ISSUES AND STRATERGIES OF DAM SAFETY MANAGEMENT IN SRI LANKA

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by

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1.0 Introduction

Dam safety is an emerging subject area in the water resources engineering. It has been a major concern of engineers even in the past but has not received this secular attention as now. With construction of bigger and bigger dams all over the world which stores not only water but also high risk, engineers are beginning to realise that focussed attention should be on dam safety without diluting dam safety inside a bigger package of water resources engineering and management. This has become a compulsion thanks to the anti-dam lobby, which also pinpoint the safety as a major issue in their agenda. Therefore dam safety is now emerging as a subject on its own, globally. This has now being widely accepted in Sri Lanka, too.

Safety of a water retaining structure is not only considered in the planning and design stages but also is continuously applied with various stages of the life of the structure. It is also considered at the construction stage, first impounding, operation, flooding and maintenance. The expertise required to handle this encompasses hydrology, hydraulics, engineering geology, hydro geology, engineering materials, mechanical engineering, instrumentation and many other subject areas. The dam safety requires integrate application of all these subject areas. It also has to cultivate certain skills such as prediction under uncertainty, decision making with less exact knowledge etc. Hence it is a complex domain which needs careful analysis and thought. The objective of this article is to highlight some of the main issues that dam safety managers would be confronted in Sri Lanka and what options they have got in resolving those issues, considering the complexity of the subject.

2.0 Issues

2.1 Ancient dams

The newly built dams are equipped with necessary instruments for monitoring, manual of procedures for operation and maintenance, standing orders for flood management and guidelines for periodic or random inspections. These are prerequisites as per the emerging dam safety discipline. Usually those are formulated at the design stage and normally reflect the design limitations and assumptions. These allow the manager to be in constant vigilance, take early prevention action and to take other action necessary to sustain the safety of the structures. However many large dams built in the past do not have such comprehensive dam safety packages. It is difficult to formulate such a package for a dam built long ago because of the absence of many design details and assumptions or assessments, which cannot now be derived. Unfortunately most of the dams operating in Sri Lanka falls into this category.

Editorial of the SLNCOLD bulletin No. 4 of volume 1 described this situation in following words. "In the case of structures whose gestation is lost in the antiquity, no plans exist and no data but the name of a king who restored the structure. This itself implies the original structure was built ages earlier. (Silva, 1989 :1)".

2.2 Ancient Trees and abandoned structures

There are huge trees in some dams, which endanger the safety. Death of such a tree will create seepage paths (a tree suspect for such a leak was removed recently at Giritale), and leaks. There are also old sluices

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in dam bodies, which have been abandoned. Those abandoned structures too can create seepage or leakages (there are already few structures that leak, eg: Two old sluices at RB and LB ends of Giritale Wewa and old sluice at Wahalkada Wewa). It is not possible to remove those without lowering the water level and without incurring a large cost and therefore they remain potential threats to the dam bodies.

2.3 Inadequate Spill capacity and Freeboard

Dams are designed for a flood of a specified magnitude (eg: 25 year, 50 year, 100 year or maximum probable flood) depending on the size of the dam and downstream developments (a kind of hazard rating in the dam safety terminology). However, when there is a cascade of minor tanks, which are designed for a 25-year flood, there is a likelihood of breaching those in a flood of a bigger magnitude creating flash floods downstream. Some of the bigger reservoirs downstream would not be able to cope up these flash floods, due to this possibility not being considered in the design stage.

Apart from the non-consideration of possibilities of flash floods in the design stage, there are instances where subsequent changes in the upstream flows due to new developments are not accommodated and the current capacities are not reviewed or updated accordingly. The diversion undertaken under Mahaweli Project has changed the inflows to many reservoirs but sufficient reviews have not been undertaken to review the peak floods taking this into account.

2.4 Inadequate gate mechanisms and primitive designs:

In old dams provision is made to close the sluice for emergency repairs and inspections by using stop logs, which cannot effectively be used in an emergency. (In 1998, during the NE monsoon, at Giritale, when the reservoir was full, sluice gate could not be closed and the emergency gates also got stuck preventing emergency repair).

Some gate arrangements have only one mode of operation. When the gates fail to operate in that mode and when they do not have optional modes, crisis situations can occur. Because of this, it is now recommended to have more than one mechanism for gate operations and more than one set of gates for each structure.

Both of the above inadequacies in the old dams make them vulnerable in emergency situations, especially during heavy floods.

2.5 Difficulty in detecting lapses in Construction

Most of the failures reported are associated with overtopping the dam due to flash floods for which the dams might not have been designed. Obstructions to spill tail and approaches can also lead to overtopping even for design floods. Any negligence in the part of the person responsible for construction of the reservoir in making proper provision for spill approach and spill tail will normally remain undetected. Especially when the design notes and construction details are not available for perusal, this is more probable. Though this mostly happens in spill tail and approach, it can happen in other items of work too.

2.6 Encroached Reservations:

Some of the reservations of the old dams have been either encroached by the people or remain as private property as acquiring has not been done. Those are neither demarcated nor managed by the custodians of these reservoirs. Hence people cultivate the toe of the dams with seepage water and as a result unusual seepage cannot be monitored. Seepage drainage paths get blocked causing danger to the safety of the dam. Tank bed cultivation close to the abutments is also frequent occurrence and this destabilises the slope of the bund and abutment.

2.7 Changes to dam and appurtenant structures

With time, capacity of the reservoir tends to decrease because of siltation. People downstream start cultivating additional acreage not anticipated at the design stage for which the managers are unable to intervene. Because of these reasons, there is pressure from users to the managers to increase spill crest level and also the bund. If the tank spills frequently and inundation is not going to effect the upstream inhabitants, the managers are forced to cater for these pressures, without adequately reviewing the original design. As a result, there could be serious consequences on the safety of the dam. For example, the seepage paths that would have been cut-off by the impervious core fill will no longer be subjected to the same barrier once the bund is raised. (Figure 1 illustrates this phenomenon.) This will lead to washing away of the bund material at the toe of the bund and will sometimes cause slip failures. Failure also can occur due to the poor bonding between the old bund and the new filling, if adequate care is not taken during the construction.

2.8 Interference of fishermen

Though fishing is common in most reservoirs proper provision (that also takes care the safety of the bund) is not made available to the fishing community. Hence, the boats are anchored in the bund, rip rap and appurtenant structures causing damage to those. The fishermen are mostly migrants who come for the seasonal harvest and then use the bund to make their temporary huts again destabilising or eroding its slopes.

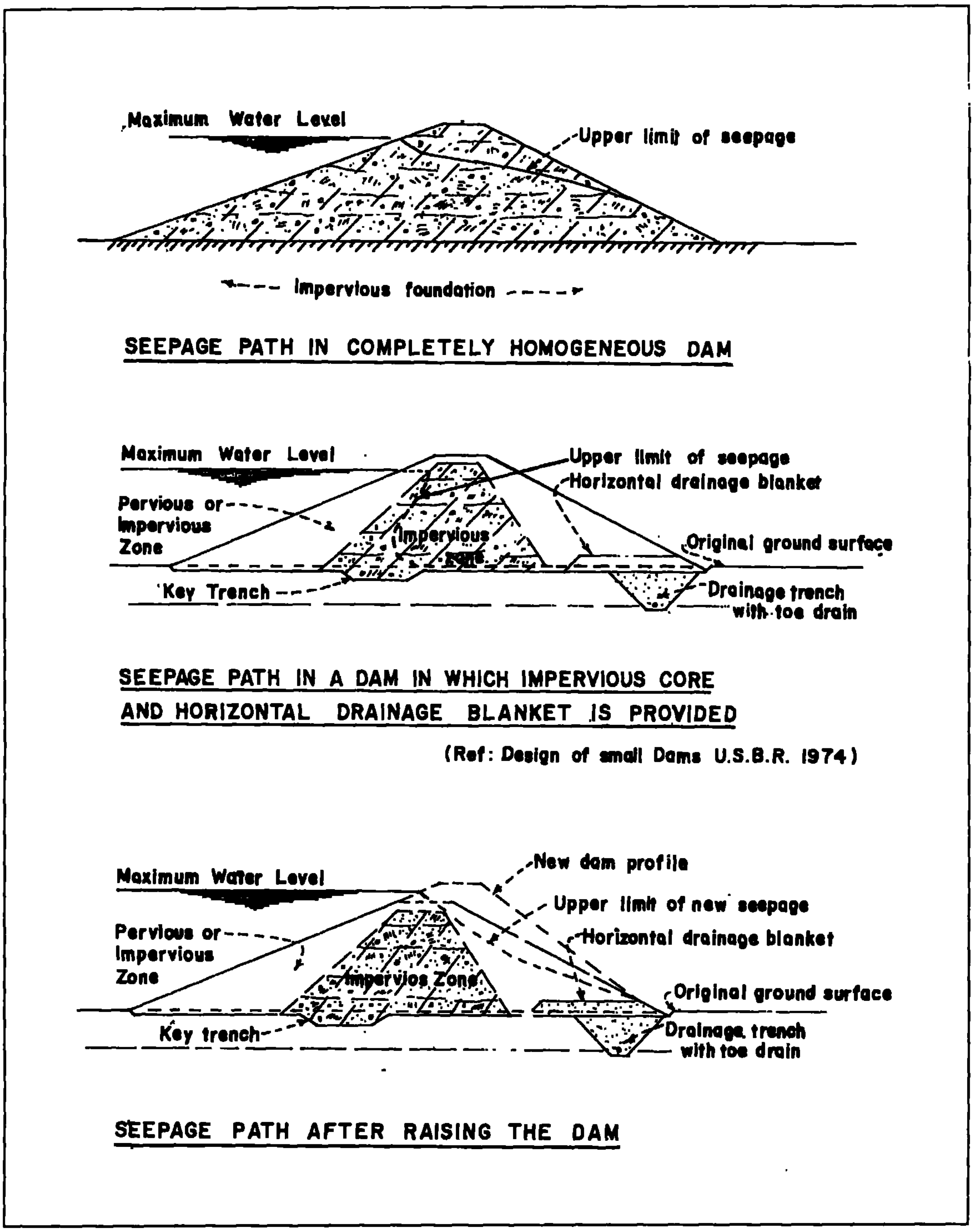
Maximum Water Level
Upper limit of seepage
Impervious foundation
SEEPAGE PATH IN COMPLETELY HOMOGENEOUS DAM
Maximum Water Level
Upper limit of seepage
Horizontal drainage blanket
Pervious or Impervious Zone
Impervious zone
Original ground surface
Key Trench
Drainage trench with toe drain
SEEPAGE PATH IN A DAM IN WHICH IMPERVIOUS CORE AND HORIZONTAL DRAINAGE BLANKET IS PROVIDED
(Ref: Design of small Dams U.S.B.R. 1974)
New dam profile
Maximum Water Level
Upper limit of new seepage
Horizontal drainage blanket
Pervious or Impervious Zone
Impervios Zone
Original ground surface
Key trench
Drainage trench with toe drain
SEEPAGE PATH AFTER RAISING THE DAM

Figure 1

2.9 Interference of people who use the tank for bathing and other personal uses

Similar interference is observed from people who use the tank for bathing, washing of vehicles and clothes. These users are rarely identified and appropriate provisions made for. Even in case where such provisions are made people without making use of those settle for other places in using the reservoir. They create footpaths all over the bund in the process and damage or dismantle the rip-rap. Magalle Tank, in Nikaweratiya Town is a classic example of such damage caused by these types of users.

The bund and surrounding areas are being used by people for various activities. Some people make use of the berms as "Kamatha", where farmers do threshing using cattle causing damage to the bund. They also allow buffaloes to enjoy the mudpools that are normally available at the toe of the bund where seepage water is pooled up. By that, they endanger the foundation of the bund. In some cases, herds of buffaloes are herded to the reservoir bed to enjoy their daily bath, causing immense damage to upstream slope of the bund.

2.10 Interference of Institutional Users

There are institutional users, both state and private organisations, who also endanger the reservoir through their activities.

Domestic Water Supply authorities are classic example for this interference. They construct and manage their intake structures built within the reservoirs and usually disturb the dam. Because these organisations do not bear any cost of construction of the dam body or the maintenance of it, probably they do not feel the consequences of their action.

Another is the agency responsible for managing the roads. In rural areas the road networks closely follow the dam axises and canal network. This happens as developments of water resources precede the road development work and also as community activities centres around irrigation schemes once they are built. When the road is laid on the bund crest or on a berm there could be a potential threat to safety of the bund, latter often creating severe issues than the former.

When road runs on bund crest it could create uneven settlements, create water pockets, and make the bund susceptible for slip failures. When a road runs on a berm (close to the toe), it could also create uneven settlements and also obstruct the drainage paths and could create larger slip failures and also foundation failures.

Though maintaining the crest or berm of the bund is vital for safety of the bund, for the Road Authority or for the organisation responsible for maintaining the road it is another stretch of their long network. Hence the same priority would not be given to maintain it compared to that given by the custodian of the bund, if it maintains the same.

Tourist industry is also a major intervenor. They are also attracted to the water bodies and situate their hotels and leisure camps around those. Though interference of these could be marginal in the short-term there could be adverse effects on the long run, as there is no regulation of their activities at present.

2.11 Multiplicity of owners/ managers of dams in a single basin

There are many organisations that own and manage dams in one single river basin. Irrigation Department, Mahaweli Authority of Sri Lanka, National Water Supply and Drainage Board, Ceylon Electricity Board, Agrarian Services Department and Provincial Councils are some of those. Farmer Organisations, after the completion of the turning over of small systems in year 2000 will get added to this list. The safety standards, operational priorities, expertise, concerns are different from one organisation to the other. However action in one could have an impact on nightmares of the dam safety managers. A classic example was the chaotic situation that occurred after the opening of floodgates at Kalaweva without intimation to the downstream Rajanganaya scheme in 1993.(Please see fig.2 for cascade system of Kala Oya basin which illustrate this situation.)

Apart from these formal organisations there are other small organisations that undertake development in the basin without formal safety standards being maintained. Those include the work undertaken by farmers under Freedom from Hunger campaign, World food aid program and Janasaviya/ Samurdhi programs. The small storage tanks restored by them are vulnerable and can breach in a flood making flash floods downstream, complicating the effects. Those also can obstruct the flood paths of major dams creating complications.

Frequent change of hands of these schemes from one organization to the other is another closely related issue. In 1970's, when the Territorial Civil Engineering Organization was formed, some of the schemes were handed over to this organisation by the Irrigation Department. When this institutional trial failed it was again taken back to the Irrigation Department. In the process many data, plans and documents had been misplaced. In addition, the continuity of the manage-

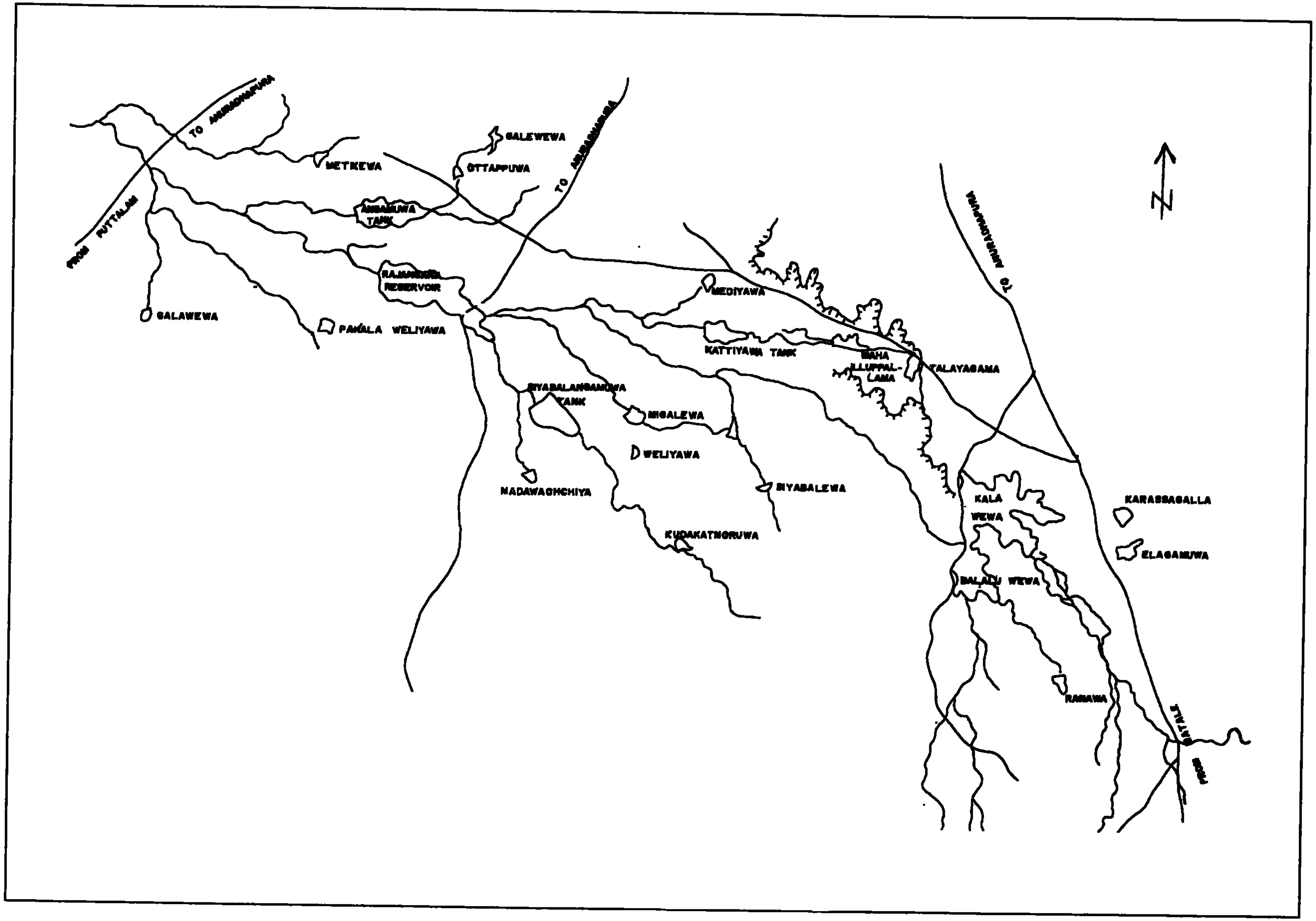

Figure 2: A Section of Kala Oya System

ment practices was lost. The effects of this are still reflected when tracing the historical data and scheme plans for identification of safety problems. Similar phenomenon is likely to follow in the other transfers (Provincial councils, farmer organisations, etc.) too.

2.12 Loss of Important data, plans and documents

Data is required to identify safety problems, predict behaviour and take precautionary action for assuring safety. Loss of data, plans and documents can be caused also by reasons such as negligence of data conservation, apart from what is mentioned in the earlier section. Not only static data like scheme plans, construction materials and techniques, foundation details, but also dynamic data (time series data) like seepage observations, ground settlements, flood performances and observations at the first impounding, are very important for dam safety managers. Absence of such data (especially the latter) could also happen due to non-collection of those appropriately. Whatever the cause, absence of such data creates many problems to managers of dams.

2.13 Changes in climate and land use

As a result of changes in the climate and the land use magnitude of probable floods can change. These changes are not in the conservative directions but always in the adverse direction. Also the retaining capacities in the tanks could change faster than expected. Hence dams could fail even before it's expected lifetime.

2.14 Landslides

Though there are significant landslides in the hill country of Sri Lanka , still there are no reported cases to indicate that landslide have caused a dam failure. However such possibility cannot be totally ignored as there had been cases in other countries. For example, "in 1985, the Tailings dam, in Italy was overtopped after a landslide which caused 150 casualties (News report in International water power journal, 1985 August.)"

2.15 Sabotage

Especially in the Sri Lankan context possibility of sabotage was not totally ruled out. Dam safety managers therefore face the challenge of taking sufficient precautions to prevent such catastrophe.

3. Resolutions of Issues

Most of the issues listed above have to be addressed in its totality than separately. Also resolving at least a large number of issues involve more than one strategy.

3.1 Awareness

Many of these issues have not surfaced and therefore have not got the attention of the dam safety Managers and their staff at the operating level. It is necessary to identify and make these hidden issues aware to not only these officers but also different users and the general public. The officers who are responsible for allocating financial and other resources for dam safety activities too need to be made aware of these issues.

3.2 Collection and maintenance of static and time series data

Once these safety issues are identified, it is necessary to assess the magnitude of the issues with respect to each scheme. In making such an assessment one needs to collect data and maintain such data in a systematic manner. Action also should be taken to preserve those data in an easily retrievable form. Data includes existing spillway capacities, catchment and its characteristics, land use patterns and changes in the land use in the catchment and the downstream, catchment developments, rainfall and rainfall distribution, siltation rates, settlement (both foundation and dam wherever appropriate) rates as indicated through installed instruments, strength of materials, ageing indicators, development of cracks, seepage rates, leak rates, etc. The data also should be collected to assess the number of casualties in the event of a failure in addition to economic damage. The latter is especially important in establishing a hazard rating to the scheme in question.

Institutional capacity should be built up to handle such a data base in all the Irrigation Institutions.

3.3 Review Design, Making changes and incorporate changes and new design data in safety management.

Once the data is available, the designs can be reviewed in the light of those data. Changes may be affected to gate arrangements, spillway provisions including spill tail and spill approach provisions, toe drain and filters, restoration of reservations, restoration of slopes, obstructing berms and laying of rip-rap etc.

Such reviewed design and changes should be incorporated in formulating safety procedures. Safety manuals should be redrafted where available, incorporating these procedures and any other standing orders deemed necessary.

3.4 Safety Manuals

Safety manuals may have to be prepared afresh for most schemes. These manuals that consist of both permanent orders and seasonal orders have to be prepared or updated by a panel of specialists and representatives from all the relevant stakeholders. It will identify different officers from different organisations who should perform the necessary functions to ensure safety of the scheme in question and specify the functions in detail. An example for the necessity of such an integrated approach could be found in the Kelani Ganga Flood Protection Scheme, where Irrigation Department, Ceylon Electricity Board, Reclamation and Drainage Corporation, etc. are to be involved.

3.5 Monitoring by Instrumentation and Inspection

To keep vigilance, necessary instrumentation should be made in place where appropriate and regular readings should be taken. Survey and settlement gauges are the simplest instruments that can be installed and monitored without much involvement. Weirs to measure seepage are also used where unusual seepage flows have been observed.

Regular inspections also should be done by either general engineers or team of multi-disciplinary engineers (disciplines mentioned in para 2 of Introduction of the document), to detect any unusual behaviour in the dam body or appurtenant structures. If an irregularity or abnormality is found, it should be monitored more frequently and if it was found by a general engineer, it should be referred to the relevant specialists for advice. These inspection teams also should ensure that regular readings are taken by instrument readers.

Both instrumentation and visual inspections can help the dam safety manager to identify potential defects that might lead to failure. However, visual inspections can identify the defects only after the defects reach to a certain level. But instruments can issue signals much earlier. According to the November, 1985 issue of the International Water Power "nearly all the major dam disasters are associated with sites having no instrumentation or instruments that were not used effectively". The cost of instrumentation is very low when compared to the benefits it would give. For these reasons, the instrumentation and inspection, should be appropriately mixed and used by the dam safety manager.

The frequency of inspection, the level and depth of inspection and the personnel who should be involved, would depend on the hazard rating of the scheme. For each scheme, a hazard rating should be done taking in to consideration, the capacity of the tank, height and length of the dam, age, downstream development and downstream human habitats and many other risk parameters. This will give an idea about the potential risk involved and guide the officers in arriving at priorities for keeping vigilance. It could be used for prioritising preventive and corrective actions later.

3.5 Documentation

The performance both good and bad should be documented and preserved for future use. Especially problems due to ageing and deterioration of materials could be detected by this documentation. This is normally given least priority by the field staff who is more oriented to carryout physical work and therefore should closely be overseen by supervising officers.

Predictions, potential weak areas, preventive action, remedial measures can be based on the lessons drawn from the past performance of the dam. For example, a slip failure in the past, which had been subsequently restored, can be a potential site for a similar failure in future. A flood of a particular intensity that caused overtopping the bund due to inadequate time to open all the spill gates could be a lesson for early and simultaneous gate operations in a similar situation in the future.

The past experience documented can be used not only for the same scheme but also for other schemes, in the region, country or even globally.

3.7 Short term and long term solutions:

It will not be possible to give a comprehensive solution immediately for various reasons (water level in the reservoir may be high and lowering would not be feasible at that moment, funding or other resources may not be available immediately, etc.). In such cases, interim solution to arrest further deterioration should be made.

3.8 Legislation

Unless the responsibility of dam safety is vested with a central authority and specified and specialised officers are employed the importance of dam safety will not be felt. This necessity is being identified worldwide and legislation is coming to being in many countries. Sri Lanka with its large dams needs to follow the same.

There are issues like how to distinguish between a human error and a natural calamity in a disaster. Especially, when the level of technology and level of data/information available is low, as in Sri Lanka, establishing this is difficult. However, law can provide a basis of establishing correct operational procedures for sustainable maintenance of dams.

Legislation could cover the aspects such as:

1. Review and approve plans and specifications for new dams or modifications of dams
2. Require certification by the responsible engineers that a dam has been constructed or modified in accordance with approved plans and specifications.
3. Issue certificates of approval containing terms and conditions for safety impounding Water behind dams.
4. Inspect dams during construction and periodically inspect all completed dams.
5. Require dam owners repair or remove that are found to be unsafe (US Committee On large dams, 1982).

3.9 Investigations, Research and use of new technology:

It may be necessary to undertake investigations and research on conditions of the dams and foundations especially in ancient dams. This needs to be done for the appurtenant structures too. Especially determining the age of the structure where such data is not available and any signs of ageing would be beneficial. Nuclear technology can be used in detecting ingress points, leakage paths and many other hidden defects without opening up the dam.

There are new gated arrangements that can be operated easily and quickly. There are also gates that automatically operate which can be used in spillways, called fuse gates. The latter can increase the reservoir capacity without raising the spill level permanently.

There are better safety arrangements available like gabions in rip-rap , geotextiles again in rip-raps and also in filters etc. Without providing a separate spill there is now a trend to have dams which could be overtopped. This can cater for very large floods. These technologies can be useful for dam safety managers for improving the safety standards where such is demanded.

3.10 Access to Dams:

While the access roads to dams should be kept in a good condition for regular inspections, operations and to effect any repairs, there should be restrictions to entry into the dam and appurtenant structures for unauthorised persons.

4. Conclusion

Dam safety, especially in the Sri Lanka context, where very old dams exist, is a challenging area in the water resource engineering. Its scope is wide and it encompasses technical, organisational, social and economic spheres. Its importance is felt increasingly due to the risks involved. In the preface of the book on "Dam Safety Practices and Concerns in the United States", James Williamson, says that "On reading these papers, one cannot help but be impressed by the scope of the dam safety problems. It is more than a technical problem, it is also an organisational one and above all, a funding one". This statement is more relevant for Sri Lanka, being a not so rich country. However, with a strategic approach as suggested in the paper, Sri Lanka, will be able to address majority of the dam safety issues.

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