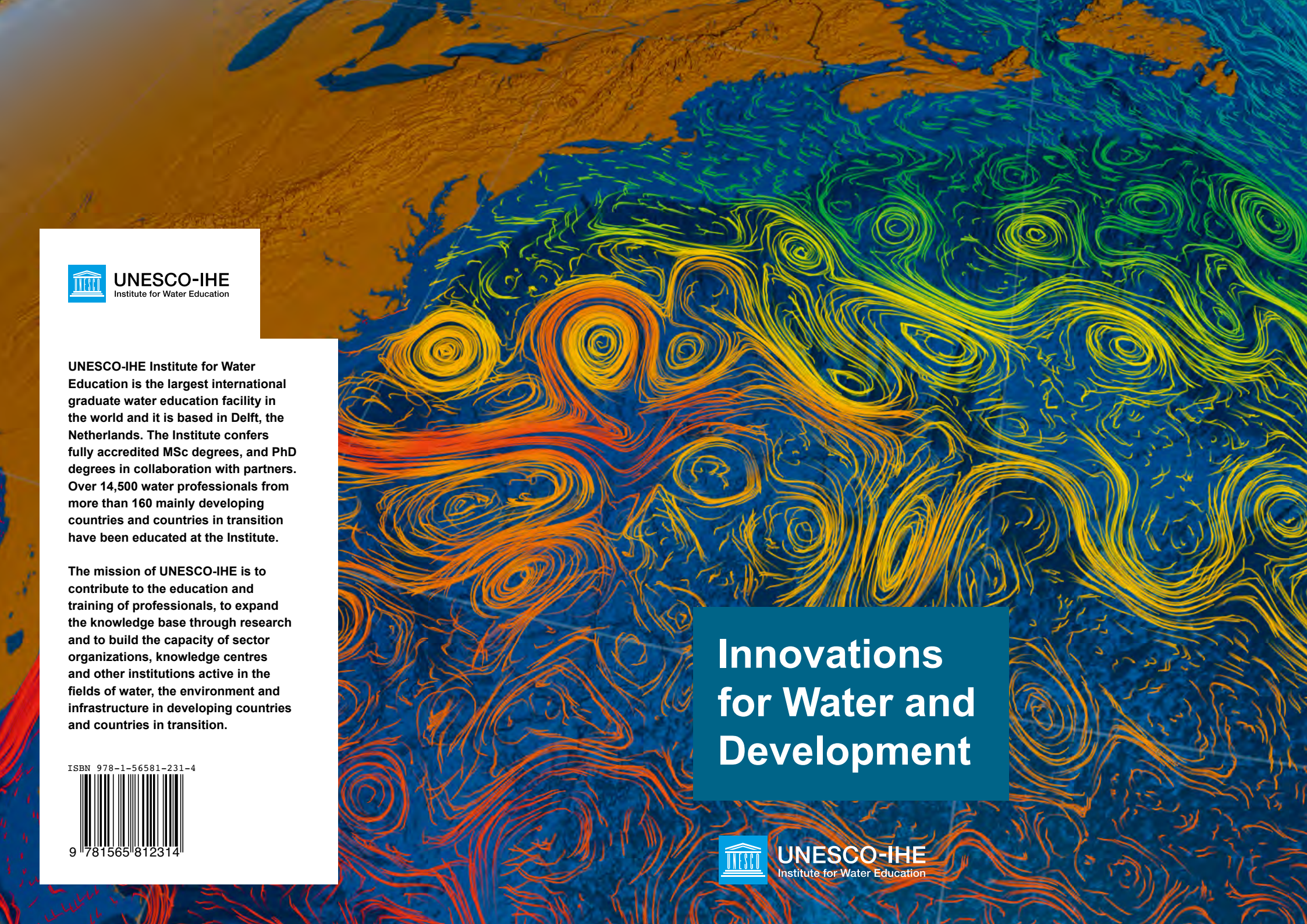

UNESCO-IHE
Institute for Water Education

UNESCO-IHE Institute for Water Education is the largest international graduate water education facility in the world and it is based in Delft, the Netherlands. The Institute confers fully accredited MSc degrees, and PhD degrees in collaboration with partners. Over 14,500 water professionals from more than 160 mainly developing countries and countries in transition have been educated at the Institute.

The mission of UNESCO-IHE is to contribute to the education and training of professionals, to expand the knowledge base through research and to build the capacity of sector organizations, knowledge centres and other institutions active in the fields of water, the environment and infrastructure in developing countries and countries in transition.

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Innovations for Water and Development

UNESCO-IHE
Institute for Water Education

UNESCO-IHE envisions a world in which people manage their water and environmental resources in a sustainable manner, and in which all sectors of society, particularly the poor, can enjoy the benefits of basic services. Realizing that present and future water-related problems require out of the box thinking, business as unusual approaches, changes of paradigms, and inventive and unconventional solutions leading to the translation of inventions into innovative products, services, processes and new activities that are introduced to the real world, UNESCO-IHE is increasingly committed to innovations concerning all three pillars of its operations, namely, research, education and capacity development.

Our innovations are often of a technological nature, but their adoption also has social, economic, environmental, governance, institutional and political dimensions. Research-based innovations originate from the six research themes of UNESCO-IHE that are well aligned with relevant international and national science programmes.

They cover core thematic areas of sustainability as well as cross-cutting themes, namely:

- Safe Drinking Water and Sanitation;
- Water Related Hazards and Climate Change;
- Water and Ecosystems Quality;
- Water Management and Governance;
- Water, Food, and Energy Security;
- Information and Knowledge Systems.

In addition, UNESCO-IHE has also developed a number of innovative products concerning education and capacity development. A common goal of the Institute staff is to maximize valorisation, defined as the utilization/uptake of research results to create socio-economic value, and this is high on the Institute's agenda.

To illustrate the innovative nature of UNESCO-IHE's operations, Professor Damir Brdjanovic initiated, upon request of the Rectorate, the collection of 50 innovations that were created with our global partnership network to develop, implement and validate novel solutions that ultimately aim to improve the quality of life on our planet.

Rectorate
UNESCO-IHE Institute for Water Education

UNESCO-IHE
Global Water Innovations

Innovation overview

		UNESCO-IHE focus areas						
		Safe Drinking Water & Sanitation	Water, Food & Energy Security	Water-Related Hazards & Climate Change	Information & Knowledge Systems	Water & Ecosystems Quality	Water Management & Governance	
1	eSOS concept	■			■	■		■
2	Wastewater treatment for aquaculture	■		■				
3	Arsenic removal family filter IHE-Adart	■						
4	Monitoring algal bloom in desalination plants	■		■	■		■	
5	Fluoride removal family filter	■		■				
6	Seawater for toilet flushing and SANI®	■		■				■
7	Extreme events and UNESCO heritage sites	■			■	■		■
8	Centralised arsenic removal IHE-Adart	■		■				
9	Quick-wins for flood protection of critical urban infrastructure				■	■		■
10	Problem-based innovative learning: Sint Maarten Group Work	■					■	■
11	Free monitor				■	■		■
12	Wing monitors			■		■	■	■
13	Seasonal hydrological drought forecasting	■		■	■	■	■	■
14	Sediment management in reservoirs			■	■		■	■
15	ESACES	■		■	■	■	■	■
16	Forecasting floods			■	■	■		■
17	Dealing with uncertainties			■	■	■		■
18	Erasmus Mundus Master in Flood Risk Management	■			■	■	■	■
19	Porous stone spillways	■		■	■	■	■	■
20	Predicting storm surges			■	■	■		
21	Roads for water	■		■	■	■	■	■
22	Improving performance of water utilities	■		■		■		■
23	Guidelines for roads development in flood plains			■	■		■	■
24	Tidal irrigation and drainage	■		■	■	■	■	■
25	Arid land greening	■		■	■			■

		UNESCO-IHE focus areas						
		Safe Drinking Water & Sanitation	Water, Food & Energy Security	Water-Related Hazards & Climate Change	Information & Knowledge Systems	Water & Ecosystems Quality	Water Management & Governance	
26	Water value maps			■		■	■	■
27	Alternative flow regime benefit assesment	■		■	■		■	■
28	eSOS smart toilet	■			■	■		■
29	Operator partnerships in WASH	■		■		■		■
30	Benchmarking water and sanitation services	■		■		■		■
31	Serious gaming and water management	■		■	■	■	■	■
32	Mapping near-shore bathymetry data				■	■	■	
33	Predicting the shape of future deltas			■	■	■	■	
34	WAMEX	■				■		■
35	Ships making waves			■	■	■	■	
36	Predicting the coastal killer waves			■	■	■	■	
37	Multi-objective rehabilitation of sewers	■				■		■
38	Photo-activated sludge process	■		■				
39	Tailored i-learning for sanitation professionals	■			■	■		■
40	Sanitizing faeces by microwaves	■		■	■			
41	Citizens as water sensors: WeSenselt			■	■			■
42	Wastewater treatment on a green roof	■		■	■		■	
43	WA+: an emerging global standard for water accounting	■		■	■	■	■	■
44	Agent-based models of sociotechnical systems	■		■	■	■	■	■
45	Uncapping MBR limitations	■		■				
46	Rapid assessment of climate change impacts on inlet-interrupted coasts			■	■	■		
47	Hybrid Master in Sanitation and Sanitary Engineering	■		■				
48	Drawing the line on coastline recession risk			■	■	■		
49	Floating solutions for upgrading wet-slums	■		■	■			
50	Ensemble hydro-meteorological prediction system			■	■			■

1

eSOS concept

The innovative eSOS (emergency Sanitation Operation System) concept is designed to provide a sustainable, innovative, holistic and affordable sanitation solution for emergencies before, during and after disasters.

eSOS not only reinvents the (emergency) toilet and treatment facilities, but also uses existing information and communication technology to bring innovation and potential cost savings to the entire sanitation operation and management chain, and most importantly, is expected to improve the quality of life of people in need.

Location: Worldwide
Coordinator: Damir Brdjanovic (d.brdjanovic@unesco-ihe.org)
Partner: Bill & Melinda Gates Foundation

The innovative Blue Label®-based experimental pilot-scale recirculation aquaculture system (RAS) for catfish production has been developed and designed (feed production, hatchery and ongrowing system) for optimization and recovery of resources in the food production chain in Cuba; with nutrients retrieval, energy recovery and wastewater reuse from RAS wastewater treatment systems.

Several other full scale RAS systems for intensive production of eel, sea bass and sea bream have been constructed in Croatia.

Wastewater treatment for aquaculture

2

Location: Cuba, Croatia
Coordinator: Hector Garcia (h.garcia@unesco-ihe.org)
Partner: HESY Aquaculture B.V.

3

Arsenic removal family filter IHE-Adart

Hundreds of millions of people, mainly in rural areas of developing countries, are exposed every day to high arsenic levels in drinking water. Arsenic is a human carcinogen, and its presence in drinking water increases cancer mortality risk, and causes liver failure, as well as cardiovascular, neurological and several other diseases.

The UNESCO-IHE award-winning Arsenic Removal Family Filter (IHE-Adart) is based on a low-cost adsorbent and has been demonstrated to effectively remove arsenic from drinking water. The filter can produce enough arsenic-free drinking water for a whole family. The filter is simple to operate, does not require electricity and can be produced locally.

"The Best Water Technology Innovation"
ID-NL Year Award 2004

Locations: Bangladesh, Jordan, Serbia, Ghana
Contact: Branislav Petrusevski (b.petrusevski@unesco-ihe.org)
Partner: Vitens

Seawater desalination technology is capable of solving water scarcity in arid regions of developed and developing countries. An emerging threat to this technology are algal blooms, which can cause shutdown of desalination plants due to operational problems caused by algal-derived substances known as transparent exopolymer particles (TEP).

UNESCO-IHE has developed a new method to monitor TEP during algal blooms to provide engineers and operators with a tool for developing strategies to mitigate operational problems in desalination plants. This method has been tested in pilot and full-scale desalination plants in several countries.

Monitoring algal bloom in desalination plants

4

Locations: Netherlands, Schotland, Spain, Cyprus
Contact: Maria Kennedy (m.kennedy@unesco-ihe.org)
Partners: Wetsus, PENTAIR, Evides

5

Fluoride removal family filter

Millions of people in Africa (Sudan, Ethiopia, Uganda, United Republic of Tanzania, Ghana, Kenya, etc.), Asia (Jordan, China, Pakistan, India, Thailand, Sri Lanka, Iraq, Iran, Morocco, Algeria, etc.), Europe, America and Australia are exposed every day to high fluoride levels in drinking water. Long-term exposure to elevated fluoride concentration in drinking water is responsible for dental and skeletal fluorosis, and increased incidence of cancer and other diseases.

The UNESCO-IHE fluoride removal family filter, based on a modified locally available low-cost adsorbent, has been demonstrated to effectively remove fluoride from drinking water. The filter is simple to operate, does not require electricity and can be produced locally.

Location: Ghana
Contact: Branislav Petrusevski (b.petrusevski@unesco-ihe.org)
Partner: Kwame Nkrumah University of Science and Technology (KNUST)

A source for toilet flushing and for cooling, sewage treatment benefits, and phosphorus recovery: direct use of seawater in an age of rapid urbanisation is being promoted by UNESCO-IHE to combat water scarcity in coastal cities. UNESCO-IHE is currently building the first application of the innovative SANI® Process outside Hong Kong for the tourism industry in Cuba.

The innovative SANI® Process technology was originally developed in Hong Kong and makes use of a common microbe called sulphate-reducing bacteria, which uses the sulphate in seawater as the medium to oxidize and eliminate pollutants. Since these microbes are highly efficient and grow slowly, it minimizes sludge production by 90%, hence the name SANI® Process, meaning 'sludge-killing' in Chinese. The ongoing joint research is extending the application of SANI® to industrial and inland situations and other geographic regions.

Seawater for toilet flushing and SANI®

6

Location: Hong Kong, Cuba
Coordinator: Carlos Lopez-Vazquez (c.lopezvazquez@unesco-ihe.org)
Partners: HKUST, University of Cape Town, Delft University of Technology

7

Extreme events and UNESCO heritage sites

A new flood-prevention approach, proposed by UNESCO by building a 1.6 metre-high permanent wall, dykes, and a new road elevation and flood-way, hopes to save the World Heritage ancient city of Ayutthaya Island. The province has sought an allocation of Bt550 million from the government to support the project, which involves the building of over 12.5 kilometres of dykes surrounding Ayutthaya Island.

The new approach is the result of two years' research into the severe flood that hit Ayutthaya in 2011. Recently, the flood model created by UNESCO Bangkok, in cooperation with the Fine Arts Department Bangkok, UNESCO-IHE, AIT, HAII and the ADB was unveiled in Ayutthaya. The model addresses the risk of extreme events in a holistic manner and is planned to assess the vulnerability to floods of UNESCO heritage sites worldwide.

Locations: Thailand, Worldwide
Contact: Zoran Vojinovic (z.vojinovic@unesco-ihe.org)
Partner: United Nations Educational, Scientific and Cultural Organization (UNESCO)

Arsenic is a human carcinogen, and its presence in drinking water increases cancer mortality risk, and causes liver failure as well as cardiovascular, neurological and several other diseases. Thousands of both small and large water supply systems that make use of arsenic-contaminated groundwater cannot provide the population with arsenic-free water due to the poor efficiency or high costs of available arsenic removal techniques.

IHE-Adart arsenic removal technology is based on arsenic adsorption by low cost media, a by-product from the drinking water industry, and a patented in situ regeneration procedure.

IHE-Adart has demonstrated potential to produce arsenic-free drinking water from groundwater with very high arsenic concentration, while the generation of waste streams is strongly reduced in comparison to other arsenic removal technologies. The filter is simple to operate, does not require electricity and can be produced locally. The IHE-Adart process is robust, simple to operate and affordable for developing countries.

Centralised arsenic removal IHE-Adart

8

Locations: Hungary, Romania, Greece, Serbia, Jordan.
Contact: Branislav Petrusevski (b.petrusevski@unesco-ihe.org)
Partners: Vitens, Water Autorithy Jordan (WAJ), PUC Subotica

9

Quick-wins for flood protection of critical urban infrastructure

Flood events can have catastrophic impacts on critical urban infrastructures and trigger cascading effects (including extended loss of power, water supply, transport and communication). These cascading effects, such as witnessed following the Asian Tsunami and more recently through super-storm Sandy, can be widespread and long lasting. Much economic damage could be avoided if the most vulnerable critical infrastructures are protected ahead of time.

UNESCO-IHE has developed a rapid screening procedure (Quick Scan) that enables service providers and operators to identify and rate infrastructure networks and hotspot buildings at risk from flooding, and to assess where interventions will be most feasible and cost-beneficial. This procedure has demonstrated potential to identify 'quick wins', which refer to those interventions that can be taken at relatively low cost and with expected high benefits of avoided secondary impacts.

Locations: Thailand, Netherlands, France
Contact: Berry Gersonius (b.gersonius@unesco-ihe.org)
Partners: HR Wallingford, Deltares, Deltasync

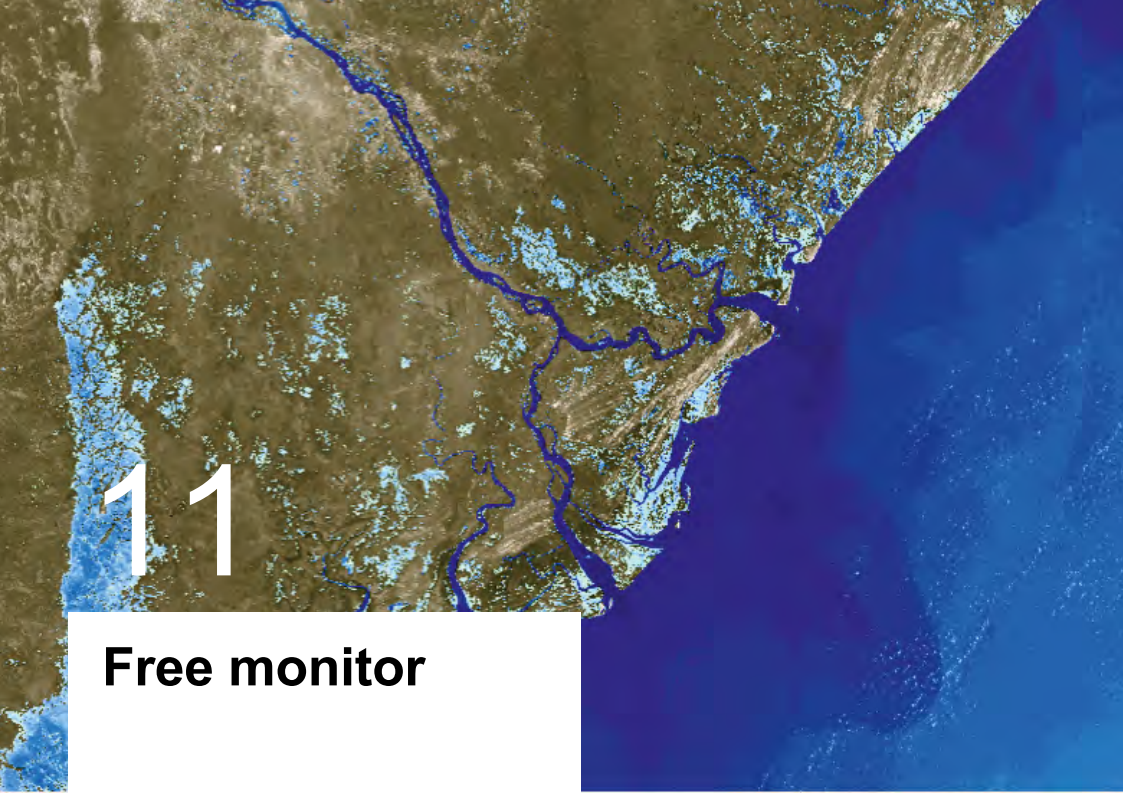
Problem-based innovative learning: Sint Maarten Group Work

Within the UNESCO-IHE Master of Science programs, the group work is the last 3-week module of the taught part of the programs. In the group work, students from the different specializations of the MSc program in Urban Water and Sanitation (UWS) work together on a joint project. The UWS group work is centred on the real-life case of the Island of Sint Maarten in the Caribbean.

Students are provided with relevant information and data, and expected to identify and analyse water-related problems and issues and propose viable, integrated approaches and solutions. Working on a real-life case enhances the learning experience, and adds to the attraction for the students. On the other hand, it also makes this not only a purely educational exercise, as the results of their work may be of practical use to the Government of Sint Maarten.

10

Locations: Netherlands, Sint Maarten
Contact: Jan Herman Koster (j.koster@unesco-ihe.org)
Partner: The Government of Sint Maarten



11

Free monitor

The application and quality of freely available remote sensing data to assess the dynamics of rivers and lakes in poorly gauged basins in developing countries is coming of age. On the one hand there is a wealth of freely available satellite data and on the other hand there is a greatly improved quality of open source and operational software that allows new integrated methods to be established quickly, and usable by various countries' agencies and stakeholders for the monitoring of rivers and lakes dynamics throughout the hydrological year.

This information, coupled with the few existing gauging stations, will allow for a low-cost, and hopefully shared, hydrological baseline that can be accessed by universities, local and national bodies, and individual users. The free monitor toolbox enables the monitoring of river, wetland and lake dynamics using freely-available multi-sensor satellite data and open source software.

Locations: Kenya, Mozambique, Tanzania
Contact: Paolo Paron (p.paron@unesco-ihe.org)

Monitoring of the quantity and quality properties of water and ecosystems has been so far conducted from point-sampling with relatively low revisit frequency due to logistic and cost concerns. UNESCO-IHE has expanded this approach to a spatially explicit sampling of both quality and quantity parameters using UAV (Unmanned Aerial Vehicles) and KAP (Kite Aerial Photography) systems, with hyper-spatial resolution and potential for daily frequency. This brings a new insight into the natural dynamics and feedback mechanisms acting in natural and anthropologically impacted ecosystems (e.g. rivers, coasts, wetlands etc.).

Wing monitors

12

Locations: Mozambique, Kenya
Contact: Paolo Paron (p.paron@unesco-ihe.org)
Partners: WWF, HighView

13

Seasonal hydrological drought forecasting

A new approach to providing forecast drought information to water users in drought-prone areas that couples seasonal meteorological forecasts and hydrological modeling has been developed by researchers at UNESCO-IHE. This methodology provides key information on the occurrence of dry spells, low soil moisture conditions and reservoir levels.

The research was developed in the context of a European 7th Framework research project focusing on drought forecasting and warning, that was carried out in close collaboration with partners across Africa and Europe. In some climatic regions of Africa forecasts were found to be reliable for selected indicators of drought up to lead times of 3-4 months allowing users such as rain-fed farmers, irrigated farmers and reservoir operators to take timely action to reduce the impacts of drought events.

Location: South Africa
Contact: Shreedhar Maskey (s.maskey@unesco-ihe.org)
Partners: European Center for Medium Range Weather Forecast (ECMWF), Deltares

Reservoir infilling is still an underestimated issue in many parts of the world, both during design and during operation that leads to reduced reservoir capacity and alteration of the original operation schemes. Sediment provenance studies have so far been conducted mostly with a mono-disciplinary approach, either it being from the mineralogical point of view or from the hydraulic modelling point of view. UNESCO-IHE has developed a combined, multidisciplinary approach to gain more realistic insights into the sediment source areas and their transport and deposition, providing more useful sediment management tools to dam operator agencies. This novel approach includes multidisciplinary assessment of sediment sources in reservoirs by combining mineralogical fingerprinting with 2/3D morphodynamic modelling.

Sediment management in reservoirs

14

Locations: Mozambique, Sudan
Contact: Alessandra Crosato (a.crosato@unesco-ihe.org)
Partners: Hydraulics Research Centre (HRC-Sudan), Ministry of Water Resources and Electricity of Sudan

15

ESACES

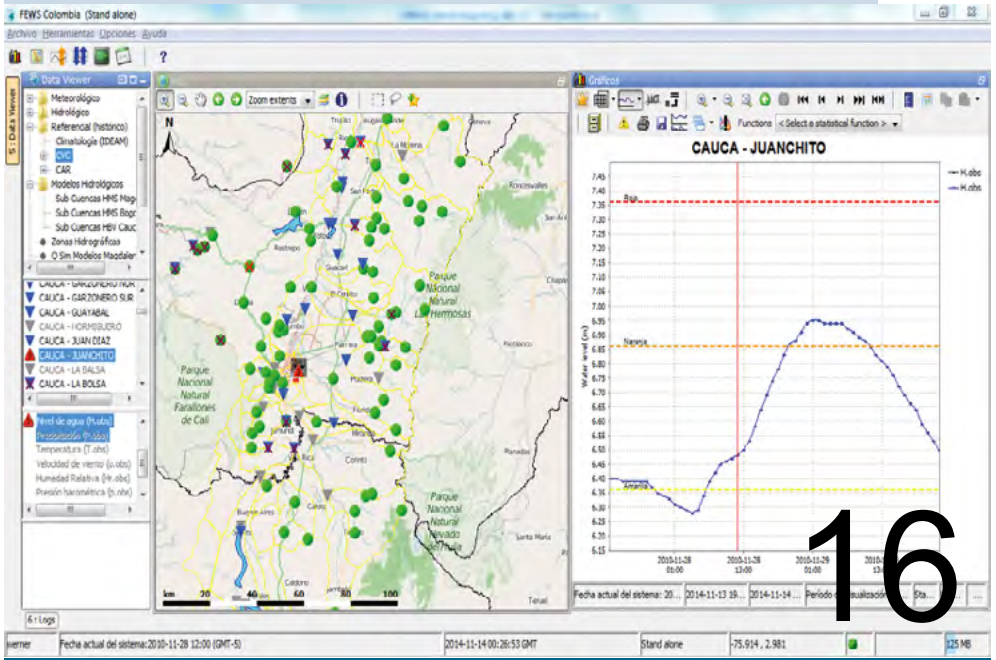
Improving the knowledge on groundwater resources in the Valle del Cauca in Colombia, and the interaction between groundwater and surface water both in times of water scarcity and of water abundance, will help the local environment agency in charge to manage the resource sustainably. In collaboration with Deltares and CVC (Regional Environment Agency in Colombia), UNESCO-IHE is researching the dynamics of groundwater in the Valle del Cauca, an area of key socio-economic importance in the country. Improving the knowledge and capacity on groundwater resources and the interaction with surface water through field research and modeling will allow the combined use of surface water and groundwater to be improved, as well as help understand the role of groundwater in flooding.

Location: Colombia
Contact: Micha Werner (m.werner@unesco-ihe.org)
Partners: Deltares, Corporación Autónoma Regional del Valle del Cauca (CVC)

State-of-the-art forecasting methods to provide operational flood forecasting in Colombia have been piloted, combining hydrometric real-time ground data with meteorological and hydrological models. Pilot applications in three basins in Colombia show the potential for providing operational forecasts to communities at risk to reduce flood damage such as that caused by the destructive floods of 2010-2011.

UNESCO-IHE has been working in collaboration with Deltares and IDEAM, the Colombian Hydrometeorological agency, as well as regional institutions on establishing an operational flood forecasting service. Through joint development in three pilot basins, knowledge and capacity have been established, and IDEAM is now working towards providing the service at a national level to all communities at risk in the country.

Forecasting floods



16

Location: Colombia | **Contact:** Micha Werner (m.werner@unesco-ihe.org)
Partners: Deltares, Instituto de Hidrología Meteorología y Estudios Ambientales (IDEAM), Corporación Autónoma Regional del Valle del Cauca (CVC), Corporación Autónoma Regional de Cundinamarca (CAR)

17

Dealing with uncertainties

Using the innovative statistical and machine learning methods of dealing with uncertainty, a model-based methodological framework allowing for flood inundation/hazard mapping has been developed. It will be used to assist the Malaysian government in making appropriate decisions for the assessment and management of flood risk based on flood mapping under uncertainty, with application to the Johor River basin.

The new approach helps understanding of how the uncertainty associated with topographic sources of digital elevation maps (DEMs, cell size for grids, spacing of river cross-sections), hydrological data (errors in observation data) as well as model structures (1D, 2D or 3D) and parameters affects the flood inundation/hazard maps.

Location: Malaysia
Contact: Dimitri Solomatine (d.solomatine@unesco-ihe.org)
Partner: Department of Irrigation and Drainage Malaysia

Since 2011 the Master Programme in Flood Risk Management has been offered by UNESCO-IHE in cooperation with the Technical University of Dresden (Germany), Barcelona Tech (Spain) and the University of Ljubljana (Slovenia). This innovative programme follows a holistic approach and is explicitly designed to cover a wide range of topics – from drivers and natural processes to models, decisions and socio-economic consequences and institutional environment, and is therefore an important advance in water education. Special attention is given to hands-on experience with the computer-based hydroinformatic tools and systems that are used by many consultants and governmental offices around the world. The associated members include European hydraulics laboratories, namely, DHI (Denmark), Deltares (the Netherlands) and HR Wallingford (UK), and key national organisations responsible for flood management, including Rijkswaterstaat (the Netherlands), ICHARM (Japan) and three organisations from Bangladesh. These partners bring their specific complementary expertise in flood risk management to the programme, involving students in their projects during the research phase of the study.

Erasmus Mundus Master in Flood Risk Management

18

Locations: Netherlands, Germany, Spain, Slovenia
Contact: Biswa Bhattacharya (b.bhattacharya@unesco-ihe.org)
Partners: Technical University of Dresden, BarcelonaTech, University of Ljubljana

19

Porous stone spillways

MetaMeta and UNESCO-IHE jointly established the Spate Irrigation Network (SpN) in 2002 to bring the vital role of Flood-based Farming Systems (FBFS) to the attention of policymakers and donors, and share experiences and innovations to increase the knowledge base. Among the many innovations is the 'porous stone spillways' that have found widespread use in Pakistan and Yemen and have successfully reduced the frequency of failure of earthen diversion bunds, increased the opportunity for irrigation, minimized the damage to irrigable land and ultimately contributed to higher agricultural production.

Floods are not always a hazard – in some of the world's poorest areas they are the main source of irrigation and food security. For decades, African and Asian lowland farmers have relied for their livelihood on FBFS that make use of occasional, short duration, often destructive floods. Their traditional earthen flood diversion bunds have, however, been frequently breached and although well organized, they have not always coped with the maintenance requirements. Consequently, poor crop yield years have become more frequent. FBFS, despite constituting poverty pockets and being significant, have been passed over in policy support, investment and by innovation as they are located in remote areas away from centres of power. They have up until the last decade been the forgotten bread baskets.

Locations: Pakistan, Yemen, Sudan, Ethiopia | **Contact:** Abraham Mehari (a.meharihaile@unesco-ihe.org)
Partners: Mekelle University, MetaMeta, Pakistan Agricultural Research Council (PARC), Hydraulic Research Center (HRC), Water of Environment Center (WEC)

Novel methods for more accurate prediction of ocean surges have been developed, and implemented in software tools. These methods are based on the methods of nonlinear dynamics, chaos theory, statistics and artificial neural networks, developed in the framework of hydroinformatics. Several enhancements and innovations have demonstrated that the predictive chaotic model can serve as an efficient tool for accurate and reliable short-term predictions of storm surges in order to support decision-makers for coastal flood prediction and ship navigation.

This approach has been thoroughly tested in predicting the North Sea surge at Hoek van Holland in the Netherlands and has excellent potential to become a complementary method used by practitioners along with the traditional numerical ocean models.

Predicting storm surges

20

Location: Netherlands
Contact: Dimitri Solomatine (d.solomatine@unesco-ihe.org)
Partners: Deltares, Delft Cluster

21

Roads for water

In Tigray, Ethiopia, Mekelle University, UNESCO-IHE and MetaMeta have been working on an innovative road design to avoid damage and make productive use of runoff. Roads are used as water harvesting structures to guide, collect and store runoff that can later be used for agriculture and livestock. Communities have built more than 100 pilots: a large number of innovative techniques were used with a major impact. On governance the main innovation has been to make sure the local roads authority and the agriculture authority dovetailed their activities.

Location: Ethiopia
Contact: Abraham Mehari (a.meharihaile@unesco-ihe.org)
Partners: Mekelle University, MetaMeta

The purpose of the CAPIWUA capacity development project is to achieve performance improvement of the water utilities of Kampala, Nakuru and Dar es Salaam in the thematic areas of governance and management, revenue collection, and services provision to the poor. The result of the project is determined by target values for a set of 10 pre-selected Key Performance Indicators that jointly cover the three thematic areas. These performance indicators are assessed at the onset, halfway and at the end of the project. The need to achieve improved performance has brought the eight project partners together more forcefully and effectively than would have been in the case in a more conventional setting where the five supporting partners would limit themselves to the design and delivery of capacity development interventions and the three beneficiary partners would need to achieve the performance improvement 'on their own'. The project set out to forge a strong partnership focused on jointly achieving performance improvement rather than on the delivery of individual inputs. This novel approach was operationalized through a number of project management tools, the cornerstone of which is the annual performance improvement plan (PIP) that is drawn up by each beneficiary utility in consultation with the partners. Each PIP defines its own rationale, deliverables, activities, and the related partner inputs and budget requirement.

Improving performance of water utilities

22

Locations: Kenya, Tanzania, Uganda
Contact: Maarten Blokland (m.blokland@unesco-ihe.org)
Partners: Consortium of 9 institutions

23

Guidelines for road development in flood plains

The economic development of river deltas requires good transport connectivity, and roads play an important role in this. However roads fragment the valuable floodplain systems and change their natural dynamics and ecology and at the same time are regularly damaged by floods resulting in costly repair works. To address these issues, improved coordination is needed between the agencies involved, as well as the introduction of adequate road planning and design options. Two basic options exist: more closed road design or more open road design, the latter aiming to maintain the natural floodplain dynamics as much as possible through culverts and bridges. Both options have different impacts on transport, ecology, agriculture, flood protection and finance.

The Roads and Floods project (UNESCO-IHE with Deltares and WWF) has developed a set of Innovative best practice guidelines for road planning and design in vulnerable floodplains based on an extensive study of the interactions between roads and floods in the Mekong delta. The study was commissioned by the Mekong River Commission, and guidelines have been adopted by its flood management programme and the Cambodian and Vietnamese National Mekong Committees.

Location: Vietnam
Contact: Wim Douven (w.douven@unesco-ihe.org)
Partner: Mekong River Commission (MRC)

The idea is to utilize high tides for irrigation and low tides for drainage and flushing, instead of using hydraulic structures (e.g. weir, dam or pumps). The innovative thinking is inspired by Banjarese and Buginese people in Kalimantan and Sumatra who reclaimed already tidal lowlands by using a simple technology. Optimizing tidal irrigation by using proper knowledge and technology has resulted in improved agricultural development and supported food security programmes in Indonesia.

Indonesia has large lowland areas with an estimated area of about 34 million ha, out of which about 20 million ha is tidal lowland.

Tidal irrigation and drainage

24

Location: Indonesia
Contact: Sur Suryadi (f.suryadi@unesco-ihe.org)
Partners: Ministry of Public Works Indonesia, Sriwijaya University

25

Arid land greening

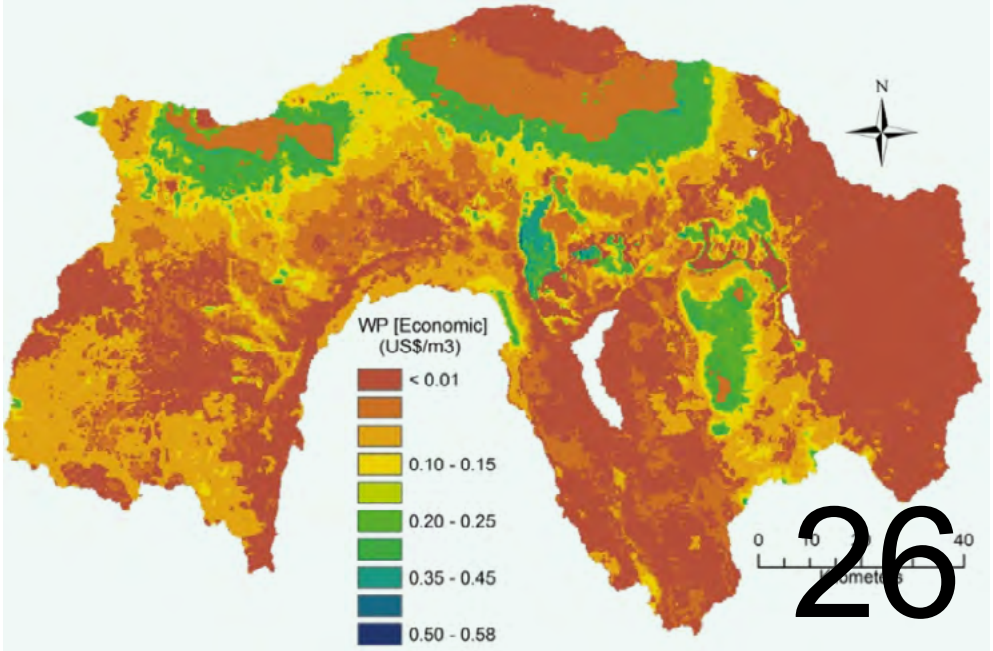
Alluvial aquifers associated with ephemeral rivers in arid lands are mainly used for domestic and livestock water supply but not often for agricultural use. However alluvial aquifers offer a considerable potential for smallholder irrigation as well (over 100 hectares per km of river reach). Such shallow aquifers offer distributed, localised storage, readily accessible to a large number of communities with limited financial resources. Small-scale water supply technologies are cost-effective and within the reach of smallholder farming communities. Supplementary irrigation in semi-arid lands not only provides food security but also generates income.

There is widespread unutilised alluvial aquifer potential in many semi-arid and arid lands in Africa. We have proven that in the Mzingwane catchment in arid southern Zimbabwe there is sufficient water hidden in these dry riverbeds to support 1,000 to 3,000 ha of irrigation year-round. A simple bedrock classification can assist in targeting favourable reaches of these sand rivers for further evaluation and possible water supply development. The method can be applied in other semi-arid areas to allow rapid targeting of sand rivers for field investigation and potential water supply development.

Location: Zimbabwe
Contact: Pieter van der Zaag (p.vanderzaag@unesco-ihe.org)
Partners: Mzingwane Catchment Council, University of Zimbabwe, WaterNet Southern Africa

Based on a detailed land use map, information on actual evapotranspiration and biomass production, and an innovative hydrological model, it is possible to develop water value maps of river basins, distinguishing economic, ecological and livelihood values. The amount of water that transpires and produces biomass are measures for either the economic value of a commercial crop (if the land use is agriculture), or the increase in value of ecosystem goods and services (if the land use is natural). Information on the origin of the water consumed, either directly from rainfall, or from groundwater, rivers and lakes, adds valuable information on the opportunity cost. Such a map is useful for planning and decision-making in river basins.

Water value maps



26

Location: Tanzania
Contact: Pieter van der Zaag (p.vanderzaag@unesco-ihe.org)
Partner: Pangani River Basin Office

27

Alternative flow regime benefit assesment

The flow regime of rivers, being an integral part of aquatic ecosystems, provides many important services benefiting humans. However, in the past water resource developments were characterized by river embankments and dams, and often dominated by one economic use of water. This resulted in a dramatically changed flow regime negatively affecting the provision of other ecosystem services sustained by the river flow. In a river that is highly modified by the presence of large hydropower dams and reservoirs, the value of alternative flow regimes was demonstrated by explicitly accounting a broad range of flow-dependent ecosystem services. A holistic and innovative ecological economic assessment approach was proposed which integrates recent advances in the conceptualization and classification of ecosystem services with the flow regime evaluation technique.

This approach allows for a systematic comparison of the economic values of alternative flow regimes, including those that are considered beneficial for aquatic ecosystems. The application for the Lower Zambezi and Mozambique showed that whereas re-operating dams to create environmentally friendly flow regimes will reduce hydropower benefits, the gains in other benefits from goods derived from the aquatic ecosystem may offset the forgone hydropower benefits, increasing the total economic value of the river flow to society. The proposed integrated flow assessment approach is a useful tool for welfare-improving decision-making in highly utilised river basins.

Location: Mozambique
Contact: Susan Graas (s.graas@unesco-ihe.org)
Partners: Universidade Eduardo Mondlane, University of Zimbabwe, WaterNet Southern Africa

In disaster areas where many people live together in poor conditions, diseases are lurking. Sanitation plays an important role – a hole in the ground or overflowing emergency toilets are breeding grounds for bacteria and viruses. If the flow of waste is better managed, the risk will be reduced and the quality of life will improve considerably. To address this issue UNESCO-IHE and partners supported by the Bill & Melinda Gates Foundation have envisioned a award-winning eSOS smart toilet (or iToilet), one that is not only hygienic, safe and affordable, but also serves as a source of information about the situation in an area and the toilet's users.

The eSOS toilet is being tested in the Philippines for functionality and acceptance. This lightweight, easy-to-maintain toilet is equipped with sensors that collect the relevant data using a specially designed operation software. Based on this information, the separate urine and faeces tanks can be emptied at precisely the right moment to be processed into water and fertilizer. Also, by tracking the individual user's data, experts can identify imminent malnourishment or dehydration (diarrheal disease) at an early stage. The toilet fits in a compact package that is easy to transport - the shipping pallet transforms into the toilet's foundation during installation. The water tanks are incorporated into the walls and the urine tank is part of the stairs. The aim was to make this toilet as functional as possible for the lowest possible price.

eSOS smart toilet

"Most Innovative New Technology of the Year "Africa Water Leadership Award 2014

"Crossover Innovation with an Impact 2014" Federation of Dutch Creative Industries

28

Location: Phillipines | **Contact:** Damir Brdjanovic (d.brdjanovic@unesco-ihe.org)
Partners: FLEX/theINNOVATIONLAB, SYSTECH.ba, University of Zagreb, Bill & Melinda Gates Foundation

29

Operator partnerships in WASH

Collaboration between water operators and water utilities around the world can significantly improve their operations and thus access of people to safe drinking water and sanitation. More than 85% of water operators worldwide are in public hands, all with the same key business processes, many operating in similar contexts and facing comparable challenges. Partnerships between operators are increasingly seen as a powerful approach to improve and sustain water services. A novel multi-path approach to monitoring and evaluating the performance of this type of partnership has been developed and tested. The multi-path approach comprises five complementary paths: (i) satisfaction of partners and stakeholders, (ii) quality of inter-organisational dynamics; (iii) project inputs are consolidated into change; (iv) organisational capacity changes; and (v) performance gains. The application of this innovative approach reveals insights into the process undergone by both partners and identifies how utilities can improve their performance. To allow broad use of this methodology an open access system is being developed by BEWOP - Boosting Effectiveness of Water Operator Partnerships, an initiative led by UNESCO-IHE and UN-HABITAT. This development will help increase the performance of water operators and thus the sustained access to safe drinking water and sanitation.

Location: Worldwide
Contact: Maria Pascual (m.pascual@unesco-ihe.org)
Partner: UN-Habitat

Services provision to the urban poor requires dedicated leadership, pro-poor technology and financial instruments, adequately capacitated and incentivized organisations and tailor-made institutional arrangements. Benchmarking is a proven tool to compare performance and to learn from those who do better, and could well be used to assist stakeholders tasked with providing the poor. However, conventional tools are not tailored for this specific use. The PROBE project has developed a new benchmarking tool to address this deficiency. Based on the work of about 15 MSc students over the past 5 years, the project has conceptualized, developed and successfully tested a pro-poor benchmarking framework with a total of 13 indicators. In 2014, a Field Manual for Pro-Poor Benchmarking of Water and Sanitation Services was developed and tested by alumni of the Institute in cities in Ghana, Nigeria, Angola, South Africa, Kenya, Uganda and Ethiopia.

Benchmarking water and sanitation services

30

Locations: Brazil, France, Ghana, India, Iran, Netherlands, Uganda, Zambia
Contact: Maria Pascual (m.pascual@unesco-ihe.org)
Partners: Consortium of 18 institutions

31

Serious gaming and water management

UNESCO-IHE has developed serious games and applied them to prepare stakeholders in transboundary river basins for potentially problematic situations, to familiarise them with existing international and regional conventions, and to train them in applying and using formally agreed procedures. This has been successfully done in the Mekong River Basin, in close collaboration with the Mekong River Commission. Many other serious water games have been developed and used in technical training and educational settings, even during conference sessions. Always with a lot of fun! Successful serious games include ShaRiva, SaMa, Libra and the Water Message Game.

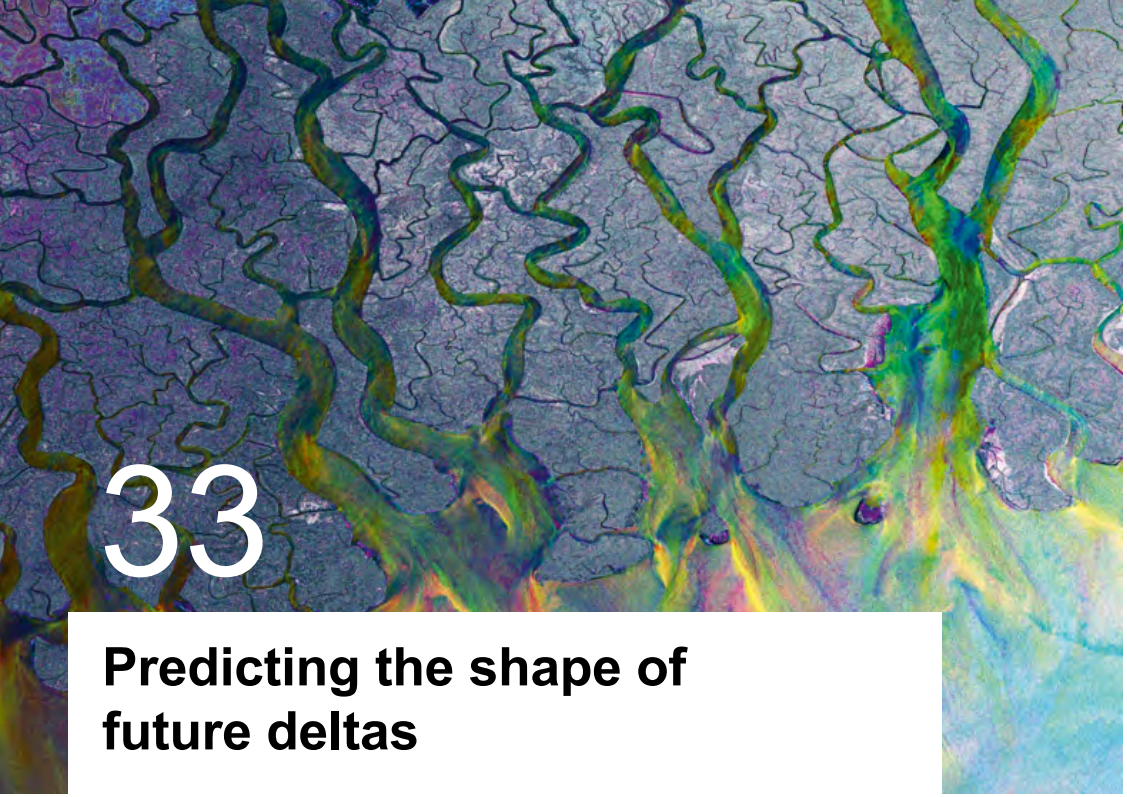
Locations: Vietnam, Netherlands | **Contact:** Wim Douven (w.douven@unesco-ihe.org)
Partners: Mekong River Commission (MRC), United Nations Educational, Scientific and Cultural Organization (UNESCO)

A cost-effective approach based on the nonlinear machine learning technique (Support Vector Machine - SVM) has been developed and applied in combination with sonar measurements and satellite imagery to estimate coastal bathymetry data. This approach was applied on Sint Maarten Island to support activities that range from day to day port management to setting up numerical models of hurricanes and tsunamis. The sonar data were used as an output whereas image data were used as an input into the SVM model. The results obtained to date confirm that the approach developed represents a cost-effective means for mapping near-shore bathymetry data for depths less than 15 m.

Mapping near-shore bathymetry data

32

Location: Sint Maarten
Contact: Zoran Vojinovic (z.vojinovic@unesco-ihe.org)
Partner: The Government of Sint Maarten



33

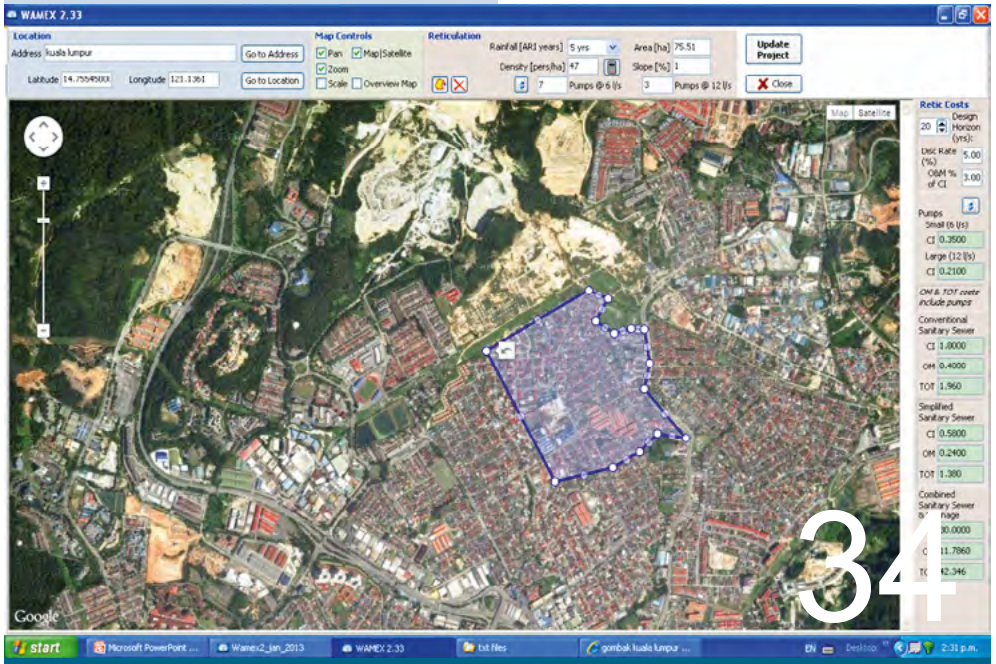
Predicting the shape of future deltas

In countries like Bangladesh, future changes in land use, sea level rise and upstream changes in the flows of water and sediment will have great impacts on the development of rivers, estuaries and coasts. The management of embankments and other flood protection measures, and the development of chars (polders) may greatly affect erosion and sedimentation patterns and extreme flood levels throughout the delta. To prepare for this, planners urgently need a tool to predict natural developments and the effects of the measures, at the scale of the whole delta system, yet sufficiently detailed to allow evaluation of local works (e.g. cross dams). In collaboration with local partners, UNESCO-IHE has developed a methodology to efficiently simulate such long-term morphological developments using Delft3D software. Though much further validation and refinement is needed, the pilot application has provided a proof-of-concept for predicting the future shape of deltas.

Location: Bangladesh
Contact: Dano Roelvink (d.roelvink@unesco-ihe.org)
Partner: Institute for Water Modelling (IWM)

WAMEX

The Asian Development Bank (ADB), together with UNESCO-IHE, has developed WAMEX as a novel and intuitive tool that aims to help decision-makers and planners develop options for addressing various scenarios related to wastewater and sanitation management. This tool is useful for the planning of new systems, upgrading of existing systems and preparing budgets and cost estimates. It also allows users to build their own 'what-if' scenarios, enabling them to explore many different wastewater schemes and sanitation options. The software tool contains a list of conventional and emerging technologies consistent with the ADB's thrust of promoting innovations in sewage collection, wastewater treatment and sanitation. It also has an intuitive built-in GIS functionality that enables users to set up and assess different wastewater reticulation options and find their optimal solutions.



34

Locations: Netherlands, Phillipines, South East Asia
Contact: Zoran Vojinovic (z.vojinovic@unesco-ihe.org)
Partner: Asian Development Bank (ADB)

35

Ships making waves

As super tankers, bulk carriers and container ships get ever bigger, so do the waves that they make. As these ships move through complex port areas with moored ships, or along banks and beaches where people are relaxing, dangerous situations arise, leading to broken moorings or personal injuries or even fatalities. Existing methods for predicting these ship waves and their impacts are incomplete in that they typically do not account for complex geometries.

In a recent development of the coastal model XBeach, the primary waves generated by such big ships can be predicted with accuracy, for arbitrary ship shapes and port or river geometries. What is more, in the same model the forces and moments on moored ships and the tsunami-like waves surging up a bank or beach can be simulated. This offers a wide range of applications, from designing mooring systems to predicting the ship-induced wave climate along wetlands or reducing the risk of accidents along navigation routes. XBeach software has been developed by UNESCO-IHE in cooperation with TU Delft, Deltares and other partners.

Location: The Netherlands
Contact: Dano Roelvink (d.roelvink@unesco-ihe.org)
Partners: Delft University of Technology, Deltares

Most people realize that storms can generate surges and big waves, and that these may inundate low-lying coasts. Existing forecasting systems duly predict such effects, and safety assessments of coastal defences take them into account. What is far less well known is that groups or sets of waves create much longer waves, with long periods of up to several minutes that do the real damage. On coasts such as those of West-Africa, sudden swell events can cause widespread inundation and erosion because of this phenomenon; during Typhoon Haiyan, entire villages were wiped out that would be considered safe according to conventional forecasting systems.

The good news is that such 'surfbeat' waves can be reliably predicted by the open-source XBeach model, developed by UNESCO-IHE in partnership with Deltares, TU Delft and other partners, as well as their impacts on various types of coasts. Connections have been made to link this model with existing forecasting systems. As we are increasingly able to see the storms and swell systems coming, this means that much better warnings can be given to vulnerable populations.

Predicting the coastal killer waves

36

Location: South Pacific
Contact: Dano Roelvink (d.roelvink@unesco-ihe.org)
Partner: Secretariat of the Pacific Community

37

Multi-objective rehabilitation of sewers

UNESCO-IHE has developed a decision support system that uses a new approach for rehabilitation of urban drainage infrastructure assets. This new approach is imbedded within the OPTimal REhabilitation of Sewer Systems software (OPTRESS) and it can be used to derive optimal sets of either wastewater or stormwater rehabilitation measures with respect to the given levels of service, total lifecycle cost of new assets and the existing asset condition. The tool uses full-fledged multi-criteria global evolutionary optimisation techniques in combination with hydrodynamic models of drainage systems and floodplains. It enables the identification of solutions that are not only cost-effective but also optimal in relation to any of the desired criteria.

Location: Netherlands
Contact: Zoran Vojinovic (z.vojinovic@unesco-ihe.org)

Wastewater treatment by the Photo-activated sludge process combines the advantages of the conventional activated sludge process with those of high rate algae ponds.

In such a symbiotic ecosystem, a consortia of algae and bacteria in well-settling flocs efficiently removes and recovers nitrogen and phosphorous at much lower energy inputs and land requirements than other competing technologies.

Photo-activated sludge process

38

Locations: Israel, USA, Zimbabwe
Contact: Peter van der Steen (p.vandersteen@unesco-ihe.org)
Partners: Aquanos, University of South Florida, Universidade Eduardo Mondlane

39

Tailored i-learning for sanitation professionals

The Graduate Professional Diploma Program (GPDP) program is a new educational product of UNESCO-IHE that disseminates sanitation and sanitary engineering knowledge to professionals without the means, time or interest to pursue an MSc degree in Sanitation and Sanitary Engineering, or with an MSc Degree in a related field and a wish to specialize professionally. The program consists of a sequence of four or five online courses, regular short courses or a combination. The number of credit points varies from 3 to 6 per course. The minimum study load for obtaining a diploma is 20 ECTS, which equals a workload of 560 hours. The online courses can be followed part-time, without interrupting a day-time career. In order to ensure that the program fits the personal circumstances of the applicant, courses will be selected and a personal study plan will be designed in collaboration with a study advisor. The total duration of the program depends on this study plan, with a minimum of 1.5 and a maximum of 4.5 years. Several new GPDPs are currently under development.

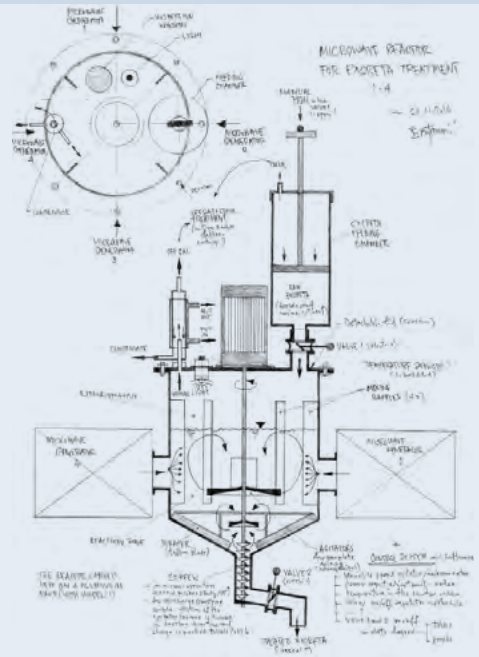
Locations: Netherlands, Worldwide
Contact: Martin Mulenga (m.mulenga@unesco-ihe.org)
Partner: Bill & Melinda Gates Foundation

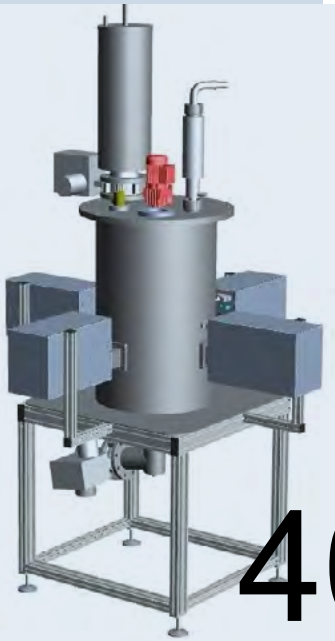
Solutions for effective and sustainable faecal sludge management (FSM) present a significant global need. Tremendous amounts of faecal sludge are produced on a daily basis globally from onsite sanitation; 2.7 billion people worldwide are served by onsite sanitation technologies, and that number is expected to grow to 5 billion by 2030. FSM presents a global challenge.

A new technological concept for excreta (faeces and urine) sterilization and dehydration has been developed by UNESCO-IHE in cooperation with Fricke und Mallah Microwave Technology GmbH and supported by the Bill & Melinda Gates Foundation.

The technology makes use of microwave generators that make up part of a specially designed reactor that can convert pathogenic human waste into clean water and inert dry material. The concept has been successfully tested in the Netherlands and Kenya and a demonstration unit is currently under construction.

Sanitizing faeces by microwaves





40

Locations: Netherlands, Kenya
Contact: Damir Brdjanovic (d.brdjanovic@unesco-ihe.org)
Partners: Fricke und Mallah Microwave Technology GmbH, Bill & Melinda Gates Foundation

Citizens as water sensors: WeSenseIt

Given the large diffusion of mobile phones, citizens can complement the often insufficient density and resolution of data collected by traditional monitoring networks. This is particularly helpful for emergency services as well as policy makers with respect to critical events such as floods and droughts. Moreover, the involvement of citizens in data collection promotes a more active role for local communities with regards to understanding and taking care of the environment. UNESCO-IHE and 13 partners from six European countries are developing new ways to capture data about the water cycle by actively involving citizens. These citizen observatories of water allow citizens and communities to become active participants in data capturing, information evaluation and decision making processes. Citizens capture hydrological data using Apps and physical sensors that can connect to portable devices such as smartphones and tablets. Relevant data is also extracted from the interactions of citizens on social media sites such as Twitter and Facebook. UNESCO-IHE is developing innovative methods to optimally design new generations of monitoring networks that include sets of dynamic sensors capturing data with diverse spatial and temporal characteristics (e.g. via smartphone video-based rainfall reports), and methods to incorporate the heterogeneous data collected via the citizen observatories into hydrological and hydraulic models. Also, through an innovative combination of governance analyses and stakeholder engagement, UNESCO-IHE is aiming to maximise the social innovation potential of citizen observatories in terms of improved community resilience and strengthened water governance.

Locations: Italy, United Kingdom, Netherlands
Contact: Leonardo Alfonso (l.alfonso@unesco-ihe.org)
Partners: Consortium of 13 institutions

Wastewater treatment on a green roof

Lack of water, lack of space and lack of green areas have stimulated new solutions for wastewater treatment like the Constructed WetRoof. The design and development of the WetRoof was encouraged by essential societal needs such as demands for sustainability and creative aspirations. UNESCO-IHE is studying the performance of this system constructed on the roof of the office building of Van Helvoirt Greenprojects Ltd.

This technology combines the benefits of a constructed wetland for wastewater treatment with those of a green roof in a single system, providing green areas in unused spaces. The WetRoof has proven to deliver an appropriate effluent quality for irrigation, toilet flushing or disposal into water bodies while it also provides a green area. This system is adaptable to different urban requirements but it is best seen as a way to solve some of the problems of megacities where the need for sanitation, water and green areas are critical due to the lack of space.

Location: Netherlands
Contact: Hans van Bruggen (h.vanbruggen@unesco-ihe.org)
Partners: ECOFYT, Van Helvoirt Greenprojects B.V.

43

WA+: an emerging global standard for water accounting

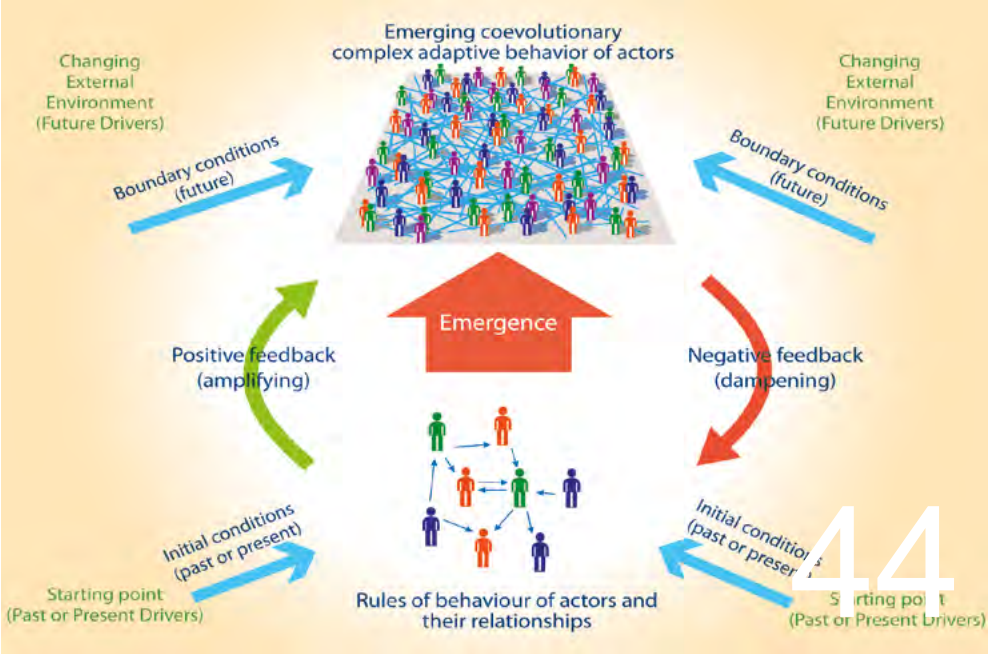
Water problems around the world are increasing, while water information useful for decision makers seems to be decreasing. Solving water problems requires information from many disciplines, and the physical accounts - describing sources and uses of water - are the most important foundation. The information has to be coherent and harmonized in order to provide an integrated picture useful for the assessment of the problems. Water accounting integrates hydrological processes with land use, managed water flows and the services that result from water consumption in river basins. Its objective is to strive to achieve equitable and transparent water governance for all water users and a sustainable water balance. Users can provide value assessments of certain process, and more accurate data sets that replace the default data collected from open access sources that represent 'best estimates'. Water accounting was originally developed by Dr. David Molden from the International Water Management Institute (IWMI) and has been modified and upgraded with inputs from Delft University of Technology.

The website www.wateraccounting.org provides the framework and results of a new Water Accounting methodology that is based on global scale public domain datasets (WA). It is a multi-institutional effort from international knowledge centres (IWMI, UNESCO-IHE and FAO) that are neither politically nor geographically connected to a given river basin. WA provides independent estimates of water flows, fluxes, stocks, consumption and services that will in the near future become certified.

Location: Worldwide
Contact: Wim Bastiaanssen (w.bastiaanssen@unesco-ihe.org)
Partners: International Water Management Institute (IWMI), Food and Agriculture Organization of the United Nations (FAO)

Agent-based models of sociotechnical systems

UNESCO-IHE has been developing Agent-Based Models (ABM) of sociotechnical systems for the purpose of understanding the evolution of extreme events. Such models provide invaluable means for understanding the behaviour of actors in order to develop adaptive risk management strategies and policies. An agent can be any entity that completes an action or takes a decision, by which it effectively interacts with its environment. It may represent an actor in a social network (e.g. a human being, an operator deciding to shut down a pumping station, or a community member who lives in a flood-prone area). It may also represent an organisation, for example a water utility company who wants to implement flood prevention measures or a government deciding on a new policy (or a design standard) for flood protection. The focus of these models is on interacting agents and how their interaction can lead to emergent phenomenon that is within the framework of models developed to show the evolution of extreme events. The idea behind ABM is to emulate, rather than to calculate, (optimal) states of the system and to explore the possible development paths (i.e. possible states of the system or possible futures). This in turn is then used to evaluate which development paths are acceptable and which are not. The model developed has been evaluated in several European and International case studies.



44

Location: Worldwide
Contact: Zoran Vojinovic (z.vojinovic@unesco-ihe.org)
Partners: King's College London, Stanford University

45

Uncapping MBR limitations

Membrane bioreactors (MBRs) combine biological with membrane filtration processes for the treatment of wastewater. MBRs produce a high quality effluent requiring small footprints. However, inefficient oxygen supply technologies not only impose a cap on the achievement of biomass concentrations higher than 15-20 g/L (impacting on the operational conditions of MBRs and preventing the achievement of even smaller footprints), but also demand high energy requirements for aeration (70% of total energy needs). Innovative supersaturated oxygen supply technologies provide alternatives for achieving much higher biomass concentrations than standard conditions, uncapping existing limitations and reducing aeration costs. Moreover, the operation of MBRs at such high biomass concentrations may promote favourable conditions for innovative applications such as the removal of emerging contaminants from wastewater by both enhancing adsorption processes as well as promoting microbial co-metabolism degradation. This pioneering and novel concept is being currently demonstrated for the first time at the UNESCO-IHE research facilities. This development is supported by OVIVO (MBR manufacturer) in partnership with innovative oxygen delivery technology manufacturers (BlueInGreen and ECO2). If successful, this innovative study can contribute to reducing operational costs and set the basis for the design of the next generation of MBRs for novel applications.

Locations: Netherlands, Croatia, Uruguay, USA
Contact: Hector Garcia Hernandez (h.garcia@unesco-ihe.org)
Partners: OVIVO, BlueInGreen, ECO2

Rapid assessment of climate change on inlet-interrupted coasts

Most coastlines around the world are interrupted by inlets connecting the ocean to estuaries, lagoons, and rivers. Coastlines in the vicinity of inlets will be affected not only by climate change driven variations in oceanic processes (e.g. sea level rise) but also by climate change-driven variations in terrestrial processes (e.g. rainfall/runoff). The combination of their sensitivity to several climate change-driven variations in system forcing and their heavy human utilisation renders the thousands of inlet-interrupted coasts around the world highly vulnerable to climate change impacts.

UNESCO-IHE has developed an innovative, easy-to-use mathematical model (SMIC-Scale aggregated Model for Inlet interrupted Coasts) to obtain estimates of local scale (< 25 km alongshore) coastline change due to all relevant climate change impacts. Model applications in four representative systems show that methods historically used to assess coastline response to climate change may be under-predicting potential coastline recession by up to 50-75%.

46

Locations: Vietnam, Australia
Contact: Roshanka Ranasinghe (r.ranasinghe@unesco-ihe.org)
Partners: Delft University of Technology, Deltares

Hybrid Master in Sanitation and Sanitary Engineering

The hybrid MSc in Sanitation and Sanitary Engineering is a new educational product under development at UNESCO-IHE and it is the first of its kind in this field internationally. It has a combined face-to-face and online mode of delivery and can be carried out on a part-time basis where the student can do part of the study in his or her home country.

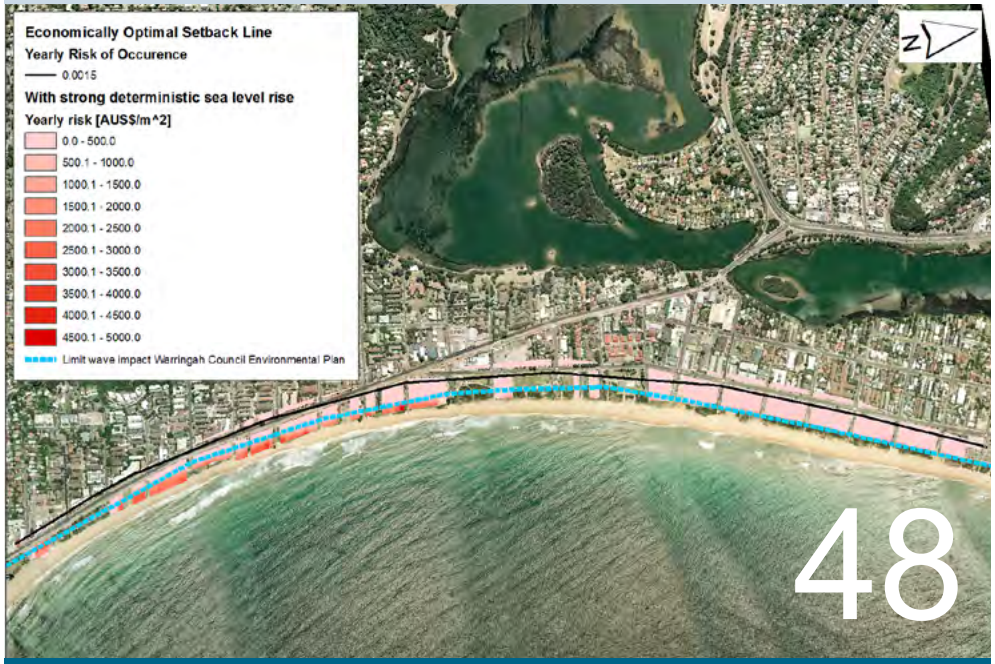
The hybrid Master consists of a sequence of online courses (and/or regular modules/ courses offered by the Sanitary Engineering (SE) specialization in Delft or double degree SE specializations in Columbia and Thailand), and a thesis (research) part that is identical to the existing Delft-based SE specialization. Students enrolled in the hybrid Master will have the choice whether to carry out research and complete a thesis at UNESCO-IHE or at the premises of one of our partners (AIT in Thailand, KNUST in Ghana, and UNIVALLE in Colombia). The total duration of the hybrid Master depends on the individual study plan and varies between 1.5 and a maximum of 4 years.

Locations: Thailand, Colombia, Ghana, Netherlands
Contact: Damir Brdjanovic (d.brdjanovic@unesco-ihe.org)
Partners: Bill & Melinda Gates Foundation, AIT, KNUST, UNIVALLE

Climate change and the growth of coastal communities will significantly increase the socio-economic risks associated with coastline recession (i.e. long term net landward movement of the coastline). Coastal setback lines are a commonly adopted management/planning tool to mitigate these risks. While it is widely recognized that planning decisions should be risk-informed, setback lines are presently determined using deterministic methods that cannot be related to considerations regarding the tolerability of risks.

UNESCO-IHE, in partnership with international and Dutch researchers, have recently developed a risk assessment approach for quantifying the risk posed by coastline recession and show how it can be used to derive economically optimal setback lines. The approach has been demonstrated at Narrabeen Beach, Sydney, Australia, and indicates that the presently adopted deterministic methods of defining setback lines may lead to economically sub-optimal stringent land-use planning decisions.

Drawing the line on coastline recession risk



Locations: Australia, Sri Lanka
Contact: Roshanka Ranasinghe (r.ranasinghe@unesco-ihe.org)
Partners: Jogejan Risk Management Consultants, Delft University of Technology, University of Queensland

49

Floating solutions for upgrading wet-slums

Among the many challenges caused by the rise of global urban population is the accompanied growth of slum population. Around one billion people live in slums - most of them being close to open water. Being most vulnerable to floods, they are least attractive for upgrading investments. Neglected by civil authorities and confounded by a lack of space and money along with vulnerability, these already precarious slums are pushed into a negative spiral.

Using a bottom-up approach, the Floating City Apps Foundation, aims to upgrade waterfront slums with small scale instant solutions. Comparable to adjusting a smart phone with apps according to changing needs, the infrastructure in a slum can be adjusted by adding functions with City Apps.

These apps are floating developments built using a standard sea-freight container. The container is assembled in the Netherlands and shipped to the wet-slum where it is placed on a locally constructed floating foundation. Because of their flexibility and small size they are suitable for installing and upgrading facilities for sanitation, housing, communication etc. They can be added to a slum using the available space on water.

Location: Bangladesh
Contact: Berry Gersonius (b.gersonius@unesco-ihe.org)
Partners: Floating City Apps, Waterstudio.NL, Cordaid

Ensemble hydro-meteorological prediction system

50

Location: Worldwide
Contact: Schalk Jan van Andel (s.vanandel@unesco-ihe.org)
Partners: Royal Netherlands Meteorological Institute (KNMI), Waterboard Rijnland

UNESCO-IHE has contributed to the novel technology of ensemble hydro-meteorological prediction systems through applied research in which a system has been developed and tested for the Rijnland Water Board in the Netherlands. The system is designed to give 50 equally likely water level forecasts. It serves as an early flood warning to allow anticipatory control of Rijnland's storage basin. In the follow-up to the successful research phase, Rijnland has contracted UNESCO-IHE for a pilot to run the system in practice. The real-time forecasts are displayed in the Hydroinformatics Laboratory of UNESCO-IHE.

UNESCO-IHE is currently involved in research projects that assess the quality of similar ensemble prediction systems for river basins in Africa and Asia.

Editor
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+31 15 215 1715
info@unesco-ihe.org
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