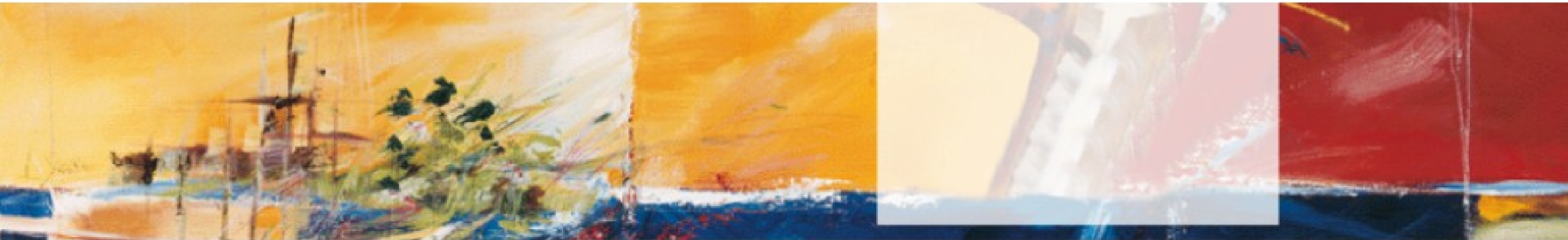
Jan Vreeburg

UNESCO-IHE
Institute for Water Education

TU Delft
Technische Universiteit Delft

kiwa
Partner for progress



Water quality in distribution: the latest developments

Q21

Q21-project: Water quality for the 21st century

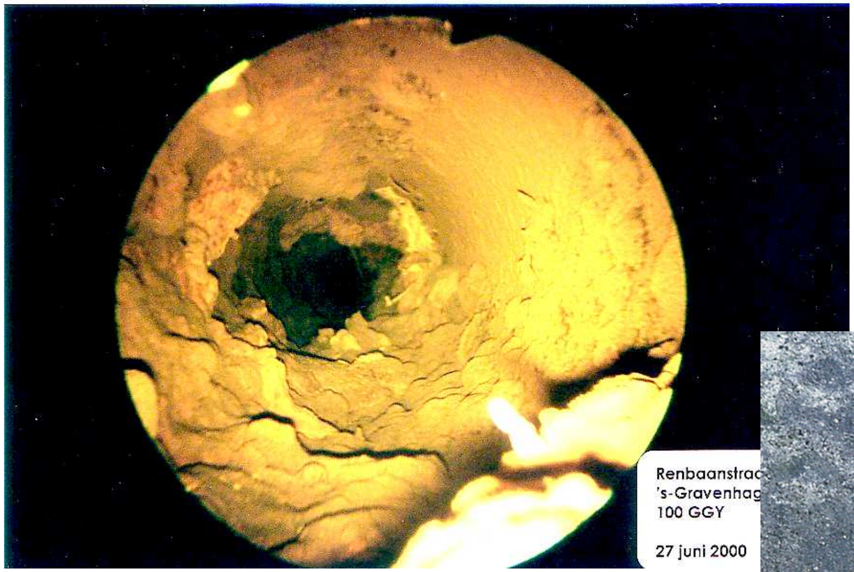
- **Ambition Dutch Water Companies Q21**
  - **Preserve the customer trust in drinking water by supplying water of impeccable quality at all times**
  - **Systematically research all relevant areas**
- **Goal distribution research Q21 Distribution**
  - **Asses the relation between water quality at the pumping station and water quality at the customers tap**
  - **Is it possible to manipulate the water quality at the pumpingstation to avoid problems in the network.**
- **Goal Microbiology Q21:**
  - **Understanding *Legionella* in networks**
  - **Understanding the biofouling of membranes**

Q21-distribution: A network of projects and researchers

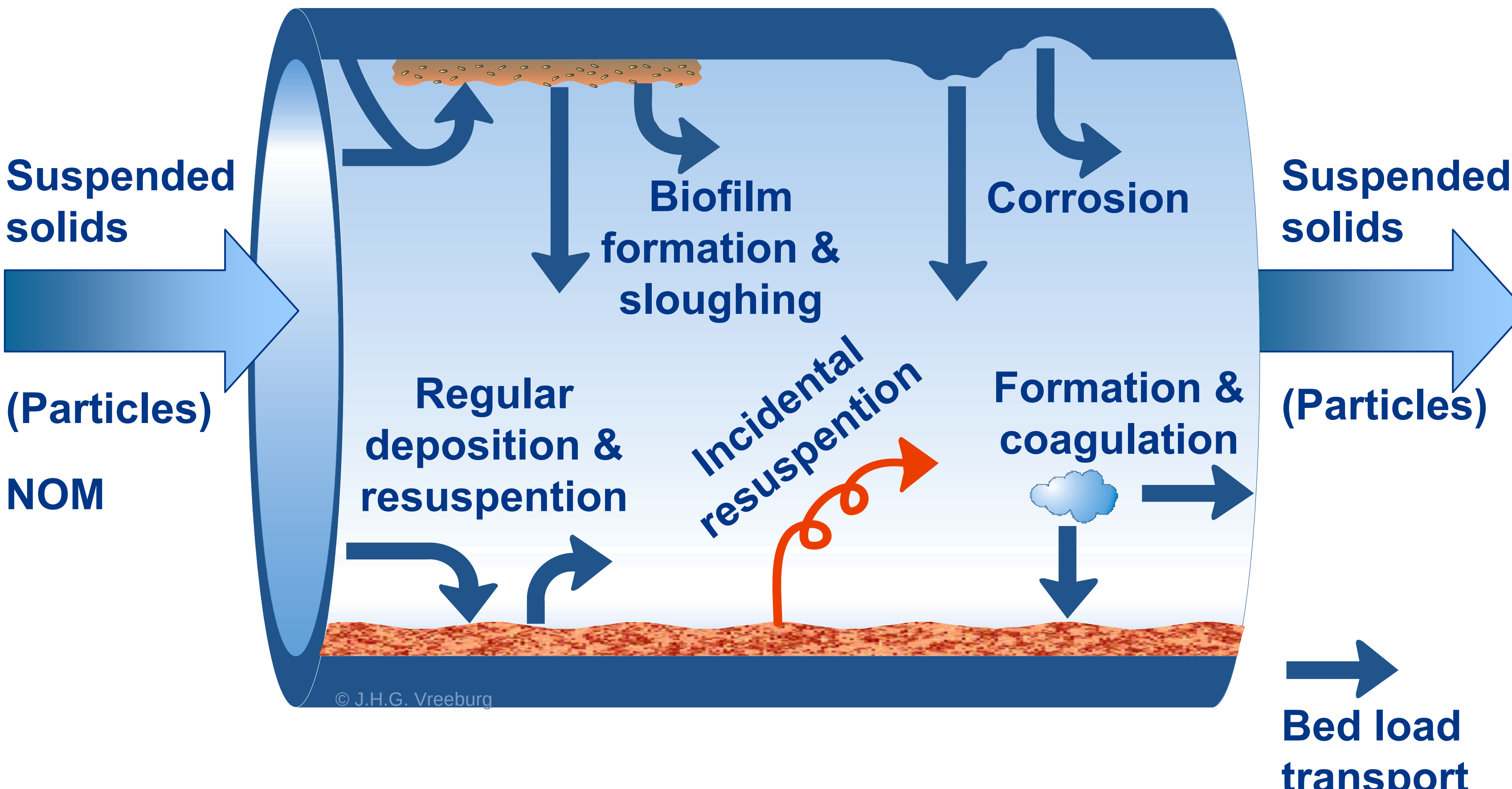
- BTO forms the base, both vision and funding
- TU Delft adopted the ambitions of program ➔ MSc and PhD students, national and international
  - Delft Cluster is co-financing research, based on BTO ambition and financing ➔ cream on top and scientific enhancement
  - NOM-project opens new oppertunities for extension and enhancement

Consequences of particles in the network

Biological activity !



Mass balance in a network

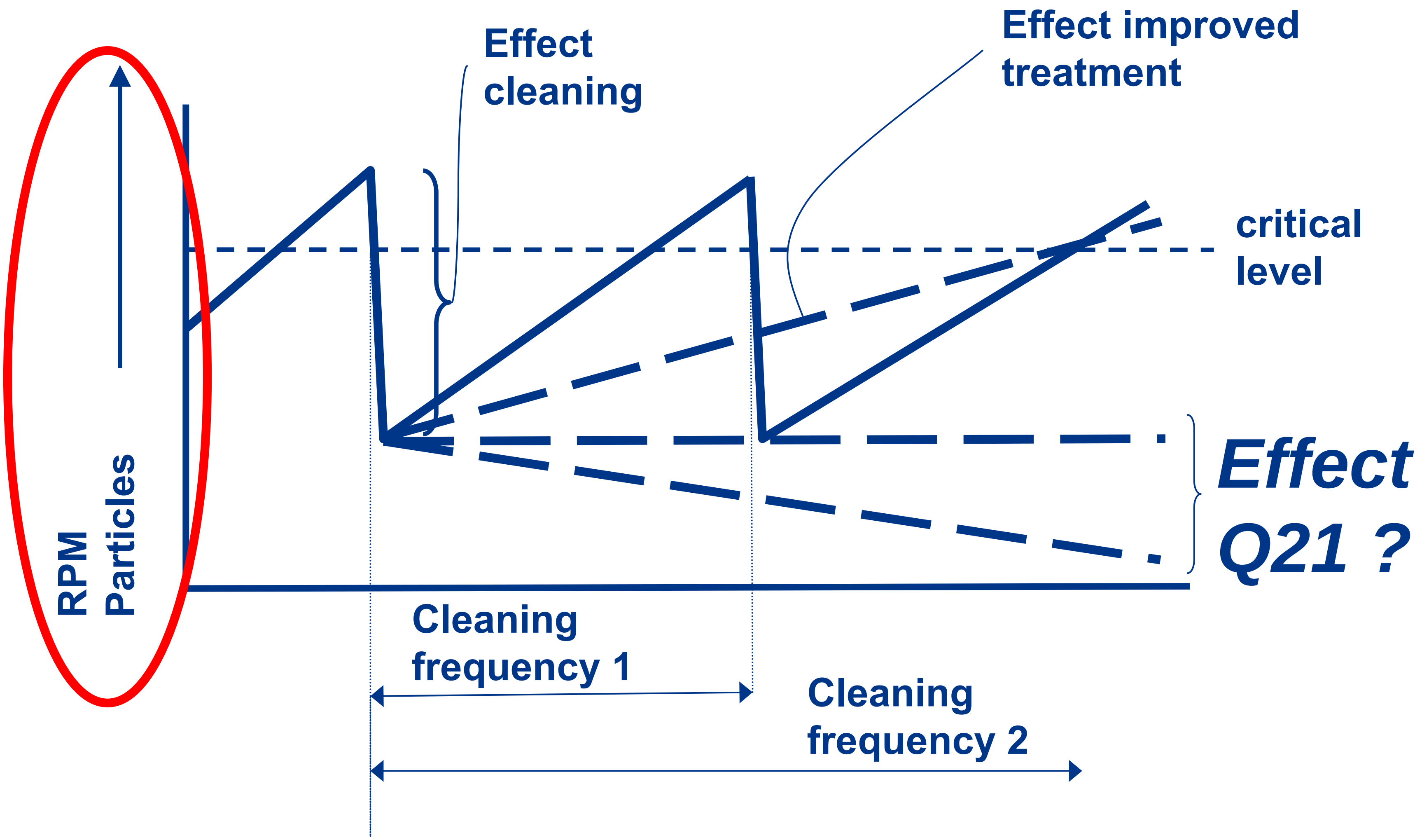


Particles in the distributioen network

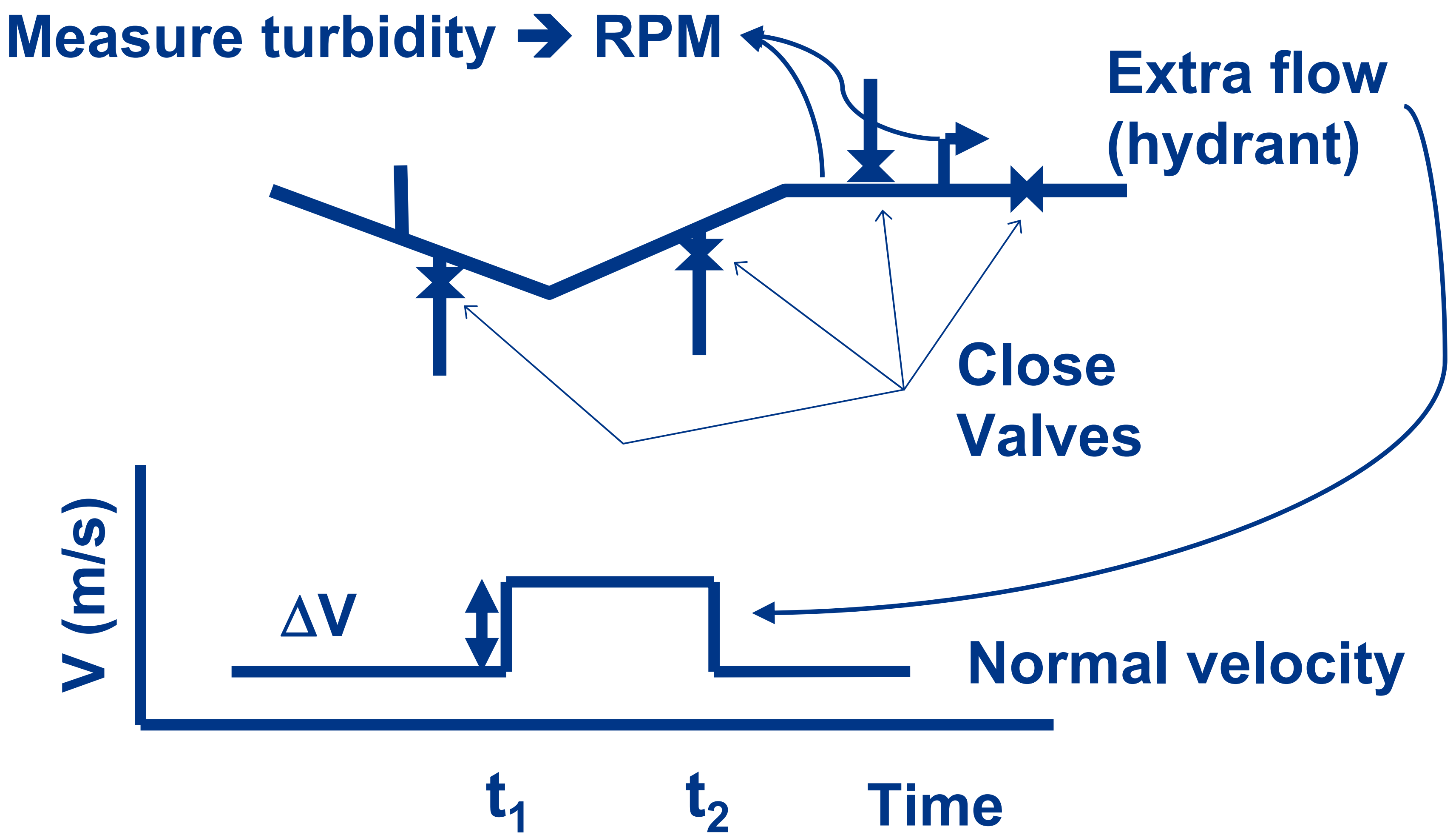
- Particles in the network are the most important cause for discolouration problems

- Reserach up till now resulted in the three-stage approach:
- Fundamental
  1. Prevent particles from entering the network or prevent formation of particles (Influence NOM?)
- Operational
  2. Prevent particle accumulation → Clean the network
  3. Prevent particle sedimentation/settling → High velocities in the pipes

Stage 1: Hypothesis effect particle load



Resuspension Potential Measurement

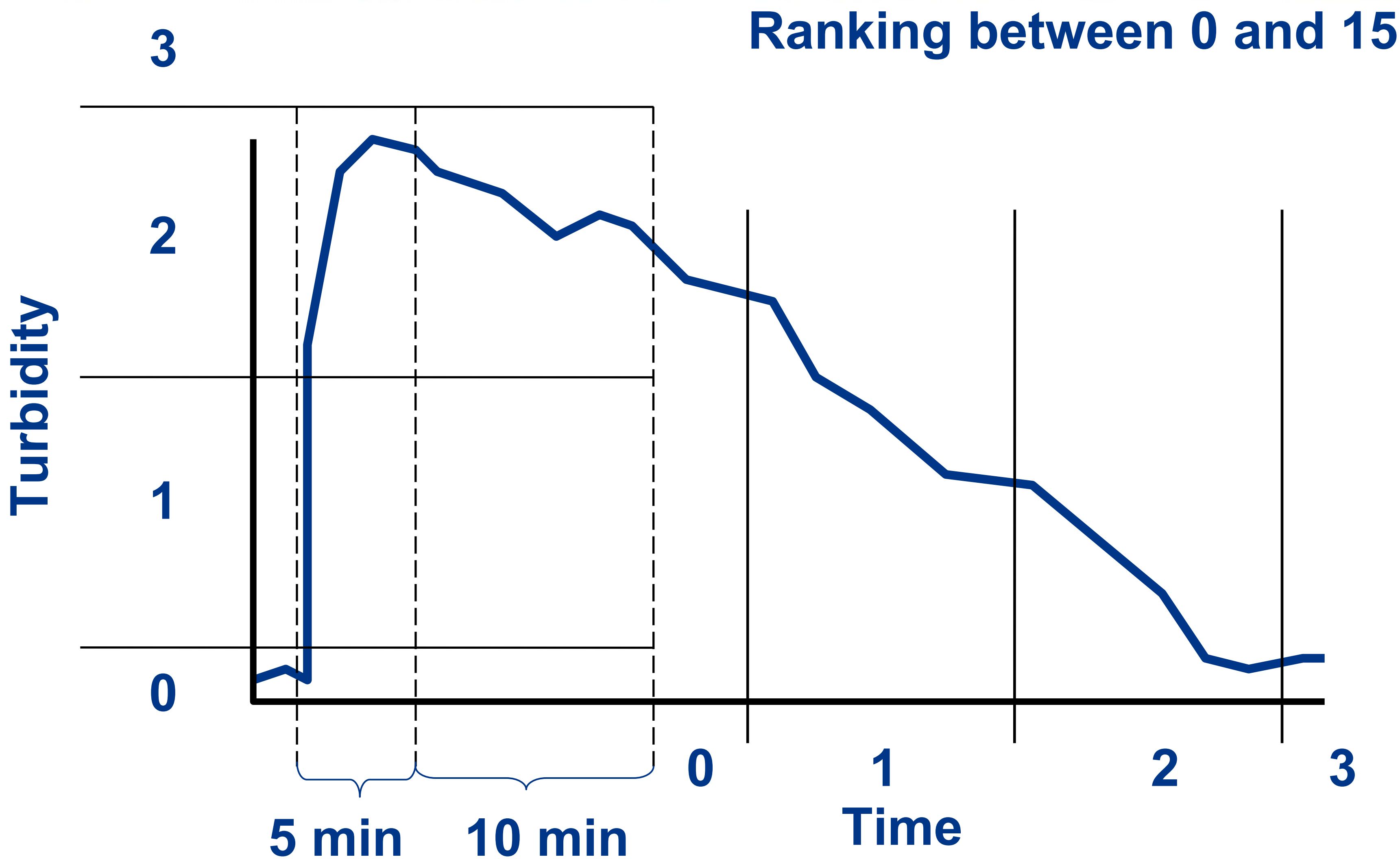


Pictures monitor connection

Resuspension Potential Method

Resuspension Potential Method

Ranking standard RPM (315 m; 0,35 m/s; 15 minutes)

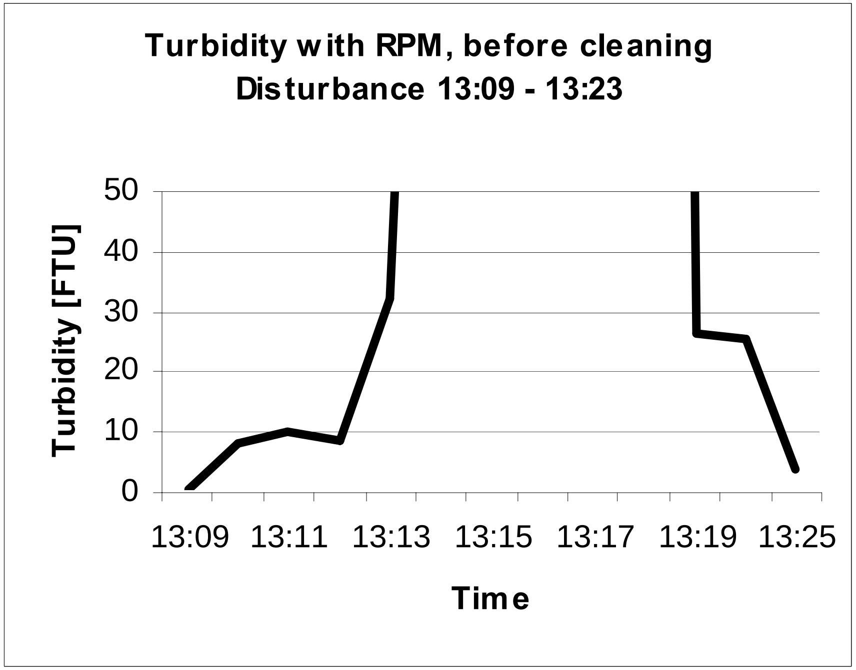


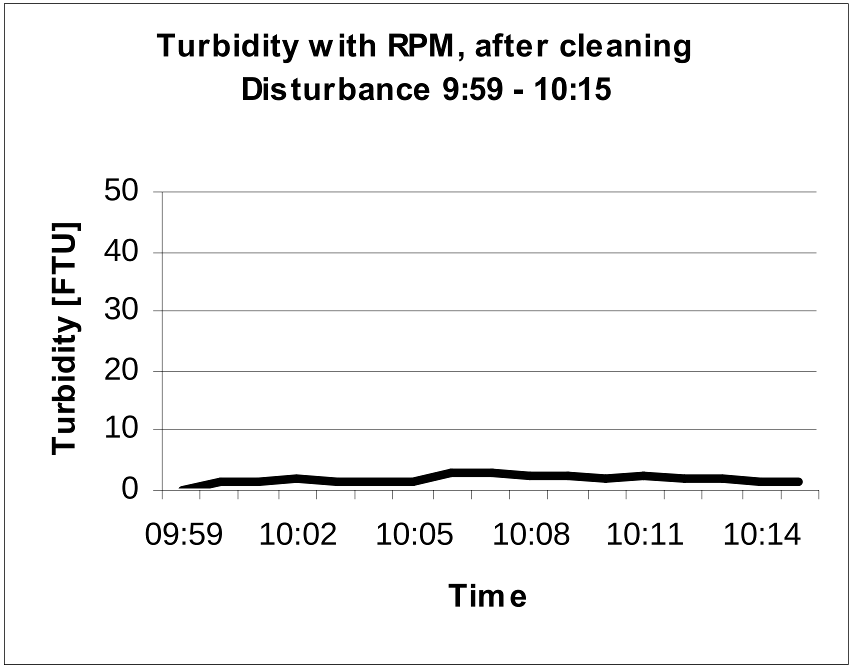
Ranking RPM

Turbidity Dr Lange, Hydrant measuring

Category \ points	0	1	2	3
Absolute max first 5 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Average first 5 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Absolute max last 10 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Average max last 10 min	<3 ftu	3 –10 ftu	10-40 ftu	>40 ftu
Time to clear	< 5 min.	5-15 min	15-60 min	>60 min

Typical RPM results
Pre and Post cleaning: Evaluation tool!

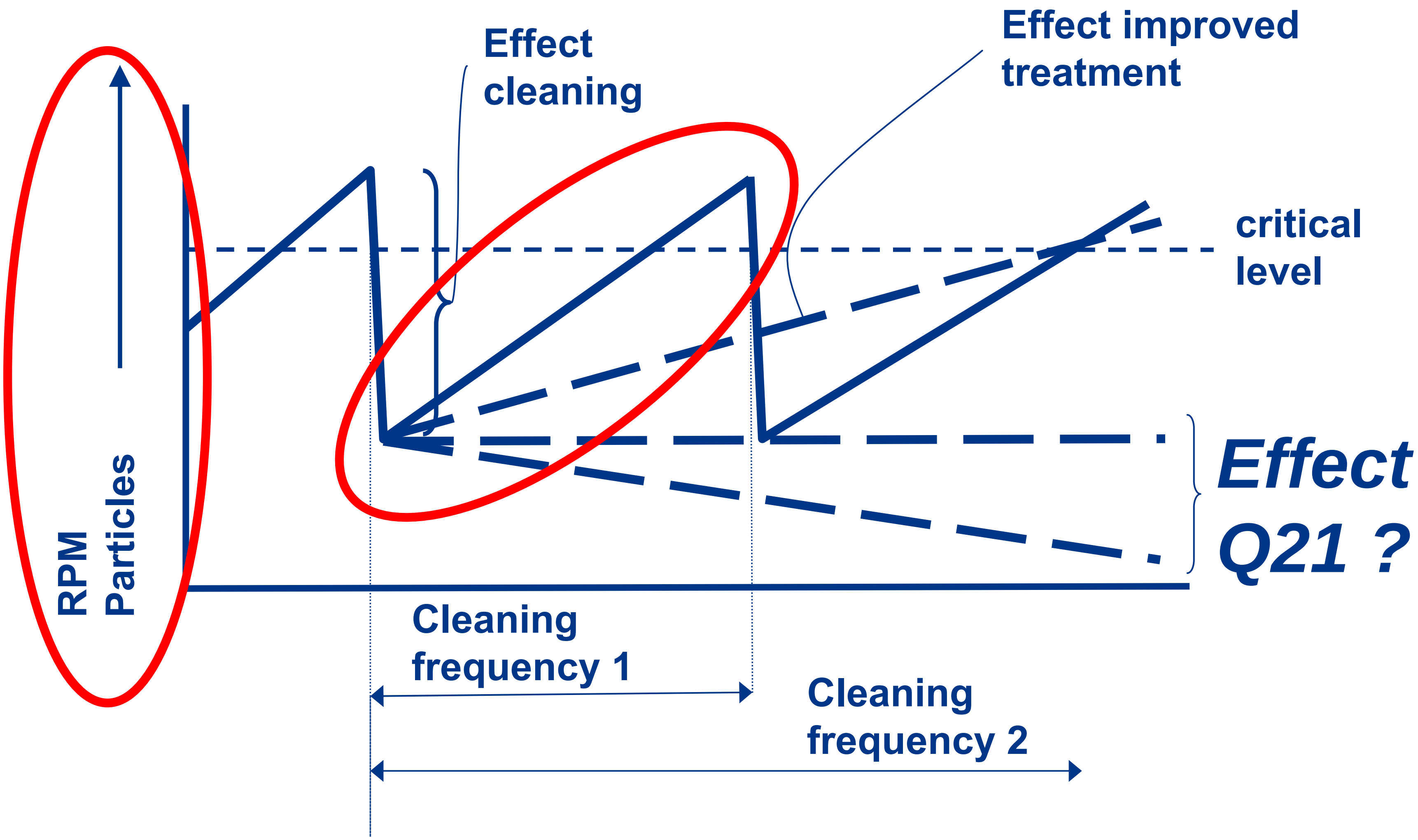




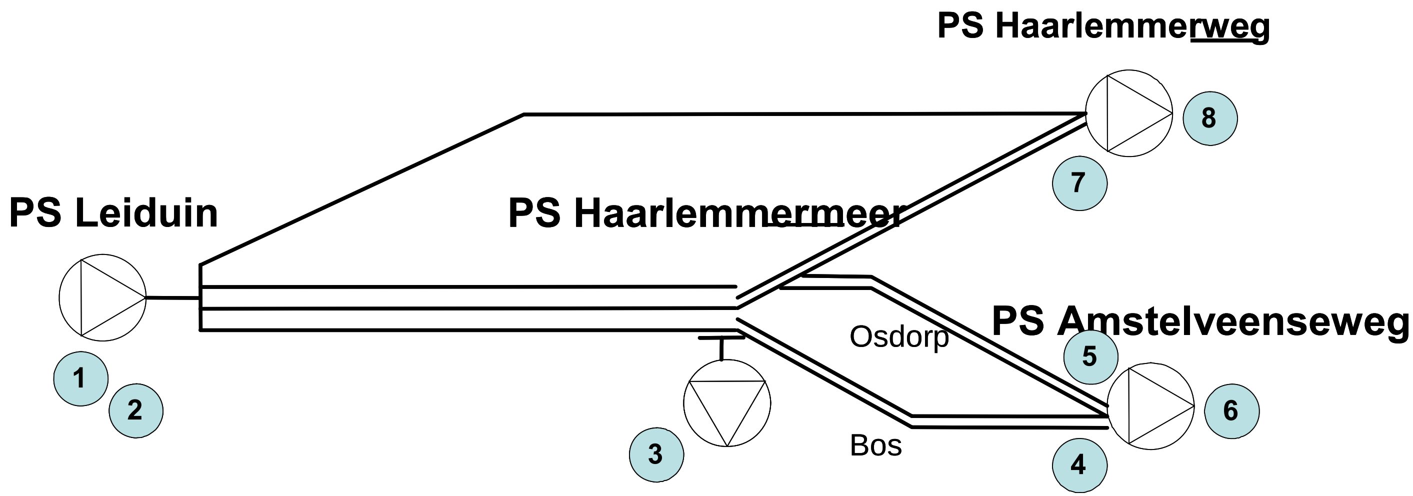
Score 14

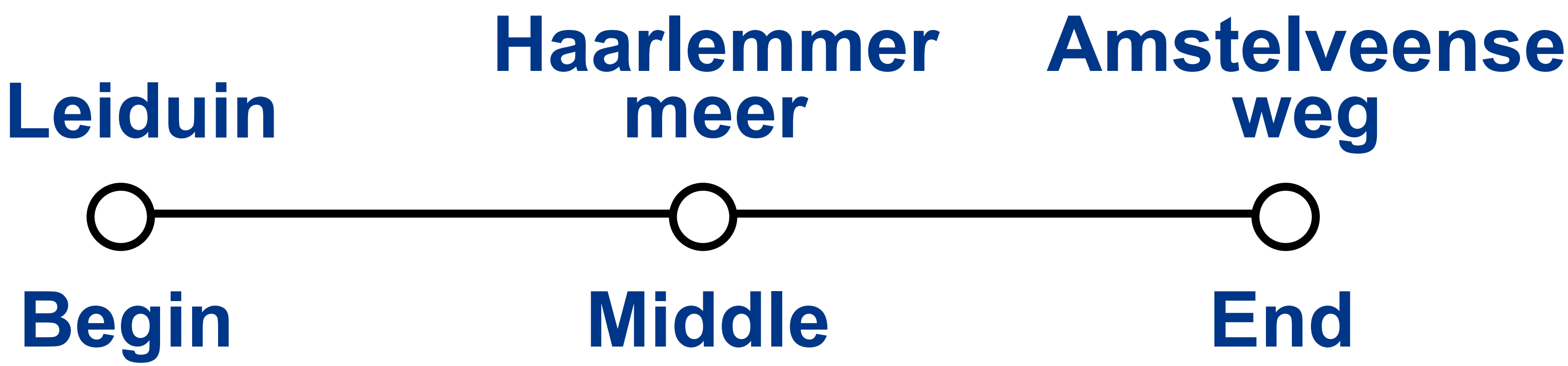
Score 1

Stage 1: Hypothesis effect particle load

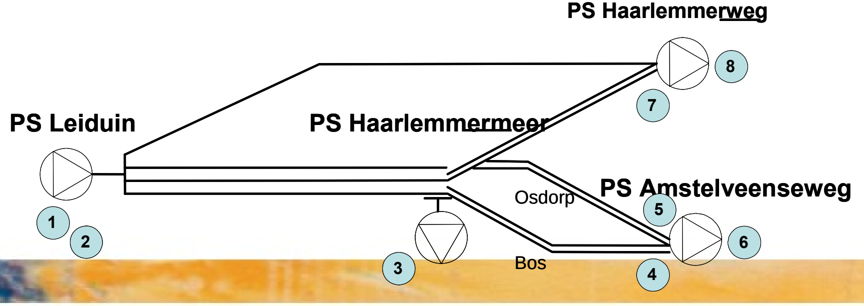


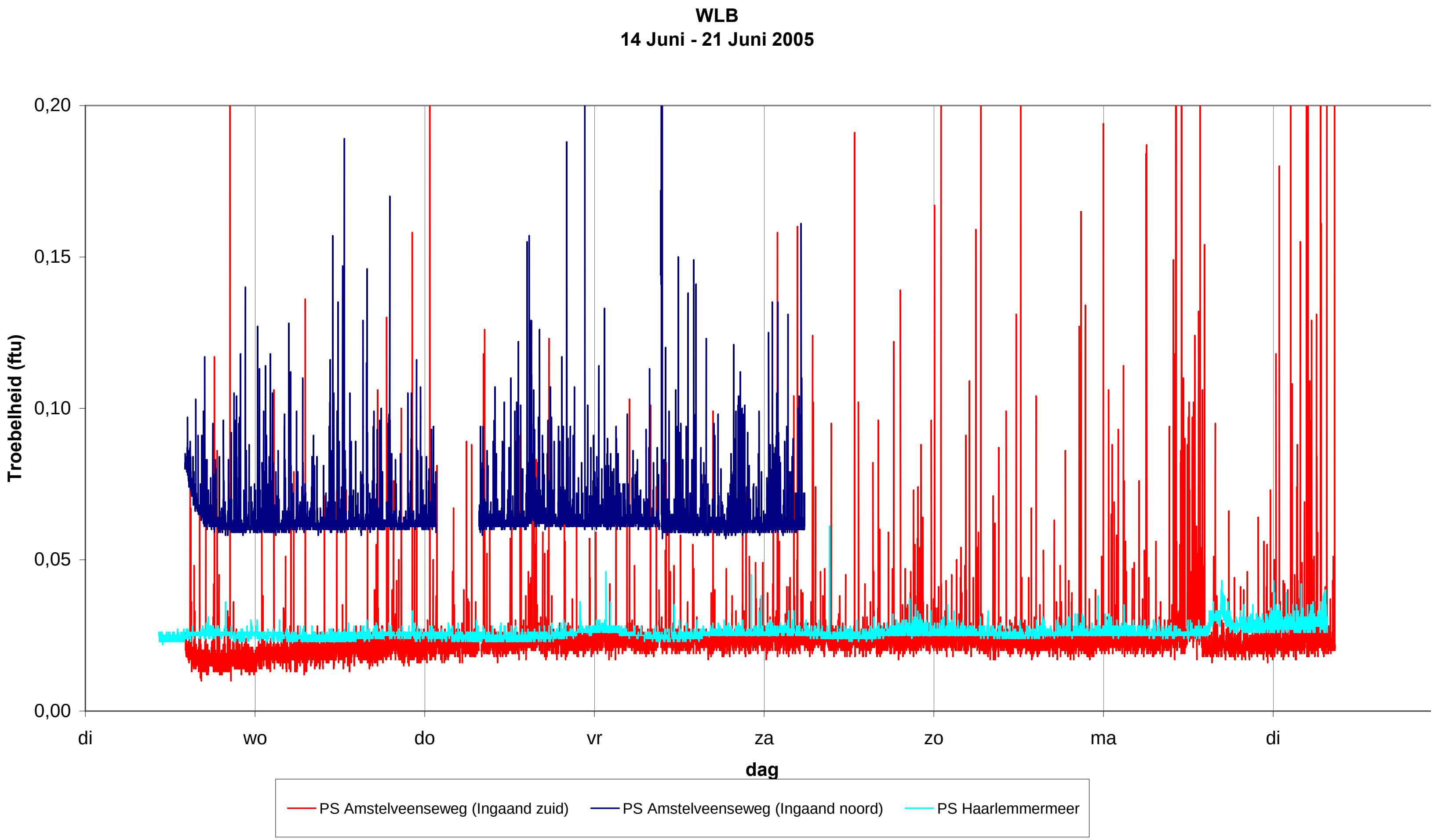
Application particle counters



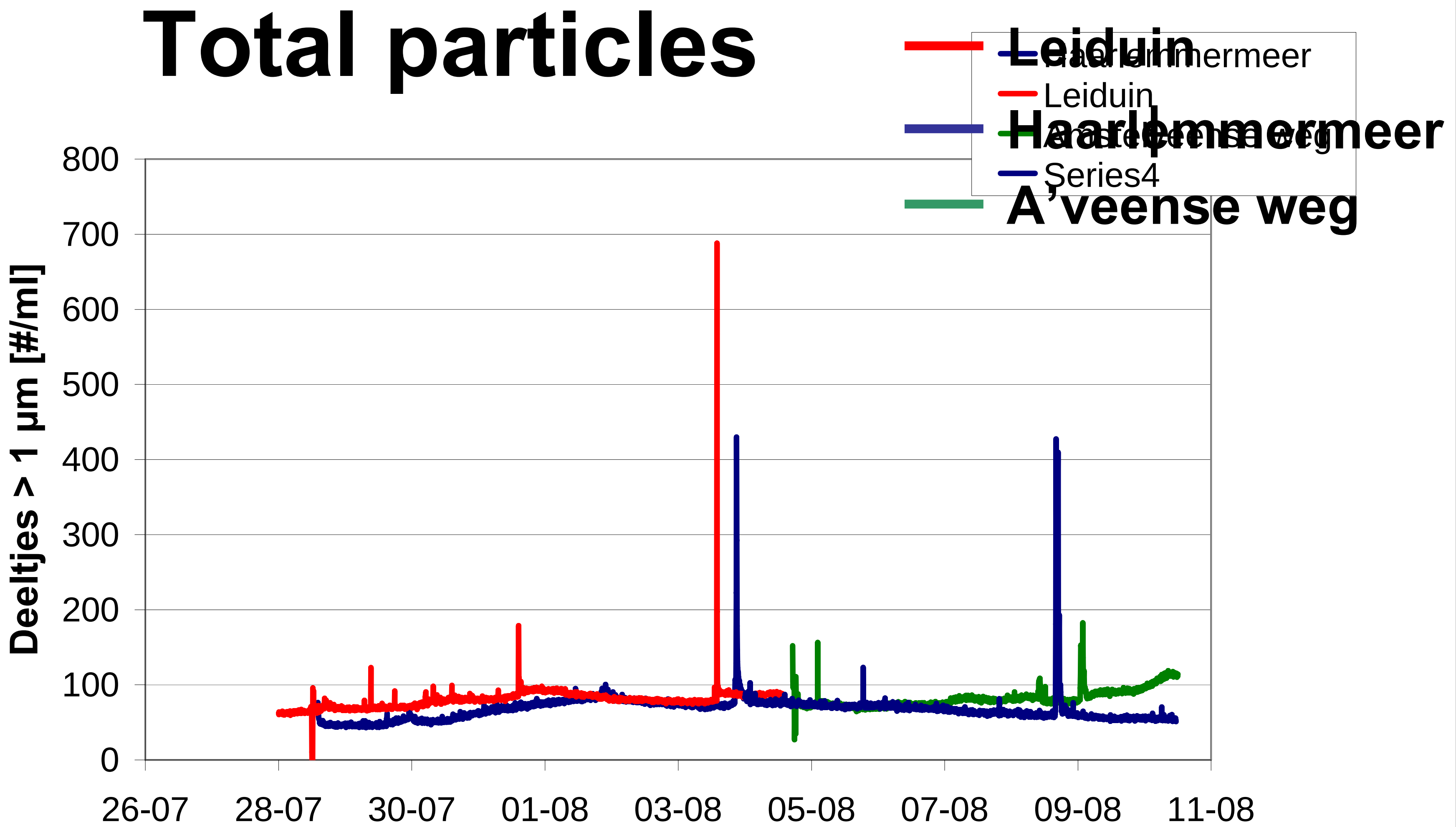


Track 3 → 4, 5 → 6
14 june – 21 june



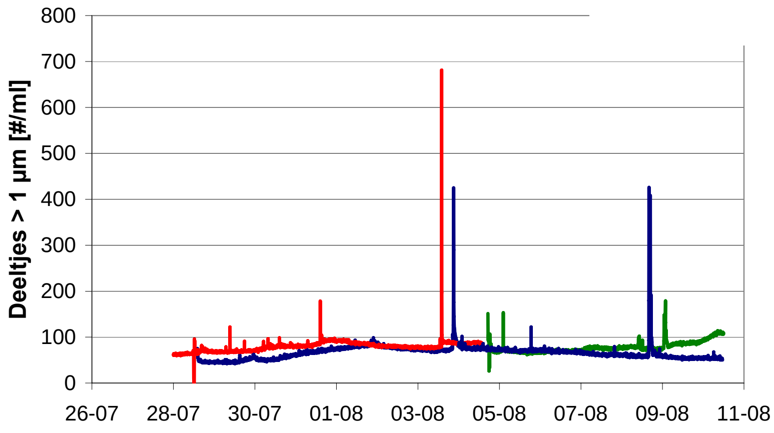


Results: a bit more nuance compared to turbidity

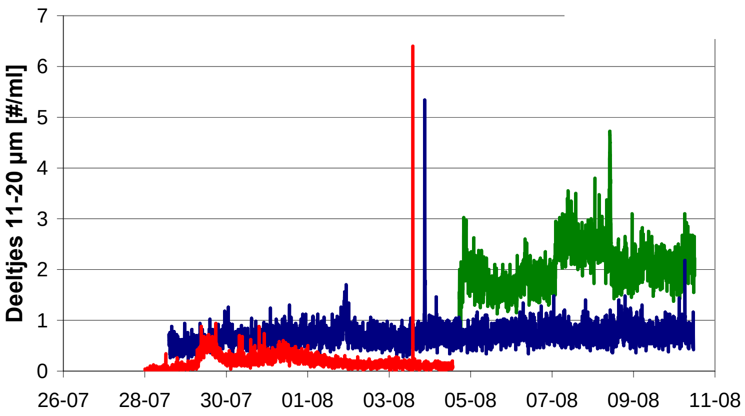


Distribution of particles: more information

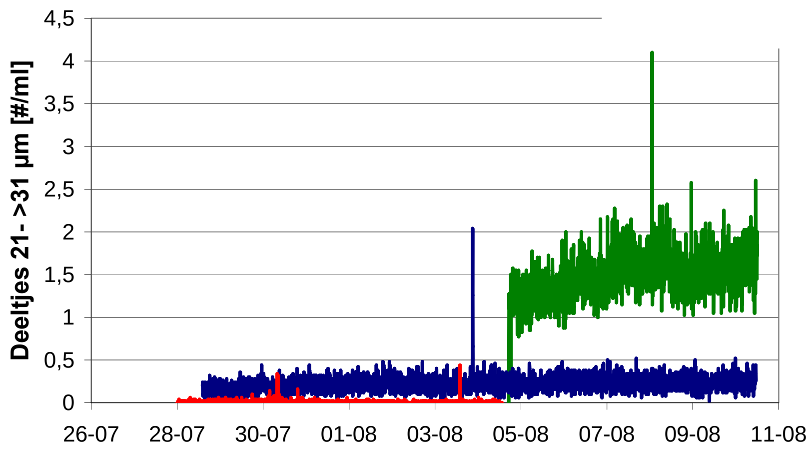
Smal particles 1-10 µm



Middle particles 11-21 µm



Large particles 20- >31 µm



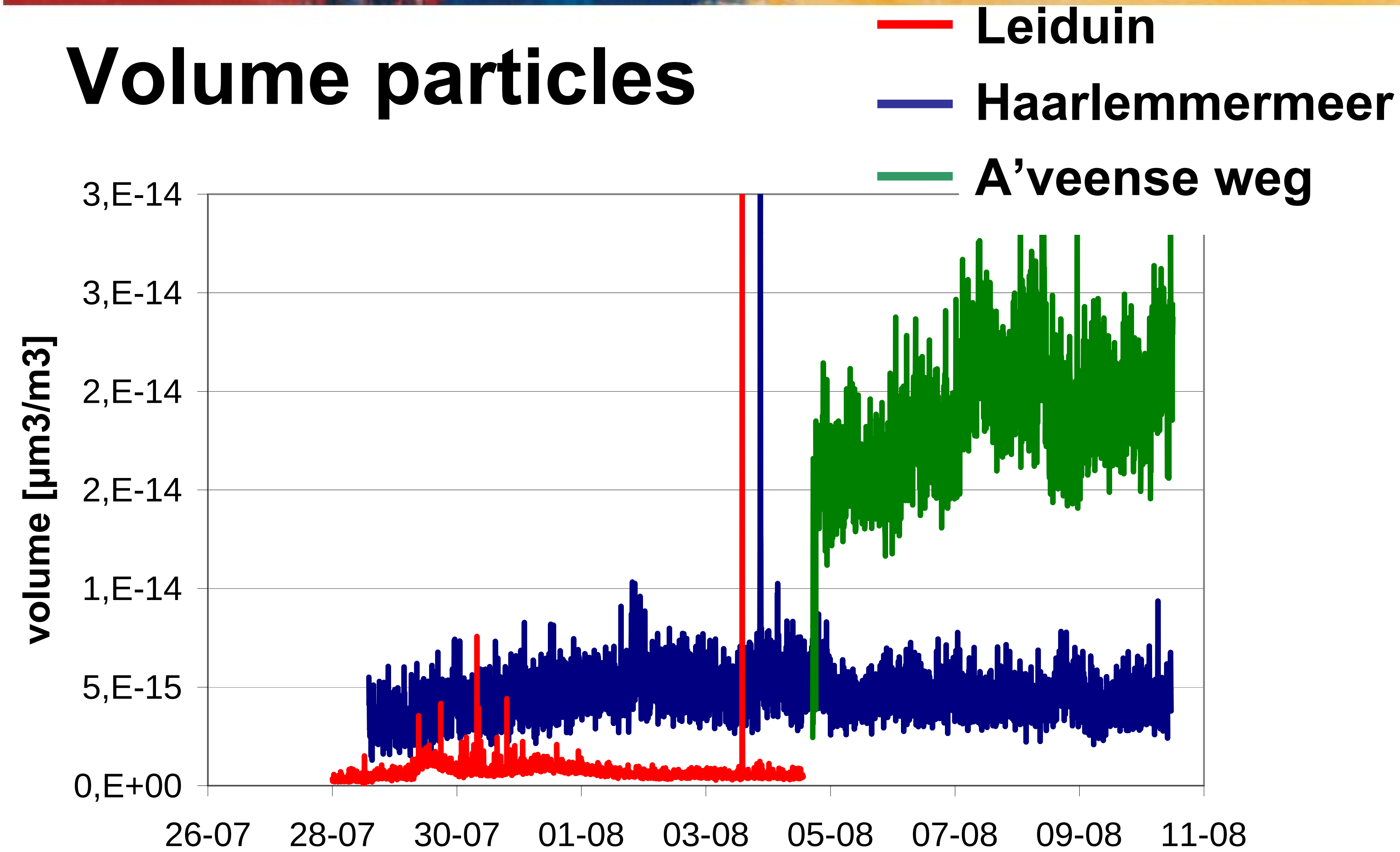
Leiduin

Haarlemmermeer

A'veense weg

Particles in diameter ranges ➔ volume

Volume particles

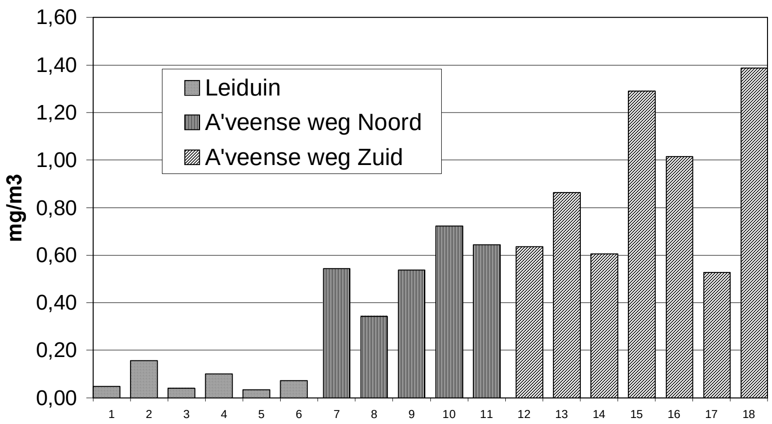


Volume → mass and composition: Time Integrated Large Volume Sampling, TILVS

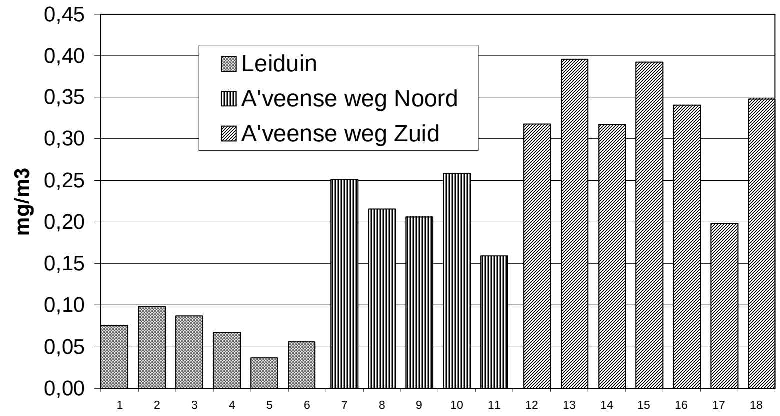
TILVS and particle counting
Cooperation illustrated

Analysis inorganics TILVS

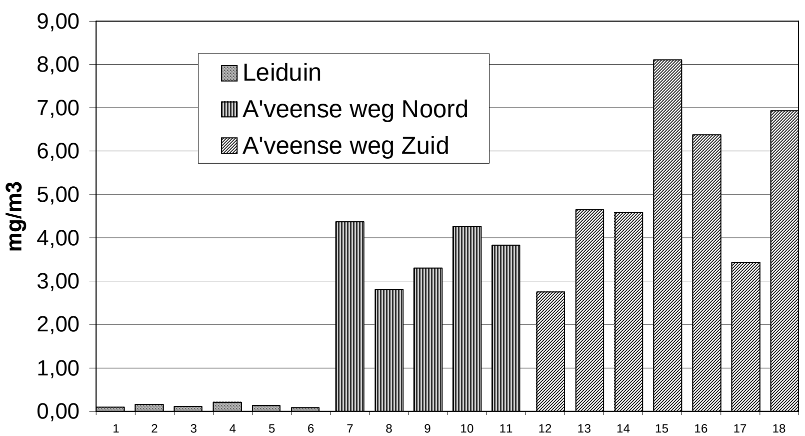
Aluminium



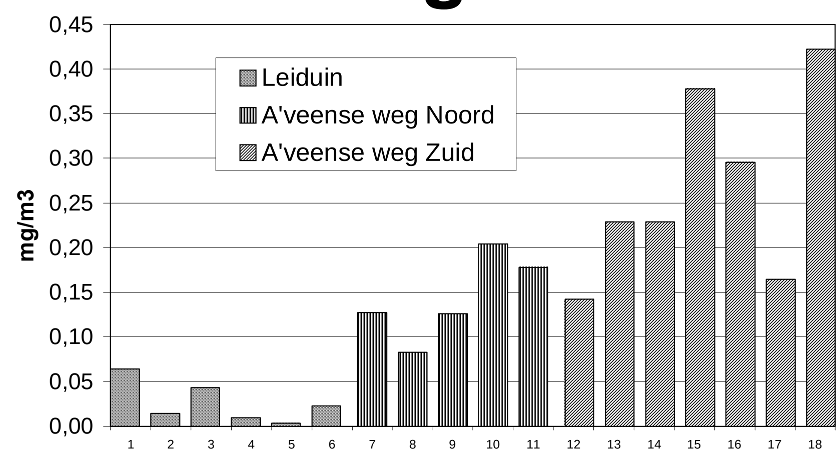
Magnesium



Iron



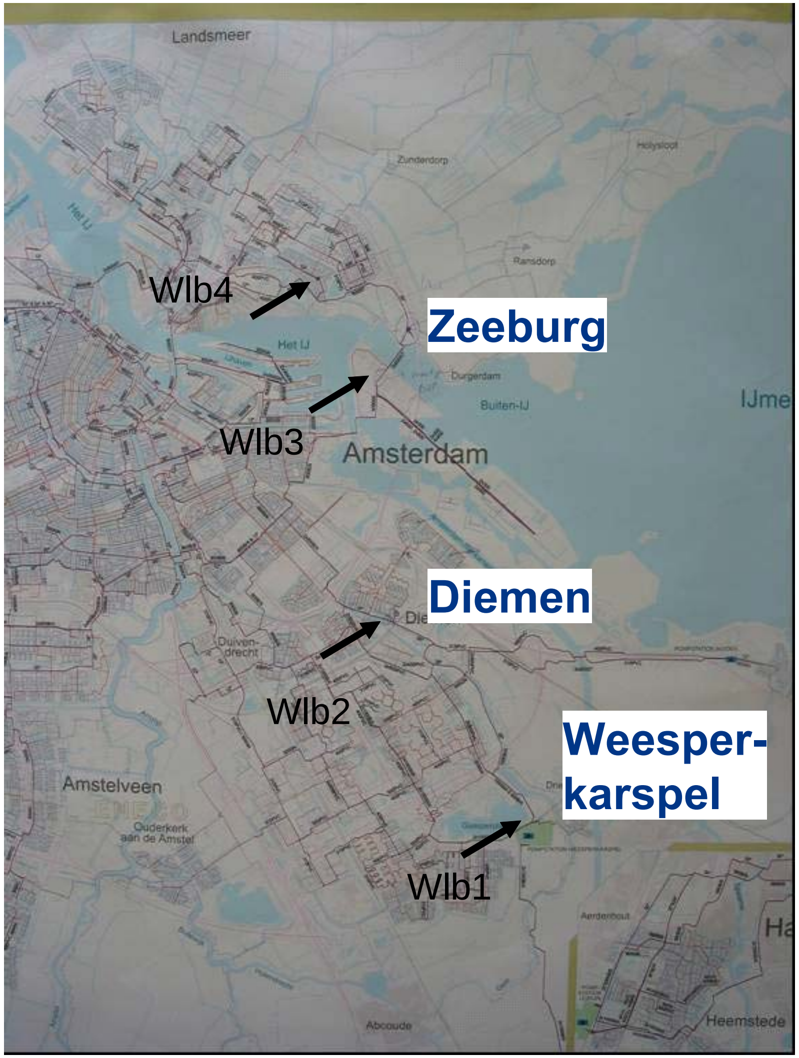
Manganese



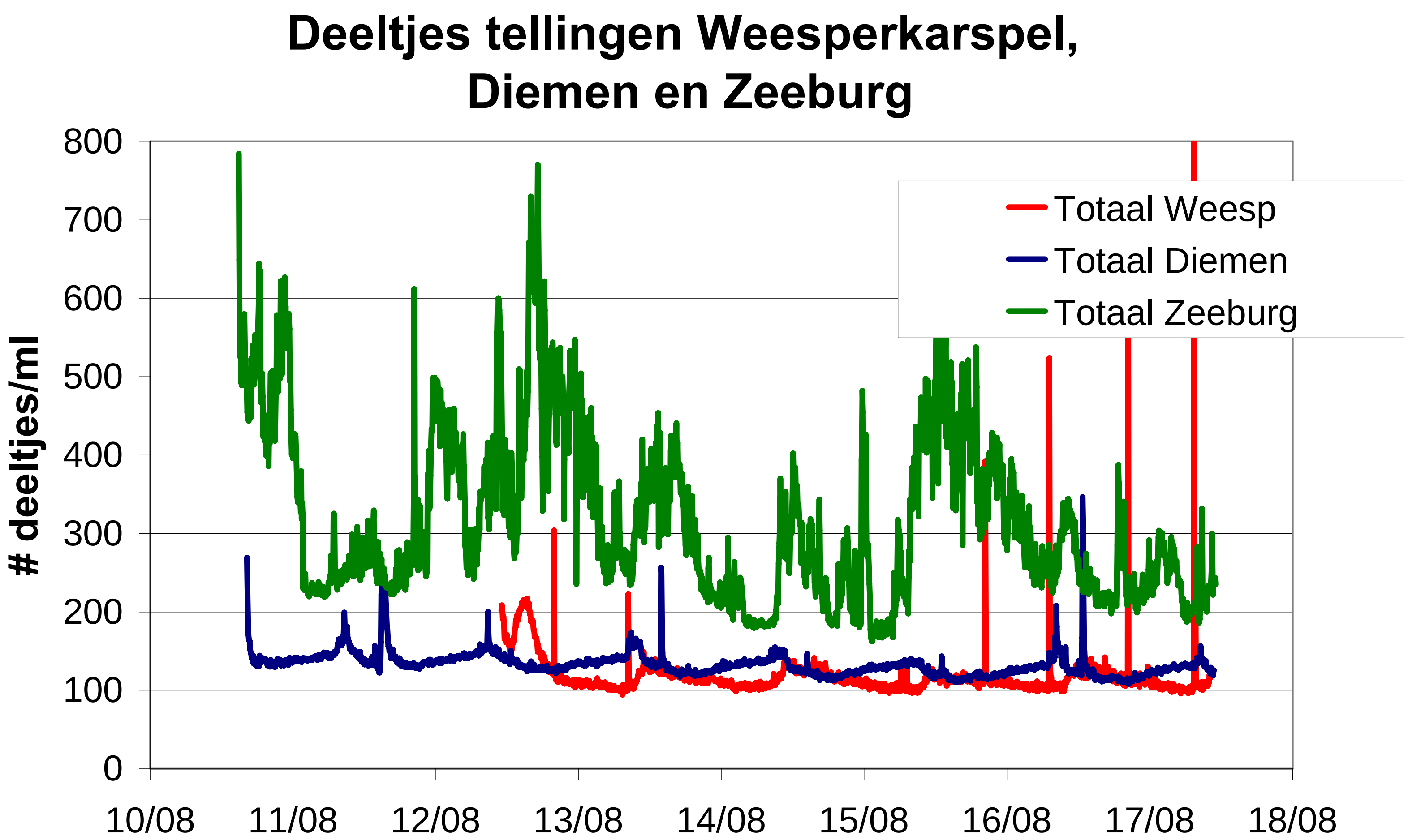
Analysis mass TILVS

- Increase organich fraction to 15 - 55%
- Increase ‘leaching elements’ factor 4-10
- Increase iron factor 30-40
- Increase manganese factor 5-10
- Enhance TILVS protocol

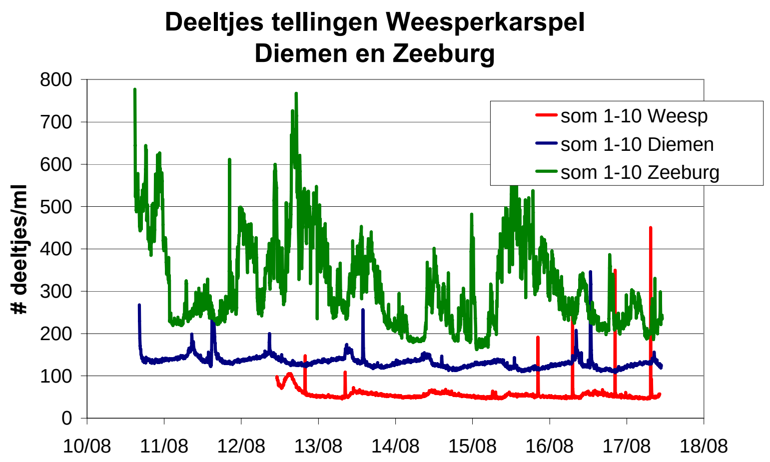
Measuring locations particle counting

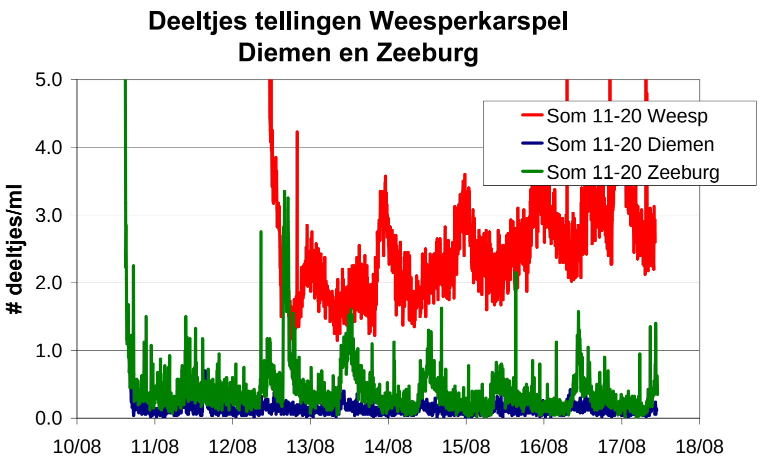


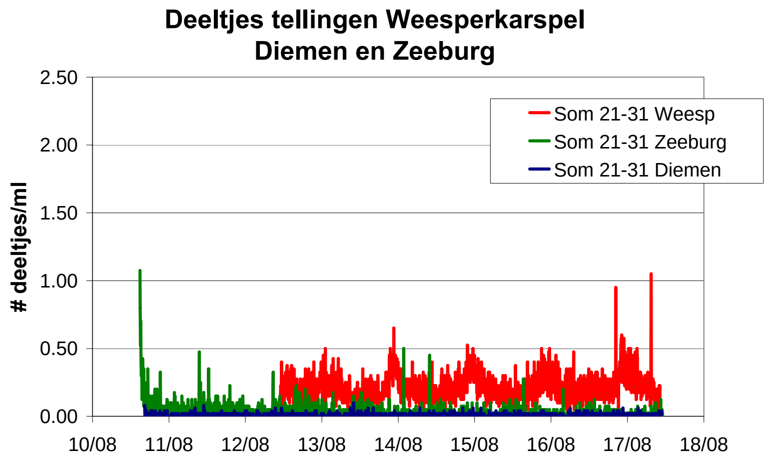
Particle counts Weesperkarspel, Diemen, Zeeburg

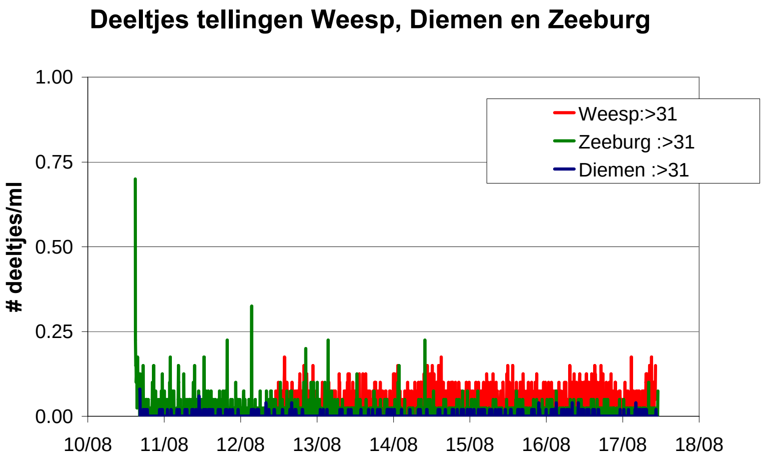


Particle ranges Weesperkarspel, Diemen, Zeeburg

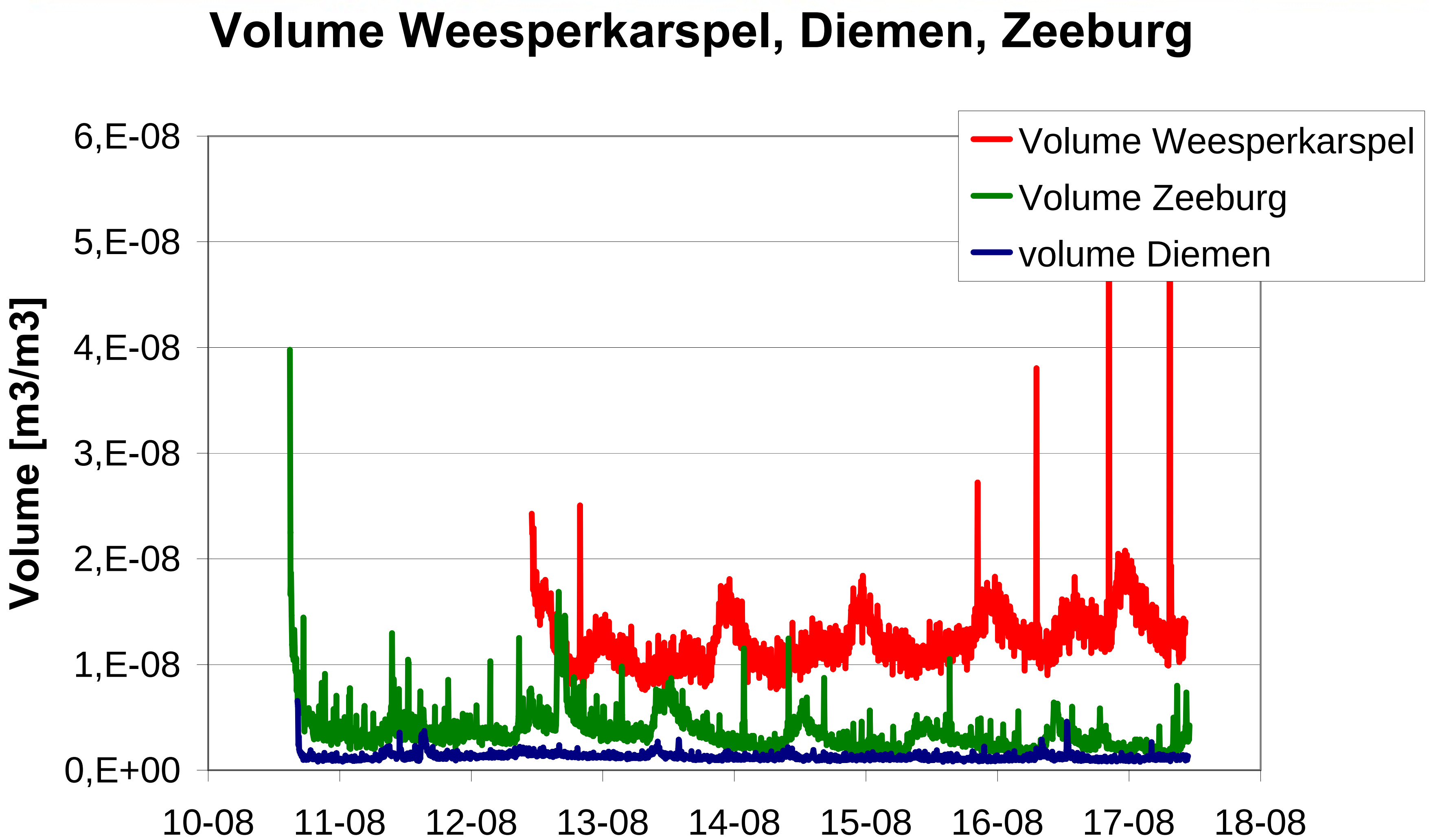




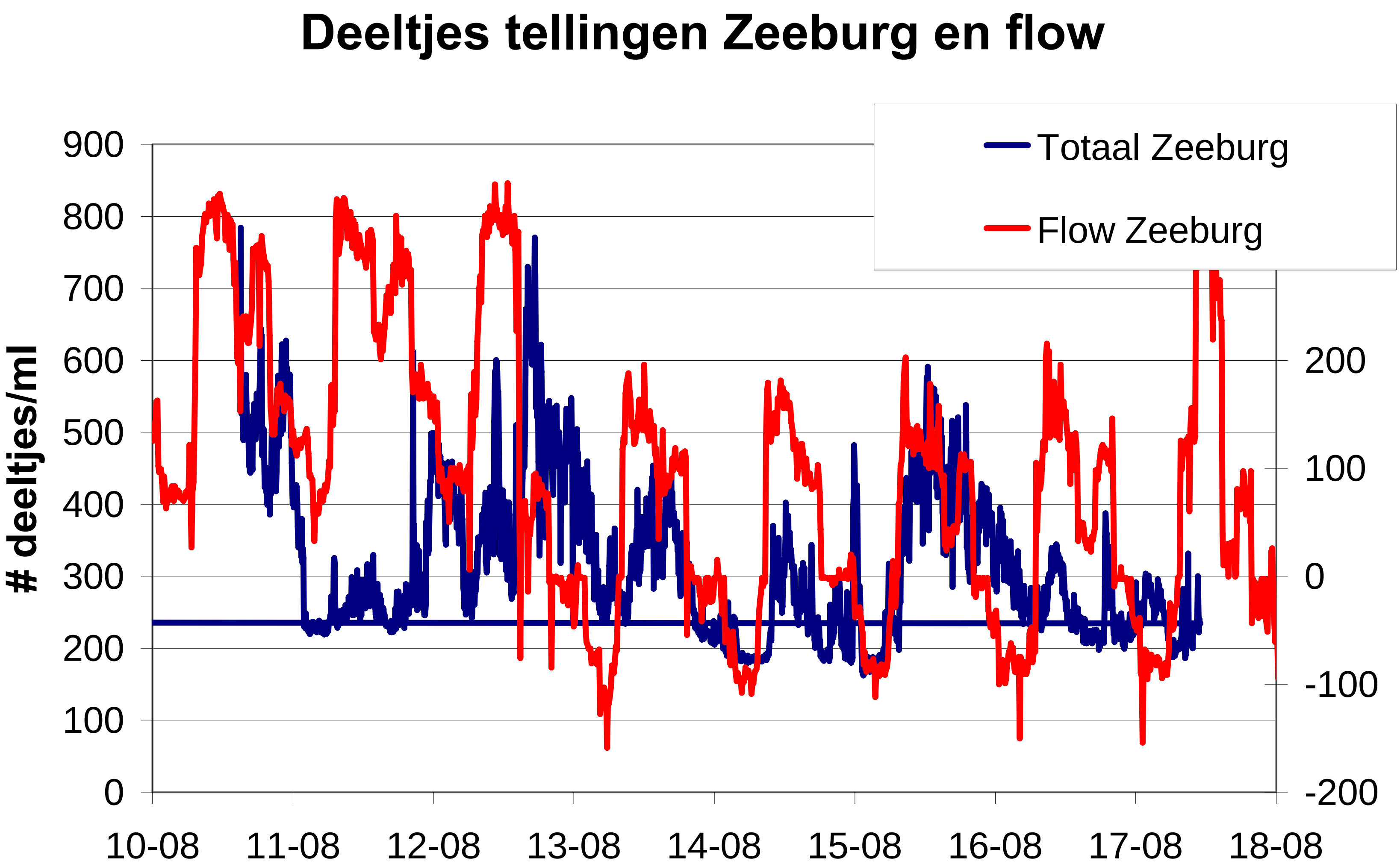




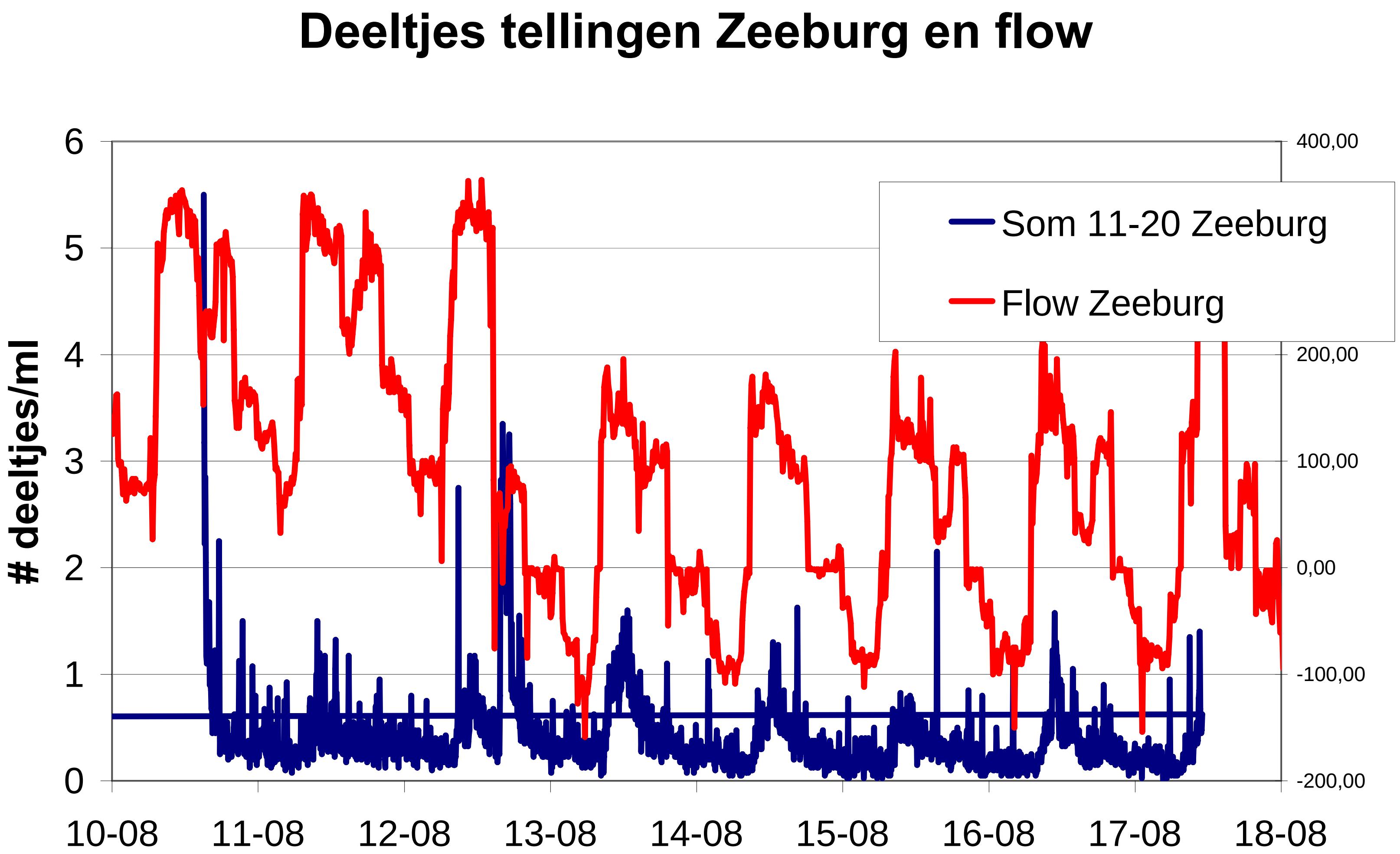
Volume particles: Volume decreases and increases



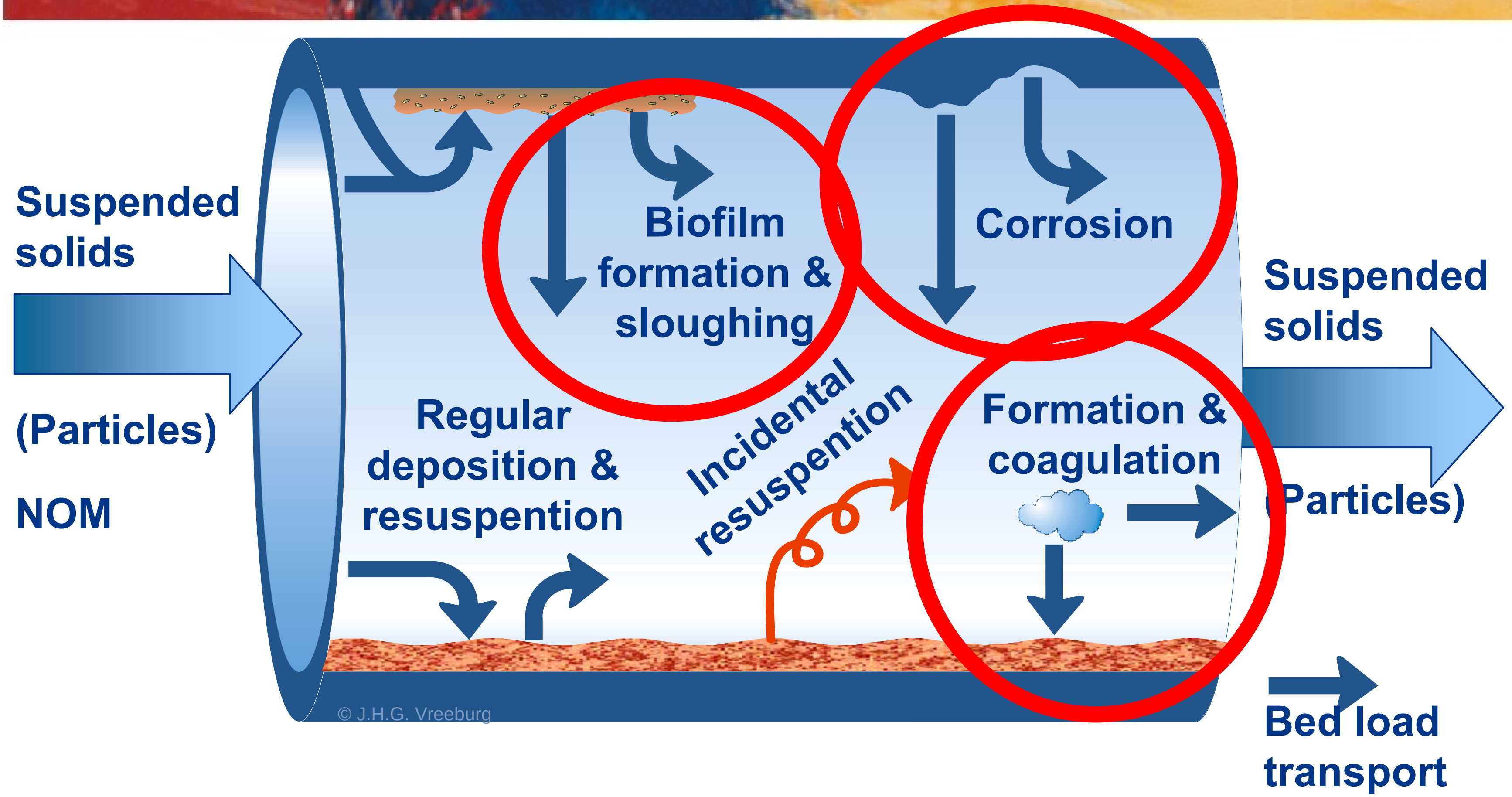
Total particles en flow ➔ resuspention?



Resuspention middle size particles

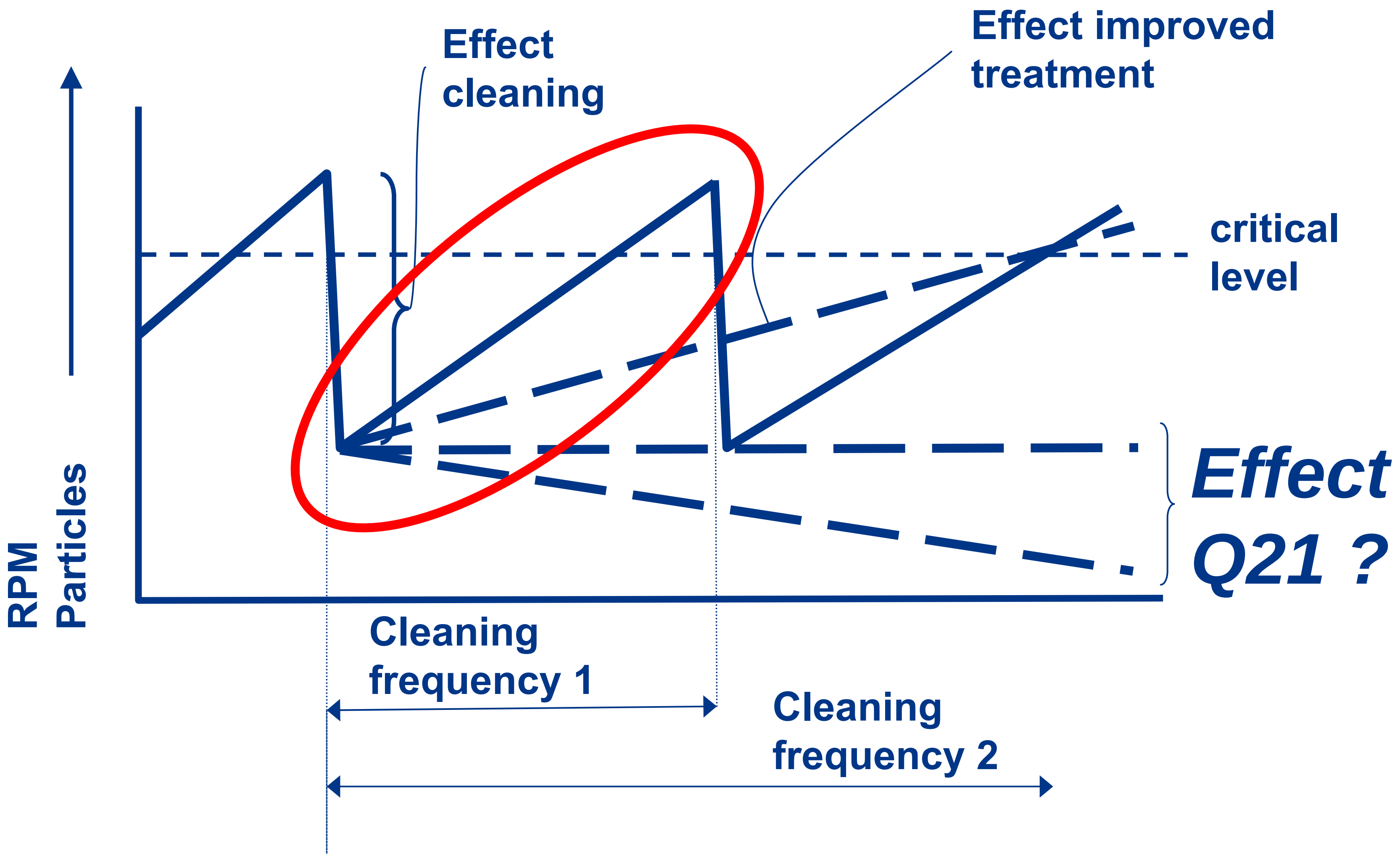


Conclusions particle counting and TILVS: three processes indentified



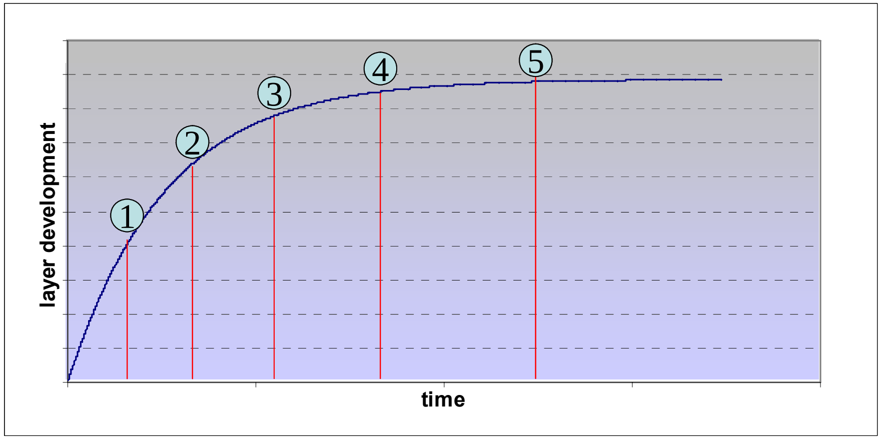
Further development interpretation particle counts: Ramiro Rodriguez

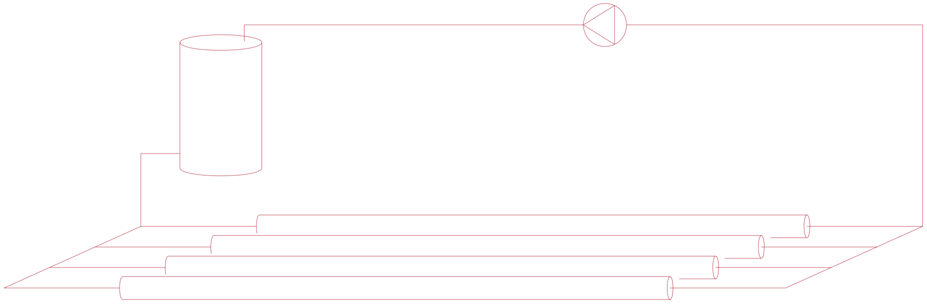
Stage 1: Hypothesis effect particle load developing a measuring method



Test rig particle load

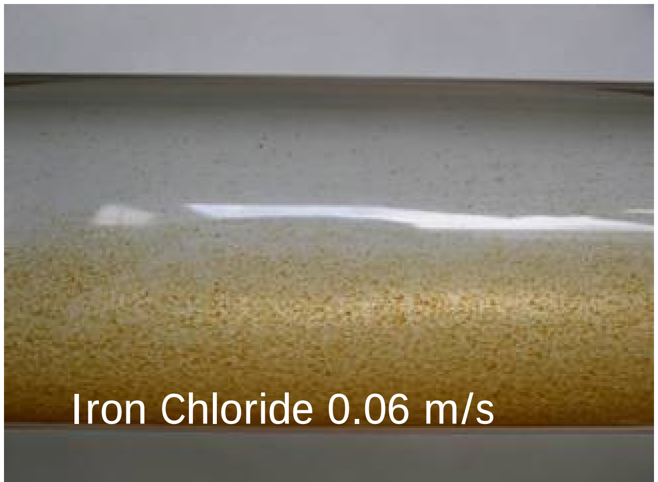
- **Test rig research**
  - Feasibility → MSc student Maarten Lut
  - Further development → MSc Student Anke Grefte
  - Practical application → MSc and PhD students

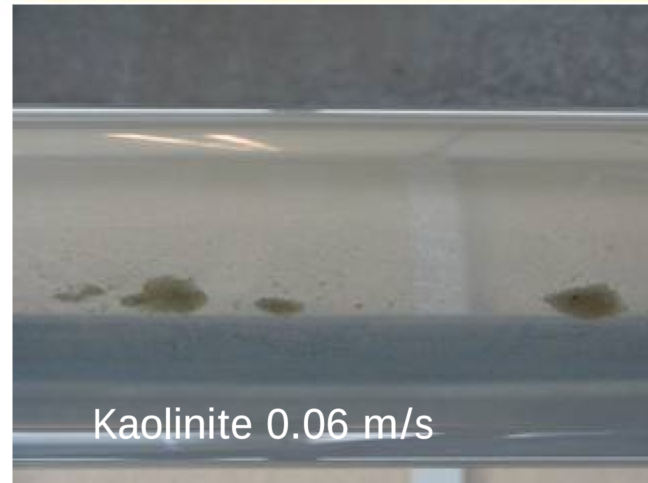


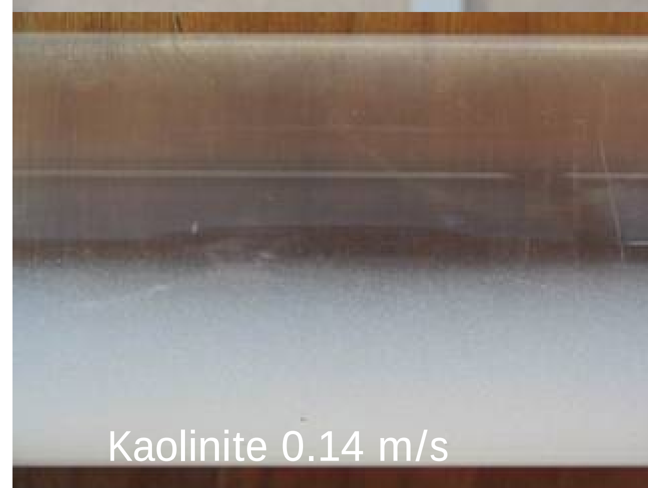


Test pipe rig Ø100

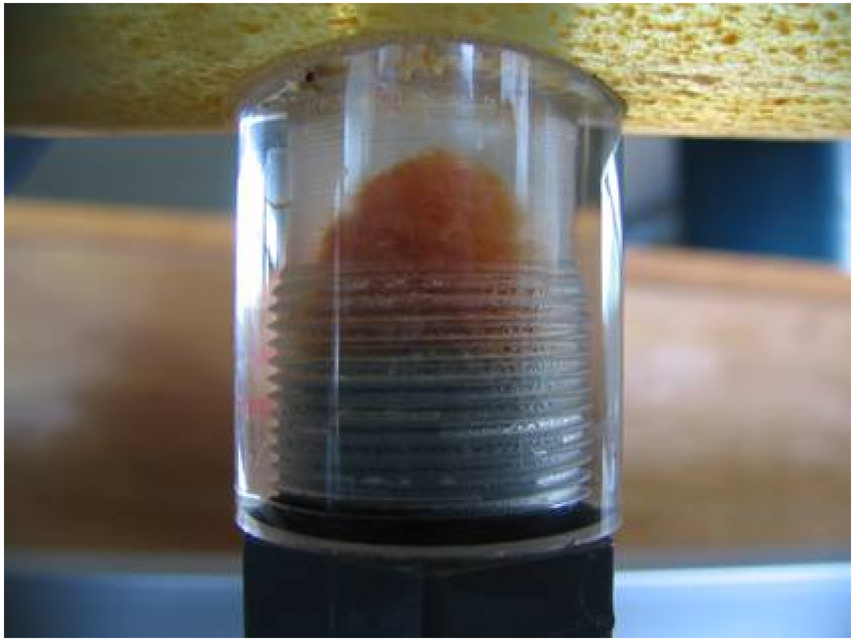
Gravitational settling is not the only process
Turbophoresis can explain this

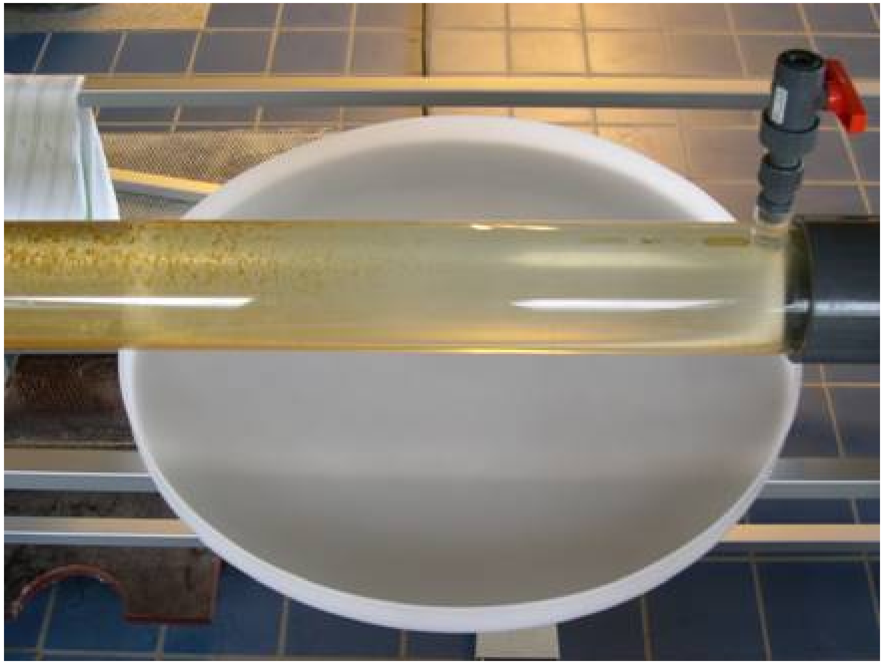






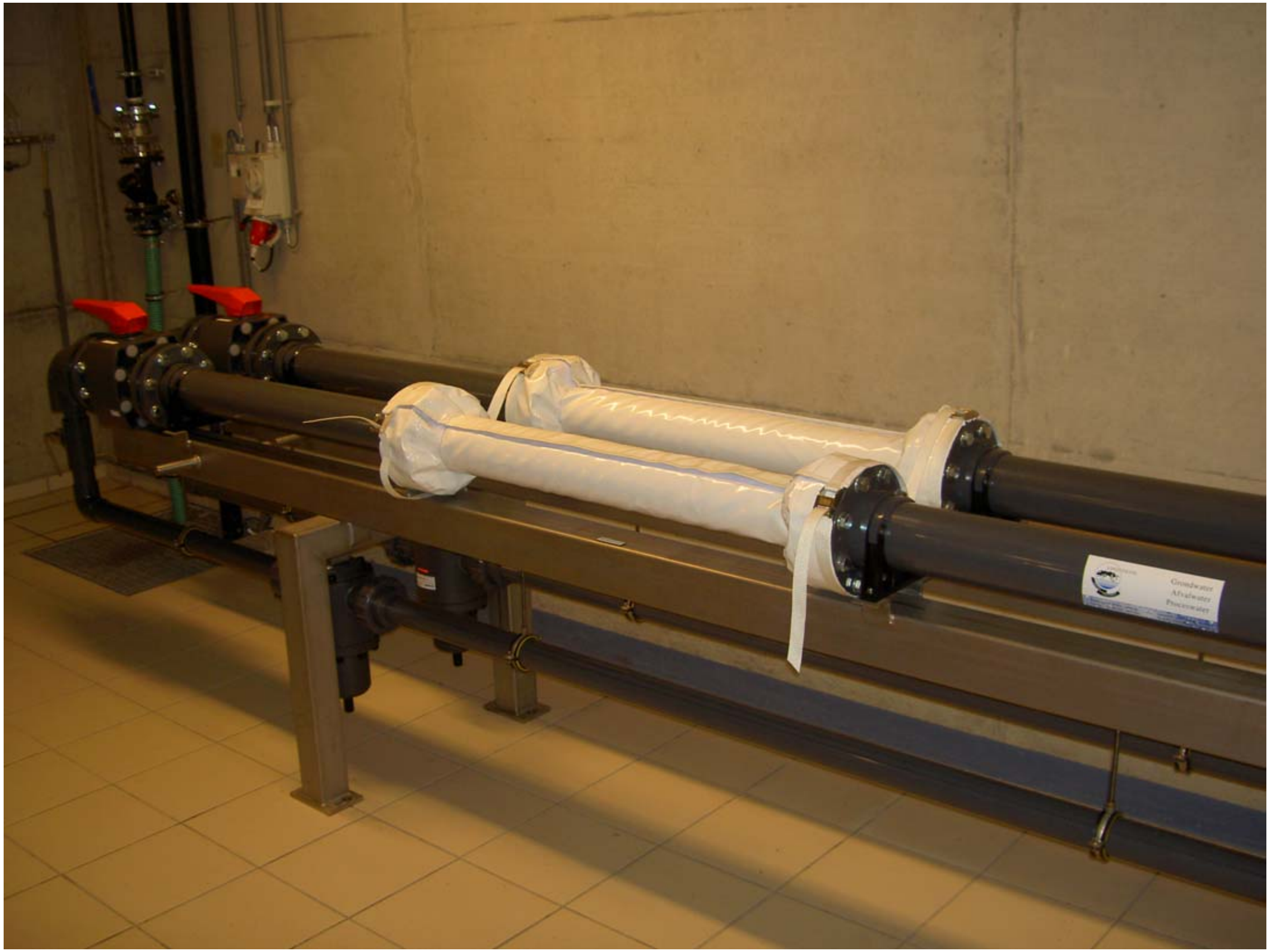
Bed load transport and influence 'bend turbulence'





'Old' and 'new' water

The test pipes



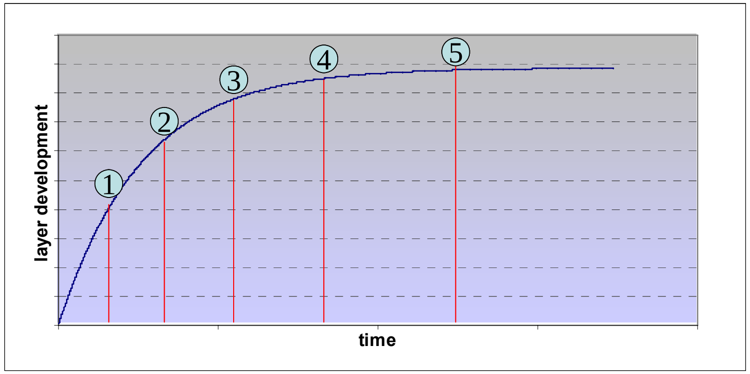
The test pipes uncovered after three (!) months

And after six months

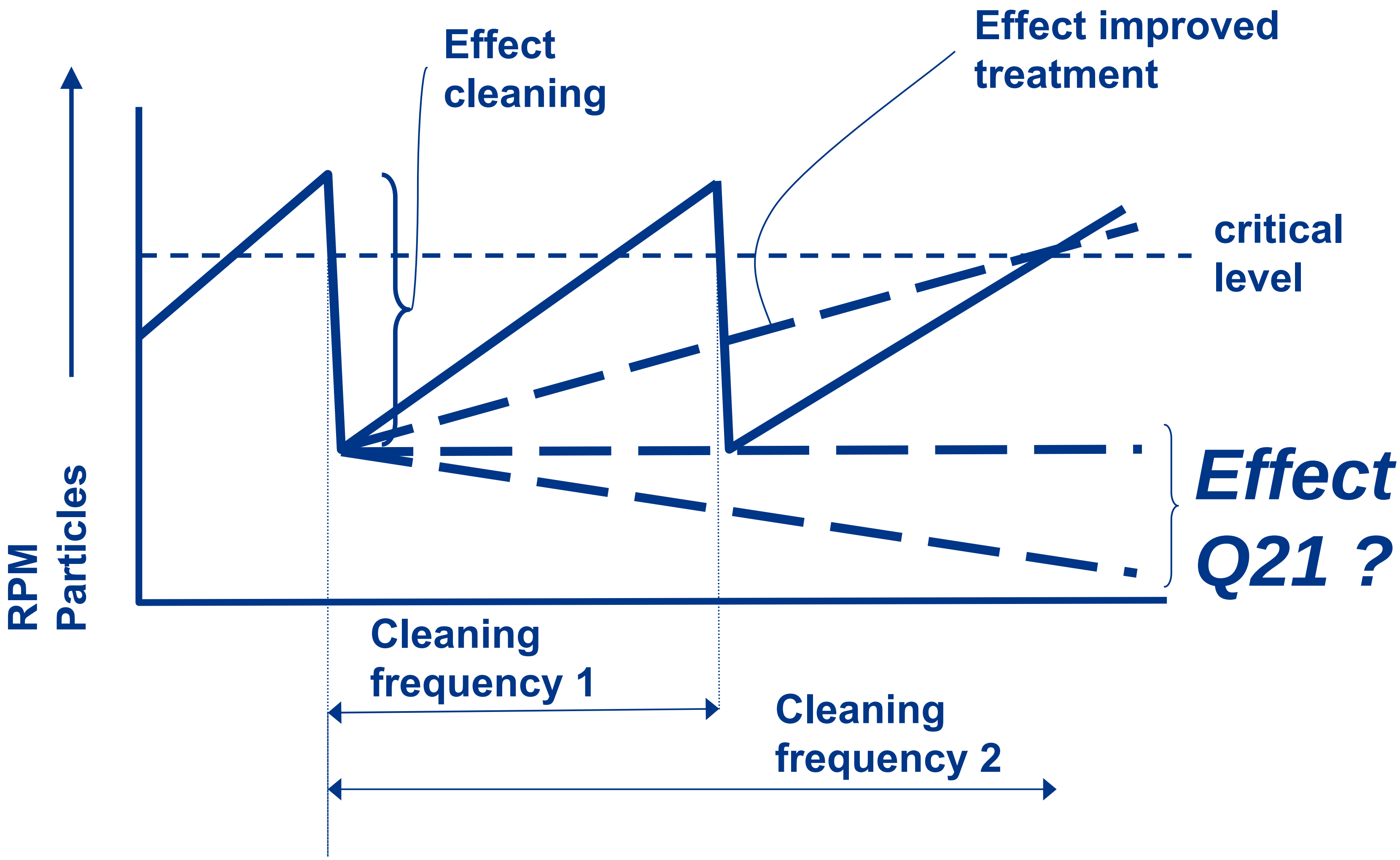
Conclusions

- The concept might work: (biofilm monitor laid down)
- The smaller pipes concept is hydraulically representative

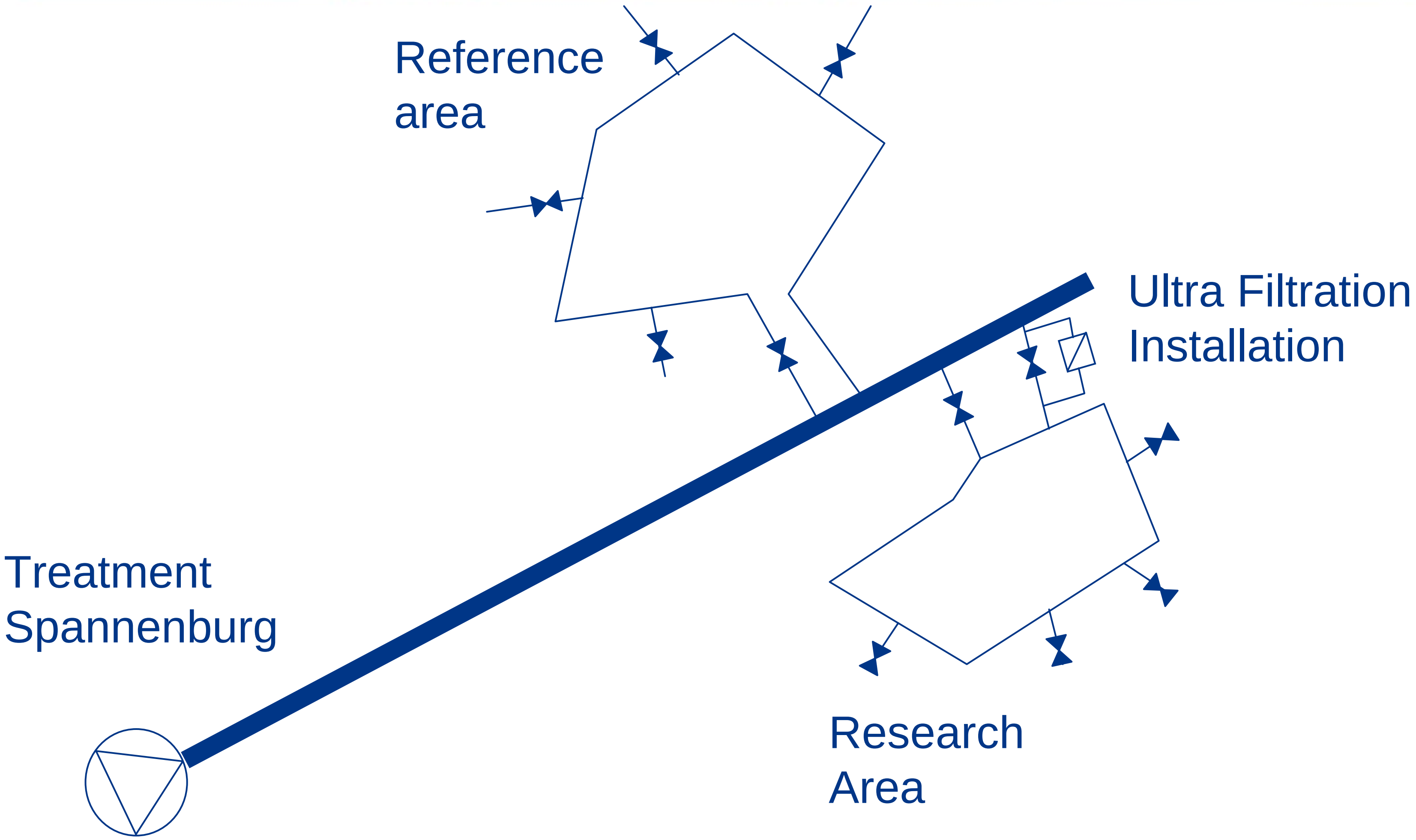
- Work out the concept in a flow through system with small pipes and test it



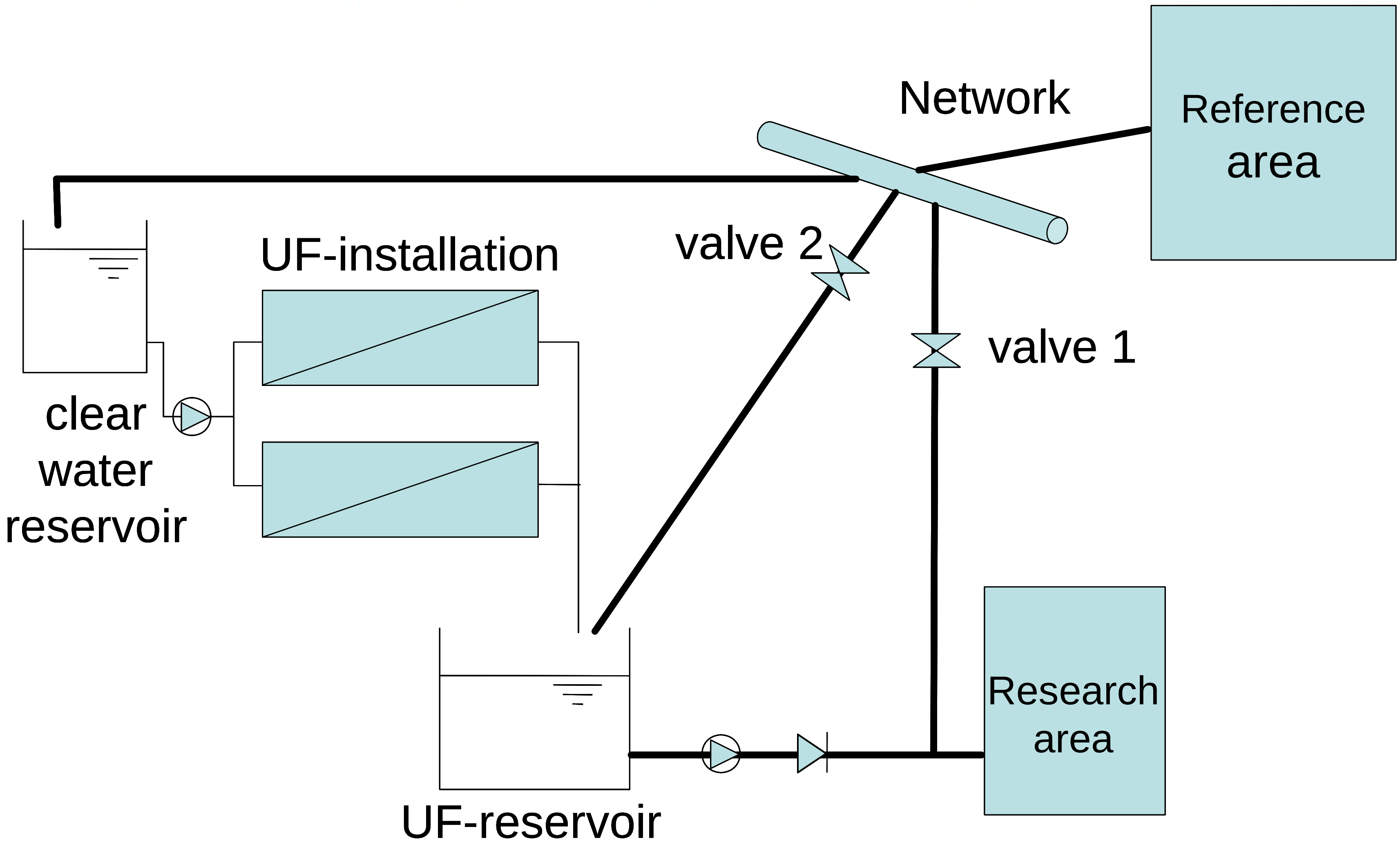
Full scale test in Franeker: What happens if particel free water is supplied to a network



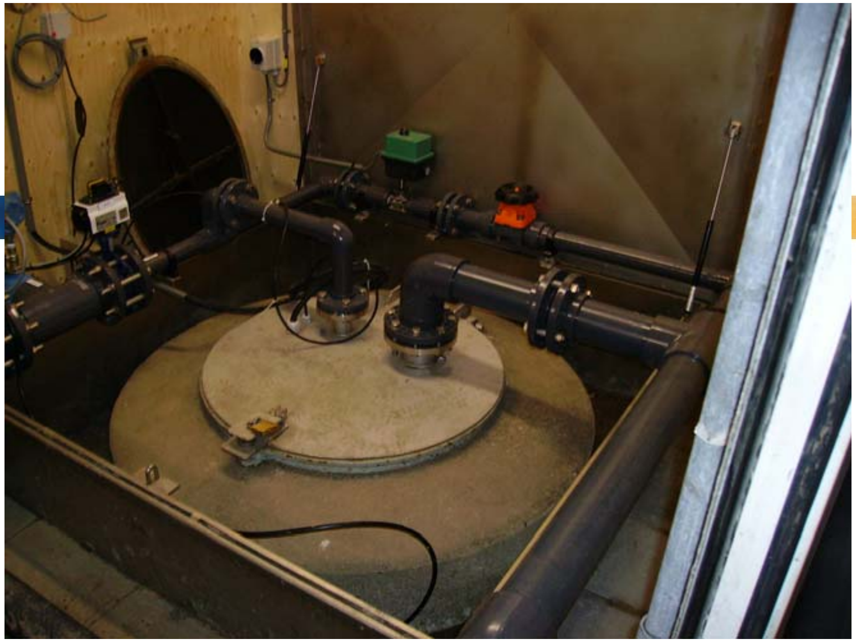
The experiment with particle free water



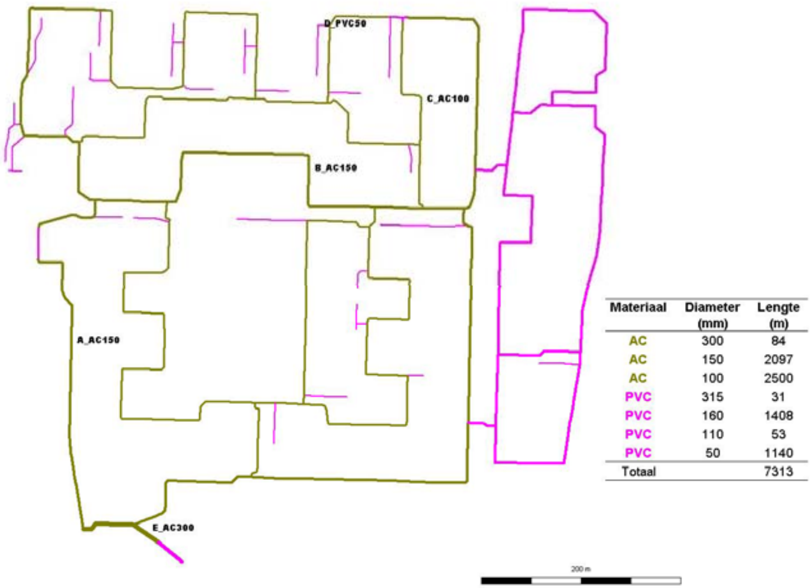
Detail connection research area



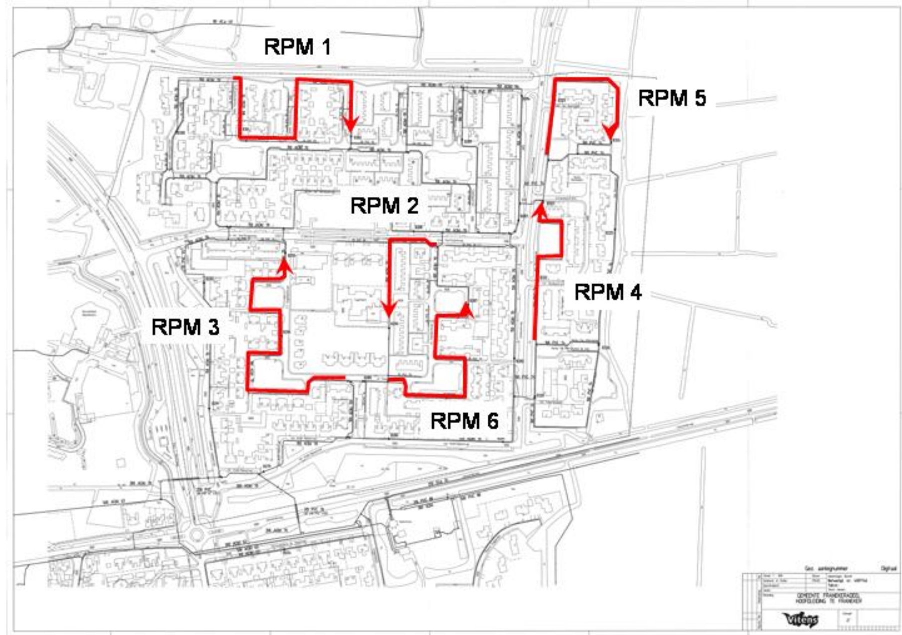
Location



The Reserach area

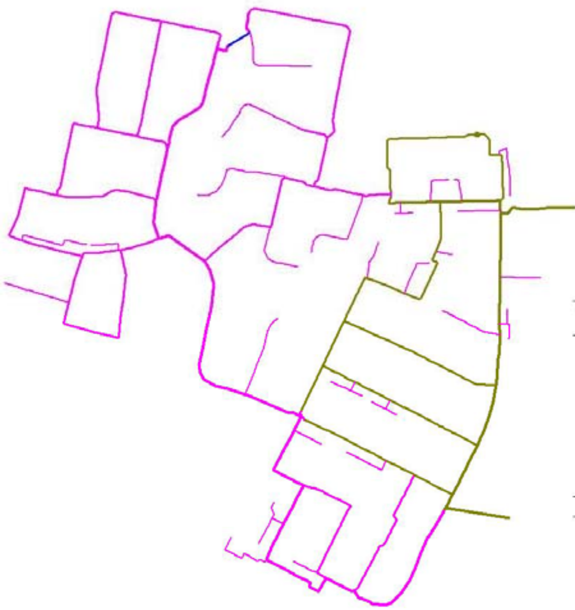


Materiaal	Diameter (mm)	Lengte (m)
AC	300	84
AC	150	2097
AC	100	2500
PVC	315	31
PVC	160	1408
PVC	110	53
PVC	50	1140
Totaal		7313



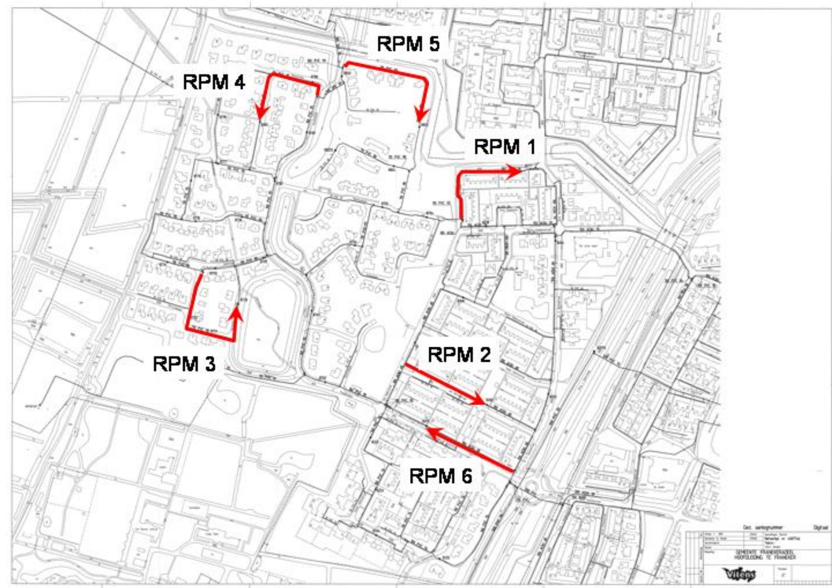
- **550 connections à 2,6 persons using 122 lppd (2004)**
- **1970 AC part; PVC part 1974**

The Reference Area



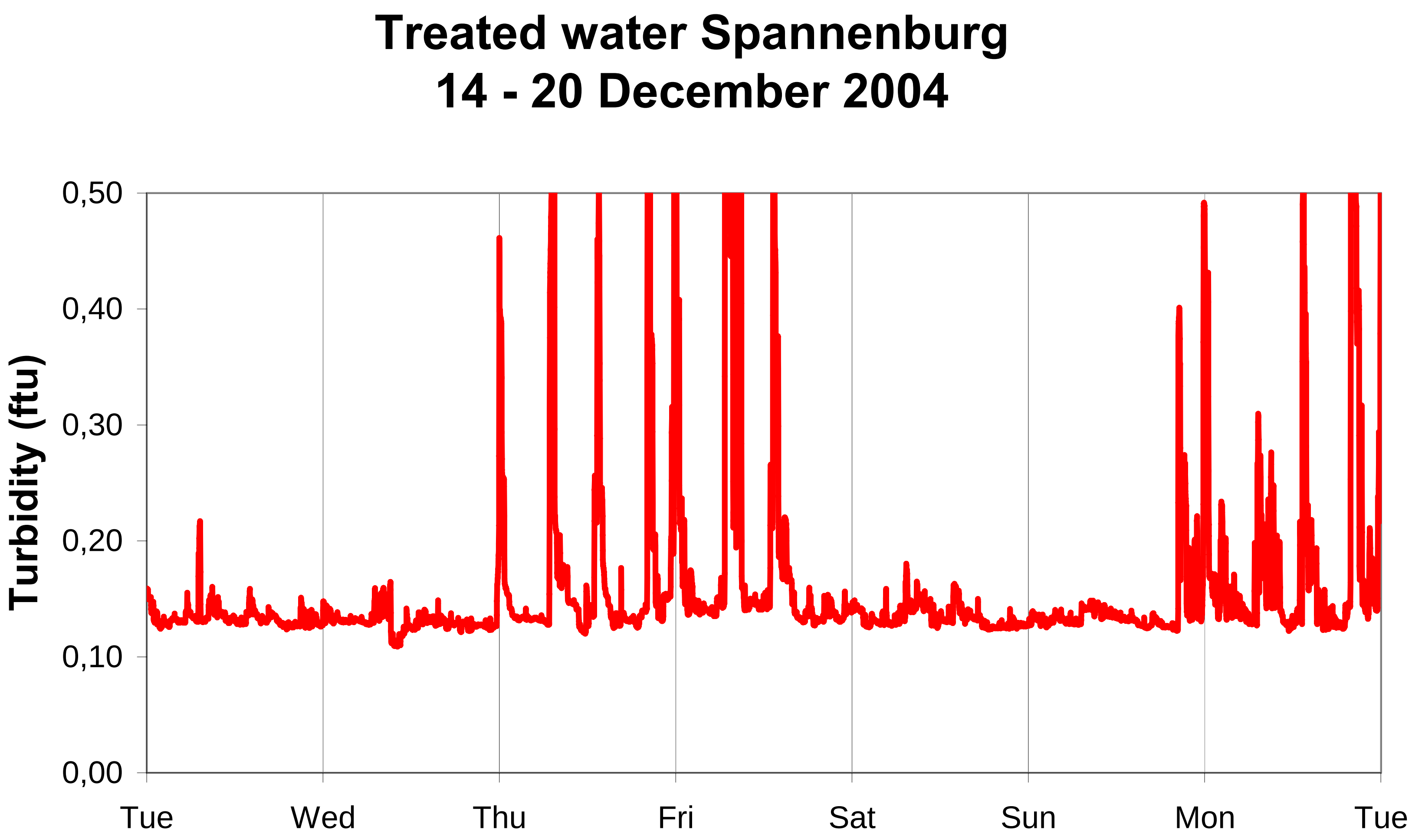
Materiaal	Diameter (mm)	Lengte (m)
AC	300	3
AC	150	611
AC	100	1273
HPE	160	31
PVC	160	1174
PVC	110	2291
PVC	75	86
PVC	50	1684
		7152

200 m



- 520 connections à 2,7 persons using 118 lppd (2004)
- 1968-1969 AC part; 1st PVC part 1974;
  2nd PVC part 1995-1999

Spannenburg



Measuring activities

	Research Area			Reference Area		
	Loc 1	Loc 2	Loc 3	Loc 1	Loc 2	Loc 3
Part count						
First period	14-3-06 / 30-3-06	21-3-06 / 30-3-06	14-3-06 / 30-3-06	30-3-06 / 10-4-06	30-3-06 / 10-4-06	30-3-06 / 10-4-06
Second period	12-10-06 / 18-10-06	12-10-06 / 20-10-06	12-10-06 / 20-10-06	30-10-06 / 10-11-06	30-10-06 / 4-11-06	30-10-06 / 10-11-06

	Research Area	Reference Area
Turbidity		Input UF installation 21-03-06 / 10-4-2006
Hemoflow	21-11-06 / 27-11-06	2-11-06/3-11-06; 3-11-06/6-11-06; 6-11-06/10-11-06; 10-11-06/13-11-06

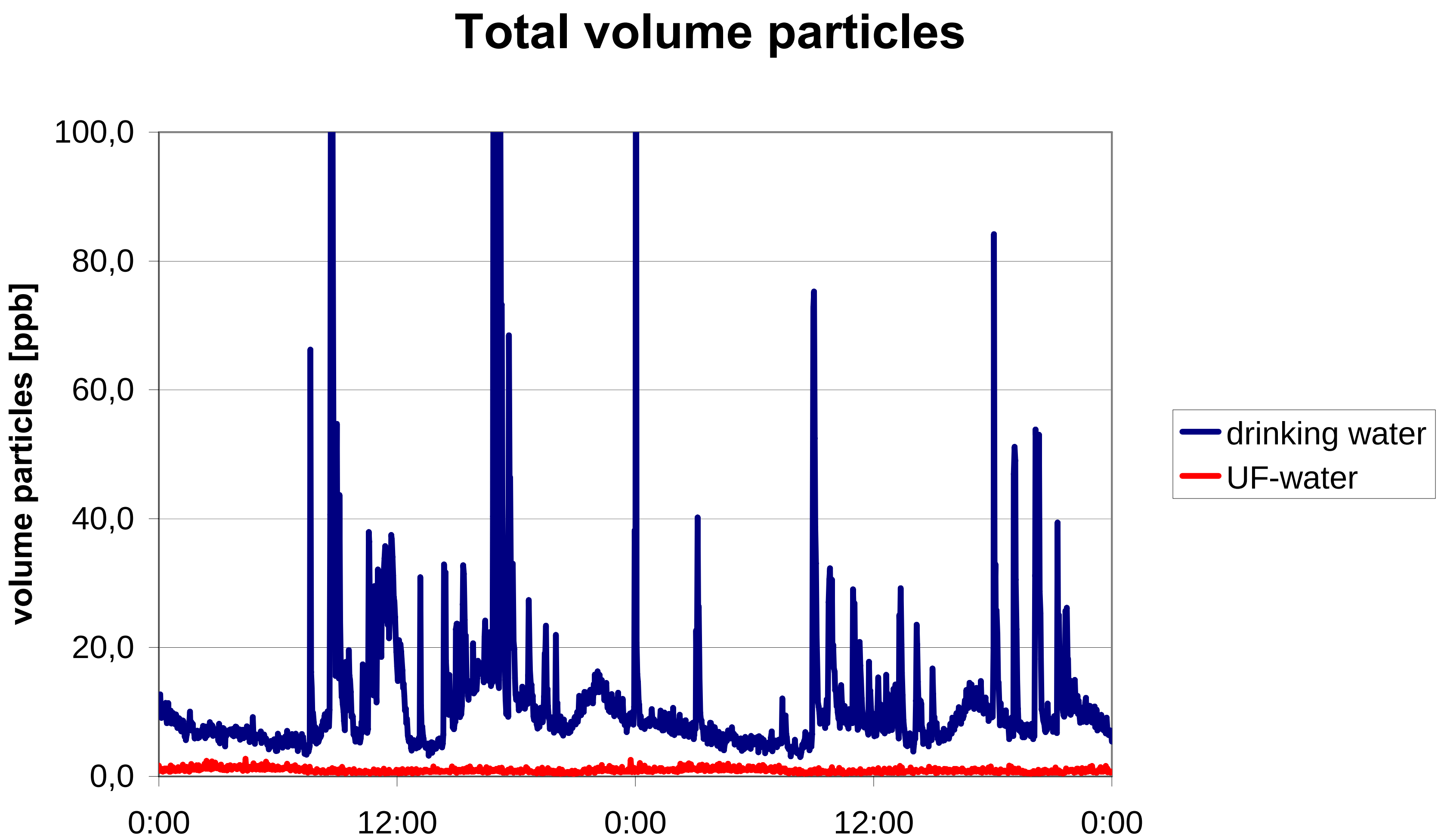
Resuspension Potential Method (RPM)

	1	2	3	4	5	6	1	2	3	4	5	6
-1 (2005)	24-6	27-6	24-6	24-6	24-6	24-6	22-6	22-6	22-6	22-6	23-6	23-6
0 (2005)	13-7	13-7	13-7	14-7	14-7	14-7	7-7	7-7	7-7	7-7	8-7	8-7
1 (2006)	14-3	14-3	-	14-3	-	-	14-3	14-3	-	14-3	-	-
2 (2006)	6-11	6-11	6-11	6-11	7-11	7-11	6-11	7-11	7-11	7-11	7-11	7-11

Cleaning period

	Research Area	Reference Area
Initial	5 October 2005	24 June 2005
End	9 and 10 November 2006	13 and 14 November 2006

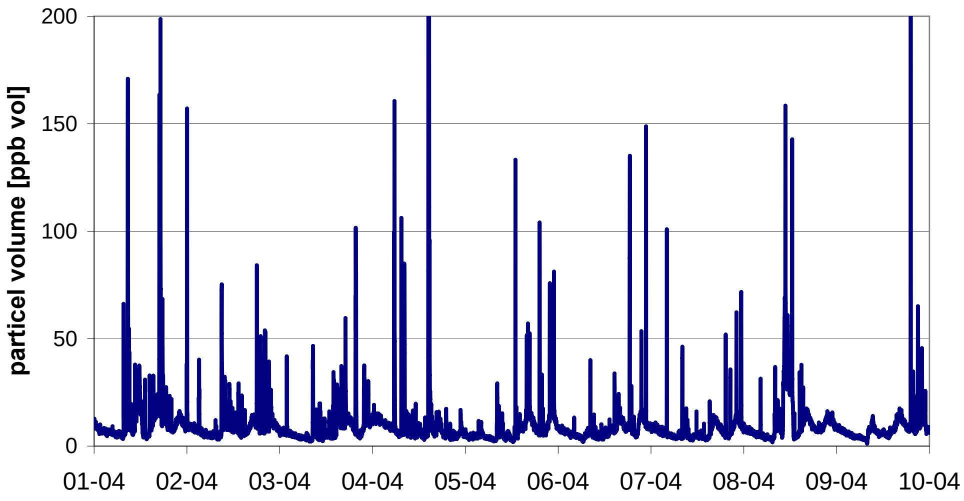
Input particle volume



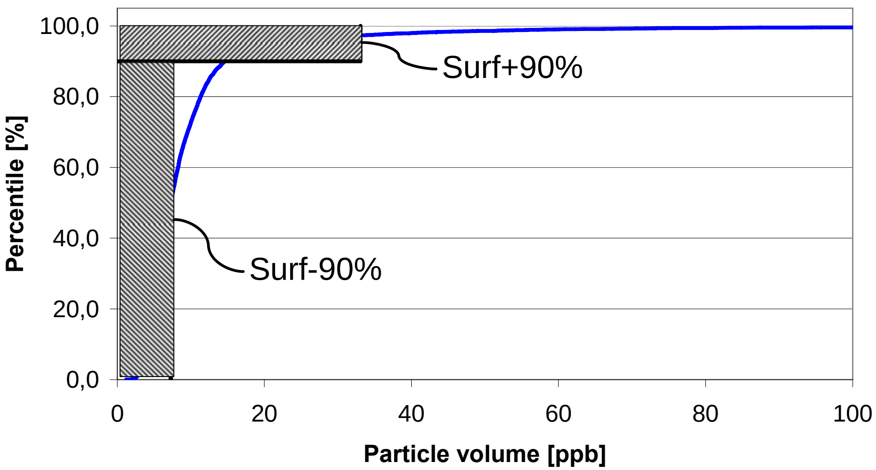
Particle count/volume data

Frequency percentile [%]	[ppb]
90,0	14,57
95,0	21,80
98,0	40,18
99,0	58,39
99,5	84,15
99,9	160,58
ratio 90/99,5	0,17
average [ppb]	9,85
surf -90 [%]	66,4%
surf +90 [%]	33,6%

Calculated particle volume



Frequency distribution calculated particle volume

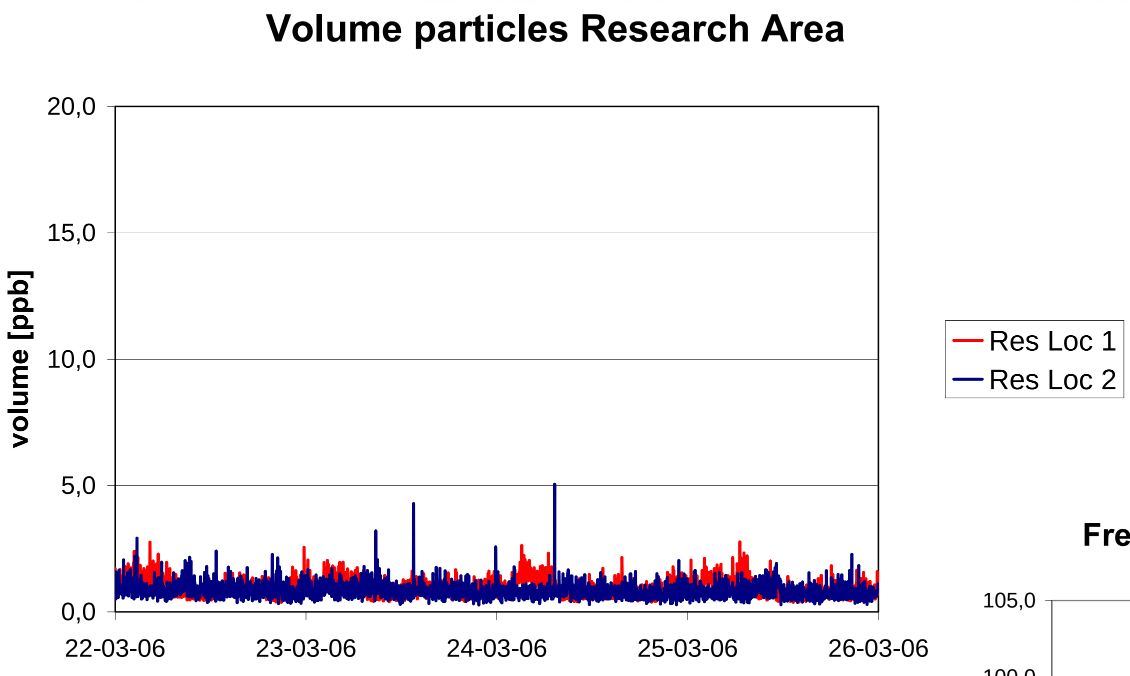


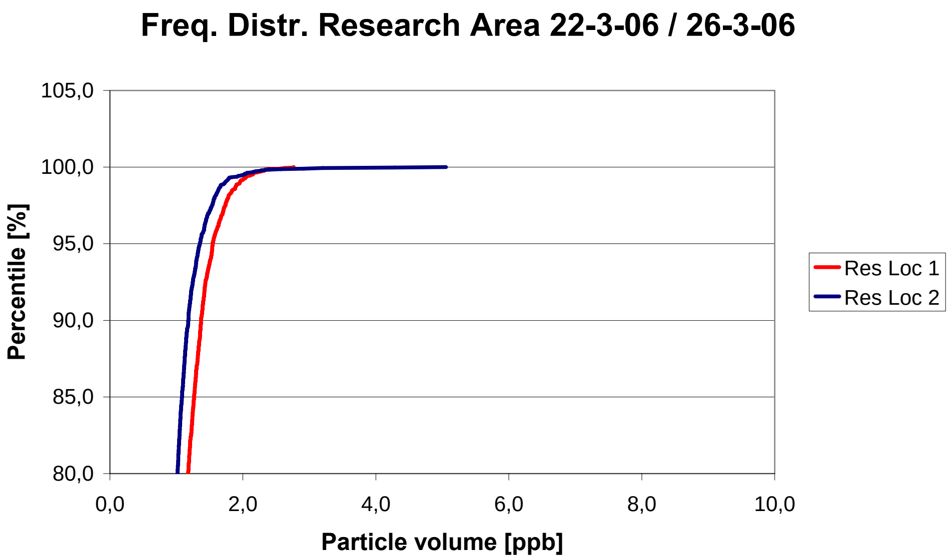
Research area first period

22-3-2006 to 26-3-200

Frequency percentile [%]	Res Loc 1 [ppb]	Res Loc 2 [ppb]
90,0	1,37	1,18
95,0	1,55	1,35
98,0	1,78	1,57
99,0	1,95	1,73
99,5	2,12	1,99
99,9	2,55	2,92

ratio 90/99,5	0,65	0,59
average [ppb	0,92	0,83
surf -90 [%]	82,3%	82,5%
surf +90 [%]	17,7%	17,4%

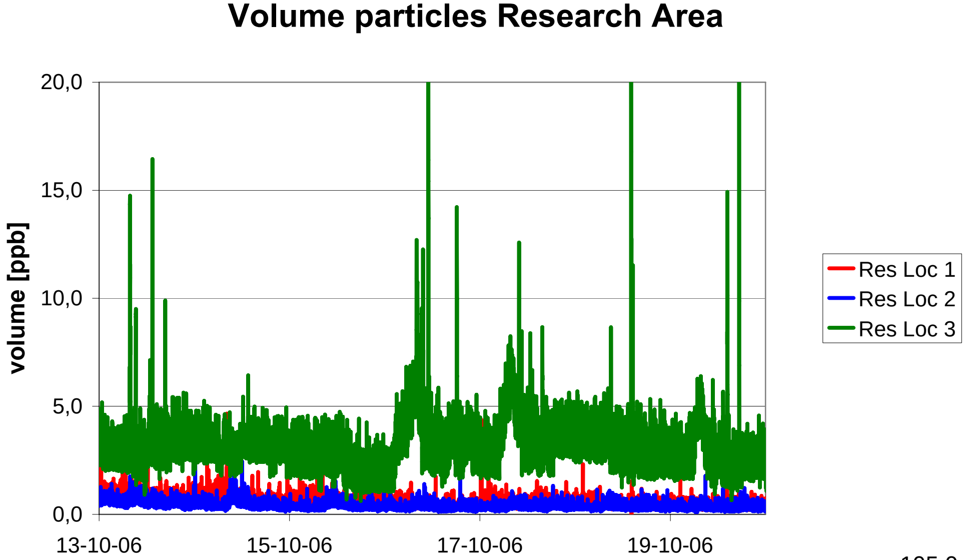


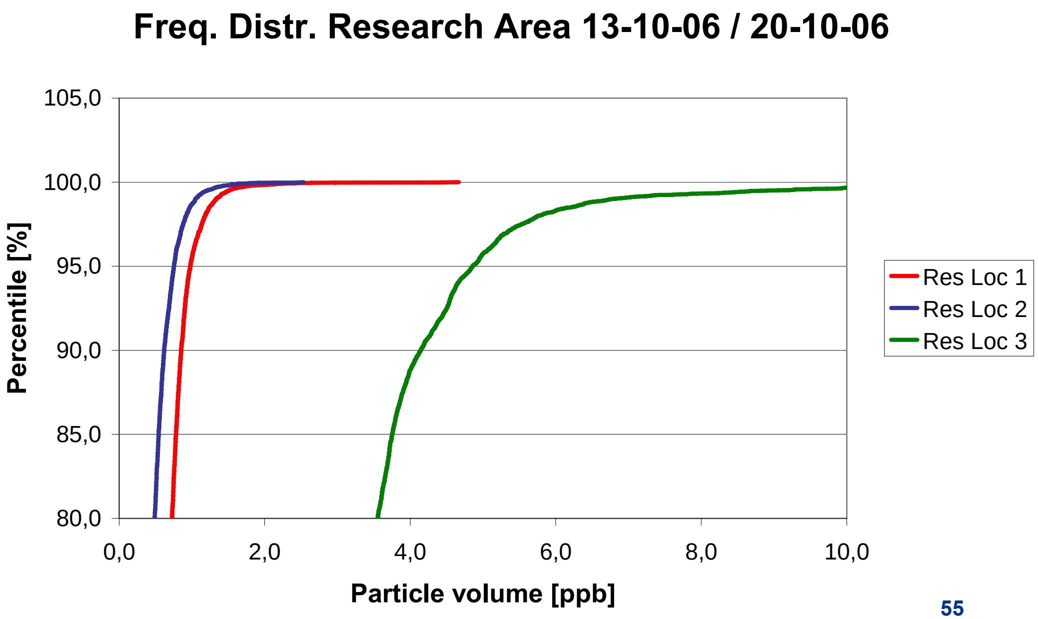


Research Area second period

Frequency percentile [%]	Res Loc 1 [ppb]	Res Loc 2 [ppb]	Res Loc 3 [ppb]
90,0	0,85	0,62	4,15
95,0	0,98	0,75	4,86
98,0	1,18	0,92	5,76
99,0	1,33	1,05	6,78
99,5	1,51	1,21	8,90
99,9	2,17	1,62	16,39

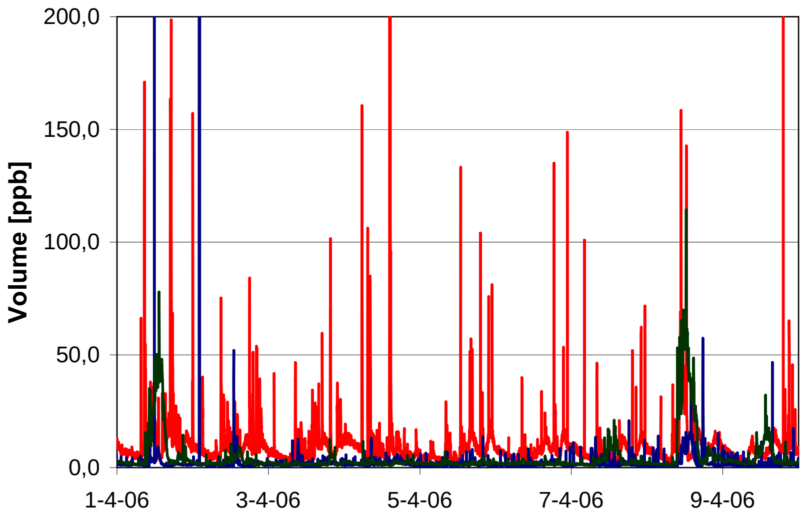
ratio 90/99,5	0,56	0,51	0,47
average [ppb]	0,55	0,38	2,93
surf -90 [%]	80,7%	78,7%	80,9%
surf +90 [%]	19,3%	21,3%	19,1%





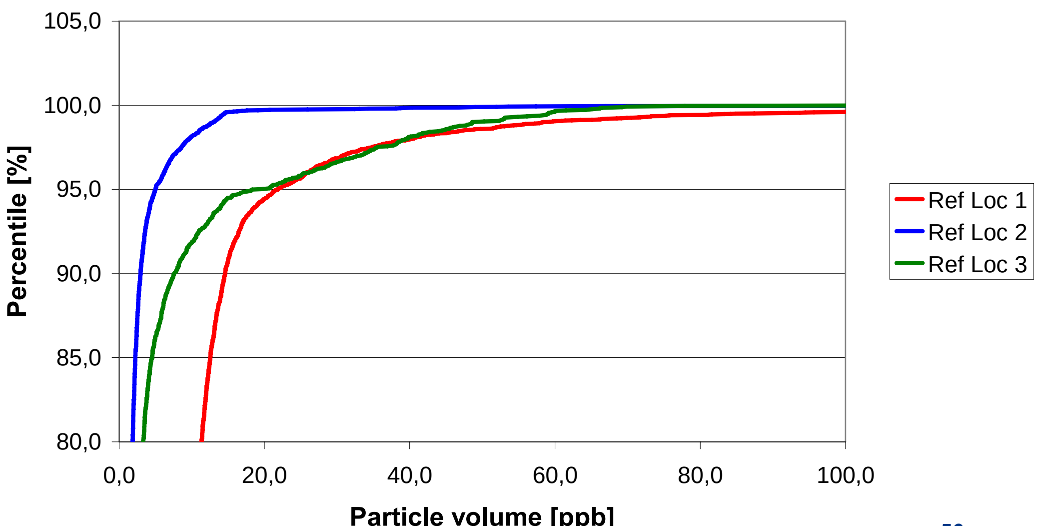
Reference Area first period

Volume particles Reference Area



Frequency percentile [%]	Ref Loc 1 [ppb]	Ref Loc 2 [ppb]	Ref Loc 3 [ppb]
90,0	14,57	2,95	7,55
95,0	21,80	5,00	18,32
98,0	40,18	9,56	39,45
99,0	58,39	12,94	48,60
99,5	84,15	14,42	59,09
99,9	160,58	49,01	69,25
ratio 90/99,5	0,17	0,20	0,13
average [ppb]	9,85	1,98	4,49
surf -90 [%]	66,4%	56,6%	43,8%
surf +90 [%]	33,6%	43,4%	54,9%

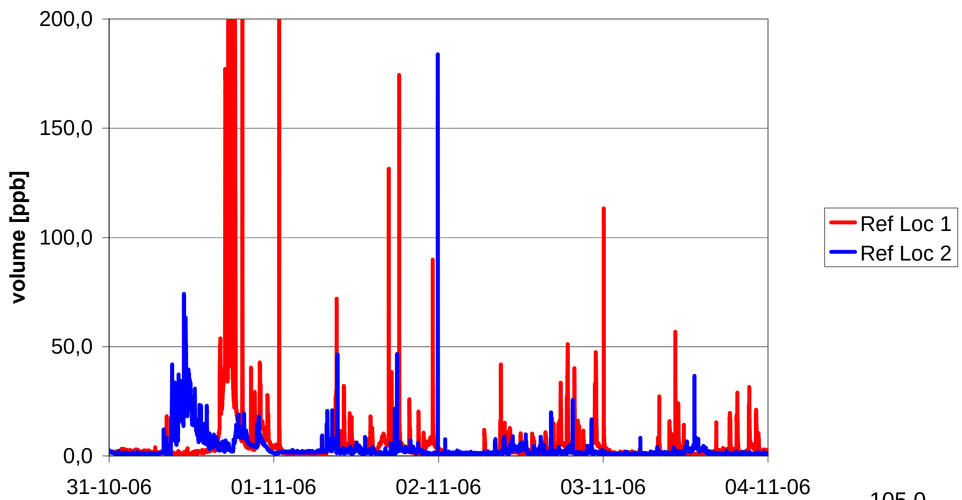
Freq. distr. Reference area 1-4-06 / 10-4-06



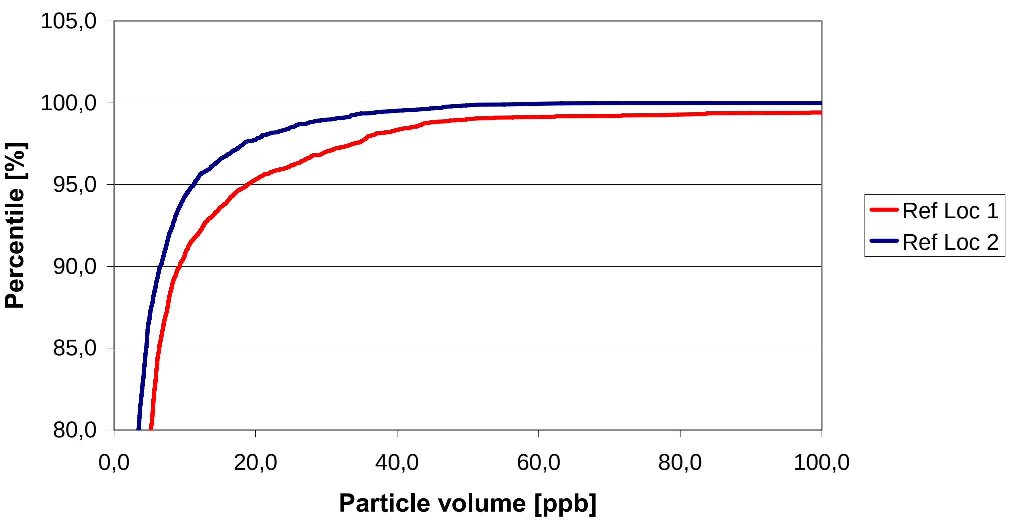
Reference Area second period

Frequency percentile [%]	Ref Loc 1 [ppb]	Ref Loc 2 [ppb]
	31-10-2006 to 4-11-2006	
90,0	9,25	6,53
95,0	18,77	11,25
98,0	36,26	20,94
99,0	49,77	30,71
99,5	117,97	39,57
99,9	307,70	55,12
ratio 90/99,5	0,08	0,16
average [ppb]	5,77	3,11
surf -90 [%]	38,2%	49,2%
surf +90 [%]	61,8%	50,4%

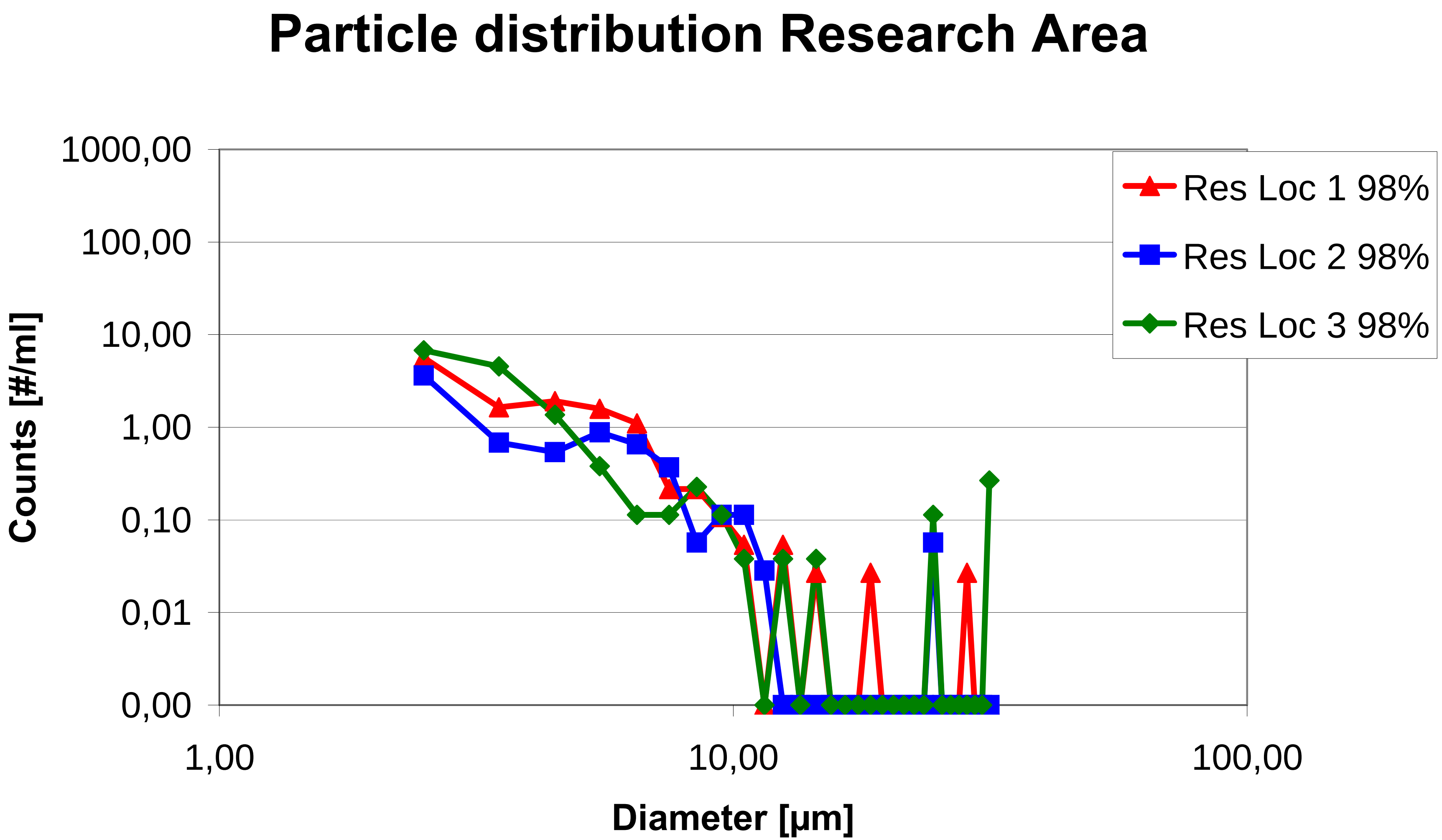
Volume particles Reference Area



Freq. Distr. Reference Area 31-10-06 / 4-11-06

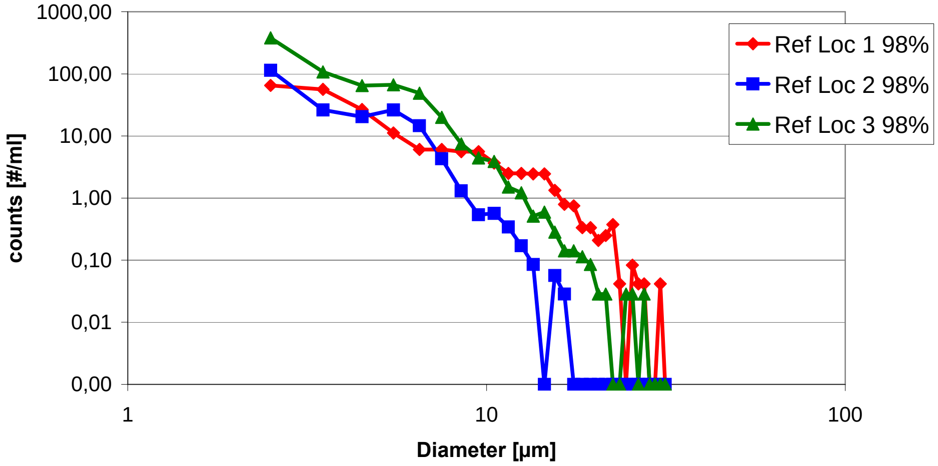


What are the particles made of

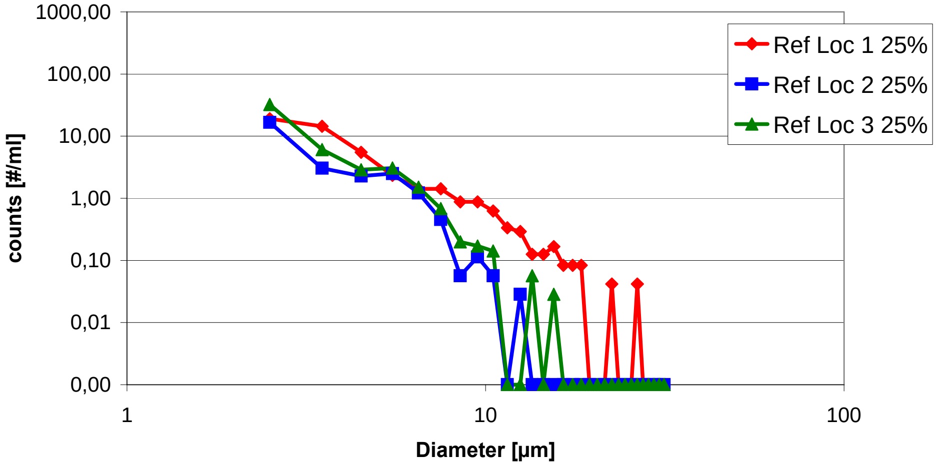


Reference Area

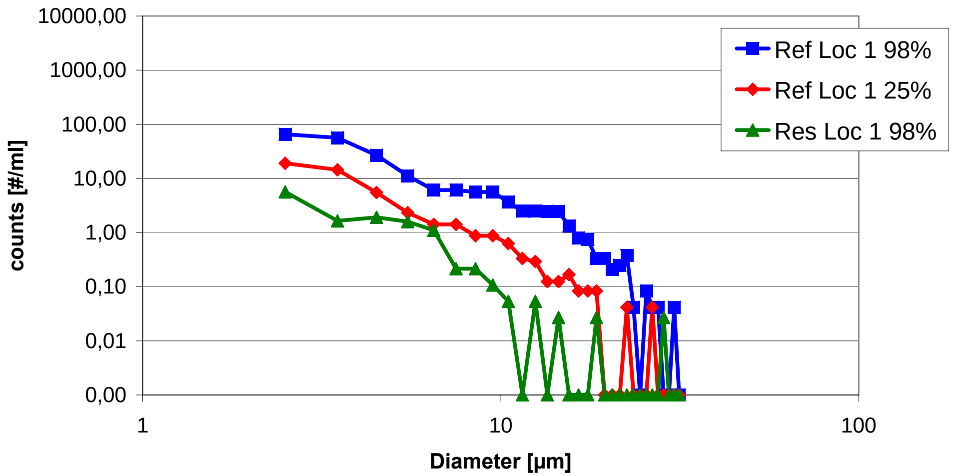
Particle size distribution Reference Area 98%

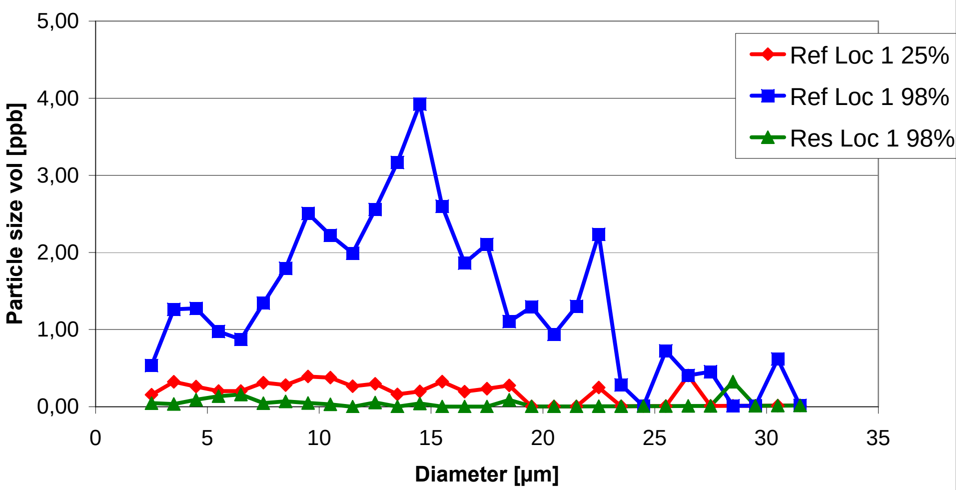


Particle size distribution Reference Area 25%



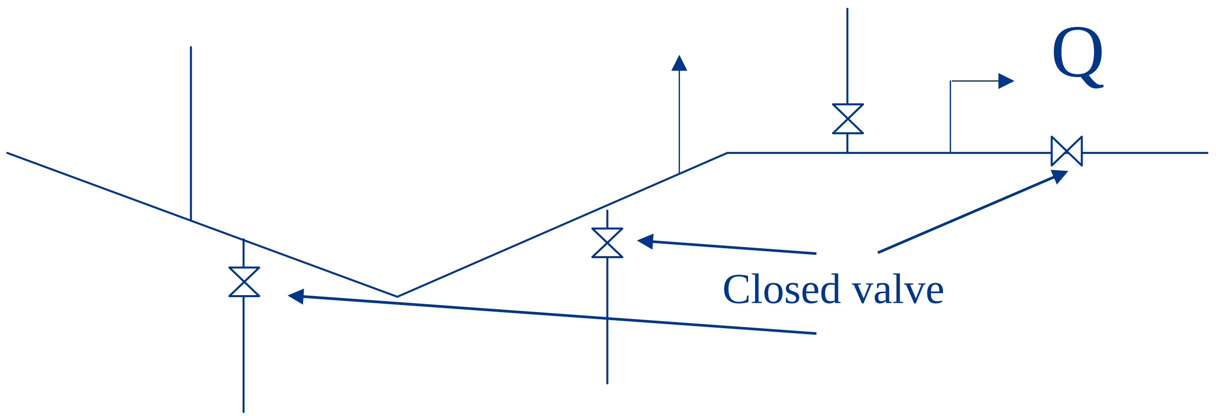
Particle size distribution and volume distribution



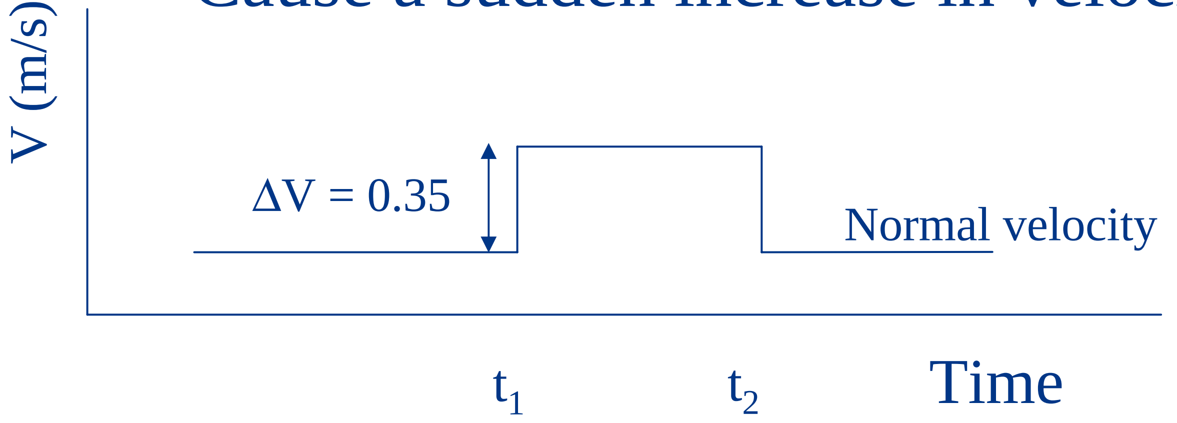


	volume particles [ppb]
Ref Loc 1 98%	40,41
Ref Loc 1 25%	5,23
Res Loc 1 98%	1,30

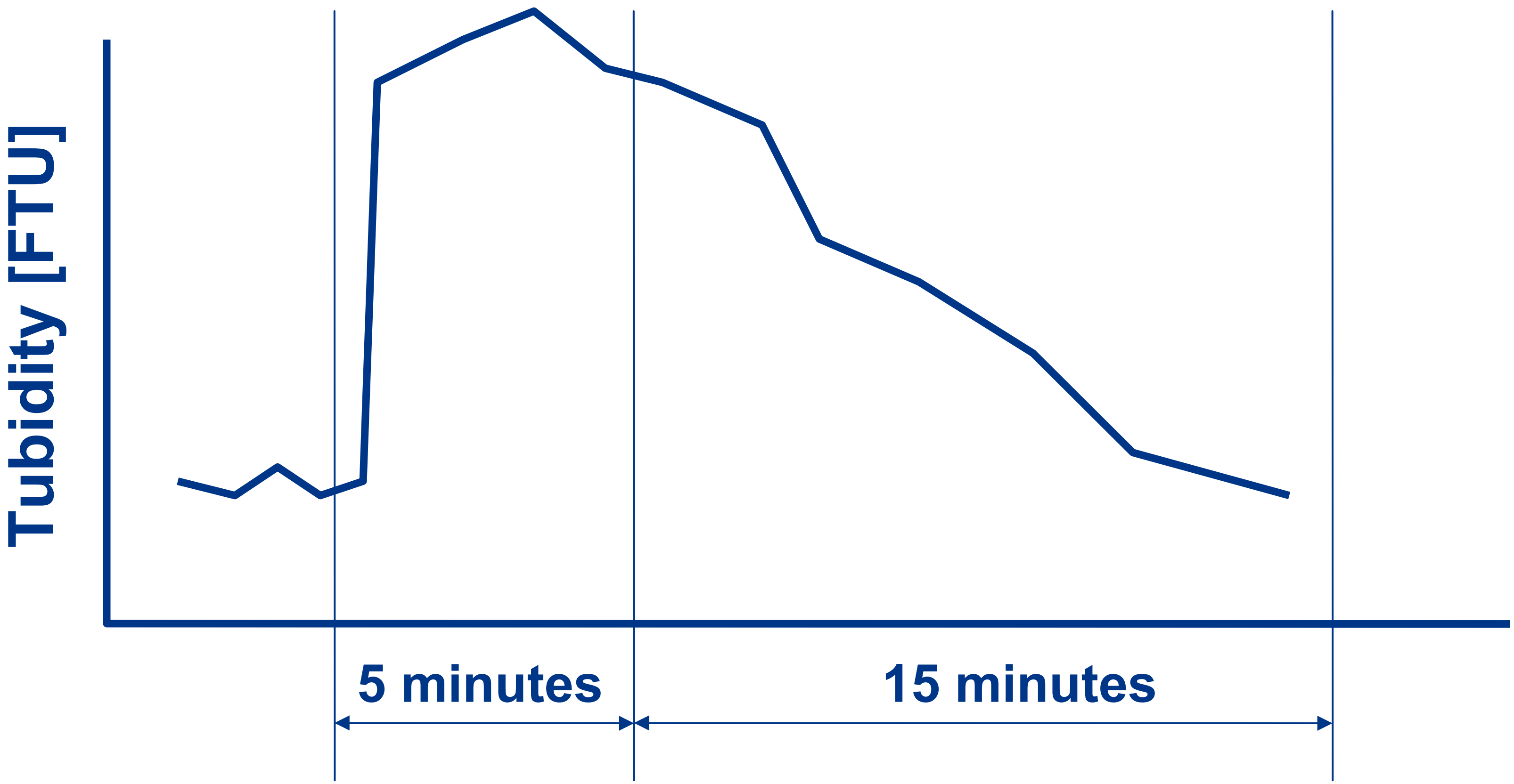
Resuspention Potential Measurement



Cause a sudden increase in velocity



Adjusted RPM: shorter disturbance



Resuspention Potential Measurements

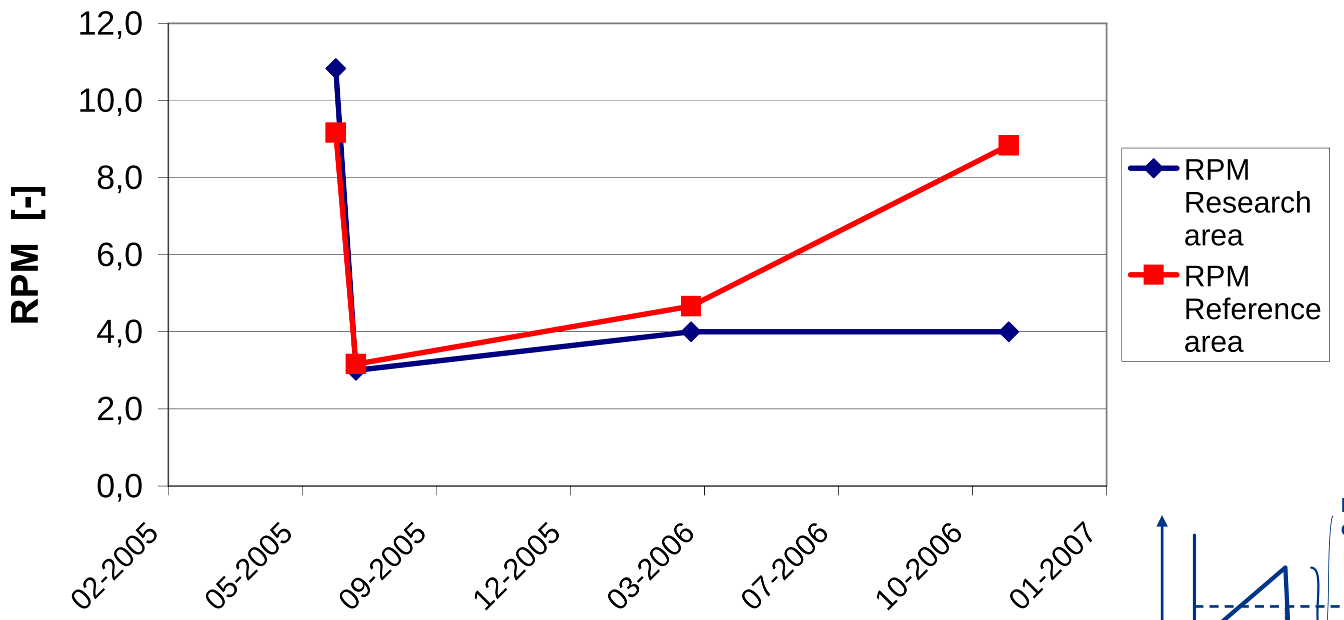
Points	0	1	2	3	4
Max during disturbance [FTU]	<1	1 -3	3 – 5	5 – 10	>10
Average during disturbance [FTU]	<1	1 -3	3 – 5	5 – 10	>10
Resettling time [min]	<1	1-5	5-10	10-15	>15

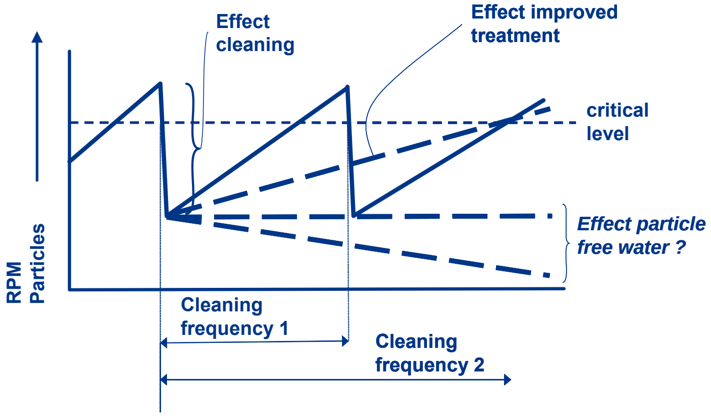
Research area	-1 measure				0-measure				1-measure				2-measure			
Date	24-6-2005				13-7-2005				14-3-2006				6-11-2006			
location				tot				tot				tot				tot
Res loc 1	4	4	3	11	1	1	1	3	2	1	0	3	3	3	2	8
Res loc 2	4	4	4	12	1	1	1	3	4	3	0	7	2	1	0	3
Res loc 3	4	4	3	11	1	0	1	2				0	2	1	0	3
Res loc 4	4	4	2	10	0	0	0	0	1	1	0	2	1	1	0	2
Res loc 5	4	4	3	11	2	1	2	5				0	1	1	0	2
Res loc 6	4	4	2	10	3	1	1	5				0	4	2	0	6
Average				10,83				3,00				4,00				4,00

Reference area	-1 measure				0-measure				1-measure				2-measure			
Date	22-6-2005				7-7-2005				14-3-2006				6-11-2006			
location				tot				tot				tot				tot
Ref loc 1	3	2	2	7	1	1	1	3	0	0	0	0	0	0	0	0
Ref loc 2	4	4	3	11	2	1	1	4	4	4	2	10	4	4	3	11
Ref loc 3	4	4	4	12	2	1	1	4				0	4	4	2	10
Ref loc 4	3	3	1	7	4	3	1	8	3	1	0	4	4	4	3	11
Ref loc 5	4	3	3	10	0	0	0	0				0	4	4	2	10
Ref loc 6	4	3	1	8	0	0	0	0				0	4	4	3	11
Average				9,17				3,17				4,67				8,83

RPM graphical

Average Resuspention Potential Measurement

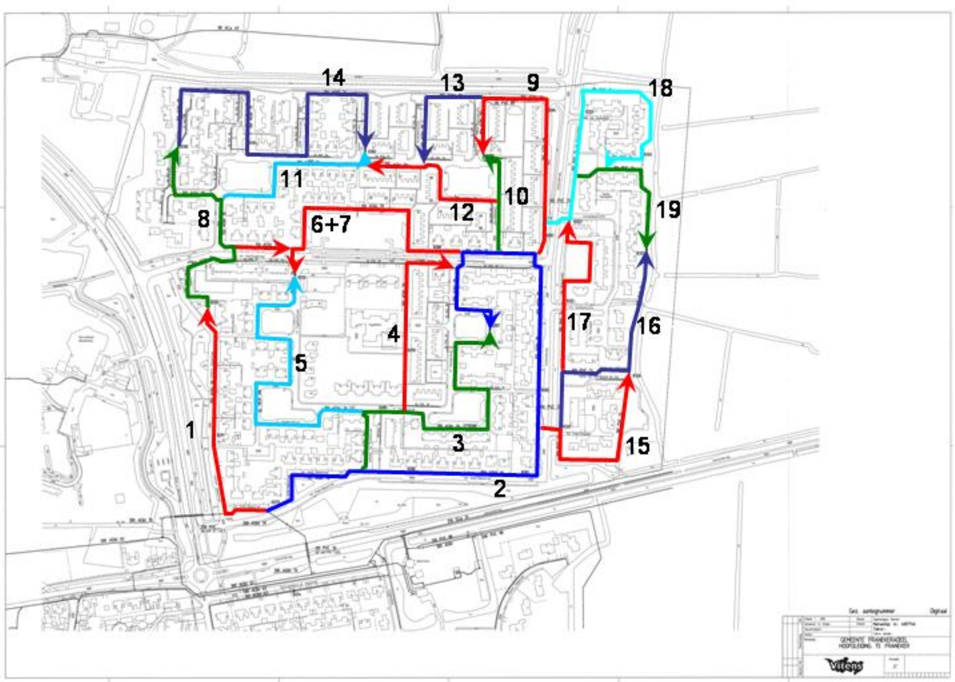


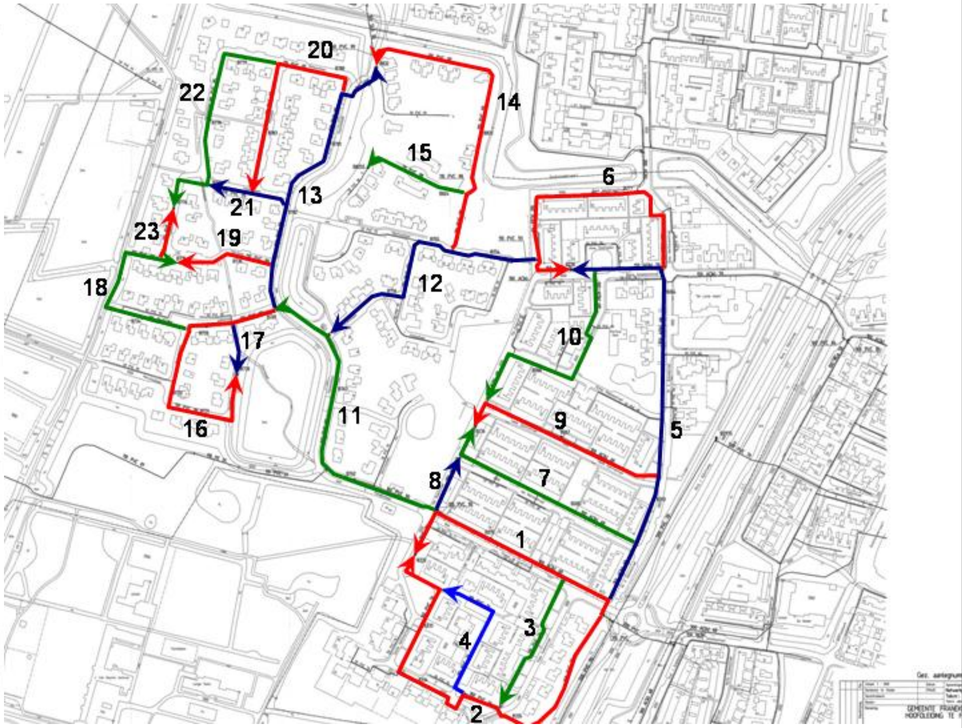


Cleaning both the areas

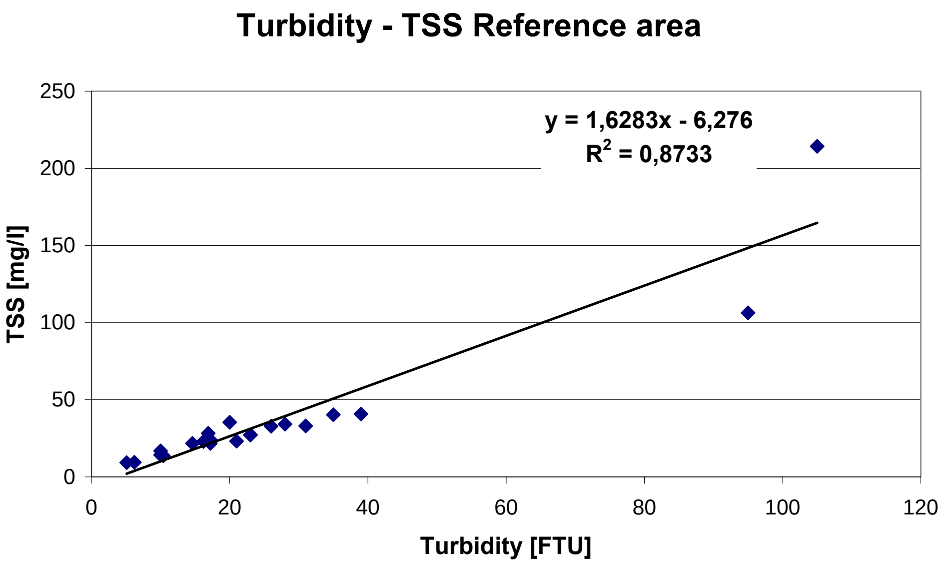
- Dedicated flushing program (1,5 m/s, uni-directional flow, clear water front)
- Continuous monitoring turbidity of flushed water
- Samples in first turn over flushed water
- Analysis samples for calibration curve TSS-FTU

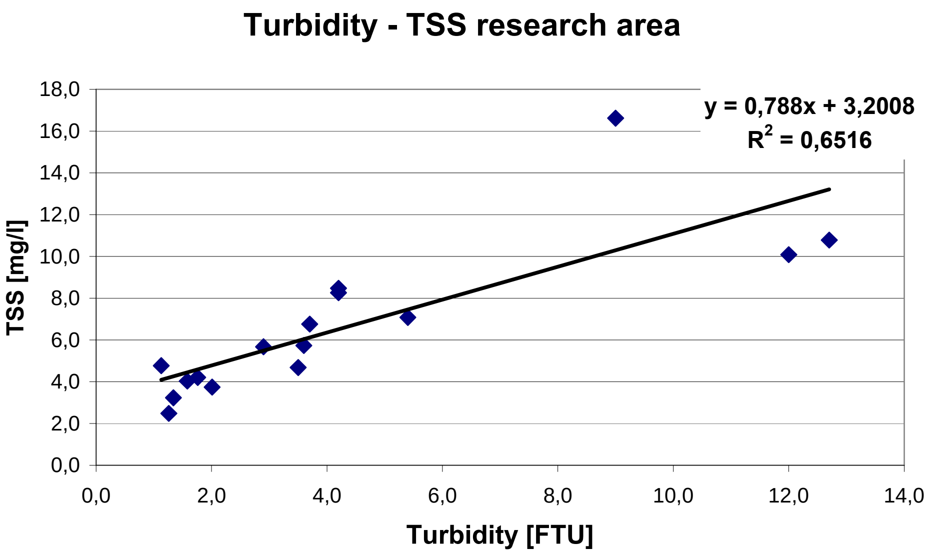
Flush plans Research Area and Reference Area





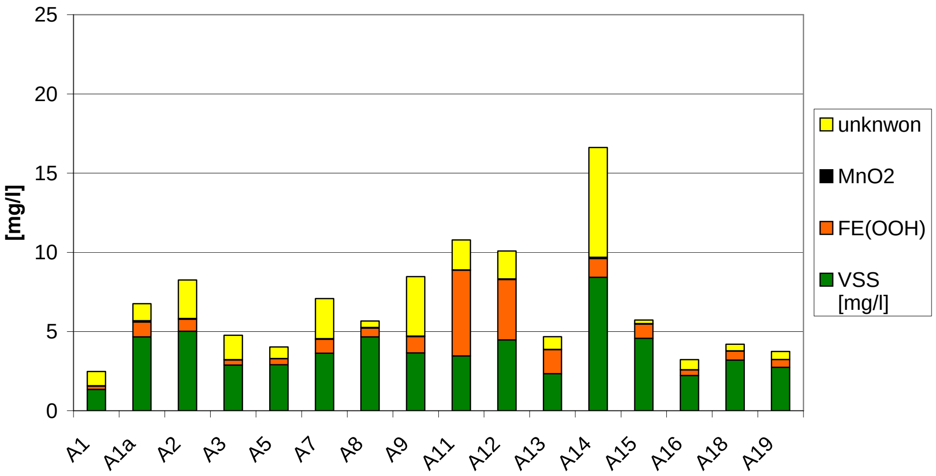
Relation TSS-Turb



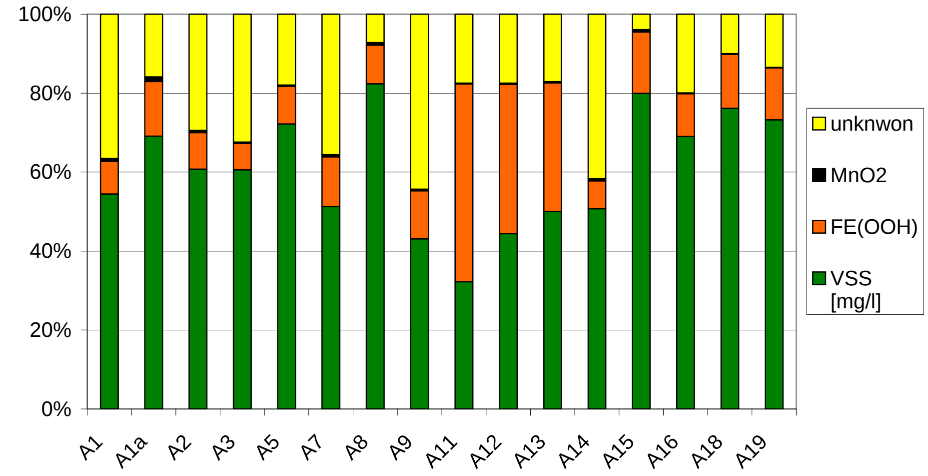


Sample analyses

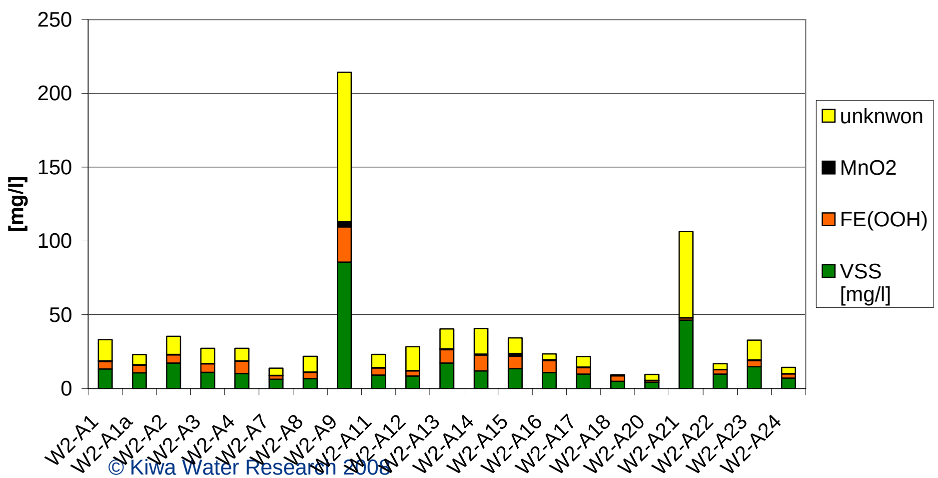
Composition flush samples Research Area



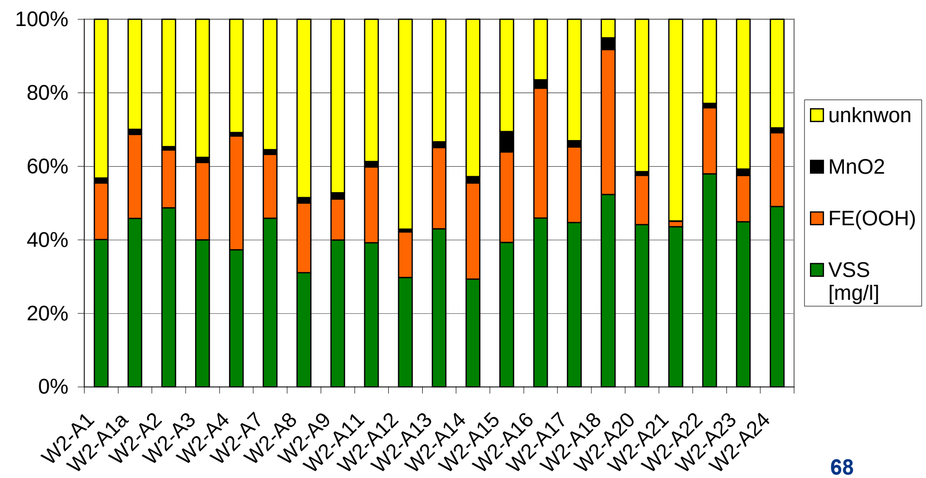
Relative comp. flush samples Research Area



Composition flush samples Reference Area



Relative comp. flush samples Reference Area



Removed TSS during flushing

	Total length flushed [m]	Removed TSS [gr]	Removed TSS per meter [mg/m]
Research	5840	525,08	89,9
Reference	5370	5752,52	1071,2

Hemoflow results

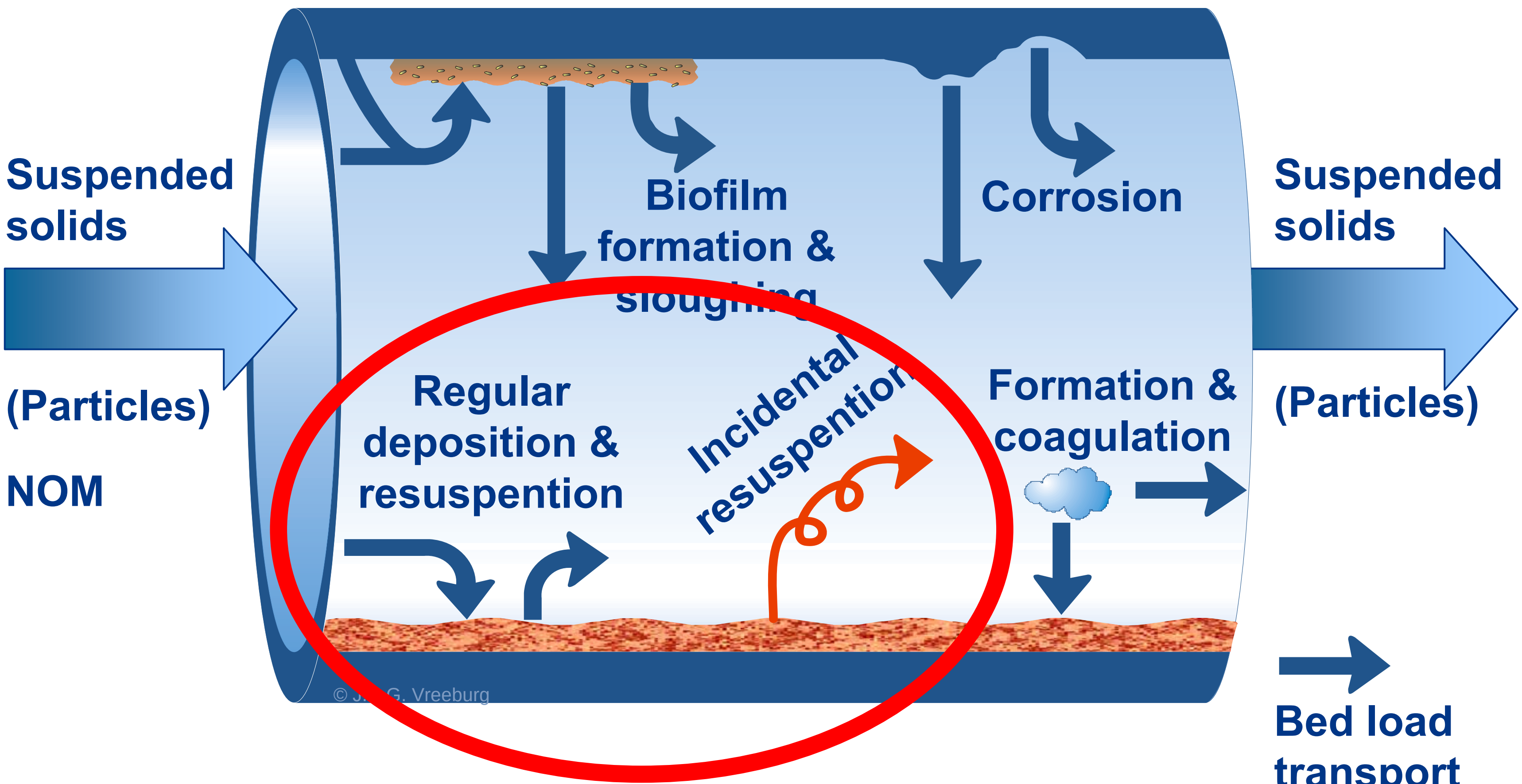
Sample	Filtered volume [l]	Sample volume [l]	Damp rest [mg]	corr [mg]	TSS absolute [mg]	VSS Absolute [mg]	TSS [µg/l]	VSS [µg/l]	VSS % TSS
2/11/2006 - 3/11/2006	1926	0,91	359,45	243,99	115,46	43,17	59,95	22,42	37,39
3/11/2006 - 6/11/2006	3613	0,695	302,33	208,76	93,56	20,61	25,90	5,71	22,03
6/11/2006 - 10/11/2006	1942	0,96	364,80	274,87	89,93	19,34	46,31	9,96	21,50
10/11/2006 - 13/11/2006	6897	0,645	364,43	194,06	170,36	44,49	24,70	6,45	26,11
Total	14378				469,31	127,61	32,64	8,88	

Total loaded : 2743 gr
Total removed: 5753 gr

Conclusions

- Sediment primairily originates from treatment
- Particle load in Reference Area reloads the system in one-and-a-half year to starting level
- Large part of the sediment is of organic nature
- Formation of sediment in the network?
- Particle free water increases cleaning frequency with factor 5-10
- Avoiding peaks will decrease the particle load significantly

Stage 2 and 3 are mainly aimed at operation of the network



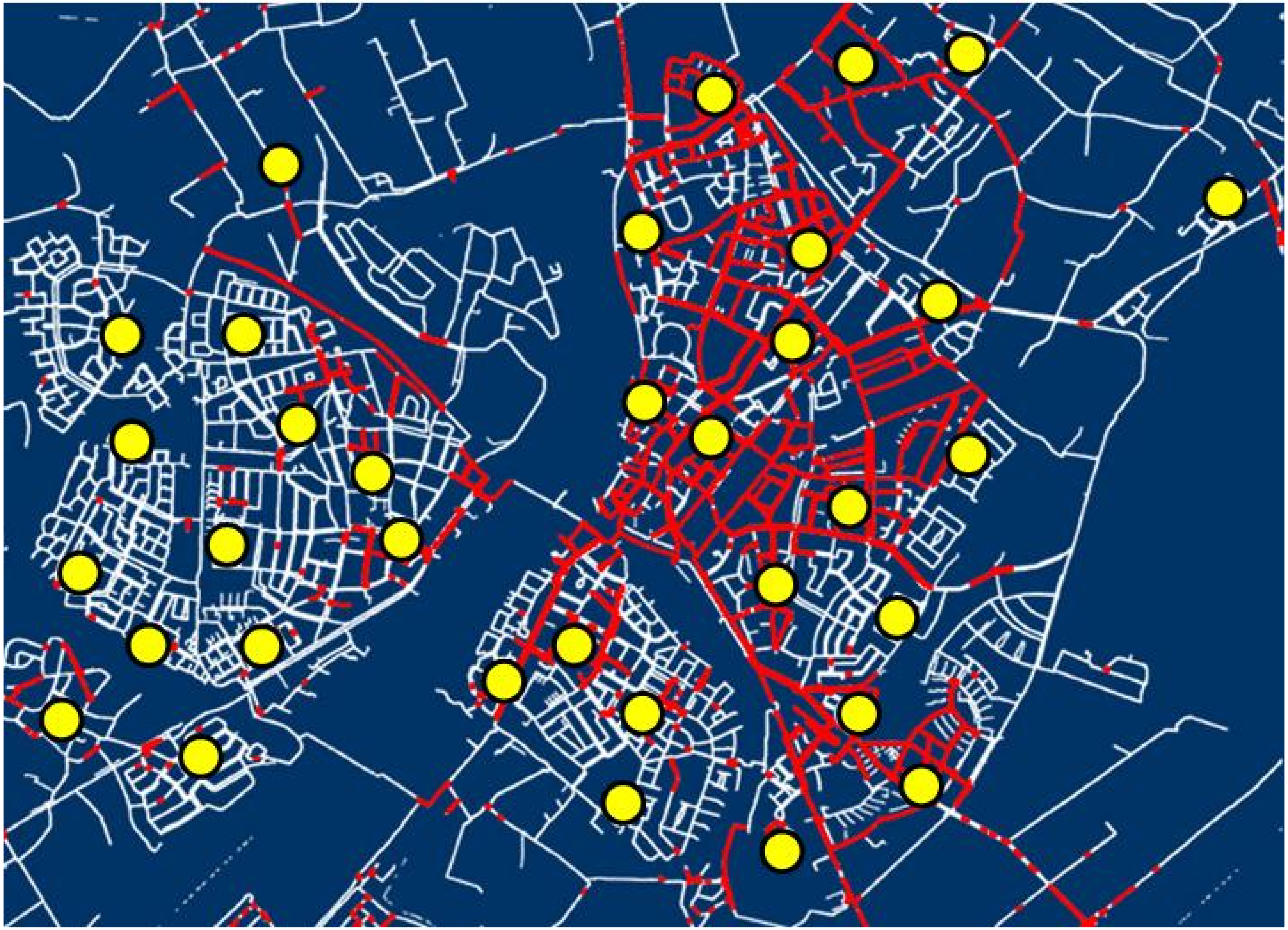
Stage 2: Prevent accumulation → cleaning

- Crude rules → Water Flushing
  - 1,5 m/s
  - Clear water front
  - 2 à 3 turnover pipe volume

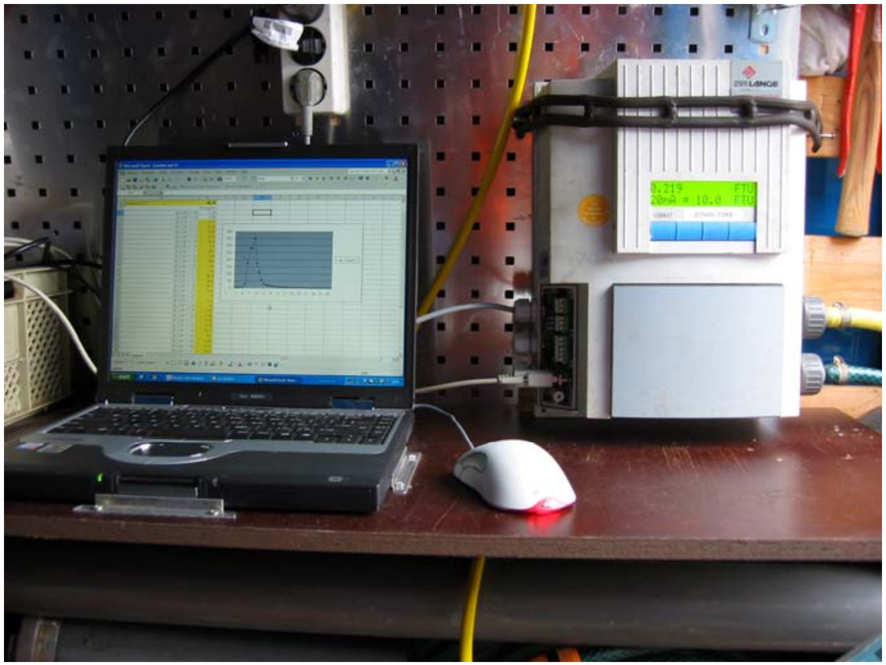
- The operational eye opener:
  It is almost always possible

- Room for further improvement

Test case Venlo: RPM locations blue: PVC/Ac; red: CI

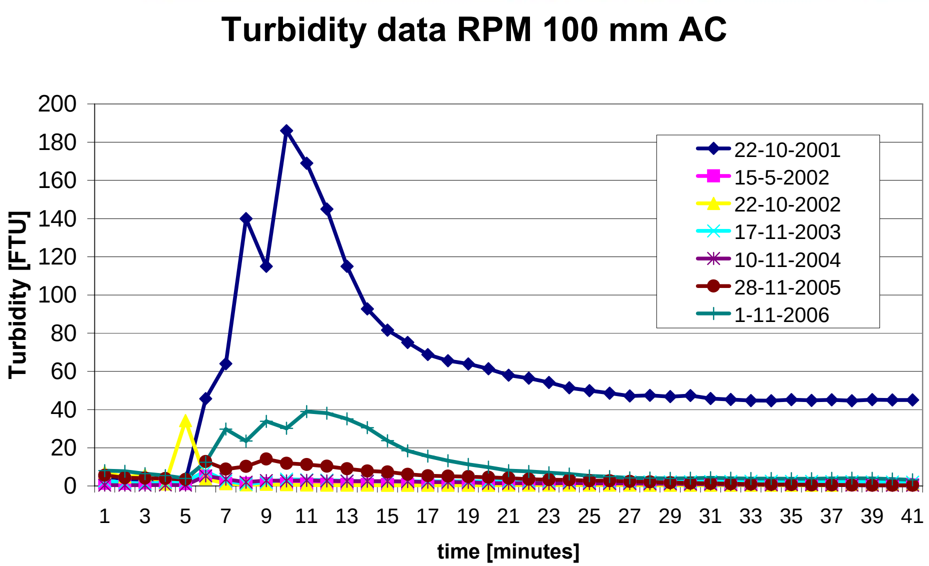


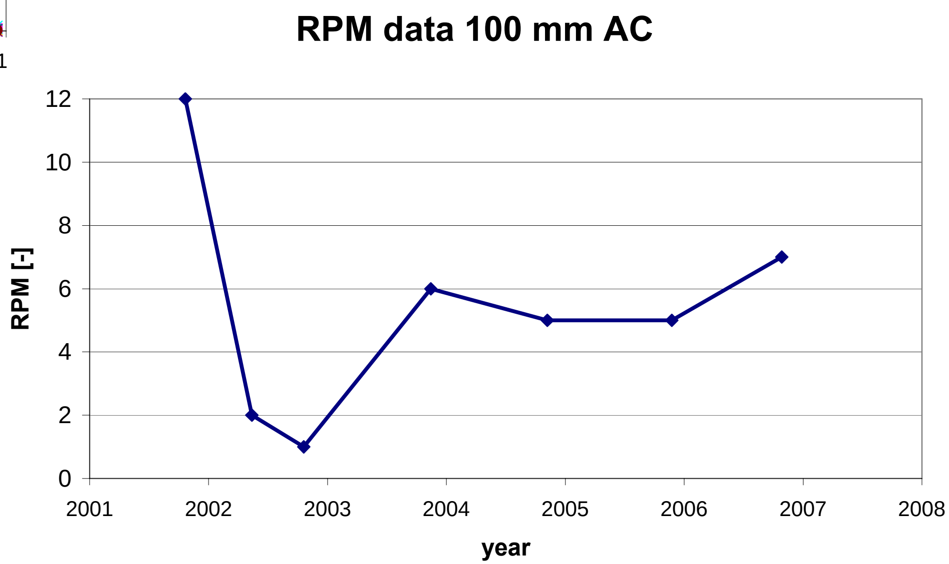
Measuring equipment



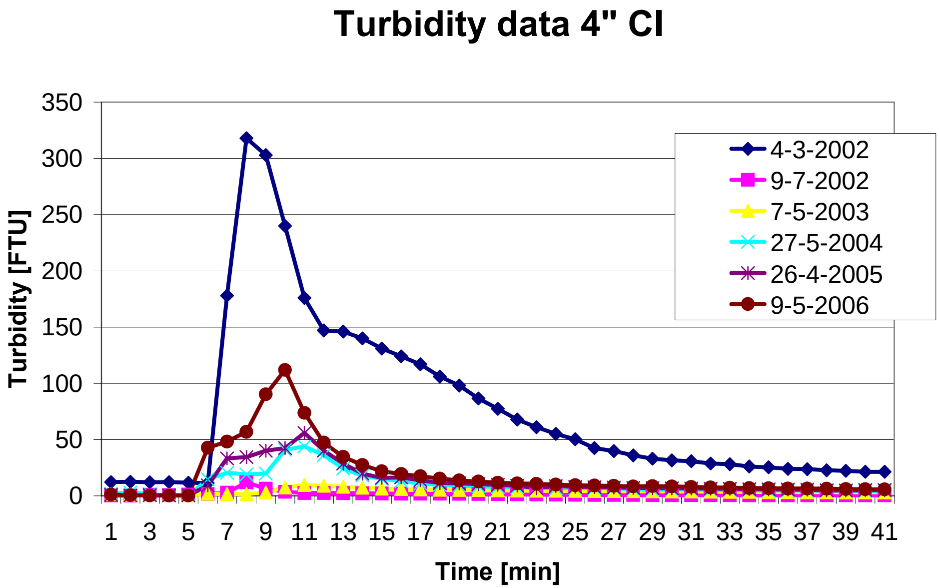
Points	0	1	2	3	4
Max 5 minutes [FTU]	<2	2-10	10-25	25-50	>50
Average 5 minutes [FTU]	<2	2-10	10-25	25-50	>50
Resettling time [min]	<5	5-15	15-25	25-30	>30

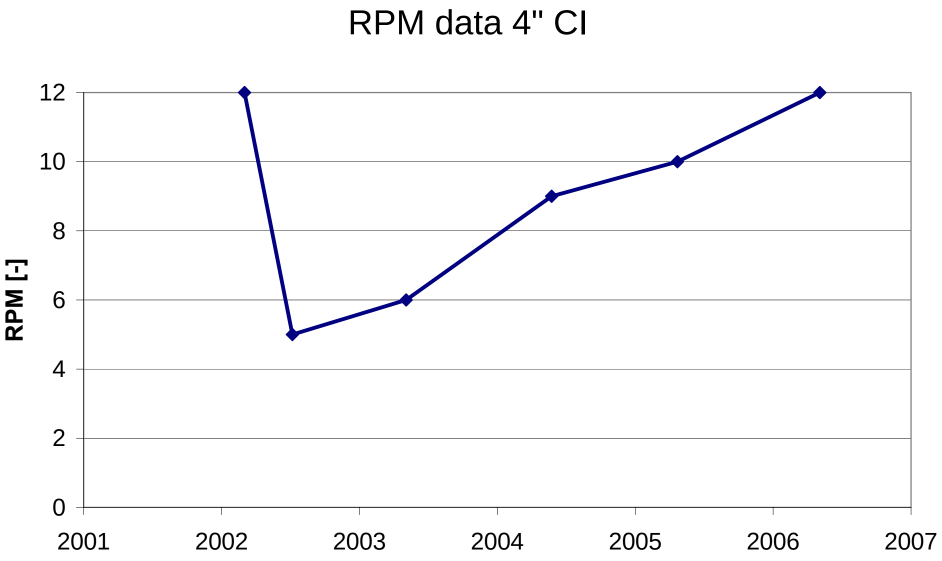
Results AC pipe



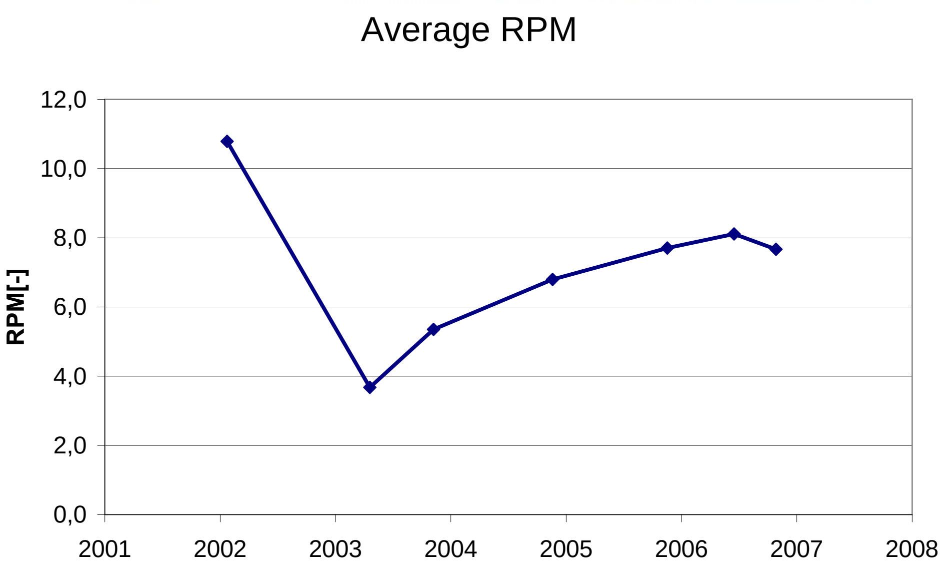


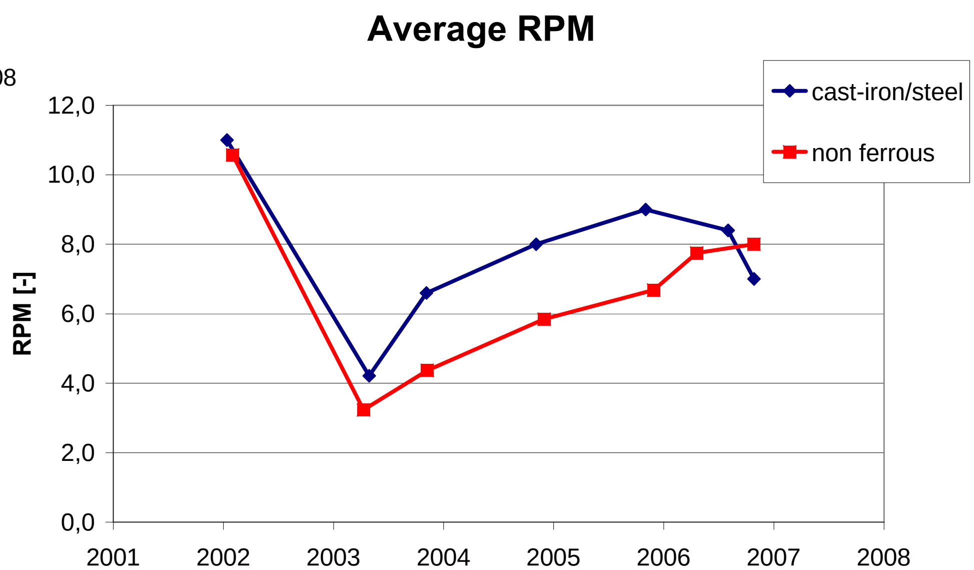
RPM results CI pipe





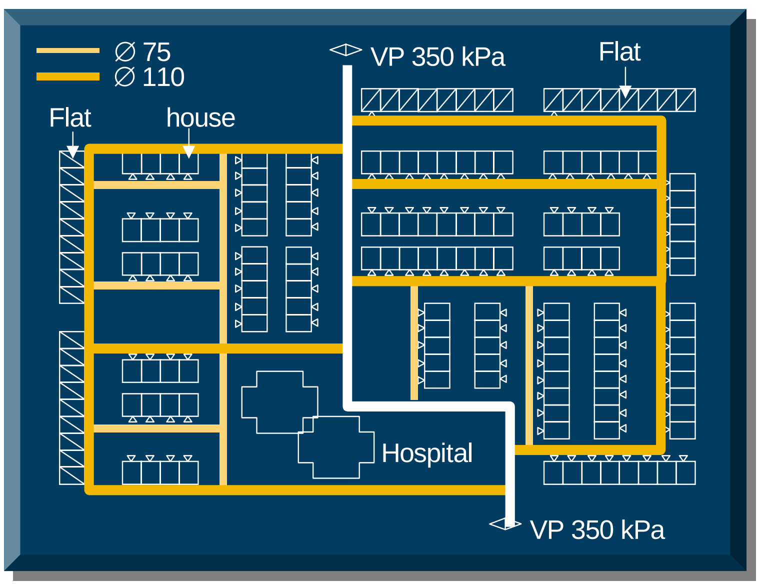
Average RPM's

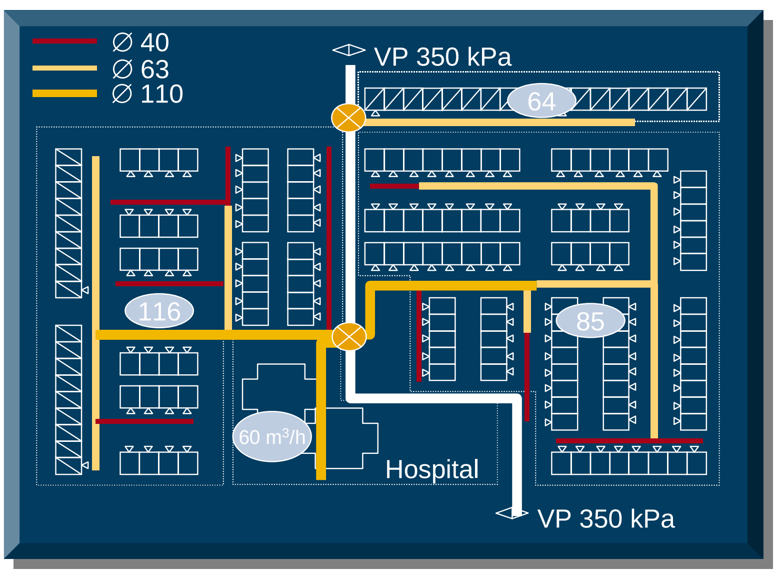




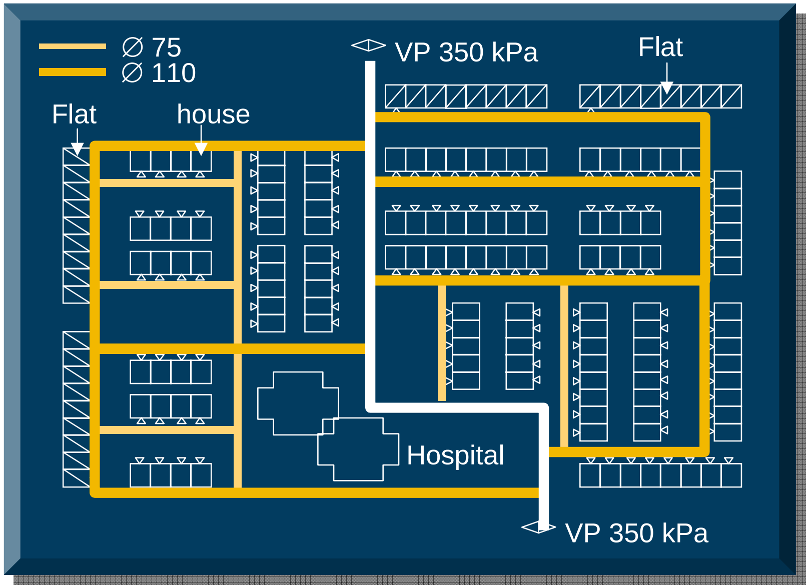
Stage 3: Prevent settling

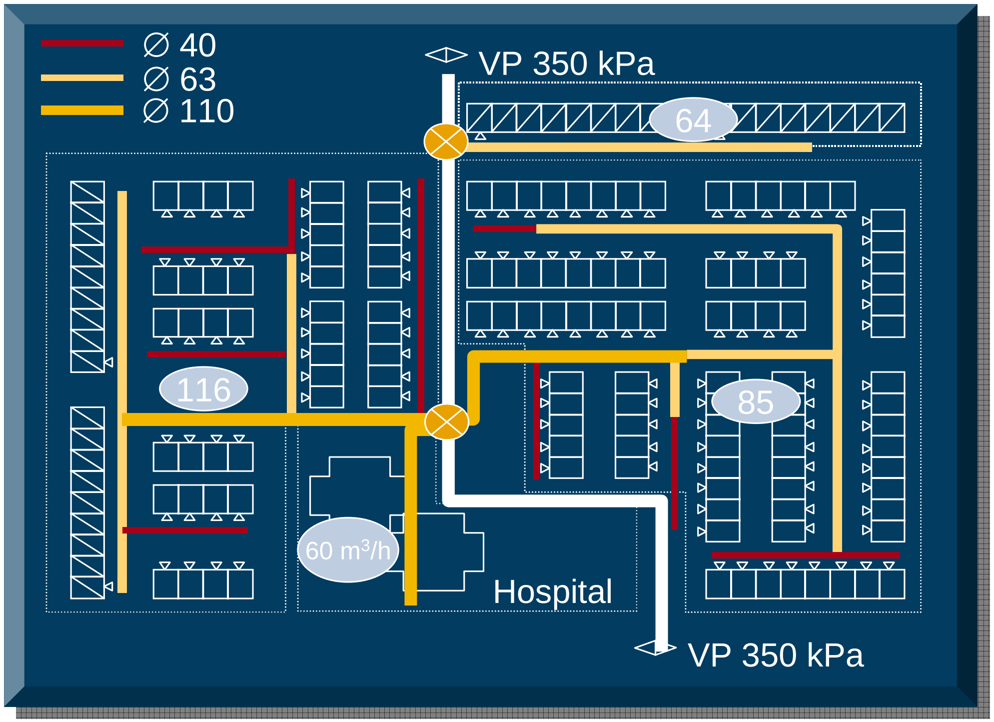
- **New design rules for distribution networks**
  - **Looped main structure**
  - **Branched and streamlined distribution pipes**
  - **20% cheaper**



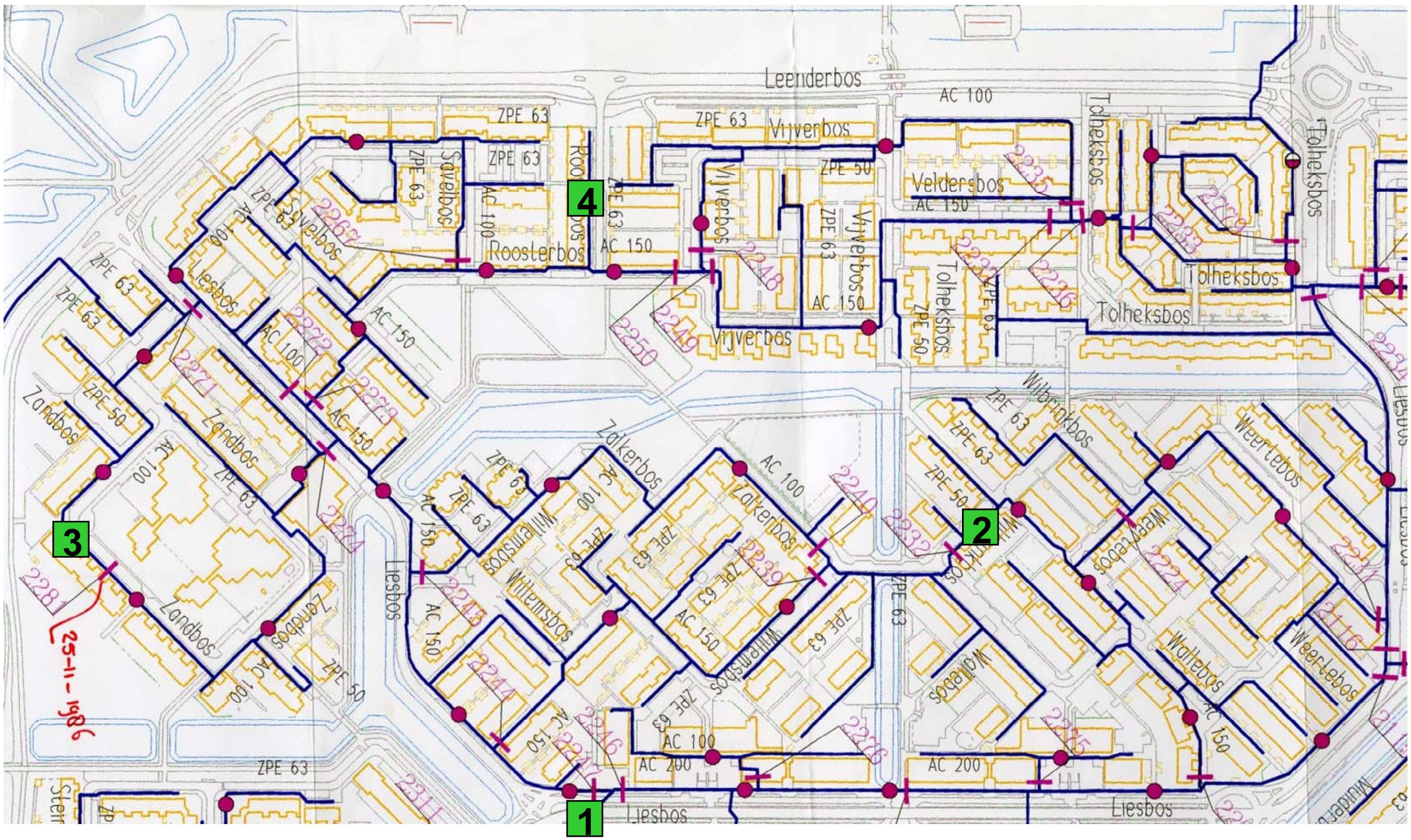


Self cleaning networks: the principle



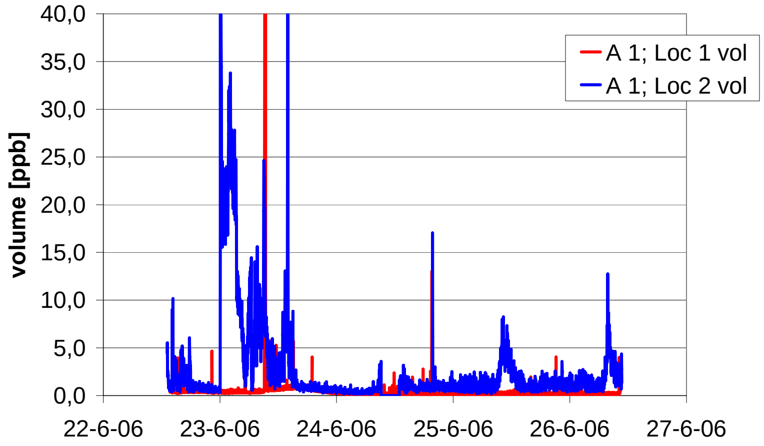


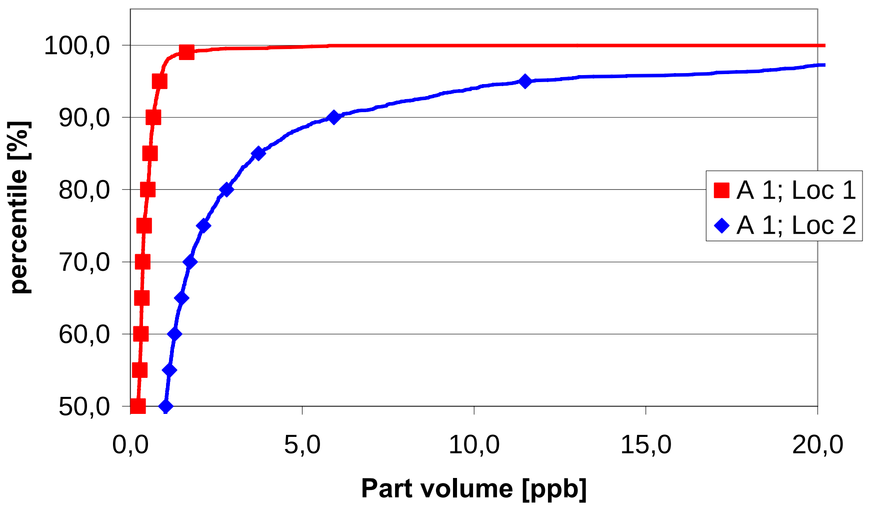
Self cleaning networks: case study comparing to conventional network

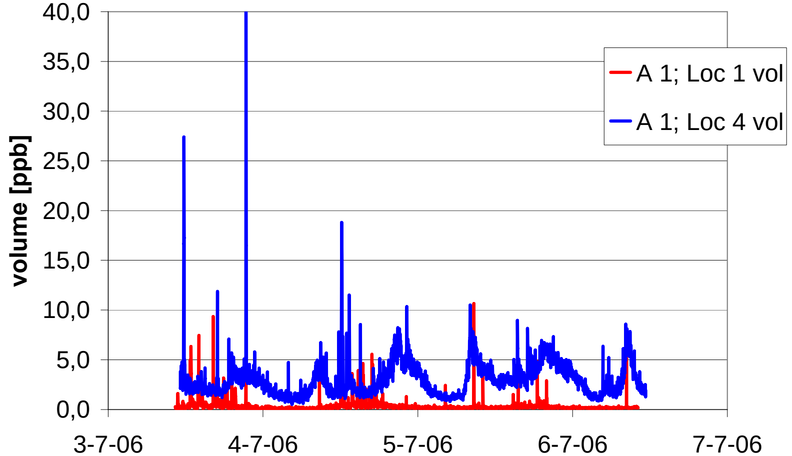


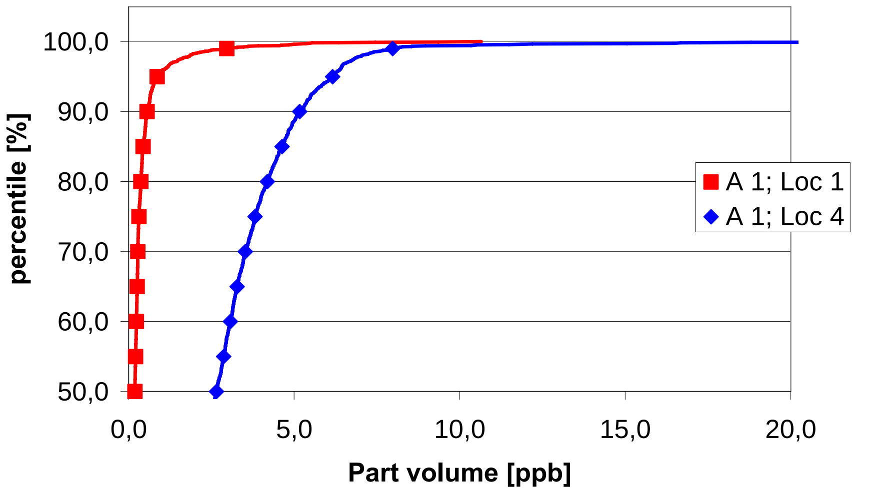
Self cleaning network

Area 1: conventional

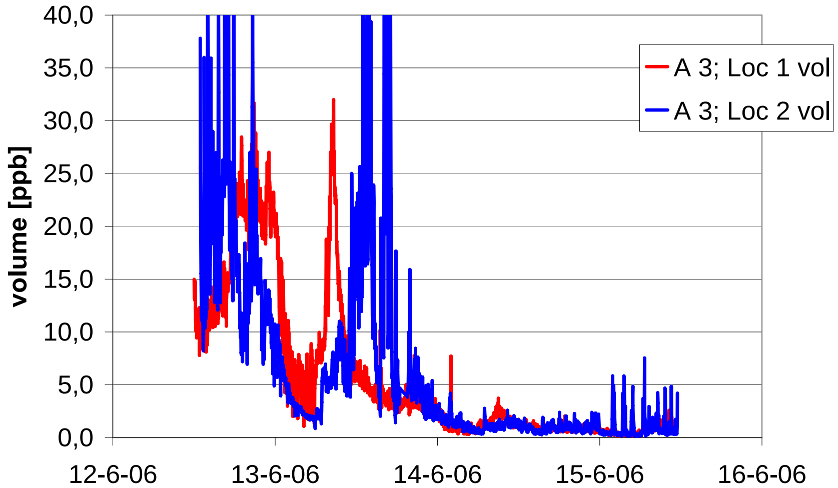


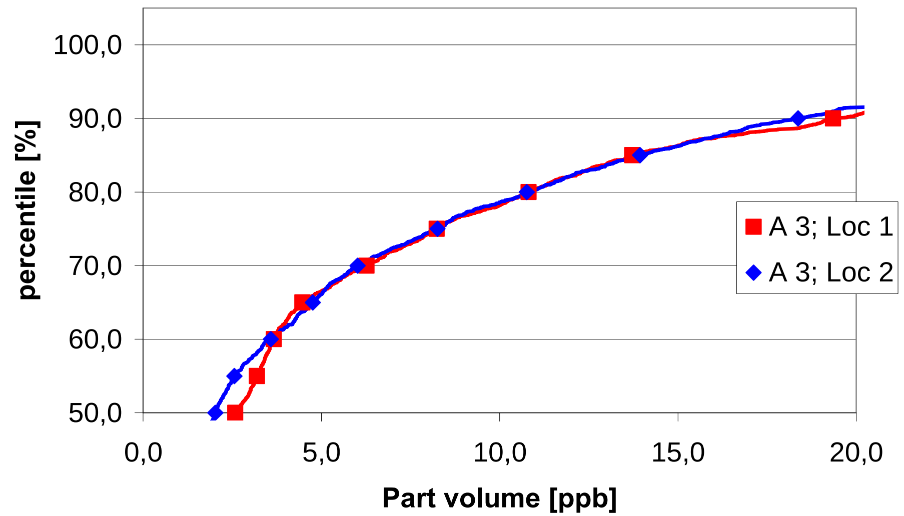


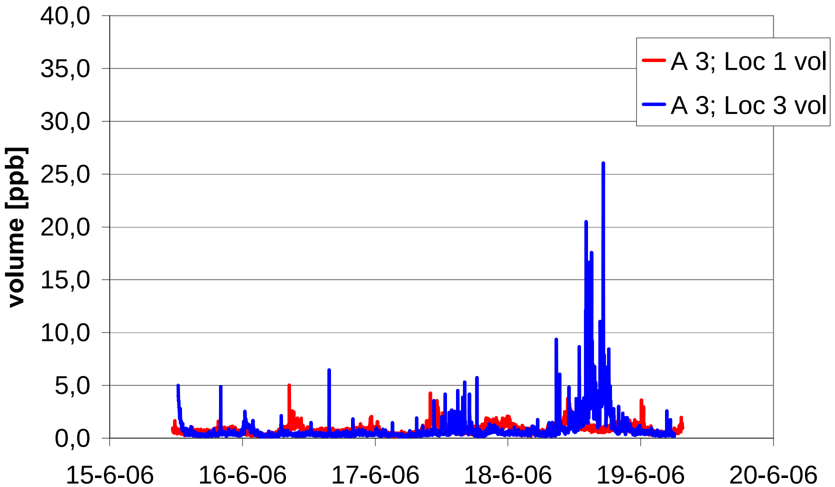


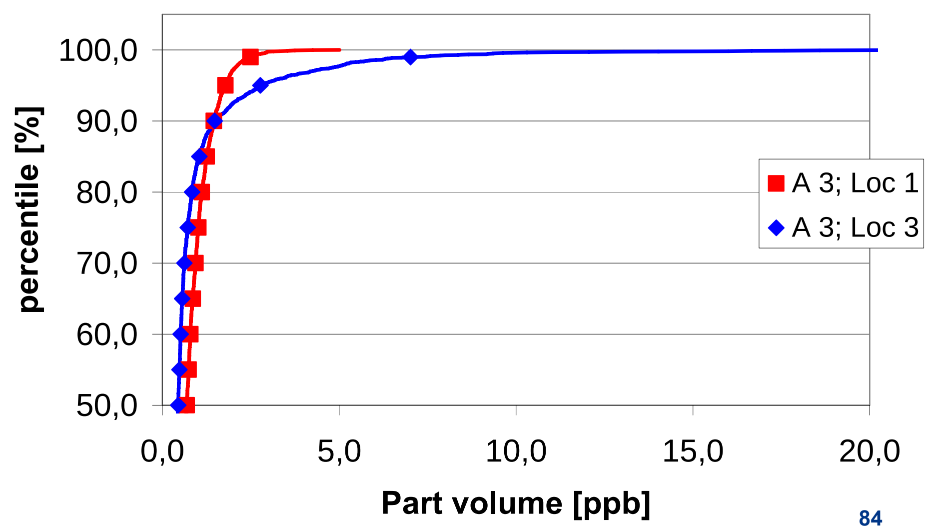


Area 3: self cleaning

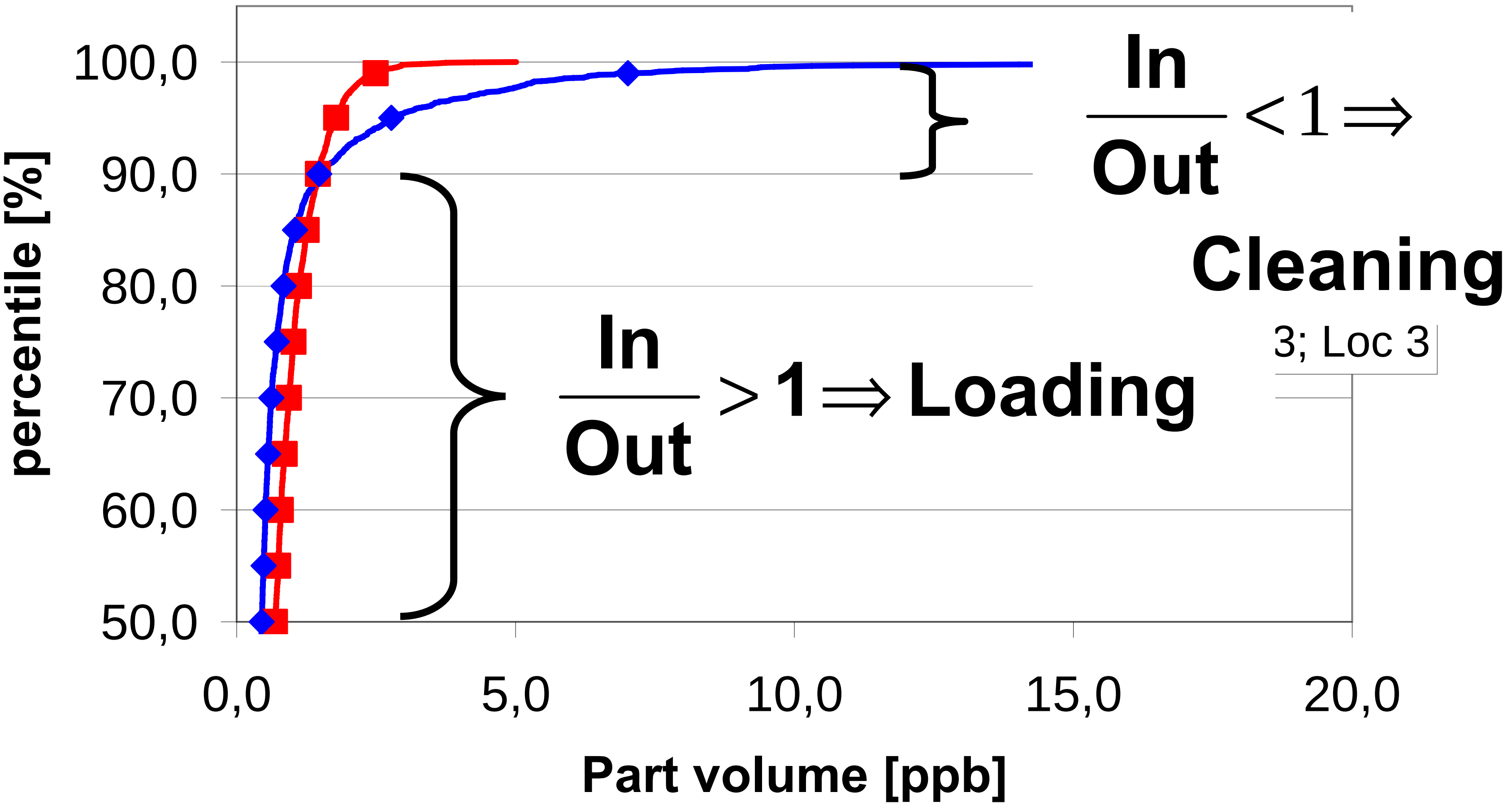




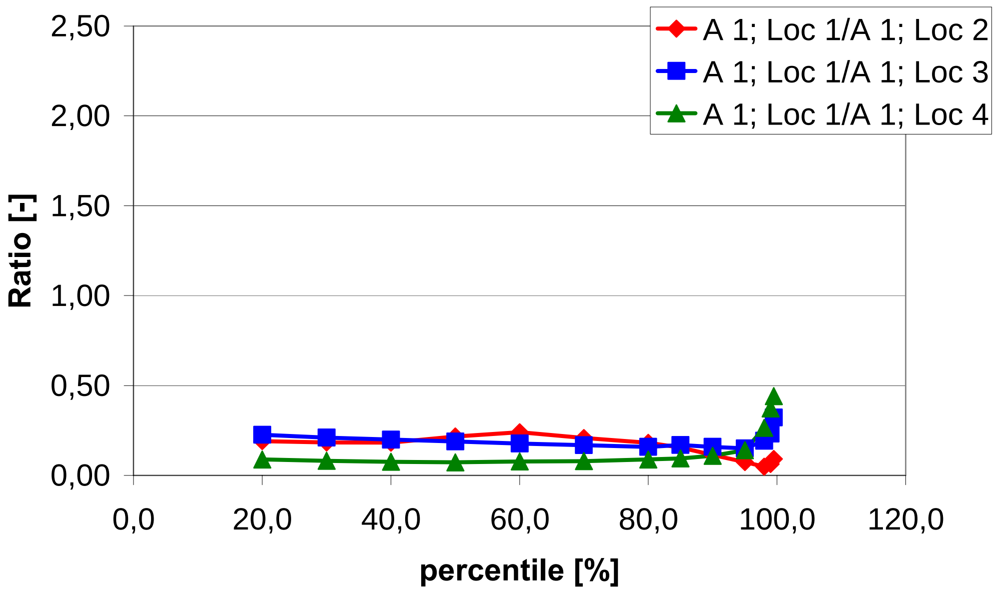


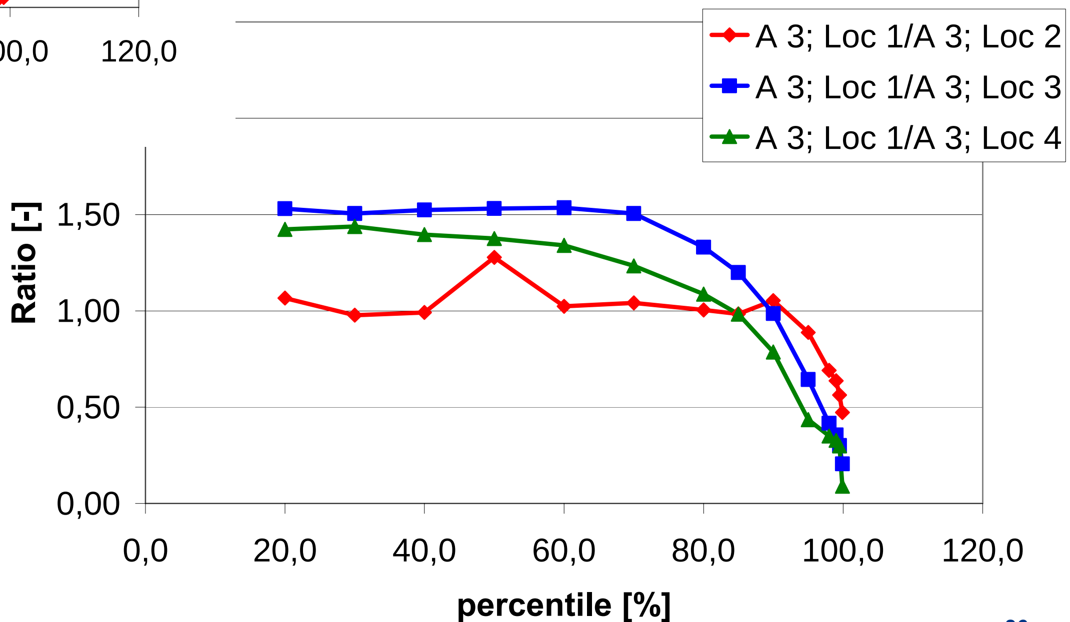


Ratio in going / out going

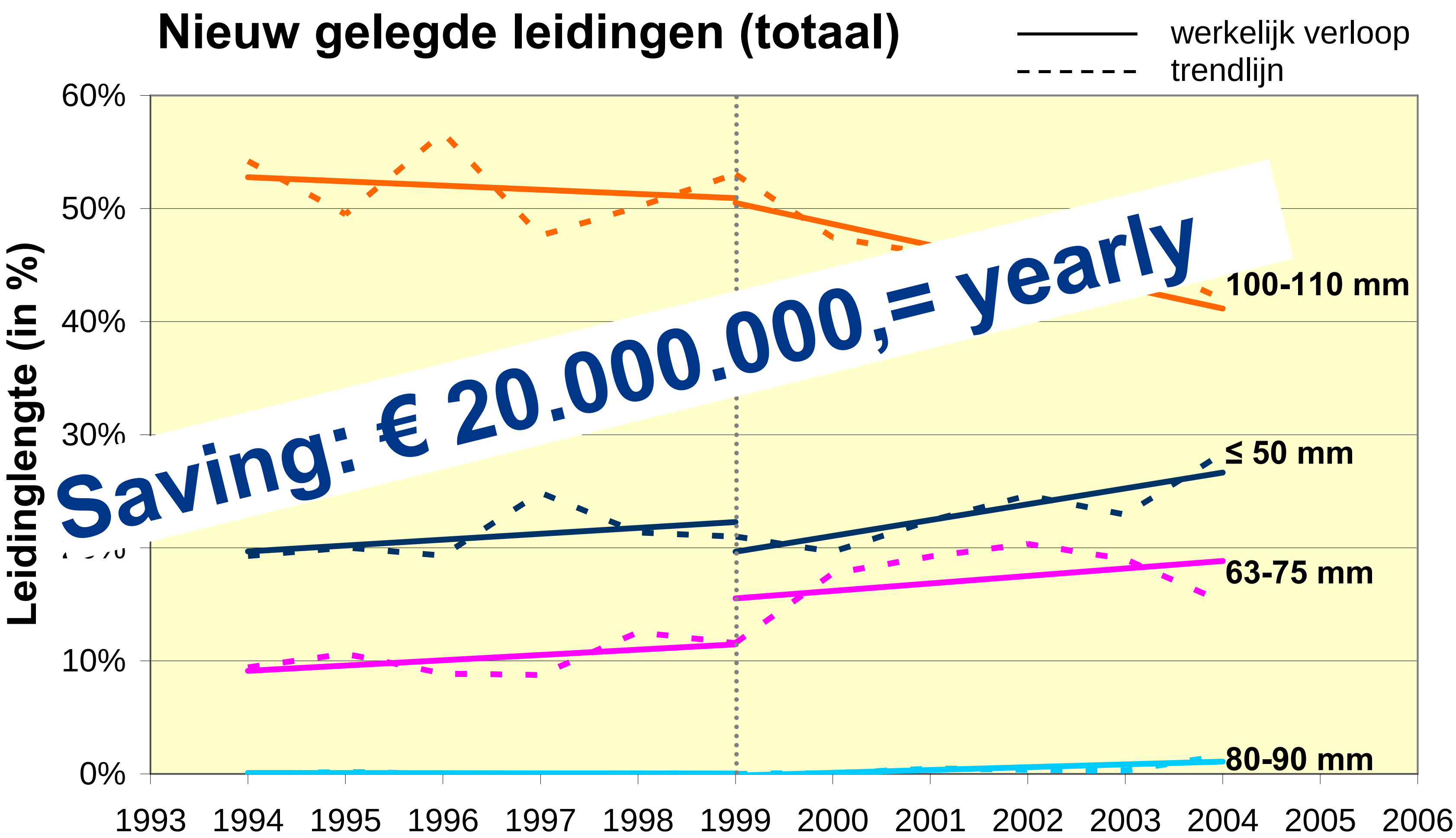


Comparison conventional ←→ Self cleaning Ratio In/Uit in different locations





It takes time to implement an innovation



Recapitulation

- Operational measures to control discolouration available ➔ further development and (international) implementation
- Fundamental knowledge about particle load, NOM and particle behavior in the network still lacking
- Measuring methods as RPM, Particle counting and TILVS must be further developed
- Test rig for quantifying effect treatment on distribution is promising

- Challenges enough!

Jan Vreeburg

UNESCO-IHE Institute for Water Education

TU Delft Technische Universiteit Delft

kiwa Partner for progress

Water quality in distribution: the latest developments

Q21