OUTLETS, SPILLWAYS AND POWER INTAKES

Professor Philippa Webb

Hearing for the First Phase on the Merits

Indus Waters Treaty Arbitration (Pakistan v. India)

PCA Case No. 2023-01

11 July 2024, The Hague

Table of Pondage and Controllable Volume

Project	Pondage, Mm³	Total Controllable Volume, Mm^3
Baglihar (NE 2007 Determination)	**32.56** Between 836.0 m – 840.0 m.	The dead storage is 363.39 Mm^3 constituting a gross storage of 395.95 Mm^3. The invert of the lowest outlet is at 808.0 m (28.0 m below DSL) which provides India a control over the storage of about **209 Mm^3**. The mean bed level is at 713.20 m.
Kishenganga (as built)	**7.55** Between 2,384.5 m – 2,390.0 m.	The dead storage is 10.80 Mm^3 constituting a gross storage of 18.35 Mm^3. The invert of the lowest outlet is at 2,370.0 m (14.5 m below DSL) which provides India a control over the storage of about **17.94 Mm^3**. The mean bed level is at 2,359.52 m.
Ratle (as designed)	**23.86** Between 1,029.0 m – 1,015.86 m	The dead storage is 54.85 Mm^3 constituting a gross storage of 78.71 Mm^3. The invert of the lowest outlet is at 985.0 m (30.86 m below DSL) which provides India a control over the storage of about **59.91 Mm^3**. The mean bed level is at 920.0 m.

Outline of submissions

1. Relationship between Paragraphs 8(d), (e) and (f)

2. Interpretation of Paragraph 8(d) on outlets

3. Interpretation of Paragraph 8(e) on spillways

4. Interpretation of Paragraph 8(f) on intakes

Outlets

Annexure D, Paragraphs 8(d), (e), (f)

No. 6032

INDIA, PAKISTAN and INTERNATIONAL BANK FOR
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INDE, PAKISTAN et BANQUE INTERNATIONALE P
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(*d*) There shall be no outlets below the Dead Storage Level, unless necessary for sediment control or any other technical purpose ; any such outlet shall be of the minimum size, and located at the highest level, consistent with sound and economical design and with satisfactory operation of the works.

(*e*) If the conditions at the site of a Plant make a gated spillway necessary, the bottom level of the gates in normal closed position shall be located at the highest level consistent with sound and economical design and satisfactory construction and operation of the works.

(*f*) The intakes for the turbines shall be located at the highest level consistent with satisfactory and economical construction and operation of the Plant as a Run-of-River Plant and with customary and accepted practice of design for the designated range of the Plant's operation.

Annexure D, Paragraphs 2(a) and (b)

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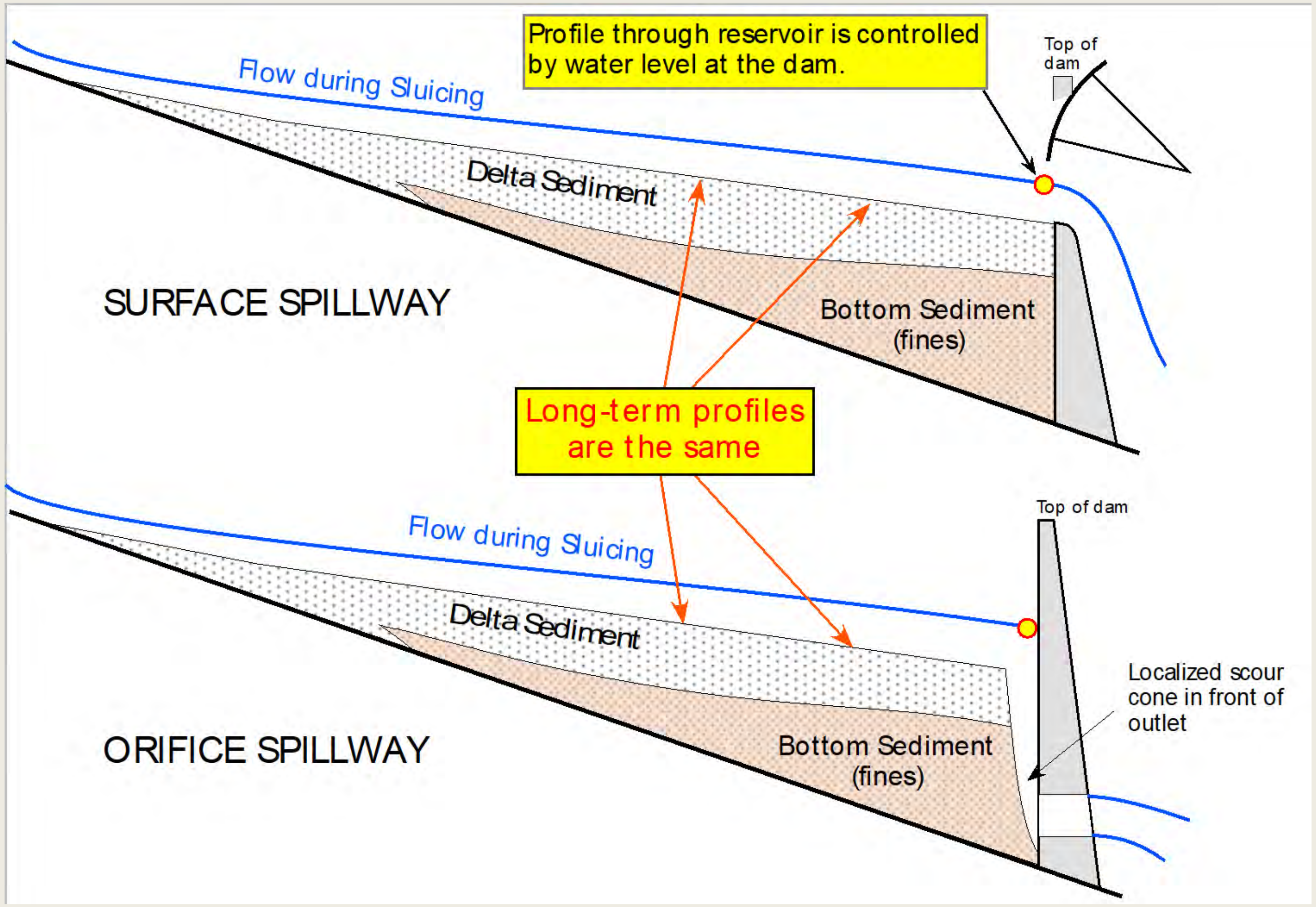
2. As used in this Annexure :

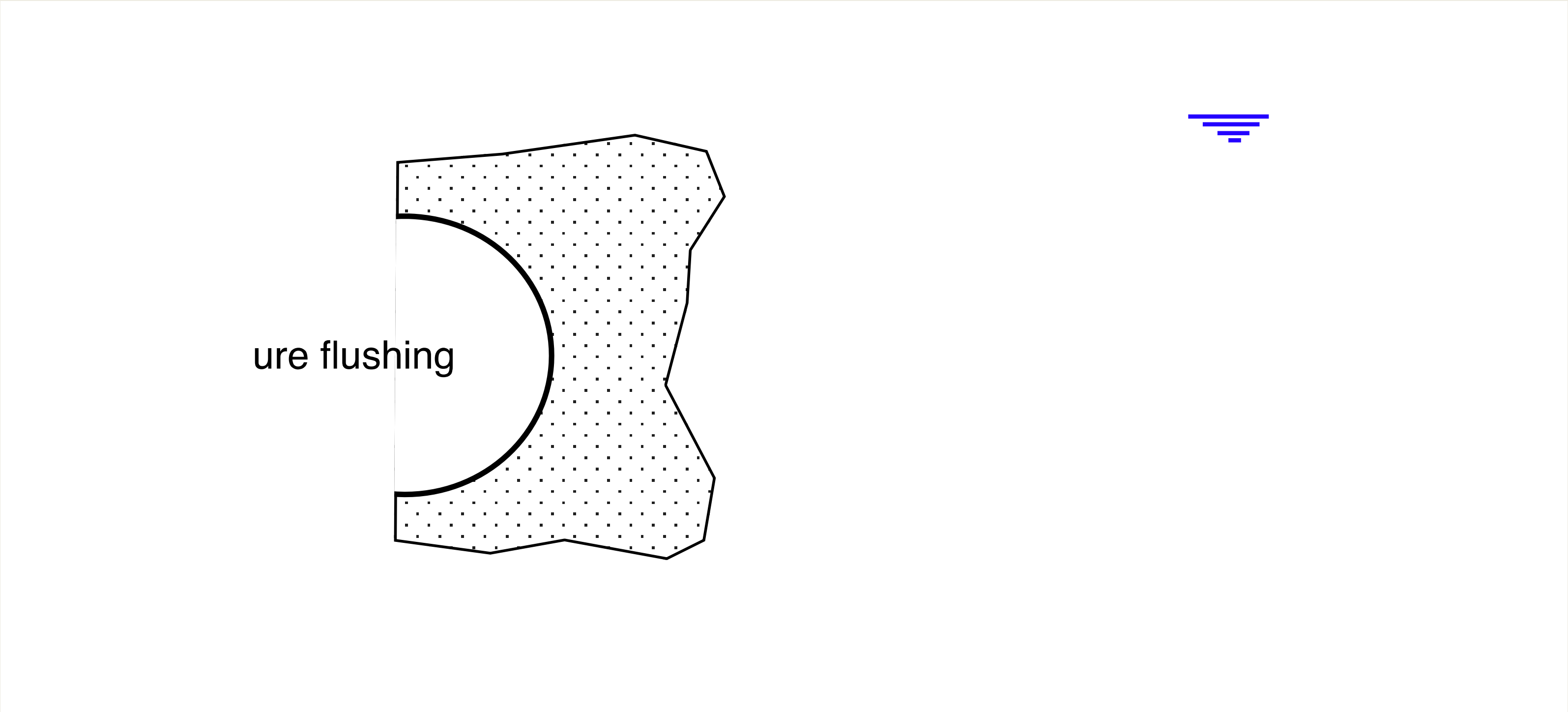
(*a*) "Dead Storage" means that portion of the storage which is not used for operational purposes and "Dead Storage Level" means the level corresponding to Dead Storage.

(*b*) "Live Storage" means all storage above Dead Storage.



Outlet placement

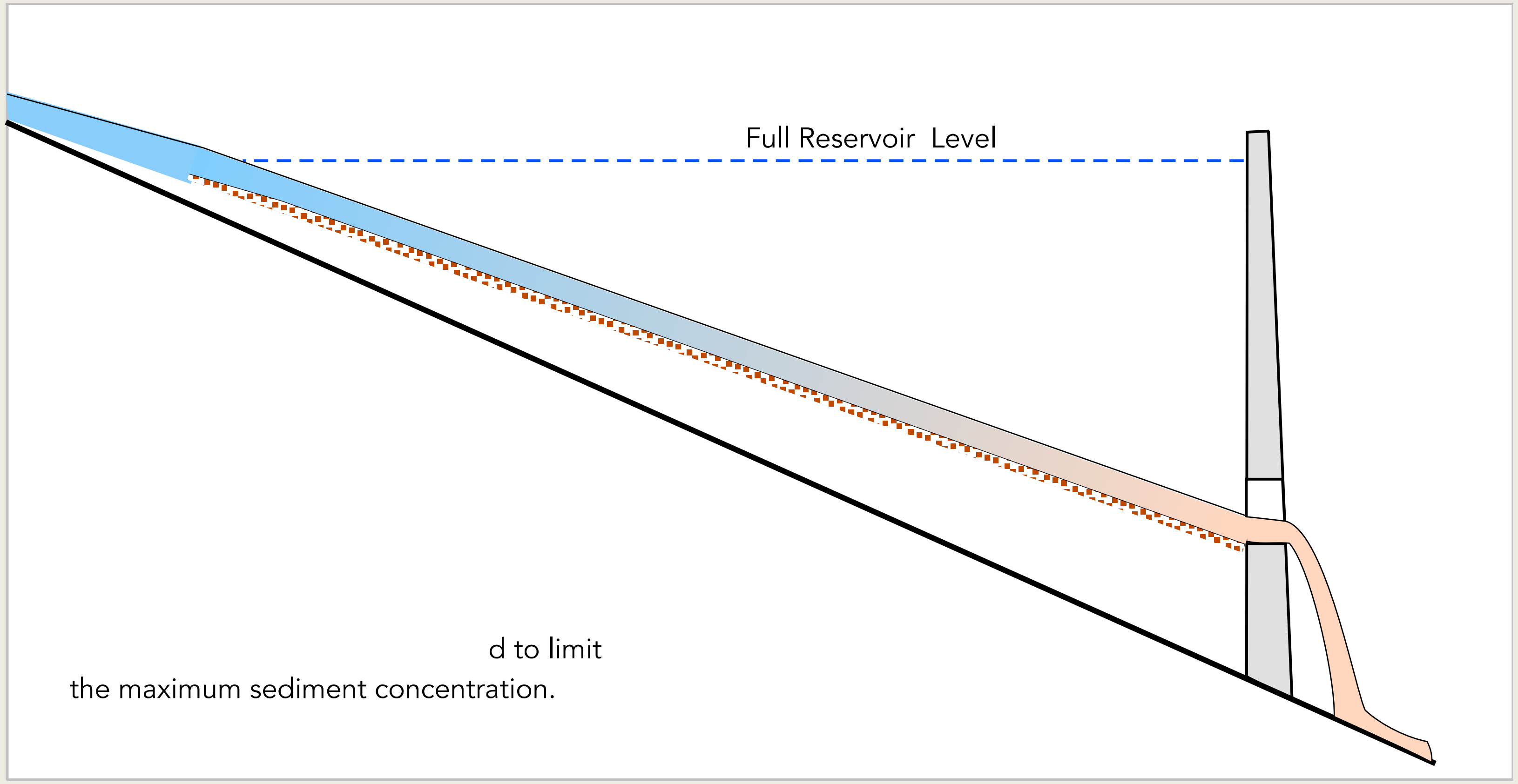
- Water level at the dam is a key factor controlling the sediment profile along the length of a reservoir.
- Changing outlet depth will not change the profile if the water level at the dam remains constant.
- A low level outlet will create a localized scour cone at the upstream side of the outlet.



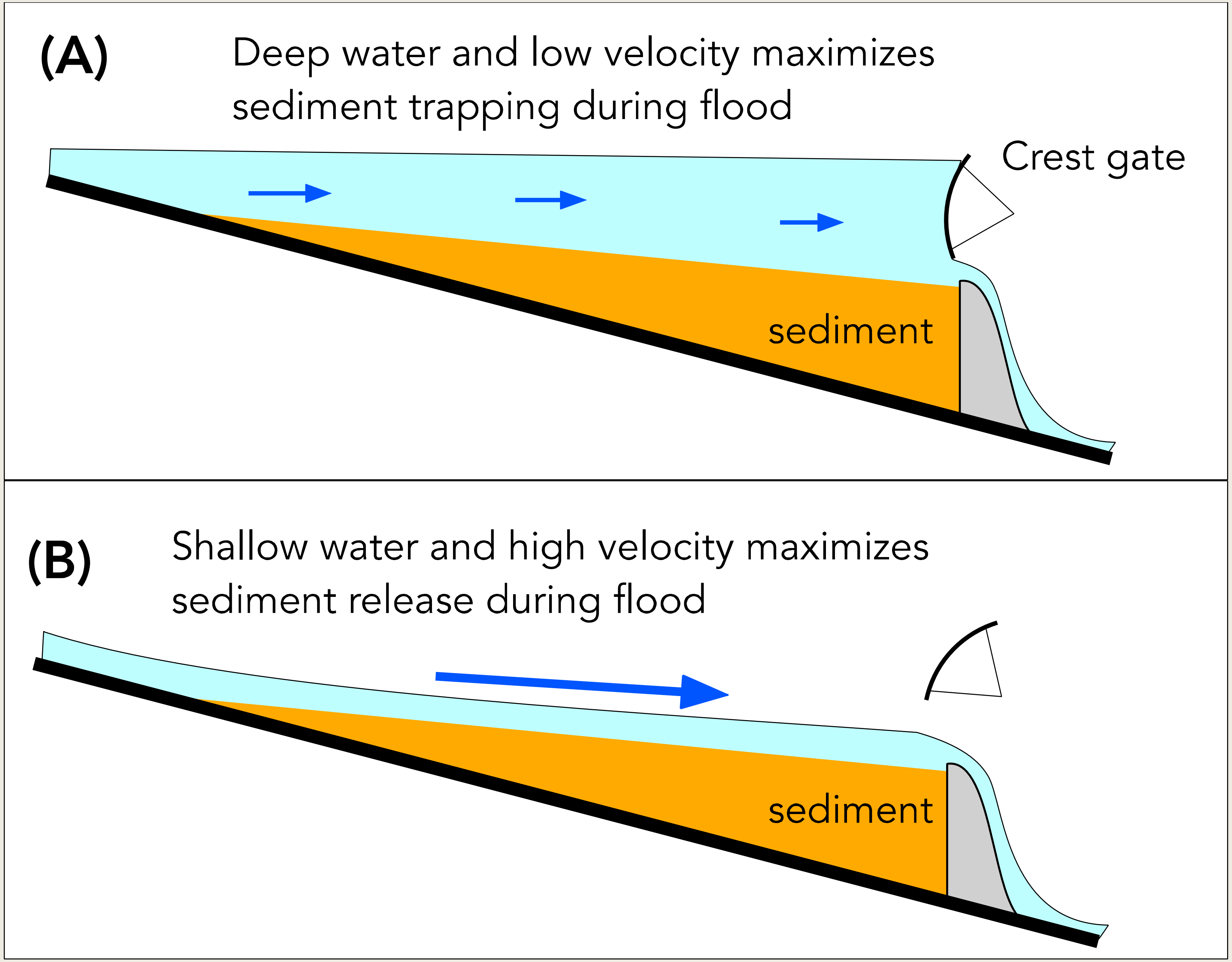
Pressure Flushing

- When a low-level outlet is opened, but the reservoir remains at a high level, a **scour cone** will develop in the immediate vicinity of the outlet.
- The process is termed **pressure flushing** because it does not involve reservoir drawdown.

Empty flushing



- Empty flushing involves **emptying the reservoir** and allowing the river to scour the sediment deposits through low-level outlets in the dam.
- Flushing often has **significant downstream environmental impact** due to extremely high sediment concentrations.
- Flushing is rarely the only available form of sediment management (cf. sluicing). Downstream impacts can be minimized through **mindful design and operation of the HEP**.



COA Site Visit, Presentation 6, Slide 17

Flood sluicing

- Pass sediment-laden floods through the reservoir at the highest possible velocity to minimize sediment trapping.
- Sediments are routed through the reservoir and exit downstream through the high-capacity gates that are opened to pass the flood.

Annexure D, Paragraph 8(d)

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(*d*) There shall be no outlets below the Dead Storage Level, unless necessary for sediment control or any other technical purpose ; any such outlet shall be of the minimum size, and located at the highest level, consistent with sound and economical design and with satisfactory operation of the works.

Paragraph 8(d) Flow Chart

LLO is necessary for sediment management or other technical purpose

Identify options: sound and economical design

Select design that allows for smallest and highest LLO

Satisfactory operation of the works

Annexure D, Paragraph 8(d)

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PLA-0001

Kishenganga Partial Award, §§397-398

"Turning to the threshold for necessity, the Court sees no need to associate this term with indispensability or emergency action, as argued by Pakistan. The concept of necessity appears elsewhere in the Treaty without such connotations, including the provisions of Annexure G interpreted by the Court in its Order on Interim Measures. **The Court sees no reason, for purposes of the Treaty, to ascribe to it any special meaning beyond the normal use of the term to describe action that is 'required, needed or essential for a particular purpose'....**

This interpretation does not, however, reduce necessity to a mere test of what is desirable, nor does it become a self-judging matter for India alone to evaluate. The Court can imagine situations in which the benefits of including the diversion of water within the scheme of a Run-of-River Plant would be so marginal that such a diversion could not fairly be termed 'necessary.' In the present case, however, the Court concludes, on the basis of its understanding of the KHEP and its appreciation of the Gurez site, that diversion from that site is, in fact, 'necessary' for India to generate significant power."

Kishenganga Interpretation or Clarification, §33

"Faced with a Treaty applicable throughout the tributary system of the Western Rivers, the Court's evaluation of alternative methods of sediment control was necessarily general, and not dependent upon the characteristics of particular sites—although as the Court also recognized, the actual impact of sediment at any particular site can only be evaluated in the context of that site. Rather than limiting the application of the Treaty's prohibition on drawdown flushing, however, this fact goes to **the question of whether a particular site will be available as a practical matter to India for hydro-electric development**. ... As the Court made clear in its Partial Award, it is for India to secure appropriate locations and to draw appropriate designs for its Run-of-River Plants, bearing in mind that the Indus Waters Treaty has foreclosed the depletion of Dead Storage for drawdown flushing."

PLA-0021

Annexure D, Paragraph 8(d)

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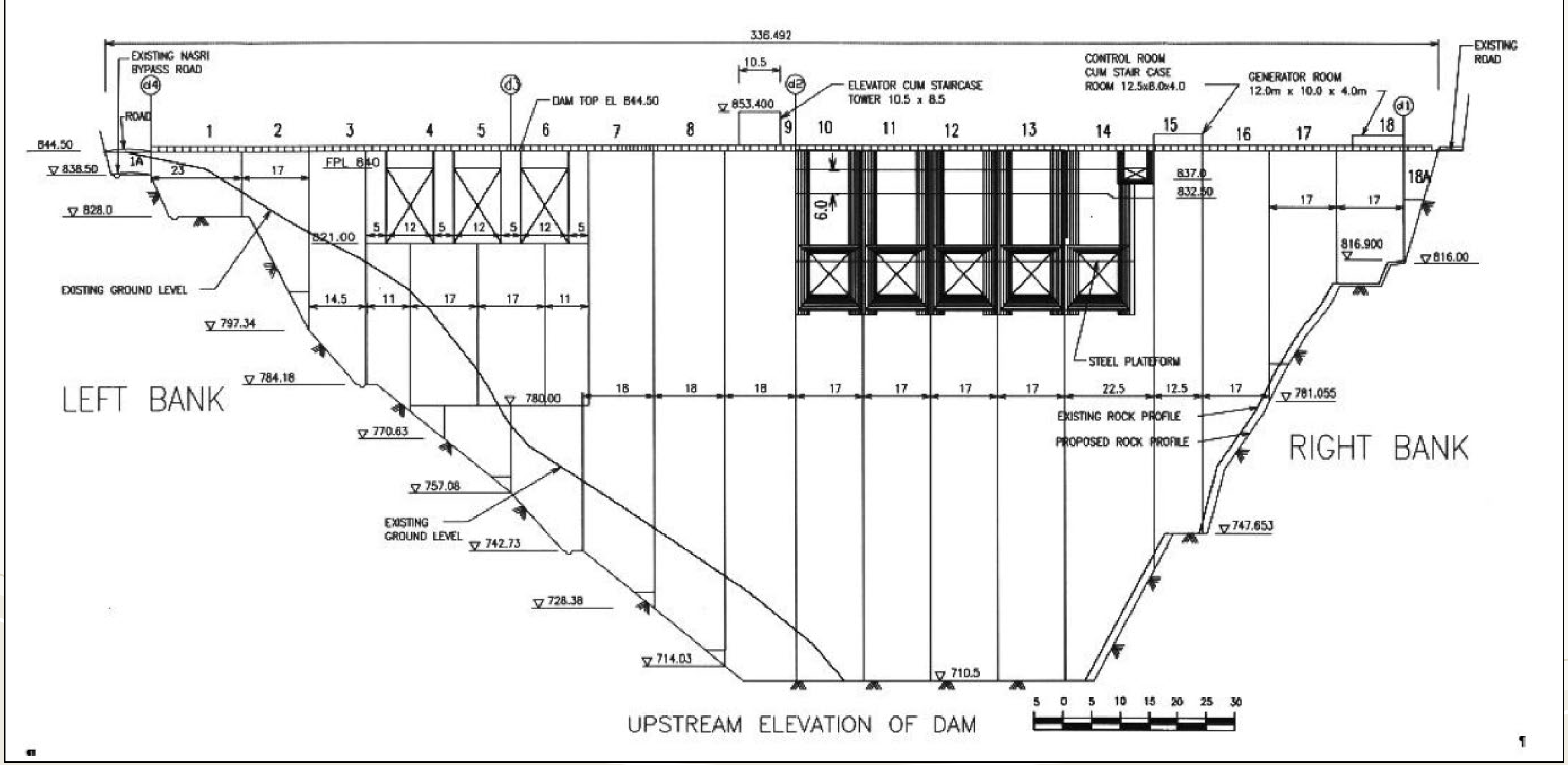

Typical Indian HEP Design

Pakistan's Memorial, Fig. 10.11

PIC 111th meeting (2015)

“PCIW said that despite the fact that clear guidelines are provided regarding sediment management in Baglihar and Kishenganga cases yet India keeps on proposing deep orifice spillways in its designs. The [Kishenganga Court] has imposed a restriction upon India that it will not draw the water level down below [Dead Storage Level] for flushing and India has given assurance to abide by the Award of the Court. PCIW further stated that Pakistan does not have any objections to sluicing but is of the view that once drawdown flushing is ruled out, crest-gated spillways can effectively pass the sediments through the reservoir.

PCIW explained that it is clear from reading of Paragraph 8 of Annexure D to the Treaty that its intent is to minimize the control over the flows by the upstream riparian and the Treaty scheme is to specify such limitations on the design so that the hydropower infrastructure that would be built by the upstream riparian would inherently get minimum control over the flows.”

PLA-0025, §§29-30

PIC 111th meeting (2015)

"Neither the Treaty nor the Court has imposed any restriction on the placement of orifice[s]. There has not been any literature which substantiates Pakistan side's view that orifice spillway can only be provided for drawdown flushing and not for sluicing. The restriction imposed by [the *Kishenganga* Court] is operational and India has given unequivocal assurance to abide by the same. India has right to manage the sediments within the means available and there is no provision in the Treaty which states orifice spillway cannot be provided by India. [The *Kishenganga* Court] has duly considered the orifice spillway configuration provided by India and has not objected to the same. India has adopted techno-economically sound design as per Treaty provisions duly considering all technical requirements including sluicing."

PLA-0025, §§29-30

Kishenganga, Partial Award, §522 fn. 739

"In the case of the KHEP, the Court is cognizant that changes to the design of the project may be required to optimize the management of sediment in light of this Partial Award. In this respect, it is provident for the Court to note that its Order on Interim Measures has temporarily restrained the construction of 'permanent works on or above the Kishenganga/Neelum riverbed,' a development that may now serve to facilitate any changes in design that India may need to implement in light of the Court's decision on drawdown flushing."

PLA-0003

Procedural Order 6,¶ 35(e)

PCA Case No. 2023-01

IN THE MATTER OF AN ARBITRATION

-before-

THE COURT OF ARBITRATION CONSTITUTED
IN ACCORDANCE WITH THE INDUS WATERS TREATY 1960

-between-

THE ISLAMIC REPUBLIC OF PAKISTAN

-and-

THE REPUBLIC OF INDIA

PROCEDURAL ORDER NO. 6

(DECISION ON FURTHER PROCEEDINGS)

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Professor Sean D. Murphy (Chairman)
Professor Wouter Buytaert
Mr. Jeffrey P. Minear
Judge Awn Shawkat Al-Khasawneh
Dr. Donald Blackmore

SECRETARIAT:

The Permanent Court of Arbitration

6 July 2023

(e) With respect to Annexure D, paragraph 8(d) of Annexure D, what is to be taken into account for the purposes of designing low-level sediment outlets for a plant and what is to be excluded?

Relevant and irrelevant factors for low-level outlets

Relevant factors

- Necessity for sediment control
- Necessity for another technical purpose
- Need for sediment control within Treaty limits
- Position of outlet relative to other structures affected by sediment
- Requirements for structural and hydro-mechanical equipment design

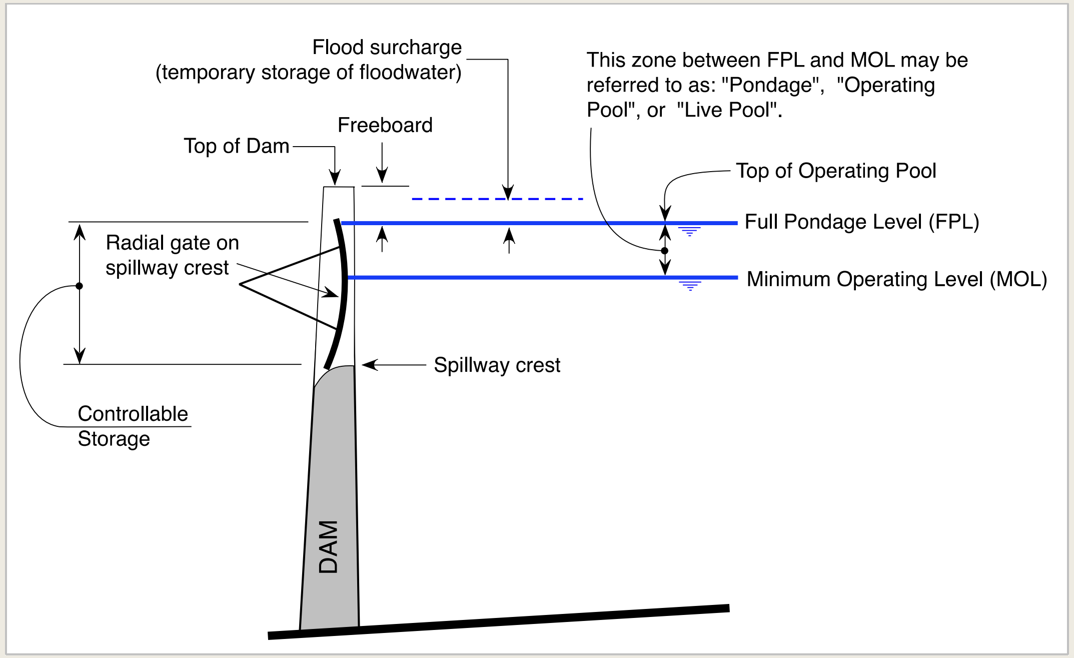
Irrelevant factors

- Ancillary, non-technical benefit
- Objectives separate from sediment management
- Construction ease and cost

Spillway

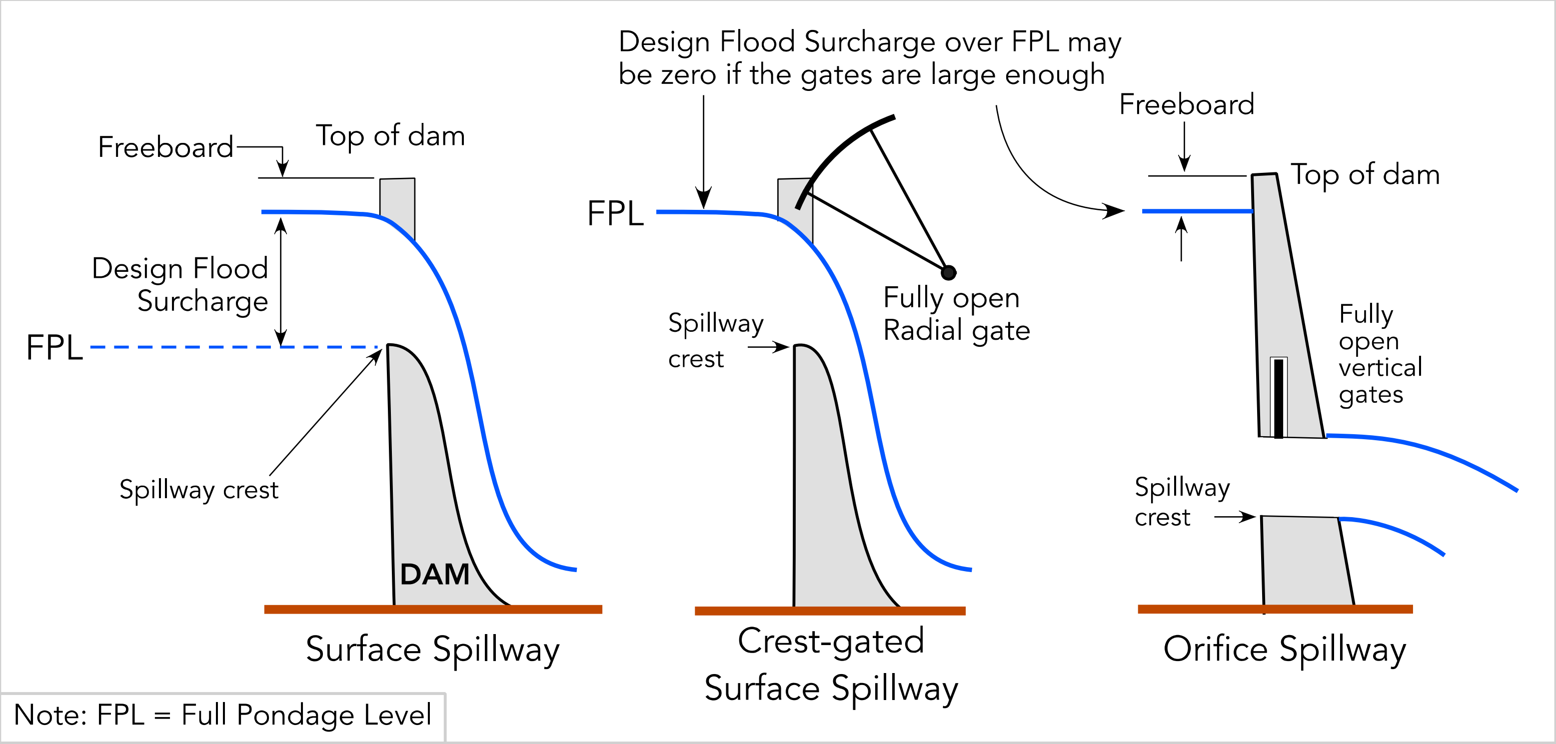
- The spillway is the principal structure by which water is passed through the dam – particularly in times of flood. It may also have other applications (e.g. sediment management).
- Multiple spillway structures may be included in the same dam.
- Usually includes a structure to prevent erosion of the riverbed at the foot of the dam.

Spillway and freeboard configuration

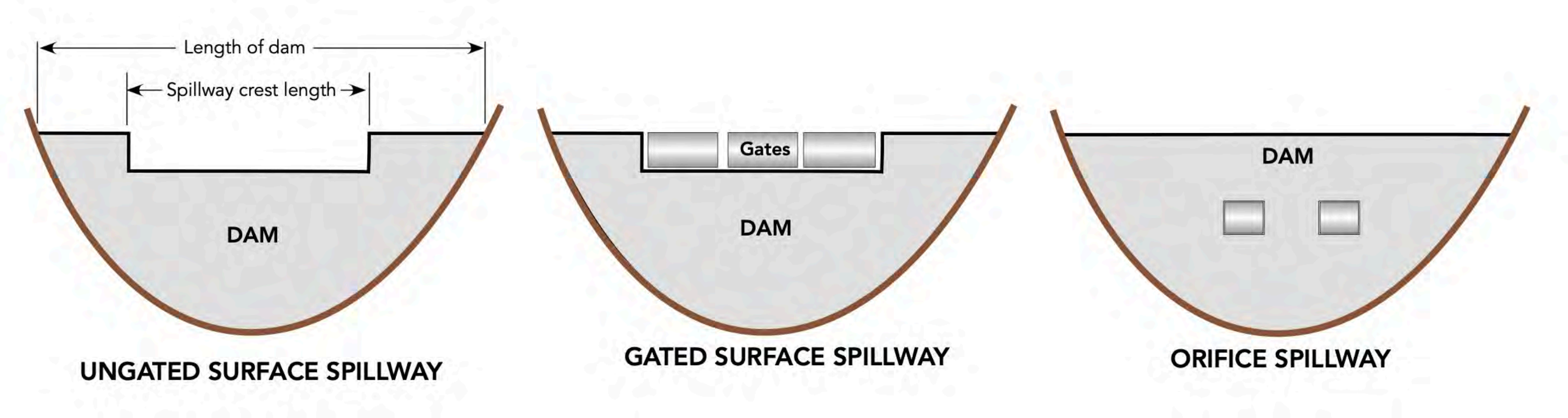


- The spillway is the principal means of releasing water through the dam and of flood control.
- It is designed to safely pass the **design** or **probable maximum flood**, which is assessed based on location.
- In the Himalaya, the design flood is usually assessed on a 10,000 year basis.
- Its placement may be relevant to the freeboard, being the portion of the dam that extends above the top of the operating pool and protects the dam from overtopping.

Spillway design



Advantages of spillway designs



Multiple spillway design

Orifice spillway

Surface gated spillway

Annexure D, Paragraph 8(e)

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(*e*) If the conditions at the site of a Plant make a gated spillway necessary, the bottom level of the gates in normal closed position shall be located at the highest level consistent with sound and economical design and satisfactory construction and operation of the works.

Paragraph 8(e) Flow Chart

A gated spillway is necessary due to conditions at the site of the Plant

↓

Identify options: sound and economical design

↓

Select design that allows for highest positioning of the bottom level of the gates when closed

↓

Satisfactory construction and operation of the works

Annexure D, Paragraph 8(e)

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ICOLD Bulletin 178, p. 3

Simplicity of design and construction is conducive to simpler operating rules, and simple rules which can be implemented quickly are quite obviously a determining factor in safety. This means that an ungated free-overflow spillway is the ideal solution which all dam operators would prefer.

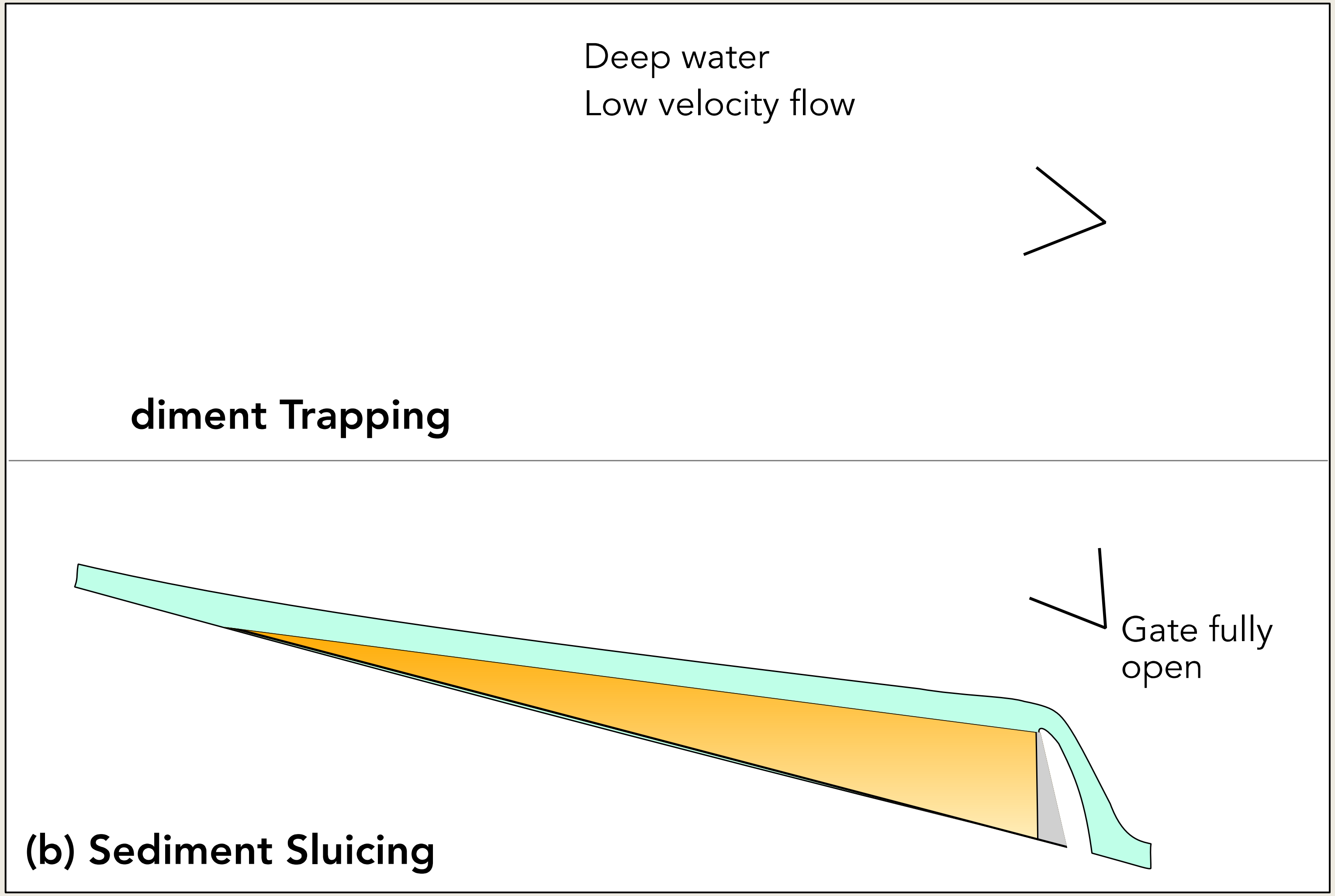
Teesta Dam Breach

Soumik Dutta, 'Teesta Dam Breach: Disregard for Green Norms, Irregularities in Focus', 22 November 2023

Narrow valley with gated spillways

https://watergis.wordpress.com/2012/03/16/the-duero-river-basin-spain/

Sluicing with gated spillway



Pakistan's Memorial, Fig. 10.6

Annexure D, Paragraph 8(e)

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Two types of gated spillway

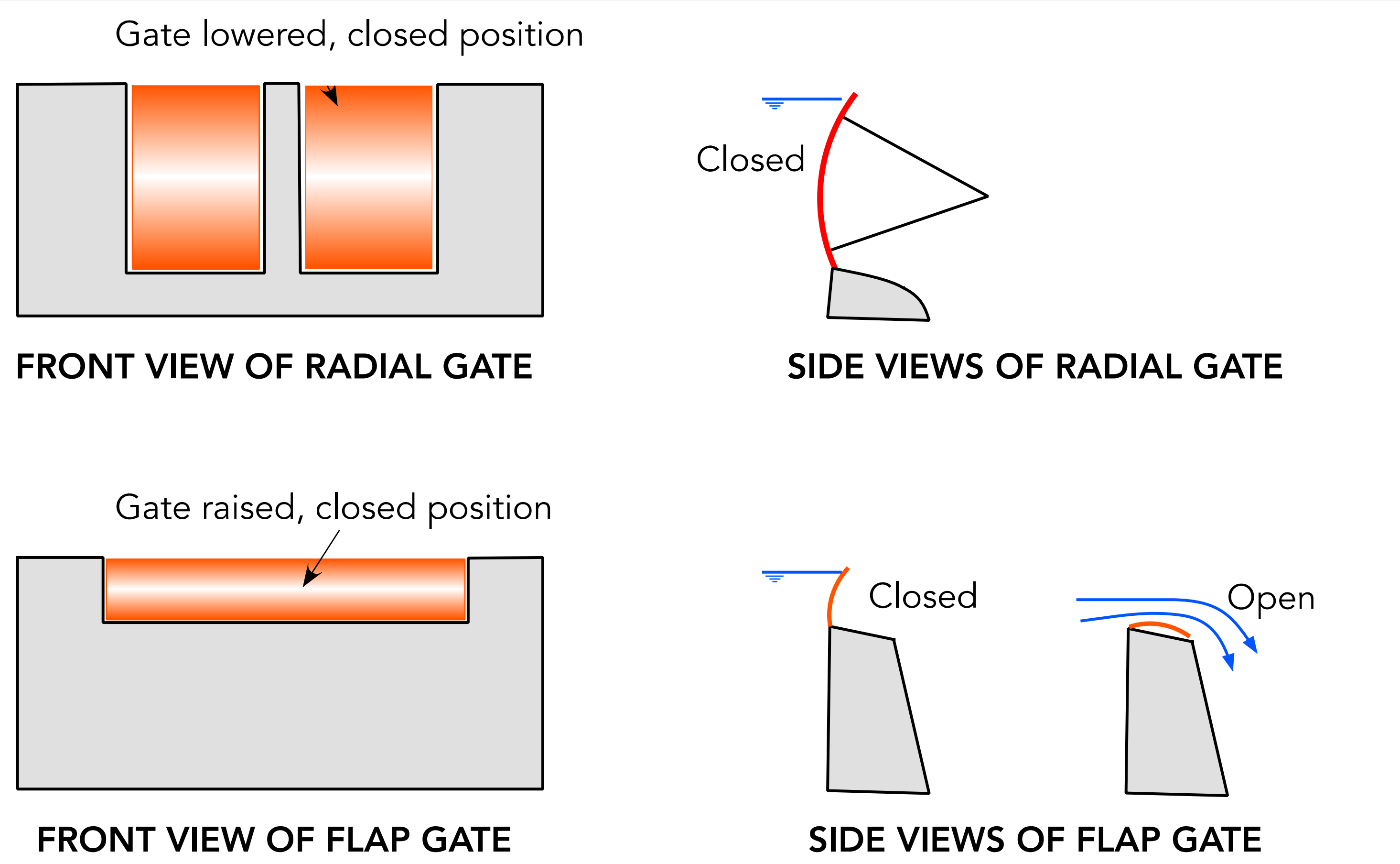

Illustration by Dr Gregory L. Morris

Annexure D, Paragraph 8(e)

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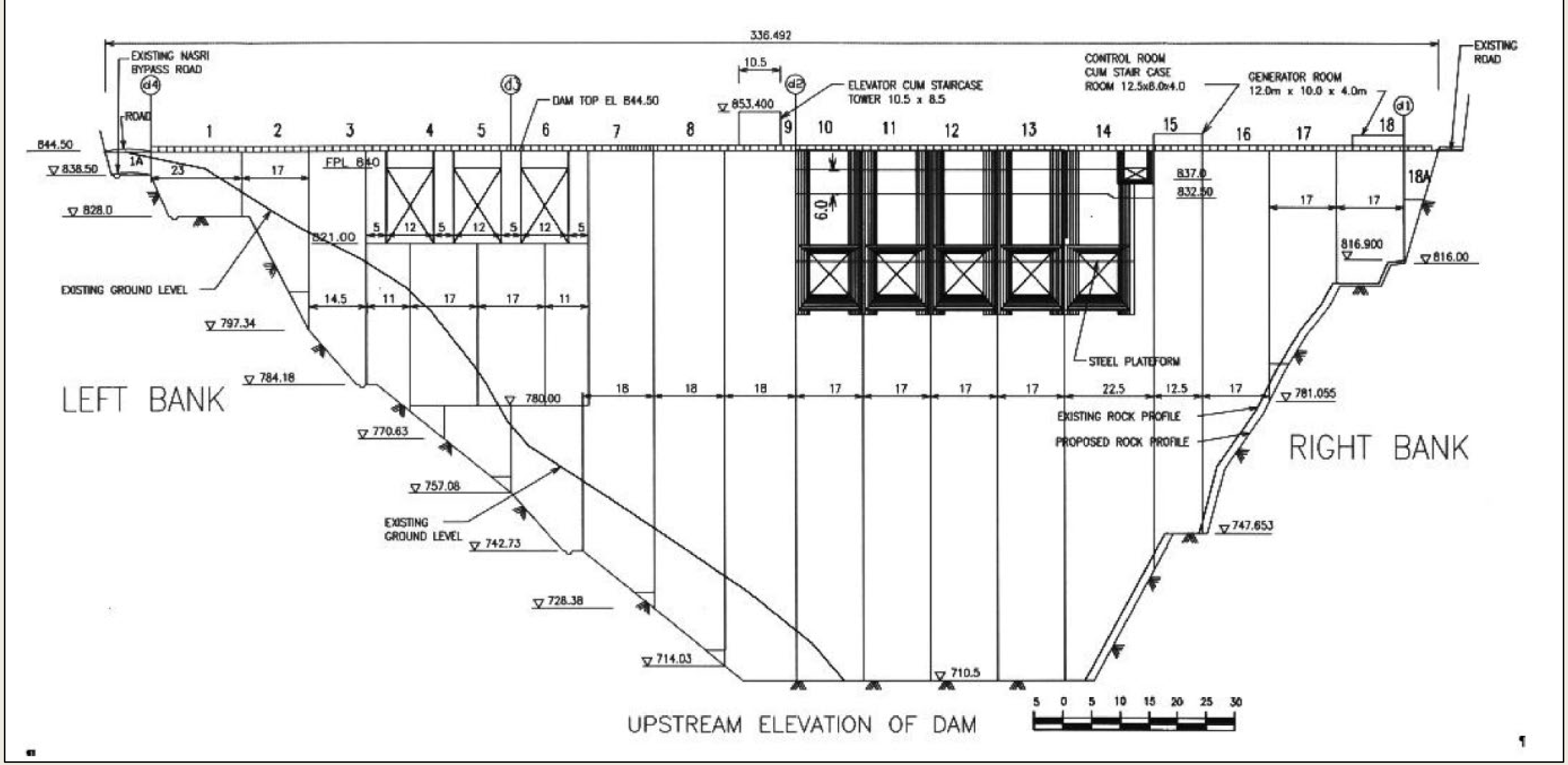

Typical Indian HEP Design

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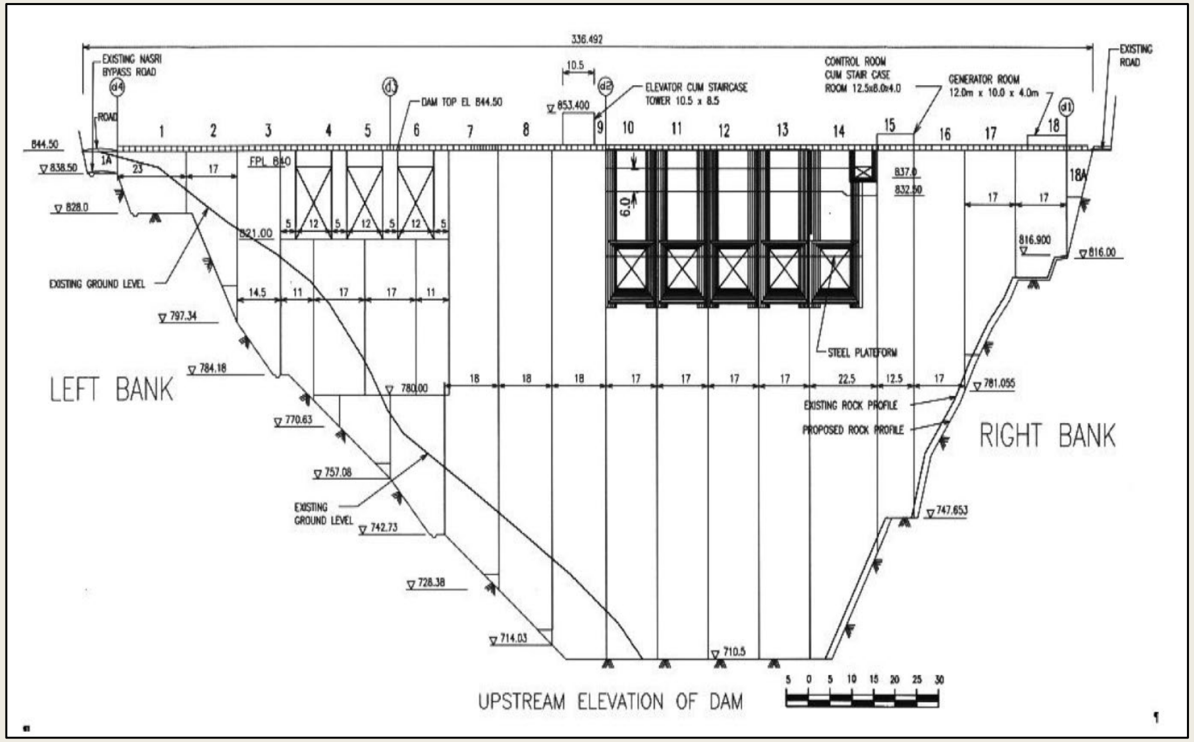
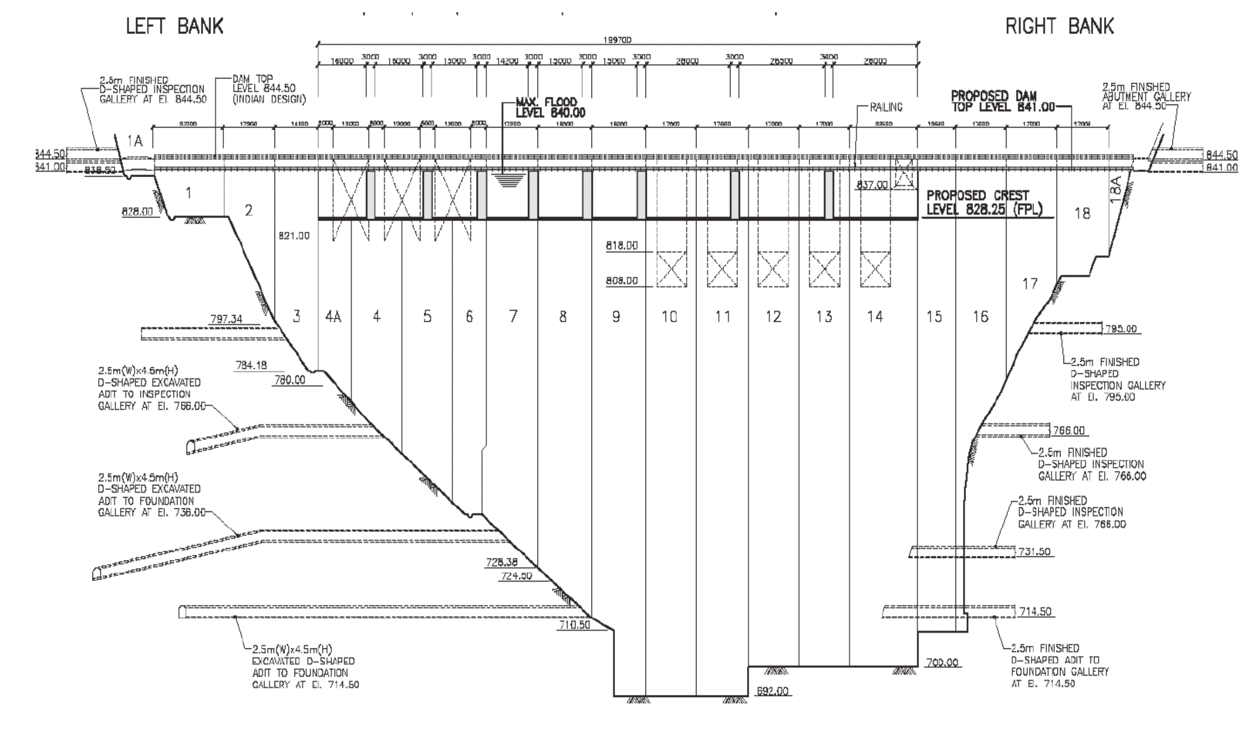
PLA-0025, §§29-30

Competing spillway designs



India



Pakistan

Baglihar Determination, PLA-0002, §§ 5.2.2. and 5.2.3

Baglihar Determination, §5.2.4

The determination of the possible arrangement of spillways must be driven by the general conditions of the site, which can be classified into the following four categories:

1. hydrology and sediment yield,
2. topography,
3. geology, and
4. seismicity

Baglihar Determination, PLA-0002, §§ 5.2.2. and 5.2.3

Errors in *Baglihar* Determination

- "for a given level of safety and taking into account site conditions, the economics of the project lead to the selection of the optimum arrangement of the spillway devices" (§5.2.4)
- Maximisation of production
- Minimisation of construction costs
- Review of other projects in Uganda, the Gambia, Sudan and Portugal

Procedural Order 6,¶ 35(f)

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Relevant and irrelevant factors for spillways

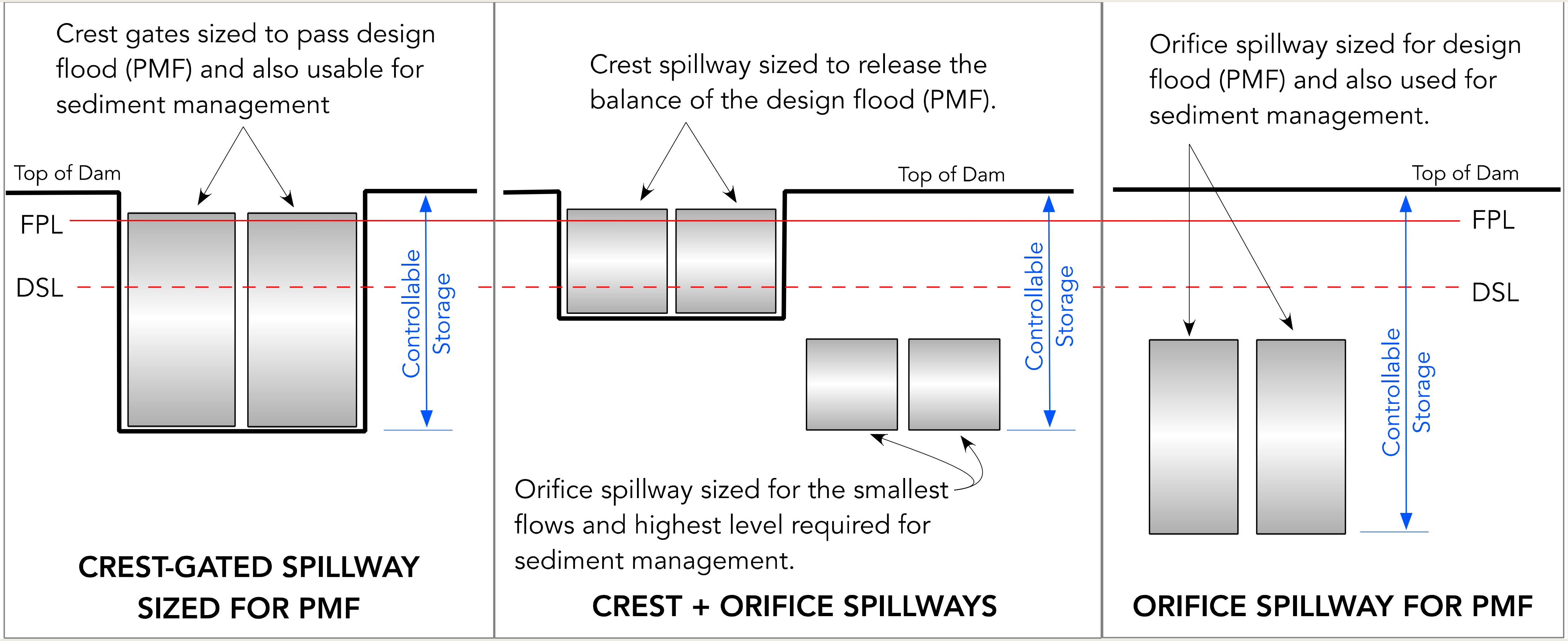
Relevant factors

- Conditions at the immediate site of the HEP
- Valley width
- Geology
- Seismicity
- Hydrography, sedimentation
- Necessity of gated spillway
- Cost and ease of construction to a satisfactory standard

Irrelevant factors

- Factors not present at the site
- Economic/cost considerations
- Wider situation away from the HEP site (upstream and downstream)

Application of Paragraphs 8(e) and (d)



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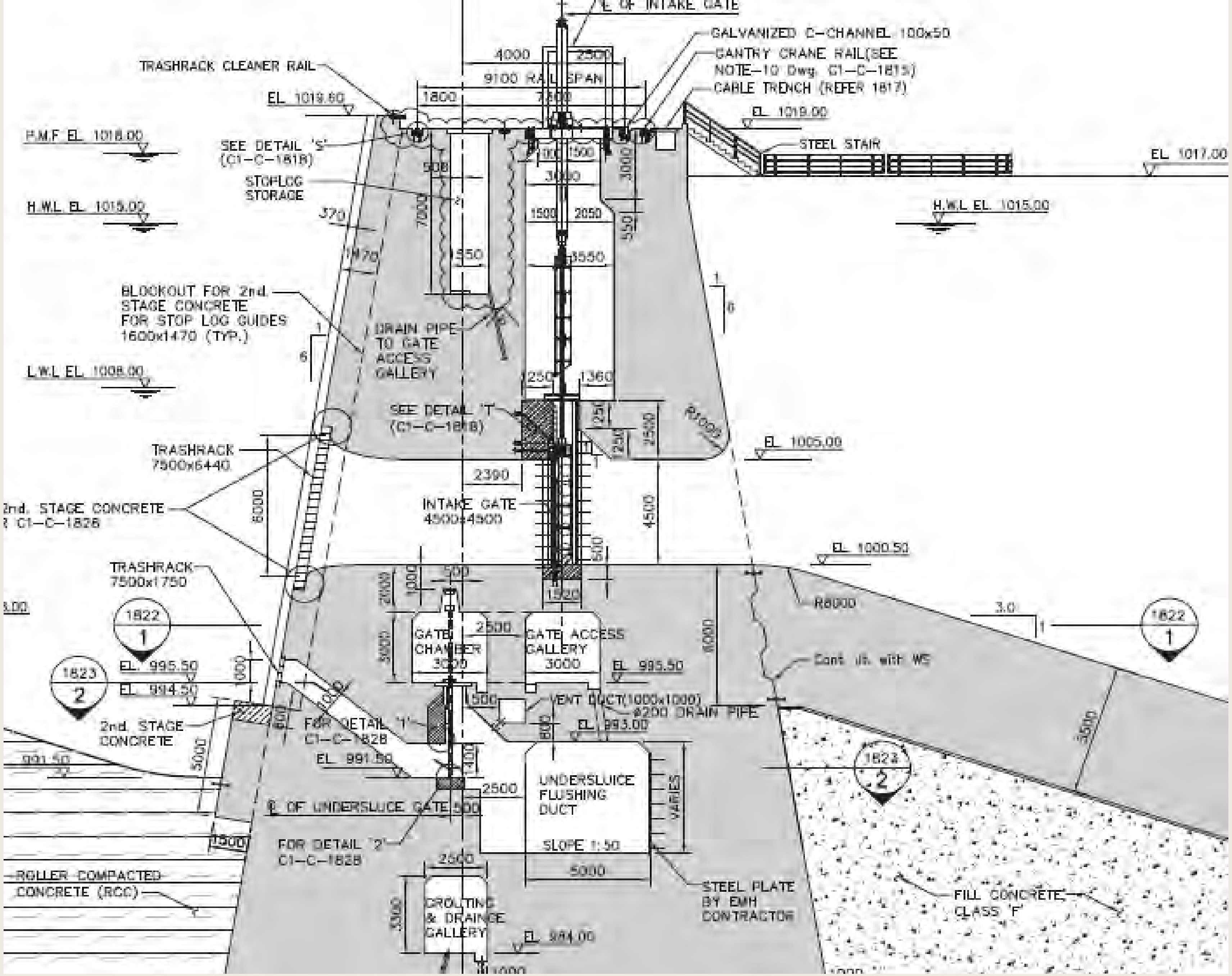
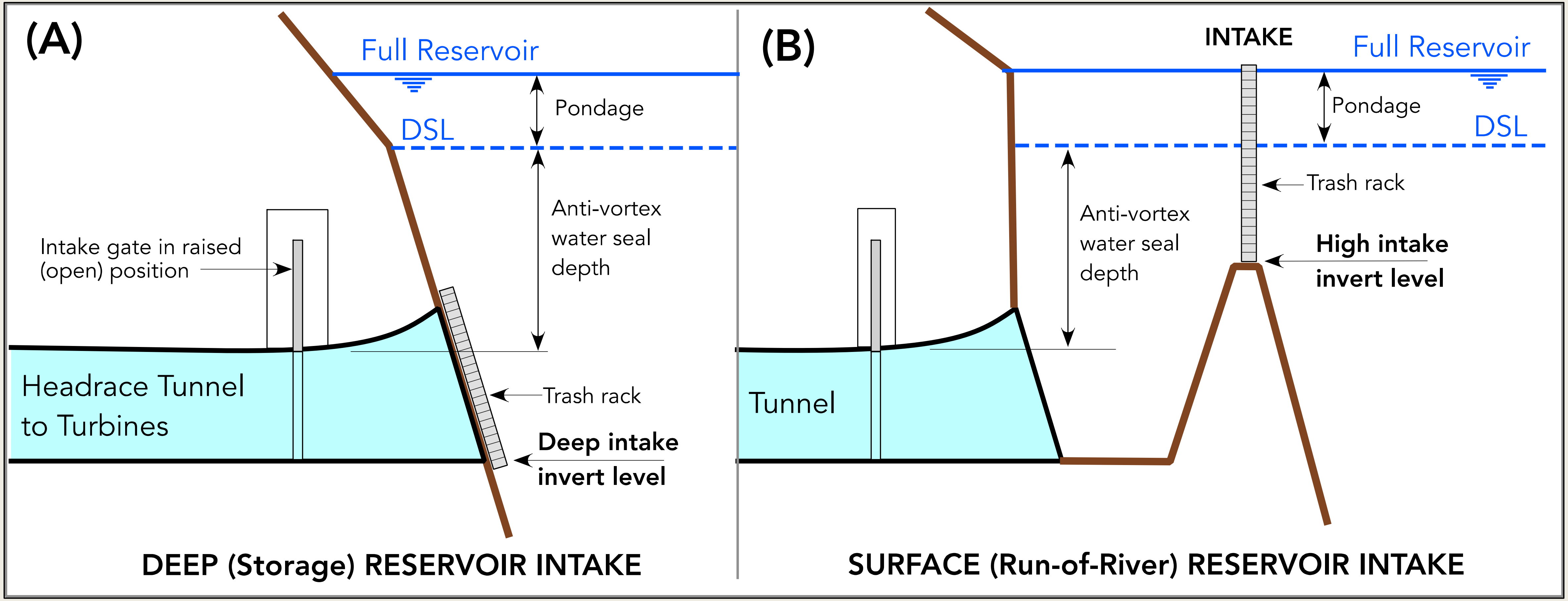


Intakes

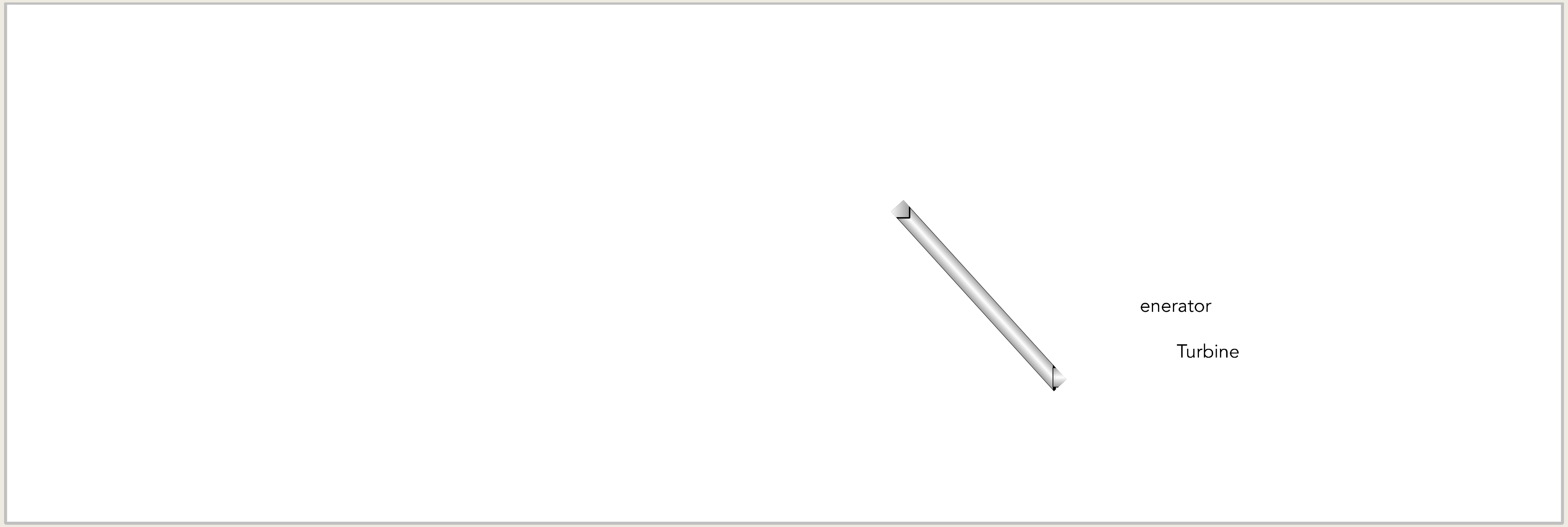
- The intakes allow water to be abstracted from the reservoir into the headrace – and on to the turbines.
- Need to be carefully designed to minimize sediment ingress and prevent vortexing.
- May include special structures to achieve both of these aims, e.g. desanders.

Potential power intake configurations



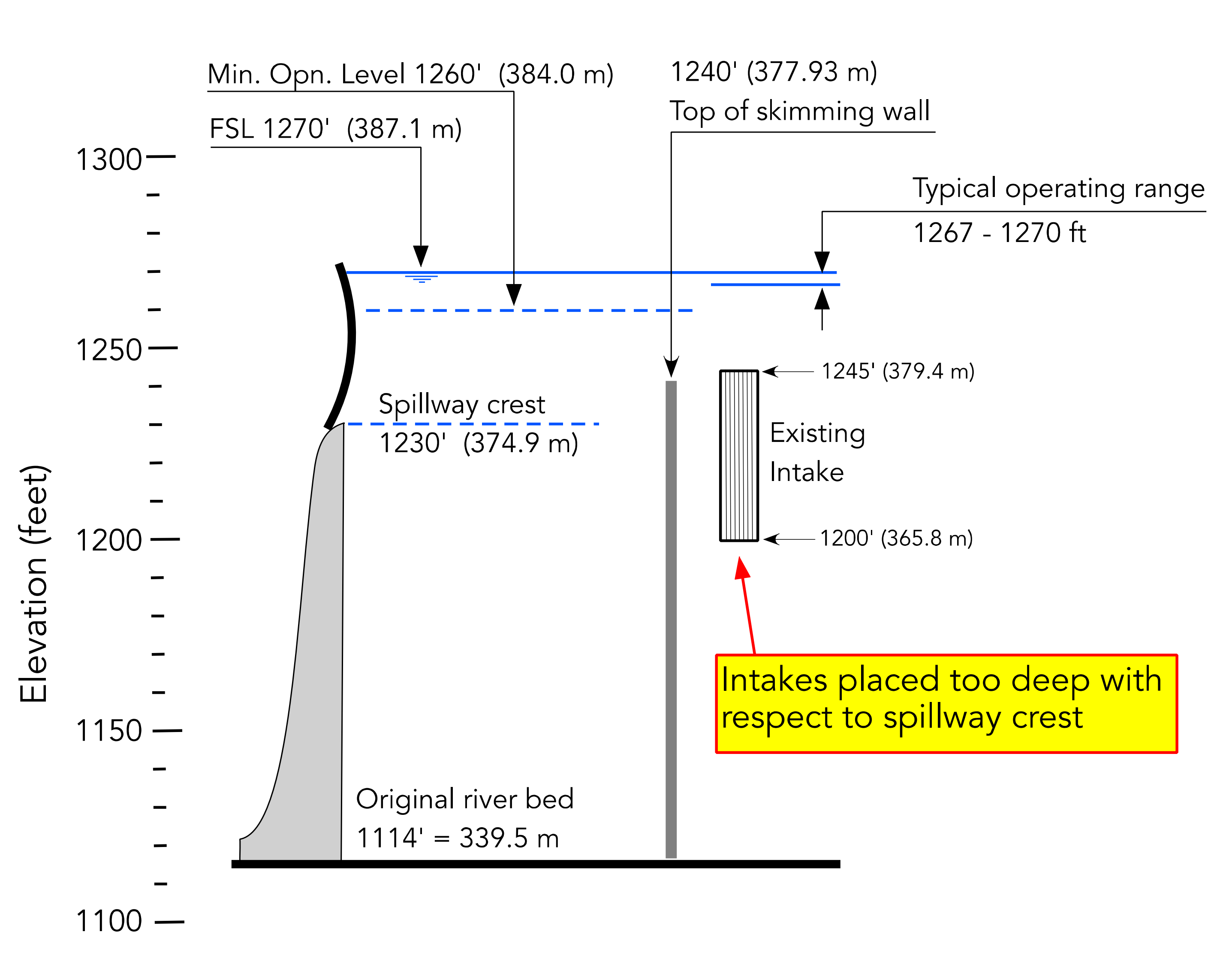
Pakistan's Memorial, Fig. 10.10

Types of conveyance elements



Intake design

- Poor intake design is a significant factor influencing sediment ingress into the turbines.
- Sediment management begins at the design stage.



Intake placement

- Sedimentation issues can be minimized by optimizing intake geometry.
- A higher intake will have fewer sediment problems as gravity causes coarser (more abrasive) sediments to sink to deeper depths.

COA Site Visit, Presentation 6, Slide 32

Annexure D, Paragraph 8(f)

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(*f*) The intakes for the turbines shall be located at the highest level consistent with satisfactory and economical construction and operation of the Plant as a Run-of-River Plant and with customary and accepted practice of design for the designated range of the Plant's operation.

Paragraph 8(f) Flow Chart

Identify options: satisfactory and economical

Select design that allowed the highest level intake in the reservoir

Consistent with customary and accepted practice of design for designated range of the HEP's operation

Annexure D, Paragraph 8(f)

(*f*) The intakes for the turbines shall be located at the highest level consistent with satisfactory and economical construction and operation of the Plant as a Run-of-River Plant and with customary and accepted practice of design for the designated range of the Plant's operation.

Annexure D, Paragraph 8(f)

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Annexure E, Paragraph 11(g)

(*g*) If a power plant is incorporated in the Storage Work, the intakes for the turbines shall be located at the highest level consistent with satisfactory and economical construction and operation of the plant and with customary and accepted practice of design for the designated range of the plant's operation.

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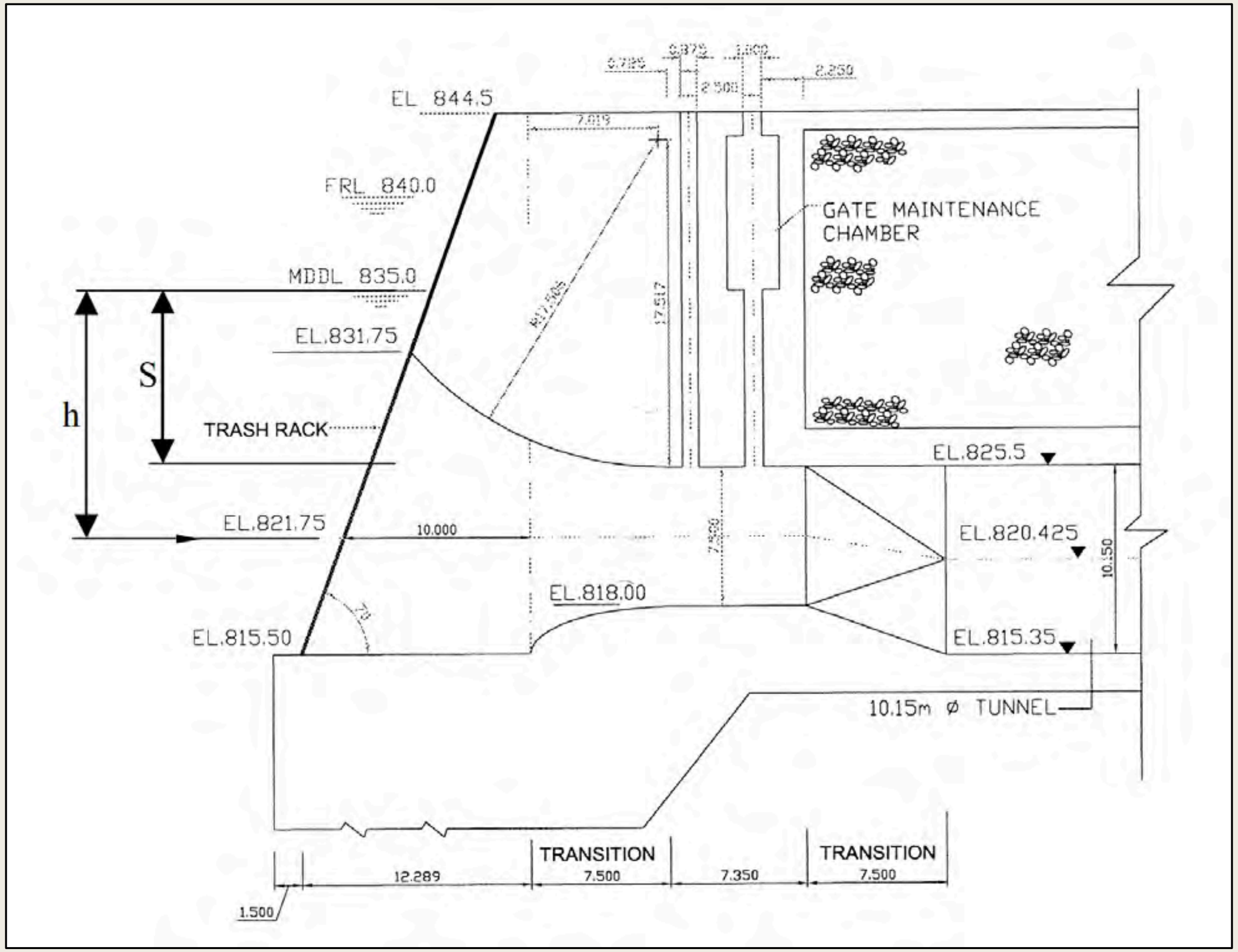
Annexure D, Paragraph 8(f)

(*f*) The intakes for the turbines shall be located at the highest level consistent with satisfactory and economical construction and operation of the Plant as a Run-of-River Plant and with customary and accepted practice of design for the designated range of the Plant's operation.



Typical Indian HEP Design - Intake

Pakistan's Memorial, Fig. 10.12

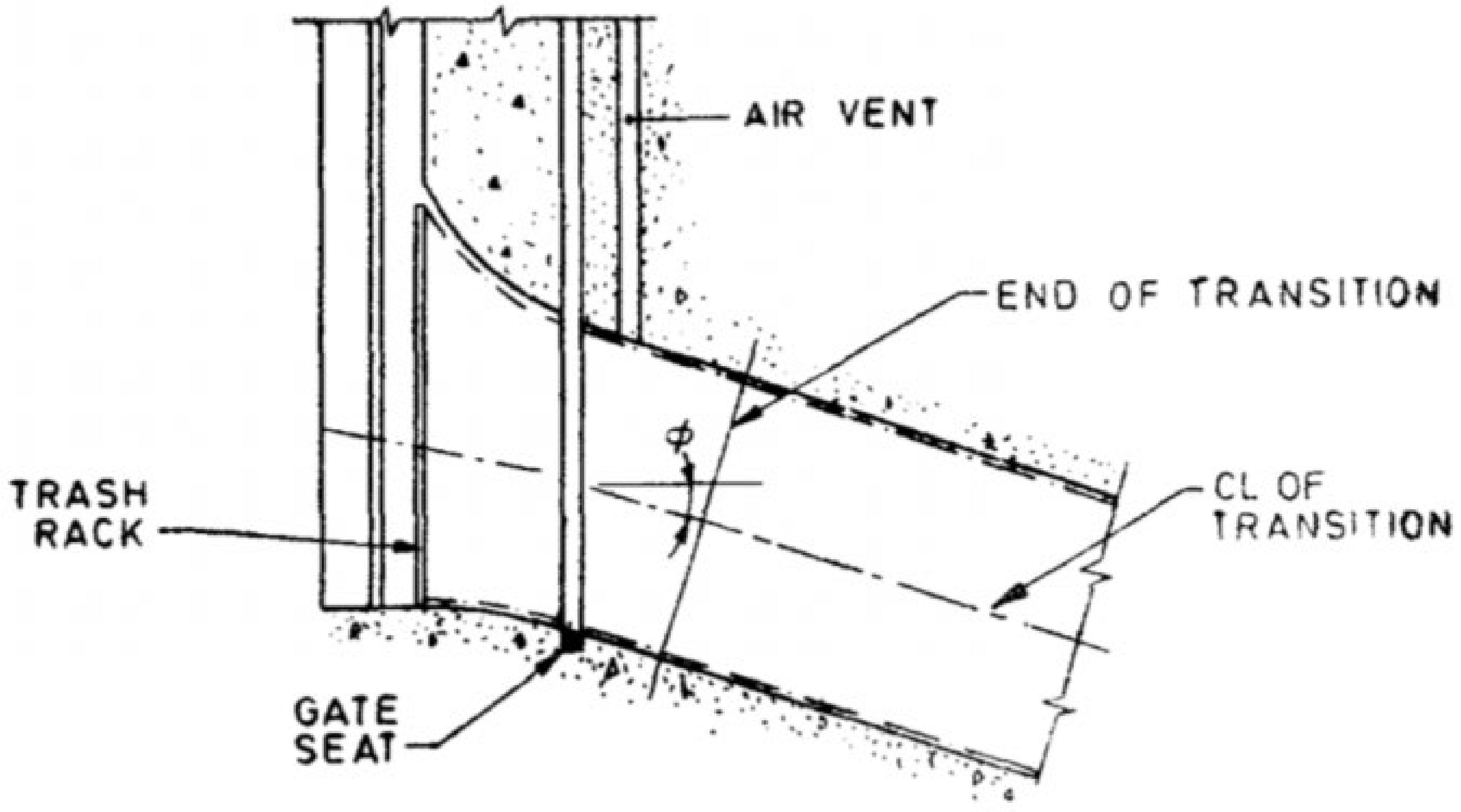


FIG. 12 STRAIGHT TYPE INTAKE

Indian straight type intake

Bureau of Indian Standards. 1995. Hydraulic Intakes - Criteria for Hydraulic Design (First Revision), IS 9781 : 1995 (reaffirmed 2000).

PIC 108th meeting (2013)

"He [PCIW] elaborated that higher Pondage created the requirement of submerged intake for which the water seal was required for protecting it from entry of air and formation of vortex at the mouth of the tunnel thus pushing the intake further down. This situation causes the intake to draw coarser sediment particles which are harmful for the turbines and exposes it to the risk of overwhelming by the deposited sediments. Pakistan Commissioner suggested that instead of providing this arrangement the designers should go for surface intake and obviate the possibility of its overwhelming by deposited sediments."

Record of the 108th Meeting of the Permanent Indus Commission, 23-26 March 2013, dated 24 September 2013, Exhibit P-0070, ¶ 5.

PIC 108th meeting (2013)

"Pondage does not dictate the type and location of the power intake. Hydraulics, topography, geology, techno-economics and many other factors play a role in the decision-making [...] [M]ore often than not, site conditions do not allow surface intake as a techno-economically feasible option. Keeping in view that Pondage is needed to meet load fluctuations, intakes accordingly provided with requisite water seal [i.e., submerged in all cases]."

Record of the 108th Meeting of the Permanent Indus Commission, 23-26 March 2013, dated 24 September 2013, Exhibit P-0070, ¶ 20.

PIC 109th meeting (2013)

"PCIW noted that reduced pondage would reduce the operational pool depth and make it "possible to provide a surface intake which can subsequently be converted to [a] pressure conduit a short distance downstream of the intake face". India replied that "satisfactory operation as well as techno-economics requires a deep seated intake as proposed by India ... at this project site the river carries significant suspended fines and hence a surface intake is not justifiable on that account."

Record of the 109th Meeting of the Permanent Indus Commission dated 22-25 September 2013, 14 July 2014, Exhibit P-0083, ¶¶ 52, 60.

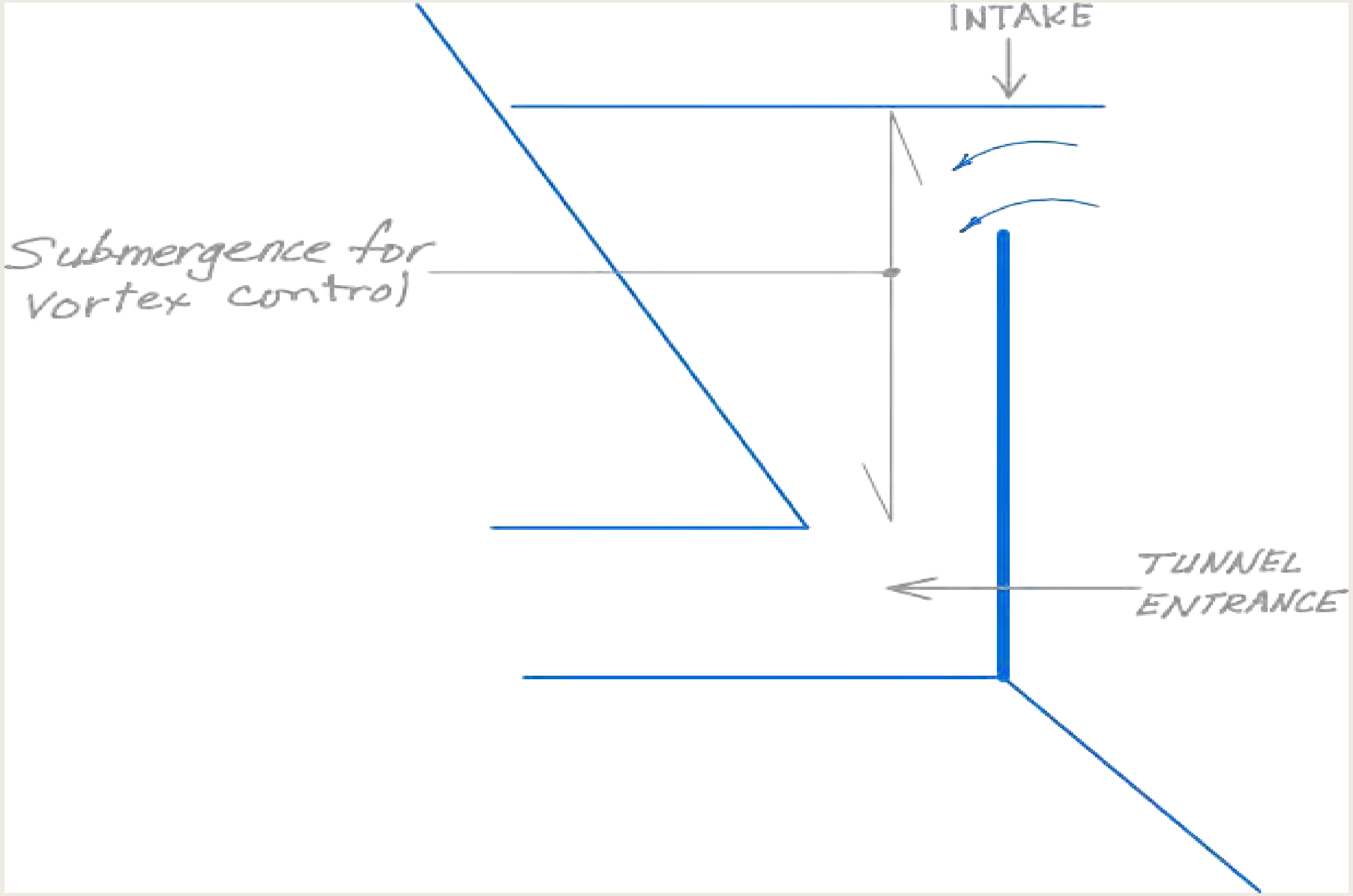


Illustration by Dr Gregory L. Morris

Comparison of Intake Designs

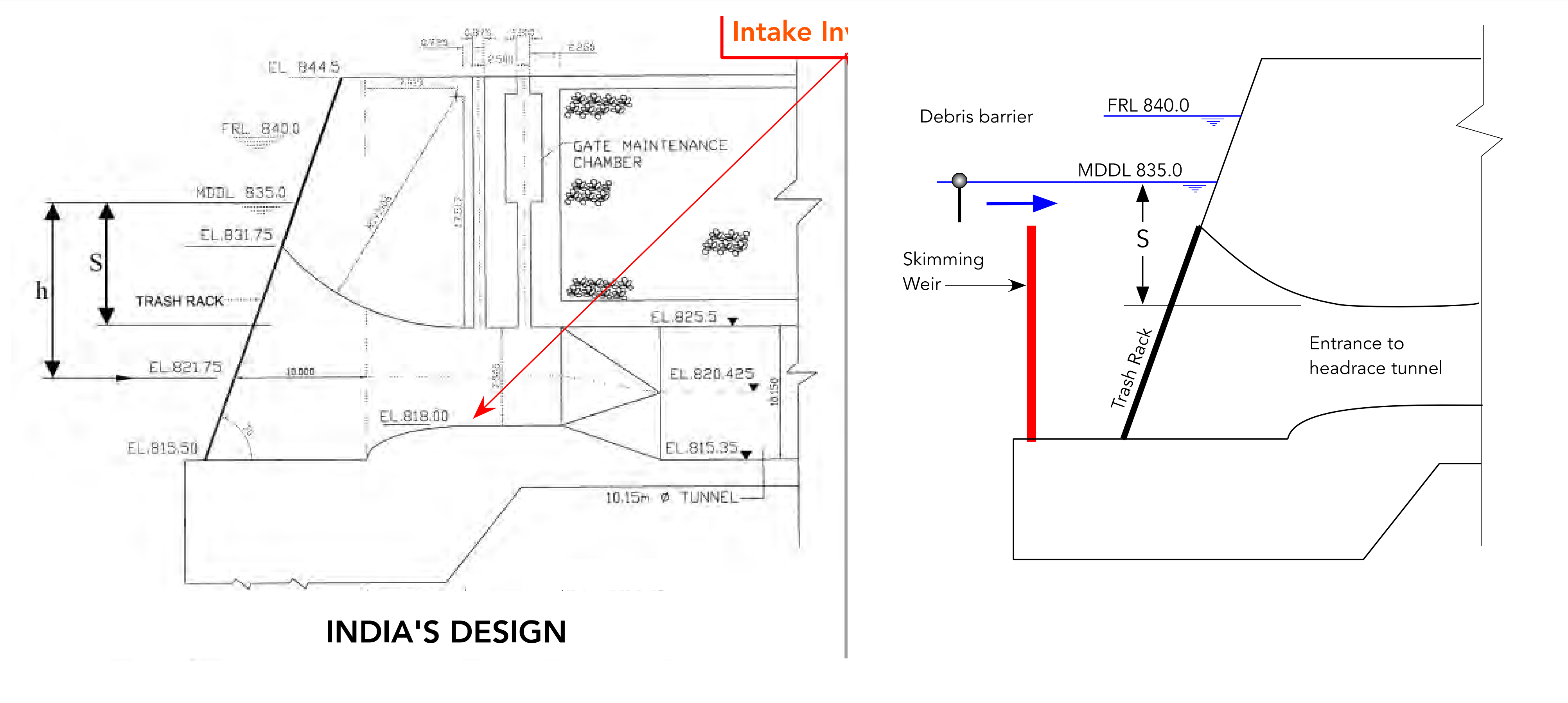


Illustration by Dr Gregory L. Morris

Errors in *Baglihar* Determination

- Only assessed under Paragraph 8(f)
- Undue weight to need to prevent vortexing
- “recourse to anti-vortex devices at the design stage is not common practice, and should be limited to particular cases where other measures cannot be undertaken to provide protection against the development of vortices” (§5.10.7)

Procedural Order 6,¶ 35(g)

PCA Case No. 2023-01

IN THE MATTER OF AN ARBITRATION

-before-

THE COURT OF ARBITRATION CONSTITUTED
IN ACCORDANCE WITH THE INDUS WATERS TREATY 1960

-between-

THE ISLAMIC REPUBLIC OF PAKISTAN

-and-

THE REPUBLIC OF INDIA

PROCEDURAL ORDER NO. 6

(DECISION ON FURTHER PROCEEDINGS)

COURT OF ARBITRATION:

Professor Sean D. Murphy (Chairman)
Professor Wouter Buytaert
Mr. Jeffrey P. Minear
Judge Awn Shawkat Al-Khasawneh
Dr. Donald Blackmore

SECRETARIAT:

The Permanent Court of Arbitration

6 July 2023

(g) With respect to Annexure D, paragraph 8(f), what is to be taken into account for the purposes of designing submerged power intakes for a plant and what is to be excluded?

Relevant and irrelevant factors for power intakes

Relevant factors

Intakes built and operated satisfactorily and economically in light of the challenges that *a Run-of-River HEP in the Himalayas* faces

Need to place the intake's invert at a level to allow pondage to be drawn upon

Irrelevant factors

Factors related to non-ROR HEPs

Factors not directly related to HEP's operation

Factors unrelated to designated range of HEP's operation

Conclusion

1. Choice of site is crucial
2. HEP’s design and operation never take place in a vacuum
3. Low-level outlets → default is not to have such an outlet
4. Spillways → default is to have surface ungated spillway
5. Intakes → most effective and Treaty-compliant design will be a surface intake largely above DSL