EVOLUTION OF ENVIRONMENTAL HYDRAULIC INSTRUMENTATION AND EXPERIMENTAL METHODS

Jochen Aberle
Norwegian University of Science and Technology, Trondheim, Norway

Vladimir Nikora
School of Engineering, University of Aberdeen, Scotland

Colin D. Rennie
Department .of Civil Engineering, University of Ottawa, Canada

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Contents

Summary

This chapter presents an overview of hydraulic instrumentation and experimental methods that are important for investigations in the field of *Environmental Hydraulics*. For this purpose, *Environmental Hydraulics* is briefly defined and its multi-disciplinary character is highlighted. Providing cross-references to relevant EOLSS-chapters, different instruments and experimental methods are introduced that are important for measurements of flow parameters, transport processes, and morphology in natural systems.

1. Introduction

Environmental Hydraulics represents a sub-branch of environmental fluid mechanics that deals with movement of water and transport processes in natural systems such as streams, lakes, estuaries, oceans, and underground aquifers (for a description of these natural systems within the EOLSS see Dolotov and Zektser, 2005; Martinez Alfaro Pedro Emilio, 2004; Dooge, 2004; Dolotov, 2004; Khublaryan, 2004; Khublaryan, 2006/Rev.2008; *etc.*) and at their interfaces (described e.g. by Cavazza and Pagliara, 2004; Berndtsson and Persson, 2003).

Environmental Hydraulics is a cross-disciplinary academic discipline combining technological, environmental and human-sociological interests (see Fernández-Cirelli, 2004; Adeloye, 2006; Gladwell, 2004) in order to provide professionals working in water-related areas with technology and knowledge to ensure a sustainable water environment and adequate water resources for upcoming generations (Rowinski, 2007). Moreover, it promotes the implementation of fluid mechanical concepts into environmental and ecological theories and is therefore relevant for many ecological research areas (e.g. Bertoni, 2011; Duarte, 2003; Zalewski et al, 2006/Rev.2007).

Environmental Hydraulics emerged from fluid mechanics and traditional hydraulics (described in the EOLSS by Bergeles, 2010; Chabard and Laurence, 2004; Jordaan, 2006/Rev.2008; Lee and Sharp, 2004)) due to increased environmental awareness of mankind and the need to protect water resources (see Frioux, 2010; Armanini, 2004; Tamai, 2005). It focuses on fundamental hydraulic phenomena and their interactions with other associated environmental processes or, in other words, on analyses of physical, chemical, and biological aspects of flowing water on multiple scales that are important for the protection, restoration, and management of environmental quality (e.g., Singh and Hager, 1996). Examples are watershed scale hydrology (e.g., Robinson et al, 2008), aquatic ecosystem functioning (e.g., Nikora, 2010), or flow vegetation interaction (e.g., Nepf 2012a, b).

Compared to engineered flows (e.g., Takahasi et al., 2004; Sparks, 2004), flows in natural systems are characterized by heterogeneities in terms of physical properties, transported matter, biological species, ecotones as well as different length and temporal scales (see Swart, 2004; Goetze et al, 2006). Due to the heterogeneous boundary conditions, natural flows cannot be perfectly replicated by design. In contrast, they are mainly observed in numerical, laboratory and field experiments in order to understand their role for environmental quality (Rowinski, 2007). The detailed investigation of the relevant physical, chemical and biological processes and parameters demands adequate experimental methods, measuring techniques, and analytical tools for data analysis and interpretation. The digital revolution and technical advance has enabled the use of highly sophisticated measurement instruments for the detailed investigation of biotic and abiotic processes in water environments with high spatial and temporal resolution. This development has contributed significantly to the better understanding of the multiple processes constituting a portfolio of *Environmental Hydraulics*.

The decision as to which investigative approach is most appropriate depends on the phenomena of interest (e.g., turbulence characteristics, waves, transport processes), the associated scale (micro to global), the accuracy of the available instruments, and the environment (ocean, coastal, estuarine, lentic freshwater, lotic freshwater, and aquifers). Many relevant instruments and experimental methods are described within different EOLSS-encyclopedias related to Environmental Sciences, for which *Environmental Hydraulics* plays a crucial role. Therefore, the intention of the following chapters is to provide brief descriptions of environmental hydraulic instrumentation and experimental methods mainly by providing cross-references to existing EOLSS chapters. The present contribution is restricted to the topics of flow measurement, transport processes and water quality, and morphology and is not exhaustive.

2. Flow Measurements

The adequate measurement of flow and fluid properties such as water level, discharge, velocity, turbulence, pressure, density, temperature etc. is a prerequisite for the analysis and interpretation of environmental flows. The available instrumentation and experimental methods are multifaceted and depend on the purpose for which the measurements are carried out. Many of the available instruments and experimental methods are described in EOLSS-theme volumes edited by Iribarne and Federico Isla (2004); Sydow (2004); Dooge (2004); Jordaan (2003); Nihoul and Chen (2003); and Takahasi (2004). Each theme is an organized set of edited chapters on the respective subjects as listed in the bibliography.

The following sections provide a brief overview on the available instrumentation and experimental methods applied for the determination of the most important flow properties, i.e., water level, velocity and discharge. Information on the principles of signal processing and related uncertainty-considerations can be found within the EOLSS in Harmancioglu and Singh (2004); Müller (2004) and Eren and Herrero (2003) and are not repeated below.

2.1. Water Level and Pressure Measurements

Instruments and methods for the measurement of water levels (stages), water depth, and pressure range from manually operated simple mechanical instruments (e.g., sounding leads, point gauges), automated pressure measurements, fully automated echo-sounders to remote sensing techniques. The EOLSS-chapters authored by Graw (2004); Teng (2006); Chantler (2004); Jordaan (2004); Warren and Yoon (2010) and Wessels and van Biljon (2004) provide a detailed overview of the available instruments and methods for measurements of water stages and pressure in closed conduits or water bodies with free surfaces.

Measurements of the ground water table are of interest for many hydrogeological applications and information on this topic can be found in Foster (2004) and/or Ando (2008/Rev 2009).

Wave measurements are of major importance for coastal engineering applications. Such measurements have been carried out by wave gauges but can, nowadays, also be carried out by airborne, satellite-borne or land-based remote sensing techniques (e.g. Teng, 2006).

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Relevant bibliography from the EOLSS

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COASTAL ZONE AND ESTUARIES
Theme Overivew
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Other Chapters in the Theme volume
- Coastal Erosion
- Waves and Sediment Transport in the Nearshore Zone
- Episodic Processes(Storm Surges and Tsunamis)
- Sediment Transport in Estuaries
- Rocky Coasts
- Coastal Barriers
- Coastal Sand Dunes and Barrier Islands
- Morphology and Morphodynamics of Sandy Beaches
- Morphology and Morphodynamics of Gravel Beaches
- Beach Plains: Formation, Evolution and Ecological Significance
- Rias and Tidal-Sea Estuaries
- Coastal Lagoons
- Primary Production in Coastal Lagoons
- Deltas
- Tidal Salt Marshes and Mangrove Swamps
- Coastal Evolution
- Anthropogenic Impacts on the Structure and Function of the Coastal Biota
- Anthropogenic Impacts on Estuaries

ENVIRONMENTAL SYSTEMS
Theme Overivew
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Other Chapters in the Theme volume
- Measurement Tools for Pollution Sources and Ambient Concentrations
  - Measurement Tools: Soil Systems
  - Measurement Tools for Atmospheric Systems
  - Measurement Tools: Water Systems (Inland Waters)
  - Measurement Tools: Water Systems (Oceans)
  - Field Techniques: Soil Systems
  - Field Techniques for Atmospheric Systems
  - Field Techniques: Inland Waters
  - Field Techniques: Water Systems (Oceans)
  - Bioindicators
  - Bioindication of Ecosystems Regeneration Ability Thresholds
- Environmental Data and Statistics
  - Spatial Environmental Data
  - Non-Spatial Environmental Data
  - Statistical Analyses' Design
  - Biostatistics
  - Data Accuracy and Validation
- Environmental Models and Simulations

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River Navigation and Associated Structures
Dredging in Rivers and Estuaries
Sedimentation of Rivers, Reservoirs and Canals
Sediment Exclusion at River Intakes
Rivers and Human Development
Potable Water
Disposal of Sewage
Sustainable Industrial Water Use in Southern Germany
Water Consumption, Fisheries and Water-Related Recreational Facilities
Human Made Lakes and Reservoirs : The Impact of Physical Alterations
Water Science and Technology:History and Future

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Other Chapters in the Theme volume

Fluids at Rest and in Motion
Fluid Mechanics
Groundwater Hydraulics
Fluid Mechanics in Pipelines
Hydroelectric Structures and the Design of Surge Chambers
Hydraulics of Two Phase Flow: Air and Water
Hydraulics of Two-Phase Flow: Water and Sediment
Hydraulic Methods and Modeling
Loads on Earth-Fill and Rock-Fill Dams Arising from Water and Wind
Sediment Phenomena
Turbulent Flow Modeling
Experimental Methods and Physical Modeling
Probabilistic Methods and Stochastic Hydrology
Applied Hydraulics and Hydraulics Instrumentation
Dredging Technology
Flow Measuring Techniques
Flow Measurement in Closed Conduits
Flow Measurement in Free Surface Flow
Control Systems for Hydraulic Structures and Equipment
Water Conveyance Systems and Flood Control Works
Design of Sustainable Hydraulic Structures
Hydraulic Structures for Pumping Equipment: Civil, Mechanical and Electrical Considerations
Water Supply: Dams, Reservoirs and Water Transfers
Hydraulic Structures in Urban Drainage Systems
Guidelines for Potable Water Purification
Tsunamis and Tsunami-Warning Systems
Abstracting Water from Sediment-Laden Streams
Large Dams
Project Design: Dams and Reservoirs
Guidelines for Sustainable Development of Water Resources
Design of Spillways and Outlet Works for Dams
Ground Level Reservoirs and Elevated Storage Tanks
Storm Water Drainage and Effluent Disposal
Hydraulics and Sustainable Wastewater Disposal in Rural Coastal Communities
Hydraulic Structures for Coastal Protection
Hydropower
Intakes on Sediment-Laden Rivers

Concrete Dam Engineering
Desalination
The Construction of Small Earth-Fill Dams
Sustainable Civil, Mechanical and Electrical Equipment in Water Supply Projects
Corrosion and the Protection of Metals
The Aging and Rehabilitation of Appurtenant Structures to Dams and the Aging of Masonry Dams
Aging of Plastics, including Resilient Non Metallic Artificial Materials Being Used in the Water Industry
Protection Against Deterioration of Materials and Structures in the Ocean Environment
Guidelines for Sustainable Community Water Supply and Sanitation Projects
Testing of Materials and Soils
Hydrological Data Acquisition Systems
Hydroinformatics
Data Acquisition Methods for Groundwater Investigation and the Siting of Water Supply Wells
Sediment Data Acquisition
Sluicing Flumes for Gauging Sediment-Laden Rivers
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Physical Oceanography
Seawater Properties, Water Masses, and Global Scale Currents
Air-Sea Interactions
Waves in the Oceans
Sea - Ice Interactions
Synoptic/Mesoscale Processes
Fronts and Mixing Processes
Coastal Oceanography
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Nutrient Cycling in the Oceans
Carbonate Chemistry of the Oceans
Natural and Anthropogenic Radionuclides
Human Perturbations
Non-Radioactive Ocean Pollution
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Oceans as Major Reservoirs of Protein
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Biographical Sketches

Jochen Aberle received his education in civil engineering from the University of Karlsruhe (TH), with a diploma in 1996 and the PhD title in 2000. After a two years postdoctoral stay at the National Institute of Water and Atmospheric Research (NIWA) in Christchurch, New Zealand, he joined the Leichtweiß-Institut für Wasserbau (LWI) at the Technische Universität Braunschweig, Germany, in 2003 as Research Associate. In 2008 he was promoted to the head of the LWI Hydraulic Laboratory. In 2012 he became a Professor at the Department of Hydraulic and Environmental Engineering at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. His general research interests are environmental fluid mechanics, sediment transport, cohesive sediment dynamics, and measurement techniques. He is particularly interested in the interaction between flow, sediment and vegetation, the near bed turbulent flow field over rough surfaces, and the statistical description of bed roughness. He authored over 20 over journal papers and is currently chair of the Committee on Experimental Methods and Instrumentation of the International Association for Hydro-Environment Engineering and Research (IAHR). He also acts as Associate Editor for Journal of Hydraulic Research and Water Resources Research.

Vladimir Nikora, FRSE, has over 30 years research experience in the area of environmental fluid mechanics, particularly in the hydrodynamics of rough-bed turbulent flows (turbulence, sediment transport, hydraulic resistance) and ecological hydrodynamics (flow-biota interactions and mass-transfer processes). Before joining Aberdeen in 2006 he was Principal Scientist and Manager of the Hydrodynamics Group at the National Institute of Water and Atmospheric Research (NIWA) in New Zealand, where he led many interdisciplinary research projects. Examples of his current projects at Aberdeen include Leverhulme Trust's "Biophysics of flow-plants interactions in aquatic systems" and EPSRC/DFG's "High-resolution numerical and experimental studies of turbulence-induced sediment erosion and near-bed transport". VN's interdisciplinary work is reported in more than 130 journal papers and two books, and has been acknowledged recently with the Hunter Rouse Hydraulic Engineering

Award of the American Society of Civil Engineers (2010). His expertise is also recognized through editorial work (e.g., he is the Editor of the IAHR Journal of Hydraulic Research).

Colin Rennie is an Associate Professor of Civil Engineering at the University of Ottawa, Canada, where he is Director of the Civil Engineering Hydraulics Laboratory. He is an Associate Editor of both the Journal of Geophysical Research – Earth Surface (AGU) and the Journal of Hydraulic Engineering (ASCE), which are the journals of record in the geophysical sciences and hydraulic engineering. He is Past-Chair of the Experimental Methods and Instrumentation Committee of the International Association of Hydro-Environment Engineering and Research (IAHR). Professor Rennie carries out research in the areas of river engineering, environmental hydraulics, river mixing, sediment transport, turbulence, and aquatic habitat, utilizing high resolution field measurements, laboratory physical models, and three-dimensional numerical modeling. He pioneered the use of acoustic Doppler current profilers for measurement of bedload transport. He has published 32 refereed journal papers and 57 refereed conference papers.