The allocation and documentation of hydrological risk

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This article relates the risks of hydrological flow rates, seasonality and extreme events. Risk is considered from the perspectives of the various players involved in projects. The analysis will consider specific issues which affect hydrological risk, such as climate-change, watershed protection and river basin management, and quality of hydrological records. The article will also attend to the issues of management and mitigation of hydrological risk throughout the different stages of a project and how this is reflected in the project and financing documents.

Hydrology is the branch of science concerned with the properties of the earth’s water, and especially its movement in relation to land, according to its dictionary definition. Hydrological risk, in particular the risk of having either too much or too little water, is a key determinant for economic development. The World Bank refers to the possibility of a country being a “hostage to hydrology” [Grey and Sadoff, 2007].

For a hydropower project, the principal issue of hydrological risk is generally seen as the risk of having insufficient water in the source river or dam to support the expected levels of electricity generation. However, hydrological risk is more complex than this, and includes related to the quantity and quality of water that can also affect a project during its planning, design, construction and financing phases, as well as other aspects of operation.

This paper relates the risks of hydrological flow rates, seasonality and extreme events. The risk is considered from the point of view of the project company (a), government, off-taker, construction contractor, lender and insurer. The authors look at specific issues which affect hydrological risk, such as climate-change, watershed protection and river basin management, storage (as opposed to run-of-river) projects, and the quality of hydrological records. The paper then discusses the issues of management and mitigation of hydrological risk throughout the various stages of a project and how this is reflected in the project and financing documents.

Key documents which deal with hydrological risk include: feasibility studies; the environmental and social impact assessment; appraisal reports (including the report of the lenders’ independent engineer); concession (or similar) agreements with host governments; power purchase agreements; construction contracts; financing documents (such as loan agreements and sponsor support agreements); and, insurance policies.

1. Manifestations of hydrological risk

In considering hydrological risk it is important to examine who bears the time, cost and other consequences of each aspect of the risk, including the potential physical and commercial impacts. In addition to the well understood issues of inadequate or excessive water during operation, other aspects of hydropower development, such as design considerations on dams and power stations, are dependent on good data on hydrology. There may also be a risk of excessive water and silt levels caused by a period of particularly intense rainfall, glacial lake outburst flood, extreme weather events (such as hurricanes) or upstream landslides.

Hydrological risk can also include the issue of excessive flows during the construction phase of the project, which may delay the works and/or increase their cost. Similarly, inadequate or excessive water levels can cause a delay in performance testing and commissioning, potentially delaying the commercial operation and technical completion of the plant.

Upstream development (causing diversion, impoundment, flooding, debris flows, siltation or sedimentation) can result in inadequate or too much water, or changes in the timing and quality of water flows. On rarer occasions, downstream development can create risks for an upstream plant, if the downstream plant is constructed such that its reservoir interferes with the upstream operation (for example by flooding the tailrace of the upstream plant).

2. Perspectives on hydrological risk

The various parties and stakeholders have different perspectives on hydrological risk. Developers’ attitudes differ: some refuse ever to take the risk of inadequate water during operation, others accept it as part of being a hydropower developer, and for others it depends on a range of factors, including the level of the tariff and expected revenue, based on different hydrology scenarios. Of course, developers prefer certainty of revenue and will generally try to shift the risk to the off-taker and/or government, though may be persuaded to accept a certain magnitude of hydrological risk if they can recover enough revenue from a conservative or low-water scenario (such as P90, a level of hydrology which occurs with a 90 per cent probability). In some cases the developer will accept protection from hydrological risk which is time limited, such as a power purchase agreement (PPA) in which the off-taker takes hydrological risk for only the first 15 years, as the project’s finances will have significantly lower sensitivity to changes in revenue after repayment of the debt. During the planning and development phase of the project, the developer will need to assess the level of hydrological risk it is willing to bear, and will need to take into account watershed or river basin issues as part of that assessment. During construction, developers need to consider the effects of flooding, drought and other hydrological events, which risks they can insure, which they can allocate to the contractor or off-taker and which they are willing to retain.

Governments may wish to protect the rights and

(a) Also referred to variously as the seller, generator, developer, borrower or employer, depending on the context.

(b) A less conservative scenario would be P50, a level of hydrology which occurs with a 50 per cent probability.
needs of other projects or uses, such as irrigation, navigation, water quality or flood control. Off-takers generally prefer to shift hydrological risk to a developer, but may be prepared to take the risk if they have a portfolio of projects over which to share it. Indeed, it has often been proposed [see, for example, Trouille, Devernay et al., 2008] that the optimum method of allocating risk would be to leave the hydrological risk with the government or state-owned off-taker, which holds all natural risks associated with its country, leaving the developer responsible for the performance of the plant and remunerating the plant largely on the basis of its availability, with only a small percentage of revenue being proportional to generation. The suggestion is that state-owned off-takers have the ability to ameliorate this risk through the diversity of the country’s energy portfolio, with thermal generation and hydropower in other parts of the country, which face different hydrological risks. The recommendation is that the plant is given part of its remuneration through a capacity or availability tariff, where a fixed amount is paid as long as the plant is available to the grid, regardless of the actual generation, and that this amount is sufficient to cover debt service [see, for example, Hoover, 2000] with an additional payment, which is proportional to the energy generated.

However, experience suggests that this is rarely implemented in practice. Brazil is an example of this, where the grid inter-connection allows for the variations in hydrology across the country to be smoothed out, and the thermal plants provide back up in the event of adverse hydrology. Many governments insist on leaving the hydrological risk with the developer, which may encourage the developer to lower generation estimates for the plant or, where concessions are based on the final electricity price, increase the price to compensate for hydrological risk. The government is often effectively paying the developer to insure it against hydrological risk. It should be noted that while this paper will discuss ways in which the developer or off-taker may avoid hydrological risk, the country concerned cannot avoid the risk of power outages which this risk implies, other than by ensuring that significant back-up power resources are available; however, these are rarely cost-effective or even possible for the least developed countries.

From the perspective of the developer, the more the off-taker shares in hydrological risk, the more it will realize two key benefits in terms of financing for the project. First, because the developer will have more secure and less variable revenues, lenders will be more willing to increase the percentage of investment covered by lending. This decreases the developer’s cost of capital, and thus also any cost-reflective tariff for the off-taker (where applicable). Second, because of the increased certainty of revenue, the developer will be in a better position to negotiate the best possible lending terms, also reducing any cost-reflective tariff. This applies to both the interest rate, and the payback period and terms. Consequently, if an off-taker shares in hydrological risk, it may pay a lower average tariff (as the higher potential gearing and lower cost of capital reduces the overall cost of the project), but the off-taker may face higher variability from year to year in the effective price it pays per kWh.

Lenders seek certainty of revenue so that they can have confidence that a developer-borrower will repay its debt. Lenders may seek sponsor (equity) support to the extent that they perceive that hydrological risk may affect the certainty of revenue. Insurers currently tend to be focused on the question of damage, as traditional insurance only pays out if there is physical damage; but other risks are insurable, albeit generally at a high price. Climate change and changes brought about by other basin and water uses can also cause changes in long term hydrology, which need to be considered when allocating risk. This paper relates the lender, insurer and climate change perspectives in Sections 5, 6 and 8 respectively. It also briefly relates the contractor perspective in Section 4.

3. Hydrological risk considerations during the planning and development phase

It will seem obvious that hydrological data forms a large part of the planning for a potential hydropower project, yet even within the planning phase, there is a range of considerations of hydrological risk. First and foremost are the hydrological records, data on both historical river flows and weather. Developers normally tend to prefer to collect their own data, but in this there is little option but to rely on the data collected by the relevant government agencies. For example, for the 100 MW Gulpur project in Pakistan, Mira Power [2014] observed that hydrological and sedimentation data were available for the period 1960-2002, together with data related to meteorological parameters such as rainfall, temperature and humidity, obtained from the meteorological station maintained at Kotli by the Pakistan Meteorological Service.

Having obtained the data, it is a standard procedure for any significant water resource development project to run the data through statistical tests and models. The Dahmen and Hall set of tests, for example, is generally considered one of the most comprehensive methodologies for analysing hydrological data [Dahmen and Hall, 1996]. However, hydrological models cannot be fully relied upon, especially in situations where the future precipitation may not follow the pattern of the past as a result of issues such as climate change. The data may also be used to prepare a hydrological study, which can include long-term estimates of the annual and seasonal distribution of flow rate, the inter-annual variability, factors influencing rainfall-runoff, the potential for increasing or decreasing trends in the stream flow, and the reliability of the estimates [Rae, 2008].

The necessity to provide adequate ecological flows within the river must also be fully appreciated. As a result, while there is a need to carry out detailed hydrological analysis and sensitivity tests, it is also necessary to make a prudent choice on the size of structure, with potential for future adjustments such as adding additional generation units or changing the project’s operating rules. The dam itself will need to be carefully designed to withstand the expected hydrological variations, such as the probability of extreme floods and their structural or seismic impacts, with the design checked and double-checked not only by the developer but also by the owner’s engineer and lenders’ independent engineer.

In the long term, after the initial pay-back period, there may be a need to consider structural alterations. It is at this time that the developer may enter into further negotiation with the government, off-taker or operator on risk sharing.

While project design and optimization is the main
concern in the early parts of project preparation, there are other issues which may affect preparation, such as the consideration of seasonal flows during construction and the process of reservoir filling. Variations in hydrology can affect the construction schedule and budget, and even threaten those living close to the project site. An emergency preparedness plan will generally cover such extreme situations, but the construction schedule and budget also need some contingency for adverse weather conditions.

The hydro project should always be configured for the optimum economic value to the country concerned. This may at times be at odds with the preferences of the developer. For example, it may be in the interests of the country to have a significant reservoir, but the developer may consider that the project is simpler and less risky to build as a run-of-river project. Conversely, the environmental impacts may suggest the need for a smaller project, while the developer would rather maximize the size. In all such cases the project should be designed in the best interests of the country, and to ensure the optimum use of its natural resources, but this may mean that the government must share some of the risk with the developer, particularly design risk, if the project is optimized before the concession is granted. Lenders, too, can be so averse to hydrological risk as to encourage the developer to approach the project from a risk minimization rather than benefit maximization perspective.

The environmental and social impact assessment and resulting environmental management plan and social management plan will cover impacts on hydrology, water quality, water use, aquatic ecology and fishing and levels of ecological flows, based on national standards [ADB, 2011]. There may also be a need for an agreed management plan for ecological flows, water sharing and/or catchment protection. For example, at the 1070 MW Nam Theun II project, the protection of forest in the catchment areas was not only an environmental off-set, but also an indispensable measure to control soil erosion, consequent reservoir siltation and even illegal logging.

As part of the lenders’ due diligence, lenders and their environmental and social advisors will review all such plans for compliance with relevant lender requirements, such as the IFC (International Finance Corporation, part of the World Bank Group) Performance Standards or the Equator Principles [IEA, 2000].

In areas at risk of glacial lake outburst floods (GLOFs), hazard analysis and on-going monitoring are required when siting new hydropower development. In such areas, it is possible for a temporary obstruction, such as a landslide, to dam the river forming a glacial lake in the upstream reaches of the river. When such a temporary dam fails, the lake outburst has the potential to cause a sudden extremely high discharge, which is what happened in Peru in 1998, leading to the flooding and burial of the Machu Pichu hydro project [Reynolds International, 2014]. All countries with glaciers are at risk of GLOFs, and those countries where this particularly needs to be taken into account in hydropower development include Bhutan, Canada, China (especially Tibet), Iceland, Nepal, Pakistan, Peru and the USA (mainly Alaska). In these areas it is necessary to consider early warning systems, mitigation and adaptation measures such as remote-sensing [Hugger, Haeberli et al., 2002], reforestation and conservation of natural pastures for water retention, better agricultural practices and integrated water management plans that consider glacier runoff [Durand, 2010].

4. Hydrological risk during the construction phase

Hydrological risk during the construction phase mainly involves the effects of delay and increased cost to construction resulting from excessive flows (such as flash floods) during the construction phase of the project, where some structures are at times very vulnerable to flooding (such as overtopping of the cofferdam and main dam under construction). Excessive flows can also affect access to the site by damaging roads and bridges, and prevent work at certain stages of construction. Floods, debris flow or changes in silt levels can be caused by GLOFs (see above), by excessive rainfall or by upstream changes in the use of the river or catchment such as diversion or impoundment. As an example, flooding and sediment transport has contributed to delays during the construction of the 168 MW Cheves hydropower project in Peru [Reynolds, 2013].

A construction contractor may have to accept the risk of flooding up to an agreed recurrence interval, or the maximum possible flood and other extreme hydrological events up to an agreed recurrence interval (or agreed absolute level), and will usually have the right to claim force majeure and a time extension in the case of events that exceed such levels.

Seasonal changes in hydrological flows can cause difficulties to early works, such as access roads, and the construction of worker accommodation camps, as well as to the main construction site. Work may need to be curtailed or may be able to be extended, depending on the unpredictable timing of the seasonal changes in flow.

One of the most significant issues, later in the construction period, is the availability of sufficient water for performance testing. The EPC (engineering, procurement and construction) contractor or electromechanical contractor rarely takes the risk of delayed testing as a result of hydrological factors such as inadequate or excessive water. The developer will often...
A glacial lake outburst flood (GLOF) in Nepal. All countries with glaciers are at risk of GLOFs; hazard analysis and on-going monitoring is recommended.

take that risk in the EPC/electro-mechanical contract, pursuant to provisions which give the contractor a time extension for such a delay, and the right to recover its cost (if the event qualifies as having the required magnitude). The developer will often then seek to pass at least some of that risk on in its concession/implementation agreement with the host government and/or power purchase agreement with the off-taker, in that it will seek hydrological force majeure as an excuse for late achievement of commercial operation date (COD) and thereby avoid liquidated damages that may be imposed failure to achieve COD by a scheduled commercial operation date. Even governments that do not take hydrological risk during the operations period may be willing to accept an extension to the scheduled commercial operation date because of inadequate water for testing (although this extension of time may sometimes have a limit). Delay in start-up insurance will not cover this risk unless the hydrological event causes physical damage. However, the project company will usually have to retain the cost impact of delayed testing/delayed revenue if hydrological factors delay testing, even if it does not have to pay any liquidated damages for this risk. Even where the off-taker does not take hydrological risk during operation, developers will often seek to share this aspect of hydrological risk with the government or off-takers.

As noted in Section 3, flooding during construction can adversely affect local people and those resettled. Flooding of the Tokwe-Mukosi dam in south eastern Zimbabwe in February 2014 displaced thousands of people, and forced the Government to declare an emergency disaster, after water levels rose higher than expected causing a partial collapse of the dam being constructed [Sibanda, 2014]. Good project preparation, underpinned by lenders’ safeguard standards, require that emergency preparedness plans, including flood warning systems, are in place for such contingencies.

5. Hydrological risk during the financing phase

The main development financing agencies do not have a particular policy towards hydrological risk and tend to view each project on its merits. Multilateral financing institutions, such as the World Bank (including the IFC) or Asian Development Bank, and bilateral financing institutions such as the Norwegian Investment Fund for Developing Countries (NORFUND), Deutsche Investitionen - und Entwicklungsgesellschaft mbH (DEG), Nederlandse Financierings-Maatschappij voor Ontwikkelingslanden NV (FMO), Société de Promotion et de Participation pour la Coopération Économique SA (Poparco) and the Finnish Fund for Industrial Cooperation Ltd (Finnfund) have contributed finance to hydropower projects with a range of hydrological risk allocation and sharing mechanisms. The financial and economic analysis carried out for such hydro project includes a range of sensitivity scenarios, looking at hydrological risk to ensure that the project company remains capable of servicing its debt and that the government achieves a suitable return for the use of its natural resources, either in monetary value or in the availability of electricity for economic development. To facilitate this, the lenders consider the quality of the historical data and the impact of likely changes in hydrology from other developments or effects such as climate change. The impact will be considered on a variety of measures, such as the level of the debt service coverage ratio (DSCR), which is typically between 1.4 and 1.6 for a hydro project, that means, the project is capable of generating at approximately 1.5 times its debt service obligations each year in the agreed base case scenario. In the case of the DSCR, lenders would be looking to see that revenue never falls below the level of the debt service obligation, that is, not below a DSCR of 1 in the worst-case combination of risk factors including cost overruns, delays and extreme low hydrology (where this adversely affects revenues).

Commercial lenders are generally somewhat more sensitive to hydrological risk than the development financiers. They may be content to accept a hydrological risk profile based on good historical data (at least 10 years and ideally at least 20 years) and relying on an average flow which has a 50 per cent probability of occurrence (‘P50’), but they will also consider in detail the question of the seasonality of flows (including changes in seasonality, such as shorter or longer wet/dry seasons) and how the consequent variations in production may match the electricity market concerned. Depending on the overall structure and dynamics of local electricity markets (and options to import or export), most lenders would not accept the project company entering into PPAs under which its supply obligations exceed (or would likely exceed) a prudent level of hydrology, if this would result in onerous liquidated damages or other penalties under such PPAs for failure to meet such supply obligations, or the necessity to buy power on a spot market at high prices to meet their obligations.

Lenders also increasingly consider climate change risk, and where existing data is inadequate, commercial lenders may require inclusion of a mechanism for recalculation of hydrological risk during the life of the loan, taking account of the hydrological experience of the plant during operation.

All lenders will also conduct due diligence on the environmental and social aspects of hydrological risk, in many cases based on internationally accepted policies.

(d) Note that this range reflects a project with a long-term PPA. Projects selling power on a merchant (short term) basis may require a higher DSCR.

(e) Commercial lenders will base such DSCR calculations on hydrological scenarios based on a thorough assessment by a qualified and experienced lenders’ independent engineer, which will have the responsibility of providing the required hydrological data for the financial model used for the debt sizing.

(f) In some hydropower-dominated electricity markets, such as Chile, the price of power in a drought will increase such that low hydrology may not necessarily mean significantly decreased revenue.
cies, such as the IFC Performance Standards, and may require a cumulative impact assessment where a project forms part of a cascade of hydro projects on the same river.

Lenders’ conclusions on the magnitude of hydrological risk faced by a project may lead to lenders requiring an increase in the size of the debt service reserve account such that the account retains sufficient cash to cover debt service for 12 months instead of the more usual six months to tide the project over its debt service obligations in the event of low hydrology affecting revenues. In addition, the lenders may request increased obligations on the sponsors. For example, at the 13 MW Bugoye run-of-river project in Uganda, Emerging Africa Infrastructure Fund (EAIF), as lender, required 10 per cent of the loan amount as sponsor support to cover hydrological risk [Davis, 20099]. This commitment will expire before the discharge of the loan, as EAIF’s exposure to low hydrology reduces as the project company repays the loan. A sponsor such as NORFUND sees no problem giving limited sponsor support for hydrological risk where it has agreed that the project company will take this risk, because it takes the view that the project should not risk a default for a short-term hydrology event when it has made an investment decision, and based the plant’s design, on long-term hydrology. The sponsor support will have a maximum amount, and, if water flows are persistently low, as a result of an error in the hydrological analysis or changed hydrology, then debt will have to be rescheduled, and the sponsor support would be an element of that work-out. However, it is recognized that other sponsors may not be willing to provide sponsor support to lenders for hydrological risk.

Lenders of all types are sensitive to issues of water sharing with other users such as irrigators. While this may be subject to a formal agreement in practice, it may be contentious to deprive irrigators of flow during times of low hydrology, and local unrest can affect plant operation. Other hydrological issues described in this paper, such as flooding or low flows during construction are also of a concern to lenders and may be subject to a requirement for additional support (funding) from the sponsor and/or a requirement upfront for additional construction works to mitigate such risks, including required teams with the requisite expertise for such works.

Lenders may also require the borrower (project company) to conduct an upstream dam safety assessment, which is a risk analysis contemplating the consequences and probability of failure of upstream dams. This should model the potential effect of downstream flood waves resulting from upstream dam failures on the project’s hydraulic structures, verify the current status of upstream dam maintenance and conditions of operation, check design floods considered in upstream dam engineering, and propose risk management strategies where appropriate10. Lenders often also require an ecological flow management plan (sometimes included in a cumulative impact assessment), which mitigates the environmental and social impact of water diverted from its natural course, including its impact on fish, river-dependent population and other site-specific factors.

Lender sensitivity analysis will usually include a worst-case hydrological scenario, which includes a number of low generation, that is, dry years during the early years of the project’s operating period. For the financial and economic study for the 250 MW Bujagali project on the Nile in Uganda, the economic analysis was based on low and high water flow scenarios, allocating a 79 per cent probability for lower water flows and 21 per cent probability for high water flows [PPA Inc, 200711]. Both lenders and sponsors seek to size the debt at sustainable levels, based on their analysis of the hydrological data. Sponsors and lenders may also consider various approaches to insuring hydrological risk, which the next section will discuss.

6. The insurance perspective

The insurance perspective on hydrological risk differs between construction period insurance and operations period insurance, and the traditional and non-traditional insurance markets.

With respect to construction period insurance, the traditional insurance market focuses on those hydrological risks which are likely to cause damage to the plant under construction. The reason is that traditional construction and property insurance policies, including Construction/Erection All Risks and Delay in Start Up, will cover the damage directly caused by a hydrological event such as flooding, cyclone, hurricane or storm, but not the financial impact of project delays and additional costs (including labour and other prolongation costs) where the insured assets do not suffer physical damage from such event. The traditional approach of insurers to due diligence on hydrological risk reflects this approach, in that insurers focus on the risks of sudden accidental and potentially catastrophic hydrological incidents rather than historic river flows and seasonal variations. The main insurers do have elaborate (although mainly backward-looking) models, which they use in an effort to predict the scale and frequency of such incidents, and they are beginning to incorporate climate change data in these models; however they all admit that these data remain unreliable.

In setting the pricing for construction period insurance for hydro projects, underwriters suffer from limited availability of actuarial data on losses to hydropower plants caused by hydrological events, although insurers have received a number of landmark claims generally arising from major flood events causing damage and delay to hydropower plants in Canada and Scandinavia (and one in Scotland as well) [Shiels, 201412]. The sum insured for Construction/Erection All Risks insurance will equal the full replacement value or an agreed limit. For Delay in Start Up insurance, the sum insured can vary from debt repayment

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3. For example, see Cheves Hydropower Project, Supplemental Environmental and Social Action Plan, IFC website, available at: http://ficext.ifc.org.
ditional insurance [WRMA, 2104 17]. Non-traditional
products to mitigate hydrological risk faced by players in
the hydropower sector, without the limitations of tra-
cditional market is directed to reducing rather than
insurers taking a portfolio rather than an engineering
approach to underwriting. Operations period insurers
provide cover on an annual basis, and diversify their
risk across types of business and locations. This makes
engineering due diligence on a project-specific basis
less necessary. Insurers covering risks during the oper-
ations period commonly use natural catastrophe mod-
els to ensure that they do not face disproportionate
exposure to any particular risk, type of asset or loca-
tion. Both the main traditional insurance policies
applying to hydrological risk, All Risks of Physical
Damage insurance and business interruption insur-
ance, require direct physical damage to the insured
property. The sum insured for All Risks of Physical
Damage insurance will equal the full replacement
value or an agreed limit. For Business Interruption
insurance, cover ranges from debt service obligations
to full loss of profit. There may also be hydrological
damage aspects to Third Party Liability and terrorism
coverage.

Having established that traditional insurance requires
a physical damage trigger, it is easy to see that such
insurance leaves many effects of hydrological events
uninsurable. For example, a Construction/Erection All
Risks policy may respond to flooding which causes
damage to equipment in the powerhouse, but it will not
respond to the effects of excessive water that does not
cause physical damage, such as lost work time or pre-
vention of certain construction activities or performance
testing and commissioning as a result of storms,
flash flooding or debris flow. A Delay in Start Up
insurance may respond to the loss of revenue caused
by damage to substation equipment caused by a freak
storm but, in the absence of physical damage, it will not
cover the loss of revenue caused by delayed com-
mercial operation as a result of inadequate water for
performance testing, which does not cause physical
damage. Nor will Business Interruption insurance
cover loss of revenue during operations caused by
inadequate water as a result of drought, low rainfall or
a lack of snow. Thus, using conventional insurance, it
seems that a lot of hydrological risk is uninsurable.
Indeed, it has been observed that the psychology of the
traditional market is directed to reducing rather than
expanding its exposure to weather.

Since 1997, a few non-traditional insurance pro-
viders have developed weather insurance products
which make use of weather data (measurable weather
variables such as temperature or precipitation) as the
basis for risk indices. This has led to a weather insur-
ance market developing, which today can tailor prod-
ucts to mitigate hydrological risk faced by players in
the hydropower sector, without the limitations of tra-
cditional insurance [WRMA, 2104 17]. Non-traditional
insurance for weather is a specialist product provided
by only a small number of insurers including
Endurance Global Weather, Munich Re, Swiss Re
Corporate Solutions, Allianz, Liberty and a few hedge
funds. Such policies are usually structured as paramet-
rpic insurances. This means that cover is triggered if
certain pre-defined event parameters are met or
exceeded. If cover is triggered, the pay-out will be
determined by the behaviour of one or more indices,
irrespective of the actual loss or damage incurred.
Thus, proponents of parametric insurance claim that it
can lead to a quick pay-out, and avoids the transaction
costs involved in loss assessment and underwriting
based engineering or portfolio due diligence.

Parametric weather insurance products have a repu-
tation for being expensive and some are sceptical of
their value for hydropower projects. However, despite
the dearth of such transactions in the public domain,
the hydropower sector has seen some large weather
insurance transactions (b). Although the cost may not be
insignificant, their value to the insured, usually the project
company, can manifest itself in one or more of
the following advantages: reduced earnings volatility;
proved project bankability; and, facilitation of the
involvement of institutional investors. For them,
hydrological risk often conflicts with their need for a
minimum guaranteed yield and require a guaranteed
yield and more financial flexibility. Furthermore, the
ability of providers in this space to tailor such products
to the specific needs of the insured means that the cost
of such products can be reduced by sharing some of
the advantages of good hydrology with the insurer. For
projects with considerable hydrological risk, this
insurance could mean the difference between some
projects proceeding or not.

Parametric weather insurance products are usually
taken out in the hydropower sector to cover the rev-

ence effects of decreased production as a result of
inadequate water during operations. However, a recent
innovative transaction (albeit not in the hydropower
sector) underlined the potential of parametric struc-
tures to cover project down times during the construc-
tion period, in that it was structured to respond to
objectively defined cyclone and rainfall events occur-
ing during the period of construction of a mine over
two cyclone seasons [Willis, 2013 19]. Hydropower
developers working in areas prone to extreme hydro-
logical events such as cyclones, hurricanes or even
certain flooding could potentially find that such poli-
cies make business sense.

Pay-out based on the measurement of rainfall or even
stream-flow against an index requires good quality
hydrological data. In practice, this means that
providers often require that data from meteorological
agencies be checked and verified by a reliable, third-
party data source. In case such third-party quality-
checked data are not available, parametric insurance
providers may ask specialized companies to set up
additional stations and calibrate measurements to his-
toric time series.

While project owners are the main customers for
parametric insurance and weather derivatives for
hydrological risk for hydropower plants, the World
Bank (with reinsurance backing from Swiss Re and
Allianz) has sold such a product to Uruguay’s state-
owned utility Administración Nacional de Usinas y
Trasmisiones Eléctricas (UTE) in what it believes to
be the first example of a state-owned utility insuring
hydrological risk. UTE is like many state-owned off-

(b) See “Weather derivatives. Come rain or shine. The outlook for the
business of hedging against the elements”, The Economist, 4 February
2012. “There have been some huge transactions with companies that
generate hydropower, which requires consistent snow and rain”; and,
“Swiss Re Corporate Solutions receives award for Weather Risk
Management Transaction of the Year 2012”, which describes a
precipitation index insurance solution for Guangdong Meylan
Hydropower Co Ltd, the first such risk transfer deal of its type in China
7. Hydrological risk during the operations phase

Hydrological risk during the operations phase of a hydropower plant may manifest itself as inadequate or excessive water, or changes in the timing of flows as a result of seasonality, climate change or other reasons. If the risk remains with the owner, then low hydrological flows will translate into lost revenue. In contrast to the potential for high losses in revenue caused by low water flows, developers are often remunerated at a much lower level for generation which is beyond the agreed dispatch, creating a mismatch between the upside and downside risks. Projects with large storage may be less vulnerable to the risk of lost revenue than run-of-river projects.

The site-specific nature of hydropower makes it difficult to make general statements about the allocation of such risk. In the early days of hydropower concessions, it appeared probable that developers would refuse to accept hydrological risk. According to Head [2001]: “There is now recognition that it is often unrealistic to expect a private owner to assume hydrological risk when he has not been party to the collection of the original data on which the river flow is assessed.”

However, more recently, as the appetite for hydropower concessions has improved, it has become apparent that some developers do accept the hydrological risks. However, the authors have found no evidence that any one element of a project affects the developer’s attitude to hydrological risk, not even the degree of design freedom which the concession allows. Every case (as with so much of hydropower development) is case-, site- and country-specific. Thus the section which follows will consider different examples of hydrological risk sharing.

7.1 Allocation of hydrological risk to the off-taker

7.1.1 New Bong Escape hydropower plant, Pakistan

The 84 MW New Bong Escape hydropower project on Jhelum river in Azad Jammu and Kashmir (AJ&K) was Pakistan’s first independent hydropower project. It is downstream of Mangla, a major storage reservoir for irrigation as well as power. Of the discharge from Mangla, a fixed amount is required for irrigation and only the excess can go to New Bong, which has no significant storage capacity. As a result, the long-term PPA with the national transmission company (Pakistan’s National Transmission and Dispatch Company Ltd, NTDC) allocates the hydrological risk to the purchaser. A guaranteed payment (take-or-pay obligation) for 470 GWh/year (c.f., annual electricity generation of 540 GWh ‘based on historic hydrology’) covers fixed costs such as debt servicing, operations and maintenance, return on equity and insurance. NTDC will pay for energy above 470 GWh at a special rate of 10 per cent of the prevailing tariff [Laraib Energy Ltd, 2014].

In this case, the Government had little option but to retain the hydrological risk through the state-owned off-taker, as the plant was effectively being managed as part of a cascade of competing water uses (the Government of Pakistan having guaranteed the payment obligations of NTDC, Government of Pakistan and Government of AJ&K, under the concession documents). In the case of such cascades, it is possible for the off-taker to absorb the hydrological risk, especially where there is a developed energy market, but this was not the case in Pakistan.

7.1.2 Singrobo hydropower project, Côte d’Ivoire

Similarly, in the case of the 44 MW Singrobo hydro project in Côte d’Ivoire, a 35-year PPA has been agreed with state utility CI-Energies, based on fixed and variable capacity payments, which allocate the risk of adequate water supply to CI-Energies, given the location of Singrobo downstream from the state-owned Taabo dam and hydropower plant [Whiteaker, 2014].

7.1.3 Bujagali hydropower project, Uganda

For the 250 MW Bujagali hydropower project on the Nile in Uganda, the off-taker, Uganda Electricity Transmission Company Limited (UETCL), takes the hydrological risk through a capacity charge which is adjusted based on the prevailing hydrology in such a way that the project company is paid irrespective of the actual production output (low or high hydrology and demand) [AFDB, 2008]. The rationale for this risk allocation was twofold: first, because of the unique hydrology of Lake Victoria and the Nile, on which even experts have widely divergent views; and second, to encourage development in Uganda, which suffered particularly high power prices.

UETCL has some protection against this allocation of hydrological risk, in that if the water flow falls below a low base level for an extended period for any reason other than a cause attributable to it or the Government of Uganda (GOU), then UETCL can terminate the PPA and purchase the plant by paying off the debt and a defined equity return [World Bank, 2007].

The allocation of the hydrological risk to UETCL was later claimed to give the GOU possible cause to overdraft water from Lake Victoria. An independent

The 84 MW New Bong Escape project, Pakistan’s first independent hydropower project. In this case the Government retained the hydrological risk through the state-owned off-taker.
7.1.4 Ruzizi III hydropower project, DRC/Rwanda

Power from the 147 MW Ruzizi III hydropower project, on the Ruzizi river between Lake Kivu and Lake Tanganyika, which forms the border between DRC and Rwanda, will be sold to the utilities of Burundi, DRC and Rwanda [EGL, 2014]. The tariff under the three PPAs for that project is being structured in much the same way as that for the Bujagali project. Observers have speculated that a similar rationale to Bujagali applies for such an approach, that is, the unique hydrology of the Great Lakes region and the development imperative.

7.2 Allocation of hydrological risk to the project company

There are many examples of projects where hydrological risk remains with the developer, despite the fact that the project company obviously will not develop and finance a project in such a way, for GOU to avoid paying for electricity not generated is to ensure that as much water as needed is made available to the dam, including in driest years. Thus, the AfDB Review Panel could not rule out the risk that the new Bujagali dam could lead to draining more water from Lake Victoria than allowed by the Agreed Curve (historically used to govern such outflows).

7.3 Sharing of hydrological risk between the off-taker and the seller

In some cases there is a sharing of the hydrological risk, or a range within which revenue can be affected by the risk.

7.3.1 Nam Theun II project, Lao PDR

At the 1070 MW Nam Theun II project in Lao PDR, the hydrological risk is shared between EGAT (the Thai off-taker) and the Nam Theun Power Company (the operator) [Sinha, 2007]. While the water management remains entirely the project company’s responsibility, the variation in revenue to Laos is limited such that (among other terms) the revenue will not fall below 86 per cent of the average annual revenue even in the driest year.

7.3.2 Brazilian hydropower

Brazil’s Energy Reallocation Mechanism [Barroso, 2003] is a complex way of managing hydrological risk, which spreads the risk across the system rather than having a defined approach for each plant which is independent of the system. The scheme effectively creates a compulsory hedging system for hydropower plants. This works because although the production of individual plants may vary, in general across Brazil the hydropower production does not vary significantly. Plants are allocated a proportion of the overall hydropower production and remunerated according to this nominal production rather than to their actual production. This reduces risk unless the overall production is reduced in the year, thus hydropower plant owners in Brazil face systemic risk at times of drought, such as in 2001 and 2014.

7.3.3 San Roque hydropower project, The Philippines

In the case of the 345 MW San Roque hydro plant in The Philippines, the utility off-taker, the National Power Corporation, shares part of the hydrological risk through a minimum payment provision. This is partly because of the project’s multipurpose aspects, with a public-sector entity overseeing the project’s non-power benefits including flood control, irrigation and water quality [Head, 2000].

7.3.4 Sub-Saharan Africa run-of-river project under development

In a Sub-Saharan Africa run-of-river project under development, the project company and the state-owned off-taker have agreed to share hydrological risk by way of a tariff structure, which oblige the off-taker to pay for a minimum volume equivalent to the annual P90 volume irrespective of hydrology. A firm-energy tariff will be sized to allow the project company to derive 90 per cent of its base case revenue (revenue required for debt service and equity return) from such P90 hydrology volume and a non-firm energy tariff will be sized to allow the project company to derive the remaining 10 per cent of base case revenue from the P90 production. By taking most of the hydrological risk in such way, the state-owned off-taker is likely to achieve a lower tariff through a lower cost of financing as well as reasonably priced equity.

7.4 River basin/watershed issues

Specific circumstances in some countries may include the issue of upstream development (causing diversion, impoundment, flooding, debris flows, siltation or sedimentation) resulting in inadequate or too much water,
or changes in the timing and quality of water flows. While this is generally covered within the Government’s basin development plan, watershed management agreement or similar, at times there can be unforeseen impacts on downstream plants, or issues which are in violation of such agreements. Similarly, there can be risks to an upstream plant if another is constructed downstream such that its reservoir interferes with the upstream operation. Generally, if such risks were known at the time of plant construction, in other words, they were already part of the basin development plan, or are part of normal plant operation such as sediment flushing, then these risks remain with the owner. However, when the risk was not known at the time of construction, or where development contravenes the watershed agreements, then the damaged plants may be entitled to compensation either from the Government or from the plant which is in contravention.

Trans-boundary issues with upstream and downstream development may be a question of relevant international water law such as the Indus Water Treaty, which governs water sharing between India and Pakistan with respect to the six rivers in the Indus system of rivers [Indus Water Treaty, 1960]. However, in most cases: “there are no widely enforceable water laws to preserve natural flows for downstream riparian states” [Head, 2000].

In the absence of established basin protocols, it is left to the cascade owners to maximize their joint production. Sometimes the owners can cooperate successfully to maximize production without formal basin protocols. Turkey, for example, has allocated some cascades to several developers in sections large enough that the daily dispatch can be managed well by each. On the Niagara river, which borders Canada and the USA, trading of water rights pursuant to a Memorandum of Understanding between the New York Power Authority and Ontario Power Generation often facilitates water allocated to one country, under the 1950 Niagara River Water Diversion Treaty, being used by the power company from the other country, which can generate more energy from the same resource. The two companies then settle the commercial gains among themselves.

In less well developed locations, hydropower development rights with respect to a watershed with multiple uses and users should be granted in conjunction with an obligation to enter into a water use agreement that establishes the amount and nature of the water available to the project, as well as details relating to its consumption, storage and release, including with respect to sharing with other users. This is in effect what is happening for the Ruzizi III project, for which a management secretariat catering for the multiple water uses of Lake Kivu and the Ruzizi forms part of the deal for the hydropower concessionaire. The Lake Kivu and Ruzizi River secretariat will be set up and operated by Burundi, DRC and Rwanda, and will give certainty to the hydropower concessionaire [EU-Africa Infrastructure, 2014] about water management and hence the hydrology available to its project.

Non-hydrological construction issues upstream can cause hydrological issues downstream. For example, the 120 MW Esti hydro project in Chiriquí Province, Panama, experienced a number of collapses in its headrace tunnel as a result of unforeseen ground conditions [Tunnel Talk, 2011], which meant that, until repair of the damage, it could not discharge the water intended to supply the downstream Gualaca facility, meaning that it prevented operation of that partially commissioned facility for approximately one year [Winner, 2010]. The Gualaca facility forms part of the 115 MW Dos Mares hydro project, which consists of a cascade of three run-of-river plants between the Esti and Chiriqui rivers in Chiriqui Province. In Panama, generators using water from the same river have no contractual relationship with each other, meaning that a generator has no contractual remedy against an upstream owner for lack of water. The downstream owner may, however, have an action in tort for negligence. A further interesting question in this context would be whether the downstream owner has any remedy against the regulator for a failure to receive the supply of water allocated by its licence.

The 120 MW Sanjani Vidytu Pariyojna (Bhaba) project on the Bhaba river in Himachal Pradesh, India, had its tailrace diverted through a tunnel so that the dam height (and hence reservoir size) of the downstream project could be raised [Chauhan, 2008]. Had this work not been carried out, the operation of Bhaba could have been significantly affected by the raising of the Nathpa Jhakri dam height.

7.5 Capacity pricing

Capacity pricing for hydropower production can represent a form of sharing of hydrological risk, although it depends on the structure of such payments as availability needs to be independent of hydrological conditions for a transfer of hydrological risk to the off-taker to occur (as it does for the Bujagali project).

The use of capacity payments can be a very effective way of moderating risk, but it can be difficult for Governments or off-takers to set the capacity payment at exactly the right level over a long-term PPA. In Colombia and some other South American countries, capacity payment values are determined through auctions among interested generators. If set correctly, capacity payments can both provide predictable revenues for operators and also protect consumers from price spikes [Campo, 2009].

However, capacity payments for hydropower plants do not fit well into a larger energy market dominated by per kWh energy prices, and incentives such as feed-in tariffs. Thus many of the more mature markets, such

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(j) Treaty Between Canada and the USA concerning the diversion of the Niagara River, 1950; available at: http://www.treaty-accord.gc.ca.
as Norway, do not use capacity-based pricing. There is a degree to which hydro-dominated markets may be self-correcting, in that during a low hydrology year, the scarcity of power will lead to price increases and hence operators sell less power but for a higher price, and vice versa in high hydrology years. However, in less developed or less hydro-dominated markets this effect will not be significant.

8. Climate change
The level of uncertainty imposed on a project by climate change considerations is significant. Climate change calls into question the value of past data and trends, and yet there is little certainty as to the direction or amount of change relating to hydrology for particular hydropower projects. One solution is to use optimization techniques such as real options analysis to consider the best decisions in light of this uncertainty. This approach has been demonstrated on the Blue Nile [Jeuland and Whittington, 2013\(^\text{36}\)\]. In this case the aim was to minimize the losses from future changes in hydrology and maximize the gains. The analysis concludes that in the case of the Blue Nile, it is better to build now, with some flexibility in plant size, rather than wait for better information: “For all reasonable investment strategies and a realistic time horizon for obtaining more information about hydrological change and development uncertainties, the economic costs of delay are greater than the benefits associated with obtaining that information”.

It is vital that each project considers climate change-related issues even if the data are inadequate, and there appears to be no effective solution; the fact that an analysis has been carried out can form a baseline when better data become available. Until the data and modelling of climate change are better and more site-specific, forecasts are available, the most appropriate way forward is to incorporate Adaptive Risk Management in water resources management, especially in planning new projects. This would entail regular monitoring, evaluations and reviews, with possible redesign of the management programme, as required, based on an appropriate set of indicators. For example, some PPAs for BOT projects in Turkey have provided for tariff adjustment to reflect changes in long-term hydrology [Head, 2000\(^\text{37}\)\].

Sometimes it will be possible to provide a range of possible impacts of climate change on hydrology. For example, the draft hydrology report for the Amaila Falls hydropower project in Guyana provided as follows [PPA Energy, 2011\(^\text{37}\)\]: “The simulated energy yields indicate that the impact of climate could result in reduction in annual energy yield from 1.3 to 2 per cent for different scenarios when reductions in rainfall range from -0.6 to -2.9 per cent.”

Some developers report that they are using a shorter sequence of hydrological data to predict future hydrology, particularly where the recent flows have been lower. This change in methodology is considered appropriate since some climate change effects are already in place, and thus recent data may provide a better predictor of future flows than long-term historical trends. However, as yet there is no strong academic basis for this approach.

From the insurance perspective, insurers do try to update their backward-looking loss models to include climate change factors, to varying degrees of reliability [Shields, 2014\(^\text{44}\)\].

9. How is hydrological risk reflected in project documentation?
Most projects will consider project risk in the basic project appraisal documentation, whether this is the detailed feasibility study or appraisal report prepared by a lender. As mentioned above, the economic analysis will generally include a sensitivity analysis, which looks at the impact on the project rate of return of variations in hydrology [World Bank and IFC, 2002\(^\text{38}\)\]. There may be a specific section of the report which analyses each risk and the possible management and mitigation, often called a ‘risk matrix’ [World Bank, 2007\(^\text{39}\)\].

In addition, a ‘risk register’ for a project may include various terms which are provided to define various risks, to identify measures to be taken in case the risk materializes and to allocate the risk to various parties. Such registers may consider (among other site-specific issues) geotechnical and geological data, seismicity, environmental issues and hydrology, including the probable maximum flood for which the dam is designed, the available data on river flows and the possibility of GLOFs. The preparation of such a register can do much to improve the understanding of the project risk by all stakeholders, and may thus help to avoid future disputes over the nature of the project risk and their allocation. Risk registers are increasingly used as part of the construction contract to define the risk sharing.

9.1 Environmental and social impact assessment
Typical environmental (and social) impact assessments (ESIA) will comment on the hydrology on which the plant design is based. This will include the mean flows, the seasonal variations, the size of the catchment, the area of the basin and the quality of the water in terms of silt and other indicators. This technical information will then be used in all subsequent considerations of the effects of issues such as in-stream flows, fisheries, other water users, local populations, water regulation, river fragmentation, local stream habitats, migration of aquatic species, erosion, transport of sediment, wetlands, seismicity and the environmental sustainability of the catchment area.

The ESIA or consequent environmental management plan (EMP) will define the level of environmental or in-stream flow which must be maintained to protect the flora, fauna and water quality of the river, which in turn must be incorporated into the project forecast hydrology\(^\text{(k)}\). The ESIA/EMP will also consider the safety implications of the level of river flow during construction, and the possibility of extreme events such as flash floods both for the construction workforce and the local populous. This will include such actions as a local area flood warning system. Water quality monitoring and management are specified in the ESIA, and would form part of the EMP or ongoing adaptive management plan.

Depending on the nature of the project, similar issues may be assessed in a cumulative impact assessment of a river system or basin area and in a review of any governing bilateral or multi-lateral agreements on the use of water in particular river systems.

\(k\) See, for example, the briefing note on environmental flows for the 120 MW Itzeho-Tezhi Hydropower Project, Zambia at: www.hydrossustainability.org.
9.2 Insurance policies

Traditional insurances will usually be documented by way of standard contracts of insurance, which set out the trigger as loss or damage to a physical asset, and certain policy conditions, deductibles and exclusions [Swiss Re, 201148]. Parametric or index-based cover may use documentation developed by the International Swaps and Derivatives Association (ISDA) for standard weather hedge structures [Speedwell, 201449] or bespoke contracts for tailored structures. For legal or regulatory reasons, the cover may be structured as a derivative rather than insurance.

9.3 Concession agreement

In addition to the foregoing documentation of a commercial and/or technical nature, the legal documentation will address hydrological risk in the Concession Agreement Power Purchase Agreement and EPC Contracts.

The key right that a developer will want protected in its legal arrangements with the government is its right to water. While the right to use a certain quantity of water is usually a feature of a generation licence from the applicable regulator, developers will often seek to include this right in the Concession Agreement, which governs the relationship between the Government and the developer with respect to the development of the project. A Concession Agreement for a hydropower project (or relevant Government permit) would usually grant water use rights to the extent and under the conditions specified in a generation licence, including the right to use flow from a certain river or rivers, and sometimes tributaries of such river(s), within a certain elevation.

Such a right may be exclusive or subject to agreement with other water users within the river basin. The right to use water during operations may be separate from the right to extract water from a watercourse during construction.

A developer will usually seek protection for its water use rights in a concession agreement. This is done by negotiating a covenant to prevent the government or any other agency, from issuing any other licence or permit for the harnessing, use, diversion or release of water resources in the catchment area of the site that would:

• substantially impair the flow of the water with the effect of reducing the average daily, seasonal or annual flow yields or volume of available water at the site to a level below that required for the plant(s) to produce electricity at the planned level of electric output; or,

• otherwise adversely affect the operation or maintenance of the plant(s).

A developer may seek to strengthen such a covenant by including a provision that obliges the government to consult with the developer first, and take all reasonable measures requested by it, to avoid an adverse effect caused by the granting of a water use right which could negatively affect the implementation and operation of the project, and to pay the developer compensation in the event of such an adverse effect. Similarly, the developer may seek to include in the concession agreement a right to compensation if the government fails to protect the upstream catchment area and it deteriorates, causing siltation of tunnels and waterways which adversely affect the project’s flow [Head, 200052]. A government, on the other hand, may seek to limit such covenants in the interest of maximizing its freedom to manage and develop the watershed further in the way it sees fit. Instead, it may seek a covenant for the developer to cooperate and coordinate its operations with other projects to be developed on the river, to optimize basin value, where consistent with the achievement of expected return on equity and share its engineering design and operating assumptions with other hydropower project developers being developed in the same basin [MOEN, 201442].

If the project is located on an international river, the developer may seek a requirement in the concession agreement for the government to notify, consult and share information with riparian states, and obtain any relevant approvals required from such states to the extent required for the project60.

A government may also seek to include certain obligations on the developer in the concession agreement with respect to hydrological matters, including:

• a covenant obliging the developer not to impair the use of the river for drinking water, irrigation, and other industrial, recreational and cultural uses without making alternative provisions to the satisfaction of the existing users; and,

• a covenant obliging the developer to ensure that the water released from the power station after COD is of the same quantity, quality and discharge rate as before COD [MOEN, 201442].

In such a case, the water released should not substantially impair the value and operation of the existing projects or projects being constructed or proposed for the future in the downstream stretches of the river. Some governments, such as the Government of Nepal, include in their concession agreements a requirement for an Environment, Social and Local Benefits Panel, whose responsibilities may include review and approval of plans, reports and implementation arrangements with respect to “upstream and downstream hydrological impacts”.

9.4 EPC and other construction contracts

Whether or not an EPC contract will allocate the risk of inadequate or excessive water during construction to the contractor or employer generally depends on the magnitude of such lack or excess of water (generally drought or flooding) and whether it constitutes force majeure. These two questions are linked, in that the EPC contract may define one of the requirements of a force majeure event by reference to an agreed recurrence interval, such as a one in 100 year flood, or an absolute level of flooding based on the maximum possible flood (as discussed in Section 4). An event which qualifies as a force majeure will excuse the EPC contractor from performance and entitle it to a time extension for completion of the works.

The standard form FIDIC construction contract, used widely in the hydropower business, defines ‘force majeure’ as ‘an exceptional event or circumstance (a) which is beyond a Party’s control, (b) which such Party could not reasonably have provided against before entering into the Contract, (c) which, having arisen, such Party could not reasonably have avoided

(1) Consider, for example, obligations under the Nile Basin Cooperative Framework Agreement, available at: http://internationalwaterlaw.org.
or overcome, and (d) which is not substantially attributable to the other Party.

The indicative list of such events includes “natural catastrophes such as earthquake, hurricane, typhoon or volcanic activity”. Parties may seek to define ‘exceptional’ further in such context, and avoid disputes over the nature of the standard, by reference to a specific recurrence interval or absolute level (sometimes differing depending on the nature of certain force majeure events). For example, the parties may agree on a flood return level based on flood hydrology studies, meaning that the employer only takes the risk if flooding exceeds a certain level. However, this approach assumes that the necessary historical hydrological data exist on which to base such risk allocation.

The FIDIC Red Book contract, often used for the civil works of a hydro project, and the FIDIC Yellow Book contract, often used for the electro-mechanical works of a hydro project, also contain the following Employer Risk: “any operation of the forces of nature which is unforeseeable or against which an experienced contractor could not reasonably have been expected to have taken adequate preventative precautions”. FIDIC defines ‘unforeseeable’ as “not reasonably foreseeable by an experienced contractor by the date for submission of the Tender”. If the contractor suffers delay and/or incurs cost from rectifying loss or damage caused by such an event, it may claim a time extension and its cost. Thus, under a FIDIC contract, a contractor will prefer to characterize flooding or drought as an ‘Employer Risk’ rather than force majeure, so it may recover its cost from such event and not just receive a time extension. Most other standard form and bespoke construction contracts do not grant a contractor recovery of cost from a force majeure event of a non-political nature. Again, some parties may seek to avoid disputes over the meaning of ‘unforeseeable’ by including recurrence intervals or absolute levels for risk allocation, rather than relying on what a court, arbitral tribunal or dispute adjudication board will consider “not reasonably foreseeable by an experienced contractor”.

The FIDIC Red Book contract and FIDIC Yellow Book contract also grant a contractor a right to an extension of time if “exceptionally adverse climatic conditions” delay completion. This could include flooding and presumably even drought, which may cause a shortage of water, delaying performance testing and commissioning. Furthermore, contractors concerned that shortage of water from drought may delay commissioning and hence handover to the client, may request a specific right to a time extension (although an employer may seek to exclude from such a right delay to completion caused by inadequate water arising from poor design by the contractor).

Extreme hydrological events may also excuse a party from performance under a construction contract pursuant to the English law doctrine of frustration. The FIDIC standard form contract includes an analogous contractual remedy as it provides that “if any event or circumstance outside the control of the parties (including force majeure) arises which makes it impossible or unlawful for either or both parties to fulfil their contractual obligations or which, under the law governing the contract, entitles the parties to be released from further performance of the contract, then upon notice by either Party to the other Party of such event or circumstance, the Parties shall be discharged from further performance”.

9.5 Power Purchase Agreements

The key approach in a PPA to the allocation of hydrological risk during operation of a hydro plant is through the payment provisions, which allocate the revenue risk of decreased production caused by low hydrology. However, PPAs also allocate hydrological risk through the concept of forced outages, the application of liquidated damages and certain covenants. PPAs for hydropower projects usually contain payment obligations, which involve either a capacity charge, an energy charge or a combination of the two. A capacity charge is a fixed payment that is paid in each billing period for each kilowatt of available capacity even if not actually dispatched (see also section 7.5). It is intended to reimburse fixed charges involved in the construction, operation, and maintenance of the powerplant, including charges for repayment of the principal, and interest on the debt used to construct the facility, a return on equity capital invested, operation and maintenance costs that are independent of the amount of energy generated (such as staffing costs, administrative expenses, operator fee, insurance premiums, and so on), demand or throughput charges, or minimum take-or-pay obligations. An energy charge is paid each period for each kilowatt-hour of energy dispatched and delivered at the agreed delivery point. It includes variable costs involved in the generation of the energy delivered, including commodity charges for each unit of fuel used, variable operation and maintenance costs (such as spare parts, lubricants, and other consumables) and a major maintenance sinking fund to cover the costs of required turbine maintenance based on usage [Nehme, 2012]. As discussed in Section 7, a PPA may use capacity payments or minimum energy charges (including take-or-pay arrangements) to allocate the hydrological risk of decreased revenue resulting from adverse hydrology.

Some companies seek to reduce the amount of hydrological risk that they incur using a PPA which contracts firm and non-firm/surplus energy. Firm energy is restricted to a conservative amount which the
operator feels can be delivered reliably. Non-firm/surplus energy is used for the sale of any additional energy available over and above the firm energy. This is effective in reducing the risk taken by the developer, but is not generally the most remunerative option, as non-firm energy receives a lower tariff than firm energy.

A failure to earn revenue may not be the only consequence of low hydrology causing lower production. A PPA may obligate the seller to pay liquidated damages (LDs) in certain cases, when it cannot generate for hydrological reasons, including an obligation to pay the buyer LDs for failure to meet the COD by the scheduled commercial operation date (as discussed above) or forced outages, that is, a failure to make available contract energy at the connection points for any reason other than a permitted outage (including maintenance and buyer risk events). While such LDs may be capped on a periodic basis or for the term of the PPA, they may still constitute a significant risk for the seller to bear, which will affect the financing terms for the project and hence the power price.

Besides the commercial terms relating to payment and LDs, a PPA may also allocate hydrological risk through its definition of force majeure. A hydropower developer may seek to include the following within the definition of force majeure, whether as a “political force majeure event” or as a specific definition for a “hydrological force majeure event”:

- “any diversion or impoundment of water upstream or downstream from, or siltation of the impoundment area immediately behind, the generation facility, caused by (i) the installation of any hydropower, irrigation, flood control or other project other than the generation facility, or (ii) any land-use activity carried out by any person other than the seller (or a person controlled by the seller), whether lawful or unlawful, or landslide, erosion or any other natural event, that occurs within, or impacts on, any portion of the watershed area for any such facility, in each case occurring after the agreement date.”

The developer will be excused from its obligations during such a hydrological force majeure event, and obtain a time extension for the duration of such an event. If the event continues for a prolonged period, usually exceeding 12-18 months, the developer often has the right to terminate the PPA and require the off-taker to buy it out for the price of the outstanding debt, plus a return on equity.

Viewed from the off-taker’s perspective, adverse hydrology may expose it to increased fuel costs for replacement thermal generation (as discussed above in the case of UTE), volatility in its revenue and even, in some cases, compensation obligations to distribution companies and other parties, including downstream parties. If the payment provisions in the PPA require the off-taker to make minimum guaranteed payments (or take-or-pay obligations) irrespective of the actual production output (low or high hydrology and demand) such as at the Bujagali project discussed in Section 7.1, the off-taker may wish to include the following additional limb (or similar) in the definition of “hydrological force majeure event”:

“Unforeseeable climatic conditions including any periods of drought, which disrupt the operation of any hydropower facility, connected to the grid system. For the purposes of this definition, ‘unforeseeable’ means a climatic condition reasonably expected to occur less frequently than once every fifteen (15) years.”

This would entitle the off-taker to be excused from its obligations and after the agreed prolonged period terminate the PPA.

9.6 Financing documents

Loan documentation, such as common terms agreements and facility agreements, do not usually contain many provisions relating to hydrological risk. The main thrust of these provisions will usually focus on covenants relating to the environmental and social aspects of hydrological risk (discussed above) and reporting obligations with respect to compliance with the Environmental and Social Management Plan, Ecological Flow Plan and other requirements. In addition to the environmental and social requirements, loan documentation will usually contain covenants obliging the borrower to notify the lenders of damage to, or delay to, the project’s completion, so this covenant will capture damage or delay caused by hydrological events during construction or operation. For projects on international rivers, lenders will allocate the responsibility of any required notification of (or approval from) riparian states to the government. Multilateral financiers will generally insist on such consultation as a pre-condition to entry into the financing.

In Section 5 above, it was noted that lenders may require sponsor support if the project company is exposed to hydrological risk of a magnitude that they cannot accept. Lenders usually request such support by way of a sponsor support agreement, according to which the sponsors agree to make available funding to the borrower if a certain trigger event occurs after the occurrence of a debt service default by the project company/borrower. This commitment will sit as a contingent liability on the respective sponsor balance sheet(s), although in some cases, depending on the strength of the balance sheet of the relevant sponsors, the lenders will require one or more sponsors to back such corporate guarantee with a letter of credit or on-demand payment guarantee.

10. Comments on the allocation and documentation of hydrological risk

The key to managing risk may well be better hydrological data. Although little can be done to improve the historical data set, governments should understand the vital importance of collecting good data for the future. This could be enhanced by sharing information across borders and regions, either bilaterally or through river basin organizations. In addition, the industry needs to use better analysis of the possible impacts of climate change and incorporate flexibility in design to deal with such impacts.

Several approaches noted in this paper deserve further investigation and consideration. In particular, the calculation of liquidated damages for forced outages and supply shortfalls caused by hydrology should take account of the purchaser’s ability to mitigate a shortfall of production through the generation mix, including as a minimum use of “conjunctive operation of power stations in the overall utility supply region” [Rae, 2008[1]]. In addition, projects could benefit from increased use of tailored parametric insurance and derivative products to facilitate hedging of hydrological risk, so that a deeper market in these products is established.

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[1] Refer to safeguard guidelines such as the World Bank’s operational policy 7.50 on the use of International Waterways.
grows, leading to a better understanding, and cost-efficient structuring of such products, and hence better mitigation and management of hydrological risk. Further, the use of hydrological baselines which are analogous to the geotechnical baseline report approach to risk sharing, and the allocation of risk based on forward-looking absolute water flow projections, rather than solely relying on backward-looking data, could also be worth consideration. While this approach also has its difficulties, the project agreements could include a built-in risk sharing mechanism for re-calibration of hydrology benchmarks based on experience.

Further analysis of the documentation of hydrological risk approaches, over and above that which is presented here, is constrained by the confidential nature of many of the project documents concerned, particularly the concession and power purchase agreements. There is more that the industry could do to share best practice. However, the analysis described in the preceding sections serves to show the complexity of this subject. As far as hydropower development is concerned there is clearly scope for more risk-sharing and a more nuanced approach to facilitate the needs of the different stakeholders, but these possibilities are often not being considered. Governments and state-owned off-takers in less developed electricity markets do not know how much it may be costing them to get developers to take hydrological risk and should consider whether the avoidance of this risk is truly cost-effective.

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References
16. Shields, T., Indecx Consulting Ltd, private correspondence with the authors; April 2014.

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