Dams for Flood Moderation

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Dams and Floods

Inter-relationship

Dams:

- alter flood routing
  - significantly reduce peak flows downstream

Floods :

- suppose a risk to the dam
  - so then the dam must be kept safe in the face of extreme floods
  - sufficient outlet discharge/ spillway capacity to be provided to prevent overtopping/ failure risk

Measures to prevent and reduce flood damages

Non-Structural measures

- Do not involve any intervention in the river itself; measures that foresee and mitigate the damages produced by floods
  - Risk maps
  - Flood plain zoning
  - Flood forecasting and flood warning systems
  - Emergency Action plans

Structural measures

- Measures that interfere in the phenomenon of flood formation
  - Dams – Flood control & regulating reservoirs
  - Hydraulic works in the river system

Dams as Flood Reduction Measures

- Among the measures used to reduce flood damages, dams constitute a very efficient structural solution
  - Although not all dams are designed to reduce flood damages downstream
- Reservoirs created by dams are the only measure that can store water in a very significant manner, and hence, modify the inflow hydrograph at critical locations downstream
- In general, the effects of regulating floods with dams and reservoirs are more pronounced with floods having low and medium return periods.
  - The reduction in peak flows could be considerable, and, in turn, significantly mitigate damages downstream.
- For extreme floods too, dams indeed help to reduce the peak flow but the effect is relatively less pronounced, mainly because of economics of scale

Dams - Flood Control or Flood Mitigation?

- An absolute zero risk level (complete flood control) cannot be attained
  - Predicting the floods is not an exact science and there is always a probability of occurrence associated with a given level of flood.
  - Economically too it would not be viable to design dams which can absorb events of any probability.
- Most Flood control dams are therefore ‘**Flood Mitigation Dams**’ or ‘**Flood Moderation Dams**’,
  - They are capable to absorb part of the flood and mitigate flood damages downstream rather than completely preventing the damage, especially in the case of extreme floods.

Flood Mitigation Dams - Hydrological criteria

Two important criteria are followed for Flood Mitigation dams:

- Reduction of flood damages
  - Usually, flood mitigation dams are designed to provide protection against floods having return period of 50 to 200 years, or in the cases of important township downstream, up to return periods of 500 to 1000 years, if possible
- Dam safety
  - Dam/ spillway system should be able to contain/ discharge safely the Inflow Design Flood (IDF)
  - Criteria for the selection of IDF is based on Dam Hazard Classification system
  - For high hazard dams the PMF or high return periods of 10,000 years are applied

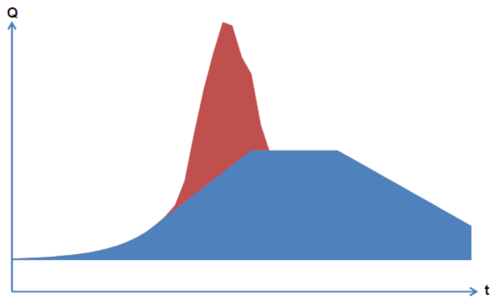
Dam Hazard Classification

- Internationally (ICOLD, CDA etc.) classify dams according to hazards that a potential failure would cause downstream
  - Criteria is based on Incremental Consequence Assessment
    - Population at risk, Loss of life, Environmental & Cultural values, Infrastructure & Economics
  - CDA Dam Safety Guidelines classify dams into five hazard classes
    - Low, Significant, High, Very High, Extreme
    - For safety against floods, Annual Exceedance probability is assigned to each class
- New emerging trend is Risk Based Approach to the Hydrological safety of the dam

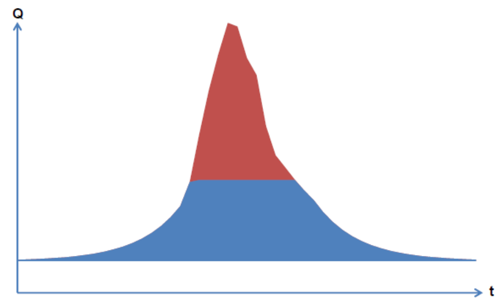
Reservoir Operation for Flood Mitigation

- In most cases, the objective of reducing damages is related to specific flood season
  - During this season the reservoir is operated with flood moderation as the primary objective
  - Other benefits such as power generation, irrigation or water supply are accordingly modified
- Reservoir Rule Curve
  - Well defined rules that govern the operation of the reservoir must be developed
  - Inflow design flood and restriction on the outflow play an important role in developing these rules
  - It is advisable to provide adequate cushions in the operating rules for possible changes and evolution in the basin, and in the downstream developments

Principles of Reservoir Operation



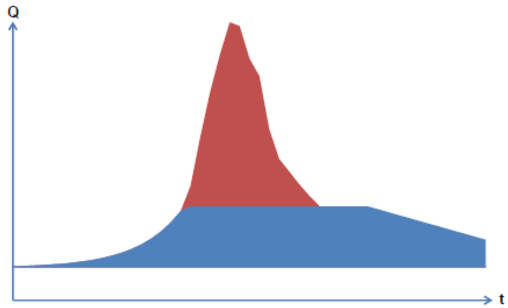
Constant Rate Control method



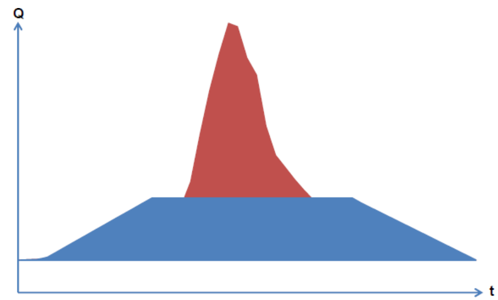
Constant Volume Discharge method

Outflow

Volume Absorbed



Constant Discharge method

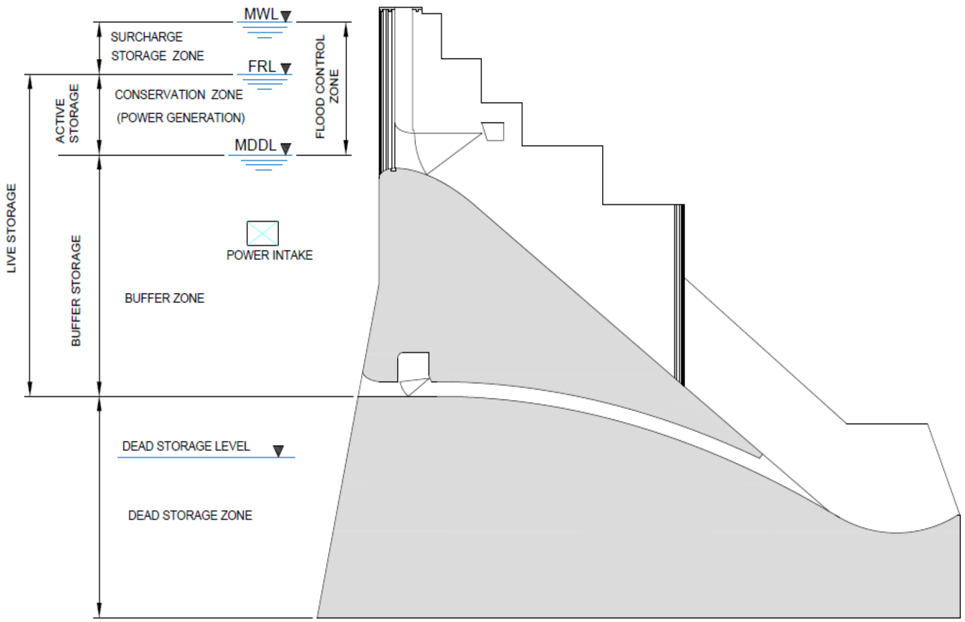


Advance Discharge Method

- In general, reservoir operation is a combination of two or more of these principles

Conflicts in Reservoir Operation of a Hydro Dam

- Two purposes
  - Conservation use for power generation
  - Flood Moderation
- These two demands are competing and conflicting
  - While flood control requires low reservoir level, power generation interests require as high a level as attainable
- The rule curve should provide a balance between the two objectives
  - Some part of the conservational storage for power generation is sacrificed for flood moderation during the early stages of the monsoon
  - The rule curve must ensure that this space is filled up during the receding monsoon months



Government Role

- Given the increasing role of private developers in developing hydropower plants and dams, projects with multipurpose benefits should be supported by the government
    - The government's role should include defining the requirements/measures related to benefits other than power
    - Costs related to providing/ensuring benefits other than power should be shared by the government
- For example, in dams where flood moderation is mandated, the extra dam height provided to absorb the flood could be borne by the government.

Existing Flood Moderation Dams

Flood Moderation Dams on Columbia river in Canada

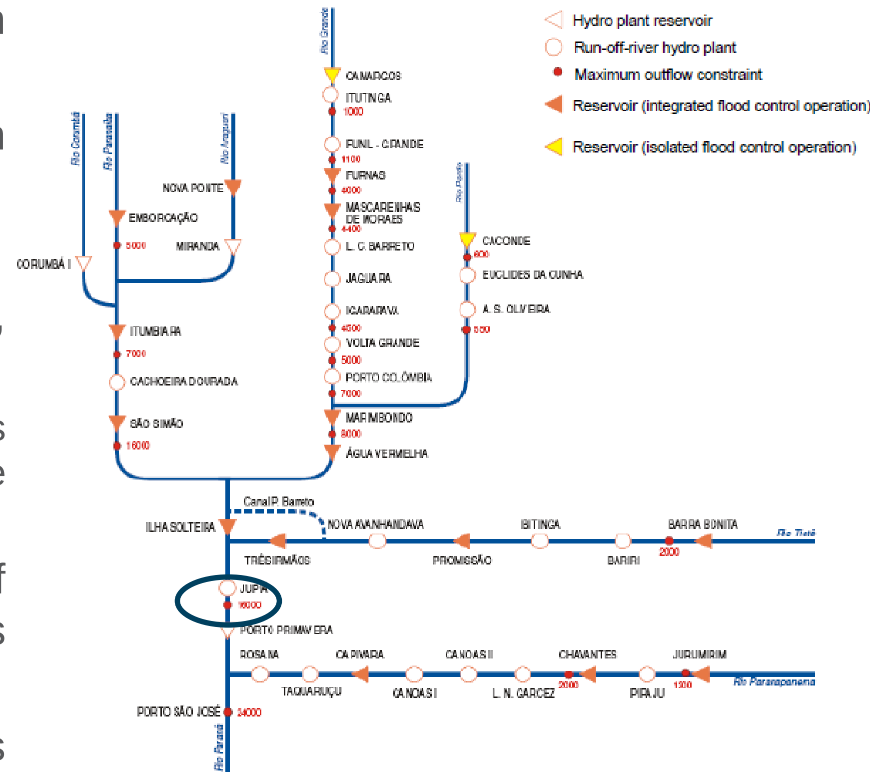
- Columbia river is trans-national river flowing from Canada to United States and finally to the Pacific ocean
- The Canadian portion of the Columbia River basin comprises only about 15% of the physical area, but contributes approximately 38% of the basin runoff
- Columbia river treaty provides flood control and hydropower benefits in both the countries
  - Under the treaty, Mica, Duncan and Keenleyside dams were constructed in Canada with flood storage capacity of 1250 MCM
  - Libby dam in US provides further flood storage capacity of 400 MCM
  - Together these dams protect major downstream habitats in the state of Oregon
- Canadian Treaty dams are drawn-down to, or below their prescribed flood control rule curves
  - These are derived from provisions within the Treaty and the USACE Flood Control Operating Plan.

Flood Moderation Dams on Columbia river in Canada (Contd. …)

- The dams have significantly reduced flood damage on the Columbia River system
  - Historically, prior to the Treaty, one-third of the years had peak flows over 17,000 m^3/s at The Dalles, Oregon
  - Since the dams were constructed, there has never been a peak flow over 17,000 m^3/s
  - There are four years on record where the peak unregulated Columbia River stream flows at The Dalles did or would have exceeded 28,000 m^3/s without Treaty storage: 1894, 1948, 1972, and 1974
  - The first two of these pre-Treaty floods caused catastrophic damage and loss of life.
  - In 2012, the Treaty dams reduced flood peaks by about 70%
  - USACE estimates of flood damages prevented are $260million, $306million and $2billion during the years 1972, 1974 and 2012.

Parana river, Brazil

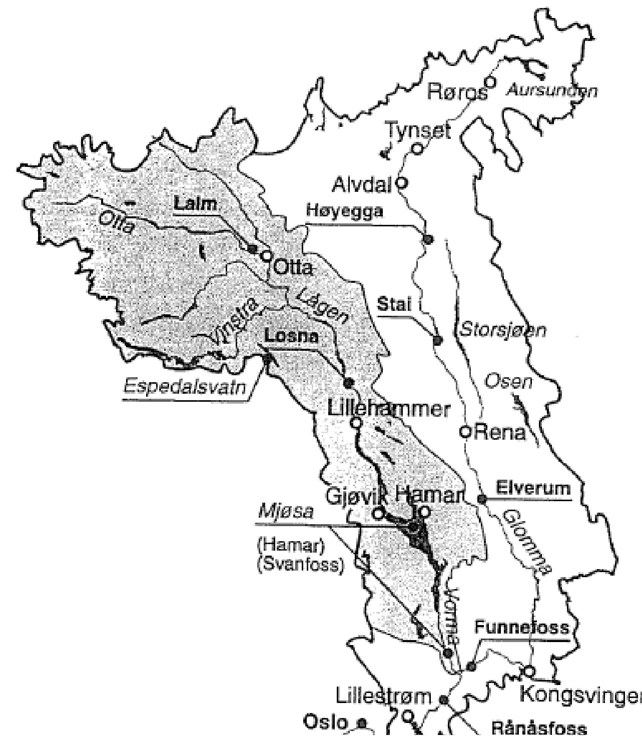
- More than 90% of the electricity generation in Brazil is from hydropower
- Energy regulation is based on the operation of large storage reservoirs
- Flood Control becomes a natural result
- For a long flood season (Dec. to mid April), the risk of not re-filling the reservoirs is high
  - To reduce this risk flood control space is gradually reduced to end of March for the same protection level
- In Parana river basin, 18 constraints of maximum outflows distributed along its main course and tributaries are considered.
- The risk of damage producing floods has been significantly reduced

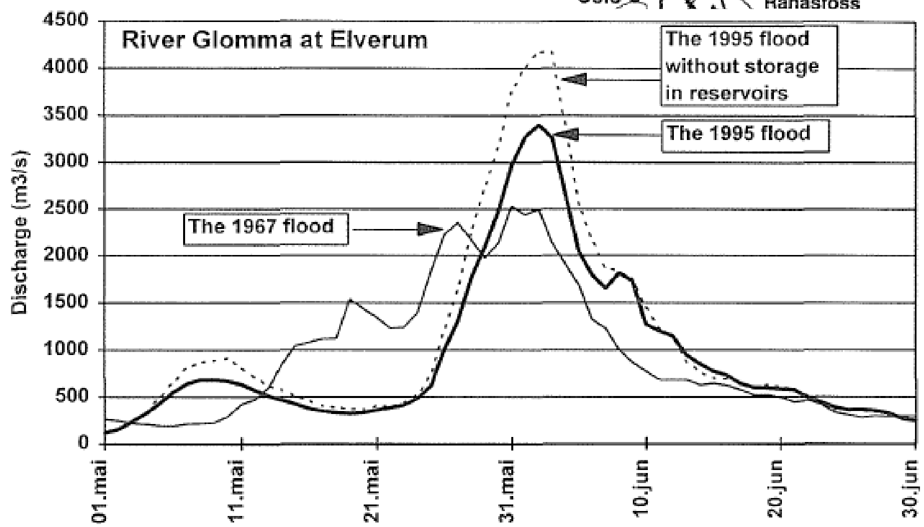


  - Natural flood return periods of 2 to 10 yrs have been reduced to the 15 to 100 yrs range
  - At Jupia, critical discharge constraint of 16,000 m^3/s (2 year return period) has been increased to 35 years.

Glomma river, Norway

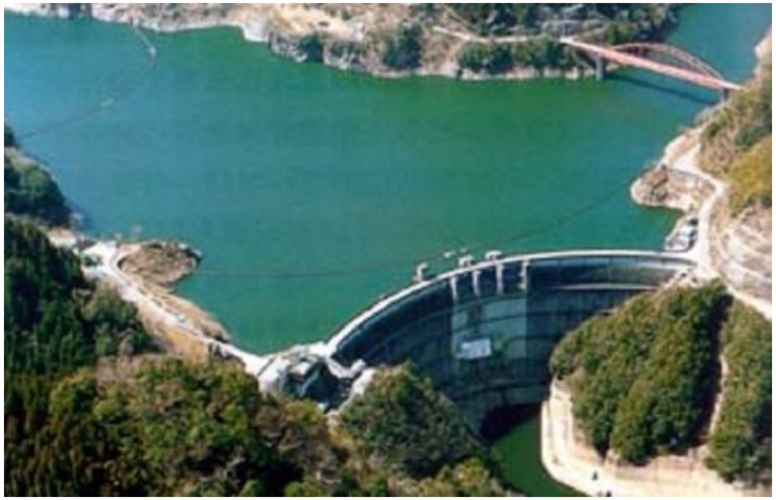
- Hydropower reservoirs in Glomma river basin have a storage capacity of 3.5 BCM
- During May 1995, the combined effect of intense snowmelt and high rainfall created a flood of 100 to 200 years return period
- With advance fore-warning system and forecasts, the reservoir operational strategy was to continue forced releasing until the actual arrival of the peak.
- The risk was that a premature reduction in release may have resulted in available storage capacity loss before the peak occurred.
  - In contrast, delay in release reduction would have increased the peak
  - The reservoirs attenuated the peak floods at strategic locations by 15 to 20%.





Flood Moderation Dams in Japan

- In Japan, many dams have been planned as multipurpose dams with flood moderation as one of the objectives
  - Around 500 dams provide total flood control capacity of 3.7 BCM on major rivers Tone, Kitakami, Yodo, Yoshino & Chikugo
- During the 1982 floods, five dams on the Tone river system contributed significantly to the reduction of flood - Shimokubo dam attenuated the flood peak by 62%
- Matsubara and Shimouke dams on the Chikugo river reduced the flood peak by 64% to 82% during the 1982 flood.
- During 2013, coordinated operation of seven dams on Yodo river system averted potentially catastrophic flood damage.



Three Gorges Dam, China

- The Yangtze river, where the Three Gorges Dam is located is known for frequent occurrences of large floods
  - 214 major floods in 2000 years
- Reservoir formed by the Three Gorges dam is 600 km long having a total storage of 39 BCM with 22 BCM (56%) for flood control.
- Major floods of more than 60,000 m^3/s affected millions of people including claiming lives of thousands
  - The 1998 flood, prior to TGP, caused loss of US$12 billion
  - During the 2010 flood, Three Gorges dam attenuated the inflow flood discharge of 70,000 m^3/s to 45,000 m^3/s

Dams in Tunisia

- The Kairouan plain has always been one of the regions in Tunisia affected by flood disaster.
- Canada-Tunisia cooperation
  - Sidi Saad dam on wadi (river) Zroud and El Haouareb dam on wadi Merguellil with total flood storage capacity of 20 MCM
- During the 1990 flood, Kairouan area was spared from damages due to above two dams

Mississipi river, USA

- The USACE has built 76 reservoirs in the upper Mississipi river basin for flood damage reduction with aggregate volume to store flood runoff of 49 BCM
- In addition, USACE has constructed 3500 km of levees

World declaration

Water Storage for Sustainable Development (Kyoto, 2012 - ICOLD, ICID, IHA, IWRA)

- There is need to accelerate the development of new water storage infrastructure for multiple purposes
  - Flood management and Energy production are among many others
- A balanced approach combining large, medium and small reservoirs is required; one that takes into account sustainable development, with full commitment to minimize negative impact

ICOLD 25th Congress

Norway, 2015

- Global trend to develop more dams specifically for flood protection
- Analysis of the construction costs show that in terms of protection of developed areas, the cost of these dams would be offset by the cost of avoided damages

Growth of flood damages in recent years indicate that in future it is imperative to increase measures to prevent and reduce damages that include design & construction of new dams with flood mitigation as an objective together with improvements in flood forecasting system for increased reliability and Emergency Preparedness Plan.

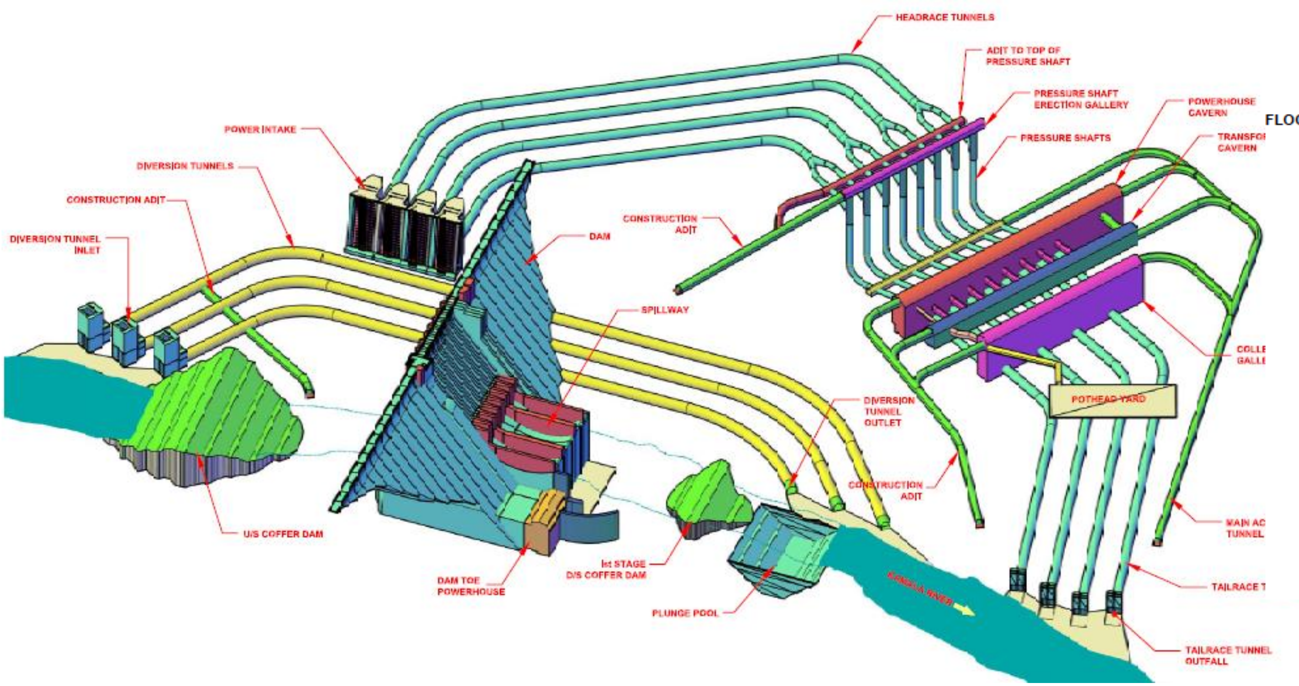
Case Study
Kamala Dam

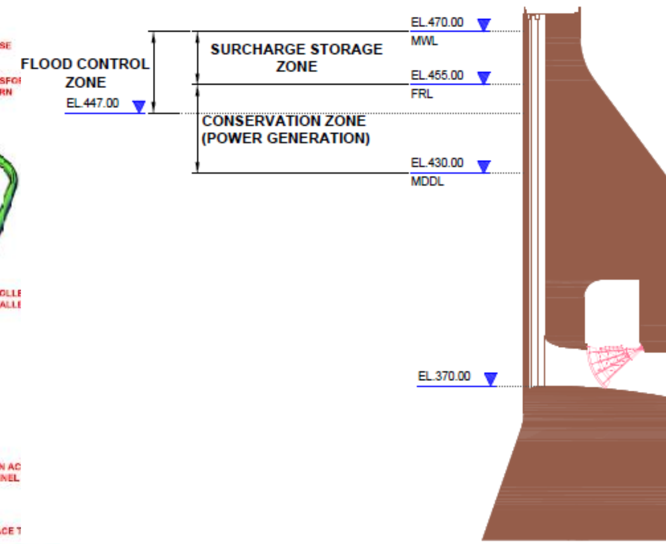
Arunachal Pradesh, India

Kamala Hydroelectric Project

- Multipurpose project with dual objectives
  - Power generation - with planned installed capacity of 1800 MW
  - Flood Moderation

- 216m high Concrete Gravity Dam
- Exclusive cushion of 15m above FRL for flood moderation
- Flood Control Storage : 660 MCM





Flood Moderation Requirement

Requirement of Flood Moderation in Subansiri basin as contemplated by "Technical Group on Flood Moderation Aspects in Brahmaputra Basin" entailed the following requirement:

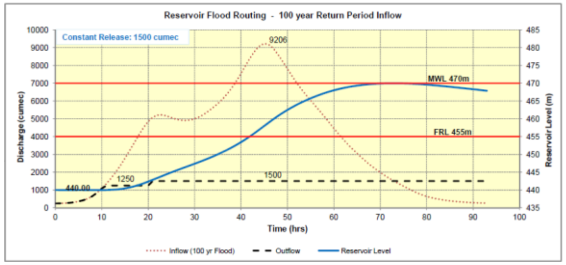
- Same Flood Moderation should be available throughout the monsoon period
  - This means that the upstream reservoirs (Kamala and Upper Subansiri) be operated at constant level throughout monsoon
- Release downstream of Subansiri Lower dam should not exceed 7000cumec
  - This restricts the release from the upper two projects so that the combined discharge including contribution of the intermediate catchment does not exceed permissible limits

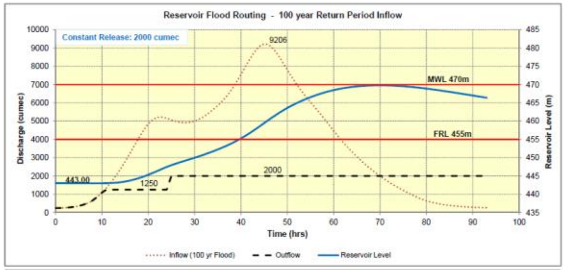
Flood Routing for 100 year Flood

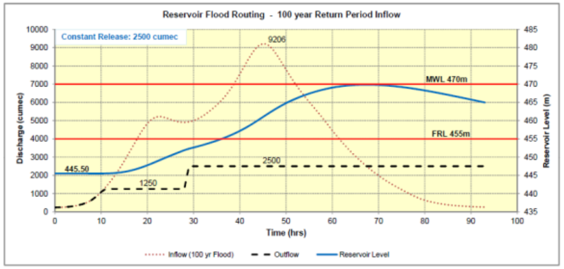
› Kamala reservoir to be kept at El. 447m during monsoon i.e. providing 23m of storage for flood moderation

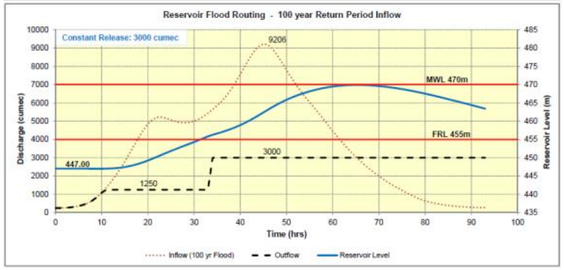
› Reservoir rule curve evolved and Index levels determined beyond which release can be more than the power discharge

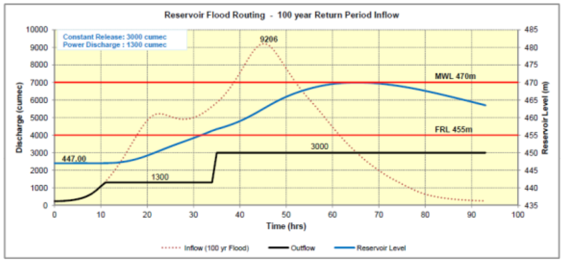
› Maximum outflow from the reservoir restricted to 3000 m^3/s

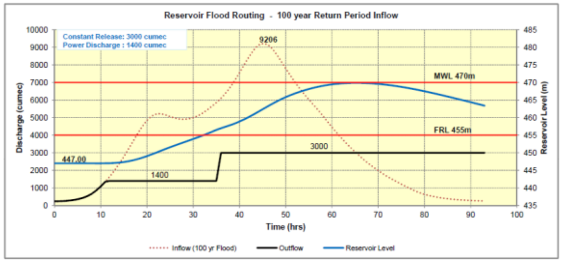






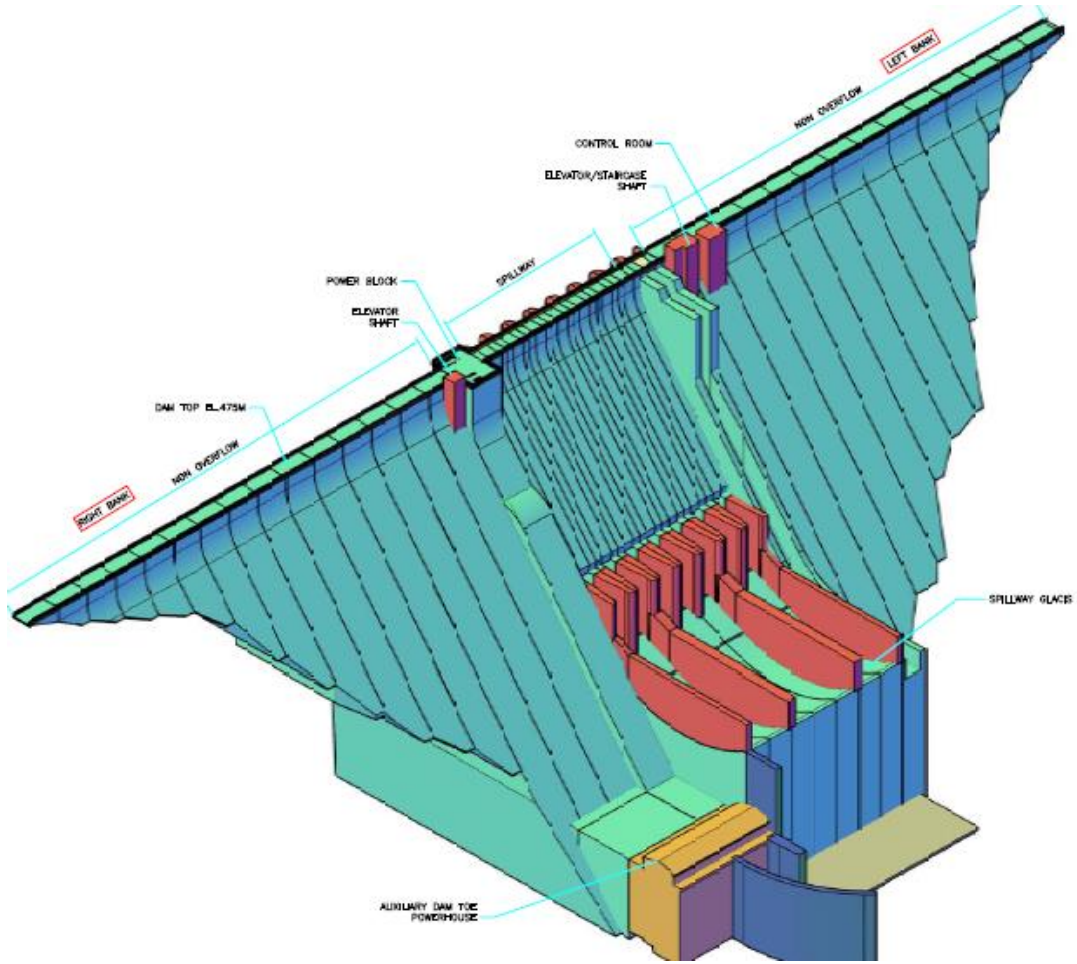






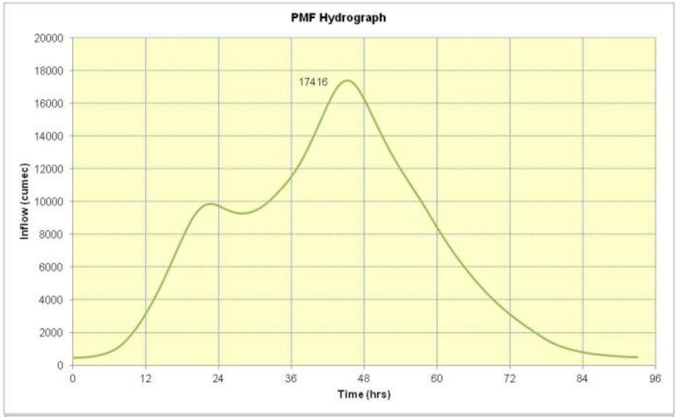
Spillway Capacity

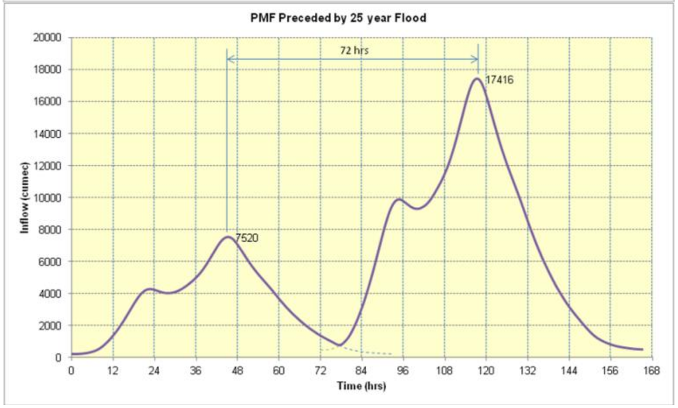
- Inflow Design Flood (IDF)
- Initial Level of Reservoir
- Reservoir Characteristics
- Malfunctioning of Gates
- Freeboard

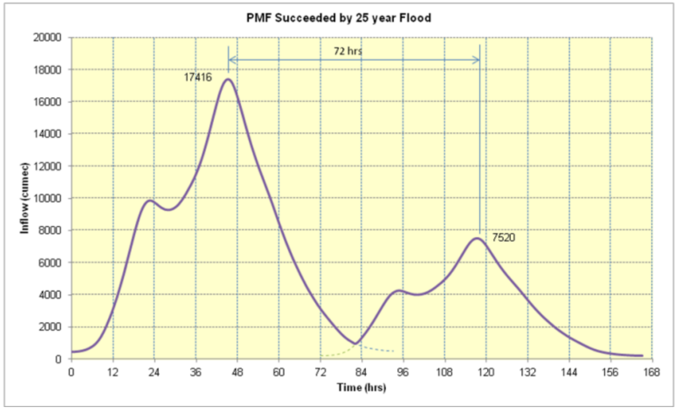


IDF & Design Conditions

- Inflow Design Flood
  - Kamala dam is categorized as large dam from both the classification criteria i.e. static head and gross storage
  - IDF for spillway is Probable Maximum Flood (PMF)
  - To assess the possibility of two floods in succession, the design condition also included occurrence of PMF preceded or followed by a 25 year flood
- Design Conditions
  - Design Flood condition - PMF
  - Design Flood with Malfunctioning of gates
  - Extreme flood condition - PMF preceded or succeeded by 25 year flood
  - Extreme flood with malfunctioning of gates
  - Extreme Wind Condition







Cost Apportionment

- Surcharge storage (15m) is an exclusive storage capacity to be utilized for flood moderation and shall remain unutilized for energy generation.
  - Providing for surcharge storage requires additional costs exclusively for flood moderation.
- In the present case, Flood Moderation would require that the reservoir be operated at a lower level during monsoons.
  - This operation would lead to loss of energy generation from the project.
- Project cost therefore has to be allocated amongst power generation and flood moderation
  - Cost of additional height of dam & appurtenances for providing surcharge storage
  - Cost due to additional period required to construct a higher dam. This primarily consists of IDC and escalation for the extra construction period
  - Loss of annual energy generation attributable to reservoir operation at lower level in monsoon as per rule curve

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We’re innovative, collaborative, competent and visionary.

Customer focus

Our business exists to serve and add long-term value to our customers’ organizations.

Strong investor return

We seek to reward our investors’ trust by delivering competitive returns.

Health & safety, security and environment

We have a responsibility to protect everyone who comes into contact with our organization.

Ethics & compliance

We’re committed to making ethical decisions.

Respect

We consistently demonstrate respect for all our stakeholders.


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