

Pwalugu Multipurpose Dam Project: story of a major collaborative project

Barrage à buts multiples de Pwalugu : histoire d'un grand projet concerté

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Abstract. The Volta River Authority is starting this year the construction of the Pwalugu Multipurpose Dam Project (PMDP) on the White Volta River across the Upper East and Northern regions of Ghana with the aim to foster economic development in several ways: (i) developing the irrigation potential of the White Volta plains, (ii) mitigating the flood impacts downstream of the dam, (iii) improving Ghana's power system and (iv) generating secondary benefits through related activities such as fishery and domestic water supply. This project, studied by Tractebel since the early 1990s, was always governed by the principle to balance the benefits between antagonistic objectives. Dedicated operation rules have been defined to improve the overall benefits. Limitation of the extent of the reservoir and its related environmental and social impacts have also been taken into account to define the final design. This paper aims to present how all these benefits have been estimated and compared to lead to the final design under implementation.

Résumé. La Volta River Authority commence cette année la construction du projet de barrage à buts multiples de Pwalugu sur la White Volta River à travers les régions du Haut Est et du Nord du Ghana dans le but de favoriser leur développement économique par plusieurs biais : (i) développer le potentiel d'irrigation des plaines de la White Volta River; (ii) atténuer les effets des inondations en aval du barrage ; (iii) améliorer le réseau électrique du Ghana et (iv) générer des bénéfices secondaires par le biais d'activités connexes telles que la pêche et l'approvisionnement en eau domestique. Ce projet, étudié par Tractebel depuis le début des années 1990, a toujours été régi par le principe d'équilibrer les bénéfices entre les objectifs antagonistes. Des règles d'exploitation spécifiques ont été définies pour améliorer les

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bénéfices globaux. La limitation de l'étendue du réservoir et de ses impacts environnementaux et sociaux connexes a également été prise en compte pour définir la conception finale. Ce document vise à présenter comment tous ces avantages ont été estimés et comparés pour aboutir à la conception finale en cours de réalisation.

1 Introduction

The project was firstly studied in 1993 at a prefeasibility level, along with two other schemes on the White Volta River (Kulpawn and Daboya) and one project on the Oti River (Juale). Pwalugu project was recommended as a priority project to foster economic development in Northern Ghana.

The project stayed on stand-by for several years until 2013 when, the Volta River Authority (VRA) and Tractebel signed a contract for the Pre-Feasibility and Feasibility studies of the Pwalugu Multipurpose Dam Project (PMDP). The Pre-Feasibility and Feasibility Studies were respectively completed in May 2014 and January 2016. The Environmental and Social Impact Assessment Study (ESIA) carried out by Mott McDonald highlighted important impacts related to the large dam reservoir and was never formally approved by the (Environmental Protection Agency) EPA.

In response to concerns about the environmental and social impact of the original dam height of 40m, the VRA requested Tractebel to conduct complementary studies to assess different project options. Therefore, five alternative scenarios were investigated which led to the reduction of the dam height to 35m.

The paper will present the story of this major collaborative project.

2 National context and regional challenges

2.1 Economic context and poverty trends in Ghana

Ghana experienced impressive economic growth from 2005 to 2011. This growth has slowed significantly between 2012 and 2015 in light of macro-economic challenges, such as high budget deficit and inflation. After a year 2015 at its lowest level since 1984, growth has returned to its pre-2005 levels and is around 6% for the years 2018 and 2019 [1].

Per capita GDP reached US\$ 2 202 in 2018, and between 1990 and 2018, the Human Development Index value increased from 0.454 to 0.596 as access to health care and education increased, making Ghana one of the few 'medium human development' countries in the region. Ghana halved extreme poverty from 37.5 percent to 9.6 percent between 1991 and 2013. Furthermore, Ghana has met the Millennium Development Goal (MDG) [2] of halving poverty and hunger before 2015. Nevertheless, 23.4 percent of the population still remains below the poverty line of GH¢1,314/per capita/per year, particularly in the Northern regions [3].

Indeed, Ghana's north has largely been excluded from that broader trend. The incidence of poverty in the Northern Regions declined only slightly over the same period (1991-2014), from 63 per cent to 61.1 per cent in the Northern region, from 88 per cent to 71 per cent in the Upper West Region and from 67 per cent to 55 per cent in the Upper East Region.

Environmental and social indicators for northern Ghana are below national average for education, health, nutrition, and access to potable water. According to the Ghana Living Standards Survey from 2017 (GLSS7), the three northern regions have the highest household size, the highest proportion of the population who have never attended school for both males

and females, the highest percentage of persons who spent more than 3 hours to travel to and from the closest health facility and the higher proportion of households that are not connected to the national grid [4].

So, while Ghana — unlike many other countries in sub-Saharan Africa — has made some notable progress on some of the Millennium Development Goal (MDGs) and Sustainable Development Goals (SDGs), that process has been very uneven within the country.

2.2 Energy and electricity sector

The Volta River Authority (VRA) was established in 1961 by an Act of Parliament (Act 46). It is the main power generation company in Ghana, solely owned by the Government of Ghana (GoG). VRA relies on hydro, thermal and solar plants to generate electricity for supply to the local and export markets.

Historically, the Electricity Supply Industry in Ghana has been dominated by hydropower, which accounted for all generation until the late 1990s. Thermal generation plants gained consistent prominence in VRA's power generation mix, since the mid 1990's when VRA commenced the diversification of its generation source beyond the Akosombo Hydro-electric plant. Since the end of 2010, Ghana's total installed thermal generating capacity has almost equalled the existing hydro generation capacity. The total installed capacity in Ghana is 4381 MW and is generated by 20 power generation plants. VRA owns ten of these power generation facilities in Ghana, with a total installed generation capacity of 2 520 MW, with a dependable capacity of 2 260 MW [5]. As at September 2017, 63.4% of electricity in Ghana was generated from fossil fuels and 36.1% from hydro power with only 0.5% being generated from renewable sources, specifically solar power. Much of northern regions' primary energy consumption, is met by traditional biofuels such as wood and charcoal.

The increase in thermal generation capacity has led to an increasing exposure to the risk of fuel price escalations, fuel supply risks (in the case of pipeline gas), and an increase in carbon emissions. This has also meant that the Ghanaian electricity consumers have been exposed to high and volatile electricity prices linked to oil prices over the last ten years [6].

Ghana is currently facing considerable constraints in the availability and stability of electricity supply. Due to the inability to meet the increasing demand for electricity and instabilities in the national grid, load shedding has been a prominent feature in the country. Strengthening energy generation will result in good opportunities for economic development. The Project location at the northern end of the national grid will reduce energy losses along the existing transmission system.

2.3 Agriculture and irrigation sector

Agriculture has a central socioeconomic position in Ghana. This sector accounts for 37.1% of the active population and 65.2% of the active rural population, 19.7% of Ghana's current GDP, and about 30% of export earnings.

Although agriculture is a key part of the country's economy, the structure of the sector is vulnerable and relies mostly on rainfed agriculture. Smallholder rain-fed farming using rudimentary technologies dominates the agricultural sector accounting for 80% of total agricultural production. Approximately 90% of smallholder farms are less than two hectares in size and produce a diversity of crops. Larger farms and plantations primarily cultivate cocoa, oil-palm, rubber and coconut, and to a lesser extent, cereals and pineapples

Farm mechanization is neither common, nor extensive with production remaining dominated by hoe and machete, albeit with some animal traction practiced here and there, especially in the North of the country. The agricultural sector is characterized moreover, by

low use of inputs with small farmers having little access to inputs such as fertilizer, insecticides, high yielding varieties or irrigation-based cultivation.

Northern Ghana is characterized by less favourable conditions for agriculture than in the South. Not only does rainfall decrease the further north one travels in Ghana, but the rain is also concentrated in shorter periods with characteristic torrential rains. As a result of the higher run-off induced by this rainfall pattern and of soils poor in organic matter, crop production can only take place in one, often erratic, season. Yet, despite these more difficult conditions, many more households in northern Ghana are dependent on agriculture than in southern Ghana. In total in Ghana, 44.1% of households own or operate a farm, while this figure is more than 70% in the three regions of the north [7].

The total potential for irrigable land is estimated to be 1.9 million ha but only 1.6% (30,900 ha) is under full and/or partial control [8]. Of this total area, 11 784 ha are distributed over 53 existing public irrigation schemes developed by the Ghana Irrigation Development Authority (GIDA) [9].

Under these conditions, irrigation development is viewed as: (i) a way to offer greater food security and bring northern Ghana out of poverty by ensuring yearlong agricultural production (ii) and as a useful strategy for adapting to climate change.

2.4 Flood hazard

Ghana is one of the countries in West Africa most affected by droughts and floods. Floods along the White Volta River are a recurrent phenomenon affecting thousands of people.

Table 1 shows examples of some major floods which occurred in the region and the damage it had generated.

Table 1. Major floods in the white Volta catchment area [10-11].

Date	Number of death	Affected people	Losses
2007	56	332,600	11,000 houses destroyed 70,500 ha of farmland destroyed Thousands of animals killed Production losses of at least 144,000 tons
2010	5	48,000	2,400 houses destroyed 8,000ha of agricultural land damaged
2018	34	31,903	11,959.6 ha of farmland have been affected
2019	30	100,000	Between 1,000 and 4,000 buildings destroyed or severely damaged
2020	19	70,000	12,000 ha affected and 5,000 houses destroyed in several districts of the Upper East Region and the North-East Region

3 Objectives of the project and description of the final design of the project

3.1 Description of the project

Pwalugu Dam site is located on the White Volta River, approximately 30 km Southwest of Bolgatanga, across the Upper East Region and the Northern Region. The Pwalugu multipurpose dam project is located between the completed Bagré (in Burkina Faso) dam upstream and Akosombo and Kpong dams downstream.

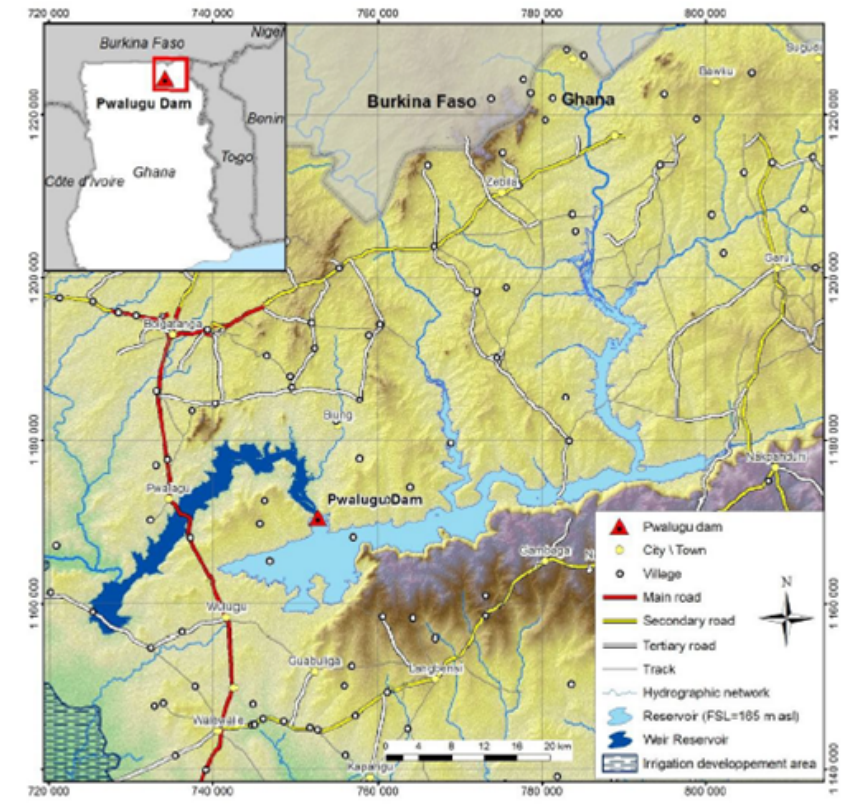


Fig. 1. PMDP location map.

The project includes:

- A roller compacted concrete (RCC) dam about 35 m high and 1.8 km long;
- A reservoir with a 2.6 billion m³ storage capacity and a 262 km² surface area;
- A powerhouse with an installed capacity of 59.6 MW;
- A diversion weir reservoir of 90 km² feeding the primary irrigation canal downstream of the main dam;
- A 20,000ha irrigation development area;
- A Solar Plant with an installed capacity of 50 MW.

The mean energy generated by the PMDP hydropower scheme is estimated to 176 GWh/year. The Hydro Power Plant (HPP) of the scheme is located at the toe of the dam. It comprises two similar Kaplan-type turbines of 29,8 MW with a rated discharge of 121.85

m³/s. The Electricity produced from the Pwalugu dam will be evacuated from the Pwalugu switch yard via a 15km high voltage line to join the existing Tamale-Bolgatanga Transmission line.

3.2 Objectives of the project

3.2.1 Context

The objective of the Pwalugu project has always been to contribute to the economic development of Northern Ghana. But the mean to achieve this objective evolved throughout the history of the project.

When firstly studied in 1993 the main objectives of the Pwalugu dam were: Energy generation, Irrigation development and Fishery development. Flood management was not mentioned. The update of the Pre-Feasibility study in 2014 and the Feasibility Study in 2016 considered the energy generation as primary purpose of the project with irrigation, flood management and fishery development as secondary purposes.

The Feasibility Study through its financial analysis revealed that most of the benefits of the Project were driven by the irrigation development (20,000 Ha by gravity in prospect).

In its final design, the PMDP is intended to contribute to the economic development of Northern Ghana by several means:

- Developing the irrigation potential of the White Volta plains;
- Mitigating floods downstream of the dam;
- Generating power to be injected on the northern end of the national grid;
- Developing other economic activities on the reservoir, such as fishery.

3.2.2 Developing irrigation

One of the main goals of the PMDP is to develop the irrigation potential of the White Volta plains through a 24,841ha irrigation scheme. This irrigation scheme will be the largest in the country; it will boost agricultural production and set basis for agro-industries, including revival of Pwalugu tomato factory. It has the potential to produce 117,000 tons of rice and 49,000 tons of maize and reduce import by 16% and 32% respectively. Other crops will benefit from increased production: onion, tomatoes, sweet potato, sweet pepper and watermelon.

3.2.3 Mitigating floods

A consultation exercise was performed during the feasibility study to assess what level of protection against flood was reasonably acceptable to farmers and agricultural agencies worldwide for being worth developing agriculture. It was assessed that farmers will be prone to settle and develop agricultural lands given their cultures can be protected against a 1 in 15 years return period flood event.

In order for the PMDP to guarantee a level of protection against respectively 10 and 15 years return period floods while minimizing the mean annual water spilled, the following operating rules have to be implemented:

- Initial reservoir levels at the beginning of the rainy season set as 157m asl for protection against a 10-year flood and at 155m asl for a 15-year flood;
- A set discharge threshold flows released by Pwalugu Dam kept below the maximum capacity of the White Volta channel i.e. 550 m³/s.

3.2.4 Improving Ghana's power system

This project will improve Ghana's power system with a coupled 59 MW hydro – 50 MW solar PV plants. The project will be put in combined operation with downstream Akosombo and Kpong upon completion of construction and will perform regulation for the 2 downstream hydropower stations.

Hydropower and solar panels will increase renewable energy capacity and enhance Ghana's climate change commitment of 10% renewable by 2030 under the United Nations Framework for Climate Change.

3.2.5 Generating secondary benefits through related activities such as fishery and domestic water supply

Co-benefits are added to the previous ones through related activities such as fishery and domestic water supply for 30,000 persons in Walewale Town. Potential for smaller irrigation schemes around the reservoir, fish farming, which will improve livelihoods and create jobs upstream of the dam.

4 History of the studies and selection of the final design

This chapter aims to present how all these benefits have been estimated and compared to lead to the final design under implementation.

4.1 Prefeasibility study (1993) and update of the prefeasibility (2014)

4.1.1 Prefeasibility study

Energy generation

Three different maximum operating levels (168, 173 and 178 m asl) and two dam axis (so called "downstream" and "upstream" axis) were investigated. The downstream axis with a reservoir storage elevation set at 168 m asl was the best alternative. At this elevation, the energy generation was 180 GWh/year.

Irrigation development

The maximum potential irrigable area downstream of Pwalugu site was estimated at around 110 000 ha. 44 000 ha were identified as alluvial plain, and 66 000 additional hectares were available upland being irrigated by gravity.

The recommended strategy to develop these irrigation areas was the development of diversion weirs across the White Volta regulated by the Pwalugu reservoir. The estimated target for the irrigation development was 20 000 ha within 8 to 10 years in a first phase, then full coverage of the alluvial plains (44 000 ha) within 20 to 30 years in a second phase. Additional pumping systems could also be implemented for the long term.

Fishery development

It was estimated that the reservoir would increase the fishing by 3 300 tons/yr.

4.1.2 Update of the prefeasibility and decision of the steering committee (2014)

The purpose of the studies was to get a clear picture of the potential of the scheme, for power generation, irrigation purposes and flood management which was added as one of the main objectives of the dam.

Reservoir simulations and Energy generation

Numerous reservoir simulations were performed on a monthly basis in order to model:

- the power production at Pwalugu,
- the irrigated area downstream of Pwalugu dam,
- the impact on the power production at Akosombo + Kpong.

The simulations were performed for several alternatives, depending on the irrigation layout to be adopted (separated or included in the dam), the extent of the irrigated area (up to 100 000 ha) and the Pwalugu Maximum Reservoir Level (ranging from 164 up to 180).

The main conclusions were the following:

- The optimum Full Supply Level was between 168 and 172 m asl;
- The study confirmed that the best strategy for the irrigation is to develop a diversion weir across the White Volta downstream of the Pwalugu reservoir. In case of a reservoir dedicated to irrigation as priority, the maximum irrigated area was estimated around 100 000 ha however without any firm energy;
- In case of a reservoir dedicated to energy production as priority, an irrigated area greater than 47 000 ha would lead to a deficit in energy;
- For a 20 000 ha irrigated area, the added production to the whole scheme Pwalugu+Akosombo+Kpong is 87 GWh/year (FSL =172m asl).

The Steering Committee selected a Full Supply Level at 170 m asl.

Irrigated area

Irrigation water requirements were calculated on climatic parameters of the irrigated area for three kinds of crops: paddy rice, vegetables (onion/tomato) and industrial crops (sugarcane). A double cropping has besides been considered for rice.

Gravity and pumping irrigation options were considered on both banks. The gravity irrigation is hardly conceivable on the Right Bank due to the very long canal associated with a reduced irrigated area given the topography. The Steering Committee decided to develop at the Feasibility phase the option of surface irrigation on the Left Bank targeting the development of 20,000 Ha, while sizing the main infrastructures for the total possible irrigated area.

Flood control

Reservoir simulations were conducted over the period 1957-2013. The following conclusions were drawn:

- Dedicated operation rules can allow the mitigation of 10-year and even 50-year floods downstream of Pwalugu dam;
- These operation rules can only be implemented with a gated spillway;

The Steering Committee selected the option of having a gated spillway [12].

4.2 Feasibility phase

Energy Generation

New reservoir simulations were performed for a FSL set at 170m asl. The main results are as follows:

- The Minimum Operating Level (MOL) fixed at 154 m asl maximizes the net energy yearly generated.
- With a live storage capacity between Elevation 154 and 170 m asl, the guaranteed power is equal to 22 MW.
- The proposed installed capacity was set at 70 MW;
- The mean energy generated by Pwalugu Hydropower Plant is estimated at 209 GWh/yr. This figure becomes 153 GWh/yr when considering the generation lost at Akosombo and Kpong due to evaporation from Pwalugu reservoir and 105 GWh/yr when considering the water lost by the gravity irrigation scheme when it is fully developed (20 000 ha).

Flood Management

A numerical hydraulic model was developed covering a river stretch from the dam site to 120 km downstream. The use of this model allowed for the definition of:

- The White Volta river capacity before flooding, which was estimated to be 550 m³/s. Above this flow the river overflows its banks.
- A relationship between the flooded area downstream of Pwalugu dam site and the peak discharge in the river.

Specific simulations were carried out to select the best suited operating rule for the project to provide a protection against the 1 in 15 years return period flood event.

Irrigation Development

The Pwalugu irrigation project extends over a 20,000-ha gross area located on the left bank of the White Volta river. According to the choices made by VRA, the feasibility was based on the following criteria:

- Water level at the upstream end of the main canal at 133 m asl,
- Water supply to the plots by gravity via a network of canals, allowing additional areas to be irrigated through pumping supply;
- Development of following variety of crops: Rice, Tomatoes: fresh market tomatoes, cherry tomatoes and processed tomatoes, Leafy vegetables, Onions, High value export crop, Chilli pepper, Sugarcane

The total cost of the project was estimated to 800 M USD [13].

4.3 ESIA for the project with a dam height at 40m

Following the ESIA carried out by Mott Macdonald in 2016 for a FSL = 170m, the following environmental and social issues were identified [14]:

- 378 km² of land, mostly forest would be flooded;
- Eight forest reserves and two important bird areas (IBA) are located in the project area;
- Modification of the sedimentary regime of the river and the morphology of the riverbed that may affect the fish fauna of the area (and therefore fishing activities);
- Permanent habitat loss and degradation;
- 369 homesteads estimated to be displaced (including 16 for the irrigation weir and primary canal). Using the average homestead size from the Project survey, this could mean approximatively 4 000 people that will need to be relocated;
- Approximatively 20 villages affected;

- Approximately 70km² of agricultural land to be inundated (35% within forest reserves);
- Permanent loss of shea nut and other trees of value;
- Short- or medium-term temporary loss of livelihood sources.

This ESIA pointed that the project will result in the permanent loss of an approximate total area of 21,100 ha of forest reserves and IBAs and in the permanent loss of habitats of medium and high conservation value (approximately 199 km²), which was considered to be of major adverse significance.

4.4 Alternatives study

In response to concerns about the environmental and social impact of the original dam height, the VRA requested Tractebel to undertake a Dam Alternative Study [15] and investigate five alternative scenarios (Alternatives 1 to 5) in addition to the one studied earlier throughout the Feasibility Study (Alternative 0).

In the previous studies, the dam design was driven by the maximisation of the energy generation and the development of 20,000 irrigated hectares in the downstream floodplain. The purpose of the alternatives study was to compare different alternative schemes with a dam sized for irrigation as the primary operational purpose.

The 5 alternatives are described below:

- Alternative 0: baseline scenario that corresponds to the Feasibility Study design with a main dam with an FSL = 170m asl, a diversion weir and irrigation area of 20,000ha;
- The arrangement of Alternative 1 is similar that of the baseline scenario, only the dam height differs. FSL = 151m asl;
- Alternative 2 differs from Alternative 1 by the location of the axis of the main dam, which is set on the so called “upstream axis” identified at the pre-feasibility study stage with a FSL at 158.5 m, a diversion weir and an irrigation area of 20,000ha;
- Alternative 3 is made of one unique reservoir. This unique dam is located on the irrigation weir axis studied and investigated during the Feasibility Study (FSL= 140.5 m asl). The irrigated areas remain the same;
- Alternative 4: Located on the same site as Alternative 3, Alternative 4 dam crest is determined so that the reservoir can store enough water to irrigate 5,000 Ha by gravity (FSL= 137.5m asl). The dam is designed to allow future heightening of the dam permitting the extension of the irrigated area up to 20,000 Ha. dam axis that corresponds to the Feasibility Study irrigation weir axis
- The arrangement of Alternative 5 is similar that of the baseline scenario (Alternative 0), only the dam height differs. FSL = 165m asl;

The Full Supply Levels of Alternatives 1 to 4 correspond to the lowest level that create active storages large enough to satisfy the irrigation and environmental water demands.

The change of the dam main objective from energy generation (Alternative 0) to irrigation (Alternatives 1 to 4) has a huge impact on the dam design as it results in a dam height divided up by around 2 as compared to the previous dam studied during the Feasibility Study. As the negative environmental and social impacts of the alternative dam schemes as well as their construction costs significantly decrease, the lowering of the dams also reduces their active storage capacity thus affecting the power generation and flood mitigation performances of the schemes.

The main issue with alternatives 1 to 4 is that none of them offers the possibility to mitigate the impact of the recurring floods that affect the northern part of the Ghanaian White Volta River. Only schemes with active storages higher than 2,000 Mm³ reveal themselves suitable reservoirs to protect the downstream plains from the most recurrent floods.

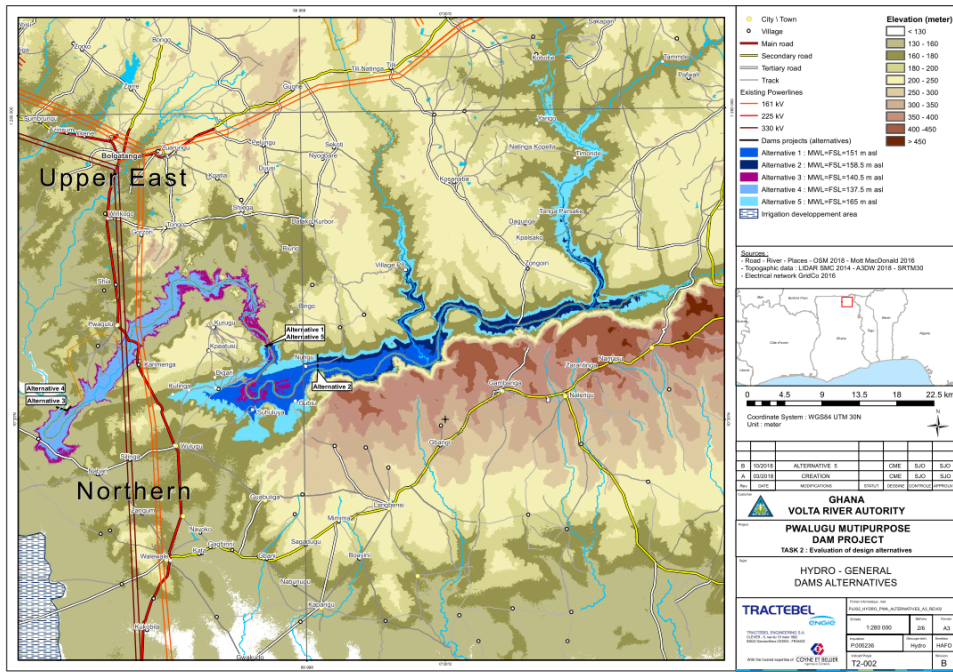


Fig. 2. Design alternatives.

A Multi-Criteria Analysis approach was carried out to assess the performance of the different alternative schemes and provide the decision-makers with strategic recommendations. The results of the Multi-Criteria Analysis comparing the individual performances of the design alternatives in the light of several techno-economic parameters is presented in the Table 2.

With a dam crest located 5 meters below that of Alternative 0, Alternative 5 generates slightly less energy (-15%) but also limits the social and environmental impacts as its total reservoir area is reduced by more than 25%. Besides, the implementation of specific operating rules can prevent the river at Pwalugu from flooding 14 out of 15 years.

Flood routing calculations were then carried out on Alternative 5 reservoir in order to determine the most extreme flood the dam scheme can mitigate. In the framework of this simulation, the Initial Water Level is taken equal to the Minimum Operating Level of Alternative 5 (152 m asl) and the outflows are equal to the inflows and limited to 550 m³/s. The most extreme flood during which Alternative 5 reservoir water level is kept below the Full Supply Level is the 50-year flood which represents the maximal capacity of the scheme.

In conclusion, Alternative 5 (165m asl) was seen as a well-balanced compromise as it manages to meet the triple objective of the dam: irrigation, energy generation and flood mitigation.

Table 2 : multi criteria analysis - summary table.

Alternative	0	1	2	3	4	5
General Layout	Main dam (FSL=170m asl) + Irrigation weir	Main dam (FSL to meet the irrigation water demand) + Irrigation weir	Main dam (FSL to meet the irrigation water demand on second axis) + Irrigation weir	Unique dam located at former weir site	Phasing (possibility to upgrade the irrigation area)	Main dam (FSL=165m asl) + Irrigation weir
Irrigated area	20,000 ha	20,000 ha	20,000 ha	20,000 ha	5,000 ha	20,000 ha
Dam height above river bed	40 m	19 m	23 m	20 m	20 m	35 m
Total reservoir area	475 km ²	170 km ²	171 km ²	109 km ²	70 km ²	352 km ²
Submersion of nature conservation area	281 km ²	97 km ²	106 km ²	31 km ²	15 km ²	217 km ²
Loss of agricultural land	162 km ²	58 km ²	48 km ²	44 km ²	33 km ²	113 km ²
HPP installed power	70 MW	18 MW	22 MW	21 MW	18 MW	59 MW
Guaranteed power	22 MW	2.2 MW	2.9 MW	2.2 MW	1.9 MW	16.5 MW
Mean annual energy	209 GWh/yr	66 GWh/yr	81 GWh/yr	64 GWh/yr	61 GWh/yr	176 GWh/yr
Possibility to protect the downstream plains against the 15-year flood	Yes	No	No	No	No	Yes
Physical displacement (households)	473	219	191	216	29	445
Total construction costs	394 M USD	169 M USD	203 M USD	161 M USD	161 M USD	287 M USD

With Alternative 5, the power capacity of the Pwalugu Hydro Power-Plant is being reduced compared to the original project. An Alternative Energy Generation Study with a view to evaluating complementary power production facilities that could combine hydro with solar and/or wind energy and provide VRA with an additional generation of 100 GWh/yr was assessed. This led to the choice of implementing a Solar Plant with an installed capacity of 50 MW. The Solar Plant will be directly connected to the Pwalugu Hydro Power-Plant Station.

4.5 Conclusion

In 2019, Government of Ghana decided to implement the project and mandated the Chinese company PowerChina for the Construction. Tractebel will act as the Owner Engineer and jointly with SRC Consulting will carry out the Environmental and Social Impact Assessment Study (ESIA) and the Resettlement Action Plan (RAP) of the Pwalugu Multipurpose Dam Project. These studies are being undertaken, the draft reports are expected to be available by March of 2021 and final reports in the first semester of 2021.

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