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Dam Safety in India: IIT Madras Study Highlights Need for Site-Specific Seismic Risk Assessment and Stronger Dam Governance

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Recent Developments: IIT Madras Study and Seismic Risk

- A **2026 IIT Madras study** developed a national-scale **Probabilistic Seismic Hazard Analysis (PSHA)** framework covering **6,545 operational dams** listed in the National Register of Specified Dams, 2025, highlighting the limitations of conventional seismic zonation for assessing risks to large dams.
- The study used regional seismic-source models, ground-motion models and a **logic-tree framework** to generate site-specific seismic hazard estimates and uniform hazard response spectra for different return periods.
- Its **PSHA-based approach** enables dam sites to be prioritised according to seismic hazard potential and supports more detailed seismic evaluation of dams located in earthquake-prone regions.
- The study is significant because many existing dams were designed using earlier deterministic approaches that may not adequately incorporate updated **seismo-tectonic information, ground-motion characteristics and site-specific effects**.
- The study also developed **PSHA_India_IITM**, a graphical tool for site-specific seismic hazard assessment, uniform hazard response spectra generation and selection and scaling of ground motions.

India's Dam Landscape and Emerging Safety Risks:

Scale and Ageing Infrastructure:

- India ranks **third globally** in terms of large dams, after China and the United States; the 2025 inventory records **6,628 specified dams**, comprising **6,545 operational dams and 83 under construction**.
- **Maharashtra** has the largest number of specified dams, followed by Madhya Pradesh, Gujarat, Chhattisgarh, Rajasthan, Karnataka and Odisha.
- More than **26% of specified dams are over 50 years old**, increasing the importance of rehabilitation, instrumentation, periodic safety evaluation and adequate maintenance.
- India's dam heritage extends to **Kallanai or Grand Anicut in Tamil Nadu**, constructed in the 2nd century CE and still functioning as a major hydraulic structure.

Major Causes of Dam Failure:

- **Poor maintenance:** Deferred repairs, deterioration and inadequate operation and maintenance can weaken structural and hydraulic safety.
- **Design deficiencies:** Older dams may not fully reflect present-day hydrological, seismic or engineering knowledge, requiring reassessment against updated design standards.
- **Extreme natural events:** Earthquakes, extreme rainfall, floods and other hazards can impose stresses beyond the assumptions used during original design.

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- **Overtopping:** Excessive inflows can exceed reservoir or spillway capacity, allowing water to flow over the dam and potentially cause erosion and breaching.
- **Inadequate monitoring:** Weak surveillance and insufficient instrumentation can delay detection of seepage, deformation, cracking or other distress.
- **Sedimentation:** Reservoir siltation reduces effective storage and can alter flood-management capacity, increasing operational and safety challenges.
- The Central Water Commission records **breaching and overtopping** among the major causes of historical dam failures in India, with breaching accounting for about **44%** and overtopping about **25%** of recorded cases in its cited dataset.

Why Dam Safety Is a Major Governance and Disaster-Management Concern:

Ageing and Structural Vulnerability:

- Age alone does not automatically make a dam unsafe; the **quality of maintenance, structural integrity, safety instrumentation and operational practices** determine its continuing safety.
- Many older dams face structural deficiencies, inadequate monitoring facilities and design assumptions that may not correspond to present hydrological and seismic conditions.
- Dam safety therefore requires a shift from one-time construction-based assessment towards **life-cycle risk management** involving surveillance, rehabilitation and periodic reassessment.

Downstream Risk and Disaster Management:

- Dam failure can produce sudden downstream flooding, affecting **human settlements, agricultural land, roads, bridges, power infrastructure and other critical assets**.
- The consequences are particularly severe where settlements and economic infrastructure have expanded downstream after dam construction.
- Effective dam safety therefore requires integration of **structural safety, flood forecasting, early-warning systems, emergency action plans and downstream preparedness**.

Dam Safety Act, 2021: Institutional Framework

National-Level Institutions:

- The **Dam Safety Act, 2021**, which came into force on **30 December 2021**, provides a statutory framework for surveillance, inspection, operation and maintenance of specified dams and prevention of dam-failure-related disasters.
- The Act created a **four-tier institutional architecture** comprising the National Committee on Dam Safety, National Dam Safety Authority, State Committees on Dam Safety and State Dam Safety Organisations.
- The **National Committee on Dam Safety** functions as the policy-oriented body responsible for evolving dam-safety policies, maintaining standards and recommending necessary regulations.
- The **National Dam Safety Authority** functions as the national regulatory and implementing body for dam-safety policies and standards and can address issues between State Dam Safety Organisations and specified-dam owners.

State-Level Institutions and Dam Owners:

- States having specified dams are required to establish **State Committees on Dam Safety and State Dam Safety Organisations**; all **28 States and 3 Union Territories** with specified dams had established the prescribed institutional structures.
- State Dam Safety Organisations undertake surveillance, inspection and monitoring, maintain dam-related information and recommend corrective measures.

- Dam owners are responsible for **operation and maintenance**, adequate funding for repairs, establishment of Dam Safety Units, regular inspections, preparation of Emergency Action Plans and periodic comprehensive safety evaluations.

Risk Assessment and Safety Evaluation:

- The regulations require specified dams to undergo **risk assessment studies** and comprehensive safety evaluations at prescribed intervals; the first comprehensive evaluation of existing specified dams is to be followed by evaluations at **10-year intervals**, or earlier where directed.
- Dam owners must also undertake **pre-monsoon and post-monsoon inspections** and inspections following calamities or signs of distress.
- Post-monsoon inspection results are categorised according to the urgency of remedial action; for 2025, **3 specified dams were placed in Category-I and 216 in Category-II**, requiring urgent or prompt remedial measures respectively.

Government Initiatives and Technology-Based Dam Safety:

DHARMA and Digital Monitoring:

- The **Dam Health and Rehabilitation Monitoring Application (DHARMA)** functions as a digital repository for dam inventories, inspection records, health assessments and rehabilitation monitoring.
- Digital recording of inspections strengthens **data-based surveillance, transparency, institutional coordination and evidence-based maintenance planning**.

Dam Rehabilitation and Improvement Project:

- **DRIP Phase II and III** focuses on improving dam safety and operational performance while strengthening institutional capacity; the programme has a **₹10,211 crore outlay**, covers **736 dams**, and is designed for a 10-year period from 2021 to 2031.
- DRIP combines **physical rehabilitation, instrumentation, emergency action planning, operation and maintenance improvements, capacity building and technical standardisation**.
- International Centres of Excellence for Dams at **IIT Roorkee and IISc Bengaluru** are supporting research and capacity building in areas including seismic analysis, sediment management, rehabilitation materials and risk assessment.

Key Challenges in India's Dam-Safety Governance:

Technical and Institutional Gaps:

- States and dam-owning agencies vary considerably in their **technical expertise, financial resources, instrumentation capacity and maintenance practices**, creating uneven safety standards.
- The growing complexity of climate and seismic risks requires continuous updating of **hydrological models, earthquake catalogues, geological mapping and design parameters**.
- The National Committee on Seismic Design Parameters continues to develop **site-specific seismic design parameters**, while revised guidelines for site-specific seismic studies were issued in 2025.

Climate Change and Compound Hazards:

- Increasing variability in extreme rainfall, floods, landslides and other hazards can alter the risk profile of existing dams.
- Dam safety planning should therefore move towards **multi-hazard risk assessment**, integrating seismic, hydrological, geological and climate-related hazards rather than evaluating them in isolation.

Way Ahead:

- **Adopt site-specific seismic assessment:** Integrate PSHA and updated seismo-tectonic information into the design, rehabilitation and safety evaluation of dams in high-risk regions.
- **Institutionalise periodic reassessment:** Combine structural evaluation with updated hydrological and seismic data, particularly for ageing and high-consequence dams.
- **Strengthen instrumentation:** Expand seismic instruments, piezometers, deformation monitoring, automated weather stations and other real-time systems at vulnerable dams.
- **Improve downstream preparedness:** Regularly update **Emergency Action Plans, dam-break analyses, flood-inundation maps and early-warning systems**, followed by mock drills involving district authorities and downstream communities.
- **Ensure dedicated financing:** Enforce the statutory requirement for dam owners to earmark adequate funds for maintenance and repairs, preventing deferred maintenance from becoming a systemic safety risk.
- **Promote risk-informed governance:** Integrate consequence classification with seismic hazard, structural condition, exposure and vulnerability to prioritise rehabilitation and inspection resources.

UPSC Relevance:

GS-I — Geography:

- Seismic zones, earthquakes, Himalayan tectonics, geological hazards, river-valley projects and reservoir sedimentation.

GS-II — Governance and Federalism:

- Dam Safety Act, 2021, Centre-State coordination, regulatory institutions, statutory responsibilities and institutional capacity.

GS-III — Disaster Management and Infrastructure:

- Dam failures, disaster-risk reduction, critical infrastructure resilience, early-warning systems, climate risks and rehabilitation of ageing infrastructure.

Essay and Ethics:

- Development versus safety, intergenerational infrastructure responsibility, precautionary principle, public accountability and technology-enabled governance.

Value Addition for UPSC:

- **Core Concept:** Dam safety is a **life-cycle risk-management issue**, not merely a structural-engineering concern.
- **Current Data:** India has **6,628 specified dams**, of which **6,545 are operational** and **83 are under construction**.
- **Key Law:** **Dam Safety Act, 2021** provides the statutory architecture for surveillance, inspection, operation, maintenance and institutional coordination.
- **Technology:** **PSHA + DHARMA + instrumentation + early-warning systems** represents a transition towards risk-informed and data-driven dam safety.
- **Analytical Link:** The IIT Madras study demonstrates why **national-scale seismic zonation should be supplemented by site-specific hazard assessment** for high-consequence infrastructure.
- **Mains Framework:** In an answer, connect **ageing dams ? multi-hazard exposure ? institutional capacity ? technological monitoring ? statutory regulation ? downstream disaster preparedness**.