Interdisciplinary approaches to catchment risk management: case studies of Timor Leste and the Solomon Islands

Bronwyn Powell[1], Peter Davies[2], Graham Costin[1], Morgan Wairiu[1] and Helen Ross[3]

1. International WaterCentre
2. University of Western Australia
3. University of Queensland

Abstract

The need for integrated and interdisciplinary management of water resources and catchments is well-recognised internationally. However, achieving these management outcomes is often hindered by poor understanding of the social, environmental and economic context and interactions within a catchment. This paper describes work being undertaken by the International WaterCentre (IWC) for the Australian Water Research Facility (AWRF), funded by AusAID, to research critical issues of interdisciplinary approaches to water and catchment management.

In late 2005, the University of Queensland, University of Western Australia, Griffith and Monash formed the International WaterCentre (IWC) in recognition of the skills of Australian researchers to contribute to sustainable and integrated water management internationally. The conceptual scientific underpinning adopted by IWC is a whole-of-water-cycle approach; that addresses the integrated nature of water across environmental, economic and social dimensions. The water cycle is considered as a closed loop with numerous factors impacting on it. Within this conceptual framework, the AWRF is focusing on water research in predominantly the “fragile” nations of the Pacific region.

Specifically, these developing countries are fundamentally challenged to manage water and reconcile a wide range of objectives such as public health, provision of sufficient water for drinking, food security, agriculture, industry, and ecosystem health. Typically, previous investigations have focussed only on fragmented aspects of water management leading to (a) a high potential for conflict in the allocation of scarce resources for multiple objectives, and (b) incomplete or ineffectual on-ground implementation. The conceptual underpinnings of the ‘whole-of-water-cycle’ approach provide a basis for concurrent consideration of multiple objectives. Within the research being undertaken by AWRF in Timor Leste and the Solomon Islands are case studies to identify where risk “resides” in the water cycle.

1 Introduction and Overview

The need for management of natural resources catchments in an integrated and interdisciplinary fashion is well-recognised internationally (Ekasingh and Letcher 2005). However, achieving these management outcomes is often hindered by poor or incomplete understanding of the social, environmental and economic interactions within a catchment. Interdisciplinary boundaries for the study of complex interactions are well-recognised but overcoming these for real environmental problem solving remains difficult. Consequently, an integrative conceptual framework, that provides a broad understanding of interactions at a catchment scale, is a necessary starting point for work of interdisciplinary teams.

The conceptual scientific underpinning adopted by the International WaterCentre (IWC)[1] is a whole-of-water-cycle approach that addresses the integrated nature of water across environmental, economic and social dimensions. The water cycle is considered as a closed loop with numerous factors and risks impacting on it. In undertaking research for the AusAID funded, Australian Water Research Facility (AWRF), the IWC team is building a spatially based conceptual framework which is general enough for application in any catchment situation (Ross et al. 2006). As a broad starting point, the 'whole-of-water cycle' conceptual framework allows interactions to be mapped by project teams addressing specific problems in conjunction with stakeholders affected by those problems. This conceptual framework and its application should be considered a work in progress; the framework will be refined as further research is undertaken in the Solomon Islands and Timor Leste.

The research team has been asked to focus on the 'fragile' nations of the Pacific region, and case studies have been chose in Timor Leste and the Solomon Islands. Both of these countries are challenged to manage water and reconcile a wide range of often competing objectives including public health, drinking water, food security, agriculture and industry, and the maintenance of ecosystem services. Typically, previous investigations have focussed only on fragmented or a single aspect of water management leading to: (a) the potential for conflict in the allocation of scarce resources for multiple objectives, and (b) incomplete or ineffectual on-ground implementation. Consequently, the conceptual underpinnings of the 'whole-of-water-cycle' approach provide a basis for concurrent consideration of multiple objectives.

Civil unrest in both Timor Leste and the Solomon Islands during 2006 have hindered our teams' on-ground activities although early analyses of key issues facing water management have been undertaken through broad stakeholder consultation. This paper maps these issues against the conceptual 'whole-of-water cycle' framework.

2 Framework for whole-of-water cycle catchment risk management

The underpinning logic of our framework is that of the water cycle. The physical aspects of the water cycle are considered; rainfall, surface, subsurface and groundwater flows, and evaporation to reconnect the cycle. Whilst interacting with soils, climate, vegetation, surface or underground storages, water is continuously moving through the hydrological cycle. These natural processes are described by the hydrological cycle (Figure 1).

[1] In late 2005, the University of Queensland, University of Western Australia, Griffith and Monash formed the International WaterCentre (IWC) in recognition of the strategic importance of sustainable and integrated water management.

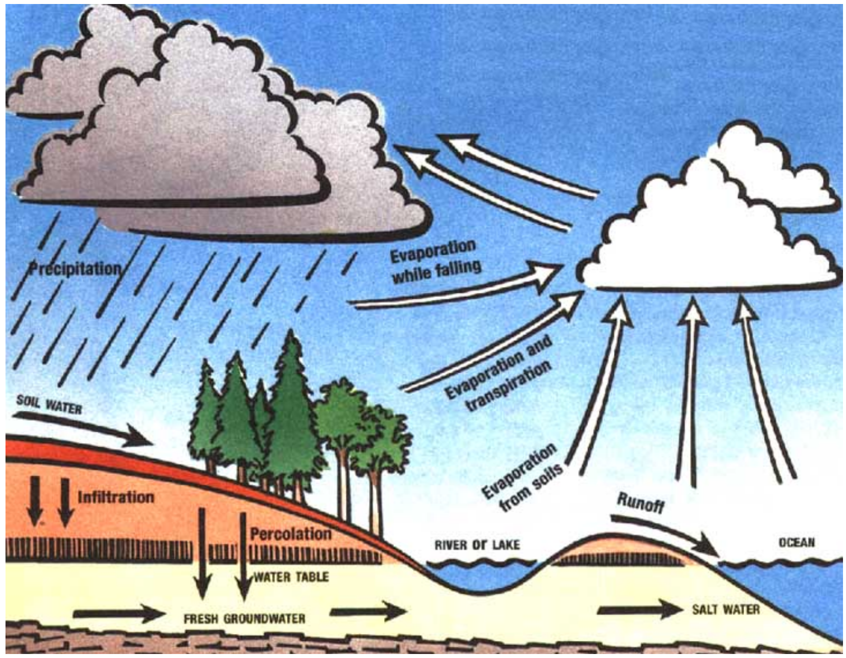

Figure 1. The initial basis for a whole-of-water cycle approach is the hydrological cycle depicted here (FAO 2006)

These physical water cycle provides the context for a complex overlay of human and environmental uses, and forms the whole-of-water-cycle approach. Abstractive uses include drinking, food production (crops and livestock), industry and manufacturing and non-abstractive include leisure and aesthetic enjoyment (see Figure 2). Modifications to the water cycle include inter-basin transfers, channelling, extraction, storage, irrigation, urbanisation, regulation, water treatment and waste water disposal systems.

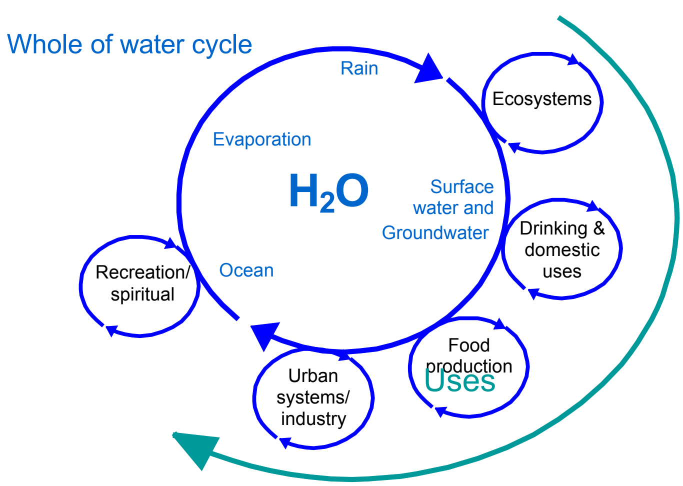

Figure 2. Whole-of-water cycle showing aspects of the hydrological cycle and water uses in human and natural ecosystems

Catchment-based schematics

The next stage for application of the framework is spatial mapping as a framework for identifying catchment-based interactions. The conceptual framework being developed by our team is necessarily spatial as this assists interdisciplinary work and allows thinking at multiple scales. There are a range of elements to the natural system and human system that can be mapped spatially and take advantage of Geographic Information Systems (GIS) technology. For example, natural systems can include:

- *Topography (e.g. digital elevation modelling)*
- *The stream and water body network, including lakes and wetlands, estuaries and coasts*
- *Aquifers and underground water*
- *Ability to add 'natural' layers of interest, e.g. climate, seasonal and inter-seasonal weather patterns; vegetation cover and types; species e.g. birds in their vegetation and water habitats; human-formed land uses and land cover e.g. agriculture, settlements*

Our team has described human modifications to the water cycle in line with a hierarchy of human needs (Maslow 1943)[2]. Research teams can add 'layers' of information of interest to their research issues, considered in relation to parts of the water cycle and to space.

Water in human modified systems covers uses, by order of hierarchical need as:

1. *Drinking and domestic water use and wastewater treatment*
2. *Food production: subsistence or large-scale which includes rain fed agriculture, irrigated agriculture, stock watering systems, water in agribusiness, etc.*
3. *Urban and industrial uses*
4. *Water resources in recreation, spiritual fulfilment and self-actualisation*

For all of these systems, it is important to know about:

- *Quantity of water through all of these, e.g. flow rates in streams, quantities of water discharged, seasonality of flows; and*
- *Quality, e.g. water quality at different points and times in the system.*

Environmental needs for water

Since the previous sections describing systems associated are inevitably anthropocentric, it is important to consider environmental needs for water. Water stresses on ecosystems can occur naturally, or be influenced by human activities. For ecosystems to retain health and ecosystem function a critical amount of water is required. Humans and other species benefit form the maintenance of essential ecosystem functions such as clean air and water, nutrient cycling and the ability of healthy ecosystems to assimilate wastes.

[2] Maslow argues that all individuals and societies need to meet five key needs, with the higher order needs becoming less relevant when the most basic needs are under threat. These are: (1) survival (water, food and shelter), (2) self-esteem, (3) social needs, (4) the respect of others, (5) self-actualisation (fulfilment). Thus water can be considered in terms of its contributions to survival needs, but also to social and self-fulfilment needs including spiritual dimensions.

Introducing the spatial element

Once an understanding of how human and natural interactions operate within a system is formed, it is possible to identify key values and assets within that system and consequently risks in the system. Figure 3 shows a schematic catchment with some layers of interactions included.

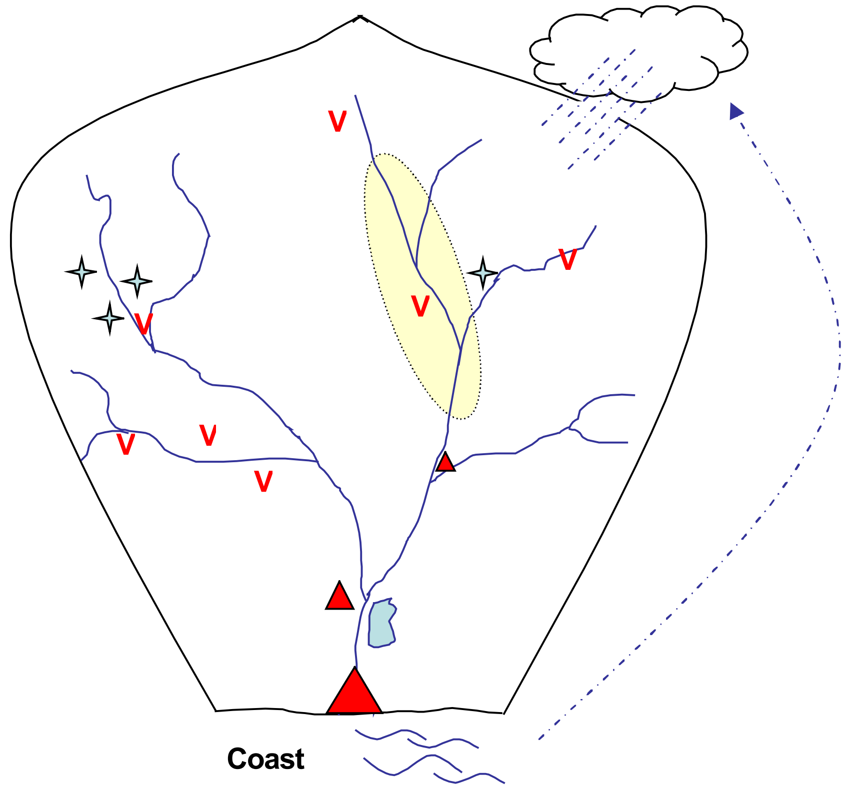

Figure 3. This figure shows a catchment scheme showing the hydrological cycle (stream network, lake, aquifer, springs, evaporation and rain) and human habitation (villages and larger urban centres).

3 Applying the conceptual framework

The conceptual framework of whole-of-water cycle mapped spatially and overlayed with water uses is a broad starting point to develop mutual understanding for water-related issues. With this framework as a foundation and common understanding, it is possible to develop more detailed modelling, problem solving and risk analysis. The framework is general enough that any of a range of research approaches and tools (systems dynamics, causal loops, etc) can be applied to develop further understanding around particular issues.

Developing a conceptual framework around a specific catchment or issue through participatory processes can assist water managers prioritise actions, and it has been demonstrated that interdisciplinary teams of researchers are well placed to facilitate this (Ekasingh and Letcher 2005). Applying a framework at a local level enables closer analysis of the interactions between social, economic and ecological problems (Keen and Lal 2002).

In the AWRF research in Timor Leste and the Solomon Islands, the conceptual framework will assist in building a mutual understanding of a selected catchment by water users and managers and the interactions within the system. The initial work undertaken for this research has involved a desk study and in-country visit to ascertain:

- *major water issues facing these countries and pressing research questions*
- *interest from local partners to collaborate on research*
- *the extent of data available to support research activities*

Whilst there is recognition for the need for interdisciplinary approaches in both countries[3], meeting basic needs takes priority, often considered in a single-disciplinary way.

The Timor Leste National Development Plan recognises*:*

> *"real lasting poverty reduction is only possible if the environment is able to provide the service people depend on, and if natural resources are used in a manner that does not undermine long-term development".*

Early work shows that human health concerns and safe water supply and sanitation unsurprisingly take precedence over the development and use of integrated water management approaches. Nonetheless, each context is showing stress and requiring integrated solutions even for solving basic problems. In addition, early approaches of water management fail to recognise the linkages between ecologically healthy rivers and streams and human health. The two countries are presented separately, with issues mapped against the key uses described in the above conceptual framework. The authors note that this is a preliminary study and not an exhaustive list; it is a guide for further research.

4 Timor Leste context

Timor Leste is the newest and poorest nation in Southeast Asia, gaining its independence from Indonesia in 1999. Timor Leste was colonized and controlled by the Government of Portugal for over 400 years until the Portuguese withdrew in 1975. Following a very brief period of independence, Timor-Leste was annexed by the neighbouring Government of Indonesia. A strong faction of the population continued to resist Indonesia's occupation, and in August 1999, a UN supported popular consultation voted for restoration of independence. Following several months of widespread violence between pro-Indonesian militia and the pro-independence faction, and extensive vandalism of public and private property, Indonesia ceded control to a United Nations Transitional Administration (UNTAET) in Nov. 1999. Timor-Leste's restored independence was internationally recognized on in May 2002.

Timor-Leste moved out of an emergency relief and reconstruction situation into more well planned development phase from 2002-03. However, following the downscaling of United Nations transitional capacity and peacekeeping support, many of the population became dissatisfied with the perceived slow progression of the nation. This dissatisfaction, in combination with political power struggles and historical geographical division (East vs West), resulted in the eruption of civil violence in May 2006. Violence is still continuing albeit at a much lesser scale after the intervention of Australian, New Zealand and Portuguese peacekeepers.

The new nation suffers from limited on-shore natural resources, very limited government capacity and poor public infrastructure and services.

---

[3] There is provision for an interdepartmental Natural Resource Coordinating Committee in Timor Leste and the Water Sector Steering Committee in Solomon Islands.

Water in Timor Leste

It is estimated that approximately five km^3 per year of water flows down the rivers of Timor-Leste, and about one km^3 per year passes through the groundwater system which is estimated to store 100 times this amount (ADB 2004). This is a huge volume of water to meet the needs of the Timorese people, however the availability of this water is very unreliable over time, uneven from place to place, and in the case of deep groundwater, expensive to access.

Many areas of Timor-Leste are "water wealthy" during the wet season and during wetter years.. However, at other times, they are "water stressed", with a shortage of water for human welfare, economic activity, and the natural environment. As the population grows and the Nation rebuilds, undoubtedly greater demands will be placed on water resources, and consequently water stress will increase.

In Timor-Leste, the removal of forest cover by "slash and burn" agricultural practices, and timber and firewood harvesting, has, in many areas, exposed the soil to high levels of erosion by both rainfall and subsequent overland flow. This has resulted in excessive soil loss on slopes, siltation of riverbeds, increased water turbidity, degradation of water quality, rapid water runoff, and flood damage to land and property downstream. The climate and geological conditions result in localized flash flooding and landslides are very common throughout the country. In other countries of Asia and the Pacific, these conditions have clogged estuaries and coastal wetlands and damaged offshore coral reefs, with severe impacts on these highly diverse and productive ecosystems.

In Timor-Leste there is concern that current forest removal, land use and sanitation practices will reduce the availability and quality of the nation's water resources. In many locations, soil erosion and pollution has made the resource frequently unsuitable for safe domestic consumption unless costly water treatment processes are employed. Short-term urban water shortages are common, particularly following heavy rains when high sediment loads in streams make the water unsuitable for treatment.

As the economy of Timor-Leste develops it will increasingly rely on water for economic purposes other than household consumption or domestic food production. It will use water as a raw material in industry, for generation of electric power, and for aesthetic values for eco-tourism pursuits.

Water is an essential and often integrating component of the natural environment, supporting biodiverse assemblages aquatic fauna and ecosystem processes in rivers, lakes, wetlands and estuaries. These have intrinsic (i.e. "existence") values, and contribute to biological diversity. However, relatively little is known of the aquatic ecosystems of Timor Leste, and consequently natural biodiversity may be lost before its' values can be fully determined.

The importance of water for human health and economic development, its role in ensuring the continuing amenity and health of the natural environment, ecosystems and biological diversity, and its intimate connections with other natural resources, all mean that Timor-Leste must pay particular attention to the way in which it manages its water resources.

Some of the more obvious examples of potential conflict and environmental degradation include the following[4]:

- Upstream agriculture may take a disproportionate share of water resources to the detriment of downstream agricultural and industrial users and urban and rural households.
- Pollution from urban waste may damage the coastal zone, causing great damage to fish-stocks, destroying local economies and livelihoods.

---

[4] Government of Timor Leste. 2003. *Natural Resources and Environment Sector Investment Program.*

- Degradation of upstream forests and watersheds for short term gains may lead to soil loss and disruption of the hydrological cycle, causing downstream damage, floods and droughts.

The Natural Resources and Environment Sector Investment Program (SIP) identified the many uses of water in Timor-Leste as a potential conflict (as observed in other countries), and notes increasing population growth and economic development will tend to increase these conflicts, notably between rural and urban users, and between upland and lowland uses. The SIP notes that as the population grows and as economic activities increase this system may come under greater strain.[5]

Table 1. This table maps keys issues for water in Timor Leste mapped across the whole-of-water-cycle conceptual framework categories.

Framework	Key problems/gaps/issues
Natural systems	
	Risks from drought and climate change poorly understood and not considered in government policy and planning
Water Resource	Lack of information on water resource to know sustainable yield or on which to base government planning (including District planning which is currently occurring based on infrastructure availability and political imperatives).
	No long-term data showing trends in water resources. This kind of information would become useful in 10 or 20 years time for long-term planning e. g. don't know how long supply to Dili will last.
	Groundwater contamination in urban areas is thought to be an increasing problem. What are the sources and causes of groundwater contamination in rural and urban areas?
	Catchment issues
Ecosystem Function	Erosion is a major issue. How many tonnes of soil are lost every year, and where is the worst erosion? Where is this material deposited?
	Some key threats to watersheds are: illegal logging, forest fire, slash and burn farming practices, overgrazing and confusion over land tenure. What is the relative and cumulative impact of each of these pressures?
	Communities are willing to put significant effort into risk mitigation (e.g. groins on rivers for flood prevention), but there isn't any mechanism for coordination or early warning system from top of catchment to bottom. What would facilitate this inter-catchment cooperation?
Human Systems	
Drinking and domestic supply	**Water supply and sanitation**
	Water supply systems do not adequately consider future demand and resource availability
	Service standards for delivery are central for selling water (e.g. in Dili). What are reasonable service standards for Timor Leste?
	Timor Leste to make sustainable use of the water resources

[5] For example the SIP quotes the following example: the country's largest coffee processing factory shares its water supply with a local village, which is important economically in the village. As a result of the bumper coffee harvest in 2002, the factory took more water and there was insufficient for villagers.

	Is there potential for rainwater to be stored?
	There are traditional beliefs about disease from rainwater
	Under the community water supply and sanitation program communities are expected to meet the maintenance costs of their supply system through charges through locally established water management groups. How much can communities really afford to pay to maintain their water supply system?
	Water supply systems under CWSSP have only taken into account drinking water supply (30L/pp/day). This is insufficient for crops and livestock, so designs and CAP process needs to take this into account (increase design for 45L/pp/day)
	Health related issues
	Kidney stones are thought to be a common problem from calcium in the water
	Increasing, but poorly maintained, water supply can increase mosquito breeding
	There is no evidence that the extensive amount of energy being spent on environmental health promotion (UNICEF, etc) is working
Survival: Food production	What are the linkages between water availability and food security?
Institutional	**National coordination, capacity building and knowledge management**
	The water activities of the various Ministries are not coordinated toward National objectives at present. How can this best be achieved?
	Lack of Government capacity to gather and store data on water resource
	Project information and research currently dispersed with no central repository or way of disseminating/accessing information within Timor Leste
	Community management
	Are there economic incentives for cooperation for the management of water and other natural resources? How can these be demonstrated? What are the drivers for collective action?
	Poor understanding of community management of water resources, and no government policy.
	Lack of social capital to assist in the functioning of water management groups
	How do traditional customs and practices impact on the management of natural resources (e.g. *lulic* and *tara bandu* practices) affect the management of water? How is this related to water supply systems their success and/or failure? Can this link into the Community Water and Sanitation Guidelines and how?
	Is the supply of water benefiting community members equally? i.e. are the livelihoods/health/etc of the very poor being improved?
	Why are weaknesses in the management of common resources (e.g. water, grasslands, etc)?

5 Solomon Islands context

The former 'British Solomon Islands Protectorate' achieved independence from Britain on 7 July 1978 and became the Independent State of Solomon Islands. The Solomon Islands has failed to achieve a level of political maturity sufficient to permit the formation of stable governments. There has been a high turnover of governments – ten in twenty-three years – and seven Prime Ministers. In recent years, the Solomon Islands has experienced considerable unrest and economic decline, the roots of which stretch back to colonial days. Serious civil unrest on the largest island of Guadalcanal, which has a large migrant population from the most populated island, Malaita began with armed conflict in late 1998, leading to a state of emergency in June 1999 and a coup in June 2000. The Townsville Peace Agreement (TPA) was signed in October 2000 between the two warring parties, Isatambu Freedom Movement and Malaita Eagle Force. Despite the peace agreement, unrest only ended with the arrival in July 2003 of the Australian-led Regional Assistance Mission to Solomon Islands (RAMSI). However, the root causes of the tensions largely remain. This was demonstrated in the tensions and destruction following the elections of May 2006.

The Solomon Islands is a collection of nearly 1000 islands totalling 28,450 square kilometres (km^2), of which land accounts for 27,540 km^2, dispersed over 800,000 km^2 of sea. By end of 2005, the population of the Solomon Islands was estimated about 457,000 at an annual growth rate of 2.8%.

Water in the Solomon Islands

Solomon Islands has abundant rainfall and water resources in nearly all provinces which could be developed to provide adequate and quality water supply to the entire population. However, the prevailing environment is such that there is low economic growth coupled with rapid population growth, and a government which is poorly-resourced, weak and inefficient in service delivery. These are major obstacles to development.

Many households in the country do not have access to water supply systems and still rely on stream and rivers to obtain water for drinking and other household use. Women and in most cases children perform household work and this involved extra workload and responsibility.

Indiscriminate land clearing through subsistence food production, for plantation and commercial logging is resulting in drying up and sedimentation of river and streams systems. Even if water supply systems are built, high sedimentation in river systems often clogs the pipes making the water dirty for drinking and household use.

Land tenure system often results in land disputes associated with water supply in the provinces and often resulted disruption to installation of water supply systems, damage and vandalism of water supply infrastructure.

No maintenance and servicing of existing water supply systems and ground water wells have ever been carried out by either the communities concerned or responsible authorities and as a result most water supply systems require repair and rehabilitation.

The groundwater in wells of most coastal villages and those on atoll islands ground water are saline. High rainfall is high in some areas like Guadalcanal "weathercoast" often affect crop growth and thus food supply tends to be disrupted in the wettest months. This is particularly marked in years where the rainfall is especially high (e.g. 2004).

The poorly-resourced Water Resources Office is a barrier to successful water resource research and development. The Division has only four officers and development of a reliable and good quality water system has never been viewed as a government priority.

One of the main issues of concern to current institutional arrangements is fragmentation of policies and plans which resulted in little co-operation among organizations responsible for water resources. This process has not adequately addressed water resources, sometimes leading to conflicting mandates and objectives at the national level.

The lack of appropriate legislation, approved water policies, guidelines and regulations form a significant barrier to the planning and development of proper water supply facilities in the country. Resources are inadequate, supply and regulation are all neglected. The Solomon Islands Water Authority (SIWA) struggles to survive and fights daily to keep maintain water supply to town residents. There is ongoing problem with inadequate water supply in towns (Honiara and Gizo) due to increasing water demand, old and deteriorating water infrastructure. There have been incidences of water contamination and, in the past, this has made the water unsafe for human consumption in Honiara and other urban centres.Landowners especially for Honiara often caused disruption to water supply at source due to dissatisfaction over lack of up to date payment of water lease by Government.

The Environmental Health Division only carries out water quality analysis to facilitate rural water supply installation and not during time of use. There is risk to water being contaminated as most reservoir tanks at source are open and unfenced. Some catchment areas are being disturbed through land clearing and logging causing high sedimentation in the river system. Villagers sometimes complain about dirty drinking water in their water supply systems.

Table 2. This table maps keys issues for water in the Solomon Islands mapped across the whole-of-water-cycle conceptual framework categories.

	Key problems/gaps/issues
Natural systems	
Water resource	Climate change impacts on rainfall, runoff, streamflows, and seawater levels unknown etc
	Honiara source has seen a drop in water availability in the catchment (50%) reduction in dam, but not sure why.
	Catchment issues
Ecosystem Function	Inadequate planning to control development in catchments and conflicting legislation (i.e. granting of development rights, logging license in catchment or conservation area)
	Erosion and downstream effects from logging operations on water supply/ water quality/reef/mangrove areas/fisheries/ etc.
	Effect of this erosion and subsequent turbidity on aquatic biodiversity
	Poor understanding of cause and effect of logging/erosion/ downstream effects on reefs/fisheries/etc amongst loggers. Uncertainty of where eroded material is deposited.
Human Systems	
Drinking and domestic supply	**Water supply and sanitation**
	Water and land ownership are a major source of conflict affecting supply.
	Lack of awareness that water is for everybody (rel. to ownership)
	High losses and leakage through water supply systems

	Maintenance of Rural Water Supply and Sanitation systems (RWSS)
	Need for better baseline information for RWSS planning
	Pollution problems increasing with rapid population growth
	Cultural understandings and beliefs about water and sanitation
Health and livelihoods	Health (particularly malaria and skin diseases) related to water supply and sanitation
Institutional	Important to understand the cultural constraints that prevent behavioural change with respect to sanitation.

6 Conclusion

This paper has applied a conceptual framework for interdisciplinary approaches to catchment research to water management issues in Timor Leste and the Solomon Islands. The framework enables a focus on the *systems* of relationships between societies and water usage, in a way that assists recognition of risks. It can also be used to support water development planning, or impact assessment. A strength of the framework is that it considers direct uses of water, alongside the institutional arrangements, cultural and economic factors which influence those uses. The general nature of this framework means that it can be applied to 'developing country' contexts, particularly where information on water resources may be scarce.

While both Timor Leste and the Solomon Islands have abundant water resources, at least at certain times of year, the high seasonality of water means that areas are short of water during dry seasons and little is understood about potential impacts of climate change. There also serious concerns about the sufficiency of water for the projected development of the capitals Dili and Honiara. Adequate water for competing needs of agriculture, human consumption, hydropower and other uses will are increasingly pressing issues as the countries develop.

The next stages of research will involve:

- *In-country collaboration to assess the water-related systems of particular catchment or sub-catchment areas*
- *Mapping linkages between catchment uses, values and risks*
- *Working with water managers and users to manage risks*
- *Continuing to learn with other regional programs (e.g. SOPAC Regional Integrated Water Resources Management program)*
- *Refining the framework into an approach useful across the Asia-Pacific region.*

References

ADB (2004) *Water Availability and Water Demand.* Hydrology and Hydrogeology of Timor-Leste, Asian Development Bank TA: TIM 3986

Costin, G. and B. Powell (2006) *Timor Leste Situational Analysis (*Report) Australian Water Research Facility. International Water Centre, Brisbane.

Ekasingh, B. and R.A. Letcher (2005) Successes and Failures of Attempts to Embed Socioeconomic Dimensions in Modelling for Integrated Natural Resource Management Lessons from Thailand. *Proceedings of the International Congress on Modelling and Simulation MODSIM2005,* MSSANZ , Zerger, A., Argent, R.M. (Eds) Melbourne, Australia , 12-15 December 2005 , 1-10 .

Food and Agriculture Organisation of the United Nations (FAO) *Water: a Finite Resource.* Accessed 26 August 2006 from http://www.fao.org/docrep/U8480E/U8480E0c.htm

Government of Timor L'Este (2003) Natural Resources and Environment Strategic Investment Plan.

Keen, M. and P. Lal (2002) Creating supportive frameworks for community based resource management. *Development Bulletin*, 58, 46 – 51.

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review*, 50, 370-396

Ross, H., J. Robinson, B. Powell, R. Johnstone and T. Chiffings (2006) Conceptual framework for catchment-scale integrated water resource management. Riversymposium conference paper

Wairiu, M. and B. Powell (2006) *Solomon Islands Situational Analysis* (Report) Australian Water Research Facility