Special Session organized by French and Swiss National Committee and the World Bank : 8:30 am – 12:00 pm Tuesday, May 31, 2022

On Recent Dam Safety Related Publications and Activities by the World Bank

Agenda No. 1 - Presentation on the Good Practice Note on Dam Safety

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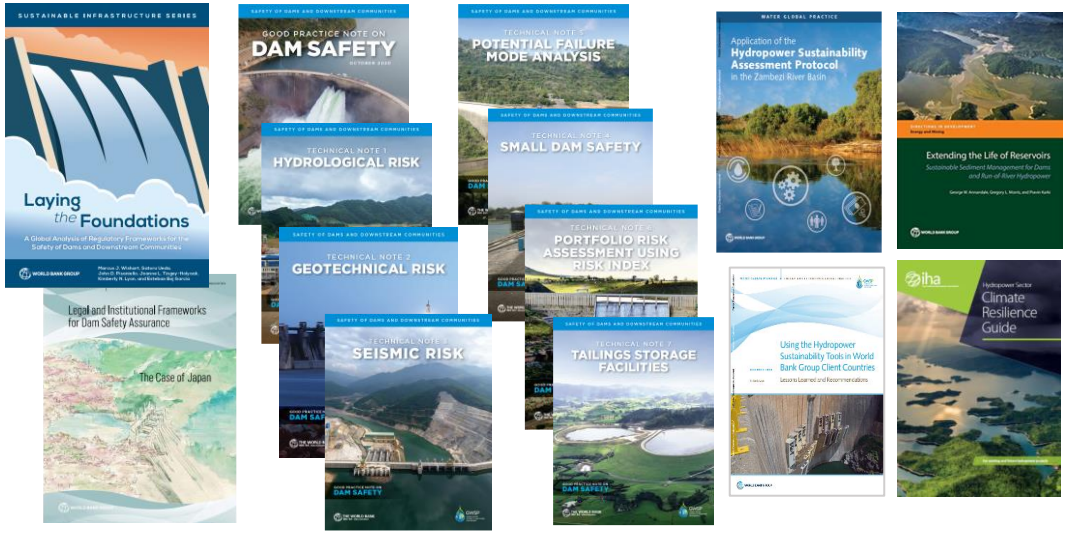
Presentation Outline

1. Dam Safety Program Overview
2. Dam-related Projects Portfolio and Examples
3. OP4.37 and ESF for Dam Safety
4. ESF Good Practice Note (GPN) on Dam Safety and Technical Notes

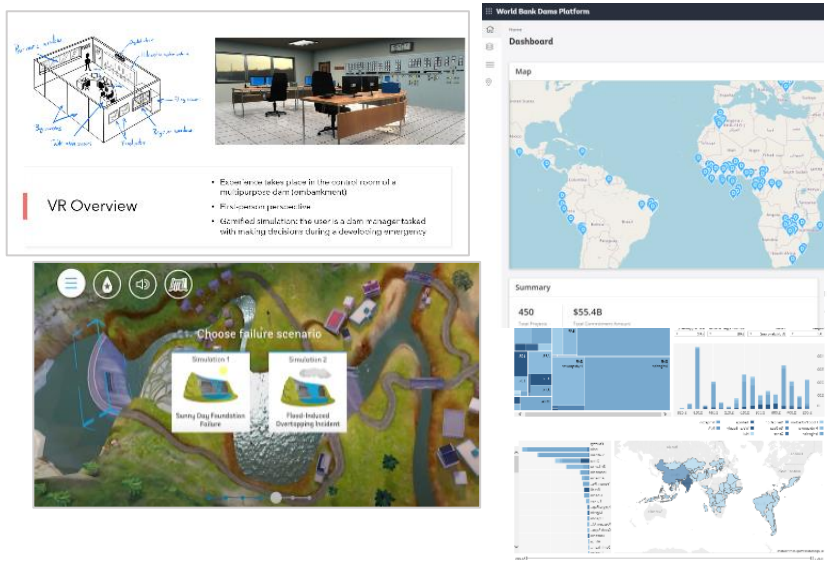
Global Program for Enhancing Resilience & Safety of Dams and Downstream Communities

Analytics and Technical Guidance



Trainings

Digital Innovation and Databases



Partnerships

CIGB ICOLD

iha international hydropower association

ICH harmonisation for better health

GWSP GLOBAL WATER SECURITY & SANITATION PARTNERSHIP

GFDRR Global Facility for Disaster Reduction and Recovery

Regional & Countries

National Dam Safety Programs

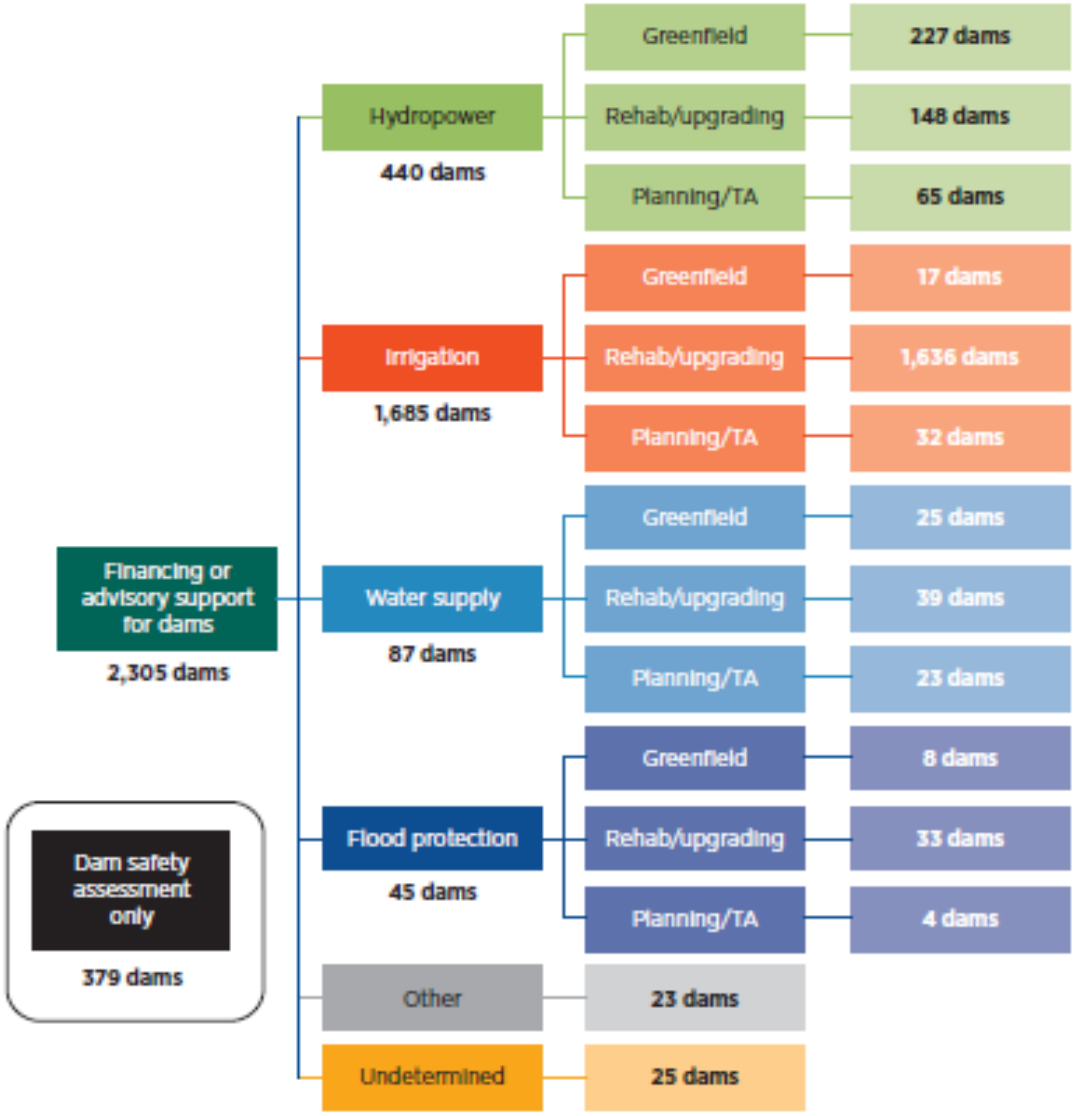
Technical Support and Quality Assurance

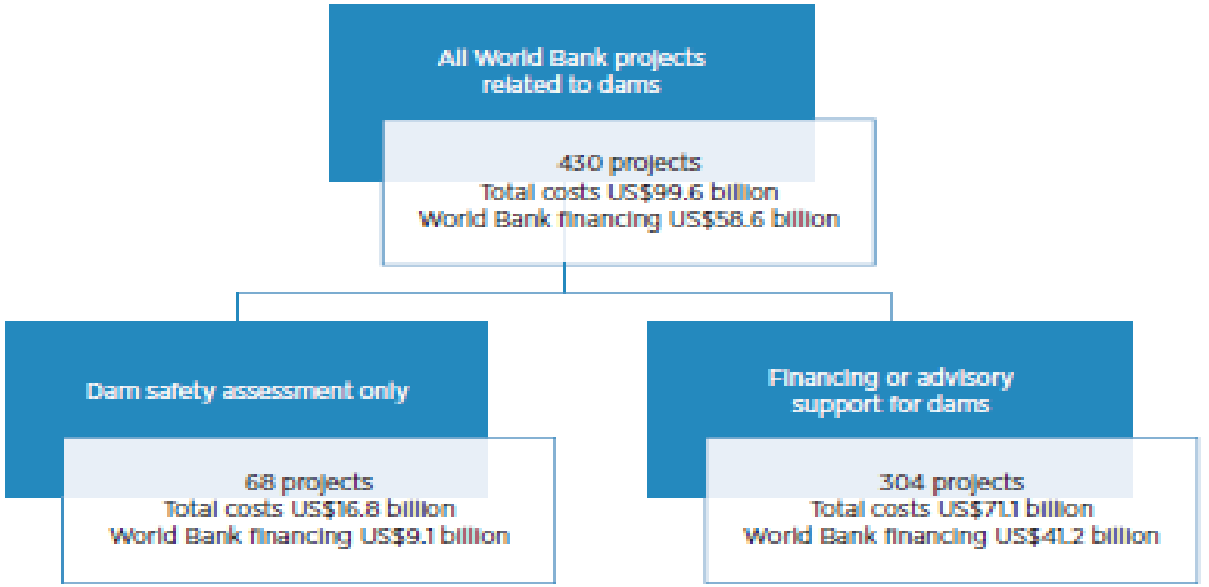
Stand-Alone Dam and Reservoir Projects

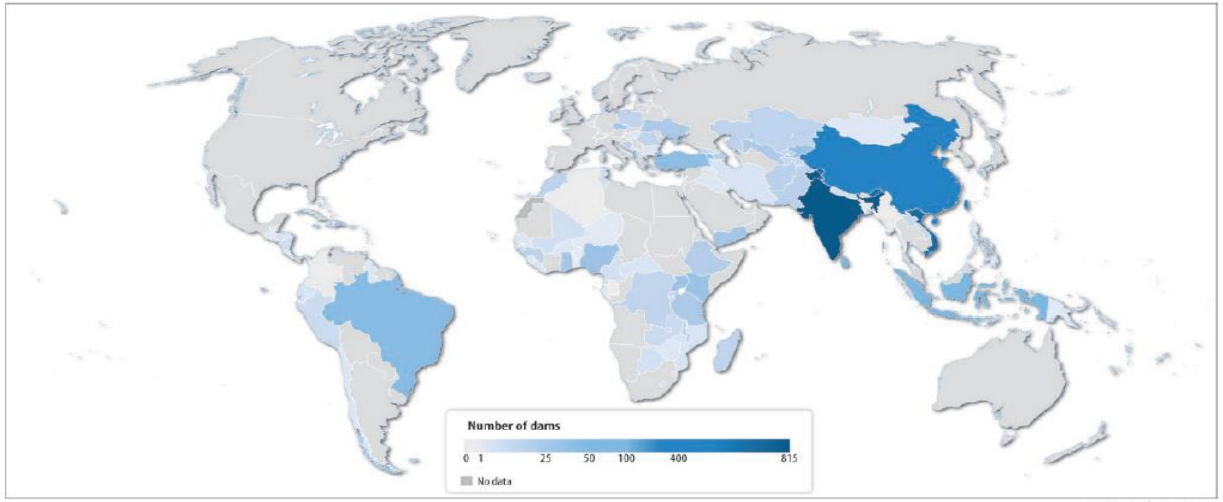
Technical Assistance Advisory Services and Analytical Work

WB Financing for Assuring the Safety of Dams and Downstream Communities

Small and Large Dams supported under WB funded projects in FY 02-FY19







New Dams Construction Examples

1. Water Supply and Multipurpose Dams

- Wuxikou (Flood control and hydropower, China)
- Plovdivtsi (Water Supply, Rudozem, etc. Bulgaria)
- Metolong (Water supply for Maseru, Lesotho)
- Mwache (Water supply for Mombasa, Kenya)

2. Hydropower Dams

- Nam Theun 2 (hydropower, Lao PDR)
- Trung Son (260 MW, Vietnam)
- Lom Pangar (30 MW + power generation increase of 9 downstream cascade plants by flow regulation, Cameroon)
- Rusumo Falls (80 MW, Rwanda, Burundi and Tanzania)
- Dasu (1st phase: 2,160 MW, and 2nd phase: 4,300 MW, Pakistan)
- Nachtigal (Hydropower, Cameroon)

3. New Dams Design & Environment Impact Assessment

- Upper Arun (335 MW, Nepal)
- Matenggeng pump storage (1,000 MW, Indonesia)

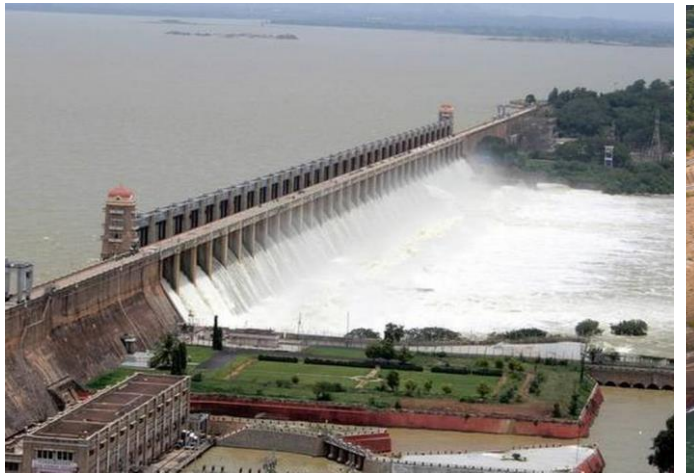
Existing Dams Rehabilitation/Upgrade Examples

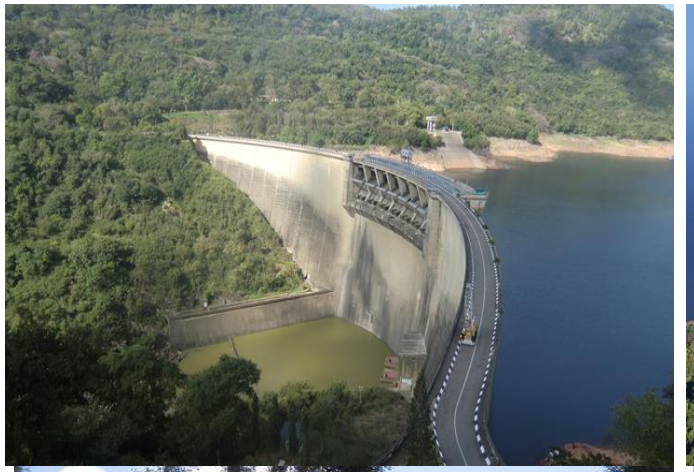
<u>National /Sub-National Dam Safety and Rehabilitation</u>

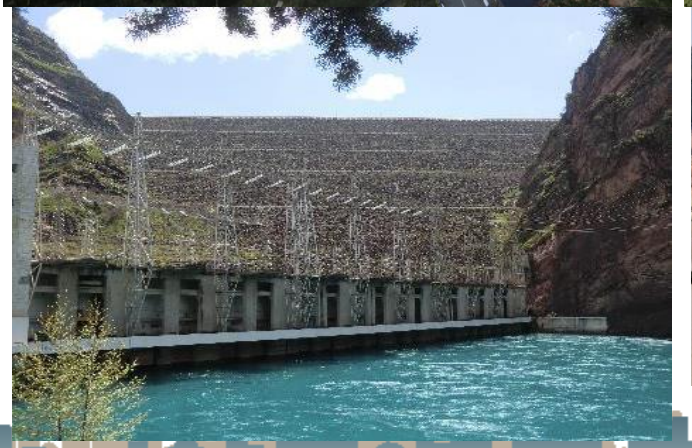
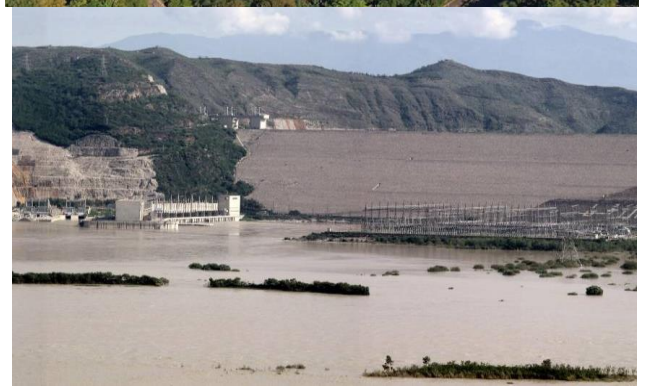
- e.g. India (Hirakud, etc.), Indonesia (Jatilhur, etc.), Sri Lanka (Victoria, etc.), Vietnam, Armenia, etc.
  - Inventory of existing dams
  - Dam safety assessment and risk / hazard classification
  - Rehabilitation / upgrade of priority existing dams
  - Advanced hydro-meteorological monitoring, flood forecasting system and optimized reservoir operation procedure
  - Emergency Preparedness Plan and downstream warning systems

<u>Single / Multiple Dams - Targeted Refurbishment, Augmentation, and Safety Measures</u>

- e.g. Kariba (Zambia/Zimbabwe), 7 Dnipro/ Dnister Rivers cascade dams (Ukraine), Nurek (Tajikistan), 3 Drin River cascade dams (Albania), Corumana (Mozambique), Tarbela (Pakistan), etc.
  - Electrical- Mechanical system refurbishment, upgrade and augmentation
  - Instrumentation upgrade
  - Spillway, outlet works, stilling basin, etc.

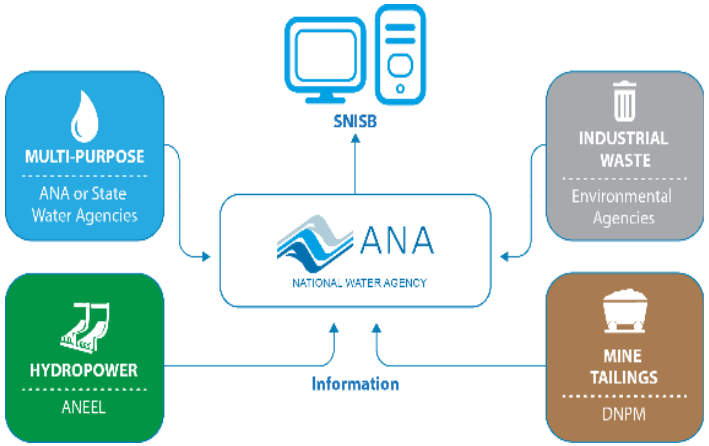




Technical Assistance and Capacity Building

- Basin-wide and regional water resources development potential assessment as well as future dams feasibility, detailed design, and environmental impact assessment: e.g. Zambezi River, Nile Basins, Kenya national and coastal region water resources assessment, etc.
- Dam Safety TA: Brazil, Nepal, Laos, Nile Basin, etc.
  - Institutional & Regulatory Framework Review
  - Inventory establishment of existing dams
  - Dams classification system review / preparation
  - Establishment of national information system for dam safety
  - Manuals/guidelines for regulators and owners
  - Technical workshops and capacity building program, etc.



- Dam Safety, Sediment Management, and other Technical Workshops (standalone or linked with lending operations): India, Indonesia, Laos, Myanmar, Sri Lanka, China, Vietnam, Bulgaria, Uruguay, etc.
- Environmental & Social safeguards, Hydropower Sustainability Assessment Protocol, etc. workshops (various places for pilots)

Overview of WB Dam Safety Requirements

- The borrower will engage experienced and competent professionals for the design and construction supervision of new dams and require the owner of the dam to adopt and implement dam safety measures during the design, bid tendering, construction, operation and maintenance of the dam and associated structures.

- For large “new” dams, the Bank requires (Para 3 ESF/ESS4):

    a) reviews by an independent **Panel of Experts** of the investigation, design, construction and start-up phases

    b) preparation and implementation of **Dam Safety Plans**

    c) prequalification of bidders during procurement and bid tendering

    d) periodic safety inspections of the dam after completion

- Small “risky” dams are also subject to these dam safety requirements

- For existing dams that require additional dam safety or remedial measures, the borrower will require that a) the dam is designed, and its construction is supervised by competent professionals and b) the dam safety plans are prepared and implemented. Furthermore, for high hazard cases involving significant and complex remedial work, a POE is also required on the basis as for a new dam

Note: ESF (Environmental & Social Framework) and ESS4 (Environmental & Social Standard 4): Community Health & Safety

Evolution of Dam Safety Policies

Note: BP = Bank Procedure; ESS = Environmental and Social Standard; OMS = operational manual statement; OP = Operational Policy.

- Older WB projects involving dams are subject to OP/BP 4.37 on Safety of Dams.
- New projects are subject to ESS4 Community Health and Safety, Annex 1 on Safety of Dams.

  (Older projects: PCN before October 1, 2018)

Three major modifications have been introduced under the provisions of the ESS4 from OP/BP4.37. These include:

1. Lowering the threshold for "**large**" dams with a reservoir capacity greater than 3 million m^3 **from 10 m to 5 m** in height;
2. All other dams regardless of size or retention capacity (referred to as "**small** dams") that could cause **safety risks** are subject to dam safety requirements;
3. The application of dam safety requirements should be **proportionate** to the size, complexity and potential risk of the dam. (Annex 1 Para 4)

Good Practice Note (GPN) on Dam Safety under the ESF and ESS4 – Community Health & Safety

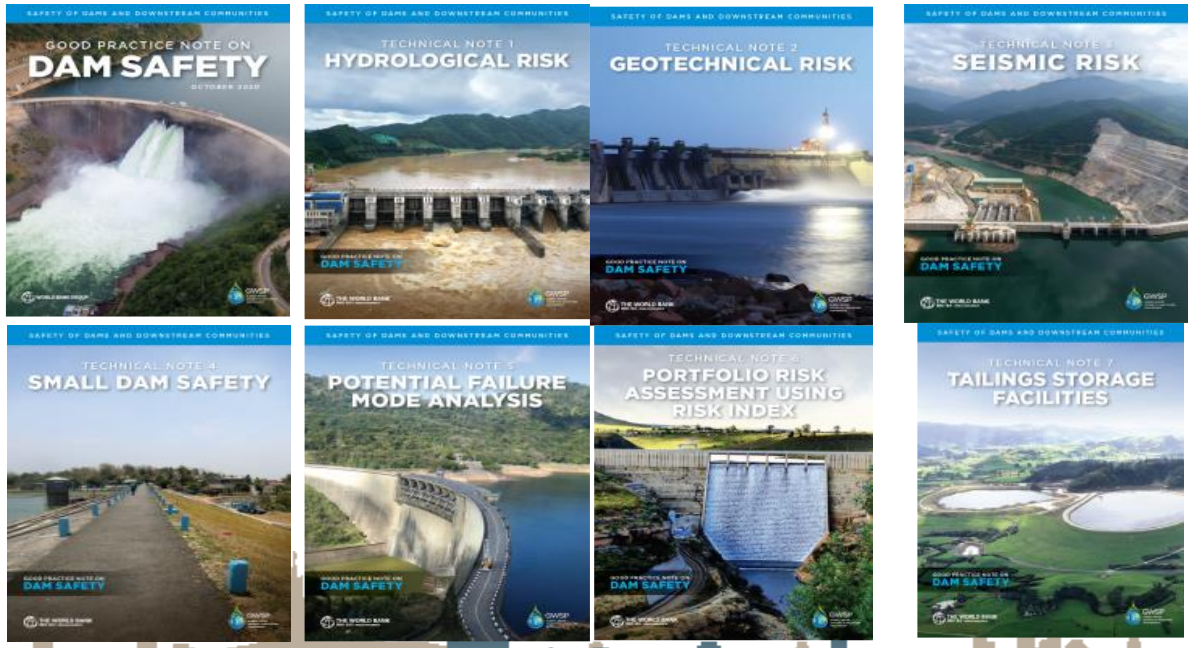
GPN on Dam Safety	a) Objective and background of the Notes b) Dam safety requirements c) Risk management approach and tools d) Application to Bank operations e) Procedural aspects & Key Steps ➢ Dam safety plans, Prequalification, Independent review, Technical assistance f) Relation to other parts of ESF
Technical Notes (TNs)	• Hydrologic Risk • Geotechnical Risk • Seismic Risk • Small Dam Safety • Potential Failure Modes Analysis • Portfolio Risk Assessment with Risk Index • Tailing Storage Facilities Safety
Annexes	Annexes of GPN / TNs including Essential References
6 Appendixes	4 Sample Dam Safety Plans, TORs for POE, and independent safety assessment of existing dams

What it is:

- Guide to task teams to support borrower implementation of ESS4/Annex 1 on Dam Safety
- Reference on good practice for dam safety and risk management approach
- Based on the principle of proportionality, a tiered approach

What it is not:

- A general guide on the Environmental & Social management of dams
- A how-to guide on dam design, construction, rehabilitation or operation
- A set of one-size fits all requirements



Guidance on the application of the ESF dam safety requirements in Bank operations

	New dam or Dam Under Construction (DUC)	Rehabilitation of Existing Dam	Project that relies or may rely on the performance of one or more existing dams and /or DUCs
a)	Reviews by an independent Panel of Experts of the investigation, design, and construction of the dam until completion of dam performance review after first reservoir filling. (See Appendix 5 for a sample TORs.)	Borrower assesses whether the dam has the potential of significant impacts downstream OR it exhibits complex technical features (substantial/high risk). One or more dam specialists may be needed to carry out the assessment including on needed rehabilitation/ safety improvement measures. A Potential Failure Mode Analysis (PFMA) conducted by an individual consultant, or a consulting firm may be necessary, depending on the above findings. High risk dam which would involve complex and significant remedial works would require reviews by POE.	Reviews Borrower's assessment report by one or more independent dam specialists on conditions of the existing dams or DUC and dam safety management system. One or more independent dam specialists may be needed to carry out the assessment of the dam's safety condition and O&M procedures, including any remedial and safety improvement measures to an acceptable standard of safety (See the para after this table and Appendix 6 for a sample TORs) . The needs of POE would be reviewed case-by-case. A Potential Failure Mode Analysis (PFMA), conducted by an individual consultant, or a consulting firm may be necessary, depending on the above findings.
b)	Preparation and implementation of the following detailed plans (Dam Safety Plans): 6 (i) Plan for Construction Supervision and Quality Assurance (ii) Instrumentation Plan, (iii) Operation and Maintenance Plan, and (iv) Emergency Preparedness Plan (EPP) (See Appendixes 1-4 for sample frameworks for the four Dam Safety Plans.)	For projects that include additional dam safety measures or require remedial works, detailed Dam Safety Plans (b (i) to b (iv)) are updated or prepared if not in place. The scope and depth of such plans should be commensurate with the works and site condition. For high and substantial risk dam OR presence of complex technical features: same provisions as "Bank financing New dam or DUC" (including independent panel of experts). Implement needed measures identified in the PFMA. Low/moderate risk dam AND absence of complex technical features: (i) Qualified engineers are involved in design and supervision of rehabilitation works. (ii) DS plans (b (i) to b (iv)) are updated or prepared if not in place.	Rehabilitation measures required: same provisions as "Bank financing rehabilitation of existing dam." No rehabilitation measures required but borrower's dam safety management system not satisfactory to the Bank: update or prepare and implement DS plans (b (ii) to b (iv)) and provide related training to dam operators.
c)	Prequalification of bidders during procurement and bid tendering	Prequalification of bidders may not be required unless the project involves substantial and complex remedial works.	If rehabilitation measures are required, suitable quality control mechanism is to be arranged.
d)	Periodic safety inspections after completion, and implementation of measures required to address safety deficiencies. Periodic safety inspection	Periodic safety inspection procedures are defined in the Operation & Maintenance Plan.	Periodic safety inspection procedures are defined in the Operation & Maintenance Plan.

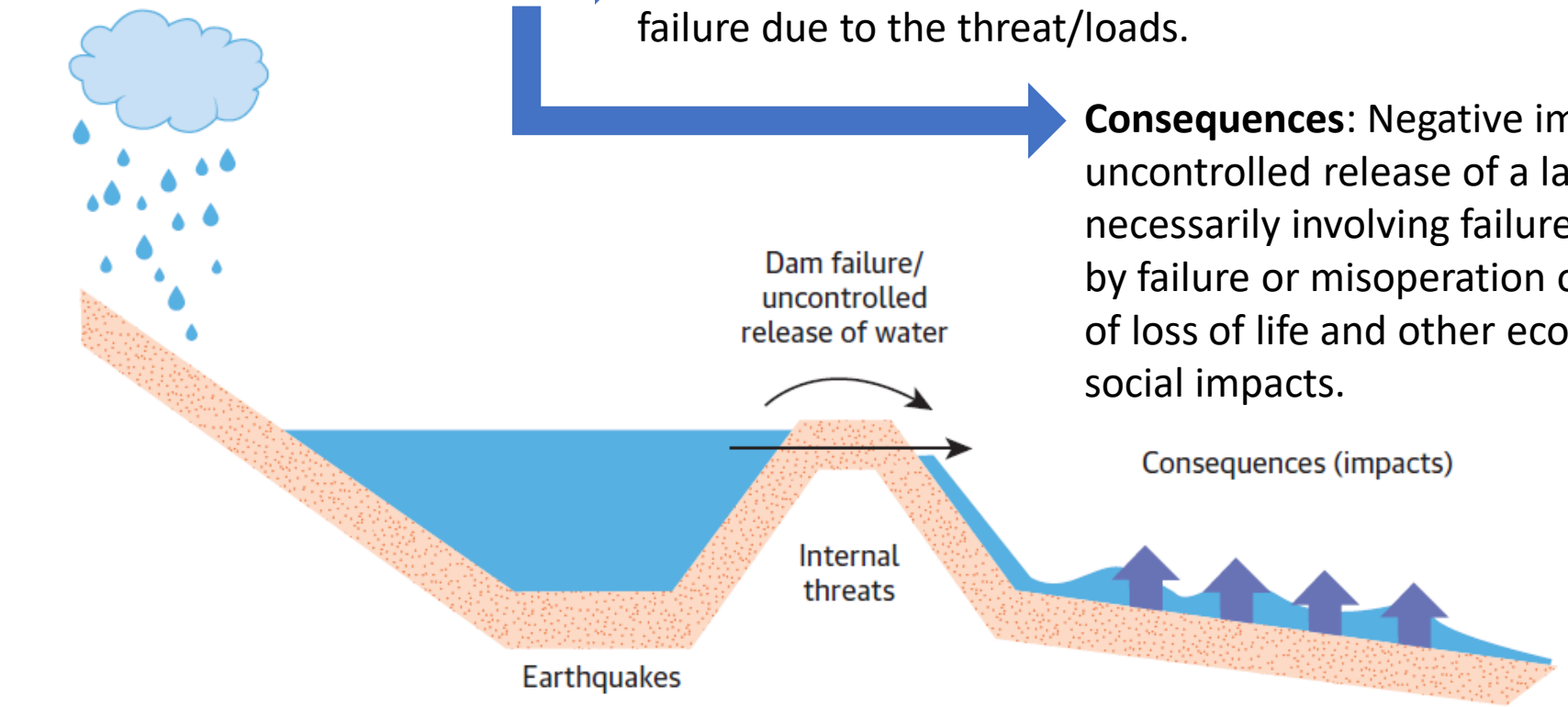
Source: GPN Table 3.1

A Risk-Management Approach to Dam Safety: Risk, Likelihood of Failure, and Consequences of Failure

Risk: Product of likelihood of dam failure and the consequences of subsequent flooding.

Probability of occurrence of the threat and loads (e.g. storm, earthquake, etc.)
Probability of the dam structure/reservoir performance or response leading to dam failure due to the threat/loads.

Consequences: Negative impacts resulting from uncontrolled release of a large amount of water (not necessarily involving failure of the dam body but caused by failure or misoperation of spillway gates, etc.) in terms of loss of life and other economic, environmental and social impacts.



Source: GPN, Fig 4.1: Adapted from Environment Agency. 2013. *Guide to Risk Assessment for Reservoir Safety Management – Volume 1.* Bristol, U.K.: Environment Agency.

Risk Management Approach to Dam Safety

- Risk management approaches are increasingly being used to inform dam safety assurance, which is likely the result of increased stock of aging dams around the world and more frequent dam safety incidents due to nonstructural and contextual causes that are not well-captured by traditional standard-based approach.
- Risk management approaches to dam safety assurance typically include the following process: a) risk analyses, b) risk assessments, c) decision making for risk control and reduction measures, and d) monitoring and evaluation, including robust feedback loop.
- Robust operation and maintenance mechanism should be established and maintained to keep effective risk management system in place throughout the life cycle of the project.
- Risk is not static but will change depending on the condition of the dam and during the project life. Consequences of dam failure and subsequent flooding can also change for various reasons, such as population growth and asset development in the downstream areas.

Risk Analysis Tools

Type of tools	Risk content	Applicability to World Bank operations
Standard-based	Risk is not explicit in design. This is the traditional approach to dam engineering, whereby risks are controlled by following established rules with varying degrees of conservatism as to design events and loads, structural capacity, safety coefficients, and defensive design measures.	Traditionally done. At the base of design criteria (hydrological, seismic safety, and so on) and compliance requirements (for example, panel of experts, dam safety management plans, prequalification of bidders, and so on).
Risk-based	Increasingly used, particularly for assessing safety of existing dams to identify higher-risk dams and prioritizing the most critical and effective remedies.	Applies to all World Bank-financed projects involving dams in a proportionate manner to size, complexity, and potential risks.
- **Qualitative methods**	Risk is explicit, but no mathematical characterization (no probabilities of failure). Risk index is the simplest method in this group and useful in risk assessment of a large portfolio of dams. It can inform decisions on monitoring and surveillance programs, prioritizing more detailed studies, and dam safety improvements.	Qualitative methods have been mostly used in World Bank operations, and it is expected that they will continue to be the main resource tool.
- **Quantitative methods**	Fully risk-based. Analysis is based on numerical values of the potential failure mode's likelihood and consequences, the intention being that such values are a valid representation of the actual magnitude of the consequences and the probability of the various failure modes/scenarios, which are examined.	Expected to be occasionally needed in World Bank operations when complicated or substantial remedial works are involved. Those cases would require specialized input in terms of both the data and expertise.

Source: GPN, Table 5.1

Tiered Approach for Risk Analyses/Assessments

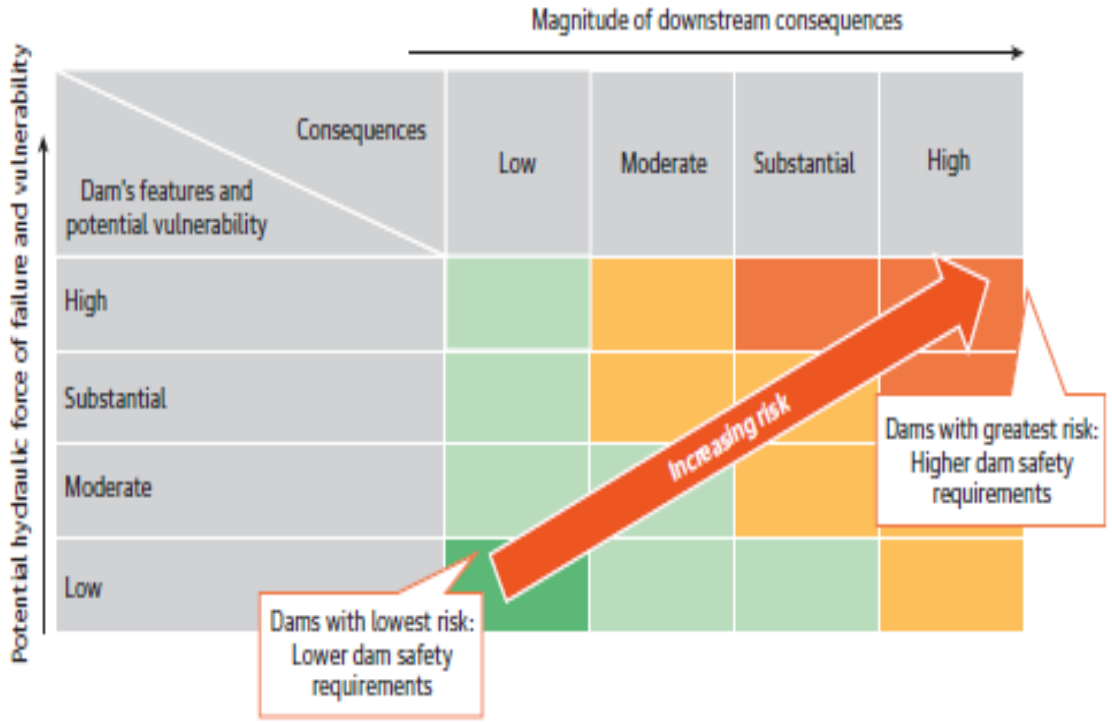
Tier	Guidance	Tools
1st Tier (essential for all dams)	Preliminary Consequence Assessment with simplified flooding maps	Preliminary assessment of i) Population at Risk (PAR); ii) Economic Impact, and iii) Environmental / Social Impact
	Preliminary Risk Classification	New dams: Classification of Dams Risk by national dams' classification or adapting international/regional references adapting to local contexts and Existing dams: Dam Safety Assessment
2nd Tier (moderate – high risk dams)	Dam Break and Downstream Flooding Impact Assessment for Consequence Assessment and Emergency Preparedness Plan (EPP)	Topography/land use maps, dam break scenarios/parameters, flooding model/mapping (water depth, velocity, timing, etc.)
	Qualitative Risk Assessment using Simplified Potential Failure Mode Analysis (PFMA), etc.	Identification / assessment of credible failure scenarios, and priority mitigation measures. Failure modes are identified by an experienced professional, in consultation with dam operator/ designers.
	Portfolio Risk Assessment (PRA) & Portfolio Risk Management (PRM) using Risk Index	PRA /PRM using Risk Index (e.g. vulnerability, consequences, etc.), i.e. a basic tool for risk profiling of portfolio dams and raking of priority remedial measures.
3rd Tier (high risk dams involving complex remedial works)	Detailed Consequence Assessment	Potential Loss of Life (PLL) considering the effectiveness of warning and emergency evacuation, etc. (e.g. Life-Safety Model)
	Potential Failure Mode Analysis (PFMA)	Potential Failure Mode Analysis (PFMA) can evolve quantitatively by adding probability assessments.
	Semi-Quantitative and Quantitative Risk Assessment	Failure modes sequence assessment and probability estimation by event or fault tree analysis, etc. Other quantitative risk assessment models using event tree analysis are also available.

Source: GPN, Figure 7.1

Risk Classification For New Dams

- Review the national laws, regulations or guidelines relating to dam safety, as countries have developed different classification systems depending on their economic, environmental, and social conditions. Criteria are generally geometrical parameters and/or incremental consequences in case of dam failure.
- If there are no national dam classification systems, the ICOLD Bulletin 72 proposes a simple risk classification using four parameters. Any such estimates should be contextualized within the economic, social, geographical conditions of the country. In particular, the downstream consequence factors should be put in the appropriate country /regional context.
- The dam safety standards and requirements should be developed in accordance with dam class in a tailored manner to each country's context.

Typical Risk Classification System for New Dams

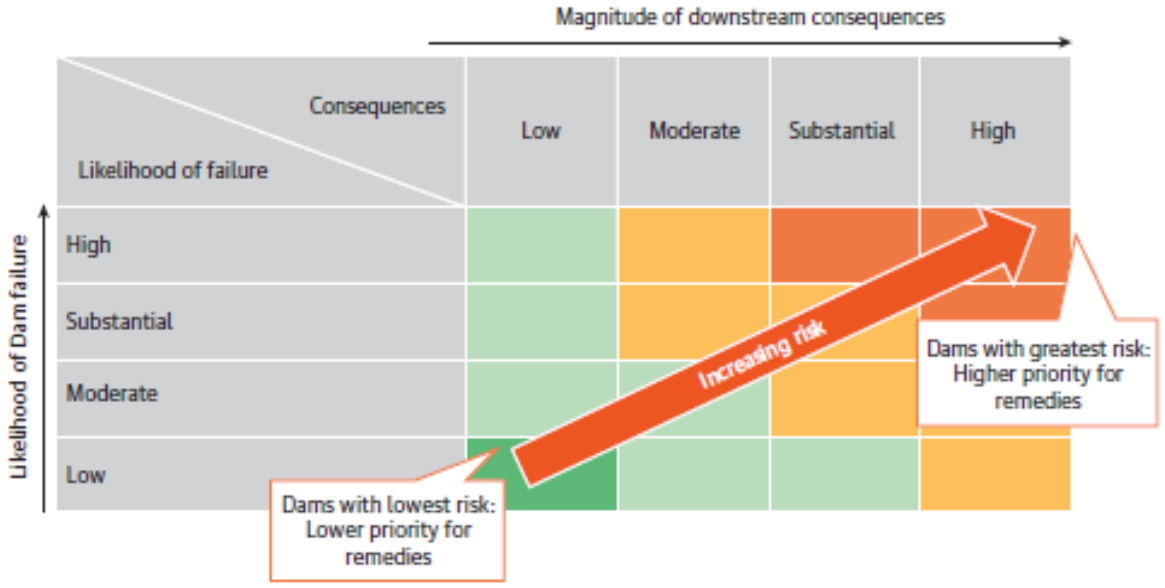


isk	Hydrological Safety Level	Seismic Safety Level	Dam Safety Review Panel	Dam Safety Plans	Supervision	Compliance Monitoring
ow	200 year	500 year	National or regional experts	Basic	Basic	Basic
Moderate	200 – 1,000 year	500 – 1,000 year	Regional or international experts	Full	Regular	Regular
ubstantial	1,000 – 10,000 year	2,500 year	Experienced international experts	Elaborate	Intensive	Intensive
ligh	10,000 year - PMF	10,000 year or MCE	Highly experienced international experts	Highly Elaborate	Highly Intensive	Highly Intensive

Risk Classification For Existing Dams

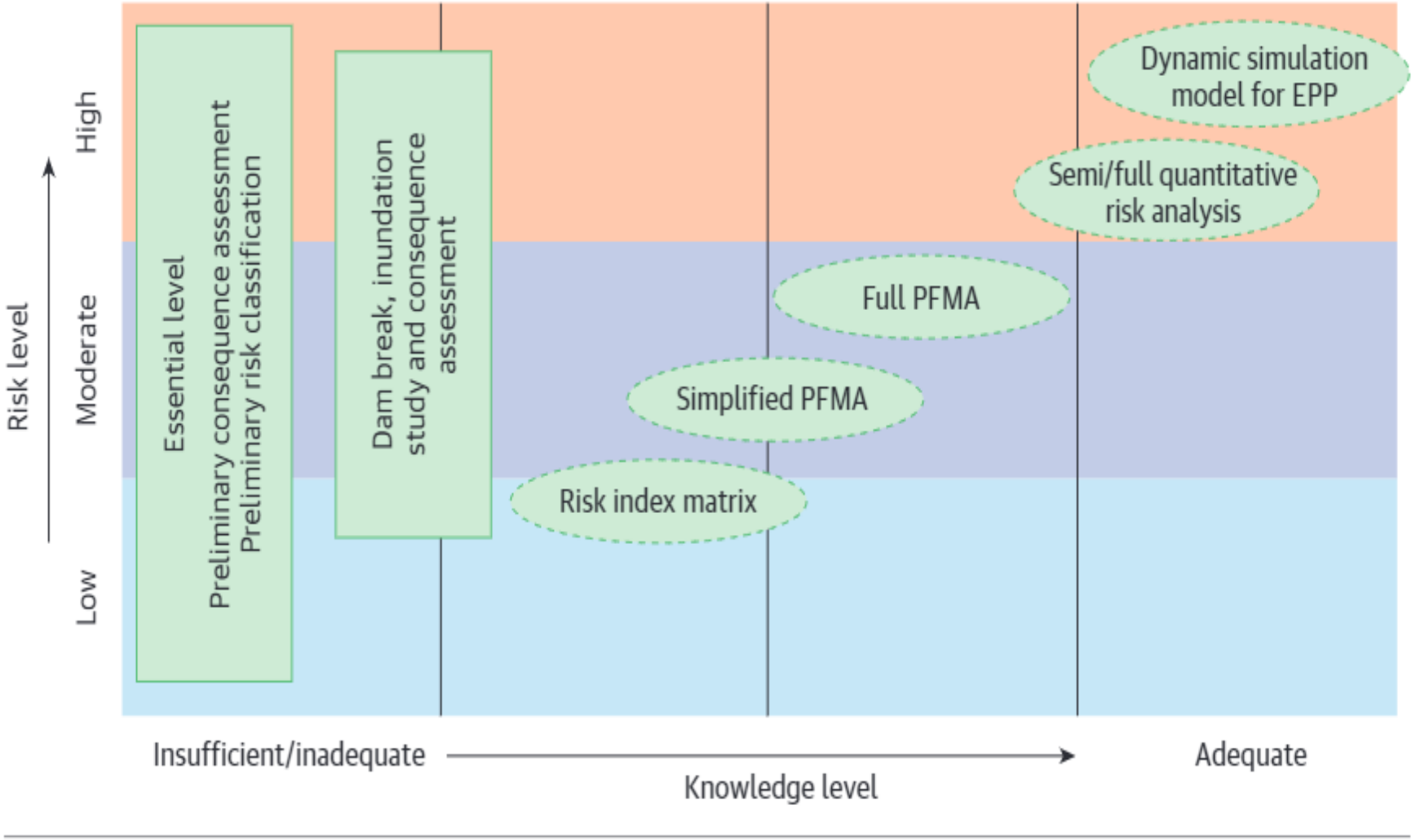
- The required dam safety measures should be defined with due consideration to the dam safety risk, i.e. product of “likelihood of dam failure” and “consequence of dam failure”.
- The level of “likelihood of dam failure” is based on the dam safety assessment preferably with identified “potential failure modes”.
- Borrower is required to hire one or more independent dam specialists / experts for dam safety assessment.
- The required level of dam safety requirements should be determined considering risk classification.

Typical Risk Classification System for Existing Dams



Risk	Dam Safety Assessment	Safety Measures & Remedies	Dam Safety Review Panel	Dam Safety Plans	Supervision	Compliance monitoring
Low	Basic	Regular O&M	Not necessary	Basic	Basic	Basic
Moderate	Detailed	Enhanced monitoring	One expert on specific technical issues	Full	Regular	Regular
Substantial	Qualitative /Semi-Quantitative	Urgent remedial works	More than one expert depending on specific technical issues	Elaborate	Intensive	Intensive
High	Advanced / Full Quantitative	Immediate remedial works	Full-fledged panel required	Elaborate	Intensive	Intensive

Risk Assessment – Concept of Proportionality & Tiered Approach



Note: EPP = Emergency Preparedness Plan; PFMA = potential failure mode analysis.

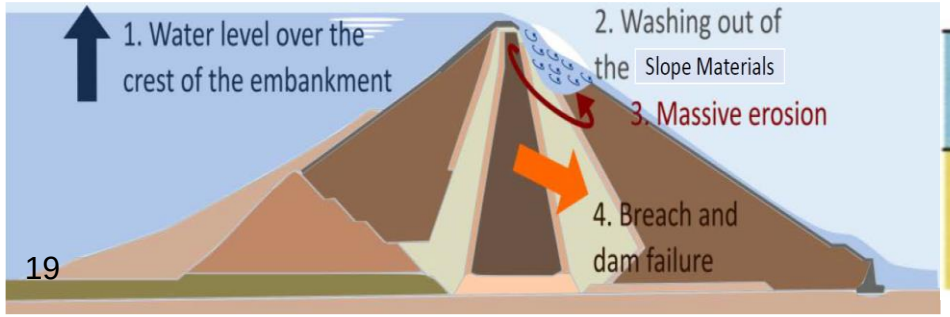
- The required level of risk analysis is recommended considering two key elements: i) Risk Level, and ii) Knowledge Level
- As tools become more detailed, the level of knowledge must increase.
- It is thus necessary to provide support for improving the level of knowledge, information, and capacity.
- The scope of any analysis needs to be fit for purpose and informed by the context and decision-making needs.

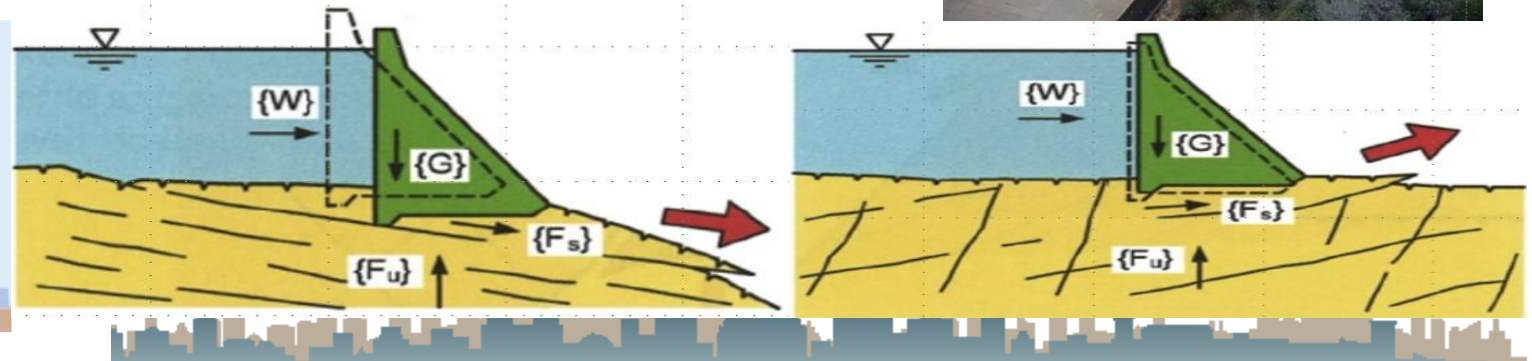
Source: GPN, Figure 6.1

Failure Modes and Consequence Assessment

Potential Failure Modes Analyses

Embankment Dams (earth fill, rockfill, zoned)	Concrete Dams (solid gravity, buttress, arch gravity, arch)
• Flood overtopping (inadequate spillway capacity or malfunctioning of spillway gates)	• Foundation failure (sliding on weak plane, compression failure in high stress zone, undermining by uncontrolled overflow)
• Internal erosion	• Sliding on weak plane or tension crack in dam body
• Slope stability (static)	• Overturning from uplift (foundation or tension crack)
• Slope stability (seismic)	• Spillway issue leading to inability to discharge
• Foundation failure	• Overtopping leading to erosion and loss of support
	• Earthquake shaking or fault movement





Consequence Assessment

- Risk= likelihood of failure * consequences
- Consequences: people, economic assets, and environment
- Dam break analyses and flooding simulation with reliable topo map / digital elevation model

Reservoir storage	Total distance downstream to route dam break flood
>2 million m^3	60 km or greater
0.2–2 million m^3	20 km or greater
<0.2 million m^3	5 km or greater

Australian National Committee on Large Dams (ANCOLD) (2012). Guidelines on the Consequence Categories for Dams.

	Difficulty Level	Sources of Information
How many people downstream?		Maps and census; start with ballpark figures
How far downstream?		Inundation maps (where available); Inundation studies at different Tiers
How many people at risk or potential loss of life?		Flooding hydraulics: Velocity and Depth. Urban/rural areas
Important economic assets at risk downstream?		Local authorities
Valuable environmental assets at risk of irreversible impacts?		Local authorities

Assessing the Capacity of the Borrower

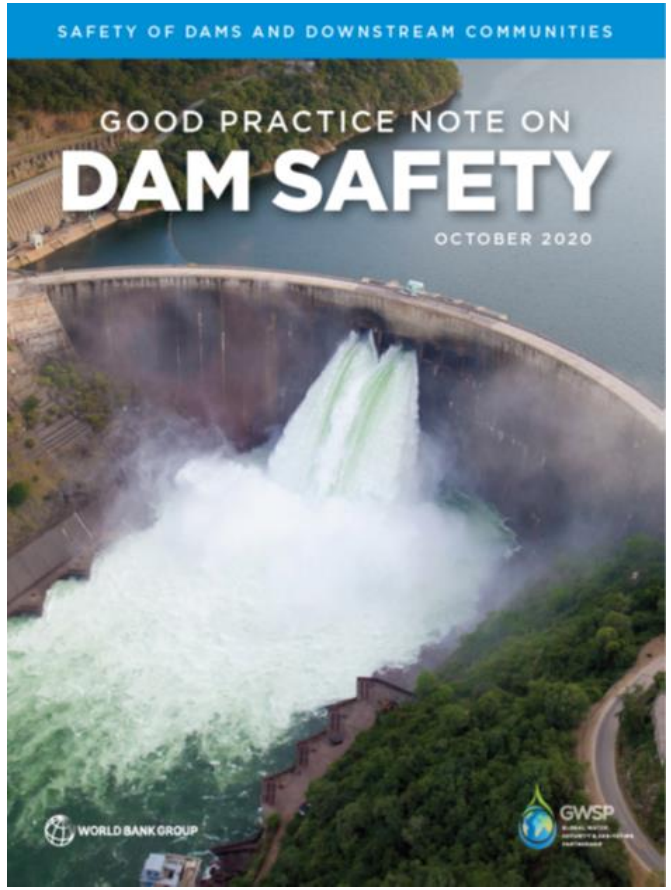
- Borrower's capacity should be assessed based on its track records of similar dams' related projects implementation and existing dams' operational and safety assurance records, etc.
- Enhanced technical support and capacity building may be required, such as an increased budget for periodic safety inspection, on the job training, more intensive Bank's supervision, compliance monitoring, etc.

Risk level	Description
Low	Borrower has a positive track record with implementation and management of dams more challenging than or similar to the project under preparation. A regulatory framework for dam safety is in place, or there is strong commitment to enhance or develop one.
Moderate	Borrower has a reasonable track record with implementation and management of dams similar to the project under preparation. Basic dam safety practice (surveillance, monitoring, inspection, record keeping, independent reviews) is satisfactory, or capacity-building programs are welcome. Borrower is committed to develop and/or enhance a framework for dam safety.
Substantial	Borrower has shown mixed performance in implementation and management of dams or limited experience only in much smaller dams than the project under preparation. Inadequate regulatory framework for dam safety in the country. Borrower intends to improve management framework/capacity.
High	Borrower has poor track record in implementation and management of dams or no experience of similar type/size of the project under preparation. No regulatory framework for dam safety in the country. Borrower has limited capacity to manage dam safety throughout the project cycle.

Source: GPN, Table 7.6

Merci beaucoup!

Good Practice Note on Dam Safety:
https://hdl.handle.net/10986/35484



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