Suggestions for a course on environment and social hydrology for hydrologists

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This note suggests the need for a course on environment and social hydrology for hydrologists, for which the contents and coverage are provided.

Our ancient scriptures had included water among the five key elements in nature, recognizing the central role that it has in life. Leonardo da Vinci, the famous scholar, artist and engineer has stated that 'water is the driving force of all nature'. Clearly, when we deal with water systems, we are directly or indirectly interacting with a facet of nature.

The history of water resources development (WRD) is closely linked with the history of humanity, because humans have been building WRD projects (reservoirs, embankments, canals, etc.) to efficiently use and manage the variabilities of this resource, and minimize the damages due to water-related hazards such as floods and droughts. WRD projects were conceived to serve societies with a range of water uses, including irrigation, municipal, industrial, hydropower, recreation, etc. In the construction and operation of these projects, interaction with administrators, policy makers and general public represents a key challenge, because of differences in perception, knowledge, vision, priorities and responsibilities.

After a detailed survey and review of large dams, the World Commission on Dams (WCD) concluded that dams have made an important and significant contribution to human development and benefits from them have been considerable[1]. However, in many cases, the social and environmental costs have been unacceptable and unnecessary. A new framework for decision-making that moves beyond simple cost–benefit trade-offs to introduce an inclusive 'rights and risks approach' which recognizes all legitimate stakeholders in negotiating development choices was suggested by WCD.

Optimal use of water resources is one of the main aims of any hydrologic study. Admittedly, WRD projects are expected to cause least negative impact to the environment and society. Numerous projects in India and the world are serving the society well for many decades. However, there are also instances where the impacts have been unwanted/undesirable, either due to deficiencies in planning and management, inadequate data or incomplete understanding of the physical system.

Problems with WRD projects

All major criticisms against interventions in the natural flow of water through WRD projects have environmental and/or social concerns at the root. An aphorism states that the hydrologist knows much about water, but not enough about the river, its environment or ecology. This aphorism may cause mixed reactions and some people may have a different opinion, but it certainly deserves consideration.

Some recently completed storage projects in India such as the Tehri Dam and the Sardar Sarovar Dam witnessed prolonged opposition from NGOs and the public, delaying their completion and upsetting economic projections. Interlinking of rivers is a vigorously debated issue in the country with sharp division of opinions.

Many canal systems have caused waterlogged tracts along their channels since more than a century ago due to various reasons. Malaria raged like an epidemic in the waterlogged areas. Soil salinization has been a corollary. Lining of canals to check seepage, installation of tube wells to lower the groundwater table and conjunctive use of water were adopted as remedial measures.

In many cases, dams and diversions deprive the downstream river of adequate flows and thereby harm aquatic life, obstruct the migration of fish, trap sediments, modify groundwater regime, submerge vegetation, displace people from their homes and affect river-based livelihoods. On the other hand, they help increase agricultural production and overcome poverty, hunger and malnutrition, generate energy, facilitate transport, attenuate floods, moderate droughts and attract tourism. Various measures are adopted to ameliorate adverse conditions, such as fish ladder and compensation for displacement, but success of such measures is not hundred per cent.

Studies on the assessment of environmental and social impacts of the proposed projects and public hearings are usually taken up during the appraisal of the project proposals for granting environmental clearance. At that late stage, mitigation measures are considered to overcome the likely adverse impacts. Needless to say, the remedial measures at the last stage are likely to be inadequate to comprehensively address the environmental and social concerns. If the issues arising at this stage could be anticipated and addressed during the planning and design stage (by involving the stakeholders as well), it will lead to a better project design and more acceptability.

Relevance of environmental and social hydrology

The relation between civil and environmental engineering has been recognized long ago. In fact, many universities in the United States and other countries have Departments of Civil and Environmental Engineering. Notwithstanding the name, the academic curricula have different degrees of contents from environmental sciences; social sciences are typically inadequately covered. To that end, Sivapalan *et al*.[2] proposed a scientific discipline called socio-hydrology which is use-inspired and aims at focusing on understanding, interpretation and scenario development of the flows and stocks in the human modified water cycle across time and space scales. They noted that a key and differentiating aspect of socio-hydrology is explicit two-way feedback between human and water systems.

Reviewing the originality, practicality and contributions of socio-hydrology, Madani and Shafiee-Jood[3] emphasized to consider humans as an integral part of water resources systems models.

Table 1. Curriculum: environmental and social hydrology

Title	Contents	Lecture hours	Scope
Introduction	Hydrologic systems, water bodies, environment, ecology and society	2	Inter-relationships between water resources and humans
Hydrologic inputs	Precipitation, snowmelt, base flow of groundwater, storm-water drainage, water in soil, wastewater inflow, tributaries	2	Understanding of the contributions of water from various sources
Hydrologic abstractions	Infiltration, storage, diversion for agriculture and hydropower generation, abstraction for domestic and industrial use, evaporation, transpiration	3	Distribution of water, hydrological processes and purposes
Hydrologic interventions	Dams, barrages, embankments, bridges	2	Features of hydro-infrastructure, impacts, significance of connectivity – lateral, longitudinal and vertical
Hydrologic studies	Hydro-ecologic modelling, river health, water quality, land use, catchment processes	4	Understanding the behaviour of catchments
Hydrologic functions	Flood plains fertilization, groundwater recharge, erosion, sediment transport, eco-services, self-purification of river	4	Main functions performed by rivers
Eco-hydrology	Environmental flows, biodiversity, aquatic habitat and ecology, bank vegetation, river development, river rejuvenation, hydrology of forests, wetlands and lakes, fisheries, ecosystem services	6	Understanding water bodies as living systems; their protection and conservation
Environmental matters	Environmental economics, mining in river beds, water pollution, laws and regulations related to water bodies	5	Environmental issues to be addressed in the management of water resources
Social matters	Livelihood, pilgrimage, mass bathing, tourism, human impacts on water systems, sustainable development, urbanization	3	Social issues related with water resources
Environmental studies	Environmental impact assessment, environmental management plan, environmental monitoring	4	Prediction and mitigation of adverse impacts on the environment
Social studies	Livelihood patterns, social impact assessment, rehabilitation of project-affected persons, social conflicts, public consultation	3	Prediction and mitigation of adverse impacts on society
Emerging environmental concerns for hydrologic activities	Inland navigation, dredging, interlinking of rivers, groundwater recharge, impact of climate change	4	Interventions that have potential to significantly impact the society

This consideration has the potential to strengthen coupled human–water systems research and management. However, Madani and Shafiee-Jood[3] stated that the current approaches and trends in socio-hydrology have the possibility to make this area less inclusive and interdisciplinary.

Environmental hydrology was recognized as a distinct subject much earlier than social hydrology. However, it was not noticed since it did not emerge from a public uproar against the impacts of large WRD projects. A book titled *Environmental Hydrology* was published in 1995. The second edition was published in 2003 and the third in 2015 (ref. 4). The scope of topics covered has enlarged in successive editions in which new authors have contributed significantly. Currently, many professional associations are active in the field of environmental and social hydrology and research papers on related topics can be seen in technical journals.

Both social hydrology and environmental hydrology aim to study the relationship between coupled systems and have all the attributes of a transdisciplinary science. Their understanding enables identification and assessment of problems likely caused by activities affecting the coupled systems, and show ways to prevent or mitigate related problems. Basically, the systems approach is applied to integrate hydrology with the underlying social and environmental concerns.

Suggested course structure

Academic institutions around the world are introducing courses from environmental and social sciences. For example, the University of Saskatchewan, Canada, has begun offering a new graduate course 'Social hydrology' from 2020. We believe that it is the right time that a course on environmental and social hydrology at the senior undergraduate (UG) or post-graduate (PG) level is introduced in academic institutions in India to provide the desired exposure to future hydrologists.

The scope of the suggested course should cover inter-relationships among water resources, environment, ecology and humans as they exist in pristine conditions and as modified by interventions caused by a WRD project. This includes the sources of water and its demand, connectivity – longitudinal, lateral and vertical – in water resources, functions performed by rivers and other water bodies and an appreciation that rivers,

lakes and wetlands are effectively living systems which need protection and which are significant for global sustainability.

Accordingly, the topics include hydrologic processes, identification of sources of water in terms of quantity and quality, features of WRD projects, the experience of impacts of such projects on the environment and society, and modern techniques for data collection and modelling. In short, the module in environmental and social hydrology should expose the hydrologist to related aspects of life sciences, economics and sustainability.

Table 1 shows the suggested course structure with the title and contents of various topics, suggested lecture hours and the scope of the module. The lecture hours total to 42 hours. A full one-semester course at an IIT like Roorkee has about 42 lecture hours.

The suggested course will supplement a full course on hydrology. With some adaptation, as necessary, the suggested course could also be found useful for courses on hydrogeology, WRD, integrated water resources management and the like. Students who take this course should also visit a few WRD projects (under construction and in operation) as part of the course.

Since civil engineers have a key role in the development of infrastructure, similar types of courses need to be designed for senior UG and PG students from other disciplines such as structures, transportation and geomatics. For that matter, awareness courses may also be designed for all engineering students on similar lines. Of course, a few technical institutes do run similar courses.

Many a times, criticism/opposition to WRD projects from the public is based on hearsay, distorted facts and rumours. Hence, along with the courses for hydrologists, students from environmental science, social science, economics and arts streams also need to be exposed to the challenges and constraints in WRD through well-structured courses. With this exposure, they will be in a position to appreciate the real-life challenges and constraints and help in finding technically sound solutions. This will help in improved and timely resolution of conflicts and sustainable WRD.

1. WCD, Dams and development: a new framework for decision-making. Report of the World Commission on Dams, 2000; http://www.futuredams.org/the-world-commission-on-dams-20-years-on/
2. Sivapalan, M. *et al.*, *Earth's Future*, 2014, **2**, 225–230; doi:10.1002/2013EF000164.
3. Madani, K. and Shafiee-Jood, M., *Water*, 2020, **12**, 1941; doi:10.3390/w12071941.
4. Ward, A. D., Trimble, S. W., Burckhard, S. R. and Lyon, J. G., *Environmental Hydrology*, CRC Press, Boca Raton, USA, 2015, 3rd edn.

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