Concept Paper for a Dam-related Hazard Warning System in Sri Lanka

A Participatory Study on Actions Required to Avoid and Mitigate Dam Disasters

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Table of Contents

List of Annexes

Background

Based on research and consultation, this paper concludes that Sri Lanka requires an empowered and efficient dam hazards unit to serve as the focal point of a comprehensive, multi-stakeholder safety program for Sri Lanka's dams and related structures and a stable and adequate funding mechanism to ensure maintenance and safety. The paper covers dam-related risk assessment, critical elements of safety/disaster planning, areas of engineering and technical oversight successes and failures, the current status of dam management, the potential dam safety uses of information technology use, and economic and governance issues.

The need for this project arose in the course of disaster-management expert consultations carried out by LIRNE*asia* and The Vanguard Foundation in the preparation of "NEWS-SL: A Participatory Concept Paper for the Design of an Effective All-Hazard Public Warning System." It was developed in a participatory, consultative, and transparent process.

An interim draft was compiled on the basis of research and an Expert Consultation held 20 May 2005 at the Distance Learning Center located on the campus of the Sri Lanka Institute of Development Administration, with participation from experts representing several decades' worth of experience in several key Sri Lankan dam administration authorities.

This draft was posted for comment on the Internet. A significant number of important comments and suggestions were received and have been incorporated into the final paper.

Subsequent to the interim paper, LIRNE*asia* and the Vanguard Foundation, in association with Sarvodaya and community leaders, conducted town meetings in three major Sri Lankan cities that lie in the flood path of the Mahaweli dam system, Kandy, Gampola (http://www.lirneasia.net/2005/07/town-meetings-in-kandy-gampola/), and Polonnaruwa (http://www.lirneasia.net/2005/07/3rd-dam-safety-town-meeting-polonnaruwa/). A short video about the experiences of survivors of the Kantale breach of 1986 made by Divakar Goswami was shown at these meetings and further circulated in the regions. These meetings sought to raise awareness of the information herein contained and to generate and receive input from this most important set of stakeholders. They served to educate the public and motivate them to support dam safety initiatives. The received input has been incorporated in the final paper.

In the face of low media interest in the town meetings conducted outside Colombo, a news conference was organized in Colombo, at the Sri Lanka Foundation Institute on 10 August 2005. In addition to the Lessons from Kantale video, the news conference was addressed by community leaders from Kandy,

Gampola and Polonnaruwa, as well a representative of the Committee on Large Dams http://www.lirneasia.net/2005/08/dam-hazard-press-conference-august-10-2005/. This resulted in significant media coverage.

Executive Summary

1.1 The dam network in Sri Lanka comprises over 350 medium and large dams, and over 12,000 small dams. Today, dams and their complementary structures shape Sri Lanka much as they did thousands of years ago. Maintenance, safety oversight, and usage rights are shared among several Ministries, Authorities, organizations, and informally stake holding nearby populations. This is natural given the multiple uses of, and demands placed on, the dam system. However, there is a great need for improved oversight of the dam system and the proper coordination of functions, especially related to safety.

1.2 Among the possible negative outcomes of under funding of and lack of emphasis on dam asset management (including operation and maintenance) are catastrophic failures of dams resulting in loss of life and property damage to the environment, affecting the well-being of the community including loss of the benefits provided to the dam. These negative outcomes can be caused by the incorrect or lack of proper operating and maintenance procedures, and lack of maintenance and required upgrades to relatively new or ageing dams, minimal education of vulnerable populations on the risks and responsibilities of those living in the shadow of dams, and poor disaster response plans. Most seriously, it appears that inadequate priority is being given to the proper maintenance and periodic upgrades of dam structures, and that the existing financial arrangements are quite unsatisfactory. Given the number and widespread distribution of dams in Sri Lanka, it is clear that the affected populations and sectors are many, and that the effects of dam-related hazards can be very serious. In the opinion of the experts the current financial, operational and regulatory arrangements are unlikely to prevent the occurrence of dam-related disasters and may even contribute to them.

1.3 The key to effective dam safety is an adequate and properly resourced dam safety program that ensures:

1.3.1 That the dams are operated and maintained in a safe manner (that correct standing operating procedures for normal operation and maintenance and emergency operating procedures are in place to manage emergencies and these procedures are reviewed annually). Operators must be trained and competent.

1.3.2 That the nature of the hazard posed by each dam is known and regularly reviewed (Dam break studies are done and the population at risk identified and possible damage to property and other infrastructure identified and costed). The hazard category of each dam must be identified.

1.3.3 That dam surveillance programmes appropriate for the hazard category are implemented.

1.3.4 That dam safety emergency plans are prepared and where appropriate warning information and inundation maps are

provided to emergency response agencies to assist in downstream emergency planning and response by these agencies.

1.3.5 That appropriately qualified, trained and experienced personnel are engaged on dam design, construction, operation and maintenance and on dam inspections and surveillance.

1.3.6 That suitable regulatory and governance structures and internal reporting procedures are in place.

1.3.7 That dam safety reviews are undertaken at the appropriate time (despite appearance of invulnerability, dams do age with time. The design bases on which they were designed will also change with advances in knowledge and technology. Hence comprehensive reviews of the structural, hydraulic, hydrological and geotechnical design of dams and their behaviors (through records of operation and maintenance and surveillance records) should be undertaken.

1.3.8 That dam safety risk assessments are undertaken and risks addressed on a priority basis (by required dam upgrades).

1.3.9 That the dam safety program be quality assured by periodic independent review.

1.3.10 That includes making the public aware of dams and dam safety issues and consulting the public about their concerns.

1.4 Early detection of signs of distress is critical to effective dam safety. If the weakening of the structure is detected very early, remedial measures may be taken to repair it and prevent it from becoming a hazard. Even if the detection of structural problems occurs relatively later, action may be taken to mitigate its effects, for example by lowering water levels. Even if it is detected a few hours prior to a breach, that would still allow for action to save lives and property.

1.5 It is accepted that human observation and judgment is critical to effective dam safety programs. But this must be supported and complemented by modern instrumentation. At present, dam hazard detection and monitoring devices are not in wide use in Sri Lanka, the most common methods being simple visual inspections conducted for the most part by inadequately prepared, lower-level staff. The Kantale dam was visually inspected six months its breach to no avail. The actual breach was detected by a villager. The most advanced equipment was installed at Lunugamvehera, one of the most recent large dams, but they have not been maintained in optimal condition subsequently. It is recognized that the sophistication of the instrumentation must correspond to the level of risk that exists.

1.6 While recognizing the costs and maintenance implications of state-of-the-art dam hazard detection and monitoring equipment, this Paper suggests that it may be

worthwhile to conduct at least two pilot projects using advanced dam hazard detection and monitoring equipment coupled with advanced information and communication technologies that would enable the data to be monitored in multiple locations including the dam's own control facility.

1.7 Even if advanced detection and monitoring systems are adopted, it is essential that the staff, the villagers and others who live by and frequent the dam area are trained to look for signs of impending hazards.

1.8 Hazard detection and monitoring information must be interpreted by skilled professionals in order to generate disaster alerts and warnings. Given the short time periods that may be available and the importance of site-specific knowledge, the responsibility for issuing alerts and warnings must reside within the dam operator, preferably with the engineer responsible for the dam. ICTs may be used to provide the decision maker with back up expertise.

1.9 It is critically important that engineers in charge of major dams and their technical staff be provided with modern communication equipment and that they are exempted from government regulations inimical to use of fixed telephones above a cost threshold. Mobile telephone use should be encouraged with cost reimbursements.

1.10 Last mile dissemination of disaster alerts and warnings should be well planned, with multiple redundant media and channels, ranging from cell broadcasts that will be limited to coverage areas of specific base stations to use of mosque loudspeakers and temple bells. Training, drills and community participation are crucial to the success of last mile dissemination.

1.11 It has been found that unsatisfactory financial arrangements, wherein dam operators supply valuable services but cannot recover their costs, contribute to the systemic problems of neglecting or postponing major and ongoing maintenance work. It is essential that an effective mechanism for reliable, predictable cost recovery that is exclusively devoted to maintenance is devised and implemented.

1.12 The government should establish a regulatory body with dam safety as its primary objective, separate from and superior to, each of the entities currently owning, operating, or using dams. It should give priority to expertise and stakeholder consultation and be insulated from day-to-day political interference. In other words, it should be independent. The current difficulty of a lack of power over peer government agencies can only be resolved by placing the dam safety functions within an organization that is accountable to Parliament and is not under a specific Minister.

1.13 The Dam Safety Management Unit (DSMU), which contains specialized expertise on dam hazard detection and monitoring, can be placed within either the Public Utilities Commission, which already has some safety regulation functions, or the

proposed NEWS:SL [National Early Warning System: Sri Lanka][1]. The larger organization will give the necessary stature, authority and independence; the focused unit structure will allow the experts to conduct their business in a professional manner.

1.14 The removal of immediate dam safety responsibilities from the persons and organizations currently in charge of the reservoirs is not proposed in any way. Those who are closest to the potential hazard-generating structure and who have the best knowledge of it must continue to perform those functions. The mandate of the DSMU should be explicitly limited to regulation, alternative dispute resolution and related practices to minimize and promptly resolve inter-agency disputes, and standard setting.

1.15 In order to enforce its directions and orders, the DSMU and its parent organization should have the power to shut down structures that are judged to pose an unacceptable risk and where the owners have not followed directions, using carefully circumscribed procedures and definitions that allow for optimum publicity and which adhere to the principles of natural justice.

[1] National Early Warning System: Sri Lanka (NEWS:SL) , A Participatory Concept Paper for the Design of an Effective All-Hazard Public Warning System, Version 2.1, at http://www.lirneasia.net/national-early-warning-system/

Introduction and Rationale

2.1 In the horrific, destructive, and costly aftermath of the Indian Ocean tsunami of 26 December 2004, the realization of Sri Lanka's need for a disaster-warning system has never been greater. However, the current preoccupation with tsunami fears has overshadowed other hazards, resulting in popular and political demands for 'tsunami warnings.' In light of the frequency of the occurrence of other natural disasters, it is critical to move away from the popular fixation with tsunami threats, examine other existing and probable risks, and plan for the effective mitigation of possible disasters in these neglected areas.

2.2 Natural hazards come in various forms; an important distinction is the scale and origins of these hazards. Large hazards, such as teletsunamis, which originate in locations far removed from potentially threatened populations, will be detected, monitored and reported in different ways than local hazards, like flash floods. Varied types of hazards are tracked differently, and present different scales of danger, in terms of both geographic area and numbers of people affected. Warnings for the various hazards must of necessity be targeted to the relevant areas and peoples for dissemination. It is of no use for Dry Zone farmers to receive warnings of landslides in Ratnapura.

2.3 This paper provides recommendations for comprehensive programs to increase dam safety in Sri Lanka. The urgent need for such programs was made clear during the development of a concept paper on an all-hazards warning system carried out by LIRNE*asia* and the Vanguard Foundation. Experts in the area of disaster prevention identified critical weaknesses in Sri Lanka's dam safety protocols; it was learned that community activists in Gampola were taking action to raise awareness of potential disasters. In the recommendations of the NEWS:SL concept paper, LIRNE*asia* and Vanguard Foundation committed to develop a participatory concept paper on dam safety. The following paper is a key component of that process, presenting a basic analysis of the existing dam safety status in Sri Lanka, and making recommendations on interventions to improve these systems. It, along with the documentary video made of the lessons learned (or not) from the Kantale dam breach, formed the basis of the town meetings conducted in Gampola, Kandy and Polonnaruwa in July 2005 and the news conference conducted with the participation of community leaders from those locations in Colombo on 10 August 2005.[2]

2.4 The dam network in Sri Lanka comprises over 350 medium and large dams, and over 12,000 small dams.[3] These structures vary in design, age, and construction. The earliest dam constructions in Sri Lanka are over 3000 years old. The renowned ancient civilizations were made possible by these constructions, which

[2] It is noteworthy that the town meetings were held in three of the four major human settlements identified by a senior dam safety expert (in Annex A). The only town that was not included was Mahiyangana.

[3] Presentation: "An overview of present dam safety management," Badra Kamaladasa, Deputy Director for Dam Safety, Department of Irrigation, 20 May 2005 Expert Consultation

stood as testament to the ingenuity of engineers, the skills of builders, and the wealth and power of rulers.

2.5 Subject experts distinguish between modern dams, where the knowledge and opportunities exist for applying dam safety techniques, and ancient and recent dams, where the task is more difficult. In the latter category, detailed information on the foundation structures are not available; the ancient sluice gates do not allow visual inspection, and so on (S. Karunaratne, Annex A).

2.6 Today, dams and their appurtenant structures shape Sri Lanka much as they did thousands of years ago. What Governor Henry Ward (1855-1860), who initiated the restoration of Sri Lanka's ancient dams said then still holds true: "in no other part of the world are there to be found within the same space, the remains of so many works of irrigation, which are, at the same time, of such great antiquity, and of such vast magnitude as Ceylon. Probably no other country can exhibit works so numerous, and at the same time so ancient and extensive, within the same limited area, as this Island." Most crucially, our dams supply irrigation water, electricity, and in some cases drinking water. The extensive irrigation systems fed by the dam network ensure water supplies for successful year-round paddy and other cultivation. As much as 60% of CEB electricity (depending on rainfall and water levels) may be generated by hydropower dams.

2.7 Additionally, dam tops are used as roads and railways. The multiuse nature of dam structures highlights their importance as elements of the Sri Lankan economic, cultural, and physical landscape. However, the multiple demands on the system have resulted in a bureaucratic tangle of ownership, management, and authority.

2.8 The primary recommendations of this paper deal with institutional reforms. The current chain of institutional responsibility for Sri Lanka's dams is complicated and ultimately ineffectual, which has in the past resulted in less-than-optimal functioning of the relevant agencies and the dams themselves. Maintenance, safety oversight, and proper usage rights are usually shared among several Ministries, Authorities, organizations, and informally stake holding nearby populations. For example, even within the Mahaweli System which was carved out and handed over to the Ministry of Mahaweli Development, there are four separate entities, the Headworks Administration, Operations and Maintenance Division (HAOM), the Residential Project Managers, the Irrigation Department and the Ceylon Electricity Board. With regard to individual dams within the system, the Department of Wildlife Conservation, the Roads Development Authority, and many other entities exercise jurisdiction. This is natural given the multiple usages and demands placed on the dam system. However, there is a great need for better oversight of the dam system and the proper coordination of functions, especially related to safety.

2.9 The current governance arrangements have contributed to several negative outcomes, notably, non-updating of and non-adherence to Standing Orders for maintenance and safety, minimal education for vulnerable populations on the risks and responsibilities of those living in the shadow of dams, and poor disaster

management plans. Given the number and widespread distribution of dams in Sri Lanka, one of the more densely populated countries in the world, it is clear that the affected populations and sectors are many, and the effects of dam-related hazards far-reaching.

2.10 The tragic and costly Kantale dam breach of April 20th 1986 illustrates the far-reaching consequences of a massive dam disaster. 127 people were killed. Over ten thousand area residents were affected, with more than a thousand homes destroyed or substantially damaged. Millions of rupees were spent to rebuild and rehabilitate the area. The breach was caused by the crumbling and collapse of one of the dam's two sluices. The ancient masonry had experienced natural deterioration, probably accelerated by pile-driving associated with a water-supply pump house project.[4] The disaster might have been prevented or mitigated had the governance arrangements, including a proper regulatory regime, created the conditions for the dam's owner, the Department of Irrigation, to diligently carry out the appropriate monitoring and warning procedures.

2.11 The creation of an entity to implement an effective regulatory regime to ensure dam safety, hereafter described as the Dam Safety Management Unit, is the central recommendation of this document. The institutional snarl around dam responsibilities and authority in Sri Lanka must be untangled in order to guard the safety and wellbeing of affected peoples, and to protect valuable public and private assets such as the dams themselves. In addition to proposing institutional reforms, this paper will suggest ways in which the current owner-operators may better manage and maintain the dams. Among the responsibilities of the dam Safety Management Unit will be the creation of conditions conducive to the development and implementation of hazard-detection and warning systems.

2.12 The creation of a system for funding regular operations and maintenance of dams based on the user-pays principle is another important recommendation. Unless a stable and adequate flow of funds for operations and maintenance can be ensured along with an accountable system of administration, it will not be possible to sustain safety regimes of any kind.

2.13 While this paper discusses advanced and emerging technologies relevant to the project herein outlined, the authors also wish to stress the importance of low-tech and human-centered interventions in preserving the integrity of the dam system and the lives and assets of people living downstream of dams. All the stakeholders living near or using a dam system are variously responsible for their safety vis-à-vis the dam. Government authorities are of course the primary managers and decision-makers for the dams themselves, but the job of everyday custodianship extends to ordinary and casual users of the dams and reservoirs, from farmers who draw irrigation waters to tourism-oriented boat safari operators. The importance of dam and watershed education for the public cannot be overstressed.

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[4] p. 61, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987

2.14 The paper does not purport to provide a complete technical feasibility assessment and blueprint for dam safety measures. This work has been undertaken by public policy and disaster communication experts who are disinterested outsiders in relation to the professional and other groupings within the dam management sector in Sri Lanka. This work has been undertaken primarily as a voluntary activity, with minimal financial resources. Its objective is awareness raising and the delineation of the broad outlines of a policy solution rather than the more detailed work that would have to be commissioned to implement the solution.

Parameters of an Early Warning System

3.1 Warning systems typically include the installation of a range of instruments and technologies to ensure early detection and monitoring of hazards. They also include scientific and organizational capacity for analyzing the collected data to determine the extent of associated risk exposure, probable impacts, and modalities for notifying those at risk in a timely fashion.

3.2 For dam-related hazards, these arrangements include the installation of sensors to measure seepage, movement, pore-pressure, moisture and temperature that provide around-the-clock, real-time data for detecting potential dam failures. The data from these sensors are the first components of an early detection and monitoring system. By analyzing and cross-checking the sensor-data and by applying professional judgment, dam engineers can predict the possibility of a dam breach and can set in motion relevant sequence of actions in the early warning system. If sensor data or visual detection warrant, alerts and warnings need to be issued on possible dam breach and flooding to those communities at risk. Warnings will trigger a pre-determined sequence of actions at the local level that will lead to the safe evacuation of vulnerable downstream communities.

3.3 The objective of an early warning system is to prevent hazards (any form of dam failure such as breach, overtopping) from becoming disasters (destruction of life and property). However, in order to achieve this objective various components of the warning system must work seamlessly. There are five inter-related components to a warning system:

- Hazard identification, risk assessment and vulnerability analysis
- Detection and monitoring
- Emergency management structure, including warning and evacuation
- Local dissemination
- Public education

3.4 Unlike most hazards occurring in nature, dam related hazards can be prevented to an extent by proper maintenance and timely remedial action. There is a considerable body of knowledge in other countries on ensuring the safety of these human-made structures. Unlike with natural hazards, effective maintenance and periodic upgrades can reduce the likelihood of the hazard occurring, not only the occurrence of the ensuing disaster.

Hazard Prevention-Dam Safety

3.5 A comprehensive program for dam safety will necessarily incorporate both hazard-prevention and hazard-mitigation procedures. These functions may be bundled together under a set of Standing Orders for operation, monitoring, maintenance, notifications and warnings.

3.5.1 **Monitoring**: continuous surveillance of the dam and appurtenant structures and seepage by visual inspection, monitoring of sensor

data, quantitative and qualitative analysis of seepage, seismic monitoring, and other.

3.5.2 **Risk assessment**: Data related to inundation mapping, dam break scenarios and analysis, flood path and force prediction, with appropriate periodic review. Modern technologies such as Light Detection and Ranging (LIDR) can be mobilized for these purposes.

3.5.3 **Remedial action**: Remedial work on dam so that it is in compliance with dam safety criteria and implementation of any statutory changes required by the DSMU. This is key to hazard prevention, but is today a problem because of constrained and unstable financial resources given by government.

3.5.4 **Safe operation**: Proper utilization of the scheduled/ordered functions of the dam, notably the operation of conveyance structures such as spillways, sluices, etc.

3.5.5 **Proper maintenance**: Keeping spillway channels free of debris, keeping dam free of trees & brushes, undertaking periodic maintenance of dam structure, keeping up-to-date manuals and procedures.

3.5.6 **Emergency management**: Planning for dam related hazards, maintaining hazard-management protocols, conducting emergency drills and ongoing personnel training.

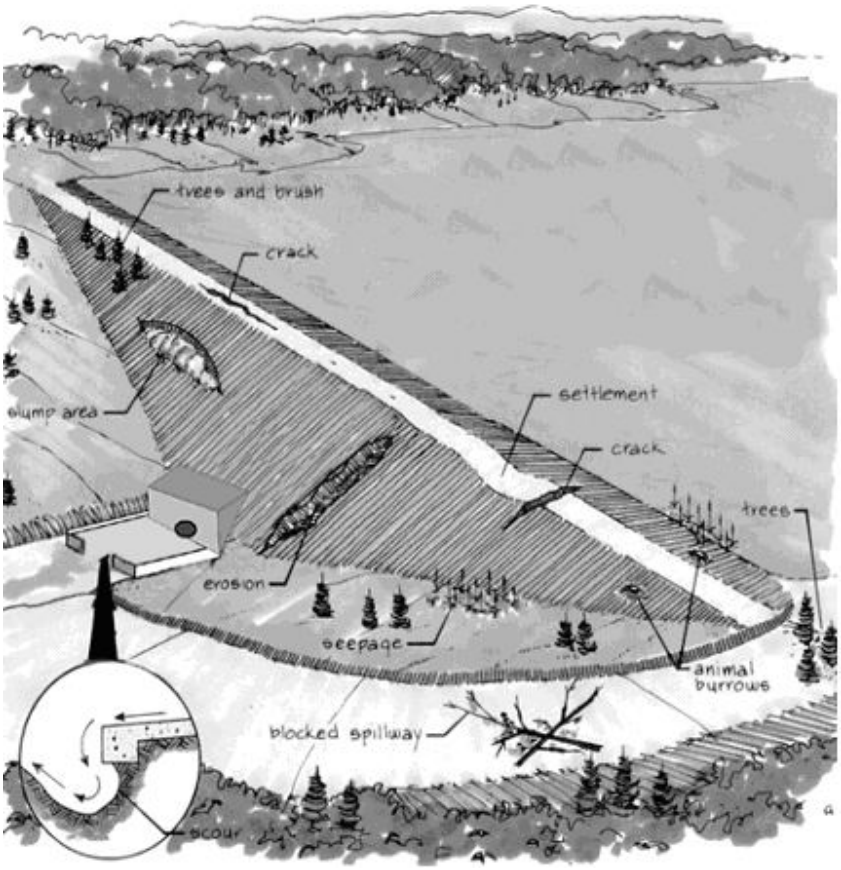
3.6 The aim of any dam safety regulatory authority, like the DSMU, is to ensure that dam operators and owners have dam management procedures in place to minimize the possibility of dam-related hazards. However this body would also be additionally responsible for assuring that contingency plans and disaster-mitigation procedures are in place, in case a hazard does occur.

Hazard identification

3.7 People are not only recipients of warning messages from experts, they are also valuable sources of hazard detection information. Many hazard warnings, in fact, are triggered by affected local residents alerting families, neighbors and local officials. In the most recent major dam breach that occurred in Sri Lanka in 1986, villagers were the first to notice the breach in the dam and alerted the dam engineers, the military and downstream villages.

3.8 But in order to identify a dam related hazard in a timely manner, villagers living close to dams as well as dam inspection staff must be trained to look for early signs of distress conditions and identify it as a potential hazard. For example, unusually high water levels in the canals or muddy discharge from seepage may be indications of a potential hazard. The villagers must be informed on how to speedily get in touch with the relevant authorities when they identify a potential hazard.

3.9 However, the long-standing seepage phenomena in Samanalawewa, a modern dam, and Parakrama Samudraya, a restored ancient dam, suggest that the deterioration of the overall governance environment may have dulled the senses of officials as well as other stakeholders, including the media. The fact that exceptions, such as the engineers from Samanalawewa who communicated with the authors of this paper on the record,[5] do exist is small comfort in an environment of lethargy and fatalism.



Source: http://www.lwbc.bc.ca/03water/dams/downloads/assessment.pdf

Risk assessment and vulnerability analysis

3.10 In analyzing the risk levels around a possible dam hazard, two potentially opposing areas must be considered. In the event of even a minor dam failure, the initial and obvious threats are to the residents and property immediately downstream of the breached structure. The people, industry, and public

[5] E-mail message from H.S.Somathilaka, Chief Engineer, Samanalawewa Power Station, reproduced in toto in Annex A

infrastructure in the dam's flood path are at the greatest risk of sustaining damage. Care should be taken to adequately educate these stakeholders on potential dangers and warn them in the event of a hazard.

3.11 In addition to the risks posed to the downstream environment by a potential dam hazard, there is also the risk that hazards can dramatically and expensively damage the breaching dam itself. Dams are costly and crucial public assets that require appropriate management and protection.

3.12 In the 1986 Kantale breach, the cost to the Government of rebuilding the breached section (LKR 186 million) was approximately three times the cost of all the Government's relief, rehabilitation, and re-housing expenditures for the affected downstream residents (LKR 65 million)[6]. These figures do not include the cost of rebuilding public properties and infrastructure, including schools, roads, railway lines, hospitals, government offices, and so forth.

3.13 From these figures it is concluded that the dam structure itself is expensively threatened by any kind of hazard related to its integrity. In other words, the consequences and costs of a breach multiply when the dam itself is at risk of major structural failure.

3.14 Risk assessment should thus weigh the costs and benefits of down-stream flooding versus the integrity of the dam structure itself. Minor, planned releases of dammed waters are definitely a better option than a breach.

3.15 For example, it may be advisable in some cases to allow or create downstream flood conditions by opening spillways when a reservoir is overly full. The potential damage of minor flooding would in such a case be less than the risks of forcing the dam to hold more pressure than its designers intended. 'Over-topping,' a type of breach resulting from a reservoir overflowing and/or washing away its dam, is an especially dangerous hazard for earth dams of all sizes[7].

3.16 In assessing the risks associated with a potential dam breach, the entire downstream network must be considered. The dam networks in Sri Lanka are sequentially situated in cascades along major watersheds. Because the flow from one dam fills the next, flooding waters from a higher dam will cause adverse consequences further down the cascade.

3.17 In a worst-case scenario, a major breach at one dam would cause a chain reaction cascading down the network. For this reason, detailed inundation plans and breach/flood scenarios must be part of any risk-reduction and disaster-management plan.

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[6] p. 51-55, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987

[7] D W R Weerakoon, Former Director General of Irrigation and Secretary, Presidential Commission on the Kantale Dam Breach, 20 May 2005 Expert Consultation

3.18 The cascade effects preclude the conceptualization of dam safety as a local problem, or even as amenable to provincial regulation. In fact, the Constitution places irrigation in the Concurrent List, with the regulation and development of inter-provincial rivers on the Reserved [for the Central Government] List.

3.19 Professionally drawn and analyzed inundation plans are available for some of Sri Lanka's larger dams. For most dams, no inundation plan or dam-break projection scenario is available. This represents a serious lack of disaster preparedness. Accurate disaster projections must be prepared[8].

3.20 A dam safety program should minimize the risk of dam failure. Risk is comprised of two elements, the likelihood (probability) of an event as compounded against the magnitude of the event's damages (consequences)[9]. Risk is calculated with appropriate recognition of the various probability and consequences of different types of hazard.

3.21 Prevention strategies, like attentive operation and maintenance, reduce the probability of a dam failure. Mitigation strategies, like public warnings systems, reduce the consequences of a dam failure.

Detection and monitoring

3.22 An effective and comprehensive public safety program rests on an accurate and reliable way of detecting hazards. In the realm of dam safety, hazard detection begins with comprehensive monitoring of the dam's physical integrity. Without this information there is no way to maintain or remediate potential flaws and failures in the structure.

3.23 Modern detection and monitoring systems are built into dams during their construction (as was the case with Lunugamvehera, one of the last major dams constructed in Sri Lanka). In the case of ancient or recent dams, the equipment has to be retrofitted. In these dams, knowledge about components such as the foundations is incomplete and many of these components are not easily accessible to install equipment or even for visual inspection. The opportunities for the use of detection and monitoring systems are thus much greater with modern dams than with ancient or recent dams.

3.24 An effective inspection/monitoring system must include the gathering of relevant data, to assure monitors of accurate safety status indications, and timely data

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[8] Comment, Mr. Dharmasena, Irrigation Department former Director, 20 May Expert Consultation

[9] Presentation: "What are international best practices in dam safety?" Nimal Wickramaratne, Director, Headworks of the Mahaweli Authority, 20 May 2005 Expert Consultation

gathering/sensing systems, to ensure that authorities have time to analyze data and issue warnings if necessary[10].

3.25 The Kantale dam had been "inspected" and found sound just six months previous to the catastrophic sluice failure[11]. Though it is possible that all the deterioration leading up to the breach took place in the intervening six months, the Commission of Inquiry argued that the ancient sluice masonry had most likely deteriorated over the decades since the British restoration projects in the 1870s.[12] The design of the sluice did not permit visual inspection of its interior and no mechanical means were used.[13]

3.26 The November 1985 inspection noted the existence of potentially dangerous runnels on the downstream slope of the Kantale dam but failed to identify an existing weakness in the sluices. The sluice failure breach proved the inspection tragically insufficient as a safety protocol.[14] An adequate inspection protocol must include appropriate, extensive, and accurate observations.

3.27 Routine inspections can and should include different types of observations. Observations are made via different sensing systems. At the high-tech extreme, one may use sophisticated systems to measure complex environmental factors and pressures within and around a dam structure. At the low-tech extreme, one may rely on the observation of potential dam related hazards by casual passersby.

3.28 Due to institutional failures, the monitoring of many dam structures has been left solely to visual inspection by dam engineers and untrained observers. The sluice disintegration at Kantale was first noted by a villager, who notified the resident

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10 Presentation: "What are some innovative technologies for hazard detection in dams?" Tissa Illangasekare, AMAX Distinguished Chair of Environmental Science & Engineering & Professor of Civil Engineering; Director, Center for Experimental Study of Subsurface Environmental Processes (CESEP) Colorado School of Mines, USA &Anura Jayasumana, Professor of Electrical and Computer Engineering & Computer Science, Colorado State University, USA; 20 May 2005 Expert Consultation

11 p. 21, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987

12 p. 6, 22, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987

13 Videoed interview of Mr Senawatta, Engineer in charge of the Kantale reservoir at the time of the breach, June 17th, 2005.

14 Presentation: "Nineteen years later, what lessons have been learnt from the Kantale breach (and what changes have been implemented)?" D W R Weerakoon, Former Director General of Irrigation and Secretary, Presidential Commission on the Kantale Dam Breach, 20 May 2005 Expert Consultation

Irrigation Engineer of unusually heavy flow from a sluice barrel[15]. This villager was not a government employee but his action in warning the Irrigation Engineer is an example of a low-tech hazard sensing system.

3.29 However, in the above case, the dam breach was a fait accompli when it was observed by the villager and the time frame between when the hazard was detected and developed into a disaster was a small one. This increased the number of casualties and possibly property damage. Increasing the time lapse between hazard detection and the hazard event provides sufficient time to warn and evacuate vulnerable communities and to take mitigating actions (like opening spillways, or planned deliberate breaching at a designated place) to minimize property damage. Early detection of a potential dam hazard may lead to remedial action that may even prevent the hazard event from occurring in the first place.

3.30 There are a number of different kinds of sensors that can be embedded in a dam that may provide information about a potential hazard long before it develops into a catastrophic event. Instruments that measure seepage, movement, pore-pressure, moisture and temperature, tiltometers etc. can provide around-the-clock, real-time data for detecting potential dam failures. These sensors can be networked and data sent remotely to computers. Computer-aided monitoring allows for continuous data collection, analysis, and archiving. These types of systems offer a great deal of flexibility in the proportion of human intervention necessary.

3.31 Distributed sensing using optical fiber has been used in a number of dams in Sweden to measure seepage and pore pressure at frequent intervals along the dam structure[16]. Since the reflection characteristics of laser light, traveling down an optical fiber, vary with temperature and strain, it is possible to discern changes in the reflection of the light and thereby variations in pressure and seepage.

3.32 Remotely installed sensors allow monitoring of difficult-to-access data (such as in areas that are underwater or underground). 'Mote' devices, tiny wireless network-forming sensor/transmitters, have been employed to monitor seismic activity and water quality. Motes can be embedded throughout the dam structure to measure relevant data and communicate the data between themselves and through a network to the local dam operators and to the DSMU. Currently, these devices are relatively expensive for the sheer numbers required for an effective

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15 p. 8, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987

16 http://www.sensornet.co.uk/industries/dams/DamMonitoringArticle.cfm

array, but in the coming years, they are expected to become so cheap as to be disposable.[17]

3.33 Motes, optical fiber and other advanced technologies may prove to be key sensor infrastructure elements for monitoring dam safety by the DSMU and the dam operators. In order to develop a better sense of the potential benefits of such systems and their comparative advantages, the deployment of a number of sensor technologies on an experimental basis on a modern dam and an ancient dam is proposed. These detection and monitoring systems can be tested in conjunction with the last-mile hazard information and training activities being undertaken by LIRNEasia and Sarvodaya, in the first instance in tsunami-affected villages.[18]

Emergency management structure

3.34 Sophisticated hazard detection systems will come to naught in the absence of functioning institutions that can ensure that those technologies are kept operable, that can get warnings and alerts quickly to vulnerable communities and undertake necessary evacuations and mitigating actions. The governance and institutional features of an early warning system for dam related hazards are dealt with in greater detail in the following section0. This section will focus primarily on the emergency management structure at the local level.

3.35 Currently, the status quo of under-prepared authorities has forced local populations to devise their own hazard-detection and safety strategies. Fearing a repetition of Kantale, for example, the townspeople and villagers living immediately downstream of the Kotmale dam are drawing up flood maps against the event of a breach. Because the appropriate authorities have given them little assurance that they are being looked after, the people are developing local safety protocols. In the presence of such active grassroots awareness, there is surely strong need to develop better official structures.

3.36 The question of developing trust between affected populations and the experts responsible for the complex technological systems centered on the dams was brought into sharp relief during the public consultations. It was clear that the affected people and their leaders had little trust that adequate safeguards were being maintained in the dams that threatened their lives. The experts were vary about sharing information saying it would cause panic,[19] but sharing information is the only way to build trust.

3.37 Sri Lanka has about 80 dams of significant size and thousands of smaller dams. The extent of inundation and the geographical impact of a dam breach will vary

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[17] Presentation: "What are some innovative technologies for hazard detection in dams?" Tissa Illangasekare &Anura Jayasumana, 20 May 2005 Expert Consultation

[18] See description and proposal at http://www.lirneasia.net/2006/01/last-mile-hazard-information-project-is-on/

[19] See Dharmasena comments in Annex A.

according to the size and location of the dam. In the case of dams with only local impact if breached, the dam sensor data will only need to go to the local dam engineer/dam operator. In the case of large dams, the sensor data may also have to bet transmitted to other locations to enable a region-wide coordinated response.

3.38 For the large number of dams that are of small size, the dissemination of alerts and warnings to the vulnerable communities is the responsibility of the local dam engineer/dam operator.

3.39 Established protocols must be in place to facilitate speedy and streamlined decision-making on the part of dam engineers and local authorities. If a dam related hazard has been detected, the dam operators should contact pre-designated emergency first responders in the local government, community level organizations and the media.

3.40 The key first step in maintaining dam is monitoring and observation. Protocols for operation and maintenance must include updated standing orders designed to incorporate these functions.

3.41 Standing orders function as a contingency-based series of procedures to be followed normally if and when conditions and inspections warrant. That is, the orders will describe the normal operation and maintenance, inspection and monitoring practices, identification of problems, remedial steps to fix these problems, emergency actions, and disaster response practices.

3.42 Disaster management plans must be specifically drawn up according to the particular features of the dam and its watershed area. These plans must include orders as to what steps on-site personnel must take to notify superiors and warnings-disseminators.

3.43 Given that every dam is different and has varying surroundings, there can be no one-size-fits-all disaster plan. Still, the plans for different dams should be similar in their structure of authority and decision-making, such that the most qualified experts are able to assist in every situation.

3.44 Currently, many of Sri Lanka's major dams have Standing Orders[20]. Their presence has not prevented mismanagement and poor physical upkeep of the dams.

3.45 The ongoing government de-prioritization of reservoir maintenance funding has resulted in shrinking Mahaweli Authority, Irrigation Department, and Ceylon Electricity Board budgets. Moreover, the funding actually received by these authorities is less than the promised allocations[21]. The financial exigencies are

[20] Presentation: "An overview of present dam safety management," Badra Kamaladasa, Deputy Director for Dam Safety, Department of Irrigation, 20 May 2005 Expert Consultation

[21] Boxed text p. 69-70, Central Bank of Sri Lanka Annual Report, 2004

likely to have contributed to the deterioration of dam management, but cannot be held solely responsible for it.

3.46 Adherence to strict maintenance schedules will prevent further deterioration requiring ultimately costlier work. Standing orders must be properly revised, updated, and followed[22]. Without monitoring and maintaining the dam structures, one cannot reduce the risk of a disaster.

3.47 The issuance of clear and unambiguous warning requires a dependable and known warning issuer. To create this public trust, the issuing agency must play a visibly dominant role in structuring safety programs and providing public information. For dam related hazards with only local impact the nodal warning agency will be physically located near the dam site. In the case of large dams with greater geographical impact, some of the warning functions may be performed by a central early warning agency, in addition to the dam operator.

3.48 ICT infrastructure may need to be in place linking on-site dam staff, regional bodies such as the Mahaweli Authority, local authorities, and the early-warning and disaster management agency.

Local dissemination

3.49 The "last mile" of an early warning system that takes the alerts and warnings to households in vulnerable towns and village is one of the most crucial links of the warning system. After a dam related hazard has been detected, warnings and alerts must be communicated to local authorities (police, local military, fire services, municipality), to religious establishments (like temples, churches and mosques), to community leaders (like grama niladharis, leaders of farmer organizations), to local, grass-roots organizations (like Sarvodaya) so that warning can be disseminated to every individual household at risk so that individuals can take necessary actions.

3.50 The local communication mechanisms used in the warning system may vary from village to town based on the level of economic development and socio-cultural factors. A combination of temple bells, mosque and church loud speakers, sirens, radios, TV sets, mobile phones and addressable satellite radios, may be available. The warning system should take into account these variations and be tailored to the local conditions.

3.51 During the Kantale disaster, the Army and Police played a large role in warning and evacuating residents. Also, a mosque loudspeaker was used to broadcast warnings[23]. These differing warning-dissemination vectors illustrate the

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[22] Presentation: "What are international best practices in dam safety?" Nimal Wickramaratne, Director, Headworks of the Mahaweli Authority, 20 2005 Expert Consultation

[23] p. 8, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987.

effectiveness and necessity of redundant and varied strategies within a dissemination system.

3.52 The early responders of a hazard have to be equipped with basic communication capabilities, including some combination of fixed phones, mobile phones, and two-way radios. Internet access is not available in most rural areas at this time, but as it becomes available it should be integrated into the communications plans. Additionally, there may be the possibility of utilizing communication channels used by the Ceylon Electricity Board for congestion-free emergency communications.[24]

3.53 Additional care must be taken in the structure of the emergency response communications network to protect it from congestion. It is most likely insufficient to use only the civilian/general communications networks because in the event of an emerging hazard the regular networks may be swamped with ordinary users trying to get information. Further, the physical communications infrastructure may be damaged by unfolding hazard conditions. "Broadcast" modes such as addressable satellite radio (e.g., the Disaster Warning, Response and Recovery system of WorldSpace can cell broadcasts over mobile networks, being trialed in a LIRNEasia-Sarvodaya pilot project for tsunami-affected villages), are of special significance because they are geographically targetable and immune to congestion.

3.54 Though ideally there would be a dedicated, secure disaster communications network, this will take time to build. In the interim, it is essential that on-site monitors, dam authorities, and warning authorities have at least basic communications facilities.[25] If there are at this date any outstation facilities with no phone or backup communications, they should be equipped immediately. Archaic and inappropriate government rules that penalize use of fixed telephones above a low threshold and do not allow for reimbursement of the costs of mobile service must be changed, at least with respect to persons with dam safety responsibilities.[26] Given the wide availability and relative cheapness of mobile and fixed phone service, there is no excuse today for neglecting this aspect of disaster management.

3.55 The stark absence of communications facilities (and/or their poor functioning) has in the past resulted in severe failures to adequately contact and warn early responders and threatened populations. In 1986 the Kantale Irrigation Engineer

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[24] Comment 20 by Lakshitha Weerasinghe on 9 February 2005 at http://www.lirneasia.net/2005/02/tsunami-warning/

[25] p. 35 NEWS:SL concept paper, Vanguard Foundation and LIRNE*asia*

[26] Mr Jayasinghe, the engineer in charge of the Kantale reservoir at the present time, stated that he and others on his staff use mobile telephones for dam safety related purposes, but have to pay for it out of their own pockets. He also stated that the fax machine at the Kantale office of the Irrigation Department is not operational because of problems in getting its repair authorized. Videoed interview, June 17th , 2005.

had no telephone and thus was forced to physically drive to different locations to notify the Police, Army, and other affected authorities. It is impossible to know what deaths and damages could have been averted had better communications been in place. Today, the Kantale Irrigation Engineer's office is equipped with telephones, but the phone lines are insufficiently manned especially during holidays.[27]

3.56 Once a hazard is identified it is the responsibility of the dam owners and the local dam engineers to issue warnings and alerts. The warning must be communicated to the affected public. As a practical matter, the public warning-notifications system must be comprehensive, specific and redundant such that vulnerable groups are assured of receiving clear messages.

3.57 Warnings and alerts, in addition to being clear, must be designed to elicit a proactive response among the threatened communities. The quality of a warning system is not only in its accuracy and timeliness but in its ability to provide the public with appropriate instructions on how to protect themselves.

3.58 These instructions will include specific information as to where the hazard is occurring, what threats the hazard includes (flood waters, landslides), what safe areas to evacuate to, when the dangerous period(s) are, and what steps will minimize threats to life and property. It is not sufficient to simply notify populations of existing or occurring threats. This final element of warning, instructions for protective measures, is necessary to give people the best chance of escaping serious harm. Information must also be provided when a warning or alert is lifted.

3.59 Though the use of television and radio broadcasting will be crucial to the warning-dissemination system, these warnings should be targeted specifically to areas affected. It is not efficient to have a general television broadcast of warnings. Resources would better be used in assuring that warnings reach threatened populations. For this reason it will be useful to investigate ways of targeting individual areas and/or districts with technologies like television, radio (terrestrial as well as satellite based), and telephones.[28]

3.60 According to 2004 survey data 74.9 per cent of Sri Lankan households have electricity; 78.3 per cent have a radio; 70.8 per cent have a TV set and 24.5 per cent have access to telecommunications in the home.[29] Actual numbers are

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[27] Video interviews Kantale residents, compiled by Divakar Goswami June 2005.

[28] Para 2.25 of the NEWS:SL concept paper recommends action to enable remote access to specific retransmission towers so that localized warnings or alerts can be issued; or better still the licensing of low-power or community broadcasting stations. Para 2.28 recommends the use of cell broadcasts in mobile telephones, a congestion-free method of communicating to targeted areas.

[29] Central Bank of Sri Lanka, 2005, Special Statistical Appendix, Table 9, excluding three districts affected by the war.

likely to be lower except in the case of telephones, because of conditions in the districts excluded from the survey due to security concerns. Thus, in order to ensure that warnings reach the maximum number of potentially affected people, there must be additional vectors for dissemination.

3.61 Multiple-media strategies should be employed, including targeted broadcasts via television, radio, and all types of phones; activation of dedicated sirens or alarms; announcements over local loudspeakers (e.g. at mosques and temples); and parties dispatched to carry out notification and evacuation, for example, Army and/or Police personnel in loudspeaker-equipped vehicles.

Public education

3.62 The public must be educated about the nature of hazards and their effects, who and what is at risk, how people will be warned, what the warnings mean and what actions must be taken. Warning systems must be tested regularly, both to ensure that the systems work and that the public understands their purpose and messages.

3.63 The success of the dam safety program will depend in large part on the abilities of the public to respond appropriately to the all-hazards warning authority's warnings, alerts and instructions, both in the case of a dam hazard and in the general and everyday use of dams and reservoirs. Local people and organizations have by far the greatest stake in, and thus the deepest motivation for, preserving the safety and utility of the dam and reservoir system. The all-hazard management authority should carry out dam-safety training programs for the affected segments of the public, preferably twice a year, prior to the onset of the monsoons.

3.64 As discussed earlier, the dams and their attending structures provide numerous resources to the public, including electricity, irrigation waters, roadways, railways, fishing waters, space for bathing and washing, and various recreational and tourism related functions. Because the dams have obvious and high value to the (resident and non-resident) population, educational programs on dam safety and usage should be designed to create a sense of custodianship in the people.

3.65 These programs must provide the public with information as to both the normal functioning of the dam systems, including proper and safe use, and hazard-related information, including disaster-response practices.

3.66 These programs should instill in the population a sense of urgency and importance of the public role in utilizing and maintaining the dams. Basic management and safety practices can be shared with the public.

3.67 For example, the growth of large trees or bushes on earth dams can be destructive to the integrity of the dam. Roots may disrupt the earthworks, and

jungle cover may obscure developing runnels or seepage problems[30]. Local people can be employed formally or informally to control plant growth on dams.

3.68 Another potential problem area is the dam-crest roads. There is no consensus as to what exactly the safety standards, like vehicle size and speed, should apply to roads atop dams[31]. They agree, however, that there is currently insufficient oversight of the loading and speed of vehicles over dams.

3.69 Dam authorities are currently unable to exercise effective oversight of activities of the types described above. Unauthorized construction and forestry projects are particularly hard to control. The main cause is the overall culture of poor governance and political and other forms of interference. On the other hand, it is necessary for dam engineers to recognize the costs and benefits of the multiple uses made of dams and appurtenant structures.

3.70 Similarly, oversight of reservoir boating activities is almost nil[32]. The waves created by high-speed boats may cause damage to the dam structures. The appropriate standards must be devised in consultation with all relevant parties and uniformly enforced. Local populations must be educated about these risks.

3.71 Care must be taken in training to highlight the safety issues around small as well as large dams. Large dam breaches are obviously more catastrophic thus more attention-grabbing, but small dams too pose risks.

3.72 There are thousands of small dams in Sri Lanka, most of which are constructed and maintained with a minimum of government oversight. Local custodianship of these small dams is particularly important because centralized management is impractical.

3.73 Finally, safety training should include information on the warning signs of a potential hazard (e.g. seepage or overtopping) and, critically, directions as to how a local resident can contact the local dam operator and the central dam hazards unit. Local people, as in the example of the Kantale breach, are a valuable and effective link in the hazard-detection system.

3.74 The dam operators will thus need to be receptive of information coming from area residents. With effective training, local people can be valuable contributors to the dams' maintenance and safety oversight.

3.75 Local organizations, notably farmers' groups, may prove valuable advocates for and allies in the protection of dams. They often play influential roles in communities, and thus can help the dam authorities deliver their dam-safety training programs effectively. At the Polonnaruwa town meeting of 16 July,

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30 p. 58, Report of the Breach of the Kantalai Tank Bund, Sri Lanka Sessional Paper No: VII—1987

31 This subject was the point of much discussion at the 20 May 2005 Expert Consultation.

32 Amarasekera, Irrigation Department, comment, 20 May 2005 Expert Consultation

farmer group representatives responded enthusiastically to the idea that they take up organizational roles in preserving dams and reservoirs, and were eager to suggest ways in which they might do so.

3.76 Further, local organizations can be given responsibilities in the custodianship of the dams and reservoirs. If the dam operators can make clear the manifest value of the dam structures and safety procedures, they stand to benefit from a great deal of public support in their safety programs.

3.77 One of the most significant benefits of the public consultation process that led to the production of this paper is the education of the dam engineer community about the potential of community involvement in implementing effective governance and safety arrangements, as stated by the SLNCOLD representative at the 10 August 2005 news conference.[33] The contribution made by the transparent and participatory process to building trust in the professionals among the community was also significant.

[33] Statement made at news conference by Mr S. Karunaratne, , former Director and Executive Director for Dams, MASL; advisor to Technical Services of Mahaweli Authority, Sri Lanka Foundation Institute, 10 August 2005.

Institutional Governance

Status quo

4.1 Currently, responsibility for building, operating, and maintaining the medium- and large-sized dams of Sri Lanka resides with several governmental authorities. All dams are owned by government entities, and operated with government funds. Small dams and other 'tertiary irrigation infrastructure' are planned and built, with local input, by different government authorities; their operation and maintenance are then handed over to local Farmer Organizations.

4.2 The Mahaweli Authority of Sri Lanka, the Ceylon Electricity Board, and the Irrigation Department are the main actors with regard to the large dams. Other players include the Highway and Railway authorities, and the National Water Supply and Drainage Board. The Sri Lanka National Committee on Large Dams is an influential organization comprised of professionals with dam-related technical expertise. The Department of Agrarian Services, the Provincial Councils, local government authorities, local/informal advocacy groups and farmer organizations are among those with an interest.

4.3 The jurisdiction and powers of the different government authorities are not well demarcated and are confusing. The different agencies have different organizational structures and management mechanisms. At the regional and national level, responsible oversight authority is in many cases unclear or absent.

4.4 The Mahaweli Authority of Sri Lanka (MASL), created in 1979, was responsible for the development of the Mahaweli river basin as a site of several large dams caching water for irrigation and power generation. Additionally, the MASL oversaw the Mahaweli Project, a program for poor and landless peoples' resettlement on lands made cultivatable via newly available irrigation waters. With the conclusion of large-scale construction projects, the agency restructured itself into a watershed/river basin management agency.

4.5 The restructuring was marked by a shift in orientation from construction to management, with a particular focus on integrated water and natural resources management planning. Among the many dams owned and operated by the MASL are the largest and most spectacular dams in Sri Lanka, the Mahaweli high dams.

4.6 The other major player in dam oversight is the Irrigation Department, which is part of the Ministry of Agriculture, Livestock, Land, and Irrigation. This agency's authority covers the whole country, including dams of reservoirs above a specified size and other irrigation infrastructure like canals. Most ancient and restored large earth dams are owned and operated by the Irrigation Department.

4.7 In addition to the Irrigation Department's specialized divisions, which deal with different aspects of irrigation oversight, is a National Dam Safety Committee. Water storage and effective utilization is the focus of the Irrigation Department's activities. Thus the Department places emphasis on water conservation, as opposed to the CEB, for whom water is an input and not a product in and of itself.

4.8 The Ceylon Electricity Board (CEB) is tasked, under the statutes of its creation, with responsibility "to construct, maintain and operate the necessary works for the generation of electricity." The CEB also transmits and distributes electricity. Hydropower dams are the main source of electricity generation.

4.9 Hydropower generation is dependent on rainfall. Recent drought years, and their consequential electricity shortages, have impressed CEB officials with the need to diversify generation strategies. Even with thermal generation capacities doubling between 1996 and 2002, as much as 60% of Sri Lanka's electricity is generated by hydropower dams when the reservoirs are full.

4.10 Though the CEB owns and operates its hydro stations, it does not always control the supplies of water for electricity generation. Water disbursement is decided twice yearly by a multilateral meeting between officials of various agencies and representatives of local interests, including agricultural officers and farmers' organization leaders. The MASL and its officials are organizationally and literally the gatekeepers of Mahaweli-cached waters, and in a position to supply the CEB with its needed hydropower input.

4.11 The CEB is the only revenue-generating component of the dam system. As a government-owned monopoly it does not recoup all its costs: "in 2001, the average tariff (Rs 5.53 per unit) was kept below the average cost (Rs 7.20 per unit) resulting in losses of about Rs 12 billion for the CEB." The actual costing of hydro power should be examined to ensure that depreciation and contributions to maintenance are included.

4.12 The current political dispute over CEB restructuring stems from the 2002 Electricity Reforms Act, which called for electricity sector restructuring, towards the goal of more stable electricity supply with reduced government subsidies. The Central Bank Annual Report for 2004 argues for exploitation of the CEB's revenue-generating capabilities to fund dam management, including safety.

4.13 The CEB and the MASL were jointly responsible for the creation in 1998 of a National Dam Safety & Water Conservation Inspectorate. This entity works through a concurrent World Bank project in the Mahaweli Basin to address dam safety and water resources management needs. The CEB outsources the safety and maintenance oversight of its properties, while the MASL has operational centers at each dam as well as a system of independent inspections.

4.14 Numerous other agencies and organizations hold stakes in the management and ownership of dams. They include agencies that use dam-related assets for other purposes, such as the Road Development Authority (RDA), which use dam crests for roads. Other organizations are concerned mainly with regulating the products of the dams, like the National Water Supply and Drainage Board and the National Aquatic Resources Authority, which include dam safety procedures under their programs.

4.15 Yet another group of parties has economic agendas related to dam products and use. This group includes Provincial and Municipal Councils, the Department of

Agrarian Development, environmental and other advocacy groups, and farmer organizations.

4.16 The media, which periodically highlight issues of dam maintenance and safety, are seen as performing the role of a pseudo-regulator. The inspection that occurred prior to the Kantale dam breach was triggered by media coverage.

Financial issues

5.1 The Annual Report of the Central Bank of Sri Lanka (CBSL) (2004) states that a dam audit has identified numerous problems with the administration of Sri Lanka's dams. The root cause of many of the problem areas—from poor maintenance schedules to human-resources mismanagement—was found to be a critical and ongoing shortage of funds. This finding was echoed by many of the participants at the 20 May 2005 Expert Consultation.

5.2 To implement a successful dam safety program, the agencies tasked with performing maintenance and safety functions must receive sufficient funding. The CBSL Annual Report suggests that additional and alternative sources of funding must be found because the government's allocations for dam maintenance are insufficient.

5.3 The budgeted allocation for basic dam maintenance had been set at LKR 300m per year in 2004. This is deemed an appropriate baseline for routine maintenance; however, in this budget there is no provision for larger, longer-term repair projects such as must be undertaken every few years. Dam experts agree that modern dams are built for a period of 50 years. That means that the dam of the Senanayake Samudra, constructed on the early 1950s, is now due for major maintenance work that will cost multiple millions. There are no allocations in the current budget for these kinds of costs.

5.4 Because of the deterioration of budgetary management and routine over-commitments to expenditures and underestimates of revenues, amounts actually disbursed by Treasury fall short of budgetary allocations, forcing the dam owners (primarily the MASL and Irrigation Department) to prioritize the most urgent maintenance projects and postpone others. The massive losses incurred by the CEB as a result of selling electricity below cost by government direction make it difficult for it to engage in any form of rational planned maintenance and upgrading. Postponement of needed maintenance raises its eventual cost and increases the risk of structural failures.

5.5 Dam experts agree that modern dams have a certain lifetime, especially the concrete structures whether appurtenant or comprising the main body of the dam itself. Large- and medium-sized concrete dams must undergo rigorous testing and maintenance work every 50 years. That means that the dam of the Senanayake Samudraya, constructed on the early 1950s, and hydropower dams of the Kelani Basin, are now due for major maintenance work that will cost multiple millions. There are no allocations in the current budget for these kinds of costs. At the expert consultation of the 20 May 2005, an engineer described how

he broke off a piece of deteriorated concrete with his bare hands within one of the sluices at Senanayake Samudraya.

5.6 The MASL is completely dependent on government funding. Water from the Mahaweli cachements is supplied free to the CEB for power generation and to farmers for irrigation purposes. Originally the Mahaweli scheme called for a graduated program of usage charges, whereby tariffs for irrigation waters would be phased in over a period of years. This system was oriented towards developing efficient irrigation practices among farmers, as well as sustainability. It was never implemented.

5.7 The CEB receives free water from Mahaweli sources. The MASL supplies the major input of the commodity's production (dammed water), while the CEB draws revenues directly from the provision of a commodity (electricity). Because electricity-generating water is not monetized, the costs of MASL water storage are thus not reflected in electricity pricing structures. The MASL is additionally unable to recoup its costs.

5.8 The dam owning-operating authorities are hamstrung by insufficient financial allocations and ever-diminishing budgets. The financial decision-making agents in the Government are not directly responsible for dam safety, and those responsible for dam safety are unable to secure needed funds. Thus the owner-operators are tasked with duties they cannot discharge.

5.9 In other countries dams may be privately or publicly owned, but usually the operating authority has the ability to generate revenues. It is highly desirable that the Sri Lankan dam authorities gain a measure of financial stability along these lines.

5.10 The Central Bank recommends several strategies by which the government could raise additional funds. A small increase in electricity tariffs (LKR 0.05 per unit) would pay for the annual LKR300m maintenance budget, thereby freeing up the current budgetary allocation for major repairs, employee and public training, safety sensing systems, and other critically needed items and programs. Unfortunately, the Central Bank does not address the problems created by charging for one use (electricity) and not others (e.g., irrigation).

5.11 The gradual introduction of irrigation tariffs, as initially planned under the Mahaweli scheme, would increase available funds as well as encouraging efficient resource usage. Other activities in and around the reservoirs, like commercial fishing, gemming and recreational/tourist usage, could be licensed under a safety program. Licensing these activities provides revenues as well as an opportunity to better regulate safe use of the dam/reservoir system.

5.12 In any other industry, the owner/operators would recognize the depreciation of the value of their assets and the need to maintain them; they would establish depreciation funds that would be credited on a regular basis; these funds would not be used for other purposes; there would be no surprise spikes in the requirements for maintenance; the maintenance would be done on time and with

adequate resources. This would be not only because of the danger that inadequate maintenance would pose to the public; it would also be driven by economic logic: if the asset is run down or destroyed, the owner/operator would not have a business to run; only millions of rupees in damages to pay.

5.13 Implementation of comprehensive water tariffs would also allow for rational tradeoffs among the multiple and competing uses of reservoir water, currently allocated among users by committees of officials. Charging for water will also create incentives for conservation and for making viable substitutes for reservoir water.

5.14 If the government believes that certain user groups such as farmers cannot afford to pay commercial tariffs or that public policy requires the production of certain goods and services using reservoir water as an input, it may choose to subsidize such users or industries. But such subsidies should be administered transparently and with low transaction costs, preferably separate from the water management regime.

5.15 The discussion of water tariffs at the community meeting in Polonnaruwa with leaders of farmer organizations, some who had been arrested for protesting water levies in the 1980s, was quite enlightening. Using traditional terms such as Velvidane Panguwa (the water manager's share), they stated their willingness to pay for maintenance. Their objections, they said, were to taxes that went outside the district and which went into the consolidated fund. What they wanted was a link between the payments and the maintenance carried out in the dams and reservoirs in their own region. The interdependent nature of the cascaded dams makes it difficult to implement a system of spending money raised from a district only for the dams in that district, but the position of the farmers who are directly affected both by taxes and by dam failures caused by delayed or neglected maintenance is far more enlightened than those of Colombo based activists who take up ideological positions against pricing water.

5.16 The implementation of the above described user-pays cost recovery scheme will require courageous policy decisions to bring the national water resources policy closer to rationality and the recognition that water is not a free good[34].

5.17 In order to implement a rational cost- recovery system for water, it will be necessary to study the experience of other countries and devise a phased transition from the current regime. Adequate and stable funding for the transition will have to be provided either directly by the government or through donor financing.

5.18 It is important that assure that the government agencies associated with dam management, in particular the Dam Safety Management Unit, receive or generate sufficient funding to carry out needed maintenance, regulation and

[34] R. Samarajiva, "The price of free," Lanka Business Online, 11 July 2005, http://www.lankabusinessonline.com/full_story_search.php?newscode=1786313422&subcatcode=24

training programs. Money will additionally need to be spent on the development and implementation of a comprehensive warning system as outlined above.

5.19 Unless the government prioritizes dam safety and assures adequate funding, the dams will further deteriorate and their operating agencies will increasingly struggle to maintain them, provide services, and assure safety. A dam disaster will be inevitable.

Organizational reform of dam operators

5.20 In Sri Lanka at present all dams of significant size are owned and operated by the government, unlike in many other countries. Because the ultimate responsibility for maintenance and safety rests on the dam operators, it is important that they be efficiently operated.

5.21 Several commenters to the draft and at the community meetings criticized the non-adherence to the Standing Orders by senior as well as junior officials of the dam operating entities (Annex A). Simply condemning the behavior of the officials or issuing exhortation that the right thing be done is unlikely to yield the desired results.

5.22 Today, much if not all of the shortcomings of the dam operators are laid at the door of inadequate funding. Inadequate and unstable funding is indeed a serious problem and the preceding section developed solutions to it. However, the problem of not updating Standing Orders and not following them to the letter is not really a problem of money; it is a failure of organization. Simply increasing funds without creating the conditions for organizational reform will not yield the desired results; it may even worsen the situation.

5.23 In many instances such as the Sri Lanka Ports Authority and the Telecommunications Regulatory Commission, it has been found that autonomy from Treasury and financial regulations and the inflow of significant funds has led to a loss of accountability and indeed to reduced efficiency and commitment. If the trust of the farmers who pay the cost-recovery levies is not to be betrayed and the objectives of efficient maintenance of facilities and the provision of safety are to be achieved, it will be necessary to set in place strong transparency and accountability provisions.

5.24 The additional inflows of funds should, among other things, be utilized to adequately resource the front-line management with adequate facilities such as working communication systems and transport facilities and even to increase their current inadequate salaries. However, these increased payments and benefits should be tied to organizational reforms that yield greater efficiency and responsibility. For example, in the new system, there should be periodic audits of maintenance activities and the scrupulous implementation of safety procedures at frontline facilities. If shortcomings are discovered, the relevant officials would have to face serious consequences. This kind of internal accountability is essential if safety regulation of dam operators is to work.

Regulation and multi-party decision-making

5.25 The dam authorities in Sri Lanka are forced to compete for priority in funding allocation and decision-making powers. There is no clear delegation of authority by the government, making oversight only as effective as the leadership of the particular agency carrying it out.

5.26 The government must vest the powers of safety oversight to one unit. Powers and functions must be clearly demarcated. In the case of an interagency conflict, there must be clear procedures to resolve disputes and solve problems. It is patently hazardous to neglect pressing maintenance, management, and use issues as is the case now.

5.27 At present, dam safety functions are vested in agencies that are also operators. It is widely recognized that regulation and operation must be separate; and that regulation must be independent. The absence of a separate and independent regulatory body undermines the effectiveness of regulatory systems. When regulation is carried out by the owning-operating party, there is always a conflict of interest. The agency has no incentives to prioritize safety in its dams; it is treated as a peer by the other agencies is thus unable to perform its regulatory functions effectively.

5.28 In lieu of an effective and transparent regulatory system, the Sri Lankan media acts as a pseudo-regulator. Even this is ineffective; in November 1985, just six months before the disaster, the *Dinarasa* newspaper reported that the Kantale dam was in danger of breaching. The then-Director of Irrigation sent a Deputy Director to inspect the dam, who seems not to have inspected the upstream side of the dam, or the later-to-fail sluice barrel. In the same way, media have carried stories of a crack in the Kotmale dam, which appears to have resulted in slightly higher attention being paid to dam safety at this time.

5.29 In December 2003, the *Ceylon Daily News* warned that heavy vehicle traffic on the restored Kantale dam was endangering the integrity of the dam. The Secretary of the Ministry responsible for irrigation quickly responded with a letter stating that Irrigation Department and independent engineers had previously investigated the problem and declared such claims unfounded. Further, wrote the Ministry Secretary, the agency had instructed the Police to prevent high-speed traffic on the dam road.

5.30 Dam owner-operators are responsible for maintenance and safety procedures. They cannot however be relied upon to carry out extensive internal safety audits. A combination of internal and external monitoring is required. This would include frequent monitoring by operations staff, annual inspection by owner-employed qualified engineers, and periodic inspection by fully independent qualified engineers.

5.31 The logical conclusion is that government should establish a regulatory body with dam safety as its primary objective, separate from and superior to, each of the entities currently owning, operating, or using dams. It should give priority to

expertise and stakeholder consultation and be insulated from day-to-day political interference. In other words, it should be independent. Independence requires that the constitution of its decision making board, the recruitment and discipline of its staff, and the overall conduct of its activities meet some minimum specified criteria. Independence also requires strict provisions for transparency and accountability. The current difficulty of a lack of power over peer government agencies can only be resolved by placing the dam safety functions within an organization that is accountable to Parliament and is not under a specific Minister.

5.32 The government need not create an entirely new agency to regulate dam safety. The DSMU, which contains specialized expertise on dam hazard detection and monitoring, can be placed within either the Public Utilities Commission, which already has some safety regulation functions (for the electricity network), or the proposed NEWS:SL national early warning system. The larger organization will give the necessary stature, authority and independence; the focused unit structure will allow the experts to conduct their business in a professional manner.

5.33 The organizations described above contain several units already pursuing dam safety agendas. The DSMU can be staffed by drawing from one or more of these entities.

5.34 It will be necessary to enact legislation to give effect to the proposals contained herein. The PUCSL Act envisages that Commission's general powers will be supplemented by industry specific acts (e.g., the Electricity Reforms Act, No. 28 of 2002). Since the NEWS:SL agency has not been created, it may be possible to include Dam Safety as a chapter in the main statute, or preferably, design that Act in the same modular form as the PUCSL Act, and link the Dam Safety Act to it.

5.35 It must be emphasized that the removal of immediate dam safety responsibilities from the persons and organizations currently in charge of the reservoirs is not proposed in any way. Those who are closest to the potential hazard-generating structure and who have the best knowledge of it must continue to perform those functions. What is proposed is not a central dam safety authority, but a central entity responsible for setting standards on dam safety and enforcing them without fear or favor. The DSMU will contain the country's best expertise on dam safety and it will have a mandate to continually seek out and apply knowledge on international best practices in this field. This means that it will be the natural place to go when anyone, including the persons in charge of the dams, need advice and assistance.

5.36 The mandate of the DSMU will be explicitly limited to regulation. The relationship between the current dam operators and the DSMU will be similar to that between a telecom or electricity operator and the relevant regulatory body. The regulatory body does not interfere in or usurp the everyday managerial functions of the dam operators. It gives directions on dam safety, leaving the details of implementation to the operators. It will specify, and enforce, periodic

internal and external audits. It may conduct public hearings, investigations, or it may direct that investigations be conducted by the operators. It may provide expert advice and training.

5.37 In the same way that large operators with market power are treated differently from small operators in telecom and electricity regulation, it will be necessary to impose differential regulatory burden on the operators of large dams with major hazard potential (e.g., the Mahaweli high dams) and the thousands of minor irrigation works under the Department of Agrarian Services.

5.38 Given the multi-use characteristics of dams and reservoirs, disputes between different users and agencies will be unavoidable. The legislation should include provisions for alternative dispute resolution by the DSMU and its parent body so that these disputes can be resolved speedily. Ideally, the DSMU will promote decision making procedures that will minimize the occurrence of disputes (known in the regulatory field as "alternative regulatory practices").

5.39 It is well known that simply giving an agency the power to issue directions is not enough. It must have the ability to follow through in the event of non-compliance. In the case of infrastructure regulation, regulatory agencies are given carefully circumscribed powers to compel regulated entities to follow directions. The DSMU and its parent organization should also be given such powers.

5.40 Most if not all operators do not directly earn revenues from the operation of dams. All the dams in Sri Lanka are owned and operated by government entities. These two facts pose a special challenge with regard to enforcement of orders and directions. Conventional infrastructure regulation assumes that the regulated entities earn revenues and do not wish to be deprived of those revenues. Therefore, enforcement rests on penalties and levies. Conventional regulation further assumes that the payment penalties and levies will actually hurt the operator and the management. In the case of fully government owned operators this assumption does not hold. If the regulator takes away a portion of the revenue of the government-owned operator, its management can simply ask the government to replenish its funds or can engage in some form of investment or service-provision "strike," postponing or reducing investments or service provision to make up for the lost revenues.

5.41 Additional creative solutions may be devised, but at this point the only feasible solution appears to be to give the DSMU and its parent the power to shut down structures that are judged to pose unacceptable risks, again using carefully circumscribed procedures that allow for optimum publicity and which adhere to the principles of natural justice.

5.42 Assume that it is found that a certain dam is found to be a potential hazard. Directions are given to prevent or mitigate the hazard. For whatever reason, possibly because of a lack of funds, the prescribed actions are not taken. Because it is pointless to fine a non-revenue generating entity that is in any case

short of funds, the solution would be to order a gradual emptying of the reservoir to the level that it ceases to be a potential hazard.

5.43 The question can be asked about getting this order enforced. If the first order was disobeyed, why will the second order be obeyed? The answer is publicity. It will be difficult for a government owned dam operator to justify the continuance of the public hazard. On the other hand, the publicity and the threat of closure will strengthen the hand of the dam operator against the government in obtaining the necessary resources. For example, the farmers who will be deprived of irrigation water may take to the streets seeking resources to prevent the closure of the reservoir. The objective, it must be recognized, is not to close dams or punish operators, but to ensure safety. Therefore, the closure powers must be used very sparingly and with as many opportunities as possible for remediation of the problem and the avoidance of the penalty.

5.44 As a regulatory body, the DSMU and its parent are responsible only for safety oversight of the dam and watershed system. It is not responsible for dam management and thus will not directly implement the safety programs outlined above. The unit will have the technical expertise and funding to aid operators in proactively developing these programs; however, implementation is ultimately the responsibility of the operators. Because the unit's primary responsibility is regulation, it will deal only with the heads of the operators or nominees on specific issues. It will keep scrupulously clear of second-guessing managers.

Recommendations

Awareness

6.1 The use of a new tool available on the web, http://maps.google.com/, will powerfully demonstrate how many inland reservoirs dot the landscape of Sri Lanka. In as much as inhabitants of this island must be aware of the benefits and dangers of living surrounded by the Indian Ocean, they must also become aware of the benefits and dangers of living in the shadow of these inland seas. It is a sign of hope that our people have recognized the dangers posed by the human constructed but ill-maintained dams before the political leaders have.[35]

6.2 It is important for the concerned professionals and the community leaders who initiated the process that led to the production of this concept paper to continue to raise the awareness of decision makers and opinion leaders of the gravity of the problem of dam safety. Unless reforms are implemented, there is only a question about when a dam breach will occur, not whether one will.

6.3 In the post-tsunami context of greater awareness of the importance of disaster preparedness, it is hoped that the government, especially the newly created Ministry of Disaster Management, will take the lead in raising awareness of the risks posed by ill-maintained dams.

Governance

6.4 The existing governance arrangements must be reformed by creating a Dam Safety Management Unit (DSMU), an independent regulatory authority that could be housed either within the existing Public Utility Commission or a National Early Warning Authority, which will be at a level above the current government-owned operators and users of dams and their products. The DSMU shall be separate from, and independent of, the operators of dams.

6.4.1 Its remit shall be limited to safety and economic regulation, including the creation of conditions for the implementation of effective safety measures by dam operators.

6.4.2 The responsibility for the safe operation of dams and reservoirs shall be clearly demarcated and shall remain the responsibility of operators.

6.4.3 The DMSU shall have the power to mediate and determine conflicts between different entities using dams, reservoirs and their products.

6.4.4 The DMSU shall have the power to order the shutting down of dams and reservoirs that pose unacceptable risks.

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[35] Translation of a comment made at the Polonnaruwa town meeting: "If a dam breach occurs it tends to have a sequential effect. It's a system; the smaller tanks can burst too. Then it will be like a tsunami."

6.4.5 The DMSU shall conduct its business in a transparent and consultative manner.

6.5 Improved governance cannot ensure safety by itself; a stable and adequate stream of funds is necessary to ensure regular maintenance and upgrade of dams. The funds must be collected on the basis of the user-pay principle. All beneficiaries of the products of the dams and reservoirs must contribute to their upkeep in good and safe order. The funds must be managed in a prudent and transparent manner. If there are specific user groups who the government considers unable to make the payments, they should be given subsidies, preferably subsidies that decline over time and which are disbursed separately from the management and regulation of the dams.

6.6 The increased inflow of stable funding will make it possible to pay the persons working on dam management adequate salaries and to give them the necessary equipment for functions such as communications, transport and hazard detection and monitoring. However, safeguard must be set in place to ensure that the resources are spent only for the intended purposes and in an accountable manner.

6.7 New legislation will be necessary to delineate the form of the new regulatory regime and the funding mechanism. Concurrently, it would be wise to discuss and adopt a new national water resources policy that recognizes the multiple demands made of water resources, the need to recover the costs of producing water in usable form, and the absolute necessity of ensuring that the dams are well maintained and that safety is invested in.

Hazard detection and monitoring and ICTs

6.8 Because Sri Lanka is a densely populated country in which large numbers of people live downstream of, and in close proximity to, dams, early detection of signs of distress in dams is very important. In the case of cyclones, detection and monitoring technologies combined with ICTs, allow for 3-4 days of warning. Even with teletsunamis generated by earthquakes in the Sunda Trench off Sumatra, it is estimated that the East Coast of Sri Lanka would have about 90 minutes of warning and the other coasts longer. By contrast, a dam failure, by its very nature as a proximate hazard, will give only a very short time for dissemination of warnings, unless the detection and monitoring system is very sophisticated.

6.9 There is no dispute that human interpretation and judgment is extremely significant in making predictions regarding dam failures and issuing warnings. However, in view of the importance of adding even a few minutes to the period from detection to the onset of the hazard, it is imperative that efforts be made to upgrade detection and monitoring systems. Because it is unlikely that there will be major new dam construction projects in Sri Lanka in the near future, there will be no opportunities for Sri Lankan engineers to engage with international best practice in the area of dam safety. Therefore, it is recommended that

6.9.1 A technical assessment of existing detection and monitoring systems in Sri Lankan dams is commissioned

6.9.2 On the basis of that assessment two pilot projects for dam hazard detection and monitoring systems be initiated, one for a high-risk modern dam and the other for a high-risk ancient or recent dam

6.9.3 If at all possible the dam hazard detection and monitoring pilot projects be coupled with last-mile hazard information communication and disaster preparedness projects in villages downstream of the dams.

Miscellaneous

6.10 The information and recommendations contained in this paper have been generated through an open consultative process driven by experts in subjects other than dam management and by civil society. It may be more comfortable for the government to appoint a panel of government officials to consider the content of this paper and the proposals contained therein at the outset.

6.10.1 The document and in particular the comments that the process generated contain a wealth of information that can form the basis of informed action.

6.10.2 It is of course to be emphasized that government should act expeditiously.

6.11 The unconventionality of the process that produced this document should not get in the way of addressing the main problem, which is ensuring that best use is made of the dams that constitute important elements of our society, economy and culture while reducing the risks to the structures themselves and the many whose lives and livelihoods are currently under unnecessary risk because of the flawed governance of this vital infrastructural resource.