



The World Bank Group

Steps to Improved Hydropower Dam
Safety in Nepal Final Report

For

Nepal Dam Safety - Advisory Support
to Improve Readiness for Hydropower
Preparation

H352327-00000-200-230-0012

Rev. 0

September 8, 2017

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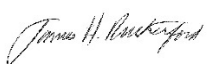


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Appendix B Nepal's Planned and Existing Hydropower

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Foreword and Acknowledgements

Hatch and MHI would like to place on record our thanks to Pravin Karki of the World Bank for his foresight in initiating this project and for his ongoing and collaborative support in developing a plan for improving dam safety in Nepal.

The Project team would also like to thank Mr. Karki's colleague at the World Bank, including Mr. Satoru Ueda as well as Dr. John Reynolds who was engaged as a Consultant on Natural Hazards by the World Bank. This project would not have been possible without the inputs of Mr. Karki and these individuals.

Abbreviations and Glossary of Key Terms

ALARP	As Low As Reasonably Practicable
ANCOLD	Australian National Committee on Large Dams
CDA	Canadian Dam Association
DBE	Design Basis Earthquake
DBM	Design Basis Memoranda
DHM	Department of Hydrology and Meteorology
DHM	Department of Hydrology and Meteorology
DoED	Department of Electricity Development
DSE	Dam Safety Engineer
DSMS	Dam Safety Management System
EAP	Emergency Action Plan
EPP	Emergency Preparedness Plan
FERC	The US Federal Energy Regulatory Commission
GBR	Geological Baseline Reports
GBR	Geotechnical Baseline Report
GDP	Gross Domestic Product
GLOFs	Glacial Lake Outburst Floods
GoN	Government of Nepal
GWh	Gigawatt hours
HPP	Hydro Power Project
IBN	Nepal Investment Board
ICOLD	International Committee on Large Dams
IDF	Inflow Design Flood
IDOF	Ice Dam Outburst Flood
IHP	Incremental Hazard classification
IPP	Independent Power Producers
IPP	Independent Power Producer
IPPAN	Independent Power Producers Association Nepal
LDOF's	Landslide Dam Outburst Floods
MCE	Maximum Credible Earthquake
MOE	Ministry of Energy
MOE	The Ministry of Energy
MW	Megawatts
MWR	Ministry of Water Resources
NEA	Nepal Electricity Authority
NEA	Nepal Electricity Authority
NOAA	National Oceanic and Atmospheric Administration

OMS Manual	Operation, Maintenance, and Surveillance Manual
PDSR	Periodic Dam Safety Review
PFMA	Probable Failure Modes Assessment
PFMs	Potential Failure Modes
PLL	Potential Loss of Life
PMF	Probable Maximum Flood
QCIP	Quality Control Inspection Program
STI	Supporting Technical Information document
USACE	US Army Corps of Engineers
USBR	US Bureau of Reclamation
USGS	United States Geological Survey
USSD	US Society on Dams
WEC	The Water and Energy Commission
WECS	Water and Energy Commission Secretariat
WREPA	Water Resources and Electricity Policy Act

Executive Summary

The power demand in Nepal is expected to increase by over 1,000 MW within the next decade with demand in neighboring India potentially adding another 1,000 GW by 2030. While Nepal has more than enough identified hydropower to meet the anticipated load growth, to properly utilize this resource, a regulatory framework needs to be in place to assure that future hydropower projects are developed in a way that minimizes the threat to life safety, economic and environmental risks and losses to significant cultural heritage.

A well-structured dam safety management program has proven to be effective in reducing the potential for dam safety incidents. For example, following the enactment of dam safety legislation in the USA in 1996, the occurrence of dam safety incidents declined significantly, dropping from an average of about 39 per year between 1995 and 2000 to about nine incidents per year after the dam safety programs began to take effect. The success of the evolving dam safety management methods is also highlighted in International Committee on Large Dams (ICOLD) Bulletin 99. In this bulletin, it is reported that the percentage of failures of large dams has shown a remarkable decrease, from 2.2% of dams built before 1950 to less than 0.5 % of dams built since 1950.

The objective of this report is to provide the guidance that the Government of Nepal needs to achieve its goal of developing world class, modern, risk informed dam safety standards that will ensure the planned future development of hydropower in the country comprehends and mitigates the risks associated with earthquakes, floods and other dam safety hazards.

Challenges to the Development of Hydropower in Nepal

In Nepal, well known natural hazards presented by flood flows and earthquakes loadings were found to be generally adequately addressed in the design of the nation's HPPs. For example, a survey of small hydro facilities indicated that seismic vibrations from the Gorkha earthquake did not cause significant damage to HPP's. Nearly half reported no damage or only minor damage and 16% reported structural damage. However, 30% experienced damage as a result of landslide induced earthquakes. It is natural hazards presented by landslides and debris flows that were found to present the greatest risks to hydropower development, new and existing, in Nepal- Hazards that are generally not well considered in the design of HPP's in Nepal or elsewhere. Project location was found to be a key factor in the severity of geohazard exposure and associated risks. As sites move closer to the Lesser Himalayas, the hazard potential increases considerably.

Status of Technical Standards in Nepal

Currently, there are no formal and accepted methods for selecting the standards that a dam must satisfy to be "safe" either nationally or provincially. Accordingly, dam design standards vary depending on the judgment and experience of the practitioner and the standards of their

home country. In many cases, international standards are used in the design of HPPs. While practice, most do not account for the site-specific issues and natural hazards that exist in Nepal.

The inconsistent standards that have been used in construction of Nepal's dams do not necessarily mean that Nepal's facilities are unsafe. However, the risks that an individual dam poses to the downstream public may vary considerably depending on the standard that was selected. An attempt was made by the DoED to provide some level of consistency through the production of three Technical Guidelines that give commentary and suggested approaches to investigation, planning, design, construction quality assurance, operation and maintenance, instrumentation and other matters related to HPP development in Nepal.

Implementation of an Enhanced Dam Safety Framework for Nepal

The GoN has appointed a committee to draft the Water Resources and Electricity Policy. It is understood that a significant amount of work has been carried out on this policy by the committee to date but the stage for approval by GoN has not yet been reached. It is further understood that the policy includes several points that will address current gaps in the institutional structure for water resource planning and dam safety.

Two alternative routes for the implementation of a suitable DSMS in Nepal were identified that could be implemented after the Water Resources and Electricity Policy Act (WREPA) is completed and approved by GoN:

1. **Pass a New Act:** Initiate a new Act based on the WREPA, to be approved by the Parliament designed to give legislative authority to the policy.
2. **Issue a New Regulation:** Issue a regulation under the existing Electricity Act, 2049 to implement the new policy on an interim basis. It is suggested that the Electricity Act (Clause 37 on appointment of Electricity Inspectors and Clause 40 on GoN setting rules on the quality and use of materials for construction and operation of hydropower plants) and Electrical Regulation, 2050 at Clauses 77 and 78 for the Electricity Inspector to inspect new hydropower projects and carry out annual inspections of operating projects would allow for this.

It was suggested that the second approach be considered for further study.

Regardless of the approach taken, industry best practice dictates that dam and HPP owners be mandated to be fully responsible for the safe construction and operation of their assets. The GoN would be responsible for ensuring compliance with dam safety principles and acting if compliance is not achieved. Under this situation, a new Dam Safety Division would;

- Set and maintain dam safety guidelines using the guidelines recommended in other reports prepared as part of this project as the base and updating these (say) every five years based on advances in the practice of dam safety.

- Approve new dam and hydropower projects in respect of their adherence to the dam safety standards of Nepal.
- Accept completed new dam and hydropower projects based on the owner's representation that the facility satisfies Nepal's dam safety requirements.
- Maintain a dam registry based on a legislated requirement for dam owners to input complete and accurate data in this registry.
- Maintain a dam safety incident registry based on a legislated requirement for dam owners to report all incidents.
- Require additional analyses to be performed to confirm the safety of structures which may include stability analyses, Dam Break Analysis, additional geotechnical exploration etc. to be performed.
- Provide an annual report on compliance, dam safety incidents and other matters.
- Approve major repairs to existing dams and hydropower plants.
- Review and approve periodic dam safety review reports for existing dams and hydropower plants.
- Review and approve DSM Plans for existing dams and hydropower plants.
- Review and accept dam classifications.
- Undertake random inspections to verify compliance.
- Approve owners nominated safety review inspectors.
- Issue orders, collect fees and levy fines.

A Proposed Dam Safety Organizational Structure

To provide a somewhat leveled dam and HPP regulatory coverage it is proposed that the new Dam Safety Division be divided into three regions, west, central and eastern Nepal.

The suggested organizational structure of this new division is illustrated in Figure ES-1.

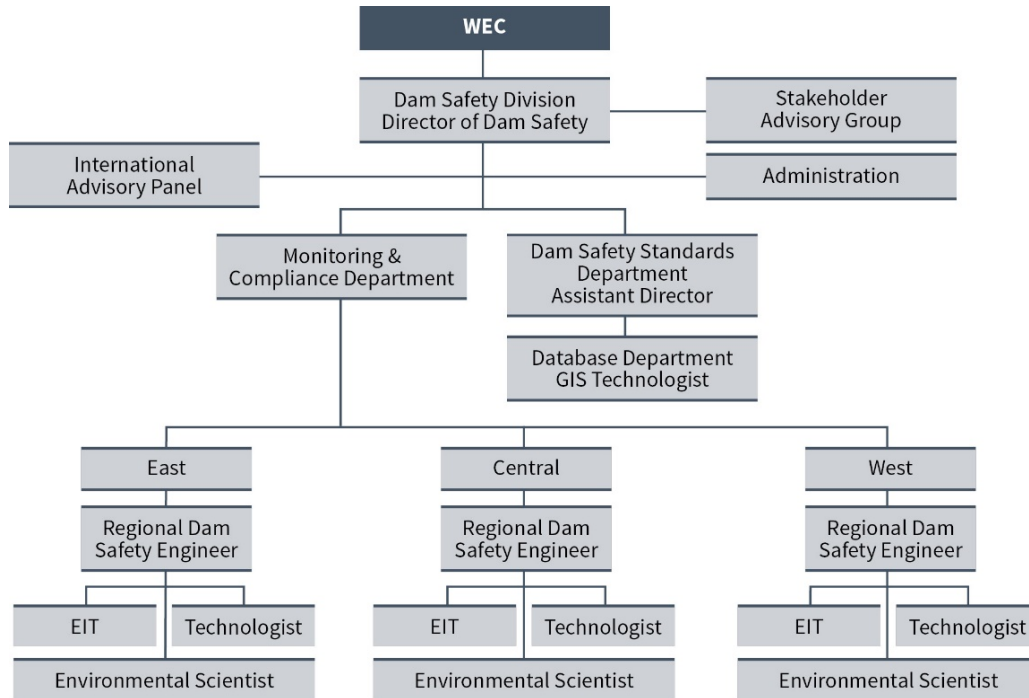


Figure ES-1: Suggested Organization Structure for Dam Safety Division

As is illustrated in Table ES-1, this would result in a similar number of facilities in the Central and Eastern Regions to be regulated. The Western region would have significantly less facilities but of a generally larger size that would imply larger dams with potentially more dam safety issues.

Table ES-1: Proposed Regional Organization of the Nepal Dam Safety Division

Region	Basin	Issued Operating License		Issued Construction License		Issued Survey License		Total		
		#	Capacity (MW)	#	Capacity (MW)	#	Capacity (MW)	#	Capacity (MW)	Avg Capacity (MW)
West	Makahali, Karnali, S. Rivers West	7	28	10	72	17	2,073	34	2,174	64
Central	Gandaki, S. Rivers Central	53	673	40	761	29	1,269	122	2,703	22
East	Koshi, S. Rivers East	32	278	41	1,419	32	1,784	105	3,481	33
Total		92	979	91	2,252	78	5,127	261	8,358	32

At the outset, given that much of the capacity in Nepal has not yet been developed, it may be possible to consolidate the divisions into one group, facilitating staff training and allowing for capacity building. As hydropower is developed in Nepal, the divisions could be expanded to suit.

The Path Forward

Currently Nepal lacks the internal capacity to establish and manage a dam safety management program. In the longer term the countries goal of constructing 10 GW of waterpower over the next decade will serve as an excellent training ground to build the capacity needed. In the short term, some specific steps are needed. As is conceptually illustrated in Figure ES-2, the process of building the needed capacity in Nepal commences with the identification and approval of the new positions in the Dam Safety Division of the responsible institution (presumably the Water and Energy Commission (“WEC”)) by the Government and the annual funding needed for these positions.

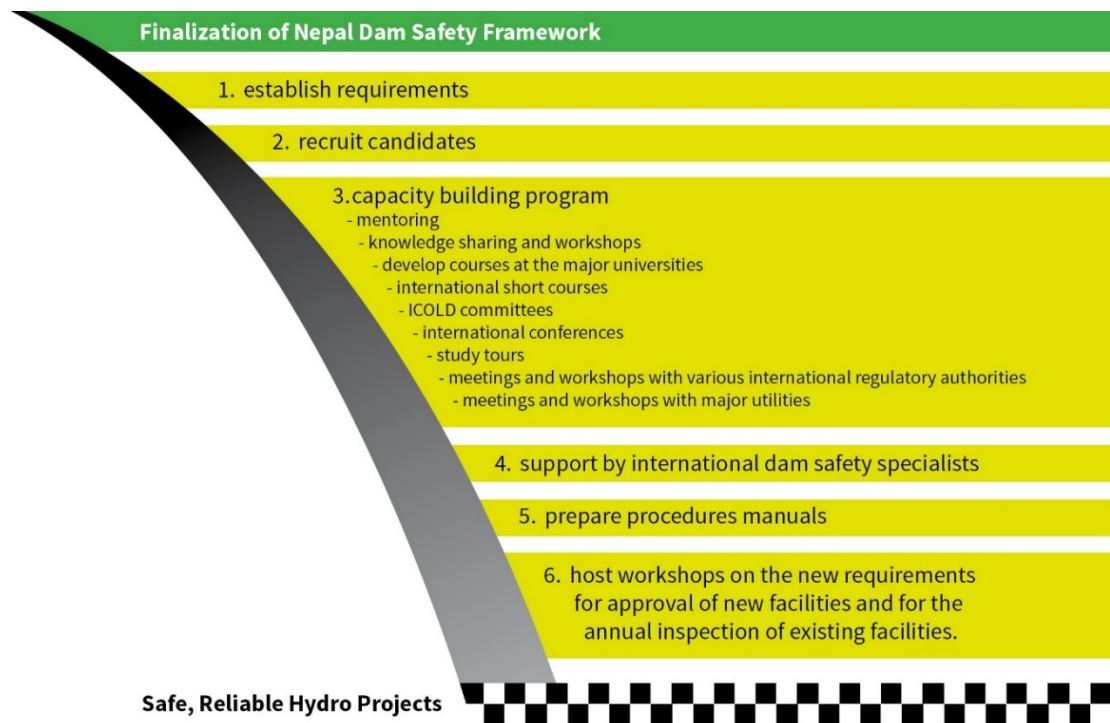


Figure ES-2: Road Map to the Development of an Enhanced Dam Safety Management Program for Nepal

1. Introduction

1.1 Background to the Report

In 2015, Nepal was devastated by two earthquakes, a magnitude 7.8 event occurring on April 25, followed by a magnitude 7.3 event on May 12. In total, it is estimated that over 8,700 people died because of the earthquakes and more than 22,500 were injured. Nepal suffered from aftershocks and associated damages for some time following the main event.

Although difficult to estimate, economic losses have been placed anywhere up to 50% of Nepal's Gross Domestic Product ("GDP") (source: United States Geological Survey ("USGS")). About 115 MW of Nepal's hydropower was severely damaged with another 60 MW impacted representing over 20% of the available capacity. Aside from hydropower losses, five of the seven major UNESCO World Heritage sites in the Kathmandu Valley were damaged or destroyed, more than 30 monuments collapsed and 120 others partially damaged. The Government of Nepal ("GoN") estimates that 784,500 houses had been damaged or destroyed as of June 2015, and significant damage to the nation's infrastructure including roads, bridges, and utilities occurred.



The power demand in Nepal is expected to increase by over 1 GW within the next decade with demand in neighboring India potentially adding another 1,000 GW by 2030. While Nepal has more than enough identified hydropower to meet the anticipated load growth, to properly utilize this resource, a regulatory framework needs to be in place to assure that future hydropower projects are developed in a way that minimizes the threat to life safety, economic and environmental risks and losses to significant cultural heritage.

The regulatory framework to accomplish the growth in water power resource desired will require the introduction of modern, well formulated dam safety standards and procedures to ensure that these new dams are designed, constructed and maintained in a consistent and safe manner in accordance with modern engineering standards and international dam safety management best practices.

1.2 Purpose of this Report

The safety of dams requires appropriate dam safety standards and guidelines that are administered by a national entity that provides a structured and formal process for dam safety management throughout all stages of the life-cycle of a hydropower project.

The objective of this report is to provide the guidance that the GoN needs to achieve its goal of developing world class, modern, risk informed dam safety standards that will ensure the planned future development of hydropower in the country comprehends and mitigates the risks associated with earthquakes, floods and other dam safety hazards.

To meet this objective the Hatch Team has

- i) assessed the current national dam safety framework and made recommendations on how to strengthen it
- ii) reviewed the current guidelines that are available for the study and design of hydropower generation projects including dam safety aspects
- iii) established Dam Safety Guidelines that are aligned with modern practices, tailored to the needs of Nepal
- iv) provided recommendations on the regulatory framework and steps to implement a modern Dam Safety Management System.

This report provides a summary of more comprehensive discussions provided in separate reports prepared under this project as are listed in Appendix A.

1.3 Outline of this Report

This report is organized in eight sections and four Appendices.

Following this introduction, [Section 2](#) provides details of the power sector in Nepal including a discussion on the existing and planned future hydropower in Nepal as well as a discussion on the need for an enhanced dam safety framework. In [Section 3](#), a summary of Nepal's current dam safety framework and existing technical standards are discussed as well as the challenges that exist with respect to hydropower development in Nepal and observation that were made as part of this assignment on damages that occurred to hydropower facilities following the 2015 Earthquake. [Section 4](#) provides a summary of a jurisdictional review of dam safety best practices that forms the basis for the development of an enhanced dam safety framework for Nepal. A suggested Dam Safety Management System based on these best practices is outlined in [Section 5](#). [Section 6](#) will reflect stakeholder input received that will be finalized after the final visit to Nepal in October 2017. In [Section 7](#), suggestions on implementing the enhanced Dam Safety Framework and standards are provided. [Section 8](#) provides a suggested roadmap for implementation and capacity building. [Section 9](#) provides

an example of the format and content of a regulation that might be used as the basis for dam safety legislation in Nepal is provided.

Appendix A provides a listing of the reports that were prepared as part of the development of the proposed dam safety framework and standards for Nepal.

Appendix B provides some details of Nepal's Planned and Existing Hydropower.

Appendix C The framework for a Dam Registry for Nepal and some of the available information is presented.

Appendix D is a suggestion for a dam safety regulation.

2. Nepal’s Hydropower Sector

2.1 Existing Power Plants and Dams in Nepal

Nepal has no known oil, gas or coal deposits, except for limited lignite deposits. All commercial fossil fuels (mainly oil and coal) are either imported from India or from international markets and are routed through India. In this context, water is an important natural resource of Nepal which is abundantly available and represents a source of potential wealth. In Figure 2-1, the location of existing and planned hydropower facilities in Nepal is shown. In Appendix B, a listing of these facilities is provided together with some details of Nepal’s existing hydropower facilities.

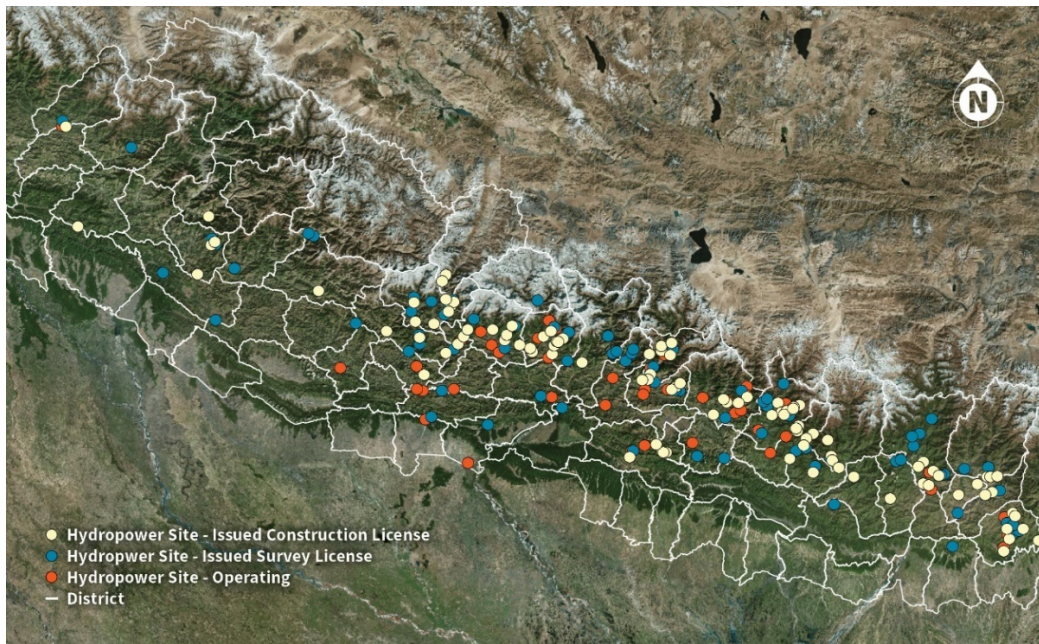


Figure 2-1: Existing Hydropower Power Plants in Nepal (data from GoN)

In Table 2-1, the hydropower capacity that has been put in service to date by Nepal Electricity Authority (NEA) and Independent Power Producers (IPP) is listed. This represents only a very small fraction of the available hydropower capacity in Nepal.

Table 2-1: Power Generation in Service in Nepal as of May, 2017

Fuel Type	MW	Percentage
NEA	468	48%
NEA Thermal	53	6%
IPP Hydro	447	46%
Total Installed Capacity	969	100%

2.2 Hydropower Potential in Nepal

The hydroelectric power generating potential in Nepal is estimated to be about 42,000 megawatts (MW) from 66 hydropower project sites. Table 2-2 provides estimates of the potential generation capacity by river basin.

Table 2-2: Nepal’s Potential Capacity for Hydropower

River Basin	Number of Project Sites	Potential Capacity (MW)
Sapta Koshi	40	10,860
Sapta Gandaki	12	5,270
Karnali	7	24,000
Mahakali	2	1,125
Southern Rivers	5	878
Total	66	42,133

Source: National Planning Commission, Nepal

So far, less than 2% of this potential has been developed. Given Nepal’s anticipated power requirements, a significant amount of hydropower development, and associated dam construction, is possible and needed.

2.3 Current Hydropower Development Plans in Nepal

According to the Hydropower & Dams World Atlas, 2015 almost 30 separate waterpower projects with installed capacities in the range of 40% to 50% of the total technically feasible hydropower have been identified in Nepal, are in construction or in the planning phases. NEA is developing new hydroelectric power plants on its own and through subsidiaries. As of July 15, 2017, NEA had approximately 1,050 MW under construction and an additional 2,770 MW in the planned or proposed stage (Page 159, NEA Annual Review 2016/2017). In addition, the NEA Annual Review indicates the following Independent Power Producer (“IPP”) projects in the development pipeline:

- Under construction – 102 projects totaling 2,044 MW.
- Have not reached financial close – 51 projects totaling 910 MW.

As further indication of the acceleration in the development of Nepal’s water resources for power generation, in January/February 2016, the Ministry of Energy (“MOE”) issued the report “A Concept Paper on National Energy Crisis Prevention and Electricity Development Decade, 2016”. This report establishes a target of 10,000 MW for the country’s generation capacity within the next ten years. Some of the larger projects that are planned and proposed are listed in Table 2-3.

Table 2-3: Planned and Proposed Hydroelectric Power Projects

Project	Owner	MW	Energy (GWh)	Capacity Factor (%)	Type	Time Frame
Tanahu	NEA	140	474	38.6%	Storage Hydro	2023-24
West Seti	IPP	750	2,993	45.5%	Storage Hydro	2025-26
Upper Karnali	IPP	900	4,025	51.0%	RoR	2025-26
Arun III	IPP	900	4,023	51.0%	RoR	2024-25
Seti	GoN/NEA	225	TBD	TBD	Hydro	Under Study
Upper Arun	GoN/NEA	225	TBD	TBD	Hydro	Under Study
Utter Ganga	GoN	828	TBD	TBD	Hydro	Under Study
Tomor Storage	GoN/NEA	762	TBD	TBD	Hydro	Under Study
Dudh Koshi Storage	GoN/NEA	300	TBD	TBD	Hydro	Under Study
Tamakoshi V	NEA	95	TBD	TBD	Hydro	Under Study
Chainpur Seti	GoN/NEA	210	TBD	TBD	Hydro	Under Studt
Andhi Khola	GoN	180	TBD	TBD	Hydro	Under Study
Budhi Gandaki	GoN	1,200	3,383	32.2%	Storage Hydro	Under Study
Total		6715	14,898	33.4%		

2.4 The Need for a Formal Dam Safety Management Program for Nepal

Most of the river systems in Nepal have a distinct seasonal flow pattern. In the dry winter months, the flow rates are much lower than during the monsoon season. Given that there is interest in developing more hydroelectric power projects with storage reservoirs that will inherently require larger dams, an enhanced, more holistic, dam safety management program in Nepal takes on an even higher importance.

A well-structured dam safety management program has proven to be effective in reducing the potential for dam safety incidents. For example, as is illustrated in Figure 2-2, following the enactment of dam safety legislation in the USA in 1996, the occurrence of dam safety incidents declined significantly, dropping from an average of about 39 per year between 1995 and 2000 to about nine incidents per year after the dam safety programs began to take effect. Dam failure rates in the USA also declined. The success of the evolving dam safety management methods is also highlighted in International Committee on Large Dams (“ICOLD”) Bulletin 99. In this bulletin, it is reported that the percentage of failures of large dams has shown a remarkable decrease, from 2.2% of dams built before 1950 to less than 0.5 % of dams built since 1950.

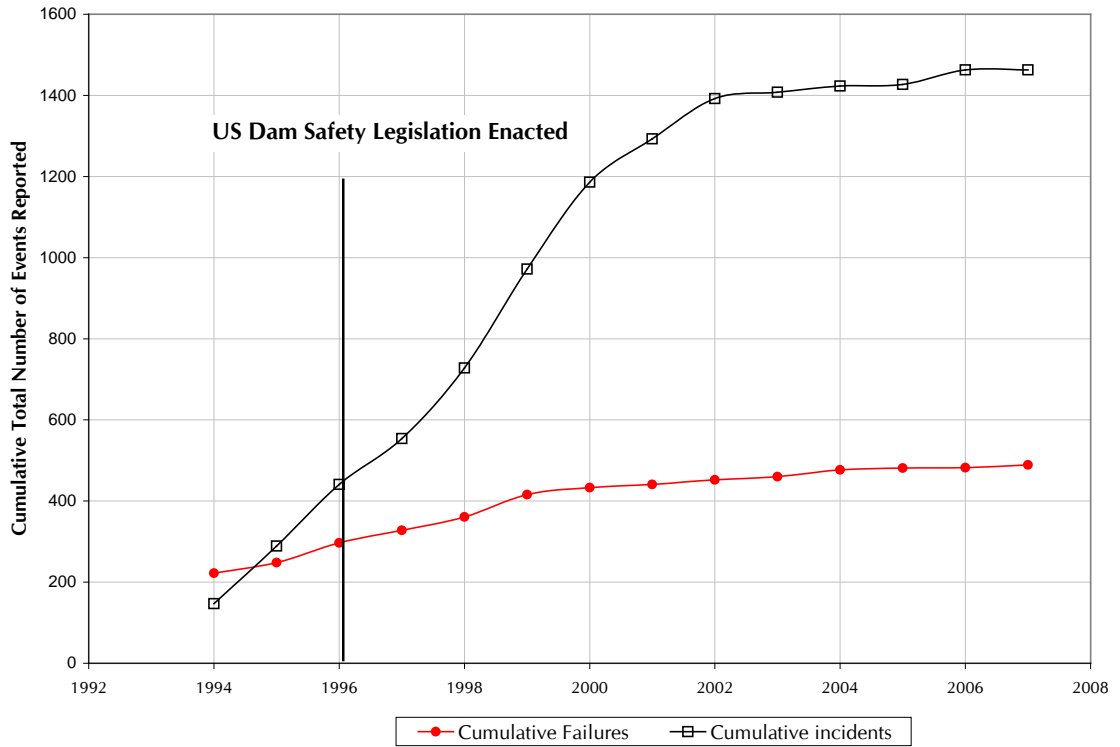


Figure 2-2: Occurrence of Dam Failures and Dam Incidents in the United States

3. Summary of Current Dam Safety Framework, Technical Standards and Challenges in Nepal

3.1 Challenges to the Development of Hydropower in Nepal

The diversity of topography, meteorology and geology across Nepal pose unique challenges to hydropower development. One of the principles of geomorphology is that processes observed today also occurred in the past and will continue to occur in the future. This principle must be understood in the context of changing climate since the types, scales and rates of geomorphological process may change significantly in the coming decades. These concepts are especially important when assessing the risk of dam safety in Nepal.

Natural hazards that pose risks to development of hydropower projects in Nepal include

- earthquakes
- floods
- landslides
- debris flows resulting from Glacial Lake Outburst Floods (“GLOFs”), Landslide Dam Outburst Floods (“LDOF’s”) and rainfall induced landslides.

Assessing the potential risks posed by one or more of these natural hazards individually or in combination in the planning, design and maintenance of hydropower facilities is essential with respect to assessing project feasibility and sustainability.

3.1.1 *Climate*

Although Nepal lies near the northern limit of the tropics, the country encompasses a wide range of climatic conditions; from subtropical in the Terai in the south to arctic in the high Himalayas in the north. The dramatic differences in elevation from the north to the south, the east-west Himalayan massifs to the north and the monsoonal alteration of wet and dry seasons contribute to climate variation within the country.

In the planning and design of hydropower facilities, the climatic conditions in which the facility will be constructed and operated are important considerations with respect to the construction season, the flow control facilities and the type of structures selected.

3.1.2 *Hydrology*

As is illustrated in Figure 3-1, there are seven major drainage basins in Nepal with Hydropower mostly concentrated in the Karnali, Gandaki and Koshi basins.

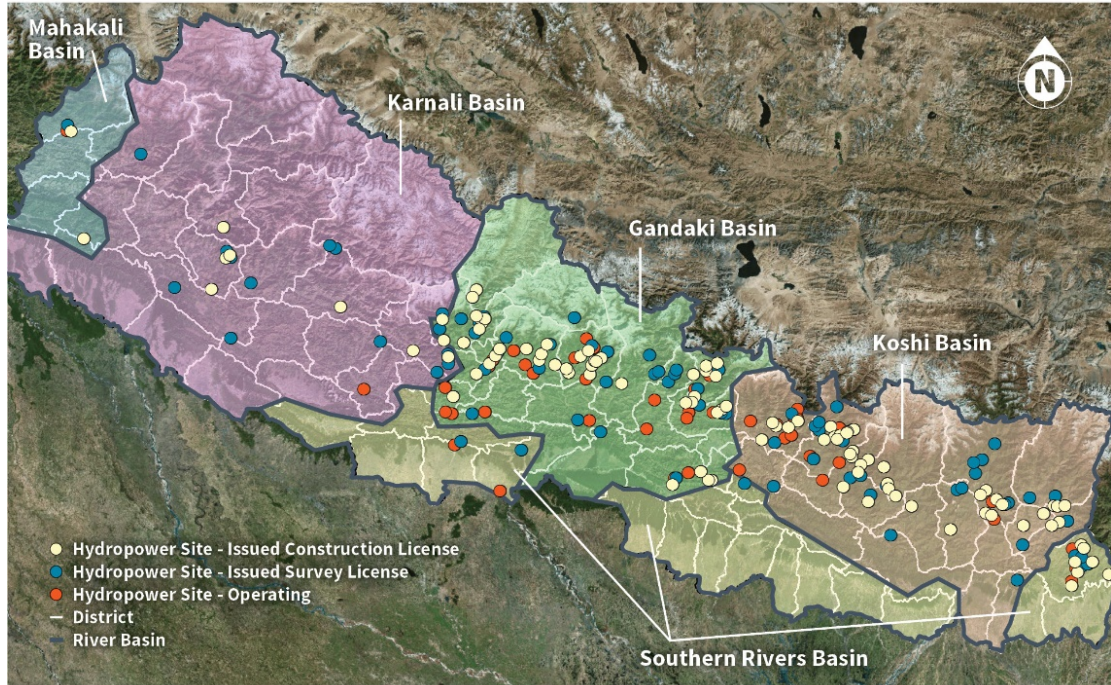


Figure 3-1: The Seven Major Drainage Basins in Nepal with Hydropower

The Mahakali, Karnali, Gandaki and Koshi are Nepal's main rivers, originating in the Himalaya's. The glacial and snow-fed melt water in these rivers provide significant flows year-round. The Babai, West Rapti, Bagmati, Kamala, Kankai and the Mechi are medium rivers that originate in the Mahabharat Range. They are fed by precipitation and groundwater regeneration (including springs). They also flow year-round but are typically characterized by wide seasonal fluctuations in discharge. There are also many small rivers in the Terai which mostly originate in the Siwalik Range. Many of these rivers are seasonal, rendering them unsuitable for year-round irrigation or hydropower generation without surface storage.

The average flow of the major rivers of the country is shown in Figure 3-2 that illustrates the importance of the four major river systems.

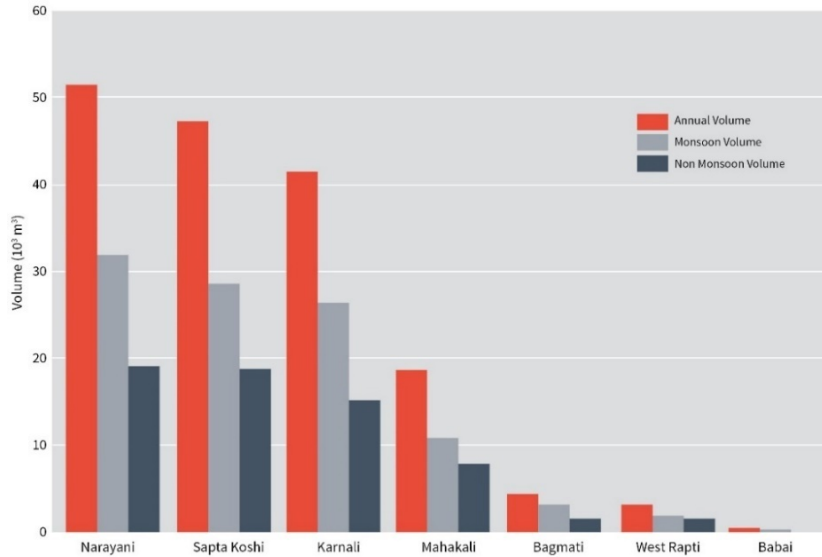


Figure 3-2: Runoff Volume of Major Rivers of Nepal (1996)

There are three categories of river found in Nepal: 1) rain-fed rivers; 2) rain and snow-fed rivers; and 3) rain-fed, snow-fed, and glacier-fed rivers. Figure 3-3, based on data from the Department of Hydrology and Meteorology (“DHM”) and the Ministry of Water Resources (“MWR”) (1993), shows how the distribution of flow varies depending on the category of the river.

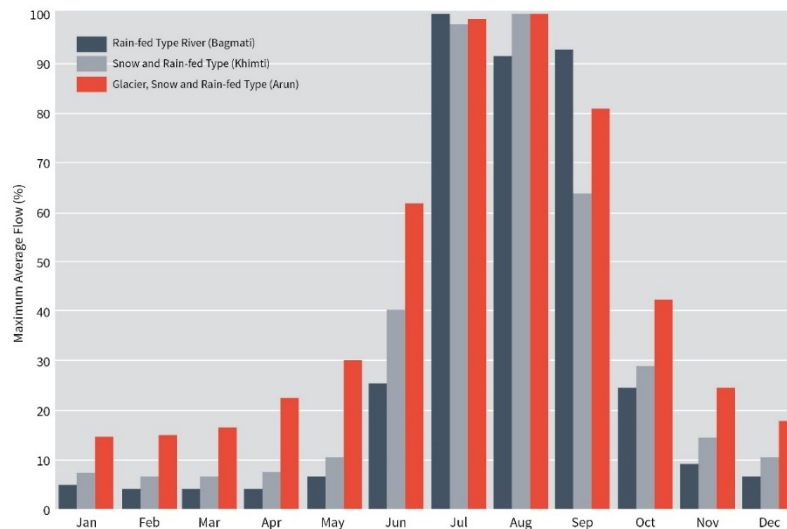


Figure 3-3: Monthly Flow Distribution¹

¹ (Khimti Khota Hydroelectric Project Feasibility Study, April 1993)¹

These results demonstrate that all the river types can be considered for hydropower development but that careful consideration of the source of water is needed when considering the installed capacity and the type of facility (run of river/storage/peaking).

3.1.3 Geology

Nepal is in the collision zone between the Indian and Eurasian plates as is illustrated in Figure 3-4.

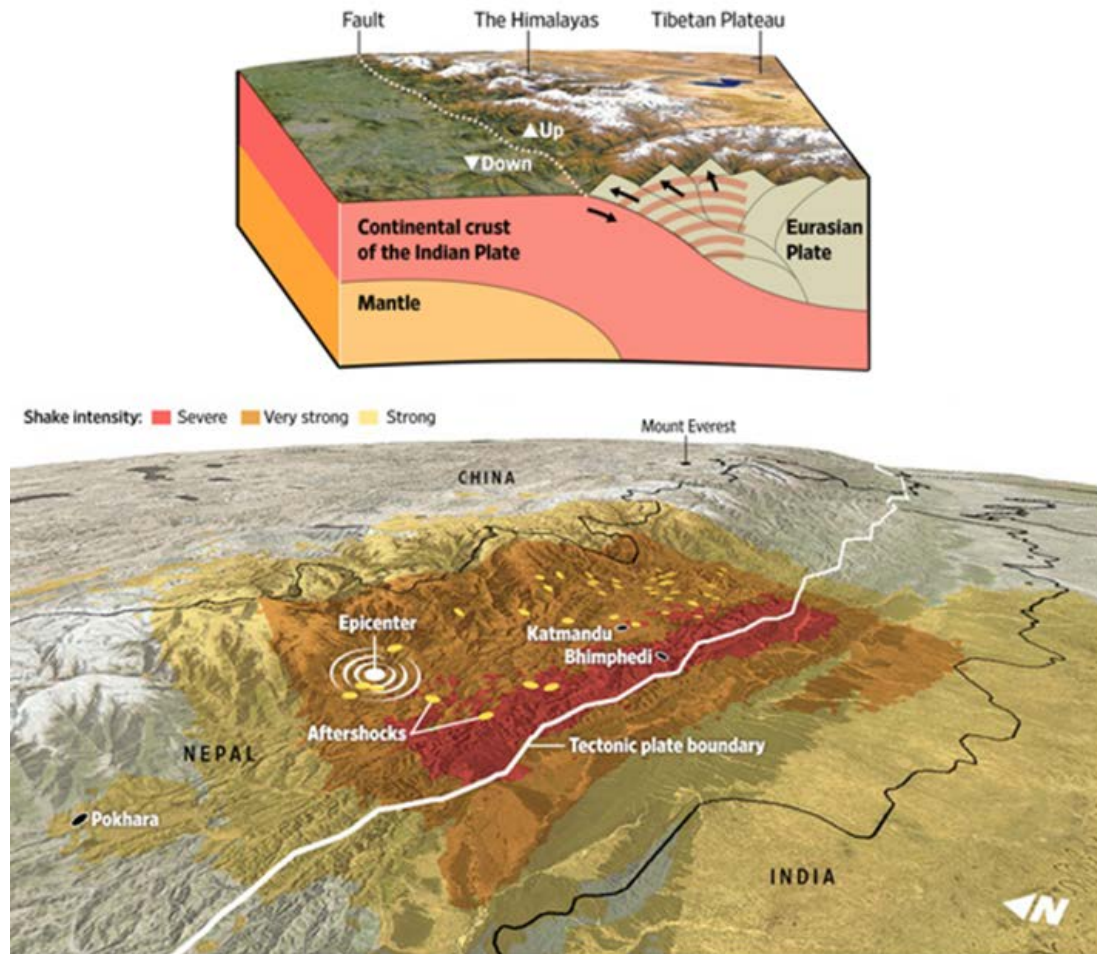


Figure 3-4: Indian-Eurasian Plates Collision and Subduction Zone

The complex geology in Nepal is characterized by six morpho-geotectonic zones characterized by distinctive stratigraphic and physiographic features. In addition, the geological processes in Nepal are more rapid than in most other regions of the world²

² The physiography of northern Nepal is like that of Northern India (Kashmir) and the Bhutanese Himalayas. There are areas in the Karakoram, Pamirs and Hindu Kush that even more extreme.

because of the rate of mountain building and the intensity of precipitation during the monsoon season.

Virtually all the potential hydropower projects in Nepal are located on rivers that cut perpendicularly through the Lesser Himalaya, Mahabharat Range/Midland Valleys, the Siwalik Hills morpho-geotectonic zones and the countries principal thrust belts. The geology of each site is unique with rock quality affecting dam foundations, underground openings, and construction materials ranging from excellent (gneiss) to poor (phyllites). This presents variable natural hazards exposure that must be carefully consider in planning, operating and maintaining hydropower resources.

3.1.4 Sedimentation

More than 80% of the land area in Nepal is mountainous and still tectonically active increasing the potential for erosion and landslides. Although deforestation, overgrazing, and intensive agriculture due to population pressure have caused accelerated erosion, it is still generally low³. The most significant cause of reservoir sedimentation is rainfall-induced landslides. However, other natural hazards, such as GLOF's and LDOF's, can contribute to the problem.

A well-studied example of the impact of landslide induced sedimentation is the case of the Kulekhani reservoir in 1993. A high-intensity rainstorm (over 500 mm in 24 hours) that occurred on July 19-20, 1993 triggered many debris flows and landslides in the Kulekhani watershed of central Nepal. While a cloudburst was the main trigger, geology, geomorphology, soil types, and slope geometries also played a significant role in accentuating the disaster. The debris flow almost completely buried the village of Phedigaun, destroyed 52 houses, and resulted in significant loss of human life (62 people). More than 300 landslides of various sizes were observed in the watershed. Two hydropower stations and the Kulekhani reservoir were also seriously affected. It is estimated that the 1993 event brought a sediment volume of 5.1 million m³ into the Kulekhani reservoir⁴

Soil erosion and the resulting reservoir sedimentation is a significant consideration in the design of hydropower facilities in Nepal. Depending on the potential for landslides and other sources of sediment, designs must consider sediment management measures to prevent the early loss of the reservoir and the need to decommission the facility.

3.1.5 Landslides

Landslides are a natural phenomenon that occur every year throughout Nepal. They generally occur in the weaker rocks of the Siwalik Range, the steep slopes in the Lesser

³ Less than 10 tonnes/ha/yr. ranging up to 56 tonnes/ha/yr. in areas under rain-fed cultivation

⁴ (Dhital, Manandhar, Hino, & Suetsugu, 2014).

Himalaya and because of a combination of the two in the Mahabharat Range and Midlands zone.

In Nepal, landslides are generally triggered by seismic activity or extreme rainfall events during the monsoon.⁵ As is illustrated in Figure 3-5, the greatest number of events occur in central Nepal, in areas of high mean annual rainfall, between Pokhara and Kathmandu. These are co-located in the river basins that have the greatest hydropower potential and are the most densely populated.

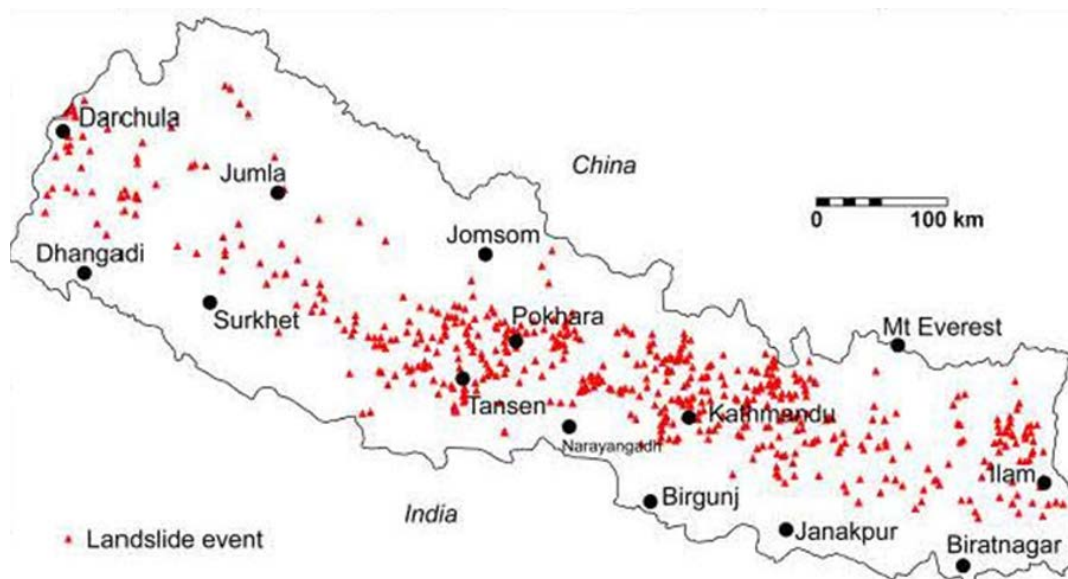


Figure 3-5: The distribution of Landslides in Nepal

Landslides can cause damage to critical infrastructure such as penstocks, as occurred at the Upper Bhotekoshi and Kulekhai I Hydro Power Projects (“HPPs”). They can also block access roads which can impact a HPPs financial feasibility. For example, at the Upper Trishuli 3 HPP, a series of landslides caused by the recent 2015 earthquakes blocked access to the site for over a year. At the time the team visited the site in October of 2016, limited access had been re-established but repairs to the facility had not re-commenced.

Landslides can also cause GLOFs, LDOF’s and, when combined with an extreme rainfall event, a debris flow such as that which damaged the Kulekhani penstock releasing water that flooded the powerhouse. Landslide-induced waves can overtop embankment dams or overburden abutments leading to failure. Landslides are also a common cause of a GLOF. Given the topography and geology of Nepal, landslides represent, perhaps, the most

⁵ Climate change is resulting in an increased potential for landslides. For example, at the previous lower limit of permafrost, destabilization of mountain flanks is occurring due to increasing temperature and previously frozen rock experiencing freeze-thaw and full melt leading to high altitude rock avalanches, landslides and mountain flank failures

significant natural hazard. As such, the potential for landslides and their effects need to be carefully reviewed in the planning of any hydropower development or the assessment of the safety of existing developments.

3.1.6 Floods

About 80% of the total annual precipitation in Nepal occurs during the summer months of June-September. Due to this temporal concentration of precipitation in Nepal, there is substantial damage caused by extreme rainfall events almost every year. Climate change model studies suggest that there will be about a 23% increase in summer precipitation with only a 13% increase in annual precipitation. Therefore, a more pronounced seasonal imbalance, and the potential for extreme flood events may be experienced in the future.

In 1975 a study performed by ASCE/USCOLD showed that there were four general causes of dam failure as depicted in Figure 3-6.

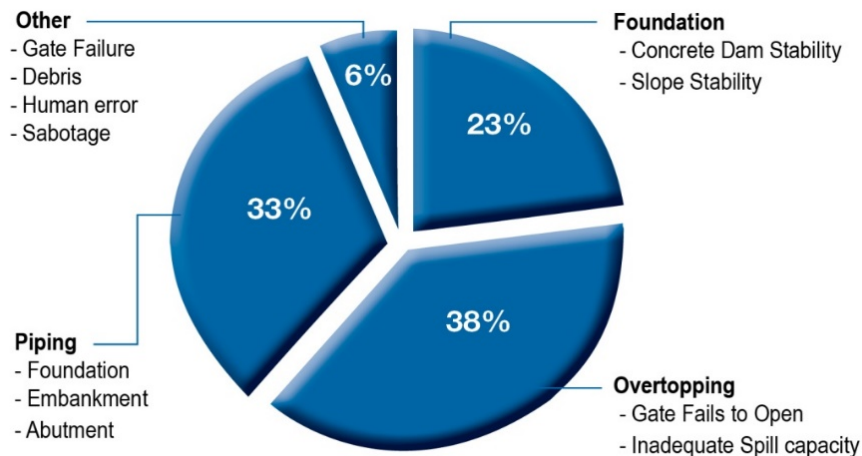


Figure 3-6: Causes of Dam Failure

The results of an assessment of the causes of dam failure as reported in ICOLD Bulletin No. 99 also showed that overtopping was the most significant dam safety hazard. As such, flood events and a potential dam breach can represent a significant hazard if not appropriately consider during the design phase of a development. This highlights the importance of gates and gate reliability in dam safety.

A dam breach dam can result in loss of life, destruction to property, environmental losses and the loss of important cultural heritage. It also causes sediment and debris to be eroded, transported, and deposited downstream which can cause significant alteration of river

channels and valley morphology⁶. Some event triggers for various types of floods are described in Table 3-1.

Table 3-1: Flooding Events in Nepal⁷

Event Trigger	Flooding Event	Scale
Earthquake	Landslides and LDOFs	Regional depending on the magnitude of the earthquake; multiple river catchments, thousands of km ² .
Extreme rainfall event.	LDOF's, GLOF's floods, debris flows, mudslides.	Regional depending on the volume, rate and duration of precipitation; multiple river catchments, thousands of km ² .
Rock-/ice-avalanche.	LDOF's, GLOF's	Single catchment, run-out distances hundreds of km ² .
Ice-dam failure ⁸ .	Ice Dam Outburst Flood	Single catchment, run-out distance can exceed 1,000 km.

3.1.7 Earthquakes

Nepal is in the Mediterranean–Himalaya seismic belt with earthquake events generally occurring because of the collision of the Indian and Eurasian tectonic plates. The first documented earthquake event in the country dates back to 1255, during the reign of King Abhaya Malla. This M7.8 event took the life of the king and wiped out a third of Kathmandu's population. The available records⁹ show that large earthquakes have occurred in every century since that time. There is also some evidence in the historical record that earthquakes in Nepal may occur in cycles with the occurrence of the Gorkha earthquake potentially being indicative of the beginning of a new M8 earthquake cycle.

For long life infrastructure, such as hydropower facilities, the occurrence of a strong earthquake during the operating life of the facility is almost a certainty. Therefore, the planning and design of any facility needs to consider the acceptability of risks associated with a M8 event located at the collision zone. While designs need to account for the effects of seismic loading, there was, in fact, little evidence of damage to concrete structures because of the Gurkha earthquake, perhaps because this hazard has been long recognized and is generally well accounted for in designs. In Nepal, the most damaging earthquake effects are seismic induced landslides that may either directly impact a site or trigger other geohazards that less directly impact a site. Therefore, designs need to account for the full range of potential earthquake hazards.

⁶ (Khimti Khota Hydroelectric Project Feasibility Study, April 1993)

⁷ (Assessment of Disaster Risk Management in the Hydropower Sector in Nepal, 2015)

⁸ In Nepal, IDOF's are extremely rare.

⁹ Disaster Preparedness Network Nepal, the National Oceanic and Atmospheric Administration ("NOAA"), the National Center for Environmental Information and the "USGS.

3.1.8 **Debris Flows (GLOFs and LDOF's and Extreme Rain Events)**

While the mechanisms that initiate debris, flows may be different, the impacts are very similar. Depending on the amount of available water the flows can range from water-saturated debris flows to predominantly debris-charged floods flows, with the latter being the norm for large events. GLOFs and other similar debris flow initiating events (i.e. rainfall induced landslides, LDOF) occur along various segments of rivers in the Himalayas. In a U-shaped valley, a debris flow may also re-activate additional landslides or cause new ones as it moves through the valley resulting in combined hazards that increase the destructive potential for the event. The Upper Bhote Koshi HPP (GLOF/LDOF initiated impact), Sun Koshi HPP (LDOF) and the Kulekhani HPP (rainfall induced landslide) are recent examples of debris flow impacts on hydropower facilities.

In the case of gently sloping rivers in the basins of such valleys, bank erosion and the river blockage caused by woody debris from those valleys often pose serious risks, particularly in terraces along the lower reaches of the rivers. Sand deposition in rivers and irrigation canals may adversely affect the downstream alluvial plain areas.¹⁰

3.1.8.1 *GLOF's*

There are reported to be over 1,000 glacial lakes situated in the catchments of the rivers that traverse Nepal which can impact existing and planned hydropower facilities. Almost all the glaciers in the Himalayas have been retreating since the Little Ice Age (1400-1650 AD). To-date, on average, they have retreated about 1 km resulting in the formation of some substantial lakes. Climate change is accelerating the retreat of mountain glaciers, enlarging existing glacial lakes and forming new ones, thereby increasing the potential hazard to a yet, unknown degree.

In Nepal, glacial lakes formed by the retreating glaciers are contained by moraines that are typically composed of over-consolidated (dense) cohesive materials. Such natural dams are generally quite stable, as evidenced by the large number of moraine-dammed glacial lakes and the relatively small number of GLOFs that have occurred historically. Most GLOFs occur because of a triggering event, such as a landslide or rock/snow avalanche collapsing into a lake producing waves that can overtop and erode the natural dam until failure occurs. Ice dams can also contain a glacial lake which, in the face of climate change may be less stable than lakes contained by glacial murrains. However, as noted earlier, ice dams are rare in Nepal.

3.1.8.2 *Ice Dams*

An ice-dam is formed when a glacier advances across and blocks a river valley, impounding water upstream. This type of natural dam is extremely rare in Nepal. An Ice Dam Outburst Flood ("IDOF") is a form of as GLOF that can produce a significant debris flow with run-out

¹⁰ (Higaki & Sato, 2012).

distances more than 1,000 km. In Pakistan, and for recent Himalayan IDOFs, run-out distances in the order of 200 km have been reported. However, pre-historical Himalayan IDOFs have reached the Bay of Bengal.

3.1.8.3 *LDOF's*

Formation of temporary lakes due to landslide damming is a relatively common phenomenon in high mountain areas where there are narrow river channels and steep mountain slopes. Eleven major LDOF's have been reported to have occurred in Nepal between 1967 and 1989 alone with many unreported minor events, or events that occurred in combination with other debris flow phenomenon. For example, evidence of LDOFs are regularly seen in the hydrographs at the Pancheshwar HPP.

The Budhi Gandaki River near Lukubesi in 1968, the Sunkoshi River near Barhabise in 1982, the Balephi Khola River in Sindhupalchok in 1982, and the Gyangphedi Khola River in Nuwakot in 1986, Kaligandaki river at Baisari, Magdi District in May 24, 2015 and many such recorded in this river before this date near to that area, were all dammed by landslides. The resultant outburst floods swept away people, houses, damaged infrastructure and flooded villages.

Because the natural dam in this case is formed because of a large landslide, such as the Juri landslide, it is generally only marginally stable as the materials that make up the dam will be close to their natural angle of repose. Therefore, failure of such a feature is far more likely that failure of the over-consolidated moraine that retains a glacial lake. However, if a landslide dam does survive it tends to become increasingly stable with time as the "dam" consolidates.

3.2 **Observations on Damages from the 2015 Earthquake**

During the period of November 19 to 29, 2016, a team of National International experts visited selected hydropower facilities in Nepal (Figure 3-7) to understand the nature of the damages caused by natural hazards in Nepal and the effects of the Gurkha earthquake and its aftershocks.

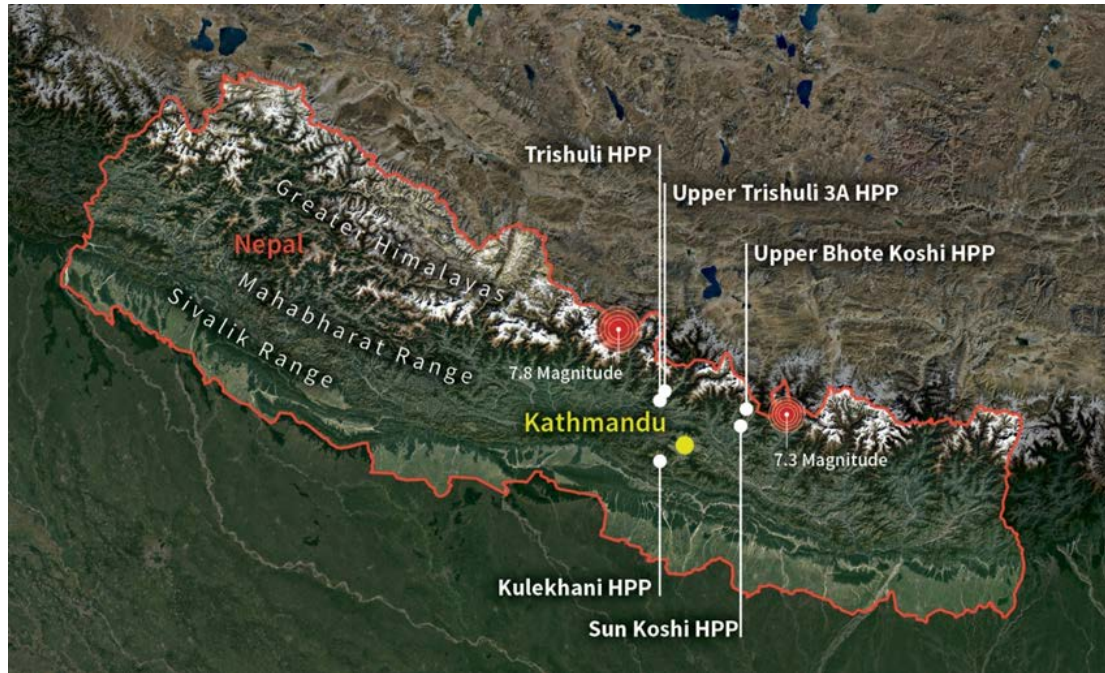


Figure 3-7: HPP's visited in Nepal

As is summarized in Table 3-2, the results of the site inspections clearly showed that, depending on the location of HPPs in Nepal, all the common natural hazards have or could cause damage to HPP's.

Table 3-2: Summary of Natural Hazard Exposures at Visited Hydropower Sites

Hazard		% of sites (occurred or credible)	Comments
Landslide	Rainfall Induced	100	Damaged penstocks at Kulekhani, blocked access and damaged structures at Upper Trishuli, credible hazard at all sites.
	Seismic Induced	100	blocked access and damaged transmission lines at Upper Bhote Koshi, credible hazard at all sites.
Earthquake	Vibrations	40	Embankment slumping at Kulekhani, damage to reinforced concrete structures at Sun Koshi, Minor cracking at other sites.
	Seiche Wave	0	Has not occurred, designs adequate such that hazard not credible.
Flood	Inadequate discharge capacity.	0	All sites had adequate discharge capacity for the Inflow Design Flood. However, most do not have the capacity to pass a debris flow.

Hazard		% of sites (occurred or credible)	Comments
Type of Debris Flow	GLOF	80	GLOF in combination with a LDOF(s) damaged Upper Bhote Koshi and occurred at the Upper Trishuli site prior to its construction. Credible hazard at Upper Trishuli and Sun Koshi.
	LDOF	60	Caused significant damage at Sun Koshi, contributed to debris flow at Upper Bhote Koshi and credible at Upper Trishuli.
	Rainfall induced landslide/debris flow.	100	Kulekhani penstock burst. Credible at any site with exposed penstocks.

Landslides and debris flows (either because of a GLOF, LDOF or a rainfall induced landslide) pose the greatest risk to the hydropower facilities visited in Nepal, followed by seismic loadings. These natural hazards can occur individually or, in combination with the cascading hazards transforming what might originally be a relatively innocuous event into a major disaster such as noncured at the Upper Bhote Koshi, HPP in July 2016.

Earthquake loadings were found to pose a somewhat reduced risk, if the facilities were adequately designed to reduce the impacts. Earthquake damage did, however, occur at some sites. For example, in the case of the Kulekhani Dam, earthquake loadings appear to have caused repeated slumping of the embankment dam. In this case, the selection of earthquake design parameters and factors of safety were found to be below current industry norms. The Sun Koshi site was the only HPP visited that showed any significant impacts from seismic loading. At this site earthquake loadings caused concrete spalling and yielding of the reinforcing steel in many of the columns that support the gate hoists. However, while this has undoubtedly weakened the columns, it did not result in a failure. However, the damage would have very likely resulted in one or more of the gates failing to operate on demand.

There were no instances of damage caused by flooding.

3.2.1 **Summary of Observations**

In most cases, the hazards presented by flood flows and earthquakes loadings appear to have been adequately addressed in designs of the facilities visited. A survey of small hydro facilities, as is summarized Figure 3-8 also indicated that seismic vibrations from the Gorkha earthquake were not a significant problem in terms of damaging these facilities. Of 31 small HPP's, nearly half reported no damage or only minor damage with 30% reporting damages because of landslides. Only 16% reported structural damage.

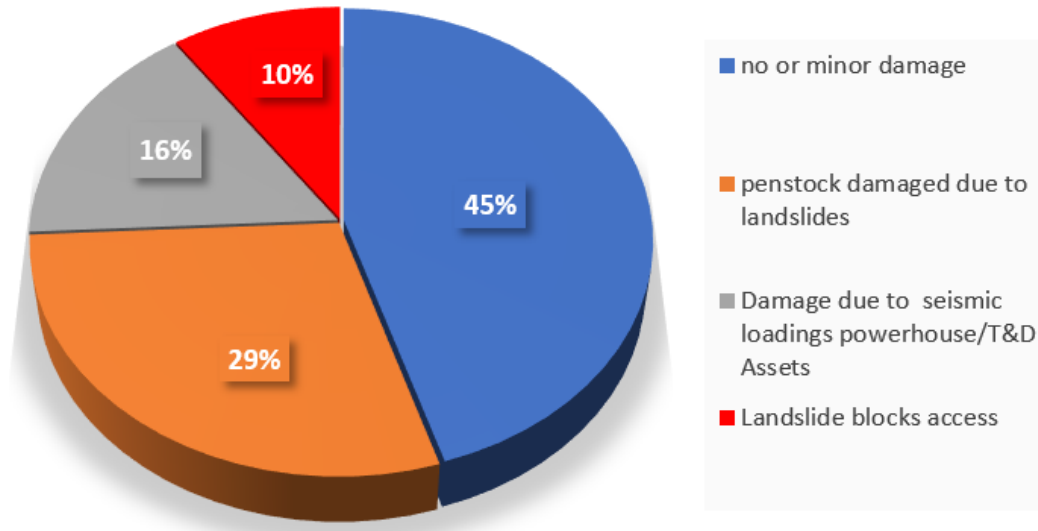


Figure 3-8: Summary of Reported Damage to Small HPP's because of the Gurkha Earthquake

Project location was found to be a key factor in the severity of geohazard exposure and associated risks. As sites move closer to the Lesser Himalayas, the hazard potential increases considerably to the point where a natural hazard can be expected during the life of a facility.

The results of this review further indicated that the criteria used in the design of hydropower projects in Nepal are inconsistent and that natural hazards, such as landslides and debris flows are often not adequately accounted for in HPP designs. The introduction of dam safety guidelines and their enforcement will improve design consistency and reduce risk exposure.

3.3 Current Institutional Framework, Capacity and Issues

3.3.1 Institutional Framework

Most of the dams and water retaining structures in Nepal were constructed for either hydropower generation facilities or water storage to supply drinking water and/or irrigation.

Nepal's institutional framework to regulate these structures is evolving. The new constitution set up seven provinces with elections being declared in all the provinces. Although there remains some dispute with respect to the provincial boundaries, the election process has under the new constitution. It is expected that the dispute will be resolved following the elections. However, there is no implementation schedule for the necessary political and administrative functions and there has been no capacity building. On this basis, the central government will continue to control the nation's natural resources including future hydropower

developments, large and small, and existing hydropower facilities. It is very likely this will include dam safety. It is understood that a new Water Resources Act is being drafted. When it is issued, it may influence how hydropower developments are regulated. For these reasons, the control over dam safety for all dams will likely stay at the national level for quite some time.

Figure 3-9 shows the institutional structure of Nepal's electric power sector and capsule comments on the primary functions of each organization/stakeholder.

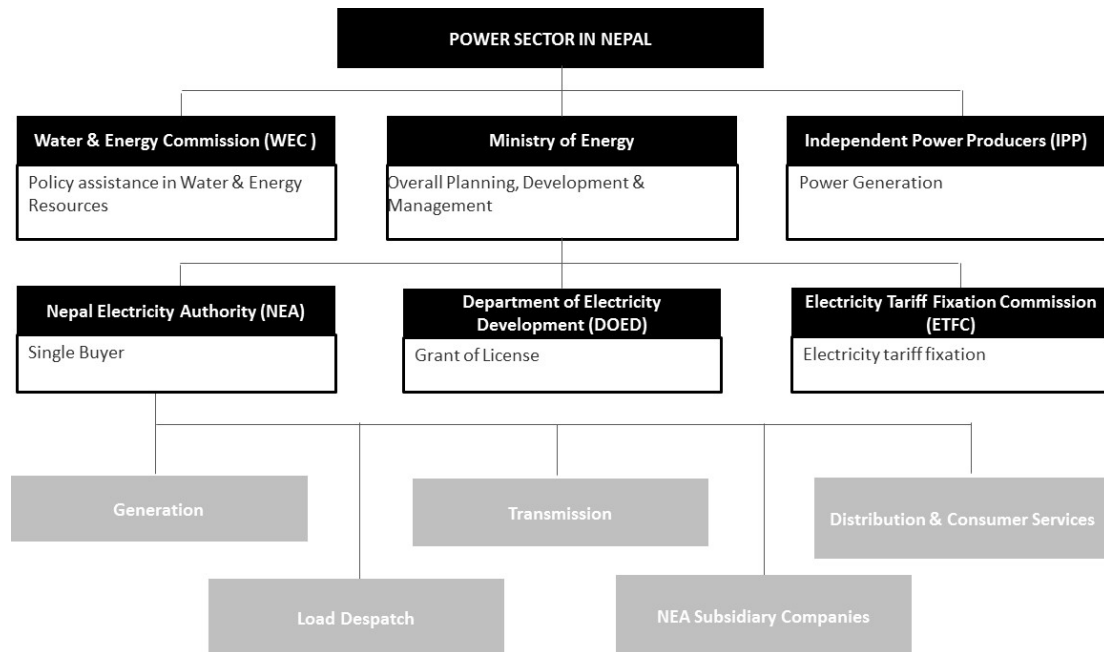


Figure 3-9: Power Sector in Nepal - Institutional Structure

[The Ministry of Energy](#), formerly the Ministry of Water Resources, plays a key role in the sector. The MoE's key agencies are indicated in Figure 3-10.

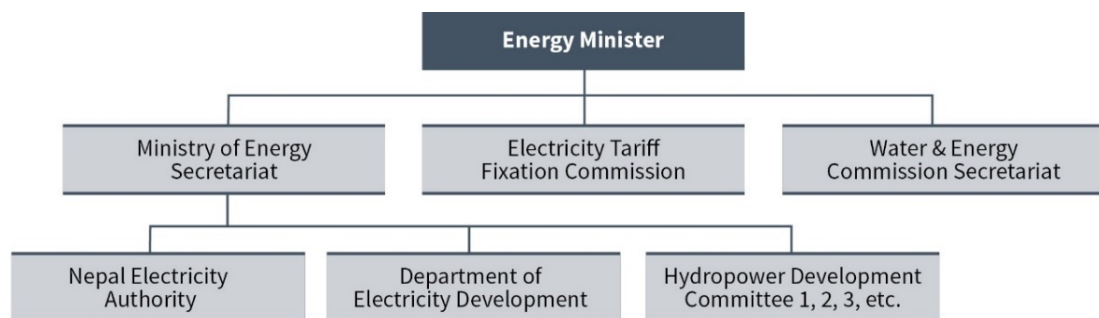


Figure 3-10: Ministry of Energy

The Water and Energy Commission (“WEC”) was established by the GoN in 1975 with the objective of developing water and energy resources in an integrated and accelerated manner. Subsequently a permanent secretariat of WEC was established in 1981 under the name, [Water and Energy Commission Secretariat](#) (“WECS”). Since it was established, the primary responsibility of WECS is to assist different ministries relating to water resources and other related agencies in the formulation of policies and planning of projects in the water and energy resources sector. The proposed organizational structure under the new Act, as illustrated in Figure 3-11 indicates that the WECS has been given authority to look after the water resources in a national context with river basin studies being a major objective.

3.3.2 **Legislation, Regulations and Policies**

The current legislation, regulations and GoN policies provide an up to date institutional framework for dam safety in Nepal. These include

- Electricity Act, 2049 (1992)
- Water Resources Act, 2049 (1992)
- Hydro-Power Development Policy, 2049 (1992)
- Electricity Rules, 2050 (1993)
- Hydro-Power Development Policy (2001)
- Water Resources Strategy (2002)
- National Water Plan (2005).

Under the new Constitution, enacted in September 2015, many responsibilities relating to the use of natural resources will shift from the national level to the provincial level. This, along with the need to update some aspects of energy sector legislation to reflect evolving international best practices, has resulted in draft legislation on

- Water Resources and Energy Policy
- Electricity Regulatory Commission
- New Electricity Act.

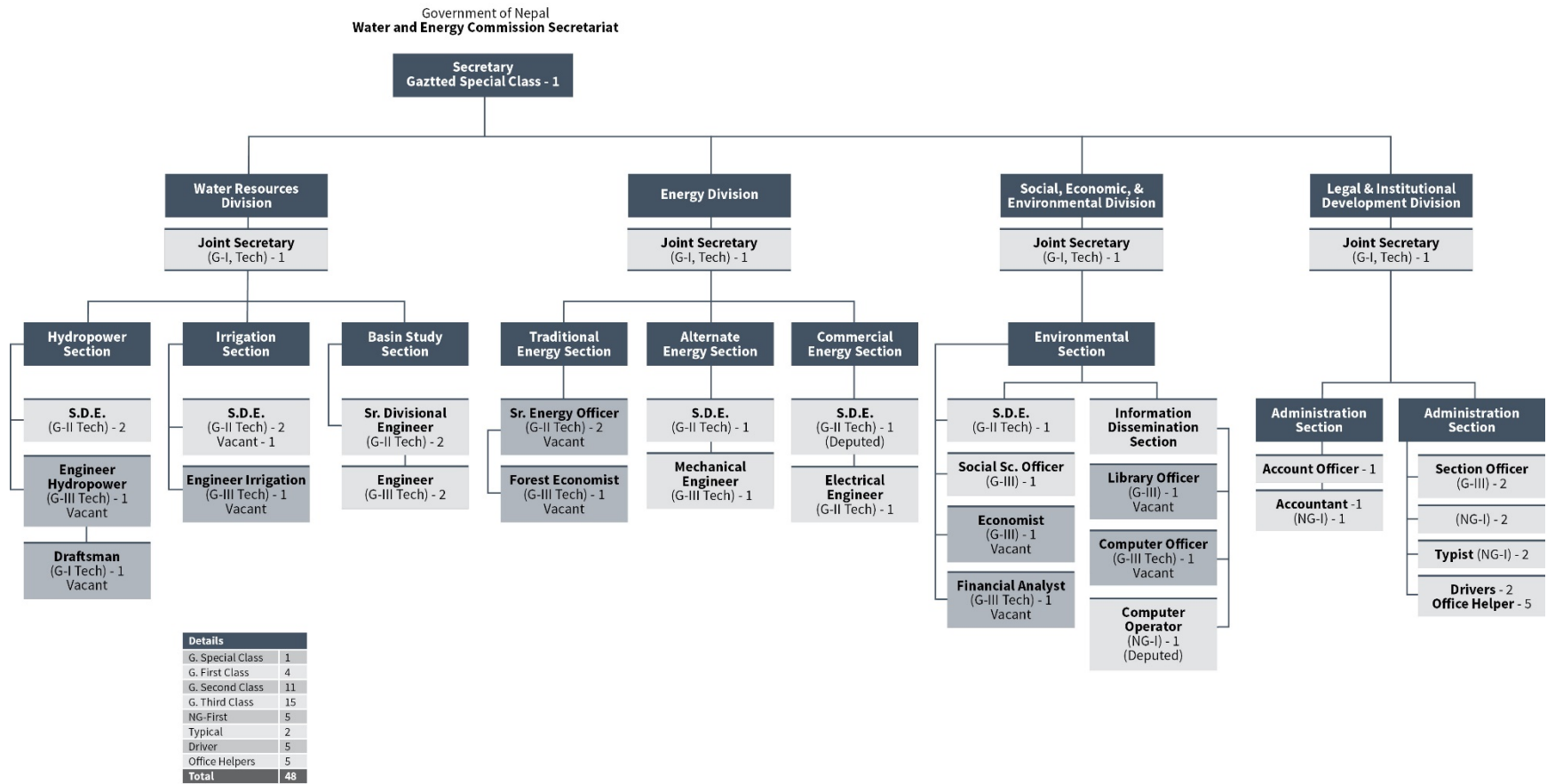


Figure 3-11: Organization Chart for WECS

It is understood that the drafting of a new Water Resources and Energy Policy by a GoN appointed committee is well advanced. This draft is reported to include certain provisions that relate directly to dam safety.

Separately¹¹, a review of dam safety regulations in 28 jurisdictions around the world is provided. This review indicates what is typically contained in dam safety regulations and what powers are vested with dam safety regulators. The results of this assessment are provided in Figures 3-12 and 3-13.

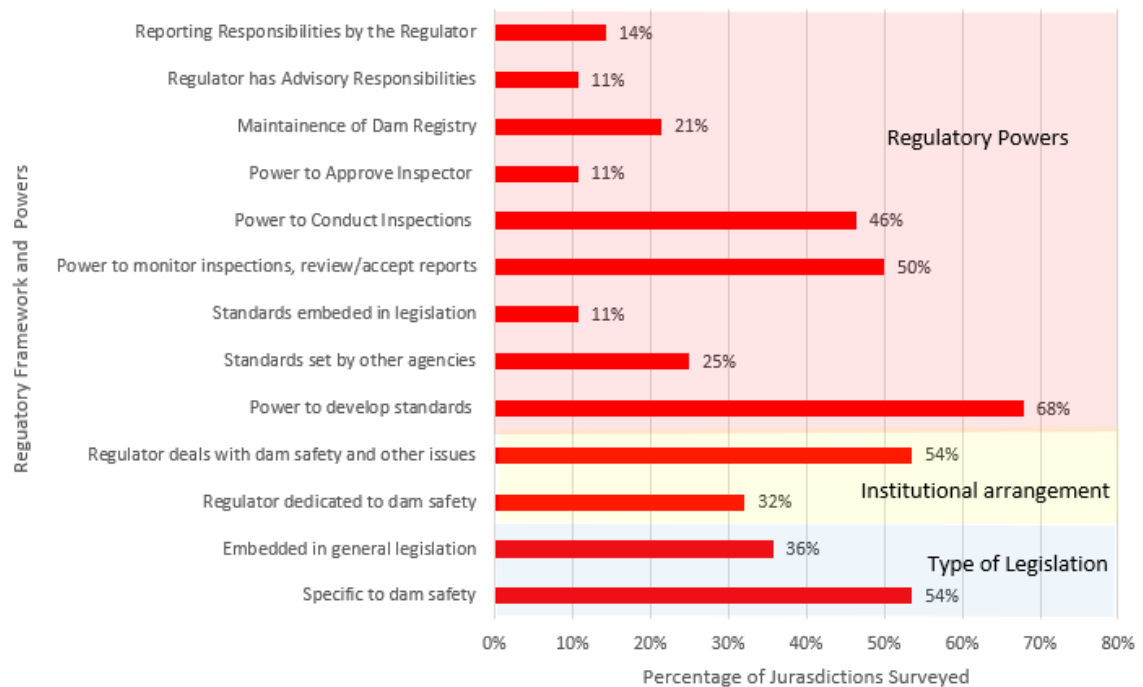


Figure 3-12: Jurisdictional Review of Regulatory Powers

¹¹ Hatch, Steps to Improved Hydropower Dam Safety in Nepal Final Report, report H352327-00000-200-230-0012¹² (ANCOLD, (Various))

Steps to Improved Hydropower Dam Safety in Nepal Final Report

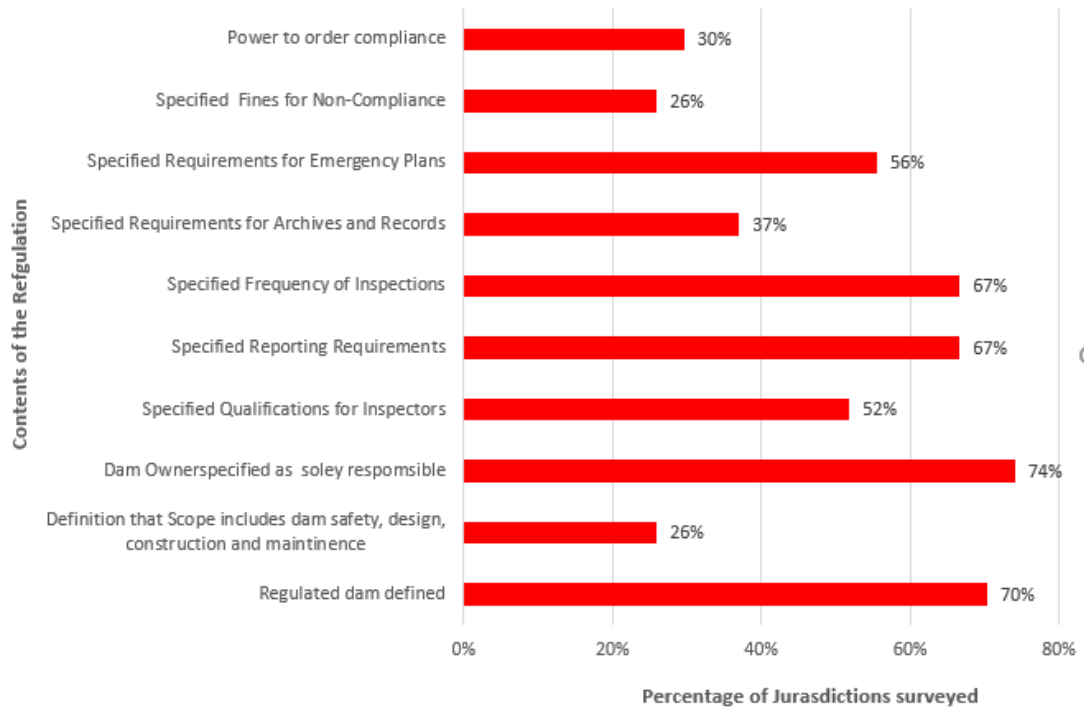


Figure 3-13: Jurisdictional Review of Contents of Dam Safety Regulations

Table 3-3 provides a review and assessment of current relevant legislation that could be used to meet some of these typical Dam Safety Management requirements.

Table 3-3: Summary of Current Regulatory Framework Relevant to Dam Safety

Act	Clause	Powers
Electricity Act, 2049 (1992)	8	Cancellation of license if rules not followed (Power to order compliance).
	24	Environmental protection.
	32	Power to inspect.
	37	Power to appoint chief inspector.
	38	Power to impose penalties.
	40	Power to frame rules.
Electricity Rules, 2050 (1993)	3,4	Requirement to provide information.
	77,78	Power to inspect.
	84	Power to set safety standards.
Hydropower Development Policy, 2001	4	Strategy on risk mitigation and allocation.
	5	provision to cover risks
An Act Made to Provide for the Management of Water Resources	20	No substantial environmental Impacts

This review shows that, while some of the basics of dam safety are already recognized in current legislation, regulation and policy, specific programs on dam safety are generally not in place. In addition, attempting to regulate a modern dam safety management program using different pieces of legislation under different government authorities would not be workable.

3.3.3 Capacity

With respect to the administration and enforcement of any potential future dam safety standards, Nepal currently lacks effective administrative capacity for inspection, monitoring, and enforcement. However, it appears that an effective dam safety program could be integrated within existing institutions that cover hydropower and dam development. It is understood that this is the organization that will be responsible for the administration of the nation's Dam Safety Management System ("DSMS") when it is developed.

3.4 Status of Dam Safety Management in Nepal

In all industries, including the dam industry, the method of ensuring that operation and maintenance activities are being effectively carried out is through a management system. In a general sense, dam safety management involves the proactive management of the risks that can impact people, property, and the environment. Many organizations around the world have identified the requirements for such a systematic approach to dam safety management. For example, The Australian National Committee on Large Dams (ANCOLD) published guidelines on Dam Safety Management¹² that state that the objective of dam safety management is to protect life, property, and the environment from the failure of any dam, and that this objective can be achieved by establishment of a dam safety program as conceptually detailed in Figure 3-14.

¹² (ANCOLD, (Various))

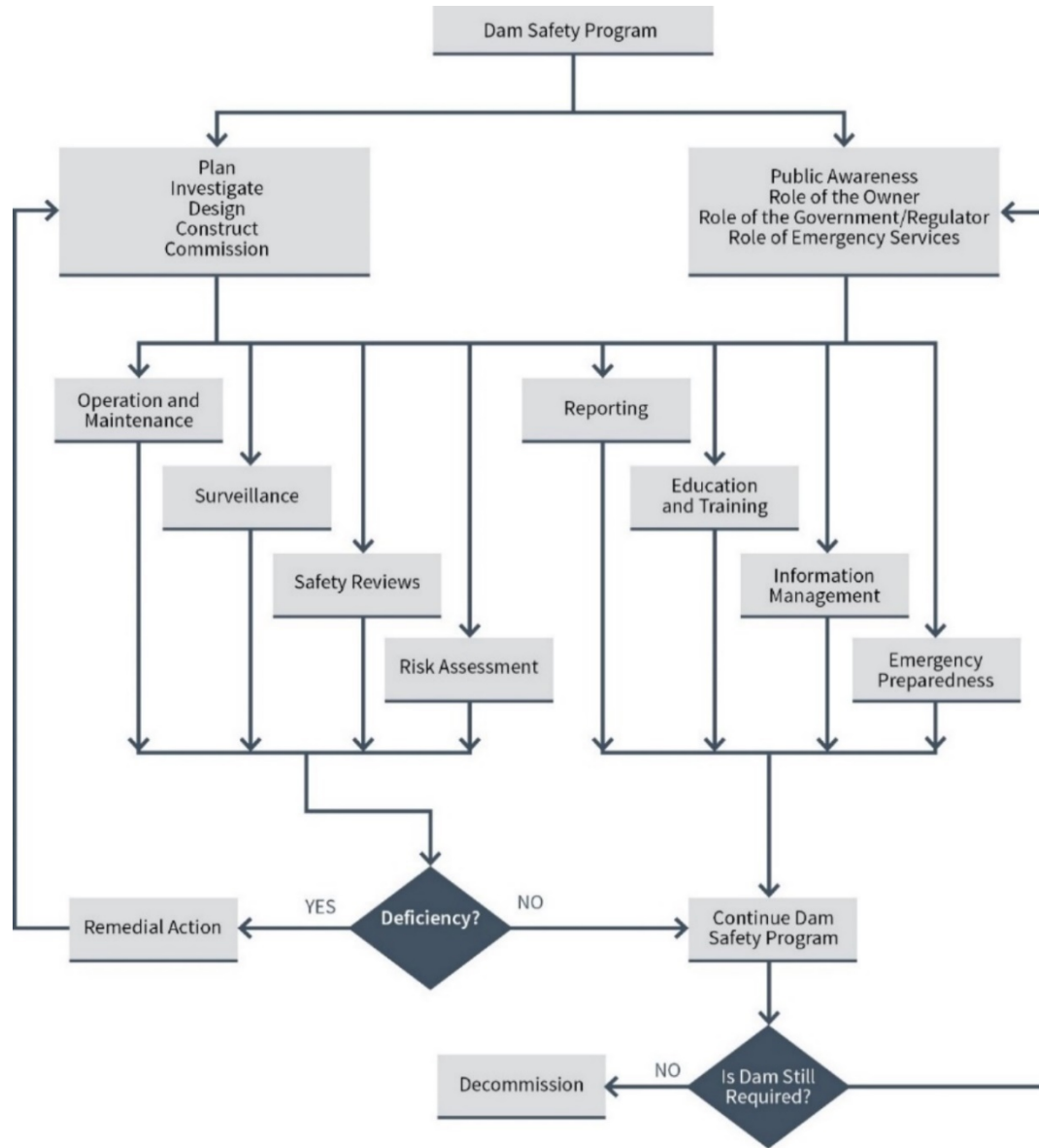


Figure 3-14: Jurisdictional Review of Regulatory Powers

3.4.1 Design Standard/Criteria and Issues

Currently, a standard dam safety management system for maintaining the safety of existing dams does not exist in Nepal. There are no formal and accepted methods for selecting the standards that a dam must satisfy to be “safe” either nationally or provincially in Nepal. Accordingly, dam design standards vary depending on the judgment and experience of the practitioner and the standards of their home country. In addition, much of the relevant design

information that does exist is not readily available, a deficiency that would hinder future dam safety reviews. In many cases the standards that are used are reported to be dam safety guidance documents developed ICOLD and design documents produced by the US Bureau of Reclamation (“USBR”) and the US Army Corps of Engineers (“USACE”). In addition, various international design consultants typically employ the standards in use by the countries they represent. However, most of the international standards that are adopted for the design of dams and HPP’s in Nepal do not account for the site-specific issues and natural hazards that vary widely in Nepal.

The inconsistent standards that have been used in construction of Nepal’s dams do not necessarily mean that Nepal’s facilities are unsafe. However, the risks that an individual dam poses to the downstream public may vary considerably depending on the standard that was selected. For example, the earthquake parameters selected for the design of the Kulekhani dam are well below modern standards. While the concrete structures at this facility performed well under the effects of the 1988 and 2015 earthquakes, continued slumping of the upstream shell of the dam and cracking of the impervious core is occurring. This appears to be due to the lack of appropriate seismic design parameters.

An attempt was made by the DoED to provide some level of consistency through the production of three technical guidelines that provide commentary and suggested approaches to investigation, planning, design, construction quality assurance, operation and maintenance, instrumentation and other matters related to HPP development in Nepal.

- Guidelines for Study of Hydropower Projects (2003)
- Design Guidelines for Headworks of Hydropower Projects (2006)
- Design Guidelines for Water Conveyance System of Hydropower Projects (2006).

The **Guidelines for Study of Hydropower Projects**, was noted to be generally complete and provides constituency in the methods that should be followed in hydropower studies. This guideline provides a structure for an effective review of studies made by developers. The primary gap in this document was the absence of a discussion on dam break analysis. The results of this analysis provide the information needed for the design of HPPs.

The **Design Guidelines for Headworks of Hydropower Projects** provides useful information for both study and detailed design. The principle data gaps are

- the need to update the document to address state-of-the-art dam design methods
- only run of river projects are specifically addressed, storage (reservoir) projects are not covered
- embankment dam foundation design is not included.

It is recommended that these guidelines be updated to address these gaps. A general comment is that consideration should be given to simply referencing existing

textbooks/publications/standards with introductory discussions, as appropriate. This would ensure that the dos to avoid the detailed technical information that is currently contained in the document will remain in accordance with the state of the art.

The **Design Guidelines for Water Conveyance System of Hydropower Projects**. Like the guide for headworks, this guideline provides useful information for both hydropower planning and detailed design. The principle data gaps are

- the lack of a general discussion on layout of waterways
- the document covers the civil aspects as well as penstocks, but does not address gates and valves, which are an integral part of almost all waterways.

The same general comments made for the headworks guidelines also apply to the guidelines on waterways. The document could be made more concise by judicious recognizing and referencing other document in the industry.

These documents do offer some good information but they do not provide many of the fundamental dam safety concepts that are required in a modern Dam Safety Management System. For this reason, a set of draft guidelines based on modern international practice and the needs of Nepal were prepared as part of this project.

3.4.2 Overview of Hazard Assessment Practices

3.4.2.1 Dam Classification

A fundamental building block in any DSMS is a well-defined dam safety classification system that defines the standard of care for a dam in relation to the hazards that it presents to the public. There is currently no consistent classification system that is used in Nepal which results in inconsistencies in the selection of dam safety design parameters and the standard of care after the HPP is constructed.

3.4.2.2 Documentation

Details of the design assumptions and parameters used in the form of Design Basis Memoranda (“DBM”), Geological Baseline Reports (“GBR”) and Record Drawings are generally not available and are not mandated to be made available.

3.4.2.3 Natural Hazard Assessments

There are inconsistent criteria used in the design of hydropower projects in Nepal. Issues such as landslide risks and debris flows that may occur because of GLOFs, LDOF and rainfall induced landslides are often not adequately accounted for in the designs. Issues associated with sedimentation do not generally appear to be considered in the design of Nepal’s HPP’s

Well established international standards for the assessment of earthquake loadings and flood flows are available that are used in the design of Nepal’s HPP’s. However, as is the case in many other parts of the world, the understanding of these hazards has evolved over time.

This can result in existing dams and associated structures not meeting modern design standards. This was the case for Nepal's highest dam, the Kulekhani rockfill dam. During the Potential Failure Modes Analysis workshop for Kulekhani HPP it was determined that the dam was designed to a significantly lower seismic design criteria than what would be required under modern dam safety standards. Ongoing slumping of this dam is believed to be occurring, in part, because of this deficiency.

3.4.3 Dam Safety Inspections and Reviews

The observational approach has long been recognized as a key component of the performance monitoring process for earthworks and foundations. Dam Safety Inspections and reviews are used to accommodate the inevitable uncertainties associated with design assumptions in materials or construction techniques. A comprehensive visual inspection can identify most issues related to dam safety and provide the owner with the opportunity to perform mitigative measures. The level of detail needed depends upon the type of inspection being performed, complexity of the site, consequences of dam failure, past performance and other relevant parameters. Therefore, routine inspections by trained on-site staff and visual inspections by qualified professional engineers are integral to an effective dam safety program.

The frequency of inspection and monitoring activities is based on regulatory requirements, consequences of dam failure, dam condition and past performance, time of development of expected failure modes, seasonal or other access constraints due to weather, and other factors. Inspection during dam construction is critical to ensure conformance to design criteria and proper construction control.

Currently, there is no regulated requirement for dam safety inspections in Nepal. Therefore, this is left up to the individual dam owners resulting in an inconsistent standard of care across the country.

3.4.4 Operations, Maintenance and Surveillance

A critical part of a DSMS and the associated Owners Dam Safety Management Plan (DSM Plan) is the development, implementation, and control of procedures for the operation, maintenance, and surveillance of the facility, considering public safety and security.

Good international practice requires that operation, maintenance, and surveillance procedures be documented in an Operation, Maintenance, and Surveillance Manual (OMS Manual) and reviewed regularly to ensure that the information is up to date. Proper operation of discharge facilities is critical to safety and performance and mitigating potential impacts to the public. Therefore, development and documentation of procedures for operation of flow control equipment under all circumstances is required.

Maintenance and testing of gates, hoists and associated systems to ensure operational availability, safe operations, and integrity of the dam and the mechanical and electrical

systems form part of the maintenance requirements. **Procedures** for regular maintenance to correct things such as settlement, and slope instability need to be defined and documented and performed as issues become apparent. Procedures and documentation of **Surveillance** and **Monitoring** to check if the dam is performing satisfactorily are required.

In Nepal, formal documented **Inspections** are not performed and there is no requirement or standards to undertake formal dam safety assessments. This means that, even if a potential dam safety issue is observed, there may not be baseline information that would allow a complete assessment of the situation and the level of risk.

3.4.5 Emergency Preparedness

An Emergency Preparedness Plan (“EPP”) is a key reference document designed to provide guidance to dam Owners and other stakeholders in the implementation of measures that need to be used to reduce the impacts associated with a dam safety incident. The EPP provides information regarding the potential consequences of dam failure, including flood inundation. An Emergency Action Plan (EAP) details the specific action to be taken in the event of a dam incident.

Typically, these documents are required for all dams whose failure could put lives at risk, or if the implementation of emergency procedures could reduce the consequences of failure associated with other losses (environmental, economic, cultural heritage). Where such documents are mandated, it is also required that they be reviewed and updated periodically throughout the life cycle of a dam. The EPP and EAP documents are also used by dam owners to undertake mandated training of their staff and the public as to the steps to be taken in the event of dam emergency.

4. Jurisdictional Review of International Standards and Best Practices

4.1 International Perspectives on Dam Safety Regulatory Practices

Surveys of international practices on dam safety have been performed by ICOLD, the World Bank Group and others. The results of these surveys have shown that dam safety regulations and the practice of dam safety management varies somewhat from jurisdiction to jurisdiction but that the process is evolving and has proven to be a very effective means of reducing the risk of dam failure.

The overall objective of any dam safety regulation and DSMS is both to reduce the likelihood of a dam failure and to reduce the overall risks associated with a dam failure by

- identifying and evaluating potential failure modes
- implementing modern design and maintenance and surveillance practices
- designing barriers to mitigate the reduce the impacts in the event a dam does fail
- implementation of effective an EPP/EAP and training for staff and the public.

Almost all developed countries and many developing countries, have a legal framework that includes dam safety requirements specifically dealing with dam safety or an overarching legal framework with a water law and a public protection act. In countries where there are no specified regulatory requirements for dam safety, regulations typically reference rules and guidelines of organizations such as ICOLD and the Canadian Dam Association (“CDA”).

An important principle in regulation, in almost all jurisdictions, is that dam owners are clearly defined as being responsible for dam safety, even in jurisdictions where most (or all) dams are owned by the state. Application of this principle requires that inspection and monitoring of dams be performed by both the dam owner and by an independent third party dam safety expert, engaged by the responsible dam owner, for regulated formal inspections.

Almost universally, in jurisdictions that have implemented a formal DSMS, dams are classified as a means establish a consistent and calibrated approach to dam design, operation, maintenance and surveillance. There are a wide range of dam classification systems that attempt to classify dams in several ways. However, more modern systems tend to view consequence or hazard classifications as offering the best mechanism to moderate risk exposure to the public, the environment and cultural heritage.

Risk informed methodologies, in combination with standards based approaches, are increasingly considered by many jurisdictions as offering the most effective means of reducing the risks associated with dam failure or operational errors, However, formal risk

assessment approaches can be complex and expensive which has led to a limited acceptance of the approach by many jurisdictions. For example, ICOLD stated that

“[The quantitative determination of risk]is in the development stage and this is especially true of its application to dams”¹³

The US Federal Energy Regulatory Commission (FERC) developed a Probable Failure Modes Assessment (“PFMA”) methodology that is becoming increasingly accepted as the best available qualitative approach to risk assessment. It offers a cost-effective, yet comprehensive, means of identifying key dam safety issues from a risk perspective, particularly when used in combination with standards based approaches.

4.2 Objectives of a Dam Safety Management System

The practice of dam safety, dam safety guidelines and regulations is a global initiative that is evolving to reduce the risks that dams present to the public and environment to As Low As Reasonably Practicable (“ALARP”).

To meet this objective a DSMS is developed for an entire jurisdiction to provide guidance to dam owners in the development of a site-specific DSM Plan. The DSMS ensures that dams are suitably designed, constructed, operated and maintained to provide for the protection of persons, property, the environment and cultural heritage and so that appropriate emergency response measures are in place to mitigate impacts in the event of a dam safety incident. This objective is achieved where it can be demonstrated that sufficient measures have been taken to effectively manage the risks associated with an existing dam and that designs for new dams have been performed in accordance with modern standards such that hazards have been identified and mitigated to the extent that is possible.

A DSMS provides the dam owner and the regulator with a clear road map for establishing a dam hazard classifications, minimum design requirements current condition and required measures to adequately manage risk. Typically, a DSMS also includes reference to appropriate design guidelines and a range of dam safety activities, including regular inspections, testing and surveillance and monitoring all designed to address the specific hazards associated with a given dam. The DSMS and the owners project specific DSM Plan needs to be reviewed and updated following the completion of the regular Periodic Dam Safety Reviews (PDSR) to provide the GoN confirmation that project specific requirements are established and compliance can be confirmed.

As is illustrated in Figure 4-1, is a typical DSMS with dam safety regulations that include specific requirements that are fundamental to dam safety and its governance. Outside of this regulatory framework, achievement of dam safety fundamentals requires that a template for

¹³ (Bulletin No. 130 - Risk Assessment in Dam Safety Management. A Reconnaissance of Benefits, Methods and Current Applications, 2005)

good engineering practice be provided. For this reason, dam safety guidelines are typically prepared that are referred to but not part of the actual regulations. This allows dam safety guidelines to be living documents that can be regularly updated to reflect the most current thinking of the dam safety community.

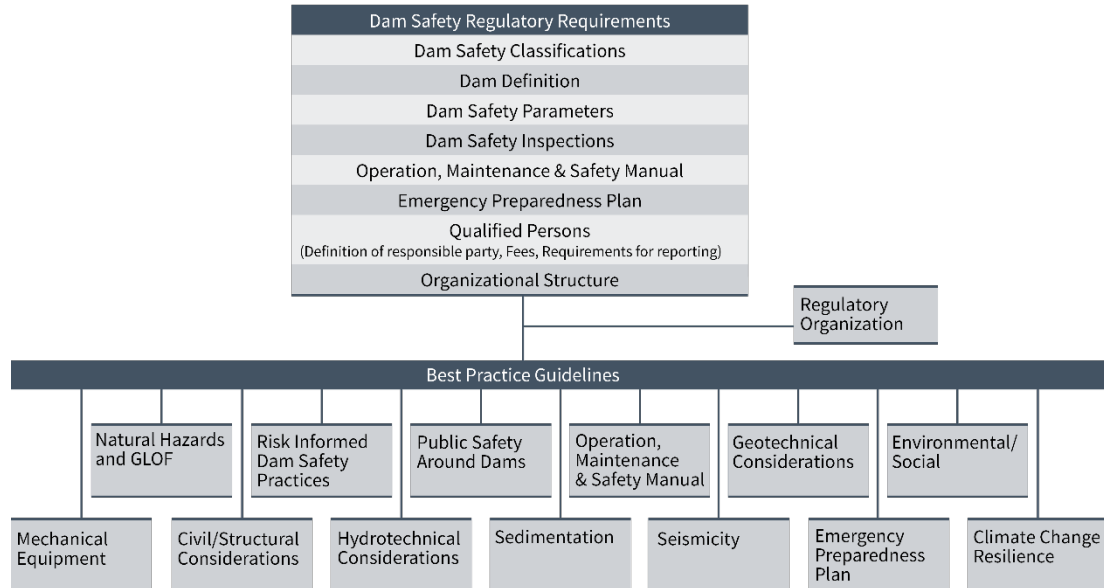


Figure 4-1: An Overview of a Dam Safety Management System

In addition to meeting the objective of achieving dam safety for existing dams, typically, the regulation and guidelines provide a framework for the design of new dams. If properly implemented, new dams are designed, constructed and operated per the relevant or best available “recognized rules of technology”.

In most jurisdictions dam safety guidelines are tailored to the specific needs of the jurisdiction making use of information available from international organizations such as ICOLD, CDA, ANCOLD, FERC etc. Usually the recommendations contained in such guidelines are not legally binding and are not mandatory for dams but are an important consideration in case dam safety issues are encountered. In Table 4-1, the fundamental aspects of dam safety that are normally enshrined in legislation that establish a DSMS.

Table 4-1: Summary of Dam Safety Concepts Typically Enshrined in Legislation

Definition of a Regulated Dam	A first step in the development of a dam safety regulation is a clear definition of dams that are to be regulated. Jurisdictions do this in different ways but modern practice would be to define a regulated dam as any that presents unacceptable risks to the public, the environment.
Definition of a Qualified Person	While definitions vary depending on the jurisdiction, a qualified person is typically defined as being a registered professional engineer with a background in the design, construction, performance analysis, and operation of dams.
Definition of Responsibility for Dam Safety	In all jurisdictions, dam owners are specifically designated as being solely responsible for the safe management of dams and ensuring that an appropriate standard of care has been exercised in the management of dam safety. Dam owners, depending on the size of the project and their portfolio, often assign a dam safety engineer to coordinate dam safety activities. Compliance with the safety criteria and associated requirements established by the GoN would not provide dam owners with any exemption from obligations for protecting persons and property from the hazards presented by their dam.
Level of Government Oversight	Consistent with the definition of responsibility for dam safety, in virtually all jurisdictions, the role of government is an auditing and approval function. The regulator would retain the power to inspect, but would do so only as part of its auditing function to verify that the information provided by the dam owner is materially correct.
Dam Classification System	Classification of dams is a way of defining the standard of care that should be applied to a regulated dam. Most modern systems classify dams in accordance with the incremental ¹⁴ hazards they present in the event of a dam failure or incremental consequences of failure. Consequence or hazard classification provides a means of grading the level of safety requirements and civil protection measures enforced by dam safety regulations to ensure a very low probability of occurrence of damage to people, property and environment without creating unrealistic safety requirements for low hazard dams.
Standard of Care	The dam safety classification system is used to establish the measures that are required under regulation to help reduce dam safety risks including <ul style="list-style-type: none"> • frequency and types of dam safety inspections and PDSR's • frequency of maintenance activities • level of details of emergency preparedness and operations and maintenance plans.

¹⁴ For many smaller dams, water levels during an extreme flood event can be many meters above the crest of the structure. In these cases, the dam becomes “drowned out” such that, even if the dam were to fail during the flood, the effects of the failure would be unnoticeable. In this case, it would not serve the purpose of providing the public to design the dam to resist the effects of an extreme flood event if the same losses would occur with or without a failure.

Requirements for Operation, Maintenance and Surveillance	Depending on the incremental hazard or consequence classification of a dam, dam safety regulations typically require that an OMS manual be in place and updated annually.
Requirements for Emergency Preparedness Plan	An EPP is a document prepared by the dam owner to understand and prepare for a dam incident; including understanding of the consequences of failure such as flood inundation. Typically, an EPP is a regulated requirement for all dams whose failure could put lives at risk, or if the implementation of emergency procedures could reduce the consequences of failure associated with other losses (environmental, economic, cultural heritage). Where an EPP is mandated, it is also required that it and associated documents be reviewed and updated periodically throughout the life cycle of a dam.
Dam Safety Register	The DSMP would require dam owners to provide details on their dams. This would include all dam safety details including dam classification, any incident reports, PDSR reports, location, details of the dam and flow control equipment, etc. The GoN would receive the information and maintain a register of regulated dams under their jurisdiction and have power to inspect selected dams to verify the accuracy of the information supplied.

4.2.1 **Fundamental Dam Classification Concepts**

Dam classification systems vary depending on the jurisdiction. In all cases, life safety is a key consideration (and occasionally the only consideration) for classifying a dam for dam safety purposes. In most modern systems, classification systems include economic, environmental and less frequently, cultural heritage loss exposure in addition to life safety.

4.2.1.1 *Legal Requirements for Dam Safety Classification*

Most countries have legislated requirements for the classification of dams either in laws or regulations, or in both. In some countries classification of dams is used to specify which acts and regulations, or which legal requirements within acts and regulations, are to be applied to dams of each class. (In Norway, for example, only a few non-technical requirements in the dam safety regulation apply to dams in the lowest consequence class.)

4.2.1.2 *Types of Systems (Hazard Based, Consequence Based, Size and Volume)*

In the past, dam safety classification was often made based on the height of the dam and/or reservoir size. This may have merit in countries where the downstream impacts of a dam failure are relatively uniform such that these parameters effectively define the dam safety risk. However, this approach does not lend itself to ensuring the public and environment are uniformly protected.

Most modern systems attempt to better define dam safety risk by means of qualitative or quantitative estimation of hazards or failure consequences. There is, however, a fundamental difference exists between an incremental hazard and an incremental consequence. When

dams are classified based on the hazard they present, the classification of the dam does not change regardless of any measures that may be implemented to mitigate the risk. For example, if, during a flood, there were an incremental risk of inundation and loss of life, the dam would be classified as a high hazard structure. This rating would not reduce if appropriate warning measures were instituted such that all persons could be effectively evacuated in the event of a dam break. In other words, the dam would still present the same level of hazard regardless of what measures are used to reduce exposure. Ratings based on failure consequence, on the other hand, would change in the event that measures are taken to reduce or eliminate incremental losses following a dam failure. For the same dam described above, if measures were taken to ensure evacuation of residents was accomplished before the flood wave reached the town site, the incremental downstream consequences would be eliminated and the ICC classification might be reduced from high to low.

4.2.1.3 *The Concept of Incremental Loss*

Classification systems are typically based on the total incremental adverse consequences of failure or operational error.

The tool used to determine these incremental losses is dam break modelling and inundation mapping. Dam breach scenarios are evaluated for both the flood and non-flood dam break assessments and then compared to the inundation that would occur without a dam breach. The zone between the two flood lines is the area where incremental loss may occur.

4.2.1.4 *Third Party Losses*

In the event of a dam failure, the owner of the dam and associated hydropower facility may often incur significant first party losses. These might include

- loss of generation
- costs to rebuild the asset; and/or
- costs to repair damages caused by flooding of generation equipment.

These losses do not impact public safety. Therefore, they are not included in the dam safety classification assessment. The concept is that the owner is responsible for maintaining sufficient insurance to protect against such eventualities.

4.2.1.5 *Transient Persons*

In most dam safety classifications systems, the potential for loss of life is based on the hazard a dam presents to permanent dwellings. Transient losses are generally not accounted for directly but are considered in situations for a non-flood failure scenario where a dam located upstream of a prime recreational or tourist area where it might be reasonably expected that someone could be present at most times during the year. In this case, they would not be

considered in a flood scenario since it would be unlikely that recreational activities would be ongoing during a major flood event.

In a related topic, workers at the waterpower facility, or at the dam, are also generally not included in the assessment of potential life safety risks since they understand the facility and are trained in the actions to take in the event of a dam safety event.

Given the complexity of this sensitive subject, it is important that, in any standard or guideline, the wording for the loss of life exposure be carefully considered to ensure that the meaning is clear to practitioners. or an evaluator, especially where recreational activities are prevalent on the reservoir or where transient individuals, such as fishermen, frequent the area downstream of the dam.

4.2.1.6 *Dam Classification Under Flood and Non-Flood Failure Scenario's*

The dam safety classification system is used to establish the standard of care for dams based on the hazards that the dam presents. This includes the selection of design parameters in accordance with the dam classification that result in increasing levels of safety for events up to and including an extreme event such as the Probable Maximum Flood ("PMF") or an unpredictable event such as the Maximum Credible Earthquake ("MCE"). The Dam Safety Classification is based on the higher of the two failure scenarios.

With respect to the selection of dam safety parameters that stream from the classification, it is necessary to consider the consequence from each failure scenario. For example, it is not in the public interest, or in accordance with dam safety principles, to design a dam to pass the PMF if the dam is assigned a HIGH dam safety classification based on losses that would occur during an earthquake.

Therefore, a dam is classified according to the failure scenario that results in the highest losses. This then dictates the standard of care for the structure to reduce the potential for these unacceptable losses. However, both failure possibilities must be considered for the purposes of selecting appropriate design parameters.

4.2.1.7 *Incremental Life Safety Loss – Persons at Risk*

Considerable variation exists between different DSMS with respect to the treatment of life safety risks. For example, current FERC Dam Safety Guidelines provides just three dam safety classifications with the "High" hazard classification assigned if one more Incremental Potential Loss of Life ("PLL") would result from dam failure. This means that the highest standard of care would be applied if a single person was at risk. Assuming a return period for the PMF in the order to 1:100,000 to 1: 1,000,000 the dam safety risk avoided is at odds with risk tolerability thresholds established by other industries. Several authors¹⁵ have provided

¹⁵ (Nielsen, Hartford, & MacDonald, 1994) and (Salmon & Hartford, 1995) for example.

details of tolerable loss of life criteria from various organizations, as is summarized in Figure 4-2.

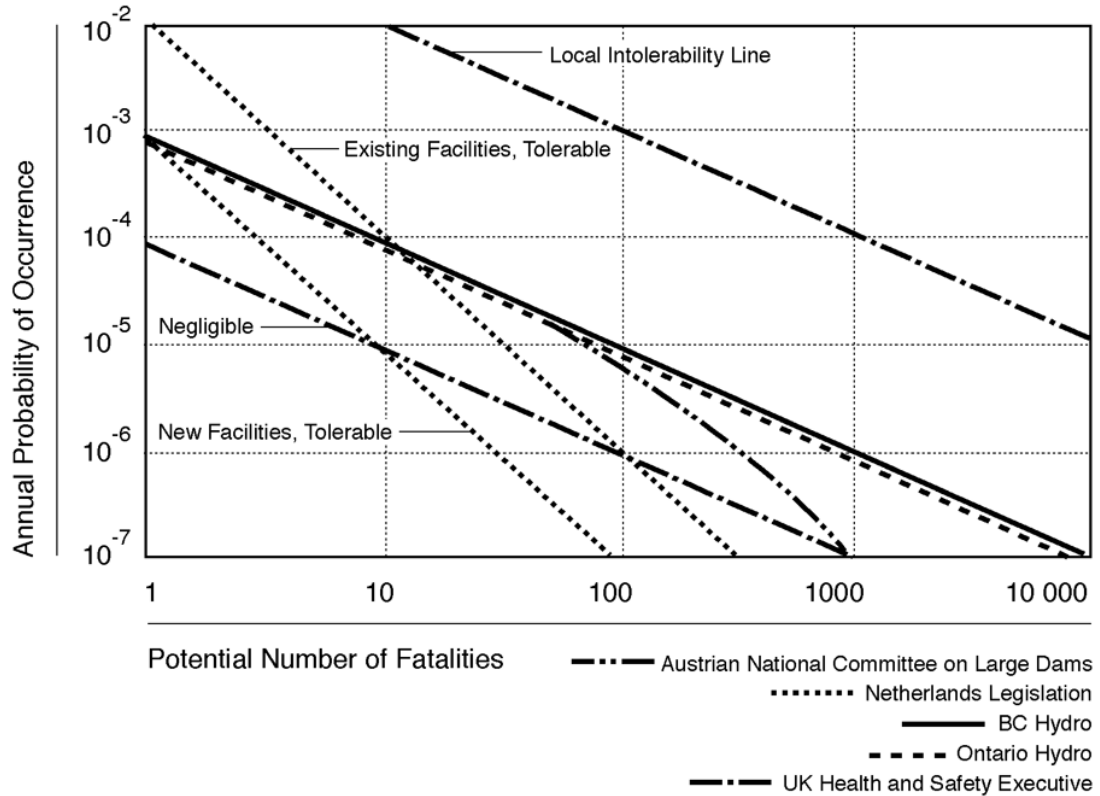
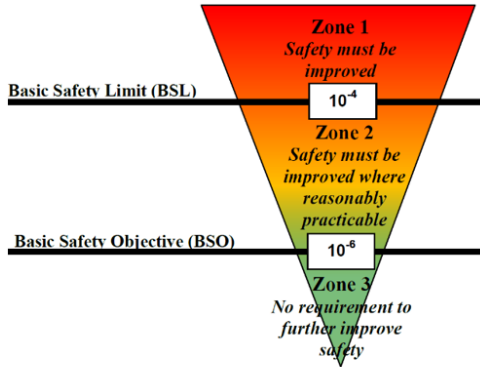


Figure 4-2: Societal Risk Criteria (after Salmon and Hartford 1995)¹⁶

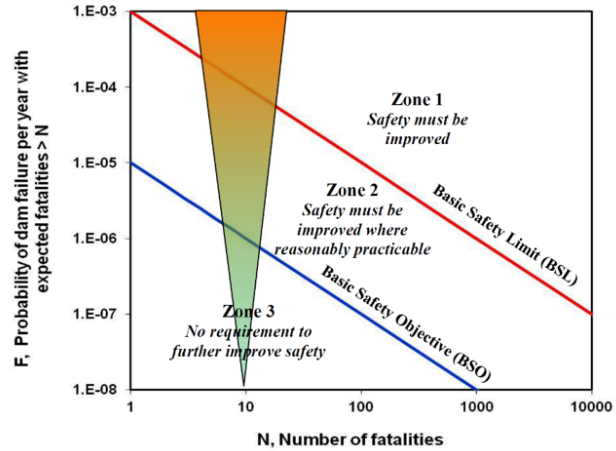
In 2013 (2007 Dam Safety Guidelines (2013 Revision), 2013), the CDA published a revision to their 2007 dam safety guidelines (2007 Dam Safety Guidelines, 2007) that specifically incorporated guidance on the use of risk informed dam safety management. They defined two levels of risk tolerability: individual risk which was set at 10^{-4} , and societal risk which has an upper limit of tolerability of 10^{-3} . Details of the risk tolerability thresholds adopted by the CDA are outlined in Figure 4-3.

¹⁶ * Note ICOLD, 2004 (Risk Assessment in Dam Safety Management. A Reconnaissance of Benefits. Methods and Current Applications, 2005) reports BC Hydro standards changed in 1997 eliminating loss of life criteria as a design standard. Ontario Hydro now defers to the CDA standards for risk tolerability

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a) Individual Life safety Criteria



b) Societal Life Safety Criteria

Figure 4-3: The CDA Risk Tolerability Thresholds (Passey, October 4-9, 2014)

While there remains some variation in the treatment of life safety, most modern jurisdictions have recognized the concept of risk tolerability and have adjusted the standard of care depending on the number of persons at risk. In some jurisdictions, there is a reluctance to specify a quantitative value to potential loss of life or persons at risk, instead adopting qualitative descriptions such as “some”, “few” or “many”. While this reluctance is perhaps understandable, the lack of guidance that results from such qualitative descriptions essentially puts the burden of defining what is acceptable on individual dam owners or their consultants. This then means that different dams can pose a different dam safety risk to the public, an outcome that a well-designed dam safety management system strives to avoid. A quantitative approach is, therefore, recommended for Nepal.

4.2.1.8 *Incremental Economic Losses*

Potential downstream property damage is limited to third-party exposures in all the guidelines reviewed. As with life safety thresholds, there is considerable variation on tolerability and a mix between quantitative and qualitative guidance. Again, for Nepal, a quantitative approach to assigning threshold levels for standard of care is recommended.

In a quantitative approach, it is important to define the year in which the values were derived and the escalation indices that should be used.

4.2.1.9 *Infrastructure and Public Utilities*

Special provisions are frequently made for important infrastructure and public utilities. These provisions usually override monetary impact of direct economic loss.

4.2.1.10 Environmental Losses

Many jurisdictions, but far from all, consider environmental issues in a qualitative manner for dam classification. A qualitative approach to this aspect of establishing the standard of care is unavoidable and needs to consider the specific needs and values of the jurisdiction in question.

4.2.1.11 Heritage/Cultural Losses

Of the jurisdictions reviewed, only the new CDA Guidelines, the ANCOLD guidelines, and the Ontario dam safety guidelines specifically deal with the matter of heritage and cultural losses, separately in the case of Ontario and ANCOLD, and grouping it as a component of the environmental loss in the case of the CDA. This again needs to follow a qualitative approach tailored to the specific needs and values of the jurisdiction in question.

4.2.1.12 Classification Classes and Thresholds

As mentioned above, some early dam safety classification systems mandated the highest standard of care if a single person was at risk which is at odds with risk tolerability thresholds established by other industries. To better align with risk tolerance in other industries, most jurisdictions have adopted four or five dam safety classifications with the highest standard of care assigned to situations where there are some significant losses. An example is shown in Table 4-2.

Table 4-2: CDA Dam Safety Classification Criteria

Dam Class	Population at Risk (Note 1)	Incremental Losses		
		Loss of Life (Note 2)	Environmental and Cultural Values	Infrastructure and Economics
Low	None	0	Minimal short-term loss. No long-term loss.	Low economic losses; area contains limited infrastructure or services.
Significant	Temporary Only	Unspecified	No significant loss or deterioration of fish or wildlife habitat. Loss of marginal habitat only. Restoration or compensation in kind highly possible.	Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes.
High	Permanent	10 or Fewer	Significant loss or deterioration of important fish or wildlife habitat. Restoration or compensation in kind highly possible.	High economic losses affecting infrastructure, public transportation, and commercial facilities.
Very High	Permanent	100 or Fewer	Significant loss or deterioration of critical fish or wildlife habitat. Restoration or compensation in kind possible but impractical.	Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances).
Extreme	Permanent	More than 100.	Major loss of critical fish or wildlife habitat. Restoration or compensation in kind impossible.	Extreme losses affecting critical infrastructure or services (e.g. hospital, major industrial complex, major storage facilities for dangerous substances).

In 2011, the Province of Ontario adopted the same numbers of classification categories but with additional guidance on the selection criteria and a recognition that life safety was the most critical dam safety issue. In the case of cultural heritage structures (for example) this system placed a cap on the dam safety classification of the structures on the basis that the structures could not survive an extreme event, and therefore designing dams to protect them from a dam failure that might occur during an extreme event, was contrary to dam safety principles. This is an approach that is recommended for Nepal.

4.3 Nepal Dam Safety Guidelines

Backstopping the dam safety regulations for Nepal are a set of comprehensible dam safety guidelines that detail the recommended methods for achieving the regulated standard of care for dams in Nepal. These guidelines complement existing manuals that have been developed by the DoED and others. It is specifically recommended that they not be made part of the regulations to ensure that they can be regularly updated in accordance with the evolving practice of dam safety based on publications such as those produced by FERC, ANCOLD, ICOLD, CDA, USACE, USBR, etc.

4.3.1 *Deterministic Dam Safety Guideline Concepts*

Established practice in the safety assessment of dams has relied on a standards-based deterministic approach. This makes use of defined mathematical approaches to establish the safety of many, but not all, of the potential causes of dam failure. The method offers several advantages

- it is transparent and scientifically defensible
- computationally straightforward
- provides the reassurance of a well-known and proven methods
- uses well known and understood numerical standards such as safety factors.

The deterministic dam safety guidelines prepared as part of this assignment provide regulators, developers, engineers and other stakeholders in Nepal with an overview of the current recommended dam safety practices that should be used in Nepal for the planning and design of new HPPs and the maintenance of existing HPPs.

A deterministic approach does not, however, account for some important failure modes. For example, it is not always the extreme event that introduces the greatest risk to a facility. As is illustrated in Figure 2-4, of the over 1900 dam safety incidents listed in the US National Performance of Dam's Database during the period of 1994 to 2007, non-structural reasons, such as debris clogging or human error, were the most common root cause of dam safety incidents and dam failures.

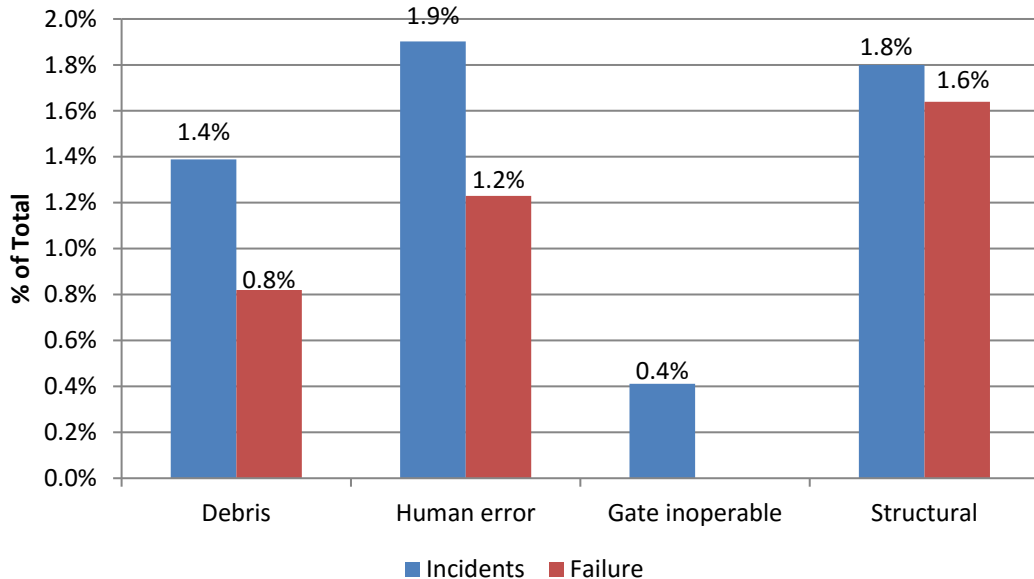


Figure 4-4: Root Cause of Dam Safety Incidents and Failures Associated with Spillway Gates (US National Performance of Dams Database, 1994 to 2007)

However, despite the shortcomings of this approach, the traditional deterministic methods have generally been very successful. They remain essential methods of dam design and dam safety management, even as emerging risk-informed approaches are introduced to provide insight into uncertainties and to improve interaction between engineers and decision-makers.

For higher hazard dams, an evolving approach is to make use of these proven standards-based approaches coupled with risk informed methodologies to better quantify all the risks a dam presents. The inclusion of Risk Informed Decision Making concepts such as Potential Failure Modes Analysis is providing insight into the risk exposure and is helping prioritize monitoring and remedial measures.

4.3.2 Risk Informed Decision Making Concepts

In the United States, following failure of several dams during the 1970's (Buffalo Creek, Kelly Barnes, Teton), federal dam building and regulating agencies were charged with a mandate to develop guidelines for assuring a comprehensive approach to dam safety. The mandate included specific direction to consider the use of risk-based approaches for dam safety.

Risk informed assessments have been used to supplement the standards-based approach in the evaluation of dam structures since at least the earlier 1980s when dam safety practitioners started incorporating the theories of risk assessments, risk analysis and reliability into the performance of dams. These theories were previously developed as part of the evolution of high risk industries such as aviation and nuclear power. Since then, various

jurisdictions and dam owners around the world have incorporated risk analysis of some type into their dam evaluation process. However, it is generally accepted that the risk analysis should be an enhancement or optional evaluation step and not a replacement of the standards-based approach. This has resulted in several approaches to assessing individual and portfolio dam safety risk.

A formal risk assessment is a structured and systematic method for understanding Potential Failure Modes (“PFMs”) and consequences, the interaction of PFMs as well as consequences, and areas of importance and uncertainty. In the traditional approach to dam safety management, regulations and standards are largely based on deterministic concepts of reliability. The likelihood of hazard occurrence and is explicitly addressed only for floods and earthquakes, whereas other adverse events or elements of outside influence are introduced through selection of viable PFMs with initiating events and consequence scenarios.

The traditional approach and the risk-informed approach complement each other to a degree, in that the overall objective in both cases is to ensure that the “dam is safe” to the extent reasonably and practicably achievable. In general, all dam safety assessments are carried out in the context of risk, with proven deterministic practices being used to varying degrees to reduce the analytical burden associated with probabilistic methods and to support decisions when quantifiable risk values are unattainable.

The same information required for a deterministic assessment is also used in a probabilistic assessment. In the latter, additional information requirements and more complex analyses are introduced to simultaneously account for uncertainties in the models and in the physical processes affecting the dam. The probabilistic approach can be used to validate deterministic results and calculate more precise results where the data are available. Thus, within the constraints of practicality, a probabilistic assessment can provide an improved basis for decision-making, prioritization if interventions are under consideration and balance social, environmental and other benefits and the residual risks of a project.

4.3.2.1 *Potential Failure Modes Analysis*

FERC in association with dam owners and the Independent Consultants who perform periodic dam safety inspections of FERC regulated projects in the United States have developed procedures to identify and evaluate PFMs. The use of PFMA procedures often leads to new perspectives on project risk exposure how to address them. Frequently the most effective way to reduce risk from specific PFMs is by adjustments to project specific surveillance and monitoring procedures, identification of key dam safety metrics and the implementation of fundamental enhancements to the inspection process.

Potential Failure Modes Analysis is a dam and project safety evaluation tool that has been made and integral part of PDSR in many jurisdictions. Traditional PDSRs have tended to

focus on a limited number of “standards based” concerns such as hydraulic capacity of spillways and stability of structures under a set of pre-defined load conditions. PFMAs are intended to broaden the scope of the safety evaluations to include potential failure scenarios that may have been overlooked in past investigations. A PFMA is an exercise to identify all PFMs under static loading, normal operating water level, debris flow, flood and earthquake conditions including all external loading conditions for water retaining structures and conveyances to assess and to highlight PFMs of enough significance to warrant continued awareness and attention. Highlight PFMs may require adjustment the Surveillance and Monitoring Plan and/or remediation as appropriate.

5. A Proposed Dam Safety Management System for Nepal

A DSMS for Nepal will require that an institutional structure be put in place that complements country specific dam safety regulations. It is proposed that dam safety focused legislation include

- fundamental principles for dam safety
- regulations and policies that specify the standards based on the fundamental principles
- an agency or agencies responsible for ensuring that the requirements established in the legislation, regulations and policies are met
- staffing requirements with clearly define roles and responsibilities
- sufficient budget to cover the staff costs and travel costs to review and inspect dams to identify any shortcomings relative to the requirements
- sufficient budget to cover the costs of an independent dam safety expert to support, in specified areas, the agency or agencies responsible for dam safety
- a system to collect and record data on the operation of all dams in the jurisdiction.

The legislation, regulations and policies should define

- a regulated dam
- a qualified reviewer
- project specific DSM Plan requirements
- requirements for inspection of the project at appropriate intervals during construction
- dam safety classification criteria based on downstream hazard, dam geometry and other project characteristics
- appropriate thresholds for life safety risks, environmental, economic and cultural heritage losses
- inspection requirements including frequency of inspection based on the classification of the dam
- operation, maintenance and surveillance requirements for dams and associated structures (such as power generation facilities) covering both maintenance of the safety of the dam, worker and public safety
- examples of appropriate design standards for new dams and for maintaining existing dams

- emergency preparedness requirements including project specific EPP and EAP
- provision that key technical and other information be provided, with periodical updates, for a national dam safety registry maintained by the GoN
- dam safety incident reporting requirements.

Powers in the regulation should include

- review and approval of the design of new dams prior to the start of construction with respect to dam safety requirements
- review and approval for the correction of any design deficiencies identified and/or operational problems identified in PDSRs
- approval of the final design prior to the issuance of a construction permit for the project
- certification of the project prior to impoundment of water and the start of operations
- maintenance of a database on all dams in the jurisdiction
- review and approval of the Owners dam safety management plan
- review and approval of periodic Dam Safety Reports
- imposition of fines and operating curtailment for offences.

In establishing new dam safety regulations, the GoN needs to consider general parameters like those noted above in the context of the countries own legal and regulatory structures and geographic/physical features to establish a program that effectively meets its needs at a reasonable cost.

5.1 Suggested Options for Implementation of a New Dam Safety Management System

The GoN has appointed a committee to draft the Water Resources and Electricity Policy. It is understood that a significant amount of work has been carried out on this policy by the committee to date but the stage for approval by GoN has not yet been reached. It is further understood that the policy includes several points that will address current gaps in the institutional structure for water resource planning and dam safety.

It is understood that WEC will have broad responsibility for water and electricity matters including dam safety with specific responsibilities for

- preparation of National Dam Safety Regulations in co-ordination with international institutions
- monitoring of existing dam infrastructure for safety concerns

- preparation of design standards based on physical infrastructure analysis, long term establishment, safety issues, optimization etc.
- preparation of national standards and supporting manuals.

On this basis, two alternative routes for the implementation of a suitable DSMS in Nepal were identified as steps that could be taken after the Water Resources and Electricity Policy Act (WREPA) is completed and approved by GoN:

1. **Pass a New Act:** Initiate a new Act based on the WREPA, to be approved by the Parliament designed to give legislative authority to the policy.
2. **Issue a New Regulation:** Issue a regulation under the existing Electricity Act, 2049 to implement the new policy on an interim basis. It is suggested that the Electricity Act (Clause 37 on appointment of Electricity Inspectors and Clause 40 on GoN setting rules on the quality and use of materials for construction and operation of hydropower plants) and Electrical Regulation, 2050 at Clauses 77 and 78 for the Electricity Inspector to inspect new hydropower projects and carry out annual inspections of operating projects would allow for this.

Given the urgency of implementing a formal dam safety program, it is suggested that the second approach be considered for further study.

5.2 Suggested DSMS Organizational Structure

In any regulation for Nepal, it is strongly recommended that dam and hydropower power plant owners be fully responsible for the safe construction and operation of their assets. Even if a more hands-on approach were desirable, Nepal lacks the technical capacity to undertake anything but an audit and approve approach to regulating the safety of the nation's dams. Under this approach, responsibilities and costs would fall to the dam owners who are generating revenues from their facilities.

The GoN would be responsible for ensuring compliance with dam safety principles and acting if compliance is not achieved. Given this fundamental principle, it is considered that the responsibilities of the Dam Safety Division should include, but not necessarily be limited to, the following items:

- Set and maintain dam safety guidelines using the guidelines recommended in other reports prepared as part of this project as the base and updating these (say) every five years because of advances in the practice of dam safety.
- Approve new dam and hydropower projects in respect of their adherence to the dam safety standards of Nepal.
- Accept completed new dam and hydropower projects based on the owner's representation that the facility satisfies Nepal's dam safety requirements.

- Maintain a dam registry based on a legislated requirement for dam owners to input complete and accurate data in this registry.
- Maintain a dam safety incident registry based on a legislated requirement for dam owners to report all incidents.
- Require additional analyses to be performed to confirm the safety of structures which may include stability analyses, Dam Break Analysis, additional geotechnical exploration etc. to be performed.
- Provide an annual report on compliance, dam safety incidents and other matters.
- Approve major repairs to existing dams and hydropower plants.
- Review and approve periodic dam safety review reports for existing dams and hydropower plants.
- Review and approve DSM Plans for existing dams and hydropower plants.
- Review and accept dam classifications.
- Undertake random inspections to verify compliance.
- Approve owners nominated safety review inspectors.
- Issue orders, collect fees and levy fines.

As is illustrated in Figure 5-1, there are seven major drainage basins in Nepal with Hydropower mostly concentrated in the Karnali, Gandaki and Koshi basins.

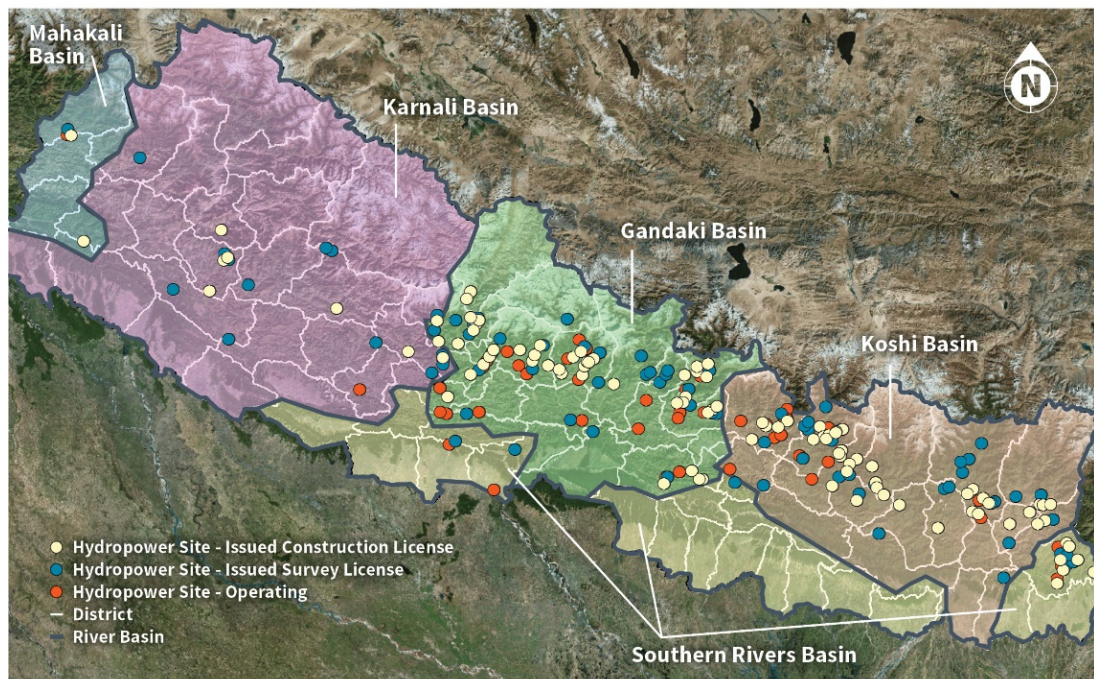


Figure 5-1: Seven Major Drainage Basins in Nepal with Hydropower

To provide a reasonable and somewhat levelized dam and HPP regulatory coverage it is proposed that the dam safety Division be divided into three regions, west, central and eastern Nepal. As is illustrated in Table 5-1, this would result in a similar number of facilities in the Central and Eastern Regions to be regulated. The Western region would have significantly less facilities but of a generally larger size that would imply larger dams with potentially more dam safety issues.

Table 5-1: Proposed Regional Organization of the Nepal Dam Safety Division

Region	Basin	Issued Operating License		Issued Construction License		Issued Survey License		Total		
		#	Capacity (MW)	#	Capacity (MW)	#	Capacity (MW)	#	Capacity (MW)	Avg Capacity (MW)
West	Makahali, Karnali, S. Rivers West	7	28	10	72	17	2,073	34	2,174	64
Central	Gandaki, S. Rivers Central	53	673	40	761	29	1,269	122	2,703	22
East	Koshi, S. Rivers East	32	278	41	1,419	32	1,784	105	3,481	33
Total		92	979	91	2,252	78	5,127	261	8,358	32

At the outset, given that much of the capacity in Nepal has not yet been developed, it may be possible to consolidate the divisions into one group, facilitating staff training and allowing for capacity building. As hydropower is developed in Nepal, the divisions could be expanded to suit.

5.3 Suggested DSMS Roles and Responsibilities

Development of a DSMS will involve the participation of a diverse range of expertise provided by several individuals and groups as discussed as follows.

5.3.1 Dam Owners

Dam owners would be responsible for the safe management of dams and ensuring that an appropriate standard of care has been exercised in the management of dam safety. The owners must demonstrate the safety of an existing dam is achieved through the development of a DSM Plan that meets or exceeds the requirements of Nepal's DSMS.

Owners would also be responsible for employing staff with the necessary qualifications, knowledge and expertise required to develop a DSM Plan and subsequent PDSR's to ensure that the owner's conclusions and supporting assessments are valid and have been verified through an internal quality assurance process and an external independent review.

The final DSM Plan and subsequent PDSR's would need to be approved by the applicable officer of the dam owning organization prior to filing with the GoN.

5.3.1.1 *Owners Dam Safety Engineer*

The dam owner would be required to assign a Dam Safety Engineer ("DSE") with the overall responsibility for implementation of, preparation and maintenance of the owner's DSM Plan and facilitation of PDSR's by a DSE on behalf of the dam owner. The DSE would be approved by the GoN and would be required to have broad experience in all facets of dam engineering and would be accountable for all facets of the DSMS and PDSR's.

5.3.1.2 *Owners Analysis Team*

The DSE would also be required to convene an Analysis Team composed of engineers knowledgeable in dam design and construction who have a specific knowledge of the dam.

Additional specialists may also need to be brought in to participate in the analysis, where deemed necessary by the DSE, that may include hydrotechnical, geological, geotechnical, mechanical, electrical, hydraulic and structural engineers as well as engineers specializing in flow control equipment. In some instances, the scope and complexity of the analysis being completed may warrant considering obtaining additional technical advice from meteorologists (for extreme precipitation estimates), Natural Hazard experts (for issues such as GLOF's LDOF's, debris flows etc.) seismologists (for earthquake hazard analysis), hydrologists (for magnitude and annual exceedance probability of floods), geologists (for understanding of foundations and natural materials), and economists (for advanced analysis of economic losses). The DSE would be responsible for determining where the scope and complexity of the analysis being completed warranted the inclusion of additional specialists.

The GoN's Dam Safety Division would retain the authority to challenge an owner to show that suitable persons have been selected to participate on the Analysis Team.

The final DSM Plan would need to be signed, sealed and dated by the DSE, the Dam Safety Reviewer and approved by the GoN.

5.3.1.3 *Owners Quality Assurance*

The DSM Plan and subsequent Periodic Dam Safety Reviews ("PDSR's") and the supporting safety case would need to be reviewed through a formal quality assurance process which meets or exceeds applicable national and the International Standards Organization ("ISO") standards. Quality assurance could be completed internally or by an external consultant. The external consultant completing the quality assurance review could be the same consultant who prepared the DSM Plan or subsequent PDSR's.

The DSE would be required to retain overall responsibility for the quality assurance process.

5.3.2 GoN's Dam Safety Division

The role of the Dam Safety Division would include providing advice to GoN and dam owners on the

- suitability of the owner's DSE and Analysis Team to prepare the DSM Plan and subsequent PDSR's
- degree to which any relevant aspects of the safety case for the dam have not received any, or adequate, consideration
- need to undertake additional studies or reviews to complete the risk assessment
- soundness of the owner's conclusions on whether the DSM Plan, once implemented, will bring the dam into compliance with the safety criteria for existing dams established by the GoN and the validity of subsequent PDSR's in maintaining the safety of the dam.

Dam owners preparing a DSM Plan and subsequent PDSR's may be required to present the results of their assessments to the GoN's Dam Safety Division depending on the hazard the dam presents and/or the complexity of the dam system.

Figure 5-2 outlines a possible structure for the Dam Safety Division within WEC. Capsule descriptions of the suggested qualifications and responsibilities of the individuals within the Dam Safety Division follow.

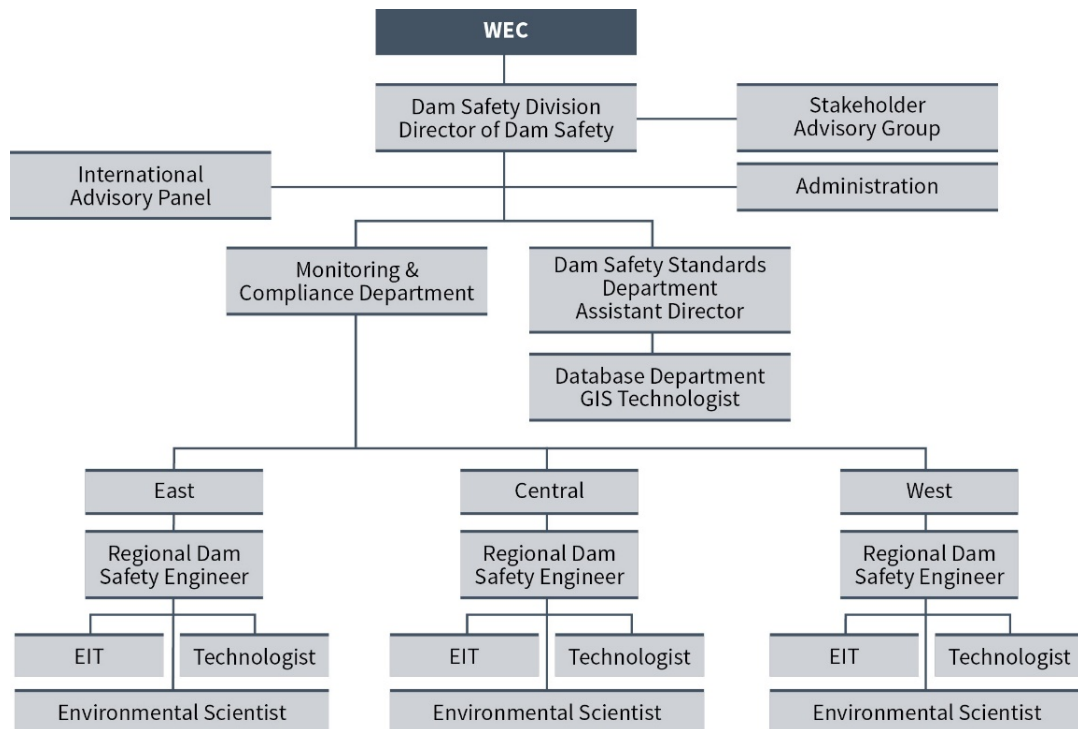


Figure 5-2: Suggested Organization Structure for Dam Safety Division

Director of Dam Safety - The Dam Safety Division should be headed by a senior engineer at the Superintendent Engineer level in the GoN civil service. This individual would be given authority to fully implement the Dam Safety Program in accordance with the requirements of the approved policies and the DSMS. Ideally, the person would have long-term experience in dam and/or hydropower power plant planning, design, construction and operation in Nepal. Full time administrative support for the division would include budgeting, accounting, secretarial and travel coordination functions.

At least in the initial phases of the dam safety division, an inter -ministerial advisory group composed of experienced international dam safety professionals, potentially meeting quarterly either in person or via teleconference would be formed to advise the director on technical issues and on the execution of the program. The group should include geotechnical, hydrotechnical, civil/structural and hydromechanical experts as well as an experienced dam safety program director from an established jurisdiction.

A stakeholder advisory group would also be established consisting of stakeholders from the industry, other ministries and the public to provide advice on issues of concern and resolution of these issues. Meetings would be held annually timed with the release of the dam safety status report.

The Dam Safety Standards and Document Control Department is suggested to be headed by an experienced dam engineer who would also serve as the Assistant Director of Dam Safety. A dam safety engineer would report to the Assistant Director who would be responsible for monitoring and updating standards, preparation of the annual report, review of submissions for compliance as requested by the monitoring and compliance department and any other reports needed by the division.

This group would be responsible for maintaining the dam safety standards that apply to each type and classification of hydropower power plant in Nepal as well as those that apply to dams that do not involve a hydropower power plant (based on agreed definitions of a regulated dam). The responsibility would include monitoring changes to international dam safety standards and include participation in international workshops. The responsibilities would also include deciding on when and how to update Nepal's dam safety standards and interpreting questions from the Monitoring and Compliance Department on how the standards should be applied to individual projects.

The Database Department would consist of a GIS technologist who would maintain records and monitor relevant macro factors (such as rainfall, snow melt, landslides, GLOF's, LDOF's, debris flows, seismic events etc.) for each river basin. Dangerous or potentially dangerous conditions would be referred to the Monitoring and Compliance Department for action.

This group would also maintain the dam safety registry for all dams in Nepal. It would include information on the original design of each facility including the current hazard classification,

location, river system, IDF, DBE, spill capacity, Periodic Dam Safety Review reports, PFMA reports and information on all structures in place and equipment installed. The group would be responsible for ensuring that Owners comply with the regulated requirement to provide the needed information. The Monitoring and Compliance department would audit the Owners to ensure that the information supplied was accurate.

A separate dam safety incident registry would also be maintained by this department. The registry would also include records and information on dam safety incidents and dam failures, the concerns identified and the mitigative measures taken. Operating certificates, any operating restrictions and any documentation on any unsafe practices observed would be included. The owners of dams and hydropower power plants would be responsible for maintain this database up to date for their projects and the Department would carry out random checks for compliance.

The database would also include the time series data for the macro data collected by the department.

The Monitoring and Compliance Department would be structured by river basin into three regions, East, Central and West as indicated in 4.2. The group would be headed by a regional dam safety engineer supported by an Engineer in Training or junior engineer for succession and capacity building purposes, an environmental specialist and a technologist. Each of the regions would be responsible for both existing and new projects.

For new projects, the regional dam safety divisions would be responsible for reviewing the dam safety classification and design proposed relative to the established Nepal dam safety standards, identifying any changes required to comply with the standards and ensuring that acceptable changes are then incorporated in the final design that is approved by the owner. Once a project begins construction, the group would be authorized to make an ad-hoc inspection identifying any concerns and then checking that any mitigations are carried out. As part of the commissioning of a project, an inspection would be carried out and an operations readiness certificate would need to be issued prior to the project being authorized to supply power to the grid, supply power to an off-grid user or store water (in the case of non-hydropower dams).

For existing projects the group would receive and undertake an initial review of periodic dam safety reviews, dam safety incident reports, dam classification, frequency of regulated inspections by the Owner, compliance with environmental requirements and audits to verify that the information provided is an accurate representation of the site.

The river basin units would also be responsible for reviewing responses and planned remediation measures to any urgent safety issues identified, ad-hoc inspection of each existing dam and hydropower power plant, review of any problem areas and verification that agreed upon mitigation measures have been implemented.

This group would also be responsible to ensure that the dam owner has adequate plans and procedures in place for responding to emergency situations which would include issuing notifications initial response, issuing alerts as defined on the EPP to the designated authorities such that public warnings or evacuations can be carried out in accordance with the agreed protocols.

5.4 Proposed Dam Safety Classification System for Nepal

The proposed dam classification system for Nepal is based on a combination of the CDA and province of Ontario’s recommendations for dam safety classification, tailored for the needs and values of Nepal. It consists of five (5) classification categories: Low, Moderate, High, Very High and extreme that define incremental losses due to dam failure based on an increasing level of magnitude.

Table 5-2: Proposed Dam Safety Classification System for Nepal

Hazard Potential	Hazard Categories – Incremental Losses			
	Life Safety	Property Losses	Environmental Losses	Cultural – Built Heritage Losses
Low	No potential loss of life.	Minimal damage to property with estimated losses not to exceed 25 Lakh rupees.	Minimal loss of fish and/or wildlife habitat with high capability of natural restoration resulting in a very low likelihood of negatively affecting the status of the population.	Reversible damage to local designated cultural heritage sites.
Moderate	No potential loss of life.	Moderate damage with estimated losses not to exceed 25 Crore rupees to agricultural, forestry, mineral aggregate and mining, other dams or structures not for human habitation, infrastructure and services including local roads and railway line. The inundation zone is typically undeveloped or predominantly rural or agricultural, or it is managed so that the land usage is for transient activities such as with day-use facilities. Minimal damage to residential, commercial, and industrial areas, or land identified as designated growth areas as shown in official plans.	Moderate loss or deterioration of fish and/or wildlife habitat with moderate capability of natural restoration resulting in a low likelihood of negatively affecting the status of the population.	Irreversible damage to local designated cultural heritage sites.

Hazard Potential	Hazard Categories – Incremental Losses			
	Life Safety	Property Losses	Environmental Losses	Cultural – Built Heritage Losses
High	Potential incremental loss of life of 1-10 persons.	Appreciable damage with estimated losses not to exceed 250 crore rupees agricultural, forestry, mineral aggregate and mining, other dams or residential, commercial, industrial areas, infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes regional roads, railway lines, or municipal water and wastewater treatment facilities and publicly- owned utilities.	Appreciable loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with reasonable likelihood of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a portion of the population of a species classified under regional guidelines on the protection of species extirpated, threatened or endangered, or <u>reversible damage</u> to the habitat of that species.	Irreversible damage to nationally designated or recognized cultural heritage sites.
Very High	Potential incremental loss of life of 11 to 100 persons.	Appreciable damage with estimated losses not to exceed 1,000 crore rupees. Typically includes destruction of, or extensive damage to, large residential, institutional, concentrated commercial and industrial areas and major infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes highways, railway lines or municipal water and wastewater treatment facilities and publicly-owned utilities.	Extensive loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with very little or no feasibility of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a <u>viable</u> portion of the population of a species classified under Nepal legislation referent to endangered species or irreversible damage to the habitat of that species.	
Extreme	Potential incremental loss of life of more than 100 persons.	Damages of more than 1,000 crore rupees. Typically includes extreme losses to critical infrastructure including hospitals, major industrial complexes, storage facilities containing hazardous waste, etc.		

6. Stakeholder Input into the Proposed New Dam Safety Management System

To come following October workshop.

6.1 Consultations and Feedback to Proposed Framework and Standards from Key GoN Stakeholders

To come following October workshop.

6.2 Proposed Options and Steps for Introducing New or Modifications to Legislation and/or Regulations

To come following October workshop.

6.3 Consultation Workshops on the New Dam Safety Framework and Standards

To come following October workshop.

7. Implementation of the New Dam Safety Framework and Standards

7.1 Dam Safety Register

7.1.1 Requirements

A fundamental building block in any DSMS is a register that lists the locations of the countries dams and key dam safety characteristics. Currently, there is insufficient information available in Nepal to identify all the existing dams and their characteristics. In Appendix C, a start of such a registry and the minimum details that would be contained in such a registry is provided.

The project data shown in Appendix C was collected for most of the hydroelectric power projects (HPPs) in Nepal. A total of 90 projects are listed in approximate chronological order from the oldest to ones that are under construction or currently planned. The earliest project that was documented is the Pharping HPP in Kathmandu that was commissioned in 1911. A total of 850 MW of installed hydroelectric capacity is accounted for on this list.

ICOLD has an established convention for data entry into the word dam register. The CDA and many other jurisdictions follows these dam standards for registering dams so the data can be shared with world institution. It is recommended that the Dam Safety Division prepare a registry that is aligned to the extent possible with the ICOLD criteria including

- name of dam
- owner
- name of the reservoir/river.
- year of completion
- special features (A=abandoned, H=heightened, L=lowered, U=unchanged, R=rebuilt, C=under construction)
- international (I=dam abutments lie in different countries)
- nearest town (town name, state or province, country)
- dam type (CB=buttress, BM=barrage, ER=rock fill, MV=multiple arch, PG=gravity, TE=earthen, VA=arch, XX=unlisted)
- position water tight member (f=Upstream facing, h=homogenous dam, i=core, x=unlisted.
- type of water tight member (a=bituminous, c=concrete, e=earth, m=metal, p=plastic, x=listed)

- foundation Type: R=rock, R/S=rock/soil, S=soil, X=unlisted
- length of Dam: Measured in meters (m) at crest
- Volume of Dam body (103 m³)
- reservoir capacity (103 m³)
- length of Reservoir: Expressed in kilometers (km) at longest part
- area of reservoir (km³)
- spillway capacity (m³/sec)
 - ◆ spillway type: L=free overspill, L/V=gated-free overspill, V=gated, X=other
 - ◆ mean annual energy (GWh/year)
 - ◆ irrigated areas (km²)
 - ◆ volume flood protection (hm³)
 - ◆ resettlement (Number of person affected by resettlement)

7.1.2 **Responsibility**

It is recommended that the responsibility for provision of the information required in the dam safety register be placed with the dam owner. All owners of existing and new dams would be required to provide the GoN will the information required under regulation.

The GoN would be responsible for hosting the registry, maintaining it and auditing dam owners to verify that the information that is provided is current and accurate. The GISW data base prepared under this project would be an excellent home for the registry.

7.2 **New Dams – Planning, Design, Construction and Approvals**

7.2.1 **Dam Safety Parameters**

7.2.1.1 *Inflow Design Flood*

Safe design and operation of a hydropower project with respect to flood handling requirements is achieved by means of an appropriate Inflow Design Flood (“IDF”). The IDF defines the minimum capacity of the project spillway, representing the most severe inflow flood (peak, volume, shape, duration, timing) for which a dam and its associated facilities are designed. Table 7-1 presents the proposed range of minimum IDF for each class of Incremental Hazard classification (“IHP”) that is proposed to be used for the design of dams in Nepal.

Table 7-1: Recommended Criteria for the Selection of the IDF for Design of Dams in Nepal

Hazard Potential Classification	Range of Minimum Inflow Design Floods			
	Life Safety		Property and Environment	Cultural – Built Heritage
LOW	1/25 to 1/100 AEP Flood			
MODERATE	1/100 to 1/1000 AEP flood			
HIGH	1-10	1/10,000 AEP flood	1/1000 AEP Flood to 1:10,000 AEP flood	1:1000 AEP Flood
VERY HIGH	11-100	1/10,000 AEP flood to the PMF ¹	1:10,000 AEP flood	
EXTREME	Greater than 100	PMF		

Note 1: For the VERY HIGH IHP category the PMF may be estimated as being two times the volume of the 1/10,000 AERP event.

7.2.1.2 Earthquake Design Parameters

As with the IDF, the IHP classification is used to select the Design Basis Earthquake (“DBE”) to estimate the seismic load levels to be used for dam design and dam safety assessments.

Table 7-2 provides the recommended design earthquakes for various IHP classifications.

Table 7-2: Suggested Design Earthquake Levels

Hazard Potential Classification	Range of Minimum Inflow Design Floods ¹			
	Life Safety		Property and Environment	Cultural – Built Heritage
LOW	1/25 to 1/100 AEP Event			
MODERATE	1/100 to 1/1000 AEP Event			
HIGH	1-10	1/10,000 AEP Event	1/1000 AEP Event to 1:10,000 AEP Event	1:1000 AEP Flood
VERY HIGH	11-100	1/10,000 AEP Event to the MCE	1:10,000 AEP flood	
EXTREME	Greater than 100	MCE		

Notes:

1 The annual exceedance probability levels are for to be used for the “mean” rather than the median estimates.

2. The selected earthquake design ground motion value should be calculated based on an M8 earthquake located at the closest point of the site from the Main Thrust Fault or the 1/10,000 AEP event, whichever is larger.

7.2.1.3 Other Parameters

Factors of Safety and other dam design parameters are not based on the IHP classification for the dam. They were defined in Nepal’s dam Safety Guidelines in accordance with current international good practice and should be reviewed and updated as the science of dam safety evolves.

7.2.2 Technical Standards/Templates for Feasibility Study and Basic Design Preparation and Check List for Review

Recommendations on the investigations, data, calculations, documents, financial details and other information required to be performed as part of a feasibility assessment for hydropower development were prepared as part of this assignment. The checklists were prepared such that the requirements for projects of any size can be assessed. However, in practice, some of the requirements indicated in the checklist may not be required depending on the characteristics and actual size of the development.

The key objective of the checklists is to provide reviewers at DoED, MoE, IBN, NEA, IPPAN and WECS, a means to ensure that the information provided by developers with respect to the technical, economic and financial feasibility of proposed hydropower projects is complete and adequate with respect to normal industry good practice. The checklists are intended to provide clear guidance on the key subjects that must be considered during the planning and design stages of any new development such that reviewers can better ensure that all the requirements for a bankable report are covered.

These checklists, used in conjunction with technical guidelines prepared under this assignment will help private developers, the GoN and other stakeholders in Nepal in the planning, design and construction of safe and reliable hydropower facilities.

This report is presented sequentially in eight sections that provide considerations and checklists of information that should be included in a feasibility level report, and the levels building up to the feasibility report for use by reviewers to help to ensure that the project has been adequately assessed such that the resulting HPP will provide reliable, cost effective, environmentally friendly, renewable energy for decades.

7.2.3 Construction Supervision and Quality Control

In 1972, Dr. Ralph Peck wrote that

"... the geological features at a site were placed there by nature and are part of the site. When the owner acquires the site, the geological features become his ..."

There are, however, very significant risks associated with unfavorable ground conditions. For example, in a 1985 survey of World Bank funded hydropower projects, the Bank determined that, of 64 Bank financed hydropower projects, 36% encountered significant geologic problems causing significant cost overruns and construction delays of 1 to 4 years. This report recommended that,

"Given the current state of the art ... Bank engineers should treat with skepticism, all cost estimates that are based extrapolations of site geology and . . . assume that costs of risky project components are unknowable within a broad range, 50 to 300% of the estimate"

In 1969, Professor R.P. Peck set out the procedures for the observational method to control construction risks, while minimizing construction costs by relying on the field engineer to properly manage the construction activities, ensure adequate quality control and quality assurance is performed throughout the construction phase and to institute appropriate design modifications during construction as field conditions are progressively better defined. Peck proposed that the design should be based on the most probable conditions with the predefined contingency designs implemented, as necessary, if the results of observations warrant changes in design.

Dam designs are prepared under the assumption that an adequate level of supervision will be provided during construction to ensure that the specified methods are carried out and that actual ground conditions are identified and corrective action taken to maintain the design intent. Where such supervision is not provided, the risks increase, for both the contractor and, in long term, the owner.

In Chapter 10 of Nepal's Dam Safety Guidelines, details of good industry practice with respect to construction management for owners who are planning new or rehabilitation construction are presented. This includes a description of such measures as the development of a Quality Control Inspection Program ("QCIP") designed to ensure accepted construction quality control inspection and documentation practices common to the hydropower industry are followed. This approach has been found to achieve good results in on FERC projects in the US and has been identified as applicable in Nepal along with good documentation of geological conditions, and the specification of a comprehensive work plan and project schedule. In addition, details of the need for a Geotechnical Baseline Report ("GBR") that summarizes and interprets site geological and geotechnical conditions relevant to the proposed project are outlined. The GBR is intended to serve as a single source document that provides contractually consistent statements describing the site geology and geotechnical conditions that are anticipated to be encountered during underground and subsurface construction. An additional important objective of the GBR is to present geotechnical and site conditions that relate to the contractor's means and methods of constructing the project with the overall goal of reducing risks associated with the variable geohazard exposure that exist at many project sites project sites.

These documents become part of the overall construction management plan that includes the

- Contractor's Work Plan
- Quality Control Inspection Plan and
- Field QC/QA Testing Program.

Together, properly administered, these plans and procedures will result in a high-quality structure that meets the intent of the designs and will provide reliable service for many decades.

7.2.4 Completion Certification and as Built Documentation

At present, there is no regulating body for new dams or modifications to the existing dams. There is a requirement under the Water Resources ACT 2049 clause 17 which deals with the safety of infrastructure but not specifically dams or HPP's. There is no requirement for an owner to supply as built documentation as to what was constructed.

Under the proposed enhanced dam safety legislation, the owner will be required to supply a project specific DSM Plan and a Supporting Technical Information document ("STI") that summarizes details of the project components that are pertinent to dam safety. The DSM Plan would be prepared by the dam owner with guidance provided by the Dam Safety Division in accordance with Nepal's DSMS.

The Owner would be responsible for compiling the STI document and maintaining this document for use by themselves and the GoN as well as other organizations concerned with dam safety. STI should include sufficient project information to fully understand the design basis and details. Project STIs should use tables, figures, and drawings in preference to text and should not include complete copies of the original documents except for documents such as the GBR and PFMA reports. To the extent possible, just key sections of original reports that provide clarity and streamline the information should be presented.

The STI would be provided to the Dam Safety Division and would include the following information:

- Dam Safety Management Plan.
- Potential Failure Mode Analysis Study Report.
- Description of Project Structures.
- Construction History.
- Standard Operation Procedures.
- Geology and Seismicity.
- Hydrology/Hydraulics.
- Surveillance and Monitoring Plan.
- Stability/Stress Analysis of Project Structures.
- Spillway Gates.
- Pertinent Correspondence Related to Safety of Project Works.
- References.

An operating license for new developments or a renewal of a license following a major modification to an existing facility would only be issued upon receipt of a certificate of completions, duly authorized by the Dam Safety Division after receipt of the STI document and inspection of the facility.

7.3 Project Oversight Mechanism and Procedures

One of the principles of the suggested DSMS for Nepal is that all HPPs, new and existing, would be subject to the same overarching dam safety standards and that the dam owner would be responsible for ensuring that dams under its control conform to these standards. This would apply to Independent power producers or the GoN intending to develop new HPPs.

The proposed Division of Dam Safety would provide oversight for existing dams and all new dam construction with respect to the owner's compliance with the requirements of the DSMS. This would include

- review and accept the dam Incremental Hazard Potential ("IHP") classification for all water retaining structures making up the HPP
- review and accept the design parameters (IDF and DBE) that were selected based on the IHP classification
- review and accept the HPP designs in relation to compliance with the new Nepal's dam safety guidelines
- review submittals by the Contractor for compliance with the contract documents and their intent
- inspect the HPP during execution and prior to acceptance and issue a certificate of compliance with the accepted designs and the DSMS
- review and accept the as constructed project information provided by the owner
- reviewed and accepted Work based on the information provided by the owner and the results of the final inspection
- review and accept the owners DSM Plan with respect to compliance with Nepal's DSMS
- ensure all needed information has been input into the dam register and verify its accuracy.

The Director of Dam Safety would have the authority to order the owner to conduct an approved independent third party review of certain details or to convene an approved panel of experts to assist in the oversight of the project during the design and construction phases as deemed necessary.

The main difference between new facilities constructed by the GoN and IPPs is that for projects sponsored by GoN agencies, the Division of Dam Safety would require the sponsoring agency to submit full documentation for review. This information would then be reviewed and accepted by a panel of experts that would include a team leader and a team of relevant experts in geology, natural hazards, Hydrotechnical engineering, hydromechanical engineering etc. prior to submission to the Division of Dam Safety.

For IPP's the dam safety division would undertake the reviews, supported by a team of experts within the division or third party experts as required. The developer would be required to submit the information needed for a dam safety related review by the Division of Dam project review team.

In both cases the Owner would require a certificate of approval as a condition of its operating license.

Major modification and remedial works would also have to be reviewed and accepted as would periodic dam safety reviews and the dam classification.

7.4 Dam Safety Management

Introduction of the enhanced Dam Safety Management System in Nepal will reduce the potential for dam failure for new and existing dams in Nepal by means of an enhanced standard of care and help to mitigate the potential effects of a dam safety incident through the implementation of standardized modern systems for emergency preparedness planning.

7.4.1 Enhanced Standard of Care

7.4.1.1 Monitoring, Surveillance and Inspection

The types of inspections proposed under the new Nepal DSMS needed to ensure the safety of dams are listed in Table 7-3.

Table 7-3: Typical Types on Inspections

Type of Inspection	Description
Routine Inspections	Routine inspections are generally completed on a weekly or monthly frequency to identify any conditions that might indicate changes in dam performance and therefore require follow-up. These inspections may be carried out by engineers or other staff trained in dam surveillance. Of significance are new occurrences or noted changes in leakage, erosion, sinkholes, boils, seepage, slope slumping or sliding, settlement, displacements or cracking of structural components, clogging of drains and relief wells, etc.
Engineering Inspection	Engineering inspections are typically performed annually or semi-annually and include a detailed visual examination of the dam and the instrumentation used to monitor dam performance. This inspection should document observations regarding the condition of the dam, with any significant condition changes from previous inspections being highlighted. Some assessment of the severity of observed anomalies as well as recommendations for maintenance, repairs, investigation, or further monitoring should

Type of Inspection	Description
	be completed. Because of this additional level of assessment, these inspections are generally performed by professional engineers.
Periodic Dam Safety Reviews	A PDSR is performed in accordance with the regulated frequency based on the IHP Classification for the dam. The PDSR must be performed by a qualified Dam Safety Engineer, approved by the GoN, in accordance with the requirements of the dam safety regulation. A PDSR requires an understanding of the construction methodology, conditions and practices used for the construction of that dam. Ideally, a complete set of records should be available for every existing dam. Record keeping should start at the early planning stage and continue throughout all phases of the dam's service life, recording any relevant information on planning, field investigations, laboratory testing, design decisions, construction and quality control, first reservoir filling, operation, maintenance, repair, and any modernization or enlargement. The records should include: design calculations; equipment specifications; as-built documents; registered data from hydrological, structural (including seismic) and operational monitoring; and all safety inspection reports. If such records are generally available, the periodic PDSR is facilitated.
Special Inspections	In addition to planned inspections, dams should be inspected during, if possible, and after unusual or extreme events, such as heavy rainfall, flooding, windstorms, severe icing, rapid snow melt, earthquakes, and exceedance of the absolute maximum operating water level (which could occur during an extreme flood or as the result of blocked discharge facilities or improper operation of the structure). Significant changes to normal operations, nearby construction activity, or other unusual events might also trigger special inspections.

The recommended inspection frequencies based on dam classification for Nepal are presented in Table 7-4.

Table 7-4: Guidelines for Inspection Frequency

Type of Inspection	Incremental Hazard Potential Classification				
	EXTREME	V HIGH	HIGH	SIGNIFICANT	LOW
Routine visual inspection	Semi-annually	Semi-annually	Semi-annually	Annually	Annually
Engineering Inspection	Monthly	Annually	Every 3 yrs.	Every 5 yrs.	Every 5 yrs.
Dam Safety Assessment	Every 5 yrs.	Every 5 -7 yrs.	Every 7-10 yrs.	Every 10 yrs.	Every 10 yrs ¹
Special Inspection	As required following a dam safety event, [piping event], flood or earthquake.				
Mechanical Equipment Testing	Annually	Annually	Annually	Every 3 yrs.	Every 5 yrs.

Note 1: PDSR is performed to confirm the HIGH classification only

7.4.1.2 *Enhanced Operation and Maintenance*

Nepal's Dam Safety Management Systems must be designed to be effective over the entire life cycle of the dam and associated structures such as spillways and gates. This life cycle consists of six phases commencing with the initial concept, through design, construction,

commissioning to operation and maintenance and, ultimately, to decommissioning. It is the operation and maintenance phase that is by far the longest, often extending for generations. For this reason, the dam industry has long recognized that the organization responsible for the dam must have an effective process in place designed in such a manner that it will remain effective over long periods of time and can proactively identify, track, and address all potential and actual problems that can impact the safety of the structure.

The development, implementation and control of procedures for the operation, maintenance, and surveillance of Nepal's dams in a manner that accounts for public safety and security is a cortical component of the DSMS. For all dams, operation, maintenance, and surveillance procedures should be documented in an OMS Manual and reviewed regularly to ensure that the information is up to date. Ongoing log books, records, or reports should be maintained to show that the specified activities and observations have been carried out and that the dam safety requirements are being met.

Documentation of procedures in the OMS manual for the operation of flow control equipment under all circumstances is also an essential requirement. Proper operation and testing of discharge facilities is critical to safety and performance and mitigating potential impacts to the public.

Maintenance and testing of gates, hoists and associated systems to ensure operational availability, safe operations, and integrity of the dam and the mechanical and electrical systems is essential. Maintenance needs for critical components or subsystems, such as power supply, backup power, mechanical components, public safety and security measures need to be prioritized, carried out in a timely manner and documented with due consideration of safety implications. Regular maintenance of dams to correct things such as settlement and slope instability would be expected to be performed annually as issues become apparent.

Surveillance, including visual inspections and instrument monitoring, is needed for checking whether the dam is performing satisfactorily. Effective dam surveillance is based on an understanding of how the dam might fail (potential failure modes), what early signs of failure to look for and what inspection or monitoring measures are available, such as piezometers, settlement monuments and weirs, to detect a developing failure. Definition of these failure modes is best achieved through the performance of a Potential Failure Modes Analysis such as was performed for the Kulekhani Dam during as part of this assignment.

7.4.2 Enhanced Emergency Preparedness Planning

A brief review of some well-known historical dam failures clearly demonstrates that warning, even in a rudimentary form, significantly reduces potential loss of life. Table 7-5 was compiled based on various accounts of dam failures. This clearly indicates the benefit of a warning in reducing the impacts of a disaster.

Table 7-5: The Impact of Warning Time on Life Safety Risks

Dam Failure	Population at Risk	Fatalities	Fatality Rate	Warning Provided
South Fork Dam, PA (1889)	Unknown	2209	--	No
Malpasset, France (1959)	Unknown	421	--	No
Vaiont Dam, Italy (1963)	Unknown	2600	--	No
Buffalo Creek, VA (1972)	4 000	125	3.10%	No
Laural Run Dam, PA (1977)	150	39	26.00%	No
Kelly Barnes Dam, GA (1976)	200	39	19.50%	No
Baldwin Hills Dam, CA (1963)	16 500	5	0.03%	Yes
Teton Dam, ID (1976)	35 000	11	0.03%	Yes
Lawn Dam, CO (1982)	4 000	3	0.08%	Yes
D.M.A.D, UT (1983)	500	0	n/a	Yes

Modern DSMS's and dam safety regulations require a dam owner to have two types of documents in place to deal with emergency situations

- a dam-specific ERP, including actions the dam owner will take in response to unusual or emergency conditions
- an EPP developed by the dam owner for external use, defining the hazards posed by the dam, the roles and responsibilities of all parties, and notifications to be made.¹⁷

Essentially an EPP is a document to designed for the owner tom understand and prepare for a dam incident including understanding of the consequences of failure such as flood inundation. An ERP (or EAP) that details the action to be taken in the event of a dam incident.

Typically, these documents are required for all dams whose failure could put lives at risk, or if the implementation of emergency procedures could reduce the consequences of failure associated with other losses (environmental, economic, cultural heritage. Where such documents are mandated, it is also required that the documents be reviewed and updated periodically throughout the life cycle of a dam.

7.4.3 Enhanced Risk Assessment and Management Procedure Reporting and Documentation

Risk, is a means of characterizing both the likelihood of an undesired event and the consequences of such an event. It can be used as a performance goal to demonstrate that required levels of safety are met. In the context of dam safety, the undesired events might include, for example, internal erosion; overtopping, slope failure, failure of the flow control equipment, remote controls, and monitoring; or human error.

¹⁷ CDA, 2007

The use of risk assessment techniques in combination with traditional standards based approaches fully defines all the dam safety risks that a dam and its associated water barrier presents. Risk informed assessments have been used to supplement the standards-based approach in the evaluation of dam structures since at least the earlier 1980s when dam safety practitioners started incorporating the theories of risk assessments, risk analysis and reliability into the performance of dams. These theories were previously developed as part of the evolution of high risk industries such as aviation and nuclear power.

Since then, various jurisdictions and dam owners around the world have incorporated risk analysis of some type into their dam evaluation process. However, it is generally accepted that the risk analysis should be an enhancement or optional evaluation step and not a replacement of the standards-based approach.

In Nepal, it is recommended that the PFMA methodology be adopted for HIGH, VERY HIGH and EXTREME IHP dams. Other more advanced risk analysis techniques may be considered in the future as Nepal's Dam Safety Program evolves.

8. Road Map for Implementation of a New Dam Safety Framework and Program for Nepal

8.1 Legislative and Regulatory Modification Process

To come after meetings in Nepal.

8.2 Institutional Arrangements Establishment

To come after meetings in Nepal.

8.3 Staffing and Budget Plan/Mobilization for Relevant Institutions

To come after meetings in Nepal.

8.4 Capacity Development Plan and Implementation Schedule

Currently Nepal lacks the internal capacity to establish and manage a dam safety management program. In the longer term the countries goal of constructing 10 GW of waterpower over the next decade will serve as an excellent training ground to build the capacity needed. In the short term, some specific steps are needed.

As is conceptually illustrated in Figure 5-3, the process commences with the identification and approval of the new positions in the Dam Safety Division of the responsible institution (presumably WEC) by the Government and the annual funding for these positions is provided, the next steps will involve

1. establish job descriptions and requirements
2. recruit candidates with the skills and experience or the potential to develop the skills needed to fulfill the specified responsibilities
3. put in place a capacity building program that could include
 - a) mentoring from senior experienced Nepalese engineers and international dam safety experts
 - a) internal knowledge sharing and workshops
 - b) development of dam and dam safety courses at the major universities
 - c) attendance at international short courses on dams and dam safety
 - d) participation on ICOLD committees
 - e) attendance at international conferences including [ICOLD](#), the annual [CDA](#) dam safety conference, the [US Society on Dams](#) ("USSD") annual conference and the [ANCOLD](#) annual conference
 - f) study tours to meet and work with selected international dam safety experts or these employees to allow them to enhance their skills and knowledge on specific topics of dam safety that relate to their areas of responsibility

- g) meetings and workshops with various international regulatory authorities who have established dam safety management programs and regulations in place. This could include FERC, the Ontario Ministry of Natural Resources and Forestry, The British Columbia Dam Safety Regulator
- h) meetings and workshops with major utilities to understand how their dam safety management program functions. This could include Electricity de France, Ontario Power Generation, BC Hydro and Snowy Mountain Hydro. These tours could be combined with visits to the regulators that oversee the various utilities.
- 4. provide for support by international dam safety specialists through long-term secondments of several such specialists for the first few years of the new dam safety program
- 5. prepare procedures manuals for the new functions considering practices used in selected jurisdictions and their lessons learned including visits and workshops with selected international regulators
- 6. host workshops for the owners/operators of existing dams and those that anticipate investing in new dams to acquaint them with the new requirements for approval of new facilities and for the annual inspection of existing facilities.

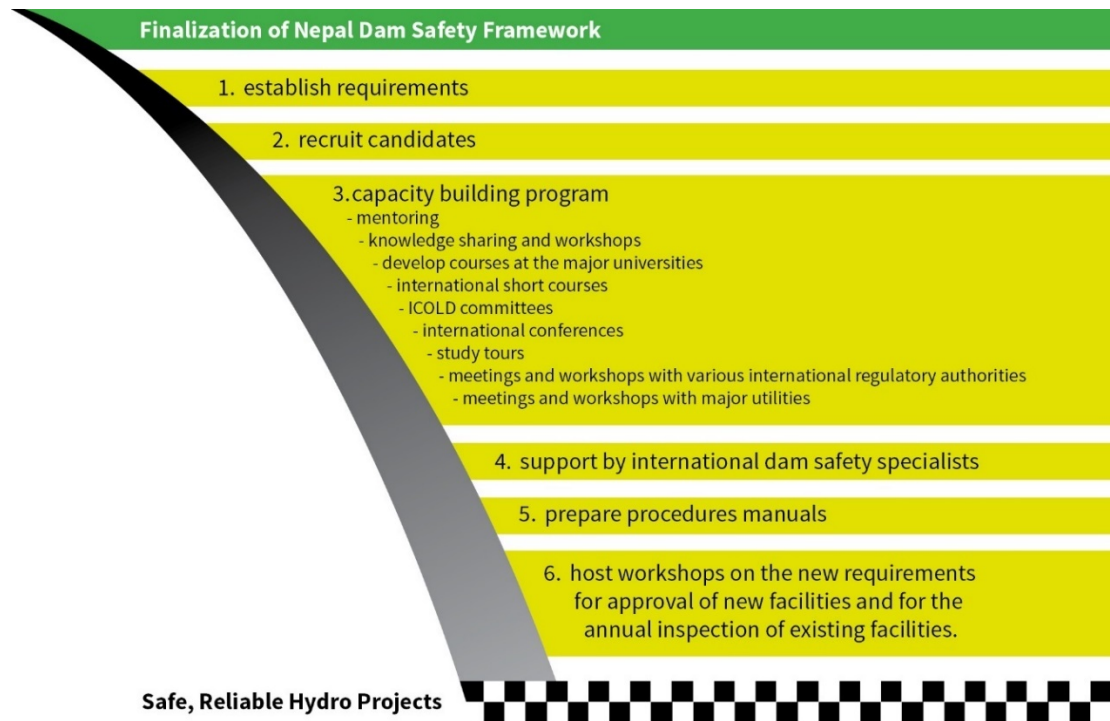


Figure 8-1: Road Map to the Development of an Enhanced Dam Safety Management Program for Nepal

9. Outline of a Potential Dam Safety Regulation for Nepal

A suggested dam safety regulation for Nepal, based on a 2017 Province of British Columbia, Canada regulation and the concepts described herein, is provided in Appendix D.

Appendix A

Summary of Project Deliverables and Description of Supporting Reports

Table A-1: Status and Description of Deliverables

Report	Deliverable	Source Documents
Project Execution Plan (PEP)		ToR, Proposal
Inception Report		PEP
PowerPoint Presentations <ul style="list-style-type: none"> Dam Safety Concepts PFMA Workshop international Best Practices Review 	1(ix) Perform three training Workshops	<ul style="list-style-type: none"> FERC, CSA and other guidelines, Deliverable 1(v).
Jurisdictional Review and International Best Practices Report	1(v) Undertake a Jurisdictional Review and review International Best Practices	<ul style="list-style-type: none"> Draft ICOLD Generic Guidelines, Section 3.2 Canadian, Australian, US, other jurisdictions guidelines and standards.
Nepal Mission No. 2 - Safety Assessment of Selected Damaged Facilities and Probable Failure Modes Analysis	<ul style="list-style-type: none"> 1(i) Undertake a site visit and safety Assessment Report of Selected damaged dams/HPPs. 1(ii) Review of Current Hazard Assessment and Design practices 1(iii) Undertake a PFMA Workshop Interim Report 	<ul style="list-style-type: none"> Post-earthquake Project Inspection Reports. DoED technical guidelines, select project technical design standards. US FERC guidelines. -Deliverables 1(i) through 1(viii), Meeting notes.
Institutional Assessment Report	<ul style="list-style-type: none"> 1(iv) Undertake Institutional Assessment of current national dam safety framework. 1(vi) Assess National Dam Safety Framework (vii) Undertake Capacity Development Needs Assessment and road map 	Nepal's current national dam safety framework.
Conceptual Dams and HPP Asset Management System Design (Hatch doc# 008)	1(viii) Conceptual design of a Dam and Hydropower Asset Management System	<ul style="list-style-type: none"> Deliverables 1(i) through 1(vii), Collected dam project data and registry. GIS study report.
2(i) Department of Energy Development Guidelines Review (Hatch doc # 0009)	2(i) Review DoED Technical Guidelines	Deliverables 1(v) through 1(viii), Meeting notes.
Checklist for Review of Feasibility Studies of Hydropower Projects (Hatch doc# 0010)	2(iii) Prepare a checklist for Feasibility Review of Hydropower Projects	"Guidelines for Study of Hydropower Projects" by DoED 2013.

Report	Deliverable	Source Documents
<u>Nepal Dam Safety Guidelines</u>	<ul style="list-style-type: none"> • 2(ii) Prepare Updated Guidelines for Key Subjects • 2(iv) Prepare Guidelines for Selected Topics 	<ul style="list-style-type: none"> • CDA Dam Safety Guidelines (2007). • FERC Engineering Guidelines for the Evaluation of Hydropower Projects • Australian National Committee on Large Dam Documents. • -Deliverables 1(i) through 1(viii),
Nepal Dam Safety - Advisory Support to Improve Readiness for Hydropower Preparation	Final Report	Hatch reports

Appendix B

Nepal's Planned and Existing Hydropower

Table B-1: Summary of Regions

Region	Basin	Issued Operating License		Issued Construction License		Issued Survey License		Total		
		#	Capacity (MW)	#	Capacity (MW)	#	Capacity (MW)	#	Capacity (MW)	Avg Capacity (MW)
West	Makahali, Karnali, Southern Rivers West	7	28	10	72	17	2,073	34	2,174	64
Central	Gandaki, Southern Rivers Central	53	673	40	761	29	1,269	122	2,703	22
East	Koshi, Southern Rivers East	32	278	41	1,419	32	1,784	105	3,481	33
Total		92	979	91	2,252	78	5,127	261	8,358	32

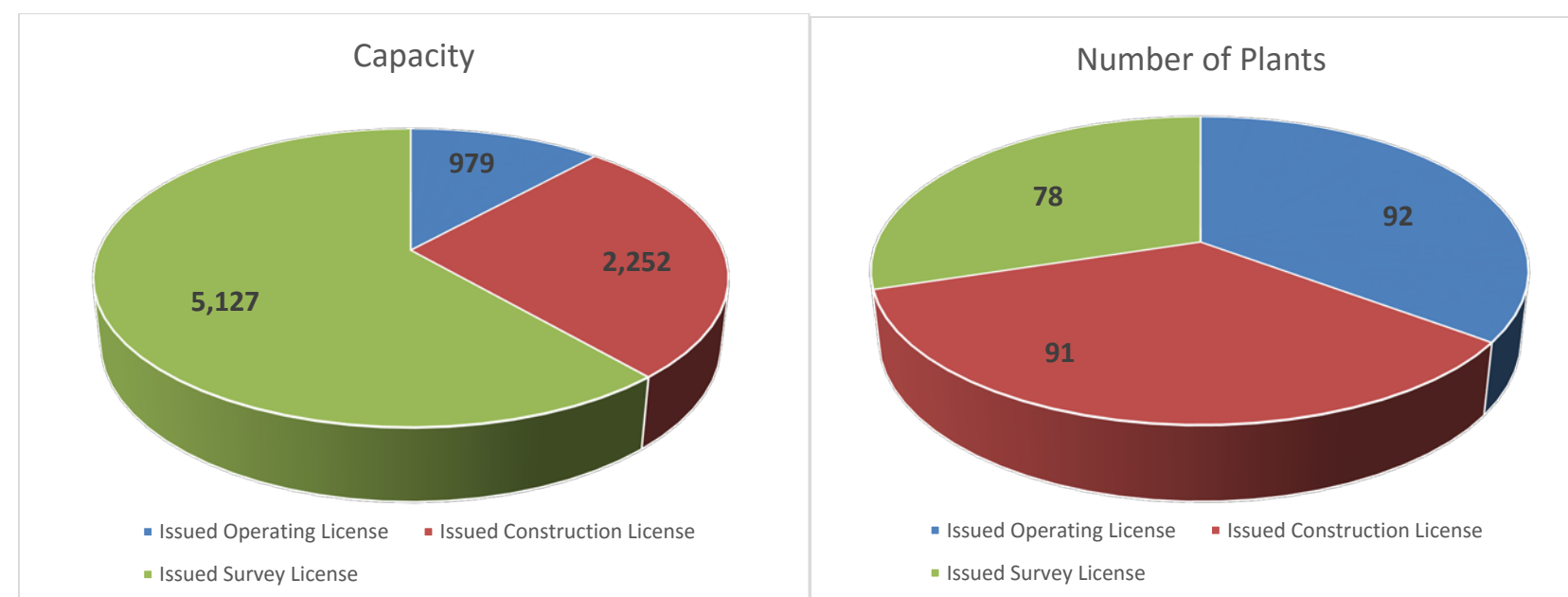


Table B-2: Western Region

Mahakali Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Status
Nau Gad Khola	29.69	80.60	8.5	Naugad	Api Power Company Pvt. Ltd	Issued Operating License
Chameliya Khola	29.68	80.63	30.0	Chameliya	Nepal Electricity Authority	Issued Construction License
Kapadigad	29.00	80.75	3.3	Kapadigad	Salmanidevi Hydropower Pvt. Ltd	Issued Operating License
Upper Naugad Gad Hydropower Project	29.72	80.61	5.0	Naugad	Api Power Company Ltd.	Issued Survey License
Total MW Basin			46.8			
Karnali Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Status
Jhimruk Khola	28.07	82.80	12.0	Jhimruk	Butwal Power Company	Issued Operating License
Dwari Khola SHP	28.92	81.82	3.8	Dwari	Bhugol Energy Development Company Pvt. Ltd.	Issued Operating License
Parajuli Khola-1	28.69	81.69	2.2	Parajuli	Rara Hydropower Development Co.	Issued Construction License
Lohare Khola	28.90	81.79	4.2	Lohore	Lohare Khola Hydropower Co. Pvt. Ltd.	Issued Construction License
Surnaiyagad			0.2	Surnaiyagad	Nepal Electricity Authority	Issued Operating License
Doti			0.2	Doti	Nepal Electricity Authority	Issued Operating License
Gamgad			0.4	Gamgad	Nepal Electricity Authority	Issued Operating License
Dhansi Khola			1.0	Dhansi	Teleye Samyak Hydropower Company Pvt. Ltd.	Issued Construction License
Upper Parajuli Khola			2.2	Parajuli	Rara Hydropower Development Co. Pvt. Ltd.	Issued Construction License
Lohore Khola			4.2	Lohore	Lohore Khola Hydropower Co. Pvt. Ltd.	Issued Construction License
Kapadi Khola			3.3	Kapadi	Salmanidevi Hydropower (P). Ltd.	Issued Construction License
Badigad HPP	28.32	83.15	6.6	Badigad	Water and Energy Nepal Pvt. Ltd.	Issued Construction License
Rukum gad	28.59	82.63	5.0	Rukumgad	Rapti Hydro and General Construction Pvt. Ltd.	Issued Construction License
Ruru Banchu - 1	29.09	81.77	13.5	Ruru Banchu	Mount Nilgiri Hydropower Company Pvt. Ltd.	Issued Construction License
Upper Karnali	28.70	81.42	900.0	Karnali	GMR, Upper Karnali Hydropower Limited	Issued Survey License
Thuli Bheri	28.97	82.58	121.0	Thuli Bheri	GAGE Nepal Pvt. Ltd.	Issued Survey License
Bauligad Khola HPP	29.55	81.15	3.4	Bauli Gad	Om Kumari Shah	Issued Survey License
Middle Daram Khola-A HPP	28.27	83.41	3.0	Daram	Dhaulagiri Cem Engineering Pvt. Ltd.	Issued Survey License
Middle Daram Khola-B HPP	28.23	83.41	4.5	Daram	Dhaulagiri CEM Engineering Pvt. Ltd.	Issued Survey License
Lower Bheri Hydropower Project	28.99	82.54	60.0	Bheri	Multi Star Energy Pvt. Ltd.	Issued Survey License
Bheri-3 storage Hydropower Project (BR-3)	28.38	81.83	480.0	Bheri	Sunrise Hydropower P. Ltd.	Issued Survey License
Daram Khola HEP	28.18	83.33	7.3	Daram	Righa Manewa Daram Khola Jalbidhyut Sahakari Sanstha Ltd.	Issued Survey License
Lower Tara Khola HPP	28.30	83.40	2.9	Tara	Pahadi Hydropower Company Pvt. Ltd.	Issued Survey License
Chera 1	28.74	81.97	148.7	Chera	Byucksan Engineering Co. Ltd. Seoul, Korea	Issued Survey License
Padam Khola SHP	28.90	81.82	4.8	Padam Khola	Dolti Power Company P. Ltd.	Issued Survey License
Upper Lohore SHP	28.94	81.79	4.9	Lohore	Bhugol Energy Dev Com	Issued Survey License
Myagdi Khola Hydropower Project	28.56	83.36	24.3	Myagdi	Hydro Village Pvt. Ltd.	Issued Survey License
Uttarganga Storage Hydropower Project	28.38	82.92	300.0	Uttar Ganga	Nepal Electricity Authority	Issued Survey License
Total MW Basin			2123.5			
Southern Rivers West						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Status
Tinau Khola HPP	27.74	83.50	1.7	Tinau	Nama Buddha Hydropower Pvt. Ltd.	Issued Survey License
Arung Khola	27.68	83.94	2.0	Arung	Shakti Hydropower Pvt. Ltd.	Issued Survey License
Total MW			3.7			
Total	34	Plants	2173.9	MW		

Table B-3: Central Region

Gandaki Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Trishuli	27.92	85.15	24.0	Trishuli	Nepal Electricity Authority	Issued Operating License
Kulekhani-II	27.50	85.04	32.0	Kulekhani	Nepal Electricity Authority	Issued Operating License
Seti	28.23	83.97	1.5	Seti	Nepal Electricity Authority	Issued Operating License
Kulekhani-I	27.54	85.14	60.0	Kulekhani	Nepal Electricity Authority	Issued Operating License
Tatopani	28.53	83.66	2.0	Tatopani	Nepal Electricity Authority	Issued Operating License
Devighat	27.89	85.13	15.0	Trishuli	Nepal Electricity Authority	Issued Operating License
Marsyangdi	27.87	84.43	70.0	Marsyangdi	Nepal Electricity Authority	Issued Operating License
Andhi Khola	27.93	83.68	9.4	Andhi Khola	Butwal Power Company	Issued Operating License
Modi Khola	28.26	83.73	14.8	Modi	Nepal Electricity Authority	Issued Operating License
Kali Gandaki A	27.92	83.44	144.0	Kali Gandaki	Nepal Electricity Authority	Issued Operating License
Sundarijal			0.6	Sundarijal	Nepal Electricity Authority	Issued Operating License
Panauti			2.4	Panauti	Nepal Electricity Authority	Issued Operating License
Fewa			1.0	Fewa	Nepal Electricity Authority	Issued Operating License
Seti II			1.0	Seti	Task Hydropower Company (P) Ltd.	Issued Operating License
Tatopani			2.0	Tatopani	Nepal Electricity Authority	Issued Operating License
Chatara			3.2	Chatara	Nepal Electricity Authority	Issued Operating License
Tinau			1.7	Tinau	Nma Buddha	Issued Construction License
Pharping			0.5	Pharping	Nepal Electricity Authority	Issued Operating License
Jomsom			0.2	Jomsom	Nepal Electricity Authority	Issued Operating License
Baglung			0.2	Baglung	Nepal Electricity Authority	Issued Operating License
Rairang Khola			0.5	dhading	Rairang Hydropower Development Co. (p) Ltd.	Issued Operating License
Sunkoshi Khola			2.5	Sunkoshi	Sanima Hydropower (Pvt.) Ltd.	Issued Operating License
Chaku Khola			3.0	Chaku	Alliance Power Nepal Pvt. Pvt. Ltd.	Issued Operating License
Baramchi Khola			4.2	Baramchi	Unique Hydrel Company Pvt. Ltd.	Issued Operating License
Sisne Khola			0.8	Siesne	Gautam Buddha Hydropower (Pvt.) Ltd.	Issued Operating License
Sali Nadi			0.3	Sali	Kathmandu Small Hydropower System Pvt. Ltd.	Issued Operating License
Pheme Khola			1.0	Pheme	Khoranga Khola Hydropower Co. Pvt. Ltd.	Issued Operating License
Pati Khola			1.0	Pati	Unified Hydropower (P) Ltd.	Issued Operating License
Upper Hadi Khola			1.0	Hadi	Cente for Power Dev and Services (P) Ltd.	Issued Operating License
Siuri Khola			5.0	Suiri	Nyadi Group (P.) Ltd.	Issued Operating License
Sipring Khola			9.7	Sipring	Synergy Power Development (P.) Ltd.	Issued Operating License
Chilime	28.15	85.30	22.1	Chilime	Chilime Hydropower Company Limited	Issued Operating License
Madhya Marsyangdi	28.14	84.41	70.0	Marsyangdi	Nepal Electricity Authority	Issued Operating License
Mailung Khola	28.07	85.19	5.0	Mailung	Mailun Khola Hydropower Company Pvt. Ltd.	Issued Operating License
Khudi Khola	28.27	84.33	4.0	Khudi	Khudi hydropower Limited	Issued Operating License
Thoppal Khola	27.82	84.84	1.7	Thoppal	Thoppal Khola Hydropower Company	Issued Operating License

Gandaki Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Mardi Khola	28.32	83.88	4.8	Mardi	Gandaki Hydropower Development Co. Pvt. Ltd.	Issued Operating License
Ridi Khola	27.93	83.39	2.4	Ridi	Ridi Hydropower Development Co Pvt. Ltd.	Issued Operating License
Lower Modi -1	28.22	83.70	10.0	Modi	United Modi Hydropower Pvt. Ltd.	Issued Operating License
Siuri Khola	28.34	84.46	5.0	Siuri	Nyadi Group Pvt. Ltd.	Issued Operating License
Ankhu Khola - 1	28.00	84.90	8.4	Ankhu	Ankhu Jalvidut Co. Pvt. Ltd.	Issued Operating License
Bijayapur-1	28.18	84.03	4.5	Bijayapur	Bhagawati Hydropower Development Company	Issued Operating License
Radhi Small	28.40	84.41	4.4	Radhi	Radhi Bidyut Co. Ltd.	Issued Operating License
Tadi Khola (thaprek)	27.92	85.32	5.0	Tadi	Aadi Shakti Bidhut Bikash Co. Pvt. Ltd.	Issued Operating License
Upper Hugdi	28.08	83.39	5.0	Hugdi	Ruru Jalbidyut Pariyojana Pvt. Ltd.	Issued Operating License
Lower Modi Khola	28.24	83.71	20.0	Modi	Manang Trade Links Pvt. Ltd.	Issued Construction License
Upper Marsyangdi A	28.29	84.37	50.0	Marsyangdi	Sinohydro-Sagarmatha Power Company Pvt. Ltd.	Issued Operating License
Daraundi A	28.11	84.66	6.0	Daraundi	Daraundi Kalika Hydro	Issued Operating License
Tungun - Thosne Khola	27.49	85.31	4.4	Tugun	Khani Khola Hydropower Company Ltd.	Issued Operating License
Khani Khola	27.49	85.28	2.0	Khani	Khani Khola Hydropower Company Ltd.	Issued Operating License
Chhandi Khola	28.25	84.47	2.0	Chhandi	Chhyandi Hydropower Co. Pvt. Ltd.	Issued Operating License
Daram Khola-A	28.28	83.41	2.5	Daram	Sayapatri Hydropower Pvt. Ltd.	Issued Operating License
Kule Khani Third	27.46	85.03	14.0	Kulekhani	Nepal Electricity Authority	Issued Construction License
Upper Madi	28.26	84.07	25.0	Madi	Madi Power Pvt. Ltd.	Issued Operating License
Upper Trishuli 3A	28.02	85.19	60.0	Trishuli	Nepal Electricity Authority	Issued Construction License
Dordi Khola	28.17	84.43	27.0	Dordi	Himalaya Power Partner Pvt. Ltd.	Issued Construction License
Rahughat	28.37	83.52	40.0	Rahughat	Nepal Electricity Authority	Issued Construction License
Tadi Khola	27.93	85.38	5.0	Tadi	Hiraratna hydropower Pvt. Ltd.	Issued Construction License
Jumdi Khola Small	28.02	83.45	1.8	Jumdi	Jumdi Hydropower Pvt. Ltd.	Issued Construction License
Mristi Khola	28.50	83.65	42.0	Mristi	Robust Energy Pvt. Ltd.	Issued Construction License
Sanjen	28.18	85.28	42.5	Sanjen	Sanjen Jalvidyut Co.	Issued Construction License
Upper Mailung -A	28.16	85.18	6.4	Mailung	Energy Engineering Pvt. Ltd.	Issued Construction License
Thapa Khola	28.71	83.61	11.2	Thapa	Mount Kailash Energy Co. Pvt. Ltd.	Issued Construction License
Midim Khola	28.18	84.28	3.0	Midim	Union Hydropower Pvt. Ltd.	Issued Construction License
Upper Sanjen	28.22	85.28	14.8	Sanjen	Sanjen Jalvidhyut Co.	Issued Construction License
Rasuwadgadi	28.23	85.36	111.0	Bhote koshi	Rasuwadgadi H P	Issued Construction License
Namarjun Madi	28.30	84.08	12.0	Madi	Himalayan Hydropower Pvt. Ltd.	Issued Construction License
Dordi-1	28.23	84.45	10.3	Dordi	Dordi Khola Jalvidyut Company Limited	Issued Construction License
Nyadi Khola	28.32	84.42	30.0	Nyadi	Nyadi Hydropower Limited	Issued Construction License
Lower Tadi	27.92	85.35	5.0	Tadi	Buddha Bhumi Nepal Hydropower Co. Pvt. Ltd.	Issued Construction License
Middle Modi	28.29	83.75	15.1	Modi	Middle Modi Hydropower Limited	Issued Construction License
Sardi Khola	28.33	83.97	4.0	Sardi	Mandakini Hydropower Pvt. Ltd.	Issued Construction License
Middle Midim	28.20	84.26	3.1	Midim	Madhya Midim Jalvidhyut Company Pvt. Ltd.	Issued Construction License

Gandaki Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Upper Trishuli 3B	27.99	85.17	37.0	Trishuli	Nepal Electricity Authority	Issued Construction License
Salankhu Khola	27.98	85.13	2.5	Salankhu	Salankhu Khola Hydropower Pvt. Ltd.	Issued Construction License
Rudi A	28.23	84.18	6.8	Rudi	Bindhabasini Hydropower Development Co. Pvt. Ltd.	Issued Construction License
Ghalemdi Khola	28.52	83.67	4.0	Ghalemdi	Ghalemdi Hydro Limited	Issued Construction License
Madkyu Khola	28.36	84.13	10.0	Madkyu	Silkes Hydropower Pvt. Ltd.	Issued Construction License
Super Dordi Kha Hydropower Project	28.27	84.52	49.6	Dordi	Peoples Hydropower Company Pvt. Ltd.	Issued Construction License
Upper Myagdi	28.52	83.36	20.0	Myagdi	Hydro Empire Pvt. Ltd.	Issued Construction License
Rupse Khola	28.54	83.61	4.0	Rupse	Research & Development Group	Issued Construction License
Upper Dordi A HEP	28.25	84.48	25.0	Dordi	Liberty Energy Hydropower Pvt. Ltd.	Issued Construction License
Bagmati Nadi	27.54	85.23	20.0	Bagmati	Mandu Hydropower Pvt. Ltd.	Issued Construction License
Durbang Myagdi Khola	28.39	83.38	25.0	Myagdi	Dhaulagiri Kalika Hydropower Pvt. Ltd.	Issued Construction License
Upper Modi A	28.33	83.78	42.0	Modi	Nepal Electricity Authority	Issued Construction License
Ghar Khola	28.46	83.63	8.3	Ghar	Myagdi Hydropower Pvt. Ltd.	Issued Construction License
Theule Khola HPP	28.17	83.61	1.5	Theule	Barahi Hydropower Pvt. Ltd.	Issued Construction License
Tanchhahara SHP	28.66	83.58	2.4	Tanchhahara	Tanchhar Hydro Pvt. Ltd.	Issued Construction License
Langtang Khola Small Hydropower Project	28.15	85.34	10.0	Langtang	Multi Energy Development Pvt. Ltd.	Issued Construction License
Upper Tadi	27.96	85.42	11.0	Tadi	Surya Kund Hydro Electric Pvt. Ltd.	Issued Construction License
Upper Trishuli-1	28.07	85.21	216.0	Trishuli	Nepal Water & Energy Development Co. Pvt. Ltd.	Issued Survey License
Rigdi Khola	27.80	84.51	1.9	Rigdi	Niltara W & E Pvt. Ltd.	Issued Survey License
Chandravati Khola	27.91	85.41	4.0	Chandravati	Public Consulting Engineers	Issued Survey License
Rapti Khola	27.50	85.05	2.2	Rapti	Sirin Hydropower Pvt. Ltd.	Issued Survey License
Lower Phalaku HPP	27.97	85.22	3.4	Phalaku	Bisham Hydropower Company Pvt. Ltd.	Issued Survey License
Chake Khola HPP	27.91	85.38	1.8	Chake Khola	Nobel Hydropower Pvt. Ltd.	Issued Construction License
Phenlun Briddhin Diversion HPP	28.19	85.37	4.5	Phenlun-Briddhin	Public Nepal Hydropower Pvt. Ltd.	Issued Survey License
Ghandruk Modi	28.41	83.83	111.0	Modi	Panchjanya Hydropower Pvt. Ltd.	Issued Survey License
Bajra Madi Hydropower Project	28.21	84.07	24.8	Madi	Bajra Energy Ventures Pvt. Ltd.	Issued Survey License
Upper Budhi Gandaki Hydropower Project	28.29	84.87	254.0	Budhi Gandaki	Nauseni Hydro Pvt. Ltd.	Issued Survey License
Garchyang Khola	28.36	84.15	6.6	Garchyang	Citizen Hydropower Company Pvt. Ltd.	Issued Survey License
Lower Modi-II Cascade HPP	28.20	83.67	10.5	Modi	United Modi Hydropower Pvt. Ltd.	Issued Survey License
Dhad Khola SHP	27.88	84.34	2.7	Dhad	Bandipur Hydropower Pvt. Ltd.	Issued Survey License
Middle Kaligandaki	28.50	83.63	25.0	Kali Gandaki	Hydro Support Pvt. Ltd.	Issued Survey License
Upper Myagdi-I HEP	28.46	83.35	80.0	Myagdi	Himalayan Infrastructure Fund Limited	Issued Survey License
Upper Ankhu Khola	28.12	85.00	35.0	Aankhu	Dhading Ankhu Khola Hydro Pvt. Ltd.	Issued Survey License
Upper Modi HPP cascade project	28.31	83.77	18.2	Modi	Nepal Electricity Authority	Issued Survey License
Tiptyang Kaligandaki HEP	28.43	83.60	95.0	Kaligandaki	Himalayan Infrastructure Fund Limited	Issued Survey License
Nilgiri Khola-II cascade Project	28.54	83.67	62.0	Nilgiri	Mountain Energy Nepal Pvt. Ltd.	Issued Survey License
Andhi Khola Storage Hydropower Project	27.92	83.58	180.0	Andhi Khola	Nepal Electricity Authority	Issued Survey License

Gandaki Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Richet Khola SHP	28.17	84.90	5.0	Richet	Richet Jalbidhyut Company Pvt. Ltd.	Issued Survey License
Upper Richet Khola SHP	28.18	84.93	2.0	Richet	Upper Richet Hydropower Pvt. Ltd.	Issued Survey License
Super Nyadi Hydropower Project	28.35	84.45	40.3	Richet	Nyadi Group Ltd.	Issued Survey License
Chino Khola HEP	28.53	84.32	5.0	Richet	Butwal Power Company Limited	Issued Survey License
Himchuli Dordi Hydropower Project	28.31	84.56	23.9	Richet	Peoples Hydropower Company Pvt. Ltd.	Issued Survey License
Super Aankhu Khola Hydropower Project	28.17	85.05	14.5	Richet	Gorakshya Hydropower Pvt. Ltd.	Issued Survey License
Thulo Khola Hydropower Project	28.52	83.50	4.9	Richet	Sungava Foundation Pvt. Ltd.	Issued Survey License
Chepe Khola HPP	28.12	84.55	9.0	Richet	Champawati Hydro Power Pvt. Ltd.	Issued Survey License
Ganesh Himal Ankhu HPP	28.20	85.06	25.0	Richet	Jalshakti Hydro company Pvt. Ltd	Issued Survey License
Gandak	27.42	83.79	15.0	Richet	Nepal Electricity Authority	Issued Operating License
Tinau	27.72	83.46	1.0	Richet	Nepal Electricity Authority	Issued Operating License
Total MW Basin			2699.9			
Central Southern Rivers						
Roshi Khola & Ladku Khola	27.5	85.5	3.0	Roshi	Premier Power Pvt. Ltd	Issued Survey License
Total		122	Plants	2702.9	MW	

Table B-4: East Region

Koshi Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Khimti -I	27.47	86.10	60.0	Khimti	Himal Power Limited	Issued Operating License
Panauti	27.55	85.51	2.4	Roshi	Nepal Electricity Authority	Issued Operating License
Sun Koshi	27.75	85.84	10.1	Sun Koshi	Nepal Electricity Authority	Issued Operating License
Upper Bhotekoshi	27.91	85.92	45.0	Bhote Koshi	Bhotekoshi Power Company	Issued Operating License
Indrawati -III	27.86	85.59	7.5	Indrawati	National Hydropower Company Pvt. Ltd.	Issued Operating License
Piluwa Khola	27.20	87.33	3.0	Piluwa	Arun Valley Hydropower Development Company Pvt. Ltd.	Issued Operating License
Sunkoshi Small	27.77	85.88	2.6	Sun Koshi	Sanima Hydropower Pvt. Ltd.	Issued Operating License
Chaku Khola	27.87	85.91	3.0	Chaku	Alliance Power Nepal Pvt. Ltd.	Issued Operating License
Khandbari			0.3	Khandbari	Nepal Electricity Authority	Issued Operating License
Phidim			0.2	Phidim	Nepal Electricity Authority	Issued Operating License
Ramechap			0.2	Ramechap	Nepal Electricity Authority	Issued Operating License
Terhathum			0.1	Terhathum	Nepal Electricity Authority	Issued Operating License
Lower Piluwa			1.0	Lower Piluwa	Baneswor Hydropower Pvt. Ltd.	Issued Operating License
Hewa khola	27.32	87.32	4.5	Hewa	Barun Hydropower Development Co. Pvt. Ltd.	Issued Operating License
Lower Chaku Khola	27.88	85.91	1.8	Chaku	Laughing Buddha Power Nepal Pvt. Ltd.	Issued Operating License
Sipring Khola	27.81	86.23	10.0	Sipring	Synergy Power Development Pvt. Ltd.	Issued Operating License
Bhairab Kund Khola	27.93	85.93	3.0	Bhairab Kund	Bhairabkund Hydropower Pvt. Ltd.	Issued Operating License
Baramchi Khola HPP	27.84	85.78	4.2	Baramchi	Unique Hydrel Pvt. Ltd.	Issued Operating License
Upper Chaku A	27.86	85.93	22.2	Chaku	Shiva Sri Hydropower Pvt. Ltd.	Issued Operating License
Charnawati Khola HPP	27.63	86.02	3.5	Charnawati	Nepal Hydro Developer Pvt. Ltd.	Issued Operating License
Jiri Khola SHP	27.59	86.22	2.4	Jiri	Bojini Company (P.) Ltd.	Issued Operating License
Middle Chaku Khola	27.87	85.93	1.8	Chaku	Laughing Budha Power Nepal	Issued Operating License
Hewa Khola A	27.17	87.79	14.9	Hewa	Panchthar Power Company Pvt. Ltd.	Issued Operating License
Puwa Khola			6.2	Puwa	Nepal Electricity Authority	Issued Operating License
Phawa khola HPP	27.28	87.76	5.0	Phawa	Shiwani Hydropower Company	Issued Construction License
Upper Tamakoshi HPP	27.82	86.17	456.0	Tamakoshi	Upper Tamakoshi Hydropower Limited	Issued Construction License
Pikhuwa Khola	27.14	87.01	2.5	Pikhuwa	Eastern Hydropower Pvt. Ltd.	Issued Construction License
Khani Khola - 1	27.80	86.33	40	Khani	Green Life Energy Pvt. Ltd.	Issued Construction License
Likhu-4	27.43	86.25	120.0	Likhu	Green Ventures Pvt. Ltd.	Issued Construction License
Jhyari Khola	27.74	85.67	2.0	Jhyari	Electrocom and Research Centre, 9851003846	Issued Construction License
Lower Khare	27.75	86.19	11.0	Khare	Universal Power Company Pvt. Ltd.	Issued Construction License
Kabeli-A	27.23	87.68	37.6	Kabeli	Kabeli Energy Limited	Issued Construction License
Upper Khimti	27.66	86.32	12.0	Khimti	Himalaya Urja Bikas Co. Pvt. Ltd.	Issued Construction License
Junbeshi	27.55	86.54	5.2	Junbeshi	Dobhan Hydropower Pvt. Ltd.	Issued Construction License
Sabha Khola	27.39	87.27	3.3	Sabha	Dibyaswari Hydropower Pvt. Ltd.	Issued Construction License
Khorunga Khola	27.16	87.53	4.8	Khoranga	Reliable Hydropower Company. Pvt. Ltd.	Issued Construction License

Koshi Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Gelun Khola HPP	27.82	85.78	3.2	Gelun	Gelun Khola Hydropower Company Pvt. Ltd.	Issued Construction License
Khani Khola (Dolakha)	27.78	86.29	30.0	Khani	Sasha Engineering Hydropower Pvt. Ltd.	Issued Construction License
Kabeli B - 1	27.27	87.78	25.0	Kabeli	Arun Kabeli Power Limited.	Issued Construction License
Lower Hewa	27.15	87.74	21.6	Hewa	Mountain Hydro Nepal Pvt. Ltd.	Issued Construction License
Madhya Bhotekoshi	27.82	85.86	102.0	Bhote koshi	Madhya Bhotekoshi Jalbidyut Company Ltd.	Issued Construction License
Rawa Khola HPP	27.30	86.74	6.5	Rawa	Dudhkoshi Power Company Pvt. Ltd.	Issued Construction License
Down Piluwa	27.24	87.27	9.5	Piluwa	River Falls Hydropower Development Pvt. Ltd.	Issued Construction License
Chake Khola	27.62	86.31	2.8	Chake	Garjyang Upatyaka HP Company	Issued Construction License
Solu Hydropower Project	27.45	86.57	23.5	Solu	Upper Solu Hydroelectric Company Pvt. Ltd.	Issued Construction License
Lower Solu HPP	27.41	86.58	82.0	Solu	Essel Clean Solu Hydropower Pvt. Ltd.	Issued Construction License
Khare HPP	27.76	86.23	24.1	Khare	Constorium Power Developers Pvt. Ltd.	Issued Construction License
Maya Khola HPP	27.23	87.31	14.9	Maya	Maya Khola Hydropower Company Pvt. Ltd.	Issued Construction License
Molun Khola SHP	27.33	86.43	7.0	Molun	Molun Hydropower Co. Pvt. Ltd.	Issued Construction License
Solu Khola (Dudha Koshi)	27.36	86.63	86.0	Solu	Hydro Venture Pvt. Ltd.	Issued Construction License
Sabha Khola A	27.36	87.23	8.3	Sabha	Deepsabha Hydropower Pvt. Ltd.	Issued Construction License
Uppper Khimti II	27.64	86.30	7.0	Khimti	Himalaya Urja Bikash Company Limited	Issued Construction License
Balephi A	27.85	85.75	10.6	Balephi	Moonlight Hydropower Company Pvt. Ltd.	Issued Construction License
Upper Hewa HPP	27.33	87.35	8.5	Hewa	Upper Hewa Khola Hydropower Company Pvt. Ltd.	Issued Construction License
Suri Khola	27.74	86.21	7.0	Suri	Suri Khola Hydropower Pvt. Ltd.	Issued Construction License
Ghatte Khola	27.77	86.28	5.0	Ghatte	Mankamana Engineering HP	Issued Construction License
Iwa Khola	27.27	87.83	9.9	Iwa	Rairang Hydropower Development Co Ltd.	Issued Construction License
Likhu -1	27.60	86.43	77.0	Likhu	Pan Himay Energy Pvt. Ltd.	Issued Construction License
Likhu -2	27.57	86.38	55.0	Likhu	Global Hydropower Associate Pvt. Ltd.	Issued Construction License
Likhu Khola 'A'	27.52	86.36	51.0	Likhu	Numbur Himalaya Hydropower Pvt. Ltd.	Issued Construction License
Upper Piluwa Khola-2 SHP	27.29	87.39	4.7	Piluwa	Menchhiyam Hydropower P Ltd. 9841521159	Issued Construction License
Singati Khola HPP	27.73	86.12	16.0	Singati	Singati Hydro Energy Pvt. Ltd.	Issued Construction License
Arun 3	27.50	87.20	900.0	Arun	Satluj Jal Vidyut Nigam Limited	Issued Survey License
Lower Balephi-3	27.72	85.76	4.5	Balephi	Kasthmandap Hydropower Development Pvt. Ltd.	Issued Survey License
Lower Khani Khola HPP	27.80	86.33	9.0	Khani	EnGen Consultancy Pvt. Ltd.	Issued Survey License
Sisa Khola A HPP	27.43	86.56	2.8	Sisa	Upper Solu Hydroelectric Company Pvt. Ltd.	Issued Survey License
Irkhua Khola-B HPP	27.40	87.06	3.5	Irkhua	Barah Multi Power Pvt. Ltd.	Issued Survey License
Lower Irkhua Khola	27.41	87.10	10.0	Irkhua	Lower Irkhua HP Co Pvt. Ltd.	Issued Survey License
Roshi Khola-1 HPP	27.44	85.75	2.4	Roshi	Natural Hydropower Pvt. Ltd.	Issued Survey License
Kasuwa Khola HPP	27.58	87.25	45.0	Kasuwa	CEDB Hydrofund Limited	Issued Survey License
Hewa A Small HEP	27.18	87.85	5.0	Hewa	Engineer's Saving and Credit Cooperative Ltd.	Issued Survey License
Dudhkoshi Storage	27.11	86.58	300.0	Dudh koshi	Nepal Electricity Authority	Issued Survey License
Upper Piluwa Hills	27.30	87.43	5.0	Piluwa	Milke Jaljale Hydropower Pvt. Ltd.	Issued Survey License

Koshi Basin						
Project	Latitude	Longitude	Capacity MW	River	Promoter	Type
Likhu Khola HPP	27.49	86.30	30.0	Likhu	P K Hydropower Pvt. Ltd.	Issued Survey License
Sepli Khola	27.38	86.44	5.0	Sepli Khola	Sepli Hydropower Development Pvt. Ltd.	Issued Survey License
Tamor Storage	27.03	87.52	200.0	Tamor	Nepal Electricity Authority	Issued Survey License
Tamor Mewa	27.33	87.58	101.0	Tamor	Spark Hydroelectric Co. Ltd.	Issued Survey License
Chisang Khola -A Small HPP	26.81	87.48	1.8	Chisang	Chisang Hydro Pvt. Ltd.	Issued Survey License
Lower Barun Khola HPP	27.68	87.34	9.6	Barun Khola	Ampik Energy Pvt. Ltd.	Issued Survey License
Jurimba Khola Small HPP	27.91	85.89	9.8	Jurimba	Jurimba Hydropower Company Pvt. Ltd.	Issued Survey License
Buku-Kapati HPP	27.50	86.38	5.0	Buku	Him Star Urja Company Pvt. Ltd.	Issued Survey License
Sagu Khola	27.80	86.08	5.0	Sagu	Him Parbat Hydropower Pvt. Ltd.	Issued Survey License
Isuwa Khola HPP	27.57	87.19	9.8	Isuwa	Dolakha Nirman Company Pvt. Ltd.	Issued Survey License
Upper Suri Khola HPP	27.73	86.25	7.0	Hulak,Kolung	Makar Jitumaya Hudropower Pvt. Ltd.	Issued Survey License
Upper Phawa HPP	27.34	87.77	4.9	Phawa	Unitech Hydropower Pvt. Ltd.	Issued Survey License
Upper Piluwa 3 HPP	27.30	87.41	4.0	Piluwa	Mabilung Energy Pvt. Ltd.	Issued Survey License
Lower Charnawati	27.61	86.04	6.4	Charnawati	Nepal Hydro Developer Pvt. Ltd.	Issued Survey License
Pegu Khola Small HPP	27.82	86.06	4.4	Pegu	Sabitri Shrestha	Issued Survey License
Upper Sagu HPP	27.84	86.08	4.7	Khartal,Kothali(Sagu)	Sanjay Shrestha	Issued Survey License
Jum Khola HPP	27.94	86.21	62.0	Jum	Sanima Hydropower Pvt. Ltd.	Issued Survey License
Total			3364.8			
Southern Rivers East						
Puwa	26.87	87.90	6.2	Puwa	Nepal Electricity Authority	Issued Operating License
Mai Khola	26.88	87.93	4.5	Mai	Himal Dolkha Hydropower Co. Ltd.	Issued Operating License
Mai	26.79	87.87	22.0	Mai	Sanima Mai Hydropower Limited	Issued Operating License
Upper Puwa-1	27.00	87.88	3.0	Puwa	Joshi Hydropower Co. Pvt. Ltd.	Issued Operating License
Upper Mai Hydropower Project	27.02	87.94	10.0	Mai	Mai Valley Hydropower Pvt. Ltd.	Issued Operating License
Mai Cascade	26.76	87.87	7.0	Mai	Sanima Mai Hydropower Limited	Issued Operating License
Jogmai Khola	26.91	88.02	7.6	Jogmai	Sanvi Energy Pvt. Ltd.	Issued Operating License
Mai Cascade HPP	26.85	87.91	8.0	Mai	Himal Dolkha Hydropower Company Pvt. Ltd.	Issued Operating License
Upper Mai -C	27.00	87.96	6.1	Mai	Mai Valley Hydropower Pvt. Ltd.	Issued Construction License
Puwa Khola-1	26.91	87.90	5.0	Puwa	Puwa Khola - 1 Hydropower Pvt. Ltd.	Issued Construction License
Siddhi Khola	26.83	88.13	10.0	Siddhi	Lumbini Builders Pvt. Ltd.	Issued Construction License
Puwa II	26.95	87.90	5.0	Puwa	Dolkha Nirman Company Pvt. Ltd.	Issued Survey License
Mai Beni HPP	26.89	87.94	9.0	Mai Khola	Samling Power company Pvt. Ltd.	Issued Survey License
Jogmai Cascade	26.90	87.99	6.0	Jogmai	Sanvi Energy Pvt. Ltd.	Issued Survey License
Super Mai Hydropower Project	26.94	87.94	6.9	Mai	Supermai Hydropower Pvt. Ltd.	Issued Survey License
Total MW Basin			116.2			
Total	105	Plants	3481.1	MW		

Table B-5: Licensed HPPS in Nepal

	Power Plant	Operation	Capacity (MW)	Annual Energy (GWh)	Capacity Factor	Owned by	Type
	Andhikhola	1991	9.4	68.38	83%	Butwal Power	ROR
	Bhotekoshi	2000	45	246	62%	BKPC	ROR
	Chaku Khola		Lower 1.8 Upper 1.76			Alliance Power	ROR
	Chilime	2003	20	101	58%	CHC	PROR
	Daraundi	2016	6.9	36	60%	Kalika Construction Ltd	ROR
	Devighat	1984	14.1	114	92%	NEA	PROR
	Fewa Canal Drop	1969	1	6.5	74%	NEA	ROR
	Gandak	1979	15	53	40%	NEA	ROR
	Gelun Khola	2014	3.3	17.1	59%	Hydro Sansar	ROR

	Power Plant	Operation	Capacity (MW)	Annual Energy (GWh)	Capacity Factor	Owned by	Type
	Indrawati	2002	7.5	60	91%	NHPC	ROR
	Jhimruk	1994	12	81	77%	BPC	ROR
	Kaligandaki	2002	144	791	63%	NEA	PROR
	Khimti	2000	62.5	353	64%	Himal Power	ROR
	Kukule Ganga	2003	120	317	30%	NEA	??
	Kulekhani I	1982	60	164	31%	NEA	STO
	Kulekhani II	1986	32	96	34%	NEA	STO
	Mai	2015	22.8	129	65%	Sanima Hydropower	ROR
	Mai Cascade	2015	7	38.42	63%	Sanima Hydropower	ROR

	Power Plant	Operation	Capacity (MW)	Annual Energy (GWh)	Capacity Factor	Owned by	Type
	Marshyangdi-1	1989	78	463	68%	NEA	PROR
	Madhya Marsyangdi	2008	70	519	85%	NEA	PROR
	Mewa Khola	2017	18	N/A	N/A	Spark Hydroelectric	ROR
	Microhydro	2003	14.5				
	Modi	2014	15	79.12	60%	NEA	ROR
	Panauti	1965 (low operation)	2.4	1.28	6%	NEA	ROR
	Pharping	1911 (irregular operation)	0.5	N/A	N/A	NEA	ROR
	Piluwa	2003	3	19.547	74%	AVHCO	ROR
	Puwa	1999	6.2	48	88%	NEA	ROR

	Power Plant	Operation	Capacity (MW)	Annual Energy (GWh)	Capacity Factor	Owned by	Type
	Sundarijal	1934 (under rehabilitation)	0.64	4.35	78%	NEA	ROR
	Sunkoshi	1972	10.05	66.38	75%	NEA	ROR
	Sunkoshi		2.6	14.5	64%	SHPC	ROR
	Syange	2001	0.183	1.19	74%	SHC	ROR
	Trishuli	1995 (rehabilitated)	24	163	77%	NEA	PROR
	Gelun Khola	2001 (currently damaged)	45	246	62%	Himal International Energy	ROR
	Upper Madi	2016	30	119.5	45%	Madi Power	ROR
	Upper Marsyangdi-A	2016/7	50	317	72%	Sinohydro-Sagarmatha Power Co	ROR

Appendix C

Framework for a Dam Registry for Nepal

APPENDIX C - NEPAL DAM REGISTRY

HATCH / TMS
Sep-17

S.No.	Project Name - Name of Dam	Status	Owner	Name of the Reservoir - River ⁽¹⁾	Location (District) ⁽¹⁾	Nearest Town ⁽¹⁾	Installed Capacity (MW)	Mean Annual Generation ⁽¹⁾ (GWh/year)	Year of Completion - Commission Date (Actual or Planned)	Project Features Summary ^(1,2)													Spillway ^(1,2)		Project Notes											
										Project Type	Dam Type ⁽²⁾	Special Features	Position and Type of Water Barrier	Foundation Type	Length of Dam (m)	Volume of Dam Body (m ³)	Reservoir Capacity (m ³)	Length of Reservoir (km)	Area of Reservoir (km ²)	Irrigated Areas (km ²)	Volume Flood Protection (m ³)	Resettlement	Height (m)	Capacity (m ³ /sec)		Spillway Type										
71	Belkhu	Operational IPP	Prime Hydropower Company Pvt. Ptd.		Dhading		0.518		2014	ROR	CGWeir																									
72	Mai Khola	Operational IPP	Sanima Hydropower Pvt. Ltd		Ilam		22		2015	ROR	CGWeir																									
73	Jiri Khola	Operational IPP	Bojini Company Pvt. Ltd		Dokha		2.2		2015	ROR	CGWeir																									
74	Upper Hugdi Khola	Operational IPP	Ruru Jabidhyut Paryojana Pvt. Ltd.		Gulmi		5		2015	ROR	CGWeir																									
75	Naugadh gad Khola	Operational IPP	Agri Power Company Pvt. Ltd.		Darchula		8.5		2015	ROR	CGWeir																									
76	Chhandi	Operational IPP	Chhyangdi Hydropower Limited		Lamjung		2		2015	ROR	CGWeir																									
77	Suspa Bukhari	Operational IPP	Kutheh Bukhari Small Hydrppower Pvt. Ltd.		Dokha		0.998		2015	ROR	CGWeir																									
78	Mai Cascade	Operational IPP	Sanima Hydropower Pvt. Ltd		Ilam		7		2016	ROR/Cascade																										
79	Daram Khola	Operational IPP	Sayapatri Hydrppower Pvt. Ltd.		Baglung		2.5		2016	ROR	CGWeir																									
80	Upper Mai Khola	Operational IPP	Mai Valley Hydropower Pvt. Ltd.		Ilam		9.98		2016	ROR	CGWeir																									
81	Upper Marsyangdi A	Operational IPP	Sinohydro-Sagarmatha Power Company (P) Ltd		Lamjung		50		2016	ROR	CGWeir																									
Ministry of Energy (MOE)																																				
82	Budhigandaki HEP	Feasibility Review	MoE-GoN				1200			SP	DR																									
83	Pancheshwar Multipurpose Project	Feasibility Review	MoE-GoN				4800																													
84	Upper Karnali	Feasibility Review	MoE-GoN				900			PROR	CG																									
85	West Seti	Feasibility Review	MoE-GoN				750			SP	CFRD																									
86	Arun III HEP	Feasibility Review	MoE-GoN				900			PROR	CG																									
87	Upper Arun HEP	Feasibility Review	MoE-GoN				400			PROR	CG																									
88	Saptagandaki	Feasibility Review	MoE-GoN				225			PROR	CG																									

Notes: 1) ICOLD suggested information field not yet completed. It is recommend that these field be completed by the new Dam Safety Division. In addition to these field it is recommended that project GPS coordinates be provided.
2) ICOLD suggested abbreviations for special features, dam type, position of water tight barrier, type of water type barrier, and foundation type should be used or referenced in the final version of the dam registry.
3) The most of the private IPPs projects have small weir and information is not available at this time. The rest of the information will be updated as & when available.

Legend⁽³⁾

PROR	= Peaking Run of River
ROR	= Run of the River
SP	= Storage Project
CG	= Concrete Gravity (conventional mass concrete or RCC)
DR	= Double Arch Dam
CFRD	= Concrete Faced Rockfill
RF	= Rockfill (zoned rockfill or zoned embankment)
* Add 1 for Dam abutments that lie in different countries	
GoN	= Government of Nepal
MOE	= Ministry of Energy
NEA	= Nepal Electricity Authority

Special Features Abbreviations⁽³⁾

A	= abandoned
H	= heightened
L	= lowered
U	= unchanged
R	= rebuilt
C	= under construction

Appendix D

A Suggested Dam Safety Regulation for Nepal

A suggested Dam Safety Regulation for Nepal

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Part 1 — Definitions, Interpretation and Application

Definitions and Interpretation

1 - (1) In this regulation:

"Act" means

"classification" means the classification of a dam determined in accordance with section 3 [*dam failure incremental hazard potential classification*]

"dam" means

- (a) a barrier constructed for the retention of water, water containing any other substance, fluid waste, or tailings, provided the barrier is capable of impounding at least 30,000 m³ of liquid and is at least 2.5 m high. Height is measured vertically to the top of the barrier (i) from the natural bed of the stream or watercourse at the downstream toe of the barrier, in the case of a barrier across a stream or watercourse; or (ii) from the lowest elevation at the outside limit of the barrier, in the case of a barrier that is not across a stream or watercourse, or
- (b) a barrier that could cause unacceptable loss in the event of its failure and
- (c) other works that are incidental to or necessary for the barrier described in paragraphs (a) and (b);

"director of dam safety" means an engineer or an officer who is designated in writing by the GoN as a director of dam safety;

"emergency plan", in relation to a dam, means

- (a) a plan that is prepared under section 9 [*dam emergency plan*] by an owner of the dam and accepted by the director of dam safety, and
- (b) the revisions, if any, to the plan referred to in paragraph (a) director of dam safety set out in a record prepared by an owner of the dam and accepted by a director of dam safety;

"Dam Safety Review Engineer" means a person who is a professional engineer as defined by the GoN

"formal inspection", in relation to a dam, means a thorough on-site inspection of the dam and dam site conducted by a person who is an owner of the dam or an agent of an owner of the dam and who is responsible for the safety of the dam;

"former regulation" means [this regulation]

"hazardous conditions", in relation to a dam, means conditions, including, without limitation, defects or insufficiencies of the dam, that

- (a) are or are likely to be hazardous to the dam, or
- (b) may reasonably be anticipated to cause all or part of the dam, or any operation or action at or about the dam, to be or become potentially hazardous to
 - (i) public safety
 - (ii) the environment
 - (iii) land or other property
 - (iv) Important cultural heritage.

"instrumentation", in relation to a dam, means instruments and equipment used to measure the following:

- (a) Hydrological and hydraulic characteristics in relation to the dam, including, without limitation,
 - (i) water levels in the dam and reservoir and at the weirs, and
 - (ii) water flow throughout the dam.
- (b) Water clarity in the reservoir and below the dam.
- (c) Seismic, geological and geotechnical characteristics in relation to the dam, including, without limitation, movement of the dam, seismic activity, pore pressures and stresses applied to the dam.
- (d) Temperature variations of the dam.
- (e) Weather conditions that may affect the operation of the dam.
- (f) Other parameters in relation to the dam.

"operation, maintenance and surveillance manual", in relation to a dam, means

- (a) a manual
 - (i) that, the operation, maintenance and surveillance manual for the dam under the former regulation,
- or

(ii) that is prepared under section 8 [*operation, maintenance and surveillance manual*] by an owner of the dam and accepted by a director of dam safety, and

(b) the revisions, if any, to the manual referred to in paragraph (a) (i) or (ii), as applicable, set out in a record prepared by an owner of the dam and accepted by a director of dam safety;

"owner", in relation to a dam, means

(a) The following persons:

(i) A person who is a licensee in relation to a license for the dam.

(ii) A person who must under the Act, but does not, hold a license for the dam.

(iii) A person who was a licensee in relation to a license for the dam immediately before the suspension, cancellation, termination or abandonment of the license.

(b) If there is no person to whom paragraph (a) applies, the following persons:

(i) An owner, as defined in the Act, of the land on which the dam is located.

(ii) A person who had the dam constructed.

"potential safety hazard", in relation to a dam, means conditions that are not yet, but have the potential to become, hazardous conditions in relation to the dam.

"site surveillance" means the monitoring of a dam and the area surrounding or adjacent to the dam

(a) through visual observation

(b) if there is instrumentation relating to the dam, through the systematic collection of instrumentation readings and analysis and interpretation of the readings.

"submit", in relation to a record that, under this regulation, must or may be submitted to a director of dam safety, means submit the record in the manner required under Section 25 (1) [*submission of records to and acceptance of records by director of dam safety*].

Application of Regulation to Minor Dam

2 - (1) Unless otherwise ordered under Subsection (2), this regulation does not apply to a dam that meets both following criteria:

(a) The dam is less than 2.5 m in height.

(b) The dam is capable of impounding at full supply level a maximum total storage volume of liquid in the reservoir of the dam of 30 000 m³ or less.

(2) Subject to Section 7 [*application of Part 3*], the GoN may order that this regulation applies to a dam described in subsection (1) of this section if the GoN is satisfied that the dam is or may become potentially hazardous to

(i) public safety,

(ii) the environment,

(iii) land or other property or

(iv) Important cultural heritage.

Part 2 — Requirements Applicable to All Dams

Dam failure consequences classification

3 - (1) An owner of a newly constructed dam must, as soon as practicable and, in any event, no later than 60 days, after completion of the construction of the dam,

(a) determine the classification of the dam in accordance with section 2 [determination of classification] of Schedule 1, and

(b) submit to a director of dam safety, immediately after the determination is completed, a record setting out a proposed classification for the dam.

(2) An owner of an existing dam must

(a) Determine the classification of the dam accordance with section 2 of Schedule 1.

(b) No less frequently than is specified in item 1 of the table in Schedule 2 for the classification of the dam, re-determine the classification of the dam in accordance with section 2 of Schedule 1 to assess whether the classification of the dam has changed.

(c) If the classification of the dam has changed, submit to a director of dam safety, immediately after the redetermination is completed, a record setting out a proposed new classification for the dam.

(3) Despite subsections (1) and (2), the GoN may order an owner of a dam to comply with subsection (1) or (2), as applicable, on or before a specified date.

(4) On receipt of a record under subsection (1) (b) or (2) (b) or paragraph (b) (ii) of this subsection from an owner of a dam proposing a classification, or a new classification, for the dam, or on receipt of information or records from an owner of a dam under paragraph (b) (i) of this subsection, a director of dam safety must give written notice to the owner of the dam who submitted the record or the information or records advising that

- (a) the director of dam safety has accepted the classification, or new classification, proposed by the owner, or
- (b) the director of dam safety has not accepted the classification, or new classification, proposed by the owner and requiring the owner to submit to the director of dam safety, on or before the date specified by the director of dam safety, either of the following:
 - (i) information or records, or further information or records that demonstrate that the classification, or new classification, proposed by the owner is correct;
 - (ii) a record setting out a different proposed classification, or new classification for the dam.

(5) In the case of a dam described in subsection (1),

- (a) until a record setting out a proposed classification for the dam is submitted under subsection (1) (b), the classification of the dam is deemed, for the purposes of this regulation, to be significant, and
- (b) between the date on which the record referred to in paragraph (a) of this subsection is submitted to a director of dam safety and the date on which a director of dam safety gives notice under subsection (4) (a) in relation to the dam,
 - (i) if the proposed classification for the dam is high, very high or extreme, the classification of the dam is deemed, for the purposes of this regulation, to be the proposed classification, and
 - (ii) if the proposed classification for the dam is low or significant, the classification of the dam is deemed, for the purposes of this regulation, to be significant.

(6) In the case of a dam described in subsection (2) in respect of which an owner of the dam submits under subsection (2) (b) a record setting out a proposed new classification for the dam, between the date on which the record is submitted and the date on which a director of dam safety gives notice under subsection (4) (a) in relation to the dam, the classification of the dam is deemed, for the purposes of this regulation, to be the more severe in consequence of the existing classification and the proposed new classification.

- (7) Despite subsections (5) and (6), if the GoN makes an order under subsection (3),
- (a) the GoN or water manager may, in the order, specify a classification for the dam that applies between the date on which the order is made and the date on which a director of dam safety gives notice under subsection (4) (a) in relation to the dam, and
 - (b) the classification of the dam is, during the period described in paragraph (a) of this subsection, deemed for the purposes of this regulation to be the classification specified in the order.
- (8) For certainty, the requirements of this regulation that apply in relation to a classification of a dam also apply in relation to a deemed classification of the dam under subsection (5), (6) or (7).
- (9) When a director of dam safety gives notice under subsection (4) (a) in relation to a dam, the classification of the dam for the purposes of this regulation is the classification accepted by the director of dam safety as set out in the notice.

Owner must Comply on Determination or Change of Classification

4 - Subject to this regulation, if the classification of a dam is determined for the first time or changes, an owner of the dam must, as soon as practicable after the owner becomes aware of the classification, or changed classification comply with the provisions of this regulation that apply to a dam having that classification or changed classification.

Responsibility of Owner for Dam Condition and Safety

- 5** - (1) An owner of a dam must properly inspect, maintain and repair the dam and related works in a manner that keeps the dam and works in good operating condition.
- (2) An owner of a dam must exercise reasonable care to avoid the risk of significant harm resulting from a defect, insufficiency or failure of the dam or other conditions at the dam or operations or actions at or about the dam to any of the following:
- (i) public safety,
 - (ii) the environment,
 - (iii) land or other property or
 - (iv) Important cultural heritage.

Prevention of Unauthorized Operation

6 - An owner of a dam must exercise reasonable care to safeguard the dam from unauthorized operation.

Part 3 — Requirements Applicable to Certain Dams

Division 1 — Application of Part 3

Application of Part 3

7 - This Part applies in relation to a dam if the dam meets the criteria set out in one or more of the following paragraphs:

- (a) The dam is
 - (i) 1 m or more in height, and
 - (ii) capable of impounding at full supply level a total storage volume of water in the reservoir of the dam greater than 1 000 000 m³;
- (b) The dam is
 - (i) 2.5 m or more in height
 - (ii) capable of impounding at full supply level a total storage volume of water in the reservoir of the dam greater than 30 000 m³.
- (c) the dam is 7.5 m or more in height
- (d) the dam has a classification of significant, high, very high or extreme.

Division 2 — General Safety Requirements

Operation, Maintenance and Surveillance Manual

8 - (1) An owner of a dam for which there is not already an operation, maintenance and surveillance manual and that has a classification of significant, high, very high or extreme must

- (a) prepare a manual, in the form and with the content specified by the GoN, that describes the operation, maintenance and surveillance procedures for the dam, and
- (b) submit the manual to a director of dam safety for acceptance by the director of dam safety.

(2) Subject to subsection (3), an owner of a newly constructed dam must comply with subsection (1) as soon as practicable and, in any event, no later than 60 days, after completion of the construction of the dam.

(3) The GoN may order an owner of a dam to comply with subsection (1) on or before a specified date.

(4) An owner of a dam for which there is an operation, maintenance and surveillance manual must, no less frequently than is specified in item 8 of the table in Schedule 2 for the classification of the dam.

(a) review and, if necessary, revise the operation, maintenance and surveillance manual.

(b) submit to a director of dam safety for acceptance by the director of dam safety

(i) a record setting out the revisions, if any, or

(ii) a written report advising that no revisions are necessary.

(5) Despite subsection (4), if the classification of a dam for which there is an operation, maintenance and surveillance manual changes to a classification that is more severe in consequence, an owner of the dam must comply with subsection (4) (a) and (b) as soon as practicable after the owner becomes aware of the change of classification or on or before a later date specified by a director of dam safety.

(6) An owner of a dam must follow the operation, maintenance and surveillance manual, if any, for the dam.

Dam Emergency Plan

9 - (1) An owner of a dam for which there is not already an emergency plan and that has a classification of significant, high, very high or extreme must

(a) prepare a plan, in the form and with the content specified by the GoN, that includes

(i) a record describing the actions to be taken by the owner if there is an emergency at the dam, and

(ii) a record containing information for the use of the local emergency authorities for the dam for preparing local emergency plans and

(b) submit the plan to a director of dam safety for acceptance by the director of dam safety.

- (2) Subject to subsection (3), an owner of a newly constructed dam must comply with subsection (1) as soon as practicable and, in any event, no later than 60 days, after completion of the construction of the dam.
- (3) The GoN may order an owner of a dam to comply with subsection (1) on or before a specified date.
- (4) A record described in subsection (1) (a) (i) must include contact information for the persons and the government agencies and other organizations that are to be contacted by the owner of the dam if there is an emergency at the dam.
- (5) A record described in subsection (1) (a) (ii) must include the name and contact information of the person who is the emergency contact for the dam.
- (6) An owner of a dam must, promptly after a plan prepared for the dam under subsection (1) is accepted by a director of dam safety, deliver a copy of the record described in subsection (1) (a) (ii) to each local emergency authority for the dam.
- (7) An owner of a dam for which there is an emergency plan must, no less frequently than is specified in item 6 of the table in Schedule 2 for the classification of the dam,
- (a) review and, if necessary, revise the names and contact information in the records described in subsections (4) and (5) of this section, and
 - (b) submit to a director of dam safety for acceptance by the director of dam safety
 - (i) a record setting out the revisions, if any, or
 - (ii) a written report advising that no revisions are necessary.
- (8) Subject to subsection (7), an owner of a dam for which there is an emergency plan must, no less frequently than is specified in item 8 of the table in Schedule 2 for the classification of the dam
- (a) review and, if necessary, revise the emergency plan
 - (b) if the record is revised, submit the revised record to a director of dam safety for acceptance by the director of dam safety.
- (9) Despite subsection (8), if the classification of a dam for which there is an emergency plan changes to a classification that is more severe in consequence, an owner of the dam must comply with subsection (8) (a) and (b) as soon as practicable after the owner becomes aware of the change of classification or on or before a later date specified by a director of dam safety.

(10) If a record described in subsection (1) (a) (ii) for a dam is revised under this regulation, an owner of the dam must, promptly after the revision is accepted by a director of dam safety, deliver a copy of the revised record to each local emergency authority for the dam.

Record Identifying Emergency Contact

10 - (1) An owner of a dam that has a classification of low must

- (a) prepare a record, in the form and with the content specified by the GoN that sets out the name and contact information of the person who is the emergency contact for the dam
- (b) submit the record to a director of dam safety
- (c) deliver a copy of the record to each local emergency authority for the dam.

(2) Subject to subsection (3), an owner of a newly constructed dam must comply with subsection (1) as soon as practicable and, in any event, no later than 60 days, after completion of the construction of the dam.

(3) A director of dam safety may specify a date on or before which an owner of a dam must comply with subsection (1) and, if the director of dam safety specifies a date, the owner must comply with subsection (1) on or before the specified date.

(4) An owner of a dam for which a record referred to in subsection (1) has been prepared must, no less frequently than is specified in item 7 of the table in Schedule 2 for the classification of the dam

- (a) review and, if necessary, revise the record
- (b) if the record is revised
 - (i) submit the revised record to a director of dam safety, and
 - (ii) deliver a copy of the revised record to each local emergency authority for the dam.

(5) If none of the owners of a dam have complied with subsection (1) within the required time, a director of dam safety may designate one of the owners of the dam to be the emergency contact for the dam.

(6) An owner of a dam who becomes the emergency contact for the dam under this section must, as soon as practicable, give to each other owner whose address is known to the owner written notice that the owner is the emergency contact.

Signs must be Posted

11 - (1) In this section:

"**emergency contact**", in relation to a dam, means the person identified as the emergency contact for the dam in the record referred to in section 9 (5) [*dam emergency plan*];

"**sign**" means a sign that meets the requirements of subsection (4).

(2) Subject to subsection (3), an owner of a dam that has a classification of significant, high, very high or extreme and that is located partly or entirely on Crown land, or on land that is surrounded by or adjacent to Crown land, must ensure that 2 signs are always posted,

(a) at each end of the top of the dam, or

(b) if a sign posted at an end of the top of the dam would not be clearly visible under all seasonal conditions to persons approaching the dam, at another location on Crown land at which the sign would be so visible.

(3) An owner of a dam is required to post only one sign under subsection (2) if a director of dam safety considers it would be impractical or unnecessary to post the other sign.

(4) Each sign that must be posted under subsection (2) must meet all the following requirements:

(a) The sign must contain, in lettering that is clearly legible from 15 m, the following information:

(i) The name of the dam.

(ii) If the dam impounds water from a stream, the name of the stream.

(iii) The following words: "If you see any dam safety concerns, please contact:", followed by

(A) The name and emergency telephone numbers for day and for night of the emergency contact for the dam.

(B) The emergency telephone number for the Provincial Emergency Program.

(b) the sign must be at least 75 cm high and 60 cm wide;

(c) the sign must be clearly visible under all seasonal conditions to persons approaching the dam;

(d) the sign and the post, if any, must be constructed from metal or other durable materials having strength suited to the location of the sign and the local environmental conditions;

(e) the sign must meet the other requirements, if any, specified by the GoN.

(5) This section is subject to the requirements of any other enactment that relate to the location, appearance or construction of a sign referred to in this section.

Division 3 — Activities at or near Dam

Authorization, change approval or order for alteration or improvement to or replacement of dam

12 - An alteration or improvement to or replacement of all or part of a dam must be authorized under the Act by an authorization, change approval or order unless the alteration, improvement or replacement is for

- (a) routine maintenance of the dam or related works
- (b) addressing hazardous conditions in relation to the dam in accordance with Section 14 (1) [hazardous conditions]
- (c) investigating described in section 16 [invasive investigations] in accordance with that section.

Requirements if Alteration or Improvement to or Replacement of Dam

13 (1) An owner of a dam must, within 30 days after completion of an alteration or improvement to or replacement of all or part of the dam, submit to a director of dam safety

- (a) a written report on the work and the way the alteration, improvement or replacement was performed, and
- (b) a copy of the as-built drawings.

(2) A report under subsection (1) (a) may be combined with a report under section 14 (2) (a) [hazardous conditions], 15 (2) (a) [potential safety hazard] or 17 (5) [removing, decommissioning, deactivating or stopping operation of dam].

(3) An owner of a dam must, promptly after an alteration or improvement to or replacement of all or part of the dam is completed

- (a) review and, if necessary, revise the operation, maintenance and surveillance manual and the emergency plan, if any, for the dam, and
- (b) submit to a director of dam safety for acceptance by the director of dam safety
 - (i) a record setting out the revisions, if any, or
 - (ii) a written report advising that no revisions are necessary.

Hazardous Conditions

14 - (1) An owner of a dam who becomes aware of hazardous conditions in relation to the dam must promptly do all the following:

- (a) Follow the emergency plan, if any, for the dam.
 - (b) Operate the dam in a manner, and initiate any remedial actions, including modifying the operations at the dam, that will
 - (i) safeguard the public, and
 - (ii) minimize damage to the environment or land or other property;
 - (c) Inform the GoN and other entities of the nature of the hazardous conditions including
 - (i) persons who are in the immediate vicinity of the dam
 - (ii) the local emergency authorities for the dam whose jurisdictional areas may be adversely affected by the hazardous conditions.
 - (d) If the nature of the hazardous conditions places persons in imminent danger
 - (i) advise persons who are in the immediate vicinity of the dam to vacate the endangered area, and
 - (ii) inform the local emergency authorities for the dam whose jurisdictional areas may be adversely affected by the hazardous conditions of the imminent danger.
 - (e) Inform the GoN or a director of dam safety of
 - (i) the nature of the hazardous conditions
 - (ii) the actions being taken by the owner to rectify the hazardous conditions
 - (iii) the time and exact nature of the information given under this section to any person in relation to the hazardous conditions.
 - (f) perform such further hazard response activities as the GoN orders.
- (2)** An owner of a dam must, as soon as practicable and, in any event, no later than 30 days, after hazardous conditions at the dam have been rectified, submit to a director of dam safety
- (a) a written report on the actions taken by the owner to rectify the hazardous conditions and the effectiveness of those actions, and

- (b) on request of the director of dam safety, copies of records in the custody or under the control of the owner in relation to those actions.

Potential Safety Hazard

15 - (1) An owner of a dam who becomes aware of a potential safety hazard in relation to the dam must do all the following:

- (a) promptly notify a director of dam safety of the potential safety hazard
 - (b) on or before the date specified by a director of dam safety
 - (i) prepare a plan, in the form and with the content specified by the director of dam safety, that sets out, in order of priority, any actions required to rectify the potential safety hazard, and
 - (ii) submit the plan to a director of dam safety for acceptance by the director of dam safety.
 - (c) if the plan referred to in paragraph (b) is accepted by a director of dam safety, implement the plan, on or before the date specified by a director of dam safety, in the order of priority identified in the plan and in accordance with any requirements or conditions specified in an authorization, change approval or order.
- (2) An owner of a dam must, as soon as practicable and, in any event, no later than 30 days, after a potential safety hazard at a dam has been rectified, submit to a director of dam safety
- (d) a written report on the actions taken by the owner to rectify the potential safety hazard and the effectiveness of those actions, and
 - (e) on request of the director of dam safety, copies of records in the custody or under the control of the owner in relation to those actions.

Invasive Investigations

16 - (1) In this section, "**invasive investigation**" means an investigation that involves drilling, trenching, excavating a test pit or performing another invasive activity within or near a dam.

- (2) An owner of a dam who intends to conduct an invasive investigation must
- (a) at least 60 days before the date on which the owner expects the invasive investigation to begin, give to a director of dam safety written notice of the proposed investigation, and
 - (b) at least 30 days before the date on which the owner expects the invasive investigation to begin

(i) prepare a plan, in the form and with the content specified by a director of dam safety in relation to the invasive investigation, and

(ii) submit the plan to a director of dam safety for acceptance by the director of dam safety.

(3) An owner of a dam must not begin an invasive investigation until a plan referred to in subsection (2)

(a) has been accepted by a director of dam safety.

(4) An owner of a dam must ensure that all drilling, trenching, test pit excavations and other invasive activities involved in an invasive investigation are directly supervised by an engineering professional who has qualifications and experience in dam design, construction and analysis.

Removing, Decommissioning, Deactivating or Stopping Operation of Dam

17 - (1) In this section, "**restricted activity**" means any of the following:

(a) removing all or a significant part of a dam.

(b) decommissioning a dam.

(c) deactivating a dam, or stopping the normal operation of a dam, for a period longer than one year.

(2) An owner of a dam who intends to perform a restricted activity must

(a) at least 120 days before the date on which the owner expects to begin work on the restricted activity, give to a director of dam safety written notice of the proposed restricted activity, and

(b) at least 90 days before the date on which the owner expects to begin work on the restricted activity

(i) prepare a plan, in the form and with the content specified by a director of dam safety in relation to the activity, and

(ii) submit the plan to a director of dam safety for acceptance by the director of dam safety.

(3) An owner of a dam must not begin work on a restricted activity until a plan referred to in subsection (2)

(a) has been accepted by a director of dam safety.

(4) Without limiting subsection (3), an owner of a dam must notify a director of dam safety of the owner's intention to begin work on a restricted activity at least 30 days before the date on which the owner expects to begin the work.

(5) An owner of a dam who has performed a restricted activity must submit to a director of dam safety, for acceptance by the director of dam safety, a written report on the work performed and the way it was performed, no later than 60 days after completion of the restricted activity or on or before a later date specified by a director of dam safety.

(6) An owner of a dam who is performing or has performed work in relation to a restricted activity must take such further actions as the GoN orders to mitigate any adverse impact on

- (a) a person,
- (b) the environment, or
- (c) land or other property.

Division 4 — Monitoring and Review of Dam Safety

Site Surveillance, Formal Inspections and Tests

18 - An owner of a dam must do all the following:

- (a) To assess the condition of the dam during the operation of the dam or the alteration or improvement to or replacement of the dam, conduct
 - (i) a site surveillance of the dam no less frequently than is specified in item 2 of the table in Schedule 2 for the classification of the dam, and
 - (ii) a formal inspection of the dam no less frequently than is specified in item 3 of the table in Schedule 2 for the classification of the dam;
- (b) Test, no less frequently than is specified in item 4 of the table in Schedule 2 for the classification of the dam, the operation of
 - (i) the outlet facilities, spillway gates and other mechanical components of the dam, and
 - (ii) the electrical and communication equipment relating to the dam.
- (c) Promptly after an activity described in this section has been performed, record the results of the activity.

Instrumentation

19 - (1) An owner of a dam must do all the following:

- (a) Install the instrumentation necessary to adequately monitor the dam and the area surrounding or adjacent to the dam.
 - (b) Maintain or replace the instrumentation referred to in paragraph (a) to ensure continuity of readings.
 - (c) Collect readings from the instrumentation referred to in paragraph (a) and analyze and interpret the readings no less frequently than is specified in item 5 of the table in Schedule 2 for the classification of the dam.
- (2) An owner of a dam who intends to install, modify, replace or remove instrumentation relating to the dam must submit to a director of dam safety, for acceptance by the director of dam safety,
- (a) a record describing the proposed installation, modification, replacement or removal at least 60 days before the date on which the owner expects the installation, modification, replacement or removal to occur, or
 - (b) an annual plan outlining all installations, modifications, replacements and removals of instrumentation proposed for the following year.
- (3) An owner of a dam must not install, modify, replace or remove instrumentation relating to the dam until the record or plan referred to in subsection (2) (a) or (b), as applicable, has been accepted by a director of dam safety.

Dam Safety Review and Report

- 20 -** (1) An owner of a dam that has a classification of high, very high or extreme must, no less frequently than is specified in item 9 of the table in Schedule 2 for the classification of the dam,
- (a) ensure that an engineering professional who has qualifications and experience in dam safety analysis
 - (i) carries out a review, in accordance with the requirements of the GoN,
 - (A) to determine if the dam is safe, and
 - (B) if it is determined that the dam is not safe, to determine what actions are required to make the dam safe, and
 - (ii) prepares, in the form and with the content specified by the GoN, a report on the safety of the dam, and
 - (b) submit to a director of dam safety, for acceptance by the director of dam safety, a copy of the report referred to in paragraph (a) (ii).

(2) Despite subsection (1), if the classification of a dam changes to a classification that is more severe in consequence, other than a change from a low classification to a significant classification, an owner of the dam must comply with subsection (1) (a) and (b) on or before December 31 of the calendar year that is 2 years after the calendar year in which the classification changes, unless the GoN specifies another date.

Division 5 — Information and Records to Be Submitted

Information and Records to be Submitted to Director of dam safety

21 - (1) In this section, "**inspection**", in relation to a dam, includes, without limitation, site surveillance of the dam and a formal inspection of the dam.

(2) An owner of a dam must, on request of a director of dam safety, submit to the director of dam safety, in the form, with the content and on or before the date specified by the director of dam safety, the following records relating to an inspection, test or review carried out in relation to a dam:

- (a) A record setting out the results of the inspection, test or review.
- (b) Records setting out the data obtained from any test or measurement taken, and analysis and interpretation of the data, including, but not limited to
 - (i) a record setting out instrumentation readings, and analysis and interpretation of the readings
 - (ii) visual records or observations
 - (iii) drawings
 - (iv) soil, aggregate and concrete test results, and
 - (v) any other test results.

(3) Despite subsection (2), an owner of a dam must promptly submit to a director of dam safety the records referred to in that subsection if an inspection, test or review carried out in relation to the dam reveals hazardous conditions or a potential safety hazard.

(4) A director of dam safety may request an owner of a dam to submit to the director of dam safety any of the following information and records that the director of dam safety considers necessary to evaluate the condition or the hazard potential of the dam and operations and actions at or about the dam:

- (a) Information and records relating to the dam and those operations and actions, including, but not limited to

- (i) information and records respecting hydraulic, hydrological, seismic, geological and geotechnical characteristics, conditions and concerns
 - (ii) foundation investigation results
 - (iii) design details and as-built drawings
 - (iv) structural analyses
 - (v) construction records
 - (vi) operation manuals
 - (vii) records relating to instrumentation
 - (viii) safety reports
 - (ix) inundation studies
 - (x) plans, that have not been previously submitted to a director of dam safety, to be implemented if there is an emergency at the dam.
- (b) The following records relating to the design or construction of the dam or an alteration to or improvement or replacement of the dam:
- (i) drawings, including, without limitation, plans and as-built drawings.
 - (ii) design notes and specifications.
 - (iii) hydraulic, hydrological, geological and geotechnical data.
 - (iv) reports and other similar records.
- (c) Information and records, including, without limitation, information and records respecting hydraulic, hydrological, seismic, geological and geotechnical characteristics, conditions and concerns, relating to the following:
- (i) The nature and use of the land that is in the immediate vicinity of the dam or the reservoir of the dam, downstream of the dam or downslope of the dam.
 - (ii) The nature and use of the stream or aquifer from which the water is being stored or diverted
- (d) Information relating to the watershed upstream of the dam.

(5) An owner of a dam, must, on receiving a request of a director of dam safety under subsection (4), submit the requested information or record in the form, with the content and on or before the date specified by the director of dam safety.

(6) If information or a record in relation to a dam that is required to be submitted to a director of dam safety under this section does not exist or is otherwise not available for submission, the GoN may order an owner of the dam to conduct an inspection, investigation, survey or test, or prepare a record in relation to an inspection, investigation, survey or test, that is necessary to provide the information or record.

Part 4 — General

Division 1 — Dams with Multiple Owners

Owners' Designate

22 - (1) The owners of a dam in respect of which there are 2 or more owners must, on request of a director of dam safety and on or before the date specified by the director of dam safety

- (a) designate one of the owners for the purposes of receiving, providing and retaining information and records in relation to the dam as required or authorized by this regulation, and
- (b) submit to the director of dam safety the designated owner's name, address and other contact information as required by the director of dam safety.

(2) If the owners of a dam to which subsection (1) applies have not complied with that subsection within the specified time, a director of dam safety may designate one of the owners for the purposes of this section.

(3) An owner of a dam who is designated under this section must, as soon as practicable after the designation, give to each other owner whose address is known to the owner written notice of the designation.

Compliance by any Owner Satisfies Requirement

23 - For certainty, if a dam has 2 or more owners, a requirement imposed by this regulation on an owner of the dam is satisfied if any of the owners of the dam complies with the requirement.

Exemption for Owner of Dam with Multiple Owners

24 - An owner of a dam in respect of which there are 2 or more owners is exempt from the requirements of this regulation in relation to the dam if

- (a) the GoN is satisfied that proper arrangements have been made for one or more of the other owners to take responsibility for meeting the requirements of this regulation in relation to the dam, and
- (b) either of the following applies in relation to the owner:
 - (i) All the owners have agreed that one or more of the other owners acceptable to the GoN are to be responsible for the dam.
 - (ii) The owner holds rights to store not greater than 5% of the quantity of water the storage rights to which are granted under the Act in respect of the dam.

Division 2 — Records

Submission of Records to and Acceptance of Records by Director of dam safety

25 - (1) A record that under this regulation must or may be submitted to a director of dam safety must be submitted in the manner specified by the director of dam safety.

(2) If a record submitted under this regulation by an owner of a dam to a director of dam safety for acceptance by the director of dam safety

- (a) is not in the form or does not contain the content required under this regulation, or
- (b) if there are no requirements under this regulation as to the form or content of the record, is not acceptable in form or content to the director of dam safety
- (c) the director of dam safety may give to the owner written notice advising that the record has not been accepted, specifying the deficiencies in the record and requiring that they be rectified.

(3) If a director of dam safety gives notice to an owner of a dam under subsection (2) in relation to a record

- (a) the owner must promptly rectify the deficiencies specified in the notice, and
- (b) the director of dam safety is not required to accept the record until the owner has rectified the deficiencies specified in the notice.

(4) If a director of dam safety accepts a record that was submitted under this regulation to the director of dam safety for acceptance, the director of dam safety must give written notice of the acceptance to the owner of the dam who submitted the record.

(5) For the purposes of this regulation, a record relating to a dam is accepted by a director of dam safety when the director of dam safety gives notice under subsection (4) in relation to the record.

Retention of Records

26 - (1) For the purposes of section 116 (1) [*records and reporting*] of the Act, each person who is or was an owner of a dam must keep information or a record described in section 116 (1) (a), (b) or (c) of the Act that relates to the dam for the period between

- (a) the date on which the information or record is obtained or prepared by the person, and
- (b) the date that is 10 years after the date on which written notice is given to a director of dam safety, by a person who is an owner of the dam when the dam is decommissioned, stating that the decommissioning of the dam is complete and the dam has been completely removed.

(2) Subsection (1) does not apply to a person in relation to information or a record if another person has been designated under section 22 [*owners' designate*] for retaining the information or record.

(3) For the purposes of section 116 (1) (b) of the Act, an owner of a dam must, in addition to the records referred to in section 116 (1) (a) or (c) of the Act, keep all other information and records in relation to the dam that, under this regulation, the owner is, or may be, required to submit to the GoN, a water manager, an engineer or a director of dam safety.

Division 3 — Advice of Independent Expert

Advice of Independent Expert may be Required

27 - (1) If the GoN considers it advisable to obtain independent expert advice in relation to an issue respecting a dam or works relating to a dam, the GoN or water manager may order an owner of the dam to retain an independent expert, satisfactory to the GoN or water manager, who has qualifications and experience described in subsection (2), to prepare a written report on resolving the issue.

(2) An independent expert retained under subsection (1) must have the following qualifications and experience:

- (a) in the case of an issue respecting a dam, qualifications and experience in dam design, construction and analysis or in dam operation and maintenance, as appropriate;
- (b) in the case of an issue respecting works relating to a dam, qualifications and experience in hydraulic, hydrological, geological, geotechnical, mechanical or structural engineering or other discipline, as appropriate.

(3) An owner of a dam who is ordered by the GoN to retain an independent expert under subsection (1) must submit to the GoN or water manager a copy of the written report referred to in that subsection promptly after the owner receives the report.

Division 4 — Offences

General Offences

28 - (1) An owner of a dam who does any of the following commits an offence:

- (a) fails to determine under section 3 (1) (a) [dam failure consequences classification], or re-determine under section 3 (2) (a), the classification of the dam as and when required to do so;
- (b) fails to submit to a director of dam safety a record under section 3 (1) (b) setting out a proposed classification for the dam, or a record under section 3 (2) (b) setting out a proposed new classification for the dam, as and when required to do so;
- (c) fails to properly inspect, maintain or repair the dam or related works contrary to section 5 (1) [responsibility of owner for dam condition and safety];
- (d) fails to exercise reasonable care to avoid the risk of significant harm as required under section 5 (2);
- (e) fails to exercise reasonable care to safeguard the dam from unauthorized operation contrary to section 6 [*prevention of unauthorized operation*].

(2) An owner of a dam who does any of the following commits an offence

- (a) fails to review or revise the operation, maintenance and surveillance manual for the dam as and when required to do so under section 8 (4) (a) or (5) [operation, maintenance and surveillance manual] or 13 (3) (a) [requirements if alteration or improvement to or replacement of dam]
- (b) fails to submit to a director of dam safety the applicable record in relation to a review of the operation, maintenance and surveillance manual for the dam as and when required to do so under section 8 (4) (b) or (5) or 13 (3) (b)
- (c) fails to follow the operation, maintenance and surveillance manual for the dam contrary to section 8 (6)
- (d) fails to deliver a record to a local emergency authority for the dam as and when required to do so under section 9 (6) or (10) [dam emergency plan] or section 10 (4) (b) (ii) [record identifying emergency contact]
- (e) fails to review or revise the emergency plan for the dam as and when required to do so under section 9 (7) (a), (8) (a) or (9) or 13 (3) (a)

- (f) fails to submit to a director of dam safety the applicable record in relation to a review of the emergency plan for the dam as and when required to do so under section 9 (7) (b), (8) (b) or (9) or 13 (3) (b)
 - (g) fails to comply with section 10 (1) (a), (b) or (c) on or before the date specified by a director of dam safety contrary to section 10 (3)
 - (h) fails to review or revise the record setting out the name and contact information for the emergency contact for the dam as and when required to do so under section 10 (4) (a)
 - (i) fails to submit to a director of dam safety the applicable record in relation to a review of the record referred to in paragraph (h) as and when required to do so under section 10 (4) (b) (i)
 - (j) contravenes section 11 [signs must be posted].
- (3) An owner of a dam who does any of the following commits an offence:
- (a) fails to submit to a director of dam safety a written report or other record as and when required to do so under section 13 (1), 14 (2) [hazardous conditions], 15 (2) [potential safety hazard] or 17 (5) [removing, decommissioning, deactivating or stopping operation of dam]
 - (b) fails to notify a director of dam safety of a potential safety hazard in relation to the dam as and when required to do so under section 15 (1) (a)
 - (c) fails to give notice of a proposed activity in relation to the dam as and when required to do so under section 16 (2) (a) [invasive investigations] or 17 (2) (a) or (4)
 - (d) fails to prepare or submit to a director of dam safety a plan for an activity in relation to the dam as and when required to do so under section 15 (1) (b) (i) or (ii), 16 (2) (b) (i) or (ii) or 17 (2) (b) (i) or (ii)
 - (e) fails to implement a plan in relation to a potential safety hazard at the dam as and when required to do so under section 15 (1) (c)
 - (f) begins an activity referred to in section 16 or 17 in relation to the dam before a plan respecting the activity has been accepted by a director of dam safety contrary to section 16 (3) or 17 (3), as applicable
 - (g) fails to ensure that an invasive activity is directly supervised by an engineering professional who has qualifications and experience as required under section 16 (4).
- (4) An owner of a dam who does any of the following commits an offence:
- (a) fails to conduct a site surveillance of the dam as and when required to do so under section 18 (a) (i) [site surveillance, formal inspections and tests]
 - (b) fails to conduct a formal inspection of the dam as and when required to do so under section 18 (a) (ii)

- (c) fails to test the operation of mechanical components of the dam as and when required to do so under section 18 (b) (i)
 - (d) fails to test the operation of electrical or communication equipment relating to the dam as and when required to do so under section 18 (b) (ii)
 - (e) fails to record the results of an activity referred to in paragraph (a), (b), (c) or (d) when required to do so under section 18 (c)
 - (f) fails to install, maintain or replace instrumentation relating to the dam as required under section 19 (1) (a) or (b) [instrumentation]
 - (g) fails to collect, analyze or interpret readings from instrumentation relating to the dam as and when required to do so under section 19 (1) (c)
 - (h) fails to submit to a director of dam safety a record or a plan for a proposed installation, modification, replacement or removal of instrumentation relating to the dam as and when required to do so under section 19 (2)
 - (i) installs, modifies, replaces or removes instrumentation relating to the dam before the notice or plan referred to in paragraph (h) has been accepted by a director of dam safety contrary to section 19 (3)
 - (j) fails to ensure that an engineering professional who has qualifications and experience as required under section 20 (1) [dam safety review and report] carries out a review of, and prepares a report on, the safety of the dam as and when required to do so under section 20 (1) (a) or (2)
 - (k) fails to submit to a director of dam safety the report referred to in paragraph (j) as and when required to do so under section 20 (1) (b) or (2)
 - (l) fails to submit to a director of dam safety information or a record in relation to the dam as and when required to do so under section 21 (2), (3) or (5) [information and records to be submitted to director of dam safety]
 - (m) fails to submit to the GoN a copy of a report of an independent expert in relation to the dam as and when required to do so under section 27 (3) [advice of independent expert may be required].
- (5) An owner of a dam who commits an offence under this section is liable on conviction to the following:
- (a) In the case of an offence that is not a continuing offence, a fine of not more than \$200 000 or imprisonment for not longer than 6 months, or both.
 - (b) In the case of a continuing offence, a fine of not more than \$200 000 for each day the offence is continued or imprisonment for not longer than 6 months, or both.

High Penalty Offences

29 - (1) An owner of a dam who does any of the following commits an offence:

- (a) Fails to follow the emergency plan for the dam contrary to section 14 (1) (a) [hazardous conditions].
- (b) Fails to operate the dam or initiate a remedial action at the dam contrary to section 14 (1) (b).
- (c) Fails to inform or advise a person or other entity respecting hazardous conditions in relation to the dam contrary to section 14 (1) (c) or (d).
- (d) Fails to inform the GoN, a water manager or a director of dam safety respecting hazardous conditions in relation to the dam as and when required to do so under section 14 (1) (e).

(2) An owner of a dam who commits an offence under this section is liable on conviction to the following:

- (a) In the case of an offence that is not a continuing offence, a fine of not more than \$1 000 000 or imprisonment for not longer than one year, or both.
- (b) In the case of a continuing offence, a fine of not more than \$1 000 000 for each day the offence is continued or imprisonment for not longer than one year, or both.

Dam Classification

Definitions

1 - In this Schedule:

"category", in relation to consequences of failure, means one of the following:

- (i) public safety,
- (ii) the environment,
- (iii) land or other property or
- (iv) Important cultural heritage.

"consequences of failure" means incremental losses or damages that are caused by a failure of a dam over and above that which would have occurred had the dam not failed;

"failure", in relation to a dam, means an uncontrolled release of all or part of the water impounded by the dam, whether or not caused by a collapse of the dam.

Determination of Classification

2 - (1) For the purposes of this regulation, the classification of a dam is to be determined in accordance with the following steps:

- (a) For each category of incremental hazards in columns 2, 3, 4 and 5 of the table, identify the losses or damages specified in the applicable column that most closely describe the losses or damages that are the most severe potential consequences of a failure of the dam.
- (b) Identify the dam failure consequences classification that is specified in column 1 of the table for the losses or damages referred to in paragraph (a) for each category.
- (c) The dam failure consequences classification identified under paragraph (b) with the most severe potential consequences is the classification of the dam.

Column 1	Column 2	Column 3	Column 4	Column 5
Hazard Potential	Hazard Categories – Incremental Losses			
	Life Safety	Property Losses	Environmental Losses	Cultural – Built Heritage Losses
Low	No potential loss of life. ¹	Minimal damage to property with estimated losses not to exceed 25 Lakh rupees.	Minimal loss of fish and/or wildlife habitat with high capability of natural restoration resulting in a very low likelihood of negatively affecting the status of the population.	Reversible damage to local designated cultural heritage sites.
Moderate	No potential loss of life. No permanent dwellings ²	Moderate damage with estimated losses not to exceed 25 Crore rupees to agricultural, forestry, mineral aggregate and mining, other dams or structures not for human habitation, infrastructure and services including local roads and railway line. The inundation zone is typically undeveloped or predominantly rural or agricultural, or it is managed so that the land usage is for transient activities such as with day-use facilities. Minimal damage to residential, commercial, and industrial areas, or land identified as designated growth areas as shown in official plans.	Moderate loss or deterioration of fish and/or wildlife habitat with moderate capability of natural restoration resulting in a low likelihood of negatively affecting the status of the population.	Irreversible damage to local designated cultural heritage sites.

Column 1	Column 2	Column 3	Column 4	Column 34
Hazard Categories – Incremental Losses				
Hazard Potential	Life Safety	Property Losses	Environmental Losses	Cultural – Built Heritage Losses
High	Potential Incremental Loss of Life of 1-10 Persons. ³	Appreciable damage with estimated losses not to exceed 250 crore rupees agricultural, forestry, mineral aggregate and mining, other dams or residential, commercial, industrial areas, infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes regional roads, railway lines, or municipal water and wastewater treatment facilities and publicly-owned utilities.	Appreciable loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with reasonable likelihood of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels. Loss of a portion of the population of a species classified under regional guidelines on the protection of species extirpated, threatened or endangered, or reversible damage to the habitat of that species.	Irreversible damage to nationally designated or recognized cultural heritage sites.
Very High	Potential incremental loss of life of 11 to 100 persons. ³	Appreciable damage with estimated losses not to exceed 1,000 crore rupees. Typically includes destruction of, or extensive damage to, large residential, institutional, concentrated commercial and industrial areas and major infrastructure and services, or land identified as designated growth areas as shown in official plans. Infrastructure and services includes highways, railway lines or municipal water and wastewater treatment facilities and publicly-owned utilities.	Extensive loss of fish and/ or wildlife habitat or significant deterioration of critical fish and/ or wildlife habitat with very little or no feasibility of being able to apply natural or assisted recovery activities to promote species recovery to viable population levels.	
Extreme	Potential incremental loss of life of more than persons. ³	Damages of more than 1,000 crore rupees. Typically includes extreme losses to critical infrastructure including hospitals, major industrial complexes, storage facilities containing hazardous waste, etc.	Loss of a <u>viable</u> portion of the population of a species classified under Nepal legislation referent to endangered species or CITES or irreversible damage to the habitat of that species.	

1. There is no identifiable population at risk.
2. People are only occasionally and irregularly in the dam-breach inundation zone, for example stopping temporarily, passing through on transportation routes or participating in recreational activities.

3. The population at risk is ordinarily or regularly located in the dam-breach inundation zone, whether to live, work or recreate.

Schedule 2

(sections 3 (2), 8 (4), 9 (7) and (8), 10 (4), 18, 19 (1) and 20 (1))

Minimum Frequency of Safety Activities

Interpretation of Schedule

1 - In this Schedule:

"**annually**" means once in each calendar year;

"**dam safety review**" means a review carried out by an engineering professional under section 20 [*dam safety review and report*];

"**DEP**" means the emergency plan for a dam;

"**DSO**" means a director of dam safety;

"**monthly**" means once in each calendar month;

"**OMS manual**" means the operation, maintenance and surveillance manual for a dam;

"**quarterly**" means once in each calendar quarter;

"**semi-annually**" means once in the period between January 1 and June 30 and once in the period between July 1 and December 31 of each calendar year.

Frequency of Activities

2 - (1) Column 1 of the table sets out an activity that must be carried out by an owner of a dam under Part 2 [*Requirements Applicable to All Dams*] or 3 [*Requirements Applicable to Certain Dams*], as indicated in the table, and column 2, 3, 4, 5 or 6 of the table sets out the minimum frequency with which the activity must be carried out for each classification.

(2) If the minimum frequency with which an activity referred to in column 1 of the table must be carried out under subsection (1) is every 7 years or every 10 years, the minimum frequency is once in the period between the date on which the activity was previously carried out and December 31 of the calendar year

that is 7 years or 10 years after the calendar year that includes the date on which the activity was previously carried out.

Item	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
	Activity	Frequency of Activity				
		Extreme Classification	Very high classification	High classification	Significant classification	Low classification
Requirements under Part 2						
1	Review classification of dam and, if necessary submit to DSO written notice of proposed new classification	annually	annually	annually	annually	annually
Requirements under Part 3						
2	conduct site surveillance	weekly unless otherwise specified in the OMS manual	weekly unless otherwise specified in the OMS manual	weekly unless otherwise specified in the OMS manual	monthly unless otherwise specified in the OMS manual	quarterly
3	conduct formal inspection	semi-annually	annually	annually	annually	annually
4	test operation of (a) mechanical components of dam, and (b) electrical and communication equipment	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually
5	collect readings from instrumentation and analyze and interpret the readings	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	annually unless otherwise specified in the OMS manual	if required by a director of dam safety
6	review contact information in DEP, revise if necessary and report to DSO	annually	annually	annually	annually	not applicable
7	review emergency contact information and, if necessary, revise and submit revision to DSO	not applicable	not applicable	not applicable	not applicable	annually
8	review OMS manual and DEP, revise if necessary and report to DSO	every 7 years	every 7 years	every 10 years	every 10 years	not applicable

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Item	Activity	Frequency of Activity				
		Extreme Classification	Very high classification	High classification	Significant classification	Low classification
9	ensure dam safety review carried out and submit report to DSO	every 7 years	every 10 years	every 10 years	not applicable	not applicable

[Provisions relevant to the enactment of this regulation: [Water Sustainability Act](#), S.B.C. 2014, c. 15, sections 124, 126, 127, 129, 130 and 131]

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