Tunnel and Underground Risk in Hydropower – a Lender's Technical Advisor Perspective

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ABSTRACT

This paper explores the role of the Lender's Technical Advisor (LTA) in identifying and mitigating risks in hydropower projects on behalf of the project lenders, in particular for the tunnel and underground aspects. It describes the typical services required to manage the four key phases of: due diligence, pre-financial close, construction financing and operational financing for hydropower projects. It draws upon the author's experience of undertaking LTA roles across each of these phases and project types across a range of geographies.

There are differing types of risk in both large and small hydro projects (contractual, commercial, participant, geotechnical, completion, country, technology, reputational, environmental and social, etc) and many of these are discussed with regard to how the lenders may be exposed if the risk eventuates and how the lenders perceive the risks. Those risks also vary with time and the perception of the risks also varies between parties, depending upon which party will be mostly impacted. The risk evolution throughout the pre-financial close to operational phases for a hydropower scheme differs for each type of risk. There are several unique features and risks associated with hydropower projects that financiers, and the borrower, need to be aware of.

The rather misleading concept of a *bankable* feasibility study is briefly explored and discusses what that really means, since stakeholders have differing standpoints. We also discuss who decides whether a feasibility study report can be considered *bankable*.

The paper draws on case studies from the Asia Pacific and African regions to illustrate the key elements in hydro project financing from the LTA's perspective, together with the author's recent and current experience on multiple hydropower projects ranging from 5MW to 500MW, across Asia and Africa in the run-of-river, storage reservoir and pumped storage type of hydropower plants, each having differing reliance on underground works.

Key Words: Tunnelling; Underground; Risk; Financing; Hydropower; Lenders.

1. INTRODUCING THE LENDERS' TECHNICAL ADVISOR (LTA)

The lenders normally prepare the request for proposal for the LTA services, tailored to their needs for the particular project and their perceived key areas for concern, but with a fairly common underlying terms of reference for most LTA roles. The LTA - also termed the Independent Engineer, Bankers' Engineer or Lenders' Independent Consultant - is selected jointly by the lenders and the project developer (the borrower) but usually contractually appointed and paid by the developer. However, the LTA's selection process is rarely as straightforward as just described, given that the lenders tend to look for experience, reputation and quality, whereas the developer will additionally be looking for the most competitive price for those services. In most cases the LTA services also include environmental and social monitoring, which is not always obvious from the term 'technical' in the role title.

2. THE LTA'S ROLE

It can be considered that the lenders and owner will have similar objectives for the project – both want a successful project delivered safely, on time and to budget. This is not surprising if we consider that the lenders are effectively the 'majority owner' throughout the tenure of the loan. Given the lenders' more likely public facing position, reputation can be more important to them and for this reason the lenders often place a higher focus on good compliance with environmental and social issues.

Flexibility is a key attribute for the LTA, which may be from the perspective of having the depth of in-house expertise to cope with issues that arise, to flexibility or 'nimbleness' to cover a wide range of issues. Such examples are:

- A recognition that the LTA's role, while necessary and important, is no more so than the owner's permanent site team and that any reviews by the LTA should be within the timescale for others so as not to cause a delay in the approvals process,
- ideally to provide a one-stop-shop covering all commercial, environmental, social and engineering disciplines required in the LTA role,
- the ability to cope with tight schedules,
- understanding and coping with the lenders' commercial administrative processes.

The selection also considers:

- strong technical track record
- credibility in the international arena
- presenting highly technical issues in a language suited to the non-technical reader
- ability to deal effectively with potential disputes.

The lender that engages the LTA is looking for advice on contractual, engineering, environmental and social matters. With the lenders' reputation at risk if a project fails to follow good practice, the importance of independent monitoring and reporting throughout the construction and operations periods is clear.

3. THE LENDERS' PERSPECTIVE OF UNDERGROUND RISK

In Project Financing, considerable attention is paid to risk and there are several unique features and risks associated with hydropower projects that financiers need to be aware of. Lenders will examine all aspects of the project in great detail to assure themselves that the project will function as planned and produce the revenues needed to meet operating expenses and service the debt. The role of the LTA is to identify risks that might influence the viability or affect the cash flow of the project and offer strategic advice on how to avoid or mitigate those risks. The lenders expect their technical advisors to point out at a high level, whether the technology adopted is appropriate and what are the potential or realised items of concern. The avoidance of reputational damage is a key aspect of lenders involvement.

This paper does not explore the lenders' perspective in depth but is included here to provide the tunnel designer (either working for a company engaged by the owner or working for a contractor on a D+C or EPC arrangement) with an overview of what issues may give rise to concern for lenders. It also needs to be understood that the ultimate objectives of the developer and lender are the same – a successful project that delivers a satisfactory and sustainable financial return. The LTA's duty of care is to the lenders, but its objectives are largely aligned with the developer's.

From general precedents of hydropower tunnels in very remote locations the lenders may well be advised of three categories of reasonable expectations of delays:

3 months for a 'realistic potential delay'

6 months for the possible delay of an unforeseen event with major consequences

12 months or more for major unforeseen conditions resulting in an extreme delay.

For tunnels in general, such delays are more likely to occur during construction however recent examples of headrace tunnel collapses soon after operations commenced made the headlines. Unlike transportation tunnels where imposed loads on the lining hardly change once the traffic or trains start using the tunnel, in hydropower tunnels the internal and external water pressures are the dominant loads. The watering up of the system and testing for sudden trips which impose high transient pressures on the lining, or on the unlined tunnel in some cases, is the first real test on the lining. Linings are mentioned here although the situation can be more severe and uncertain in unlined tunnels; observed stable ground during construction may disguise the softening or other change in characteristic of the rock once wetted, and particularly when the tunnel is dewatered and subjected to a fairly rapid build up of net external pressure.

Delays to tunnelling may lead to delays in wet commissioning of the station, i.e. if the tunnel and underground works are on the critical path (which they usually are) no water can be made available for trial runs until the waterway is fully connected.

When structuring the conditions of the loan and the payback model, the LTA may recommend that the model takes account of the likelihood for delays resulting in consequential delays to the owner's ability to generating revenue and to begin to repay the loan.

4. TUNNELLING FOR HYDROPOWER TUNNELLING

4.1. Overview

An aim of this paper is to provide an insight to the considerations and challenges faced by designers and constructors of tunnels and shafts for hydropower projects in remote locations and is structured to provide a reminder against each section that the tunnel designer's aim is to meet the ultimate purpose of a hydropower scheme which is to generate electricity and for the owner to generate revenues from the sale of the electricity. Contrasting the typical factors that govern the design of urban transportation tunnels with those for remote hydropower tunnels, and prepared for a tunnelling audience that is likely to be dominated by engineers experienced in urban transportation tunnels for rail, road and water facilities, it is hoped that some of the author's experiences of remote hydropower tunnels can be shared.

Tunnelling for hydropower projects can be a very challenging component of the overall development. In contrast to urban transportation tunnelling where the logistics for access and supply of electrical power, water and other essentials are readily available, hydropower projects are usually in very remote locations with challenging steep terrain and all necessary plant, equipment, spares and materials need to be brought in and the site must function as a self sufficient unit.

For a large scheme the river diversion tunnel(s) are usually on the initial phase critical path in order to meet the non-negotiable deadline of river diversion before the onset of the next wet season. A newly formed tunnelling crew, once mobilised to the site for the project, will face the first major learning curve of the project's systems and logistics during this critical tunnelling activity. This in itself is a challenge where systems and procedures are still being bedded down.

Power tunnels convey the water to the turbines in the powerhouse and are usually on the critical path for the main works, especially if the scheme comprises a powerhouse located within an underground cavern. A modern cavern arrangement requires a complex warren of various openings: access adits, ventilation/cable tunnels, shafts, surge tunnels, etc.

4.2. Freedom of alignment

Unlike the urban transportation tunnel which is designed to carry trains / cars / services which normally dictate the alignments, grades and layouts for passenger safety, hydro tunnels are dealt a different set of constraints. The hydropower tunnels designer views the absence of the transport tunnel geometrical constraints as an advantage, giving the designer a back-to-basics freedom to optimize the underground space to suit the function. However, even the hydropower pressure tunnels that appear to be 'simple' because they are usually circular and only carry water are subjected to a completely different set of operational conditions to urban civil facilities and so this paper will describe some of the many features that the urban tunneller does not need to consider.

4.3. Constructability

Hydropower tunnel construction tends to be dominated by tunnel boring machines (TBMs) or drill-and-blast excavation techniques and each has its challenges in very remote locations. Roadheaders are less common in hydropower projects. TBMs have long lead times as for any type of project, but additionally require a thorough roads and bridges infrastructure assessment of the country from the port of entry to the site to ensure a problem-free delivery. In some cases the project also requires the establishment of a complete precast concrete segment production facility and the space for creation of laydown areas; there is no 'just-in-time' supply industry applicable to remote hydropower sites.

5. HYDROPOWER SCHEMES WITH TUNNELS AND SHAFTS

The three main types of hydropower schemes that normally utilise tunnels are storage reservoirs, run-of-river diversions and pumped storage reservoirs.

5.1. Storage reservoir schemes

5.1.1. Overview

This is the most well known type of hydropower scheme. Most medium to large sized dams will require the river to be temporarily diverted during construction of the dam through a diversion tunnel or multiple tunnels depending upon the size of river.

5.1.2. River diversion tunnels

Such tunnels feature high on the risk assessments of hydropower projects not only because of their function which is to have a short operational lifespan, say two to three years (up to three wet seasons), while carrying high velocity silt-laden water and possibly flood debris through the tunnel, but also because they are normally on the first stage critical path which is governed by seasonal river flows thus placing increased pressures on the organizational skills of the newly mobilized site team. Unless the project's dam construction phase can withstand a potential delay equal to the length of the seasonal wet season, a missed diversion date can be very costly and so the tunnelling schedule is normally non-negotiable. Given that for many projects the actual contractual commencement date is rarely as planned it is even more important to understand the implications of river diversion scheduling. A major project risk is the early onset of a wet season bringing early floods in the river and the construction team needs to have contingencies in place.

The designer needs to understand what range of flows and possible debris or siltation loads could be carried. Flat or large-radius inverts are commonly used because they offer advantages for construction equipment and in times of low flows the erosion forces from heavy silt loads are better distributed over a wider surface. The long term durability aspects may be of lesser concern if there is to be no future use of the diversion tunnel, however there is normally at least part of the tunnel that becomes connected to an outlet or is plugged with a flooded section upstream, or other configuration, thereby requiring that the tunnel still be designed for the full project life. The main duty though is to withstand the high velocity conveyance of the river diversion flows and to ensure that it has a very robust lining that meets the hydraulic requirements and is not adversely affected by erosion from silt or damage from debris. The diversion tunnel will be subjected to relatively low internal pressures during its diversion phase. Figure 1 shows an impressive shutter for a 15m high horseshoe shaped diversion tunnel on a large hydropower scheme.

Figure 1. An impressive 15m high diversion tunnel lining shutter

There are few opportunities for pushing the design envelope in diversion tunnels and such is the criticality of the diversion tunnel that a tried and tested approach is recommended. The designer can defend this conservative position given the high risk profile applied to these tunnels.

5.1.3. Headrace and Tailrace tunnels

Headrace tunnels are located upstream of the turbines and in most cases deliver water that is under pressure. In smaller run-of-river schemes some headrace systems adopt open-channel (non pressurized) flow.

It is important to ensure that rocks over a certain size do not get carried into the turbine. In lined tunnels and shafts this should not be a problem because the intake structure will screen for a given particle size and the only harmful fragments entering the tunnel downstream of the screens might be from inferior quality shotcrete that could become detached, or may break up if not properly designed for pressure pulsations. For unlined tunnels and shafts however it is often necessary to provide a rocktrap, typically comprising a simple arrangement of underground chambers beneath the normal invert level that have open slots into which rocks carried along the invert by the flow of water, will fall.

The tailrace tunnel returns the water back to the river after passing through the turbines. Consequently the pressure is much lower than in the headrace system as the turbine-generators extract the energy for the generation of electricity. The configuration of the tailrace tunnel needs to be assessed across the full operating flow range for both the submerged and open flow conditions in the tailrace tunnel(s). The designer must also consider the operation of the scheme and how the waterways will drain when the station is shut down. During maintenance periods the pressurized tunnel would normally require to be pumped out which results in additional time for this task and hence more down time.

5.1.4. Transfer aqueducts

Given their purpose of transferring water inter-basins, or over long distances, they are necessarily long tunnels and therefore risks to timely completion need to be weighed with the impoundment schedule for the recipient reservoir. The late completion of a transfer aqueduct tunnel may prevent impoundment of the main reservoir with serious commercial consequences.

Where a pressurized transfer aqueduct is provided however, the tunnel can only be drained by gravity by the provision of a dewatering adit from the low point (ideally not located at the recipient reservoir); this is a factor to be given early consideration.

5.1.5. Access adits, services tunnels and cavern complexes

Hydropower schemes that contain headrace tunnels, shafts or caverns will require access adits. For schemes with a powerhouse cavern there could be several kilometres of tunnels spiraling down from the surface to cavern level. Consideration must therefore be given to flooding of the decline during operation, permanent dewatering arrangements and provision of fresh air to the decline(s) during maintenance inspections.

5.2. Run-of-river schemes

Hydropower is not all about large dams. The run-of-river plant, as the name suggests, only uses a portion of the water available in the river at any given time of the year to generate electricity and therefore typically has only modest storage volumes behind a low diversion weir. The required pressure head of the scheme is created by transferring the diverted water along headrace channels, tunnels, pipes or conduits to a point downstream over which the head is developed. In medium to large run-of-river schemes this transfer is usually by tunnel, either as a pressurized conduit or simply a tunnel carrying an open channel.

The route from intake to powerhouse needs to be of a form that preserves as much head as possible and so there are a variety of options available to the designer to achieve this. Where an open channel or a boxed culvert solution is used these will remain at a shallow gradient and generally follow the contours to a point where the water can be conveyed back down to river level within a pressurized penstock pipe over as short a distance as is feasible. In these situations tunnels are probably only used to carry the headrace channel or penstock pipe through a hillside to shorten the route of a channel option, or to carry the penstock along a more direct route.

The alternative arrangement is to convey the water through a tunnel over its full length from weir to powerhouse, in which case it will operate predominantly as a pressurized tunnel.

5.3. Pumped storage schemes

Pumped storage hydropower is becoming increasingly prevalent in countries where other forms of renewable energy such as wind and solar power have expanded. The grid requires stability which is offered by the near instantaneous generation of electrical power when a pumped storage scheme starts up and can be used to balance the supply when other supply schemes have fluctuating outputs.

The concept is to use a closed system of water, of fixed volume (excluding evaporation from the reservoirs) to generate electricity by allowing water to flow by gravity from an upper reservoir to a lower reservoir through tunnels, shafts and turbines. The same water is later pumped up from the lower to upper reservoirs through the same facilities. A key aim of the designer for pumped storage schemes is to develop as much head over as little horizontal distance as possible, in other words to minimize the L/H ratio. This is principally for economic reasons and means that the tunnel waterways designer needs to understand the economic driver for the optimum layout.

A high proportion of total civil engineering costs will be associated with the tunnels and shafts in a typical pumped storage scheme because the head is created within the underground works and the storage reservoir embankments/ dams are usually only low to medium height. Whilst not in the same league as large dams they may still be categorized for dam safety purposes as 'large dams' due to consequences of failure. The optimization of layouts and the linings is where efficiencies can be gained and this means that the value engineering cost savings in civil works are focused on the tunnels and shafts.

However, the greater the operating head usually means the greater the constructability challenges. Deep shafts usually in excess of 300m, and up to 1,000m, are often required in such schemes and an obvious optimization is to consider reducing the total waterway length by making a steeply inclined shaft and shortening the lower tunnel length; conceptually this all makes good sense providing that the time and cost and risks are appropriately considered with experienced constructors during the design phase. A vertical raisebore shaft say 500m deep is far more straightforward than an inclined 60-degree shaft although there can be significant cost savings in material costs in shortening the overall waterway lengths especially if the shaft and lower tunnel are to be steel lined, and there are plenty of precedents where the steeply inclined shaft was selected.

6. RISK MANAGEMENT OF UNDERGROUND WORKS

6.1. Overview

Risk management for the underground works is at the core of the LTA's role, whether at the early due diligence phase, throughout the construction phase, or into the operational phase. From a lender's perspective the definition of risk is *the probability of a cashflow outcome different from the one projected / forecasted*. From an investor's point of view the definition might also include the possibility of *not achieving the expected financial return*.

6.2. Contracts review

The LTA will review the technical aspects of the construction contracts, often in parallel to a legal review undertaken by the lenders' legal advisors (LLA) and an insurance review by the lenders' insurance advisors (LIA). A key topic is that of liquidated damages that may be imposed upon the owner (the signatory to the power purchase agreement (PPA)) if the scheme fails to meet agreed levels of output performance, and the assessment of whether the contract provisions have adequate pass-through down to the contractor, in the case of an EPC agreement, of those aspects that are relevant to the EPC's supplied plant.

The LTA will advise on a suitable 'stress test' to be applied to the financial model based upon technical assumptions in the event that the project commissioning date is delayed or if there are major cost overruns. As a rule of thumb, at least six months schedule overrun is recommended to be applied as a stress test, or more in complex projects with known geological risks, to assess the impact on the borrower's financial situation if, when late, a whole set of additional costs are directed at the borrower: prolongation costs of owner's site team, lost earning opportunity from delayed commissioning, additional financing costs, additional LLA, LIA, LTA and other advisor's costs, and possible LDs for late completion. While some of these may be recoverable from the contractor if it is the contractor's fault, any money for prolongation will usually have to be initially met by the borrower until the contractual issues are resolved. In this regard, the LTA is truly part of the collective lenders' team whereby the lenders will assess the financial aspects, the LLA the legal aspects, the LIA the insurance aspects and the LTA feeding into each of these where technical or E&S aspects relate.

6.3. Underground works risk sharing

For a large storage scheme there might be a typical split of costs of:

- Dams and reservoirs – 20%
- Underground works – 30%
- Electro-mechanical works – 30%
- Transmission line – 10%
- Other – 10%

This simplified example demonstrates that underground works costs may not dominate the entire project cost. However, the unforeseen risks lie mostly here and so a target price type of contract can be developed with only the underground subjected to such an approach. This gives a better risk apportionment between the employer and the contractor and does make sense given that the owner essentially owns the ground through which the contractor is contracted to excavate. Various approaches are made but the concept is explained in this simplified example where there are five different underground works elements:

- Low pressure headrace tunnel
- Vertical shaft
- High pressure headrace tunnel
- Powerhouse caverns
- Tailrace tunnel.

In conjunction with a geotechnical baseline report (GBR), which sets the boundaries of certain geological characteristics as derived from the pre-tender stage site investigation, and thereby sets a trigger level for exceedance, the target price mechanism (TPM) aims to deal with risk apportionment.

Each element would have assumed lengths of each rock category and the contractor would price the unit length of each category for each of the five elements, thereby building up the Tender Price. As the excavation proceeds the outturn price will be adjusted depending upon actual ground conditions encountered. There will be an upper and lower bound price adjustment to the Tender Price for all underground works included as part of the TPM, and outside of this range, either higher or lower, there will be a cost sharing equation on a sliding scale which might be split such as in Table 1.

Table 1. Simplified outline for Target Price Mechanism

Payment of additional costs (the outturn cost of worst ground conditions across all elements)		
Up to:	**Owner**	**Contractor**
110%	0%	100%
120%	55%	45%
130%	85%	15%
130% +	100%	0%
Sharing of savings (the outturn cost of better ground conditions across all elements)		
Up to:	**Owner**	**Contractor**
90%	0%	100%
80%	55%	45%
70%	85%	15%
70% -	100%	0%

6.4. Technical risk: decision on TBM vs D&B vs Roadheader

The most common tunneling techniques in urban schemes are tunnel boring machines (TBMs) and roadheader, and sometimes drill-and-blast for certain applications. TBMs are rarely constrained from being used for such schemes on alignment/ geometrical grounds as the gradients and curve radii dictated by operational requirements normally govern the alignment and the tunnel lengths in major projects justifies their use. But for hydropower schemes TBMs will mostly be excluded from choice for many of the scheme's complex warren of tunnels due to the tunnels' multiple curves and steep grades.

For hydropower therefore, TBMs lend themselves only to reasonably long headrace or tailrace tunnels, say where the length is at least 600 times the diameter and the gradient less than 5%. However if the project is a design-and-construct contract where the choice of method is open, then there may not be the opportunity to carry out sufficient site investigation works to confirm the feasibility of the use of TBMs. This topic may appear contrary to the experiences of the urban tunneller where the time and costs required to obtaining reliable topographic and geotechnical studies along the proposed route are modest, but as described earlier it is a different case in steep mountainous terrain or remote jungle.

In remote areas the use of drill-and-blast with multiple headings is still commonplace. When considering for example a 20km length transfer tunnel of diameter 5m, there will be clear advantages and disadvantages for both the TBM and drill-and-blast options. The 5m diameter sits neatly within the comfort zone for both methods so the decision comes down to schedule, economics, logistics and availability of suitably skilled labour. A 20km tunnel is too long for a single TBM given the time constraints that most projects have, so therefore two or three TBMs might be considered viable to meet the schedule and budget. However the mobilization of multiple TBMs to a remote area is a major undertaking. With modern computer controlled drilling jumbos the progress rates are impressive despite the likely need for multiple access adits to be constructed to service the multiple drill-and-blast headings.

6.5. Evolution of the risk profile

6.5.1. Overview

A project's overall risk profile will change over time, often following a bell curve that rises steeply during construction with the peak of risks culminating near the end of construction and the start of commissioning. At this point virtually all monies have been loaned, the technical issues might be at the forefront due to teething problems (the first watering-up of a high pressure waterway system or impounding of a large dam can be a nervous time for all participants) and the developer's cash flow is probably at its worst position since the project began, especially if the project was delivered late despite the causes or blame for the lateness.

Liquidated damages provisions in the construction contract provide only limited mitigation against completion risk or risk of plant performance below guarantee values, since the cap may only be ten or twenty percent of contract value – normally adequate incentive to perform, but inadequate to save the project if things turn very bad. A robust mitigation strategy is to at least ensure sound performance warranties and contractual terms, and that all parties to the contract(s) are able to deliver on their respective obligations. This is effectively seeking a full pass through of liquidated damages.

In Table 2 a typical evolution of lenders' risk exposure is presented showing how the risks for various aspects vary over the four main stages of lenders' involvement.

Table 2. Evolution of Lenders' Perceived Risks Exposure

Risk Area: / **Phase of Project for the Lenders**	**Commercial (PPA, EPC Contracts)**	**Approvals/ Challenges**	**Environment & Social**	**Reputation**	**Safety**	**Technical**	**Time Delays and Cost Overruns**
Due diligence	LOW	LOW	LOW	MED	LOW	LOW	MED
Construction	HIGH	MED	HIGH	HIGH	HIGH	MED	HIGH
Commissioning	HIGH	MED	MED	HIGH	MED	MED	MED
Operation	MED	LOW	LOW	LOW	MED	LOW	LOW

6.5.2. Risk profile prior to financial close

As covered in previous papers by the author, there is an observation of a growing trend for projects attempting to reach financial close on the basis of a feasibility study. This can be straightforward, but given the original limitations on budget for such a study (i.e. it is not known to be feasible until the study is completed) there is a risk that certain key aspects of that study may have been skipped or inadequately covered. Most lenders have strict requirements to achieve credit approval which is a condition precedent for loan signing and if the developer has not understood those from an early stage, i.e. during the feasibility study stage, there is a likelihood of delays in reaching credit approval until the gaps in information are filled.

This is one area where the LTA performs a key role, in sifting through what's important and looking for what is not included but which the lenders will need to know. Among the key issues that lenders to need know to obtain credit approval, the following items tend to dominate:

- Price certainty of the overall development,
- Will the project be fully compliant with the stipulated levels of environmental and social framework? – such as IFC Performance Standards, or World Bank Guidelines and Safeguards, or local regulations. In other words, will it pass a 'good practice' test as well as whatever specific guideline is stipulated?
- Contractual arrangements :
    - Engineer-Procure-Construct (EPC) or split contracts?
    - Credentials of main contractors and equipment suppliers – have they recent and relevant experience?
    - Implications of performance guarantees not being met
- Accurate timelines for all steps – pre-financial closure; construction; commissioning
- Operation and Maintenance (O&M) Agreements –
    - in-house or through a long-term services agreement?
    - Credentials of operator organisation – have they recent and relevant experience?
    - Implications of performance guarantees not being met.
- Grid interconnection and other local infrastructure (roads, quarries, spoil disposal areas, etc)
- Appropriateness of Owner's organisation, competence of its personnel, strength and presence of the Owner's Engineer and operational readiness of the completed facility.

7. THE BANKABLE FEASIBILITY STUDY

To give further reasoning as to why gaps are usually identified in reviews of feasibility studies, the notion of a *bankable* feasibility study is discussed. It is less common these days to see feasibility studies that claim in their titles to be *bankable* and the term is misleading anyway. No feasibility study at the time of submission can claim to be *bankable* until it is accepted by a lender and there are several steps to go through before that occurs. The feasibility study should prove a project's technical and economic viability, but not necessarily the bankability; it is the steps that follow which concern the bankability of the project, not the bankability of the feasibility study report itself.

The bank will decide what is *bankable* – after all, the bank provides the funds and should be considered as the majority owner throughout the tenure of the loan, assuming a typical 70:30 debt:equity ratio. The lenders will aim to make changes to construction contract provisions that actually are in the owner's (borrowers) interest, to ensure the borrower swims rather than sinks.

While any feasibility study needs to describe (and challenge) the technical risks, the 'other' risks that have been addressed (participant risk, legal risk, regulatory risk, etc) should be covered by a risk mitigation plan for those assessed risks. Moreover, the bank will engage its own team of advisors – own staff specialists and/or independent advisors for technical, legal and insurance advice.

The developer's stance of *bankable:* experienced developers will know what is required but the first time hydropower developer may be anticipating that the full feasibility study is a ticket to financial close; however, the reality is far from this. It is quite common for a project to bridge the gap between the feasibility study and financial close, without an interim design stage, in the case of a direct step to an EPC contract. For this to be successful, the feasibility study for a greenfield site needs to be a very thorough study and one that adequately covers all the topics that lenders will require to have been addressed. The factors that a developer needs to ensure are adequately covered include a robust assessment of the environmental and social aspects as well as the technical engineering.

The summary issues which determine the *bankability* are:

- Financial metrics
- Contractual terms and conditions
- Technical engineering
- Risks and risk allocation
- Borrower's management team (supervision of contractor, Owner's Engineer for design reviews, etc.)
- Operations and maintenance team
- Environmental and Social compliance, eg IFC Performance Standards compliance
- Summary : is the project now deemed "ready to lend"?

To be considered *bankable* by the banks, the risk allocation needs to be firmly understood and be satisfactory to the lenders. So the contract terms and conditions need to be *bankable* too. This is clearly a topic beyond the typical feasibility study which brings us to conclude that a feasibility study itself could never reach *bankable* status in its first edition. Lenders will assess the project holistically but the factors must be appropriate to the bankability test (whether a large or small project), which are:

- Completion price certainty (EPC is best here, even though total out-turn price will be higher than split contracts)
- Completion date certainty (EPC is best here)
- Guarantees for output
- Full pass-through of liquidated damages.

The author considers that there is no such thing as a *bankable* feasibility study upon delivery of that report. Unless the terms of reference for a technical feasibility study were developed to address the key issues that are of interest to prospective lenders, then it remains likely that those lenders during their due diligence process will require additional updates in one or more fields. Those supplementary studies are therefore not part of the feasibility study – they instead form part of a post-due diligence phase, or rather more accurately, a pre-financial close phase.

What is important, is to plan the feasibility study from the outset with the next step in mind, in particular the contracting strategy. If the developer is contemplating taking the large step from feasibility to financial close, assuming the EPC contracting model, this can work but the entire feasibility study should be planned with due consideration in advance of what the lenders will be looking for and ensure there are no gaps. For the underground works components of a project this clearly means attending to the risk apportionment between the employer and contractor.

8. CONCLUSION

The risk profile on the underground works from a lender's perspective does change over the life of a hydropower project, from due diligence stage, through construction financing and the operation financing, but it does not diminish altogether. Most attention of course is paid at the pre-financial close phase as this is when the lenders' influence, through the LTA, LLA and other advisors, can impose further risk mitigations if considered necessary.

The LTA fulfills a valued role for the lenders in identifying and making recommendations to mitigate the risks to the lenders, across a range of topics. The LTA has a wide remit in operating essentially as the eyes and ears for the lenders but spends the majority of effort in the initial stages in ensuring that the total contractual package is appropriately apportioned for risk.

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