Master thesis in M.Sc. Geoscience

Numerical modeling of the effects of climate change on Bremerhaven's groundwater

Sina Julius

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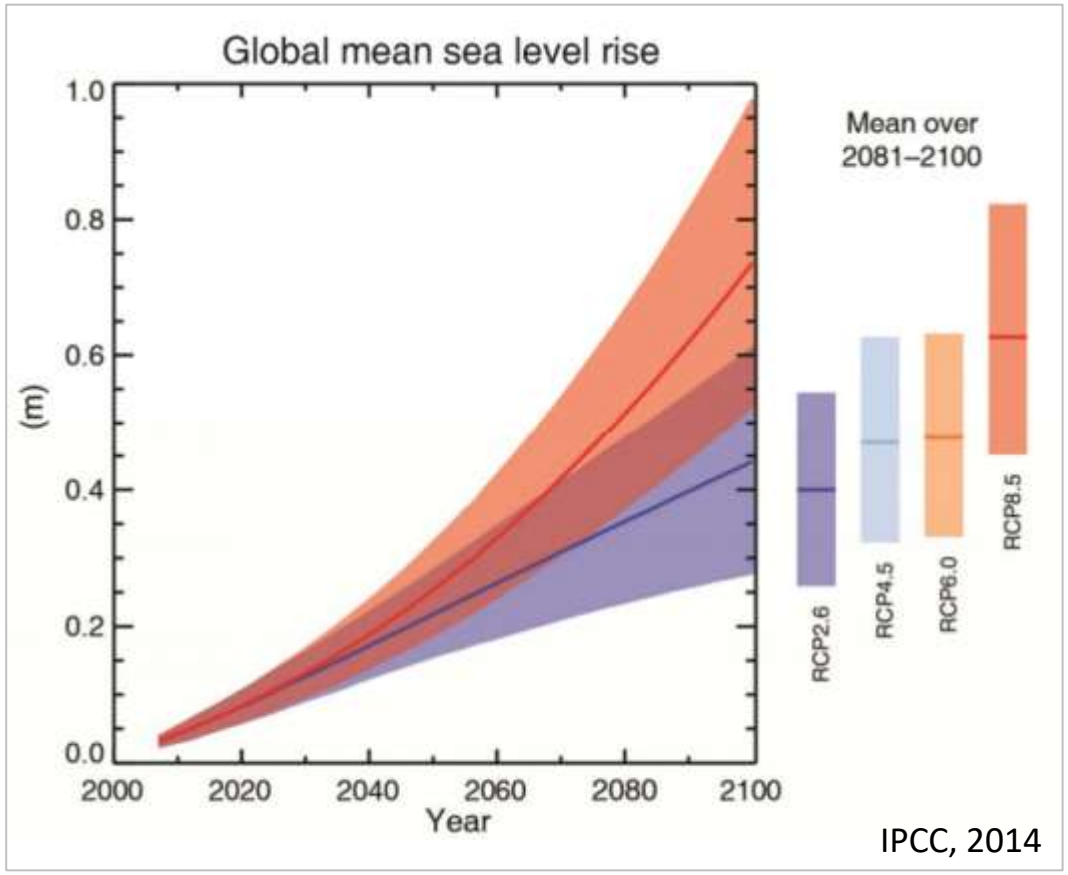
Universität Bremen

TOP SOIL Interreg North Sea Region European Regional Development Fund EUROPEAN UNION

Geologischer Dienst für Bremen GDfB

Climate change in Bremerhaven



- sea level rise
- decrease of the groundwater recharge rate

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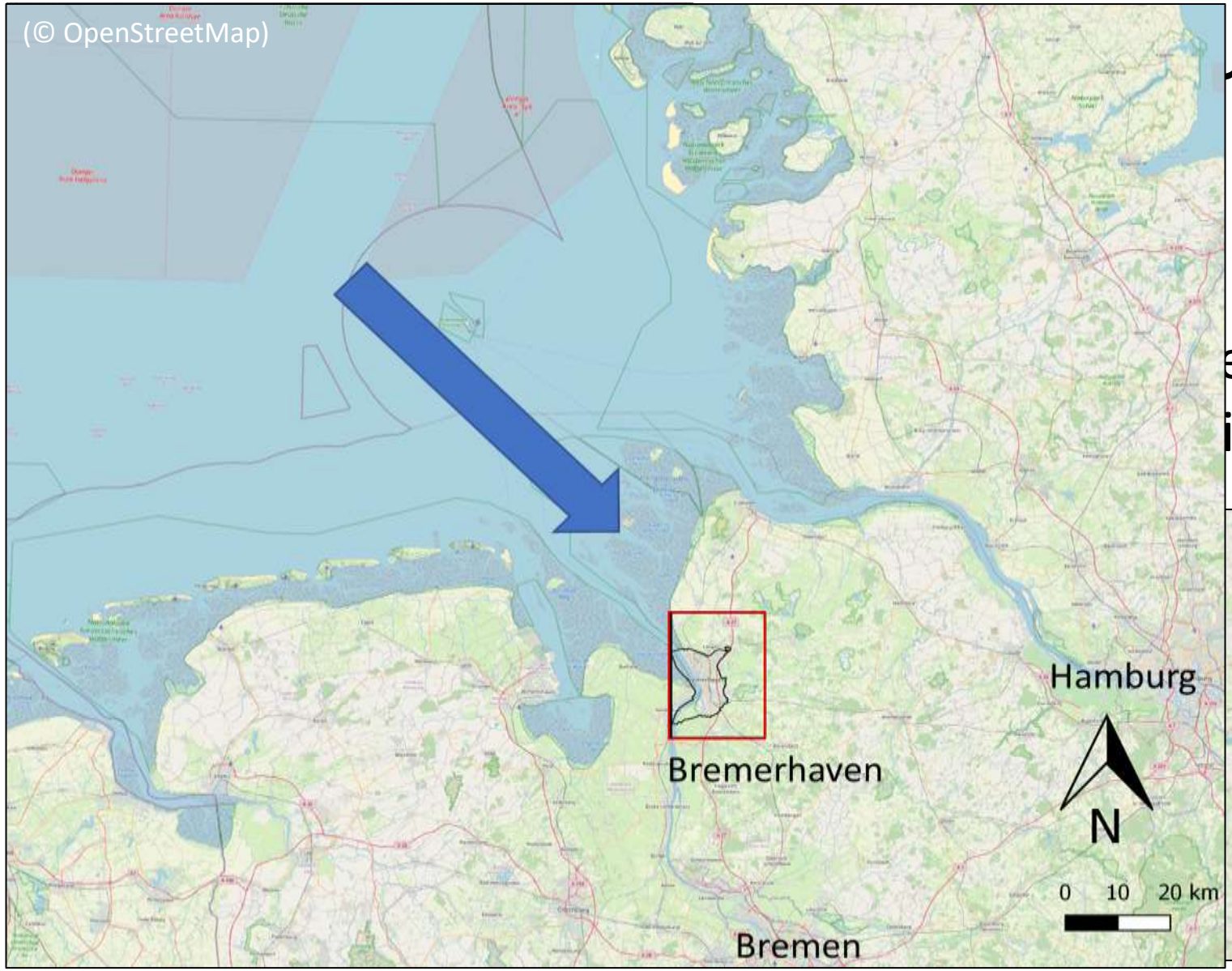
ells

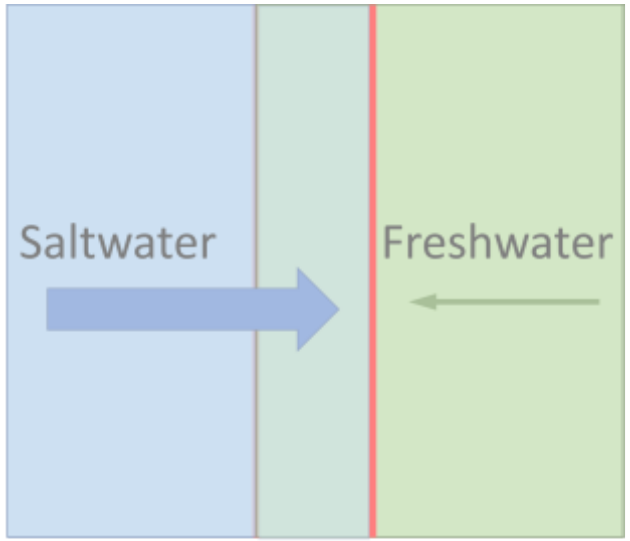
il the year 2100

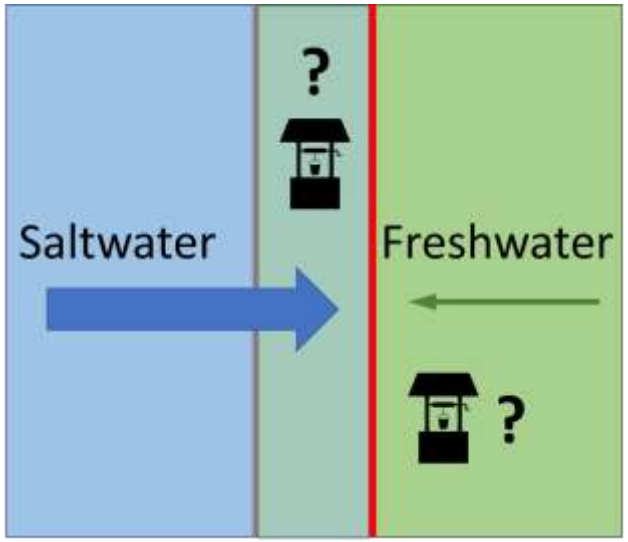


Work Hypotheses

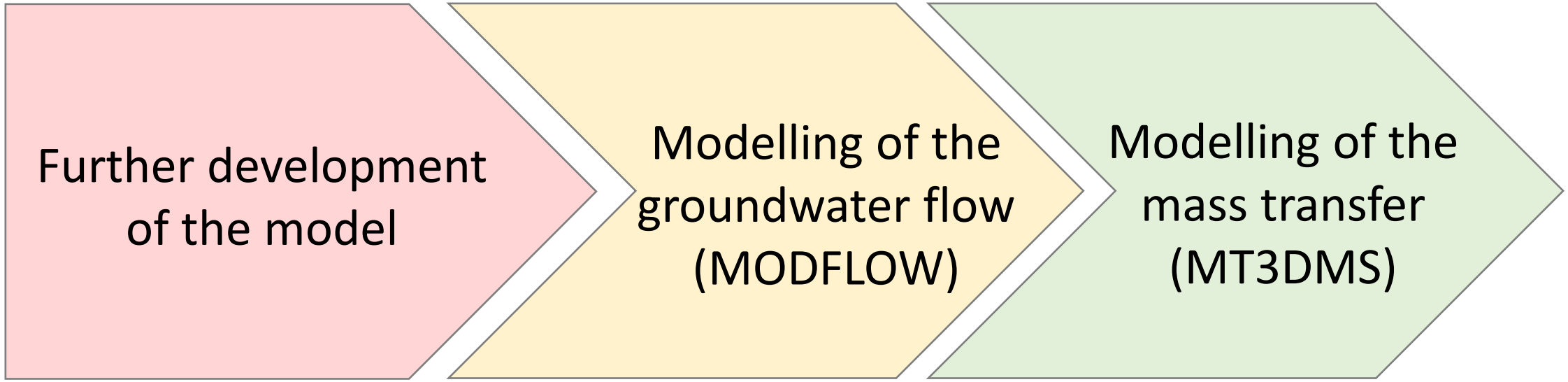
A. The rising sea level and the decreasing groundwater recharge rate will cause a saltwater intrusion of several 100 meters into Bremerhaven's groundwater towards the interior of the city by the year 2100.

B. The intrusion of salt water into the groundwater will affect the production of drinking and process water in Bremerhaven until the year 2100.



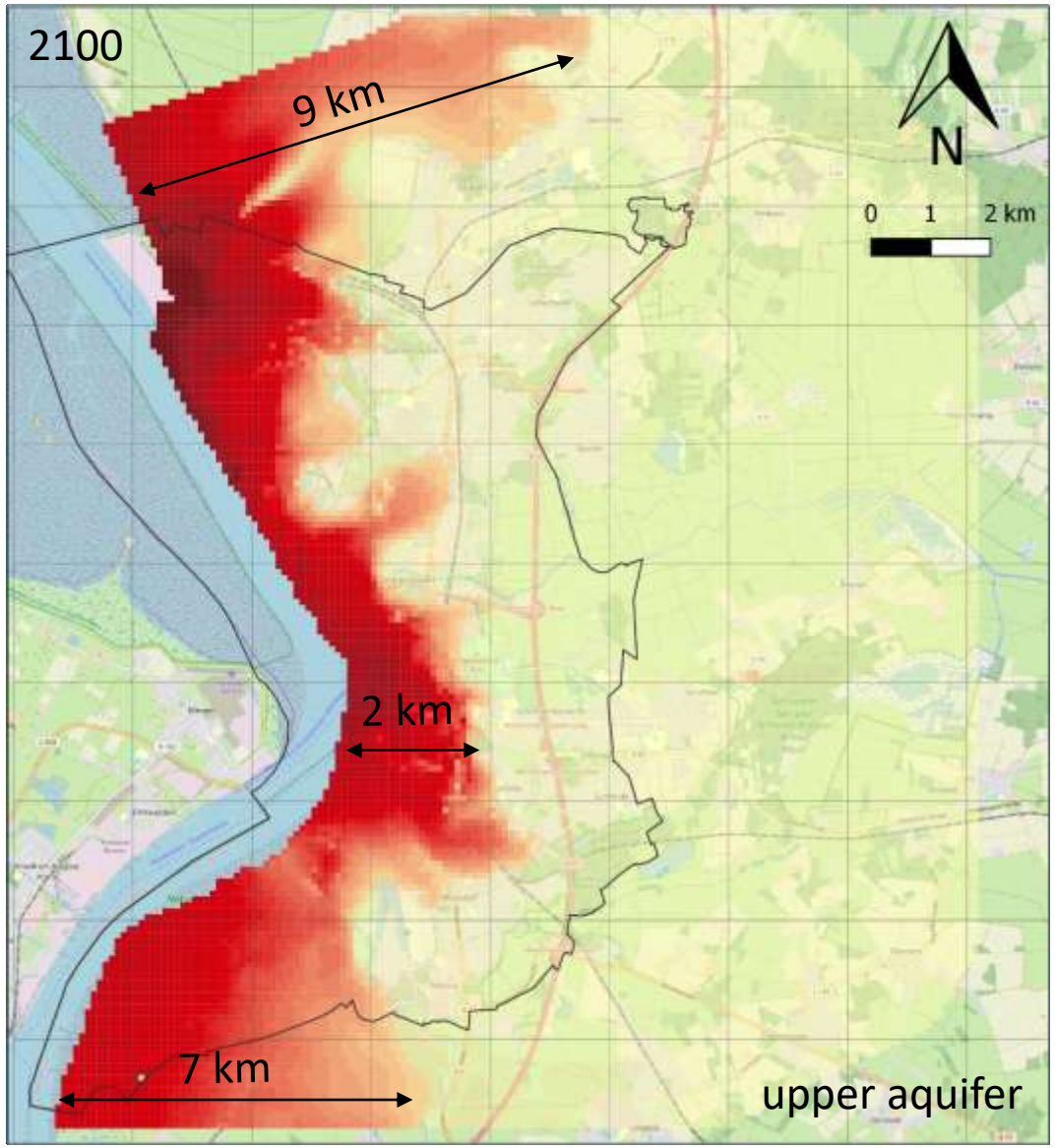


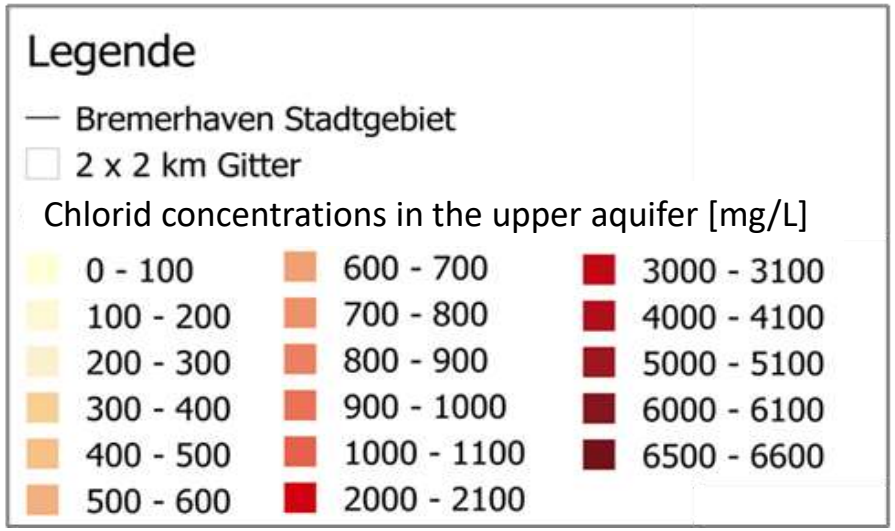
Model Work



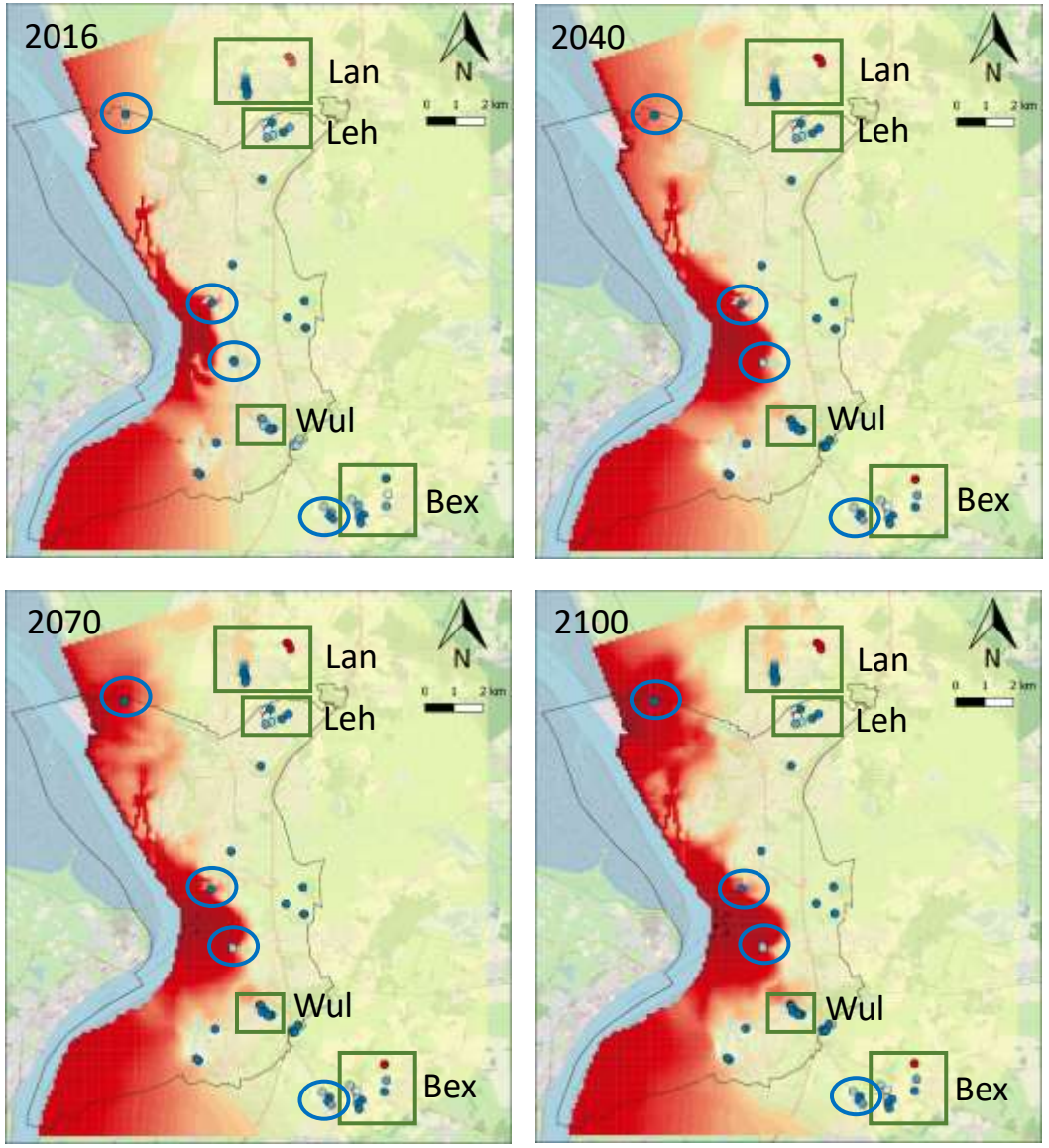
- verification of the existing model
- Implementation of current withdrawal quantities and current groundwater levels
- Implementation and interpolation of chloride measurements

Hypothesis A (salt water intrusion)





Hypothesis B (Danger to wells)



Legende

— Stadtgebiet Bremerhaven

Groundwater extraction [m3/d]

- 1400 - 1585
- 1200 - 1400
- 1000 - 1200
- 800 - 1000
- 600 - 800
- 400 - 600
- 200 - 400
- 0 - 200

Chlorid concentration in upper aquifer [mg/L]

- 300 - 400
- 600 - 700
- 1000 - 1100
- 5000 - 5100
- 8000 - 8100
- 10100 - 10177

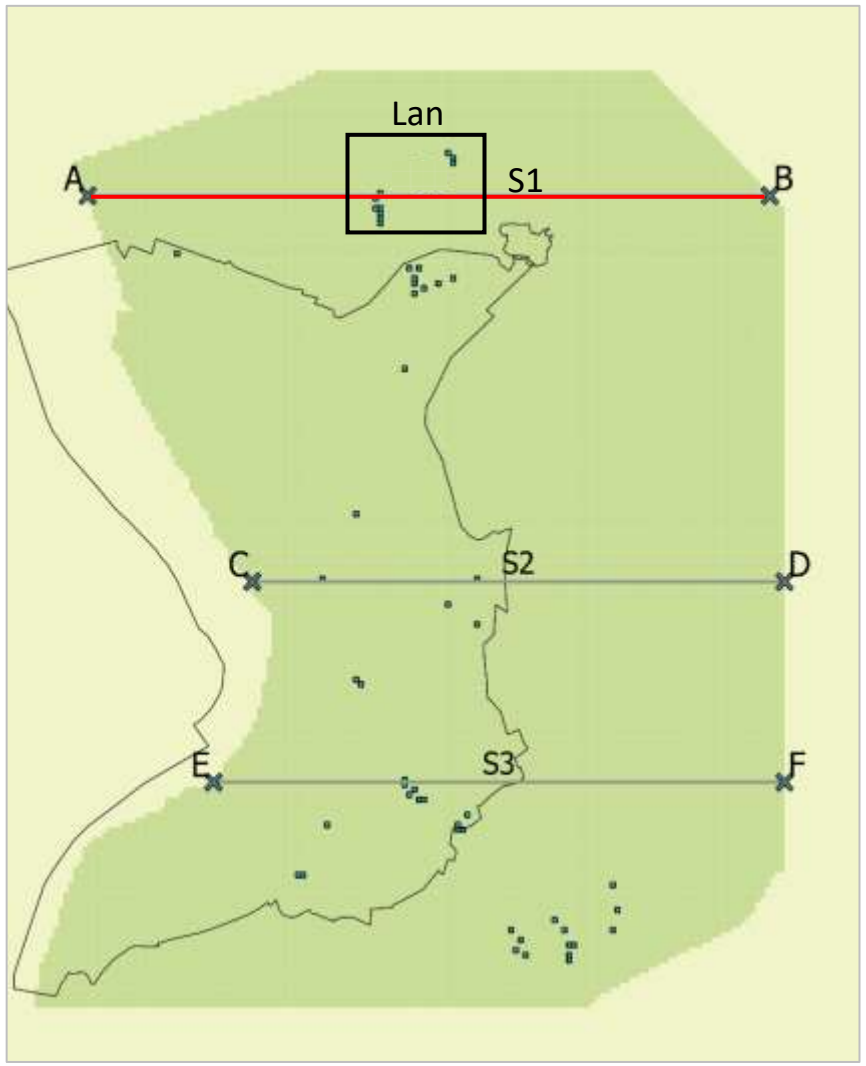
Waterworks

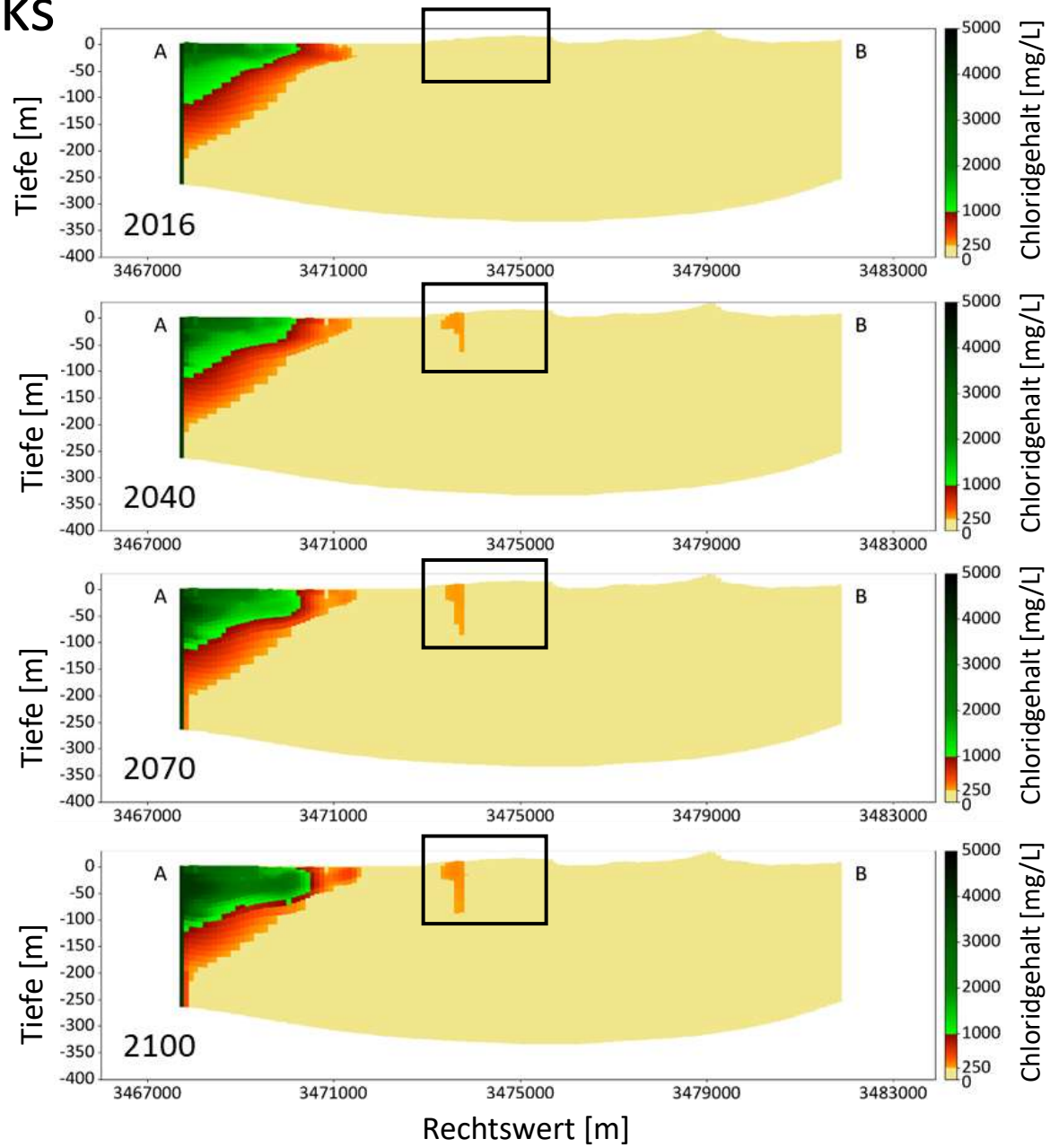
- Langen
- Leherheide
- Wulsdorf
- Bexhövede

Wells (from N to S)

- Kläranlage
- Technische Marine-schule
- Institut für Fischerei-ökologie
- Emery Oleochemicals

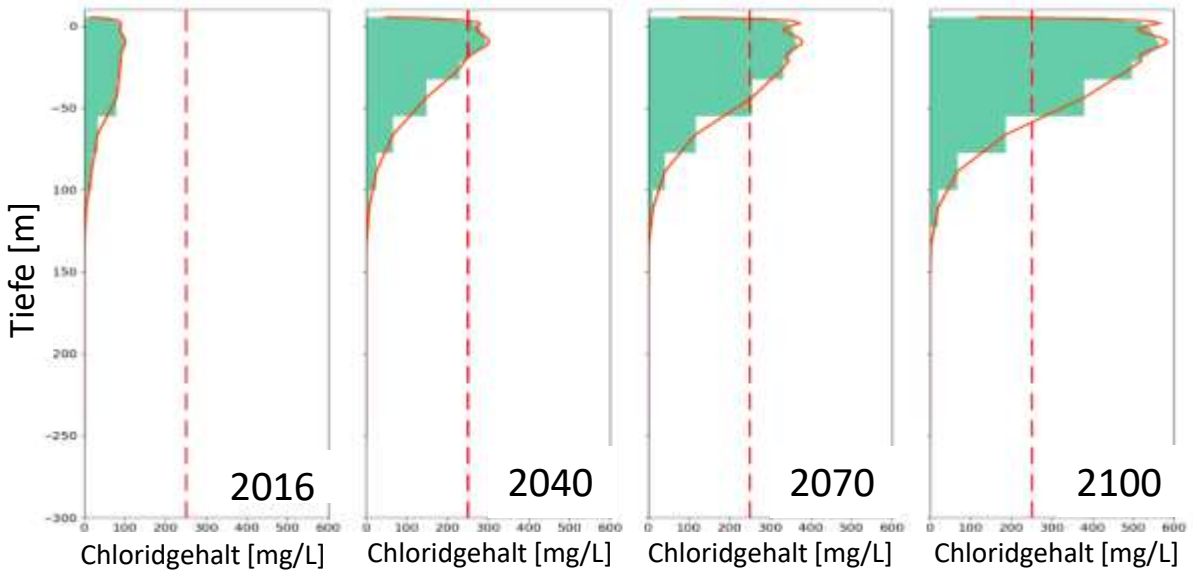
Danger to the Langen waterworks

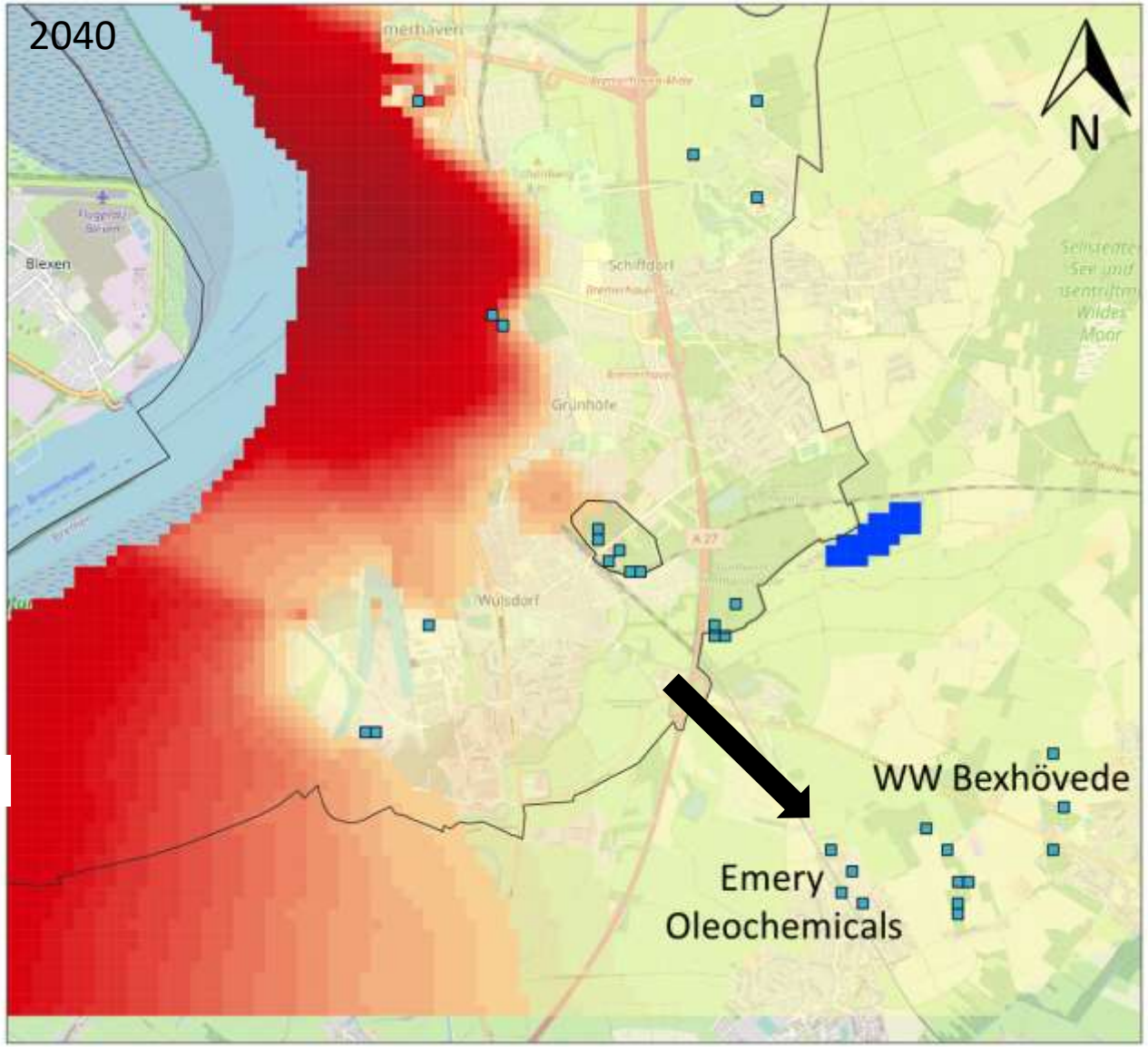




Danger to the Bexhövede waterworks

Wells Oleochemicals





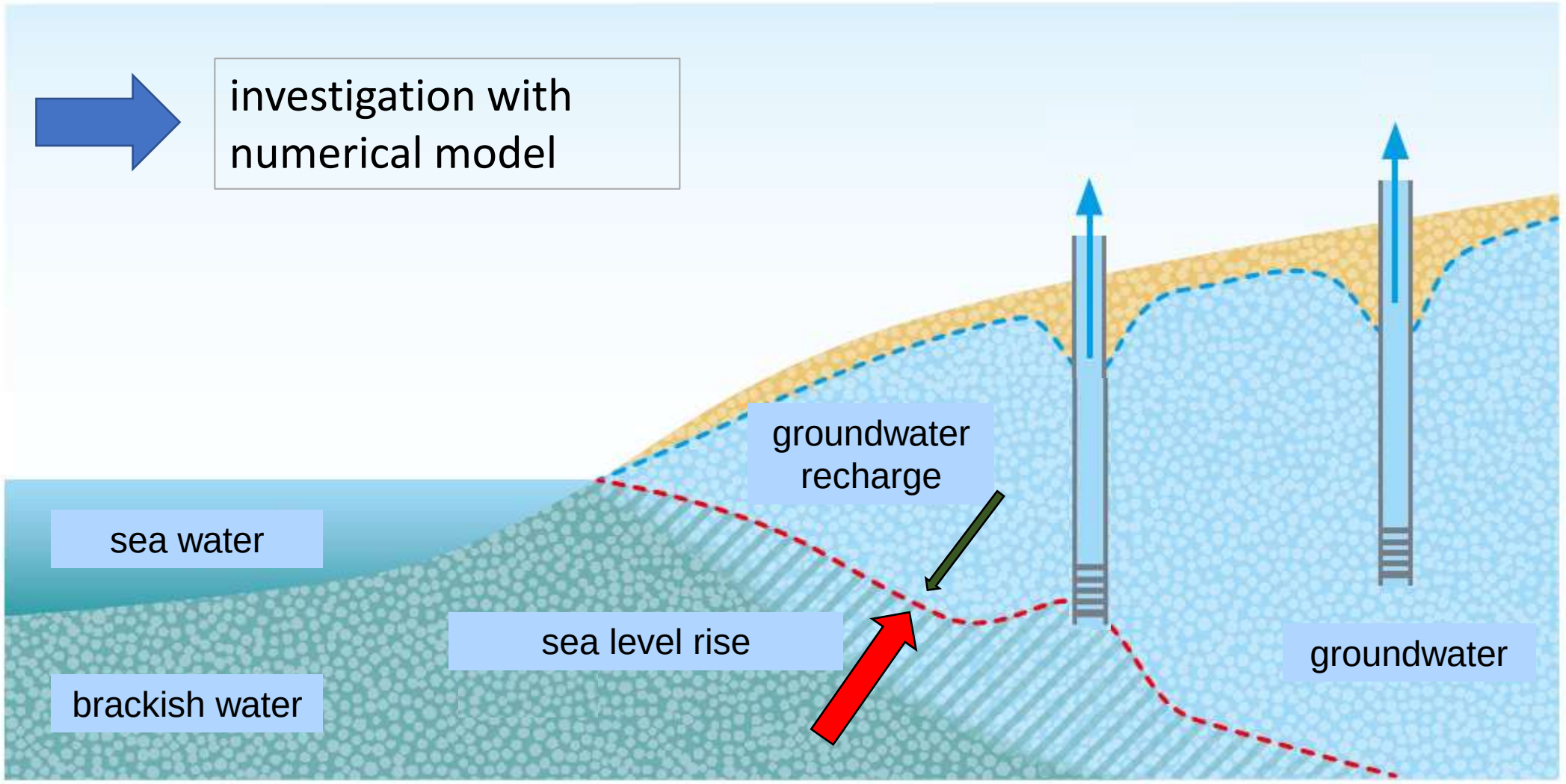
Outlook

- Simulation of possible countermeasures in the area of WW Langen and WW Bexhövede
- Improvement of the data basis
  - update the climatic influences
  - update the measured values
  - extend the measured values

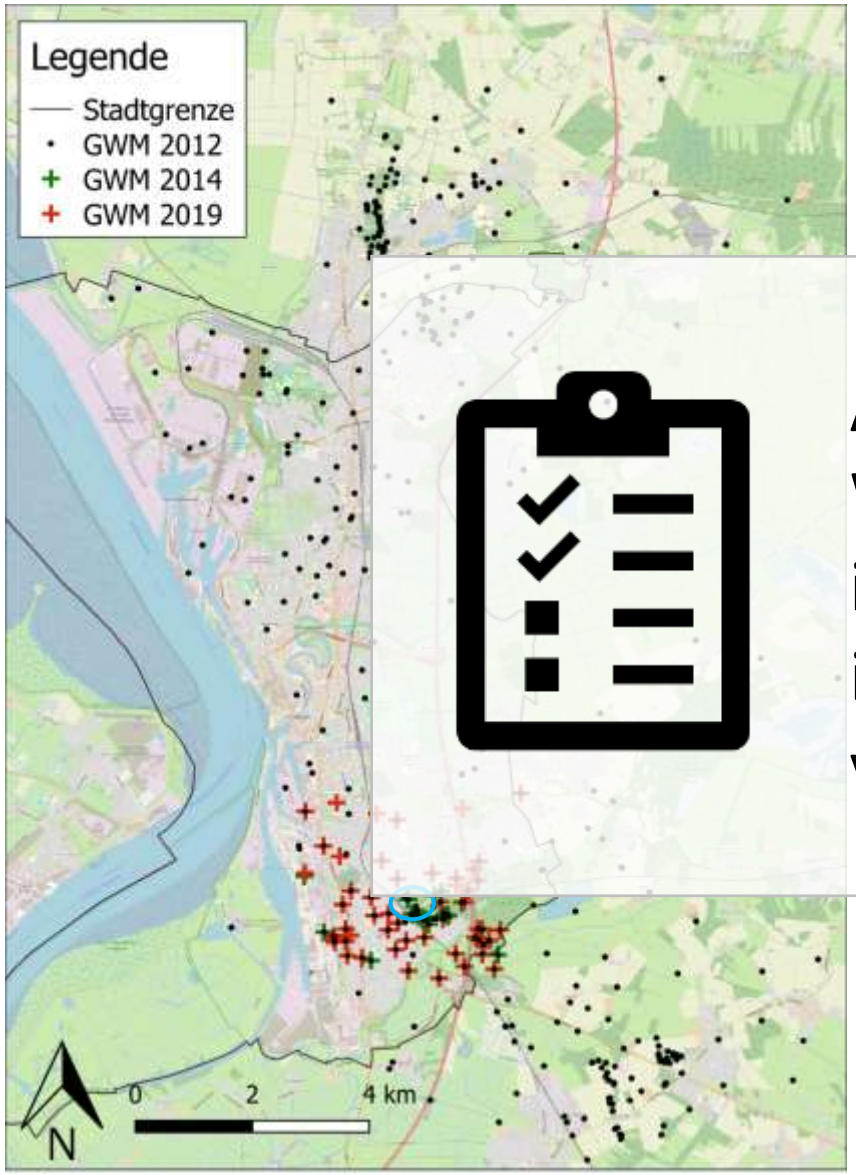
References

- Geodaten (2020) © OpenStreetMap und Mitwirkende, CC-BY-SA
- https://www.nonstopnews.de/thumbs/8c/8c7a077212cda99a3fcdcad60d5f050b.jpg
- https://www.nord24.de/Bilder/Bereits-am-Montag-war-es-wegen-einer-Sturmflut-zu-43408.jpg
- Panteleit, Björn; Jensen, Sven; Seiter, Katherina; Siebert, Yvonne (2018): Das Bremerhavener Grundwasser im Klimawandel. In: *Grundwasser* 23 (3), S. 233–244. DOI: 10.1007/s00767-017-0385-9.
- USGS (2008): SEAWAT Version 4. A Computer Program for Simulation of Multi-Species Solute and Heat Transport (Techniques and Methods Book 6, Chapter A22).

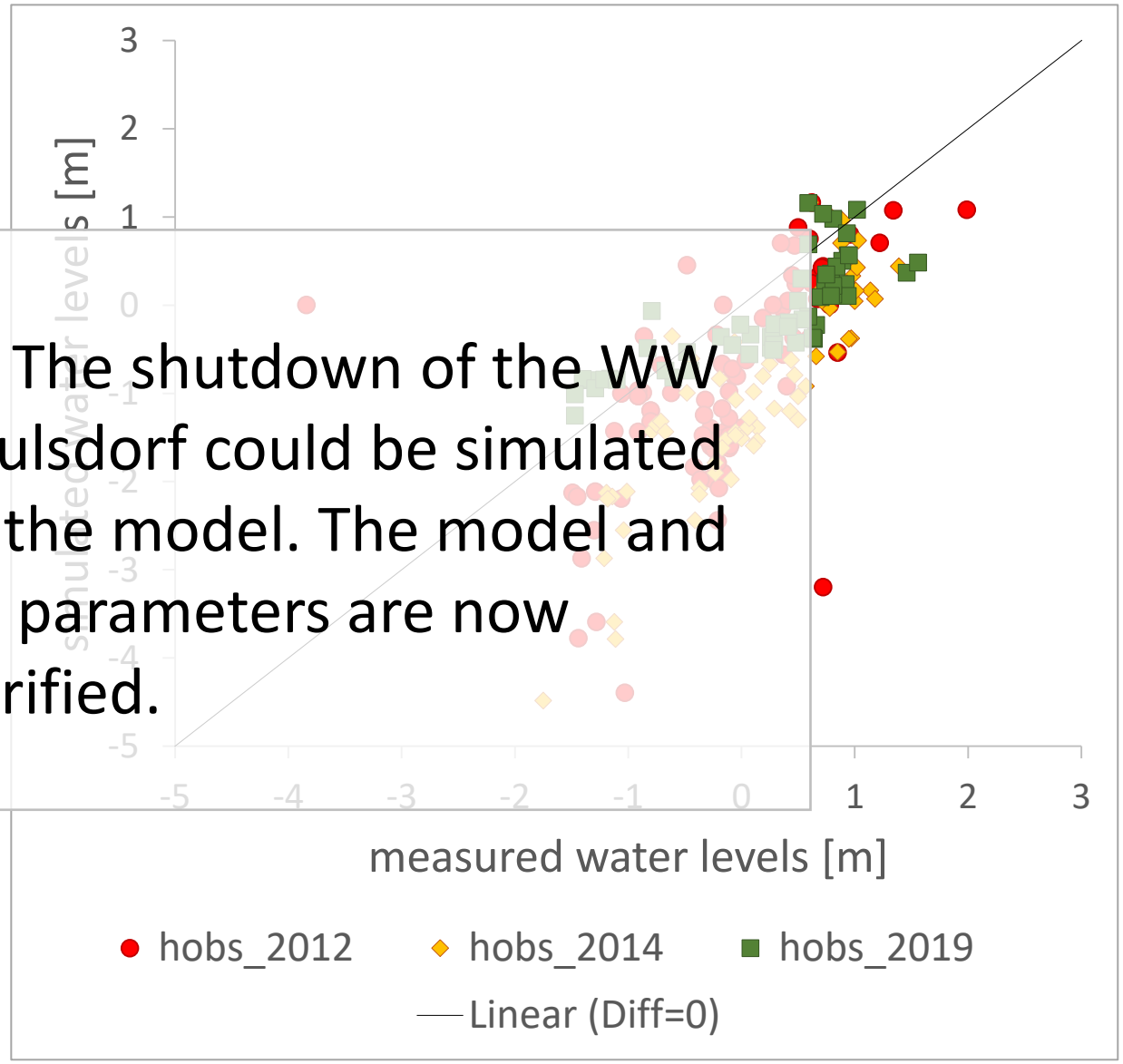
Climate influences on the groundwater



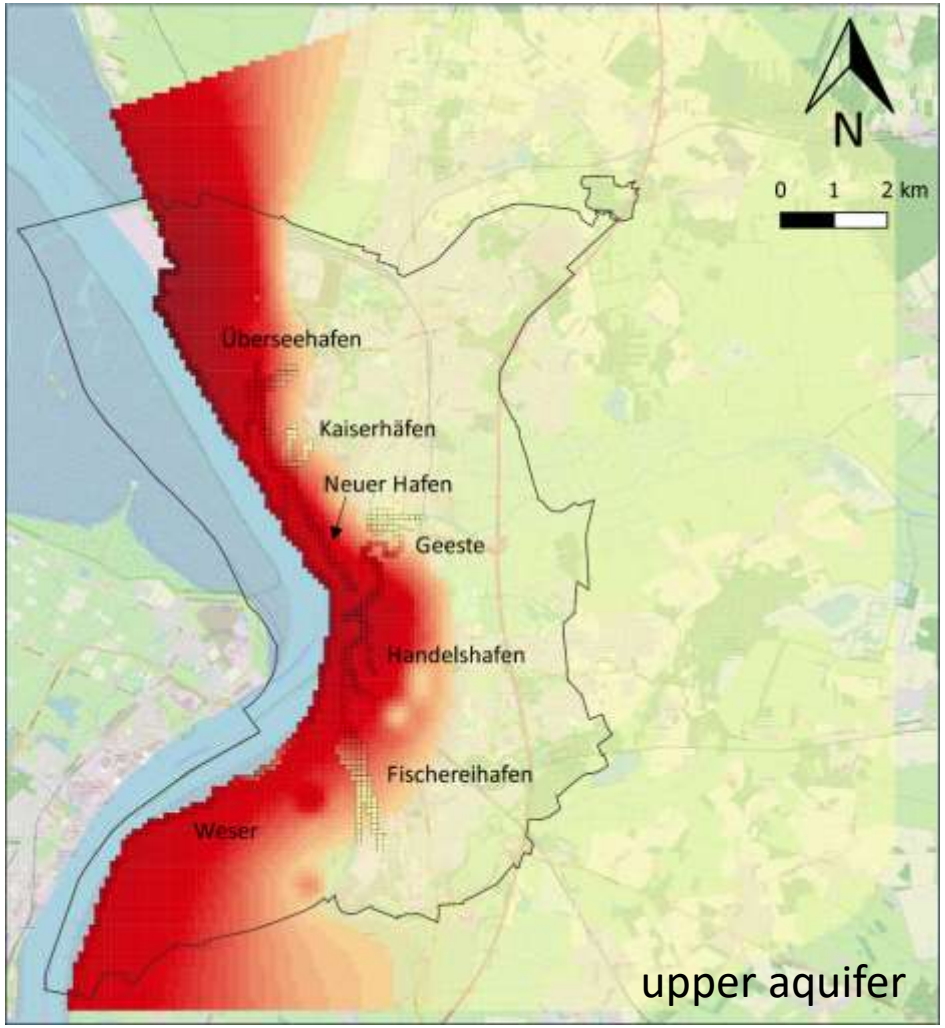
Hypothesis A (model verification)

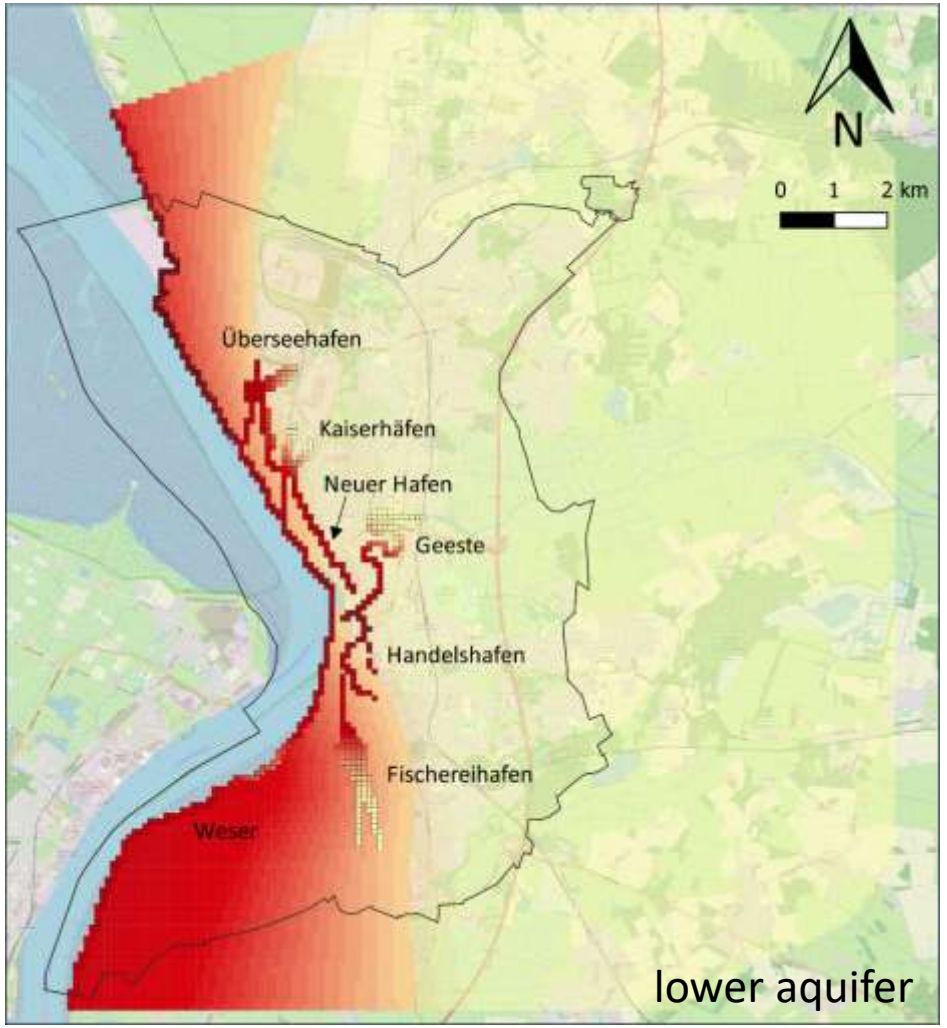


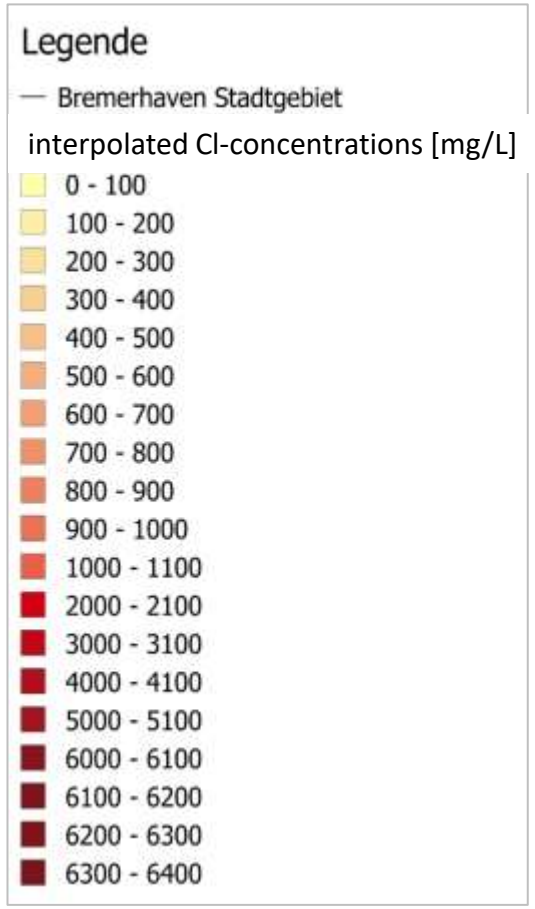
A) The shutdown of the WW Wulsdorf could be simulated in the model. The model and its parameters are now verified.



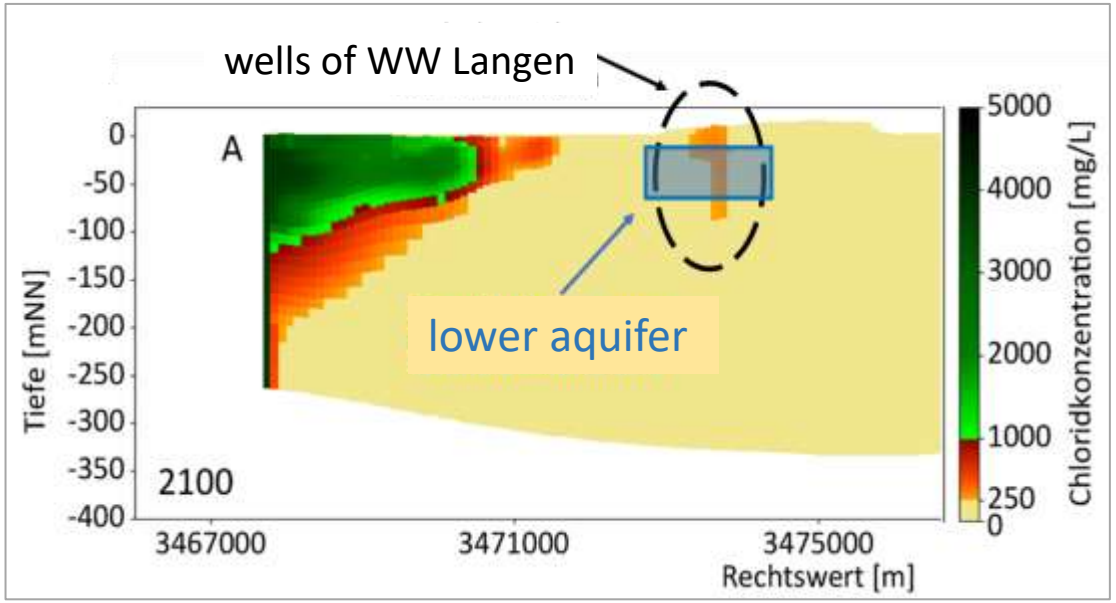
Interpolation of the measured chloride values (n=117)

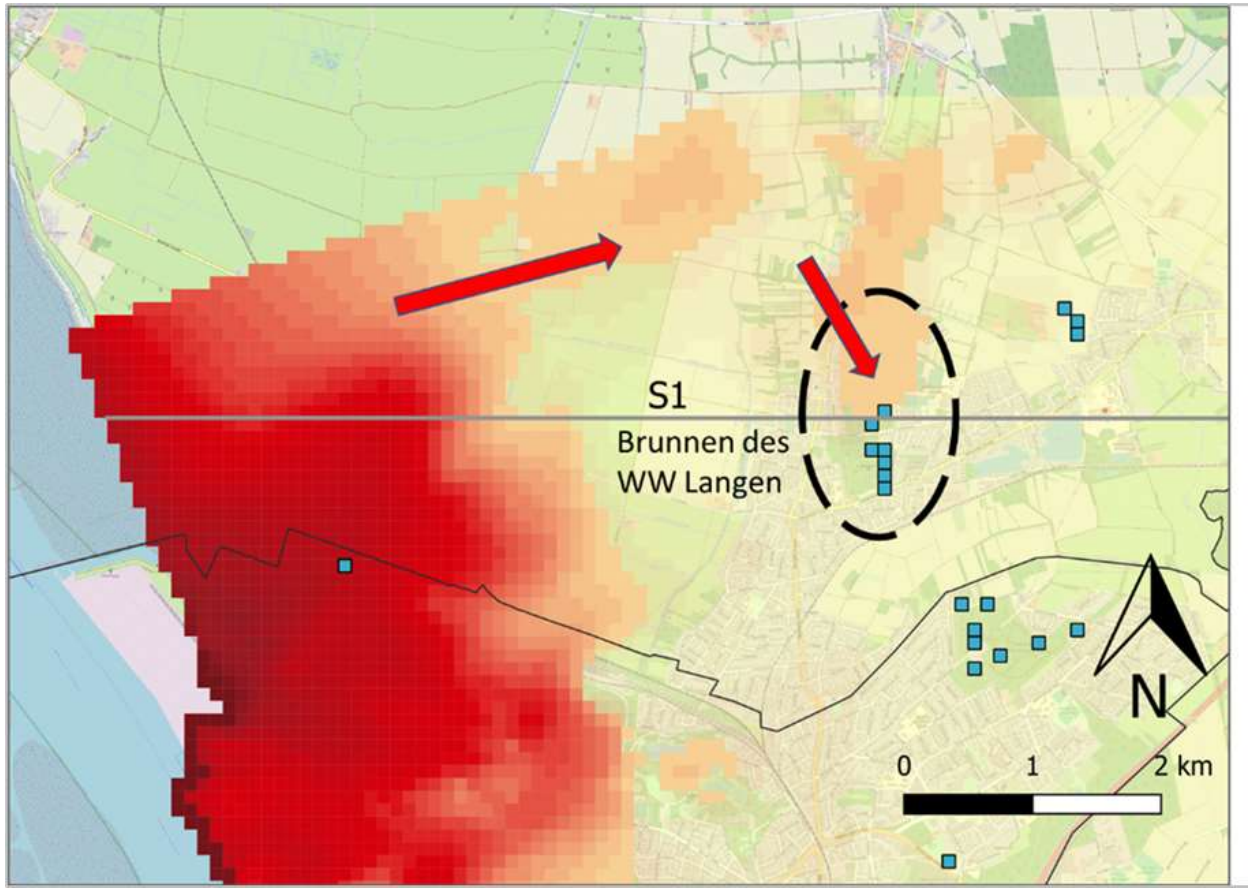


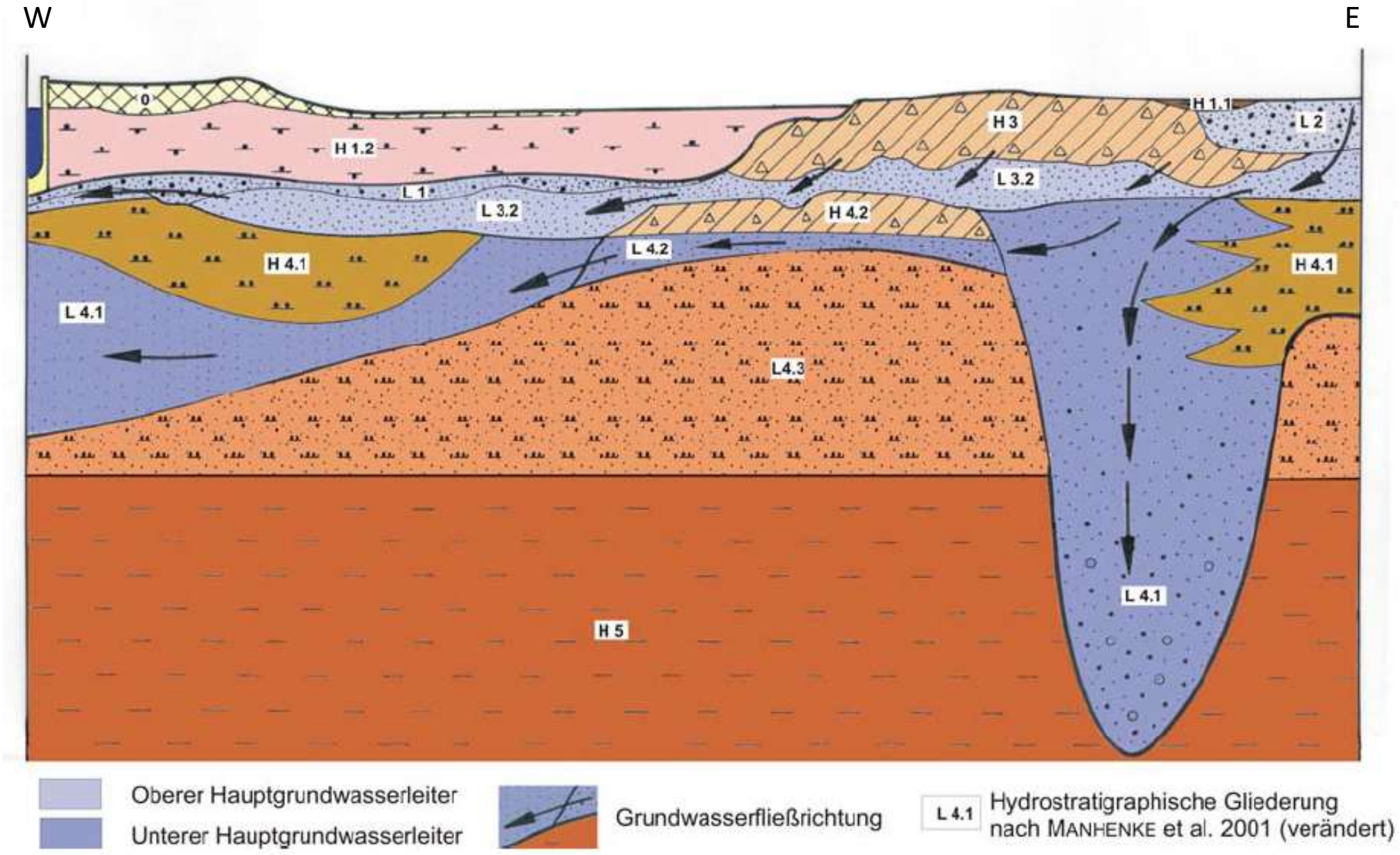


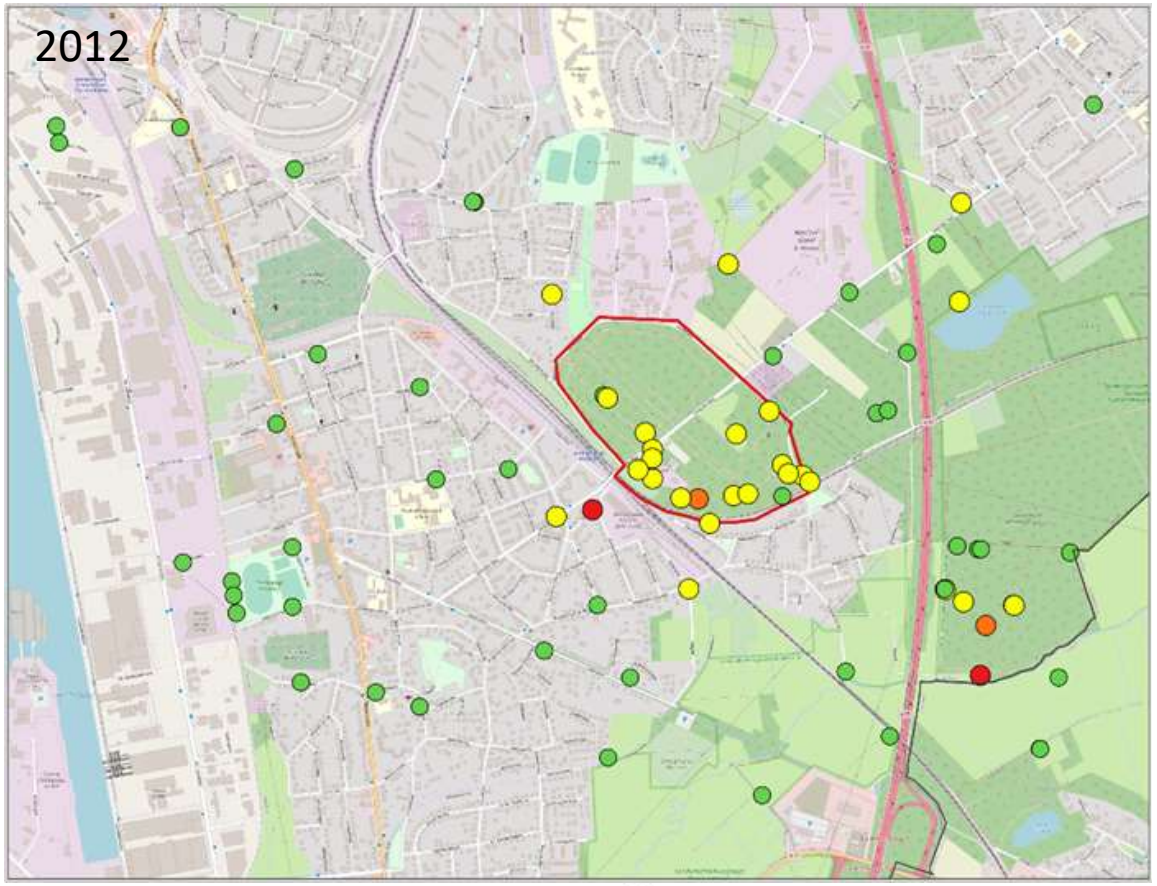


Gefährdung des Wasserwerks Langen






W
E
0
H 1.2
L 1
L 3.2
H 4.1
L 4.1
L 4.2
H 4.2
H 3
H 1.1
L 2
L 3.2
H 4.1
L4.3
L 4.1
H 5
Oberer Hauptgrundwasserleiter
Unterer Hauptgrundwasserleiter
Grundwasserfließrichtung
L 4.1
Hydrostratigraphische Gliederung
nach MANHENKE et al. 2001 (verändert)


2012
Legende
Gebiet des Wasserwerks Wulsdorf
Differenzen des Layers hobs_2012_WW
3.00 - 3.92
2.00 - 3.00
1.00 - 2.00
0.00 - 1.00
-0.93 - 0.00
N
0 250 500 m

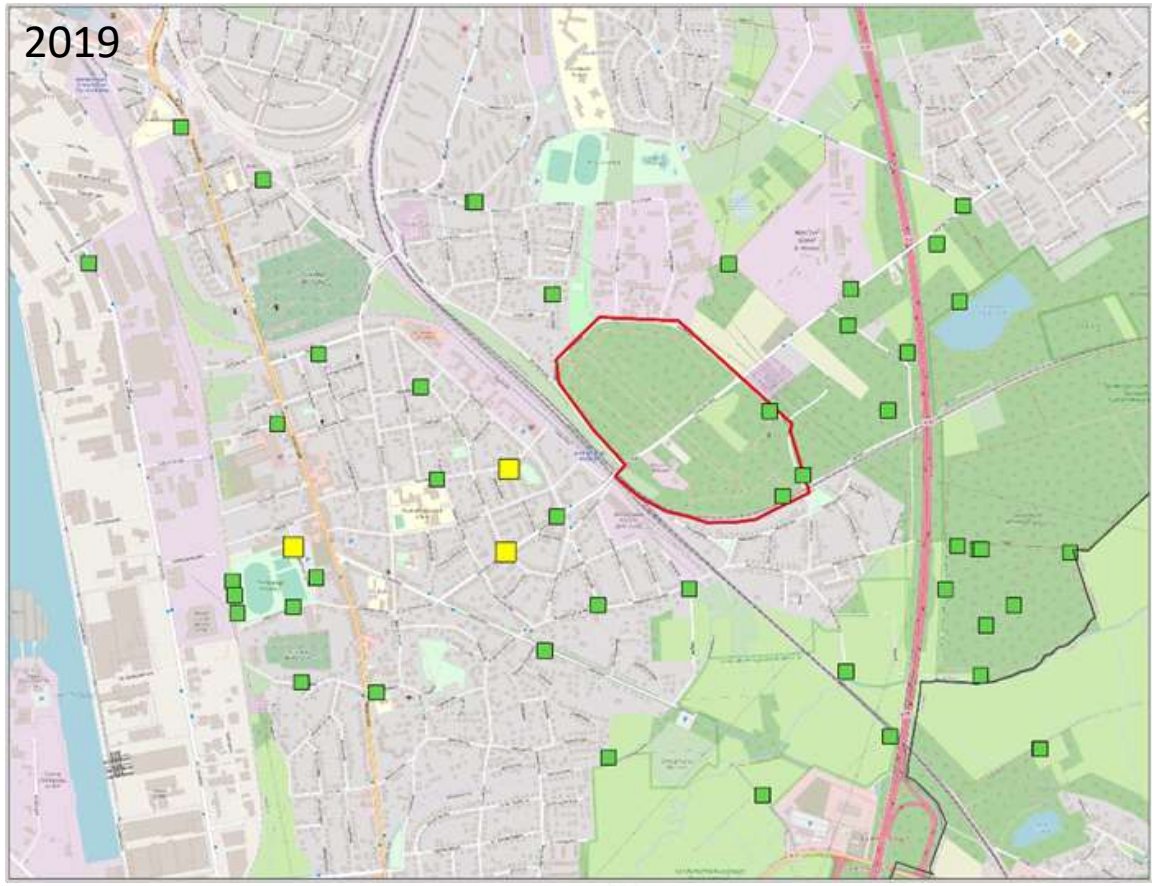

2019
Legende
Gebiet des Wasserwerks Wulsdorf
Differenzen des Layers hobs_2019_WW
1.000 - 1.090
0.000 - 1.000
-0.720 - 0.000
N
0 250 500 m

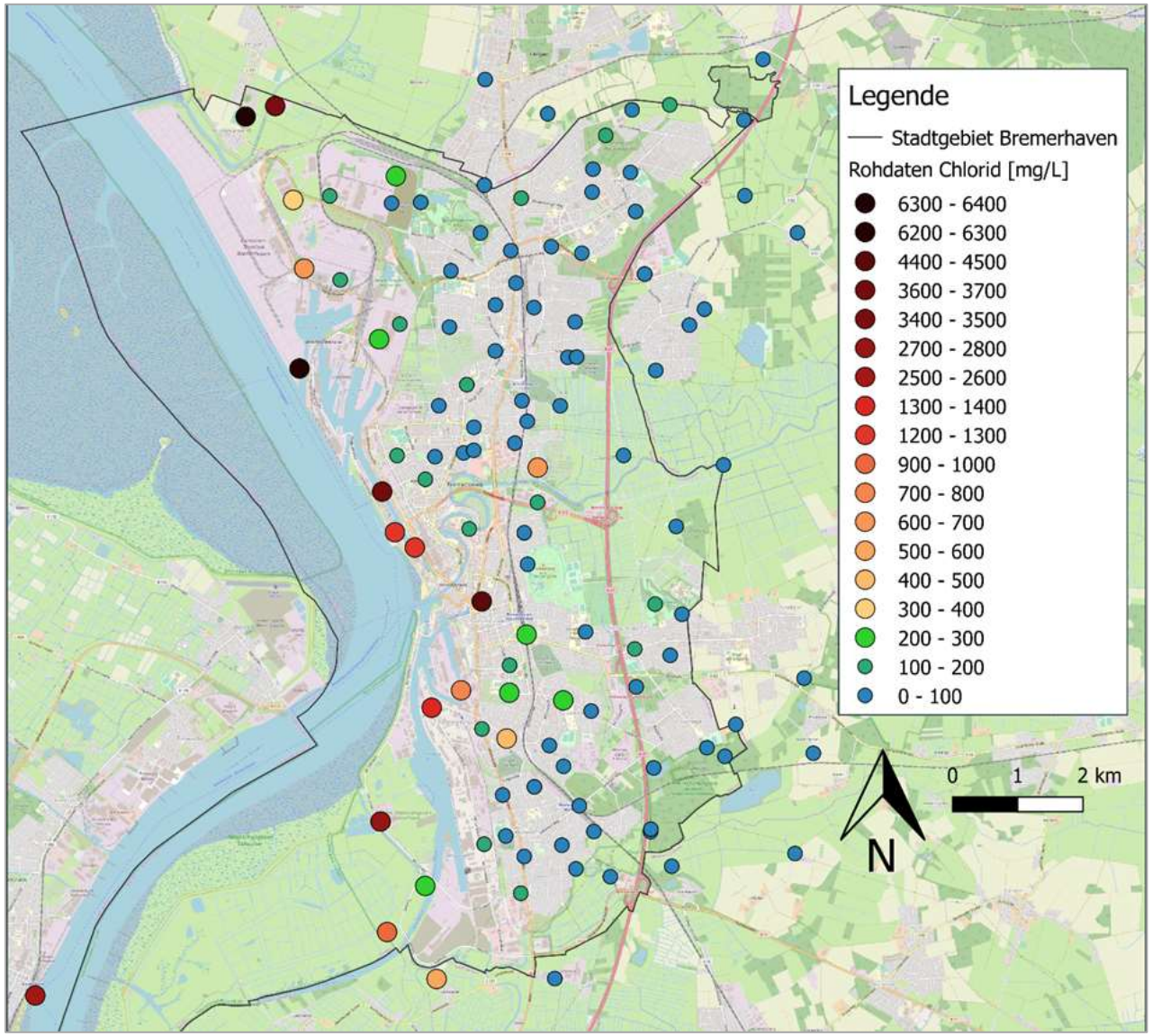
Tabelle 7: Statistische Analyse der Differenzwerte (observiert - simuliert) der Grundwassermessstellen in den Jahren 2012, 2014 und 2019 im Bereich des Wasserwerks Wulsdorf.

hobs_2012_WW	n = 85	Mittelwert $\bar{x}$	0,82 m
		Standardabweichung s	0,80 m
hobs_2014_WW	n = 69	Mittelwert $\bar{x}$	1,14 m
		Standardabweichung s	0,60 m
hobs_2019_WW	n = 62	Mittelwert $\bar{x}$	0,32 m
		Standardabweichung s	0,47 m

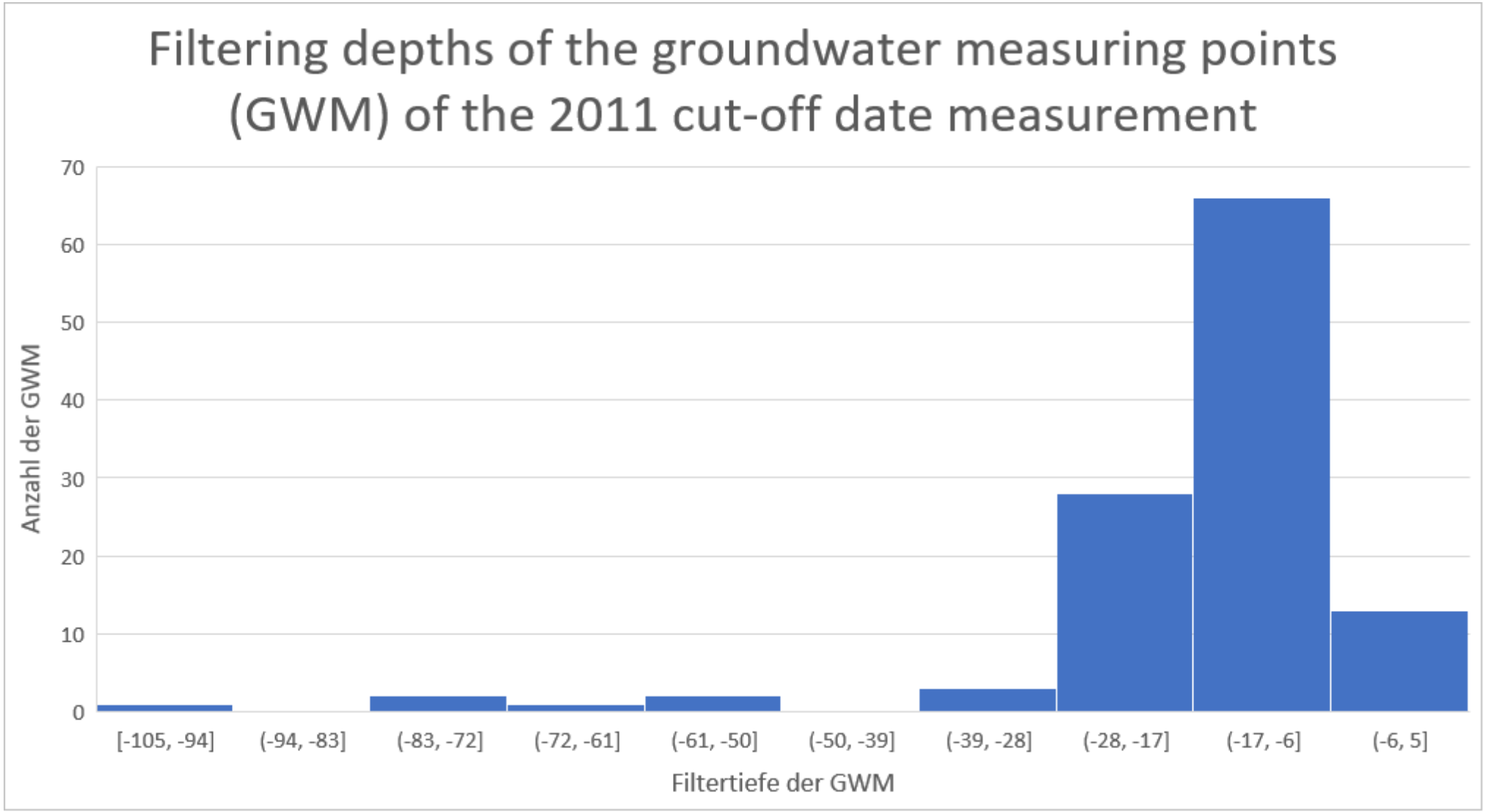
withdrawal quantities in the model area

Förderbrunnen	Gesamtfördermenge [m^3/d]
Wasserwerk Langen	7.564
Wasserwerk Bexhövede	7.105
Wasserwerk Leherheide	4.669
Institut für Fischereiökologie	1.159
Emery Oleochemicals	1.084
Technische Marineschule	4,85
Kläranlage Nord	0,86

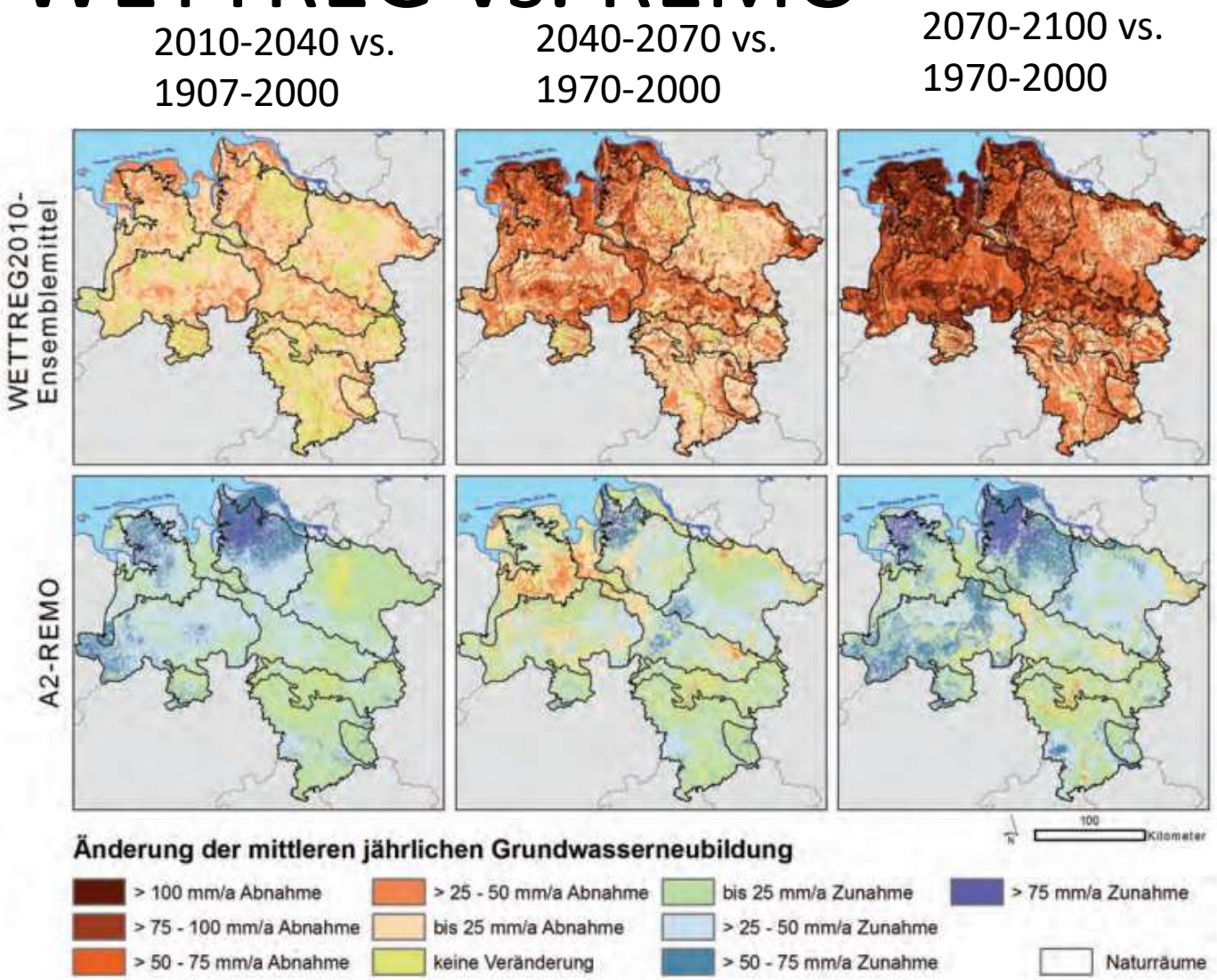
Data base (Chlorid mass transfer)



Chlorid Grenzwert für Trinkwasser:
250 mg/L


Filtering depths of the groundwater measuring points (GWM) of the 2011 cut-off date measurement
Anzahl der GWM
70
60
50
40
30
20
10
0
[-105, -94]
(-94, -83]
(-83, -72]
(-72, -61]
(-61, -50]
(-50, -39]
(-39, -28]
(-28, -17]
(-17, -6]
(-6, 5]
Filtertiefe der GWM

WETTREG vs. REMO



- different data bases contain high variances in the forecasts
- REMO shows larger annual fluctuations
- WETTREG is worst-case-scenario

Fresh water production

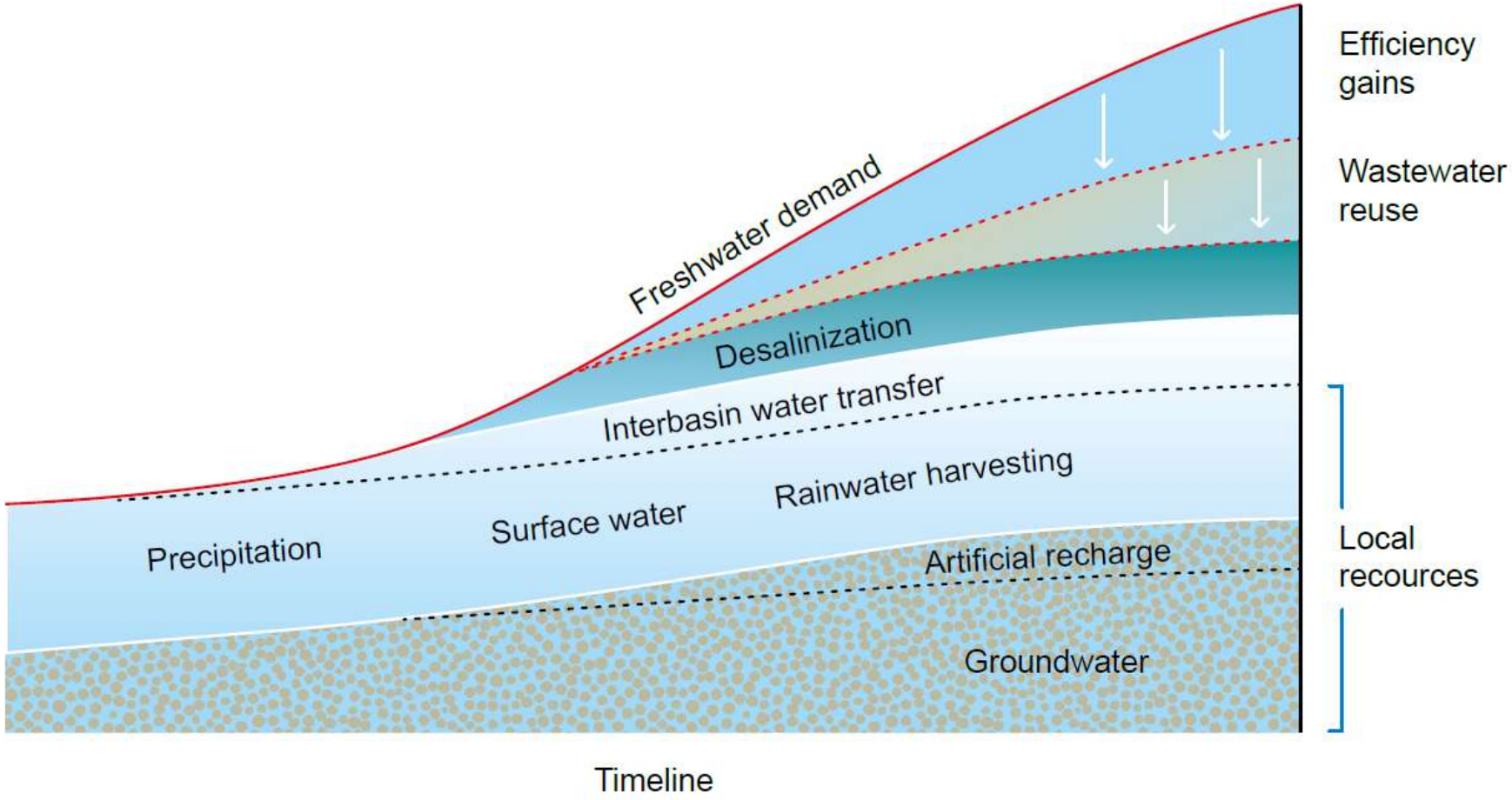
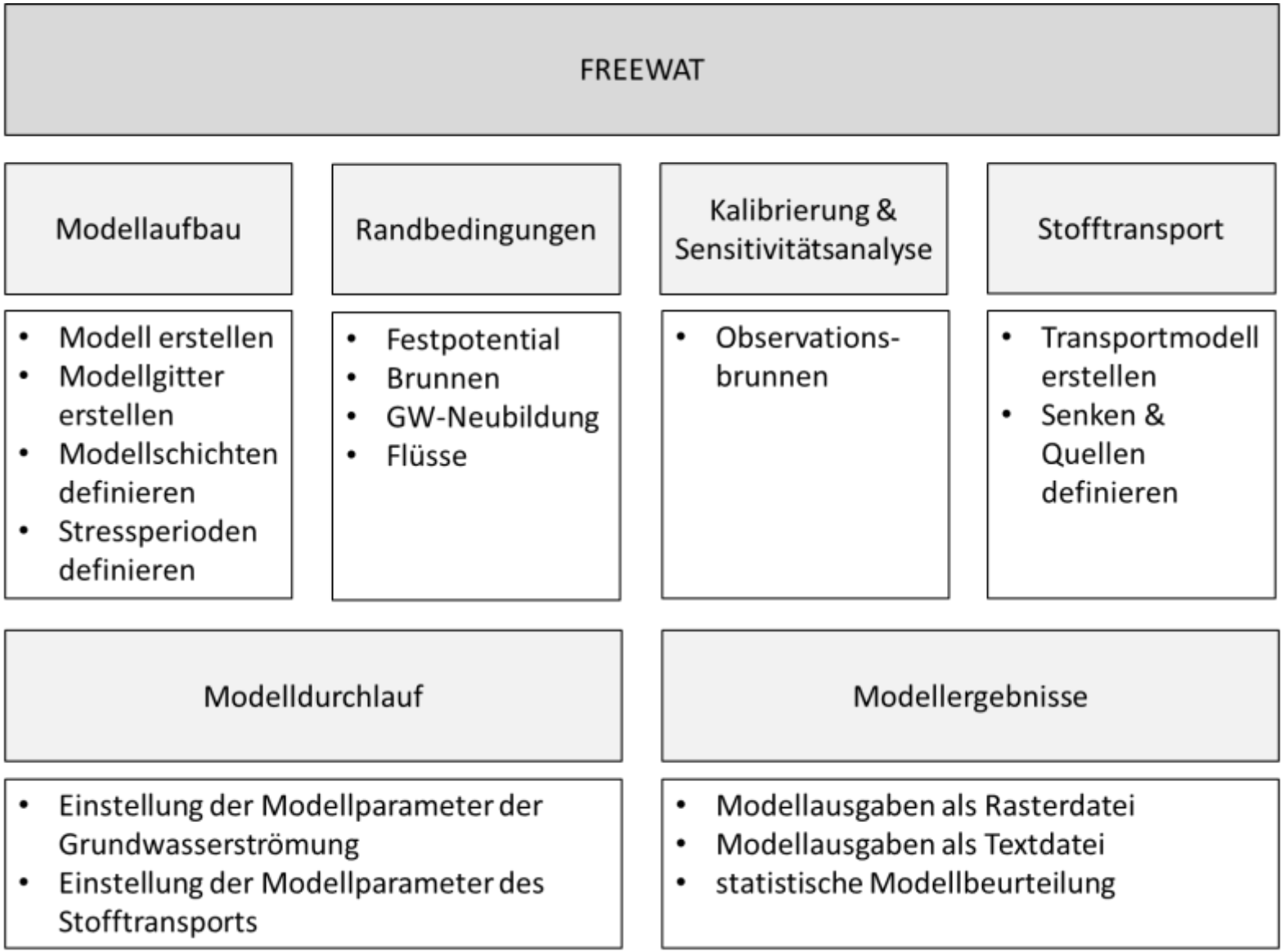


Figure 6.1: Overview of the development of coastal water supply options

Post et al. 2018

Aufbau der genutzten Modellier-funktionen in FREEWAT



Modellierparameter für Stressperioden

SP	Zeitraum	Dauer (d)	Zeit-schritte	Strö-mung	MS (m)	Ø GWN (mm/a)
1	2010 - 31.06.2016	2342	1	SS	0	150
2	01.07.2016 - 2040	8615	43	TR	0	150
3	2040-2070	10958	55	TR	0,18	147
4	2070-2100	10957	55	TR	0,45	105
	2100				0,78	62

MT3DMS Modellierparameter

Parameter	**Wert**
Längsdispersivität (LONG_D)	50 m
Verhältnis zwischen transversaler Querdispersivität zur Längsdispersivität (TRPT)	0,1
Verhältnis zwischen vertikaler Querdispersivität zur Längsdispersivität (TRPV)	0,01
Koeffizient der molekularen Diffusion (DMCOEF_1)	$1*10^{-5}$ m^2/d