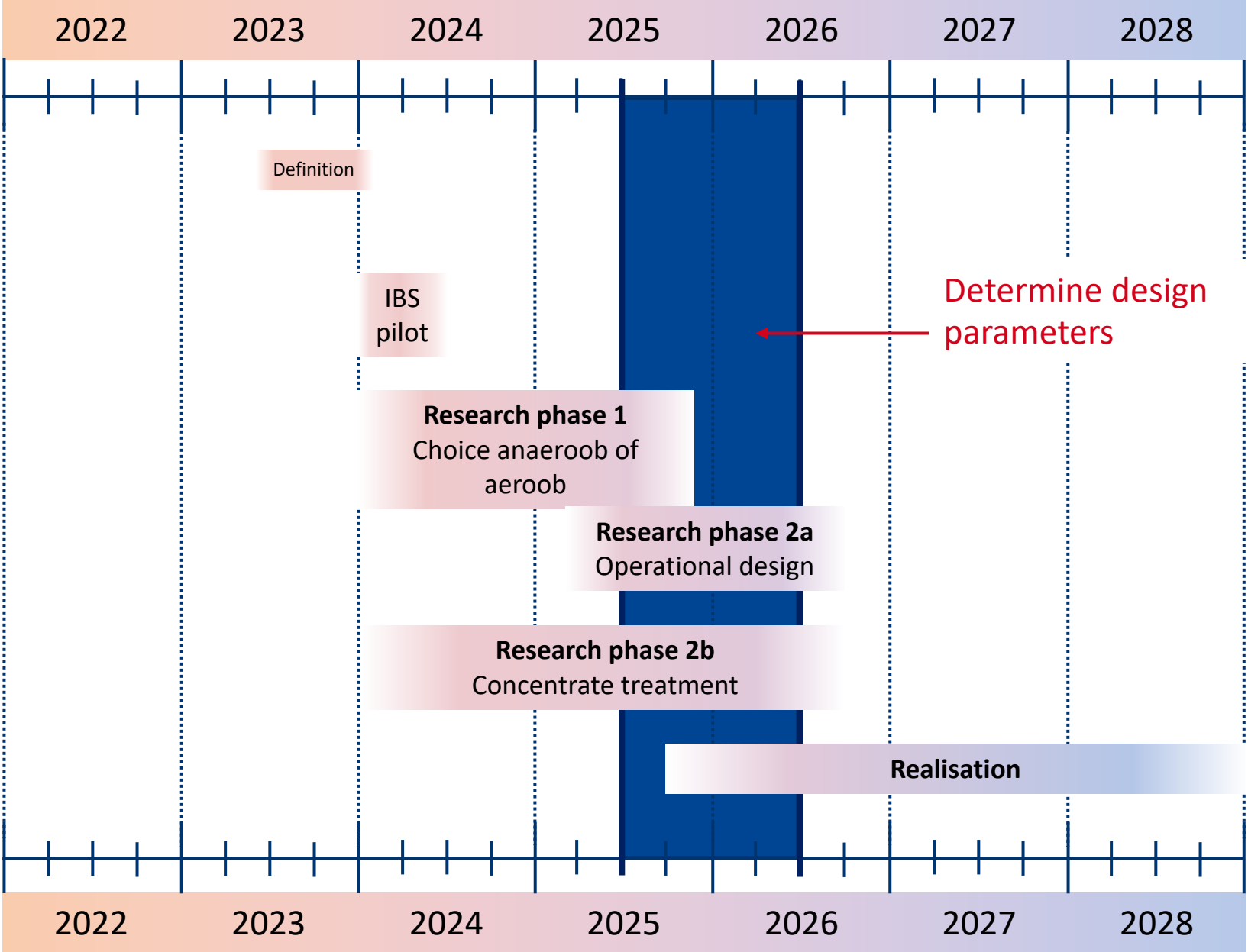
	[1]	[2]	[3]	[4]	[6]	[7]	[8]	[9]	[10]	[11]	
Capaciteit [m³/h]	Winning	Anaerobe RO	2nd Pass RO	BOT	Snelfilter (? x)	Aerobe RO	Marmor filter (2 x)	Overig Pilots	Spoelwater (opt.)	Mengtank	Buffer
- ontwerp	20	7,0	0,6	0,6	7,0	7,0	0,4	4,0/7,0	4,0	0,2	1,0
- min.	0	-	-	-	-	-	-	-	-	-	-
- max.	20	10,0	1,2	1,2	10,0	10,0	0,6	-	20,0	0,3	2,0



Note 1: Afvoer spoelwater en Mengtank / permeaat bepalen  
 Note 2: Gebruik mengtank om mengkwaliteit met drinkwater te onderzoeken  
 Afvoer C1, C2 en C3 maken daar ook onderdeel vanuit  
 Note 3: Optioneel MgCl<sub>2</sub> dosering

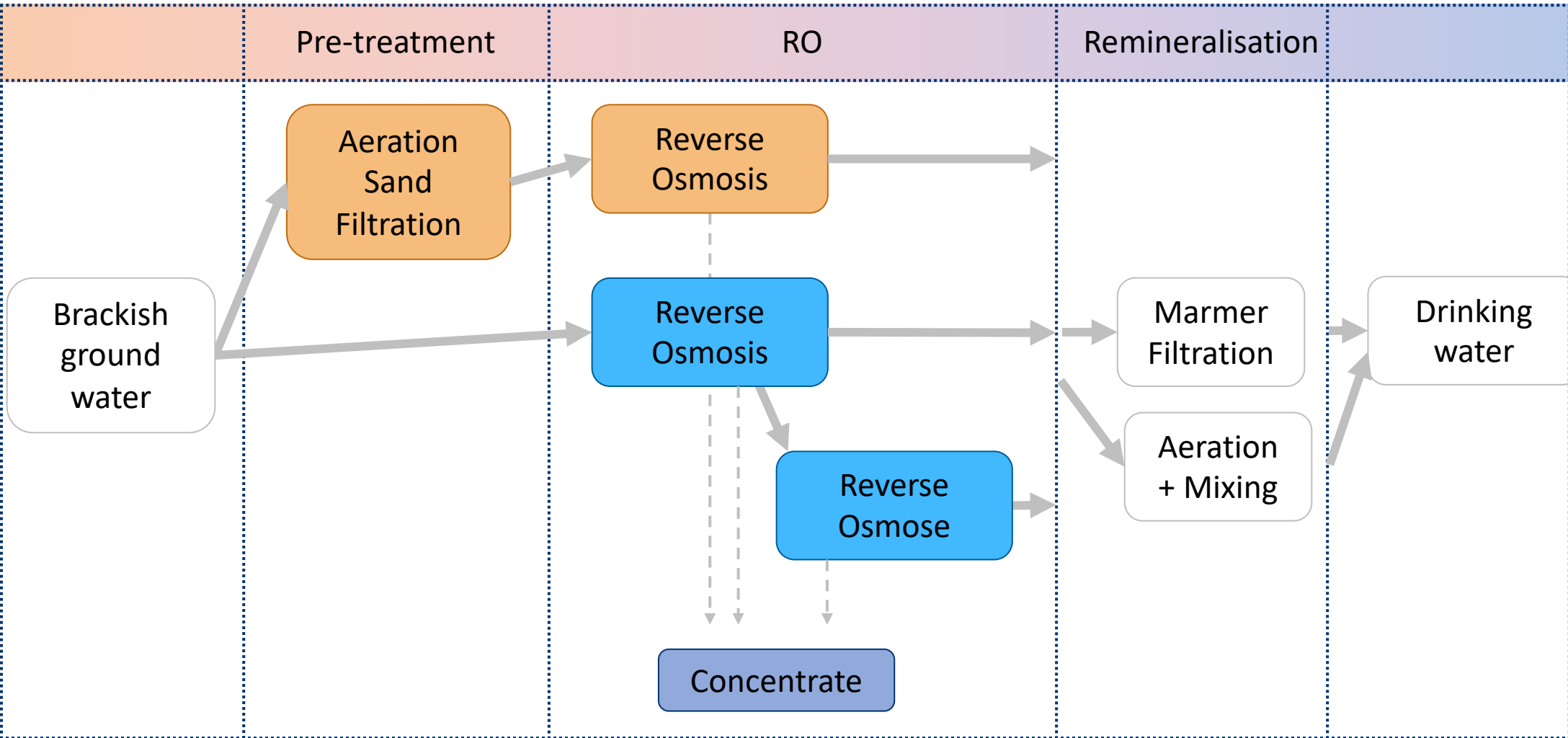
E	31-8-2023	JAR	Project	Pilothal brakwaterzuivering Genderen
D	8-8-2023	JAR	Client	Brabant Water
C	7-8-2023	RBe	File number	406189
B	26-6-2023	RBe		
A	26-5-2023	RBe		
rev.	date	Drw.		

Drw.	RBE	Seen:	RBE	Size:	
Scale	n.a.				A3
Last edition:	6-9-2023				
Filename	Visio schema - Brakwaterpiloot Brabant Water v6.0.vsd				
Drawing Number	406189.301	Page	2		



Questions?

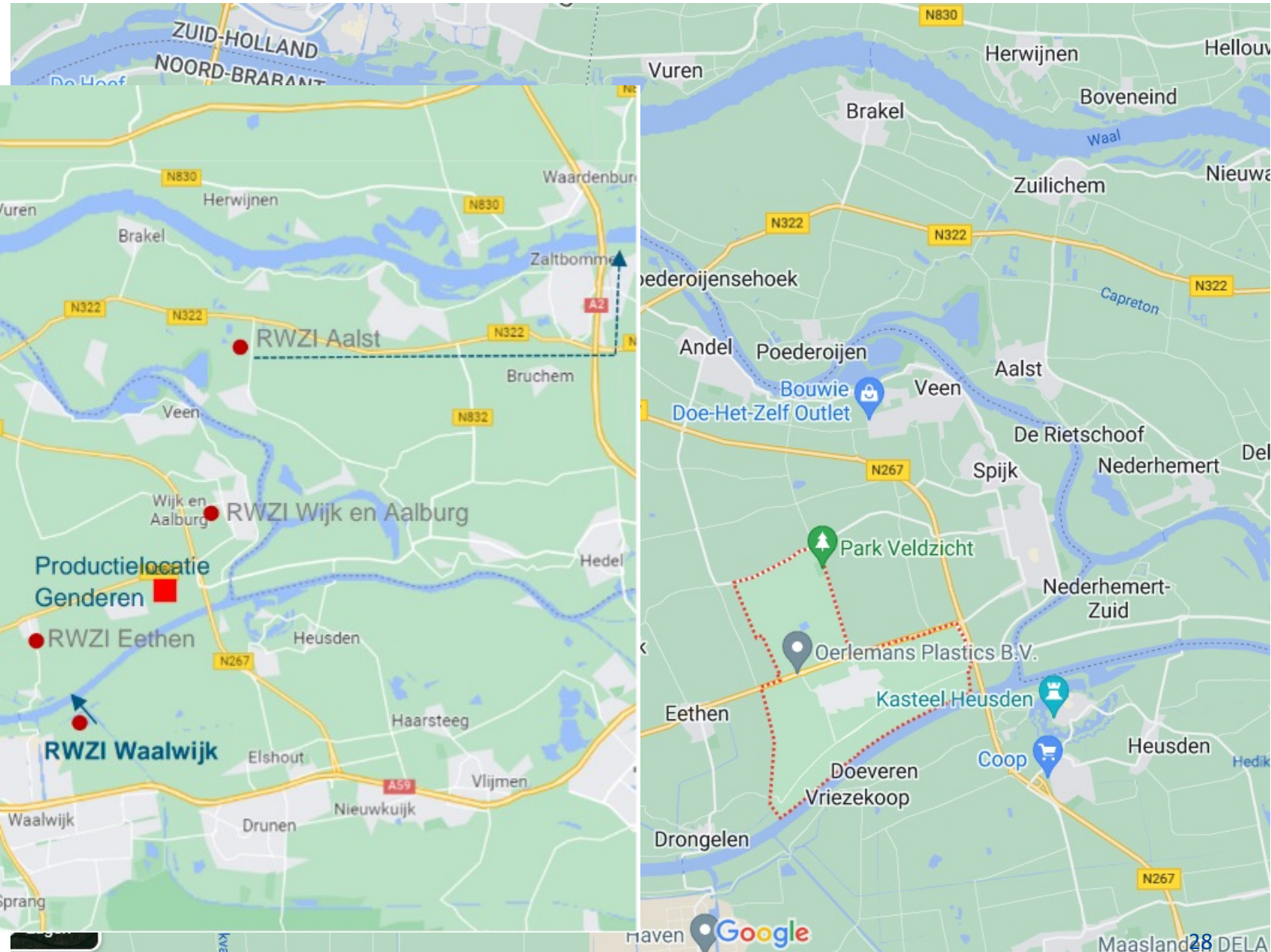




**Onderzoekslijnen**

- Aeroob
- Anaeroob
- Concentraat-behandeling

# Lozingsopties



# Reststroom / concentraat

- 307 m<sup>3</sup>/uur gemiddeld (2,7 Mm<sup>3</sup>/jaar)

Reststroom Genderen en Drongelen (recovery 65%)		Genderen	Drongelen
Zuurgraad	pH-eenheden	7,86	8,09
Waterstofcarbonaat, gefiltreerd	mg/l HCO <sub>3</sub>	576	751
Natrium, gefiltreerd (ICP-MS)	mg/l Na	5.091	681
Chloride, gefiltreerd	mg/l Cl	9.493	1.085
IJzer, gefiltreerd (ICP-MS)	µg/l Fe	3.128	2.091
Mangaan, gefiltreerd (ICP-MS)	µg/l Mn	1.065	1.590
Ammonium, gefiltreerd	mg/l NH <sub>4</sub>	23	5
Arseen, gefiltreerd (ICP-MS)	µg/l As	71	139
Calcium, gefiltreerd (ICP-MS)	mg/l Ca	265	77
Magnesium, gefiltreerd (ICP-MS)	mg/l Mg	470	118
Boor, gefiltreerd (ICP-MS)	µg/l B	5.077	1.089
Osmotische druk	bar	13,4	2,1

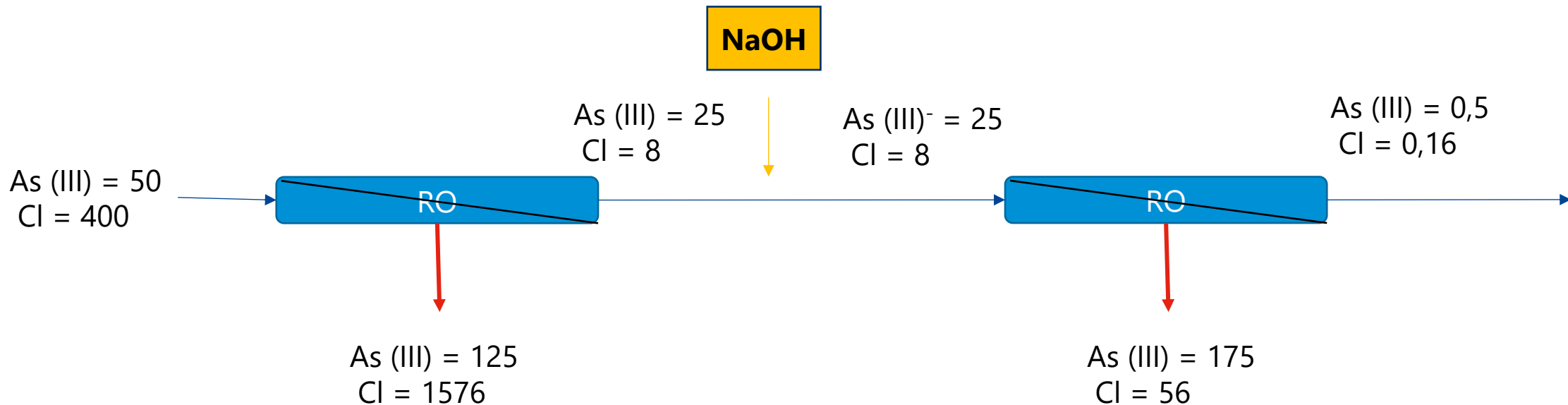
# Handout Water quality

Brackish groundwater quality		Drongelen	Goal		Concentrate
<b>pH</b>	pH-units	7,93	7,8-8,3		8,09
<b>Hydrogen bicarbonate</b>	mg/l HCO <sub>3</sub>	288	>75		751
<b>Sodium</b>	mg/l Na	242	<75		681
<b>Chloride</b>	mg/l Cl	<b>384</b>	<b>&lt;75</b>		1.085
<b>Iron</b>	µg/l Fe	733	<10		2.091
<b>Manganese</b>	µg/l Mn	557	<10		1.590
<b>Ammonia</b>	mg/l NH <sub>4</sub>	1,8	<0,005		5
<b>Arsenic</b>	µg/l As	49,2	<1		139
<b>Calcium</b>	mg/l Ca	27,0	Nr		77
<b>Magnesium</b>	mg/l Mg	41,3	Nr		118
<b>Boron</b>	µg/l B	473	<500		1.089

# Handout Pilot Anaerobic RO – double pass

Flow rates in double pass anaerobic RO

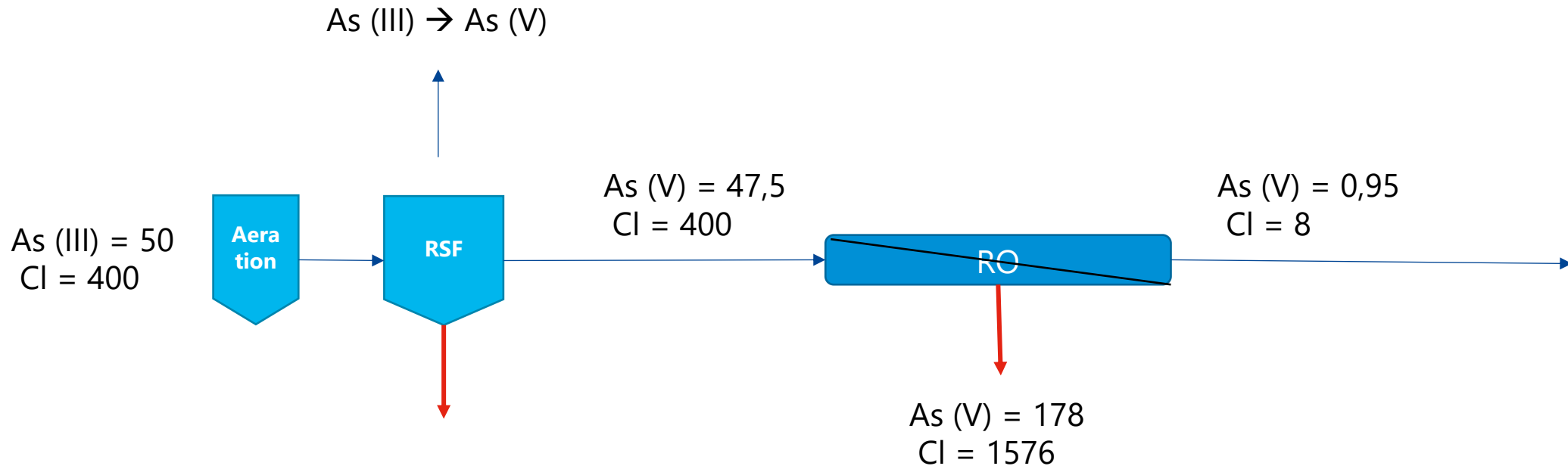
RO feed (1)	RO (1) permeate	RO (1) concentrate	RO feed (2)	RO (2) permeate	RO (2) concentrate
887 m <sup>3</sup> /h	665 m <sup>3</sup> /h	222 m <sup>3</sup> /h	665 m <sup>3</sup> /h	572 m <sup>3</sup> /h	93 m <sup>3</sup> /h



# Handout Pilot Aerobic RO

Flow rates in aerobic RO

Incoming water	RO feed	Back wash water (RSF)	RO permeate	RO concentrate
795 m <sup>3</sup> /h	779 m <sup>3</sup> /h	16 m <sup>3</sup> /h	572 m <sup>3</sup> /h	191 m <sup>3</sup> /h



Additional advantage: no Fe, Mn and NH<sub>4</sub> in RO concentrate stream

# Wat is brak water? - definitie

## Rapport Wibo

### 1 UITGANGSPUNTEN

In samenspraak met Brabant Water zijn uitgangspunten en randvoorwaarden vastgelegd voor de zoektocht naar een brakke grondwaterwinning:

- Brak grondwaterwinning voor de productie van 10 tot 20 miljoen m<sup>3</sup>/jaar aan drinkwater;
- één of meerdere locaties;
- focus op peilgestuurd gebied NW-Brabant, inclusief Land van Heusden en Altena, exclusief Brabantse Wal (zie afbeelding 1.1);
- chloride brakwater: 150 - 1000 mg/l;
- focus op Oosterhout zanden, Breda zanden, Maassluis zanden (zie bijlage 1.2);
- mogelijk infiltratie in diep pakket (RO concentraat).

Drinkwaternorm <150 mg/l (0,15 promille)

WHO norm <500 mg/l (0,5 promille)

## Brak water

**Brak water** is zoutachtig water dat minder zout is dan **zeewater**. Het komt van nature voor op de overgang van **zoet-** naar **zeewater**, vaak bij riviermondingen. De grens tussen zoet- en brak water is tamelijk arbitrair en wordt meestal bij 0,3 - 0,5 **promille** (totaal zout) gelegd. Een andere manier om de grens tussen zoet en brak aan te geven is of het nog geschikt is als drinkwater. Ook deze grens is onscherp.

### Aanduidingen voor de saliniteit van water (in ‰, delen per 1000)

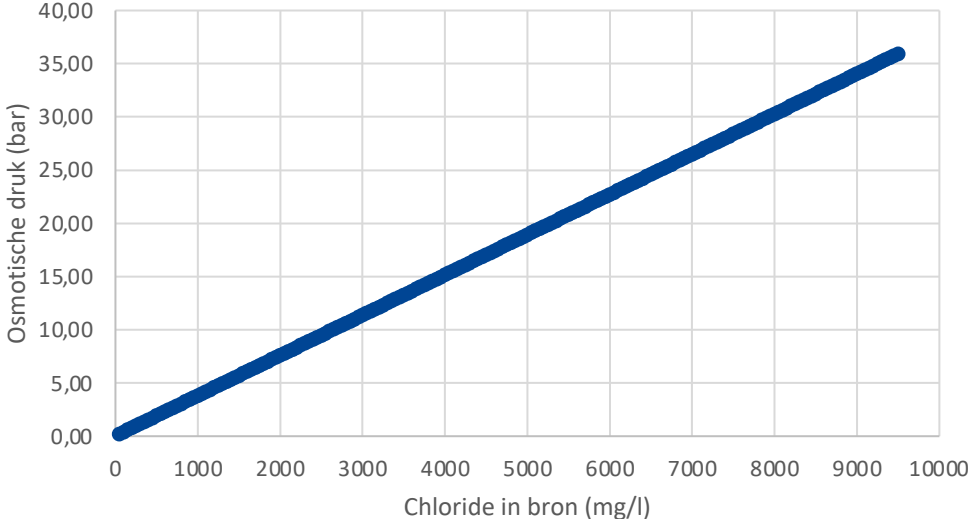
Zoet	Brak	Licht zilt	Matig zilt	Zeer zilt	Zout	Pekel
< 0,5	0,5-1	1-3	3-10	10-30	30-50	> 50

Tabel 8.1 Locaties en kenmerken potentiële winningen brak grondwater.

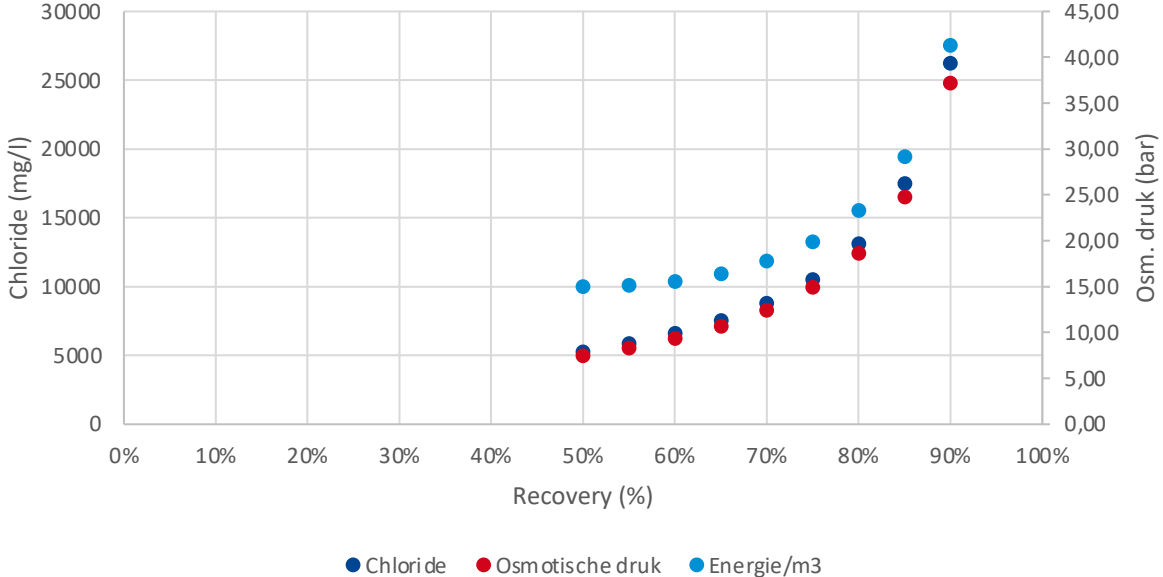
Nr	Locatie	Formatie winning	Diepte winning in model m NAP)	Doorlaatvermogen (m <sup>2</sup> /d)	Verwacht gemiddeld chloride gehalte (mg/l)
1	Genderen	Oosterhout	-200 tot - 280	1325	710 - 1650
2A	Zeven-bergen	Maassluis	-65 tot -110	305+520	80 -120
2B	Zeven-bergen	Oosterhout	-145 tot -200	1115	170 - 390
3	Land van Heusen en Altena	Oosterhout	-21 tot -330	1227	1380 - 3640 (vrij hoog voor brakwater, minder geschikt?)
4A	Dinteloord	Maassluis	-65 tot -100	587	370 - 470
4B	Dinteloord	Oosterhout	-120 tot -210	1660	130 - 330 (er treedt hier inversie op)
5	Lith	Breda	-260 - -360	70	330- 950
6	Seppe-diep	dieper dan	niet in model	onbekend	onbekend

# Chloride vs Energie vs Recovery

Osm druk concentraat vs chloride in bron bij 65 % recovery



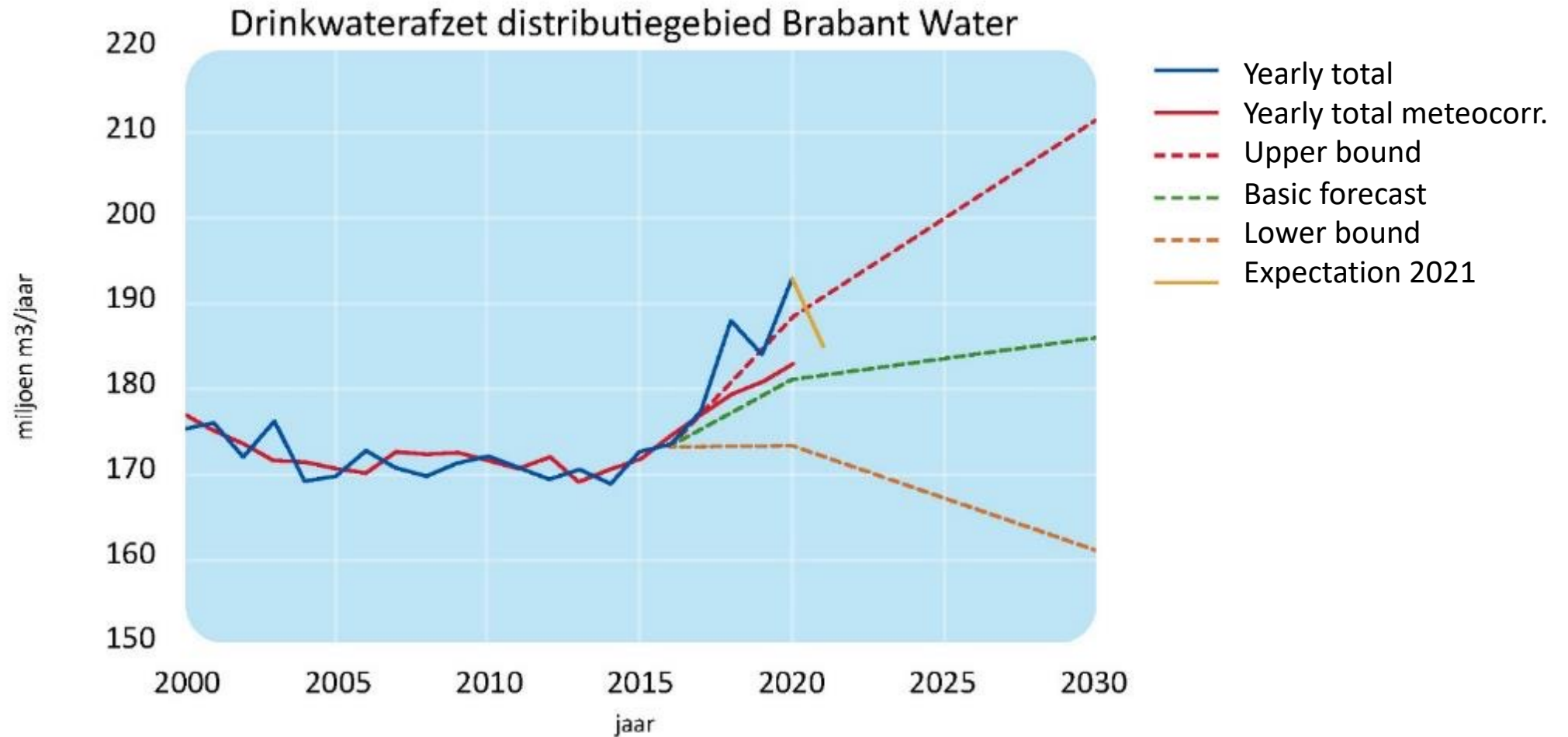
Recovery vs druk vs energie (bij 2700 mg/l)



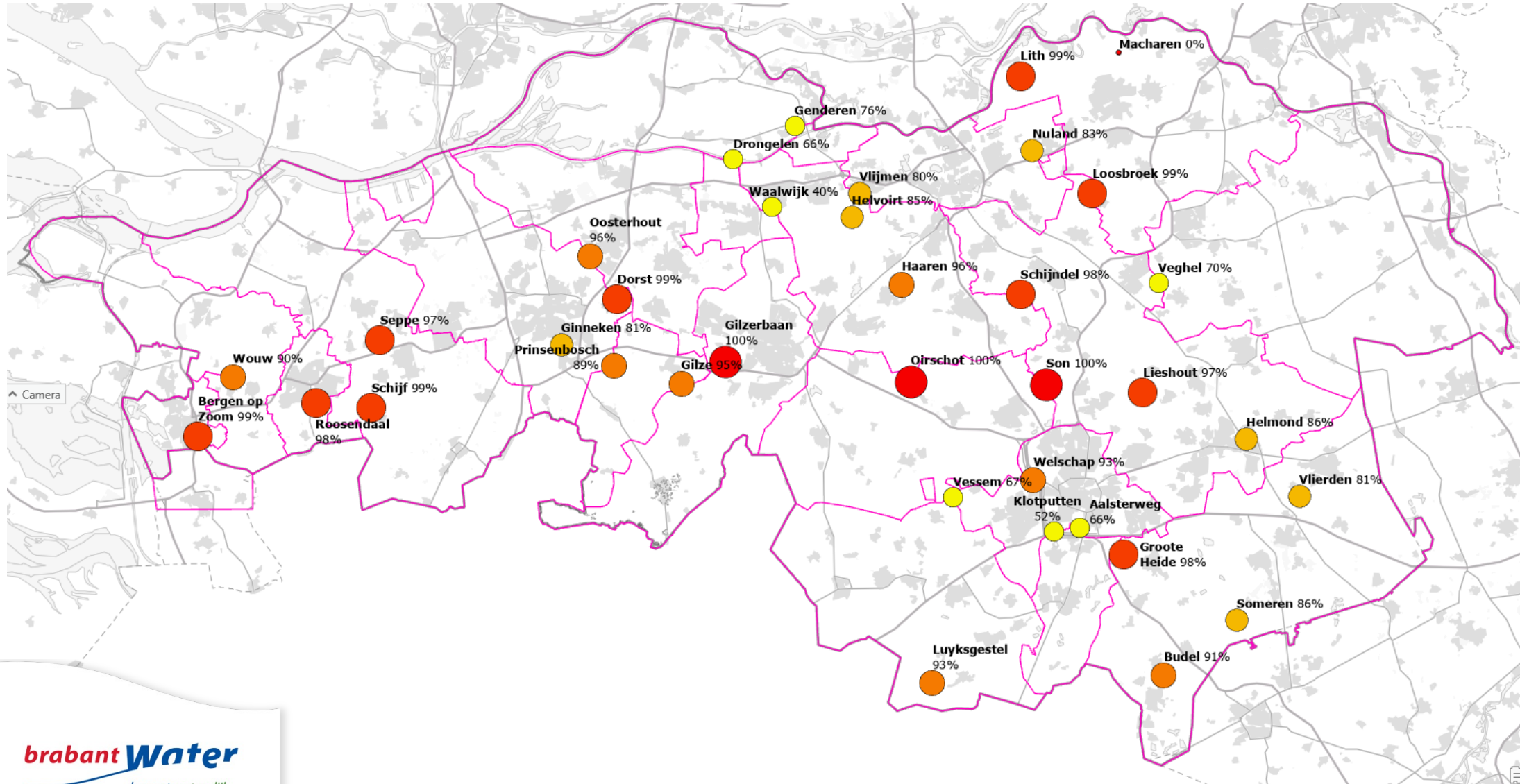
	Zeewater	Genderen	Zevenbergen
Chloride	15-20	2,5-3,5	0,25-0,4
Recovery	30%	65%	75%
Energie RO	45 bar	15 bar	5 bar
Energie m3	150 bar	23 bar	7 bar



# Water supply: increase in demand for drinking water

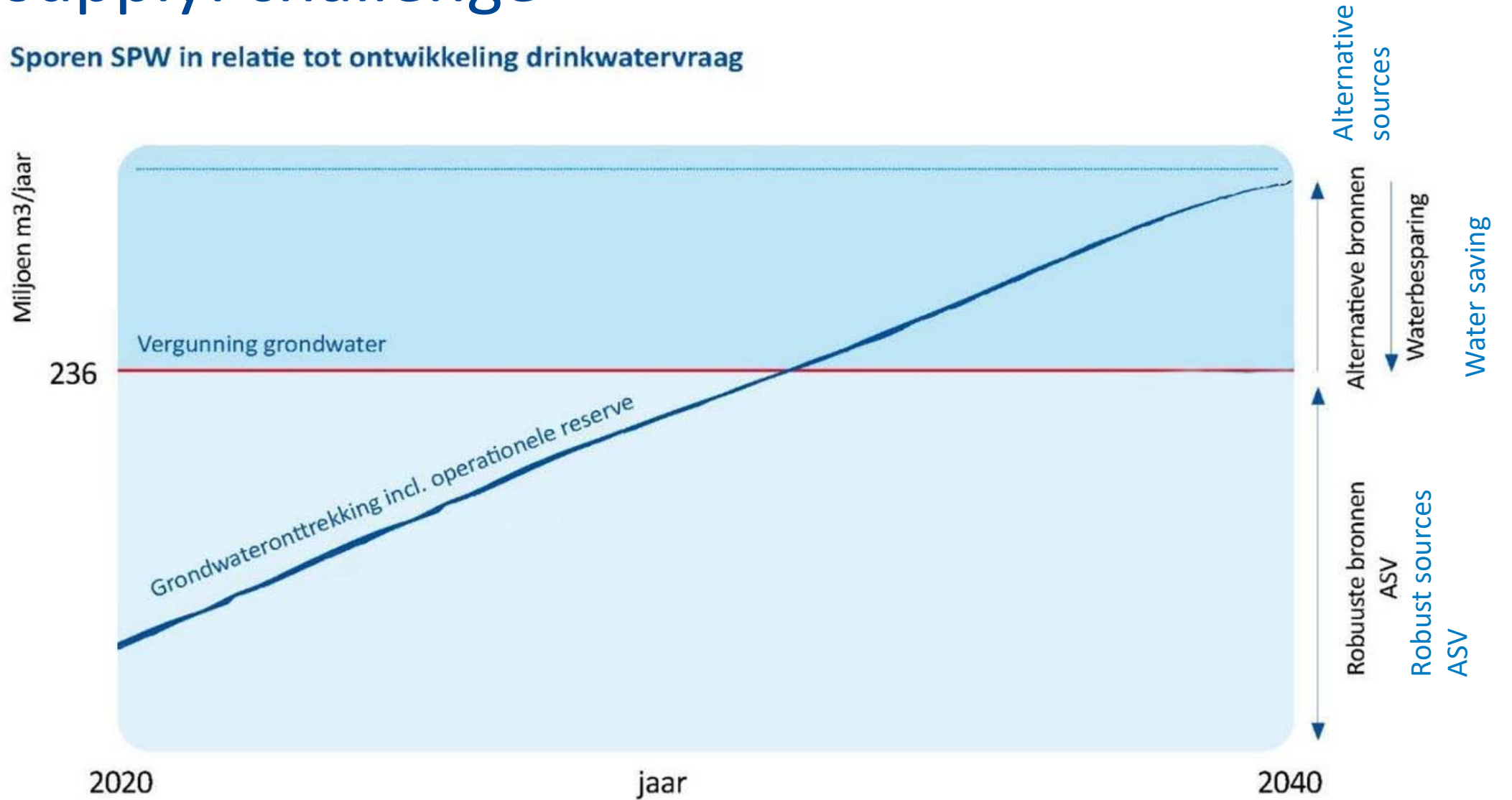


# Percentage of permits used in 2020



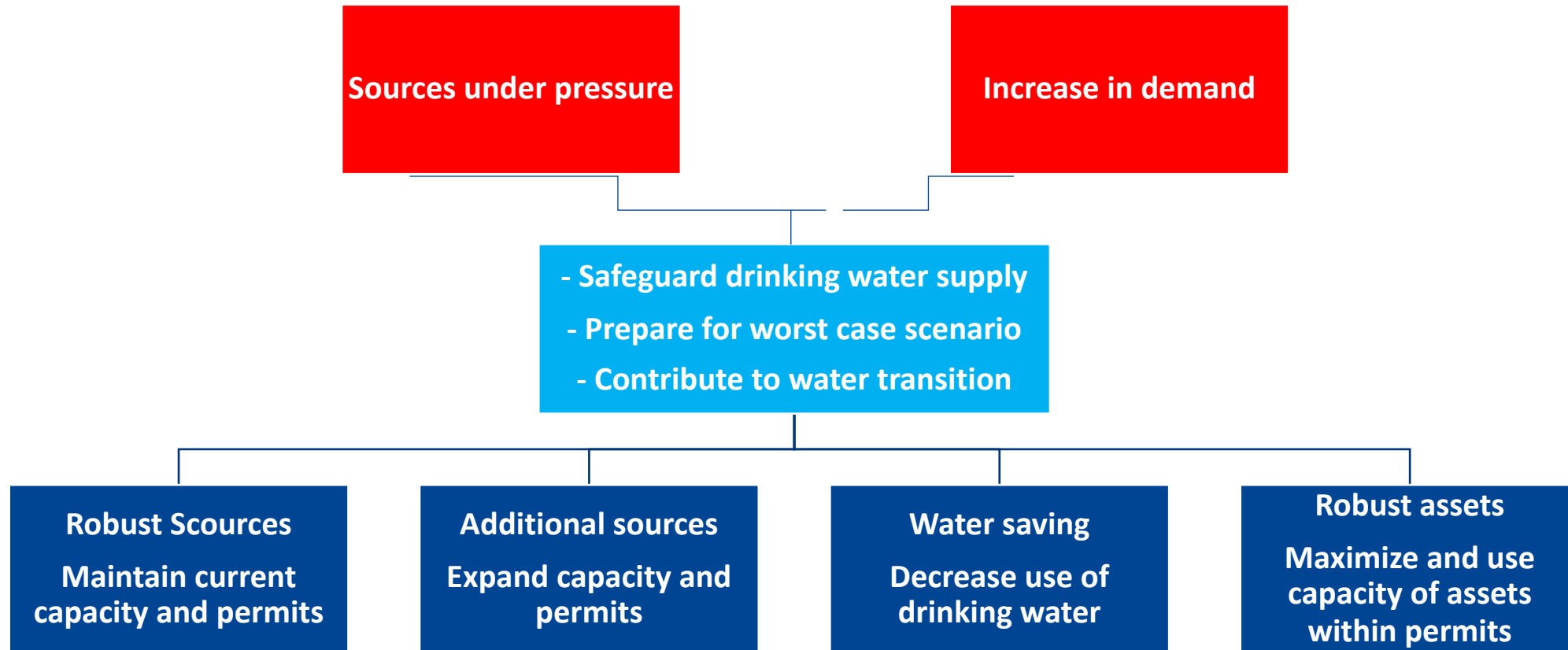
# Water supply: challenge

Sporen SPW in relatie tot ontwikkeling drinkwatervraag



# Our strategy

*Our strategy in four tracks*



# Goal / Assignment / ambitions

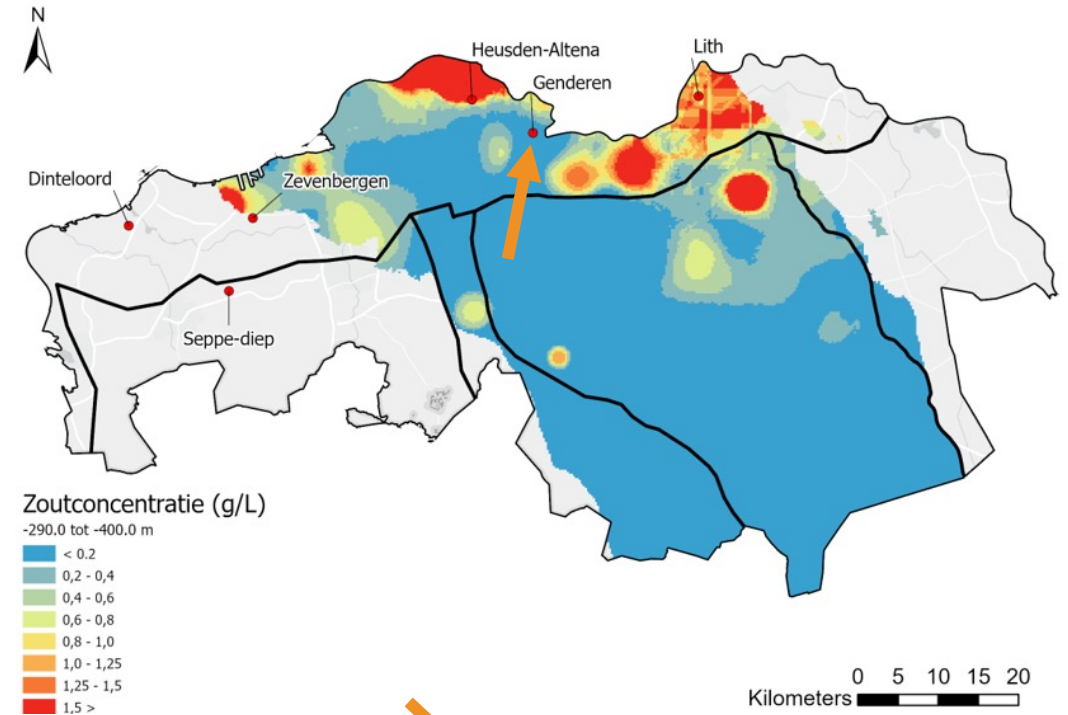
- Brabant Water wants to produce 20 million m<sup>3</sup>/y drinking water from additional sources before 2030
- Focus on brakisch and sea water.
- Contribute to the water transition of Province of Noord-Brabant
  
- Project Brakisch Water Genderen: Produce 5 million m<sup>3</sup>/y drinkwater from brakisch ground water.
- After succesfull implementation, a 2nd location will be started
- Sea water project at Bergen op Zoom has started

# Tasks project team

## Produce 5 million m<sup>3</sup>/y drinking water from brackish ground water\*

- Ground water abstraction 8,3 million m<sup>3</sup>/y
- Desalination via (RO), produces concentrate stream
- Abstraction at Drongelen, transport and treatment at Genderen
- Mix treated brackish water with drinking water Genderen for remineralisation
- First testing (pilot & abstraction test) for desired treatment, water quality, abstraction effects, soil structure and characteristics, ...
- Work together and find partnerships with province, regional water autoraties, nationwide autoraties; finding a solution for the concentrate stream

Afbeelding 9.3 Chloridegehalte diepte interval 290 tot 400 m - mv



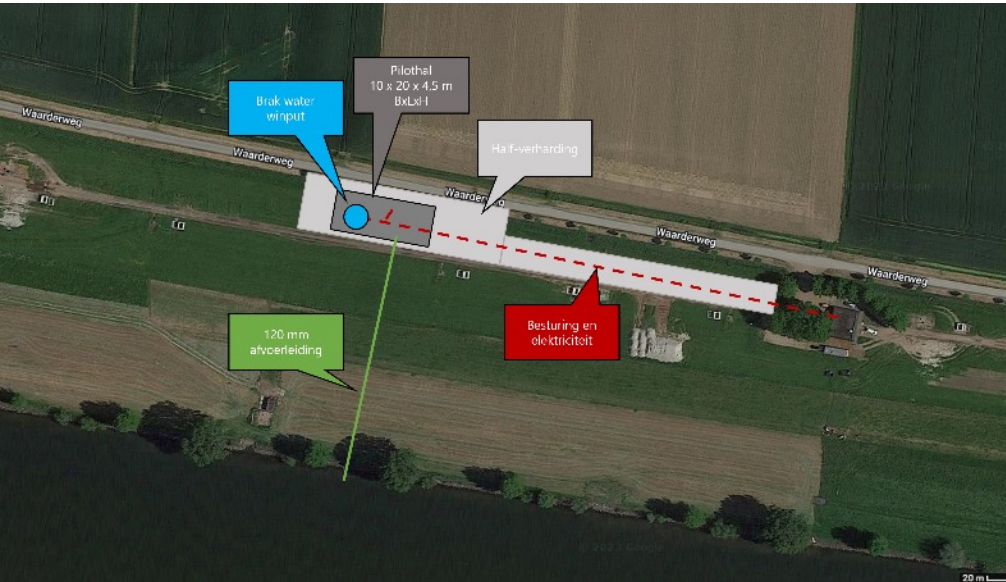
# Research phase

## Pumping / abstraction test

- One abstraction well and approx 12 measuring wells
- One month abstraction (max. 200 m<sup>3</sup>/h) to measure effects

## Pilot

- Pilot treatments (20 m<sup>3</sup>/h max.)
- Min. 2 year testing for optimal treatment, water quality and waste stream



# Pilot Anaerobic

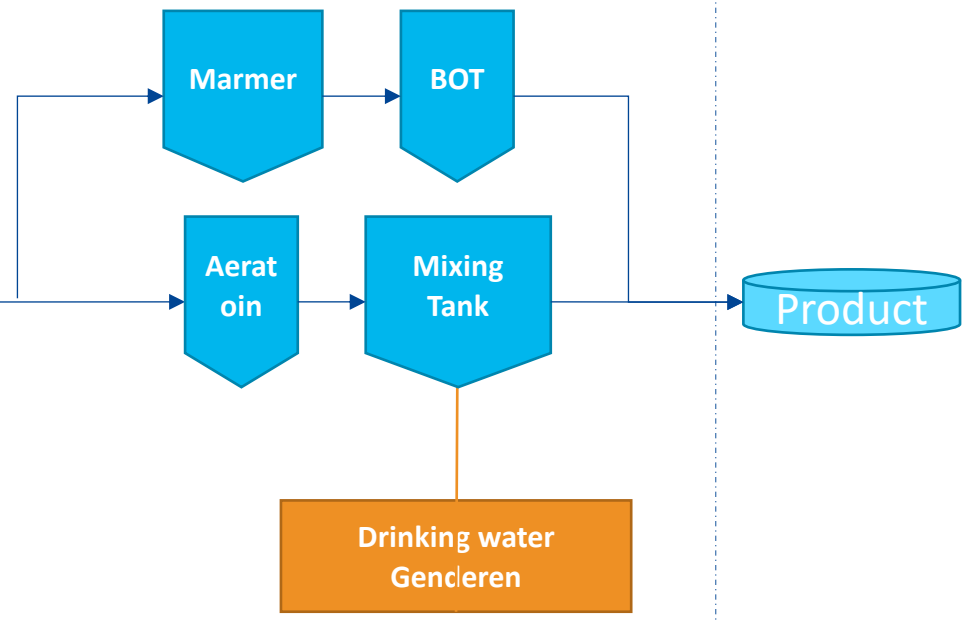
As = 50    30-40% retention    As = 30-35    →    **X**



RO

Location  
MgCl<sub>2</sub> dosing

NaOH/HCl  
conditioning



Remineralisatie