A use-inspired approach to sustainable water management

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In a world threatened by climate change and a burgeoning global population, government alone cannot address the challenges arising from increasing demand for water access. Universities must play a key role by helping governments determine how to manage and allocate water resources and provide water services. Recognizing this, Universiti Sains Malaysia (USM) has been taking proactive measures to play its part, focusing on research initiatives and education-based capacity-building. USM's approach to water research is guided by the identified sustainability challenges that a wide spectrum of water users is currently experiencing. Our research is proactively designed to be need-based and is inspired by the goal of putting the results to immediate use in finding solutions.

There follows an account of USM's experiences in integrated approaches to river and stormwater management, modelling for scenario generation[1] and our ongoing Polar Research Initiative, polar@USM.[2] These illustrate the need for science and values-based decision-making for people-centred water cooperation as a new paradigm for integrated water management.

Background

Ensuring the free flow of water for all is a major sustainability challenge that is felt across the world. In order to manage one of the most crucial natural resources for human survival effectively and to ensure the "water future we want" the United Nations Conference on Sustainable Development was held in Rio in 2012. Here, the global community "reaffirmed the commitment made in the Johannesburg Plan of Implementation and the Millennium Declaration regarding halving by 2015 the proportion of people without access to safe drinking water and basic sanitation and the development of integrated water resource management and water efficiency plans, ensuring sustainable water use."[3] By declaring 2013 the International Year of Water Cooperation, the United Nations has specifically acknowledged the urgency of mainstreaming "water and sanitation as a sustainable development goal that corresponds and responds to multidimensional challenges."[4] UN-Water has called upon the United Nations

Image: REDAC USM

BIOECODS approaches to integrated water management

Educational, Scientific and Cultural Organization (UNESCO) to lead the International Year of Water Cooperation activities.

Despite the vital importance of water to life on Earth, there are major gaps in our understanding of water availability, quality and dynamics, and of the impact of global changes on water systems. Through place-based research and integrative modelling, USM has been pursuing education- and research-based capacity-building and policy interactions to enhance our understanding of water system and land use changes, the built environment, ecosystem functions and services and climate change and variability, and to predict how each of these will impact the others.

Flooding is the most common natural disaster encountered in Malaysia. Both monsoon floods and flash floods are frequent. The Department of Irrigation and Drainage in Malaysia has estimated that about 29,000 km^2 (9 per cent of the total land area) and more than 4.82 million people (22 per cent of the population) are affected by flooding annually. The damage caused by flooding is estimated to be about RM 915 million (£160 million). Monsoon floods are caused by long durations of heavy rainfall, but more localized flooding, which occurs especially in newly developed town areas, is part of the dynamics of the built environment. The River Engineering and Urban Drainage Research Centre (REDAC), the School of Engineering, the School of Biology, the Geography Department, and the Centre for Global Sustainability Studies (CGSS) are among the sections of USM currently active in the research and capacity-building area of water management. In order to facilitate international cooperation, since 2004, REDAC has been holding a triennial international conference on rivers.[5]

Use-inspired research for water cooperation

Integrated river management, stormwater management and computer modelling are three areas of active research at USM.

Integrated river management

The sustainable management of Malaysia's waterways is a central issue for national development. Various users of river water want to prioritize it for their own purposes, resulting in competing demands. This inevitably creates complex pressures on the water system, and integrated approaches are required to find solutions. Government has traditionally been responsible for managing rivers, but increasingly the public, non-governmental organizations, industrialists, farmers and other stakeholders are also playing greater roles. In a 2005 paper, Weng explains at length the need for the involvement of multiple players who are strategic, need-based and inspired by a vision for finding practical solutions to water issues.[6] Weng proposes 'PEOPLE' as an acronym standing for the ingredients necessary for integrated river management to work most effectively: Public participation; Environmental conservation; Ordeals; Politics and pollution; Learning; Equity; and Economics. He then expands on each of these elements, citing numerous examples of existing problems and of ongoing projects in sustainable river management. The important point here is that the involvement of multiple players has to be strategic, need-based and inspired by a vision for finding practical solutions to water issues.

In Malaysia, natural and man-made waterways are interconnected, especially in the more developed areas of Peninsular Malaysia. They include the various river systems, of which there are 89 in Peninsular Malaysia, 22 in Sarawak and 78 in Sabah;[7] several artificial water infrastructures consisting of large lakes such as Kenyir Lake and Temenggor Lake in Terengganu; and many smaller ponds, swales and urban drainages. Water from all these sources must support agriculture, domestic and other industrial uses as well as various engineering projects such as hydroelectric and wastewater treatment. To help meet this challenge, USM researchers from the

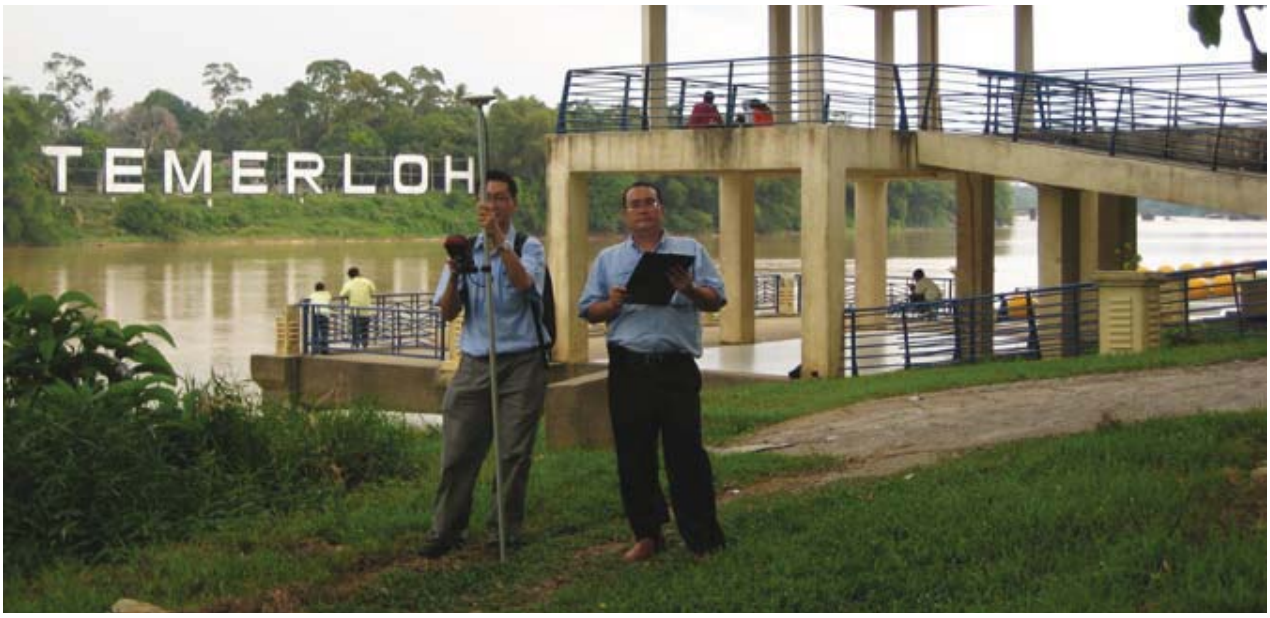

Image: REDAC USM

Modelling for digital flood mapping, erosion and sediment control in Malaysia

biological sciences, humanities and engineering schools, particularly REDAC and CGSS, have been working on:

- flood forecasting, digital mapping, risk studies and flood mitigations
- simulation of tsunami currents, for example Merbok Estuary in Kedah
- assisting government agencies like the Department of Drainage Malaysia on water issues such as preparing the new version of MSMA, the Urban Storm Water Management Manual for Malaysia
- rehabilitation of degraded and polluted rivers
- sustainable urban drainage systems
- community-based vulnerability and adaptation to flood and food security (Kuala Nerang, Kedah).

An integrated and sustainable urban drainage system, known as Bio-Ecological Drainage Systems (BIOECODS), was designed by REDAC and subsequently constructed in 2002 at the USM Engineering Campus in Penang to help address the issues of flash floods, river pollution and water scarcity.[8]

Another important area of research concerns community-based adaptation and disaster risk management (DRM) in response to climate change-induced floods and food security issues. DRM must be defined inclusively to cover both 'rapid-onset, high-impact' events such as floods and 'slow-onset, high-impact' disasters such as climate change and poverty. Recognizing that most present-day sustainable development (SD) challenges belong to the latter category, CGSS conducted a community-based climate adaptation and food security project in Kuala Nerang, Kedah, in Northern Peninsular Malaysia. This project involved stakeholder consultation and capacity-building; assessment of community vulnerability to flood-related food insecurity and prospects for adaptation to climate change; and community empowerment through physical and process-based adaptation implementation assistance. For the long term, a new pathway that connects DRM to SD (Neo DRM-SD) could be found that addresses poverty, debilitating disasters and diseases, rapid loss of biodiversity, and depleting capital within an integrated and cooperative regime.[9]

Stormwater management

The volume of stormwater, the timing of surges within the system and the contaminants that stormwater may contain present the most severe challenges to urban water management. Other environmental issues caused by stormwater include increased turbidity from erosion, habitat destruction and heightened seasonal variation in water levels. USM scientists have developed the BIOECODS integrated solution for sustainable urban drainage systems to address these multiple challenges. The application of several best management practice options including swales, wet ponds, detention ponds and wetlands, allows BIOECODS to remove stormwater pollutants effectively. Bioecological swales target urban rooftops and car parks, while underground bioecological detention storages and bioecological dry ponds help restore water quality.[10]

Computer modelling

USM has been working closely with Malaysian water authorities and stakeholder groups to provide them with water scenarios for the future. We are using a variety of computer modelling approaches to study issues relating to scour, sediment transport, land use changes, flood levels and tsunamis. The 2011 *REDAC Profile*[11] includes examples such as scour modelling, integrated river basin management, flood plain modelling and tsunami modelling.

Scour modelling — using soft computing techniques such as artificial neural networks, ANFIS and Gene expression programming, researchers have modelled scour problems and conducted training based on their findings.

Integrated river basin management — geographic information system-assisted models have been used for water quantity (flood) and sediment yield from the catchment area of the Bukit Merah dam using HEC-HMS and SWAT methodologies. The results show that land-use projections through 2015 are suitable for flow but not for sediment yield. This has implications for the management of the catchment, dam operations and land management.

Flood plain modelling — USM researchers often use computational and numerical models to predict water flow and quality, sediment transport and toxic contaminant concentration in river and estuarine basins and catchment areas. For example, using modelling results for flood levels along Sungai Selangor (~106 km long) and its flood plains between cross-section km 53 to km 67, shows that the areas flooded are 736 and 889 hectares for 50-year and 100-year floods respectively. Such river flood risk maps are useful for development planning in the river basin.[12]

Tsunami modelling — USM researchers have modelled the role of mangrove trees on the hydrodynamic processes of tsunami waves and studied the potential effects of tsunami waves from the South China Sea on the east coast of Malaysia.[13]

Image: REDAC USM

Field research on water quality

USM's polar research

Beginning in 1983, Malaysia has strategically engaged within the United Nations General Assembly to ensure that Antarctica is recognized and safeguarded as our common heritage on Earth. Malaysia's interest in Antarctica was rooted in the opportunity it provides for cooperative research of immense global scope in the areas of science, diplomacy, management of international space, earth system and cosmology studies, polar oceans and ice-core studies, southern ocean research, development of early warning systems and science for international collaboration. The Malaysian Antarctic Research Programme (MARP) was established in November 1997 following negotiations between Malaysia and New Zealand for bilateral scientific cooperation. In 2006, MARP extended its activities to the Arctic as well.

MARP's major research interest was to establish the interrelationship between equatorial and polar regions when it comes to the causes and effects of global warming, environmental change and impacts on the aquatic microbial community. A number of universities in Malaysia are cooperating in this area of work. MARP has also been organizing seminars and workshops at the national and international levels to promote research and foster scientific collaboration. The first biennial Malaysian International Seminar on Antarctica (MISA) was held at Universiti Malaya in May 2002. The sixth MISA will be held from 8-9 October 2013 at Penang.

During his visit to USM, Paul Berkman, Chair of the International Board for the Antarctic Treaty Summit, said that the Antarctic Treaty is often seen as a visionary precedent for governing the 'global common' – that is, regions and resources beyond national jurisdictions – and that it is also very important, with regard to the Arctic Ocean, to establish a process of continuous policy development that explicitly promotes cooperation and prevents discord.

Images: USM polar team

The polar@USM team in action

As a member of the MARP team, USM has shown great dedication to realizing MARP's objectives to increase the nation's scientific capacity and research outputs. USM is privileged to have nine researchers who have been to Antarctica and two who have been to the Arctic.[14] At the international level, the Foundation Director of CGSS, Professor Datuk Seri Zakri Hamid, played a key role in the fiftieth anniversary Summit on Science-Policy Interactions in International Governance at the Smithsonian Institution in Washington DC in 2009. Through its participation CGSS@USM co-signed the 'Forever Declaration', one of the major outcomes of the summit.[15]

Cooperation through people-centered decision-making

Water is our world's most important natural resource. It makes our planet unique among other known planets. Given the multiple pressures on this invaluable resource, it is evident that in the future, water management will have to be integrated, interdisciplinary and people-centred in order to minimize the risk of water conflicts. Such conflict management will require scientific evidence and practical value judgements to secure lasting solutions. Knowledge and skills acquired through education and work experience will not be sufficient, by themselves, for managing sustainability issues. We need in addition the ability to see issues in perspective and to clarify and prioritize our value systems before major decisions are made. In other words, we need to go beyond knowledge to understanding and wisdom in order to make balanced decisions that will accommodate multiple interests in a give-and-take manner, fully realizing that in negotiated settlements there are always trade-offs.[16]

For example, we know that communities value water for various reasons, such as food, bathing, domestic and spiritual uses, recreation, drainage, irrigation, industrial production and waste removal. So long as supply and demand are balanced, there is no conflict. When the demand exceeds supply, tensions start. This has been the case for millennia. What has changed is the scale: there are many more people on Earth now, and we are approaching water resource scarcity. This puts the various 'water values' listed above into competition with one another, because allocating water resources to fulfil one value reduces the availability of water for another. This is why we require scientific evidence and practical value judgments to secure lasting solutions, knowing where and how to prioritize one value over another.[17] Decisions must be inclusive after all views have been considered, and they must be taken in the collective interest. We must always be open to further iterations of the process when there are clear changes in stakeholder priorities.

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A use-inspired approach to sustainable water management: USM's experiences of cooperation through research and capacity-building

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Ecohydrology – transdisciplinary sustainability science for multicultural cooperation

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