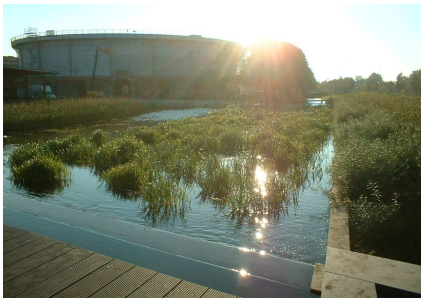
LESSONS LEARNED FROM OVER TWO DECADES OF CONSTRUCTED WETLAND USE FOR URBAN STORMWATER IN THE NETHERLANDS



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Dr.ir.F.(Floris)C.Boogaard

York, 14 September 2015

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INTRODUCTION

Blue Green Dream stowa skint

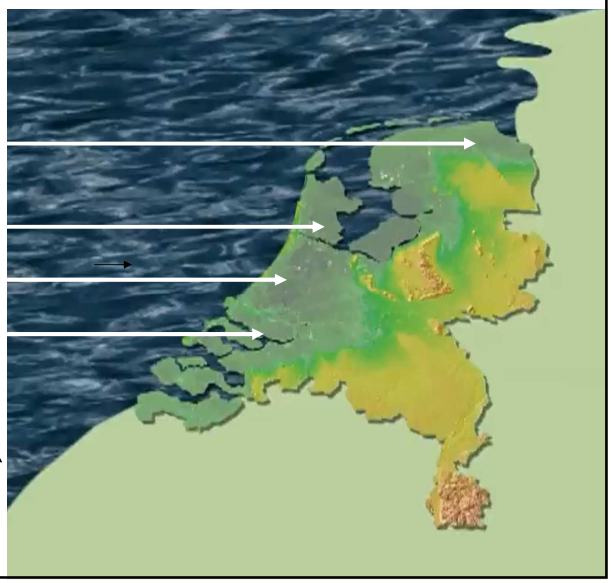
Hanzehogeschool Groningen University of Applied Sciences

Tauw

TU Delft Delft University of Technology

indymo

Research
Education
Consultancy



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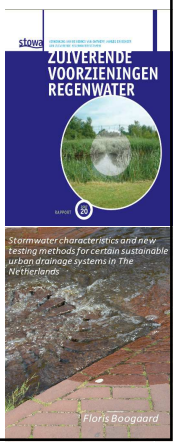
Content

1. Introduction
   - Challenges in The Netherlands
2. Stormwater Quality Characteristics
3. Dutch constructed wetlands:
   1. Removal efficiency
   2. Cost
   3. Esthetics
   4. Lifespan
   5. Monitoring (innovation)
4. Tools and information
5. Conclusions

Focus: 'old low tech wetlands in urban area



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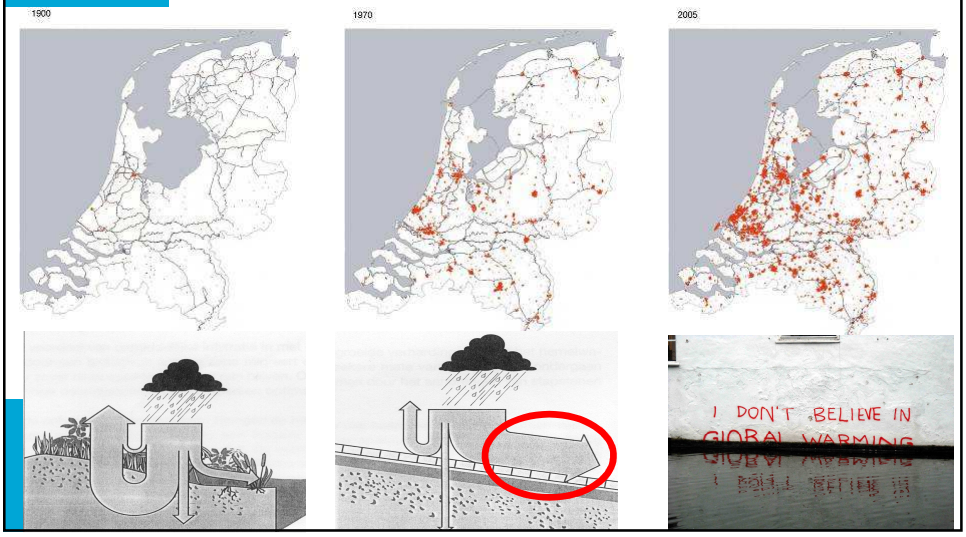
DUTCH WATER MANAGEMENT WATERSTORAGE (AND INFILTRATION)

1900 **1970** **2005**



Stormwater quality

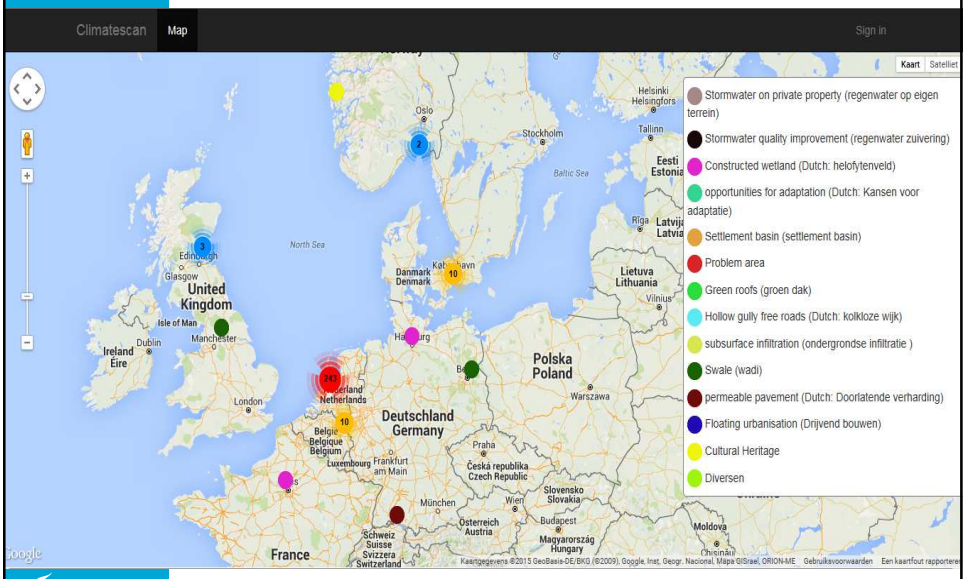
101 SOLUTIONS: SUDS

DUTCH CONSTRUCTED WETLANDS






MAPPING SUDS



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Tipping J., Boogaard F. Jaeger R., Duffy A., Klomp T., Manenschijn M., Climatescan.nl: the development of a web-based map application to encourage knowledge-sharing of climate-proofing and urban resilient projects, International waterweek 2015, Amsterdam.

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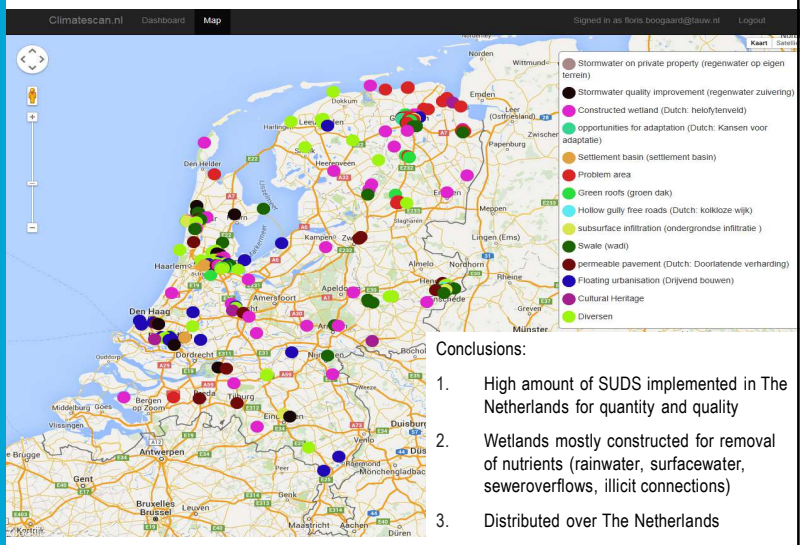
MAPPING WETLANDS
WWW.CLIMATESCAN.NL



Conclusions:

1. High amount of SUDS implemented in The Netherlands for quantity and quality
2. Wetlands mostly constructed for removal of nutrients (rainwater, surfacewater, seweroverflows, illicit connections)
3. Distributed over The Netherlands
4. Small amount is being monitored

Tipping J., Boogaard F. Jaeger R., Duffy A., Klomp T., Manenschijn M., Climatescan.nl: the development of a web-based map application to encourage knowledge-sharing of climate-proofing and urban resilient projects, International waterweek 2015, Amsterdam.

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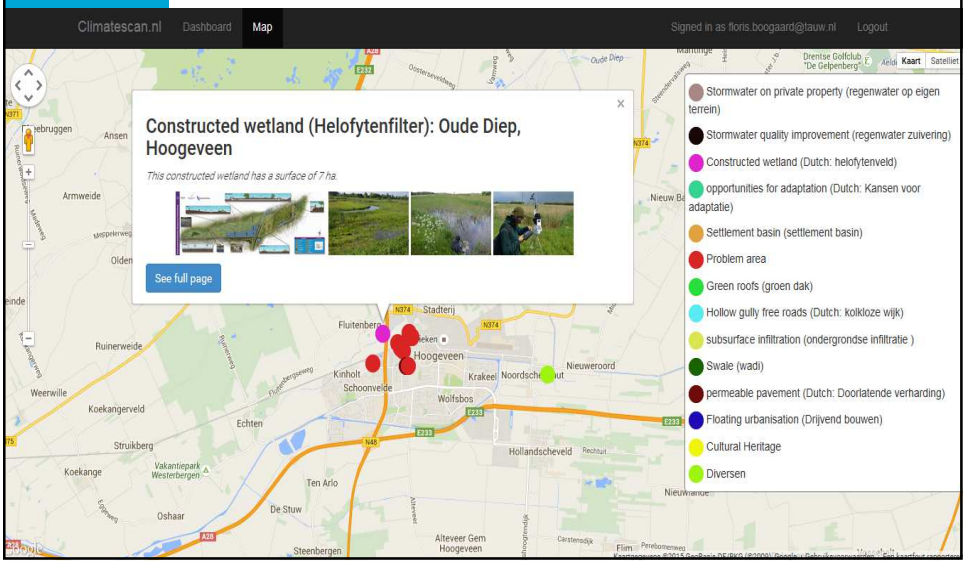
RESULTS
WWW.CLIMATESCAN.NL



RESULTS
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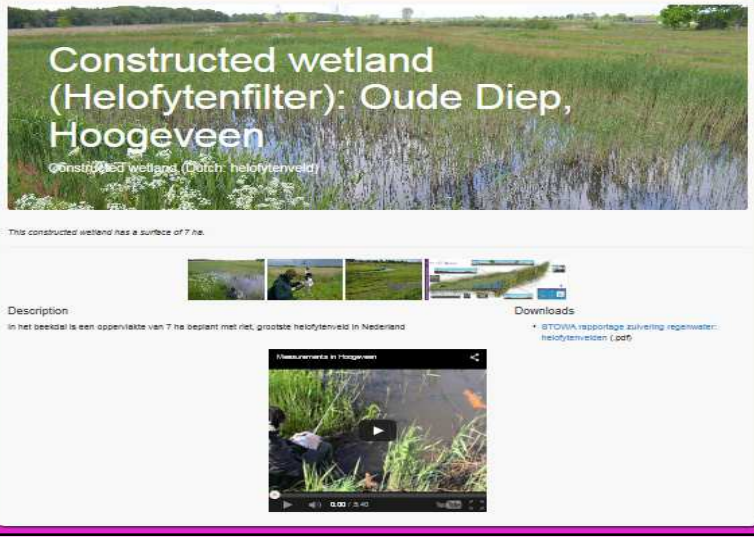
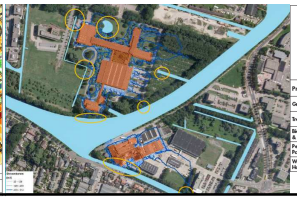


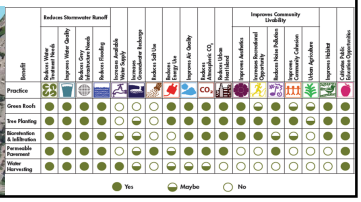
Main Dutch objectives to implement SUDS/constructed wetlands

1. Water storage
2. Improving water quality
3. Multifunctional

- Heatstress
- Disaster modelling

Water, Energy, Air quality, Climate Change, The urban heat island effect, Community liveability, Habitat improvement and Public education





Results: characteristics of stormwater

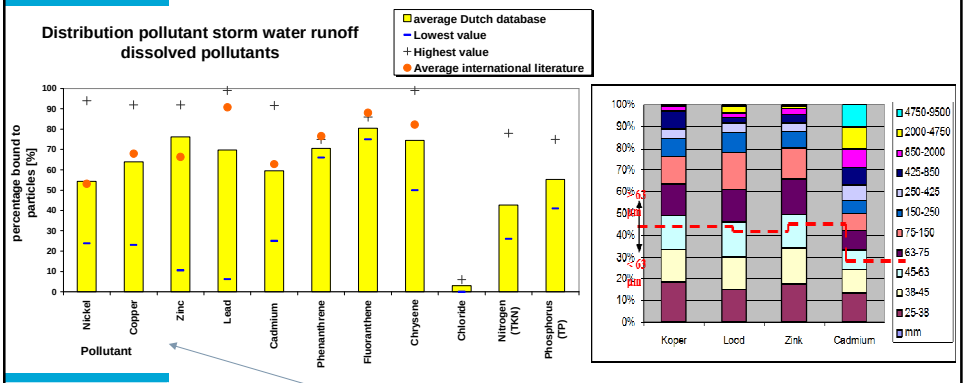
- Detailed information on suspended sediment characteristics in stormwater is essential
- Database: >150 locations (the Netherlands); 7,652 individual storm events/15 years.

- As the fine fraction is responsible for most of the pollution load, it is important to know whether SUDS as constructed wetlands are capable of removing the finer solids. *Pollution load: majority from finer fraction*

	Cd	Cr	Cu	Hg	Pb	Ni	Zn	PAH10	PAH16
	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
mean	0.27	6.2	19	0.05	18	5.6	102	0.8	60.9
median	0.15	1.1	11	0.06	6	3.6	60	0.8	1.5
90 percentile	0.50	12.0	35	0.08	43	10.0	250	1.1	1.5
n measurements	152	141	686	118	682	155	684	145	106
MAC solved	0.4	8.7	1.5	0.20	11.0	5.1	9.4	2.3	
MAC total	2.0	84	3.8	1.2	220	6.3	40	4.3	4.3
required R	0.0%	0.0%	**80.5%**	0.0%	0.0%	0.0%	**60.7%**	0.0%	

Boogaard F.C. Stormwater characteristics and new testing methods for certain sustainable urban drainage systems in The Netherlands, Delft 2015.

Results: characteristics of stormwater



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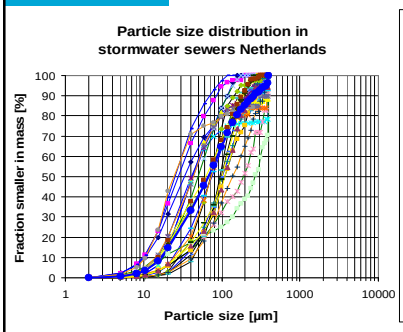
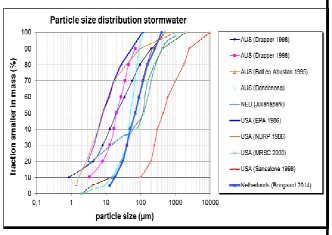
Results: characteristics of stormwater





- Conclusions: pollution levels do not meet requirements of European (MAC/WFD) on heavy metals and nutrients.
  - Example: 80% removal rate is needed to achieve MAC for copper, (bound for 65% to suspended solids: unlikely to achieve MAC values with sedimentation so filtration/ adsorbtion is needed).
  - Low tech, low cost: from ponds/sedimentation devices to wetlands, vegetated swales

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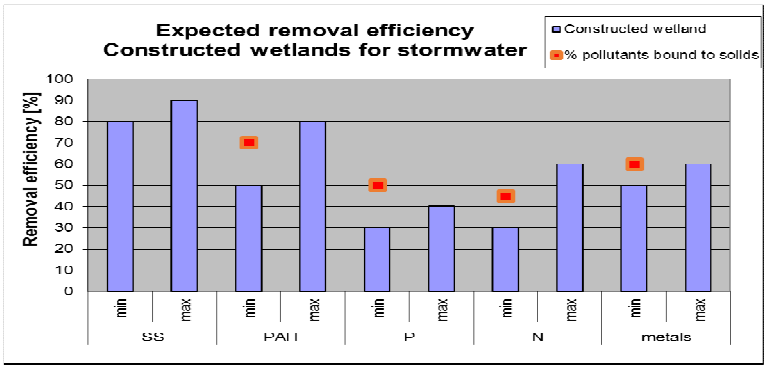
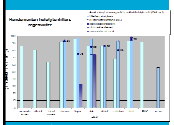
Boogaard F.C. Stormwater characteristics and new testing methods for certain sustainable urban drainage systems in The Netherlands, Delft 2015.

REMOVAL EFFICIENCY





- Correlation with amount of bound particles
- The removal efficiency of constructed wetlands derived from existing monitoring results differ from study to study, but are mostly within the ranges of international literature.

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Boogaard F.C., van de Ven F.H.M. Langeveld J, Giesen van de N. Stormwater Quality Characteristics in (Dutch) urban areas and performance of settlement basins, challenges 2014.Wilson, S.; Bray, R.; Cooper, P. Sustainable Drainage Systems, Hydraulic, Structural and Water Quality Advice; London 2004 CIRIA C609.2004 RP663 ISBN 0-86017-609-6.
Woods-Ballard B., Wilson S., Udale-Clarke H., Illman S., Kellagher R B B., Ashley R M., Scott T. SuDS Manual Construction Industry Research and Information Association, in press, 2015.

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DEVELOPMENT/INNOVATION: DIKES HIGHER REMOVAL EFFICIENCY

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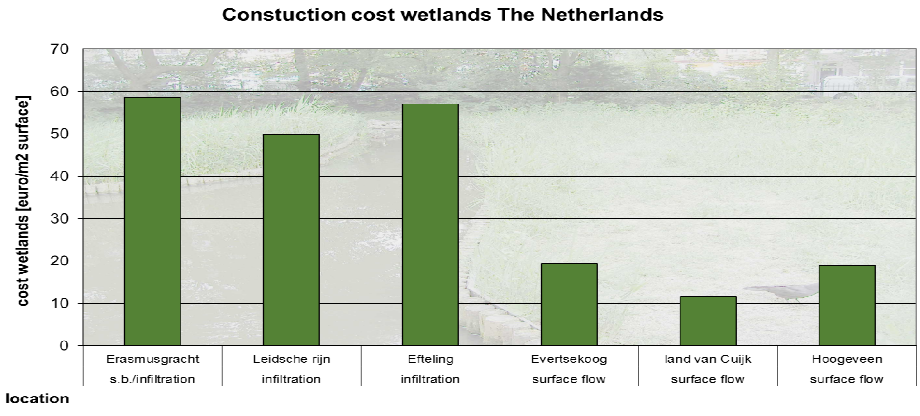
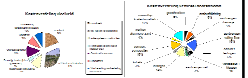
CONSTRUCTION COST



- The average cost of implementation of vertical flow wetlands were in the order of 55 euros/field area in contrast to the cost of the surface flow wetlands (15 euros/field area).



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STOWA (authors: Bogaard F.C., Rombout J.) SUDS recommendations for design, implementation and maintenance (in Dutch: zuiverende voorzieningen regenwater 'verkenning van de kennis van ontwerp, aanleg en beheer van zuiverende regenwaterstystemen') STOWA 2007.

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IMPROVEMENTS? (NON TECHNICAL)

- "interviews focused on the level of appreciation of the constructed wetlands and general perceptions pertaining to this type of SUDS, decades after implementation. "

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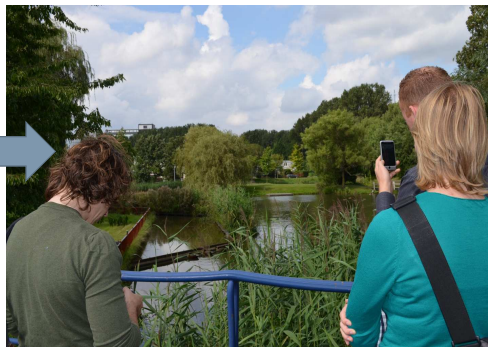
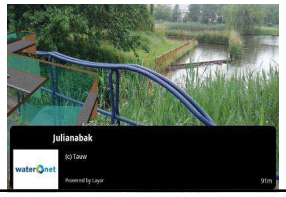
IMPROVEMENTS ESTHETICS/EXPERIENCE

http://www.ateliergroenblauw.nl/architectuur/erasmusgracht-amsterdam/

IMPROVEMENTS ESTHETICS/AUGMENTED REALITY





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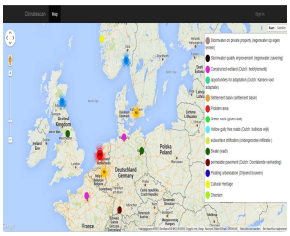
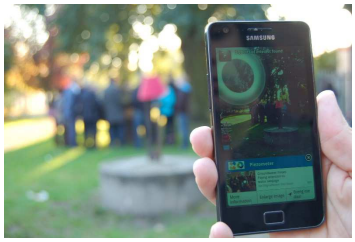
INTERACTIVE COMMUNICATION: INTERACTIVE

MEETINGS, FIELDTRIPS, INTERVIEWS, COURSES, SEMINARS, JOBROTATION, AUGMENTED REALITY, SERIOUS GAMING, ...





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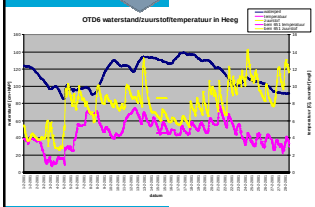
Innovation: New monitoring method

From point samples to better understanding of spatial distribution of parameters in the constructed wetlands.
The tool is a semi-autonomous underwater drone, equipped with several sensors and video cameras.

"x mg"



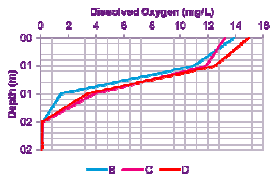


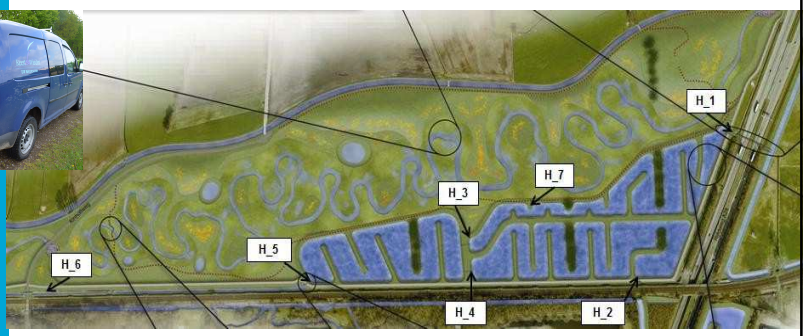
Figure 1. The underwater drone with the attached equipment

Attached Equipment:
(1) In-situ TROLL 9500 Sensors:
- Nitrate and Ammonium ISE
- Rugged Dissolved Oxygen

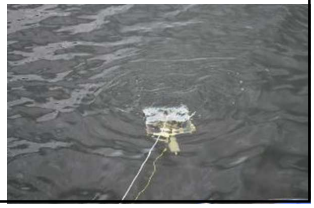
(2) CTD Diver :
- Temperature
- Pressure
- Conductivity

(3) Diving light
(4) HD Video Camera (GoPro 3+)

HOOGEVEEN CONSTRUCTED WETLAND



- Grab samples water: lab/on site analysis
- Drone in water with multisensors: Surrounding area of grab sample



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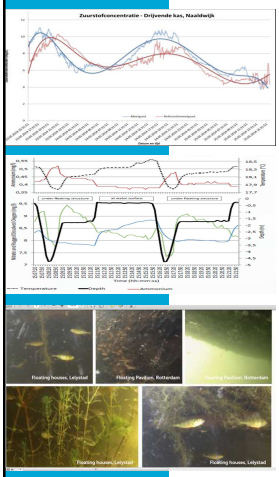
COMPARISON TWO METHODS



	Grab sample (conventional)	Underwater Drone
Location	Point sample	**Extended area and depth**
Standardization	Follows National Standard in lab analysis	Quality of multisensor/ion selective sensor
Parameters	All	If sensor available
Sample size	Small	Potentially very large
Added value	Precise	- **Spatial variation** - **video** - **Big data**
Cost	Sampling, lab, reporting	Application, reporting
Availability	High	Low now
Development needs	Low	**High (phds)**

- Monitoring methods, aquatic drones are cost effective for insight into the spatial variation of quality and video footage of biodiversity. Drones reach areas within the constructed wetland that are usually omitted in monitoring, thus extending the knowledge on the wetland. 25

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RESULTS
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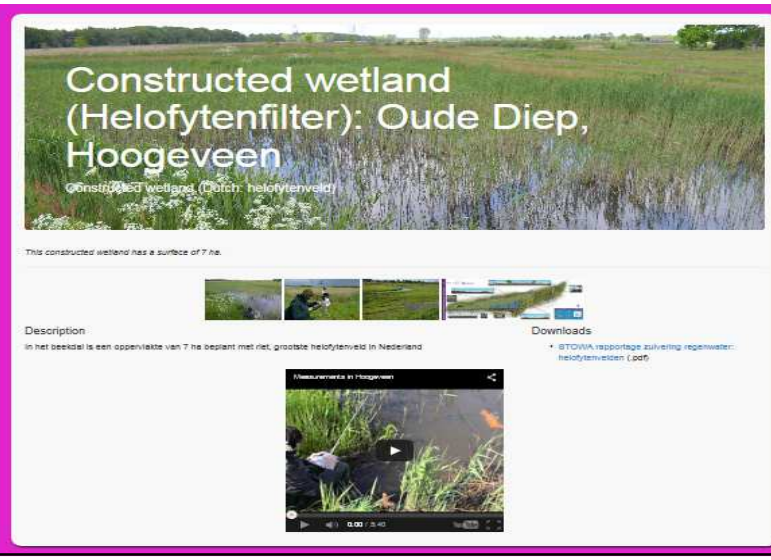

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Do SUDS work years after implementation?

+ Factor time

→ Permeable pavement

→ Swales

→ Constructed wetlands

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Full scale hydraulic testing SUDS: wetlands

Full scale test at swale (left) and full scale test at permeable pavement (right).

Full scale test at watersquare (left) and full scale test on filter drains (right).

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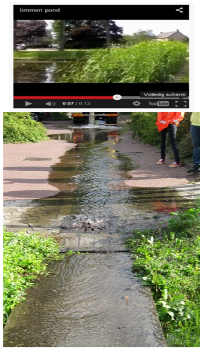
LIFESPAN: RESULTS FULL SCALE TESTING WETLANDS AND (WET VEGETATED) SWALES

Small low tech wetlands in the urban area of Holland >10 years

Municipality	infiltration rate [m/day]**
Purmerend	0.09
Purmerend	0.14
Purmerend	0.25
Purmerend	0.24
Oostzaan	0.24
Haren	0.11
Haren	0.08
Utrecht	0.15
Noordoostpolder	1.21
Enschede	0.13
Almelo	0.09
Arnhem	2.16



* infiltration rates are lower than 0,125 m/d which is needed to empty 25 cm in 48 hours

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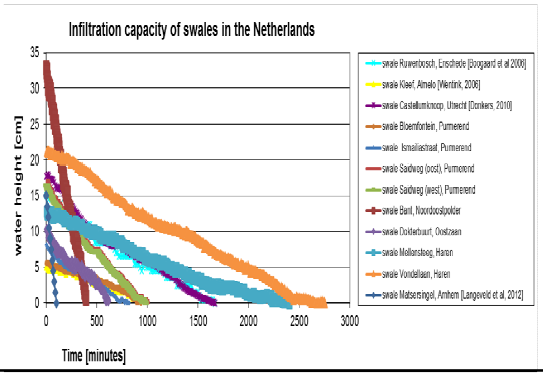
HYDRUALIC LIFESPAN

- appr. 10 years old, low maintenance
- variation of the infiltration capacity of 0.08 to 2.16 m/d.
- 75% will empty its storage volume within 48 hours
- Clogging with good vegetation is limited

These results are encouraging and important for the implementation of low tech/cost of wetlands in the Netherland and other areas in the world with comparable hydraulic circumstances.



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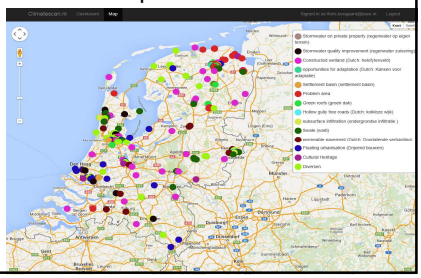
(FIRST) CONCLUSIONS

- SUDS with sedimentation (eg ponds) will not meet MAC values/WFD: wetlands/vegetated swales are implemented
- The average cost vertical flow wetlands: appr. 55 euros/field area surface flow wetlands (15 euros/field area).
- Variation infiltration capacity of 0.08 to 2.16 m/d, 75% will empty its storage volume within 48 hours, clogging with good vegetation is limited. Long-term performance however remains an issue.
- Monitoring methods, aquatic drones can be cost effective: spatial variation of quality and video footage of biodiversity.
- International knowledge exchange: available tool www.climatescan.nl. This tool is available for all, and everybody is encouraged to add functioning SUDs to this public database.



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