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

CERTIFIED TRANSCRIPT
(SITE VISIT)

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

CERTIFIED PURSUANT TO PARAGRAPH 19 OF ANNEXURE G

26 April 2024

ON BEHALF OF THE COURT OF ARBITRATION:

Sean D. Murphy

Professor Sean D. Murphy
Chairman

Arbitration pursuant to Article IX and Annexure G
of the Indus Waters Treaty 1960

NJHEP Dam Site
Pakistan-administered
Kashmir and Jammu region

Day 4 Friday, 26th April 2024
Site Visit

Before:

PROFESSOR SEAN D MURPHY
PROFESSOR WOUTER BUYTAERT
MR JEFFREY P MINEAR
DR DON BLACKMORE
MR STEPHEN POMPER, NEUTRAL OBSERVER

BETWEEN:

THE ISLAMIC REPUBLIC OF PAKISTAN
-and-
THE REPUBLIC OF INDIA

Transcript produced by Trevor McGowan, Lisa Gulland
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Friday, 26 April 2024

THE CHAIRMAN: Okay, let me start for us, if I can, just by noting that we're continuing our visit here at the dam and we're looking forward to two different presentations today. As I understand it, we will have the first presentation this morning, largely. If we need to spill over to the afternoon, that's fine too. But this will be presentation 5. And we will go until roughly 12.50 this morning.

Then we had a glitch yesterday in our videography of the walk around, where we had video throughout, but we lost the audio for about ten minutes. It was at the point where we were looking at the spillway. So what I'd like to do is have us, around 12.50/1.00, go back to the spillway and, Mr Miana, if you could just explain what we were looking at there, that would be very helpful, so we capture that on the audio of the video.

Then we'll finish that around 1.30 or so. We could have our lunch break at that time and then resume in the afternoon. If we haven't finished the presentation we're about to embark on, presentation 5, we can finish that off in the afternoon and then move on to presentation 6, if that's agreeable. Okay? Good.

Alright. I think with that said, Mr Alauddin, it's over to you.

MR ALAUDDIN: Thank you, Mr Chairman.

Presentation 5: Run-of-river hydroelectric plant basics

MR ALAUDDIN: Mr Chairman, members of the Court of Arbitration, I think there is no need of my introduction, as you are already familiar with me, and now you will have to bear me again for ...!

THE CHAIRMAN: We look forward to it.

MR ALAUDDIN: Thank you very much.

In this presentation with me is Mr Umar Farooq, senior engineer at NESPAK, whom you know from the previous session. We are also joined by Dr Yasir Abbas, chief engineer at NESPAK.

The presentation we are about to give is the first of two concerning what might be called run-of-river HEP basics. Why this is necessary, a summary of key issues: it attempts to give you an overview of how a run-of-river HEP functions in the Himalayas. In this sense, it restates and builds on some of the material introduced in earlier presentations, particularly presentation 2, on HEP design, construction and operation.

This part of the presentation addresses what might probably be called flood and storage issues at a run-of-river HEP headworks. The second part, which follows directly after this presentation as presentation 6, deals with sedimentation issues at the same.

Before I turn to the issue, I recall also what you heard yesterday: that we will endeavour to address the Court's five questions in the course of these two presentations.

Slide 2, please.

With that in mind, we propose to proceed as follows.

First, I will provide an overview of a run-of-river HEP headworks. In so doing, I will revisit and reinforce some familiar concepts, but situate them within the design of the NJHEP.

Second, Mr Farooq will address you on HEP storage issues and the role of live and dead storage in our HEP reservoir.

Third, Dr Abbas will address you on HEP spillways and freeboard, being this element of the headworks that plays the most material role in flood control.

Slide number 3, please.

Now, with this, I start with the first topic: that is the headworks. You have already seen in detail the different components of our headworks. I shall just repeat important components of the headworks.

Again, you see this is our dam. And on the upstream side is the River Neelum, coming from the line of

control. And now this is our reservoir. This is our dam. The length of it is 250 metres from this end to this end (indicating). There are our six intake gates, and this is our spillways. This you can see is basically a gantry crane. This is the debris flow channel and this is our rockfill dam.

You can also see this desander. The length of desander is 275 metres. And then you can see this collecting canal. We have already been there, you have seen that. From the collecting canal, water goes into a 28-kilometre tunnel, and then eventually goes into our power station, where, through four (indistinct), we generate 9 MW of electricity.

Slide 4, please.

Now, this is basically the drawing of the same photograph and slightly rotated. And the purpose is to brief you or inform you about further detail in this.

You see this blue line showing the water flows. Starting from here, we have a collecting canal. We have -- sorry. First, this yellow strip is basically the headworks, total headworks. Length from here to here (indicating) is 88 metres. Then we have spillways here. In Neelum-Jhelum there is orifice spillways. And with that is attached -- this is another structure here, which is our debris channel. This is also sort of a spillway, but it is a crest-gated spillway. So we have a combination of orifice spillways and crest-gated spillways.

As regards the sizes, you were already informed on the site that the size of each spillway is 12 metres, width is 12 metres and its height is 15 metres. Regarding the sizes of the debris channel, the sizes of the gates are: its height is 8 metres and width is 9 metres.

At the left side, the extreme left side, is our rockfill dam. You see, you are seeing this line here (indicating) in the briefing on geology of area. It has already been informed to you that a number of fault lines are there in this area. One is main boundary thrust, which we call it "MBT". You see MBT is passing here, this area. This is at the right side of -- almost at the right side or right bank, near the right bank.

At this place, you see the -- let me tell you the original design of the headworks was a concrete gravity dam. But as a result of 2005, investigative -- extensive studies were carried out about the seismic parameters on this fault line. So when it was identified that concrete gravity dam will not be suitable for this location, so the designer then selected that this part should be constructed as

rockfill dam. So this 65 metres, this is the rockfill dam. We have a hybrid structure: it is a composite concrete gravity and a rockfill dam.

Slide 5, please.

As I already mentioned, we have a hybrid structure. Now, above the dam, for a run-of-river HEP, the dam is usually situated in a valley, allowing a narrow reservoir to fill behind it. This creates head for power generation.

Second, the dam structure is very depending on location. The three major types are earthen, concrete and rock-filled dam. NJHEP is a hybrid: the main dam is concrete, with a rock-filled section, straddling a geological fault, the main boundary thrust.

You see now this is the cross-section of the rockfill dam. As far as the important parts are concerned, you see it has a central clay core. Over that, there is a layer of fine filter and coarse filter, then it's rockfill, and then it's a grouted riprap here. This is the upstream side. And here also the same: fine filter, coarse filter, rockfill, and then riprap of 1 metre.

So this is basically core, clay core.

DR BLACKMORE: Sorry, just -- the side slopes, are they 2:1? So I'm reading that correctly? The slope is 2:1?

MR ALAUDDIN: Yes.

DR BLACKMORE: Okay. I want to come back to the foundations when you've moved through a little bit, if that's okay, sir. I want to ask questions about the foundations here.

MR ALAUDDIN: Yes, about the foundation, yes.

About the foundation, you see it's a plain concrete bed here. And underneath, a grout curtain has been provided, up to 25 metres depth; or in certain cases where there was no sandstone, further deeper grouting was done. So a minimum 25-metre curtain grouting has been provided. This is not only here, but throughout the -- along the dam itself.

DR BLACKMORE: So there is only one -- so I'm assuming that the grout line is this way (indicating), across the dam, and you don't have two grout lines, you just have one, one grout line 25 metres deep?

MR ALAUDDIN: Yes.

DR BLACKMORE: Okay. Like, very standard --

MR ALAUDDIN: Yes, this is quite a standard practice.

DR BLACKMORE: So my only question is that you've now put a flexible dam --

MR ALAUDDIN: Yes.

DR BLACKMORE: -- on top of a very rigid foundation with a fault line. So if the fault line moves, I think the

dam is okay; I just wonder about the grout curtain. Have people thought about whether the grout curtain will be stable?

MR ALAUDDIN: You see, there may be some movement. But the main concern is that -- you see it's quite deeper here, deeper here and extensive grouting has been done. But you see, the geological consideration is that seismic movement under the ground seems to be less serious as compared to on the top.

But as far as your question is concerned, let me consult, let me deliberate further, then I shall revert to you.

DR BLACKMORE: It's not a concern; I'm just trying to understand. Because if you're going to have a flexible dam on a rigid base, but the rigid base is on a fault line, it does raise engineering questions about what you could do if you do have the bad -- if we do have the inevitable, which is some movement on that fault line, how do we make sure the integrity of that core remains. That's all.

MR ALAUDDIN: Right. So you have already mentioned that this is a flexible structure, and (indistinct) has a plastic behaviour and self-healing characteristics. So you see that's how we have constructed this line.

There was some minor drop of seismic event, and we

have monitored it after that and we found it quite in sound condition. So ...
DR BLACKMORE: Sorry, my follow-up question I was going to bring on later was: what monitoring do you have in place? And do you have a gallery -- like a gallery that's built across -- in the concrete section at all that you've got monitoring that's close to bedrock?
MR ALAUDDIN: Yes, we have a drainage gallery underneath, drainage galleries where there are drainage holes, and which there are piezometers there. And also we have V-notch weirs there to see the drainage water, the amount of drainage water which is coming to the drainage gallery.
Regarding the monitoring movement, we have extensive monitoring system here. We have surface markers, we have piezometer on both sides, upstream and downstream side, from which we can realise any movement in the dam. So all sorts of instruments which are required for a dam are there.
DR BLACKMORE: Okay. Sorry, I just happen to own a dam that moved, so I'm sort of a little nervous and focused on it.
MR ALAUDDIN: I understand.
DR BLACKMORE: It flooded people for 400 kilometres downstream. So you can understand that I get a little

nervous about it.
MR ALAUDDIN: I understand.
Slide 6.
Now coming to the spillways. Spillway is considered another important structure of a headwork. Spillway is the principal structure by which water is passed through the dam, particularly in times of flood. It may also have other application, like sediment management.
Multiple spillways structures may be included in the same dam. You usually include a structure to prevent erosion in the riverbed and the foot of the dam.
Now, this photograph is the spillway of Tarbela Dam project. Tarbela Dam is one of the biggest rockfill dams, having a generation capacity of about 4,800-4,900 MW and a storage capacity of 442 million cubic metres.
You see, as already mentioned, there could be two or three types of spillways in one intake section on a dam. Here is a crest-gated spillway. This is the crest-gated spillway. We have the crest-gated spillway like this. So spillway is considered an important component. There will be further briefing on types of spillways and on the sedimentation storage in the presentation nos. 5 and 6.
[Slide] 7, please.

Now coming to the intake structure. Intake structure is considered one of the most important components. This is the drawing of -- this is the cross-section of the intake of the Neelum-Jhelum Hydropower Plant.
The intakes allow water to abstracted from the reservoir into the headrace, and thence on to the turbines. [They] need to be carefully designed to minimise sediment ingress and prevent vortexing. [They] may include special structures to achieve either or both of these aims.
Now, you see, this is the intake of Neelum-Jhelum Project. Its height is 4.5 metres, width is 4.5 metres. And from this, water goes into this desander structure.
Intakes need to be very carefully designed; in the design and construction, effort made that it should be at higher levels, so that ingress of sediments be avoided to the possible extent.
The Neelum-Jhelum Project, underneath there is undersluice gates also provided. There are six intake gates, but underneath there are three undersluice gates. The height of the undersluice gates is 1 metre and the width is 4.5 metres.
The purpose is that sediment may be not deposited directly underneath. You see it is a difference of

4 metres from here to here (indicating), about 4 metres. So the sluicing is regularly carried out to avoid any sediment deposition under this intake structure.
Through the intake structure, water goes into our desander area. The design of the intake as well as the desander in Neelum-Jhelum Project seem to be quite effective, and this is obvious from the condition of the reservoir, which we inspect [from] time to time. And even after running of five years, the condition of the turbine is very good, exceptionally good. So it means the effectiveness of our desander structure and design.
DR BLACKMORE: I'm just wondering -- I like the design, by the way. I like the design --
MR ALAUDDIN: Thank you.
DR BLACKMORE: -- for passing sediment. I'm just wondering about the erosion of the concrete chutes where the gates are, because you've got different-level outlets passing different amounts of sediment. And I'm just wondering whether there's any issue around erosion of concrete in those chutes or whether there was any special treatment to strengthen the concrete in those areas.
MR ALAUDDIN: That is a high-strength concrete, and we [from] time to time monitor the chutes that you mentioned. So far, they are found to be in good condition, except some issues on the ogee, ogee of the

spillways. As you know that water [at] very high velocity passes over the ogee, we faced some problems, but those have been rectified.
MR MINEAR: What is the grouting and drainage gallery? What is the purpose of that, at the bottom of the slide?
MR ALAUDDIN: Yes. Grouting and drainage gallery is that drainage gallery has been first made -- through the drainage galleries, the grouting underneath the dam had been carried out. Through this gallery, it had been carried out. Not in the bottom, but all around it.
And also there are drainage holes in it. If there is some excessive pressure on the upstream/downstream side, so it can relieve that pressure also.
So first is any -- in the drainage gallery, we have different instruments also there. So function of the drainage gallery is very important for the inspection purposes and monitoring purposes.
Thank you.
THE CHAIRMAN: So before the water goes to the intake gate, I see that there's a trashrack on the left-hand side. That's keeping out debris --
MR ALAUDDIN: Exactly.
THE CHAIRMAN: -- from going in. And we saw some of this debris yesterday when we were walking around; even saw it being taken up by a crane, or whatever that device

is. So that's the purpose of that trashrack?
MR ALAUDDIN: Yes, yes.
THE CHAIRMAN: Okay.
And then down below the intake gate but above what Mr Minear was pointing to, we have the undersluice flushing duct. And we saw the water coming out yesterday on the side.
MR ALAUDDIN: Yes.
THE CHAIRMAN: It looks like I too get to point out things here. This undersluice flushing duct is what we saw water coming out of on the side.
MR ALAUDDIN: Yes, exactly.
THE CHAIRMAN: Could you just explain again what I thought I heard yesterday during the walkaround: that this is an additional way of regulating the reservoir in a much more precise manner? Is that correct?
MR ALAUDDIN: Sure. You are absolutely right. During the low-flow season, we operate these undersluice gates for removing the sediments, and also inflow is also released from this. And you are very right that these floodgates are bigger in size, so minor adjustment can be made from it.
DR BLACKMORE: Sorry, I'm just interested in your little tunnel down the bottom down there. They are my least favourite place, because that's where I spent a long

part of my life at an earlier age, and I'm really not that in love with them. So you're going to have inclinometers, you're going to have piezometers. Is there anything -- have we got any seismic measurement on site, any --
MR ALAUDDIN: Accelerograph.
DR BLACKMORE: Yes. Do you have one in the gallery?
MR ALAUDDIN: Yes. And there's a pendulum also in the gallery.
DR BLACKMORE: Yes, okay. So you have pendulum coming all the way through?
MR ALAUDDIN: Yes.
DR BLACKMORE: In an oil bath at the bottom?! Don't answer it. That was my favourite thing, to go and measure whether the dam was moving downstream.
MR ALAUDDIN: So I think I've explained about these intakes and there's a good discussion with you members. So please, slide number 8.
Now coming to the reservoir. Not part of the headworks per se, but an important component of the HEP. A run-of-river HEP can function without a reservoir, but its power-generation potential would be limited. A run-of-river HEP tends to have small reservoirs for the purpose of developing head and improving power production in the dry season.

So you see we have small reservoirs: the capacity of live storage of it is 3.8 million cubic metres. You see, run-of-river project, it is found to be useful for giving the project peaking capability. So with this we can have peaking capability during the low-flow seasons.
This is a view -- we have already shown it -- this is basically the reservoir, just 4.5 kilometres from here. And this is the Lower Jhelum which you can see here.
Next slide, please, slide number 9.
With that overview concluded, I will now hand over to Mr Farooq to address how the reservoir is used in a run-of-river HEP. Before I do, however, may I ask if the members of the Court have any questions, please.
DR BLACKMORE: I just have one. It may be covered under live and dead storage. But I'm just wondering whether the sediment profile in the river, do we get a delta forming at the top, where your full supply level eventually reaches, 3, 4, 5 kilometres up? I imagine the velocity is high enough not to form any delta or any accumulation of material?
MR ALAUDDIN: The thematic survey which we have carried out is not reflecting any serious concern regarding the delta which we have mentioned, because of steep slope and small reservoir.

DR BLACKMORE: Just one other thing, sorry. My concern was -- I didn't think we'd have one that was a permanent delta. My concern was that we would get, under low-flow sequences, the build-up of a delta and an increased supply of sediment material that, once we went into the high-flow period, we'd have to deal with at the dam because it would be moved in. Has that been an issue at all?
MR ALAUDDIN: We are further monitoring it. Recently, bathymetric survey is going on. So we are basically -- so far, we haven't realised any formation of any delta. But the bathymetric survey is being carried out at site to have a clear picture of that.
PROFESSOR BUYTAERT: I've got a question -- yes, sorry.
MR ALAUDDIN: Sorry, sorry. I'm sorry.
PROFESSOR BUYTAERT: So you explained that the gate, that this is a crest-gated spillway for this design. Would you, in these conditions here, consider an open spillway a feasible infrastructure for this site, or do you think this needs a gated spillway?
MR ALAUDDIN: I think that would be covered in the next presentation.
PROFESSOR BUYTAERT: Okay, perfect. I'm happy to wait. Thank you.
MR ALAUDDIN: Thank you very much.

THE CHAIRMAN: Whenever you're ready, Mr Farooq.
MR FAROOQ: Mr Chairman and members of the Court, I will be addressing you on storage issues arising from a run-of-river HEP's reservoir.

Slide number 10. The starting point is to explain the role that storage plays in an HEP in the Himalayas.

Where an HEP is reliant solely on the natural flow of the river, there will typically be a significant drop in power production during the dry season, when the lack of snow and glacial melt causes the water to drop significantly. If an HEP includes a water storage component, however, this will be able to supplement the flow of the river in order to maintain or increase power production.

We can therefore divide HEPs into categories based on how much storage they have.

First, here, there are HEPs attached to storage reservoirs capable of storing months or even years' worth of water.

The guaranteed availability of massive storage means that these HEPs can have a very large installed capacity, such as Tarbela hydroelectric project, which is currently 4,888 MW and projected to increase to 6,418 MW when the plant Tarbela 5 Extension comes online. They can also be run for long periods,

producing baseload power. By this, we mean the delivery of power on a constant basis over a 24-hour period.

Second, here, at the other end of the spectrum, we have a run-of-river HEP with no storage, which is effectively a turbine placed in the river or an adjoining canal. As noted, such HEP will entirely be dependent on the natural flow of water, and suffers somewhat in the dry season as a consequence.

These plants tend to be on the smaller side, such as 13.5 MW Shadiwal hydroelectric project, at the tail of Upper Jhelum Canal in Punjab, or 84 MW New Bong Escape project, downstream of Mangla Dam. Such plants are also used for baseload power, running constantly.

Third, here, we have the category of HEP with which we are concerned: the run-of-river HEP with storage. This HEP has capacity to store water, and so in the dry season can be peaked, storing water for part of the day and then releasing it during periods of peak demand in a given 24-hour period. During the wet season, when water is plentiful, the HEP can provide baseload power.

There are other ways of defining categories of HEPs. Another dividing line is the difference between an HEP that creates generating head with a high dam and a short tunnel, and an HEP that creates generating head with a low dam and a long tunnel.

Slide 11. On this slide we see a diagram showing how storage in a run-of-river HEP reservoir works. I am going to use it to introduce some key generic storage concepts: most importantly, the notion of "live" and "dead" storage. I note that there are some circumstances where these ideas are given a special meaning. I use them here only in the generic sense.

On the diagram is a concrete gravity dam with a crest-gated spillway, here (indicating), and the reservoir to the right, with water levels shown.

The two most important water levels for present purposes are the full pond level and the minimum operating level. The space in the reservoir between these two levels here is known as "operating pool".

The operating pool is used for storage of pondage, being the water that can be used to improve HEP's power generation in times of low flow. As such, the operating pool forms HEP's live storage.

Above the operating pool is HEP's flood surcharge, as you can see between the solid blue line and the dotted blue line, which is used for the temporary storage of floodwater that exceeds the full pondage level.

The type of storage that is in the reservoir below the operating pool is defined by the invert of the lowest outlet, which in this case is the spillway crest, as you can see here. Any water below that point is beyond the control of HEP operator, as it cannot be released from the reservoir through intakes, spillways or any other outlet. It is trapped in place and cannot be used, and so is referred to as "dead storage".

Anything above the level of the dead storage is capable of being manipulated by the operator. In this sense, it can be released from the reservoir, and so forms part of what is called the HEP's "controllable storage".

Depending on the location of intakes in HEP, controllable storage could also be potentially used for power generation, and so may also form part of HEP's live storage. All depends on the configuration of a particular reservoir.

Slide 12. We can see an example of this in the image on the slide, which is the longitudinal view or "L-section" of NJHEP's reservoir. The scale is distorted, with the true length of the reservoir being much greater than its depth. The dam wall is represented by Y-axis here (indicating), with the X-axis representing the distance from the dam wall here.

As can be seen from the Y-axis, the dam extends from just over the 972 metres above the main sea level to the

1,019 metres here. So 47 metres is the height of the dam. The reservoir [runs] through the valley up 4.8 kilometres from the dam wall.

The solid red line, this one (indicating), tracks the level of the riverbed throughout the reservoir, sloping progressively upward, with the three dotted lines reflecting various levels of the reservoir. The blue dotted line, at 1,018 metres, is the high flood level, which reflects the uppermost limit of the flood surcharge.

The green dotted line is at 1,015 metres, this one (indicating). It is the full pondage level, reflecting the top of the operating pool. And the red dotted line, this one (indicating), at 1,008 metres, is the minimum operating level, reflecting the level just above the intakes.

THE CHAIRMAN: Can I ask a question on this? And maybe it helps to go back to the prior slide (11) for just a moment. But the minimum operating level is not all the way down at the spillway crest, the bottom of the spillway. And so my question is: what is the reason why you can't have a minimum operating level all the way down at the bottom of the spillway?

MR FAROOQ: Yes. Mr Chairman, as we have some structures to be placed and designed below the minimum drawdown

level -- for example, intakes, the desanders -- and if we go down below the -- or near to the bed, we need a lot more excavation for the placement of those structures as well. And we also [need] to provide some allowance for settling of the sediment. So that is why we cannot draw down the level to its minimum or near to the bed, in view of these considerations.

THE CHAIRMAN: No, I understand that it technically is difficult and expensive to go further down. But maybe I just didn't understand the answer: why can't the minimum operating level be lower than where it's located here? Why can't you use the pondage all the way down to the point where you can no longer control it?

MR FAROOQ: Okay, I'll try again to explain.

THE CHAIRMAN: I'm sorry I didn't follow.

MR FAROOQ: No, it's okay. As you go down, you can see here, your minimum operating level at the moment is here (indicating). And you go all the way down, say, at this level, yes?

THE CHAIRMAN: Well, I understand why you couldn't do that, because you can't operate below the bottom of the spillway. But why is it you can't go at least down to the bottom of the spillway?

MR FAROOQ: Because as you go down, you have to place your intake below the minimum drawdown level, say here

(indicating). Or if you go down below that, then you have to place your intakes more low.

THE CHAIRMAN: I see, okay.

MR FAROOQ: So in view of these considerations, you will be requiring more excavation and placement of the desanders, that it will include more cost for placing those structures in terms of excavation. So these are the considerations.

THE CHAIRMAN: So is another way to understand this: the intakes are going to be at the level between the minimum operating level and the spillway crest, in order to have the -- or lower, in order to go into the intake?

MR FAROOQ: Maybe. But in all the cases, it will be below the minimum operating level.

THE CHAIRMAN: Yes, okay, I understand. Thank you.

DR BLACKMORE: Just so that I'm clear now, I understood the answer to all of that, but wouldn't one of the controlling issues be the amount of money you're going to make by generating power? So if you were to drop the minimum operating level by 20 metres, say, or 15 metres, you would reduce your potential power by a huge amount, and at huge cost.

MR FAROOQ: Yes.

DR BLACKMORE: So it's a combination of the location of the power station, and height and depth. I think -- I'm

just trying to -- that was my reading of it.
MR FAROOQ: Yes, yes, it is one of the factors, yes.
DR BLACKMORE: Yes, okay.
MR FAROOQ: As you go down, you lose your head.
PROFESSOR BUYTAERT: Just a quick follow-up question, or a reformulation perhaps. I guess it's technically feasible that the minimum operating level is below the spillway crest, isn't it?
MR FAROOQ: Sorry?
PROFESSOR BUYTAERT: It is technically possible to have a minimum operating level below the spillway crest?
MR FAROOQ: Yes, it is technically possible, yes.
PROFESSOR BUYTAERT: Yes. So that perhaps clarifies your question as well. Thank you.
MR MINEAR: My question relates to the next slide. The space between the green dotted line and the blue dotted line, is that the surplus storage portion of the reservoir? Would you call that "surplus storage"?
MR FAROOQ: It is, sir, basically the surcharge storage, which is only filled in case we have a design flood situation at our dam site.
MR MINEAR: Sure. I'm just trying to make sure I'm clear on the terminology. Elsewhere I've seen that referred to as "surplus storage", and it sounds like it is.
MR FAROOQ: No, it is only surcharge storage only in case

the design flood is happening.
PROFESSOR BUYTAERT: Okay, thank you.
THE CHAIRMAN: Good. Thank you. Continue, please.
MR FAROOQ: From this, it follows that the space between the red and the green dotted line is NJHEP's operating pool, constituting pondage. Given its height in the reservoir, the operating pool stretches between 3.8 kilometres to 4.4 kilometres from the reservoir, a considerable quantity of water. Were the minimum operating level to be reduced even fractionally, or be raised above full pond level, it would result in a considerable increase in the amount of pondage available to the NJHEP operator.
This is an opportune time to answer the Court's question no. 4, which is as follows: what are the different methods that might be employed for determining the optimal pondage at a run-of-river HEP, such as pondage intended to be of a magnitude to meet fluctuation in the discharge of the turbines, or pondage intended to be in a relationship to the minimum mean discharge at a site of a plant? How are such calculations performed?
The short point is this: there is no fixed method for calculating pondage. The provision of pondage, and as you will see in presentation 6, ensuring it remains

free of sediment will incur some operational and capital cost.
Put simply, a large operating pool, while it allows for more flexibility in power production, may also be more expensive to create and maintain. And put even more simply, the bigger the reservoir, the bigger the dam; the bigger the dam, the more money required for its construction. There has to be a balance between this expense and income anticipated from the delivery of power in peak hours, where energy prices are higher.
As to the specific language of the Court's question, pondage is not normally intended to have a relationship to the minimum mean discharge. That is not the term that you usually employ for a hydropower design.
As for the discharge to the turbines, this depends on the reason for such discharge. The fluctuations may be caused by variations in the natural flow of the water, or they may be caused by peaking plant imposed by HEP's operator. Both may be valid reasons for calculation of pondage.
In terms of factors that may influence such a calculation, three may be mentioned.
First, site constraints such as topography and the cost necessary to [adapt] to those site constraints. This is a question of civil engineering.

Secondly, variability in flow of the watercourse; for example, due to upstream regulation or seasonal variations.
And third, the assigned target, duration and flow rate when the plant is taking out daily peaking operations. Both of these depend on the inflow hydrology and the financial model of the anticipated market.
As I said before, it will be hard to say that there exists a single, universally accepted customary method for pondage calculation. But as an illustration, from a practical standpoint I would like to refer to NJHEP.
As you have noted in previous sessions, the NJHEP incorporates pondage of 3.8 million cubic metres in its operating pool, which is believed to cater for 4 hours peaking in a typical winter day. In other words, the pondage volume of 3.8 million cubic metres at NJHEP is considered optimal to run its all four turbines at full capacity by supplying required discharge of 280 cubic metres per second for 4 hours continuously in a given winter day.
It is intriguing to learn that, how a typical winter day flow is comparable with the 280 cubic metres per second -- maximum discharge required to run all four turbines of NJHEP at full capacity and generating

969 MW.
In this regard, Mr Chairman and members of the Court, the stream flow records suggest that the months from November to February define winter or dry season for Neelum River. During these months, the discharge in the river averages around 53 cubic metres per second. For ease of reference, I may refer the 53 cubic metres per second discharge of Neelum River at NJHEP Dam site as prevalent winter season river flow. It is just 19% of the 280 cubic metres per second -- the maximum discharge required to run all four turbines of NJHEP at full capacity.
DR BLACKMORE: So in the low flow period that we're talking about, you would just use the dam for peaking power? So when you've got 53 cubic metres per second, and then you've got an amount you need to pass down for compensation flow or whatever -- I'm not sure how much that is -- how much water are you required ...?
MR FAROOQ: 20 cumecs.
DR BLACKMORE: So you've got 33?
MR FAROOQ: No. I mean, it is --
DR BLACKMORE: Net. 53 net?
MR FAROOQ: 53, I am quoting in view of the pondage volume.
DR BLACKMORE: Yes.
MR FAROOQ: But the preference is to release 20 cumecs of

water downstream of the dam in terms of eflows [environmental flows]. The first preference is for the eflows.
DR BLACKMORE: Yes.
MR FAROOQ: So you can refer to that. For example, you can increase this 53 to 73 in a case when we are required to meet the 20 cumecs of eflow first.
DR BLACKMORE: So under what conditions don't you have to meet the environmental flow? When would you go below 20 cubic metres per second --
MR FAROOQ: If we go below 20 cubic metres per second, whatever we are getting we will be releasing downstream of the dam.
DR BLACKMORE: Okay.
PROFESSOR BUYTAERT: Just as a quick clarification, you mentioned that 53 cubic metres a second is a prevalent winter season flow. Is that inflow in the reservoir?
MR FAROOQ: Yes.
PROFESSOR BUYTAERT: Okay.
MR FAROOQ: So in terms of eflow consideration, you can take this 53 to 73. For example, if you have, say, 73, 20 cumecs you are releasing for eflows, and then 53 cumecs is the net discharge that you are getting in the reservoir.
PROFESSOR BUYTAERT: Okay. But if you have 53 inflow, and

you need to release 20, obviously that only remains 33 to --
MR FAROOQ: Yes, then we will be recording 33.
PROFESSOR BUYTAERT: Okay. Yes, thank you.
DR BLACKMORE: Sorry, and that 33, you are only going to use for peaking flow?
MR FAROOQ: Yes.
DR BLACKMORE: For peak-peak?
MR FAROOQ: Yes.
DR BLACKMORE: Not just ...
MR FAROOQ: Yes. So in that case, the peaking may not be for the 4 hours: it may be for less duration than the 4 hours, yes.
In order to increase the prevalent winter season flow of 53 cumecs, or 53 cubic metres per second, to 280 cubic metres per second in a given winter day, it is essential to store the water for a certain number of hours and release it in the remaining. The duration of storage can thus be simply calculated as: volume of the 53 cubic metres per second flows stored for 81% of the time in a 24-hour period, to release it in the remaining 19% of the same 24-hour period, to supply 280 cubic metres per second to the turbines.
Putting it in simple words, the time to store becomes about 20 hours, leaving behind the 4 hours in

which the 53 cubic metres per second river flow can be supplied at a rate of 280 cubic metres per second.
In case of providing the pondage more than the volume of 24 hours prevalent winter season flow, the same could not be filled in a 24-hour period, and hence would render part of the operating pool as redundant, which would cost in several other ways.
As I mentioned, it is reiterated that this method of pondage calculation may be considered as an illustration specific to NJHEP, and should not be considered as a universally adopted customary practice for pondage calculation.
Slide 13. The next issue to be addressed is how HEP storage is actually used. And we have two graphics on the slide -- this one and this one (indicating) -- that illustrates this. The bottom image -- this one (indicating) -- is what is called a "hydrograph", showing yearly inflow into HEP's reservoir. The red dotted line -- this one (indicating) -- just above 250 cubic metres per second, shows the flow rate that will meet HEP's installed capacity. Where the river flows at this level or above, and that flow is delivered into HEP's turbines, the HEP will be able to produce, at its installed capacity, continuously, without the need for assistance from storage.

The blue line shows inflow; this one (indicating). In the wet season, in summer, it rapidly climbs above 250 cubic metres per second for months at a time. During this time, the HEP can produce constant power at its installed capacity.

In the dry season, in winter, conversely, the flow will drop below the level you can see here, here and here (indicating). The flow will drop below the level necessary to maintain HEP's installed capacity. During this time constant power at the installed capacity will not be possible. The plant will need to store water for part of the day in its operating pool, and to be released into the turbines when needed the most, say at the times of peak electric demand.

If we look now at the image above, we can see what that looks like; this one (indicating). The blue dashed line -- here (indicating) -- shows the level of HEP's operating pool. In the wet season, the pool is drawn down to the minimum operating level; this is the minimum operating level (indicating). The natural flow of river is sufficiently plentiful that the plant can be run at its installed capacity without assistance, and so no operating pool is required. As will be more fully investigated in the presentations following this one, this may also assist with sediment management.

In the dry season, however, the operating pool is filled to its full level, say here (indicating), and then discharged to the turbines so that the plant can be run at higher capacity for a shorter period of time in a given day. Once the pool is empty, say to this level (indicating), the minimum operating level, the turbines must be shut off or run at a reduced capacity so that the pool can be refilled, creating the fluctuating power peaking pattern you can see here; this one (indicating).

Slide 14.

PROFESSOR BUYTAERT: Can I ask a question before you move on?

MR FAROOQ: Yes, sir.

PROFESSOR BUYTAERT: Thank you. The discharge time series you show at the bottom, is that here from the Neelum River?

MR FAROOQ: Sorry?

PROFESSOR BUYTAERT: The discharge time series at the bottom graph, is that here for the Neelum?

MR FAROOQ: Yes.

PROFESSOR BUYTAERT: Because you mentioned that indeed, mostly in the wet season, flow is plentiful. But of course if you look at the last wet season, 2022-2023, there you can see that not always the flow is sufficient to maintain the plant at full capacity. So obviously if

you would keep the reservoir at minimum operating level, you'd lose out on power. Is that the case, or do you raise it higher in order to accommodate those periods that the flow drops below the plant's capacity?

MR FAROOQ: You see, it is one year out of the lot, say it may be a dry year, but as it is in the series. So if you provide some -- I would say a facility which you provide -- the probability of which is very less for use -- for example, in this case it is one out of four -- so that may not be economical. I mean, I'm saying this in a general sense. And because for the three years, you have a good period of time when the plant is running at full capacity without -- I mean, at least for three to four months in a year. So it is a typical dry year, and normally ... yes, sir?

PROFESSOR BUYTAERT: So here, for example, for the case of NJHEP, if such a dry year occurs, and you keep the level at minimum operating level, and the flow decreases beyond the plant's capacity, do you then effectively reduce the power output, or do you try and anticipate that and, for example, raise -- keep the level higher such that you can, to some extent, bridge those moments of lower flow? Is there any policy or practice here?

MR FAROOQ: Yes. You see, it is on the operator, and it is from the system how much demand we are getting and how

operator wants to operate the plant, whether he wants to operate it with a reduced capacity or maybe store water for part of the day and release for part of the day. I mean, operator can do as --

PROFESSOR BUYTAERT: Yes. So that means that during the wet season it is possible that the water level in the reservoir is higher than the minimum operating level that's shown on the upper graph?

MR FAROOQ: Yes, yes.

PROFESSOR BUYTAERT: Okay, yes, thank you.

MR FAROOQ: Slide 14. Previously we saw a hypothetical example. This is the full range of operation for NJHEP -- this one (indicating) -- using what is called 12.00 am daily data from 2018 to 2023. This tells us what the water level in NJHEP reservoir is at midnight every day. Because it is a daily snapshot, we do not see the daily variations within the operating pool. But we see the broad pattern of a full pond level in the wet season and depleted pool in the dry season. Over the course of that time, the full range of operating pool is used.

That concludes this section of the presentation of HEP storage and reservoir use. Subject to any question that you may have, I will now hand over to Dr Abbas to address you on spillways and freeboard.

Questions from THE COURT
PROFESSOR BUYTAERT: I would be interested knowing more generally how the capacity of this plant of 969 MW has been determined. I don't know if that's something you can shed some light on here now, or later on: simply what factors were taken into account to determine that here a plant will be build of that specific capacity of 969 MW.
MR FAROOQ: Sir, as a general practice that I understand is: the capacity of a plant is generally determined by the site hydrology first. And then you develop a financial model saying that: if I install this much of the capacity, this would be the cost I need to incur on the project, and this would be benefit, in terms of finances, that I'm going to get out of it. And at a point when your cost-to-benefit gets flat, there you fix your megawatts or the generation capacity of the plant.
PROFESSOR BUYTAERT: Yes. So I agree that that's indeed the way it's done. I wonder whether it's possible to give some more information about how specifically that procedure was implemented here for this plant: for example, what hydrological data were used, and what demand estimates are being used. I realise that's a broad question that encompasses more than what you've

prepared now.
MR FAROOQ: It's okay, sir, but I need it get back to the project authorities for this information.
PROFESSOR BUYTAERT: Thank you.
THE CHAIRMAN: Okay, Mr Farooq, I don't think we have any more questions right now for you. But I would like to ask: will you be here throughout the day in case we do have a follow-up question?
MR FAROOQ: Sir, I'm at your disposal.
THE CHAIRMAN: Excellent. Thank you so much. Thank you for your presentation.
DR ABBAS: Well, Mr Chairman and the members of the Court, I am Dr Yasir Abbas and I am leading the team of hydrologists and sediment modellers at water and agriculture division in NESPAK.
(Slide 15) In this last part of this presentation, I will be discussing various aspects of spillways and freeboard in general, and for Neelum-Jhelum Project specifically.
Slide 16. We have seen this figure already. My colleague Umar has demonstrated very clearly the different levels related with minimum operating level, full pondage level, and different aspects of the dam spillway. But now I will be discussing in more detail about this part of the dam: I mean the portion of the

dam above this flood surcharge level.
We see there that an area of flood surcharge has been accommodated within the design. But at the top of flood surcharge, the dam wall continues to extend, here (indicating), until it terminates. That area of dam wall is known as "freeboard".
Flood surcharge exists in order to ensure that reservoir never overflows. Between the spillway and the flood surcharge, the dam will always be able to evacuate floodwater from the reservoir before the ultimate capacity of the reservoir is exceeded or the dam gets damaged.
Now, how are designers able to ensure this? In the process of designing the hydroelectric project, they take account of various flood conditions that may occur, generally known as the "design flood". For a dam, it must be capable of discharging the design flood without damaging the dam structure.
What exactly is considered for the design flood will depend on the conditions at the dam site, in terms of the river flow and precipitation, as well as the consequences if the dam were to collapse. In the Himalayas, dams are designed with a 1-in-10,000-year flood in mind.
Aside from these statistical-based floods, the dam

is also checked to confirm it is safe for probable maximum flood, or we say it like "PMF". The PMF is the flood that can be expected from the most severe combinations of critical meteorological and hydrological conditions that are reasonably possible in a region. As such, it is generally considered as the upper limit of spillway design.
DR BLACKMORE: So 1 in 10,000 is an arbitrary number. We've made a decision to use 1 in 10,000 as a risk profile. What is the difference between a 1-in-10,000-year flood and a PMF for this site? So what's the difference between them? Is a PMF twice the volume, or only 5% more?
DR ABBAS: Sir, what I understand is that 1 in 10,000 is a statistical parameter that relates with some extreme conditions of the flood. And the PMF is related generally with the possible maximum flood in a catchment --
DR BLACKMORE: Yes.
DR ABBAS: -- under a given combination of extreme meteorological and hydrological conditions.
DR BLACKMORE: Yes, thank you.
I was just wondering though: you've made a decision to design at 1 in 10,000 years, and I understand why you've done that -- like, in my world, with my dams,

they're all PMF, which is 1-in-300,00-year flood, about -- because the consequences are much higher if you lose something and drown people.

But just to try and understand the hydrology, I was just trying to work out whether, [if] a 1-in-10,000-year flood is a certain number, 20,000 cumecs, is a PMF flood 30,000 or is it 21,000 cumecs? I'm just wondering what the risk profile is.

DR ABBAS: You see, when they come up with the PMF estimate, that is basically a phenomenon-based estimate, not statistical-based. Whatsoever the figure you achieve with the phenomenon-based estimates of the PMF, that is again checked with the frequency. And it may be possible that the PMF may come around 1-in-20,000 return period.

DR BLACKMORE: It could come next year though?

DR ABBAS: Yes, yes.

DR BLACKMORE: That's what worries all of us.

THE CHAIRMAN: Well, let's hope at least not today!

DR ABBAS: Yes, let's hope!

THE CHAIRMAN: Continue, Dr Abbas.

DR ABBAS: Well, having discussed on the PMF, let's come back on the freeboard.

The freeboard, on the other hand, serves a slightly different purpose. It also exists to ensure that the

reservoir does not overflow, considering overtopping aspects. Overtopping will occur when wind blowing across the surface of the reservoir causes waves to form, which could then spill over the dam wall, causing erosion at its base, and in time, causing it to collapse.

Slide 16(a).

Mr Chairman, the Court asked a question about freeboard height as its question no. 5, which was: what are the range of circumstances at a dam that would warrant an increase in freeboard height, taking into account the need to prevent overtopping and to allow for the dam safety? Does keeping the crest gate top at full pond level prevent raising the water level artificially?

Well, answering the first part of this question, we can see the bullets on the right side of this slide. It indicates various circumstances, like flood surcharge, wave action, type of dam and the operational reliability. I will be discussing one by one in detail.

First, flood surcharge. As Umar has already explained earlier, this is the uncontrollable storage above the operating pool, which is used when the pool level must be raised above the maximum operating level to achieve the design flood discharge. This is an essential first component of the freeboard.

The amount of flood surcharge depends on the spillway design and the size of the gates, and if the gates are large enough, it may be reduced to zero.

An increase in flood surcharge may be warranted if the dam site is constrained by the site geometry: for example, a very narrow canal, which requires a higher surcharge to compensate for having a limited crest length on the dam for the placement of the spillway.

The second factor, on the right side, in the bullets: the wave action.

Wave action produced is generally by high winds. A higher freeboard will be required in reservoirs with a larger water surface. This increases the distance -- we say it like the "fetch" -- along which the wind can act on the water. A higher freeboard will also be warranted in a region which is subject to high winds.

Third factor: type of dam. An embankment dam has a high risk of damage or failure due to overtopping as compared to a concrete dam. For this reason, an embankment dam warrants a higher freeboard than a concrete dam, keeping all other things being equal.

And finally, the last one: operational reliability. In areas where there are uncertainties in relation to the reliability of gate or other operations, the designers may feel that this warrants additional

freeboard.

It should be noted that freeboard is not usually constructed simply for the sake of freeboard. A dam is expensive to construct, and so designers will not normally provide for more freeboard than is necessary in a given case. If more freeboard were provided than necessary, it would not be economically rational and would need to have some other motivation.

As far as the second part of the Court's question is concerned, the short answer is: yes. A crest-gated spillway is designed such that there is a gap at the top of the gate to allow for water to overflow the gate if the water level rises too high. If the top of the gate is at the full pond level, this will prevent the deliberate raising of the operating pool above this level.

Slide 17.

PROFESSOR BUYTAERT: Sorry, can I ask a question on this slide (16(a)), if you don't mind.

The figure you show here on the left-hand side, you say rising water level will overflow the gates. But in this particular figure, given that it's a gated spillway, one would assume that the water level doesn't overflow, but that gate is operated such that the water level is low enough to account for the flood surcharge,

because the reason to have a gated spillway to be able to control the water and keep the flood surcharge to a minimum, or ideally zero. Am I correct?
DR ABBAS: Yes. The gates are operated in a way to minimise the surcharge that may be possible in the passage of high flood.
PROFESSOR BUYTAERT: Yes. So in this case, that particular case of the figure, one would expect the flood surcharge to be minimal, or even zero, given that you can regulate the water?
DR ABBAS: Exactly. Exactly.
PROFESSOR BUYTAERT: Okay, thank you.
DR BLACKMORE: I'm not sure this is the right time to ask this question, because I think it was on the previous slide, but I'm not sure what's coming next.
So I want to go back to the 1-in-10,000-year flood and climate change, and what account is taken. Because the 1-in-10,000 flood is historically: standing here, looking backwards with the records and projecting them out and coming to a number. But we're now seeing some climate change influence. I'm just wondering, as a hydrologist and somebody working in this space: are we starting to see changes in the number that we would start designing for, based on climate change?
DR ABBAS: Well, sir, this is a very pertinent question

related with the hardcore hydrology. I would like to explain in more detail.
Sir, as you said very rightly, when we start projecting some flood, we have to take account for the historic events we have, okay? And the historic events we have, if you talk about the last 50 years, we don't have any impact of climate change. It means that if we are taking care of the recent events in our projections that have some incorporation or, you can say, some impact of the climate change in them, so we are somehow incorporating the impact of climate change in the projected estimates.
DR BLACKMORE: That's true for the climate change that's already happened as we're moving down the journey.
I won't take the question any further because it's a difficult subject. But it does affect whether it's 1 in 10,000 or 1 in 5,000 if climate change is a significant issue, that's all.
DR ABBAS: Yes, sir. I do agree that a flood that has been estimated earlier has some magnitude, and if you just incorporate the new events that have some high peaks, that magnitude may get updated.
THE CHAIRMAN: I had a question on slide 16(a).
DR ABBAS: 16(a).
THE CHAIRMAN: Yes.

So yesterday we walked along the top of the dam here, and if it had been wet on the top of the dam, I could imagine that it would be a little less safe. So my question is: is safety one of the factors that one would take into account in setting the freeboard, to avoid water being on the top of the dam, or are you placing that under operational reliability? It sounded like that wasn't really what you were talking about.
So my question is whether safety is also one of the factors.
DR ABBAS: Mr Chairman, yes. Safety is the utmost important aspect for any dam in the world.
THE CHAIRMAN: So the safety of the individuals working at the dam, needing to cross the top of the dam in some situations, you might set the freeboard to avoid the water --
DR ABBAS: Exactly.
THE CHAIRMAN: -- to be sure everyone is safe?
DR ABBAS: Exactly. Further, you see at the top of the dam, when we talk about the particular aspect you are talking, we have some minor slopes there to drain out the water that is coming from the rain.
THE CHAIRMAN: In addition to just that design, the freeboard itself is helpful in ensuring safety?
DR ABBAS: Yes.

THE CHAIRMAN: Okay.
MR MINEAR: If we could go back to slide 16, please.
DR ABBAS: Please.
MR MINEAR: I just have a question on terminology.
Is freeboard always measured from the top of the dam to the full pondage level? Because I've seen in some other publications where it's measured to the flood surcharge level. So we could be talking about two very different measurements.
What should I understand to be the correct terminology?
DR ABBAS: Sir, I would like to refer here [to] USACE understanding of this particular aspect.
It is generally, you can say, considered above the full pond level, okay? And it incorporates various factors, as I've explained earlier. It incorporates the surcharge required for passing of the extreme flood; and above that surcharge is the wave-related safety that we require at the freeboard to avoid its overtopping. So it comes out to be two or three things that need to be there above the full pondage level.
MR MINEAR: The Corps of Engineers' documentation provides a specific definition?
DR ABBAS: Yes.
MR MINEAR: Thank you.

DR BLACKMORE: This is just an observation, sir.
A 1-in-10,000-year flood -- there is a lot of mechanical and electrical infrastructure right on top of the dam, at ground zero. So I'm assuming you are going to get all the people off the dam. I'd be the first one to leave, so I just let you know that! But you've got a huge amount of infrastructure: power cables, pumps and so on. So if we were to top the dam in a 1-in-10,000-year event, we'd be certainly restricted in what we could do to recover as the flood went away.
Just an observation that ...
THE CHAIRMAN: I don't think that was a question. So, please, Dr Abbas continue.
DR ABBAS: I think I was at 16(a). Slide 17.
Now, sir, I will be discussing the design flood at the Neelum-Jhelum Project.
The most important aspect for dam safety is whether the dam is able to pass the design flood or not. The design flood is calculated by reference to the hydrology of the river basin on which the project is situated.
We can see on this slide the final results of the analysis related with the different return periods of the flood. The hydrology of the Neelum-Jhelum basin shows that once every ten years, flood conditions of just under 2,000 cubic metres per second will occur.

This is again a statistical-based estimate using the available datasets at the particular site.
In the next data point to the right, once every 100 years, flood conditions of just under 4,000 cubic metres per second inflow will occur. And further continuing to the right, once every 1,000 years, flood conditions of just under 8,000 cubic metres per second inflow will occur. And finally, once every 10,000 years, flood conditions of just under 10,000 cubic metres per second inflow will occur.
Where you are seeing this red line, this is the probable maximum flood at the Neelum-Jhelum Project: that is 12,500 cubic metres per second. Again, this PMF has been estimated based on phenomenon-based studies.
PROFESSOR BUYTAERT: Sorry, can I ask you a question about this.
So you have the bright red line as the probable maximum flood. But if I'm correct, didn't you identify or define the design flood as the 1-in-10,000-year event, in which case it should be the rightmost point on the dark red curve, isn't it? While in the legend you've got "PMF" and in between brackets "(Design Flood)".
So the red line is not the design flood; am I correct?

DR ABBAS: Perhaps you have rightly pointed out this slide.
The spillways are designed for the 10,000-year flood --
PROFESSOR BUYTAERT: Yes, which is around, sorry, 9,500 --
DR ABBAS: But this is basically a safety check.
PROFESSOR BUYTAERT: Okay. So the design flood here, if I read the graph correctly, is just below 10,000 cumecs --
DR ABBAS: Yes.
PROFESSOR BUYTAERT: -- while the PMF is above 12,000?
DR ABBAS: Yes.
PROFESSOR BUYTAERT: Okay, yes. Thank you.
DR ABBAS: Thank you.
Slide 18.
The most important tool for management of the design flood is the spillway. Another familiar event is on the slide showing the different configurations. You have seen it before.
After discussing various spillway configurations, now I will take this opportunity to answer the Court's question 1, which is as follows: what are the range of circumstances where a gated spillway might even be beneficial or required for run-of-the-river plant on the Western Rivers of the Indus Basin?
Before we answer this question, we must understand what we are comparing a gated spillway to: the ungated

or the surface spillway.
As you can see on this slide, on the left side of the slide, this is the most basic spillway design. This design is actually recommended as the default by many engineering standards, despite its relative lack of complexity. Why? Precisely because of that lack of complexity.
A gated spillway has to be open in order to function. As such, it may suffer from human or mechanical error and be stuck in the closed position during a flood: a very serious situation. An ungated spillway has none of these issues. Like all objects without moving parts, it is difficult to break.
Slide 18(a).
PROFESSOR BUYTAERT: I wonder whether now is a good time to ask again my previous question.
So you rightly pointed out that the surface spillway is the default option, but clearly that option wasn't chosen here for the NJHEP. And I wondered what criteria were used to determine whether, in this specific context, an open surface spillway was not the best option.
DR ABBAS: Well, I would like to, I think, address this question in a sequence.
First of all, you have seen yesterday different

components of the dam at site. You must have noticed some rockfill dam portion, and you have also noticed the area for the desander. So one thing is clear: that you are not going to have a spillway in these two embankments, because of the requirement of certain features of the dam. So what shall be left is the centre of the dam. And I think during the design phase it must have been evaluated that: if the surface spillway is there, can it pass the design flood under the given circumstances?

So I believe that for Neelum-Jhelum Project, all these exercises have been concluded, and based on the optimal solution, what you are seeing right now is there.

PROFESSOR BUYTAERT: Thank you.

MR MINEAR: One more question. I just want to make an observation. This slide shows my confusion with regards to the terminology.

The freeboard on the first slide is measured to the design flood surcharge; in the other two slides, it's measured to the full pondage level. But your note above explains that the design flood surcharge may be zero if the gates are large enough.

So I think that is what resolves my confusion I had earlier about the terminology.

DR ABBAS: Sir, in principle, it's above the full pond level, okay? Here in this case, this is the surcharge. And above the surcharge is the requirement for the wave accommodation.

MR MINEAR: Great, thanks.

DR ABBAS: Thank you.

DR BLACKMORE: So just back to your explanation. I understood the explanation very clearly, so thank you for that. But an observation or a question.

So if we went for a free overflow surface spillway here, just assuming we had the space, we would have to allow an elevation drop. So the dam would have to be bigger, taller, to do that, otherwise we'd lose available head to get into the spillway?

DR ABBAS: Exactly.

DR BLACKMORE: So I was wondering whether that was a more important characteristic: that we didn't want to build the dam higher, so we had a surface spillway; we wanted to have the dam at this level, so all the other mechanical and hydraulic bits fitted together.

DR ABBAS: Perhaps this is what I am going to explain in detail in my coming slides.

Slide 18(a). So what you have seen in the previous slide, you are seeing again the elevation of those three types of spillways.

The big issue with an ungated spillway is that its discharge capacity is fixed by the length of the spillway, which is fixed by the width of the valley itself in which the dam is located. We can see this represented on the slide.

If the valley is insufficiently wide for the ungated spillway to pass the design flood, the designer has two options. First, the valley might be widened by excavation or tunnelling, to allow for an ungated spillway of the required length to be built, or you can say to accommodate that surface spillway requirement within that valley. Second, if the geology of the valley does not allow the valley to be widened safely, or the cost of the widening is prohibitive, a gated spillway would be introduced in the design.

With the gates close, located at the crest of the spillway, this may be considered the next best alternative to an ungated spillway in some cases, especially when it is considered that a gated spillway may play a role in sediment management. There is usually no need for large amount of flood surcharge to be accounted for in a crest-gated spillway, provided the gates are large enough. This is what we were discussing earlier.

At the same time, if the top of the gate is not at

the full pond level, any flood surcharge between the full pond level at the top of the gate can be converted into controllable storage, and the pond overfills deliberately. This will allow the maximum operating level to be raised, increasing the pressure head against the turbine and increasing power production.

And finally, we have this orifice spillway. This is also a gated spillway, but with the gates themselves located deep in the reservoir, potentially below the minimum operating level.

The benefit of this, when compared to a crest-gated spillway, is that the additional pressure with which the water is discharged from the orifice means that the discharge capacity of a high spillway can be obtained in certain conditions, but with a smaller orifice.

If there are geometric conditions that can limit the spillway width, this can be useful, this option.

Another benefit of an orifice spillway is that it allows the designer to situate the spillway in the middle of the dam, as opposed to its crest, potentially reducing construction costs.

Of course, this comes at a cost: the increased velocity and the density of the resulting water jet exiting from the orifice spillway tends to erode the riverbed at the foot of the dam to a greater extent than other spillway designs. Moreover, the gates themselves need to be designed to deal with greater water pressure compared to these two spillways.

Mr Chairman, let me summarise the circumstances in which gated spillway might be beneficial or required, as follows.

First, the lack of valley width at the dam site we elaborated earlier.

Second, limitation in dam height due to site constraints, as we discussed, like geology or chance of upstream population submergence.

Third, augmenting the flood-passing capacity of ungated spillways, as we will discuss shortly.

To this, I should also add that a gated spillway of any kind may play a role in sediment management, what we will be discussing in detail in presentation no. 6.

Slide 19.

THE CHAIRMAN: Can I just ask one question before you move past this slide? And if you are already addressing this in the future, that's fine.

But on the orifice spillway, it's a higher pressure pushing of the water through the orifice spillway, because it's lower down and you have the pressure of the reservoir essentially pushing the water; is that correct?

And further, however, there's a disadvantage here because it can only push through as much water as that orifice will allow, which means that if all you have is the orifice spillway, you may not be able to clear the amount of volume of water that you would like to, and that would be an advantage of the first two spillways; is that correct?

DR ABBAS: Sir, absolutely right interpretation. I would explain it further.

THE CHAIRMAN: Please.

DR ABBAS: You see, in case of ungated surface spillway, more discharge can be passed by just increasing the head over the spillway. But in this case, orifice spillway, we have a fixed flow area, so it means that this particular type of spillway has some limitation in passing certain range of discharge.

And another important aspect that relates with the hydraulic engineering is basically how to deal with the higher velocities with these orifice spillways. So there are certain, you can say, upper limits available for design velocities in such type of spillways, to avoid damage to the concrete structure.

THE CHAIRMAN: And in your experience, would you typically not have just an orifice spillway? Would you combine it with a gated spillway or an ungated spillway? Or is it

possible, in certain conditions, that you would just have the orifice spillways?

DR ABBAS: Mr Chairman, I would like to address this particular query in my coming slide. But in sequence of priority, this should be the priority.

THE CHAIRMAN: Yes, okay.

DR BLACKMORE: I am just interested in the electromechanical support needed for the gated spillway and the orifice spillway. So you need infrastructure, you need power. And we want these things to be effective in a flood of some sort, let's say a one in 2,000 year flood, where all the indigenous power is gone, the power lines will be gone -- well, they certainly are in Australia.

So I'm wondering how much of the contingency planning is in place to operate these gated spillway structures, either orifice or gated, in the event of regional power being out. Do we have backup power? Are we able to get access to the backup power to do it?

DR ABBAS: Sir, this is what we were discussing earlier as the operational reliability, and that is very much highlighted with the spillways like orifice spillways.

Here, at Neelum-Jhelum, we have a proper contingency plan available. As per the operational guidelines, there [is] always a backup there in the form of generators that can operate the spillways in case of

power failures.

THE CHAIRMAN: If I recall correctly, the first stop on our walk-around yesterday was a series of generators right next to this building that you would use to operate your gates if there is a power outage.

DR ABBAS: Yes. May I proceed to next slide?

THE CHAIRMAN: Yes, please.

DR ABBAS: Thank you. Slide 19.

In many situations, however, the optimal spillway solution for a particular dam is to include multiple spillways, in the design of different circumstances. The risks of gate failure in an orifice spillway may be eased by including an ungated spillway for which gate failure is not an issue.

Conversely, the lack of a valley wide enough for an ungated spillway that can pass the design flood may be eased by including a supplementary gated spillway in the design, as we were discussing earlier.

In some cases, all three basic spillway types may be included in the same design. An example of this methodology is from Karun-3 Dam in Iran.

This combination was selected for several reasons. Let me discuss here.

The ungated surface spillway was selected to provide security in case of gate failures, and to provide an outlet for landslide-generated waves, and as a part of the total PMF discharge; whereas the gated surface spillway was to deal with most of the design flood discharge, but the space available was limited. These were designed to 300 cubic metres per second of rate of flow, so could not discharge more.

The orifice spillway -- in the centre of this slide -- was used to make up the total PMF discharge, but also functioned to vent the suspended sediments during the flood.

So this is what, sir, you were asking, that how different types of spillways can be integrated in a single scheme of a dam.

Slide 20. Sir, many of the points just made can be found in summary on this slide, which introduces the combination spillways at the Neelum-Jhelum Project as well.

Spillways can be combined in different configurations to meet different challenges at the project sites; for example, flood or sediment management. If one design is not possible, a work-around may be developed. For example, an orifice spillway may be included as the main spillway, with a surface spillway incorporated for use if the discharge capacity of the main spillway is exceeded.

The Neelum-Jhelum Project is one such design, incorporating orifice and surface gated spillways, together with undersluices built into the intake structure for sediment management.

Slide 21. You can see how this looks in real life on this slide. So you have seen this yesterday from the viewpoint as well. So what's different in this slide is: those parts of the structure that are visible here were not visible yesterday because they were submerged in the water.

You can see here the intake structure. Six intakes are there, and here we have undersluices. And this is the central part of the dam, having gated spillway or orifice spillway. And this is the debris channel or the flat bed spillway.

MR MINEAR: On this slide, can you show with your pointer where the full pondage level would be? In other words, if there was water in the reservoir, where would the full pondage level be? If you can point to it.

DR ABBAS: I think here (indicating).

MR MINEAR: Okay, thank you.

DR ABBAS: Somewhere here. Again, this is an estimate.

Slide 22. Sir, what you have seen in the elevation, this is what you see in the record drawing. Again, on the left you have six intakes. In the middle of the dam

we have a gated spillway. And this is the debris channel or flat gate spillway. And on the right side we have rockfill dam.

THE CHAIRMAN: Can I just confirm that -- the gated spillways are here, and then there's orifices down here (indicating)?

DR ABBAS: The orifices are here (indicating).

THE CHAIRMAN: Okay.

DR ABBAS: Slide 23.

Sir, having some discussion on the upstream elevation, now I am showing you the downstream elevation at the time of construction of this project.

So you can see here different aspects. Again, in the middle of this snap, you can see three individual gates of the spillway. You can see here this gate is fully open, while two others are partially open. And here, these are the walls of the sedimentation basin that is being constructed. And this part is still to be constructed there.

Slide 24. This is, sir, what you see in the record drawing: again, all those features that I have shown you earlier. In the middle of the slide, the gated spillway. The floodgate, which was under construction; and this was also under construction in the previous snap. And here, these are the walls you have seen in

the previous picture.

Slide 25. Sir, you spent a reasonable time yesterday on this orifice spillway, so you might have noticed something I will be explaining here.

This photograph was taken at the top of the deck unit where the gates for the orifice spillway are housed, looking upstream. The radial gate of this spillway is in the fully closed position and is holding the river back. It's basically resting on the crest right now. We are looking upstream.

Radial gates of this kind are often used on larger spillways. They are the easiest and most reliable gates to operate.

Slide 26. Now I come to some more details. We can see the close detail of this in the record drawing of the orifice spillway. Shown here is the longitudinal elevation. The flow direction is from left to right. So this is the radial gate I explained earlier, and this is the opening here. So water, when it flows from here, goes ultimately to the downstream, where it dissipates energy there and goes to the natural river further.

Slide 27. This is the surface gated spillway. Yesterday you have seen that the water was flowing over it. What you are seeing right now is basically it's holding the water upstream.

As with the equivalent for the orifice spillway, this is taken downstream of the spillway at the top of the gateway. The gate is holding back the flow at the top of the reservoir. It is designed so that, in flood conditions, the reservoir can flow freely over the gate, without damaging it or its mechanism.

Slide 28. The close detail of the spillway design is again visible on this slide. So what you have seen in the last slide is shown here. So the basic operation is like this: if this is the crest, the flap basically operates like this (indicating). Unlike the gated spill way, if this is the crest, the gated spillway operates like this (indicating).

Slide 29. Sir, this ends this portion of the run-of-the-river HEP basic presentation. The second portion, on sediment management, will start after a short break. I think I am right on time!

For now, on behalf of Mr Alauddin, my colleague Umar Farooq, I thank you for your time. If you have any questions, I am pleased to address.

THE CHAIRMAN: Thank you, Dr Abbas, let me look to see if there are any questions at this time. No.

That was a very helpful presentation, we appreciate it very much, and you are to be commended for hitting your time mark almost perfectly!

MR FAROOQ: Thank you.

THE CHAIRMAN: So thank you. I will end then this presentation now, and we'll look forward to the second presentation in the afternoon. And perhaps now we'll do our little walkabout, if that's possible. Thank you.

Presentation 7: Dam Walkaround and Reservoir Inspection (II)

THE CHAIRMAN: So, Mr Alauddin, as we lost the audio on our walkaround yesterday, perhaps we could start here again today and have you just explain to us where we are at this point on the dam.

MR MIANA: Sure. We are on the pier of the dam. The elevation at this level is about 1,019 metres above sea level. On our left, we can see the river is coming from this side. This is the upstream side of the river, and this is the reservoir. And on the left side we have the left embankment over there. There we have the intake gates and the undersluice gate, and also the radial gates. So the radial is on the right side. And beside the radial gate we have the cascade, the floodgate over there. (Pause)

And now we can see from here the maximum level of 1,015 that was questioned in the meeting as well. So you can see this is the maximum level for which the reservoir is supposed to be at the maximum level. And above that is a freeboard available, as was explained by

the three persons in the presentation no. 5 just now.

And beside that we have the floodgate, and this floodgate -- both are open now just to maintain the level over there. So these are the positions for the regulation of the water from this point, for Neelum-Jhelum Hydropower Project.

THE CHAIRMAN: Okay, very good. Any question?

MR MIANA: So we move to the other installation over here.

As explained, these are the feeder beams that we use to put in under our stoplog outside, just to avoid the accumulation of sand and sediments in these lots. So this is very helpful because, if it is not put in that place, then the sediment can accumulate. And this sediment then will restrict the complete closing of the lowest part of the stoplog. So that is helpful. All the sediments are then accommodated in this one (indicating) and then taken out, and then we are safe to place our -- these stoplogs in there.

So all these six lots, for all three gates, are placed now, even now at the bottom of that one.

THE CHAIRMAN: There is one down there right now?

MR MIANA: Two.

THE CHAIRMAN: Two, collecting sediments.

MR MIANA: Sometimes two, sometimes three.

THE CHAIRMAN: Okay.

MR MIANA: But we have the provision we can put up to this level. But that is not required because sediments are not coming too high.

THE CHAIRMAN: One question.

PROFESSOR BUYTAERT: How do you take them out if they are in there now?

MR MIANA: With this crane (indicating).

PROFESSOR BUYTAERT: Okay. You kind of fish them out?

MR MIANA: Yes. We have a device for lifting them out.

PROFESSOR BUYTAERT: Okay, yes, thank you.

THE CHAIRMAN: Mr Miana, is this also out on the -- is this the same one that was out on the desander?

MR MIANA: No, I think there is a second one.

MR ALAUDDIN: That's a different one.

THE CHAIRMAN: It's a different one.

MR ALAUDDIN: These are being used for taking water samples.

THE CHAIRMAN: Okay. And the one that was out on the desander that we saw yesterday, perhaps you could explain again the function of it in the desander.

MR ALAUDDIN: We are using -- that is being used for taking water sample also. But sometimes we have another task: to measure the velocity within the desander so that those are as per the design parameters.

THE CHAIRMAN: Okay. So when we saw a similar one on the desander yesterday, you explained this was to test the

velocity within the desander.
MR ALAUDDIN: Yes, through the same equipment. With having some additional equipment, we can also ...
THE CHAIRMAN: Very good, thank you.
MR MIANA: So the stoplogs for the ogees cleared, if we want to have there in the downstream of the radial gates, we just stop these -- we place these stoplogs in their slots. There are seven (indistinct) leaves to complete one clear of the radial gate opening.
This is the gantry again, to handle these gates as the last filler beams. The capacity of this gantry crane is about 80 tonne.
To our left now, we will proceed to the floodgates.
MR ALAUDDIN: We can see that this other floodgate is fully open. And maybe that is partially open, just to release the water level. (Inaudible) in the morning, (inaudible) minor increase, but it remains the same. The level increases up to 1,012.3. But it is again (inaudible) now.
MR MINEAR: What is the flow rate today compared to yesterday?
MR MIANA: Almost similar.
THE CHAIRMAN: And did you say you pass debris through this as well?
MR MIANA: All the floating debris passes --

THE CHAIRMAN: Through here.
MR MIANA: This is a section to other inflow (inaudible).
THE CHAIRMAN: Yes.
MR MIANA: So once the water is coming to this side (inaudible).
Would you like to see the second one?
PROFESSOR BUYTAERT: Are the gates fully open now?
MR MIANA: Yes, this one is fully open.
This is partially, you can see. This is partially, as of yesterday. (Inaudible).
THE CHAIRMAN: So this gate is partially open; the other one is fully open.
MR MIANA: Is fully open. We can recognise the waves of the hydraulic (inaudible).
DR BLACKMORE: You don't have a fish ladder or anything on here for environmental purposes?
MR MIANA: Fish ladder? No, there is no fish ladder.
DR BLACKMORE: Are there no fish?
MR MIANA: There should be!
Can we move to the --
THE CHAIRMAN: Should we take a look at the --
MR MIANA: -- inside the --
THE CHAIRMAN: Yes. (Pause)
MR MIANA: So this is the control for both the floodgates. We have the electrical panel outside. And on this side

we have electrical motors and hydraulic units, for the operation of both. And this is our system for the operation of the equipment.
We have also the facility to operate both these gates, floodgates 1 and 2, from the control room. It's usually in our control building, but most of the time we come here just to see the physical operation of the gate as well. But we have facility in both.
THE CHAIRMAN: I think I asked you yesterday just to be sure that you can operate the gates either from here or from the control room.
MR MIANA: Yes, we have the facility for that.
DR BLACKMORE: So is this motor the critical point if you had overtopping? These motors would be flooded if you overtopped through the (inaudible) here?
MR MIANA: Normally we have motors on the top of them. All the elevations are below that one. So this is the top one, to avoid this one to be in contact with the water.
DR BLACKMORE: So this is for a 1-in-10,000-year flood, this one here?
MR MIANA: Exactly.
So we will also see and Dr Hayat will explain about this. You want to explain something about the MBT and this one? Please take the mic.
DR HAYAT: We are now standing on top of the embankment dam.

So that is the hybrid portion of the dam. The MBT actually runs approximately in this direction, as we saw in some of the photographs that were shown. And you can see the different colour of the formations on both sites. You can see the graphitic schist here, some limestone and a whole lot of things. And this is a different formation. This is Panjal formation; that is the Murree formation.
In this dam, as you can might have noticed, there were some questions from one of the honourable members of the Court about the movement of the MBT. And what happens is: what we design for is there should be no damage to the dam in an OBE earthquake; that is operating basis earthquake.
However, in a safety evaluation earthquake, or what was previously called the "MCE", maximum credible earthquake, some damages are expected, which can be repairable. So in that case, if we calculate the expected fault movement in case of an MCE, and we design the downstream filters to be taken off, that they are not short circuited. So if there is a movement, you will still have a portion of the downstream filter which will protect any downstream seepage.
Same goes for the grout curtain, because this is solid rock, so we are not that much concerned if the

grout curtain is sheared. Then you can go ahead later on, after the event, and come back and regrout in that area.
DR BLACKMORE: What thickness is the filter?
DR HAYAT: There are two filters. One is the fine filter and one is the coarse filter. Both are 4 metres.
DR BLACKMORE: 4 metres? Wow!
DR HAYAT: Normally it would be like a metre or 2 metres.
DR BLACKMORE: Yes, it's high.
DR HAYAT: So it's to cater for that.
DR BLACKMORE: Okay.
THE CHAIRMAN: Any other questions?
MR MIANA: So we'll go to the desanders. And the same route I would like to --
DR HAYAT: One other question was about the grout curtain and the drainage curtain. So the grout curtain would be at the centre line of the dam, and it will be slightly inclined upstream. The drainage curtain will be straight, so that is to catch any seepage that will still pass the grout curtain. And it will then drain into the drainage gallery that you saw on the drawings. And there, there are measurements also that you make, and you want on see, over a period of time, how the seepages are happening.
And the main purpose of the drainage curtain is to

ensure that there are no undue uplift pressures on the dam, because that would make it unstable -- could potentially make it unstable.
DR BLACKMORE: Do you have any drainage monitoring down here, through --
MR FAROOQ: Yes, between the drainage gallery and --
DR BLACKMORE: So the gallery goes under here as well?
MR FAROOQ: It goes under here, but --
DR BLACKMORE: Yes. Oh, so it goes back that way? Okay.
MR ALAUDDIN: It is up to that line (indicating).
MR FAROOQ: But here we have the piezometers and all those things. So we know the (indistinct) line, how the water line actually is developing in the dam.
THE CHAIRMAN: Very good. Off to the desander, perhaps. Okay.
(Pause)
MR MIANA: Yes, surface monitor. So this that he was talking about: that we have further monitoring, we check these regularly.
THE CHAIRMAN: Just hang on.
MR MIANA: Okay.
THE CHAIRMAN: Wouter and Don, he was about to say something.
MR MIANA: So these are the surface monitors that were just for monitoring purpose, at different locations in all of

the dam site?
MR ALAUDDIN: Sir, yesterday was questions about the sedimentation or the desander structure. You see, the rate of coming the sediments into this depends upon: in high flow, more sediments come; in low flow, less sediments come.
So as far as the cleaning is concerned, that depends. We have to make more frequent cleaning during the high-flow season, and naturally less during the low-flow season. So it depends upon the operator: he has to decide when to carry out, based on the layer of the sediments at the bottom, here, here and here, and the rate of the concentration which are passing on through the intake into this. So --
Yes. Regarding the sizes, you see we have recently -- before coming, we basically carried out some tests of the water sample for the sizes. This desander has been designed to trap grain sizes, sediment sizes, more than 0.15 millimetres, 0.15 millimetres will settle, and they may go -- they might go into that. But that also depends upon ...
So, so far we have seen that the design consideration which we made, this structure is behaving far better. And this structure is quite effective because of the reason that I have already mentioned in

my briefing: that five years have passed, and because of the effectiveness of this structure, we are getting little wear and tear, or we should say that we're getting fair wear and tear, even after five years. And they're operational. They haven't carried out any major repair to the dam.
(Pause)
MR MIANA: There's a surface monitor here. The surface monitor, the second one on this one. That we saw just now, the second one, on this side.
(Pause)
So first, again, we will see that diversion tunnel, just to speak about -- something about that. And looking at the gates from the downstream side. Also looking at the discharge for the flushing of the desanders whilst we are there.
Four gates each, connecting the desander with the collecting tunnel. And beneath this one, we have the gate for the flushing of the desanders. And for flushing, we just close the intakes for that and just flush it for that. And normally this is hydraulic flushing. If we need the mechanical, yesterday as I explained, then we can use these pipes, the pressurised water, for that one.
(Pause)

So here is the diversion tunnel that was used during the construction. This is the outlet of that diversion tunnel. It is coming from the upstream of the dam side. And from upstream of the dam side, we are already flushing. Now, however, it is from this side it's open. And with this, we can also see the outlet for the flushing of the desanders from there, and we can also see now that two are in operation: the undersluice is also in operation for the fine-tuning.
MR MINEAR: And we are doing the sluicing again (inaudible).
MR MIANA: Yes, yes, undersluice again. Because they just try to fine-tune about the regulation and the water level.
THE CHAIRMAN: So I think that our audio from yesterday resumed at this point.
MR MIANA: Okay.
THE CHAIRMAN: And therefore, unless there's any particular questions from here on, I think we're basically done and can just walk back to the --
MR MIANA: The normal room.
THE CHAIRMAN: Yes. Is that okay?
MR MIANA: Okay, let's go.
THE CHAIRMAN: Okay, let's go.
(End of walkaround)

Presentation 6: Run-of-river HEP basics (II)
DR ABBAS: Mr Chairman, members of the honourable Court of Arbitration, it is a pleasure to address you again. Along with me, my colleague Umar Farooq will be presenting on sediment management, a crucial aspect of hydroelectric power plant design, operation and maintenance.
In this presentation, we will proceed in three parts.
In the first part, I will provide you with an overview of sediment aspects, including key concepts and features of sediments in the Himalayas.
In the second part, my colleague Umar Farooq will address you on the first purpose of sediment management: I mean to say the maintenance of live storage or operational storage. This is generally achieved by preventing sediment accumulation in the reservoir to preserve the plant's live storage.
And in the last part of this presentation, I will return back to take you through the second purpose of the sediment management: I mean to say minimising the sediment entering the plant's turbines, which causes damages to the turbines' plates.
Please do not hesitate to ask any question.
Slide 2. I will be discussing here different

sediment issues.
Slide 3. Mr Chairman, starting from the size of the sediments.
As you know, sediment is generated when rocks break down into smaller and smaller particles by natural weathering process. These particles are delivered into rivers through rainfall erosion, landslide and debris flows.
Sediment sizes vary greatly. They are commonly measured according to the Wentworth scale, which classifies them by grain size.
The largest sediments we deal with in the Himalayas are boulders, which are 10 million times larger than the smallest sediment. These are the boulders, about 1.6 metres in height. And you can see the boulders can be as long as up to 4 metres and beyond, starting from a foot of length to 4 metres.
Our rivers carry a sediment load that includes fine sediments, mostly silt and clay, and coarse sediment, sand and gravels, along with the cobbles and boulders.
Mr Chairman, now I would like to show you different sizes of the sediments. The samples we are going to describe you have been extracted from the bed upstream of this reservoir.
These two (indicating) are basically representing

the silt. You can see the fineness in it. And from here onward, up to this tissue-paper box, this is all sand. And they have been placed in increasing order. So this is the coarsest sand, up to 2-millimetre size. And from here onwards, it's gravel.
THE CHAIRMAN: On the far side of the tissue?
DR ABBAS: Yes.
THE CHAIRMAN: The tissue is not part of the ...!
DR ABBAS: Yes, definitely. (Pause)
These are gravels.
Mr Chairman, just focus on those two stones: they are cobbles.
THE CHAIRMAN: In the bag?
DR ABBAS: These ones (indicating).
THE CHAIRMAN: Oh, all the way over there?
DR ABBAS: Yes.
THE CHAIRMAN: Okay.
We have one question.
MR MINEAR: Doctor, what is the composition of these materials? Is it sandstone or schist or a mixture?
DR ABBAS: Well, I think at the feasibility stage, samples were collected from the bed and they were analysed for, you can say, mineralogical aspects. So as far as composition is concerned, they are mostly composed of quartz and some hard material. And if you talk about

the percentage, so the harder material in these samples are around 70%.

Slide 4. Now, sir, I will be explaining different modes of transport of the sediment within a stream.

In the Himalayas, almost all sediment is eroded and transported during the wet season. Spring and early summer flows are mostly from snow melt. Late-summer flows are mostly from mountain range and glacial melts.

Fine sediments, including the sands, are eroded from hillsides and are easily transported downstream by rivers. The large material on the riverbed is transported by hydraulic forces on the riverbed generated by large or extreme floods.

As you can see in this slide, [there are] two basic modes of the sediment transport in a stream.

The great majority of sediment in rivers is transported in suspension. And the amount of sediment being passed in suspension, when it comes to be in terms of magnitude, we determine it as the "sediment load", or you can say "suspended load".

You can see rivers turns a muddy colour during floods due to the sediment they are carrying. Suspended sediments do not have significant interaction with the riverbed; they are generally in suspension. They usually enter into river due to erosion of the land

surface, especially due to heavy rainfall.

Now coming towards the bed load. Bed load is movement of the bed material, the sediment found on the riverbed. It moves by rolling and bouncing along the river. As you look in the river, you can see the material in the riverbed is quite large.

Now if I talk about sand. Sand can be transported as either suspended load or bed load, depending on the flow velocity, the strength of the turbulence in the water. In steep mountain rivers, sand is normally transported as suspended load.

Mr Chairman, the samples between these two tissue boxes are the sand. And these particles certainly come in suspension in high flows and they also move along the bed.

Slide 5. Here are two snaps of Himalayan river beds during the winter dry season. This is the best time to visualise what's on the bank.

On the left, we have the Indus River above Tarbela Dam in Pakistan. This photo was taken at Besham Qila gauge station in dry season. You can just compare the scale of this material with the man's height.

You can see the sand in suspension that was deposited high up the riverbank as the river level dropped. Just look at these sand deposits. The large

bed material is visible in the foreground.

The snap on the right shows the Kali Gandaki River in Nepal, again in dry season. A similar pattern: once again, the larger bed material is seen in the foreground, and the sand is deposited at high levels by the receding waters of the monsoon. You can see here the sand deposits.

Mr Chairman, I will request you to, while you are going down to Muzaffarabad, just focus on the river: you will also notice the sand deposits there along your way.

Slide 6. This snap is a close-up of sand from Marsyangdi River in Nepal on the palm of the hand. Here, Mr Chairman, I would like to invite your attention towards how it looks when you magnify it. Just focus on two things: (1) the angularity or roundness; and (2) the material that is sparkling or shining.

As you can see, Himalayan sand is dominated by quartz. Again, what you have seen right now is basically extracted from the middle jar, okay? Himalayan sand is dominated by quartz. 70% quartz is rather typical. This is highly abrasive and angular. You have seen a similar texture through magnifying. It is harder than steel used in hydropower turbines, a point that I will come back [to] in the third part of this presentation.

Slide 7. This graph shows the seasonality of the daily flows of water in the period 2019 up to 2023. As you can see, most of the precipitation that occurs in the high mountain in the winter is discharged as meltwater in the summer, supplemented by late monsoon summers.

Yesterday, sir, there was a question that: is there a relation between the sediment that is coming specially from the snow melt? So we came up with the data, and it indicates that about 30% of the total sediment at this location is attributed to the sediment in the snow melt periods.

Nearly all sediment is eroded and transported downstream during the high flows of the summer wet season.

Slide 8. Sir, after discussing not only the size of the sediments, the mode of the transport and its characteristics, now I will be discussing how it interacts with the water body when there is a pond.

This slide shows the pattern of reservoir sedimentation. All reservoirs will eventually fill with sediments. But this problem is particularly acute in run-of-the-river reservoirs because of their typically small storage capacity.

Looking at the top image, you can see the sediment

deposits in different zones. The coarser sediments here (indicating) settle to create a delta at the upstream end of the reservoir. Fine sediments, silt and clay, settle downstream of the delta. The delta will grow downstream over time, eventually reaching the dam. This part (indicating) gradually moves towards the dam.
Now, looking at the bottom image, reservoirs will fill until they can hold no more sediment. Sediment balance is achieved when multi-year sediment inflow and outflow are matched. Sediment may accumulate some years and get scoured when gates are opened during large floods. My colleague Umar Farooq will be describing this respect in more detail. A long-term stable profile is controlled by water level at the dam during the floods that are responsible for most sediment scour and transport.
Slide 9. These two photos are examples of reservoir deltas.
On the left, you see a sandy delta at the Porce II hydropower reservoir in Colombia. The flow direction is from left to right, and the dam is around 4 kilometres from here. It is advancing downstream towards the dam.
The second photo, on the right, is the top of the delta advancing towards the Tarbela Dam on the Indus River in Pakistan. This dam is about 100 kilometres

west of the Neelum-Jhelum Project. The Tarbela delta is composed of about 50% silt and 50% of fine sands.
Mr Chairman, unless we have any questions, I can switch to my colleague Mr Umar Farooq for the second part of this presentation.
THE CHAIRMAN: Questions?
No, I don't think we do have any -- oh, we do have a question.
PROFESSOR BUYTAERT: Sorry.
So you didn't show us clay, if I'm not mistaken. Does that mean there is no clay in the sediment here in the river?
DR ABBAS: For clay, you need to have some hydrometric tests to distinguish between the finer particles, clay and silt. For now, although there are some clay particles, if you come about the overall composition or distribution of the total sediment at Neelum-Jhelum site, so it's around 20% of the sand and 60% of the silt and 20% of the clay.
PROFESSOR BUYTAERT: 20% is clay. Okay, thank you.
And perhaps a follow-up question: do you do any bathymetry measurements here in the reservoir to see how quickly -- if any -- sediment accumulates?
DR ABBAS: Yes. As per part of their routine observation plan, the operator is, you can say, at the regular

intervals taking bathymetric surveys. The last bathymetric survey was in 2021. And now it's being carried out: I think you may see some team going on the boat in the reservoir taking measurements. So I hope the recent bathymetry will be completed by the end of May, I think so.
PROFESSOR BUYTAERT: Okay, yes. Thank you.
DR BLACKMORE: So for a dam like Tarbela, which has got a lot of sediment in it now, have you done any studies on liquefaction when you have an earthquake? So we have a 7 or a 7.5: is liquefaction likely to be a problem in the sediments?
DR ABBAS: Sir, what I remember, or you can say as per my knowledge, I have seen some reports of liquefaction potential at Mangla. As far as Tarbela is concerned, I will like Dr Tahir to respond on this.
DR HAYAT: Studies have been carried out. Because as you said, you know, you very rightly pointed out that if you have a seismic area and you have sand and silt, these are all -- they have a potential to liquefy. These are recent sediments, they are saturated, and with an earthquake there is always a chance that they will liquefy.
So, yes, a lot of studies are done. And people are very aware of the potential dangers, especially when the

delta moves close to the dam, that in any earthquake it may then flow into the turbines and block those. So they are mindful of that. As a precaution, in case of any earthquakes, when we have the green, yellow and red drills, they shut off the turbines, at least just to see that, you know, something is not happening.
THE CHAIRMAN: I have one question. There was a prior slide, I don't know if it's 7 or 6, that had the stable situation for the sediment. Yes, this one (8), on the bottom of the slide, "Long-term (stable) profile".
So is it the case that above this bottom part, we've got a sluice located there, and all either coarse or fine sediment is supposed to be flowing across the top of that delta sediment and into the sluice, and clearing through so that it doesn't build up? Is that the idea?
DR ABBAS: In case of some sluice here? Are you talking about somewhere here?
THE CHAIRMAN: Well, maybe you want to explain again this particular part of the slide. But my understanding was that there's a radial gate there that is part of a sluice, basically, that's allowing --
DR ABBAS: Sir, can you use your highlighter?
THE CHAIRMAN: Sorry.
So this is a lower part of the dam, basically, right? And this is a radial gate. And the reason why

this is a stable profile is we've got a filled-in bottom sediment, we've got this delta sediment, this is creating a sort of a single bed of sediment; and whatever else is coming down the river, whether it's coarse or whether it's fine, it's basically, you know, flowing across the top of this and through the sluice, and therefore it's not building up any more in a way that would affect your intakes. Is that correct?
DR ABBAS: Yes.
THE CHAIRMAN: Okay.
DR ABBAS: You see, when there is a sediment balance, after some time, so whatever is coming in in a natural way is going down in the same natural way. It means whatsoever is the deviation in the summer and in the winter, whatsoever is the variation between the coarser and the finer sediment, all going down in the same manner. Or you can say it's just a riverine condition restored.
THE CHAIRMAN: And so if you did not have that radial gate, it would keep building up and up --
DR ABBAS: Exactly.
THE CHAIRMAN: -- and eventually cover your intakes and whatever else is up there. Okay. Great.
All good? Okay, Dr Abbas, thank you so much for your presentation. I think we are on to Mr Farooq again.

MR FAROOQ: Mr Chairman and members of the Court of Arbitration, I am pleased to be able to address you again.
As you have heard, the sediment management is a crucial part of HEPs' design and operation.
Slide 11. My colleague showed you the photos of the delta at Tarbela Dam a moment ago. These two graphs depict the impact of sedimentation at the Tarbela Dam.
It started operating around five decades ago. Himalayan sediment yields are high. For example, the sediment yield for per unit area above the Tarbela Dam is 1,195 tonnes per square kilometre per year. This places it in the top 8% of 862 river gauging stations worldwide, as reported in the United Nations AQUASTAT database. Tarbela reservoir has lost about 40% of its usable capacity due to sedimentation.
On the left, this one (indicating), you see progression of delta in this direction, from the original bed's location until 2013. On the right here, this one (indicating), there is a clear correlation between the delta's advancement towards the dam and loss of usable capacity in the reservoir.
In run-of-river HEPs, there is little or no capacity available for sedimentation storage, so available storage can quickly fill up. Tarbela, as a storage

reservoir, has lost 40% over 50 years. In contrast, a typical run-of-river plant may lose the same amount of storage in 5 years or less without sediment management. We therefore need sustainable long-term sediment management solutions during the design and operation phases of a plant.
I now turn to solutions to the accumulation of sediment: slide 12.
Sediment management seeks to balance sediment flows entering and leaving the reservoir while sustaining project functions, while minimising environmental consequences.
On the left here, this one (indicating), you can see that before a dam is built, sediment flows are balanced: there is nothing obstructing the flows and causing accumulation.
The centre image, this one (indicating), shows that when the dam is in place, it causes a sediment imbalance, trapping sediment in the reservoir.
On the right, these two images (indicating), you can see that this situation calls for a management decision. Here at the top, this one (indicating): achieve a sediment balance while maintaining live storage; or at the bottom, this one (indicating), do nothing and render the plant inoperable in due course.

Effective sediment management often involves using multiple techniques that increase financial and operation cost. For sediment management, it's the price we pay for attaining long-term sustainable operation.
Slide 13. This slide shows that sediment management can be built into the design of an HEP, including through the outlet placement.
I will take this opportunity to answer the Court's question 2, which is as follows: what are the range of circumstances where an outlet below dead storage level might be either beneficial or required for a run-of-river hydroelectric project on the Western Rivers of the Indus Basin, in particular for the purpose of sediment control?
I mention two main circumstances.
First, to release flow with the water level at the minimum operating level requires the crest of the outlet to be set below the minimum operating level.
Second, sediment management to maintain reservoir storage capacity requires establishing a new riverbed profile through the reservoir, as seen in the top image of the slide. The new profile will be defined by the water level at the dam during flood flows responsible for most sediment scour and transport.
However, as seen in the lower image here, once the

outlet has been set at the location needed to produce the target water level, further lowering of the outlet will produce no beneficial change in the profile other than to create a highly localised cone -- as you can see here (indicating) -- highly localised cone of scour at the upstream face of the outlet.

Slide number 14. There are a variety of sediment strategies. This figure classifies the approaches into four categories: reduce sediment yield; route sediments; remove deposited sediments; or the adaptive strategies.

While talking about the first one, reduce sediment yield, two basic strategies may be used to reduce sediment yield and entering the reservoir from the upstream watershed: (1) control soil and channel erosion at its source; or (2) trap eroded sediment upstream of the reservoir.

Now talking about route sediments. These techniques take advantage of the seasonal variability of sediment. The idea is to manage flows during the periods of highest sediment yield to minimise sediment trapping. The two approaches are: (1) sediment bypass strategies; and (2) sediment pass-through strategies.

Talking about number 3, remove deposited sediments. The main techniques used to remove sediment deposits are: (1) mechanical removal through the dry excavation

or dredging; (2) hydraulic scour through flushing events.

Now about number 4, the adaptive strategies. These aim to mitigate the impacts of sedimentation but do not involve handling reservoir sediments.

At Neelum-Jhelum Hydroelectric Project, we are using a combination of option 3 and option 4 to manage this sediment, which involves desanders, turbine coatings and hydraulic scouring of sediments from the reservoir.

Slide 15.

There is no "one size fits all" approach for sediment management at a particular site. Typically, more than one strategy is used, either concurrently or sequentially. Selection of the strategies requires a case-by-case approach.

This slide sets out the variety of factors to be considered: for example, economics, the economic imperative of maintaining HEP storage; the physical conditions, which relates to the hydrology, sediment characteristics at the site, reservoir geometry and dam configuration; and social and legal constraints, which involve the community and legal imperatives that will influence sediment management options. Allow me to now develop some of these strategies in a little more detail and with examples.

Slide 16.

Erosion control can be achieved through the restoration of vegetation to protect the soil. This is relatively economical and also self-renewing.

This photo, and this one, show the Debre Yakob watershed in the Ethiopian Highlands. On the left here, this one (indicating), you see severe erosion in January 2012. And just three years later, as you can see here (indicating), in February 2015, due to better management of livestock grazing, the vegetation has recovered and erosion has been significantly reduced.

Slide 17. I now turn to the strategy of routing sediments; that is, flood sluicing.

A large section of sediment load is associated with floods. The top image, this one (indicating), shows sediment trapping, which is what we want to avoid. Sediment trapping is maximised when the deep water results in low flow velocity, resulting in a large percentage of the inflowing sediment load being trapped in the reservoir during a flood.

The bottom image, this one (indicating), shows sluicing being used to pass the sediment-laden flows through the reservoir at the highest possible velocity to minimise amount of trapped sediments. Sediments are routed through the reservoir and exit downstream through

the high-capacity gates that are open to pass the flood at the lowest water level consistent with the other operational parameters.

The strategy is to convert the reservoir into fast-flowing river during the sediment-laden floods. The high velocity is used to minimise deposition of sediments and also to scour existing sediment in a manner similar to the reservoir flushing, but without emptying the reservoir. This also avoids the very high sediment concentrations normally associated with empty flushing.

Slide 18.

Sluicing can be performed during a major storm or for a significant portion of a monsoon season.

Image A, this one (indicating), you can see operation of a reservoir at full pond level during the monsoon. The operating pool acts like a sediment trap. As water flows into the operating pool, it carries with it sediment, which becomes trapped.

In contrast, image B here shows the reservoir held at a minimum operating level during the monsoon, which maintains the operating pool empty and thus minimises its capacity to trap the sediment. Simply put, sediment will not be trapped in the operating pool while it is empty.

The bottom frame here, this one (indicating), shows the variation in operational levels over the course of the year under this management approach. During the dry season, the pondage pool level will fluctuate due to power peaking. In the wet season, however, the pond is held at the minimum level to prevent sediment from being deposited. And please note that this "MDDL" is the minimum drawdown level or minimum operating level.

Seasonal sluicing is one of the techniques used to control sediment at the Three Gorges hydropower dam in China, which is the world's largest hydropower plant. The reservoir is operated at a low water level during the wet season to control sediment.

Slide 19.

Sediment concentrations and load varies considerably over time. Bypass strategies focus on excluding sediment in floods, and diverting to storage only the water with lower sediment concentrations. The strategy can be summarised as: store clean water and release muddy flows.

On the left, this one (indicating), you see a diagram of a flood bypass. As you can see here, this one: this is the flood bypass. A bypass system has an inlet upstream of the storage volume, here (indicating), and diverts large sediment-laden flows to

a point below the dam, here (indicating).

Bypass systems typically use a sediment bypass tunnel. A bypass system can be designed to divert both suspended and bed load or suspended load only.

In the middle, here (indicating), we have an off-stream reservoir, which can be created outside of the natural river channel by either impounding a side tributary or constructing the impoundment on an upland area. Clear water is diverted into the off-stream reservoir by a river intake, but large sediment-laden floods are passed beyond intake and are not diverted into the storage.

On the right here, this one (indicating), there is a compartmented reservoir. The reservoir is subdivided by an internal barrier. The basic operating strategy is to direct sediment-laden floods directly to the spillway, to maximise sediment release downstream, while minimising the entrance of sediment-laden flood flows into the main storage zone.

Slide 20.

A bypass tunnel can be used to divert heavy sediment loads around the storage area that is being protected against sedimentation. The construction of a bypass tunnel requires certain site characteristics, and may be installed during original construction or as a retrofit

to an existing project. They may be constructed for supercritical flow, with maximum velocities around 10 metres per second.

This is an environmentally friendly strategy because the river stays reasonably close to its natural state. However, if combined with flushing, the adverse consequences of flushing will need to be considered and mitigated.

Slide 21. This photo shows the sediment bypass tunnel in Asahi Dam in Japan. We are looking downstream: the water flows from this side to this side (indicating), in this direction. The metal structure is the flow diverting structure, this one (indicating). And to the right of it, you see the tunnel entrance here (indicating).

Basically, the concept is that water flows in this direction (indicating), and this weir acts as a barrier and the sediment -- and especially the bed sediment -- is diverted to the river downstream of this reservoir through this tunnel inlet. And the water overtops this crust over here, and clear water is provided into the storage here (indicating).

Slide 22.

Here we have a diagram of two off-stream reservoirs in Colombia, the San Francisco Reservoir and the

Cameguadua Reservoir. They have been constructed outside of the natural river channel. Off-channel reservoirs minimise, but do not entirely prevent, sediment accumulation. Because of the low sediment rate at this project that was built in 1969, dredging was only required after more than 30 years of operation. This reduced sediment load makes infrequent dredging much more economical as compared to a project that is completely dependent on dredging.

Slide 23. This is photo of a different off-stream reservoir. It is in Chile. And I beg your pardon if I pronounce its name incorrectly. Its name is Tinguiririca. Yes, I think I have pronounced this name correctly.

This off-stream reservoir is fed by an intake and a desander. The river flows in this direction (indicating), from top to the bottom. Here is the desander structure, which collects the sediment and removes into this river channel again, and comparatively sediment-free water is diverted here in this dam.

Only water with low sediment concentration is passed into the reservoir. Large sediment-laden floods run downstream, in this direction (indicating), along the river channel, but are not diverted into the reservoir.

Off-stream reservoirs can be highly effective in the

Himalayan environment, leaving the off-stream pondage empty during the monsoon and operating the pondage only during the dry season, using water that is largely free of sediment. It does not alter the natural pattern of sediment transport along the river. The main limitation is that most hydro sites do not offer the required topography.

Slide 24.

One of the strategies for removing deposited sediment is pressure flushing.

In the left frame, (a), this one (indicating), you see a plan view, looking down from the top. When a low-level outlet is opened but the reservoir remains at a high level, a scour cone will develop only in immediate vicinity of the outlet. In the right, here (indicating), image (b) or section A-A, showing the side view of the outlet and scour cone.

This process is termed "pressure flushing" because it does not depend on reservoir drawdown. It is used to keep immediate vicinity of an intake free of sediment, but cannot remove sediment accumulation at any distance from the outlet.

This is a photo of the scour cone, as you can see here -- this is the scour cone (indicating) -- at the outlet of sedimented reservoir on Rio San Antonio in

Brazil. You can see the limit of the cone in the semicircle outline of the water, this one (indicating).

Slide number 26.

Empty flushing or drawdown flushing is when low-level outlets -- this one (indicating) -- are used to empty the reservoir such that river flow scours the exposed sediment bed and carries the eroded sediment through the outlet and downstream of the dam. For this to work, the low-level outlet would normally be located near the bottom of the dam, near the original stream bed.

The full sequence requires days or weeks between drawdown, flushing and refilling of the reservoir, depending upon the reservoir size, type of dam, the sediment volume and downstream environmental limitations.

Empty flushing often has significant downstream impacts, due to extremely high sediment concentrations which can injure aquatic life, impair water quality for downstream users, and increase sedimentation in the downstream river and irrigation intakes and canals. Typically, it is not the only available form of sediment management.

Slide 27. This photo shows the empty flushing in the Middle Marsyangdi hydropower reservoir in Nepal.

The flow is towards the left, from this side to this (indicating). Notice that the water is turbulent, scouring the bottom. And also notice the high sediment concentrations, which are visible as dark colour of the water.

Slide number 28.

Another method for removing deposit sediments is mechanical removal, such as dredging. This photo shows the Bajo Anchicayâ hydropower reservoir in Colombia, which has been dredged continuously since 1962.

Even though dredging is costly, the advantage is that it does not interfere with the hydropower operations, unlike flushing. That requires power production to be stopped.

Environmental impacts depend on how sediments are delivered to the river below the dam. In Himalayan environments, the disposal of dredged sediments to an upland area is not possible in the long run, owing to the massive volumes of sediments involved and lack of disposal sites.

This presentation has given you a bird's eye view of the wide variety of strategies that can be used to management sediment. It will depend on the site and other factors.

My colleague Dr Abbas will address you on intakes

and turbines, and if you have any questions before that.

PROFESSOR BUYTAERT: Thank you very much.

I don't think you mentioned density current flushing. Is that operated at all here in Pakistan?

MR FAROOQ: Density current flushing?

PROFESSOR BUYTAERT: Yes.

MR FAROOQ: At the moment, density current flushing is not implemented at any site, but it is under study at the Bhasha Dam site for sediment management.

PROFESSOR BUYTAERT: Okay, thank you.

A follow-up question. You did mention off-stream storage. Are there any off-stream storage dams? I know you mentioned that you need very specific geographical conditions. But are there any examples of off-stream storage here in Pakistan?

MR FAROOQ: In Pakistan, there is an off-stream storage that is at the planning stage at the moment. But I think it's -- if I could correctly recall its name. It is maybe Akhori Dam. So it is a kind of an off-stream storage, but it is at the planning stage at the moment.

PROFESSOR BUYTAERT: Okay, yes. Thank you.

THE CHAIRMAN: So I had just a question about, I guess, pressure flushing. And I don't know if we can go back to the slide that showed the pressure flushing (24). But it's just a question as to the worst case scenario

for a dam operator.
Are there situations where the sediment actually blocks the orifice below, boulders came through or something happened that that actually fills up the orifice? What's the worst case scenario?
MR FAROOQ: Yes, I mean, sir, it's common, I think, with the orifice outlet, that it gets blocked due to the sedimentation. And if you don't operate or keep it closed for a longer period of time, the sediment tends to come near the mouth of the orifice, and when you need to operate the gate, so you need some maintenance before that. I mean, it is quite normal.
THE CHAIRMAN: Does --
MR FAROOQ: And yes, it is also an implication of having an orifice as well.
THE CHAIRMAN: And to deal with that, in terms of maintenance, is it a matter of trying to dredge out that material with the orifice closed, to unblock it, or do you have to drop the reservoir down entirely to get at the orifice? How do you deal with that problem?
MR FAROOQ: I think Mr Arfan Miana has come across such a situation at some dam location. I'm not very well aware of that. He may be in a good position to answer this question.
THE CHAIRMAN: That's fine. We can ask him when he comes

back. That's fine.
Any other questions?
DR BLACKMORE: I'm wondering -- if you go back to slide 12, please. I'm not sure it's slide 12, it might be 13, but ... Just go back to the one before that. Yes. Now go to 13, please.
So when you've got that orifice spillway at the bottom, I'm just wondering whether there is a relationship between the size of the orifice spillway, here (indicating), the gradient of the dam, the size of the orifice spillway obviously for the amount of flow you can get through it, for how far you can influence this sedimentation.
So I understand for relatively small orifices, this is what you're going to get. But you've taken a decision on this dam to have, you know, very large gates going down close to bed level, which I didn't see in the presentation, but ...
So my question is: isn't it a function of how big the orifice is, down here (indicating), and obviously that's the amount of flow, and that will change this bed profile back to something other than that? What do you think?
MR FAROOQ: Sir, with the little knowledge that I have, I can tell you that this placement or opening of the

outlet is mainly governed by the water level in the reservoir for sediment management. If you have a large outlet at the bottom, but you keep your water level high, it may not be that effective in a case when you have a comparatively small outlet and you vary your water level for the sediment management.
But as far as I understand, I mean, it is not that simple for me to have an idea about what should be the outlet size and what should be the reservoir level, what should be the optimum reservoir level for sediment management. I think it is a combination that depends upon the hydrology of the area, sedimentation and operational criteria, and that it may be simulated through the model to check what is the effectiveness over the period of time or duration of operation.
So in that case, it may be you can get a good idea whether a large outlet at the bottom would be effective or I need to squeeze its size or reduce its size, or where I should keep the water level in the reservoir.
DR BLACKMORE: So you model it?
MR FAROOQ: Yes.
THE CHAIRMAN: Okay. Thank you so much Mr Farooq.
Do I understand that Dr Abbas is back up for the next segment? Very good.
DR ABBAS: Mr Chairman, members of the Court of Arbitration,

I will now address the second challenge of sediment management: I mean to say high sediment concentrations specially sands, which cause abrasion damage, a loss in efficiency, which requires frequent repairs.
Slide 30.
Coarse sediment can cause catastrophic damage to all types of hydromechanical equipment, including what you see in this magnified image. In order to understand the scale of this image, the width of this image is about one fifth, okay? And in this one fifth you can see the impact of abrasion on the turbine runner.
The rate of abrasion on a turbine and other hydraulic equipment increases as the head increases. The larger the head, the higher the abrasion rate. For example, the rate of abrasion on a turbine operating at 800 metres of head will be much faster than a turbine operating at only 50 metres of head.
The rate of turbine abrasion also increases with the grain size. Sand particles are much more abrasive than smaller silt particles because sand has more momentum and strikes the runner blades with greater force. Sand particles larger than approximately 0.2 to 0.4 millimetres are specially damaging.
As I mentioned in my overview, Himalayan rivers carry a high content of sand compared to most other

rivers. This contains silica, a mineral that is much harder than steel. It will abrade turbines. And if the sand grains are angular, as you have seen through the magnifier, they are approximately twice as abrasive.

Turbine abrasion increases costs. Each Francis turbine runner [costs] between US$3-4 million to purchase a large runner. It can take several weeks to change out. Power generation efficiency also declines due to abrasion.

However, in some cases, repairs and acceptance of efficiency loss may be the most cost-effective approach as compared to other options. This is specially true for the areas of monsoon climate, where there is excess water available during summer months to offset the efficiency loss of the turbine due to defamation of abrasion.

Slide 31.

My colleague Mr Ayub Malik has shown you some intake designs in his presentation. In this snap, we have an example of a problematic design at Pakistan's Warsak Dam. This dam is on the Kabul River coming out of Afghanistan. The dam was built in 1960 and provided a deep intake with no effective way to manage sediment.

This snap shows the 14-metre-deep intake that is right now submerged under the sediment. And this

intake, you can see here that this is the pond level, or you can see the flood line in which this dam operates, and right now you are seeing the situation when the reservoir is drawn down. So this is what happens when you keep your intakes quite deep.

Slide 32. What you have seen in my last slide has been shown in detail here, in terms of elevations and depths.

The watermark I was showing you was this (indicating), and you were seeing in the last slide the top of this intake. And you have observed that up to this level, or you can say up to the spillway crest, all intake has been buried in the sediment.

At this plant, despite this abrasion problem, it has been possible to sustain planned power production by passing more water through the turbines during the monsoon, when most power is produced, to offset the loss in turbine efficiency due to abrasion. With regular repair circles of the turbine, this is another example showing that even with difficult sediment problems, there are solutions that make economic sense.

Mr Chairman, this is a good time to answer the Court's question no. 3, which is: what are the range of circumstances where it might be either beneficial or required to locate at a relatively low level the power

intake for the turbines of a run-of-river hydroelectric project on the Western Rivers of the Indus Basin?

In the context of a run-of-river headworks, let's discuss the requirement for, or benefit of, a deeper intake. We can list out four circumstances.

A lower-level intake can be beneficial to minimise the entry of floating debris.

The second circumstance is: for sediment control, placing the intake at a lower level will not be beneficial or required; in fact, it will be harmful, as it will increase coarse sediment ingress.

Number 3: beyond the minimum depth required to control vortex formation, additional lowering of the intake will not be beneficial.

Number 4: as far as cleaning and maintenance issues are concerned, the deeper intake will not be beneficial or required, due to the increased difficulty of removing debris trapped against the deeper intake trashracks, as you have seen here at Warsak in Pakistan.

Slide 33.

Mr Chairman, now I turn to adaptive strategies for dealings with sediments.

One strategy involves covering the turbine runner with a thin layer of abrasion-resistant material, such as tungsten carbide, an extremely hard ceramic. It may

be renewed every few years. These coatings can significantly retard, but not eliminate, abrasion damage.

In this photo, this has been taken at this project, Neelum-Jhelum Project, after four years' operation of the runner. You can see the situation here. You can compare the difference between the coated part of the wicket gate on the left -- you can see this is coated part, which remains smooth -- with the part on the right, where the coating has been removed by sediment abrasion and cavitation damage. Excessive abrasion can also cause the turbine to vibrate. Operation with a heavily damaged turbine runner can pose a safety risk as well.

In general, where an uncoated runner will require repair after one year, a coated runner may extend the repair cycle to around four years. Coating can therefore be an economical, long-lasting and effective strategy against abrasion.

Coatings will need to be reapplied every few years, at a cost of around US$0.5 million. It's not the ideal solution for all the projects.

Slide 34.

Now I come to my last point of this presentation: the sediment load on the turbines can also be minimised

by using a settling basin or a desander. As seen in the conceptual sketch, it consists of a tank constructed between the intake and the turbine, and designed to settle out and remove heavier particles from the water.
So the flow direction is from left to right. The heavier particles tend to settle at the start of this basin, along this way to the outlet, and the finer particles settle here (indicating).
This is the strategy that is employed at many plants worldwide, and we have used it also in Neelum-Jhelum Project. It ensures the turbine intake water is as free from sand as possible.
You can see on the slide, run-of-river plants without storage for sediment trapping will typically divert water from the river into sedimentation basin to trap larger sediment particles that are highly abrasive, and which also settle more rapidly.
Sedimentation basins can be constructed: (1) on the surface, as you have seen at the Neelum-Jhelum Project; or (2) as large underground tanks, when surface space is not available.
Slide 35. Mr Chairman, you have seen this desander while walking around along this direction.
So here in Neelum-Jhelum we have three chambers. The length of the desander is around 275 metres. The

width, or you can say the top surface, is around 25 metres. And the depth of these desanders varies from 20 metres to 23 metres. It has a slope of 1% along its length. So higher depths are there, as compared to lower depths here (indicating). A typical pattern of, you can say, a reservoir in which the coarser particles settle at upstream part and the finer particles go down.
THE CHAIRMAN: Can I ask -- I can understand why you would want two desanders, so that you can use one while you're flushing out the second one, but I'm not sure why you have three desanders. What's the advantage of having that third desander?
DR ABBAS: It's basically -- you can say the designers usually take care of redundancy in their design. So at one time, only one chamber will be evacuated. So the design is in a way that two of the chambers will be continuously supplying 280 cumecs of the flow required at the tunnel.
Slide 36.
As you can see from this graph, properly designed desanders can be very efficient at trapping sediments. The Neelum-Jhelum Project desander has been designed to trap essentially all sediments larger than 0.14 millimetres, which is the most problematic for turbine abrasion. Even the grain as small as

0.1 millimetre, the Neelum-Jhelum Project desander is designed to trap 89% of particles.
You can see here the sand particles which are being removed from the desander. From here onwards, or you can say from this jar (indicating) onwards, all the sediment particles are being excluded. So these finer fractions are going there.
Slide 37.
Mr Chairman, on behalf of Mr Farooq, I thank you, members of the Court, for your kind attention. If you have any questions.
DR BLACKMORE: Thank you for that. This is a left-field question.
So you are now recovering this sand material as a high-quality product. You've dropped it out. It's coarse, like it's granular. Do you sell it, or do you dump it in the river?
Just a question, because I know how much it costs to buy if you're in Australia.
MR ALAUDDIN: (Inaudible) ... downstream.
DR BLACKMORE: Okay.
THE CHAIRMAN: So it's placed back in the river?
DR BLACKMORE: It's a mining operation.
PROFESSOR BUYTAERT: Would you be able to go back to slide 31, the dam with the sediment problems. I didn't

get which dam is this. What's the location?
DR ABBAS: It's the Warsak Dam.
PROFESSOR BUYTAERT: Okay.
DR ABBAS: It's just close to the border with Afghanistan, coming from the western side.
PROFESSOR BUYTAERT: Okay, thank you.
I take it that this dam design doesn't have any deep orifices for drawdown flushing; is that right?
DR ABBAS: No.
PROFESSOR BUYTAERT: Would that, in this particular case, solve the problem of the sedimentation? Or the other way --
DR ABBAS: We are dealing with the sediment problem there.
PROFESSOR BUYTAERT: Do you know why they did not include deep orifices or drawdown flushing in this particular design?
DR ABBAS: It's a typical design issue, I can generally say.
PROFESSOR BUYTAERT: Okay. Yes.
DR ABBAS: It's a design problem.
PROFESSOR BUYTAERT: Okay, thank you.
THE CHAIRMAN: If I recall correctly, that one was built in 1960?
DR ABBAS: Yes.
THE CHAIRMAN: And therefore at an earlier stage, and perhaps you've gotten better at designing your dams.

So I had a leftover question that I think we decided Mr Miana might be able to answer it. So if we could go back to slide 13 here.

My question, Mr Miana, which we weren't entirely comfortable answering earlier without your expertise, my question was: when you have an orifice that you are using to try to flush the sediment, are there situations where something happens, a large boulder drops down into that area of the orifice or maybe even this delta collapses in some way, and you actually block up the orifice? Does that happen? I'm asking about the worst case scenario here.

MR MIANA: For the last two years I am here and I did not observe that phenomenon. And we have been operating these orifices for passing the flood in the monsoon season. I think before that it never happened.

MR ALAUDDIN: After T4 project?

MR MIANA: T4 project? Not this one, no.

THE CHAIRMAN: I was really just asking generally, in your knowledge of dams.

MR ALAUDDIN: (Inaudible, no microphone) has referred to this, that he had experience.

MR MIANA: T4 project ...

MR ALAUDDIN: (Inaudible, no microphone)

MR MIANA: No, no, no, that was not inlet, that was outlet.

MR ALAUDDIN: That was outlet? Okay.

MR MIANA: Yes, that was the outlet gate, and the gate stuck in the silt only. And we have to then, I mean, liquefy that silt and then take away the outside. We had no issue of the boulder, only sticking of the gate with the silt and the clay, that we have seen in the gates fine clay or whatever.

THE CHAIRMAN: So just generally speaking, you're not aware of situations where there's some sort of catastrophic collapse where the sediment ends up blocking entirely the orifice?

MR MIANA: No, never. The Tarbela, we never heard about this. I am working at Tarbela since 1992. My first posting was at Tarbela, and at different times of my professional life I have been posted there. So we never heard about the blockage of any of the tunnels from intake side.

THE CHAIRMAN: Do you have a sense, over time, what will happen at Tarbela if that delta keeps approaching the dam, what might be expected, or how you would try to avoid the sediment build-up from preventing the operation of the dam?

MR MIANA: Actually, at present, with the project of Tarbela 4, we have already raised the intakes of Tarbela 3 and Tarbela 4. Tarbela 1 and 2 already have

raised that 1,225 feet above sea level, and now it has been raised to, if I remember, 1,300-something over there, at the level of this one. So all of the intakes has been raised, just to avoid the ingress of that one.

DR BLACKMORE: But eventually you've got a dam that's full of sediment that's going to continue to build sediment up, so at some stage you've got to be able to pass it or manage it. Because I think that sort of sediment going through the tunnel at Tarbela and the turbines would be potentially very bad.

MR MIANA: I think they are just managing with increasing the minimum operating level just to avoid that.

DR BLACKMORE: To buy time?

MR MIANA: For the time being.

THE CHAIRMAN: Very good. Okay, I think that's it for ... (Pause)

MR MINEAR: First of all, I'd like to thank all the presenters for the very informative information you've conveyed. It's all been very helpful.

I'd like to revisit an issue that I think Mr Farooq raised, and that was the discussion of optimal pondage and how to calculate that. And I'd just like to have some additional clarification on that, if I could.

Let's assume a situation where we don't have any legal or regulatory limits on the determination of

pondage. I understand from your presentation that the determination of pondage is just one variable in the overall design, and it's a function of the power demand, the height of the dam, the discharge into the reservoir. And it is calculated in the course of the -- at least in the engineering study and perhaps before then.

Is that all basically correct?

MR FAROOQ: Will you please repeat your question?

MR MINEAR: Sure. I'd just like to have a discussion with you about determining optimal pondage in a situation where it's determined primarily as a matter of the efficiency or the economic viability of the dam.

I understood -- I just want to make sure I understood what you said -- that that determination is made on the basis of your power demand, the discharge into the reservoir, the height of the reservoir, perhaps the head as well, and so it is just a dependent variable of these other factors. Is that basically correct?

MR FAROOQ: Yes, it could be. I mean, it depends on one or more factors. But the most important factor for determine of the pondage is the flows in the winter.

MR MINEAR: Yes. So the minimum mean flow, roughly, in the winter.

MR FAROOQ: I mean at least you have some flow in a day that you can fill the storage at part of the day and use it

for remaining part of the day.
MR MINEAR: Okay, so let's take a concrete situation, and I think NJHEP might be a good example.
I believe you said you require 283 cubic metres per second of flow to optimise the design of the turbine, to get maximum power from the turbines. Is that correct?
MR FAROOQ: I wouldn't like -- I may ask if you repeat this question once again, please.
MR MINEAR: Yes. We talked about the design flow that was necessary for the maximum discharge from the turbines, and I think you said that was 283 cubic metres per second; is that right?
MR FAROOQ: 280.
MR MINEAR: 280, okay. And I think you said that the inflow in the winter into the reservoir was 53 cubic metres per second?
MR FAROOQ: Sir, 53 is, you can say, the prevalent flows for the winter season, which I am referring from November to February.
MR MINEAR: Yes.
MR FAROOQ: Yes.
MR MINEAR: Okay. So then to determine the pondage, what you want to do is determine the amount of pondage that's necessary to provide that maximum turbine energy production over a period of time, realising you're going

to have to shut down the turbines, let the pondage build up, and that would be the level of the operating pool that you're basically trying to build. Is that right?
MR FAROOQ: Yes. For Neelum-Jhelum Hydroelectric Project, it is the case, for example, you have the prevalent flow of 53 cumecs for the winter season. And with this, you store water for part of the day, say for 20 hours; and then with the 20 hours of storage, you would be able to generate 4 hours of peak energy at the Neelum-Jhelum Hydroelectric Project by operating it at the discharge of 280 cubic metres per second.
MR MINEAR: Yes. But in making that determination then, you'll have to, in the design phase of building the project, you need to know what the power output you are seeking to have, right?
MR FAROOQ: Yes.
MR MINEAR: You need to know what the flow is into the reservoir?
MR FAROOQ: Yes.
THE CHAIRMAN: Are there other factors that come into play here? Like the possible height of the reservoir, does that make any difference? Is that a limiting factor?
MR FAROOQ: Sir, for determination of pondage, I mean, it is basically a combination of all.
You can say that first you determine -- as far as

I know, or on the basis of knowledge that I have, first the hydropower potential at a site is determined by the overall hydrology at the dam site. For example, you don't pick or choose one month and ignore the other months; you try to base on the hydrology over the 365 days in a year. And based on the long-term hydrology, first you determine that: yes, this is the hydropower potential at site which I can use optimally where my cost is comparatively less and my benefits are relatively high.
Once you have determined the hydropower potential at a site, then on the basis of -- now, for example, in the case of Neelum-Jhelum Hydroelectric Project, 969 MW is the optimum installed capacity at my plant. And in view of the -- now, here comes second part: that, yes, I am going to make a 969 MW [plant] at this location. But I have winter flows, because it is a run-of-river hydroelectric project.
And then you see: what are my winter flows, or the prevalent winter flows. And based on the prevalent winter flows, then -- I mean, if I can, for example, 20 hours of the day, I can store only 4 million cubic metre of water, there is no sense to provide 6 million cubic metres, or maybe 8 or maybe 10, because I am not going to use that, and this would be redundant

for me. And to create that high storage, I would be putting in more money with no additional benefit.
MR MINEAR: Yes, okay. This is all very helpful for me.
Can I ask: when in the design process would the determination of the pondage be determined?
MR FAROOQ: Sir, as far as I know, it is basically a collective process, when you put in multiple criteria, into it the decision metrics, and then you can come up with: yes, these are the numbers which are -- on the basis of this criteria, this criteria and this criteria, this is the overall optimal picture or optimal project features that I can put into implementation.
MR MINEAR: I see.
Now, in presentation no. 2 by Dr Hayat, he described the various steps from concept and feasibility and engineering. Where in that cascade do you think pondage would be determined?
MR FAROOQ: I think it should be determined at the pre-feasibility or feasibility stage.
MR MINEAR: Okay.
MR FAROOQ: Yes.
MR MINEAR: Okay. And this of course is assuming this is all just being done on an economic basis as well.
MR FAROOQ: Yes.
MR MINEAR: There's no other constraints that might come-

into play.
MR FAROOQ: Yes. Because at feasibility stage, the economics of the project is established and then you move ahead. So at least by the feasibility stage, I think the operational pool volume should be determined.
MR MINEAR: Okay. Thank you very much. This is all very helpful for me.
MR FAROOQ: Thank you, sir.
PROFESSOR BUYTAERT: Can I ask a quick follow-up question. So during the dry season, when there's not enough water to operate the turbines at full power for 24 hours, you said that you reduce the time you operate them. But do you always operate them at maximum capacity and reduce the time, or does it also happen that you reduce the power outputs for longer periods? Can you, for example, run them 4 hours at full capacity or, say, 8 hours at 50%? Do you vary both? Or is it always full power for whatever period of time you can afford, given the inflows?
MR FAROOQ: Sir, I would say that it is basically choice of the operator. For example, if I have not enough flow in my operating pool, then I may decide whether I would like to operate the four turbines for, say, 1 hour, or maybe I would like to operate two turbines for the

2 hours, or maybe 1.5 hour, or maybe some more time. So it is, I mean, choice of the operator.
PROFESSOR BUYTAERT: Okay, thank you.
MR MINEAR: As a follow-up to our engineer's question here, does the factor of peak demand enter into that determination; in other words, the electricity demand at any given time, when the turbine is at full or half speed?
MR FAROOQ: Sir, yes, I would say that the operators -- I mean, the operation is controlled here in Pakistan, I think, through NPCC, basically, which is controlling what and where is being produced and how it is being transported in other part of the country.
MR MINEAR: Thank you very much.
THE CHAIRMAN: So thank you very much, Dr Abbas. Thank you very much, Mr Farooq. I don't think we have any other questions on this presentation.
What I would propose is that we perhaps take a break now and allow the Court to just check in with itself to see if we have any further general questions. I don't know if now is a good time to have tea or coffee as well.
MR MIANA: It is ready.
THE CHAIRMAN: Perfect. Then why don't we have a break of, say, about 15 minutes or so, and then we'll come back in

to finish up.
(A short break)
THE CHAIRMAN: Okay. So we have met among ourselves and decided we have no additional questions for you today, because we asked many questions over the course of the day and your group was very responsive. I'm directing my comments to Mr Miana just because he seems to be the boss at the dam.
So we don't have any follow-on questions. I do want to say a few things though before we finish up for the day.
First of all, I want to thank you deeply, Mr Miana, for hosting us here at the dam these past few days. I envisage this as your home, and you've welcomed us into your home and done a wonderful job of helping us understand how the dam works and aspects beyond the dam, the way dams, generally speaking, in this region work. The Court knows you're very busy, others who are here today are very busy, and we appreciate the time you've taken to be with us and help us work our way through these issues.
We appreciate the excellent hand-on materials that we had, whether it be the sediments or the rocks. I'm glad you didn't bring a boulder into the room! But it helped bring alive the issues that we're interested in,

so thank you for that.
Particularly thank you for answering the questions that the Court asked in advance of this site visit. We did have some issues that we weren't sure if you were going to address them in the course of the presentations, and we just wanted to be sure that you thought about them and reflected on them and had the opportunity to give us some of your guidance on that.
So thank you for all of that. Thank you as well for the tea, the coffee, the food. You took good care of us while we were here. You not just walked us around the site once, but a second time as well, and we're very grateful for that.
One point just to be noted, and this may be more for the external counsel team. Several presenters had numbers they were saying in the course of their presentations, which may not have been caught completely at the audio, we don't know. But at the point when you're checking the transcript, we'd be very grateful if we could be sure that we have accuracy of the basic numbers and other details of that sort that were provided to us.
Beyond that, I take it we will see many of you tomorrow at the power station. We're looking very much forward to that visit. If there are any that we aren't

going to be seeing there tomorrow, let me just say thanks on behalf of the Court now for you. But we look forward to that visit, and expect a few more questions tomorrow from us.

Okay? Very good. Thank you so much.

(The day concluded)