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TECHNO-ECONOMIC ASSESSMENT STUDY FOR ROGUN HYDROELECTRIC CONSTRUCTION PROJECT

PHASE II: CONCLUSIONS AND RECOMMENDATIONS

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Volume 7: Conclusions and Recommendations

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1 DESIGN APPROACH FOR THE PRESENTED ALTERNATIVES

As per the scope of services defined in the Terms of Reference (ToR), an extensive techno-economic assessment has been carried out on all existing design work to date and made available to the Consultant. All design change recommendations resulting from this assessment strictly comply with the design criteria laid down by the Consultant in Volume 3 Chapter 1 (Design Criteria) of the Phase II Report. These criteria are based on internationally accepted standards and state of the art engineering practice for large hydropower projects. This approach ensures full transparency in the methodologies and concepts adopted in the assessment as well as recommended design changes.

The same strict principles have been applied to the different alternatives presented in this report, ensuring an equal design basis for the presented options. These design criteria have been established with the objective of combining quality, performance, sustainability and cost optimization for all proposed options as further elaborated below.

1.1 Quality

The design criteria used in this assessment are based on internationally recognized standards and best industry practice. They aim to guarantee, if the recommendations are strictly followed, that the quality of works potentially derived from these concepts is ensured. Long term safety of the works is of prime importance and is the driving force behind all of the design concepts developed in this report.

1.2 Performance

All structures have been designed to ensure optimal performance during the project operation, once safety of operation has been guaranteed.

1.3 Sustainability

Long term Safety and Performance of the proposed Rogun project shall be guaranteed. In the particular case of the proposed Rogun project and given the magnitude of the works to be implemented by the Government of Tajikistan, all efforts have been made to ensure that the final hydro project facility will not become a liability for the Country at any point in time. The assessment has therefore been carried out keeping in mind long term impacts and end of life aspects of the project, once the facility can no longer produce energy.

1.4 Cost Optimization

Once Quality, Performance, Safety and Sustainability have been guaranteed, cost optimization is taken into account when completing the design, in line with the best interests of the Client developing the project.

1.5 Risk Management

A thorough risk register has been developed for the project to exhaustively identify potential future risks for all alternatives, if the project were to be implemented. All project alternatives have been found to have the same list of risks.

For each identified risk, feasible mitigation measures have been recommended. The objective was in each case to reduce the risks to an acceptable level in compliance with the indicated Quality, Safety, Performance and Sustainability requirements.

2 CONTEXT OF THE PROJECT ALTERNATIVES

The proposed alternatives have been duly derived taking into account the complex features of Rogun project context:

2.1 Natural Conditions

2.1.1 Geology and Salt Dome

The proposed alternatives duly account for the complex geology of the site. An extensive review of the existing data and additional site investigations have allowed, during the course of the assessment, a better understanding of the site conditions, in particular on the downstream right bank.

The presence of a salt body located within the dam footprint of all alternatives has been studied in detail. This is the subject of the Phase 0 Report that includes numerical models and physical investigations to carefully address this issue. All alternatives are equally exposed to the risk inferred by the presence of the salt dome. However, with the implementation of the recommended mitigation measures described in the Phase 0 Report, this risk can be reduced to a level that ensures the long term safety of the proposed dam alternatives.

2.1.2 Seismicity

A deterministic approach has led to a preliminary assessment of the seismic design parameters against which the stability of the different dam alternatives shall be ensured. As detailed in the Dam Stability Report, all three different dam alternatives are designed to withstand the Peak Ground Acceleration corresponding to the Maximum Credible Earthquake (estimated to be 0,71g). This is in full compliance with international design criteria adopted for dams of this magnitude.

2.1.3 Hydrology

Design floods have been derived from extensive hydrological series. The Probable Maximum Flood (PMF) has been considered as the design flood for all dam alternatives, with a value of 7800 m^3/s.

Water management studies for the three proposed alternatives and corresponding energy generation have been derived from the same series. The comparison of benefits for each alternative is therefore based on a long data set, considered reliable for determining the economic viability of the proposed design alternatives.

2.1.4 Sedimentation

The sedimentation study has been based on available data, including existing surveys of the Nurek reservoir. In order to appropriately address uncertainties, the same conservative approach has been used to define the different lifetimes of the proposed alternatives. The annual inflow of sediments in the reservoir has been considered to be 100 million m^3 / year.

It should be noted that due to the high level of sediment inflows in the Vakhsh River, all the proposed dam alternatives have a limited lifetime. The Rogun reservoir is bound to be filled with sediment in a given period of time. Therefore, specific end-of-life strategy for all dam alternatives has been planned.

2.2 Existing Assets

All alternatives have been designed to appropriately incorporate the existing facilities previously constructed at the Rogun site. A thorough assessment of these facilities was carried out and detailed in the Phase I Report. The aim of the assessment was to determine the suitability of these structures with respect to the proposed Rogun alternatives. Where necessary, mandatory remedial measures have been recommended to bring the structures up to the safety and performance standards required for the project.

All three proposed alternatives try to incorporate existing equipment and facilities where possible. It is in the best interests of the Client developing the project to optimize the overall project cost.

Each Rogun alternative is proposed to work in tandem with the Nurek dam in order to derive full benefits from what is a major asset in the overall Tajik existing hydro portfolio. All efforts have been made to ensure energy production maximization of the Nurek HPP during the most extended period possible.

2.3 Water Sharing Institutional Framework

All project alternatives have been defined within the strict constraint that the Vakhsh cascade operation principle downstream of Nurek remains unchanged during the implementation (filling) and operation of any of the Rogun alternatives. In practice this means that, every year, the combined reservoirs of Rogun and Nurek will be operated in a manner ensuring that the water volume transferred from summer to winter is consistent with that transferred at present. Future use of its water share by Tajikistan has been incorporated in the model, in strict compliance with the existing practice for water allocation on the Vakhsh River.

It should therefore be highlighted that all proposed dam alternatives can be operated under a regime which will not change seasonal water availability in the downstream area and will remain similar to the way the Cascade is operated today. The only sizable change will be future use of Tajik water share initially for filling the reservoir and then for irrigation, as per the agreements and practice currently in place.

2.4 Environmental and Social Impacts

The Environmental and Social Impact Assessment (ESIA) was carried out in parallel by the ESIA consultant based on the technical features of the proposed alternatives defined in the Phase II Report.

The analysis of environmental and social impacts of the three alternatives carried out by the ESIA consultant did not lead to eliminate any of the proposed options. It was verified in considering the comparison of the three alternatives that none of them had unacceptable level of Environmental and/or Social impacts – although the highest dam does require significantly more resettlement than the other two dam height options.

All Environment and Social cost for the different dam alternatives as estimated by ESIA consultant were duly taken into account to derive the overall capital cost of each proposed options. In accordance with the scope of TEAS Consultant, environment and social impacts are therefore reflected in the economic comparison of alternatives.

2.5 Electricity Demand Forecast and Market

All the proposed Rogun alternatives will generate electricity that can be used both to meet the domestic demand and as well as provide exports via interconnectors to neighboring countries. A detailed forecast of domestic demand growth, including assessment of currently unmet demand, has been carried out. This analysis forms an integral part of the assessment, ensuring that all the proposed alternatives are adequately adapted to the existing markets and their future trends.

2.6 Least Cost Expansion Plan and Economic Analysis

The Least Cost Expansion Plan and Economic Analysis of all proposed Rogun alternatives show that each Rogun design option is forecast to provide significant total system cost savings and generate positive Net Present Value (NPV) under a wide range of assumptions. This benefit largely derives from the controllable nature of generation from the Rogun project. All the Rogun design alternatives are better suited to demand (in particular in winter) and also provide greater levels of exports than other production alternatives in Tajikistan.

3 BROAD CONCLUSIONS OF THE ALTERNATIVES STUDY

3.1 Main Technical Features

The same design criteria have been used to derive nine Rogun alternatives as presented in Volume 3 Chapter 3 (Design of Alternatives) of the Phase II Report. These nine design options comprise of three dam height alternatives (FSL 1290 m.a.s.l., FSL 1255 m.a.s.l. and FSL 1220 m.a.s.l.) with three different installed capacities (MW) for each dam height.

The details for the nine design options, all of which are considered technically feasible, are described below:

3.1.1 Dam Features

	FSL – 1290	FSL – 1255	FSL – 1220
Dam crest (m.a.s.l.)	1300	1265	1230
Foundation level (m.a.s.l.)	965	965	965
Dam height (m.a.s.l.)	335	300	265
Total reservoir capacity (hm^3)	13 300	8 550	5 220
Stage 1 elevation (m.a.s.l.)	1110	1090	1075

Table 3.1: Dam alternatives main features

3.1.2 EM Equipment Characteristics

Total Capacity Installed (MW)	3600	3200	2800
Number of units	6	6	6
Number of units reused (*)	2	2	2

Table 3.2: EM Equipment - Final Dam Elevation 1290 m.a.s.l.

Total Capacity Installed (MW)	3200	2800	2400
Number of units	6	6	6
Number of units reused (*)	2	2	2

Table 3.3: EM Equipment - Final Dam Elevation 1255 m.a.s.l.

Total Capacity Installed (MW)	2800	2400	2000
Number of units	6	6	6
Number of units reused (*)	2	2	2

(*) Adopting final runners since the commissioning

Table 3.4: EM Equipment - Final Dam Elevation 1220 m.a.s.l.

3.2 Implementation Schedule and Logistics

All alternatives have been thoroughly analyzed to derive a detailed construction schedule. The resulting different construction periods for the three dam alternatives are as presented in Table 3.5:

	FSL 1290	FSL 1255	FSL 1220
TEAS validation and GoT decision to proceed with the project	0	0	0
River Diversion date	28	28	28
End of cofferdam construction	36	36	36
End of stage 1 dam construction	58	53	49
End of dam construction	163	142	120

Table 3.5: Implementation Schedule - Key data - Time from Pre-Contract (in months)

As detailed in the main Phase II Report, the extent to which facilities, existing infrastructure and access tunnels need to be developed for construction works of the magnitude of the proposed Rogun project are similar for all alternatives. Implementing any of the different alternatives will require sustained quality control and organization on site. It is to be noted that the main difference in project construction period is related to the dam fill placement. This means that activities with a high level of risk and contingencies as underground structures and tunnels are of similar nature for the three alternatives. Consequently, in this particular case, an increased construction period does not necessarily mean an increase in implementation risks for a given option.

For all project alternatives, due to the very challenging nature of the Project and of its tight scheduling, the Consultant recommends the careful selection of experienced and highly qualified Main Contractor/Contractors (and potentially Sub-Contractors) as well as Designers and Owner’s Engineers.

3.3 Early Generation Concept

Considering the long duration of the construction period for all the proposed dam alternatives, an early impounding and early generation concept has been adopted for all options. This will allow for the early generation of benefits during the lengthy implementation (filling) stage of the project.

During construction, the operation of Rogun has also been optimized in order to increase the energy output from the whole cascade as early as possible with the following main results:

Dam alternative	FSL 1290	FSL 1255	FSL 1220
Time to reach Normal Operation	16 years	13 years	9 years
Additional energy produced by the cascade during construction compared with "no Rogun" option	111 TWh	68.9 TWh	37.2 TWh
Equivalent years of normal operation	7.7 years	5.5 years	3.7 years

Table 3.6: Energy production during construction for all dam alternatives

3.4 Energy Generation and Date of Commissioning

As discussed above, early generation together with the progressive installation of units (turbines) has been adopted for the project. The main dates of commissioning of the different units are reproduced below and have been derived from a detailed analysis of the implementation schedule:

	FSL 1290	FSL 1255	FSL 1220
TEAS Validation and GoT decision to proceed with the project	0	0	0
Diversion	28	28	28
Commissioning U 6 Temp.	73	73	82 (*)
Commissioning U 5 Temp.	75	75	84 (*)
End of Erection U4	85	85	85
End of Erection U3	98	98	98
End of Erection U2	112	112	112
End of Erection U1	112	112	112
Minimum Reservoir level reach	112	94	80
Temp U5 and U6 shut down	117	114	(*)
Commissioning U 4	115	101	101
Commissioning U 3	117	114	114
Commissioning U 2	119	116	116
Commissioning U 1	121	118	118
Commissioning U 6	123	120	(*)
Commissioning U 5	127	122	(*)

(*) U5-U6 of alternative FSL1220 are directly installed with final configuration (i.e. with final runners and final generators). For alternatives FSL 1255 and 1290 installation is made with final runners and temporary generators.

Table 3.7: Implementation Schedule - Key data (2) – Time from Pre-Contract (in months)

For the baseline scenario discussed in the Reservoir Operation Chapter (Vol. 3, Chap. 5), the following average yearly energy outputs E_{Rogun} are expected to be produced by the different proposed design alternatives during normal operation:

Dam Alternative FSL 1290 m.a.s.l.	
Capacity	Average Yearly Energy in GWh
3600 MW	E_{Rogun}=14 398
3200 MW	E_{Rogun}=14 288
2800 MW	E_{Rogun}=14 066

Table 3.8: Average Yearly Energy - Dam Alternative FSL 1290 m.a.s.l.

Dam Alternative FSL 1255 m.a.s.l.	
Capacity	Average Yearly Energy in GWh
3200 MW	E_{Rogun}=12 391
2800 MW	E_{Rogun}=12 295
2400 MW	E_{Rogun}=12 072

Table 3.9: Average Yearly Energy - Dam Alternative FSL 1255 m.a.s.l.

Dam Alternative FSL 1220 m.a.s.l.	
Capacity	Average Yearly Energy in GWh
2800 MW	E_{Rogun}=10 121
2400 MW	E_{Rogun}=10 037
2000 MW	E_{Rogun}=9 800

Table 3.10: Average Yearly Energy - Dam Alternative FSL 1220 m.a.s.l.

3.5 Investment Cost

A detailed cost estimate (including unit rate analysis) has been established for the nine proposed alternatives. The main results of the cost to completion estimate, including physical contingencies, are reflected below:

	Design Alternatives								
USD million	**FSL 1290 m.a.s.l.**			**FSL 1255 m.a.s.l.**			**FSL 1220 m.a.s.l.**		
	3600 MW	**3200 MW**	**2800 MW**	**3200 MW**	**2800 MW**	**2400 MW**	**2800 MW**	**2400 MW**	**2000 MW**
Civil works (*)	3,398	3,398	3,398	2,876	2,876	2,876	2,199	2,199	2,199
Hydro-mechanical and electromechanical equipment and TL/SS (*)	1,176	1,081	1,013	1,060	993	916	945	868	798
Administration + engineering	229	224	221	197	193	190	157	153	150
Resettlement and infrastructure replacement cost	408	408	408	248	248	248	165	165	165
Total	**5,211**	**5,111**	**5,040**	**4,381**	**4,310**	**4,229**	**3,467**	**3,386**	**3,313**

(*) These costs include physical contingencies

Table 3.11: Investment cost break down for all proposed alternatives (in million USD)

3.6 Project Life

As already mentioned above, based in the estimated range of solid run off, the ultimate reservoir lifespan (when there is no more regulation possible in the reservoir) can be calculated for each alternative (see Table 3.12).

	Operating Lifetime
FSL=1290 masl	115 years
FSL=1255 masl	75 years
FSL=1220 masl	45 years

Table 3.12: Estimated Rogun reservoir ultimate lifespan

Note that rising of the intakes during the life of the project has been proposed in order to extend the life of each project alternatives to the maximum possible. An annual inflow of sediments of 100 hm^3 / year has also been assumed to derive these figures.

As discussed in Volume 2 Chapter 6 (Sedimentation), a free surface overflow spillway with adequate aeration and a dissipation device is mandatory. The proposed solution needs to be implemented in order to safely pass on the long term the design flood (i.e. PMF) when the spillway tunnels will cease to function due to blockage by sedimentation.

At this end of life stage, this surface spillway could also discharge the solid inflows and manage the sediment balance, long after the plant and the other spillway facilities will be put out of operation.

For all proposed options, an ultimate end of life management option could be to remove the gates from the surface spillway allowing the sediments to carve an incised channel through the spillway and underlying rock over a period of several decades. This solution is applicable for all proposed alternatives.

4 DETERMINATION OF PREFERRED PROJECT CONFIGURATION

4.1 Economic Evaluation

The economic analysis demonstrates the economic viability of all the Rogun design options under a range of assumptions as reflected in the following recapitulative table:

Dam alternative	Installed Capacity	Investment cost[1]	All-in levelised costs (2013-2050)[2] @ 10%	Probability-weighted PV of TSC savings[3] @ 10%	Probability-weighted Economic NPV[4] @ 10%
(FSL m.a.s.l)	(MW)	(USD million)	(USD/MWh)	(USD million)	(USD million)
1290	3600	5,211	57.78	640	800
	3200	5,111	56.89	674	841
	2800	5,040	56.55	632	817
1255	3200	4,381	58.20	640	702
	2800	4,310	57.57	622	721
	2400	4,229	57.11	569	724
1220	2800	3,467	50.31	450	609
	2400	3,386	49.97	424	616
	2000	3,313	50.88	393	560

Note: The colour coding is used to highlight the relative values for each parameter, not across all cases: red = worst (highest cost, lowest benefit), yellow = middle, green = best (lowest cost, highest benefit).

[1]: Investment cost is the simple sum of 1) Civil works, 2) Hydro-mechanical & electromechanical equipment, 3) Administration + engineering, and 4) Resettlement and infrastructure replacement (environment cost). Interest during construction is not included.

[2]: All-in levelised cost is the ratio of the present value (PV) of the investment cost to the PV of the generation, using a discount rate of 10%.

[3]: Total System Costs (TSC) for Tajikistan is defined as the sum of annualised capital expenditure repayments, non-fuel operating and maintenance (O&M) costs, fuel costs, flood protection benefits, and the net financial benefits from net exports. The savings are calculated compared to the situation where Rogun is not built, and presented here including a terminal value to the end of life for each design option. A reference set of assumptions plus eight sensitivities to this were examined, and the probability-weighted result across all these nine cases is shown here.

[4]: The Net Present Value (NPV) is the present value sum of the economic benefits (including downstream flood protection) less all economic costs. As with the TSC savings these have been calculated to the end of life for each design option, and assessed across the reference assumptions and eight sensitivities.

Table 4.1 : Results of Economic Analysis

The FSL 1290 m.a.s.l. alternative with installed capacity of 3200 MW shows the highest Total System Cost Saving and the highest Net Present Value of economic benefits. That shows that the incremental cost of implementing the highest alternative is compensated by the incremental benefits derived during the Project life. These results are reinforced with a lower discount rate, which apportions a greater weight to the long term benefits of the Project.

On a purely economic point of view, the highest dam alternative and intermediate installed capacity (FSL 1290 m.a.s.l. and 3200 MW) is the most attractive option.

4.2 Life Span and Economic Analysis

As shown above, the different proposed dam design alternatives have significantly different life expectancies (115 years, 75 years and 45 years for FSL 1290 m.a.s.l., FSL 1255 m.a.s.l. and FSL 1220 m.a.s.l. respectively). The difference in lifetimes between the proposed dam alternatives is a significant factor as Rogun project is a large investment for Government of Tajikistan as well as a major asset in both the overall energy sector of the country and the region.

Unfortunately, there are limitations in reflecting key economic parameters beyond 50 years, therefore the Least Cost Expansion Plan and Economic Analysis focuses on the period through to 2050. Moreover, long term benefits of such a large project are difficult to adequately assess, despite the inclusion of a terminal value calculation in the analysis, due to the damping effect of the discounting factor. However, the sensitivity analysis on discounting factor carried out clearly shows that any reduction in the discount rate significantly improves the net benefits from the highest dam option (FSL 1290 m.a.s.l.) showing that on the long run, the largest dam plays a major long term role in the Tajik energy system.

It is also clear that such a strategic investment for Tajik Government cannot be decided based on a 50 years study window, but should be seen as a legacy for future generations. This is a major argument in favor of the highest dam (FSL 1290 m.a.s.l.), that provides the longest project life, guaranteeing low cost energy production for the longest period to Tajik energy system and more generally to the Region as a strategic export project.

4.3 Sustainability and Long Term Management

As previously mentioned, the end of the life management of such a large asset will need to be dealt at the inception of the project and will require large investments (e.g. maintenance of the surface spillway used to evacuate the river flow when the dam will be filled with sediment).

The Consultant recommends putting a de-commissioning fund in place as early as possible, fed with part of the project benefits in order to finance these end of life costs. Financing such a fund will be easier for a project with an extended life that will provide benefits on a much larger period of time. It may also be assumed that engineering practices will have evolved during the life of the project. This definitely goes in favor of the alternatives with a longer life span.

4.4 Water Sharing Institutional Framework Opportunities

The different proposed Rogun dam alternatives will not impact the seasonal flow pattern downstream of Nurek. In addition, the operation strictly complies with existing agreements and practices on allocation of water shares. However, in this operative mode the largest reservoir at FSL 1290 m.a.s.l and the intermediate reservoir at FSL 1255 m.a.s.l, will not be fully utilized and have an unused live storage capacity as shown in the following table:

	Rogun 1290	Rogun 1255	Rogun 1220
Min Operation (masl)	1185	1161	1137
Total Reservoir Volume (Mm3)	13 800	8 490	5 210
Unused live storage	60%	35%	0%

Table 4.2 : Unused live storage

This could represent a potential opportunity for cooperation within the entire Amudarya basin, bringing additional storage capacity that could be possibly mobilized during dry years to sustain the irrigation needs of the riparian countries. The highest dam alternative provides the greatest potential for storage and the associated economic benefits this could bring. Trade off mechanisms would need to be institutionalized between the concerned countries to better leverage these benefits as well as ensure the long-term viability of such a benefit-sharing approach.

Significant potential for the highest dam option (FSL 1290 m.a.s.l.) and possibly the intermediate option (FSL 1255 m.a.s.l.) may be reaped if international agreements can be agreed upon with downstream countries.

4.5 Extreme Flood Safety of Vakhsh Cascade

As explained in Volume 3 Chapter 3, the Vakhsh Cascade as of today is not designed to handle the PMF. This is in particular true for Nurek Dam, one of the largest dams in the world.

Simulations show that only dam alternatives with FSL at 1290 m.a.s.l. and 1255 m.a.s.l. can safely handle the PMF and protect the downstream structures from overtopping. This function cannot be guaranteed by the lowest dam alternative (FSL 1220 m.a.s.l.), requiring immediate large upgrading works on the downstream structures that could correspond to an overall investment of at minimum 318 MUSD for Nurek alone and up to 1 billion USD for the full cascade. This is also a major technical drawback for the 1220 m.a.s.l. that cannot ensure this function without significant additional investments and large works on the cascade.

The significant difference in life expectancy between the FSL 1255 m.a.s.l. alternative (75 years) and the 1290 m.a.s.l. (115 years) and in order to ensure that such a positive benefit is being brought to the cascade safety for the longest period of time, the FSL 1290 m.a.s.l. alternative brings appears the most suitable as it will remain operational for PMF management on a larger time span. This is also consistent with the idea of end-of-life funds to be gathered during project life to ensure financing of upgrade works required for downstream projects to safely pass the PMF. The 1 billion USD investments will in any case be required when storage capacity will be lost for all alternatives, and consequently in a farther time horizon for the highest dam alternative.

The Consultant recommends that a flood forecasting system be operated at the reservoir. During exceptional years where conditions could be favorable to the occurrence of an extreme flood of the magnitude of the PMF, the reservoir levels of Rogun and Nurek would need to be lowered before the flood season. If ultimately no flood is observed during this wet season, the reservoir would remain empty after the summer months. This will have a detrimental impact on energy production for both Rogun and Nurek in that given year.

However, given that the highest alternative of Rogun dam would have significant remaining storage capacity, the reservoir refill can be made on several successive years and the loss of energy could be spread over several years, reducing its impact the project benefits. This would also mean satisfying the Power Purchase Agreements (PPA) and other offtake agreements with fewer penalties. Thereafter, the refilling of Rogun could be distributed over the following years. It is clear from that perspective that the highest alternative provides the best flexibility to handle such an exceptional situation.

4.6 Climate Change and Carbon Release Avoidance

Reservoir projects are found to be more adaptive to variations in design flood due to climate change. The additional reservoir capacity for flow regulation available in the two highest dam alternatives and unused in the present simulation can bring more flexibility to handle hydrology variability. This could be increased in the design flood (PMF) or better management of dry years, depending on the effects of Climate Change in future. This goes in favor of the alternatives with the most unused storage capacity and gives more potential to the higher dam alternatives.

Moreover, generation from reservoir projects can substitute generation using fossil fuels, leading to a reduction in emissions of carbon dioxide (CO_2). This aspect has not yet been taken into account in the economic analysis presented above but we can say that tThe bigger the annual hydropower energy produced, the higher the avoided emissions and therefore the potential benefits from CO_2 emissions savings. This argument favors the highest dam alternatives. During the next phase of the study, an evaluation of the potential economic benefits attributed to CO_2 emissions reductions will be incorporated into the overall economic analysis.

4.7 Installed Capacity and Peaking

The Least Cost Expansion Plan undertaken for Tajikistan and its neighbors suggests that the incremental net benefit of adding capacity beyond a particular point is limited. Note that average annual generation (measured in terms of energy, MWh) from each dam alternative is very similar and not affected by installed capacity. The benefit of additional peak capacity (measured in capacity MW available at times of peak demand) is limited by interconnector constraints and the level of achievable prices in Tajikistan and Pakistan (which is the principle export market for Tajikistan). This explains why the 3600 MW option at FSL 1290 m.a.s.l. is less attractive than the 3200 MW according to the economic analysis undertaken thus far.

However, there might be other criteria to consider such as the option of expanding installed capacity later on. One solution could be to leave one unit pit empty and decide on the installation of another unit at a later stage. Moreover if the incremental cost of adding one unit is not major, it should be noted that this additional unit could bring more flexibility in the generating system by allowing standby periods for maintenance without loss of overall annual energy generation. The incremental cost would be recovered by the avoided loss of generation during maintenance. This should be studied in more detail in the next phase of the studies.

5 CONCLUSION AND RECOMMENDATION

Based on the above considerations, the Consultant recommends that the highest dam alternative (FSL = 1290 m.a.s.l.) is taken forward for detailed consideration. This alternative will become a major asset in the Tajik generation system as well as the regional energy market, providing sustained low cost production for the longest time span. It will also protect the Vakhsh Cascade against extreme floods with no additional investment for the longest period, avoiding large rehabilitation works to be implemented on the Cascade.

As the economic results provided by the different installed capacities alternatives are relatively similar, it is recommended that the final optimization of the unit sizing be studied in more detail. Based on the analysis performed for Phase II, it appears that an intermediate installed capacity would be sufficient (3200 MW), because of the difference in initial equipment investment and very little additional energy generation from a greater installed capacity option.

A number of recommendations have been made on further investigations and analyses that should be carried out for the detailed design of the project.

6 DETAILS OF THE RECOMMENDED ALTERNATIVE

6.1 Dam

	FSL = 1290 masl
Dam crest	1300 masl
Foundation level	965 masl
Dam height	335 m
Crest length	660 m
Crest width	20 m
Core crest level	1296.25 masl
Maximum water level	1296 masl
Minimum operational level	1185 masl
Reservoir active storage	10 300 hm^3
Total reservoir capacity	13 300 hm^3
Average yearly inflows	20 100 hm^3
Dam slopes	US 2.4 H/1V DS 2 H/1V
Stage 1 elevation	1110 masl
Core crest thickness	8 m
Core slopes	US: 0.5 H/1V DS -0.1 h/1V
Filters thickness	US: 2 layers of 10 m each above the minimum operation level and one layer of 10 m below DS : 2 layers of 10 m each

6.2 River diversion structures

	FSL = 1290 masl
Diversion tunnel 1	
Total tunnel length	1439.5 m
Pressure Stretch Section (D-Shape)	96.55 m²
Low intake level	989.60 masl
High intake level	1020 masl
Design head	120 m
Minimum operational level	989.60 masl
Maximum operational level	1110 masl
Design discharge	2490 m3/s
Diversion tunnel 2	
Total tunnel length	1420.7 m
Pressure Stretch Section (D-Shape)	96.55 m²
Low intake level	1001.80 masl
High level intake	1020 masl
Design head	120 m
Minimum operational level	1001.80 masl
Maximum operational level	1110 masl
Design discharge	2490 m^3/s
Diversion tunnel 3	
Total tunnel length	1560 m
Diameter of Pressure Stretch	15 m
Intake level	1035.0 masl
Outlet portal level	1023.45 masl
Design head	150 m
Minimum operational level	1035 masl
Maximum operational level	1160 masl
Design discharge	3694 m3/s

The data refer to the condition of maximum exceptional head.

6.3 Spillways

6.3.1 Middle level outlet

	FSL = 1290 masl
Middle level outlet 1	
Total tunnel length	1464.0 m
Diameter of Pressure Stretch (Circular)	15 m
Intake level	1083.50 masl
Outlet tunnel level	1077.60 masl
Design head	150 m
Minimum operational level	1100.0 masl
Maximum operational level	1215.0 masl
Design discharge	3685 m3/s
Middle level outlet 2	
Total tunnel length	1117.0 m
Diameter of Pressure Stretch (Circular)	15 m
Intake level	1140 masl
Outlet tunnel level	1026.80 masl
Design head	150 m
Minimum operational level	1155 masl
Maximum operational level	1270 masl
Design discharge	3710 m3/s

The data refer to the condition of maximum exceptional head.

6.3.2 High level tunnels

	FSL = 1290 masl
High level tunnel 1	
Total tunnel length	1264.1 m
Diameter of Pressure Stretch (Horse-shoe)	10 m
Intake level	1190 masl
Outlet tunnel level	1177.70 masl
Outlet Structure level	1000.00 masl
Outlet Spillway length	440.3 m
Design head	100 m
Minimum operational level	1190 masl
Maximum operational level	1290 masl
Design discharge	1570 m3/s
High level tunnel 2	
Total tunnel length	1410.1 m
Diameter of Pressure Stretch (Horse –shoe)	10 m
Intake level	1190 masl
Outlet tunnel level	1176.57 masl
Outlet Structure level	1000 masl
Outlet Spillway length	415.9 m
Design head	100 m
Minimum operational level	1190 masl
Maximum operational level	1290 masl
Design discharge	1570 m^3/s
High level tunnel 3	
Total tunnel length	
Diameter of Pressure Stretch (Horse –shoe)	
Intake level	
Outlet tunnel level	
Outlet Structure level	
Outlet Spillway length	
Design head	
Minimum operational level	
Maximum operational level	
Design discharge	

The data refer to the condition of maximum exceptional head.

6.3.3 Multi-level Intakes

	FSL = 1290 masl
Intakes culverts developed length	312.5 m
Culverts Inner Dimensions	16 x 12 m
Upper Power Intakes level (Units 1, 2, 5, 6)	1167 masl
Lower Power Intakes level (Units 3, 4)	1152 masl
Number of Intakes active inlets	4
Higher Intakes active inlets level	1179.3 masl
Lower Intakes active inlets level	1104.3 masl
Power Intakes Gates Design Head	140 m

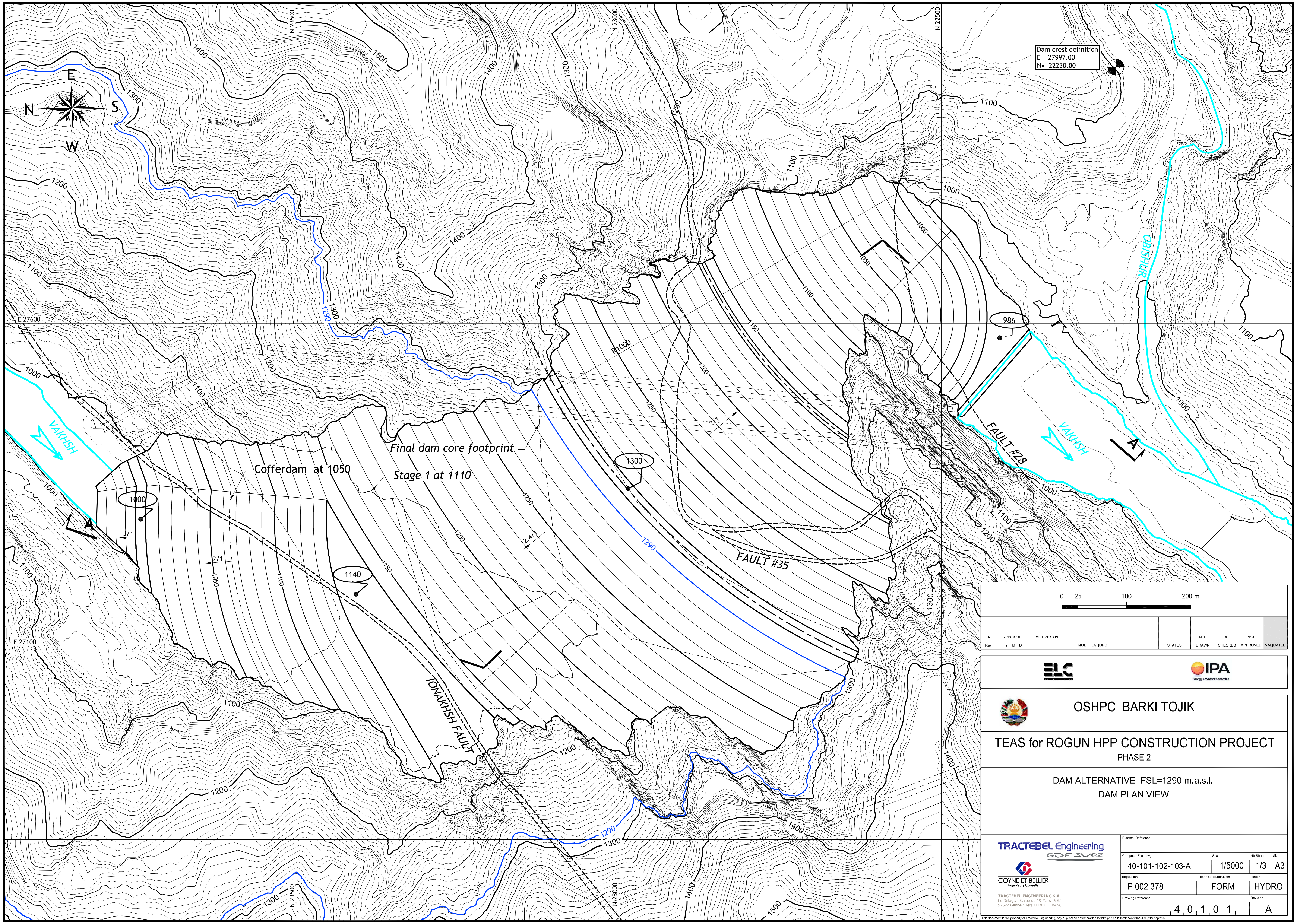
6.3.4 Surface spillway

	FSL = 1290 masl
First Stage	
Number of modules	1
Number of tunnels	2
Final Stage	
Number of modules	3
Number of tunnels	6
Tunnel width (D-shape)	9.40 m
Tunnel height (D-shape)	15 m
Fall height	224 m
Number intermediate spillways	2
Width of intermediate spillways	33 m
Design discharge (PMF)	7800 m^3/s
Sill level	1284 masl
Flip bucket exit level	1060 masl
Minimum operational level	1284 masl
Maximum operational level	1296 masl

6.4 Power house and EM Equipment

Total Capacity Installed (MW)	3600	3200	2800
Number of units	6	6	6
Number of units reused (*)	2	2	2
Pmax (MW)	615	533.3	466.7
Pmin (MW)	360	270	245
Hmax (m)	320	320	320
Hmin (m)	185	185	185
Hrated (m)	285	285	285
rpm	166.7	166.7	166.7

6.5 Drawings



Rev.	Y M D	MODIFICATIONS	STATUS	DRAWN	CHECKED	APPROVED	VALIDATED
A	2013 04 30	FIRST EMISSION		MEH	OCL	NSA	

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OSHPC BARKI TOJIK

TEAS for ROGUN HPP CONSTRUCTION PROJECT

PHASE 2

DAM ALTERNATIVE FSL=1290 m.a.s.l.
DAM PLAN VIEW

TRACTEBEL Engineering
GDF SUEZ

COYNE ET BELLIER
Ingénieurs Conseils

TRACTEBEL ENGINEERING S.A.
Le Delage - 5, rue du 19 Mars 1962
92622 Gennevilliers CEDEX - FRANCE

External Reference

Computer File .dwg	Scale	Nb Sheet	Size
40-101-102-103-A	1/5000	1/3	A3

Imputation	Technical Subdivision	Issuer
P 002 378	FORM	HYDRO

Drawing Reference	Revision
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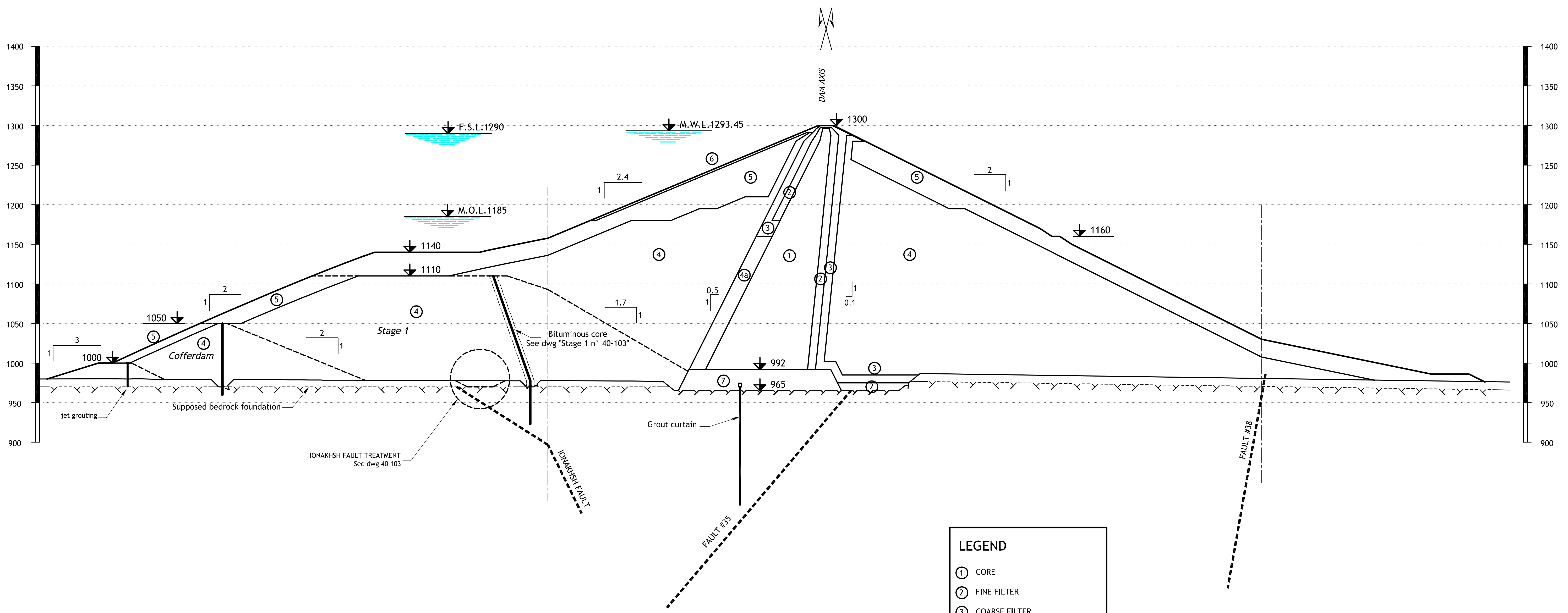
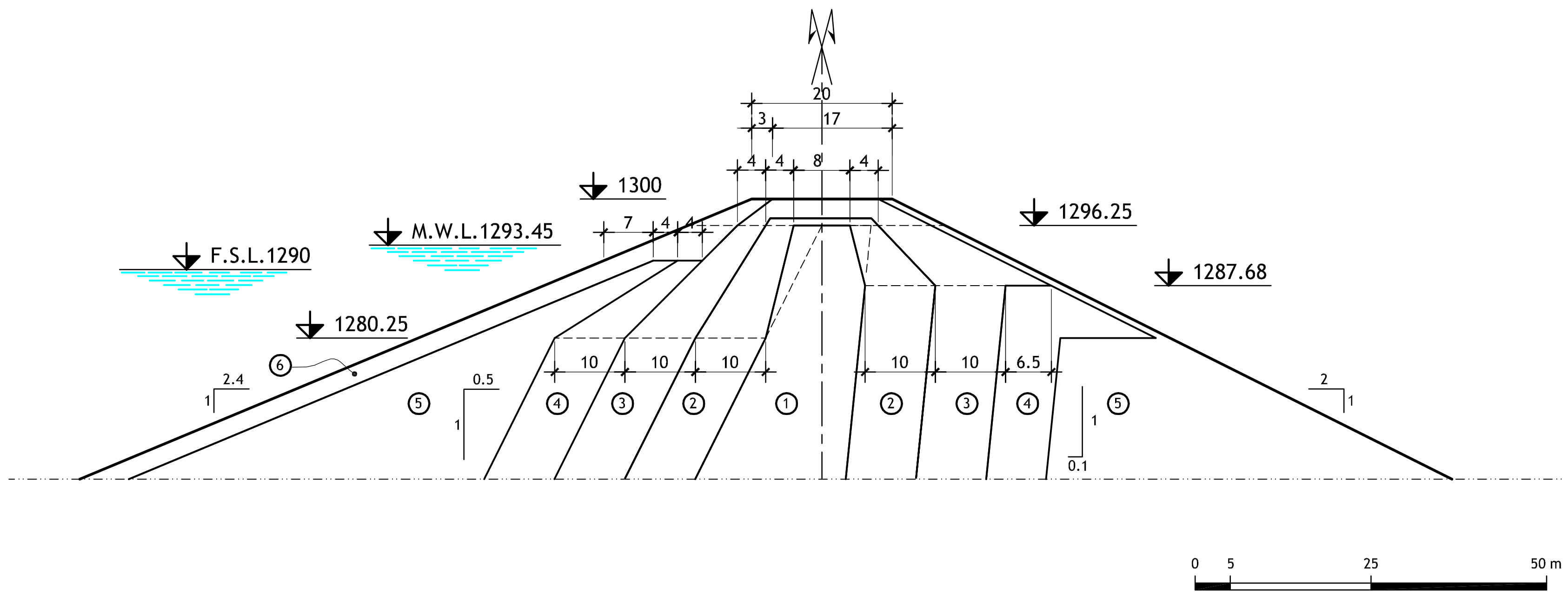
SECTION A-A



LEGEND

1. CORE
2. FINE FILTER
3. COARSE FILTER
4. ALLUVIUM SHELL
4a. ALLUVIUM SCREENED (<200mm)
5. ROCKFILL SHELL
6. RIP RAP
7. CONCRETE FOUNDATION

CREST DETAILS



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TEAS for ROGUN HPP CONSTRUCTION PROJECT
PHASE 2

DAM ALTERNATIVE FSL=1290 m.a.s.l.
SECTION A-A
CREST DETAILS

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40-101-102-103-A	1/5000	2/3	A3
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Drawing Reference: 4 0 1 0 2	Revision: A		

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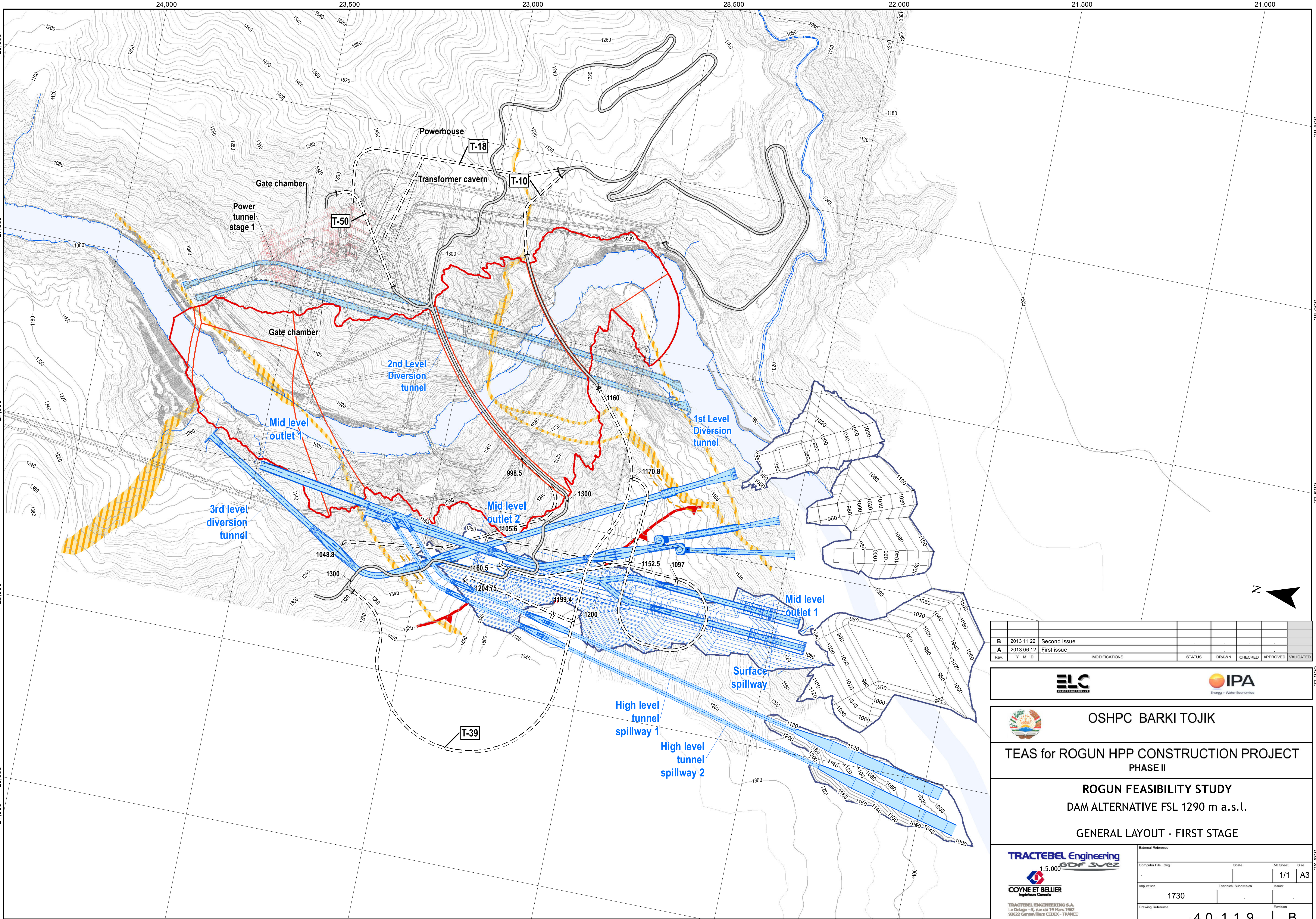

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B	2013 11 22	Second issue	.	.	.	.	
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TEAS for ROGUN HPP CONSTRUCTION PROJECT
PHASE II

ROGUN FEASIBILITY STUDY

DAM ALTERNATIVE FSL 1290 m a.s.l.

GENERAL LAYOUT - FIRST STAGE

TRACTEBEL Engineering GDF SUEZ

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TRACTEBEL ENGINEERING S.A.
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Computer File .dwg	Scale	Nb Sheet	Size
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Imputation	Technical Subdivision	Issuer	
1730	.	.	
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