Resource Material in a Nutshell

by Jayati Chourey

Thinking in terms of ecosystems is the key to achieving sustainability because an ecosystem approach places equal emphasis on concerns related to environment, economy and community. The theme assumes the centre stage in the present compendium. It first describes the benefits of combining ecology and water management. Subsequent section addresses the role and significance of environmental flows in the ecosystems. Following which the collection also sheds light on the relationship between ecological and hydrological sciences. Given that these aspects are of utmost importance, especially with regard to sustainable management of aquatic ecosystem, the compendium provides a collection of readings on the issues of impact of water pollution and ecosystem monitoring. The debate within the ambit ecological economics, food security and ecosystems, gender, stakeholder participation are also covered in the compendium.

Section1. Ecosystem Based Approaches to Water Resources Management

1.1 Inland Water Systems

The inland water systems generally include habitats such as lakes and rivers, marshes, swamps and floodplains, small streams, ponds, and cave waters. All such habitats have a variety of biological, physical, and chemical characteristics. The inland water habitats and species are in a state which are far worse when compared to those of forest, grassland, or coastal systems (medium certainty). It is often speculated that more than half of the inland water habitats were lost during the last century. This chapter includes a brief description of the services provided by inland waters, along with their condition and trends of their habitats and species.

Reference: Millennium Ecosystem Assessment.2005. 'Inland Water Systems', in Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: Current State and Trends: Findings of the Condition and Trends Working Group (Millennium Ecosystem Assessment Series), pp. 551-583. Washington, D.C.: Island Press. Available online at http://www.maweb.org/documents/document.289.aspx.pdf (accessed in November 2011).

1.2 A Six-Step Framework for Ecologically Sustainable Water Management

The paper discusses the six step framework which has been developed by The Nature Conservancy. This particular framework acts as a guide for achieving for ecologically sustainable water management. The six steps include is: Step 1: Estimate ecosystem flow requirements; Step 2: Determine the influence of human activities on the flow regime; Step 3: Identify incompatibilities between human and ecosystem needs; Step 4: Foster collaborative dialogue to search for solutions; Step 5: Conduct water management experiments to resolve uncertainties; and Step 6: Design and implement an adaptive management plan.

Reference: Mathews, Ruth.2005. 'A Six-Step Framework for Ecologically Sustainable Water Management', *Journal of Contemporary Water Research & Education*, Vol.131, No. 1, pp. 60-65. Available online at http://www.ucowr.org/updates/131/12_matthews.pdf (accessed in November 2011).

1.3 Ecosystem-Based Management: Markers for Assessing Progress

This paper deals with a framework which disaggregates the goal of sustainable development into an order of several tangible levels of achievement. The concentration is on outcomes rather than management processes. Various sets of markers or indicators are given which can be used to assess progress in integrated management of river basins, coasts or large marine ecosystems and also for programmes that link across these systems. The paper highlights the major learning's emerging from coastal and water resources management. It also offers guidance on the aspects of design and conduct of ecosystem-based management initiatives which addresses not only the impacts of anthropogenic activities but also the need to sustain or restore goods and services, generated by healthy ecosystems.

Reference: Olsen, Stephen Bloye, Niels Ipsen and Martin Adriaans. 2006. 'Ecosystem-Based Management: Markers for Assessing Progress', Report by United Nations Environment Programme (UNEP) and Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA). Hague: UNEP/GPA. Available online at http://www.unep.org/pdf/GPA/Ecosystem_based_Management_Markers_for_Assessing_Progress.pdf (accessed in November 2011).

1.4 Relevance of Ecosystems in Integrated Water Resources Management

This lecture note intricately assesses the extent of ecosystems relevance in the principles of IWRM, which can be defined as a step by step process for development, allocation and monitoring of water resources to meet the objectives in the context of social, economic, environmental and institutional parameters. Five ecosystems - forests, cultivated, urban ecosystems, inland wetlands and coral islands, and their role in water resources management have been studied in relation to hydrologic regime and biochemistry. The role played by IWRM in ecosystem conservation to function as an 'environmental reserve' has also been highlighted.

Reference: James, E. J. 2010. 'Relevance of Ecosystems in Integrated Water Resources Management', Lecture note prepared for Training of Trainers in Integrated Water Resources Management held at Kandy, Sri Lanka from 16-25 September 2010.Available online at http://www.saciwaters.org/CB/water_and_ecosystem/lecture%20notes/1.4.Relevance%20of%20Ecosystems%20in%20Integrated%20Water%20Resources%20Management_James%20E%20J.pdf (uploaded in December 2011).

1.5 Incorporating Ecosystem Perspective in River Basin Planning Illustrated by Case Studies on Wetland Ecosystems

This lecture note focuses on the need for Integrated River Basin Management (IRBM) and its integral role in conserving ecosystems, especially in the context of wetlands, has been focussed on. Various case studies derived from the Indian subcontinent have been used to highlight IRBM's importance with due coverage provided to wise use of wetlands. Case study of the Ganges-Brahmaputra-Meghna deltaic system discusses the need for international cooperation in managing wetland ecosystems. A case study on the Chilika Estuary in the state of Orissa focuses on the complications due to over-exploitation of rivers finally draining into the wetland. Another case study on the Indus delta demonstrates the adverse affects of large-scale diversions in the upstream region on downstream floral and faunal population in the river. Also, case studies on the South-West coast bring out the necessity for IRBGM, by taking downstream wetlands into consideration. Management strategies recommended for coastal wetlands have also been highlighted. The case study of Loktak Lake in Manipur focuses on issues the ecosystem faces, due to development being confined to a single sector, hydropower generation. Results from majority of case studies have endorsed for IRBM to reduce inequalities in areas of water availability, quality and use pattern in various sub-basins upstream and downstream reaches.

Reference: James, E. J. 2010. 'Incorporating Ecosystem Perspective in River Basin Planning Illustrated by Case Studies on Wetland Ecosystems', Lecture note prepared for Training of Trainers in Integrated Water Resources Management held at Kandy, Sri Lanka from 16-25 September 2010. Available online at http://www.saciwaters.org/CB/water_and_ecosystem/lecture%20notes/1.5.Incorporating%20Ecosystem%20perspective%20in%20River%20Basin%20Planning_James%20E%20J.pdf (uploaded in December 2011).

1.6 Water Management and Ecosystems: Living with Change

The document tries to understand the relationships between human beings, water resources and the ecosystem. It also reinforces the idea of conserving ecosystems, and the ways for it to be incorporated in agendas involving principles of IWRM. Although IWRM and ecosystem conservation are driven by the same principles, the various schools of thought involved and their divergent viewpoints make it difficult for the twain thoughts to be integrated into a meaningful whole. Recent trends though have shown that IWRM and ecosystem conservation can simultaneously exist. The paper subsequently demonstrates a framework which can combine the ecosystem perspective with economic and social ones thus arriving towards a more holistic and multidimensional way of natural resources management.

Reference: GWP (Global Water Partnership) Technical Committee (TEC).2003. 'Water Management and Ecosystems: Living with Change', TEC Background Paper No. 9. Stockholm: GWP. Available online at http://www.gwptoolbox.org/images/stories/gwplibrary/background/tec_9_english.pdf (accessed in July 2011).

1.7 Vision for Water and Nature: A World Strategy For Conservation And Sustainable Management of Water Resources in The 21st Century

Water over the years has transformed itself from being revered due to its life-giving properties to another commodity. Most of the times, it is supposed to be readily available and thus exploited. It has been predicted that by 2025, water abstractions will grow by over 50 per cent and 18 per cent in developing and developed economies, respectively.

This will lead to dramatic changes in natural ecosystems. This document gives a fresh perspective on water resources management and use on a global level. The paper tries to envisage a scenario in the world where environmental, social and economic security are guaranteed due to basic attitudinal and behavioural changes in human beings towards freshwater and related ecosystems. Starting from a brief on the present and problems foreseen, the paper presents a conceptual framework, which is based on crucial human interactions with nature. This is then followed by a comprehensive Plan of Action (PoA). The consequences of further anthropogenic factors resulting in increased water reduction will lead to absolute degradation or destruction of terrestrial, freshwater and coastal ecosystems that are critical for the existence of each life form.

Reference: IUCN (International Union for Conservation of Nature)- the World Conservation Union.2000. 'Vision for Water and Nature: A World Strategy For Conservation And Sustainable Management of Water Resources in The 21st Century', Vision document prepared by IUCN-The world Conservation Union. Available online at http://www.rivernet.org/general/docs/VisionWaterNature.pdf (accessed in November 2011).

1.8 Ecosystem Approaches in Integrated Water Resources Management (IWRM): A Review of Transboundary River Basins

IWRM has always recognized the economic benefits due to management of water and related natural resources in an integrated manner. This provides for high levels of Ecosystem Services (ES). While the rationale has been conceptually clear for synergistic use of IWRM and ES paradigms clear, many trans-boundary watershed managers also tend to focus on an IWRM Framework that looks at traditional water resources such as water quantity, navigation, and hydropower. This can be concluded from the review of seven case studies of prominent trans-boundary basins, where IWRM is being implemented. The document while providing a detailed review of select trans-boundary basins to ascertain application of ecosystem-based approaches, also draws specific lessons for effective IWRM implementation in the global context. Basins representing Africa, Asia and the Pacific, Europe, Latin America and the Caribbean, North America, and West Asia, have been selected, which showcase the regional variables and a range of ecosystem service vulnerabilities, clearly. The analyses show a lack of focus on ecosystem services and a focus skewed towards more conventional services.

Reference: Roy, Dimple, Jane Barr and Henry David Venema.2011. 'Ecosystem Approaches in Integrated Water Resources Management (IWRM): A Review of Transboundary River Basins', Report by the United Nations Environment Programme and International Institute for Sustainable Development. Available online at http://iwlearn.net/publications/ll/ecosystem-approaches-in-integrated-water -resources-management-iwrm-a-review-of-transboundary-river-basins (accessed in November 2011).

1.9 Integrated Management of Chilika Lagoon, India, Case #268

The case study involves a framework for integrated lagoon basin management and includes interventions made in both coastal processes and on the river basin itself for restoration purposes of a severely threatened lagoon, following an ecosystem approach. GIS and remote sensing tools have been applied, which have been useful tools for monitoring and assessing the lagoon. There has been significant improvement in the ecological health of the lagoon due to this, including a substantial rise in the per capita income of the fishing community due to restoration efforts.

The key lessons include implementation of a flexible, pragmatic and non-bureaucratic management set-up with high-levelsof political support. Committed leadership and participatory involvement and stewardship of local communities in the practical sense, was also another learning point. Also, sound and holistic understanding of the ecosystem processes of the lagoon itself has been essential. After receiving the Ramsar Wetland Conservation Award in 2002, the case has received recognition globally. Various experiences from the approach demonstrate the promising potential in reforming the management frameworks of vital coastal wetlands in the Asian region.

Reference: Pattnaik, Ajit, L.C. Trisal. n.d. 'Integrated Management of Chilika Lagoon, India, Case #268', Global Water Partnership (GWP) Tool Box. Available online at
http://www.gwptoolbox.org/images/stories/cases/en/cs%20268%20india.pdf (accessed in November 2011).

1.10 Conservation and Management of Bhoj Wetlands, India #329

The case study dwells in detail on the implementation of various conservation programmes undertaken for the conservation as well as management of the Bhoj Wetlands, a Ramsar site situated in the state of Madhya Pradesh, India.

The basic objectives of the project were not only to improve the water quality but also to increase the storage capacity of these lakes. The programmes included both preventive and curative measures like increasing storage capacity through de-silting, de-weeding to control weeds, preventing lake pollution through diversion and treatment of sewage, protection of catchment areas through creation of buffer zones etc. Following the implementation of these activities led to increase in the water holding capacity of Upper Lake by about four percent. The water quality monitoring after the project, confirms the improvement in water quality when compared with data prior to implementation of the project. During implementation of the conservation measures, various kinds of administrative, social and legal issues were also encountered. The case study also discusses on how these issues were addressed while implementing the conservation measures.

Reference: Mukerjee, Aniruddhe. n.d. 'Conservation and Management of Bhoj Wetlands, India #329', Global Water Partnership (GWP) Tool Box. Available online at http://www.gwptoolbox.org/images/stories/cases/en/cs_329%20_full_india_final.pdf (accessed in November 2011).

1.11 Flowing Forward: Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation

Considering the available climate projections, there will be significant pressures on freshwater ecosystems and their ecology by the middle of the 21st century. These impacts will be severe, complex and would be hard to predict. This WWF review aims to develop the basic outline by providing the guiding principles, processes, and methodologies for incorporating anthropogenic climate change within an analytical framework. These guidelines are for evaluating water sector projects and impacts on freshwater ecosystems and probably provide a systematic approach to climate change adaptation in the World Bank's water and environment sectors.

Reference: Quesne, Tom Le, John H. Matthews, Constantin Von der Heyden, A.J. Wickel, Rob Wilby, Joerg Hartmann, Guy Pegram, Elizabeth Kistin, Geoffrey Blate, Glauco Kimura de Freitas, Eliot Levine, Carla Guthrie, Catherine McSweeney and Nikolai Sindorf.2010. 'Flowing Forward: Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation', Water Working Notes No.28. Washington D.C. Available online at http://www.worldwildlife.org/climate/Publications/WWFBinaryitem17968.pdf (accessed in November 2011).

Section 2. Environmental Flow and Ecosystem Services

2.1 Securing Water for Ecosystems and Human Well-being: The Importance of Environmental Flows

This report focuses on healthy ecosystems and their service oriented roles in helping water managers meet their goals of maximising economic and social welfare for all water users, on an equitable basis. Services termed as ecosystem services have real economic value today and have special importance in mitigating future problems and economic losses related to climate change. To preserve and benefit from these services on a perpetual basis, the water manager must ensure that an environmental flow regime is maintained in both rivers and wetlands. There are continuing efforts to sustain ecosystems, which contribute to social welfare and reduce economic costs. In the era of climate change, healthy aquatic ecosystems are looked upon for their adaptive value and superior resilience. This report examines each of these topics individually and associates them to the flow, which is the most fundamental variable in water science and management.

Reference: Forslund, Anna, Birgitta Malm Renöfält, Stefano Barchiesi, Katharine Cross, Sarah Davidson, Tracy Farrell, Louise Korsgaard, Karin Krchnak, Michael McClain, Karen Meijer and Mark Smith. 2009. 'Securing Water for Ecosystems and Human Well-being: The Importance of Environmental Flows', Swedish Water House Report 24. Stockholm: Stockholm International Water Institute. Available online at http://www.siwi.org/documents/Resources/Reports/Report24_E-Flows-low-res.pdf (accessed in November 2011).

2.2 Meeting Ecological and Societal Needs For Freshwater

The human society in general has used freshwater available from rivers, lakes, groundwater, and wetlands for various uses viz., urban, agricultural, and industrial activities, but has overlooked its value in supporting ecosystems. The report attempts to explain how the integrity of freshwater ecosystems depends upon adequate quantity, quality, timing, and temporal variability of water flow. Defining these requirements in a detailed yet general manner provides a good enough foundation for including them in debates about allocation of water resources, both present and future. It is this way that the needs of freshwater ecosystems can both be recognized and addressed, legitimately.

This report also includes recommendations by which freshwater ecosystems can be protected, maintained, and restored. The structure and function of a freshwater ecosystem are intricately linked to the watershed or catchment, which they are a part of.

Reference: Baron, Jill S, N. Leroy Poff, Paul L. Angermeier, Clifford N. Dahm, Peter H. Gleick, Nelson G. Hairston, Jr, Robert B. Jackson, Carol A. Johnston, Brian D. Richter and Alan D. Steinman. 2002. 'Meeting Ecological and Societal Needs For Freshwater', *Ecological Applications,* Vol.12, No.5, pp. 1247–1260. Available online at http://www.biology.duke.edu/jackson/ea02.pdf (accessed in November 2011).

2.3 Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity

The present paper offers a working framework for developing an ecologically sustainable water management program, in which anthropogenic needs for water are met by storing and diverting it in a manner that can sustain or restore ecological integrity of affected river ecosystems. The paper goes ahead in discussing a six-step process in which this can be achieved, which includes: (1) developing initial numerical estimates of key aspects of river flow necessary to sustain native species and natural ecosystem functions; (2) accounting for human uses of water, both current and future, through development of a computerized hydrologic simulation model that facilitates examination of human-induced alterations to river flow regimes; (3) assessing incompatibilities between human and ecosystem needs with particular attention to their spatial and temporal character; (4) collaboratively searching for solutions to resolve incompatibilities; (5) conducting water management experiments to resolve critical uncertainties that frustrate efforts to integrate human and ecosystem needs; and (6) designing and implementing an adaptive management program to facilitate ecologically sustainable water management for the long term. Lastly, case studies from around the world have been included to illustrate our framework, which suggests that ecologically sustainable water management in the vast majority of the world's river basins is attainable.

Reference: Richter, Brian D., Ruth Mathews, David L. Harrison and Robert Wigington. 2003. 'Ecologically Sustainable Water Management: Managing River Flows for Ecological Integrity', *Ecological Applications,* Vol. 13, No.1, pp. 206–224. Available online at
http://www.ag.auburn.edu/auxiliary/alcfwru/fisheries/fish7380/richter_paper.pdf (accessed in November 2011).

2.4 How Much Water Does a River Need?

This paper introduces a novel approach for setting stream flow-based river ecosystem management targets known as the 'Range of Variability Approach' (RVA). This approach derived from aquatic ecology theory concerns the critical role of hydrological variability and associated features of timing, frequency, duration, and rates of change in sustaining aquatic ecosystems. The approach is intended for application on rivers the primary river management objectives are conservation of native aquatic biodiversity and protection of natural ecosystem functions. The RVA targets are intended to facilitate design of river management strategies (e.g. reservoir operation rules, catchment restoration) that will lead to attainment of these targets, annually. The RVA enables defining and adopting interim management targets before conclusive, long-term ecosystem research results are available.

Reference: Richter, Brian D., Jeffrey V. Baumgartner, Robert Wigington and David P. Braun.1997. 'How Much Water Does a River Need?', *Freshwater Biology,* Vol. 37, No.1, pp. 231–249. Available online at http://www.eflownet.org/downloads/documents/Richter&al1997.pdf (accessed in November 2011).

2.5 An Assessment of Environmental Flow Requirements of Indian River Basins

The primary objective of the report is to stimulate debate about environmental water allocations or Environmental Flow (EF) in the Indian context, where the concept has started beginning to receive the necessary attention and recognition. The report begins with description of India's physiography, water resources and water resources related challenges. Subsequently, it proceeds by reviewing the emerging development of EF philosophy in India. This is followed by reviews of the present status of quick desktop EF estimation methods globally and examines their applicability with those available in the Indian context. It then formulates a simple EF assessment method which accounts for the limitations of available information in the country and illustrates its application using several major Indian River basins as illustrations. Finally, this is followed by recommendations on the immediate steps that need to be taken in EFA in the context of NRLP and for a longer-term EF research program.

Reference: Smakhtin, V. And M. Anputhas. 2006. 'An Assessment of Environmental Flow Requirements of Indian River Basins', Research Report 107 of International Water Management Institute (IWMI). Colombo: IWMI. Available online at http://www.iwmi.cgiar.org/publications/IWMI_Research_Reports/PDF/PUB107/RR107.pdf (accessed in November 2011).

2.6 Environmental Flows in River Basins: A Case Study of River Bhadra

Environmental flow, sometimes referred to Environmental Water Requirement, is an arrangement between water resources development and maintenance in case of a river in ecologically acceptable or agreed conditions. Thus, it can be deduced that adequate water is left in our rivers, which is subsequently managed to ensure benefits downstream concerning environmental, social and economic perspectives. Given its importance, quite a few countries have ensured making environmental flows mandatory. This article presents a summarised account of the present scenario in Bhadra River, which has one big dam over it, leading to altering of its natural flow. The study is based on both field studies and secondary data investigation. The present study focuses on, (a) the present environmental flow rates in a river; (b) the ideal/optimal environmental flows to be maintained in the Tungabhadra, and (c) potential benefits.

Reference: Babu, K. Lenin and B. K. Harish Kumara. 2009. 'Environmental Flows in River Basins: A Case Study of River Bhadra', *Current Science*, Vol.95, No. 4, pp. 475-479. Available online at http://www.indiaenvironmentportal.org.in/files/Environmental%20flows%20in%20river%20basins.pdf(accessed in November 2011).

Section 3. Applied Hydro-ecology & Eco-Hydrology and Integrated Water Resources Management

3.1 Applied Hydro-Ecological Science for the Twenty-First Century

There have been studies on ecology linking distribution of freshwater biota to physical factors like water velocity and temperature. Over the past three decades or more, debates have continued on how these linkages can be used in a river management context. This paper provides an overview regarding the need for sound science on which regulated river management decisions can be derived from. A tool-box of various techniques for informing these river management decisions is introduced from the context of several recently constituted institutional developments. These developments have hitherto provided management agencies increased powers to manage river flows in an integrated way. The paper also reviews the importance of applied hydro-ecology, proving that our knowledge in this science is incomplete and there are various barriers, including financial ones that limit its day-to-day application. The paper subsequently focuses on the common themes arising from the accompanying group of papers, and to link them to a broader context of applied hydro-ecology.

Reference: Dunbar, M.J. and M.C. Acreman. 2001. 'Applied Hydro-Ecological Science for the Twenty-First Century', in M.C.Acerman (ed) *Hydro-Ecology: Looking Hydrology and Aquatic Ecology,* pp. 1-18. Oxfordshire: International Association of Hydrological Sciences. Available online at http://iahs.info/redbooks/a266/iahs_266_0001.pdf (accessed in November 2011).

3.2 Ecohydrology and Hydroecology: A 'New Paradigm'?

'Hydroecology and Ecohydrology', which include the sub-discipline of ecohydraulics, indicate the interface between hydrological and biological i.e. ecological sciences. This paper provides a critical perspective of identifying the defined core of hydroecology and ecohydrology multidisciplinary nature of these disciplines. Clarity on numerous questions have been provided like – the actual meanings of hydroecology and ecohydrology and as to whether these are clearly defined and understood, whether these terms signify real change or are they a repackaged version of well-established research elements within hydrology or ecology. These questions are addressed by reviewing scientific literature and categorizing available bibliographic search data.

Reference: Hannah, David M., Paul J. Wood and Jonathan P. Sadler. 2004. 'Ecohydrology and Hydroecology: A 'New Paradigm'?', *Hydrological Processes*, Vol. 18, No.17, pp.3439-3445. Available online at http://ocw.um.es/ciencias/ecologia/ejercicios-proyectos-y-casos 1/Hannah%20et%20al%202004.pdf (accessed in November 2011).

3.3 The Role of Hydro-Ecological Models in the Development of Sustainable Water Resources

One of the significant elements in the overall development of sustainable water resources is assessing resource development on freshwater ecology. Being a relatively new area of science, hydro-ecological modelling requires development in the longer run as well as validation of existing techniques. Development of ground as well as surface water resources for purposes like water supply, irrigation or hydropower will ultimately result in modification of the natural flow regime of rivers. Major advances in the field of hydrological models and decision support systems have ultimately led to overall improvements in design and operation of resource schemes. But on the flip side, the ability to model impacts on freshwater ecosystems is a recent phenomenon. In the UK, the Instream Flow Incremental Methodology (IFIM) using the Physical Habitat Simulation (PHABSIM) system is now being used for assessment of sensitivity due to habitat change ranging from a given species to a flow regime change. The paper details this approach for modelling riverine habitats and provides illustrations of how this model has been used to facilitate towards sustainable water resources development in the context of UK.

Reference: Gustard, Alan and Craig R. N. Elliott. 1997. 'The Role of Hydro-Ecological Models in the Development of Sustainable Water Resources', Paper presented at the Rabat symposium on Sustainability of Water Resources under Increasing Uncertainty, Rabat, Morocco, 23 April- 3 May. Available online at http://iahs.info/redbooks/a240/iahs_240_0407.pdf (accessed in November 2011).

3.4 A Spatial Assessment of Hydrologic Alteration within a River Network

It helps in maintaining natural hydrologic variability as it forms an essential role in conserving native riverine biota and river ecosystem integrity. Hydrologic variation plays a vital role in structuring biotic diversity within riverine ecosystems as it controls key habitat conditions within the river channel, floodplain, and hyporheic (stream-influenced ground water) zones. Alterations in the stream flow regimes may modify quite a few habitat attributes and impair ecosystem connectivity. The use of 'Range of Variability Approach' is demonstrated for assessing hydrologic alterations at available stream gauge sites throughout a river basin is provided. We then illustrate a technique for spatially mapping degree of hydrologic alteration for river reaches at and between stream gauge sites. Such maps can be used to assess loss of natural hydrologic variations at river basin scale, thereby facilitating river restoration planning.

Reference: Richter, Brian D., Jeffrey V. Baumgartner, David P. Braun and Jennifer Powell. 1998. 'A Spatial Assessment of Hydrologic Alteration within a River Network', *Regulated Rivers Research Management,* Vol.14, No.4, pp. 329-340. Available online at http://acousticfiles.com/4LRLRms/Ashley's%20papers/Richter_1998_spatial%20hydrologic%20alteration.pdf (accessed in November 2011).

3.5 A Method for Assessing Hydrologic Alteration within Ecosystems

Hydrologic regimes play a vital role in determining various parameters viz., biotic composition, structure, and function of aquatic, wetland, and riparian ecosystems. But anthropogenic uses of land and water are substantially altering hydrologic regimes around the world. A method is proposed for assessing the degree of hydrologic alteration attributable to human influence within an ecosystem, which is referred to as the “Indicators of Hydrologic Alteration,” based upon analysis of hydrologic data available from existing measurement points within an ecosystem (like stream gauges or wells) or model-generated data. There were 32 parameters used, which were organized into five groups, to statistically characterize hydrologic variation within individual year. These 32 parameters provide information on ecologically significant features of both surface and ground water regimes influencing aquatic, wetland and riparian ecosystems. Subsequently, hydrologic perturbations associated with activities such as dam operations, flow diversion, groundwater pumping, or intensive land-use conversion by comparing measures of central tendency and dispersion for each parameter between user-defined “pre-impact” and “post-impact” time frames, generating 64 Indicators of Hydrologic Alteration is assessed. The intended use of this method is for use with other ecosystem metrics in inventories of ecosystem integrity, in planning ecosystem management activities, and in setting and measuring progress toward conservation or restoration goals.

Reference: Richter, Brian D., Jeffrey V. Baumgartner, Jennifer Powell, David P. Braun. 1996. 'A Method for Assessing Hydrologic Alteration within Ecosystems', *Conservation Biology,* Vol.10, No. 4,pp. 1163–1174. Available online at http://www.tufts.edu/water/pdf/iha_meth.pdf (accessed in November 2011).

3.6 Impact of Climate Change on Freshwater Ecosystems: A Global-Scale Analysis of Ecologically Relevant River Flow Alterations

The various River flow regimes like long-term average flows, seasonality, low flows, high flows and other types of flow variability, play vital roles for freshwater ecosystems. Freshwater ecosystems are thus affected by climate change by increased temperatures as well as altered river flow regimes. In this paper, the impact of climate change in 2050s is compared in relation to the impact of water withdrawals and dams on natural flow regimes which have occurred by 2002. Climate change was computed accordingly to alter seasonal flow regimes significantly, which is more than 10% on almost 90% of the land area globally and excluded Greenland and Antarctica. This was compared with only a quarter of land area that had impacted from significant seasonal flow regime alterations due to dams and other water withdrawal processes. The paper has based its study on available knowledge regarding ecosystem responses to flow alterations and data on flow alterations by dams and water withdrawals, and it is inferred that computed climate change induced river flow alterations will impact freshwater ecosystems significantly strongly when compared to anthropogenic alterations in the past.

Reference: Doll, P and J. Zhang.2010. 'Impact of Climate Change on Freshwater Ecosystems: A Global-Scale Analysis of Ecologically Relevant River Flow Alterations', *Hydrology and Earth System Sicences,* Vol.14, No.1, pp. 783-799. Available online at http://www.hydrol-earth-syst-sci.net/14/783/2010/hess-14-783-2010.pdf (accessed in November 2011).

3.7 Integrated Watershed Management- Ecohydrology & Phytotechnology

The present manual concentrates on the methodology and various practical aspects of implementing Ecohydrology and Phytotechnology concepts for Integrated Watershed Management. It can be used as complement to guidelines for Integrated Management of the Watershed (2002), published by UNEP-IETC and UNESCO-IHP. The present guidelines for the first time, lays out the general philosophy of Ecohydrology and Phytotechnology. The manual provides a new, multi-disciplinary approach to water resources management, from the perspective of a catchment. It provides the decision makers with a broader understanding of phytotechnology methods by using practical examples of implementation. Additionally, it also enhances understanding of the relationships between hydrology and biota and their use (ecohydrology), while showing the need for a broader view on catchment management. This involves application of new strategies by understanding ecosystem properties in order to enhance their capacity.

Reference: Zalewski, Maciej, Iwona Wagner-Lotkowska and Richard D. Robarts. 2004. 'Integrated Watershed Management- Ecohydrology & Phytotechnology', Manual prepared by United Nations Environment Programme. Available online at
http://www.unep.or.jp/ietc/publications/Water_Sanitation/integrated_watershed_mgmt_manual/index.asp (accessed in November 2011).

Section 4. Water Pollution and Ecosystem Monitoring

4.1 Impacts of Water Use on Water Systems and the Environment

A chapter of the World Water Development Report 3, it focuses on the influence of water use on water systems and the environment. Globally, depletion and pollution of certain economically valuable water resources have been beyond limits, and a real scenario of managing not so reliable water resources systems is now emerging really fast. Due to increased groundwater use, mainly due to policies like subsidised rural electrification for use of water in agriculture, economies have become more dependent on groundwater. But their future faces a real threat due to aquifer depletion and pollution. It is a fact that failure to monitor negative impacts of water use on the environment and prevalent institutional weaknesses in certain developing countries prevents the effective enforcement of regulatory provisions. It is ironical that relevant information on pollution loads and changes in water quality lacks in areas where there is intense water use, in densely populated developing economies. Due to this, the serious impacts of activities promoting pollution and deteriorating human health and degrading ecosystems largely go unreported. But there are positive trends of progress in the areas of how pollution and risks of pollution can be mitigated, thus reversing the trends of environmental degradation.

Reference: Björklund, Gunilla, Jake Burke, Stephen Foster, Walter Rast, Domitille Vallée and Wim van der Hoek. 2009. 'Impacts of Water Use on Water Systems and the Environment', in World Water Assessment Programme, The United Nations World Water Development Report: Water in a Changing World, pp. 127-149. Paris: United Nations Educational Scientific and Cultural Oragnisation and London: Earthscan. Available online at http://unesdoc.unesco.org/images/0018/001819/181993e.pdf#page=152 (accessed in November 2011).

4.2 Impact of Agricultural and Industrial Pollution on Ecosystem and Water Quality

Numerous valuable environmental functions are performed by aquatic ecosystems. Some of these include recycling nutrients, purifying water, attenuating floods, augmenting and maintaining stream flow, recharging ground water, providing habitat for wildlife and recreation for people. Rapid population increase in several parts of India – accompanied by intense industrial, commercial, and residential development, has led to pollution of surface water by sewage, industrial waste, fertilizer, insecticide, toxic landfill leachates, and feedlot waste. The objective of the lecture note is to increase the awareness of the participants on the nature and magnitude of pollution generated from various sources including domestic, industrial and agricultural activities. It would also make them aware of the various impacts of pollution on water quality and ecosystem including oxygen depletion, nutrient enrichment leading to eutrophication, toxicity etc. They would also learn regarding the fate of different pollutants in aquatic ecosystems including interaction between hydrological conditions, watershed processes and in-stream processes.

Reference: Trivedi, R.C. 2007. 'Impact of Agricultural and Industrial Pollution on Ecosystem and Water Quality', Lecture note prepared for Staff training programme in Water and Ecosystem, held at Kathmandu, Nepal , from November 26- December 3 2007. Available online at http://www.saciwaters.org/CB/water_and_ecosystem/lecture%20notes/Trivedi-Impact.pdf (uploaded in December 2011).

4.3 The Effects of Industrial Pollution on Ecosystems and Human Well-Being

Human beings have been and are dependent upon ecosystem services like air, water, food, and also for provision of materials involved in development and construction. Although the value of ecosystems and their related services cannot ignored, anthropogenic and natural processes have changed the way they function, limiting their capacity to deliver. This article, explores links between ecosystems and human well-being and the resultant effects of industrial pollution on water quality and their impacts. The pathways to arrive at sustainable management of human activities and processes within ecosystems have also been discussed which can go a long way to improve water quality globally.

Reference: Chiramba, Thomas and Peter Manyara. 2010. 'The Effects of Industrial Pollution on Ecosystems and Human Well-Being', Article by Stockholm International Water Institute (SIWI). Stockholm: SIWI. Available online at http://www.siwi.org/documents/Resources/Water_Front_Articles/2010/The_Effects_of_Industrial_Pollution_on_Ecosystems_and_Human_Well-Being.pdf (accessed in November 2011).

4.4 Introduction to Agricultural Water Pollution

Probably food supply stands next to availability of drinking water, as the most important priority globally. Agriculture is the single largest user of freshwater resources across the world, using up 70% (global average), of all surface water supplies. The increased pressure to produce enough food to feed an ever-growing population has had a worldwide impact on agricultural practices. Due to this pressure, in many countries has led to expansion of agriculture into marginal lands, where agriculture as an activity is usually associated with subsistence farming. In others, food requirement has resulted in expansion of irrigation and steady but sure increase in the fertilizers and pesticides usage to achieve and sustain higher yields. Thus, agriculture is both a cause and victim of water pollution. It causes water pollution through discharge of pollutants and by sedimentation to surface and/or groundwater, through soil loss by poor agricultural practices, and also through salinization and water logging of irrigated land. It becomes a victim as waste water; polluted surface and groundwater contaminate crops and transmit diseases to farm hands and eventually the consumer. This paper deals particularly with the role of agriculture in determining freshwater quality. Non-point source impact categories specifically sediments, pesticides, nutrients, and pathogens have been identified along with their respective ecological, public health and, as appropriate, legal consequences. Finally, recommendations have been made on evaluation techniques and control measures.

Reference: Ongley, Edwin D.1996. 'Introduction to Agricultural Water Pollution', in Edwin D Ongley, Control of Water Pollution from Agriculture Food and Agriculture Organisation (FAO) Irrigation and Drainage paper 55. Rome: FAO. Available online at http://www.fao.org/docrep/w2598e/w2598e04.htm (accessed in November 2011).

4.5 Agriculture, Water, and Ecosystems: Avoiding the Costs of Going too Far

In the past century, the process of agricultural management has led to wide scale changes in land cover, water courses, and aquifers, and contributing extensively to ecosystem degradation and undermining processes which support ecosystems and range of ecosystem services. There is always a need for an integrated approach for managing these land

and water resources, and ecosystems that accept the varied functionalities of agro-ecosystems towards supporting food production and ecosystem resilience. This chapter recommends for improvement in agricultural technology and management practices to enhance ecosystem services resulting in benefits to the rural poor. These practices though, should maintain biodiversity which in turn strengthens ecosystem services. One should also strive for ecosystems should be managed in a way such that they mimic their natural state and character. Thus, it is imperative that these efforts are supported by raising awareness of the roles and values of ecosystem services through discussions and dissemination with diverse stakeholders. Also, close monitoring of inventories, assessments and monitoring of factors related to ecosystem resilience is required.

Reference: Falkenmark, Malin., C. Max FinlaysonLine, J. Gordon, : Elena M. Bennett, Tabeth Matiza Chiuta, David Coates, Nilanjan Ghosh, M. Gopalakrishnan, Rudolf S. de Groot, Gunnar Jacks, Eloise Kendy, Lekan Oyebande, Michael Moore, Garry D. Peterson, Jorge Mora Portuguez, Kemi Seesink, Rebecca Tharme, and Robert Wasson. 2007. 'Agriculture, Water, and Ecosystems: Avoiding the Costs of Going too Far', in David Molden, *Water for Food, Water for Life,* pp. 233-277. London: Earthscan. Available online at http://www.iwmi.cgiar.org/assessment/water%20for%20food%20water%20for%20life/chapters/chapter%206%20ecosystems.pdf (accessed in November 2011).

4.6 Sri Lanka's Environmental Challenges

The South Asian country of Sri Lanka is known as one of the top biodiversity areas in the Asian region. In comparison to its contemporaries, it makes far greater efforts for conserving its environment. But even here, following inadequate commitment and dedication from both the public and state have led to the growth of possibly serious environmental threats in recent years. This article puts forward questions on the current challenges facing effective environmental conservation like deforestation, freshwater and air pollution, noise pollution, soil erosion, wildlife poaching, coastal degradation, and mangrove reduction in this island nation.

Reference: Alagan, Ram. n.d. 'Sri Lanka's Environmental Challenges'. Available online at http://www.gvglobalvision.org/publications/Sri%20Lanka%92s_Environmental_Challenges.pdf (accessed in November 2011).

4.7 Assessment of Eco-environment Quality and Monitoring & Maintenance of Ecosystems

For planning rationally on any eco-restoration program, there should be adequate knowledge of the existing status of quality of eco-environment. This helps in proper identification of the nature and magnitude of pollution control required, prioritization of pollution control efforts and evaluation of effectiveness of pollution control programs. The objective of the lecture note is to make participants aware of techniques to assess water quality, sediment and biota. It would also expose them to various standard operating protocols for sampling, laboratory analysis, data handling, reporting, information generation and use. It would also give ideas on how monitoring data can be used for formulation of ecosystem restoration and maintenance program.

Reference: Trivedi, R.C.2007. 'Assessment of Eco-environment Quality and Monitoring & Maintenance of Ecosystems', Lecture Note prepared for Staff training programme in Water and Ecosystem held at Kathmandu, Nepal, from November 26-December 3 2007. Available online at http://www.saciwaters.org/CB/water_and_ecosystem/lecture%20notes/Trivedi-Assessment.pdf (uploaded in December 2011).

4.8 Water Quality for Ecosystem and Human Health

The management of water quality facilitates achieving targets of all eight MDGs set out by the UN, both directly and indirectly, albeit most closely it is tied to specific targets of Goal 7, which is to ensure environmental sustainability. This document intends to provide an overview of the major components of surface and ground water quality and their linkages to ecosystem and human health. Water quality monitoring data at local, regional and global assessments have been used to indicate the key features of aquatic environments, and also to demonstrate how anthropogenic activities influences water quality, positively or negatively. A clear understanding on water quality can serve to support other water assessments. The report presents data and analyses from GEMStat, a global water quality database created by UNEP's GEMS/Water Programme.

Reference: Carr, Geneviève M and James P. Neary. 2006. 'Water Quality for Ecosystem and Human Health', Report prepared by United Nations Environment Programme (UNEP) Global Environment Monitoring System (GEMS)/Water Programme. Burlington: UNEP -GEMS. Available online at http://www.gemswater.org/digital_atlas/digital_atlas.pdf (accessed in November 2011).

4.9 Water Pollution Control - A Guide to the Use of Water Quality Management Principles

The most critical challenge facing water quality management is water pollution control. Today, industrialised countries not only have wide-ranging experience of problems caused by water pollution but also lack the much required strategies and technologies to control it. Although in developing economies, pollution is increasing greatly with rise in both urbanisation and industrialisation, very few countries have experience of pollution control measures in a limited way or institutional and legislative frameworks needed for these measures to be effective. With absence of an urgent and properly directed action, developing countries are facing or will have to mount their efforts to prevent and control disease proliferation, environmental degradation and economic stagnation, as water resources which have become precious get more and more contaminated. This detailed manual on water pollution control could be a valuable tool for policy makers and environmental managers, especially in developing and newly industrialised countries as they look forward to face the challenges of damaging health, environmental and economic impacts of water pollution.

Reference: Helmer, Richard and Ivanildo Hespanhol (eds).1997. Water Pollution Control - A Guide to the Use of Water Quality Management Principles. London: E & FN Spon. Available online at http://www.who.int/water_sanitation_health/resourcesquality/watpolcontrol.pdf (accessed in November 2011).

4.10 Water Quality Monitoring in India- Achievements and Constraints

Rivers in India have and are polluted due to release of untreated sewage and industrial effluents. The paper discusses the method of monitoring water quality which has been adopted in the country and includes its achievements and possible limitations. The Central Pollution Control Board (CPCB) authority has put a widespread network of 870 monitoring stations across 26 states and 5 Union Territories on rivers across the nation. The inland water quality monitoring network runs as a 3-tier programme namely, (a) GEMS, (b) Monitoring of Indian National Aquatic Resources System, and (c) Yamuna Action Plan. The water samples collected in these monitoring stations are analysed for 28 parameters consisting of both physico-chemical and bacteriological parameters for ambient water samples, which excludes analyses carried out for field observations. Additionally, nine trace metals and fifteen pesticides are analysed for in selected samples. Also, bio-monitoring is carried out in specific locations. The data derived are reported in the Water Quality Statistics Yearbooks. It has been found from water quality monitoring in major rivers that there exists a predominance of organic pollution with contamination in almost all surface water sources by Coliform Group of Bacteria which makes them unfit for human consumption unless disinfected.

Reference: Bhardwaj, R.M.2005. 'Water Quality Monitoring in India- Achievements and Constraints', Paper presented at International Work Session on Water Statistics from 20-22 June, Vienna, Austria. Available online at http://unstats.un.org/unsd/environment/envpdf/pap_wasess5a2india.pdf (accessed in November 2011).

Section 5. Ecological Economics for Water Resources Management

5.1. Water Resources Sustainability: An Ecological Economics Perspective

Sustainability should bring forth life towards its concept and goals by demonstrating the best possible solutions. It is quite a challenge to create a functional and operational definition of sustainability. The field of ecological economics facilitates decision making for sustainable water resources in three vital ways – (a) Provides a need based theoretical revision to neo-classical economic analysis, (b) The theoretical perspective indicates toward better methodologies for measuring value of water in case of competing uses, and (c) Identify program of institutional reform that has the likeliest chance of delivering further sustainable water resources management practices.

Reference: Lant, Christopher.2004. 'Water Resources Sustainability: An Ecological Economics Perspective', Water Resources Update, No. 127, pp. 20-30. Available online at
http://opensiuc.lib.siu.edu/cgi/viewcontent.cgi?article=1095&context=jcwre&sei-redir=1&referer=http%3A%2F%2Fwww.google.co.in%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3Decological%2520economics%2520and%2520water%2520resources%2520management%26source%3Dweb%26cd%3D5%26ved%3D0CEsQFjAE%26url%3Dhttp%253A%252F%252Fopensiuc.lib.siu.edu%252Fcgi%252Fviewcontent.cgi%253Farticle%253D1095%2526context%253Djcwre%26ei%3DBnzXTsieMcPQrQetuu3JDQ%26usg%3DAFQjCNERkuT7lfj0DvoNZq64NwHPVVzboQ#search=%22ecological%20economics%20water%20resources%20management%22 (accessed in November 2011).

5.2 The Economics of Ecosystems and Biodiversity

Nature provides human society a wide array of benefits including food, fibres, clean water, healthy soil and carbon capture and more. The well-being of human society is very much dependent upon the availability of these "ecosystem services", which are primarily public goods having no markets or prices although they are valuable and are rarely identified by conventional economics. Subsequently, there is a decline in biodiversity with ecosystems being continuously degraded and the entire human society suffering the resultant consequences. This interim report brings together results of Phase I of the Economics of Ecosystems and Biodiversity (TEEB) Project and demonstrates an increased significance of ecosystems and biodiversity and threats to human welfare if there is no action taken to reverse the current damage and losses. The project's absolute aim is to facilitate policy makers by providing them with tools, required to incorporate the true value of ecosystem services into their policies/regulations.

Reference: TEEB (The Economics of Ecosystems and Biodiversity) Project . 2008. 'The Economics of Ecosystems and Biodiversity', Interim Report. Available online at http://ec.europa.eu/environment/nature/biodiversity/economics/pdf/teeb_report.pdf (accessed in November 2011).

5.3 Water Ecosystem Services and Poverty under Climate Change: Key Issues and Research Priorities

The report presents results of the research programme on the captioned topic. The research objective was to identify knowledge gaps and thus improve sustainability and equity of water provision and water ecosystem services management, in the background of climate change, in developing countries of Africa and Asia by referring to lessons learnt from Latin America. The objectives also specified identifying the most effective means by which in these countries, research can contribute to achieve more sustainable and equitable water services and ecosystems management. Besides summarising the approaches taken, including identification of key issues, consultations, specialist inputs, country-specific studies and a workshop, the paper analysed issues revealed during the study, using a drivers–state–impacts–response conceptual framework; examines the extent and use of existing knowledge, and gaps in knowledge, referring from literature and activities conducted for this study; and it also looks at research organisation and delivery mechanisms. At the end of the report, specific recommendations have been provided on research content, its organisation and delivery.

Reference: Mayers, James, Charles Batchelor, Ivan Bond, Rob Hope, Elaine Morrison and Breana Wheeler. 2009. 'Water Ecosystem Services and Poverty under Climate Change: Key Issues and Research Priorities', Report. London: International Institute for Environment and Development. Available online at http://pubs.iied.org/pdfs/13549IIED.pdf (accessed in November 2011).

5.4 Environmental Valuation: A Worldwide Compendium of Case Studies

The compendium is the sum total of many years of collaborative work between researchers across developing countries and countries in transition (CITs), and has been facilitated and coordinated by the Economics, Trade and Environment Unit of the United Nations Environment Programme (UNEP). The cases included in the compendium will also prove to be a useful material for researchers and university lecturers in the areas of both environmental economics and environmental policy. This compendium intends to fulfil three main purposes: (i) to provide evidence of feasibility of using valuation methods in developing countries and CITs; (ii) to provide guidance practically on particular issues, to be addressed in using valuation methods in these countries; and (iii) to give researchers in these countries by authoring the papers, an opportunity to critique the applications described, in their own way.

Reference: Abaza, Hussein and Jennifer Rietbergen-McCracken (eds). 1998. 'Environmental Valuation: A Worldwide Compendium of Case Studies', Environmental Economics Series No.26 of the United Nations Environment Programme. Available online at http://cmsdata.iucn.org/downloads/09_compendium_of_case_studies_introduction.pdf (accessed in November 2011).

5.5 Environmental Valuation: Challenges and Practices

Environmental valuation unlike environmental evaluation puts monetary values on environmental Goods and Services (G&S), a majority of which have no easily observed market prices. Thus, in order to value such G&S, economists have developed a whole "tool box" of valuation techniques, which are well developed, commonly used, and quite robust. Many examples are available of their use. This discipline has grown from a stage where environmental values were

"unknowable" or "invaluable" (somewhere in the range of zero and infinity) to a place where all kinds of estimates have been made and published. A number of challenges and opportunities still exist. The subject of economic valuation is as much art as it is science and thus valuation results are not decided in terms of correct analyses and their use or incorrect analyses and their misuse. This paper also discusses the improper use various valuation techniques pose.

Reference: Dixon, John A. 2008. 'Environmental Valuation: Challenges and Practices', Conference Synthesis note on Economics and Conservation in the Tropics: A Strategic Dialogue. Available online at http://www.rff.org/Documents/08_Tropics_Conference/Tropics_Conference_Papers/Tropics_Conference_Dixon_Environmenal_Valuation.pdf (accessed in November 2011).

5.6 Environment Valuation, Project Appraisal and Political Consensus in the Third World

This paper considers various environment valuation methods including top-down CBA. Institutions at national and international levels promote decentralisation in decision-making and good environment planning should always involve local population, planning and valuation. The paper discusses partial measures of environment valuation of non-market goods and services including Benefits Transfer Method and Contingent Valuation (CV), and Hedonic Pricing, which are still frequently used despite their poor records in the past. The present emphasis of multilateral project evaluation is on Financial Rate of Return and Weighted Average Cost of Capital which emphasizes the growing importance of commercial and national rather than local and social factors in public projects. The paper also dwells and debates on ethical and economic contexts of environment valuation and is summarized with a critique of the CBA. Despite growing opinions about endorsing a local and democratic approach, the same is not reflected practically in environment valuation.

Reference: McFarquhar, Alister.2000. 'Environment Valuation, Project Appraisal and Political Consensus in the Third World', *Planning and Markets*. Available online at http://www-pam.usc.edu/volume4/v4i1a3print.html (accessed in November 2011).

5.7 Economic Tools for Valuing Freshwater and Estuarine Ecosystem Services

A large number of services are provided by healthy ecosystems, integral to both human and non-human life including air and water purification, flood control, climate regulation, plant pollination, and food and fiber production. The paper is a review on the increasing volume of research on the economic value of ecosystem services, particularly water quality and quantity in both freshwater and estuarine ecosystems. Although the paper is focused on valuation of water services, it can also be a useful for understanding the application of economic valuation towards other ecosystem goods and services. The different components used to determine overall value of freshwater and estuarine ecosystems and also tools economists use to estimate these values are illustrated by using case studies which have shown these tools in use. The concluding part discusses implications of this literature towards improved management of water resources.

Reference: Kramer, Randall A.2005. 'Economic Tools for Valuing Freshwater and Estuarine Ecosystem Services', International Waters Learning Exchange and Resource Network. Available online at http://iwlearn.net/abt_iwlearn/events/ouagadougou/readingfiles/dukeuniversity-valuing-freshwater-estuarine-services.pdf (accessed in November 2011).

5.8 The Economic Value of Wetland Services: A Meta-Analysis

Wetlands since time immemorial have been viewed as an utter waste of land whose value can be further enhanced through drainage and destruction of the wetland. Although, there is widespread recognition in today globally on the valuable ecological services wetlands provide, there are still debates on whether particular wetlands are in their peak economic utilisation levels, and the extent to which both public and private resources need to be used for wetlands protection and restoration. This paper assesses any systematic trends that can be deduced from various wetland valuation studies conducted till date and also sheds light on parameters determining their value. About 46 studies were reviewed and data from 39 valuation studies were identified that had common grounds to allow inter-study comparisons. The paper starts with a brief overview on wetland valuation economics. The ecological functions as well as economic services provided by wetlands were analysed. These were the basis for valuation, also techniques used to place an economic value on wetlands was studied. The paper also provides a brief of meta-analysis as a tool which explores trends in the data, identifying sources of variability in wetland values. The paper ends with the authors concluding by reflecting on implications of the analysis for understanding of wetland values and also for research in this field in future.

Reference: Woodward, Richard T. and Yong-Suhk Wui. 2000. 'The Economic Value of Wetland Services: A Meta-Analysis', *Ecological Economics*, Vol.37, No.2, pp. 257-270. Available online at http://www.unepscs.org/Economic_Valuation_Training_Materials/06%20Readings%20on%20Economic%20Valuation%20of%20Coastal%20Habitats/23-Economic-Value-Wetland-Services.pdf (accessed in November 2011).

5.9 Water Pollution and Economic Growth: An Environmental Kuznets Curve Analysis at the Watershed and State Level

Post liberalisation in the 1990's, India's economy entered a new stage of development and this brought progress to many facets of the country. Along with the benefits of high growth, there have been problems like severe environmental degradation, due to this growth. Environmental pollution is one such critical problem faced by the people. This paper examines this relationship between economic growth and environmental degradation by using the variables of per capita income and water pollution in 16 states of India over a period of two decades (1981 to 2000). There are varied problems on assessing the effects of socio-economic variables on water quality, including a spatial mismatch of biophysical and economic data. While on one hand, water quality is measured at certain specific areas of a river, which may or may not reflect the effects of various economic activities within a watershed draining into that specific river, on the other hand, economic data are available for administrative boundaries and not at the watershed level, thus not matching watershed boundaries. Most Environmental Kuznets Curve (EKC) studies have focused on the national level and ignoring regional level biophysical and socio-economic differences, which are nonetheless important. This paper focuses on watershed and state levels and how to deal with these data problems. It also analyses relationship between income growth and water pollution.

Reference: Barua, Anamika and Klaus Hubacek. 2008. 'Water Pollution and Economic Growth: An Environmental Kuznets Curve Analysis at the Watershed and State Level', *International Journal of Ecological Economics and Statistics*, Vol.10, No. 8, pp. 63-78. Available online at http://homepages.see.leeds.ac.uk/~leckh/Barua%20and%20Hubacek%20EKC%20final%20version%20Preprint.pdf (accessed in November 2011).

Section 6. Water-Agriculture-Food-Ecosystem Linkages

6.1 Ecosystems for Water and Food Security

With expected global population to reach 9.1 Billion in 2050, the increasing impacts of climate change, sustainable use of water and ecosystems for food security would be the paramount challenges. It is important to gather a wider and improved understanding of how terrestrial and aquatic ecosystems function and their interrelation in the scenario of water availability and water quality. This will cause for modifications in the management of ecosystems and water within them, for food security. The current document is an important contribution to assess the important role of ecosystems in increasing resilience and providing food in a sustainable manner to future generations. We take an ecosystem perspective, where agro-ecosystems are considered as providers of food security and water, contrary to other studies that place ecosystems more at the negative spectrum.

Reference: Atapattu, Sithara, Jennie Barron, Prem Bindraban, Stuart W. Bunting, David Coates, Katrien Descheemaeker, Nishadi Eriyagama, Max Finlayson, Line Gordon, Elizabeth Khaka, Gareth James Lloyd, Fergus Sinclair, Elaine Solowey, Luke Sanford, David Stentiford and Lamourdia Thiombiano. 2011. 'Ecosystems for Water and Food Security', Background document and synthesis of United Nations Environment Programme (UNEP). Nairobi: UNEP and Colombo: International Water Management Institute. http://www.unep.org/pdf/depi-ecosystems-food-secur.pdf (accessed in November 2011).

6.2 The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management

The paper discusses regarding a new concept where water resources are considered into two types, (a) blue-water resource in aquifers, lakes, and dams, and (b) green-water resource as moisture in the soil. These are complemented by two water flows, (a) the liquid blue-water flow through rivers and aquifers, and (b) the green vapour water flow which goes back to the atmosphere. Traditionally, water-resource planning and management focus has been on liquid or blue water. This focus served the needs of engineers who were primarily involved in water supply and infrastructure projects. However, this blue water which has conventionally dominated water perceptions only represents one-third of the real freshwater resource, rains. Most of the water received as rainfall, returns to the atmosphere as vapour flow,

mainly through consumptive water use by the floral population. Therefore it is important that while analyzing food production, we need to incorporate this second form, rainfall that is absorbed naturally into the soil and flows back to the atmosphere. Finally, the paper concludes by stating that a mandatory development in IWRM is to include land use, thus emphasising Integrated Land and Water Resource Management (ILWRM).

Reference: Falkenmark, M and J. Rockström. 2006. 'The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management', *Journal of Water Resources Planning and Management*, Vol.132, No. 3, pp.129-132. Available online at https://wiki.umn.edu/pub/Water_Sustainability/ReferencesAttached/Falkenmark_and_Rockstrom.pdf (accessed in November 2011).

6.3 Agricultural Green and Blue Water Consumption and its Influence on the Global Water System

The paper represents a study enumerating, spatially explicitly and through a consistent modelling framework (Lund-Potsdam-Jena Managed Land) globally, the consumption of blue water withdrawn for irrigation from rivers, lakes and aquifers and green water through precipitation by rain-fed and irrigated agriculture and by non-agricultural terrestrial ecosystems. Also, individual effects of anthropogenic induced land area change and irrigation were quantified for assessing the total hydrological impact of agriculture in the last century globally.

Reference: Rost, Stefanie, Dieter Gerten, Alberte Bondeau, Wolfgang Lucht, Janine Rohwer and Sibyll Schaphoff.2008. 'Agricultural Green and Blue Water Consumption and its Influence on the Global Water System', *Water Resources Research*, Vol.44, pp. 1-17. Available online at http://www.gwsp.org/fileadmin/downloads/2007WR006331.pdf (accessed in November 2011).

6.4 Virtual Water Trade: A Realistic Concept for Resolving the Water Crisis?

A concept based on trade policy approach, “Virtual Water Trade” is discussed in the study, which envisages resolving the global water crisis. Varied opinions are now available on this approach and this concept is being debated globally and it is steadily gaining importance. This paper examines for the first time the concept of Virtual Water Trade comprehensively, including it being a multidisciplinary form and in varied scenarios. At the start, the concept of Virtual Water Trade is defined with its objectives from different perspectives including its practicability. There are for and against arguments on the perspectives, possible implications and consequences have been weighed and an attempt has been made to gauge the importance and needs to be attached to the concept. At the end the future relevance of the concept is discussed in relation to various countries globally and contributions which development cooperation can potentially make.

Reference: Horlemann, Lena and Susanne Neubert. 2006. 'Virtual Water Trade: A Realistic Concept for Resolving the Water Crisis?', Study report by the Federal Ministry for Economic Cooperation and Development. Available online at http://www.die-gdi.de/CMS-Homepage/openwebcms3.nsf/(ynDK_contentByKey)/ENTR-7BMEGX/$FILE/Studies%2025.pdf (accessed in November 2011).

6.5 Virtual Water in Food Production and Global Trade Review of Methodological Issues and Preliminary Results

The water consumed in the production process of an agricultural or industrial product has been called the 'virtual water' contained in the product (Allan, 1998). If one country exports a water intensive product to another country, it exports water in virtual form. In this way some countries support other countries in their water needs. Virtual water has not attracted much research so far. What are the volumes involved? Do these volumes represent a significant part of the blue or of the green water volumes used in agriculture? What are the current tendencies? Which are the countries exporting most of the virtual water and which are the ones that import it? Which are the products responsible for the most important transfers? There is even no clear methodology to evaluate the virtual water contents of food products. The present paper attempts to quantify these volumes.

Reference: Zimmer, Daniel and Daniel Renault. n.d.'Virtual Water in Food Production and Global Trade Review of Methodological Issues and Preliminary Results', Food and Agriculture Organisation water papers on virtual water. Available online at http://www.fao.org/nr/water/docs/VirtualWater_article_DZDR.pdf (accessed in November 2011).

Section 7. Ecosystem Based Management and Stakeholder Participation

7.1 The Sharing of Water between Society and Ecosystems: From Conflict to Catchment-Based Co-Management

To help minimise water shortage for humans and to prevent undesirable environmental impacts in the future, there is a requirement for increased equitable sharing of water resources between society and nature. This would necessitate placing quantities and social values on requirements of both human and aquatic ecosystems. The present water valuation systems are inclined towards economic values and the paper discusses new methods of quantification and valuation which increasingly factors of human well-being as well as environmental impacts. One of the methods to ensure effective implementation of such equitable water allocation methods is by considering catchment-based Integrated Water Resources Management models. Being a holistic framework, it better understands human and ecosystem water requirements and interactions between them. This understanding provides a suitable ground for including social factors which are actually relevant for water policies and laws to be developed that would make best use of the limited water resources available. Adoption of a catchment based co-management model would facilitate ensuring increased effective sharing of water between nature and humans.

Reference: Wallace, J. S, M. C. Acreman and C. A. Sullivan.2003. 'The Sharing of Water between Society and Ecosystems: From Conflict to Catchment-Based Co-Management', *Philosophical Transactions of the Royal Society,* Vol.358, No.1440, pp. 2011-2026. Available online at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1693290/pdf/14728795.pdf (accessed in November 2011).

7.2 Unpacking "Participation" in the Adaptive Management of Social–Ecological Systems: A Critical Review

Adaptive management can make environmental management more participatory through involvement of different stakeholders, thus making it democratic. This article is a study from three case studies which reflect different scales followed for adaptive management processes, critically reflecting role of stakeholder participation in each case. It specifically examines the stages where various stakeholders can play key roles and ways that each might be involved. Analysis shows that a plethora of participatory mechanisms could be employed at different stages of the adaptive cycle, and these can work together to create conditions for social learning and favourable outcomes for diverse stakeholders. This analysis highlights the need for greater reflection on the case study research in order to refine participatory processes within adaptive management, further. This should not only address shortcomings and successes of adaptive management as a form of democratic environmental governance, but should also unveil links between science, institutions, knowledge, and power.

Reference: Stringer, Lindsay C., Andrew J. Dougill, Evan Fraser, Klaus Hubacek, Christina Prell and Mark S. Reed. 2006.'Unpacking "Participation" in the Adaptive Management of Social–Ecological Systems: A Critical Review', *Ecology and Society,* Vol.11, No. 2. Available online at http://www.ecologyandsociety.org/vol11/iss2/art39/ (accessed in November 2011).

7.3 Climate Change, Adaptation and Adaptive Governance in Water Sector in South Asia

Historically, the South Asia region has been exposed to climatic extremes and following the phenomenon of climate change the vulnerability will possibly be higher in the future. Due to factors like low per capita income, absence of access to social capital, administrative and politically disconnected functionalities, coping capacity of major par of the population is limited. Studies available on the consequences of climate change on water show that there could be increase in floods frequency and droughts in the South Asia region, resulting in increased economic and social damage. The intensity of probable difficulties to be faced by people could be reduced by increasing their adaptive capacities by way of providing institutional support at various levels. This present paper dwells on the present status of both adaptation and coping mechanisms in the water sector of the South Asia region. The paper also discussed about the implications of climate change in the future and the processes by which adaptive governance in institutions will go a long way in reducing vulnerability and increasing adaptive capacities. Processes include climate focus development, and also mainstreaming climate change into development planning and institutional reform.

Reference: Mirza, Monirul. 2007. 'Climate Change, Adaptation and Adaptive Governance in Water Sector in South Asia', Paper presented for Amsterdam Conference on the Human Dimension of Global Enviromental Change, 24-26 May, Amsterdam, The Nethderlands. Available online at http://www.2007amsterdamconference.org/Downloads/AC2007_Mirza.pdf (accessed in November 2011).

7.4 Participatory Skills: Establishing and Strengthening Local Communities' and Indigenous People's Participation in the Management of Wetlands

The recommendation 6.3 from the 6th Conference of the Contracting Parties to the Convention on Wetlands (Brisbane, Australia, 1996) invited parties to make concerted efforts to encourage active and informed participation from local and indigenous people at wetlands which are Ramsar listed (Wetlands of International Importance) or otherwise. This handbook includes the Resolution, Annexed Guidelines and also the Resource Paper. It is intended to be an easily accessible reference material on implementation of participatory approaches in the context of wetland management. The guidelines in Section I provides a summary overview of the major lessons which have been learnt from global participatory management experiences and various steps taken in developing and implementing participatory approaches. In Section II, the resource paper covers the same subject matter in greater detail. Both sections make complete use of select case studies on successful local involvement.

Reference: Ramsar Convention Secretariat. 2010. Participatory Skills: Establishing and Strengthening Local Communities' and Indigenous People's Participation in the Management of Wetlands. *Ramsar Handbooks for the Wise Use of Wetlands 4th Edition, Vol. 7*. Gland: Ramsar Convention Secretariat. Available online at http://www.ramsar.org/pdf/lib/hbk4-07.pdf (accessed in November 2011).

7.5 The Role of NGOs and Civil Society in Global Environmental Governance

Five major roles that civil society can play in global environmental governance have been identified in this chapter, (a) Collecting, disseminating, and analyzing information; (b) providing inputs for agenda-setting and policy development processes; (c) performing operational functions; (d) Using environmental agreements to assess environmental conditions and monitoring compliance; and (e) advocating environmental justice. Three case studies of, the Crucible Group, TRAFFIC, and global ecosystem assessment processes illustrate the success NGOs have had in getting into these roles. Internationally decision making processes look forward to legitimacy by involving civil society, but surprisingly mechanisms for formal participation by NGOs within the UN system remain limited. It is high time ad hoc civil society participation should be replaced by a strengthened, more formalized institutional structure for engagement. The chapter comes up with concrete suggestions for such measures.

Reference: Gemmill, Barbara and Abimbola Bamidele-Izu. n.d. 'The Role of NGOs and Civil Society in Global Environmental Governance'. Available online at http://environment.research.yale.edu/documents/downloads/a-g/gemmill.pdf (accessed in November 2011).

7.6 Scaling up Community-based Co-Management of Wetlands and Fisheries in Bangladesh

The loss of wetlands, use of dry season surface in agriculture amongst other land uses, and increased exploitation of natural fisheries, has led to a threatened status for the rural poor of their principal diet (fish), which is also a major source of livelihood for millions. Although this is a common link amongst the natural fisheries status globally, Bangladesh has always managed to do that little bit extra like innovating local institutions that can successfully indulge in wetland management. It is a challenge as well as an opportunity to develop successful and working community based co-management arrangements that ensure sustainability of wetlands, fisheries which are productive and also which meet the needs of the poor. This paper focuses on scaling up challenges and how the same may be best achieved.

Reference: Thompson, Paul. n.d. 'Scaling up Community-based Co-Management of Wetlands and Fisheries in Bangladesh', Policy brief 7 of Management of Aquatic Ecosystem through Community Husbandry. Available online at http://pdf.usaid.gov/pdf_docs/PNADJ856.pdf (accessed in November 2011).

7.7 Natural Resource and Watershed Management in South Asia: A Comparative Evaluation with Special References to Nepal

The paper discusses various approaches adopted in watershed management programs in South Asian countries, with special reference to Nepal based on available literature and field study experiences. Degradation of watershed, a reality the in mountainous areas, is a critical problem for South Asian countries. Many developing countries, including those from South Asia have adopted a participatory approach in watershed and natural resource management during the past decade. This participatory community-based watershed management approach is viewed from two perspectives. One perspective is the success of conservation of natural resources with formation and strengthening of local level institutions in rural areas. The other perspective relates to multiplier effects in social mobilization, women

empowerment, community development and livelihood improvement and also includes good governance at local level. Presently, participatory watershed management must include environmental protection and also support for poor and disadvantaged segments of society in improving livelihoods.

Reference: Tiwari, Krishna R., Roshan M. Bajracharya and Bishal K. Sitaula. 2008. 'Natural Resource and Watershed Management in South Asia: A Comparative Evaluation with Special References to Nepal',The Journal of Agriculture and Environment, Vol. 9, pp. 72-89. Available online at http://www.moac.gov.np/publications/journal/10tiwari_etal.pdf (accessed in December 2011)

7.8 India: A Campaign for Conservation of Water Bodies by Water User Groups (#246)

The district of Tikamgarh, Uttar Pradesh has a large number of water bodies, generally used for irrigation, fisheries and drinking purposes. The water bodies include tanks constructed during the 8th and 9thcenturies till the present time. Presently, they are in utter state of neglect and at various stages of degradation, siltation and consequent reduction of storage capacity, with weed growth due to anthropogenic activities. The district also faced extreme scarcity of water during the years, from 2000 to 2003. Following this, the people including the district administration, realised the need for initiating concrete measures to restore these water bodies, with the district administration deciding to coordinate the programme. Within the period of a week activities such as de-silting, Ipomearemoval, removal of water hyacinth and red algae in 319 water bodies, construction of structures to preventsoil runoff and preparation of compost pits to promote recycling of organic waste, were completed. These activities had participation from water user groups, fishermen societies, self-help groups, urban, and rural local bodies without any monetary assistance from the district administration. This week long campaign demonstrated to be a catalyst for expansion of water conservation activities in the district for the future by community based institutions and for raising the “can do” levels among the dormant water user groups, who actually are managers of water resources under their jurisdiction.

Reference: Mukerjee, Aniruddhe. n.d. 'India: A Campaign for Conservation of Water Bodies by Water User Groups (#246)', Global Water Partnership Tool Box. Available online at http://www.gwptoolbox.org/images/stories/cases/en/cs%20246%20india.pdf (accessed in November 2011).

7.9 Protected Areas in Pakistan: Management and Issues

In Pakistan the continuing ecological trend of greatest concern is ecological loss, fragmentation and degradation of natural as well as modified habitats. Ecosystems considered important such as forests, freshwater and marine ecosystems have been lost or threatened with further destruction. As part of its efforts to conserve species and ecosystems, Pakistan has a network of 225 protected areas. These include nine wetland sites of international importance, also known as Ramsar sites. This paper identifies quite a number of important gaps and needs relating to management of protected areas in Pakistan which, can be filled through convincing and coordinated efforts across varied segments of society.

Reference: Khan, Zafar Iqbal.2003. 'Protected Areas in Pakistan: Management and Issues', *Journal of the National Science Foundation*, Vol.31, No.1 and 2, pp. 239-248. Available online at www.sljol.info/index.php/JNSFSL/article/download/3036/2428 (accessed in November 2011).

7.10 Gender and Stakeholder Participation (in Ecosystem Management)

There has been increase in gender inequalities, environmental deterioration, and deepening poverty. However, improvements in any one of the three aspects can influence improvements in the other two. One of the challenges in combining poverty, gender, and environmental analysis is because “gender” often disappears or is included into "social". In many instances in community or stakeholder participation, gender blind perspectives of "community/stakeholder” is resulted. Experience over the years suggests that participatory approaches and processes are not gender or power sensitive. Local participation is generally dominated by elders, wealthy people, from the dominant particular caste or ethnicity, and men. Women may feel inhibited from participating due to factors like workload, cultural norms which may require them to travel or speak in meetings and relations of respect and deference to elders and to men. The present lecture note finally advocates gender sensitive approaches to be promoted with meaningful involvement of and inclusion of all community members in resource development.

Reference: Goodrich, Chanda Gurung. 2007. 'Gender and Stakeholder Participation (in Ecosystem Management)', Lecture note prepared for the Staff training programme in Water and Ecosystem, held at Kathmandu, Nepal from November 26- December 3 2007. Available online at http://www.saciwaters.org/CB/water_and_ecosystem/lecture%20notes/new%20Notes_on_Gender_and_participation.pdf (uploaded in December 2011).

7.11 Women and Water Management: An Integrated Approach

To quote Dublin Principle 3, “Women play a central part in the provision, management and safeguarding of water.” There has been increased awareness of the importance a gender approach has in the areas of water supply and management (Francis, 2003). The present chapter investigates value of water systems and also looks at the reproductive and productive roles of women as they relate themselves to using and managing resources. It also delves into lessons drawn regarding role of women from recent experiences in policies and programmes.

Reference: UNEP (United Nations Environment Programme). n.d.'Women and Water Management: An Integrated Approach', in UNEP, Policy Series, Women and the Environment, pp.60-83. Available online at http://www.unep.org/pdf/women/ChapterFive.pdf (accessed in November 2011).

7.12 Role of Mountain Women in Environment Governance in India

This paper focuses upon potential of women movements and networks to influence principles and practices of Global Environmental Governance (GEG). It is maintained that, principally, women are uniquely placed to oppose dominant norms informing GEG; and that women participation would be crucial to achievement of equitable and environmentally sound forms of governance. In practice, number of factors combined to create divisions between women, and hence impede trans-national mobilization by women around environmental issues. Women who live in rural or mountain areas have special relationship with the environment. The first objective of the paper is to highlight the importance of mountain women in the management of sustainable ecosystem. The second objective is to increase role of women in decision making processes. The third objective specified the need to establish a Mountain Women Forum at the global level which can provide a common platform for women from various regions of the world to exchange and share their views, ideas, issues, problems, priorities and also learn from others experiences.

Reference: Tyagi, Rani.n.d. 'Role of Mountain Women in Environment Governance in India'. Available online at http://www.ecoinsee.org/fbconf/Sub%20Theme%20F/rani_tyagi.pdf (accessed in November 2011).