

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

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CERTIFIED TRANSCRIPT  
(SITE VISIT)

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COURT OF ARBITRATION:

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

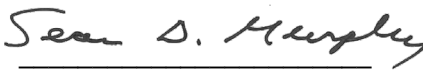
SECRETARIAT:

The Permanent Court of Arbitration

ON BEHALF OF THE COURT OF  
ARBITRATION:

CERTIFIED PURSUANT  
TO  
PARAGRAPH 19 OF ANNEXURE G

26 April 2024

  
\_\_\_\_\_  
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  
Site Visit

Friday, 26th April 2024

Before:

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

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BETWEEN:

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

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Transcript produced by Trevor McGowan, Lisa Gulland  
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1 Friday, 26 April 2024  
 2 THE CHAIRMAN: Okay, let me start for us, if I can, just by  
 3 noting that we're continuing our visit here at the dam  
 4 and we're looking forward to two different presentations  
 5 today. As I understand it, we will have the first  
 6 presentation this morning, largely. If we need to spill  
 7 over to the afternoon, that's fine too. But this will  
 8 be presentation 5. And we will go until roughly 12.50  
 9 this morning.  
 10 Then we had a glitch yesterday in our videography of  
 11 the walk around, where we had video throughout, but  
 12 we lost the audio for about ten minutes. It was at the  
 13 point where we were looking at the spillway. So what  
 14 I'd like to do is have us, around 12.50/1.00, go back to  
 15 the spillway and, Mr Miana, if you could just explain  
 16 what we were looking at there, that would be very  
 17 helpful, so we capture that on the audio of the video.  
 18 Then we'll finish that around 1.30 or so. We could  
 19 have our lunch break at that time and then resume in the  
 20 afternoon. If we haven't finished the presentation  
 21 we're about to embark on, presentation 5, we can finish  
 22 that off in the afternoon and then move on to  
 23 presentation 6, if that's agreeable. Okay? Good.  
 24 Alright. I think with that said, Mr Alauddin, it's  
 25 over to you.

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1 MR ALAUDDIN: Thank you, Mr Chairman.  
 2 Presentation 5: Run-of-river hydroelectric plant basics  
 3 MR ALAUDDIN: Mr Chairman, members of the Court of  
 4 Arbitration, I think there is no need of my  
 5 introduction, as you are already familiar with me, and  
 6 now you will have to bear me again for ...!  
 7 THE CHAIRMAN: We look forward to it.  
 8 MR ALAUDDIN: Thank you very much.  
 9 In this presentation with me is Mr Umar Farooq,  
 10 senior engineer at NESPAK, whom you know from the  
 11 previous session. We are also joined by Dr Yasir Abbas,  
 12 chief engineer at NESPAK.  
 13 The presentation we are about to give is the first  
 14 of two concerning what might be called run-of-river HEP  
 15 basics. Why this is necessary, a summary of key issues:  
 16 it attempts to give you an overview of how  
 17 a run-of-river HEP functions in the Himalayas. In this  
 18 sense, it restates and builds on some of the material  
 19 introduced in earlier presentations, particularly  
 20 presentation 2, on HEP design, construction and  
 21 operation.  
 22 This part of the presentation addresses what might  
 23 probably be called flood and storage issues at  
 24 a run-of-river HEP headworks. The second part, which  
 25 follows directly after this presentation as

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1 presentation 6, deals with sedimentation issues at the  
 2 same.  
 3 Before I turn to the issue, I recall also what you  
 4 heard yesterday: that we will endeavour to address the  
 5 Court's five questions in the course of these  
 6 two presentations.  
 7 Slide 2, please.  
 8 With that in mind, we propose to proceed as follows.  
 9 First, I will provide an overview of a run-of-river  
 10 HEP headworks. In so doing, I will revisit and  
 11 reinforce some familiar concepts, but situate them  
 12 within the design of the NJHEP.  
 13 Second, Mr Farooq will address you on HEP storage  
 14 issues and the role of live and dead storage in our HEP  
 15 reservoir.  
 16 Third, Dr Abbas will address you on HEP spillways  
 17 and freeboard, being this element of the headworks that  
 18 plays the most material role in flood control.  
 19 Slide number 3, please.  
 20 Now, with this, I start with the first topic: that  
 21 is the headworks. You have already seen in detail the  
 22 different components of our headworks. I shall just  
 23 repeat important components of the headworks.  
 24 Again, you see this is our dam. And on the upstream  
 25 side is the River Neelum, coming from the line of

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1 control. And now this is our reservoir. This is our  
 2 dam. The length of it is 250 metres from this end to  
 3 this end (indicating). There are our six intake gates,  
 4 and this is our spillways. This you can see is  
 5 basically a gantry crane. This is the debris flow  
 6 channel and this is our rockfill dam.  
 7 You can also see this desander. The length of  
 8 desander is 275 metres. And then you can see this  
 9 collecting canal. We have already been there, you have  
 10 seen that. From the collecting canal, water goes into  
 11 a 28-kilometre tunnel, and then eventually goes into our  
 12 power station, where, through four (indistinct), we  
 13 generate 9 MW of electricity.  
 14 Slide 4, please.  
 15 Now, this is basically the drawing of the same  
 16 photograph and slightly rotated. And the purpose is to  
 17 brief you or inform you about further detail in this.  
 18 You see this blue line showing the water flows.  
 19 Starting from here, we have a collecting canal. We  
 20 have -- sorry. First, this yellow strip is basically  
 21 the headworks, total headworks. Length from here to  
 22 here (indicating) is 88 metres. Then we have spillways  
 23 here. In Neelum-Jhelum there is orifice spillways. And  
 24 with that is attached -- this is another structure here,  
 25 which is our debris channel. This is also sort of

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1 a spillway, but it is a crest-gated spillway. So we  
 2 have a combination of orifice spillways and crest-gated  
 3 spillways.  
 4 As regards the sizes, you were already informed on  
 5 the site that the size of each spillway is 12 metres,  
 6 width is 12 metres and its height is 15 metres.  
 7 Regarding the sizes of the debris channel, the sizes of  
 8 the gates are: its height is 8 metres and width is  
 9 9 metres.  
 10 At the left side, the extreme left side, is our  
 11 rockfill dam. You see, you are seeing this line here  
 12 (indicating) in the briefing on geology of area. It has  
 13 already been informed to you that a number of fault  
 14 lines are there in this area. One is main boundary  
 15 thrust, which we call it "MBT". You see MBT is passing  
 16 here, this area. This is at the right side of -- almost  
 17 at the right side or right bank, near the right bank.  
 18 At this place, you see the -- let me tell you the  
 19 original design of the headworks was a concrete gravity  
 20 dam. But as a result of 2005, investigative --  
 21 extensive studies were carried out about the seismic  
 22 parameters on this fault line. So when it was  
 23 identified that concrete gravity dam will not be  
 24 suitable for this location, so the designer then  
 25 selected that this part should be constructed as

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1 rockfill dam. So this 65 metres, this is the rockfill  
 2 dam. We have a hybrid structure: it is a composite  
 3 concrete gravity and a rockfill dam.  
 4 Slide 5, please.  
 5 As I already mentioned, we have a hybrid structure.  
 6 Now, above the dam, for a run-of-river HEP, the dam is  
 7 usually situated in a valley, allowing a narrow  
 8 reservoir to fill behind it. This creates head for  
 9 power generation.  
 10 Second, the dam structure is very depending on  
 11 location. The three major types are earthen, concrete  
 12 and rock-filled dam. NJHEP is a hybrid: the main dam is  
 13 concrete, with a rock-filled section, straddling  
 14 a geological fault, the main boundary thrust.  
 15 You see now this is the cross-section of the  
 16 rockfill dam. As far as the important parts are  
 17 concerned, you see it has a central clay core. Over  
 18 that, there is a layer of fine filter and coarse filter,  
 19 then it's rockfill, and then it's a grouted riprap here.  
 20 This is the upstream side. And here also the same: fine  
 21 filter, coarse filter, rockfill, and then riprap of  
 22 1 metre.  
 23 So this is basically core, clay core.  
 24 DR BLACKMORE: Sorry, just -- the side slopes, are they 2:1?  
 25 So I'm reading that correctly? The slope is 2:1?

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1 MR ALAUDDIN: Yes.  
 2 DR BLACKMORE: Okay. I want to come back to the foundations  
 3 when you've moved through a little bit, if that's okay,  
 4 sir. I want to ask questions about the foundations  
 5 here.  
 6 MR ALAUDDIN: Yes, about the foundation, yes.  
 7 About the foundation, you see it's a plain concrete  
 8 bed here. And underneath, a grout curtain has been  
 9 provided, up to 25 metres depth; or in certain cases  
 10 where there was no sandstone, further deeper grouting  
 11 was done. So a minimum 25-metre curtain grouting has  
 12 been provided. This is not only here, but throughout  
 13 the -- along the dam itself.  
 14 DR BLACKMORE: So there is only one -- so I'm assuming that  
 15 the grout line is this way (indicating), across the dam,  
 16 and you don't have two grout lines, you just have one,  
 17 one grout line 25 metres deep?  
 18 MR ALAUDDIN: Yes.  
 19 DR BLACKMORE: Okay. Like, very standard --  
 20 MR ALAUDDIN: Yes, this is quite a standard practice.  
 21 DR BLACKMORE: So my only question is that you've now put  
 22 a flexible dam --  
 23 MR ALAUDDIN: Yes.  
 24 DR BLACKMORE: -- on top of a very rigid foundation with  
 25 a fault line. So if the fault line moves, I think the

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1 dam is okay; I just wonder about the grout curtain.  
 2 Have people thought about whether the grout curtain will  
 3 be stable?  
 4 MR ALAUDDIN: You see, there may be some movement. But the  
 5 main concern is that -- you see it's quite deeper here,  
 6 deeper here and extensive grouting has been done. But  
 7 you see, the geological consideration is that seismic  
 8 movement under the ground seems to be less serious as  
 9 compared to on the top.  
 10 But as far as your question is concerned, let me  
 11 consult, let me deliberate further, then I shall revert  
 12 to you.  
 13 DR BLACKMORE: It's not a concern; I'm just trying to  
 14 understand. Because if you're going to have a flexible  
 15 dam on a rigid base, but the rigid base is on a fault  
 16 line, it does raise engineering questions about what you  
 17 could do if you do have the bad -- if we do have the  
 18 inevitable, which is some movement on that fault line,  
 19 how do we make sure the integrity of that core remains.  
 20 That's all.  
 21 MR ALAUDDIN: Right. So you have already mentioned that  
 22 this is a flexible structure, and (indistinct) has  
 23 a plastic behaviour and self-healing characteristics.  
 24 So you see that's how we have constructed this line.  
 25 There was some minor drop of seismic event, and we

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

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

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1 nervous about it.  
 2 MR ALAUDDIN: I understand.  
 3 Slide 6.  
 4 Now coming to the spillways. Spillway is considered  
 5 another important structure of a headwork. Spillway is  
 6 the principal structure by which water is passed through  
 7 the dam, particularly in times of flood. It may also  
 8 have other application, like sediment management.  
 9 Multiple spillways structures may be included in the  
 10 same dam. You usually include a structure to prevent  
 11 erosion in the riverbed and the foot of the dam.  
 12 Now, this photograph is the spillway of Tarbela Dam  
 13 project. Tarbela Dam is one of the biggest rockfill  
 14 dams, having a generation capacity of about  
 15 4,800-4,900 MW and a storage capacity of 442 million  
 16 cubic metres.  
 17 You see, as already mentioned, there could be two or  
 18 three types of spillways in one intake section on a dam.  
 19 Here is a crest-gated spillway. This is the crest-gated  
 20 spillway. We have the crest-gated spillway like this.  
 21 So spillway is considered an important component. There  
 22 will be further briefing on types of spillways and on  
 23 the sedimentation storage in the presentation nos. 5  
 24 and 6.  
 25 [Slide] 7, please.

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1 4 metres from here to here (indicating), about 4 metres.  
 2 So the sluicing is regularly carried out to avoid any  
 3 sediment deposition under this intake structure.  
 4 Through the intake structure, water goes into our  
 5 desander area. The design of the intake as well as the  
 6 desander in Neelum-Jhelum Project seem to be quite  
 7 effective, and this is obvious from the condition of the  
 8 reservoir, which we inspect [from] time to time. And  
 9 even after running of five years, the condition of the  
 10 turbine is very good, exceptionally good. So it means  
 11 the effectiveness of our desander structure and design.  
 12 DR BLACKMORE: I'm just wondering -- I like the design, by  
 13 the way. I like the design --  
 14 MR ALAUDDIN: Thank you.  
 15 DR BLACKMORE: -- for passing sediment. I'm just wondering  
 16 about the erosion of the concrete chutes where the gates  
 17 are, because you've got different-level outlets passing  
 18 different amounts of sediment. And I'm just wondering  
 19 whether there's any issue around erosion of concrete in  
 20 those chutes or whether there was any special treatment  
 21 to strengthen the concrete in those areas.  
 22 MR ALAUDDIN: That is a high-strength concrete, and we  
 23 [from] time to time monitor the chutes that you  
 24 mentioned. So far, they are found to be in good  
 25 condition, except some issues on the ogee, ogee of the

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

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

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

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

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

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1 producing baseload power. By this, we mean the delivery  
 2 of power on a constant basis over a 24-hour period.  
 3 Second, here, at the other end of the spectrum, we  
 4 have a run-of-river HEP with no storage, which is  
 5 effectively a turbine placed in the river or  
 6 an adjoining canal. As noted, such HEP will entirely be  
 7 dependent on the natural flow of water, and suffers  
 8 somewhat in the dry season as a consequence.  
 9 These plants tend to be on the smaller side, such as  
 10 13.5 MW Shadiwal hydroelectric project, at the tail of  
 11 Upper Jhelum Canal in Punjab, or 84 MW New Bong Escape  
 12 project, downstream of Mangla Dam. Such plants are also  
 13 used for baseload power, running constantly.  
 14 Third, here, we have the category of HEP with which  
 15 we are concerned: the run-of-river HEP with storage.  
 16 This HEP has capacity to store water, and so in the dry  
 17 season can be peaked, storing water for part of the day  
 18 and then releasing it during periods of peak demand in  
 19 a given 24-hour period. During the wet season, when  
 20 water is plentiful, the HEP can provide baseload power.  
 21 There are other ways of defining categories of HEPs.  
 22 Another dividing line is the difference between an HEP  
 23 that creates generating head with a high dam and a short  
 24 tunnel, and an HEP that creates generating head with  
 25 a low dam and a long tunnel.

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1 THE CHAIRMAN: Whenever you're ready, Mr Farooq.  
 2 MR FAROOQ: Mr Chairman and members of the Court, I will be  
 3 addressing you on storage issues arising from  
 4 a run-of-river HEP's reservoir.  
 5 Slide number 10. The starting point is to explain  
 6 the role that storage plays in an HEP in the Himalayas.  
 7 Where an HEP is reliant solely on the natural flow  
 8 of the river, there will typically be a significant drop  
 9 in power production during the dry season, when the lack  
 10 of snow and glacial melt causes the water to drop  
 11 significantly. If an HEP includes a water storage  
 12 component, however, this will be able to supplement the  
 13 flow of the river in order to maintain or increase power  
 14 production.  
 15 We can therefore divide HEPs into categories based  
 16 on how much storage they have.  
 17 First, here, there are HEPs attached to storage  
 18 reservoirs capable of storing months or even years'  
 19 worth of water.  
 20 The guaranteed availability of massive storage means  
 21 that these HEPs can have a very large installed  
 22 capacity, such as Tarbela hydroelectric project, which  
 23 is currently 4,888 MW and projected to increase to  
 24 6,418 MW when the plant Tarbela 5 Extension comes  
 25 online. They can also be run for long periods,

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1 Slide 11. On this slide we see a diagram showing  
 2 how storage in a run-of-river HEP reservoir works. I am  
 3 going to use it to introduce some key generic storage  
 4 concepts: most importantly, the notion of "live" and  
 5 "dead" storage. I note that there are some  
 6 circumstances where these ideas are given a special  
 7 meaning. I use them here only in the generic sense.  
 8 On the diagram is a concrete gravity dam with  
 9 a crest-gated spillway, here (indicating), and the  
 10 reservoir to the right, with water levels shown.  
 11 The two most important water levels for present  
 12 purposes are the full pond level and the minimum  
 13 operating level. The space in the reservoir between  
 14 these two levels here is known as "operating pool".  
 15 The operating pool is used for storage of pondage,  
 16 being the water that can be used to improve HEP's power  
 17 generation in times of low flow. As such, the operating  
 18 pool forms HEP's live storage.  
 19 Above the operating pool is HEP's flood surcharge,  
 20 as you can see between the solid blue line and the  
 21 dotted blue line, which is used for the temporary  
 22 storage of floodwater that exceeds the full pondage  
 23 level.  
 24 The type of storage that is in the reservoir below  
 25 the operating pool is defined by the invert of the

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1 lowest outlet, which in this case is the spillway crest,  
 2 as you can see here. Any water below that point is  
 3 beyond the control of HEP operator, as it cannot be  
 4 released from the reservoir through intakes, spillways  
 5 or any other outlet. It is trapped in place and cannot  
 6 be used, and so is referred to as "dead storage".  
 7 Anything above the level of the dead storage is  
 8 capable of being manipulated by the operator. In this  
 9 sense, it can be released from the reservoir, and so  
 10 forms part of what is called the HEP's "controllable  
 11 storage".  
 12 Depending on the location of intakes in HEP,  
 13 controllable storage could also be potentially used for  
 14 power generation, and so may also form part of HEP's  
 15 live storage. All depends on the configuration of  
 16 a particular reservoir.  
 17 Slide 12. We can see an example of this in the  
 18 image on the slide, which is the longitudinal view or  
 19 "L-section" of NJHEP's reservoir. The scale is  
 20 distorted, with the true length of the reservoir being  
 21 much greater than its depth. The dam wall is  
 22 represented by Y-axis here (indicating), with the X-axis  
 23 representing the distance from the dam wall here.  
 24 As can be seen from the Y-axis, the dam extends from  
 25 just over the 972 metres above the main sea level to the

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1 1,019 metres here. So 47 metres is the height of the  
 2 dam. The reservoir [runs] through the valley up  
 3 4.8 kilometres from the dam wall.  
 4 The solid red line, this one (indicating), tracks  
 5 the level of the riverbed throughout the reservoir,  
 6 sloping progressively upward, with the three dotted  
 7 lines reflecting various levels of the reservoir. The  
 8 blue dotted line, at 1,018 metres, is the high flood  
 9 level, which reflects the uppermost limit of the flood  
 10 surcharge.  
 11 The green dotted line is at 1,015 metres, this one  
 12 (indicating). It is the full pondage level, reflecting  
 13 the top of the operating pool. And the red dotted line,  
 14 this one (indicating), at 1,008 metres, is the minimum  
 15 operating level, reflecting the level just above the  
 16 intakes.  
 17 THE CHAIRMAN: Can I ask a question on this? And maybe it  
 18 helps to go back to the prior slide (11) for just  
 19 a moment. But the minimum operating level is not all  
 20 the way down at the spillway crest, the bottom of the  
 21 spillway. And so my question is: what is the reason why  
 22 you can't have a minimum operating level all the way  
 23 down at the bottom of the spillway?  
 24 MR FAROOQ: Yes. Mr Chairman, as we have some structures to  
 25 be placed and designed below the minimum drawdown

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1 level -- for example, intakes, the desanders -- and if  
 2 we go down below the -- or near to the bed, we need  
 3 a lot more excavation for the placement of those  
 4 structures as well. And we also [need] to provide some  
 5 allowance for settling of the sediment. So that is why  
 6 we cannot draw down the level to its minimum or near to  
 7 the bed, in view of these considerations.  
 8 THE CHAIRMAN: No, I understand that it technically is  
 9 difficult and expensive to go further down. But maybe  
 10 I just didn't understand the answer: why can't the  
 11 minimum operating level be lower than where it's located  
 12 here? Why can't you use the pondage all the way down to  
 13 the point where you can no longer control it?  
 14 MR FAROOQ: Okay, I'll try again to explain.  
 15 THE CHAIRMAN: I'm sorry I didn't follow.  
 16 MR FAROOQ: No, it's okay. As you go down, you can see  
 17 here, your minimum operating level at the moment is here  
 18 (indicating). And you go all the way down, say, at this  
 19 level, yes?  
 20 THE CHAIRMAN: Well, I understand why you couldn't do that,  
 21 because you can't operate below the bottom of the  
 22 spillway. But why is it you can't go at least down to  
 23 the bottom of the spillway?  
 24 MR FAROOQ: Because as you go down, you have to place your  
 25 intake below the minimum drawdown level, say here

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1 (indicating). Or if you go down below that, then you  
 2 have to place your intakes more low.  
 3 THE CHAIRMAN: I see, okay.  
 4 MR FAROOQ: So in view of these considerations, you will be  
 5 requiring more excavation and placement of the  
 6 desanders, that it will include more cost for placing  
 7 those structures in terms of excavation. So these are  
 8 the considerations.  
 9 THE CHAIRMAN: So is another way to understand this: the  
 10 intakes are going to be at the level between the minimum  
 11 operating level and the spillway crest, in order to have  
 12 the -- or lower, in order to go into the intake?  
 13 MR FAROOQ: Maybe. But in all the cases, it will be below  
 14 the minimum operating level.  
 15 THE CHAIRMAN: Yes, okay, I understand. Thank you.  
 16 DR BLACKMORE: Just so that I'm clear now, I understood the  
 17 answer to all of that, but wouldn't one of the  
 18 controlling issues be the amount of money you're going  
 19 to make by generating power? So if you were to drop the  
 20 minimum operating level by 20 metres, say, or 15 metres,  
 21 you would reduce your potential power by a huge amount,  
 22 and at huge cost.  
 23 MR FAROOQ: Yes.  
 24 DR BLACKMORE: So it's a combination of the location of the  
 25 power station, and height and depth. I think -- I'm

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

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1 the design flood is happening.  
 2 PROFESSOR BUYTAERT: Okay, thank you.  
 3 THE CHAIRMAN: Good. Thank you. Continue, please.  
 4 MR FAROOQ: From this, it follows that the space between the  
 5 red and the green dotted line is NJHEP's operating pool,  
 6 constituting pondage. Given its height in the  
 7 reservoir, the operating pool stretches between  
 8 3.8 kilometres to 4.4 kilometres from the reservoir,  
 9 a considerable quantity of water. Were the minimum  
 10 operating level to be reduced even fractionally, or be  
 11 raised above full pond level, it would result in  
 12 a considerable increase in the amount of pondage  
 13 available to the NJHEP operator.  
 14 This is an opportune time to answer the Court's  
 15 question no. 4, which is as follows: what are the  
 16 different methods that might be employed for determining  
 17 the optimal pondage at a run-of-river HEP, such as  
 18 pondage intended to be of a magnitude to meet  
 19 fluctuation in the discharge of the turbines, or pondage  
 20 intended to be in a relationship to the minimum mean  
 21 discharge at a site of a plant? How are such  
 22 calculations performed?  
 23 The short point is this: there is no fixed method  
 24 for calculating pondage. The provision of pondage, and  
 25 as you will see in presentation 6, ensuring it remains

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

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1 Secondly, variability in flow of the watercourse;  
 2 for example, due to upstream regulation or seasonal  
 3 variations.  
 4 And third, the assigned target, duration and flow  
 5 rate when the plant is taking out daily peaking  
 6 operations. Both of these depend on the inflow  
 7 hydrology and the financial model of the anticipated  
 8 market.  
 9 As I said before, it will be hard to say that there  
 10 exists a single, universally accepted customary method  
 11 for pondage calculation. But as an illustration, from  
 12 a practical standpoint I would like to refer to NJHEP.  
 13 As you have noted in previous sessions, the NJHEP  
 14 incorporates pondage of 3.8 million cubic metres in its  
 15 operating pool, which is believed to cater for 4 hours  
 16 peaking in a typical winter day. In other words, the  
 17 pondage volume of 3.8 million cubic metres at NJHEP is  
 18 considered optimal to run its all four turbines at full  
 19 capacity by supplying required discharge of  
 20 280 cubic metres per second for 4 hours continuously in  
 21 a given winter day.  
 22 It is intriguing to learn that, how a typical winter  
 23 day flow is comparable with the 280 cubic metres  
 24 per second -- maximum discharge required to run all four  
 25 turbines of NJHEP at full capacity and generating

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1 969 MW.  
 2 In this regard, Mr Chairman and members of the  
 3 Court, the stream flow records suggest that the months  
 4 from November to February define winter or dry season  
 5 for Neelum River. During these months, the discharge in  
 6 the river averages around 53 cubic metres per second.  
 7 For ease of reference, I may refer the 53 cubic metres  
 8 per second discharge of Neelum River at NJHEP Dam site  
 9 as prevalent winter season river flow. It is just 19%  
 10 of the 280 cubic metres per second -- the maximum  
 11 discharge required to run all four turbines of NJHEP at  
 12 full capacity.  
 13 DR BLACKMORE: So in the low flow period that we're talking  
 14 about, you would just use the dam for peaking power? So  
 15 when you've got 53 cubic metres per second, and then  
 16 you've got an amount you need to pass down for  
 17 compensation flow or whatever -- I'm not sure how much  
 18 that is -- how much water are you required ...?  
 19 MR FAROOQ: 20 cumecs.  
 20 DR BLACKMORE: So you've got 33?  
 21 MR FAROOQ: No. I mean, it is --  
 22 DR BLACKMORE: Net. 53 net?  
 23 MR FAROOQ: 53, I am quoting in view of the pondage volume.  
 24 DR BLACKMORE: Yes.  
 25 MR FAROOQ: But the preference is to release 20 cumecs of

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1 water downstream of the dam in terms of eflows  
 2 [environmental flows]. The first preference is for the  
 3 eflows.  
 4 DR BLACKMORE: Yes.  
 5 MR FAROOQ: So you can refer to that. For example, you can  
 6 increase this 53 to 73 in a case when we are required to  
 7 meet the 20 cumecs of eflow first.  
 8 DR BLACKMORE: So under what conditions don't you have to  
 9 meet the environmental flow? When would you go below  
 10 20 cubic metres per second --  
 11 MR FAROOQ: If we go below 20 cubic metres per second,  
 12 whatever we are getting we will be releasing downstream  
 13 of the dam.  
 14 DR BLACKMORE: Okay.  
 15 PROFESSOR BUYTAERT: Just as a quick clarification, you  
 16 mentioned that 53 cubic metres a second is a prevalent  
 17 winter season flow. Is that inflow in the reservoir?  
 18 MR FAROOQ: Yes.  
 19 PROFESSOR BUYTAERT: Okay.  
 20 MR FAROOQ: So in terms of eflow consideration, you can take  
 21 this 53 to 73. For example, if you have, say, 73,  
 22 20 cumecs you are releasing for eflows, and then  
 23 53 cumecs is the net discharge that you are getting in  
 24 the reservoir.  
 25 PROFESSOR BUYTAERT: Okay. But if you have 53 inflow, and

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1 you need to release 20, obviously that only remains 33  
 2 to --  
 3 MR FAROOQ: Yes, then we will be recording 33.  
 4 PROFESSOR BUYTAERT: Okay. Yes, thank you.  
 5 DR BLACKMORE: Sorry, and that 33, you are only going to use  
 6 for peaking flow?  
 7 MR FAROOQ: Yes.  
 8 DR BLACKMORE: For peak-peak?  
 9 MR FAROOQ: Yes.  
 10 DR BLACKMORE: Not just ...  
 11 MR FAROOQ: Yes. So in that case, the peaking may not be  
 12 for the 4 hours: it may be for less duration than the  
 13 4 hours, yes.  
 14 In order to increase the prevalent winter season  
 15 flow of 53 cumecs, or 53 cubic metres per second, to  
 16 280 cubic metres per second in a given winter day, it is  
 17 essential to store the water for a certain number of  
 18 hours and release it in the remaining. The duration of  
 19 storage can thus be simply calculated as: volume of the  
 20 53 cubic metres per second flows stored for 81% of the  
 21 time in a 24-hour period, to release it in the remaining  
 22 19% of the same 24-hour period, to supply  
 23 280 cubic metres per second to the turbines.  
 24 Putting it in simple words, the time to store  
 25 becomes about 20 hours, leaving behind the 4 hours in

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1 which the 53 cubic metres per second river flow can be  
 2 supplied at a rate of 280 cubic metres per second.  
 3 In case of providing the pondage more than the  
 4 volume of 24 hours prevalent winter season flow, the  
 5 same could not be filled in a 24-hour period, and hence  
 6 would render part of the operating pool as redundant,  
 7 which would cost in several other ways.  
 8 As I mentioned, it is reiterated that this method of  
 9 pondage calculation may be considered as an illustration  
 10 specific to NJHEP, and should not be considered as  
 11 a universally adopted customary practice for pondage  
 12 calculation.  
 13 Slide 13. The next issue to be addressed is how HEP  
 14 storage is actually used. And we have two graphics on  
 15 the slide -- this one and this one (indicating) -- that  
 16 illustrates this. The bottom image -- this one  
 17 (indicating) -- is what is called a "hydrograph",  
 18 showing yearly inflow into HEP's reservoir. The red  
 19 dotted line -- this one (indicating) -- just above  
 20 250 cubic metres per second, shows the flow rate that  
 21 will meet HEP's installed capacity. Where the river  
 22 flows at this level or above, and that flow is delivered  
 23 into HEP's turbines, the HEP will be able to produce, at  
 24 its installed capacity, continuously, without the need  
 25 for assistance from storage.

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1 The blue line shows inflow; this one (indicating).  
 2 In the wet season, in summer, it rapidly climbs above  
 3 250 cubic metres per second for months at a time.  
 4 During this time, the HEP can produce constant power at  
 5 its installed capacity.  
 6 In the dry season, in winter, conversely, the flow  
 7 will drop below the level you can see here, here and  
 8 here (indicating). The flow will drop below the level  
 9 necessary to maintain HEP's installed capacity. During  
 10 this time constant power at the installed capacity will  
 11 not be possible. The plant will need to store water for  
 12 part of the day in its operating pool, and to be  
 13 released into the turbines when needed the most, say at  
 14 the times of peak electric demand.  
 15 If we look now at the image above, we can see what  
 16 that looks like; this one (indicating). The blue dashed  
 17 line -- here (indicating) -- shows the level of HEP's  
 18 operating pool. In the wet season, the pool is drawn  
 19 down to the minimum operating level; this is the minimum  
 20 operating level (indicating). The natural flow of river  
 21 is sufficiently plentiful that the plant can be run at  
 22 its installed capacity without assistance, and so no  
 23 operating pool is required. As will be more fully  
 24 investigated in the presentations following this one,  
 25 this may also assist with sediment management.

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1 you would keep the reservoir at minimum operating level,  
 2 you'd lose out on power. Is that the case, or do you  
 3 raise it higher in order to accommodate those periods  
 4 that the flow drops below the plant's capacity?  
 5 MR FAROOQ: You see, it is one year out of the lot, say it  
 6 may be a dry year, but as it is in the series. So if  
 7 you provide some -- I would say a facility which you  
 8 provide -- the probability of which is very less for  
 9 use -- for example, in this case it is one out of  
 10 four -- so that may not be economical. I mean, I'm  
 11 saying this in a general sense. And because for the  
 12 three years, you have a good period of time when the  
 13 plant is running at full capacity without -- I mean, at  
 14 least for three to four months in a year. So it is  
 15 a typical dry year, and normally ... yes, sir?  
 16 PROFESSOR BUYTAERT: So here, for example, for the case of  
 17 NJHEP, if such a dry year occurs, and you keep the level  
 18 at minimum operating level, and the flow decreases  
 19 beyond the plant's capacity, do you then effectively  
 20 reduce the power output, or do you try and anticipate  
 21 that and, for example, raise -- keep the level higher  
 22 such that you can, to some extent, bridge those moments  
 23 of lower flow? Is there any policy or practice here?  
 24 MR FAROOQ: Yes. You see, it is on the operator, and it is  
 25 from the system how much demand we are getting and how

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1 In the dry season, however, the operating pool is  
 2 filled to its full level, say here (indicating), and  
 3 then discharged to the turbines so that the plant can be  
 4 run at higher capacity for a shorter period of time in  
 5 a given day. Once the pool is empty, say to this level  
 6 (indicating), the minimum operating level, the turbines  
 7 must be shut off or run at a reduced capacity so that  
 8 the pool can be refilled, creating the fluctuating power  
 9 peaking pattern you can see here; this one (indicating).  
 10 Slide 14.  
 11 PROFESSOR BUYTAERT: Can I ask a question before you move  
 12 on?  
 13 MR FAROOQ: Yes, sir.  
 14 PROFESSOR BUYTAERT: Thank you. The discharge time series  
 15 you show at the bottom, is that here from the Neelum  
 16 River?  
 17 MR FAROOQ: Sorry?  
 18 PROFESSOR BUYTAERT: The discharge time series at the bottom  
 19 graph, is that here for the Neelum?  
 20 MR FAROOQ: Yes.  
 21 PROFESSOR BUYTAERT: Because you mentioned that indeed,  
 22 mostly in the wet season, flow is plentiful. But of  
 23 course if you look at the last wet season, 2022-2023,  
 24 there you can see that not always the flow is sufficient  
 25 to maintain the plant at full capacity. So obviously if

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1 operator wants to operate the plant, whether he wants to  
 2 operate it with a reduced capacity or maybe store water  
 3 for part of the day and release for part of the day.  
 4 I mean, operator can do as --  
 5 PROFESSOR BUYTAERT: Yes. So that means that during the wet  
 6 season it is possible that the water level in the  
 7 reservoir is higher than the minimum operating level  
 8 that's shown on the upper graph?  
 9 MR FAROOQ: Yes, yes.  
 10 PROFESSOR BUYTAERT: Okay, yes, thank you.  
 11 MR FAROOQ: Slide 14. Previously we saw a hypothetical  
 12 example. This is the full range of operation for  
 13 NJHEP -- this one (indicating) -- using what is called  
 14 12.00 am daily data from 2018 to 2023. This tells us  
 15 what the water level in NJHEP reservoir is at midnight  
 16 every day. Because it is a daily snapshot, we do not  
 17 see the daily variations within the operating pool. But  
 18 we see the broad pattern of a full pond level in the wet  
 19 season and depleted pool in the dry season. Over the  
 20 course of that time, the full range of operating pool is  
 21 used.  
 22 That concludes this section of the presentation of  
 23 HEP storage and reservoir use. Subject to any question  
 24 that you may have, I will now hand over to Dr Abbas to  
 25 address you on spillways and freeboard.

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1 Questions from THE COURT  
 2 PROFESSOR BUYTAERT: I would be interested knowing more  
 3 generally how the capacity of this plant of 969 MW has  
 4 been determined. I don't know if that's something you  
 5 can shed some light on here now, or later on: simply  
 6 what factors were taken into account to determine that  
 7 here a plant will be build of that specific capacity of  
 8 969 MW.  
 9 MR FAROOQ: Sir, as a general practice that I understand is:  
 10 the capacity of a plant is generally determined by the  
 11 site hydrology first. And then you develop a financial  
 12 model saying that: if I install this much of the  
 13 capacity, this would be the cost I need to incur on the  
 14 project, and this would be benefit, in terms of  
 15 finances, that I'm going to get out of it. And at  
 16 a point when your cost-to-benefit gets flat, there you  
 17 fix your megawatts or the generation capacity of the  
 18 plant.  
 19 PROFESSOR BUYTAERT: Yes. So I agree that that's indeed the  
 20 way it's done. I wonder whether it's possible to give  
 21 some more information about how specifically that  
 22 procedure was implemented here for this plant: for  
 23 example, what hydrological data were used, and what  
 24 demand estimates are being used. I realise that's  
 25 a broad question that encompasses more than what you've

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

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

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

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1 they're all PMF, which is 1-in-300,00-year flood,  
 2 about -- because the consequences are much higher if  
 3 you lose something and drown people.  
 4 But just to try and understand the hydrology, I was  
 5 just trying to work out whether, [if] a 1-in-10,000-year  
 6 flood is a certain number, 20,000 cumecs, is a PMF flood  
 7 30,000 or is it 21,000 cumecs? I'm just wondering what  
 8 the risk profile is.  
 9 DR ABBAS: You see, when they come up with the PMF estimate,  
 10 that is basically a phenomenon-based estimate, not  
 11 statistical-based. Whatsoever the figure you achieve  
 12 with the phenomenon-based estimates of the PMF, that is  
 13 again checked with the frequency. And it may be  
 14 possible that the PMF may come around 1-in-20,000 return  
 15 period.  
 16 DR BLACKMORE: It could come next year though?  
 17 DR ABBAS: Yes, yes.  
 18 DR BLACKMORE: That's what worries all of us.  
 19 THE CHAIRMAN: Well, let's hope at least not today!  
 20 DR ABBAS: Yes, let's hope!  
 21 THE CHAIRMAN: Continue, Dr Abbas.  
 22 DR ABBAS: Well, having discussed on the PMF, let's come  
 23 back on the freeboard.  
 24 The freeboard, on the other hand, serves a slightly  
 25 different purpose. It also exists to ensure that the

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1 The amount of flood surcharge depends on the  
 2 spillway design and the size of the gates, and if the  
 3 gates are large enough, it may be reduced to zero.  
 4 An increase in flood surcharge may be warranted if  
 5 the dam site is constrained by the site geometry: for  
 6 example, a very narrow canal, which requires a higher  
 7 surcharge to compensate for having a limited crest  
 8 length on the dam for the placement of the spillway.  
 9 The second factor, on the right side, in the  
 10 bullets: the wave action.  
 11 Wave action produced is generally by high winds.  
 12 A higher freeboard will be required in reservoirs with  
 13 a larger water surface. This increases the distance --  
 14 we say it like the "fetch" -- along which the wind can  
 15 act on the water. A higher freeboard will also be  
 16 warranted in a region which is subject to high winds.  
 17 Third factor: type of dam. An embankment dam has  
 18 a high risk of damage or failure due to overtopping as  
 19 compared to a concrete dam. For this reason,  
 20 an embankment dam warrants a higher freeboard than  
 21 a concrete dam, keeping all other things being equal.  
 22 And finally, the last one: operational reliability.  
 23 In areas where there are uncertainties in relation to  
 24 the reliability of gate or other operations, the  
 25 designers may feel that this warrants additional

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1 reservoir does not overflow, considering overtopping  
 2 aspects. Overtopping will occur when wind blowing  
 3 across the surface of the reservoir causes waves to  
 4 form, which could then spill over the dam wall, causing  
 5 erosion at its base, and in time, causing it to  
 6 collapse.  
 7 Slide 16(a).  
 8 Mr Chairman, the Court asked a question about  
 9 freeboard height as its question no. 5, which was: what  
 10 are the range of circumstances at a dam that would  
 11 warrant an increase in freeboard height, taking into  
 12 account the need to prevent overtopping and to allow for  
 13 the dam safety? Does keeping the crest gate top at full  
 14 pond level prevent raising the water level artificially?  
 15 Well, answering the first part of this question,  
 16 we can see the bullets on the right side of this slide.  
 17 It indicates various circumstances, like flood  
 18 surcharge, wave action, type of dam and the operational  
 19 reliability. I will be discussing one by one in detail.  
 20 First, flood surcharge. As Umar has already  
 21 explained earlier, this is the uncontrollable storage  
 22 above the operating pool, which is used when the pool  
 23 level must be raised above the maximum operating level  
 24 to achieve the design flood discharge. This is  
 25 an essential first component of the freeboard.

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1 freeboard.  
 2 It should be noted that freeboard is not usually  
 3 constructed simply for the sake of freeboard. A dam is  
 4 expensive to construct, and so designers will not  
 5 normally provide for more freeboard than is necessary in  
 6 a given case. If more freeboard were provided than  
 7 necessary, it would not be economically rational and  
 8 would need to have some other motivation.  
 9 As far as the second part of the Court's question is  
 10 concerned, the short answer is: yes. A crest-gated  
 11 spillway is designed such that there is a gap at the top  
 12 of the gate to allow for water to overflow the gate if  
 13 the water level rises too high. If the top of the gate  
 14 is at the full pond level, this will prevent the  
 15 deliberate raising of the operating pool above this  
 16 level.  
 17 Slide 17.  
 18 PROFESSOR BUYTAERT: Sorry, can I ask a question on this  
 19 slide (16(a)), if you don't mind.  
 20 The figure you show here on the left-hand side, you  
 21 say rising water level will overflow the gates. But in  
 22 this particular figure, given that it's a gated  
 23 spillway, one would assume that the water level doesn't  
 24 overflow, but that gate is operated such that the water  
 25 level is low enough to account for the flood surcharge,

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

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1 related with the hardcore hydrology. I would like to  
 2 explain in more detail.  
 3 Sir, as you said very rightly, when we start  
 4 projecting some flood, we have to take account for the  
 5 historic events we have, okay? And the historic events  
 6 we have, if you talk about the last 50 years, we don't  
 7 have any impact of climate change. It means that if we  
 8 are taking care of the recent events in our projections  
 9 that have some incorporation or, you can say, some  
 10 impact of the climate change in them, so we are somehow  
 11 incorporating the impact of climate change in the  
 12 projected estimates.  
 13 DR BLACKMORE: That's true for the climate change that's  
 14 already happened as we're moving down the journey.  
 15 I won't take the question any further because it's  
 16 a difficult subject. But it does affect whether it's  
 17 1 in 10,000 or 1 in 5,000 if climate change is  
 18 a significant issue, that's all.  
 19 DR ABBAS: Yes, sir. I do agree that a flood that has been  
 20 estimated earlier has some magnitude, and if you just  
 21 incorporate the new events that have some high peaks,  
 22 that magnitude may get updated.  
 23 THE CHAIRMAN: I had a question on slide 16(a).  
 24 DR ABBAS: 16(a).  
 25 THE CHAIRMAN: Yes.

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

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

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

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1 DR ABBAS: Perhaps you have rightly pointed out this slide.  
 2 The spillways are designed for the 10,000-year flood --  
 3 PROFESSOR BUYTAERT: Yes, which is around, sorry, 9,500 --  
 4 DR ABBAS: But this is basically a safety check.  
 5 PROFESSOR BUYTAERT: Okay. So the design flood here, if  
 6 I read the graph correctly, is just below  
 7 10,000 cumecs --  
 8 DR ABBAS: Yes.  
 9 PROFESSOR BUYTAERT: -- while the PMF is above 12,000?  
 10 DR ABBAS: Yes.  
 11 PROFESSOR BUYTAERT: Okay, yes. Thank you.  
 12 DR ABBAS: Thank you.  
 13 Slide 18.  
 14 The most important tool for management of the design  
 15 flood is the spillway. Another familiar event is on the  
 16 slide showing the different configurations. You have  
 17 seen it before.  
 18 After discussing various spillway configurations,  
 19 now I will take this opportunity to answer the Court's  
 20 question 1, which is as follows: what are the range of  
 21 circumstances where a gated spillway might even be  
 22 beneficial or required for run-of-the-river plant on the  
 23 Western Rivers of the Indus Basin?  
 24 Before we answer this question, we must understand  
 25 what we are comparing a gated spillway to: the ungated

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1 This is again a statistical-based estimate using the  
 2 available datasets at the particular site.  
 3 In the next data point to the right, once every  
 4 100 years, flood conditions of just under 4,000 cubic  
 5 metres per second inflow will occur. And further  
 6 continuing to the right, once every 1,000 years, flood  
 7 conditions of just under 8,000 cubic metres per second  
 8 inflow will occur. And finally, once every  
 9 10,000 years, flood conditions of just under  
 10 10,000 cubic metres per second inflow will occur.  
 11 Where you are seeing this red line, this is the  
 12 probable maximum flood at the Neelum-Jhelum Project:  
 13 that is 12,500 cubic metres per second. Again, this PMF  
 14 has been estimated based on phenomenon-based studies.  
 15 PROFESSOR BUYTAERT: Sorry, can I ask you a question about  
 16 this.  
 17 So you have the bright red line as the probable  
 18 maximum flood. But if I'm correct, didn't you identify  
 19 or define the design flood as the 1-in-10,000-year  
 20 event, in which case it should be the rightmost point on  
 21 the dark red curve, isn't it? While in the legend  
 22 you've got "PMF" and in between brackets  
 23 "(Design Flood)".  
 24 So the red line is not the design flood;  
 25 am I correct?

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

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1 components of the dam at site. You must have noticed  
 2 some rockfill dam portion, and you have also noticed the  
 3 area for the desander. So one thing is clear: that you  
 4 are not going to have a spillway in these two  
 5 embankments, because of the requirement of certain  
 6 features of the dam. So what shall be left is the  
 7 centre of the dam. And I think during the design phase  
 8 it must have been evaluated that: if the surface  
 9 spillway is there, can it pass the design flood under  
 10 the given circumstances?  
 11 So I believe that for Neelum-Jhelum Project, all  
 12 these exercises have been concluded, and based on the  
 13 optimal solution, what you are seeing right now is  
 14 there.  
 15 PROFESSOR BUYTAERT: Thank you.  
 16 MR MINEAR: One more question. I just want to make  
 17 an observation. This slide shows my confusion with  
 18 regards to the terminology.  
 19 The freeboard on the first slide is measured to the  
 20 design flood surcharge; in the other two slides, it's  
 21 measured to the full pondage level. But your note above  
 22 explains that the design flood surcharge may be zero if  
 23 the gates are large enough.  
 24 So I think that is what resolves my confusion I had  
 25 earlier about the terminology.

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1 The big issue with an ungated spillway is that its  
 2 discharge capacity is fixed by the length of the  
 3 spillway, which is fixed by the width of the valley  
 4 itself in which the dam is located. We can see this  
 5 represented on the slide.  
 6 If the valley is insufficiently wide for the ungated  
 7 spillway to pass the design flood, the designer has two  
 8 options. First, the valley might be widened by  
 9 excavation or tunnelling, to allow for an ungated  
 10 spillway of the required length to be built, or you can  
 11 say to accommodate that surface spillway requirement  
 12 within that valley. Second, if the geology of the  
 13 valley does not allow the valley to be widened safely,  
 14 or the cost of the widening is prohibitive, a gated  
 15 spillway would be introduced in the design.  
 16 With the gates close, located at the crest of the  
 17 spillway, this may be considered the next best  
 18 alternative to an ungated spillway in some cases,  
 19 especially when it is considered that a gated spillway  
 20 may play a role in sediment management. There is  
 21 usually no need for large amount of flood surcharge to  
 22 be accounted for in a crest-gated spillway, provided the  
 23 gates are large enough. This is what we were discussing  
 24 earlier.  
 25 At the same time, if the top of the gate is not at

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1 DR ABBAS: Sir, in principle, it's above the full pond  
 2 level, okay? Here in this case, this is the surcharge.  
 3 And above the surcharge is the requirement for the wave  
 4 accommodation.  
 5 MR MINEAR: Great, thanks.  
 6 DR ABBAS: Thank you.  
 7 DR BLACKMORE: So just back to your explanation.  
 8 I understood the explanation very clearly, so thank you  
 9 for that. But an observation or a question.  
 10 So if we went for a free overflow surface spillway  
 11 here, just assuming we had the space, we would have to  
 12 allow an elevation drop. So the dam would have to be  
 13 bigger, taller, to do that, otherwise we'd lose  
 14 available head to get into the spillway?  
 15 DR ABBAS: Exactly.  
 16 DR BLACKMORE: So I was wondering whether that was a more  
 17 important characteristic: that we didn't want to build  
 18 the dam higher, so we had a surface spillway; we wanted  
 19 to have the dam at this level, so all the other  
 20 mechanical and hydraulic bits fitted together.  
 21 DR ABBAS: Perhaps this is what I am going to explain in  
 22 detail in my coming slides.  
 23 Slide 18(a). So what you have seen in the previous  
 24 slide, you are seeing again the elevation of those three  
 25 types of spillways.

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1 the full pond level, any flood surcharge between the  
 2 full pond level at the top of the gate can be converted  
 3 into controllable storage, and the pond overfills  
 4 deliberately. This will allow the maximum operating  
 5 level to be raised, increasing the pressure head against  
 6 the turbine and increasing power production.  
 7 And finally, we have this orifice spillway. This is  
 8 also a gated spillway, but with the gates themselves  
 9 located deep in the reservoir, potentially below the  
 10 minimum operating level.  
 11 The benefit of this, when compared to a crest-gated  
 12 spillway, is that the additional pressure with which the  
 13 water is discharged from the orifice means that the  
 14 discharge capacity of a high spillway can be obtained in  
 15 certain conditions, but with a smaller orifice.  
 16 If there are geometric conditions that can limit the  
 17 spillway width, this can be useful, this option.  
 18 Another benefit of an orifice spillway is that it  
 19 allows the designer to situate the spillway in the  
 20 middle of the dam, as opposed to its crest, potentially  
 21 reducing construction costs.  
 22 Of course, this comes at a cost: the increased  
 23 velocity and the density of the resulting water jet  
 24 exiting from the orifice spillway tends to erode the  
 25 riverbed at the foot of the dam to a greater extent than

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1 other spillway designs. Moreover, the gates themselves  
 2 need to be designed to deal with greater water pressure  
 3 compared to these two spillways.  
 4 Mr Chairman, let me summarise the circumstances in  
 5 which gated spillway might be beneficial or required, as  
 6 follows.  
 7 First, the lack of valley width at the dam site we  
 8 elaborated earlier.  
 9 Second, limitation in dam height due to site  
 10 constraints, as we discussed, like geology or chance of  
 11 upstream population submergence.  
 12 Third, augmenting the flood-passing capacity of  
 13 ungated spillways, as we will discuss shortly.  
 14 To this, I should also add that a gated spillway of  
 15 any kind may play a role in sediment management, what we  
 16 will be discussing in detail in presentation no. 6.  
 17 Slide 19.  
 18 THE CHAIRMAN: Can I just ask one question before you move  
 19 past this slide? And if you are already addressing this  
 20 in the future, that's fine.  
 21 But on the orifice spillway, it's a higher pressure  
 22 pushing of the water through the orifice spillway,  
 23 because it's lower down and you have the pressure of the  
 24 reservoir essentially pushing the water; is that  
 25 correct?

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1 And further, however, there's a disadvantage here  
 2 because it can only push through as much water as that  
 3 orifice will allow, which means that if all you have is  
 4 the orifice spillway, you may not be able to clear the  
 5 amount of volume of water that you would like to, and  
 6 that would be an advantage of the first two spillways;  
 7 is that correct?  
 8 DR ABBAS: Sir, absolutely right interpretation. I would  
 9 explain it further.  
 10 THE CHAIRMAN: Please.  
 11 DR ABBAS: You see, in case of ungated surface spillway,  
 12 more discharge can be passed by just increasing the head  
 13 over the spillway. But in this case, orifice spillway,  
 14 we have a fixed flow area, so it means that this  
 15 particular type of spillway has some limitation in  
 16 passing certain range of discharge.  
 17 And another important aspect that relates with the  
 18 hydraulic engineering is basically how to deal with the  
 19 higher velocities with these orifice spillways. So  
 20 there are certain, you can say, upper limits available  
 21 for design velocities in such type of spillways, to  
 22 avoid damage to the concrete structure.  
 23 THE CHAIRMAN: And in your experience, would you typically  
 24 not have just an orifice spillway? Would you combine it  
 25 with a gated spillway or an ungated spillway? Or is it

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1 possible, in certain conditions, that you would just  
 2 have the orifice spillways?  
 3 DR ABBAS: Mr Chairman, I would like to address this  
 4 particular query in my coming slide. But in sequence of  
 5 priority, this should be the priority.  
 6 THE CHAIRMAN: Yes, okay.  
 7 DR BLACKMORE: I am just interested in the electromechanical  
 8 support needed for the gated spillway and the orifice  
 9 spillway. So you need infrastructure, you need power.  
 10 And we want these things to be effective in a flood of  
 11 some sort, let's say a one in 2,000 year flood, where  
 12 all the indigenous power is gone, the power lines will  
 13 be gone -- well, they certainly are in Australia.  
 14 So I'm wondering how much of the contingency  
 15 planning is in place to operate these gated spillway  
 16 structures, either orifice or gated, in the event of  
 17 regional power being out. Do we have backup power? Are  
 18 we able to get access to the backup power to do it?  
 19 DR ABBAS: Sir, this is what we were discussing earlier as  
 20 the operational reliability, and that is very much  
 21 highlighted with the spillways like orifice spillways.  
 22 Here, at Neelum-Jhelum, we have a proper contingency  
 23 plan available. As per the operational guidelines,  
 24 there [is] always a backup there in the form of  
 25 generators that can operate the spillways in case of

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1 power failures.  
 2 THE CHAIRMAN: If I recall correctly, the first stop on our  
 3 walk-around yesterday was a series of generators right  
 4 next to this building that you would use to operate your  
 5 gates if there is a power outage.  
 6 DR ABBAS: Yes. May I proceed to next slide?  
 7 THE CHAIRMAN: Yes, please.  
 8 DR ABBAS: Thank you. Slide 19.  
 9 In many situations, however, the optimal spillway  
 10 solution for a particular dam is to include multiple  
 11 spillways, in the design of different circumstances.  
 12 The risks of gate failure in an orifice spillway may be  
 13 eased by including an ungated spillway for which gate  
 14 failure is not an issue.  
 15 Conversely, the lack of a valley wide enough for  
 16 an ungated spillway that can pass the design flood may  
 17 be eased by including a supplementary gated spillway in  
 18 the design, as we were discussing earlier.  
 19 In some cases, all three basic spillway types may be  
 20 included in the same design. An example of this  
 21 methodology is from Karun-3 Dam in Iran.  
 22 This combination was selected for several reasons.  
 23 Let me discuss here.  
 24 The ungated surface spillway was selected to provide  
 25 security in case of gate failures, and to provide

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1 an outlet for landslide-generated waves, and as a part  
 2 of the total PMF discharge; whereas the gated surface  
 3 spillway was to deal with most of the design flood  
 4 discharge, but the space available was limited. These  
 5 were designed to 300 cubic metres per second of rate of  
 6 flow, so could not discharge more.  
 7 The orifice spillway -- in the centre of this  
 8 slide -- was used to make up the total PMF discharge,  
 9 but also functioned to vent the suspended sediments  
 10 during the flood.  
 11 So this is what, sir, you were asking, that how  
 12 different types of spillways can be integrated in  
 13 a single scheme of a dam.  
 14 Slide 20. Sir, many of the points just made can be  
 15 found in summary on this slide, which introduces the  
 16 combination spillways at the Neelum-Jhelum Project as  
 17 well.  
 18 Spillways can be combined in different  
 19 configurations to meet different challenges at the  
 20 project sites; for example, flood or sediment  
 21 management. If one design is not possible,  
 22 a work-around may be developed. For example, an orifice  
 23 spillway may be included as the main spillway, with  
 24 a surface spillway incorporated for use if the discharge  
 25 capacity of the main spillway is exceeded.

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1 The Neelum-Jhelum Project is one such design,  
 2 incorporating orifice and surface gated spillways,  
 3 together with undersluices built into the intake  
 4 structure for sediment management.  
 5 Slide 21. You can see how this looks in real life  
 6 on this slide. So you have seen this yesterday from the  
 7 viewpoint as well. So what's different in this slide  
 8 is: those parts of the structure that are visible here  
 9 were not visible yesterday because they were submerged  
 10 in the water.  
 11 You can see here the intake structure. Six intakes  
 12 are there, and here we have undersluices. And this is  
 13 the central part of the dam, having gated spillway or  
 14 orifice spillway. And this is the debris channel or the  
 15 flat bed spillway.  
 16 MR MINEAR: On this slide, can you show with your pointer  
 17 where the full pondage level would be? In other words,  
 18 if there was water in the reservoir, where would the  
 19 full pondage level be? If you can point to it.  
 20 DR ABBAS: I think here (indicating).  
 21 MR MINEAR: Okay, thank you.  
 22 DR ABBAS: Somewhere here. Again, this is an estimate.  
 23 Slide 22. Sir, what you have seen in the elevation,  
 24 this is what you see in the record drawing. Again, on  
 25 the left you have six intakes. In the middle of the dam

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1 we have a gated spillway. And this is the debris  
 2 channel or flat gate spillway. And on the right side we  
 3 have rockfill dam.  
 4 THE CHAIRMAN: Can I just confirm that -- the gated  
 5 spillways are here, and then there's orifices down here  
 6 (indicating)?  
 7 DR ABBAS: The orifices are here (indicating).  
 8 THE CHAIRMAN: Okay.  
 9 DR ABBAS: Slide 23.  
 10 Sir, having some discussion on the upstream  
 11 elevation, now I am showing you the downstream elevation  
 12 at the time of construction of this project.  
 13 So you can see here different aspects. Again, in  
 14 the middle of this snap, you can see three individual  
 15 gates of the spillway. You can see here this gate is  
 16 fully open, while two others are partially open. And  
 17 here, these are the walls of the sedimentation basin  
 18 that is being constructed. And this part is still to be  
 19 constructed there.  
 20 Slide 24. This is, sir, what you see in the record  
 21 drawing: again, all those features that I have shown you  
 22 earlier. In the middle of the slide, the gated  
 23 spillway. The floodgate, which was under construction;  
 24 and this was also under construction in the previous  
 25 snap. And here, these are the walls you have seen in

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1 the previous picture.  
 2 Slide 25. Sir, you spent a reasonable time  
 3 yesterday on this orifice spillway, so you might have  
 4 noticed something I will be explaining here.  
 5 This photograph was taken at the top of the deck  
 6 unit where the gates for the orifice spillway are  
 7 housed, looking upstream. The radial gate of this  
 8 spillway is in the fully closed position and is holding  
 9 the river back. It's basically resting on the crest  
 10 right now. We are looking upstream.  
 11 Radial gates of this kind are often used on larger  
 12 spillways. They are the easiest and most reliable gates  
 13 to operate.  
 14 Slide 26. Now I come to some more details. We can  
 15 see the close detail of this in the record drawing of  
 16 the orifice spillway. Shown here is the longitudinal  
 17 elevation. The flow direction is from left to right.  
 18 So this is the radial gate I explained earlier, and this  
 19 is the opening here. So water, when it flows from here,  
 20 goes ultimately to the downstream, where it dissipates  
 21 energy there and goes to the natural river further.  
 22 Slide 27. This is the surface gated spillway.  
 23 Yesterday you have seen that the water was flowing over  
 24 it. What you are seeing right now is basically it's  
 25 holding the water upstream.

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1 As with the equivalent for the orifice spillway,  
 2 this is taken downstream of the spillway at the top of  
 3 the gateway. The gate is holding back the flow at the  
 4 top of the reservoir. It is designed so that, in flood  
 5 conditions, the reservoir can flow freely over the gate,  
 6 without damaging it or its mechanism.  
 7 Slide 28. The close detail of the spillway design  
 8 is again visible on this slide. So what you have seen  
 9 in the last slide is shown here. So the basic operation  
 10 is like this: if this is the crest, the flap basically  
 11 operates like this (indicating). Unlike the gated spill  
 12 way, if this is the crest, the gated spillway operates  
 13 like this (indicating).  
 14 Slide 29. Sir, this ends this portion of the  
 15 run-of-the-river HEP basic presentation. The second  
 16 portion, on sediment management, will start after  
 17 a short break. I think I am right on time!  
 18 For now, on behalf of Mr Alauddin, my colleague  
 19 Umar Farooq, I thank you for your time. If you have any  
 20 questions, I am pleased to address.  
 21 THE CHAIRMAN: Thank you, Dr Abbas, let me look to see if  
 22 there are any questions at this time. No.  
 23 That was a very helpful presentation, we appreciate  
 24 it very much, and you are to be commended for hitting  
 25 your time mark almost perfectly!

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1 MR FAROOQ: Thank you.  
 2 THE CHAIRMAN: So thank you. I will end then this  
 3 presentation now, and we'll look forward to the second  
 4 presentation in the afternoon. And perhaps now we'll do  
 5 our little walkabout, if that's possible. Thank you.  
 6 Presentation 7: Dam Walkaround and Reservoir Inspection (II)  
 7 THE CHAIRMAN: So, Mr Alauddin, as we lost the audio on our  
 8 walkaround yesterday, perhaps we could start here again  
 9 today and have you just explain to us where we are at  
 10 this point on the dam.  
 11 MR MIANA: Sure. We are on the pier of the dam. The  
 12 elevation at this level is about 1,019 metres above sea  
 13 level. On our left, we can see the river is coming from  
 14 this side. This is the upstream side of the river, and  
 15 this is the reservoir. And on the left side we have the  
 16 left embankment over there. There we have the intake  
 17 gates and the undersluice gate, and also the radial  
 18 gates. So the radial is on the right side. And beside  
 19 the radial gate we have the cascade, the floodgate over  
 20 there. (Pause)  
 21 And now we can see from here the maximum level of  
 22 1,015 that was questioned in the meeting as well. So  
 23 you can see this is the maximum level for which the  
 24 reservoir is supposed to be at the maximum level. And  
 25 above that is a freeboard available, as was explained by

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1 the three persons in the presentation no. 5 just now.  
 2 And beside that we have the floodgate, and this  
 3 floodgate -- both are open now just to maintain the  
 4 level over there. So these are the positions for the  
 5 regulation of the water from this point, for  
 6 Neelum-Jhelum Hydropower Project.  
 7 THE CHAIRMAN: Okay, very good. Any question?  
 8 MR MIANA: So we move to the other installation over here.  
 9 As explained, these are the feeder beams that we use  
 10 to put in under our stoplog outside, just to avoid the  
 11 accumulation of sand and sediments in these lots. So  
 12 this is very helpful because, if it is not put in that  
 13 place, then the sediment can accumulate. And this  
 14 sediment then will restrict the complete closing of the  
 15 lowest part of the stoplog. So that is helpful. All  
 16 the sediments are then accommodated in this one  
 17 (indicating) and then taken out, and then we are safe to  
 18 place our -- these stoplogs in there.  
 19 So all these six lots, for all three gates, are  
 20 placed now, even now at the bottom of that one.  
 21 THE CHAIRMAN: There is one down there right now?  
 22 MR MIANA: Two.  
 23 THE CHAIRMAN: Two, collecting sediments.  
 24 MR MIANA: Sometimes two, sometimes three.  
 25 THE CHAIRMAN: Okay.

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1 MR MIANA: But we have the provision we can put up to this  
 2 level. But that is not required because sediments are  
 3 not coming too high.  
 4 THE CHAIRMAN: One question.  
 5 PROFESSOR BUYTAERT: How do you take them out if they are in  
 6 there now?  
 7 MR MIANA: With this crane (indicating).  
 8 PROFESSOR BUYTAERT: Okay. You kind of fish them out?  
 9 MR MIANA: Yes. We have a device for lifting them out.  
 10 PROFESSOR BUYTAERT: Okay, yes, thank you.  
 11 THE CHAIRMAN: Mr Miana, is this also out on the -- is this  
 12 the same one that was out on the desander?  
 13 MR MIANA: No, I think there is a second one.  
 14 MR ALAUDDIN: That's a different one.  
 15 THE CHAIRMAN: It's a different one.  
 16 MR ALAUDDIN: These are being used for taking water samples.  
 17 THE CHAIRMAN: Okay. And the one that was out on the  
 18 desander that we saw yesterday, perhaps you could  
 19 explain again the function of it in the desander.  
 20 MR ALAUDDIN: We are using -- that is being used for taking  
 21 water sample also. But sometimes we have another task:  
 22 to measure the velocity within the desander so that  
 23 those are as per the design parameters.  
 24 THE CHAIRMAN: Okay. So when we saw a similar one on the  
 25 desander yesterday, you explained this was to test the

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

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1 THE CHAIRMAN: Through here.  
 2 MR MIANA: This is a section to other inflow (inaudible).  
 3 THE CHAIRMAN: Yes.  
 4 MR MIANA: So once the water is coming to this side  
 5 (inaudible).  
 6 Would you like to see the second one?  
 7 PROFESSOR BUYTAERT: Are the gates fully open now?  
 8 MR MIANA: Yes, this one is fully open.  
 9 This is partially, you can see. This is partially,  
 10 as of yesterday. (Inaudible).  
 11 THE CHAIRMAN: So this gate is partially open; the other one  
 12 is fully open.  
 13 MR MIANA: Is fully open. We can recognise the waves of the  
 14 hydraulic (inaudible).  
 15 DR BLACKMORE: You don't have a fish ladder or anything on  
 16 here for environmental purposes?  
 17 MR MIANA: Fish ladder? No, there is no fish ladder.  
 18 DR BLACKMORE: Are there no fish?  
 19 MR MIANA: There should be!  
 20 Can we move to the --  
 21 THE CHAIRMAN: Should we take a look at the --  
 22 MR MIANA: -- inside the --  
 23 THE CHAIRMAN: Yes. (Pause)  
 24 MR MIANA: So this is the control for both the floodgates.  
 25 We have the electrical panel outside. And on this side

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

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

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

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

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

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

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1 So here is the diversion tunnel that was used during  
 2 the construction. This is the outlet of that diversion  
 3 tunnel. It is coming from the upstream of the dam side.  
 4 And from upstream of the dam side, we are already  
 5 flushing. Now, however, it is from this side it's open.  
 6 And with this, we can also see the outlet for the  
 7 flushing of the desanders from there, and we can also  
 8 see now that two are in operation: the undersluice is  
 9 also in operation for the fine-tuning.  
 10 MR MINEAR: And we are doing the sluicing again (inaudible).  
 11 MR MIANA: Yes, yes, undersluice again. Because they just  
 12 try to fine-tune about the regulation and the water  
 13 level.  
 14 THE CHAIRMAN: So I think that our audio from yesterday  
 15 resumed at this point.  
 16 MR MIANA: Okay.  
 17 THE CHAIRMAN: And therefore, unless there's any particular  
 18 questions from here on, I think we're basically done and  
 19 can just walk back to the --  
 20 MR MIANA: The normal room.  
 21 THE CHAIRMAN: Yes. Is that okay?  
 22 MR MIANA: Okay, let's go.  
 23 THE CHAIRMAN: Okay, let's go.  
 24 (End of walkaround)  
 25

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1 sediment issues.  
 2 Slide 3. Mr Chairman, starting from the size of the  
 3 sediments.  
 4 As you know, sediment is generated when rocks break  
 5 down into smaller and smaller particles by natural  
 6 weathering process. These particles are delivered into  
 7 rivers through rainfall erosion, landslide and debris  
 8 flows.  
 9 Sediment sizes vary greatly. They are commonly  
 10 measured according to the Wentworth scale, which  
 11 classifies them by grain size.  
 12 The largest sediments we deal with in the Himalayas  
 13 are boulders, which are 10 million times larger than the  
 14 smallest sediment. These are the boulders, about  
 15 1.6 metres in height. And you can see the boulders can  
 16 be as long as up to 4 metres and beyond, starting from  
 17 a foot of length to 4 metres.  
 18 Our rivers carry a sediment load that includes fine  
 19 sediments, mostly silt and clay, and coarse sediment,  
 20 sand and gravels, along with the cobbles and boulders.  
 21 Mr Chairman, now I would like to show you different  
 22 sizes of the sediments. The samples we are going to  
 23 describe you have been extracted from the bed upstream  
 24 of this reservoir.  
 25 These two (indicating) are basically representing

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

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

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1 the percentage, so the harder material in these samples  
 2 are around 70%.  
 3 Slide 4. Now, sir, I will be explaining different  
 4 modes of transport of the sediment within a stream.  
 5 In the Himalayas, almost all sediment is eroded and  
 6 transported during the wet season. Spring and early  
 7 summer flows are mostly from snow melt. Late-summer  
 8 flows are mostly from mountain range and glacial melts.  
 9 Fine sediments, including the sands, are eroded from  
 10 hillsides and are easily transported downstream by  
 11 rivers. The large material on the riverbed is  
 12 transported by hydraulic forces on the riverbed  
 13 generated by large or extreme floods.  
 14 As you can see in this slide, [there are] two basic  
 15 modes of the sediment transport in a stream.  
 16 The great majority of sediment in rivers is  
 17 transported in suspension. And the amount of sediment  
 18 being passed in suspension, when it comes to be in terms  
 19 of magnitude, we determine it as the "sediment load", or  
 20 you can say "suspended load".  
 21 You can see rivers turns a muddy colour during  
 22 floods due to the sediment they are carrying. Suspended  
 23 sediments do not have significant interaction with the  
 24 riverbed; they are generally in suspension. They  
 25 usually enter into river due to erosion of the land

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1 bed material is visible in the foreground.  
 2 The snap on the right shows the Kali Gandaki River  
 3 in Nepal, again in dry season. A similar pattern: once  
 4 again, the larger bed material is seen in the  
 5 foreground, and the sand is deposited at high levels by  
 6 the receding waters of the monsoon. You can see here  
 7 the sand deposits.  
 8 Mr Chairman, I will request you to, while you are  
 9 going down to Muzaffarabad, just focus on the river: you  
 10 will also notice the sand deposits there along your way.  
 11 Slide 6. This snap is a close-up of sand from  
 12 Marsyangdi River in Nepal on the palm of the hand.  
 13 Here, Mr Chairman, I would like to invite your attention  
 14 towards how it looks when you magnify it. Just focus on  
 15 two things: (1) the angularity or roundness; and (2) the  
 16 material that is sparkling or shining.  
 17 As you can see, Himalayan sand is dominated by  
 18 quartz. Again, what you have seen right now is  
 19 basically extracted from the middle jar, okay?  
 20 Himalayan sand is dominated by quartz. 70% quartz is  
 21 rather typical. This is highly abrasive and angular.  
 22 You have seen a similar texture through magnifying.  
 23 It is harder than steel used in hydropower turbines,  
 24 a point that I will come back [to] in the third part of  
 25 this presentation.

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1 surface, especially due to heavy rainfall.  
 2 Now coming towards the bed load. Bed load is  
 3 movement of the bed material, the sediment found on the  
 4 riverbed. It moves by rolling and bouncing along the  
 5 river. As you look in the river, you can see the  
 6 material in the riverbed is quite large.  
 7 Now if I talk about sand. Sand can be transported  
 8 as either suspended load or bed load, depending on the  
 9 flow velocity, the strength of the turbulence in the  
 10 water. In steep mountain rivers, sand is normally  
 11 transported as suspended load.  
 12 Mr Chairman, the samples between these two tissue  
 13 boxes are the sand. And these particles certainly come  
 14 in suspension in high flows and they also move along the  
 15 bed.  
 16 Slide 5. Here are two snaps of Himalayan river beds  
 17 during the winter dry season. This is the best time to  
 18 visualise what's on the bank.  
 19 On the left, we have the Indus River above  
 20 Tarbela Dam in Pakistan. This photo was taken at Besham  
 21 Qila gauge station in dry season. You can just compare  
 22 the scale of this material with the man's height.  
 23 You can see the sand in suspension that was  
 24 deposited high up the riverbank as the river level  
 25 dropped. Just look at these sand deposits. The large

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1 Slide 7. This graph shows the seasonality of the  
 2 daily flows of water in the period 2019 up to 2023. As  
 3 you can see, most of the precipitation that occurs in  
 4 the high mountain in the winter is discharged as  
 5 meltwater in the summer, supplemented by late monsoon  
 6 summers.  
 7 Yesterday, sir, there was a question that: is there  
 8 a relation between the sediment that is coming specially  
 9 from the snow melt? So we came up with the data, and it  
 10 indicates that about 30% of the total sediment at this  
 11 location is attributed to the sediment in the snow melt  
 12 periods.  
 13 Nearly all sediment is eroded and transported  
 14 downstream during the high flows of the summer  
 15 wet season.  
 16 Slide 8. Sir, after discussing not only the size of  
 17 the sediments, the mode of the transport and its  
 18 characteristics, now I will be discussing how it  
 19 interacts with the water body when there is a pond.  
 20 This slide shows the pattern of reservoir  
 21 sedimentation. All reservoirs will eventually fill with  
 22 sediments. But this problem is particularly acute in  
 23 run-of-the-river reservoirs because of their typically  
 24 small storage capacity.  
 25 Looking at the top image, you can see the sediment

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

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

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

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

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

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

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

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

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<p>1 outlet has been set at the location needed to produce                  2 the target water level, further lowering of the outlet                  3 will produce no beneficial change in the profile other                  4 than to create a highly localised cone -- as you can see                  5 here (indicating) -- highly localised cone of scour at                  6 the upstream face of the outlet.                  7 Slide number 14. There are a variety of sediment                  8 strategies. This figure classifies the approaches into                  9 four categories: reduce sediment yield; route sediments;                  10 remove deposited sediments; or the adaptive strategies.                  11 While talking about the first one, reduce sediment                  12 yield, two basic strategies may be used to reduce                  13 sediment yield and entering the reservoir from the                  14 upstream watershed: (1) control soil and channel erosion                  15 at its source; or (2) trap eroded sediment upstream of                  16 the reservoir.                  17 Now talking about route sediments. These techniques                  18 take advantage of the seasonal variability of sediment.                  19 The idea is to manage flows during the periods of                  20 highest sediment yield to minimise sediment trapping.                  21 The two approaches are: (1) sediment bypass strategies;                  22 and (2) sediment pass-through strategies.                  23 Talking about number 3, remove deposited sediments.                  24 The main techniques used to remove sediment deposits                  25 are: (1) mechanical removal through the dry excavation</p> <p style="text-align: center;">Page 93</p>	<p>1 Slide 16.                  2 Erosion control can be achieved through the                  3 restoration of vegetation to protect the soil. This is                  4 relatively economical and also self-renewing.                  5 This photo, and this one, show the Debre Yakob                  6 watershed in the Ethiopian Highlands. On the left here,                  7 this one (indicating), you see severe erosion in                  8 January 2012. And just three years later, as you can                  9 see here (indicating), in February 2015, due to better                  10 management of livestock grazing, the vegetation has                  11 recovered and erosion has been significantly reduced.                  12 Slide 17. I now turn to the strategy of routing                  13 sediments; that is, flood sluicing.                  14 A large section of sediment load is associated with                  15 floods. The top image, this one (indicating), shows                  16 sediment trapping, which is what we want to avoid.                  17 Sediment trapping is maximised when the deep water                  18 results in low flow velocity, resulting in a large                  19 percentage of the inflowing sediment load being trapped                  20 in the reservoir during a flood.                  21 The bottom image, this one (indicating), shows                  22 sluicing being used to pass the sediment-laden flows                  23 through the reservoir at the highest possible velocity                  24 to minimise amount of trapped sediments. Sediments are                  25 routed through the reservoir and exit downstream through</p> <p style="text-align: center;">Page 95</p>
<p>1 or dredging; (2) hydraulic scour through flushing                  2 events.                  3 Now about number 4, the adaptive strategies. These                  4 aim to mitigate the impacts of sedimentation but do not                  5 involve handling reservoir sediments.                  6 At Neelum-Jhelum Hydroelectric Project, we are using                  7 a combination of option 3 and option 4 to manage this                  8 sediment, which involves desanders, turbine coatings and                  9 hydraulic scouring of sediments from the reservoir.                  10 Slide 15.                  11 There is no "one size fits all" approach for                  12 sediment management at a particular site. Typically,                  13 more than one strategy is used, either concurrently or                  14 sequentially. Selection of the strategies requires                  15 a case-by-case approach.                  16 This slide sets out the variety of factors to be                  17 considered: for example, economics, the economic                  18 imperative of maintaining HEP storage; the physical                  19 conditions, which relates to the hydrology, sediment                  20 characteristics at the site, reservoir geometry and dam                  21 configuration; and social and legal constraints, which                  22 involve the community and legal imperatives that will                  23 influence sediment management options. Allow me to now                  24 develop some of these strategies in a little more detail                  25 and with examples.</p> <p style="text-align: center;">Page 94</p>	<p>1 the high-capacity gates that are open to pass the flood                  2 at the lowest water level consistent with the other                  3 operational parameters.                  4 The strategy is to convert the reservoir into                  5 fast-flowing river during the sediment-laden floods.                  6 The high velocity is used to minimise deposition of                  7 sediments and also to scour existing sediment in                  8 a manner similar to the reservoir flushing, but without                  9 emptying the reservoir. This also avoids the very high                  10 sediment concentrations normally associated with empty                  11 flushing.                  12 Slide 18.                  13 Sluicing can be performed during a major storm or                  14 for a significant portion of a monsoon season.                  15 Image A, this one (indicating), you can see                  16 operation of a reservoir at full pond level during the                  17 monsoon. The operating pool acts like a sediment trap.                  18 As water flows into the operating pool, it carries with                  19 it sediment, which becomes trapped.                  20 In contrast, image B here shows the reservoir held                  21 at a minimum operating level during the monsoon, which                  22 maintains the operating pool empty and thus minimises                  23 its capacity to trap the sediment. Simply put, sediment                  24 will not be trapped in the operating pool while it is                  25 empty.</p> <p style="text-align: center;">Page 96</p>

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

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

14 Slide 19.

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

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

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1 a point below the dam, here (indicating).  
 2 Bypass systems typically use a sediment bypass  
 3 tunnel. A bypass system can be designed to divert both  
 4 suspended and bed load or suspended load only.

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

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

20 Slide 20.

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

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1 to an existing project. They may be constructed for  
 2 supercritical flow, with maximum velocities around  
 3 10 metres per second.

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

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

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

23 Slide 22.

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

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

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

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

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

25 Off-stream reservoirs can be highly effective in the

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1 Himalayan environment, leaving the off-stream pondage  
 2 empty during the monsoon and operating the pondage only  
 3 during the dry season, using water that is largely free  
 4 of sediment. It does not alter the natural pattern of  
 5 sediment transport along the river. The main limitation  
 6 is that most hydro sites do not offer the required  
 7 topography.  
 8 Slide 24.  
 9 One of the strategies for removing deposited  
 10 sediment is pressure flushing.  
 11 In the left frame, (a), this one (indicating), you  
 12 see a plan view, looking down from the top. When  
 13 a low-level outlet is opened but the reservoir remains  
 14 at a high level, a scour cone will develop only in  
 15 immediate vicinity of the outlet. In the right, here  
 16 (indicating), image (b) or section A-A, showing the side  
 17 view of the outlet and scour cone.  
 18 This process is termed "pressure flushing" because  
 19 it does not depend on reservoir drawdown. It is used to  
 20 keep immediate vicinity of an intake free of sediment,  
 21 but cannot remove sediment accumulation at any distance  
 22 from the outlet.  
 23 This is a photo of the scour cone, as you can see  
 24 here -- this is the scour cone (indicating) -- at the  
 25 outlet of sedimented reservoir on Rio San Antonio in

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1 Brazil. You can see the limit of the cone in the  
 2 semicircle outline of the water, this one (indicating).  
 3 Slide number 26.  
 4 Empty flushing or drawdown flushing is when  
 5 low-level outlets -- this one (indicating) -- are used  
 6 to empty the reservoir such that river flow scours the  
 7 exposed sediment bed and carries the eroded sediment  
 8 through the outlet and downstream of the dam. For this  
 9 to work, the low-level outlet would normally be located  
 10 near the bottom of the dam, near the original stream  
 11 bed.  
 12 The full sequence requires days or weeks between  
 13 drawdown, flushing and refilling of the reservoir,  
 14 depending upon the reservoir size, type of dam, the  
 15 sediment volume and downstream environmental  
 16 limitations.  
 17 Empty flushing often has significant downstream  
 18 impacts, due to extremely high sediment concentrations  
 19 which can injure aquatic life, impair water quality for  
 20 downstream users, and increase sedimentation in the  
 21 downstream river and irrigation intakes and canals.  
 22 Typically, it is not the only available form of sediment  
 23 management.  
 24 Slide 27. This photo shows the empty flushing in  
 25 the Middle Marsyangdi hydropower reservoir in Nepal.

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1 The flow is towards the left, from this side to this  
 2 (indicating). Notice that the water is turbulent,  
 3 scouring the bottom. And also notice the high sediment  
 4 concentrations, which are visible as dark colour of the  
 5 water.  
 6 Slide number 28.  
 7 Another method for removing deposit sediments is  
 8 mechanical removal, such as dredging. This photo shows  
 9 the Bajo Anchicayá hydropower reservoir in Colombia,  
 10 which has been dredged continuously since 1962.  
 11 Even though dredging is costly, the advantage is  
 12 that it does not interfere with the hydropower  
 13 operations, unlike flushing. That requires power  
 14 production to be stopped.  
 15 Environmental impacts depend on how sediments are  
 16 delivered to the river below the dam. In Himalayan  
 17 environments, the disposal of dredged sediments to  
 18 an upland area is not possible in the long run, owing to  
 19 the massive volumes of sediments involved and lack of  
 20 disposal sites.  
 21 This presentation has given you a bird's eye view of  
 22 the wide variety of strategies that can be used to  
 23 management sediment. It will depend on the site and  
 24 other factors.  
 25 My colleague Dr Abbas will address you on intakes

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1 and turbines, and if you have any questions before that.  
 2 PROFESSOR BUYTAERT: Thank you very much.  
 3 I don't think you mentioned density current  
 4 flushing. Is that operated at all here in Pakistan?  
 5 MR FAROOQ: Density current flushing?  
 6 PROFESSOR BUYTAERT: Yes.  
 7 MR FAROOQ: At the moment, density current flushing is not  
 8 implemented at any site, but it is under study at the  
 9 Bhasha Dam site for sediment management.  
 10 PROFESSOR BUYTAERT: Okay, thank you.  
 11 A follow-up question. You did mention off-stream  
 12 storage. Are there any off-stream storage dams? I know  
 13 you mentioned that you need very specific geographical  
 14 conditions. But are there any examples of off-stream  
 15 storage here in Pakistan?  
 16 MR FAROOQ: In Pakistan, there is an off-stream storage that  
 17 is at the planning stage at the moment. But I think  
 18 it's -- if I could correctly recall its name. It is  
 19 maybe Akhori Dam. So it is a kind of an off-stream  
 20 storage, but it is at the planning stage at the moment.  
 21 PROFESSOR BUYTAERT: Okay, yes. Thank you.  
 22 THE CHAIRMAN: So I had just a question about, I guess,  
 23 pressure flushing. And I don't know if we can go back  
 24 to the slide that showed the pressure flushing (24).  
 25 But it's just a question as to the worst case scenario

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

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

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

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1 I will now address the second challenge of sediment  
 2 management: I mean to say high sediment concentrations  
 3 specially sands, which cause abrasion damage, a loss in  
 4 efficiency, which requires frequent repairs.  
 5 Slide 30.  
 6 Coarse sediment can cause catastrophic damage to all  
 7 types of hydromechanical equipment, including what you  
 8 see in this magnified image. In order to understand the  
 9 scale of this image, the width of this image is about  
 10 one fifth, okay? And in this one fifth you can see the  
 11 impact of abrasion on the turbine runner.  
 12 The rate of abrasion on a turbine and other  
 13 hydraulic equipment increases as the head increases.  
 14 The larger the head, the higher the abrasion rate. For  
 15 example, the rate of abrasion on a turbine operating at  
 16 800 metres of head will be much faster than a turbine  
 17 operating at only 50 metres of head.  
 18 The rate of turbine abrasion also increases with the  
 19 grain size. Sand particles are much more abrasive than  
 20 smaller silt particles because sand has more momentum  
 21 and strikes the runner blades with greater force. Sand  
 22 particles larger than approximately 0.2 to  
 23 0.4 millimetres are specially damaging.  
 24 As I mentioned in my overview, Himalayan rivers  
 25 carry a high content of sand compared to most other

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1 rivers. This contains silica, a mineral that is much  
 2 harder than steel. It will abrade turbines. And if the  
 3 sand grains are angular, as you have seen through the  
 4 magnifier, they are approximately twice as abrasive.  
 5 Turbine abrasion increases costs. Each Francis  
 6 turbine runner [costs] between US\$3-4 million to  
 7 purchase a large runner. It can take several weeks to  
 8 change out. Power generation efficiency also declines  
 9 due to abrasion.  
 10 However, in some cases, repairs and acceptance of  
 11 efficiency loss may be the most cost-effective approach  
 12 as compared to other options. This is specially true  
 13 for the areas of monsoon climate, where there is excess  
 14 water available during summer months to offset the  
 15 efficiency loss of the turbine due to defatation of  
 16 abrasion.  
 17 Slide 31.  
 18 My colleague Mr Ayub Malik has shown you some intake  
 19 designs in his presentation. In this snap, we have  
 20 an example of a problematic design at Pakistan's  
 21 Warsak Dam. This dam is on the Kabul River coming out  
 22 of Afghanistan. The dam was built in 1960 and provided  
 23 a deep intake with no effective way to manage sediment.  
 24 This snap shows the 14-metre-deep intake that is  
 25 right now submerged under the sediment. And this

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1 intake for the turbines of a run-of-river hydroelectric  
 2 project on the Western Rivers of the Indus Basin?  
 3 In the context of a run-of-river headworks, let's  
 4 discuss the requirement for, or benefit of, a deeper  
 5 intake. We can list out four circumstances.  
 6 A lower-level intake can be beneficial to minimise  
 7 the entry of floating debris.  
 8 The second circumstance is: for sediment control,  
 9 placing the intake at a lower level will not be  
 10 beneficial or required; in fact, it will be harmful, as  
 11 it will increase coarse sediment ingress.  
 12 Number 3: beyond the minimum depth required to  
 13 control vortex formation, additional lowering of the  
 14 intake will not be beneficial.  
 15 Number 4: as far as cleaning and maintenance issues  
 16 are concerned, the deeper intake will not be beneficial  
 17 or required, due to the increased difficulty of removing  
 18 debris trapped against the deeper intake trashracks, as  
 19 you have seen here at Warsak in Pakistan.  
 20 Slide 33.  
 21 Mr Chairman, now I turn to adaptive strategies for  
 22 dealings with sediments.  
 23 One strategy involves covering the turbine runner  
 24 with a thin layer of abrasion-resistant material, such  
 25 as tungsten carbide, an extremely hard ceramic. It may

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1 intake, you can see here that this is the pond level, or  
 2 you can see the flood line in which this dam operates,  
 3 and right now you are seeing the situation when the  
 4 reservoir is drawn down. So this is what happens when  
 5 you keep your intakes quite deep.  
 6 Slide 32. What you have seen in my last slide has  
 7 been shown in detail here, in terms of elevations and  
 8 depths.  
 9 The watermark I was showing you was this  
 10 (indicating), and you were seeing in the last slide the  
 11 top of this intake. And you have observed that up to  
 12 this level, or you can say up to the spillway crest, all  
 13 intake has been buried in the sediment.  
 14 At this plant, despite this abrasion problem, it has  
 15 been possible to sustain planned power production by  
 16 passing more water through the turbines during the  
 17 monsoon, when most power is produced, to offset the loss  
 18 in turbine efficiency due to abrasion. With regular  
 19 repair circles of the turbine, this is another example  
 20 showing that even with difficult sediment problems,  
 21 there are solutions that make economic sense.  
 22 Mr Chairman, this is a good time to answer the  
 23 Court's question no. 3, which is: what are the range of  
 24 circumstances where it might be either beneficial or  
 25 required to locate at a relatively low level the power

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1 be renewed every few years. These coatings can  
 2 significantly retard, but not eliminate, abrasion  
 3 damage.  
 4 In this photo, this has been taken at this project,  
 5 Neelum-Jhelum Project, after four years' operation of  
 6 the runner. You can see the situation here. You can  
 7 compare the difference between the coated part of the  
 8 wicket gate on the left -- you can see this is coated  
 9 part, which remains smooth -- with the part on the  
 10 right, where the coating has been removed by sediment  
 11 abrasion and cavitation damage. Excessive abrasion can  
 12 also cause the turbine to vibrate. Operation with  
 13 a heavily damaged turbine runner can pose a safety risk  
 14 as well.  
 15 In general, where an uncoated runner will require  
 16 repair after one year, a coated runner may extend the  
 17 repair cycle to around four years. Coating can  
 18 therefore be an economical, long-lasting and effective  
 19 strategy against abrasion.  
 20 Coatings will need to be reapplied every few years,  
 21 at a cost of around US\$0.5 million. It's not the ideal  
 22 solution for all the projects.  
 23 Slide 34.  
 24 Now I come to my last point of this presentation:  
 25 the sediment load on the turbines can also be minimised

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

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1 width, or you can say the top surface, is around  
 2 25 metres. And the depth of these desanders varies from  
 3 20 metres to 23 metres. It has a slope of 1% along its  
 4 length. So higher depths are there, as compared to  
 5 lower depths here (indicating). A typical pattern of,  
 6 you can say, a reservoir in which the coarser particles  
 7 settle at upstream part and the finer particles go down.  
 8 THE CHAIRMAN: Can I ask -- I can understand why you would  
 9 want two desanders, so that you can use one while you're  
 10 flushing out the second one, but I'm not sure why you  
 11 have three desanders. What's the advantage of having  
 12 that third desander?  
 13 DR ABBAS: It's basically -- you can say the designers  
 14 usually take care of redundancy in their design. So at  
 15 one time, only one chamber will be evacuated. So the  
 16 design is in a way that two of the chambers will be  
 17 continuously supplying 280 cumecs of the flow required  
 18 at the tunnel.  
 19 Slide 36.  
 20 As you can see from this graph, properly designed  
 21 desanders can be very efficient at trapping sediments.  
 22 The Neelum-Jhelum Project desander has been designed to  
 23 trap essentially all sediments larger than  
 24 0.14 millimetres, which is the most problematic for  
 25 turbine abrasion. Even the grain as small as

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1 0.1 millimetre, the Neelum-Jhelum Project desander is  
 2 designed to trap 89% of particles.  
 3 You can see here the sand particles which are being  
 4 removed from the desander. From here onwards, or you  
 5 can say from this jar (indicating) onwards, all the  
 6 sediment particles are being excluded. So these finer  
 7 fractions are going there.  
 8 Slide 37.  
 9 Mr Chairman, on behalf of Mr Farooq, I thank you,  
 10 members of the Court, for your kind attention. If you  
 11 have any questions.  
 12 DR BLACKMORE: Thank you for that. This is a left-field  
 13 question.  
 14 So you are now recovering this sand material as  
 15 a high-quality product. You've dropped it out. It's  
 16 coarse, like it's granular. Do you sell it, or do you  
 17 dump it in the river?  
 18 Just a question, because I know how much it costs to  
 19 buy if you're in Australia.  
 20 MR ALAUDDIN: (Inaudible) ... downstream.  
 21 DR BLACKMORE: Okay.  
 22 THE CHAIRMAN: So it's placed back in the river?  
 23 DR BLACKMORE: It's a mining operation.  
 24 PROFESSOR BUYTAERT: Would you be able to go back to  
 25 slide 31, the dam with the sediment problems. I didn't

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1 get which dam is this. What's the location?  
 2 DR ABBAS: It's the Warsak Dam.  
 3 PROFESSOR BUYTAERT: Okay.  
 4 DR ABBAS: It's just close to the border with Afghanistan,  
 5 coming from the western side.  
 6 PROFESSOR BUYTAERT: Okay, thank you.  
 7 I take it that this dam design doesn't have any deep  
 8 orifices for drawdown flushing; is that right?  
 9 DR ABBAS: No.  
 10 PROFESSOR BUYTAERT: Would that, in this particular case,  
 11 solve the problem of the sedimentation? Or the other  
 12 way --  
 13 DR ABBAS: We are dealing with the sediment problem there.  
 14 PROFESSOR BUYTAERT: Do you know why they did not include  
 15 deep orifices or drawdown flushing in this particular  
 16 design?  
 17 DR ABBAS: It's a typical design issue, I can generally say.  
 18 PROFESSOR BUYTAERT: Okay. Yes.  
 19 DR ABBAS: It's a design problem.  
 20 PROFESSOR BUYTAERT: Okay, thank you.  
 21 THE CHAIRMAN: If I recall correctly, that one was built in  
 22 1960?  
 23 DR ABBAS: Yes.  
 24 THE CHAIRMAN: And therefore at an earlier stage, and  
 25 perhaps you've gotten better at designing your dams.

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1 So I had a leftover question that I think we decided  
 2 Mr Miana might be able to answer it. So if we could go  
 3 back to slide 13 here.  
 4 My question, Mr Miana, which we weren't entirely  
 5 comfortable answering earlier without your expertise, my  
 6 question was: when you have an orifice that you are  
 7 using to try to flush the sediment, are there situations  
 8 where something happens, a large boulder drops down into  
 9 that area of the orifice or maybe even this delta  
 10 collapses in some way, and you actually block up the  
 11 orifice? Does that happen? I'm asking about the worst  
 12 case scenario here.  
 13 MR MIANA: For the last two years I am here and I did not  
 14 observe that phenomenon. And we have been operating  
 15 these orifices for passing the flood in the monsoon  
 16 season. I think before that it never happened.  
 17 MR ALAUDDIN: After T4 project?  
 18 MR MIANA: T4 project? Not this one, no.  
 19 THE CHAIRMAN: I was really just asking generally, in your  
 20 knowledge of dams.  
 21 MR ALAUDDIN: (Inaudible, no microphone) has referred to  
 22 this, that he had experience.  
 23 MR MIANA: T4 project ...  
 24 MR ALAUDDIN: (Inaudible, no microphone)  
 25 MR MIANA: No, no, no, that was not inlet, that was outlet.

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1 raised that 1,225 feet above sea level, and now it has  
 2 been raised to, if I remember, 1,300-something over  
 3 there, at the level of this one. So all of the intakes  
 4 has been raised, just to avoid the ingress of that one.  
 5 DR BLACKMORE: But eventually you've got a dam that's full  
 6 of sediment that's going to continue to build sediment  
 7 up, so at some stage you've got to be able to pass it or  
 8 manage it. Because I think that sort of sediment going  
 9 through the tunnel at Tarbela and the turbines would be  
 10 potentially very bad.  
 11 MR MIANA: I think they are just managing with increasing  
 12 the minimum operating level just to avoid that.  
 13 DR BLACKMORE: To buy time?  
 14 MR MIANA: For the time being.  
 15 THE CHAIRMAN: Very good. Okay, I think that's it for ...  
 16 (Pause)  
 17 MR MINEAR: First of all, I'd like to thank all the  
 18 presenters for the very informative information you've  
 19 conveyed. It's all been very helpful.  
 20 I'd like to revisit an issue that I think Mr Farooq  
 21 raised, and that was the discussion of optimal pondage  
 22 and how to calculate that. And I'd just like to have  
 23 some additional clarification on that, if I could.  
 24 Let's assume a situation where we don't have any  
 25 legal or regulatory limits on the determination of

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1 MR ALAUDDIN: That was outlet? Okay.  
 2 MR MIANA: Yes, that was the outlet gate, and the gate stuck  
 3 in the silt only. And we have to then, I mean, liquefy  
 4 that silt and then take away the outside. We had no  
 5 issue of the boulder, only sticking of the gate with the  
 6 silt and the clay, that we have seen in the gates fine  
 7 clay or whatever.  
 8 THE CHAIRMAN: So just generally speaking, you're not aware  
 9 of situations where there's some sort of catastrophic  
 10 collapse where the sediment ends up blocking entirely  
 11 the orifice?  
 12 MR MIANA: No, never. The Tarbela, we never heard about  
 13 this. I am working at Tarbela since 1992. My first  
 14 posting was at Tarbela, and at different times of my  
 15 professional life I have been posted there. So we never  
 16 heard about the blockage of any of the tunnels from  
 17 intake side.  
 18 THE CHAIRMAN: Do you have a sense, over time, what will  
 19 happen at Tarbela if that delta keeps approaching the  
 20 dam, what might be expected, or how you would try to  
 21 avoid the sediment build-up from preventing the  
 22 operation of the dam?  
 23 MR MIANA: Actually, at present, with the project of  
 24 Tarbela 4, we have already raised the intakes of  
 25 Tarbela 3 and Tarbela 4. Tarbela 1 and 2 already have

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1 pondage. I understand from your presentation that the  
 2 determination of pondage is just one variable in the  
 3 overall design, and it's a function of the power demand,  
 4 the height of the dam, the discharge into the reservoir.  
 5 And it is calculated in the course of the -- at least in  
 6 the engineering study and perhaps before then.  
 7 Is that all basically correct?  
 8 MR FAROOQ: Will you please repeat your question?  
 9 MR MINEAR: Sure. I'd just like to have a discussion with  
 10 you about determining optimal pondage in a situation  
 11 where it's determined primarily as a matter of the  
 12 efficiency or the economic viability of the dam.  
 13 I understood -- I just want to make sure  
 14 I understood what you said -- that that determination is  
 15 made on the basis of your power demand, the discharge  
 16 into the reservoir, the height of the reservoir, perhaps  
 17 the head as well, and so it is just a dependent variable  
 18 of these other factors. Is that basically correct?  
 19 MR FAROOQ: Yes, it could be. I mean, it depends on one or  
 20 more factors. But the most important factor for  
 21 determine of the pondage is the flows in the winter.  
 22 MR MINEAR: Yes. So the minimum mean flow, roughly, in the  
 23 winter.  
 24 MR FAROOQ: I mean at least you have some flow in a day that  
 25 you can fill the storage at part of the day and use it

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

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1 I know, or on the basis of knowledge that I have, first  
 2 the hydropower potential at a site is determined by the  
 3 overall hydrology at the dam site. For example, you  
 4 don't pick or choose one month and ignore the other  
 5 months; you try to base on the hydrology over the  
 6 365 days in a year. And based on the long-term  
 7 hydrology, first you determine that: yes, this is the  
 8 hydropower potential at site which I can use optimally  
 9 where my cost is comparatively less and my benefits are  
 10 relatively high.  
 11 Once you have determined the hydropower potential at  
 12 a site, then on the basis of -- now, for example, in the  
 13 case of Neelum-Jhelum Hydroelectric Project, 969 MW is  
 14 the optimum installed capacity at my plant. And in view  
 15 of the -- now, here comes second part: that, yes, I am  
 16 going to make a 969 MW [plant] at this location. But  
 17 I have winter flows, because it is a run-of-river  
 18 hydroelectric project.  
 19 And then you see: what are my winter flows, or the  
 20 prevalent winter flows. And based on the prevalent  
 21 winter flows, then -- I mean, if I can, for example,  
 22 20 hours of the day, I can store only 4 million  
 23 cubic metre of water, there is no sense to provide  
 24 6 million cubic metres, or maybe 8 or maybe 10, because  
 25 I am not going to use that, and this would be redundant

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

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

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1 into play.  
 2 MR FAROOQ: Yes. Because at feasibility stage, the  
 3 economics of the project is established and then you  
 4 move ahead. So at least by the feasibility stage,  
 5 I think the operational pool volume should be  
 6 determined.  
 7 MR MINEAR: Okay. Thank you very much. This is all very  
 8 helpful for me.  
 9 MR FAROOQ: Thank you, sir.  
 10 PROFESSOR BUYTAERT: Can I ask a quick follow-up question.  
 11 So during the dry season, when there's not enough  
 12 water to operate the turbines at full power for  
 13 24 hours, you said that you reduce the time you operate  
 14 them. But do you always operate them at maximum  
 15 capacity and reduce the time, or does it also happen  
 16 that you reduce the power outputs for longer periods?  
 17 Can you, for example, run them 4 hours at full capacity  
 18 or, say, 8 hours at 50%? Do you vary both? Or is it  
 19 always full power for whatever period of time you can  
 20 afford, given the inflows?  
 21 MR FAROOQ: Sir, I would say that it is basically choice of  
 22 the operator. For example, if I have not enough flow in  
 23 my operating pool, then I may decide whether I would  
 24 like to operate the four turbines for, say, 1 hour, or  
 25 maybe I would like to operate two turbines for the

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1 2 hours, or maybe 1.5 hour, or maybe some more time.  
 2 So it is, I mean, choice of the operator.  
 3 PROFESSOR BUYTAERT: Okay, thank you.  
 4 MR MINEAR: As a follow-up to our engineer's question here,  
 5 does the factor of peak demand enter into that  
 6 determination; in other words, the electricity demand at  
 7 any given time, when the turbine is at full or half  
 8 speed?  
 9 MR FAROOQ: Sir, yes, I would say that the operators --  
 10 I mean, the operation is controlled here in Pakistan,  
 11 I think, through NPCC, basically, which is controlling  
 12 what and where is being produced and how it is being  
 13 transported in other part of the country.  
 14 MR MINEAR: Thank you very much.  
 15 THE CHAIRMAN: So thank you very much, Dr Abbas. Thank you  
 16 very much, Mr Farooq. I don't think we have any other  
 17 questions on this presentation.  
 18 What I would propose is that we perhaps take a break  
 19 now and allow the Court to just check in with itself to  
 20 see if we have any further general questions. I don't  
 21 know if now is a good time to have tea or coffee as  
 22 well.  
 23 MR MIANA: It is ready.  
 24 THE CHAIRMAN: Perfect. Then why don't we have a break of,  
 25 say, about 15 minutes or so, and then we'll come back in

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

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

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1 going to be seeing there tomorrow, let me just say  
2 thanks on behalf of the Court now for you. But we look  
3 forward to that visit, and expect a few more questions  
4 tomorrow from us.  
5 Okay? Very good. Thank you so much.  
6 (The day concluded)

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