NGONYE FALLS HYDROELECTRIC PROJECT

HYDROLOGY RISK MITIGATION AND WATER AVAILABILITY

7th January 2025

Western Power

HYDROLOGY RISK FOR HYDRO PROJECTS

As with any hydroelectric project, the Ngonye Falls run-of-river hydroelectric project may be exposed to two separate sources of hydrology risk (ie 'fuel supply risks') that need to be mitigated if the project is to be "bankable" and successfully financed, **Natural Hydrology Risks*** and **Man-made Hydrology Risks**.

These two separate risks need to be allocated to the parties best placed to carry them through the project *Power Purchase Agreement* and *Implementation Agreement*.

For the Ngonye Falls run-of-river project, Western Power intends to take the full **Natural Hydrology Risk** through a *take-or-pay, energy-only PPA* and is not asking for any downside risk protection from ZESCO (under the PPA) or GRZ (under the IA). Ie no drought protection.

For the very different class of risks characterised here as **Man-made Hydrology Risks,** WPC is seeking protection under the IAA only for actions caused or allowed to be caused by GRZ that have a demonstrable long-term impact on energy production by the power station.

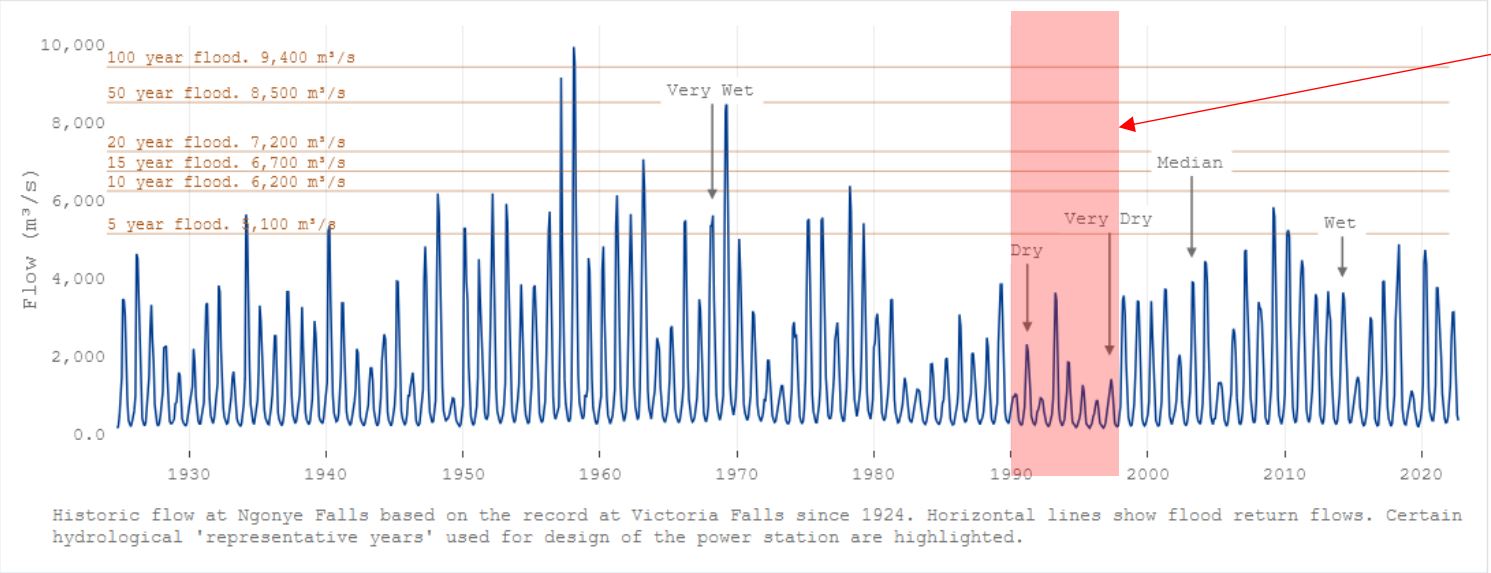
*In this classification, Natural Risks also include any human-induced climate change impact (on rainfall or runoff) on the longterm average river flow or variability in flows from year to year.

A] NATURAL HYDROLOGY RISK

Natural Hydrology Risk* means changes in rainfall and runoff from year-to-year due to natural variability in climate as well as any climate change impacts of whatever cause leading to variations from year to year in the timing and or total volume of water flows arriving at the power station and available for generation.

Drought years – or a succession or drought years is the most obvious **Natural Hydrology Risk** but for run-of-river projects such as Ngonye Falls, significant floods can also impact negatively on generation by reducing the available generation head to such an extent that the turbines cannot operate.

Natural Hydrology Risks are transient (one or a few seasons long) and unpredictable[+] – although this does not mean they are resistant to statistical analysis.



In the historic record, Natural Hydrology Risk is clearly demonstrated in the 1990s where a succession of drought seasons occurred.

*In this classification, Natural Risks also include any human-induced climate change impact (on rainfall or runoff) on the long-term average river flow or variability in flows from year to year.

[+] Some Climate Change impacts may be permanent – e.g. decrease or increase in mean annual flow

B] MAN-MADE HYDROLOGY RISKS

Man-made Hydrology Risks include any changes or obstructions in the path of the river or any significant new abstraction of water in the river, undertaken by people, and leading to a change in the timing of river flows or total volume of water flows arriving at the power station and available for generation which, in-turn, lead to a demonstrable long-term reduction in power generation from the power station.

Due to the complex interplay of flow, head and generation at Ngonye Falls (see the presentation '*Ngonye Falls – Climate Variability and Climate Change Resilience*' for more details), **Man-made Hydrology Risks** can only be demonstrated with respect to annual power generation and not (mean or min etc) river flow.

The most obvious **Man-made Hydrology Risk** is abstracting large quantities of water upstream of the project site for some other use – for example abstracting water into a canal or pipeline to serve a major metropolitan centre (e.g. the pipelines carrying water to Lusaka from the Kafue River). Because of the size of the Zambezi River and the design of the Ngonye Falls run-of-river project – which during flood periods only uses a small proportion of the total river flow, any such abstraction would have to be very large across the whole year to have a demonstrable impact on power generation.

The construction of other hydroelectric projects (storage or run-of-river) upstream of Ngonye would almost certainly not trigger a **Man-made Hydrology Risk** as the only net loss of water due to these would be minor (from evaporation) and any regulation of flows due to storage reservoirs would most likely increase annual generation at Ngonye Falls rather than decreasing it.

Man-made Hydrology Risks are generally permanent once they have been caused and are completely predictable – because the action that caused them has been planned and executed by some man-made project.

HYDROLOGY RISK MITIGATION – PPA AND IA

Historically the two classes of hydrology risk, **Natural Hydrology Risks** and **Man-made Hydrology Risks** have often been lumped together and transferred away from the IPP:

1. To the energy offtaker through a *capacity-based Power Purchase Agreement (PPA)* where the IPP is paid to have the power station available whether or not the river flows are as expected or predicted.

2. To the host government – through *Implementation Agreement* (IA) clauses that limit the IPPs downside risk using a hydrology limit (e.g. mean annual flow < P90 historic annual flow).

Or, a combination of both of these mechanisms.

However, more recently, offtakers including ZESCO have, correctly, preferred *take-or-pay, energy-only PPAs* where the IPP is paid only for the energy actually produced by the power station.

This leads to more transparent pricing, and a more equitable risk allocation between the IPP (natural hydrology risk) and the offtaker (offtake & dispatch) risk.

NATURAL HYDROLOGY RISK MITIGATION

With a take-or-pay, energy-only PPA, the IPP carries all of the **Natural Hydrology Risk** - to the extent that there is no additional mitigation in the IA that transfers any of this risk to the host government.

IA mitigation for Natural Hydrology Risk usually takes the form of a floor on some measure of annual river flow below which the government is required to make payments sufficient for the project to cover its ongoing debt obligations. Equity returns may not be covered as this is effectively an insurance provided by government against unlikely events for the benefit of the lending banks. The government is not 'at fault' for these events but is shouldering this risk in order to make the project bankable.

For an IPP to carry Natural Hydrology Risks, it needs to have enough data on historic flow patterns and variability to predict future flows and can also use other measures (e.g. cash reserves, debt sculpting, or parametric insurance) to mitigate this risk. As risk always carries a cost, IPPs with energy-only PPAs will require to build some risk cost into their energy tariff (this is most often achieved by basing DSRA sizing in financial models on an energy yield lower than the P50 annual energy – e.g. 15-year-P75 annual energy)

The Ngonye Falls project has the benefit of 100 years of daily historical flow records for the Zambezi - satisfying the historic data requirement and will structure its debt on the basis of carrying all of the **Natural Hydrology Risk.** Due the scheme design and the nature of the Zambezi River and Ngonye Falls, WPC has also been able to demonstrate that this risk is relatively low (see the presentation '*Ngonye Falls – Climate Variability and Climate Change Resilience*' for more details).

Western Power Company has therefore signed a take-or-pay, energy-only PPA with ZESCO and believes (following discussions with financiers) that the project can be banked with WPC taking all of the **Natural Hydrology Risk**.

WPC is not therefore seeking any Natural Hydrology Risk protection from GRZ in the Impementation Agreement at this time.

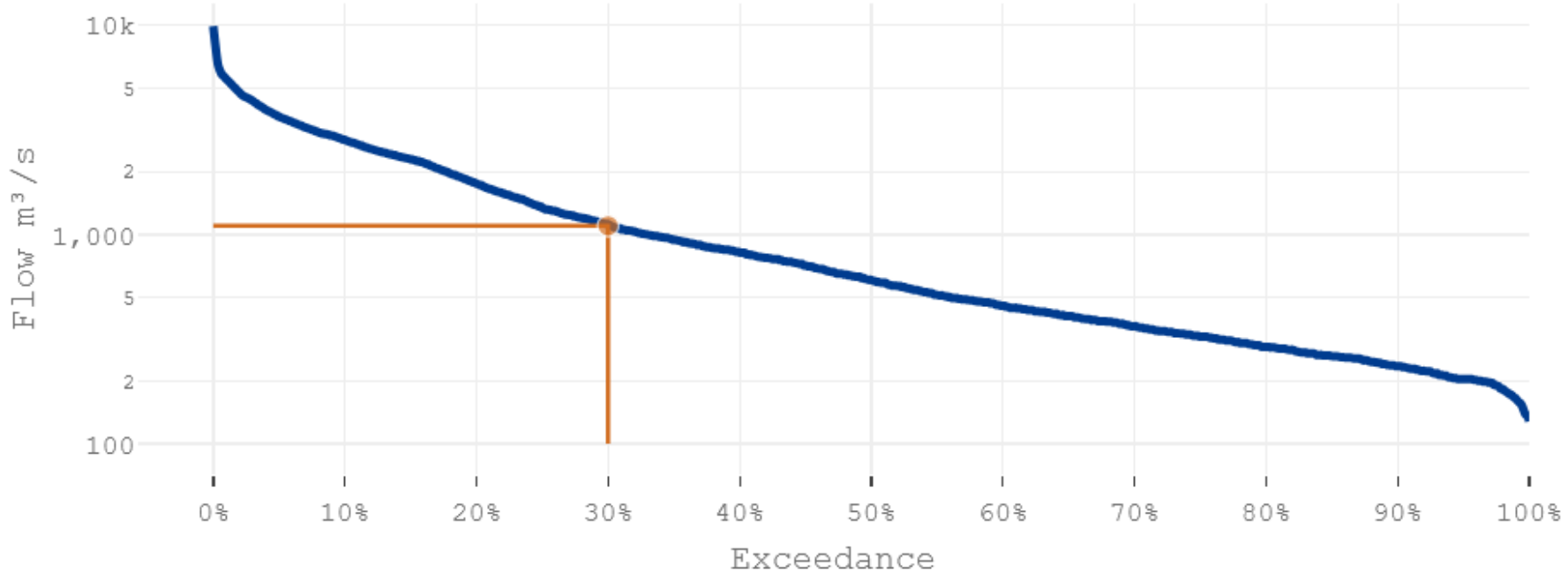
MAN-MADE HYDROLOGY RISK MITIGATION

Man-made Hydrology Risks cannot, by their nature, be carried by the IPP as they are completely outside the project's control. To protect the project from any Man-made Hydrology Risk and ensure bankability provisions are required in the Implementation Agreement specifically to cover instances of Man-made Hydrology Risk.

Unlike any provision relating the Natural Hydrology Risk (e.g. 1-in-90-year drought), IA cover for Man-made Hydrology Risk is not acting as a form of insurance (for the debt only) against a natural condition but rather to protect against an event caused by a GRZ entity. For this reason, full protection of both debt and equity is needed to achieve project bankability.

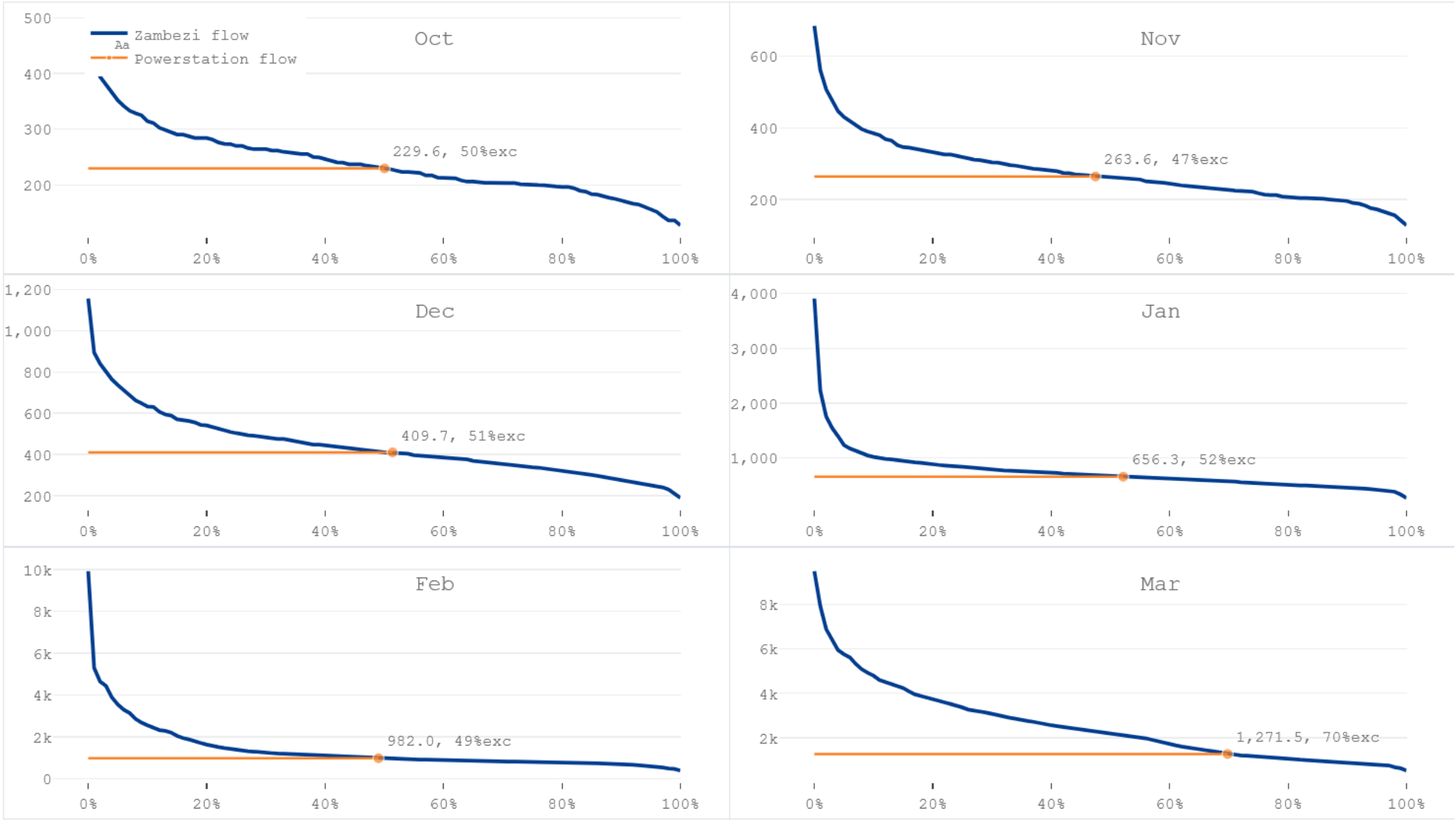
Consideration has been given to placing a minimum threshold on the trigger of any Man-made Hydrology Risk (e.g. energy reduced by at least 1%). Although this is entirely possible, WPC will be required by its lenders in this case to fully cost this risk into the energy tariff. This will require assuming that the plant is curtailed by e.g. 1% of energy production in every year of operation with a consequent 1% rise in energy tariff. WPC believes that the requirement to demonstrate through independent expert hydrological and engineering modelling that an adverse event is occurring acts as a sufficient barrier to mitigate against any frivolous claim and an artificial rise in tariff should be avoided.

WATER USE FOR GENERATION

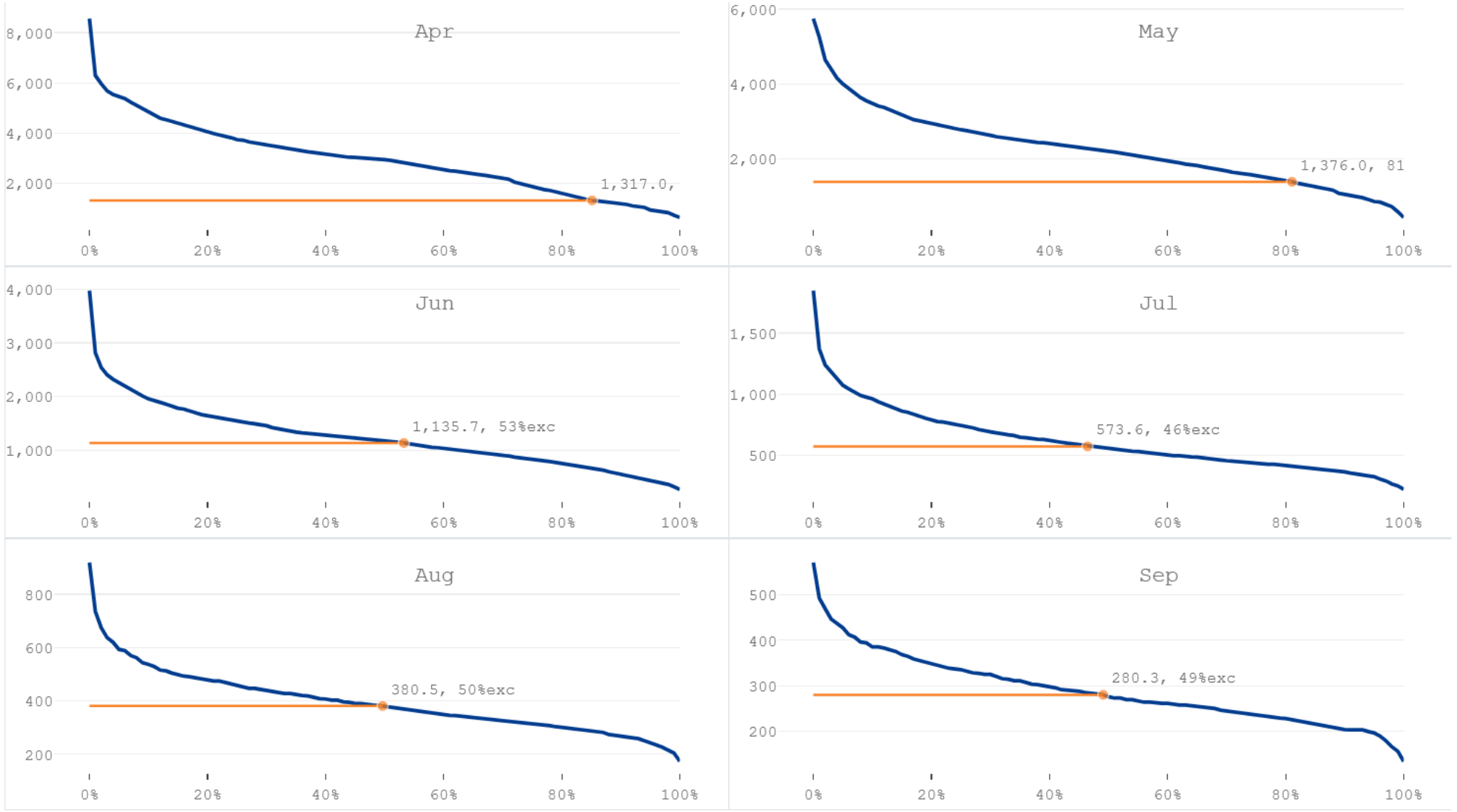


Daily Flow Duration Curve – FDC or Exceedance curve for the Zambezi River at Ngonye Falls showing the proportion of time in each year that flow exceeds the given value. The design discharge and canal capacity of the power station is 1,100m³/s which is the P30 river flow (exceeded in 30% of days).

WATER USE FOR GENERATION – MONTHLY 1



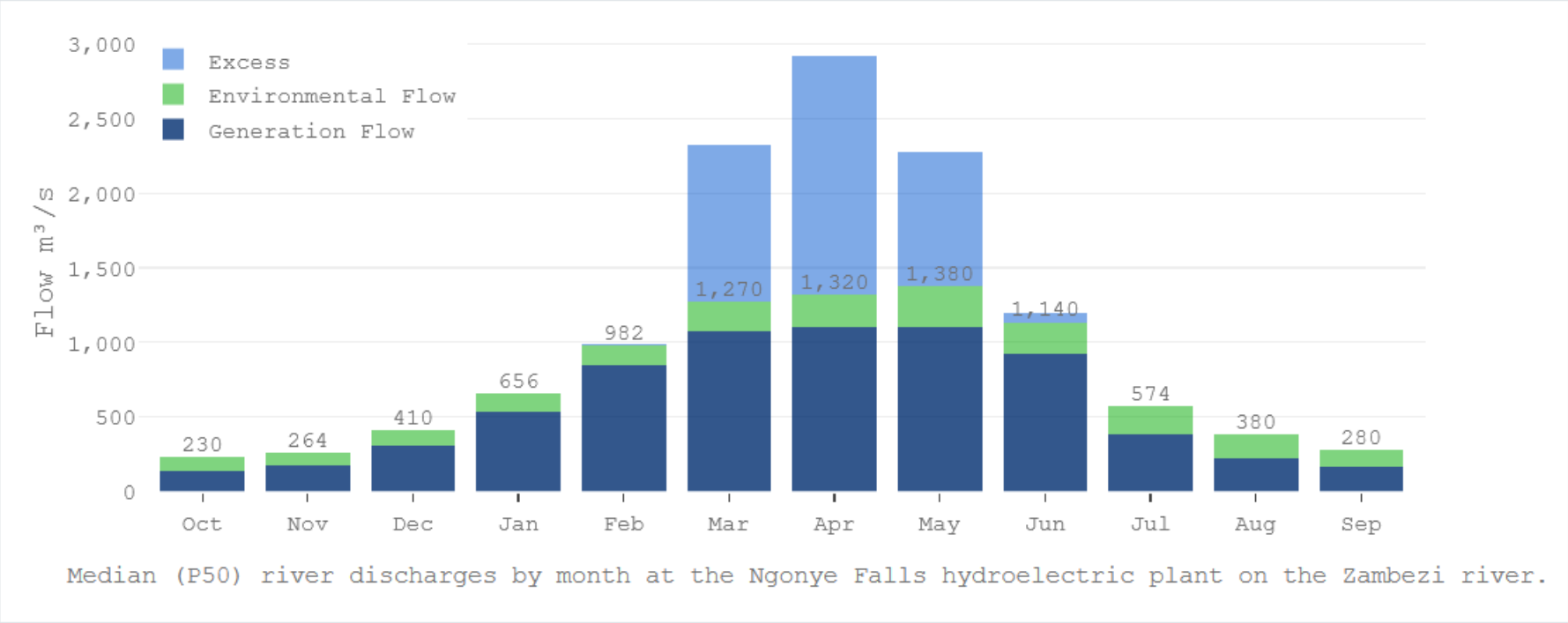
WATER USE FOR GENERATION – MONTHLY 2



WATER AVAILABILITY – DEVELOPMENT OF EXCESS FLOW

As a run-of-river plant without any storage reservoir, the Ngonye Falls plant has been optimised at 180MW of capacity to only generate with flows (in the power canal) up to 1,100m^3/s. Even when the required Environmental Flows are added to these generation flows, the very large flood flows in the Zambezi river mean that there is significant additional water that is never used by the power station and could be extracted upstream without any impact on generation. The total of these 'excess' flows over an average year is 9,600 Mm^3 (or 9.6 cubic kilometres of water).

This volume of water is enough to support the development of an additional 1.3 million hectares of irrigation (e.g. 18,500 new 70ha centre-pivot fields) of crops such as maize or wheat over the life of the 25-year PPA. For comparison, the whole of Zambia currently has around 70,000 hectares of irrigation in total and the Western Province only has a few hundreds of hectares of these.



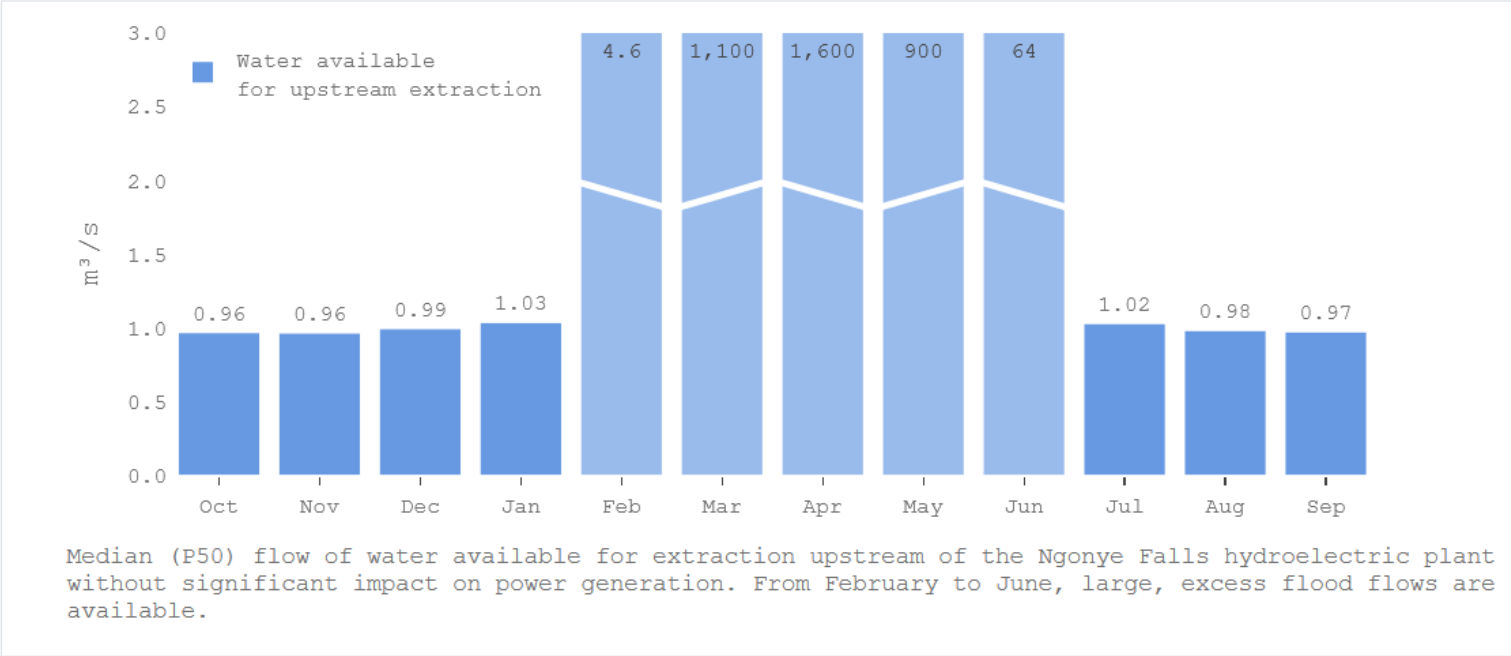
Median (P50) river discharges by month at the Ngonye Falls hydroelectric plant on the Zambezi river.

WATER AVAILABILITY – LOW FLOW MONTHS

Because of the very large flows of water in the Zambezi river, a large volume of water can be extracted upstream of the project site without any significant impact on power generation. From July to January (i.e. the low flow months) an average of around 2.5 Mm^3 per month can be extracted upstream of the project site without any significant impact on power generation.

This is equivalent to approximately 85Mlt/day (*mega-litres per day* is the unit usually used for municipal/domestic water supply and consumption reporting).

For context, the original pipeline from the Kafue river used to supply the water needs of Lusaka has a capacity of 100Mlt/day and the new pipeline, recently commissioned has a capacity of 50Mlt/day.



Median (P50) flow of water available for extraction upstream of the Ngonye Falls hydroelectric plant without significant impact on power generation. From February to June, large, excess flood flows are available.

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