Project: “Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation” Interreg CBC Italy-Croatia 2014.-2020.

Priority Axis: Safety and resilience

Specific objective: Improve the climate change monitoring and planning of adaptation measures tackling specific effects, in the cooperation area

(D_3.2.3) Report on the flume experiments: Croatian tests

Work Package 3: Studying

Activity 2: Laboratory investigations

Partner in charge: PP4 (UNIST-FGAG)

Partners involved: PP4 (UNIST-FGAG), PP5 (CROATIAN WATERS), PP6 (DUNEA)

Final version

Public report

September, 2022

Contents

Experiments overview

For the purpose of the project MoST we separately have shown the laboratory infrastructure as well as experiments control a data acquisition. Hereby, we summarize and show the organization of the experiments, their performance, results and conclusion. This report demonstrate the peculiarities of the passive seawater intrusion experiments with a main purpose to investigate:

- Seawater intrusion and retreat reflecting the cline characteristics;
- Influence of density difference between the seawater and freshwater;
- Conditions of different gradients controlling the seawater cline dynamics and features.

The overview of the experiments performed and relevant parameter values can be found in Table 1.

Table 1 Experiments and parameter values overview

	Date	Grain size [mm]	SW density [g/l]	TDS [g/l]	Δh [cm]
CONFINED AQUIFER	18-Jun-21	1,00-1,30	1025,16	37,15	2,2
					1,9
					1,6
	15-Jun-21	1,00-1,30	1025,19	37,15	1,6
					1,9
					2,2
	26-Jul-21	1,00-1,30	1030,31	43,52	2,2
					1,9
					1,6
	28-Jul-21	1,00-1,30	1030,4	43,52	1,6
					1,9
					2,2
	17-Aug-21	1,00-1,30	1020,47	32,41	2,2
					1,9
					1,6
	19-Aug-21	1,00-1,30	1020,72	32,32	1,6
					1,9
					2,2
	23-Aug-21	0,75-1,00	1020,68	32,3	2,2
					1,9
					1,6
	26-Aug-21	0,75-1,00	1020,94	32,26	1,6
					1,9
					2,2

Hydraulic conductivity determination

Prior the experiments conductance, separate attention has been given to the determination of the hydraulic conductivity. To mimic aquifer conditions, glass beads have been used with a characteristic as provided by the producer. Glass beads selected for experiment conductance are produced and delivered by SiLi GMBH produced with five specific diameters:

- 1.00– 1.30 mm;
- 0.80 – 1.00 mm;
- 0.40 – 0.60 mm;
- 0.30 – 0.40 mm
- 0.04 - 0.07 mm.

Producer SiLi GMBH delivered all technical details like chemical compounds content, particle roundness, elasticity module, porosity, granular distribution definition and other parameters relevant for experiment conductance (Figure 1 - Figure 10).

Product Data Sheet

The German spirit of quality since 1854

SiLi SIGMUND LINDNER

SiLibeads® - Glass beads for water filtration

First created on: 2020-01-29 Updated on: 2020-01-30
Next inspection on: 2020-12-31 Printed on: 2020-01-30 Version: 1/2020

Product: SiLibeads® Glass beads

Material: Polished glass beads made of soda lime glass
Specific weight: 2.50 kg/l
Hydrolytic resistance: (DIN ISO 720) HGB 3 [< 9.0 mm] / HGB 3 [> 9.5 mm]
Acid resistance: (DIN 12116) S 1 [< 9.0 mm] / S 1 [> 9.5 mm]
Alkali resistance: (DIN ISO 695) A 1 [< 9.0 mm] / A 2 [> 9.5 mm]

Fields of application: High performances filter media for single-, multi-layer and multi-media filtration at water reclaiming and water treatment systems.

Major Advantages of Glass beads:

- Precise and narrow gradations for an applied filter bed design and dust-free filter charging.
- High fracture strength and abrasion resistance for mechanical and chemical stability.
- Highly effective filtering process due to optimal hydraulic conditions.
- Excellent self-cleaning and fluidization-properties during back wash.
- Significant reduction of the need of water and energy due to reduced back wash duration.
- Reduction of chemical agents and extended service intervals.
- Almost unlimited durability.

Technical Data:

Sizes:	see table of standard sizes
Deformation temperature:	600 °C
Softening point (Littleton point):	741 °C
Melting point:	1475 °C
Specific thermal Conductivity:	1.135 W/(m·K)
Hardness according to Mohs:	≥ 6

Chemical Analysis; Glass beads made of soda lime glass; CAS-Nr. 65997-17-3 / EINECS 266-046-0:

Name	Method	Weight (reference values)	CAS-No.	EINECS
Silicon dioxide SiO_2	DIN 51001	65.0 - 75.0 %	7631-86-9	231-545-4
Sodium oxide Na_2O	DIN 51001	12.0 - 17.0 %	1313-59-3	215-208-9
Calcium oxide CaO	DIN 51001	< 10.0 %	1305-78-8	215-138-9
Aluminium oxide Al_2O_3	DIN 51001	< 5.0 %	1344-28-1	215-691-6
Magnesium oxide MgO	DIN 51001	< 5.0 %	1309-48-4	215-171-9

The heavy metal content of the Glass beads keeps the permitted limits of EU directive 2011/65/EC (RoHS).			
Lead < 1000 ppm	Cadmium < 100 ppm	Chrome VI < 1000 ppm	Mercury < 1000 ppm

Assessment acc. to Food Legislation:
Glass beads are a consumer good in the sense of §2 Abs. 6 No. 1 German Code for Food Stuff (LFGB), Commodities and Feeding Stuff.
Glass beads comply with the requirements of the European Food Regulation 1935/2004/EC, Article 3 and fulfill the micro biological requirements according to DIN EN ISO 14698-1 and VDI 6022.

Free of Silanes / Glycol / Epoxy:
We hereby confirm that Silanes, Glycol or Epoxy are not used during the production and packaging process.

Filename: PDS en Water Filtration Page 1 of 3

Figure 1 SiLi glass beads product data sheet – page 1

Product Data Sheet

The German spirit of quality since 1854

SiLi SIGMUND LINDNER

SiLibeads® - Glass beads for water filtration

First created on: 2020-01-29 Updated on: 2020-01-30
Next inspection on: 2020-12-31 Printed on: 2020-01-30 Version: 1/2020

NSF-Certificate No. C0104873-01 / Conformity to BS 6920:2000:

Sigmund Lindner is NSF International certified and complies with NSF/ANSI61 requirements and fulfill the criteria set out in BS 6920: Part 1: 2000 "Specification" and thus complies with the requirements of the "Water Regulations Advisory Scheme Tests of Effect on Water Quality".

NSF Certified to NSF/ANSI 61

Standard Sizes (special diameters by request):

Article	Name	Diameter	Bulk density (Reference values)	Resistance to *) compression	Roundness **)
Art. 5216	SiLibeads® FM MICRO	0.20 – 0.30 mm	1.44 kg/l	---	0.89
Art. 5223	SiLibeads® FM MICRO	0.30 – 0.50 mm	1.46 kg/l	---	0.89
Art. 45015	SiLibeads® FM MICRO	0.40 – 0.60 mm	1.47 kg/l	---	0.95
Art. 45016	SiLibeads® FM MED	0.40 – 0.80 mm	1,48 kg/l	---	0.95
Art. 4502	SiLibeads® FM MED	0.50 – 0.80 mm	1.49 kg/l	---	0.95
Art. 4503	SiLibeads® FM MED	0.80 – 1.00 mm	1.50 kg/l	170 N	0.95
Art. 4504	SiLibeads® FM BIG	1.00 – 1.30 mm	1.51 kg/l	250 N	0.95
Art. 4505	SiLibeads® FM BIG	1.25 – 1.65 mm	1.51 kg/l	370 N	0.95
Art. 4506	SiLibeads® FM BIG	1.55 – 1.85 mm	1.52 kg/l	520 N	0.95
Art. 4507	SiLibeads® FM BIG	1.70 – 2.10 mm	1.52 kg/l	620 N	0.95
Art. 4508	SiLibeads® FM XXL	2.00 – 2.40 mm	1.53 kg/l	770 N	0.95
Art. 4510	SiLibeads® FM XXL	2.40 – 2.90 mm	1.53 kg/l	920 N	0.95
Art. 4511	SiLibeads® FM XXL	2.85 – 3.45 mm	1.53 kg/l	1,270 N	0.95
Art. 4512	SiLibeads® FM XXL	3.40 – 4.00 mm	1.53 kg/l	1,550 N	0.95
Art. 4513	SiLibeads® FM XXL	3.80 – 4.40 mm	1.53 kg/l	1,900 N	0.95
Art. 4514	SiLibeads® FM XXL	4.50 – 5.50 mm	1.49 kg/l	2,350 N	0.94
Art. 4515	SiLibeads® FM XXL	5.00 – 6.00 mm	1.47 kg/l	3,150 N	0.92
Art. 5016	SiLibeads® FM XXL	9.50 – 10.50 mm	1.45 kg/l	6,000 N	0.98
Art. 5017	SiLibeads® FM XXL	10.50 – 11.50 mm	1.45 kg/l	7,500 N	0.98
Art. 5018	SiLibeads® FM XXL	11.50 – 12.50 mm	1.45 kg/l	10,500 N	0.98
Art. 5021	SiLibeads® FM XXL	13.50 – 14.50 mm	1.43 kg/l	---	0.98
Art. 5023	SiLibeads® FM XXL	15.20 – 16.80 mm	1.43 kg/l	---	0.98
Special Mixtures					
Art. 4500412	SiLibeads® FM FINE	0.40 – 1.20 mm	1.49 kg/l	---	0.95
Art. 4500510	SiLibeads® FM FINE	0.50 – 1.00 mm	1.49 kg/l	---	0.95
Art. 4500713	SiLibeads® FM FINE	0.70 – 1.30 mm	1.50 kg/l	---	0.95
Art. 4501019	SiLibeads® FM BIG	1.00 – 1.90 mm	1.51 kg/l	---	0.95
Art. 4501029	SiLibeads® FM BIG	1.00 – 2.90 mm	1.51 kg/l	---	0.95
Art. 4501225	SiLibeads® FM BIG	1.20 – 2.50 mm	1.51 kg/l	---	0.95
Art. 4501521	SiLibeads® FM BIG	1.50 – 2.10 mm	1.51 kg/l	---	0.93
Art. 4502029	SiLibeads® FM XXL	2.00 – 2.90 mm	1.53 kg/l	---	0.95
Art. 4502035	SiLibeads® FM XXL	2.00 – 3.50 mm	1.53 kg/l	---	0.95
Art. 4502535	SiLibeads® FM XXL	2.50 – 3.50 mm	1.53 kg/l	---	0.95
Art. 4502840	SiLibeads® FM XXL	2.80 – 4.00 mm	1.53 kg/l	---	0.95
Art. 4503455	SiLibeads® FM XXL	3.40 – 5.50 mm	1.53 kg/l	---	0.95
Art. 4503860	SiLibeads® FM XXL	3.80 – 6.00 mm	1.53 kg/l	---	0.95

*) Resistance to compression: internal test with Compressive strength inspector No. 10004.1, Company Hegewald & Peschke

**) Ratio width/length (xmin/xmax): internal test with Retsch-Camsizer

Filename: PDS en Water Filtration Page 2 of 3

Figure 2 SiLi glass beads product data sheet – page 2

Product Data Sheet

The German spirit of quality since 1854

SiLi SIGMUND LINDNER

SiLibeads® - Glass beads for water filtration

First created on: 2020-01-29	Updated on: 2020-01-30			
Next inspection on: 2020-12-31	Printed on: 2020-01-30			Version: 1/2020

Additional Information:

Storage:	Store containers (big bags) in a dry place, protected from direct sunlight.
Disposal:	Please consult national laws and local regulations in force for disposal or landfill.
Safety advice:	High risk of slipping due to spillage of the product
Product information:	Sample card SiLibeads* Material safety data sheet "SiLibeads for Water wells + Water filtration"

Certifications: according to DIN EN ISO 9001:2015; according to HACCP-Standard for glass beads in contact with food stuffs

Manufacturer/Supplier:
Sigmund Lindner GmbH
Oberwarmensteinacher Str. 38
95485 Warmensteinach / GERMANY
Phone: +49-9277-9940
Fax: +49-9277-99499
E-Mail: sili@sigmund-lindner.com
Web: www.sili.eu

All data are reference values – subject to change without prior notice

Filename: PDS en Water Filtration — Page 3 of 3

Figure 3 SiLi glass beads product data sheet – page 3

Product Data Sheet

The German spirit of quality since 1854 — SiLi SIGMUND LINDNER

SiLibeads SOLID Micro Glass Beads

First created on:	2017-04-06	Updated on:	2020-01-31
Next inspection on:	2020-12-31	Printed on:	2020-01-31

Version: V6/2020

Produkt:	**SiLibeads SOLID Micro Glass Beads**
Material:	polished Glass beads made of soda lime glass Specific weight: 2.50 kg/l Hydrolytic: DIN ISO 720 HGB 3 Acidic class: DIN 12116 S 1 Alkaline class: DIN ISO 695 A 1
Application:	Filling material in the chemical-, paper- and synthetic materials industry; Filling material for the modification of the physical properties of thermoplast and duroplast; Glass beads for shot peening of the surface of metal, plastics, ceramics and wood; Decorative filling material in wall-papers and wall-plasters; and further technical applications

Technical Data:

Roundness:	≥ 0.89 (ratio width/length (x_{min}/x_{max})
Refractive index:	1.52
Size (Diameter):	between 0 and 800 µm (see table Standard Sizes)
Transformation temperature:	549 °C
Softening point (Littleton point):	734 °C
Melting point:	1446 °C
Specific thermal Conductivity:	1.129 W/(m·K)
Thermal expansion:	$9.05\ 10^{-6}\ K^{-1}$ [20 °C] (Coefficient of linear expansion **α**)
Specific thermal capatcity:	1.329 kJ/kg K [>600 °C]
Youngs-Module:	63 GPa
Hardness according to Mohs:	≥ 6

Assessment acc. to Food Legislation:

The Glass beads are a consumer good in the sense of §2 clause 6 no. 1 German Code for Food Stuff (LFGB), Commodities and Feeding Stuff. Therefore they have to comply with the legal requirements.
The Glass beads comply with the requirements § 31 of the German Food and Feed Code (LFGB) and of the European Food Regulation 1935/2004/EC, Article 3.

Chemical Analysis; Glass beads made of soda lime glass; CAS-Nr. 65997-17-3 / EINECS 266-046-0:

Name	Method	Weight	CAS-No.	EINECS
Silicon dioxide SiO_2	DIN 51001	72.30 %	7631-86-9	231-545-4
Sodium oxide Na_2O	DIN 51001	13.30 %	1313-59-3	215-208-9
Calcium oxide CaO	DIN 51001	8.90 %	1305-78-8	215-138-9
Magnesium oxide MgO	DIN 51001	4.00 %	1309-48-4	215-171-9
further		1.50 %		

The heavy metal content of the Glass beads keeps the permitted limits of EU directive 2011/65/EC (RoHS).

Lead < 1000 ppm	Cadmium < 100 ppm	Chrome VI < 1000 ppm	Mercury < 1000 ppm

Data file: PDS en SiLibeads SOLID Micro Glass Beads — Page 1 of 2

Figure 4 SiLi glass beads technical sheet – page 1

Product Data Sheet

The German spirit of quality since 1854 — SiLi SIGMUND LINDNER

SiLibeads SOLID Micro Glass Beads

First created on: 2017-04-06 Updated on: 2020-01-31
Next inspection on: 2020-12-31 Printed on: 2020-01-31
Version: V6/2020

Standard Sizes – special diameters available by request:

Article	Diameter	Bulk density
5209	0 – 20 µm	0.70 kg/l
5210	0 – 50 µm	1.30 kg/l
5211	40 – 70 µm	1.33 kg/l
5212	70 – 110 µm	1.37 kg/l
5213	90 – 150 µm	1.40 kg/l
5214	100 – 200 µm	1.42 kg/l
5215	150 – 250 µm	1.43 kg/l
5216	200 – 300 µm	1.44 kg/l
5220	200 – 400 µm	1.45 kg/l
5223	300 – 400 µm	1.46 kg/l
5218	400 – 600 µm	1.47 kg/l
5219	400 – 800 µm	1.49 kg/l

Possible Silane-Coatings:

Si1	Gamma-Methacryloxypropyltrimethoxysilane
Si2	Gamma-Glycidoxypropyltrimethoxysilane
Si3	Gamma-Aminopropyltriethoxysilane
Si4	Gamma-Mercaptopropyltrimethoxysilane
Si5	n-Octyltriethoxysilane

Additional Information:

Storage indication: Store in a dry manner in closed (original) container by room temperature. When stored in unheated rooms at winter temperatures, the balls should be pre-heated for at least 72 hours before use.

Disposal: Please consult national laws and local regulations in force for disposal or landfill.

Safety advice: High risk of slipping due to spillage of product

Product information: Safety Data Sheet SiLibeads SOLID Micro Glass Beads; Test Reports

Manufacturer/Supplier:

Sigmund Lindner GmbH
Oberwarmensteinacher Str. 38
95485 Warmensteinach / GERMANY
Phone: +49-9277-9940
Fax: +49-9277-99499
E-Mail: sili@sigmund-lindner.com
Web: www.sili.eu

All data are reference values – subject to change without prior notice

Data file: PDS en SiLibeads SOLID Micro Glass Beads Page 2 of 2

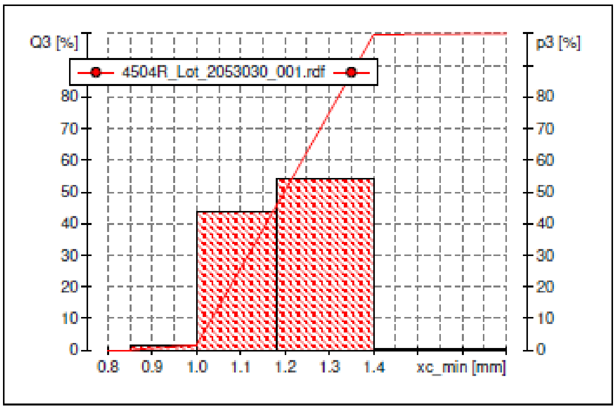
Figure 5 SiLi glass beads technical sheet – page 2

CAMSIZER®

4504R 1.00-1.30 mm

Firma:	Sigmund Lindner GmbH
Benutzer:	Quality Control
Ergebnisdatei:	\...s\Glaskugeln Typ S \4504R_Lot_2053030_001.rdf C:\Camsizer\CAMSYS\4504R 1.00-1.30-- 07
Messaufgabe:	07-10.afg
Zeit:	22.06.2020, 12:29, Dauer 5 min 46 s bei 0.3 % Flächendichte , Bildrate 1:1und 60 mm Rinne mit Leitblech
Größendefinition:	xc_min
Partikelanzahl:	CCD-B = 79850 , CCD-Z = 8991
Anpassung:	nein
Material:	Glass Beads Typ S
Kommentar:	p3 < 1.0 max. 5%; p3 > 1.4 max. 10% p3 > 1.7 max 2%; b/l3=mind. 0.950

Kornklasse [mm]	[mm]	p3 [%]	Q3 [%]	1-Q3 [%]	b/l3
	< 0.850	0.04	0.04	99.96	0.936
0.850	1.000	1.49	1.53	98.47	0.973
1.000	1.180	43.78	45.31	54.69	0.975
1.180	1.400	54.35	99.66	0.34	0.978
1.400	1.700	0.34	100.00	0.00	0.973
> 1.700		0.00	100.00	0.00	



Kenngrößen

Q3 [%]	x [mm]
10.0	1.079
50.0	1.191
90.0	1.301
Sm =	20.176 cm²/g

x(Q3=10.00 %) = 1,079 mm
x(Q3=60.00 %) = 1,215 mm
D60/D10 = 1,126
p3(0.100 mm,1.000 mm) = 1,52 %
p3(1.400 mm,3.000 mm) = 0,34 %
p3(1.700 mm,3.000 mm) = 0,00 %

1-Q3 (b/l=0,93) = 96,2 % Mittelwert (Sphericity) b/l3 = 0,977

Benutzer

CAMSIZER: 0245 1 / 1

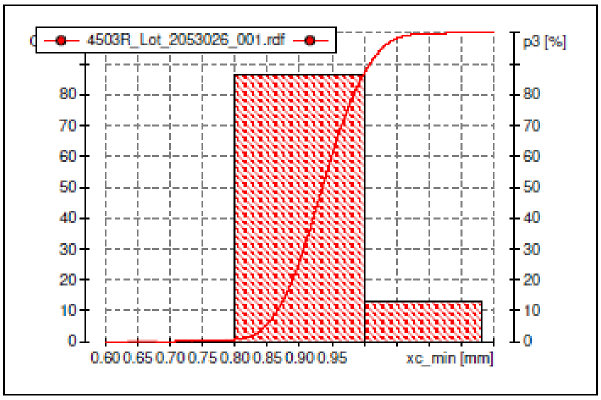
Figure 6 Granular distribution of glass beads diameter 1.00- 1.30 mm

CAMSIZER®

4503R 0.8-1.0 mm

Firma:	Sigmund Lindner GmbH
Benutzer:	Quality Control
Ergebnisdatei:	Glaskugeln Typ S\4503R_Lot_2053026_001.rdf
Messaufgabe:	C:\Camsizer\CAMSYS\4503R 0.8-1.0mm 07-03-01.afg
Zeit:	28.05.2020, 7:24, Dauer 3 min 24 s bei 0.5 % Flächendichte , Bildrate 1:1und 60 mm Rinne mit Leitblech
Größendefinition:	xc_min
Partikelanzahl:	CCD-B = 117229 , CCD-Z = 8834
Anpassung:	nein
Material:	Glass Beads Typ S
Kommentar:	p3 < 0.71 max. 5%; p3 > 1.0 max. 10% p3 > 1.18 max. 2%; b/l3 = mind. 0.930

Kornklasse [mm]	[mm]	p3 [%]	Q3 [%]	1-Q3 [%]	b/l3
0.003	0.600	0.01	0.01	99.99	0.953
0.600	0.710	0.09	0.10	99.90	0.970
0.710	0.800	0.54	0.64	99.36	0.936
0.800	1.000	86.33	86.97	13.03	0.969
1.000	1.180	13.02	99.99	0.01	0.965
1.180	1.320	0.01	100.00	0.00	0.579



Kenngrößen

Q3 [%]	x [mm]
10.0	0.865
50.0	0.935
90.0	1.009
Sm =	25.494 cm²/g

x(Q3=10.00 %) = 0,865 mm
x(Q3=60.00 %) = 0,949 mm
D60/D10 = 1,097
p3(0.100 mm,0.710 mm) = 0,10 %
p3(1.000 mm,2.000 mm) = 13,03 %
p3(1.180 mm,2.000 mm) = 0,01 %

1-Q3 (b/l=0,93) = 92,4 %   Mittelwert (Sphericity) b/l3 = 0,968

Benutzer

CAMSIZER: 0245   1 / 1

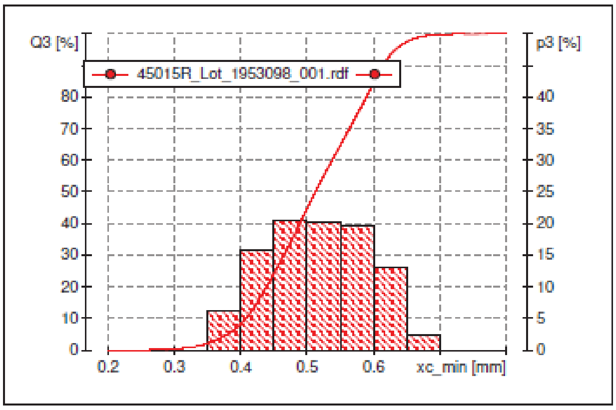
Figure 7 Granular distribution of glass beads diameter 0.80.- 1.00 mm

CAMSIZER®

45015 R Typ S 0,4-0,6 mm

Firma:	Sigmund Lindner GmbH
Benutzer:	Quality Control
Ergebnisdatei:	Glaskugeln Typ S\45015R_Lot_1953098_001.rdf
Messaufgabe:	C:\Camsizer\CAMSYS\45015 R 0.4-0.6mm 07-03-01.afg
Zeit:	31.07.2019, 8:34, Dauer 5 min 46 s bei 0.5 % Flächendichte , Bildrate 1:1und 60 mm Rinne mit Leitblech
Größendefinition:	xc_min
Partikelanzahl:	CCD-B = 804183 , CCD-Z = 49934
Anpassung:	nein
Material:	Glass Beads Typ S
Kommentar:	p3 < 0.425 max. 5%; p3 > 0.6 max. 10% p3 > 0.71 max. 2%; b/l3 = mind. 0.930;

Kornklasse [mm]	[mm]	p3 [%]	Q3 [%]	1-Q3 [%]	b/l3
0.003	0.350	2.05	2.05	97.95	0.975
0.350	0.400	6.14	8.19	91.81	0.978
0.400	0.450	15.90	24.09	75.91	0.978
0.450	0.500	20.58	44.67	55.33	0.977
0.500	0.550	20.07	64.74	35.26	0.973
0.550	0.600	19.65	84.39	15.61	0.973
0.600	0.650	13.10	97.49	2.51	0.972
0.650	0.700	2.28	99.77	0.23	0.962
0.700	1.022	0.23	100.00	0.00	0.821



Kenngrößen

Q3 [%]	x [mm]
10.0	0.408
50.0	0.513
90.0	0.615
Sm =	44.335 cm²/g

x(Q3=10.00 %) = 0,408 mm
x(Q3=60.00 %) = 0,538 mm
D60/D10 = 1,318
p3(0.100 mm,0.425 mm) = 15,06 %
p3(0.600 mm,1.000 mm) = 15,61 %
p3(0.710 mm,1.000 mm) = 0,15 %

1-Q3 (b/l=0,93) = 92,9 % Mittelwert b/l3 = 0,974

CAMSIZER: 0245 1 / 1

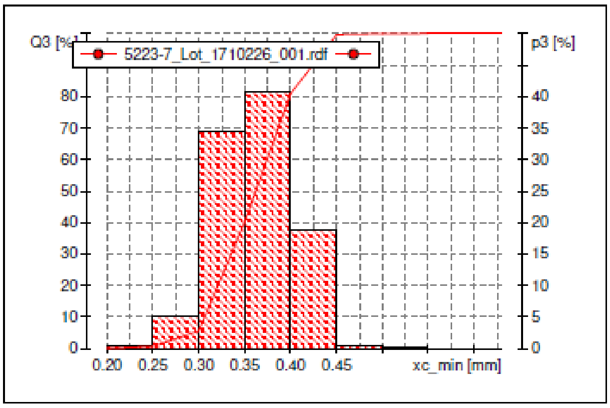
Figure 8 Granular distribution of glass beads diameter 0.40.- 0.60 mm

CAMSIZER®

Art. 5223 / 300-400 µm

Firma:	Sigmund Lindner GmbH
Benutzer:	Quality Control
Ergebnisdatei:	Glaskugeln Typ S Microglas\5223-7_Lot_1710226_001.rdf
Messaufgabe:	C:\Camsizer\CAMSYS\5223 300-400- 07-02-26.afg
Zeit:	05.04.2018, 11:50, Dauer 5 min 23 s bei 0.5 % Flächendichte , Bildrate 1:1und 60 mm Rinne mit Leitblech
Größendefinition:	xc_min
Partikelanzahl:	CCD-B = 273738 , CCD-Z = 16564
Anpassung:	nein
Material:	Glass Beads Typ S
Kommentar:	Sollwert: p3 (0.250mm; 0.450mm) = 95% b/l3 (= Rundheit) mind. 0.85

Kornklasse [mm]	[mm]	p3 [%]	Q3 [%]	b/l3
	< 0.150	0.01	0.01	0.427
0.150	0.200	0.06	0.07	0.452
0.200	0.250	0.48	0.55	0.593
0.250	0.300	5.08	5.63	0.783
0.300	0.350	34.51	40.14	0.923
0.350	0.400	40.77	80.91	0.933
0.400	0.450	18.75	99.66	0.945
0.450	0.500	0.28	99.94	0.737
0.500	0.550	0.05	99.99	0.904
> 0.550		0.01	100.00	



Kenngrößen

Q3 [%]	x [mm]
10.0	0.310
50.0	0.362
90.0	0.414

Sm = 66.057 cm²/g

Mv2_Sv(x) = 0.357 mm
Sigma2_Sv(x) = 0.041 mm

x(Q3=10.00 %) = 0,310 mm
x(Q3=60.00 %) = 0,373 mm
D60/D10 = 1,203
p3(0.250 mm,0.450 mm) = 99,10 %

Mittelwert (Sphericity) b/l3 = 0,922

Benutzer

CAMSIZER: 0245 1 / 1

Figure 9 Granular distribution of glass beads diameter 0.30.- 0.40 mm

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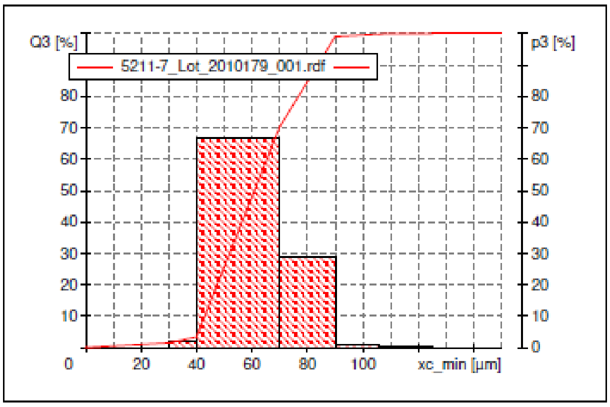
CAMSIZER X2 Retsch TECHNOLOGY

Art. 5211 / 40-70 µm

Firma:	Sigmund Lindner GmbH
Benutzer:	Quality Control
Ergebnisdatei:	Glaskugeln Typ S Microglas\5211-7_Lot_2010179_001.rdf
Messaufgabe:	C:\CamsizerX2\CAMSYS\5211 40-70micro- 19-05-09.afg
Zeit:	25.06.2020, 9:59, Dauer 2 min 41 s bei 0.2 % Flächendichte , Bildrate 1:1, mit X-Jet, Spaltbreite = 4.0 mm, Dispergierdruck = 60.0 kPa
Größendefinition:	xc_min
Partikelanzahl:	CCD-B = 3038120 , CCD-Z = 32675
Geschwindigkeitsanpassung:	nein
Anpassung:	nein
Material:	Glass Beads Typ S
Kommentar:	Sollwert: p3 (40µm; 70µm) = 75 % b/l3 (= Rundheit) mind. 0.85

Größenklasse	[µm]	p3 [%]	Q3 [%]	b/l3
0.0	30.0	1.41	1.41	0.917
30.0	40.0	1.90	3.31	0.826
40.0	70.0	66.98	70.29	0.897
70.0	90.0	28.78	99.07	0.918
90.0	106.0	0.83	99.90	0.849
106.0	125.0	0.08	99.98	0.887
125.0	192.1	0.02	100.00	0.927



Kenngrößen

Q3 [%]	x [µm]
10.0	49.6
50.0	63.6
90.0	79.0

Sm = 392.180 cm²/g

x(Q3=10.00 %) = 49,6 µm
x(Q3=60.00 %) = 66,5 µm
D60/D10 = 1,340
p3(40.0 µm,70.0 µm) = 66,98 %

Mittelwert (Sphericity) b/l3 = 0,896

Benutzer

CAMSIZER X2: 1219270218 1 / 1

Figure 10 Granular distribution of glass beads diameter 0.04.- 0.07 mm

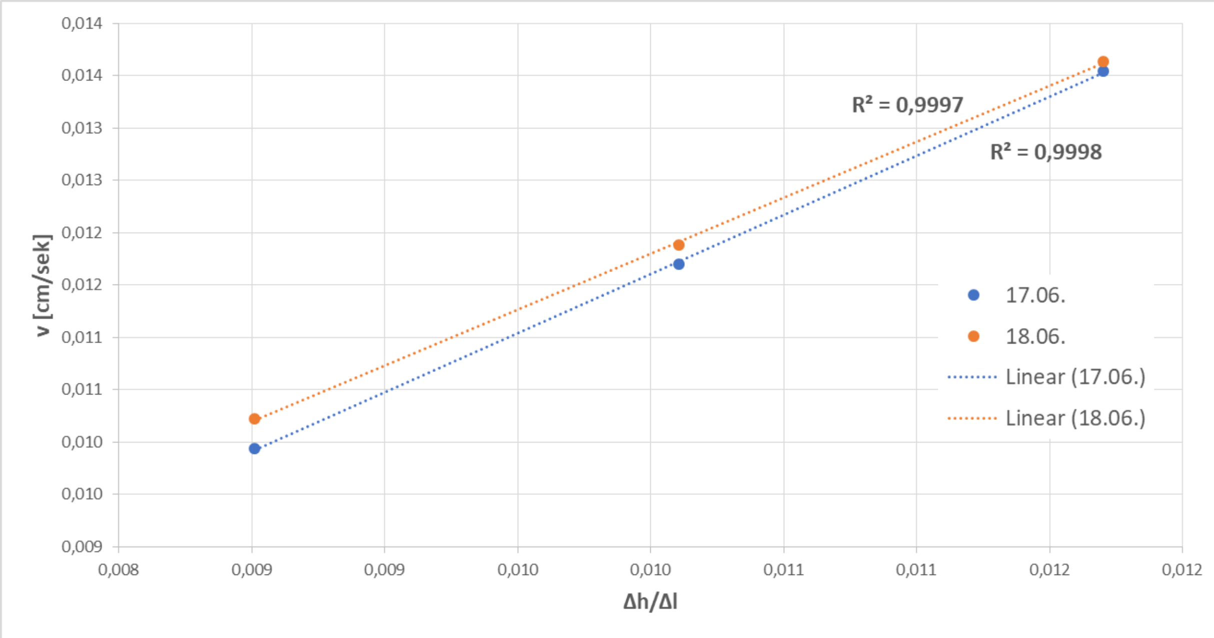


Figure 11 Determination of the hydraulic conductivity

Determination of the hydraulic conductivity of the glass beads has been performed by the application of Darcy law within the laboratory flume. After setting the boundary conditions within the boundary chambers, a gradient has been created to force the water flow through the porous media. As soon as stationary conditions have been reached, volumetric discharge has been measured at the flume outlet. This value was used when applying the Darcy law which enabled the determination of the hydraulic conductivity. As seen in Figure 11, results indicate linear relationship between the gradient and the seepage velocity thus leading towards the value of the hydraulic conductivity equals to 1.20 cm s^{-1} for the glass beads diameter 1.00 – 1.30 mm..

Visual observations and results

Due to the scope of laboratory infrastructure, one needs to enable clear and temporally synchronized snapshots of the cline within the flume. For this purpose, operative and controlling equipment are controlled together with GoPro7 high resolution camera. Light effect has been given by the use of 150 W LED reflector.

Prior the experiment conductance, marks are placed onto front glass plate (Figure 12) to enable spatial referencing system use while analyzing the seawater cline. After flow boundary conditions are set up and steady state condition is reached, red color dye is introduced into seawater chamber until homogeneity is ensured.

During the experiment, GoPro10 camera is set up to create a snapshot of the operative chamber front side every 60 s. This gives full information on transient nature of cline features unless steady state is reached.

To demonstrate real visible results from the experiments we show in Figure 12 - Figure 34:

- Results from 0 – 90 minutes with time step of 10 minutes;
- Results from 90 – 570 minutes with time step of 30 minutes.

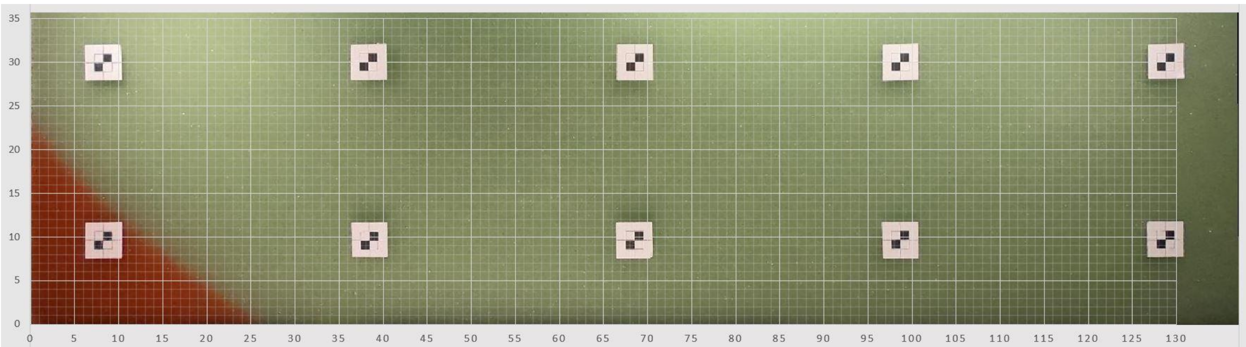


Figure 12 SWI cline t= 10 min

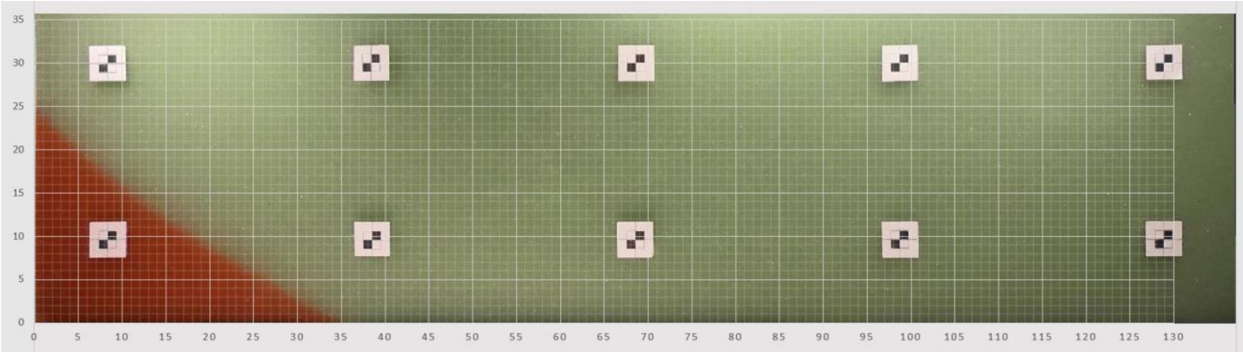


Figure 13 SWI cline t= 20 min

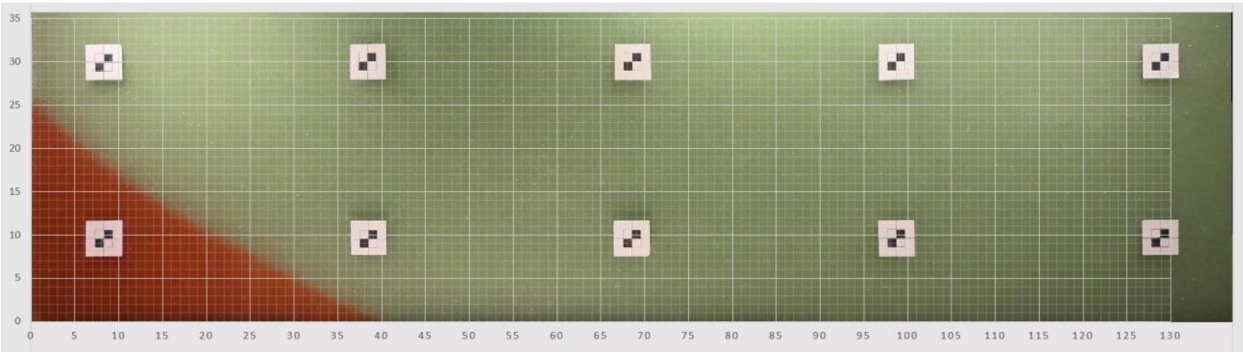


Figure 14 SWI cline t= 30 min

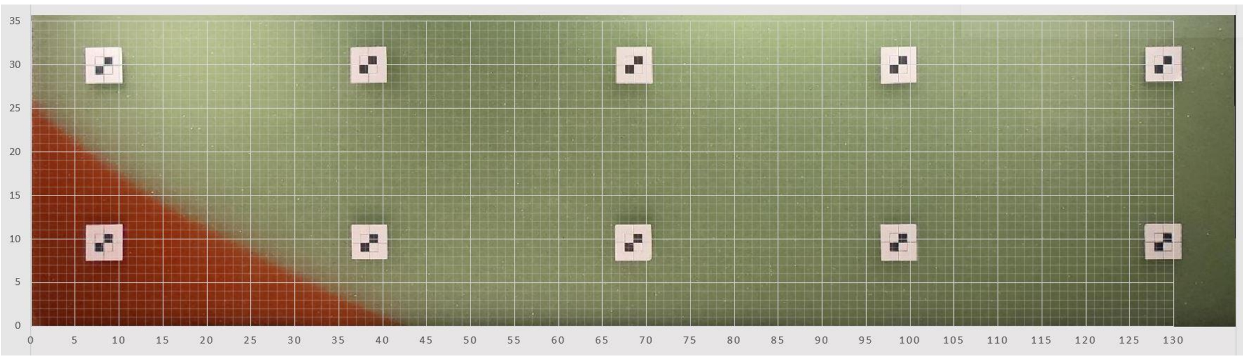


Figure 15 SWI cline t= 40 min

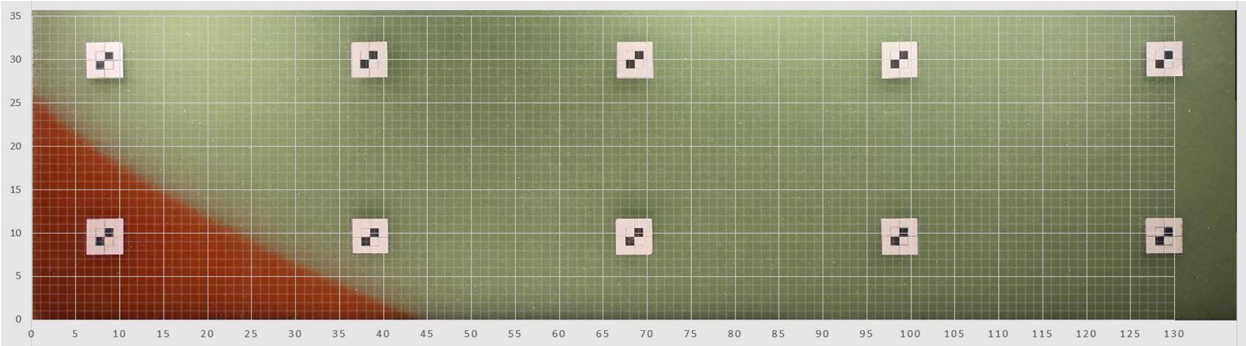


Figure 16 SWI cline t= 50 min

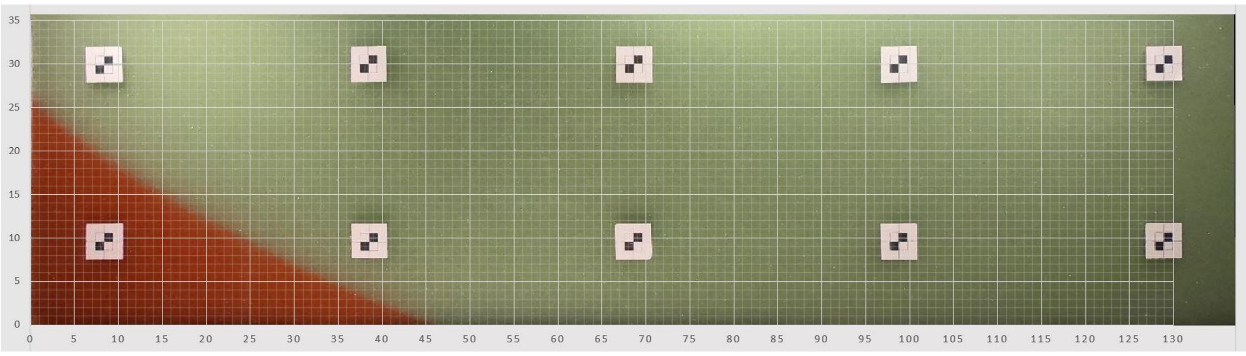


Figure 17 SWI cline t= 60 min

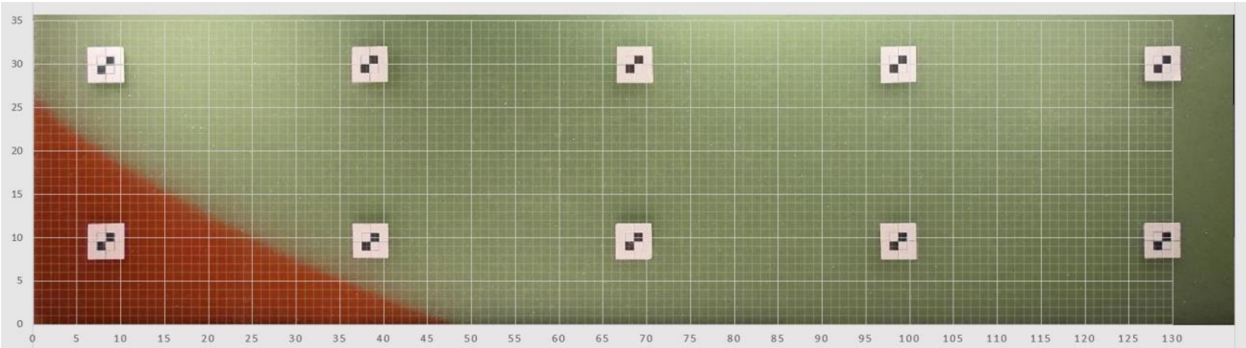


Figure 18 SWI cline t= 90 min

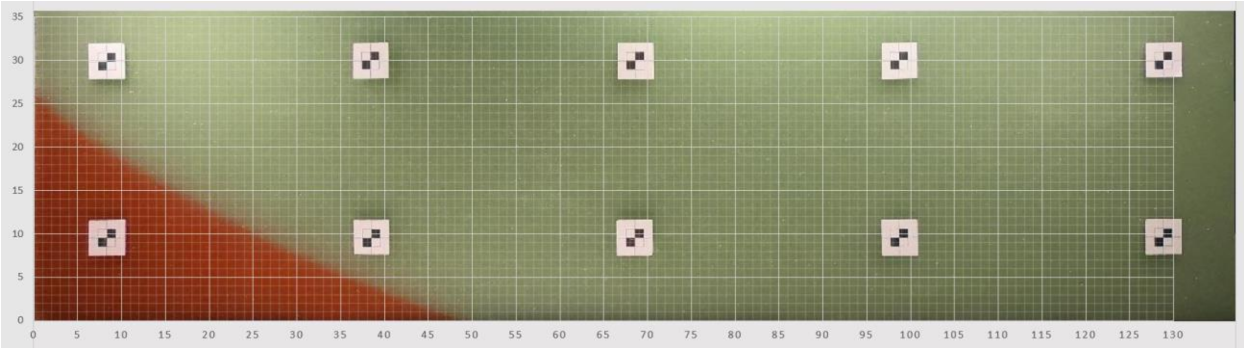


Figure 19 SWI cline t= 120 min

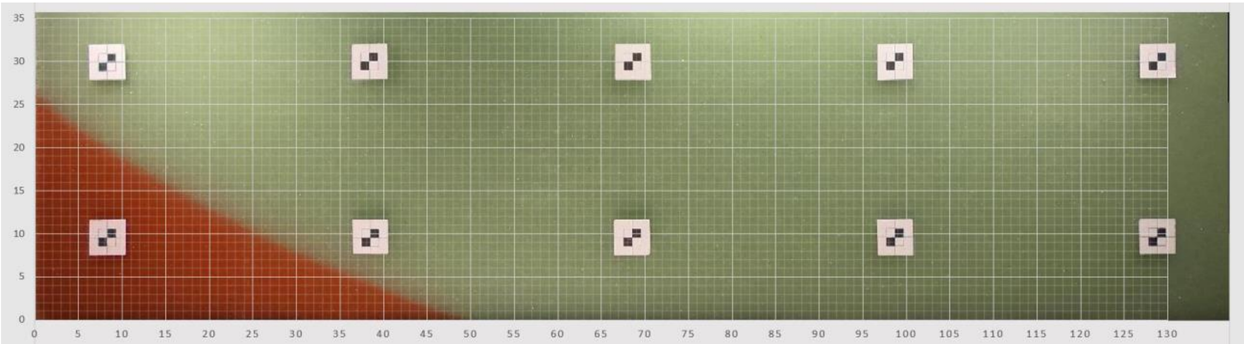


Figure 20 SWI cline t= 150 min

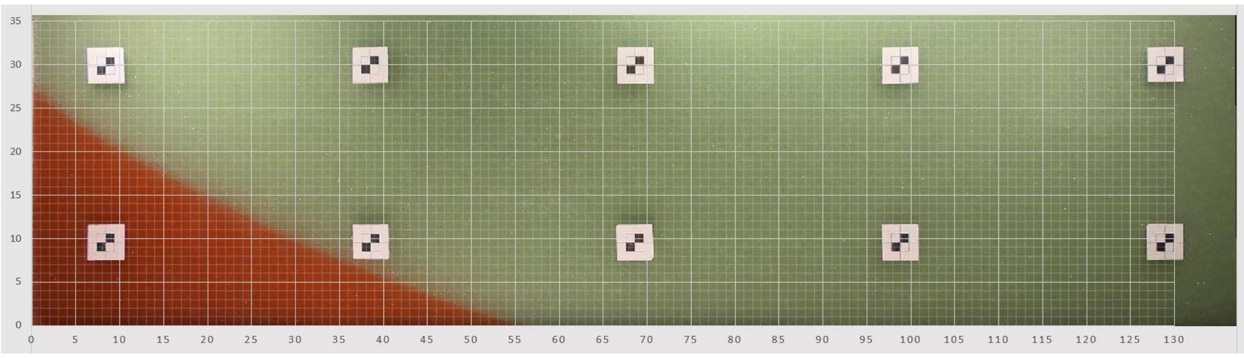


Figure 21 SWI cline t= 180 min

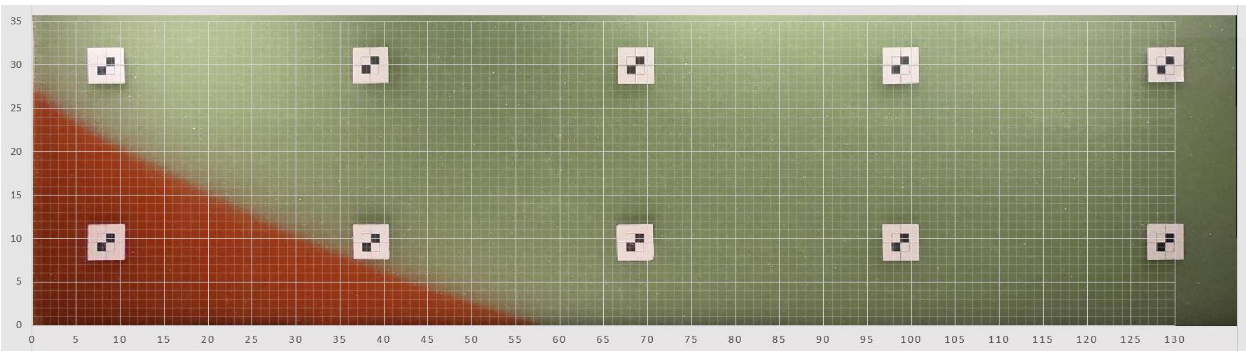


Figure 22 SWI cline t= 210 min

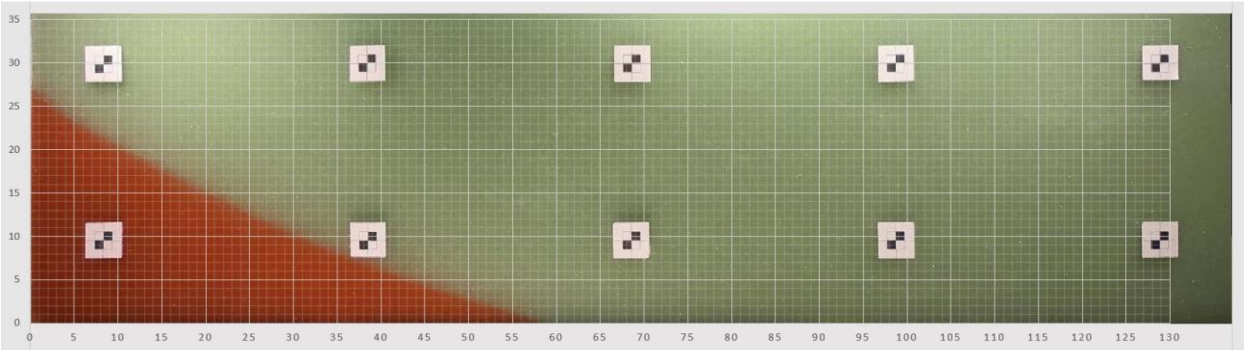


Figure 23 SWI cline t= 240 min

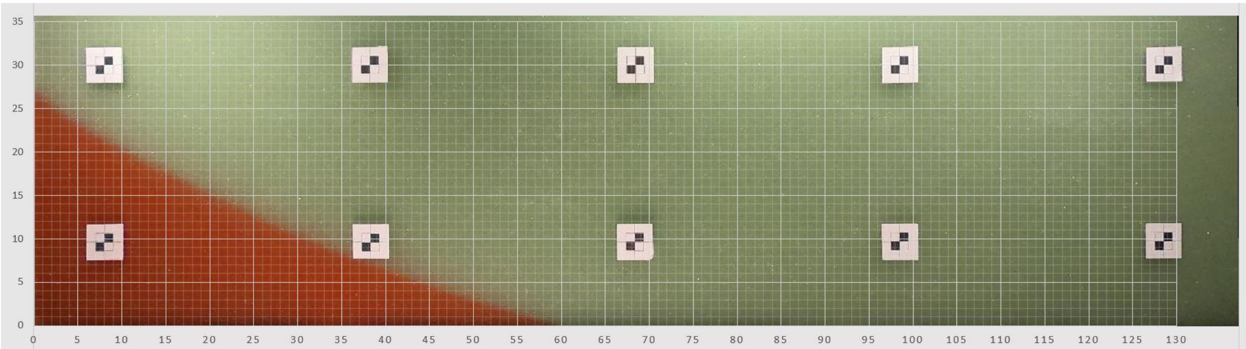


Figure 24 SWI cline t=270 min

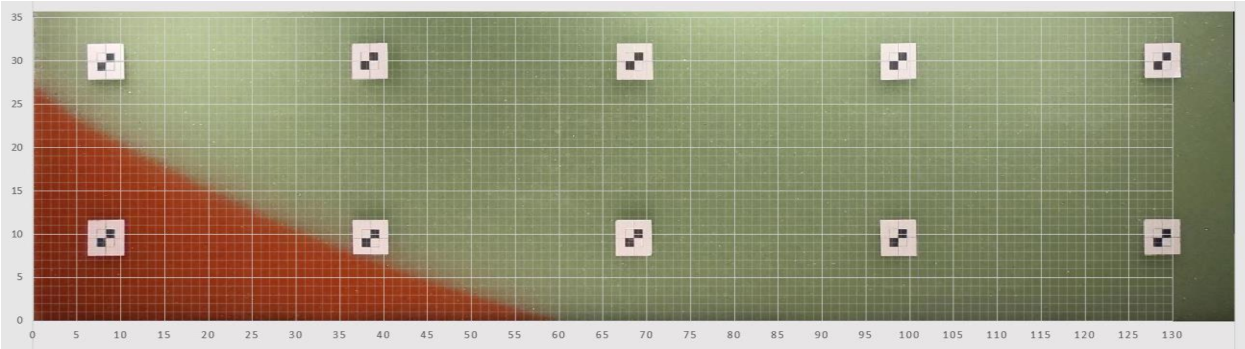


Figure 25 SWI cline t= 300 min

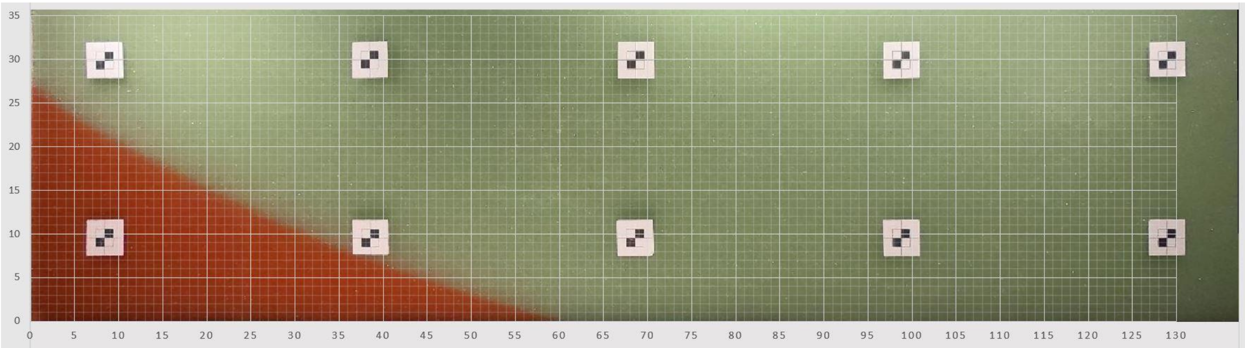


Figure 26 SWI cline t= 330 min

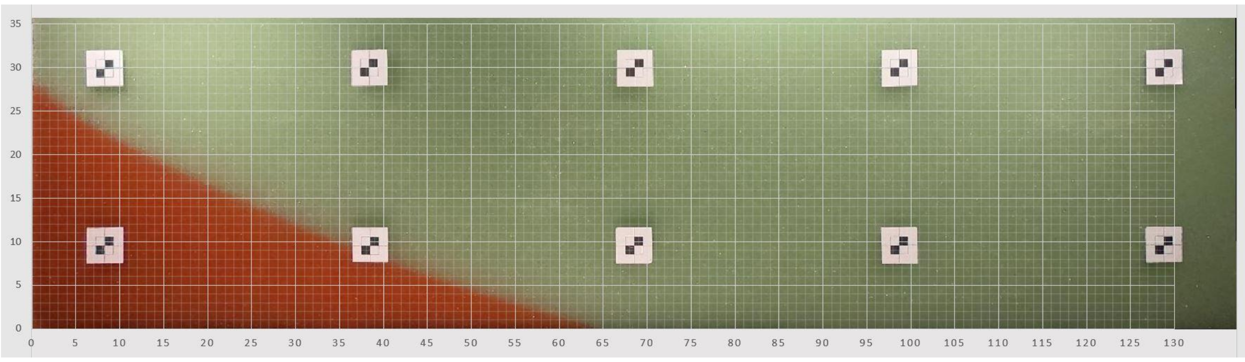


Figure 27 SWI cline t= 360 min

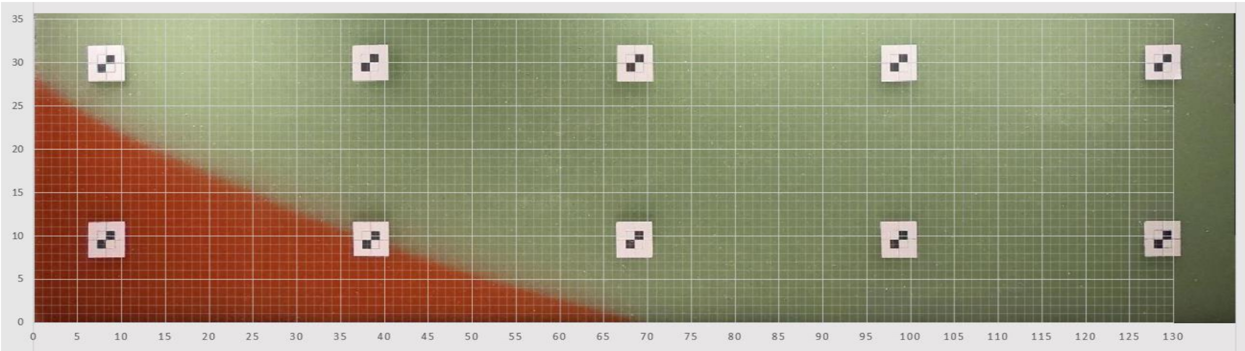


Figure 28 SWI cline t= 390 min

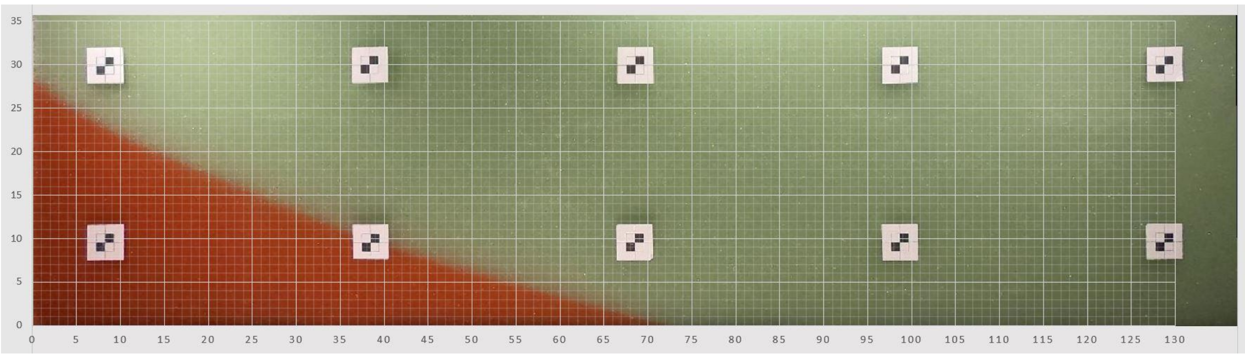


Figure 29 SWI cline t= 420 min

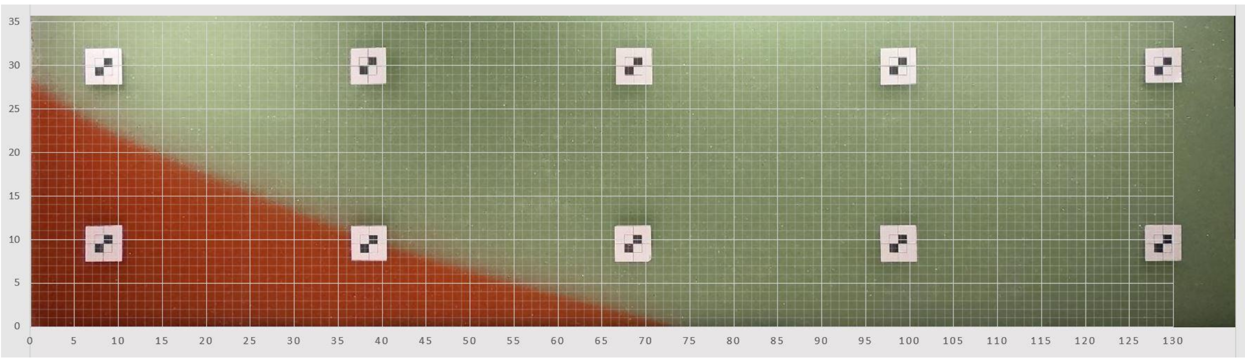


Figure 30 SWI cline t= 450 min

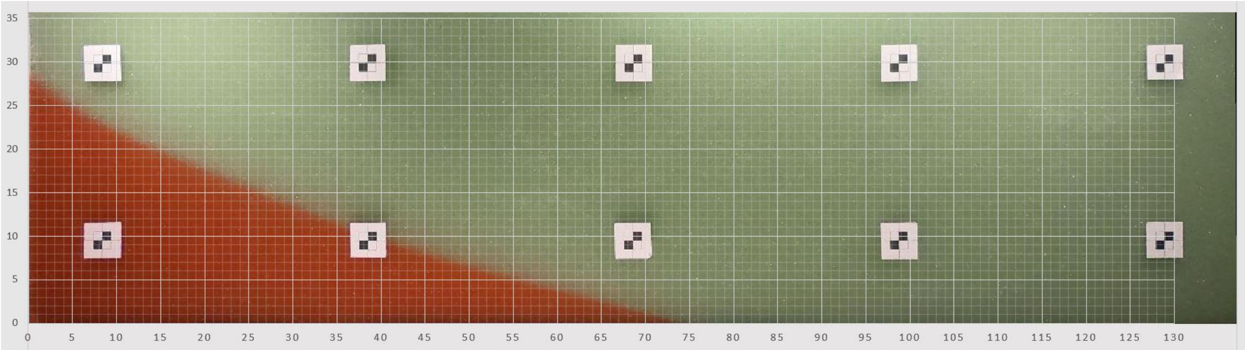


Figure 31 SWI cline t= 480 min

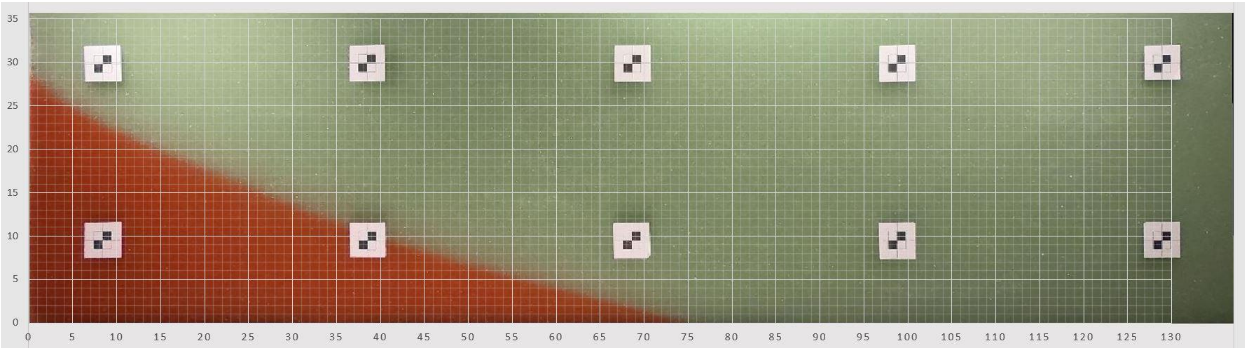


Figure 32 SWI cline t= 510 min

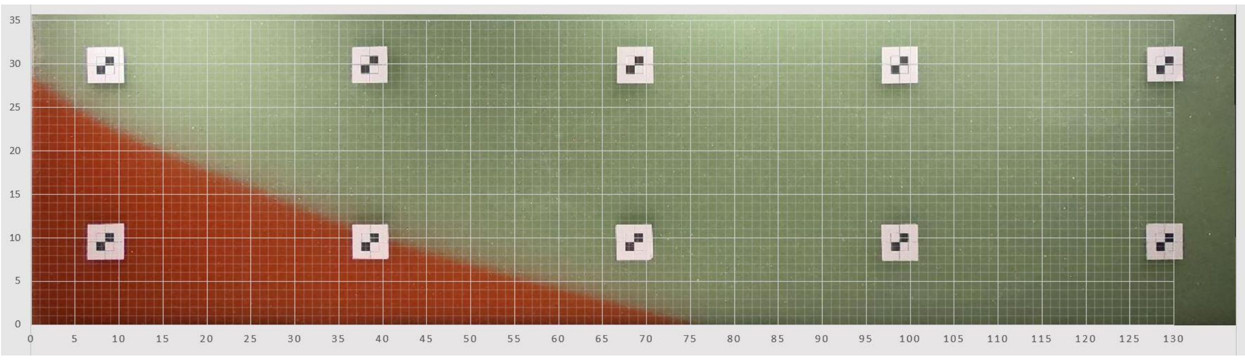


Figure 33 SWI cline t= 540 min

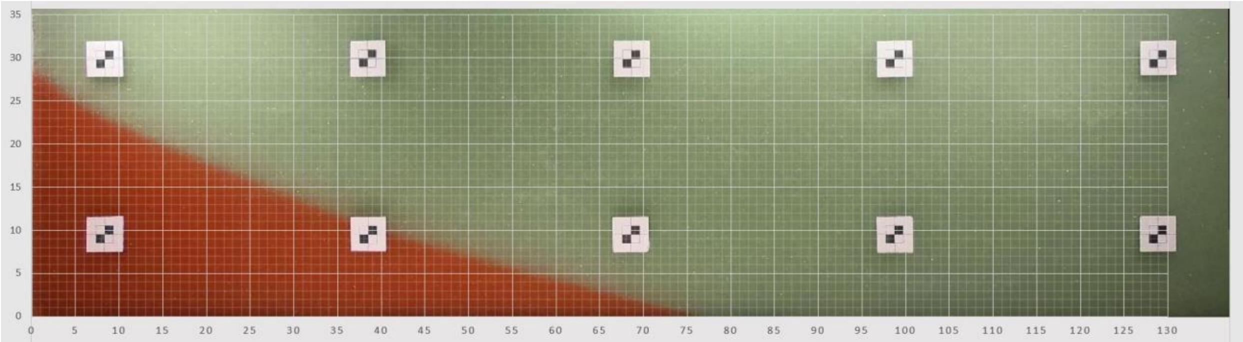


Figure 34 SWI cline t= 570 min

SWI intrusion features and conclusions

Main results and outcomes are presented below with emphasis to toe length and wedge height.

Seawater intrusion and retreat

Inspection of the peculiarities of seawater intrusion (SWI) and seawater retreat (SWR) and specific insight to cline toe length and wedge height in Figure 35 - Figure 37. Unless no significant difference has been observed in toe length characteristics between SWI and SWR, wedge height shows sensitivity. Higher wedge height has been observed for SWR.

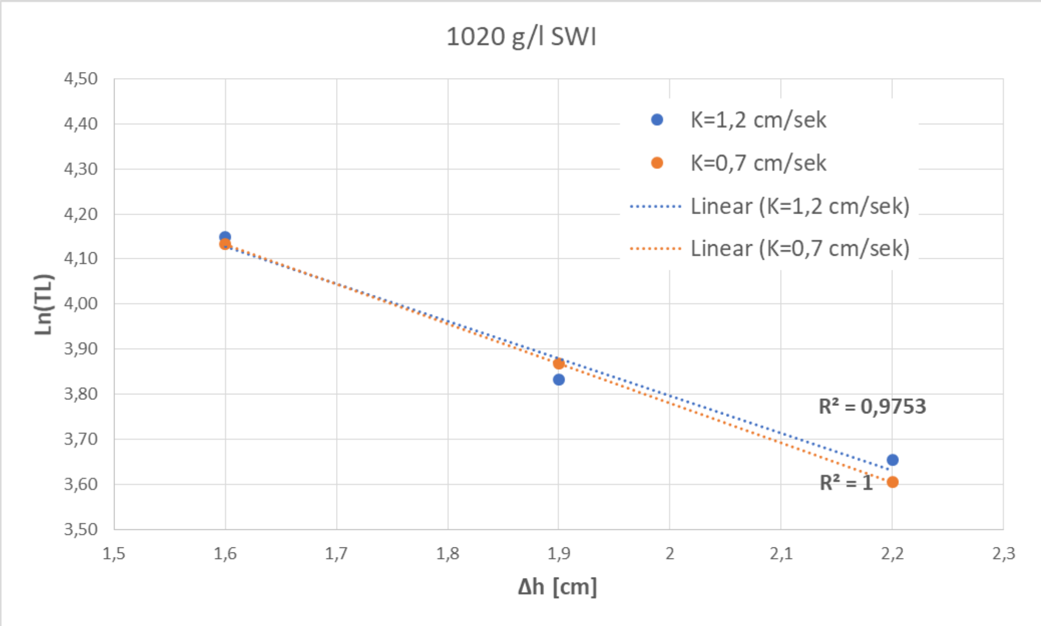


Figure 35 SWI toe length observed under stationary conditions

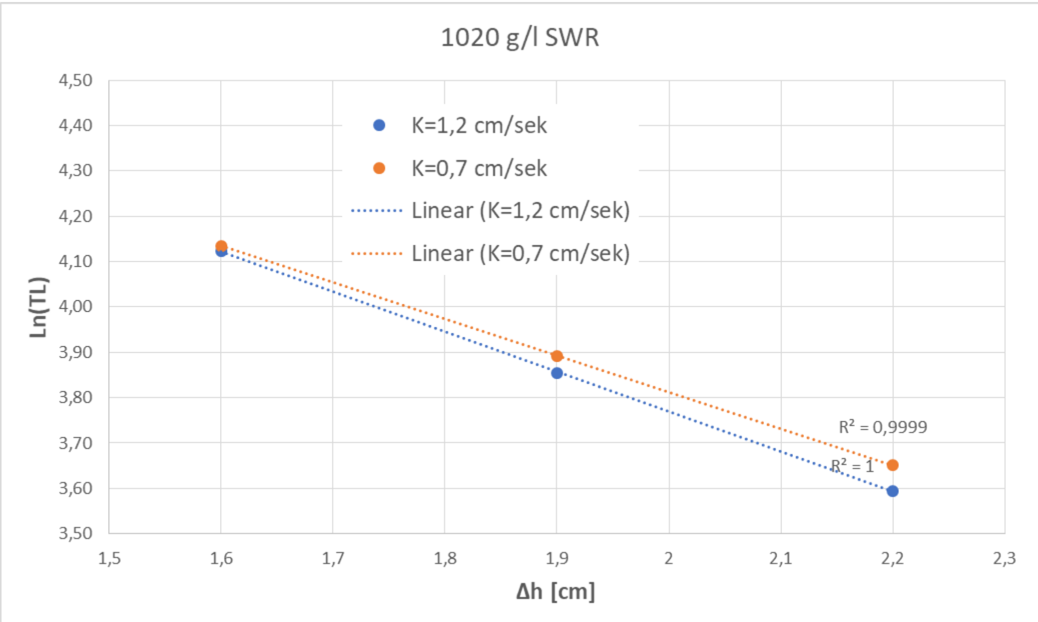


Figure 36 SWR toe length observed under stationary conditions

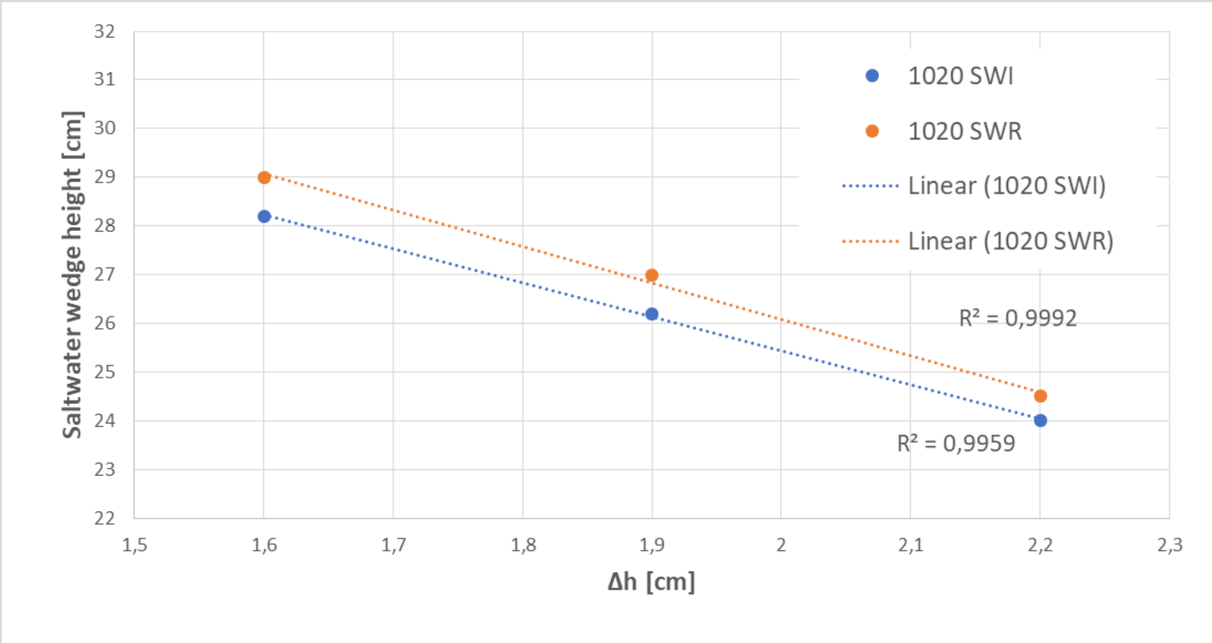


Figure 37 SWI and SWR wedge height observed under stationary conditions

Hydraulic conductivity influence to SWI

Hydraulic conductivity has been shown to be of minor impact to seawater cline parameter values under stationary conditions (Figure 38 and Figure 39). Although not visible on figures attached, hydraulic conductivity significantly influences the time scales of seawater cline for both SWI and SWR.

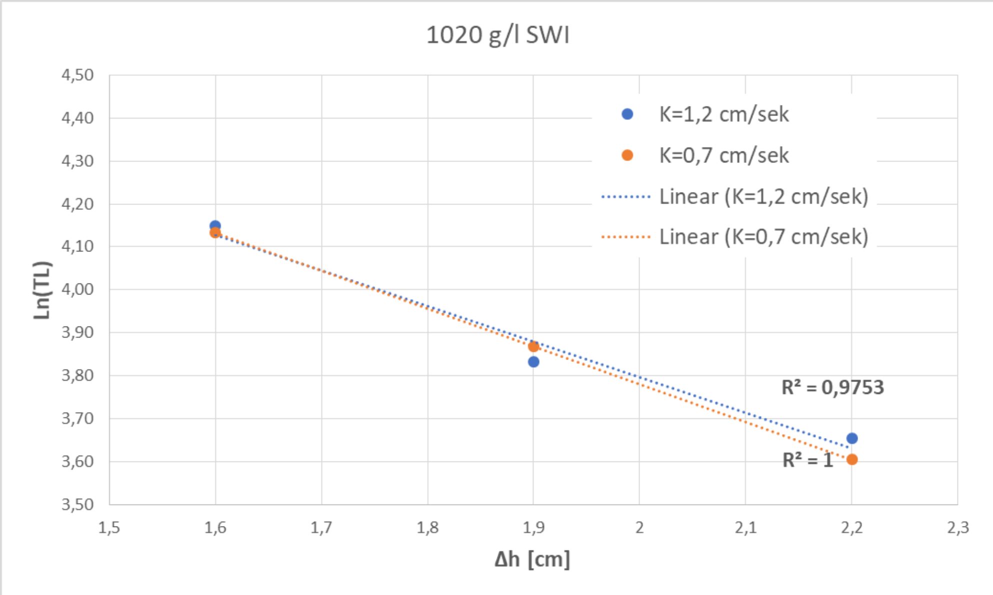


Figure 38 SWI toe length observed under stationary conditions for variable K

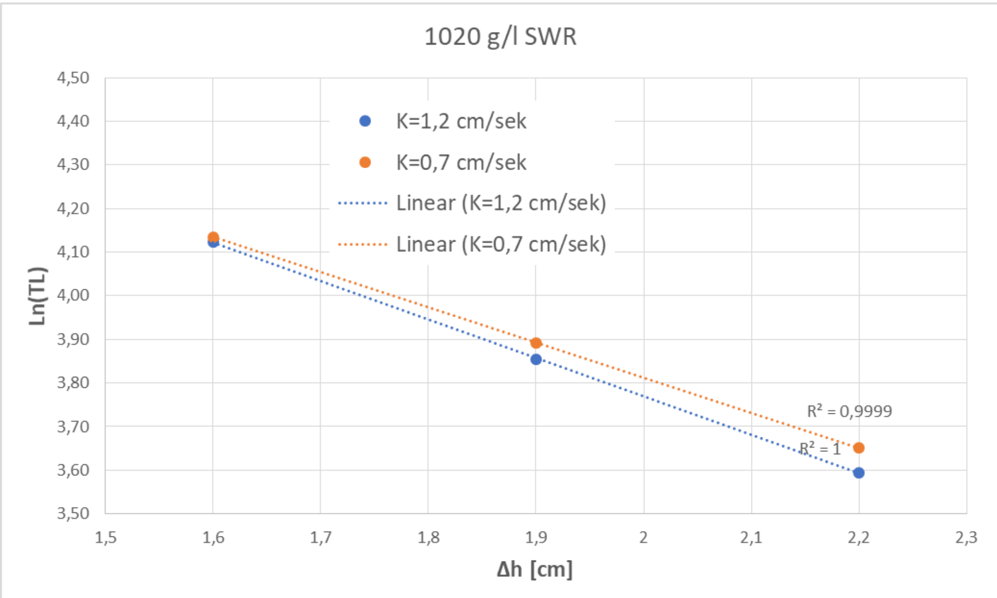


Figure 39 SWR toe length observed under stationary conditions for variable K

Effects of density differences

Density effects are shown to be important factor controlling the seawater parameters when observed during experiments as shown in Figure 40.

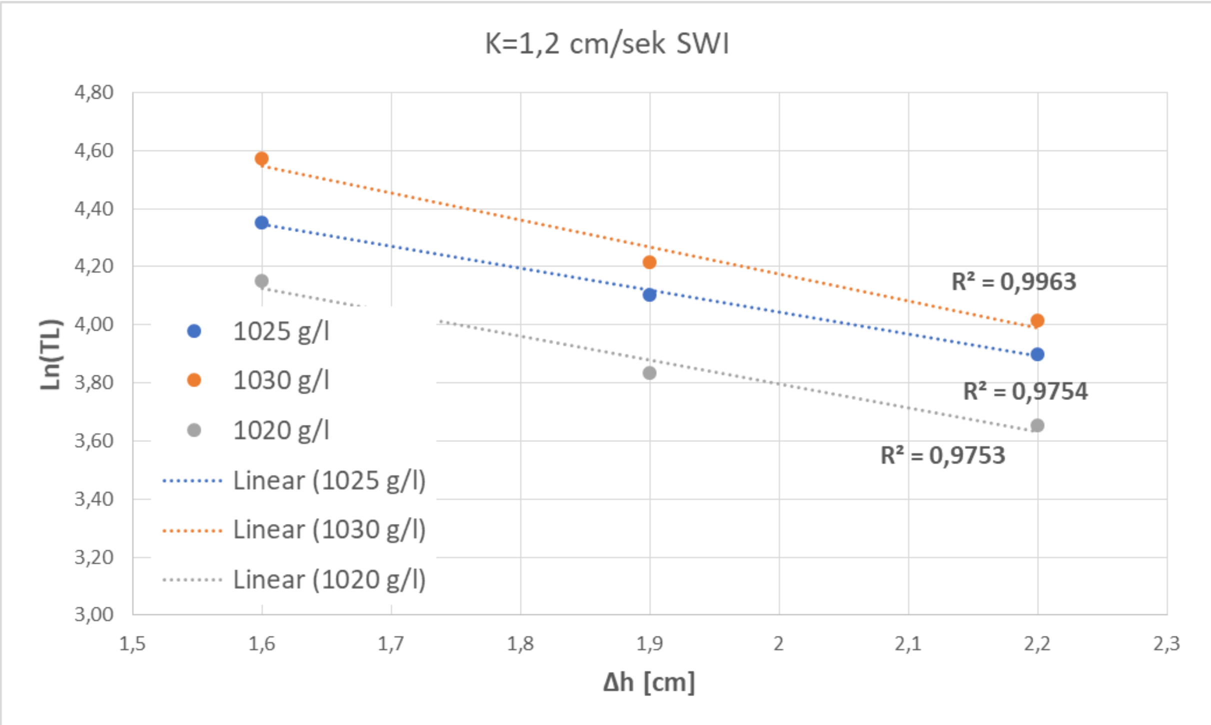


Figure 40 SWI toe length observed under stationary conditions for variable seawater density

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