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A Review of Dam Break Risk Assessment and Hydraulic Modelling for Climate-Resilient Reservoir Management: A Review with Application to Basnagoda Reservoir, Sri Lanka

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Abstract*— Dam failures can cause severe downstream flooding, infrastructure damage, environmental impacts, and loss of life. Climate related changes in extreme rainfall further emphasize the need for robust dam break risk assessment and flood hazard modelling. This review examines dam failure mechanisms, hydraulic modelling approaches, extreme rainfall assessment, and risk-assessment methods relevant to the Basnagoda Reservoir in the Aththanagalu Oya Basin, Sri Lanka. Published studies were reviewed and grouped according to failure mechanisms, hydrological and hydraulic modelling, uncertainty assessment, and Sri Lankan dam-safety applications. The reviewed literature identifies overtopping, piping and internal erosion, structural instability, and seismic or other natural hazards as important failure mechanisms. Hydrological assessment, including probable maximum precipitation (PMP) and probable maximum flood (PMF), is relevant to defining extreme inflow conditions, while HEC-RAS 1D and 2D models are widely applied to simulate breach flood propagation and estimate inundation depth, velocity, and extent. Case specific dam break modelling and inundation information for Basnagoda Reservoir were not identified in the reviewed literature. Therefore, the reviewed evidence provides a methodological basis for a Basnagoda focused assessment that integrates extreme rainfall analysis, breach scenarios, hydraulic modelling, GIS based hazard assessment, and uncertainty analysis. Moreover, Geographic Information System (GIS)- based Land Use and Land Cover (LULC) analysis is included to assess environmentally sensitive areas and vulnerable infrastructure that may be subject to inundation. The present paper investigates a significant aspect related to dam overtopping features, which are the result of overflowing associated with excessive inflow over the normal capacity in any reservoir system in order to develop an appropriate identification procedure for assessing potential risks linked with various extreme flood scenarios and proposes a comprehensive methodology for integrating hydrological and hydraulic analyses into reservoir risk assessment While numerically simulating results is outside the capabilities of this preliminary investigation data, the suggested framework lays out a systematic evaluation for dam safety under projected in extreme weather conditions. this review is expected to contribute to improved reservoir design, emergency preparedness, dam breach, and sustainable water resource management in Sri Lanka.

Keywords - Dam Breaks, Risk Assessment, Overtopping, Piping, Structural Instability, HEC-RAS

I. INTRODUCTION

Dam failures have severe consequences on human life and property. Dams are hydraulic structures built across a watercourse, creating a reservoir in which water is stored to serve multiple purposes, such as flood risk management, navigation, hydropower generation, and water supply. However, dams are also among the most dangerous hydraulic structures, as failures tend to trigger catastrophic downstream scenarios by releasing large volumes of water stored in reservoirs, causing damage to infrastructure, ecological damage, and loss of life. Dam failures have recently had a large, disastrous effect on downstream areas in many countries. Between 2000 and 2009, more than 200 notable dam failures occurred worldwide [13]. As such, a thorough assessment of potential dam safety issues is an integral part of water resources planning [1].

Public concern has led to an increased focus on dam safety and imposed responsibility on decision-makers. Dam-break-induced disasters may occur more frequently as infrastructure ages. Emergency planning, as a non-structural measure to minimize flood impacts, plays an important role in crisis management. One of the

keys to preventing and reducing losses from flood disasters is obtaining reliable information about the flood risk through flood inundation maps [14].

The causes of dam failures can be broadly divided into two categories: natural and human related. Natural causes can be further divided into external and internal causes. External causes include natural events such as heavy rainfall, hurricanes, floods, and earthquakes, which can place excessive pressure on dams. Internal causes include the aging of construction materials, defects in the dam structure, foundation problems, and other structural weaknesses that may develop over time. Human-related causes can also increase the risk of dam failure. Global warming and climate change can lead to more frequent and intense rainfall, glacier retreat, and the formation of glacial lakes, increasing the possibility of flooding and dam failure. Other human related causes include terrorist attacks, wars, and large-scale construction projects that may affect the stability of dams or their surrounding areas.

Dam failures generally occur due to three principal mechanisms: overtopping, piping (internal erosion), and structural instability. Overtopping occurs when inflow exceeds the spillway discharge capacity, allowing water to flow over the crest and erode the dam body. Piping results from progressive internal erosion caused by seepage through the dam or its foundation, while structural instability arises from excessive loading, material deterioration, poor design, or seismic activity. Understanding these failure mechanisms is essential for developing realistic dam break scenarios and implementing effective mitigation strategies.

Basnagoda Reservoir was selected as the study area because it is a newly constructed dam located in the Gampaha District, where dam break risk has received comparatively limited research attention. As the reservoir is a relatively new water infrastructure project, only a limited number of studies have been conducted specifically on its dam-break and downstream flood risk. Furthermore, the reservoir is intended to support domestic and industrial water requirements and agricultural activities, increasing the importance of ensuring its safety and assessing potential consequences of a possible dam failure. Therefore, conducting a comprehensive dam-break analysis of Basnagoda Reservoir using hydrological and hydraulic modelling can help identify potential downstream inundation areas and provide useful information for dam safety planning, risk assessment, and emergency preparedness in the surrounding areas of Gampaha District. Figure 01 below shows the view of the Basnagoda Reservoir and dam.



Figure 1 Basnagoda Dam

II. MECHANISMS AND CAUSES FOR DAM FAILURE

The figures illustrate the main dam failure mechanisms considered in the reviewed studies, as illustrated in the following figures:

A. Overtopping Failure – Occurs when the reservoir water level exceeds the dam crest or the inflow exceeds the spillway capacity, causing uncontrolled flow and erosion.

B. Structural Failure – Results from structural or geotechnical instability caused by excessive loading, foundation problems, deformation, deterioration, or seismic forces.

C. Piping and Erosion Failure – Develops when seepage through the dam or foundation progressively erodes internal materials, forming a pipe or flow channel that may eventually lead to a breach.

D. Seismic and Other Natural Hazards – Earthquakes, floods, mass movements, and other natural hazards can directly damage the dam or initiate secondary failure mechanisms such as cracking, piping, and slope instability.

A. Overtopping failure

Overtopping is one of the major failure mechanisms associated with embankment dams. It occurs when the reservoir water level exceeds the dam crest or when inflow exceeds the capacity of the available spillway and outlet structures. Because embankment materials are generally not designed to withstand prolonged uncontrolled overflow, overtopping can initiate erosion on the downstream face and progressively develop into a breach. Figure 1 depicts the failure mechanism of the overtopping dam break failure

Experimental studies demonstrate that overtopping failure is a progressive process rather than an instantaneous event. Surface erosion may initially develop into localized channels, followed by head-cut formation, enlargement of the eroded section, and eventual breach development [3]. The interaction between hydraulic forces and erodible dam material is therefore important in determining breach formation and the resulting downstream flood hydrograph [19].

The severity of an overtopping failure depends on several factors, including reservoir volume, inflow, dam geometry, material characteristics, spillway capacity, and breach development. Once a substantial breach develops, rapid reservoir release may generate high-velocity downstream flooding that can affect communities and infrastructure [20]. Climate variability is also relevant to overtopping risk. Many existing reservoir systems were designed using historical hydrological conditions. Changes in rainfall intensity and extreme rainfall behavior can affect catchment runoff and reservoir inflows, potentially increasing spillway loading and the risk of overtopping [12], [18], [31]. Therefore, extreme hydrological conditions should be considered when developing overtopping scenarios for dam-break assessment.

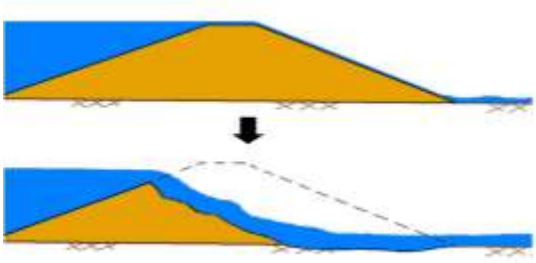


Figure 2 Overtopping failure

B. *Structural Failure*

Structural instability in embankment dams represents a critical failure mode distinct from hydraulic overtopping or internal piping, primarily driven by the loss of geotechnical equilibrium under static or dynamic loading conditions. This category of failure encompasses slope instability, foundation failure, and deformation-induced structural compromise, often exacerbated by seismic activity, rapid reservoir drawdown, or inadequate compaction during construction. The risk assessment of structural instability requires a rigorous integration of geomechanically modeling, probabilistic reliability analysis, and downstream consequence evaluation to account for the complex interactions between soil mechanics and hydrostatic pressures. Recent literature emphasizes that structural failures are frequently preceded by measurable deformations, making the identification of critical deformation zones a prerequisite for accurately defining breach scenarios [22]. Unlike sudden hydraulic breaches, structural instabilities may evolve over time, allowing for potential detection through monitoring systems, yet the ultimate failure can still result in catastrophic reservoir release if not mitigated [23]

When pore water pressures rise due to inadequate drainage or high reservoir levels, the effective stress within the soil matrix decreases, reducing shear strength and increasing the potential for sliding on downstream or upstream slopes. This process is particularly dangerous in dams with impervious cores, where differential settlement can create cracks that further compromise structural integrity and facilitate concentrated leaks, thereby accelerating the instability process [24]. Figure 2 shows the Dam external instability failure.

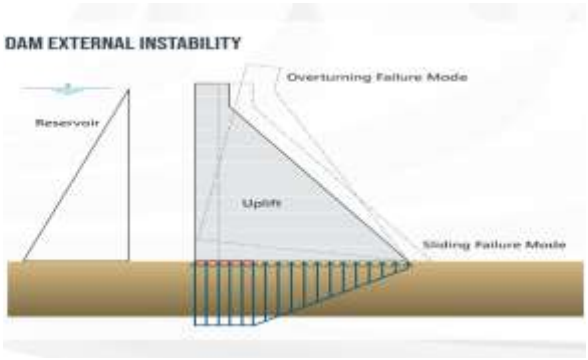


Figure 3 Structural failure

Structural instability due to Overstressing Forces: This failure mode occurs when a portion or the entirety of the dam structure is suddenly removed due to forces exceeding the structural capacity.

Dominant Dam Types**:** It primarily affects rigid structures such as concrete arch and concrete gravity dams. Triggers**:** Causes of overstressing include Inadequate design, Excessive external forces from flood overtopping or earthquakes, and Deterioration of abutment or foundation materials [4].

C. *Piping & Erosion Failure*

Piping failure represents a critical mechanism of internal erosion in embankment dams, characterized by the progressive removal of soil particles due to seepage forces, which can lead to catastrophic structural collapse and downstream flooding [25],[26]. The risk assessment of such failures requires a multidimensional approach that integrates geotechnical analysis of soil heterogeneity, hydrodynamic modeling of breach progression, and probabilistic evaluation of downstream consequences [27],[28]. Recent advancements in risk assessment frameworks have shifted from deterministic empirical formulas to stochastic models that account for the spatial variability of soil properties and the epistemic uncertainties inherent in erosion mechanisms [29].

Characteristics of loess in the saturated state for preventing dam break [5]. During a piping failure, the water seeps in at a significant rate through the dam. As the material is eroded, a large hole forms. HEC RAS has two methods for assessing dam breach characteristics: user-entered and simplified physical. During the piping process, erosion and head cutting begin on the downstream side of the dam, eventually widening the breach. Depending on the water volume in the reservoir, widening continues until the natural channel bed is reached [6].

Mitigation strategies derived from these risk assessments often involve implementing filters and drains to control seepage and prevent piping. Experimental investigations into hole erosion filter tests (HEFT) have shown that properly designed downstream filters can trap eroded soil particles, thereby halting the progression of internal erosion [25].

Piping channels easily form under the action of force and collapsibility. Near-static liquefaction of the loess in the dam body under saturated conditions will lead to piping or loss of soil strength. Therefore, it is of great significance to study the mechanical. Figure 3 shows the Dam Piping failure.

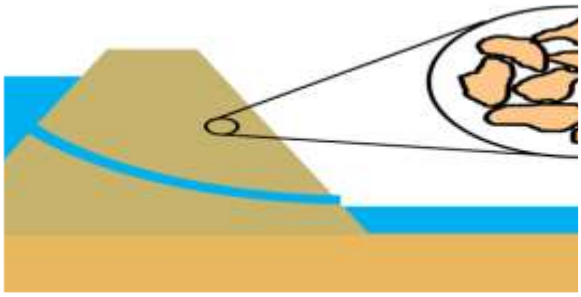


Figure 4 Piping Failure

D. *Seismic & Other natural Hazard*

Seismic activity and other natural hazards constitute primary external triggers for dam failure, necessitating a robust risk assessment framework that integrates geodynamic loading, hydrological extremes, and structural response modeling. The interaction between seismic forces and dam infrastructure can induce immediate structural collapse or initiate secondary failure mechanisms such as piping and slope instability, which subsequently lead to catastrophic reservoir release [22].

Among the others, earthquakes, floods, and aging are the main natural hazards for most of the concrete dams. The earthquake for large storage dams is a multiple hazard which includes the following feature such as; Ground shaking causing vibrations in dams, Fault movements or discontinuities in dam foundation, if activated can cause structural distortions, Fault displacement in the reservoir bottom causing water waves or loss of freeboard, Mass movements (rockfalls) causing damage to appurtenant structures, e.g., gates, spillway, etc., Mass movements into the reservoir causing impulse waves, Settlements due to liquefaction and densification of soil, causing distortions in dams [7].

These deformation zones are not merely static weaknesses; they serve as the physical basis for subsequent failure scenarios, such as piping-induced breaches triggered by seismic cracking . Seismic deformation can create transverse cracks in the impervious core, reducing the soil's effective shear strength and providing pathways for concentrated seepage, thereby coupling mechanical instability with hydraulic erosion [22].

III. Hydraulic Dam Break Modeling Approaches

A. *1D Hydraulic Modeling*

One-dimensional (1D) hydraulic modeling remains a foundational approach for simulating dam-break flood-wave propagation, particularly in long, narrow river valleys where lateral flow variations are minimal relative to longitudinal dynamics. While two-dimensional (2D) and three-dimensional (3D) models offer superior resolution of complex topographies and turbulent structures near the breach site, 1D models provide significant computational efficiency, making them ideal for preliminary risk assessments, large-scale

watershed analyses, and scenarios requiring extensive Monte Carlo simulations for probabilistic risk assessment [27].

The primary mathematical framework for 1D dam-break modeling relies on the Saint-Venant equations, which consist of the continuity and momentum equations for unsteady open-channel flow [30]. These equations are typically solved using numerical methods such as the finite-difference method, finite-volume method, or characteristic methods, often implemented in software platforms such as HEC-RAS 1D, MIKE 11, or Sobek [32]. presented a one-dimensional numerical model for simulating dam-break flows in real river systems. The 1D approach is appropriate when the flow is predominantly along the main river direction or when a highly detailed spatial resolution is unnecessary. A critical aspect of 1D dam-break modeling is the accurate representation of the breach formation process, which serves as the upstream boundary condition for the flood wave propagation. Since 1D models do not simulate the physical erosion of the dam structure, they rely on empirical or semi-empirical relationships to estimate breach parameters such as final breach width, depth, and formation time [33].

B. 2D Hydraulic Modeling

Two-dimensional (2D) hydraulic modeling has emerged as the predominant standard for simulating dam-break flood wave propagation and downstream inundation, offering a superior balance between computational efficiency and hydrodynamic accuracy compared to one-dimensional (1D) or three-dimensional (3D) approaches. By solving the depth-averaged Shallow Water Equations (SWEs), 2D models effectively capture lateral flow variations, complex topographic interactions, and wetting-drying processes that are critical for accurate hazard mapping in urban and agricultural environments [30], [27]. The integration of these hydrodynamic solvers with Geographic Information Systems (GIS) and probabilistic frameworks further enhances their utility in contemporary risk assessment, enabling comprehensive evaluation of breach scenarios under varying epistemic uncertainties [32].

The accuracy of 2D simulations depends heavily on the precise definition of breach parameters, which serve as upstream boundary conditions for flood wave propagation. Since 2D hydrodynamic models do not inherently simulate the physical erosion of the dam structure, they rely on empirical or semi-empirical relationships to estimate final breach width, depth, and formation time. Deterministic empirical formulas often fail to capture the epistemic uncertainties associated with these parameters, leading to biased risk estimations. To address this limitation, recent methodologies have incorporated probabilistic frameworks, such as the Probabilistic Hydro-Risk Forecasting System (PHRFS), which integrates Latin Hypercube Sampling (LHS) with HEC-RAS 2D modeling [32]. The integration of GIS tools, such as HEC-GeoRAS, with 2D hydrodynamic models facilitates the rapid extraction of geometric data and the seamless translation of hydraulic outputs into spatial hazard maps [32]

C. HEC-RAS for Dam Break Modeling

HEC-RAS (Hydrologic Engineering Center's River Analysis System) serves as a cornerstone computational tool for simulating dam-break failures, offering robust capabilities for both one-dimensional (1D) and two-dimensional (2D) hydraulic modeling. The software enables engineers and researchers to predict the downstream consequences of structural failure by solving the Saint-Venant equations for unsteady flow, thereby facilitating critical risk assessments, emergency action planning, and hazard zoning [27].
The terrain information generates an unsteady state flow simulation of the dam breach. The process for gathering and preparing data, estimating breach parameters, and creating one-dimensional and two-dimensional unsteady-flow models in HEC-RAS [10]. Recent advancements in HEC-RAS, particularly the integration of 2D flow areas and its coupling with GIS tools like HEC-GeoRAS, have significantly enhanced its ability to model complex topographic interactions and lateral flood-wave propagation with high spatial resolution [32].In following table 01 is shown some literature studies of using HEC-RAS model for dam break failure analyzing of Sri Lanka and the other country.

Table 01 HEC-RAS tool studies

Author	Topic	Details/Methods	Findings
Edirisooriya, Neluwala and Weerakoon, 2022	Flood Inundation Modelling in Greater Colombo Region Using HEC-RAS 2D	1.roughness coefficients were assumed, not measured . 2.Scenario assuming Fixed breach formation time 0.1 hr. and simplified breach shape as rectangular	1.The occurrence of operational gate failure or spillway blockages can result in a range of different overtopping depths can lead to dam failure 2.Flood waves mostly remain confined within the river valley
Xiong,2011	A Dam Break Analysis Using HEC-RAS	1.Only piping break mode was analyzed 2.HEC-RAS depends on input geometry and boundary conditions	1.Impact near tha dam is high & impact in downstream is less 2.Peak outflow occurs after breach formation

Two-dimensional modeling within HEC-RAS has become increasingly preferred for dam-break analyses due to its superior ability to capture the spatial distribution of flood depths and velocities across broad inundation zones. Unlike 1D models, which assume uniform flow across cross-sections, 2D models solve the depth-averaged shallow water equations, allowing for the simulation of flow around obstacles, through urban environments, and over complex floodplains [34]. In addition to standalone hydraulic modeling, HEC-RAS is frequently coupled with other specialized tools to address multi-hazard scenarios. For example, seismic deformation zones identified using geotechnical software such as PLAXIS can serve as the basis for defining breach locations in HEC-RAS, enabling the simulation of earthquake-induced dam failures [22]. his integrated approach ensures that the hydraulic model reflects realistic failure triggers derived from structural and geotechnical analyses. The Tambling Dam case study in Indonesia further illustrates the practical application of HEC-RAS 5.0.7 in conjunction with hazard classification systems to assess impacts on downstream communities, schools, and public facilities, demonstrating the software's utility in regulatory compliance and public safety planning [33]. The dam-break tool in HEC-RAS can simulate the breach of an in-line structure [11].

IV. DAM BREAK STUDIES IN SRI LANKA

Dam breach and break studies in Sri Lanka represent a critical area of hydrological and geotechnical research, driven by the nation's extensive heritage of ancient irrigation reservoirs and the increasing need for modern disaster risk reduction strategies. The island’s hydraulic infrastructure, dating back to the sixth century BC, includes thousands of dams and reservoirs that are vital for agricultural development and water security [35]. However, the aging nature of many earthen dams, particularly those located in the dry zone, necessitates rigorous risk assessment and hydraulic modeling to mitigate the catastrophic consequences of potential failures [36]. Recent academic efforts have focused on simulating plausible hazard scenarios using advanced two-dimensional (2D) hydraulic models, assessing structural vulnerabilities through seepage analysis, and integrating machine learning for smart dam

control systems [37]. This research employs the Hydrologic Engineering Center's River Analysis System (HEC-RAS), a widely recognized tool for simulating unsteady flow and dam-break scenarios, to model potential breach outcomes [37].

Climate change is expected to alter rainfall patterns, temperature, and the frequency and intensity of extreme rainfall events, increasing the risk to dams and reservoirs in Sri Lanka. Changes in extreme rainfall can increase reservoir inflows and spillway loading, potentially increasing the probability of overtopping and dam failure [12]. Therefore, incorporating projected climate variability into reservoir operations and dam-break assessments is essential for improving dam safety, flood risk management, and the resilience of water infrastructure [12].

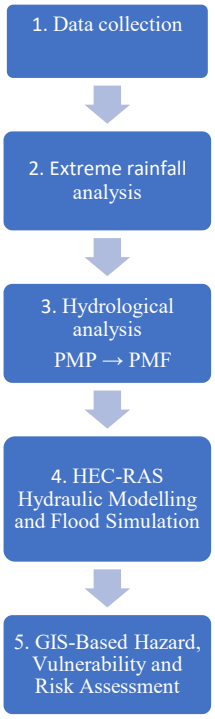
The specific dam break studies focusing exclusively on the Aththanagalla Oya and the Basnagoda Reservoir are not explicitly detailed in the provided peer-reviewed literature. The available source materials primarily focus on other major reservoirs in Sri Lanka, such as the Kantale Dam, and provide broader risk assessments for a selection of 32 major dams across the country [37]. Consequently, specific numerical data, breach parameters, or inundation maps for the Basnagoda Reservoir cannot be obtained from the provided documents. However, the methodologies and general findings from these studies are highly relevant to understanding the risk profile and modeling approaches applicable to the Basnagoda Reservoir and similar ancient earthen structures in Sri Lanka [35].

Dam failures in Sri Lanka can cause significant loss of life, property, infrastructure, and environmental resources, particularly in downstream communities. Although dams provide essential benefits such as water supply, irrigation, flood control, and hydropower, their failure can generate severe downstream flooding. The study highlights Early Warning Systems (EWS) as an important mitigation measure for reducing the impacts of dam-break disasters. Effective EWS should provide timely detection, reliable flood forecasting, rapid communication, and appropriate emergency responses to protect communities and reduce social, economic, and environmental losses. These findings are relevant to dam-break risk assessments in Sri Lanka, including the assessment of downstream flood hazards associated with reservoirs such as Basnagoda [13].

V. DAM FAILURE AND DAM BREAK RISK

The accuracy of dam-break simulations is heavily influenced by the selection of breach parameters, such as final breach width, depth, and formation time, which are often subject to significant epistemic uncertainty [39], [40]. Deterministic models relying on single-value estimates may lead to biased risk assessments, prompting the adoption of probabilistic frameworks [12],[13]. Probabilistic methods, such as Latin Hypercube Sampling (LHS), allow for the generation of ensemble scenarios that account for the variability in breach parameters and reservoir levels, providing a more robust estimation of flood risks [41].
The Probabilistic Hydro-Risk Forecasting System (PHRFS), for example, integrates LHS with HEC-RAS 2D modeling to evaluate a spectrum of potential outcomes, enhancing the reliability of emergency action plans [27]. In Sri Lanka, the risk assessment of dams is particularly critical due to the prevalence of ancient earthen structures that have served for centuries but may not meet modern safety standards. Seepage and internal erosion are major concerns for these earthen dams, especially those in the dry zone, where condition assessments have revealed vulnerabilities requiring immediate attention [36]. A comprehensive risk assessment of 32 major dams highlighted the varying degrees of renovation required and the need for prioritized investment in maintenance and rehabilitation [35]. The integration of machine learning and Internet of Things (IoT) technologies offers a novel approach to monitoring these structures, enabling real-time detection of anomalies such as unusual seepage patterns or structural deformations [49]. An integrated smart dam control system developed for Sri Lanka automates sluice gate operations and utilizes machine learning for crack analysis, thereby reducing the risks associated with manual operation and potential overtopping [42].

VI. PROPOSED METHODOLOGY



The proposed methodology is developed based on the findings and limitations identified from the reviewed literature. The framework integrates rainfall analysis, extreme flood estimation, dam-break scenario development, hydraulic modelling, and GIS-based vulnerability assessment to evaluate potential downstream risks associated with the Basnagoda Reservoir.

Step 1
Data Collection
The required hydrological, hydraulic, topographical, and spatial datasets will be collected from relevant authorities, available records, field surveys, remote sensing sources, and GIS databases. A Digital Elevation Model (DEM) and land-use/land-cover data will be prepared for hydraulic and vulnerability analysis

Step 2
Extreme Rainfall Analysis
Historical rainfall data will first be screened and analyzed to identify extreme rainfall characteristics Probable Maximum Precipitation (PMP) will then be estimated using the Hershfield method and the relevant WMO-based approach

Step 3
Hydrological Analysis
After the finding Probable maximum precipitation , we can find Probable maximum flood for the area and find maximum flood from flood hydrograph.
PMP → PMF

Step 4
HEC-RAS Hydraulic Modelling and Flood Simulation
The prepared dam, reservoir, river, terrain, and boundary-condition data will be incorporated into the HEC-RAS model. A suitable 2D model will be developed to simulate the propagation of the dam-break flood wave downstream

Step 5

GIS-Based Hazard, Vulnerability and Risk Assessment
The hydraulic model outputs will be integrated with GIS-based spatial information, including land use/land cover, settlements, roads, public facilities, agricultural areas, and environmentally sensitive locations. The inundation depth, velocity, and spatial extent obtained from HEC-RAS will be used to identify potentially vulnerable downstream areas. The results will be used to develop dam-break hazard and risk maps and to identify areas requiring improved emergency preparedness, early warning, and risk-reduction me

VII. Conclusion

This review examined the major dam-failure mechanisms, dam-break hydraulic modeling approaches, and risk-assessment methods relevant to reservoir safety, with particular emphasis on the Basnagoda Reservoir in the Aththanagalu Oya Basin, Sri Lanka. The literature indicates that dam failures may result from overtopping, piping, internal erosion, structural instability, seismic activity, and other natural hazards. Among these mechanisms, overtopping is strongly associated with extreme inflow conditions and inadequate spillway capacity, whereas piping and structural instability can develop due to seepage, deterioration, deformation, and foundation-related problems. Therefore, realistic dam-break assessment requires consideration of multiple possible failure scenarios rather than relying on a single failure mechanism. The review also demonstrates the importance of integrating hydrological and hydraulic analyses for reliable dam-break risk assessment. Extreme rainfall can increase reservoir inflows and spillway loading, making PMP and PMF important components of extreme-flood assessment. The reviewed studies show that 1D hydraulic models are computationally efficient and suitable for relatively simple river systems and preliminary assessments, whereas 2D models provide a more accurate representation of lateral flow, complex topography, floodplain interactions, inundation depth, and flow velocity. HEC-RAS is considered a suitable tool for dam-break analysis because it supports both 1D and 2D unsteady-flow modeling and can be used to estimate downstream flood depths, velocities, inundation extents, and flood-wave propagation [44]. Integration with GIS further enables the spatial representation of flood hazards and the identification of vulnerable downstream areas. However, the accuracy of dam-break modeling is strongly influenced by breach width, breach depth, breach formation time, reservoir level, terrain data, and other uncertain parameters. Recent research, therefore, indicates the importance of probabilistic approaches for representing these uncertainties rather than relying only on deterministic breach parameters.

For Sri Lanka, dam-break risk assessment is particularly important because reservoirs provide essential services such as water supply, irrigation, flood control, and other water-resource functions, while failure can produce severe downstream consequences. Climate variability and changes in extreme rainfall may further increase reservoir inflows and the risk of overtopping. The literature also emphasizes early warning systems, emergency preparedness, and improved monitoring as important measures for reducing the consequences of dam-break disasters [45, 46].
Based on the reviewed literature, an integrated methodology combining rainfall and hydrological analysis, PMP and PMF estimation, dam-break scenario development, HEC-RAS 1D/2D hydraulic modeling, GIS-based inundation and land-use assessment, and uncertainty or probabilistic analysis is recommended for the Basnagoda Reservoir [47, 48]. Such an approach can provide a more comprehensive understanding of potential downstream flood hazards and vulnerable locations. The review, therefore, provides a methodological foundation for a detailed future numerical investigation of the Basnagoda Reservoir and can support dam safety planning, emergency action planning, early warning systems, and sustainable water resource management in Sri Lanka. The proposed study can generate site-specific information on potential inundation areas, flood depths, flow velocities, and vulnerable locations downstream of the reservoir. Such information can contribute to dam-safety assessment, emergency preparedness, flood-risk management, and the development of appropriate early-warning and emergency-action planning for areas potentially affected by a Basnagoda Reservoir failure

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