Sudan University of Science and Technology

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MSc.in Construction Engineering

Evaluation of the Initial Filling Stage for Dams

Case Study:Dam Complex of Upper Atbara and Setit Reservoir

تقييم مرحلة الملء الأولى للسدود

دراسة حالة: بحيرة سدي أعالي عطبرة وسيتيت

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الآية

بسم الله الرحمن الرحيم

أَلَمْ تَرَ أَنَّ اللَّهَ أَنزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجْنَا بِهِ ثَمَرَاتٍ مُّخْتَلِفًا أَلْوَانُهَاوَمِنَ الْجِبَالِ جُدَدٌ بِيضٌ وَحُمْرٌ
مُّخْتَلِفٌ أَلْوَانُهَا وَغَرَابِيبُ سُودٌ (27) وَمِنَ النَّاسِ وَالدَّوَابِّ وَالْأَنْعَامِ مُخْتَلِفٌ أَلْوَانُهُ كَذَٰلِكَ إِنَّمَا
يَخْشَى اللَّهَ مِنْ عِبَادِهِ الْعُلَمَاءُ إِنَّ اللَّهَ عَزِيزٌ غَفُورٌ (28)

صدق الله العظيم

سورة فاطر: الآيات 27– 28

Dedication

To My Mother

To my family

To My Colleagues and Friends

Acknowledgements

I would like to express my special appreciation to my supervisor

Dr. Osama Mohamed Ahmed

For the guidance, assistance, criticism, and suggestions on this research Appreciation to my organization DIU (dam's implementation unit) whose help to complete this research. Also I would like to thank my Colleagues and Friends whose had given a lot of encouragement and motivation to complete this study

Abstract

This research deals the initial filling stage of dams reservoir as the real test of the dam components (embankments, foundations, concrete bodies), as it gives a real assessment of the suitability of the theoretical design of the dam to the reality after construction and operation, and it expresses the extent of the dam for the purposes for which it was created (irrigation, hydropower generation, flood control and protection, etc.).

The Dam Complex of Upper Atbara Project (DCUAP) is selected as a case study, because of the unique design of this giant project in terms of storing water from two different rivers having different hydrological and geological nature in one reservoir by constructing a connecting channel in the upstream between the two dams (Upper Atbara and Setit).

The researcher developed a mathematical model on excel format basis on water balance calculations of upper Atbara and setit dams as described below:

- The daily measured time series of inflow at Burdana hydrological station which is located on the downstream setit dam & Rumela hydrological station which is located on the downstream upper atbara dam had been used.
- The statistical analysis erected on discharge measurements shows that 2011 data is representing a dry year (worst case), for the normal year the averaged inflow of the **5** years had been used.
- The start of the filling is intended to be as late as possible in order to minimize the sedimentation in the reservoir.
- The required storage volume is determined by the water requirements for irrigation, urban water supply, environmental flow and hydropower.
- Various rates of filling are used to ensure the dam safety and to calculate the increase in water level and water content in the reservoir and to determine the period required to achieve targeted level.

DCUAP initial filling stage had been planned to start in the flood season (2014) to reduce to the maximum operation level (521) ASL, however, due to some constraints the construction progress of the project was delayed, consequently the impounding also delayed. the initial filling took place between (15Augest to 19 October 2015) with final elevation of 514 m ASL .since, DCUAP is part of the national water resources management system, and due to unexpected demand (for

power generation) in Merowe Dam, the filling was stopped at level 514.00 m ASL on 8 November 2018, with a total accumulative storage of 1.993 million cubic meters. Inflow was released in order to satisfy the demand in Merowe Dam.

During and after filling a daily inspection program was carried out for all dam components to monitor and observe damages usually caused by the initial filling, it turns out that there is no signs of failure or any damage in the embankments, foundations.

DCUAP first filling stage has achieved the target objectives from the point of view of the researcher, and it became clear after the evaluation and technical analysis of many data and information (design documents, construction methods, hydrological observations, and the engineer (LI) recommendations).

المستخلص

تناول هذا البحث التعرف علي مرحلة الملء الأول لبحيرات السدود بإعتبارها هي الاختبار الحقيقي لمكونات السد المختلفة (الردميات، الأساسات، الأجسام الخرسانية)، وذلك لأنها تعطي تقييمًا حقيقيًّا لمدى ملاءمة التصميم النظري للسد للواقع الحقيقي له بعد التشييد والتشغيل، كما أنها تعبر عن مدى تحقيق السد للأغراض التي أنشئ من أجلها (الري، التوليدالكهرومائي، الحماية من الفيضانات، إلخ...).

تم إختيار مشروع مجمع سدي أعالي عطبرة وسيتيت ليمثل دراسة حالة لهذا البحث بسبب التصميم الفريد لهذا المشروع العملاق من حيث تخزين المياه من نهرين مختلفين في الطبيعة الهيدرولوجية في بحيرة واحدة عن طريق تشييد قناة ربط مشتركة بينهما أمام السدين (أعالي عطبرة وسيتيت).

حسن الباحث نموذج ريلضي ببرنامج أكسيل مبني علي حسابات الموازنة المائية لسدي أعالي عطبرة وسيتيت كما موضح أدناه:

- بيانات الوارد اليومية المستخدمة مقاسة عند محطة بردانة الهيدرولوجية والتي تقع أدني سد سيتيت ومحطة الرميلة الهيدرووجية والتي تقع أدني سد أعالي عطبرة.
- التحليل الإحصائي للبيانات الهيدرولوجية أوضح أن بيانات العام 2011 م تمثل سنة جافة (حالة حرجة) ، وللسنة العادية تم استخدام متوسط ايراد 5 سنوات.
- يجب تأخير بداية التخزين بقدر الإمكان لتقليل الأطماء في البحيرة .
- الحجم المطلوب للتخزين محدد بالإحتياجات المائية للري ومياه الشرب والتصريف البيئي والتوليد.
- تم إستخدام معدلات تخزين مختلفة للتأكد من سلامة السد ولحساب الزيادة في منسوب المياه والمخزون المائي في البحيرة لتحديد الفترة المطلوبة للوصول للمناسيب المستهدفة .

كان من المخطط أن يبدأ التخزين الأولي ببحيرة المشروع خلال موسم خريف العام 2014م بغرض الوصول لمنسوب التشغيلي الأقصي (521) متر فوق سطح البحر ولكن لظروف تأخر إكتمال الأعمال الإنشائية المرتبطة بالتخزين لإعتبارات كثيرة تأخر موقف تقدم أعمال التشييد بالمشروع وبناءاً علي ذلك تم تأخير التخزين .

تم تنفيذ مرحلة التخزين الأول مابين (15 أغسطس- 19 أكتوبر 2015) ولأن السد جزء في منظومة الموارد المائية االقومية وبسبب وجود إحتياجات مائية غير متوقعة (التوليد) في سد مروي توقف التخزين في منسوب 514متر فوق سطح البحر بتاريخ

2015/11/8م وبمخزون تراكمي 1.993 مليون متر مكعب , وتم تصريف المياه الوارد للبحيرة للإيفاء بالإحتياجات في سد مروي .

أثناء وبعد إكتمال مرحلة التخزين الأول تم تنفيذ برنامج تفتيش يومي لكل مكونات السد لمراقبة ومتابعة الأضرار التي يتخوف منها عادة في مرحلة التخزين الأول ، ونتج عن ذلك عدم ملاحظة أي مؤشرات للإنهيار أو أي أضرار في الردميات ، الأساسات .

حققت مرحلة التخزين الأول بالمشروع الأغراض المنشودة من وجهة نظر الباحث، واتضح ذلك بعد التقييم والتحليل الفني الموضح في هذا البحث.

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CHAPTER ONE

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1. Introduction

The initial filling of a reservoir is the first test that the dam will perform the function for which it was designed. A carefully managed first filling is crucial to the future success of the dam. According to a study completed by the Bureau of Reclamation on internal erosion failure modes, “approximately two-thirds of all failures and one-half of all dam incidents occur on first filling or in the first 5 years of reservoir operation.”

Dams are constructed primarily to impound and store a large body of water. During the construction of a new dam, diversion channels and cofferdams are used to prevent water from entering the construction area. However, when the dam construction is complete, the flow resumes to the dam site and the reservoir begins to be filled with water. The first filling of a reservoir can be defined as the increase in water level behind the dam from the time construction is complete until it reaches the desired operating level. Depending on the location, type, size, and intended purpose of a dam, the duration and rate of its first filling can vary. Regardless of whether it takes several months, several years, occurs naturally, or with the aid of pumping units, the first filling of a reservoir should be planned, controlled, and closely monitored in order to reduce the risk of failure.

Because the first filling of the reservoir is a critical phase in the life of the dam, it is vital for dam operators and engineers to have as much control over the first filling as possible, allowing as much time as needed for appropriate surveillance, including the observation and analysis of instrumentation data. The first filling should be scheduled to occur after construction of the dam and all necessary appurtenances (i.e. spillways and outlet works) have been completed, as well as the installation of appropriate instrumentation. Specifications regarding the rate of reservoir rise should be developed to allow the dam to adjust to the forces it will experience as the water level behind it increases. These plans should be documented in a design memorandum that may also include:

reservoir regulations during project construction, a water control plan, project surveillance, cultural site surveillance, flood emergency plan, public affairs, safety plan, and transportation and communications.

In addition to dam failure, it is common for design, construction, and/or material deficiencies of a new dam to become apparent during the first filling. For example, evidence of seepage, cracking, and erosion are often noted when the reservoir is raised to new levels for the first time. Inspection and assessment of these potentially hazardous conditions prior to the completion of filling is important, and it may be necessary to halt filling, or in some cases lower the reservoir before the desired operating water level is achieved, to investigate signs of seepage, cracking and erosion. Repairs to any project features that did not function as designed can be re-evaluated and modified to ensure the dam operates according to its original design.

The research case study is Dam complex of Upper Atbara Project (DCUAP), which is located on Upper Atbara River and Setit River, approximately 20 km upstream of their confluence, 80 km upstream of the Khashm El Girba Dam, and approximately 30 km south of the small town El Showak in the Gedaref State in Eastern Sudan.

The objective of the project is to support the development of Eastern Sudan, through enhancement of agricultural production, generation of hydropower and potable water by utilizing locally available water resources. The project also aims to increase agricultural production in the New Halfa's area currently irrigated by Khashm El-Girba Dam, and the development of new agricultural lands consisting of 150,000 hectares (370,000 acres) in Upper Atbara. Additionally, the dam complex will provide flood protection measures along the river banks through the regulation of the river flow in the project area.

1.2. Statement of the problem

Dam Complex consists of an earth-fill embankment dam in the main river bed and a system of dykes with total length of 13km. It is expected to occur Embankment failure due to seepage, piping and overtopping.

Suspended sediments concentration of upper Atbara and Setit rivers can increase in the future due to climate change in the upstream catchment area, and it is expected to reduce the storage capacity of the reservoir due to sedimentation.

The connection channel (CC) can be subjected to high and rapid deposition in the initial impounding years if the dam operated in inappropriate manner with distribution movement on sedimentation.

In the connection channel inlet/ outlet areas, the erosion might occur if the water transferred from Setit reservoir to upper Atbara reservoir with high current velocity.

For dam safety (structural stability)The Engineer recommends Water level rising rates not significantly higher than the excepted values (10- 20) cm /day for levels above 507masl ASL this may not be compatible with water availability in this water system due to the operation of Tekazi dam (TK5) which located in the upstream of setit dam in Ethiopia border. The Tekazi dam started operation in 2010.

1.3. Significance of research

The importance of this research comes from that:

Implementation of Initial Filling Stage (IFS) in dams requires an integrated plan, which involves the provision and analysis of many data and information (hydrological data, instrumentation data, construction data and other information), using a large number of devices, equipment and hydraulics equations, with appropriate experience in this field.

Evaluation of the Initial Filling Stage (IFS) in dams Operating Policies is very important to establish the basis of future filling plans, by comparing the target water levels, reservoir capacities and the structural behavior of dam components, with the real results of impounding analysis, as well as the evaluation of deviations from the plan, if any.

1.4. Research Objectives

The objective of this research is to clarify the methods of implementation and evaluation of the Initial Filling Stage (IFS) in dams taking the Dam Complex of Upper Atbara Project as a case study, and it comprises the following:

1. To evaluate the hydrology and hydraulic components which might affect reservoir initial filling stage .
2. To design operation policies for the initial filling stage and future impounding.
3. To demonstrate the assessment of impounding (results of analysis of the Filling, observation deviations from the plan, if any).
4. To desire the early warring hazard for unexpected filling.
5. To develop mathematical model basis on excel format.

1.5. Research Geographical scope

The Geographical scope of this research is limited to the evaluation of the Initial Filling Stage of dams and was taken the Dam Complex of Upper Atbara Project as a case study, which located on the Atbara River and the Setit River, approximately 20 km upstream of their confluence, 80 km upstream of the Khashm El Girba Dam, and approximately 30 km south of the small town El Showak in the Gedaref State in East Sudan.

1.6. Structure of the Research

1.6.1. Chapter 1: Introduction

This Chapter outlines, introduction about subject of research, problem statement and illustrates the aim and hypothesis of the study and specific objective.

1.6.2. Chapter2: Literature Review, Theory Related

Chapter two involves of literature review, which brings out the main sources of the secondary data collection deals with the extant literature. It is an overview of the dam's definition, objectives, history, implementation and operation.

1.6.3. Chapter3: Research methodology

This chapter describes the methodology used to conduct the research. It also includes the Geographical scope, time scope, Research sample, and finally how the data collected.

1.6.4. Chapter4: Evaluation of the initial Filling Stage for Dam Complex of Upper Atbara (DCUAP) Reservoir as case study

This chapter presents the methods of implementation of the Initial Filling Stage (IFS) in dams taking the Dam Complex of Upper Atbara project as a case study;

Includes introduction, description of project components, hydrological activities, purpose of the Initial Filling and data collection and Processing.

1.6.5. Chapter5: conclusion and recommendations

This section contains the general conclusion of the research and sets out recommendations.

CHAPTER TWO

LITERATURE REVIEW

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Adam is a hydraulic structure of fairly impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes. These purposes may be Irrigation, Hydropower, Water-supply, Flood Control, Navigation, Fishing and Recreation. Dams may be built to meet the one of the above purposes or they may be constructed fulfilling more than one. As such, Dam can be classified as: Single-purpose and Multipurpose Dam.

2.1.1. History of Dams

The first constructed dams were gravity dams, which are straight dam made of masonry (stone brick) or concrete that resists the water load by means of weight. ." Around 2950-2750 B.C, the ancient Egyptians built the first known dam to exist. The dam was called the Sadd el-Kafara, which in Arabic means "Dam of the Pagans. The dam was 37 ft tall, 348 ft wide at the crest and 265 ft at the bottom. The dam was made of rubble masonry walls on the outsides and filled with 100,000 tons of gravel and stone. A limestone cover was applied to resist erosion and wave action. The structure had no need for cement because the shear weight of the structure was sufficient to ensure stability. Using the expected hydrology for ancient times, the capacity was estimated to be 20 million cubic ft. or 460 acre-ft. The dam failed after a few years and it was concluded that overflow was the cause of failure. The poor workmanship from a hasty construction leads to the failure. The dam was not watertight and water flowed through the structure quickly eroding it away. Once the water overflowed the crest, it quickly eroded away the dam. The dam was a failure and the Egyptians never attempted to build another dam until modern times.

The second type of dam known to have been built was an earth dam called Nimrod's Dam in Mesopotamia around 2000 BC. Earth dams are massive dams similar to gravity dams except they are made of soil. The dam is made watertight, with a core wall and filled with an impervious center usually made of clays. Nimrod's dam was built north of Baghdad across the Tigris and was used to prevent erosion and reduce the threat of flooding. The intention was to divert the flow in the river and help irrigate the crops. The dam was built of earth and wood, so it is difficult to be certain of the exact characteristics of the dam.

Around 100 AD the Romans were the first civilization to use concrete and mortar in their gravity dams. The dam at Ponte di San Mauro has a great block of concrete among its remains. The evidence indicates that a large slab of concrete was used as the core and the outer layer finished with masonry.

Due to the large size and amount of building material need to construct these dams, the arch dam was invented. An arch dam is dependent on its shape for strength, requires less material to build, and is relatively thin. The first known arch dam is Kebar, which was built around 1280 AD in the Mongol period. The limestone dam is located near the ancient town of Quam and stands 85 ft. high; 180 ft. long at the crest, 16 ft thick at the crest and has a constant radius of curvature of 125 ft. An arch dam needs to be supported by the surrounding geology; the rock formations on either side support the arch.

In the seventeenth century Spanish dam building was superior to all other civilizations. A Spaniard named Don Pedro Bernardo Villarreal de Berriz wrote the first book on designing dams in 1736. In Don Pedro's time only two types of dams were built, arch dams for narrow gaps where the foundations had good solid rocks or gravity dams where the site was wide and shallow. Don Pedro's book suggested how to design dams properly and introduced new ideas such as a multiple arch dam. Don Pedro suggested that multiple arch dams would need artificial supports or buttresses to support the arches. This theory indirectly led to the invention of the buttress dam.

The buttress dam uses a series of cantilevers, slabs, arches or domes to support the face of the dam from the force of the water. Almendralejo dam is one of the earliest examples of a large buttress dam and is able to store water hydropower. Meer Allum dam is the earliest known examples of a true buttress dam of the multiple arch types.

The Spanish brought the art of dam building from Spain to the Americas. The idea of buttress dams was current in Spain, so many small buttress dams were used for irrigation purposes. In California, the Jesuit fathers established missions along the coastal regions. The Old Mission Dam built across the San Diego River in 1770 was one of the first dams in California. The dam was only 5ft tall and made of masonry and mortar. Soon modern multiple arch dams were built with concrete and rock filled dams was formed from dumped rock. A rock filled dam uses the large stone for stability and is filled with an impervious water face membrane and core wall. In 1884 the arch Bear Valley dam was built of masonry and mortar but replaced with a concrete multiple arch dam in 1910. The large increase in dam building did not come.

2.1.2. Dams Main Objectives

- Water supply
- Irrigation
- Electricity generation
- Flood control
- Navigation
- Recreation

Water supply

Since the water stored in dams is fresh water, it can then be used for drinking water in nearby towns and cities. Some cities get their water from rivers and streams in other states. The water is transported through large canals and waterways.

Irrigation

Dams and waterways store and provide water for irrigation so farmers can use the water for growing crops. This idea goes way back into history. Irrigation is an important part of using water. In areas where water and rain are not abundant (like the desert), irrigation canals from rivers and dams are used to carry water.

Electricity generation

Hydroelectric power is made when water passes through a dam. The electricity is made by a device called a turbine. These are made of metal coils surrounded by magnets. The magnets spin over the coils to produce electricity. Turbines are found in dams. The water going through a dam spins the magnets. The energy made is clean and pollution free. From this power we can turn lights on in our houses.

Flood Control

Dams help in preventing floods. They catch extra water so that it doesn't run wild downstream. Dam operators can let water out through the dam when needed. The first upstream flood control dam was built in 1948, Cloud Creek Dam in Oklahoma.

Navigation

Rivers and streams provide a great opportunity for transportation. Barges and ships can navigate along a river carrying large loads of food and merchandise. This style of transportation is effective because the loads carried can be quite large.

Recreation

Dams provide a wonderful opportunity for recreation. In building a dam water is stored behind it. This water is called a reservoir. Reservoirs are used to store water, especially during times of excess. They provide activities like fishing, boating, swimming, camping, and hiking.

2.1.3. Various types of dams

Dams can be classified in number of ways. But most usual ways of classification of dams are mentioned below:

2.1.3.1. Based on the functions of dam, it can be classified as follows:

Storage dams: They are constructed to store water during the rainy season when there is a large flow in the river. Many small dams impound the spring runoff for later use in dry summers. Storage dams may also provide a water supply, or improved habitat for fish and wildlife. They may store water for hydroelectric power generation, irrigation or for a flood control project. Storage dams are the most common type of dams and in general the dam means a storage dam unless qualified otherwise.

Diversion dams: A diversion dam is constructed for the purpose of diverting water of the river into an off-taking canal (or a conduit). They provide sufficient pressure for pushing water into ditches, canals, or other conveyance systems. Such shorter dams are used for irrigation, and for diversion from a stream to a distant storage reservoir. A diversion dam is usually of low height and has a small storage reservoir on its upstream. The diversion dam is a sort of storage weir which also diverts water and has a small storage. Sometimes, the terms weirs and diversion dams are used synonymously.

Detention dams: Detention dams are constructed for flood control. A detention dam retards the flow in the river on its downstream during floods by storing some flood water. Thus the effect of sudden floods is reduced to some extent. The water retained in the reservoir is later released gradually at a controlled rate according to the carrying capacity of the channel downstream of the detention dam. Thus the area downstream of the dam is protected against flood.

Debris dams: A debris dam is constructed to retain debris such as sand, gravel, and drift wood flowing in the river with water. The water after passing over a debris dam is relatively clear.

Coffer dams: It is an enclosure constructed around the construction site to exclude water so that the construction can be done in dry. A cofferdam is thus a temporary dam constructed for facilitating construction. A coffer dam is usually constructed on the upstream of the main dam to divert water into a diversion tunnel (or channel) during the construction of the dam. When the flow in the river during construction of the dam is not much the site is usually enclosed by the coffer dam and pumped dry.

Sometimes a coffer dam on the downstream of the dam is also required.

2.1.3.2. Based on structure and design, dams can be classified as follows:

Gravity Dams: A gravity dam is a massive sized dam fabricated from concrete or stone masonry. They are designed to hold back large volumes of water. By using concrete, the weight of the dam is actually able to resist the horizontal thrust of water pushing against it. This is why it is called a gravity dam. Gravity essentially holds the dam down to the ground, stopping water from toppling it over.

Gravity dams are well suited for blocking rivers in wide valleys or narrow gorge ways. Since gravity dams must rely on their own weight to hold back water, it is necessary that they are built on a solid foundation of bedrock.

Examples of Gravity dam: Grand Coulee Dam (USA), (Nagarjuna Sagar Dam (India) and Itaipu Dam (Between Brazil and Paraguay).

Earth Dams: An earth dam is made of earth (or soil) built up by compacting successive layers of earth, using the most impervious materials to form a core and placing more permeable substances on the upstream and downstream sides. A facing of crushed stone prevents erosion by wind or rain, and an ample spillway, usually of concrete, protects against catastrophic washout should the water overtop the dam. Earth dam resists the forces exerted upon it mainly due to shear strength of the soil. Although the weight of the earth dam also helps in resisting the forces, the structural behavior of an earth dam is entirely different from that of a gravity dam. The earth dams are usually built in wide valleys having flat slopes at flanks (abutments).The foundation requirements are less stringent than those of gravity dams, and hence they can be built at the sites where the foundations are less strong. They can be built on all types of foundations. However, the height of the dam will depend upon the strength of the foundation material.

Examples of earth fill dam: Rongunsky dam (Russia) and New Cornelia Dam (USA).

Rock fill Dams: A rock fill dam is built of rock fragments and boulders of large size. An impervious membrane is placed on the rock fill on the upstream side to reduce the seepage through the dam. The membrane is usually made of cement concrete or asphaltic concrete. In early rock fill dams, steel and timber membrane were also used, but now they are obsolete.

Mohale dam, Lesoto Africa

A dry rubble cushion is placed between the rock fill and the membrane for the distribution of water load and for providing a support to the membrane. Sometimes, the rock fill dams have an impervious earth core in the middle to check the seepage instead of an impervious upstream membrane. The earth core is placed against a dumped rock fill. It is necessary to provide adequate filters between the earth core and the rock fill on the upstream and downstream sides of the core so that the soil particles are not carried by water and piping does not occur. The side slopes of rock fill are usually kept equal to the angle of repose of rock, which is usually taken as 1.4:1 (or 1.3:1). Rock fill dams require foundation stronger than those for earth dams.

Examples of rock fill dam: Mica Dam (Canada) and Chicoasen Dam (Mexico)

Arch Dams: An arch dam is curved in plan, with its convexity towards the upstream side. An arch dam transfers the water pressure and other forces mainly to the abutments by arch action. An arch dam is quite suitable for narrow canyons with strong flanks which are capable of resisting the thrust produced by the arch action.

Hoover Dam, USA

The section of an arch dam is approximately triangular like a gravity dam but the section is comparatively thinner. The arch dam may have a single curvature or double curvature in the vertical plane. Generally, the arch dams of double curvature are more economical and are used in practice.

Examples of Arch dam: Hoover Dam (USA) and Idukki Dam (India)

Buttress Dams: Buttress dams are of three types: (i) Deck type, (ii) Multiple-arch type, and (iii) Massive-head type. A deck type buttress dam consists of a sloping deck supported by buttresses. Buttresses are triangular concrete walls which transmit the water pressure from the deck slab to the foundation. Buttresses are compression members. Buttresses are typically spaced across the dam site every 6 to 30 meter, depending upon the size and design of the dam. Buttress dams are sometimes called hollow dams because the buttresses do not form a solid wall stretching across a river valley. The deck is usually a reinforced concrete slab supported between the buttresses, which are usually equally spaced.

Fig. (2.1) it shows Buttress Dam in a simple model

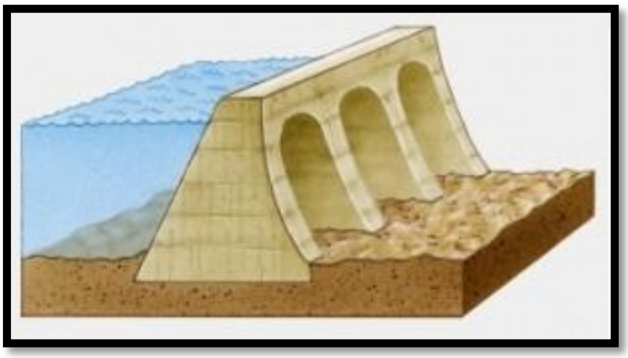


Fig. (1.1) Model of Buttress Dam

In a multiple-arch type buttress dam the deck slab is replaced by horizontal arches supported by buttresses. The arches are usually of small span and made of concrete. In a massive-head type buttress dam, there is no deck slab. Instead of the deck, the upstream edges of the buttresses are flared to form massive heads which span the distance between the buttresses. The buttress dams require less concrete than gravity dams. But they are not necessarily cheaper than the gravity dams because of extra cost of form work, reinforcement and more skilled labor. The foundation requirements of a buttress dam are usually less stringent than those in a gravity dam.

Examples of Buttress Dam: Bartlett dam (USA) and the Daniel-Johnson Dam (Canada)

Steel Dams: A steel dam consists of a steel framework, with a steel skin plate on its upstream face. Steel dams are generally of two types: (i) Direct-strutted steel dams, and (ii)

Fig . (2.2) it shows Buttress Dam in a simple model

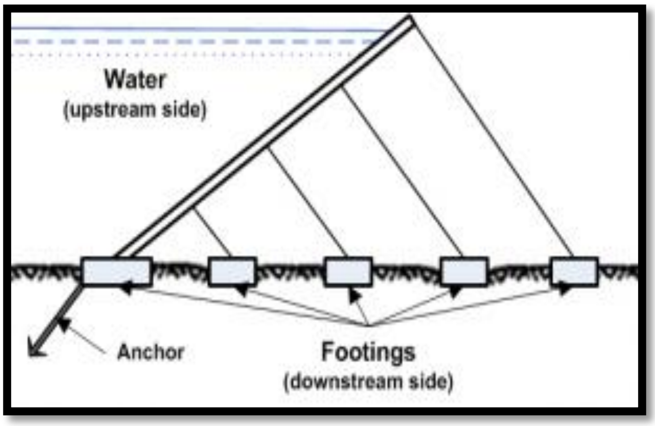


Fig. (2.2) Model of Steel Dam

Cantilever type steel dams. In a direct strutted steel dam, the water pressure is transmitted directly to the foundation through inclined struts. In a cantilever type steel dam, there is a bent supporting the upper part of the deck, which is formed into a cantilever truss. This arrangement introduces a tensile force in the deck girder which can be taken care of by anchoring it into the foundation at the upstream toe. Hovey suggested that tension at the upstream toe may be reduced by flattening the slopes of the lower struts in the bent. However, it would require heavier sections for struts. Another alternative to reduce tension is to frame together the entire bent rigidly so that the moment due to the weight of the water on the lower part of the deck is utilized to offset the moment induced in the cantilever. This arrangement would, however, require bracing and this will increase the cost. These are quite costly and are subjected to corrosion. These dams are almost obsolete. Steel dams are sometimes used as temporary coffer dams during the construction of the permanent dams. Steel coffer dams are supplemented with timber or earth fill on the inner side to make them water tight. The area between the coffer dams is dewatered so that the construction may be done in dry for the permanent dam.

Examples of Steel Dam: Redridge Steel Dam (USA) and Ashfork-Bainbridge Steel Dam (USA)

Timber Dams: Main load-carrying structural elements of timber dam are made of wood, primarily coniferous varieties such as pine and fir. Timber dams are made for small heads (2-4 m or, rarely, 4-8 m) and usually have sluices; according to the design of the apron they are divided into pile, crib, pile-crib, and buttressed dams.

Timber Dam

The openings of timber dams are restricted by abutments; where the sluice is very long it is divided into several openings by intermediate supports: piers, buttresses, and posts. The openings are covered by wooden shields, usually several in a row one above the other. Simple hoists—permanent or mobile winches—are used to raise and Dam illustration.

2.1.4. Different parts & terminologies of Dams:

Fig . (2.3) it shows Different parts & terminologies of Dams

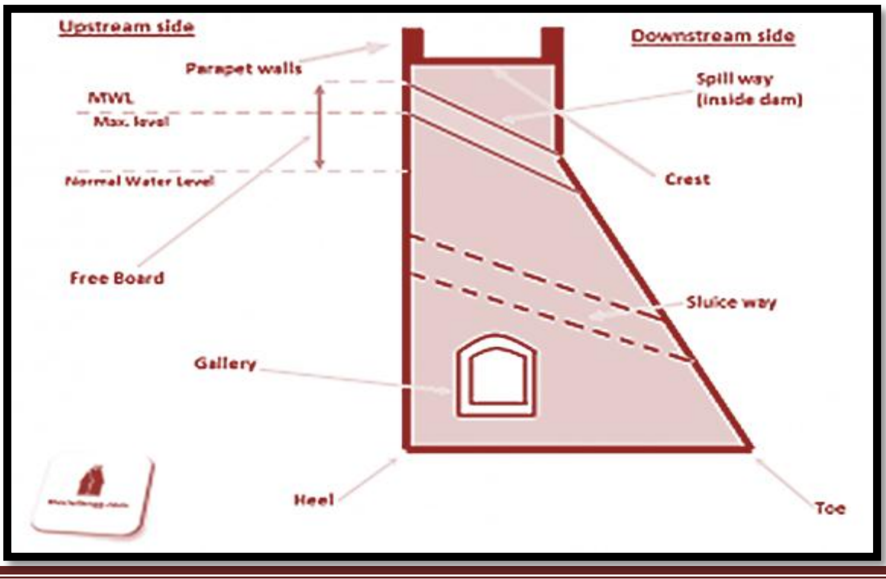


Fig. (2.3) Different parts & terminologies of Dams

- Crest: The top of the Dam. These may in some cases be used for providing a roadway or walkway over the dam.
- Parapet walls: Low Protective walls on either side of the roadway or walkway on the crest.
- Heel: Portion of Dam in contact with ground or river-bed at upstream side.
- Toe: Portion of dam in contact with ground or river-bed at downstream side.
- Spillway: It is the arrangement made (kind of passage) near the top of dam for the passage of surplus/ excessive water from the reservoir.
- Abutments: The valley slopes on either side of the dam wall to which the left & right end of dam are fixed to.
- Gallery: Level or gently sloping tunnel like passage (small room like space) at transverse or longitudinal within the dam with drain on floor for seepage water. These are generally provided for having space for drilling grout holes and drainage holes. These may also be used to accommodate the instrumentation for studying the performance of dam.
- Sluice way: Opening in the dam near the base, provided to clear the silt accumulation in the reservoir.
- Free board: The space between the highest level of water in the reservoir and the top of the dam.
- Dead Storage level: Level of permanent storage below which the water will not be withdrawn.
- Diversion Tunnel: Tunnel constructed to divert or change the direction of water to bypass the dam construction site. The dam is built while the river flows through the diversion tunnel.

2.1.5. How Dams Work?

A typical dam is a wall of solid material built across a river to block the flow of the river thus storing water in the lake that will form upstream of the dam as water continues to flow from the river upstream of the dam.

The main purpose of most dams is to create a permanent reservoir of water for use at a later time. The dam must be watertight (i.e. impermeable or impervious to water) so that water does not leak out of the dam and escape downstream. An essential part of a dam is therefore the "impermeable membrane", i.e. the watertight part of the dam that prevents water leaking out. As we shall see later, it is not necessary that the entire dam wall be watertight. The natural earth or rock on which the dam is built (in the dam foundation) must also be watertight as must the river valley in which the storage reservoir forms. If these natural areas (dam foundation and storage area) are not watertight then water could leak out of the reservoir even if the dam itself is watertight.

As well as being watertight a dam must also be stable i.e. the dam wall must have sufficient strength to firstly, stand permanently under its own weight especially when at least part of the dam wall is saturated with water and secondly, resist the water pressure in the lake upstream of the dam. This water pressure exerts a force on the dam wall tending to push it downstream. The higher the dam, the greater the depth of water stored behind the dam and the greater the water pressure on the dam wall. The dam must also have sufficient strength to resist other forces to which it may be subjected from time to time e.g. shaking from earthquakes. The threat that earthquakes pose to dams varies widely depending on the region of the world in which the dam is located.

A dam must have some way of releasing water in controlled amounts as it is needed ie an outlet valve of some type. Depending on the purpose of the dam the water may be released into a pipeline to supply a city with water, or into a hydro-electric power station to generate electricity or the water may simply be released into the river bed downstream of the dam and allowed to flow naturally down the river, eventually to be pumped out and used for irrigation of crops further downstream. The outlet valve must be connected via a pipe or tunnel to some type of intake structure where the water is actually drawn from the storage reservoir.

When the river on which the dam has been built floods a very large volume of flood water will flow into the storage reservoir. Usually this is very, very much more water than can be released through the outlet valve.

A dam must have some means whereby these large volumes of flood water can flow around the dam without causing damage to the dam itself; i.e. a spillway which, in most cases, is an open cut channel large enough to carry the flood water around the dam. If the dam is built of concrete the spillway may form part of the dam wall itself. However, if the dam is built of earth and/or rock fill (i.e. soil and broken rock) the spillway must be a separate structure because flood waters cannot be allowed to flow over the top of a fill (or embankment) dam which would be quickly washed away by the flood water if this was to happen.

A large dam project may involve many types of construction apart from building the dam wall itself e.g. tunneling for diversion or outlet works; road building to replace roads flooded by the reservoir; quarrying to obtain rock fill and other construction materials; excavation of open cuts for the spillway, access roads and road deviations.

2.1.6. Strength and Stability of Dams

Consider a concrete gravity dam with a vertical upstream face, a common design for this type of dam. The pressure of the water stored in the reservoir acts equally in all directions (hydrostatic pressure); because the dam's upstream face is vertical the water pressure on the dam wall will act in the horizontal direction and will tend to push the dam wall downstream. The weight of the dam wall acts vertically downwards. In order for a dam to be stable and therefore safe the design engineers and engineering geologists must make sure that;

- the foundation rock mass on which the dam is built must have adequate strength (bearing capacity) to support the dam wall, especially in the saturated state;
- the dam must be able to resist the tendency of gravity dams to overturn about the downstream toe at the foundation;
- The dam must be able to resist the tendency to slide downstream under the pressure from the water in the reservoir.
- Uplift pressures (water pressure acting vertically upwards in horizontal cracks within either the dam wall or the foundation rock) are taken into account in assessing the stability of the dam

because these pressures tend to destabilize the dam. In early gravity dams uplift pressures were not allowed for during the design.

The strength of a dam depends on the materials used to built it. A gravity dam is proportioned so that its own weight resists the forces acting on it.

Gravity dams built by the Ancient Romans had a base width to height ratio of about 3 whereas, in modern concrete gravity dams, this ratio is significantly less than 1 e.g. Warragamba Dam has a base width to height ratio of 0.8. To achieve the same level of stability an embankment dam, built from broken rock and clay, must be very much wider at the base than a dam of the same height built out of concrete e.g. Windamere Dam, an earth and rock fill dam, has a base width to height ratio of 3.7.

An arch dam is much thinner than a gravity dam: it contains less concrete and is therefore cheaper to build but the weight of the dam wall is not enough, on its own, to resist the forces acting on the dam. Concrete arch dams rely on the strength of the rock masses forming the bottom and sides of the valley in which they are built to help resist the forces acting on them. It is very important that a good, high strength foundation be found for any proposed arch dam.

2.1.7. Geology and Dams

On a large dam construction project the engineering geologist is concerned with:

- The geology of the dam site including the foundation for the dam itself and the sites for other structures such as spillway, diversion tunnel and outlet works. Questions that need an answer include whether the dam foundation has sufficient strength and durability to support the type of dam proposed, whether the foundation is watertight and if not how much grouting will be required and whether the spillway will require concrete lining;
- The geology of the area to be occupied by the reservoir once the dam is completed. Questions often asked here include whether the storage area is watertight or are there areas of cavernous limestone

which might lead to the dam not retaining water and whether landslides into the reservoir are possible which might cause a wave of water to be pushed over the top of the dam;

- Finding sources of the construction materials which will be needed to build the dam.

Extensive site investigations are usually required to answer these questions. No two dam sites are identical as far as geology is concerned so each new dam construction project must be investigated individually. Some dam sites may be relatively uniform in their geology is one rock type with a simple structure and a regular pattern of surface weathering. More often though the geology will be complex with several different rock types with different physical properties such as strength, durability and susceptibility to weathering . The geological structure may also be complex with geological units folded and faulted into a complicated, difficult to interpret pattern. Degree of surface weathering may vary suddenly from one geological unit to another further complicating the task of the engineering geologist.

The following two examples are of dams where the site geology was a very significant factor in the design and overall layout of the entire project:

Glennies Creek Dam: A 10 meter thick layer of completely weathered, non-welded tuff (a soil type material) at the dam site had a controlling influence on the choice of type of dam and the siting of the dam, diversion tunnel and the spillway; in fact, the whole project layout was determined by the outcrop and weathering pattern of the non-welded tuff.

Windamere Dam: The embankment dam was built on a weathered, sedimentary rock foundation. The rock fill construction material to build the dam was obtained from an unlined rock cut spillway in weathered andesite about 1 km from the dam site. If a spillway had been built adjacent to the dam in the weathered sedimentary rocks it would have had to have been lined with concrete to prevent erosion, at a greatly increased cost.

In the design of embankment dams there are two major decisions which have to be taken, both of which depend on geological factors:

- The extent to which it will be necessary to provide concrete lining and/or energy dissipation structures in the dam spillway.
- The extent to which the spillway excavation will be able to supply fill for use in the construction of the dam embankment.

The geology of the dam spillway is thus important to the overall design and layout of the whole dam construction project.

2.1.8. Dam Failures

Dam failures are of particular concern because the failure of a large dam has the potential to cause more death and destruction than the failure of any other man-made structure. This is because of the destructive power of the flood wave that would be released by the sudden collapse of a large dam. Tailing dams, which sometimes store toxic materials, may pose additional dangers e.g. Omai Tailings Dam, Guyana failed in 1995 releasing cyanide slurries and Stava Tailings Dam, Italy failed in 1985 killing 268 people. Many dams, both large and small, have failed but only a few have had a significant impact on the practice of dam design and engineering geology. The most common causes of dam failures are:

Overtopping of embankment dams due to inadequate spillway discharge capacity to pass flood waters. This is one of the most common causes of dam failures and has nothing to do with the geology of the dam site. Any embankment dam will fail if the spillway is too small and flood waters raise high enough to flow over the top of the dam wall. The estimation of the size of the maximum flood a dam will have to survive during its life is a science which has undergone continuing evolution over the last century with the result that many dams built decades ago may now be judged to have inadequate spillways even though the spillways were designed to standards of safety which were accepted as adequate at the time of construction of the dam. Many millions of dollars has been spent upgrading the flood handling capacities of many existing dams, both embankment and concrete dams, as a result.

The Burrinjuck Dam Flood Security Upgrading project is a recent example.

Faults in construction methods (e.g. inadequate compaction of fill) or use of the wrong type of construction materials (e.g. silt) may lead to internal erosion or piping failures of embankment dams. An example is the failure of the Teton Dam in Idaho, USA in 1976.

Geological problems with the dam foundation. The failure of the St. Francis Dam falls into this category. After the failure it was found that some of the foundation rock, a conglomerate, disintegrated when the rock was immersed in water so that the rock lost all its strength when saturated. This is exactly what happened as the newly completed dam filled with water for the first time and the dam failed shortly afterwards. Another example of a dam break due to foundation failure is the Malpasset Dam in France which failed in 1959. This was the first collapse of a modern, thin concrete arch dam.

Landslides which fall into the storage reservoir, sending a wave of water over the top of the dam may cause a dam to fail, or the dam may survive if made of concrete but a destructive flood may still devastate the river valley downstream as happened at the Vaiont Dam in Italy in 1963 when over1900peoplewerekilled.

Earthquakes can certainly cause damage to dams but complete failure of a large dam due to earthquake damage appears to be very rare. The Lower San Fernando Dam in California, USA did fail during an earthquake in 1971 which caused the fill in the dam wall to liquefy resulting in the collapse of the upstream part of the dam. A disastrous flood was only prevented because the reservoir level happened to be low at the time of the earthquake and no water escaped downstream.

Dams are likely to exist, perhaps for hundreds of years, even after they are no longer required for their original purpose. During these years, dangerous alterations to the operation of the dam and/or its structure may lead to failure e.g. South Fork Dam (Johnstown) which failed in 1889. Incorrect operation of a dam at any time can result in overtopping and failure e.g. Euclides da Cunha Dam, Brazil which failed in 1977.

2.1.9. Dams and the Environment

A dam built across a river will obviously have a major effect on the river valley upstream of the dam which will be flooded as the new storage reservoir fills. Less obvious is that the river downstream of the dam will also be significantly affected. Large dam projects are highly individual in their design, geological setting and the construction materials used to build them. They are also individual in their impact on their environment. Some large dam projects in tropical Africa have created lakes hundreds of kilometers long in areas which had large local populations. The major impacts that these projects had on the plant, animal and human population of the area have been well documented, however it would be a mistake to assume that all dam projects necessarily have similar major impacts on the environment.

Some adverse effects of building a dam are easy to mitigate during the design of the dam as the following example shows. Fifty years ago a typical dam could release water only from the bottom of the storage reservoir. This water was very different from the water that would have flowed down the river before the building of the dam. Water from the bottom of storage is usually cold and depleted in oxygen compared to normal river water and this had adverse effects on animal life in the river downstream of the dam. Since about the 1980s dam outlet works are usually specifically designed so that the adverse effects described above do not occur when water is released from the dam. Today's dams have an intake tower with withdrawal ports at different levels so that water can be released from the top layer of the reservoir regardless of the storage level at the time.

Provision of fish ladders is another example where dam design can remove or reduce an adverse effect of dam building. Today every reasonable effort is usually made to reduce the effect of the dam project on the environment eg borrow areas for clay, sand and gravel construction materials needed to build the dam are located, if possible, in the area which will be flooded by the reservoir so that the disturbed areas will not be visible after the dam is completed.

Not all adverse effects can be so easily removed. Building a dam changes forever the flow regime in the river: floods are much reduced in frequency and size and the natural pattern of short duration floods and long periods of low flows is changed to a less variable flow regime. In fact the reduction in flooding may be one of the reasons for building the dam in the first place. Flooding is damaging to humans and their property but may be necessary in the life cycles of some species of trees, fish and birds. It may be possible to at least partially mitigate these adverse effects on the natural environment by arranging water releases from the dam at specific times of the year to mimic the natural flooding that occurred before the dam was built.

"The Dam Site" tries to take an objective and scientific approach to the advantages and disadvantages of dams. Many large cities and developed, industrial societies could not exist without large dams but it cannot be denied that some large dams have caused major environmental problems as described on the following sites:

2.1.10. Alternatives to Dams

When a proposal to build a new dam is put forward two types of studies are usually carried out:

- Firstly, the cost/benefit ratio of the dam project is calculated, i.e. does the value of the benefits that will be obtained by building the dam exceed the cost of building the dam? This study is intended to determine if the building of the dam is economically justified.
- Secondly, the effect of the new dam on the environment is assessed in an Environmental Impact Statement (EIS).

One question usually asked is; "Is a new dam really needed or could the objectives of the dam project be achieved in some way other than by building a new dam?" The answer to this question depends on what the objectives of the dam project are, e.g. if the dam is to be built to meet the additional demand for water supply to a growing city it might be possible to meet this demand by obtaining water from another source, e.g.

groundwater pumped from underground aquifers, or the demand for water might be reduced by, for instance, increasing the cost of water to the consumer. In either case, it might be decided that the construction of a new dam is not required after all.

In the case of a dam which is to be built to generate electricity it might be similarly possible to reduce demand by increasing cost or the electricity might be able to be generated in some other way, e.g. solar, coal fired or nuclear power stations. Obviously many factors, both economic and environmental, have to be considered before it can be decided, for example, whether a new dam or a new coal fired power station is more desirable.

Dams do create some adverse environmental impacts and some high profile; large dam projects in the past are now thought by some to have caused unacceptable environmental damage. Others would say that the environmental problems associated with dams can be successfully managed in the dam design process and, provided that this is done, dams can be less damaging to the environment than coal fired or nuclear power stations.

2.2. Dam's construction & Operation Stages

2.2.1. Introduction

The designer engineer’s responsibility is to provide safety. The designed structures must act with integrity giving due consideration to the purpose of the project and the ultimate effects of the project on fellow human beings.

At the same time the Engineers are responsible to the community for the cost of the structure. There is always a limit to the finance, so any cut in cost must not sacrifice safety.

The Engineers also carries a legal responsibility, and are responsible at all times for both what they do and what they say.

2.2.2. Dam's construction

2.2.2.1. Dams design Stage

2.2.2.1.1.Sequence of Dam Design

1- Specify the purpose for the dam project

- Water supply (requires a high reservoir)
- Irrigation
- Silt retention
- Transportation
- Electricity generation
- Recreation and beautification (requires a constant reservoir level)
- Flood mitigation (requires a low reservoir)

2- Architecture layout and choosing the best spot for the dam

- In the planning stage possible dam sites will have been chosen from contour maps and aerial photography, selected primarily on topography. An arrow gorge is best, hoping for minimum quantities in the dam and a valley opening upstream to provide the required storage. There may be alternative sites along the length of a river and hence further investigation has to be done to ascertain the best possible position.
- Depends on many considerations, such as the narrowest stream width, the location of the reservoir, geological formation at the site, and what the purpose of the dam was.

3-Site Investigation

- Most failures are due to lack of appreciation of how the particular dam site would react to the superposition of the dam and reservoir. It is therefore essential that a detailed site investigation takes place and Engineers appropriately use the results.
- A Geologist will assist the Engineer in the selection of the dam site, and a construction Engineer will study the access and possible sources of materials.

4- Laboratory and Field Testing

- All the parameters used in the design such as soil shear strength, unit weight, maximum dry density,…….etc., should be estimated from different types of field and laboratory tests.

5- Hydrology study

- Hydrology is a science of prediction - the likelihood of recurrence of natural events. Mathematicians may try to predict events based on past history but Nature is unpredictable as to time and magnitude of occurrence.
- Based on past information the low flow characteristics of the river will control the storage required and hence the normal full supply level of the reservoir. High flow records and flood forecasting techniques provide the basis for design of the spillway, and hence the flood storage required above normal full supply level.
- The hydrology study also involves determining the storage capacity of the reservoir, the workable lake elevation for navigation or power supply, and the design of emergency spillway.

6- Loading and Factor of Safety – Static and Dynamic Loading

Both static and dynamic (like earthquake) loads acting on the body of the dam are calculated.

Fig. (2.4) the minimum factors of safety for embankment dams

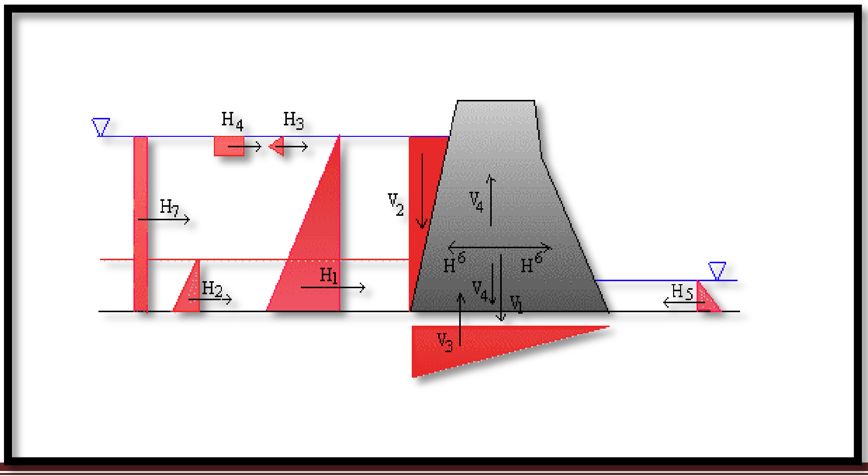


Fig. (2.4) the minimum factors of safety for embankment dams

The minimum factors of safety for embankment dams would be:

Upstream Slope

Immediately after completion with full construction pore pressure 1.3-1.5

Following rapid drawdown (slip circles between high and low water levels) 1.2-1.3

Downstream Slope

Earthquake and Reservoir Full 1.2

Reservoir full - steady seepage 1.5

In an area subject to earthquakes the following factors are indicative of acceptable values:

Seismic coefficient	0.1	FoS	1.8
Seismic coefficient	0.3	FoS	1.15

7- Foundation Design

- The foundations of a dam must be able to withstand without unacceptable deformation the loads imposed upon it by the structure, both immediately after filling the reservoir and in the long term.
- With time, deterioration by saturation and percolation of water can occur, whilst soft rocks and clays usually exhibit lower residual strengths under sustained loading than under rapid testing. It is the 10-20m of rock immediately below the dam that is of greatest importance.
- Terzaghi’s advice might well apply to foundation testing - "...because of unavoidable uncertainties involved in the fundamental assumptions of the theories and the numerical values of the soil constants, simplicity is of much greater importance than

accuracy. “The Engineer must use all the available resources, concentrating on the zones of foundation that appear weak and that will be subject to stresses once loaded.”

- Construction of a dam and filling of the reservoir behind it create load stresses on the floor and sides of a valley that did not exist previously.
- The kinds and distributions of imposed stresses created by a dam on its foundation depend on the shape of the dam and the materials used in its construction.
- Dams built of masonry or concrete can be considered to behave as cohesive, rigid, monolithic structures. The stresses acting on the foundation is a function of the gross weight of the dam as distributed over the total area of the foundation on which the dam rests.
- Earth and rock fill dam's exhibit gross semi-plastic behavior, and the pressure on the foundation at any point depends on the thickness of the dam above the point.
- The pressures exerted by earth and rock-fill dams resemble in some respects those exerted by the water in a reservoir, but pressure distribution is modified by the fact that the materials of construction have some inherent strength, and fail only after some threshold stress has been exceeded. Pressures exerted by water in the reservoir behind a dam are hydrostatic and increase linearly with depth.

8- Seepage control design

- Seepage under an embankment is much more dangerous than that for a concrete dam, since embankments are usually built on soft material which is liable to be scoured out and it is also vulnerable to influx of water; whereas a concrete dam is usually built on rock which is not worn away so rapidly by the scouring action of water; and even then a defective dam will not necessarily be endangered by passage of water through it or even under it.
- Stored water behind dams, gives rise to three basic seepage problems, which can lead to difficulties and in serious cases to total failure:

1. Piping occurs when water picks up soil particles and moves them through unprotected exits, developing unseen channels or pipes through a dam or its foundation.
2. Heave or slope failures caused by seepage forces.
3. Excessive loss of water.

- Three basic methods for controlling seepage are:

1. Use of filters to prevent piping and heave
2. Seepage reduction
3. Drainage

9- Slope Stability

- Failure of an embankment dam can result from instability of either the upstream or downstream slopes. The failure surface may lie within the embankment or may pass through the embankment and the foundation soil. The critical stages in an upstream slope are at the end of construction and during rapid drawdown. The critical stages for the downstream slope are at the end of construction and during steady seepage when the reservoir is full.
- It is common to install piezometers to measure pore water pressures and compare data with the predicted values used in design. Since pore water pressures are a dominant influence on the factor of safety of slopes, remedial action should be taken if the factor of safety, based on the measured values, is considered to be too low.
- To ensure stability a number of conditions must be investigated:

1. The slopes must be safe against surface slipping. To ensure this the slopes must be no steeper than the angle of repose
2. The dam must be safe against sliding on the foundation
3. The mass of the embankment must be safe against a circular arc failure or composite linear failure. This is likely to occur within an earth core or weak foundation

10- River Diversion design

- Regardless of the type of dam, it is necessary to de-water the site for final geological inspection, for foundation improvement and preparation, and for the first stage of dam construction. The magnitude, method and cost of river diversion works will depend upon the cross-section of the valley, the bed material in the river, the type of dam, the expected hydrological conditions during the time required for this phase of the work, and finally upon the consequences of failure of any part of the temporary works.
- At most sites it will be necessary to move the river whilst part of the dam is constructed; this part will incorporate either permanent or temporary openings through which the river will be diverted in the second stage. If the first diversion is not large enough the initial stages of construction will be inundated, if the second stage outlets are too small, the whole works will be flooded.
- At some sites there is a distinct seasonal pattern of river flows and advantage can be taken of such conditions but noting that Nature is random.

2.2.2.2. Dams Implantation Stage

2.2.2.2.1. Construction of a Dam

There are four main steps for dam construction, as described below:

Step 1:

To build a Dam the engineers must first de-water the part of the river valley in which they wish to place the dam. This is usually achieved by diverting the river through a tunnel. The tunnel is built through one side of the valley around the planned construction area. A series of holes is drilled in the rock. Explosives are placed in the drill holes, blasting takes place and broken rock is then removed. This procedure re is repeated many times until the tunnel is completed. Diversion tunnels are often lined with concrete.

Step 2:

Work on diverting the river starts in summer when river levels are low. Earth-moving equipment is used to build a small dam (called a cofferdam) upstream of the main construction area. This acts as a barrier to the river and causes it to flow through the diversion Tunnel.

Another cofferdam is built downstream of the main dam site to prevent water flowing back into the construction area. Pumps are used to remove any water that seeps through the cofferdams.

Diversion tunnels are not always necessary when concrete dams are being built. The river can sometimes be channeled through a large pipe and the dam constructed around it.

Step 3:

The construction methods used in building a dam depend on the type of dam being built. The first stage normally involves the removal of loose rock and rubble from the valley walls and river bed.

Concrete-faced rock fill dams require a footing (or plinth) to be constructed around their upstream edge. The plinth is made from concrete and serves as a foundation or connection

Between the dam and the valley walls and floor . It has an important role in preventing water leakage around the edges of the dam. The area under the plinth is waterproofed by drilling holes and pumping cement grout into cracks in the rock. The thin concrete face on the upstream side of the dam is connected to the plinth via stainless steel and rubber seals called water stops.

Step 4:

During dam construction the associated power station and intake works are also being built.

When the dam is completed the diversion tunnel is closed and the lake begins to fill.

The Closure of the diversion tunnel has two phases.

During low flow a large re-usable steel gate is lowered across the entrance. The diversion tunnel is then permanently blocked off by the construction of a concrete plug. In some instances dewatering outlets are built into the plugs so water can be released during

An emergency.

2.2.3. Dams Operation Stage

2.2.3.1. Definition

Currently, New Hampshire’s statues state that a dam means any artificial barrier, including appurtenant works that impounds or diverts water, and which has a height of six feet or more or is located at the outlet of a great pond A roadway culvert shall not be considered a dam if its invert is at the natural bed of the water course, it has adequate discharge capacity,

And it does not impound water under normal circumstances. Artificial barriers that create surface impoundments for liquid industrial or liquid

Commercial wastes, seepage or sewage, regardless of height or storage capacity, shall be considered dams. An artificial barrier at a storm water detention basin, which impounds 0.5 acre-foot or less of water during normal conditions, shall not be considered a dam unless its height is 10 feet or greater or its maximum storage is six acre-feet or greate Elements of a typical embankment dam.

2.2.3.2. Overview

Whether you are contemplating the construction of a new dam or performing maintenance or operation activities on an existing dam, there are a number of considerations, which if applied can improve longevity and performance and reduce the long- term maintenance effort, as well as minimize environmental degradation. Some of these considerations are outlined below.

2.2.3.3. Planning

The reasons for constructing a dam are many. Current trends indicate that runoff detention, fire protection, aesthetics, wildlife and irrigation are the most frequent reasons cited. When the main purpose of the dam has been set, the next step should be to select a design and location such that the benefits of the dam are maximized and the disturbances to the environment or hazards to downstream inhabitants are minimized. For example, perhaps the best location for a supply pond is at a high point on the property so that gravity feed can be used rather than pumping, or perhaps there is a natural rise in the ground just downstream of a depression thereby minimizing the amount of embankment fill and pond excavation required during construction.

2.2.3.4. Design

The design is likely the most important element in determining the long-term effectiveness and Maintainability of the dam. Here again, the basic purpose for constructing the dam, as well as site factors, will have a large part to do with what the end result should be. Some important site factors relating to the type of dam include location, size, drainage area, existing site conditions and accessibility to the site. The dam should be built with a spillway of sufficient size to pass the flows anticipated from the water shed without causing the dam to be overtopped and damaged/washed away. Also, if the dam's purpose is to provide fire protection to adjacent structures, it should be built in an area with sufficient base flows to keep the pond filled—even during dry periods.

It's important to note that during the planning and design processes, while ensuring that the basic purpose of the dam will be achieved, there may be other factors to consider including compliance with federal, state or local regulations. These regulations could pertain to such things as the design of the dam, emergency planning, environmental impacts or mitigation.

Some general best management practices associated with a dam's design are listed below.

Discharge capacity.

This should be based on an hydrologic analysis of the drainage area and

Sufficient to safely pass the flow resulting from the 50 year storm event .

Embankment slopes.

These should be as flat as possible (no steeper than 3h: 1v) for stability

And maintenance considerations and covered with an erosion resistant treatment to keep erodible soil in place.

Embankment crest.

This should be wide enough for a service vehicle, slightly inclined in either direction so as to shed rainfall, and protected by an erosion resistant treatment.

Cross section of an embankment dam2

Spillways .

These should be sized to provide the necessary discharge capacity, checked frequently for debris accumulation, stable during use and durable over the long term.

Low-level outlets.

These should be provided for the purpose of draining the pond, if necessary, and should be easily operable and sized to discharge enough water to drain the pond under most flow conditions.

Vegetation .

The preferred vegetative cover for embankment crests, slopes and vegetated spillways is any hearty variety of grass. Trees and brushy-type growth are unable to provide the earth retaining characteristics necessary to prevent embankment soil from being washed away.

Erosion protection.

Where grass cannot be used or where other types of materials are available, coverings such as fractured stone (riprap), keyed stone or other types of durable, well anchored and non-erodible layers can be used as substitutes.

Trash racks.

These should be provided when drop inlet type spillways are used to prevent larger debris from falling into and clogging outlet pipes.

Anti-seep collars.

These, when properly attached to low level pipes and coupled with adequate embankment soil compaction, reduce the possibility of seepage along the exterior of the pipes and potential dam failure.

Freeboard.

This distance between the maximum anticipated water level and the top of the dam should be large enough so that the dam can pass the flow safely and so the action of the wind induced waves cannot cause the dam to be overtopped.

2.2.3.5. Maintenance

Even when applying the above management practices it is imperative that periodic visits be made to the dam to ensure that all of its components are functioning properly. There is invariably some degree of maintenance to be carried out at the dam. Anyone with a lawn is aware that without attention, weeds and bare spots will develop and proliferates. The same is true with the dam embankment. Over time an adjacent wooded area or field will encroach on the dam and require a regime of mowing or brushing-out. As you’ll see, your maintenance requirements will be directly based on the location of the dam. If there are a lot of leafy trees overhanging the pond or if beavers live nearby you’ll be cleaning up plenty of floating debris from spillways. Whereas if the dam is on a major river or stream, you'll likely be constantly dealing with maintenance

Items associated with large sustained flows like soil erosion or larger river-borne debris. The activities of beavers are legendary. Although well-meaning, beavers can block a spillway or clog an outlet pipe or even build a dam directly upstream of yours—overnight! Proper maintenance

Helps to insure that the dam will function as it was intended to. The need for periodic inspection and constant attention to a dam cannot be overstated.

2.2.3.6. Operation

As discussed above, planning and designing a dam are thought provoking tasks. With those done and construction complete, maintaining and operating what you've built should be fairly straightforward.

Right? Generally, yes. Since most small dams are designed to safely pass a certain amount of flow, usually the 50-year storm event, under normal conditions the dam will operate itself. This will only occur, however, if the proper maintenance discussed above is being carried out.

Operating a dam involves becoming acquainted with how the dam reacts to outside influences.

Just like the machine that needs to be warmed up before it runs well, some dams may need to be operated differently in varying weather conditions or in different seasons. Frequent observation of the dam will help you learn its normal routine. Remember, a dam is designed and built to perform a certain way configuration of the dam be maintained. Sometimes things occur that shrink the limits, which within certain limits. Therefore, it is very important that the original may result in the required freeboard of the dam being reduced to something less than what was designed and increasing the risk of overtopping should there be a significant rainfall.

There may also be times when the dam has been designed to pass a certain amount and is being maintained properly but there comes a storm event that produces more flow than the spillway is capable of passing. These types of events usually occur without warning and may lead to damage or failure of dams. At these times or when overtopping is imminent, it may be necessary to open low level outlets and release water to provide more storage area in the pond or to implement emergency measures such as sandbagging along the crest of the dam. It is strongly

Recommended that dam owners develop contingency plans and monitor their dams frequently during times of severe weather .

Dam owners should also be aware of the riparian rights of those living downstream. Riparian rights, simply stated, are defined as the rights of a stream bank property owner to have reasonable use of the natural waters. This means that dam owners cannot shut off their dams or divert the stream to another channel and dry up the stream or river. Generally, no special dam operations are necessary to ensure stream flows because base flows are usually high enough to keep water flowing through the spillway. At times of low flow, when evaporation and/or consumption are greater than base flows, water may drop below the invert of the spillway. When this occurs provisions should be made to release some amount of flow through gates, sluices or spillways so that inflow into and out of the pond are balanced.

Trees along embankment crest create concentrated flow that can cause erosion of grass and soils surrounding them during overtopping of dam. Vegetation at and around dams can impact dam performance and lead to failure.

2.3. Dams in Sudan

2.3.1. Sinnar Dam

Built in 1926 on the Blue Nile, Sinnar Dam is the oldest dam in Sudan; it was constructed in order to irrigate the Gezira Scheme. Over half of Sudan's agricultural production is reliant upon the water provided by the dam, making it essential to the country's economy. Located approximately 300 kilometers south of Khartoum, it is the reservoir that provides irrigation water.

2.3.2. Jabal Awlia Dam

Built in 1937 on the White Nile, Jabal Awlia Dam sits about 50 kilometers southwest of Khartoum. The purpose behind its construction

Was to provide support to the Aswan Dam in southern Egypt. It was not until 1977 that control of the Jabal Awlia Dam was given to the Sudanese government. The lake that results from the dam provides an estimated 15,000 tons of fish every year, much of which gets transported to Khartoum.

2.3.3. Khashm el-Girba Dam

Built in 1966 on the upper Atbara River, Khashm el-Girba Dam is a gravity and embankment composite dam on the Atbara River about 4 km (2 mi) south of Khashm El Girba in Eastern Sudan. The primary purpose of the dam is irrigation.

The dam is equipped with canal headwork, located on its left bank, which divert water into a canal. When water levels in the reservoir are low, three pumps move water into the canal.

The main portion of the dam is an earthen embankment; the spillway and irrigation headwork's sections are concrete gravity.[1] The dam has a small hydroelectric power station, which was upgraded during the period 2002-04 to its current installed capacity of 10 megawatts (13,000 hp).

2.3.4. Rosaries Dam

Built in 1966 on the Blue Nile, Rosaries Dam is about 500 kilometers south-east of Khartoum. It sits on the Blue Nile, the part of the river that flows out of Ethiopia to meet the White Nile in Khartoum. Almost half of Sudan's power output is supplied by the 280 MW hydro-electric plants. However, generation fluxuates dramatically throughout the year, based on changing river flows. In addition, the Rosaries Dam supplies the Gezira Plain with irrigated water.

2.3.5. Merowe Dam

Built in 2003, Merowe Dam is a multipurpose scheme for hydropower generation. Merowe Dam Project is situated on the Nile River, close to the 4th Cataract where the river divides into multiple smaller branches with large islands in between, near Merowe city, which is 350 km to the north of Khartoum. The dam is located at longitude 32 E, and latitude 19 N. Almost 60% of Sudan's power output is supplied by the 1250 MW hydro-electric plant that is found at the dam

2.3.6. Dam complex of Upper Atbara

Built in 2010, Upper Atbara and Setit Dam Complex is a twin dam complex currently under operation and comprising Upper Atbara Dam on Upper Atbara River and Setit Dam on Setit River in Eastern Sudan. The site of the twin dam is located 20 kilometers (12 mi) upstream from the junction of the rivers and about 80 kilometers (50 mi) to the south of the Khashm el-Girba Dam.

The project aims to provide irrigation water for new Halfa Agricultural Project, provide fresh water for humans, animals and agriculture, provide irrigation water for Upper Atabra Agricultural Project, power output is supplied by the 320 MW hydro-electric plant that is found at the dam, supply Gadarif area with water and increase fish production in the area.

CHAPTER THREE

METHODOLOGY

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This chapter comprises of the method and the design that was used to conduct this research. Data and information used in this research were collected from Dam Complex of Upper Atbara Project (DCUAP), and other references.

3.2. Research Design

In the preparation of this Thesis, the researcher relied on a scientific methodology that focused on two frameworks:

3.2.1. Theoretical framework

In which the researcher was acquainted with many references: Internet, specialized technical studies, previous researches, personal experience in the field and his technical observations through his practical experience in this field.

3.2.2. Practical framework

In the evaluation of the Initial Filling Stage of Dam Complex of Upper Atbara Project, the researcher relied on the analysis of the inputs and outputs of hydrological and hydraulic data using mathematical model ,other technical information collected from Dam Complex of Upper Atbara Project, and classified , reviewed ,processed , analyzed and presented the results in the form of Graphs using Excel format, and interpreted the results obtained to reach general recommendations in the field of study Construction and operation of dams in Sudan.

3.3. Research Techniques

In this study Dam Complex of Upper Atbara Project was chosen as a case study to represent the method of evaluating the first Initial Filling Stage in dams.

3.4. Development of the mathematical model

In this research amathematical model on excel format was developed basis on water balance of upper Atbara and setit rivers as described below:

- The daily measured time series of inflow at Burdana & Rumela measuring stations had been used, we focused only on measured data after TK5 starts operation (2010, 2011, 2012, 2013 and 2014).
- The statistical analysis erected on discharge measurements shows that 2011 data is representing a dry year (worst case), for the normal year the averaged inflow of the 5 years had been used.
- The start of the filling is intended to be as late as possible in order to minimize the sedimentation in the reservoir. The later filling starts that means lower sediment load in the reservoir, but at the same time early filling date is required to make sure that we may reach the maximum operation level in the reservoir at the end of the flood season.
- The required storage volume is determined by the water requirements for irrigation, urban water supply, environmental flow and hydropower which are considered as the lowest priority water user in this filling.
- Various rates of filling are used to ensure the dam safety and to calculate the increase in water level and water content in the reservoir and to determine the period required to achieve targeted level.

3.4.1 Some of the equations of the mathematical model

Water Balance:

- Total Inflow (Mm3) K = A + F, at A = Upper Atbara Inflow (Mm3), F= setit Inflow (Mm3)

- Total ΔS (Mm3) L = D + I at D= Upper Atbara Reservoir (Mm3) ΔS, I= setit Reservoir (Mm3) ΔS

- Outflow (Mm3) M= K- L

Relationship between (Elevation & Volume):

Y=3.699 x2 -36355.6x+893324, at y = Reservoir Volumes, x = Reservoir water levels

Spillways capacity:

- B.O Dis.Cap=Cd*n*w*h*√ (2gh), at B.O Dis.Cap = Bottom outlets discharge capacity, Cd= coefficient of discharge, w = Gate width, h = Gate Height,g= Acceleration of Gravity constant

- $S.O\ Dis.Cap=Cd*n*w*\surd\ (2gh^3)$, at S.O Dis.Cap = surface Bottom outlets discharge capacity

3.5. Data collection

This is referred to as the gathering or collection of information from participant of the project to suitably answer the research objectives in this study.

3.5.1. Main data

The Main data for case study (water level observations, discharge measurement, sediment concentration, etc...) provided by Dam Complex of Upper Atbara Project officially, the advantages of this method of data collection include; reliability and accuracy .

3.5.2. Secondary data

The secondary data refers to that information which have already been collected, analyzed, documented and published by some other researcher as previous studies, in addition to some papers literature review, which brings out the main source of the secondary data collection deals with the extant literature. In this study, our secondary data was collected from references and previous studies.

3.6. Time scope

The research was at the time period between Augusts - November 2015.

CHAPTER FOUR

CASE STUDY

CHAPTER FOUR

Case study

4.1. Introduction:

Dam complex of Upper Atbara Project (**DCUAP**) is located on the Atbara River and the Setit River, approximately 20 km upstream of their confluence, 80 km upstream of the Khashm El Girba Dam, and approximately 30 km south of the small town El Showak in the Gedaref State in East Sudan.

Fig. (4.1) shows The General Layout of Dam complex of Upper Atbara Project

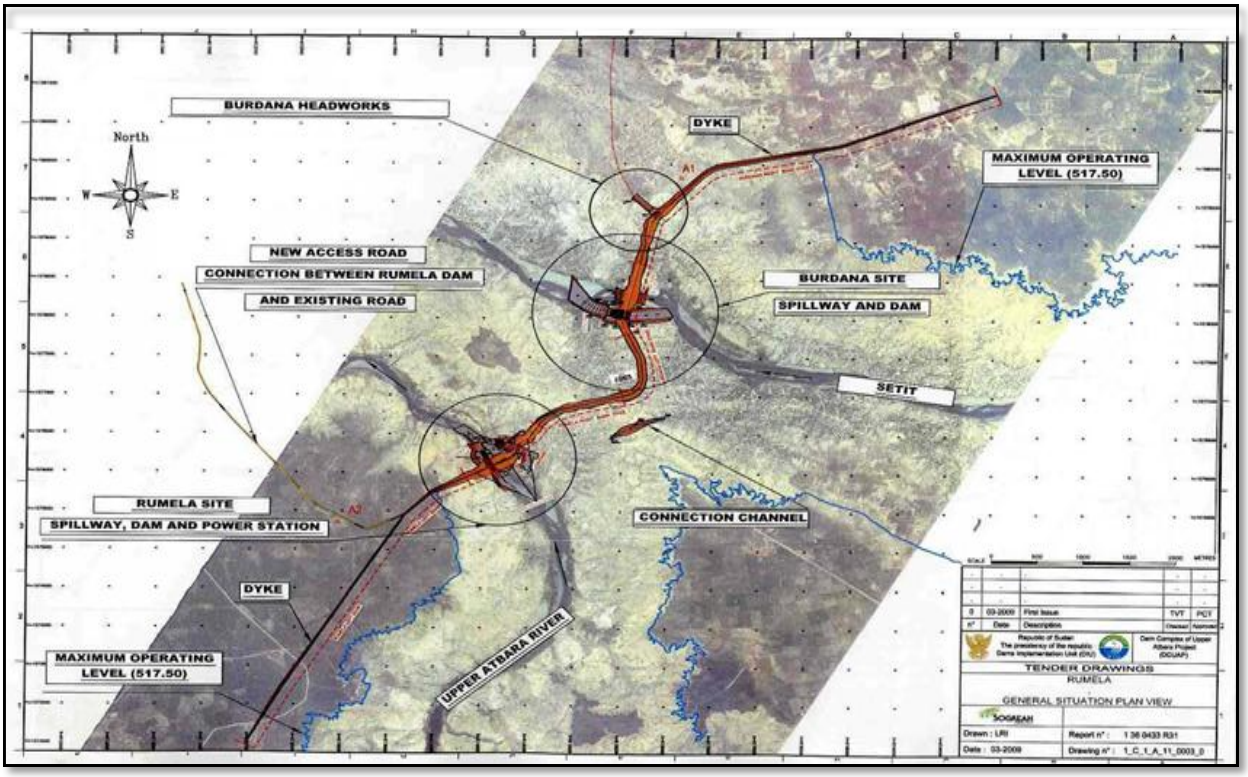


Fig. (4.1) General Layout of Dam complex of Upper Atbara Project

4.2. Description of the Project

The project consists of two dams: Upper Atbara Dam, located on the Upper Atbara River, and the Setit Dam, located on the Setit River.

Each of these two dams consists of an earth-fill embankment dam in the main river bed and a system of dykes on either side of their river banks. The combined embankments with crest level at 524.80 m a.sl will impound both rivers, Upper Atbara and Setit, and will create the DCUAP reservoir with a total storage volume of nearly 3.7 billion m³.

Fig. (4.2) shows 3D Model of Upper Atbara Spillway

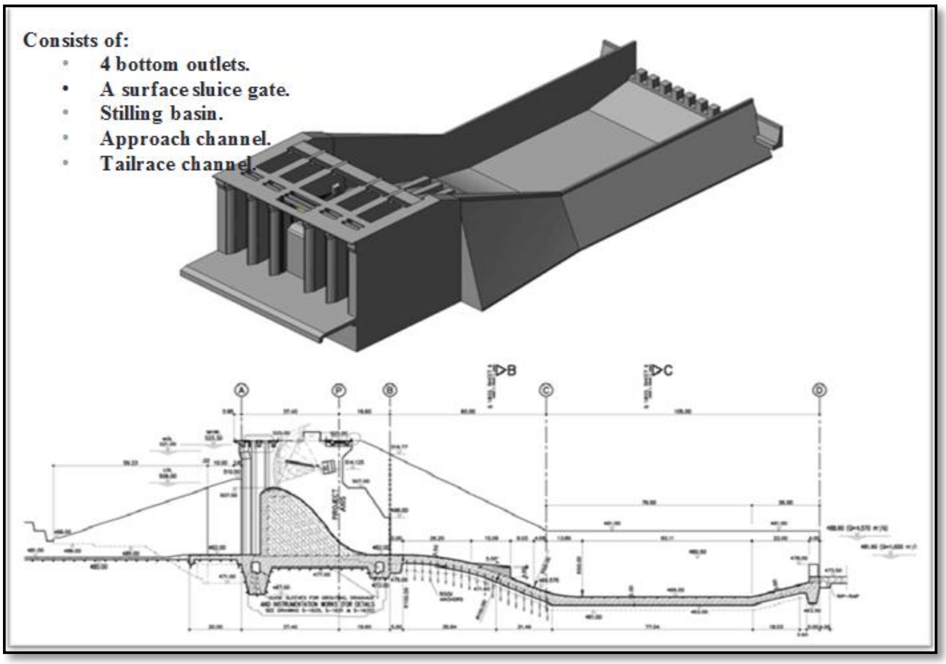


Fig. (4.2) shows 3D Model of Upper Atbara Spillway

Fig. (4.3) shows 3D Model of Setit Spillway

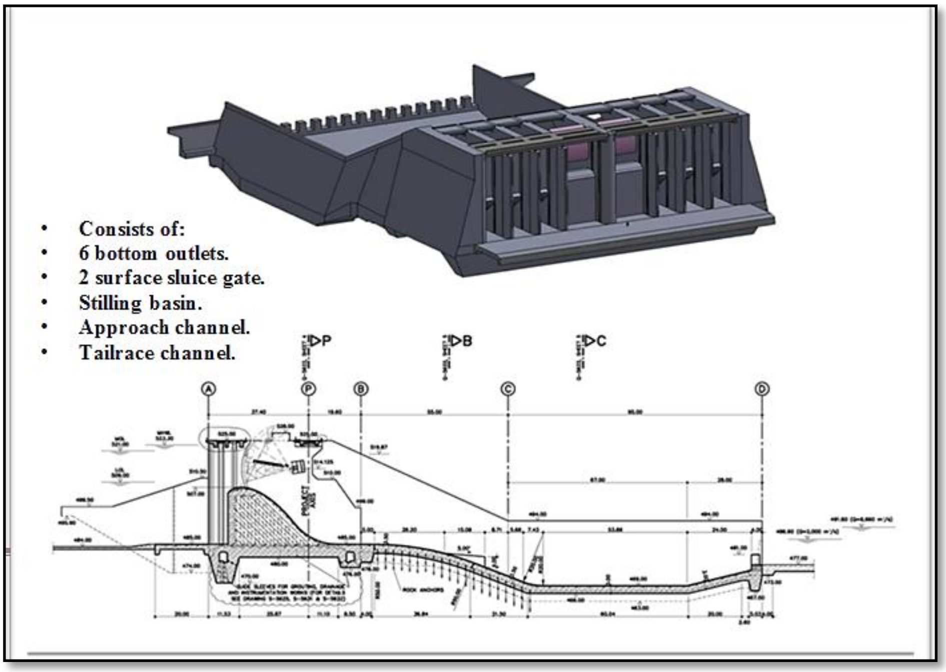


Fig. (4.3) shows 3D Model of Setit Spillway

Due to the topographic conditions, both rivers respectively dams have to be considered separately during the construction period.

However, after completion of the construction, both dams are connected together with a connection channel form one common reservoir. Therefore, only a combined reservoir inflow from both rivers, the Setit River and the Upper Atbara River, must be considered for the final design. Similarly, the two physically separate spillway structures are to be considered as one entity for the flood release.

DCUAP consists also at the Upper Atbara Dam of a Power Intake and a Power house equipped with 4 Kaplan turbines 80 MW each, the total installed capacity is 320 MW, which will be operated on peaking hours.

4.2.1. Project Components

Table (4.1) Project Components

Description	**Setit River (Burdana) Dam**	**Upper Atbara (Rumela) Dam**
Embankment		
Main Dam	Clay core dam	Clay core dam
Dykes	Clay core dyke Length: 5098 m	Clay core dyke Length: 5620 m
Concrete Structures		
Spillway	Location: left bank Gates: 5 (4 deep sluice gates, 1 surface gate) Discharge: 5300 m3/sec	Location: Left bank Gates: 8 (6 deep sluice gates, 2 surface gates) Discharge: 8800 m3/sec
Description	Upper Atbara (Rumela) Dam	Setit River (Burdana) Dam
Concrete Structures		
Power Intake	Location: right bank Gates: 4	-
Power Station	Location: right bank No. of Turbines: 4 Kaplan Turbines each of 80 MW	-

4.2.2. Contractual parties of the project

The project implementation commenced on 15.05.2010 by Chinese Contractor **CWE-CTGC-JV** under the Supervision of **Lahmeyer International GmbH (LI).**

In addition to the project implementation costs there are hydroelectric and electric costs, technical and consultancy service costs, land owning and population resettlement costs and project implementation management and supervision costs by Sudan's **Dams Implementation Unit (DIU).**

4.2.3. Project Main Objectives

- ✓ Supply of irrigation water for the existing New Halfa agricultural scheme
- ✓ Alleviation of siltation problem in the KED reservoir
- ✓ Power Generation (320 MW) at Upper Atbara Dam Power Station
- ✓ Supply irrigation water for the proposed UAIP Supply of drinking water supply for Gadaref area
- ✓ Provide water for the D/S and U/S local people
- ✓ Raising living level of the affected people

4.2.4. Project Studies and Design

- ✓ Studies for (DCUAP) started in early 1970s by **Sogreah** Company.
- ✓ **Sogreah** reviewed and updated the previous studies and designs.
- ✓ New studies were carried out by (DIU) from 2007 to 2009.
- ✓ **Sogreah** updated the project design and issued the Tender Documents
- ✓ **Lahmeyer** International GmbH reviewed the project design.
- ✓ **Deltares** Implemented the Sedimentation and Operation Study for Atbara Dams Complex- 2014 (SOSADC).

4.3. DCUAP Works and activities related to the Initial Filling Stage

The technical engineering Works and activities carried out in the project and which are directly related to the Initial Filling Stage are:

- Embankment Works
- Concrete Works
- Hydro mechanical Works
- Instrumentation and Monitoring Activities

- Hydrological activities

The researcher focused on the hydrological activities (data collection & processing) required for the implementation of the Initial Filling Stage, and in particular how to prepare the Initial Filling Plan (IFP) in terms of hydrology because this is the basis of achieving the Target of the Initial Filling from the point of view of the researcher.

4.3.1. Embankment Works

Upper Atbara and Setit dams consist of an earth-fill embankment dam in the main river bed and a system of dykes on either side of their river banks with a total length of 12.5 km, the combined embankments with crest level at 524.80 m a.sl.

The results of the tests of Upper Atbara and Sitet Spillways Physical Scale Model Studies, which were carried out by Sogreah Company in France, showed that there are specific areas in the upstream and the downstream of dam that need to be protected from erosion by covering them with different types of Riprap .

To avoid potential faller by over toping and erosion, the Embankments, must reach a level above the maximum intended water level for the Initial filling. And ensure that all areas that can be destroyed by the Initial filling are protected.

4.3.2. Concrete Works

There are two large reinforced concrete spillway structures for flood control and passing water to the downstream, one at the Upper Atbara dam and one at the Setit dam. Both spillways are equipped with gated Bottom Outlet Sluices and gated Surface Sluices for a design discharge of 5,100 m^3/s (Upper Atbara Dam spillway) and 9,000 m^3/s (Setit Dam spillway), respectively, at a Maximum High Water Level (MHWL) of 523.30 m a.sl.

The project consists also at the Upper Atbara Dam of a Power Intake and a Power house equipped with 4 Kaplan turbines 80 MW each, the total installed capacity is 320 MW, which will be operated on peaking hours.

Before commencement of the Initial filling stage, all Concrete elements (spillways, intakes, etc...) should be completed to ensure that the full control of Initial filling and release of water.

4.3.3. Hydro-mechanical equipment Works

The Works shall include the engineering, detailed design, manufacturing, shop assembly, testing, anti-corrosive treatment and painting, safely packing, transport to Site, storage, erection, testing and commissioning of the hydro-mechanical equipment as their scope is defined under these Particular Technical Requirements (PTR).

The Scope of the hydro-mechanical Includes equipment and activities as described below:

- Radial Gates (control of upstream water level).
- Steel lining (concrete surfaces protection).
- Penstocks (Water transporter).
- Trash-rack (providing clean water to power house).
- Gantry Cranes (Stop log gates operating).
- Hydraulic Hoist (Radial Gates operating).
- Power Hydraulic & Control (control of operation).
- Earthling system of the Dams (release of electric charges)
- Dewatering system of the Dams (release of leakage and seepage Waters)

Before commencement of the Initial filling stage, all hydro-mechanical elements (Gates, Gantry Cranes, Dewatering system, etc...) should be operational to ensure that the full control of Initial filling and release of water.

Fig. (4.4) shows Example Cross Section of Hydro mechanical Equipment's in upper Atbara Spillway.

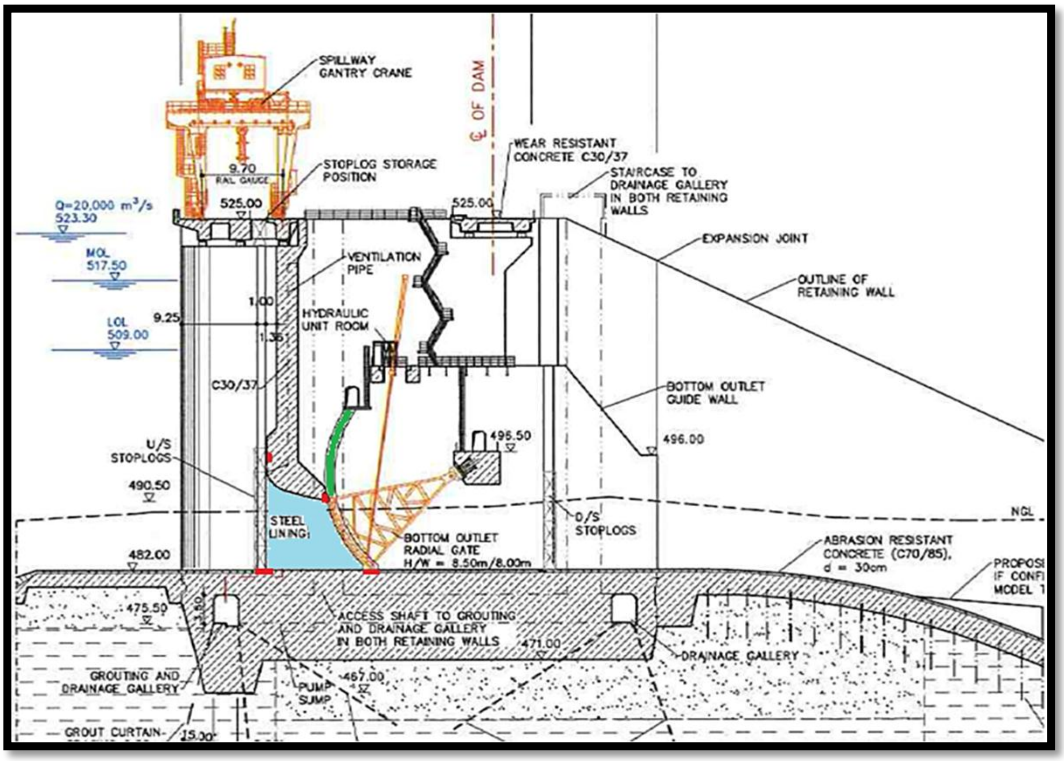


Fig. (4.4) Example Cross Section of Hydro mechanical Equipment's in upper Atbara Spillway

4.3.4. Instrumentation and Monitoring Activities in DCUAP

The main purpose of instrumentation and monitoring is to maintain and improve dam safety by providing information to evaluate whether a dam is performing as expected, and warn of changes that could endanger the safety of a dam.

The principal causes of embankment dam failures and incidents

- Overtopping from inadequate spillway capacity, spillway blockage, or excessive settlement resulting in erosion of the embankment.
- Erosion of embankments from failure of spillways, failure or deformation of outlet conduits causing leakage and piping, and failure of riprap.
- Embankment leakage and piping along outlet conduits, abutment interfaces, contacts with concrete structures, or concentrated piping in the embankment itself.

4.3.4.1. DCUAP instrumentation

4.3.4.1.1. Instrumentation and monitoring devises

Table (4.2) Instrumentation and monitoring devises

	Name of device	Location	Quantity NO	Remarks
1.	**Pore pressure**	**Upper Atbara & Setit Spillways** **Power Intake** **Upper Atbara Irrigation Intake** **Upper Atbara & Setit Embankment**	**312**	
2.	**Magnetic settlement system**	**Upper Atbara & Setit Embankment**	**9**	
3.	**2D Joint meter**	**Power Station**	**12**	
4.	**Extensometer**	**Upper Atbara & Setit Spillways** **Power Intake**	**8**	
5.	**Stand pipe piezometer**	**Upper Atbara & Setit Spillways** **Power Intak** **Upper Atbara & Setit Embankment**	**60**	
6.	**Seepage weir**	**Upper Atbara & Setit Spillways** **Power Intake**	**10**	
7.	**Survey Monument**	**Upper Atbara & Setit Spillways** **Power Intake** **Upper Atbara Irrigation Intake** **Upper Atbara & Setit Embankment**	**191**	
8.	**Levelling Benchmarks**	**Upper Atbara & Setit Spillways** **Power Intake** **Power Station**	**42**	
9.	**Staff Gauges**	**Upper Atbara & Setit Spillways**	**106**	

During this phase performance monitoring activities (visual and instrumented monitoring) are most critical – the dam is being tested for the first time in terms of:

- Seepage resistance
- Structural stability

During this phase instrumentation typically is used for:

- Providing an early indication of unusual or unexpected performance
- Providing confirmation of satisfactory performance
- Providing information and data so that actual performance of the dam (under reservoir load) is better understood

The table below shows the type of devices used in monitoring and their location in the project:

Before commencement of the Initial filling stage, all Instrumentation and monitoring elements (devices, Systems, etc...) should be Installed and operational to ensure that the full control of Initial filling and release of water.

Fig. (4.5) shows Locations of Stand pipe piezometers

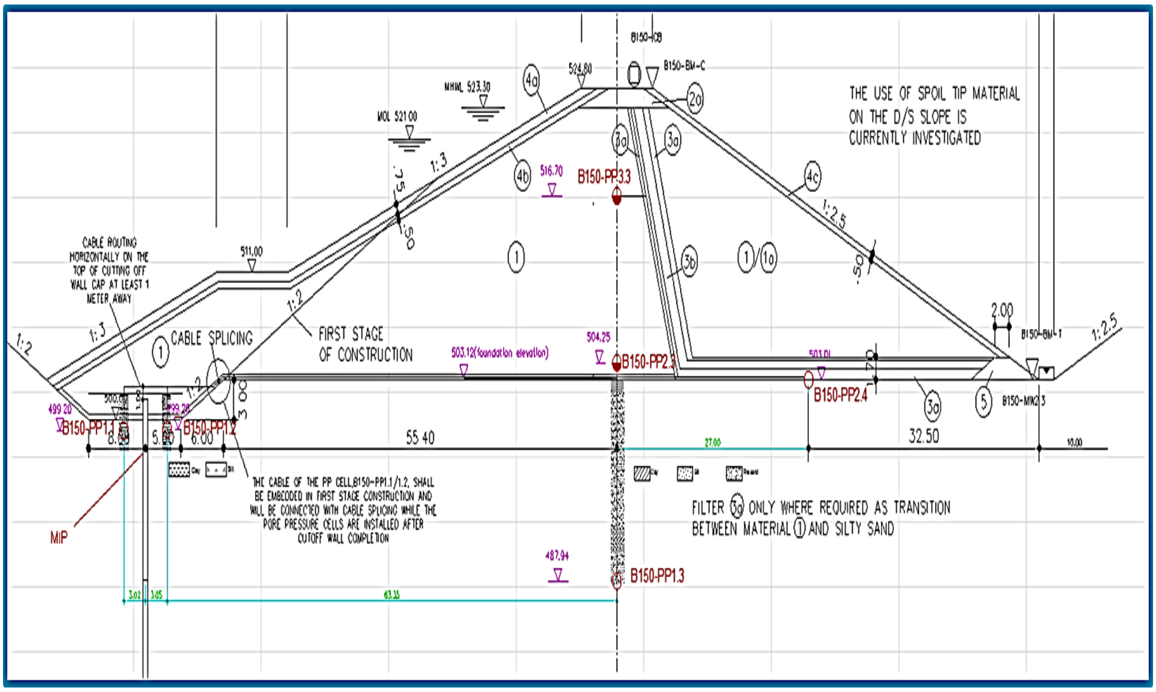


Fig. (4.5) Locations of Stand pipe piezometer

Example Cross Section (B0+150:

Stand pipe piezometers are installed alongside the downstream toe drain to monitor the uplift pressures in the downstream side of the dam.

Fig. (4.6) shows Plot of piezometric pressures at Section B 0+150

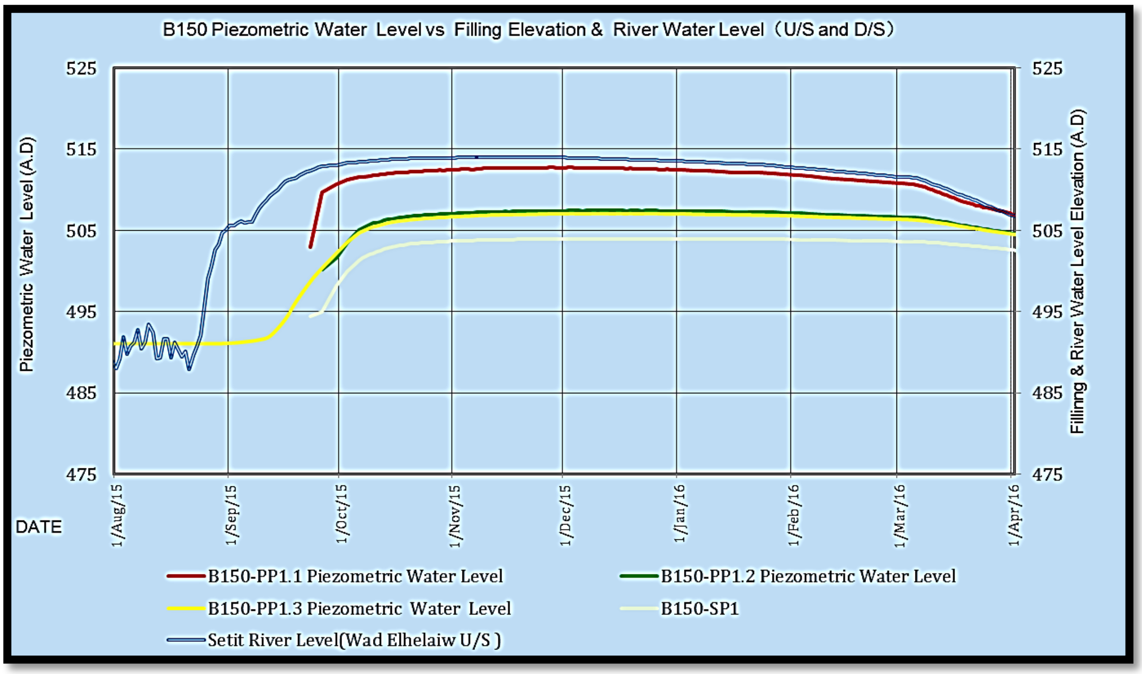


Fig. (4.6) Plot of piezometric pressures at Section B 0+150

4.3.5. Hydrological Works

Based on the previous hydrological studies carried out in the project area, a precise system for hydrological monitoring of Upper Atbara and Setit rivers was designed and implemented before and during the construction phase, the first filling and the normal operation. It is based on the analysis of the hydrological data collected from a network of hydro metrological stations covering the dam area and the reservoir boundary.

4.3.5.1. Hydrological activities

Management of dam and reservoir operating program (filling program, gate opening and closing, monitoring observations .

- Management and execution of hydrological measurements (water level observations, discharge measurements, sedimentation measurements, and weather parameters measurements.
- Following up of the project technical studs and reports (Hydraulics, hydrology).
- Provide specialized technical information to assist of decision making concerning of water resources management in Sudan.
- Following up of the correspondence concerning to the hydrology-department.

- Execution of hydrological method statement during the project construction and operation phases.
- Monitoring of climate change affected to the project
- Following up of the programs of building capacity of hydrologist staff.
- Provide specialized information's to researchers in hydrology field.
- Preparation and distribution of daily bulletin to stakeholders.
- Participation in regional hydrological workshops.
- Execution of theoretical and field works in bathymetric survey and Processing of relevant reports.

4.3.5.2. Hydrological Stations

There are 10 hydrological stations in the project distributed in the form of a network covering all the dam and reservoir boundaries which is arranged in upstream of the dam as shown below:

1. **Elaserah station**: Located on the branch of Atabrawi – upper Atbara River.
2. **Basalam** station: Located on the branch of Basalam- upper atbara river.
3. **El Sufi Bashir** station: Located on the upper atbara river.
4. **Upper Atbara U/S and D/S** station: Located on the upper atbara dam crest.
5. **Rumela station**: Located on the upper atbara river.
6. **Humdayeet station**: Located on setit river.
7. **Wad Elhalhio** station: Located on setit river.
8. **Setit U/S and D/S station**: Located on the setit dam crest.
9. **Shawak station**: Located on the atbara river.
10. **Khashm El Girba** station: Located on the atbara river.

The map below shows the location and distribution of hydrological stations in the project

Fig. (4.7) shows map of the location and distribution of hydrological stations in the project

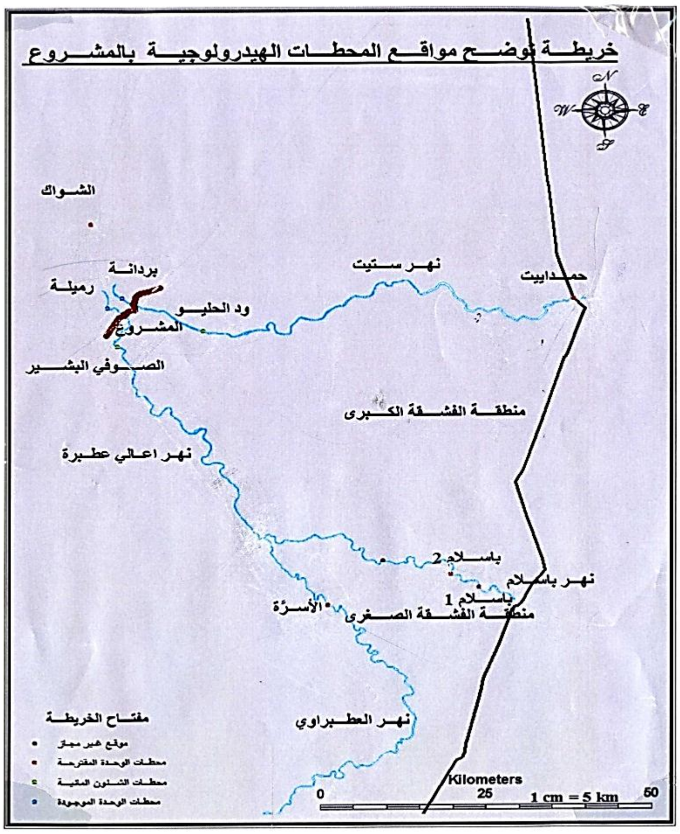


Fig (4.7) map of the location and distribution of hydrological stations in the project

4.3.5.3. Hydrological Measurements

- Water Level Observation
- Discharge Measurement
- Sedimentation Measurement
- Weather Parameters Measurement

4.3.5.3.1. Water level Observations:

Water levels observations are the process by which the recording of water levels at a certain section of the Stream Flow (hydrological station) and it is calculated in units, for example, longitudinal (m).

Monitoring water levels are divided to:

- ✓ Staff Gauges
- ✓ Automatic Gauges

Staff Gauges

Permanent

temporary

Automatic Gauges

Bubbler system

Radar Sensor

4.3.5.3.2. Discharge measurements:

Discharge of water is the volume of water passing at a certain section of the Stream Flow (hydrological station) during a period of the time and it is calculated in units of volumes / units of time, for example, (m3 / s).

Discharge measurements are divided to:

- Current meter Method Measurements
- ADCP Method Measurements (Acoustic Doppler Current Profiler)
- Weirs Method Measurements

Sedimentation measurements are divided to:

Suspending sedimentation: usually measured by concentration by evaporation or filtering.

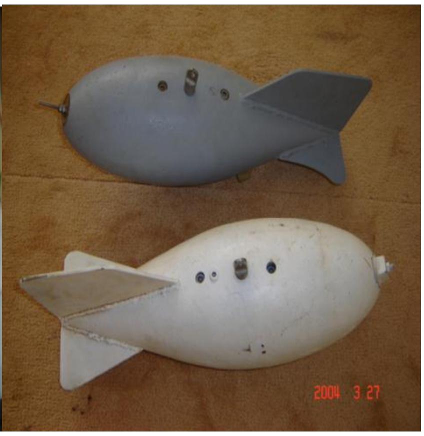
Bed Load Material

Bed Load Transport

Last two types are being to test gradation of silt by analysis using sieves or by using a Hydrometer if the particle size is less than 0.63 micrometers

Sedimentation analysis and sampling

Sedimentation analysis



Bed Load Material (BM54)

Bed Load Transport Sampler

Depth point Sampler (P61)

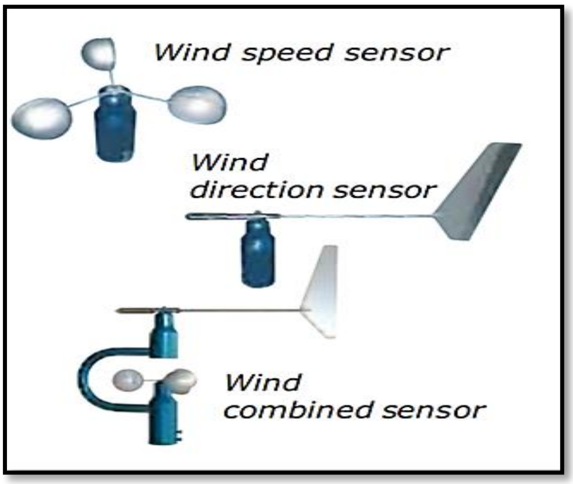
4.3.5.3.3. Meteorology measurements

The currently meaning for this science was known as group of scientific disciplines to study the atmosphere that focuses on weather conditions and weather forecasts.

Weather Parameters which to be measured in DCUAP:

- Air Temperature
- Evaporation
- Rain Fall
- Atmospheric pressure
- Radiation
- Wend Speed &Direction

DCUAP Whether Station



4.3.5.3.4. Bathometric survey:

Bathymetry is the study of underwater depth of reservoirs or ocean & Rivers through depth sounding.

- Early techniques used pre-measured heavy rope or cable lowered over a ship's side.
- Today techniques used Depth Souder &Sonar Devises mounted over a ship's side.

4.4.Engineer (LI) Constrains Related to the Initial Filling Stage

For the safety of the dam the engineer (LI) has identified certain conditions to be observed as described below:

- Rising Rate of Reservoir Water Levels
- Erosion of Connection Chanel Inlet/ Outlet Areas
- Spillways Gate Opening

4.4.1. Rising Rate of Reservoir Water Levels

For dam safety The Engineer recommends Water level rising rates not significantly higher than 1m/day for Water levels lower than 500 masl, not more than 0.4 m/day for Water levels between 500 and 507masl, and in the following to limit the water rising rate to 0.2m/day for Water levels above 507masl< above 513 m ASL the filling rates shall be limited to 10-20 cm The lower rising rates are recommended in order to avoid too fast loading of the dam particularly during the Initial Filling.

4.4.2. Erosion of Connection Chanel Inlet/ Outlet Areas

The IFP presumes a transfer of water from Setit to upper Atbara reservoir of about78m3/s through the connection channel to avoid erosion, and it is better to have water levels in the two lakes of 507mASLat the same time.

4.4.3. Spillways Gate Opening

The Engineer does not recommend maintaining gates opening heights significantly less than 5%(42.5cm) for longer time, as damages of the sealing, the fixing ,the radial gate itself and of the near concrete may be the consequence due to the very high flow velocities and there for possibly occurring cavitation.

Here under only describes the hydro-mechanical equipment and associated auxiliaries to be designed and installed for the upper spillway.

4.5. Initial Filling Stage Plan

Introduction

DCUAP had been planned to start the initial impounding in the flood season (2014). However, due to some constraints the construction progress of the project was delayed, consequently the impounding also delayed. The impounding took place between (15Augest 2015 to 15October 2015) with final elevation of 521.00 m ASL.

However, DCUAP is part of the national water resources management system; and due to unexpected demand (for power generation) in Merowe Dam reservoir the DCUAP initial impounding is stops at level 514.00 m ASL. And Inflow was released in order to satisfy the demand.

However, due to unachieved goals last season, this new filling plan is initiated for season 2015 and considers among others:

- The plan considers 50% to 20% probability of inflow non exceedance, as explained in SOSADC report. This means early start of filling would be on Aug 16th 2015 and the late on Aug 28th 2015.

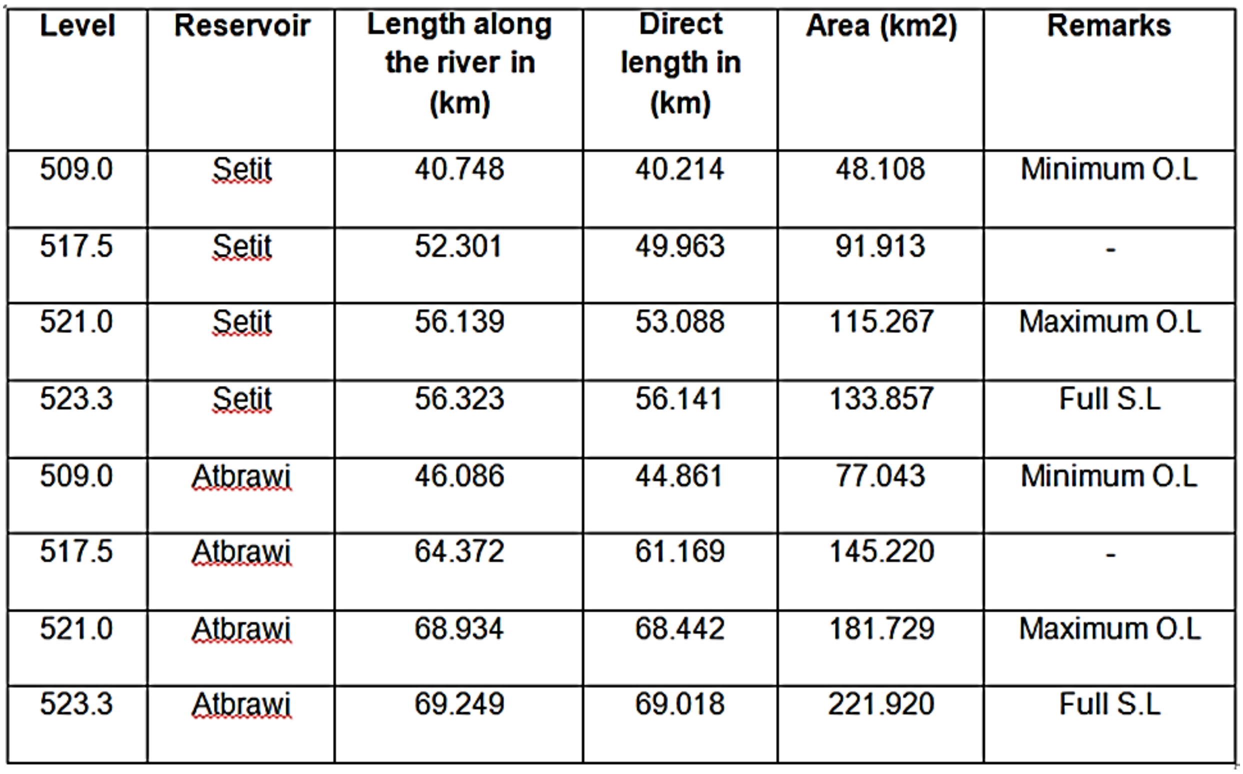
- Suitable filling rate implemented is according to SOSADC report, LI, the experience gained from the last filling and expert opinions.
- Upper Atbara and Setit reservoirs shall reach elevation 507 m ASL at the same time.
- The triggers of the filling start, between 16~28 August, shall be the inflow magnitude and the sediment concentration.
- Chapter 7 and 8 of SOSADC report shall be considered as the base to this plan.
- The following information will explain the methodology and data used to generate a new IFP for 2015 flood season.

4.5.1. General information

Upper Atbara Reservoir length will reach up to 69 km upstream the dam at elevation 521 m ASL, while Setit reservoir length is around 56 km upstream the dam as explained in the below tables. The combined reservoir surface area is around 300 km2.

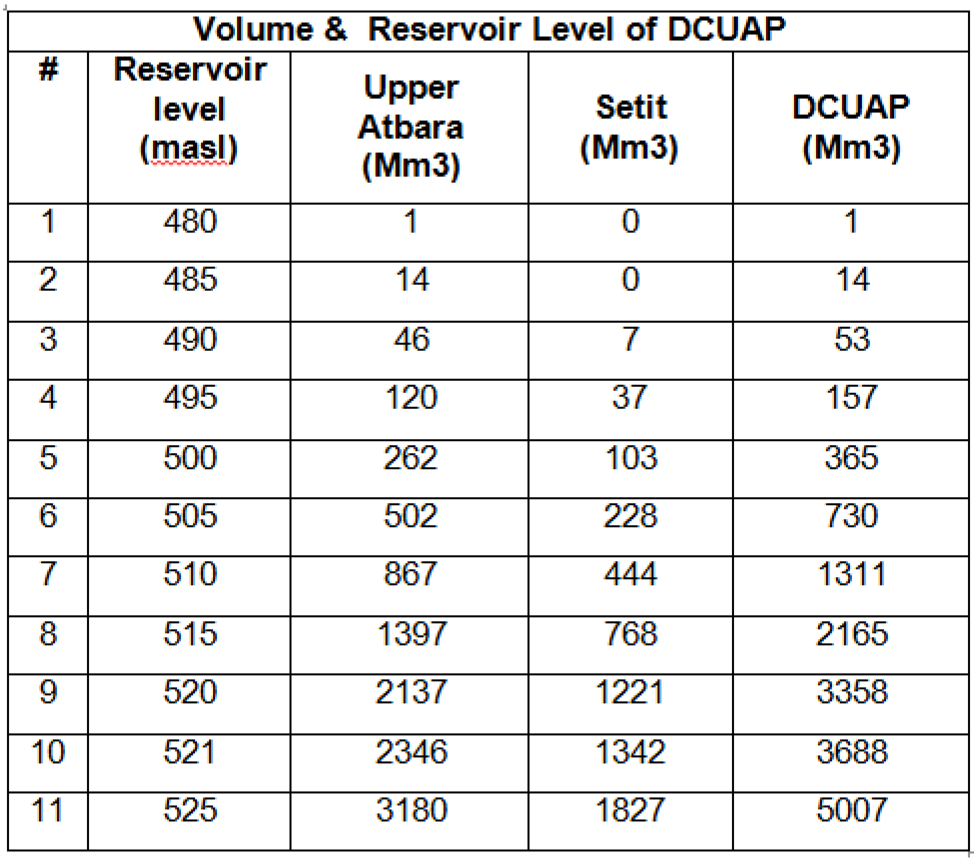
The total combined reservoir volume is 3.688 billion m3. However, almost two third of the total capacity is stored in Upper Atbara reservoir.

Table (4.3) Upper Atbara & Setit Reservoirs Characteristics



Level	Reservoir	Length along the river in (km)	Direct length in (km)	Area (km2)	Remarks
509.0	Setit	40.748	40.214	48.108	Minimum O.L
517.5	Setit	52.301	49.963	91.913	-
521.0	Setit	56.139	53.088	115.267	Maximum O.L
523.3	Setit	56.323	56.141	133.857	Full S.L
509.0	Atbrawi	46.086	44.861	77.043	Minimum O.L
517.5	Atbrawi	64.372	61.169	145.220	-
521.0	Atbrawi	68.934	68.442	181.729	Maximum O.L
523.3	Atbrawi	69.249	69.018	221.920	Full S.L

Table (4.4) Upper Atbara & setit Reservoirs Levels &Volumes



Volume & Reservoir Level of DCUAP				
#	**Reservoir level (masl)**	**Upper Atbara (Mm3)**	**Setit (Mm3)**	**DCUAP (Mm3)**
1	480	1	0	1
2	485	14	0	14
3	490	46	7	53
4	495	120	37	157
5	500	262	103	365
6	505	502	228	730
7	510	867	444	1311
8	515	1397	768	2165
9	520	2137	1221	3358
10	521	2346	1342	3688
11	525	3180	1827	5007

4.5.2. Monitoring Routine

In general, two types of measurements are done: regular water level readings and less frequent

Discharge measurements by current meter from a cableway for the open river sites. ADCP measurements were practiced at the new sites of Setit and Upper Atbara Dams. The water levels readings are translated into discharges with help of stage-discharge relations (rating

Curves) that are derived from the current meter/ADCP measurements. The river is morphologically very active and for the sites upstream of the KED, the river bed is rising continuously. This means that the rating curves need to be updated regularly and this is in principle done annually.

The water level is measured by staff gauge (marbles gauges), attached to masonry bricks. Frequency of reading varies seasonally and per location. Usually readings are made 3 times a day - at 6:00 am, 12:00

pm and 6:00 pm - and more frequently (up to hourly) during flood season. In general observers' readings are good, except in few locations where it is found

That reading is erroneous.

Additional automatic water level gauging stations have been installed at Setit and Upper Atbara Dam which monitor water levels on an hourly basis.

4.5.3. Sediment Data

The suspended sediment concentration is sampled on daily basis at most of the sediment monitoring stations during the flood season from July to October. The collected samples are analyzed at the laboratory to determine the sediment concentration which is expressed in grams of sediment per liter of water, or in part per million (ppm) by weight.

4.5.4. Advanced software

Advanced software's described below are used in the Sedimentation and Operation Study for Atbara Dam Complex (SOSADC) which was done by Deltares, which are the basis of this initial Filling plan.

Delft3D

It is a multidisciplinary simulation program for rivers, lakes and estuaries. The program simulates the nature of water in terms of flow, quality, sediment transport as well as morphological changes.

RIBASIM

Is a modeling program to analyze the behavior of river basins under different hydrological conditions? It is a comprehensive and flexible tool that links hydrological water inputs in different locations and identifies water users in the basin. The program used to assess a variety of measures related to infrastructure and management of processes, demand and results in terms of water quantity and water quality.

4.5.5. Purposes of IFP

This plan aims to:

- Initial filling is to test Dam efficiency and structure stability.
- Impounding with lowest sedimentation rates.
- Power generation.

4.5.6. Boundaries and Constraints

4.5.6.1. Inflow to the reservoir

The inflow data used are the time series of the discharge from 2010 to 2014, because the flow pattern changes after TK5 starts operation in 2010. The following graphs show the discharge inflow of the above mentioned 5 years.

Table (4.5) Upper Atbara & setit inflows 1981/1982

Year :1981/1982			
month/year	Burdana Inflow [Mm^3/month]	Rumela Inflow [Mm^3/month]	Total Inflow [Mm^3/month]
1-Jul	701	1136	1837
1-Aug	2459	2071	4530
1-Sep	535	1687	2222
1-Oct	1052	420	1472
1-Nov	282	58	340
1-Dec	287	24	311
1-Jan	291	12	303
1-Feb	261	7	268
1-Mar	299	0	299
1-Apr	296	0	296
1-May	303	0	303
30-Jun	264	52	316
Total/year	7030	5468	12498

Figure (4.8) explains the form of discharge time series at Rumela station

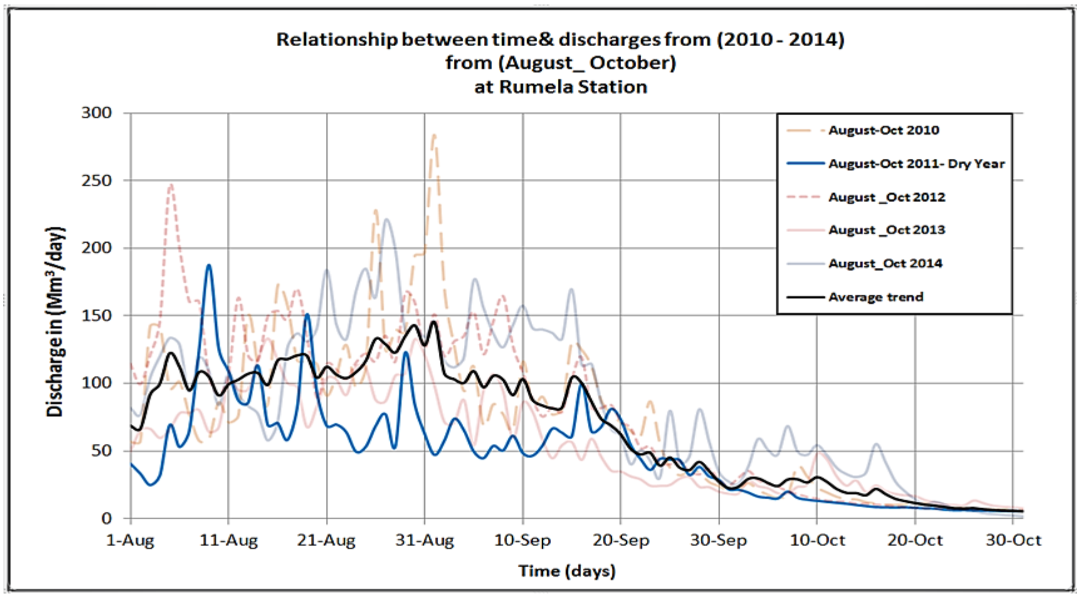


Figure (4.8) discharge time series at Rumela

Figure (4.9) explains the form of discharge time series at Burdana station

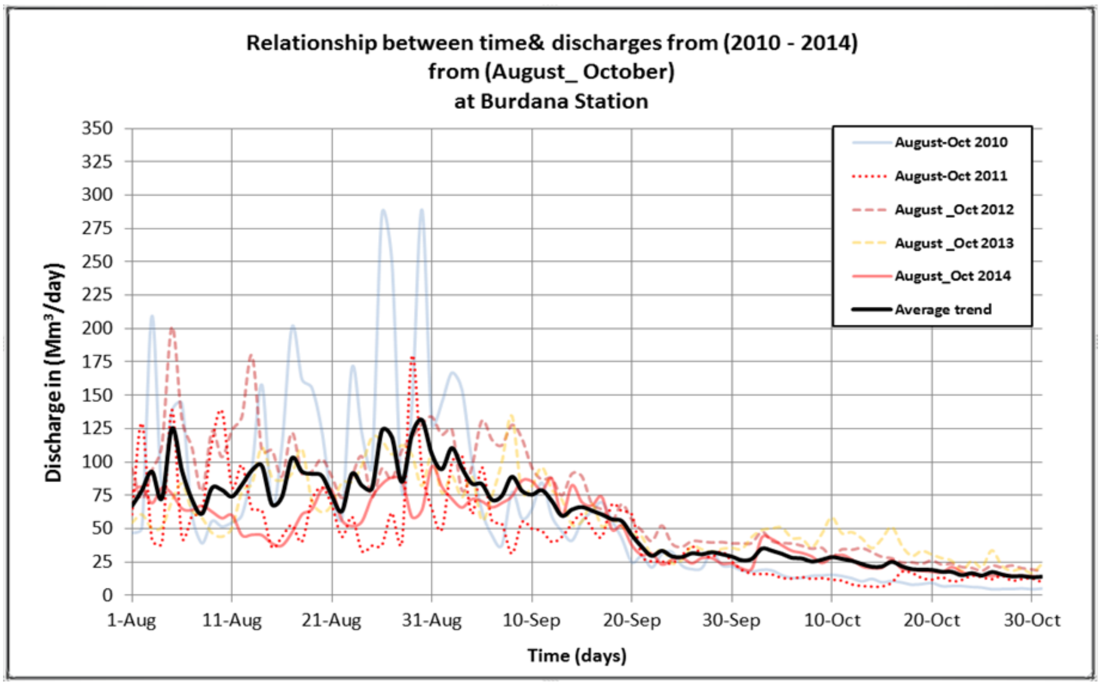


Figure (4.9) discharge time series at Burdana station

The figures above show the average or normal year with black line. This black line obtained by averaging the inflow of the five years (2010~2014). The inflow of 2011 is selected to represent the dry year as it is the minimum year flow measured after TK5.

4.5.6.2. Sediments concentration

The suspended sediment concentration is sampled twice to three times a week at most of the sediment monitoring stations. The collected samples are analyzed at the laboratory to determine the sediment concentration which is expressed in grams of sediment per liter of water, or in part per million (ppm) by weight.

In Sudan the one of the triggers to start reservoir filling to have water with sediment concentrations between 2-4 g/l and that would be one of the governing triggers to decide the filling starting date. The flowing graphs used to understand the magnitude of suspended sediment concentration.

Figure (4.10) explains the form of suspended sediment concentration of Setit River measured at Burdana Station

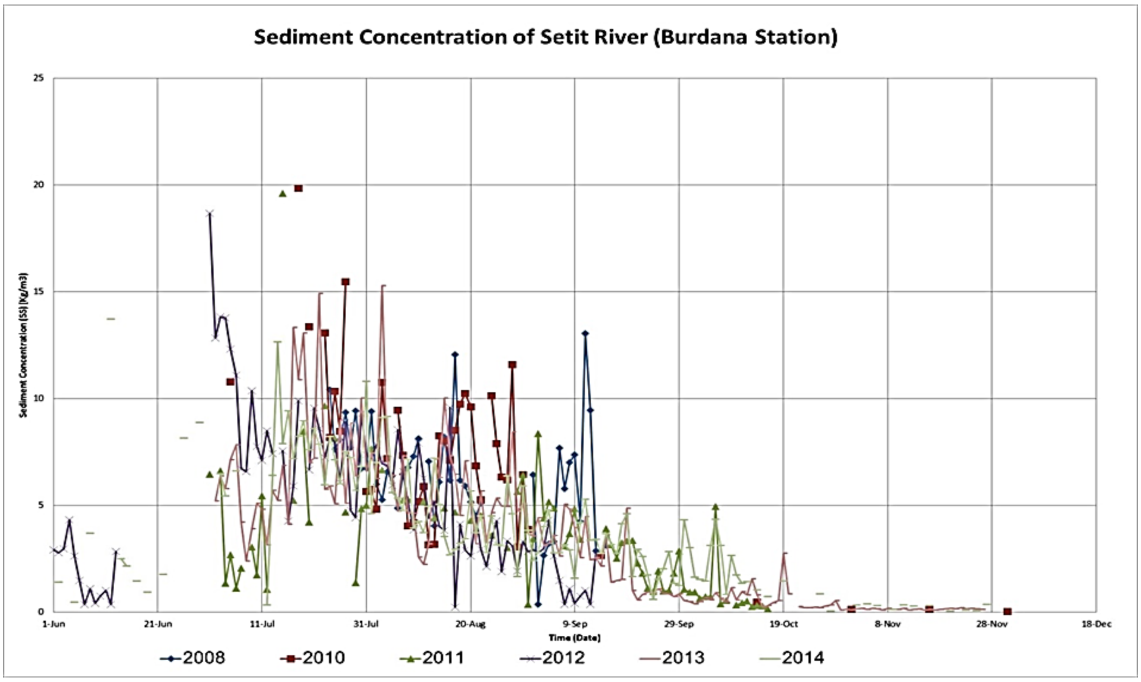


Figure (4.10) the suspended sediment concentration of Setit River measured at Burdana Station

Figure (4.11) explains the form of the suspended sediment concentration of Upper Atbara River measured at Rumela Station for the last5years

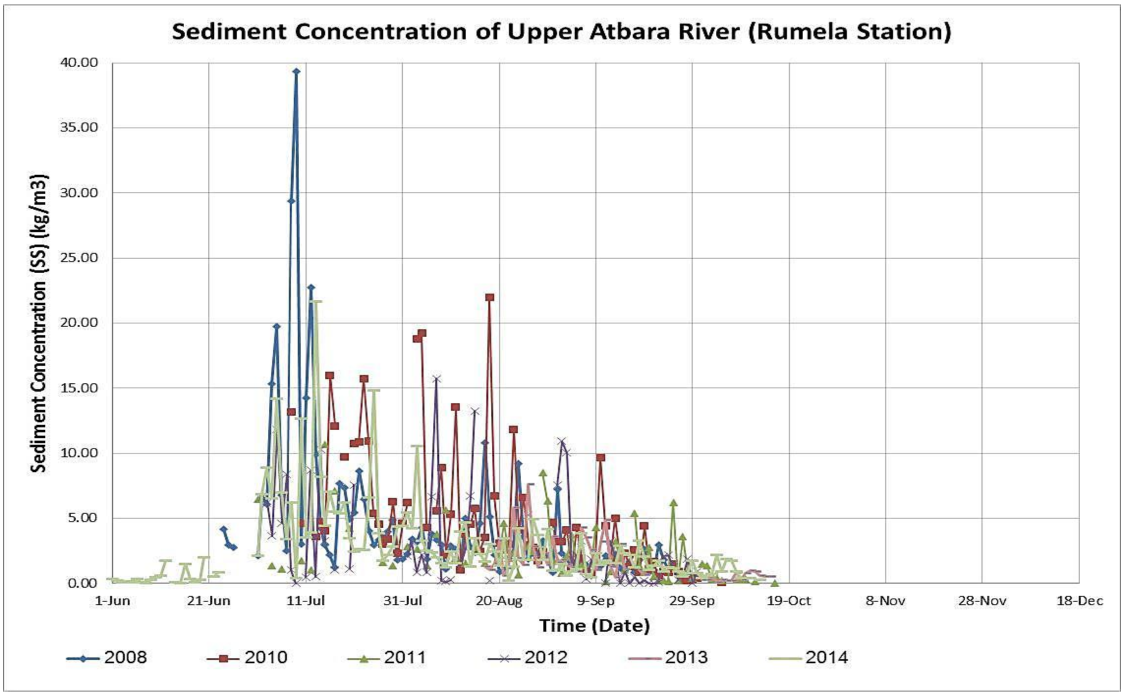


Figure (4.11) suspended sediment concentration of Upper Atbara River measured at Rumela Station for the last5years

It is clear that the peak of suspended sediment concentration in July, while the concentration after 16 August would be, mostly, less than 10 g/l and after 28 Aug around 5 g/l and less.

4.5.6.3. Rate of filling

Dam has to be operated in a way that the structural stability is ensured; therefore the rate of water level rise, suggested to meet IFP purposes, has to be chosen carefully.

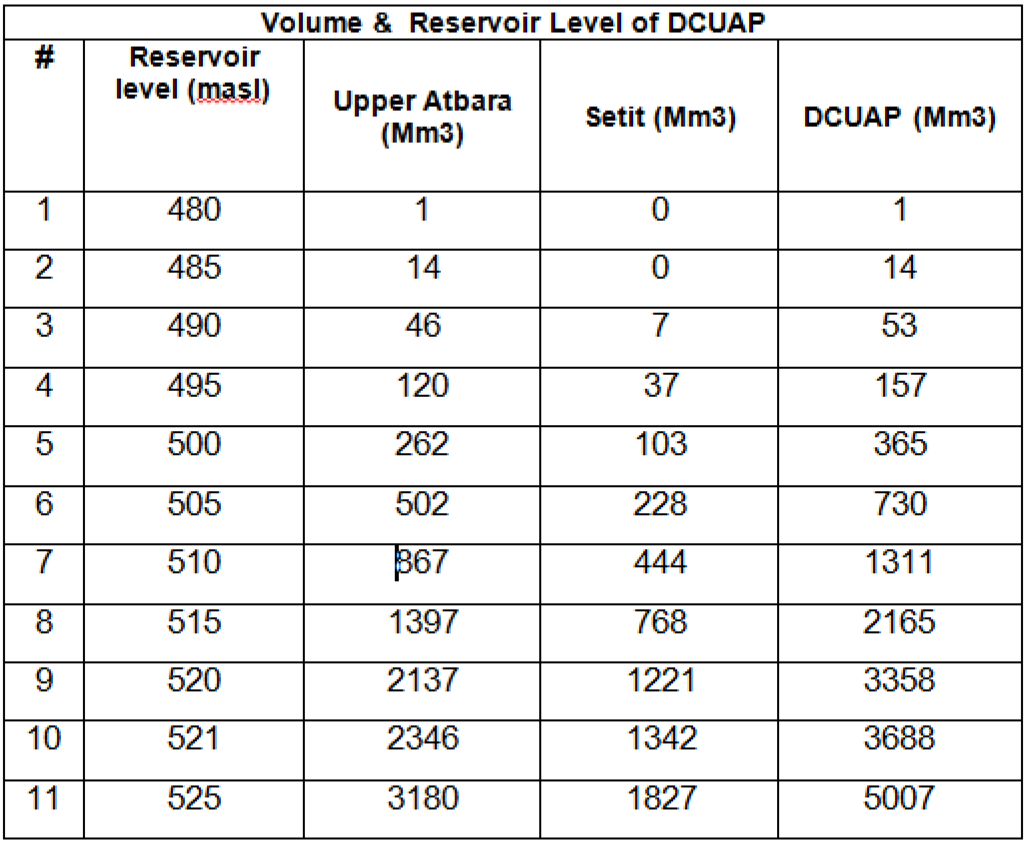
According to **Prof. Pedro Pinto** (Former president of International society for soil mechanics and geotechnical engineering) a rate of 1.5 m/d can be applied to fill reservoir till maximum elevation if dam is well constructed, and from observations of this year previous impounding where a rate of 3 m/d was applied at the beginning of filling unintentionally and nil negative impact on dam stability is observed, consequently rates of filling proposed for this IFP are as follows:

- 1.5 m/d for water levels < 495.70 m ASL
- 1.0 m/d for levels < 507.00 m ASL.
- < 1 m for levels above 507 m ASL depend on the water availability.

4.5.6.4. Reservoir storage

Relation between Elevation and volume is used to calculate quantity of water required to raise the water level, the following table shows that.

Table (4.6) DCUAP Reservoir volume-level relations



Volume & Reservoir Level of DCUAP				
#	Reservoir level (masl)	Upper Atbara (Mm3)	Setit (Mm3)	DCUAP (Mm3)
1	480	1	0	1
2	485	14	0	14
3	490	46	7	53
4	495	120	37	157
5	500	262	103	365
6	505	502	228	730
7	510	867	444	1311
8	515	1397	768	2165
9	520	2137	1221	3358
10	521	2346	1342	3688
11	525	3180	1827	5007

(LI-POE _ complementary presentation)

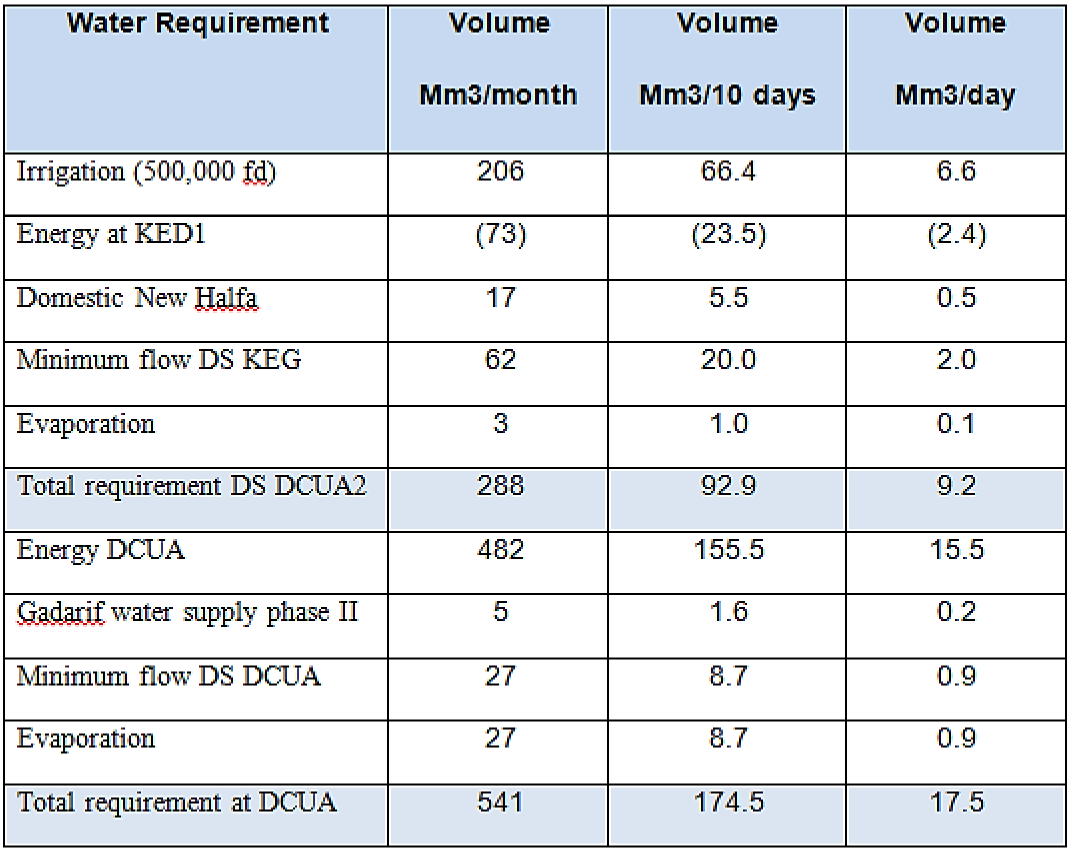
4.5.6.5. Connection channel

As long as a significant differential head of the two Reservoirs prevails, an erosion process is expected to occur at Connection Channel Inlet / Outlet areas, so it's not recommended, by the designer transferring water in speeds higher than 3.5 m/s through the CC. In this Filling plan the water level is expected to be upraised slowly between elevation 506 ~507 m ASL to minimize level variation.

4.5.6.6. Downstream Demand

According to SOSADC report, the downstream demand is calculated to be around 9.2 Mm3/day, in addition to the evaporation in DCUA reservoir as shown in the following table.

Table (4.7) the water requirement of DCUA reservoir, as shown in chapter 7 of SOSADC report



Water Requirement	Volume Mm3/month	Volume Mm3/10 days	Volume Mm3/day
Irrigation (500,000 fd)	206	66.4	6.6
Energy at KED[1]	(73)	(23.5)	(2.4)
Domestic New Halfa	17	5.5	0.5
Minimum flow DS KEG	62	20.0	2.0
Evaporation	3	1.0	0.1
Total requirement DS DCUA[2]	288	92.9	9.2
Energy DCUA	482	155.5	15.5
Gadarif water supply phase II	5	1.6	0.2
Minimum flow DS DCUA	27	8.7	0.9
Evaporation	27	8.7	0.9
Total requirement at DCUA	541	174.5	17.5

[1] satisfied automatically by providing the irrigation

[2] excluding energy generation at KED

In this plan the minimum downstream demand is considered to be 10 Mm3/day.

4.5.7. Methodology

The following are the steps executed to generate this impounding plan:

The daily measured time series of inflow at Burdana & Rumela measuring stations had been used, we focused only on measured data after TK5 starts operation (2010, 2011, 2012, 2013 and 2014).

The statistical analysis erected on discharge measurements shows that 2011 data is representing a dry year (worst case), for the normal year the averaged inflow of the 5 years had been used.

It is considered that during the initial filling, the reservoir might be filled up to the maximum operation level (521 m ASL).

The filling calculation is based on:

$$\frac{\Delta \mathrm{H}}{\Delta \mathrm{T}} = \Delta \mathrm{S} = \mathrm{Qin} - \mathrm{Qout} - \mathrm{E}$$

ΔH: Change in Water Level

ΔT: Change in Time

ΔS: Change in Storage

Qin: Inflow Discharge

Qout : Outflow Discharge

E: total Losses (Evaporation)

The start of the filling is intended to be as late as possible in order to minimize the sedimentation in the reservoir. The later filling starts that means lower sediment load in the reservoir, but at the same time early filling date is required to make sure that we may reach the maximum operation level in the reservoir at the end of the flood season.

The required storage volume is determined by the water requirements for irrigation, urban water supply, environmental flow and hydropower which are considered as the lowest priority water user in this filling.

Various rates of filling are used to ensure the dam safety and to calculate the increase in water level and water content in the reservoir and to determine the period required to achieve targeted level.

4.5.8. Initial filling scenarios plan

Many scenarios are executed according to the following table. However, the exact date of start filling may depend on the magnitude of inflow and inflow sediment concentration

Table (4.8) the initial filling scenarios plan

Senario No.	The inflow time series	Starting date
S1	2011 (Dry year)	16Aug
S2		28Aug
S3	Average of 2010 to 2014 (Normal year)	16Aug
S4		28Aug

Figure (4.12) explains the initial filling plan of scenario (S1) (Dry year _16 Aug)

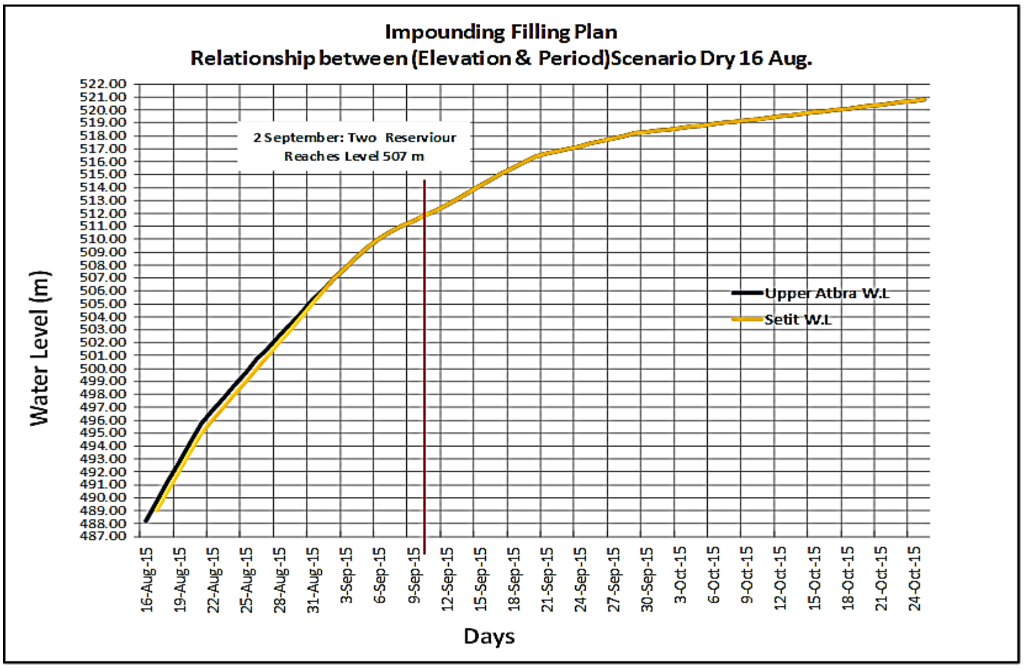


Figure (4.12) IFP of (S1) (Dry year _16 Aug)

In this scenario the reservoir may reach the maximum operation level, if we use the following rate of filling:

Figure (4.13) explains the following rate of filling of **(S1)**

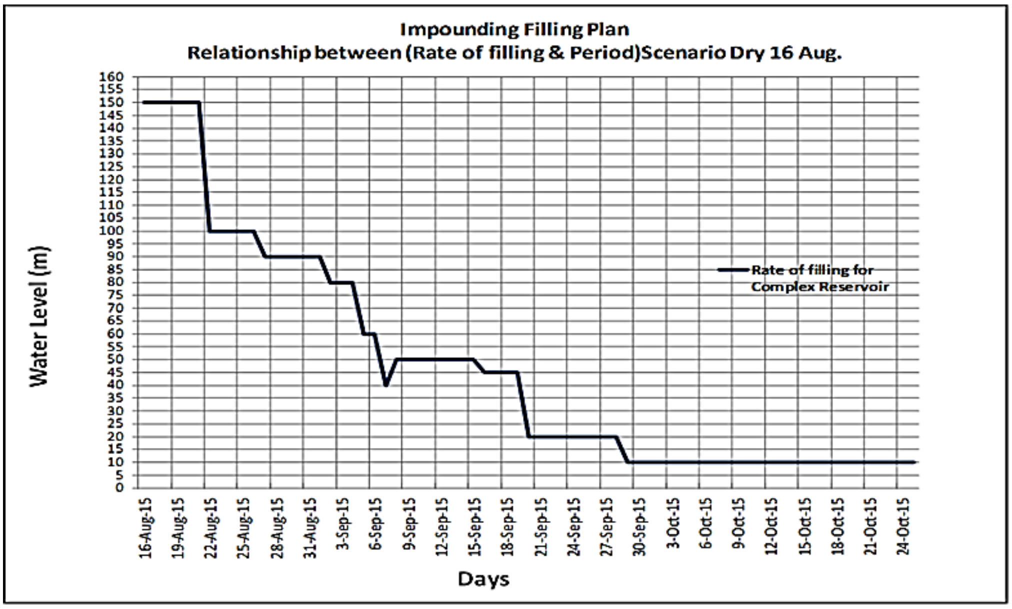


Figure (4.13) rate of filling of (S1)

Figure (4.14) explains the initial filling plan of scenario (S2) (Dry year _28 Aug)

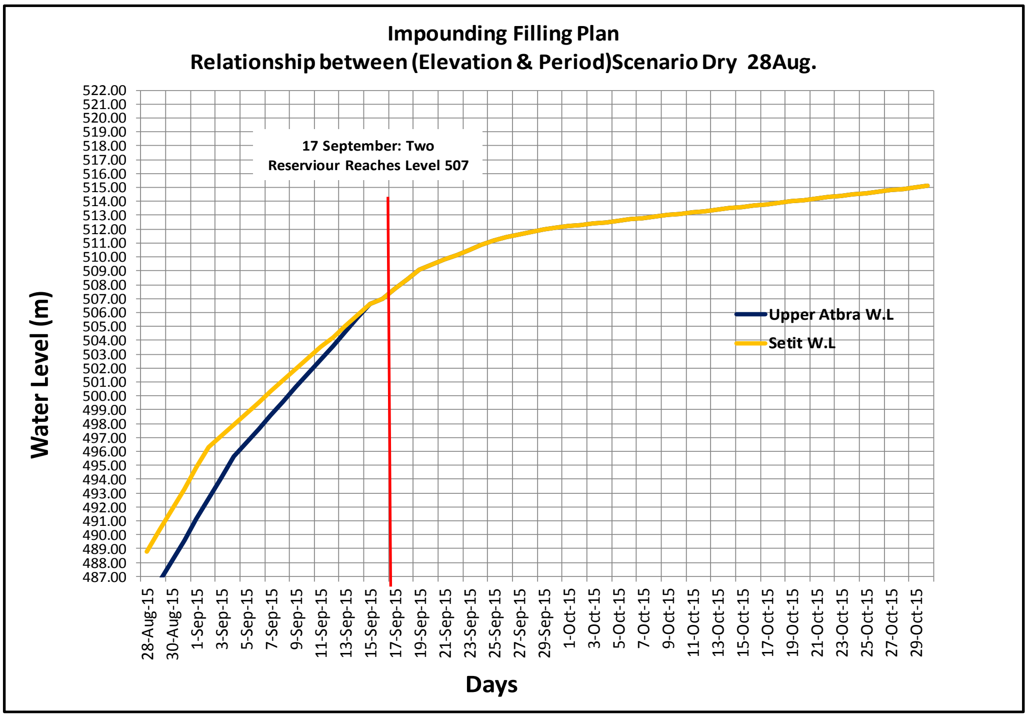


Figure (4.14) IFP of (S2) (Dry year _28 Aug)

In this scenario the reservoir may reach the **515.10m** level, if we use the following rates of filling to fill the reservoir.

Figure (4.15) explains the following rate of filling of **(S2)**

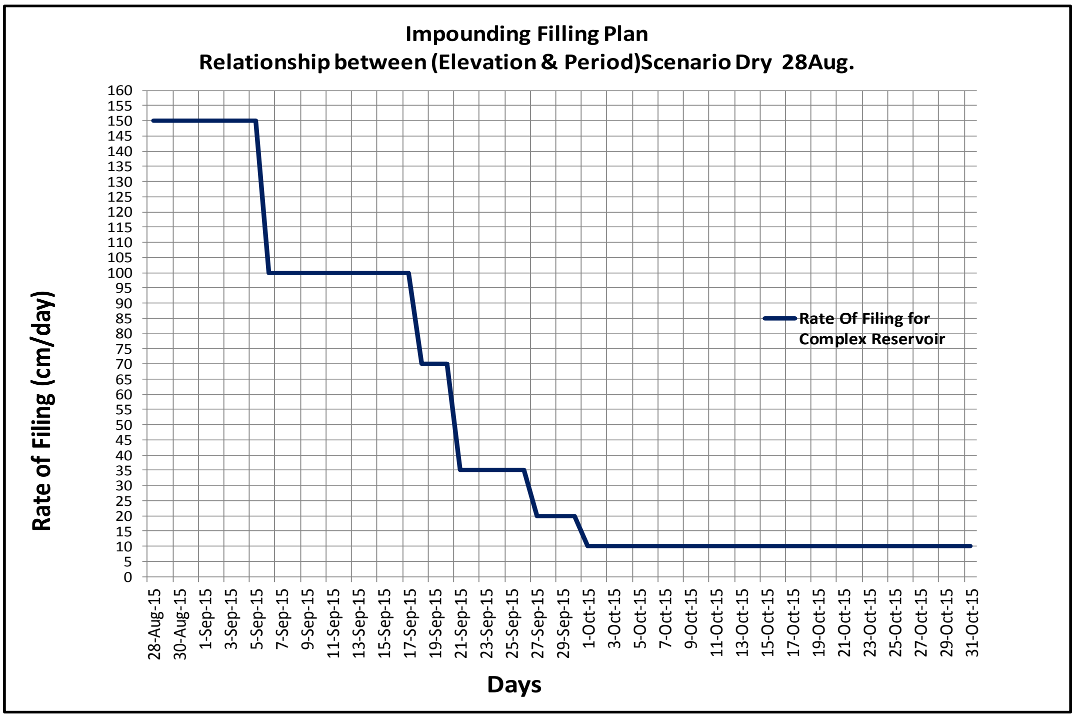


Figure (4.15) rate of filling of (S2)

Figure (4.16) explains the initial filling plan of scenario (S3) (Normal year _16Aug)

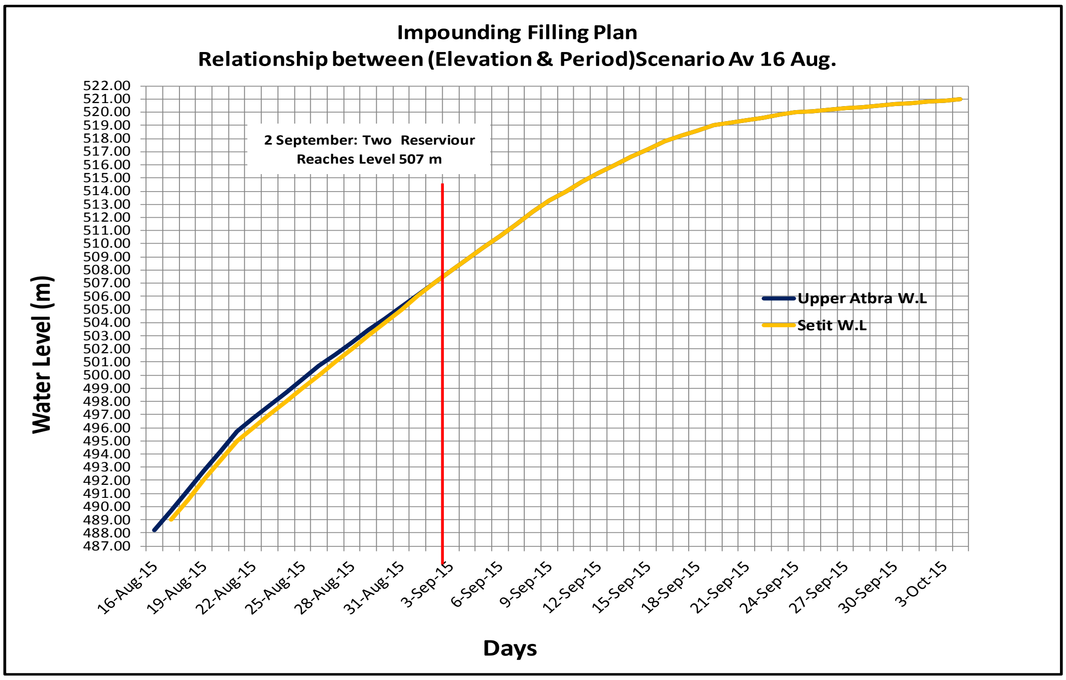


Figure (4.16) IFP of (S3) (Normal year _16Aug)

In this scenario the reservoir may reach the maximum operation level, if we use the following rates of filling to fill the reservoir.

Figure (4.17) explains the following rate of filling of **(S3)**

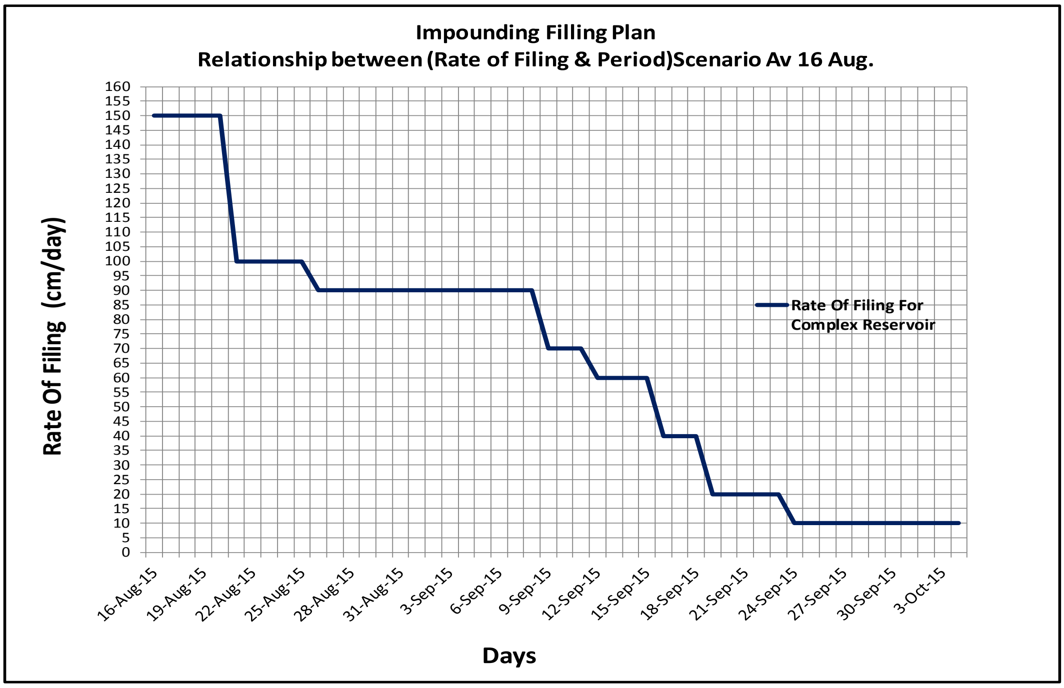


Figure (4.17) rate of filling of (S3)

Figure (4.18) explains the initial filling plan of scenario (S4) (Normal year _28Aug)

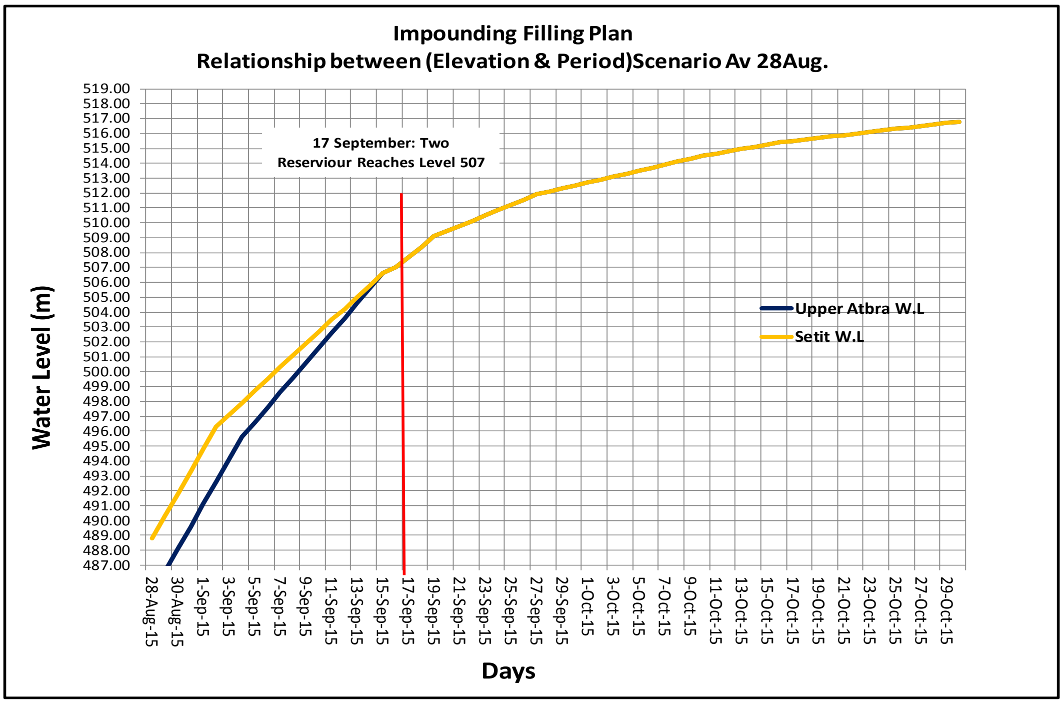


Figure (4.18) IFP of (S3) (Normal year _28 Aug)

In this scenario the reservoir may reach the **516.80** m level, if we use the following rates of filling to fill the reservoir.

Figure (4.19) explains the following rate of filling of **(S4)**

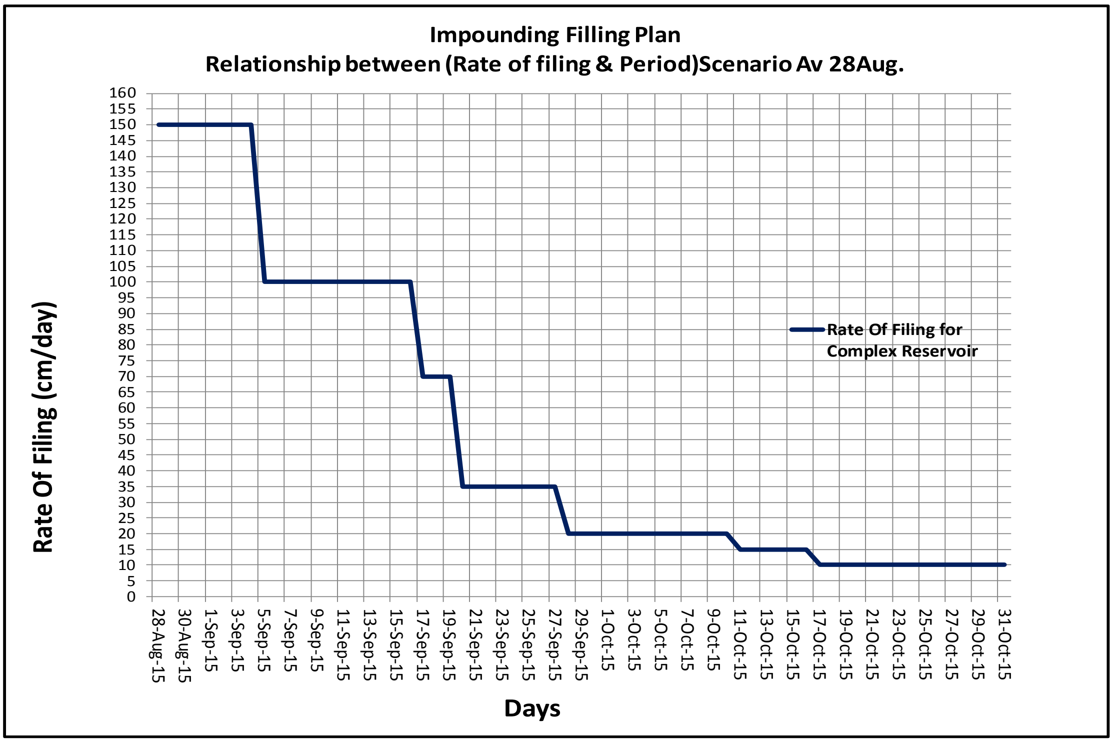


Figure (4.19) rate of filling of (S4)

Table (4.9) the released water from DCUA reservoir for every Scenario, considering the deduction of a daily 10 Mm3 for the downstream demand of both cascading dams

#	The Released Water between 16 – 25 August (Mm3)	The Released Water between 25Aug -30 Sep (Mm3)	The Release Water between - 28 Aug- 30 Sep (Mm3)
S1	954.59	1296	
S2			1864.82
S3	1632.61	2235.2	
S4			3078.81

As shown in the above table the following could be concluded:

- Amount of water expected to be released from DCUA in the period of 16-25 August (954.59 Mm3) is More than 103 Mm3 (the storage required in KH reservoir to reach 467 m ASL). This means the flushing is doable to be planned and coordinated in the same time if the filling of DCUA reservoir started between 16 to 25

Aug. However, it may be more positive if the flushing of KH reservoir executed before the start of filling of DCUA reservoir.

- The normal filling of the KH reservoir might also start as normal (the lowest calculated release is 1296 Mm3), however it may takes longer time than before to reach the maximum level. This may not be an issue as the downstream demand of KH Dam is already fulfilled.

This plan together with the physical models results of the spillways and the experience during the previous filling shall be used to calculate gates closing and opening considering the four scenarios to ensure the rate of filling and the releases according to the inflow

4.5.9. Classification of hydrological year 2015 (flood season 2015)

- After the analysis of the upper Atbara and setit rivers inflows, the hydrological year 2015 was classified as a dry year.
- The decision was made to follow Scenario S1: (Dry year_ 16Aug)
- For impounding.

4.6.Evaluation of the Initial Filling Stage for Dam Complex of Upper Atbara Reservoir (DCUAP R)

Scenario **S1: (Dry year_ 16Aug)**:

Satisfy all Initial Filling plan (IFPT) targets; hence Impounding is to be Started on 16.08.2015 with acceptable rate of filling of dry year, to reach final elevation of 521.00 (m.a.s.l) for both reservoir.

Figure (4.20) explains the Initial Filing Planned and Actual / Relationship between Elevatio& period / scenario 16 August / dry Year

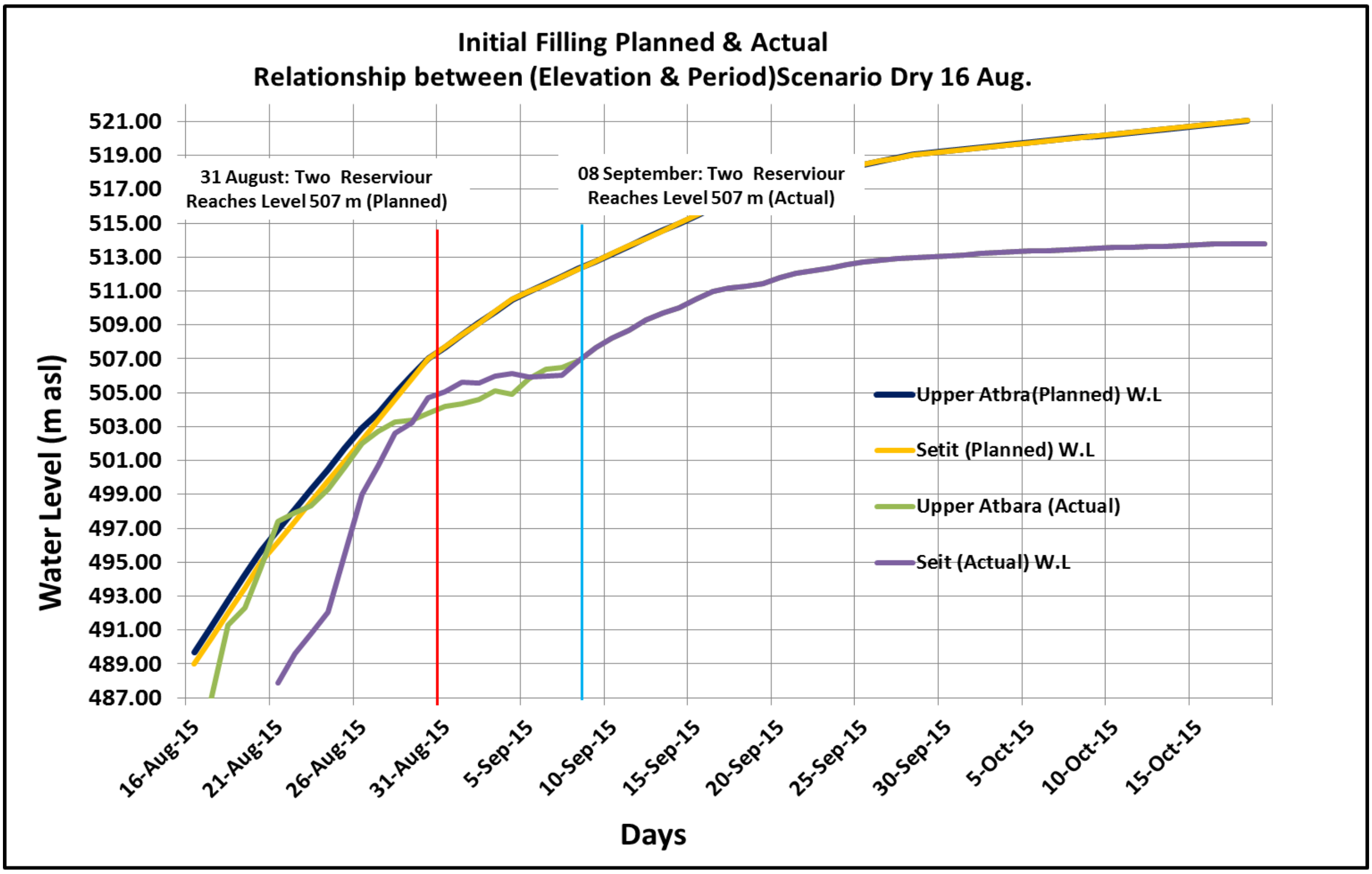


Figure (4.20) Initial Filing Planned and Actual / Relationship between Elevation& period / scenario 16 August / dry Year

4.6.1. Discussion and analysis

4.6.1.1. Start Impounding and Rising Rate of Reservoir Water Levels

Impounding Started in upper Atbara reservoir on 16/08/2015From level 485.80 mASL&in Setit reservoir on 21/08/2017 from level 487.90 masl, and both of the two reservoirs reached level 507mASL(the compound reservoir Water level) on 08/09/2015.

Water level rising rates not significantly higher than 1 m/day for Water levels lower than 500 masl, not more than 0.4 m/day for Water levels between 500 and 507masl, and in the following to limit the water rising rate to 0.2m/day for Water levels above 507masl< above 513 mASLthe filling rates shall be limited to 10-20 cm.

Comparison between the filling and the Engineer recommendation:

- The beginning of Impounding in Upper Atbara reservoir was according to the planned date (16/08/2015), but the beginning of Impounding in Setit reservoir was delayed 5 days from the planned Les. The delayed coms from the sediment concentrations of Setit River did not relate to the acceptable impounding concentration, which is equivalent to the rate between 2-4 g/l Therefore; storage was delayed due to fear of siltation and accumulation of this sludge in the reservoir, which reduces the capacity of the reservoir at the long term. Impounding started on 21/08/2015 after the sediments concentrations reached the planned rats

- Both of the two reservoirs reached level 507mASLthe compound reservoir Water level on 08/09/2015 with a delay of 8 days for the plan, Because Setit reservoir impounding was delayed 5 days already.

- The impounding program followed the engineer recommendation regarding to the water level rising rates.

In this aspect, the researcher believes that the Actual situation before filling with in the acceptable rang, and the plan achieved the target and followed the Engineer (LI) recommendations.

Table (4.10) the Initial Filling Stage Actual upstream water level

Initial Filling Stage Actual U/S WL for Dam				
Date	UA U/S W.L	SE U/S W.L	Res. W.L	Res. Con
			(masl)	(Mm3)
16-Aug-15	485.80	489.30	-	24.22
17-Aug-15	486.90	491.20	-	38.46
18-Aug-15	491.30	490.50	-	76.18
19-Aug-15	492.30	489.40	-	88.70
20-Aug-15	494.70	490.12	-	127.86
21-Aug-15	497.40	487.90	-	201.83
22-Aug-15	497.90	489.60	-	219.00
4-Sep-15	504.91	506.11	-	766.08
5-Sep-15	505.80	505.93	-	819.69
6-Sep-15	506.37	506.00	-	861.91
7-Sep-15	506.49	506.05		872.08
8-Sep-15	507.00	507.00	507.00	921.93
9-Sep-15	507.66	507.66	507.66	1007.45
30-Sep-15	513.04	513.04	513.04	1832.35
9-Oct-15	513.50	513.50	513.50	1909.81
7-Nov-15	513.98	513.98	513.98	1990.68
8-Nov-15	514.00	514.00	514.00	1993.47

Figure (4.21) explains the Relationship between Elevation& Volume from Level (485-514)

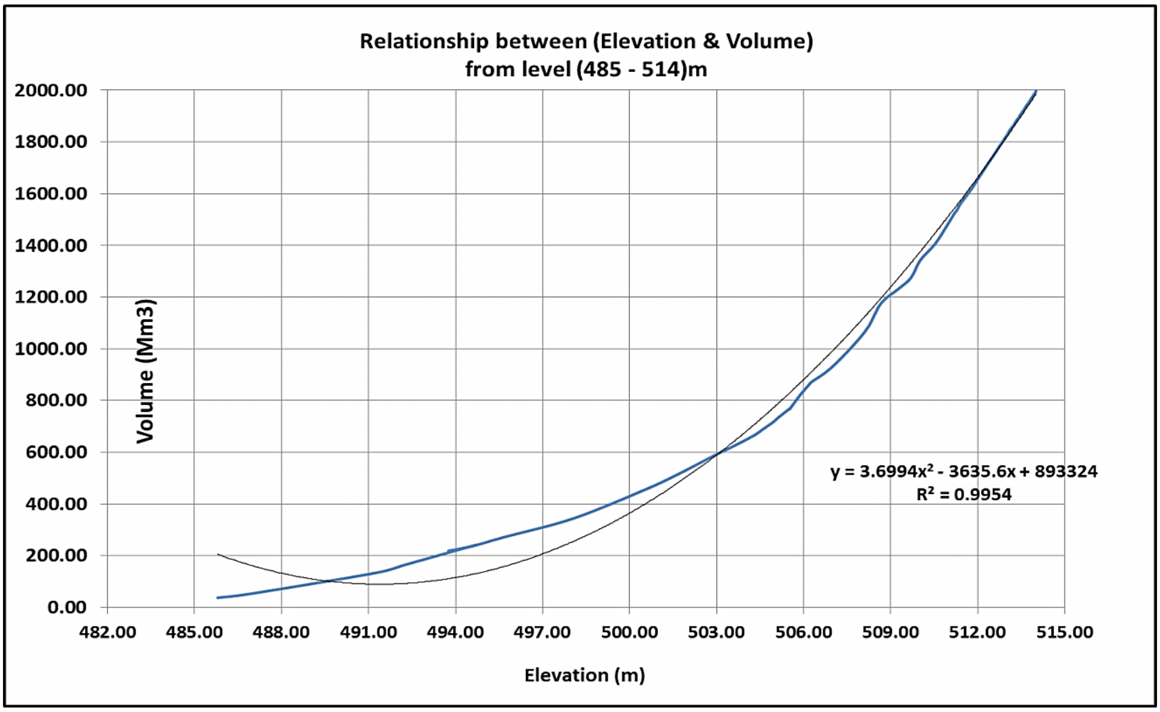


Figure (4.21) Initial the Relationship between Elevation& Volume from Level (485-514)

Figure (4.22) explains the Relationship between Elevation & period scenario Dry 16 Aug

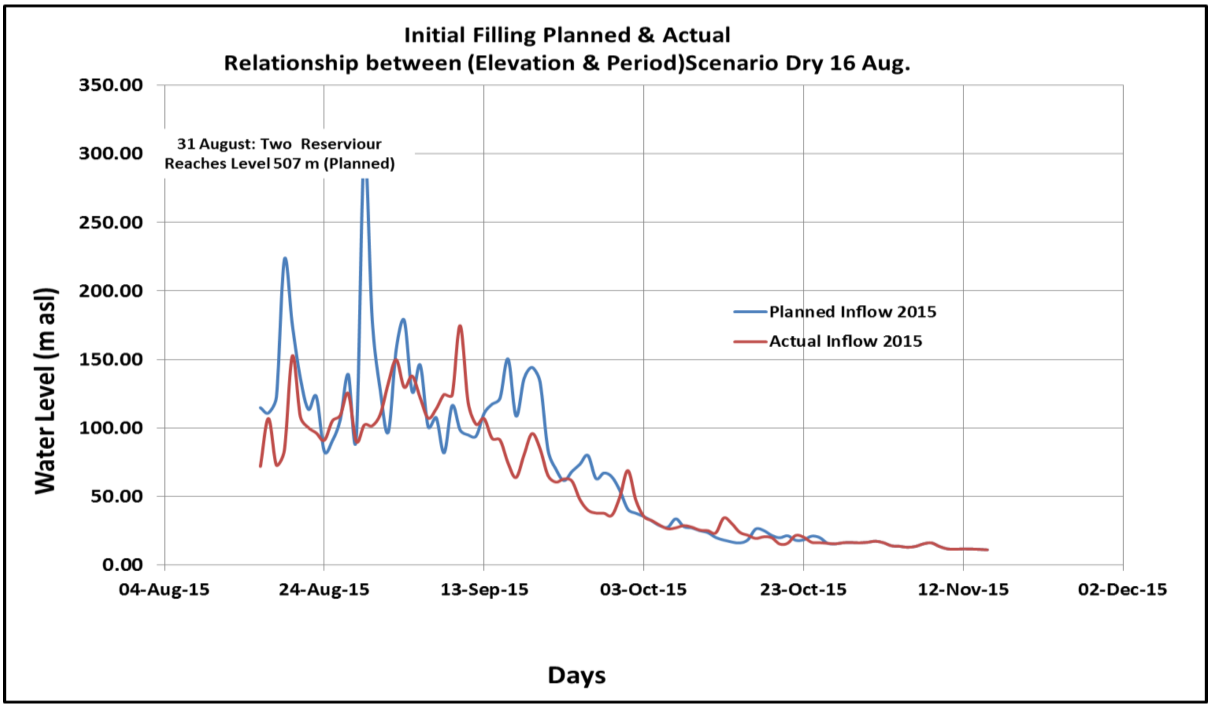


Figure (4.22) the Relationship between Elevation & period scenario Dry 16 Aug

Discussion and analysis:

Maximum Water Level and reservoir Capacity: The maximum water level of Impounding is 514m ASLdated on 08/11/2015, and the total reservoir capacity is 1993m3.

Comparison between the planed and Actual:

- The maximum level of Impounding is less than planned by 7 m because the Actual total inflows far less than expected in the plan, In addition, the Engineer requested to maintain a fixed water level at levels greater than 513 mASLfor the purpose of conducting dam safety tests.
- Regarding to the construction progress of work related to the power station, the start of generation is delayed to 2016 and the available water Stored in the reservoir (1993m3) it is enough to the dawn stream demands (17.5Mm3 /day).
- The Engineer has conducted several important tests for dam safety for Embankment, foundations and concrete bodes (settlement, Seepage ,Uplift, etc…)

In this aspect, the researcher believes that the Actual situation before filling with in the acceptable rang, and the plan achieved the target and followed the Engineer (LI) recommendations.

4.6.1.2. The Situation of some Other Engineer Constrains after impounding

4.6.1.2.1. Erosion of Connection Chanel Inlet/ Outlet Areas after Filling

By daily monitoring and observation, it was noted that there was no **Erosion** in the connection channel.

Comparison between the planed and Actual:

The Actual maximum current velocity in the Inlet/ Outlet of the channel did not exceed78m/s.

In this aspect, the researcher believes that the Actual situation before filling with in the acceptable rang, and the plan achieved the target and followed the Engineer (LI) recommendations

4.6.1.2.2. Spillways Gate Opening and hydro-mechanical elements after Filling

Operation of the spillways gates was in accordance with the recommendations of the engineer, no damages was observed of the sealing also not observed cavitation on the concrete surface near the gates.

All hydro-mechanical elements (Gates, Gantry Cranes, Dewatering system, etc...) In upper Atbara and Setit dams was operational before the filling Start.

Comparison between the planed and Actual:

- Gates Opening heights significantly not less than 5 %(42.5cm) for longer time.

4.6.1.2.3. Embankment Elevations after Filling

The dam's Embankment (main river bed, dykes) are reach level 523.30 be for the filling start. It is higher than the maximum operation water level 521 masl.

Comparison between the planed and Actual:

- No damages (over toping, erosion) were observed.

4.6.1.2.4. Instrumentation and monitoring after Filling

Before commencement of the Initial filling stage, most of the Instrumentation and monitoring elements (devices, Systems, etc...) are Installed and operational.

Following figures show the status of dam safety:

Vertical deformation by Magnetic settlement

During construction

Figure (4.23) shows the Rate of settlement during construction

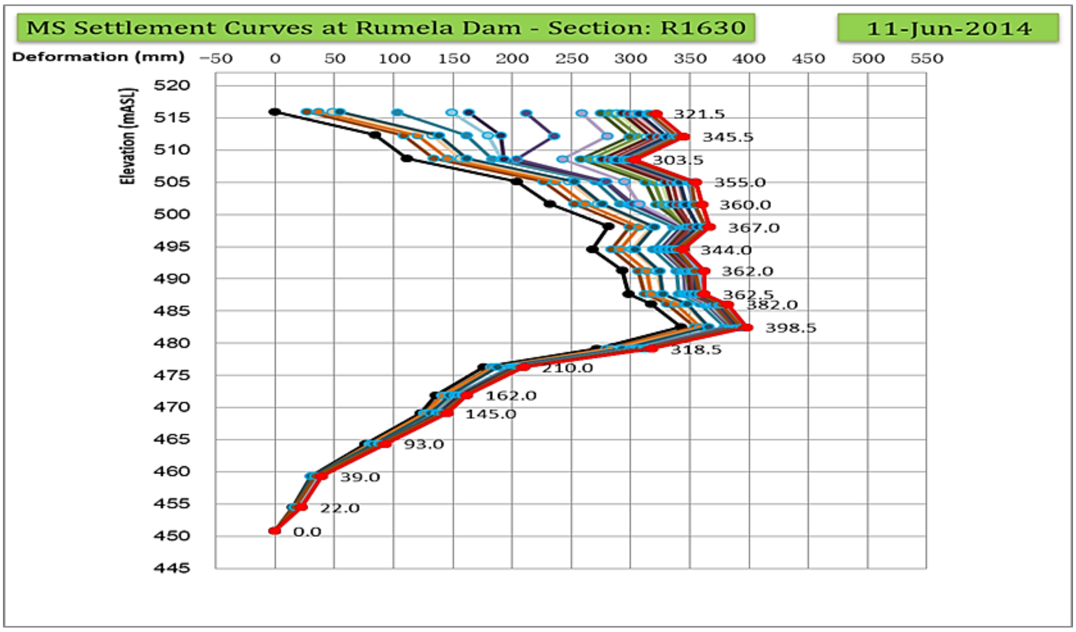


Figure (4.23) Rate of settlement during construction

Rate of settlement = 1.8 mm/day

Before initial impounding 2015

Figure (4.24) shows the Rate of settlement before initial filling 2015

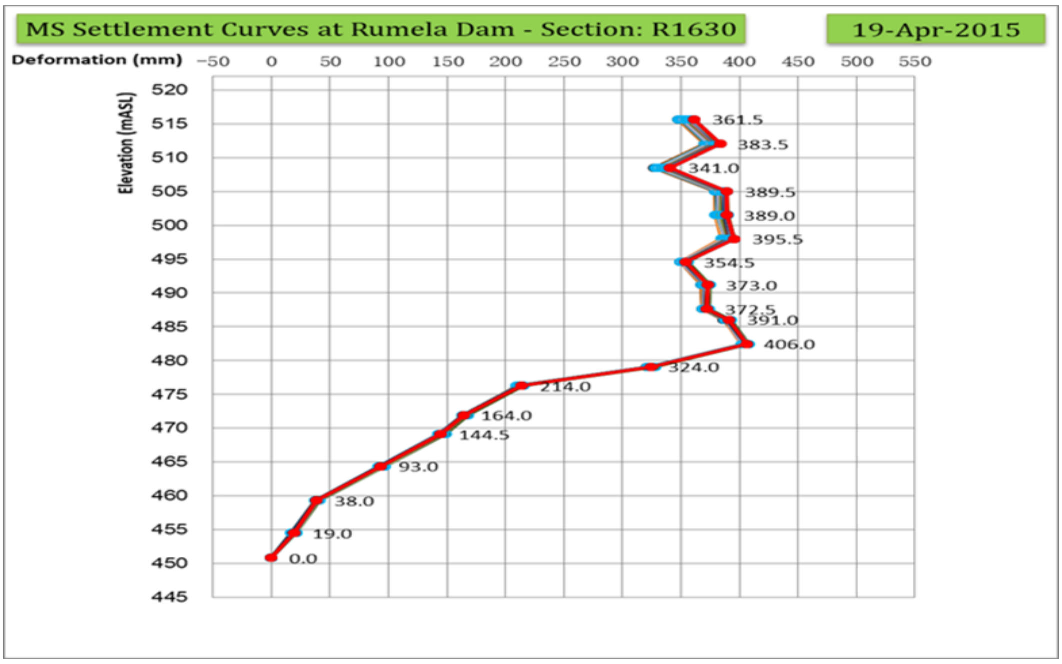


Figure (4.24) Rate of settlement before initial impounding 2015

Rate of settlement = 0.12 mm/day

After initial impounding 2015

Figure (4.25) shows the Rate of settlement after initial filling 2015

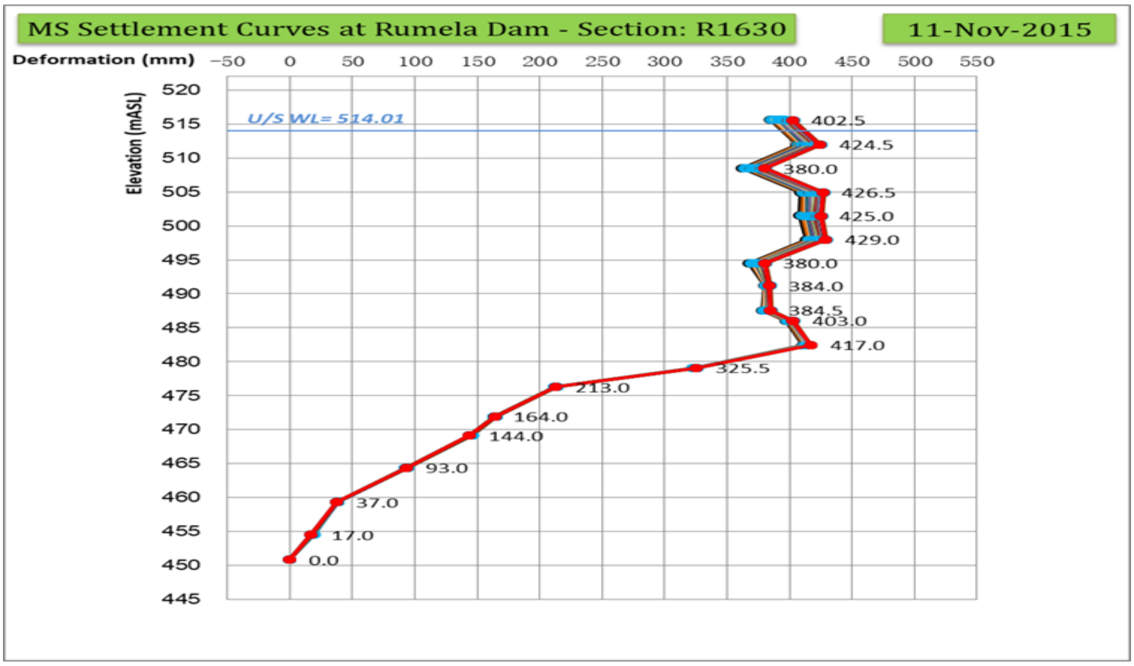


Figure (4.25) Rate of settlement after initial impounding 2015

Rate of settlement = 0.13 mm/day

Discussion and analysis:

Comparison between the planed and Actual:

- If we compare the values of settlement before the initial impounding 2015and real values after impounding (514masl), we notice that the real settlement is very small = 0.13-0.12= .01 mm/day

Note: The levels did not reach the maximum operational level

Measurements of Seepage

Table (4.11) Rate of seepage after initial Filling 2015, and after filiing2016

U/S water level	max planed seepage L/s per 100 meter	year 2015	year 2016
507.66	231	0	12.82
508.22	231	0.03	
508.67	231	1	
509.27	231	1.03	
509.70	231	1.62	14.22
510.02	231	2.26	
510.53	231	2.73	
510.96	231	3.18	13.48
511.17	231	3.47	
511.29	231	3.75	
511.41	231	4.49	
511.79	231	5.72	14.11
512.03	231	7.28	
512.20	231	9.27	
512.35	231	9.62	14.07
512.55	231	10.573	
512.73	231	11.398	
512.83	231	11.311	
512.89	231	11.729	15.83
512.94	231	11.648	
512.99	231	11.454	
513.04	231	11.931	26.06
513.10	231	12.43	
513.24	231	12.87	
513.29	231	12.538	
513.31	231	13.336	30.00
513.36	231	13.288	
513.39	231	13.594	
513.44	231	13.364	
513.46	231	13.931	
513.50	231	13.88	
513.55	231	14.42	
513.59	231	14.17	
513.62	231	13.8	
513.63	231	14.15	34.77
513.69	231	14.98	

513.74	231	14.54	
513.77	231	14.75	
513.78	231	14.82	
513.79	231	15.1	
513.80	231	16.28	
513.84	231	15.01	
513.84	231	15.46	
513.85	231	15.68	
513.87	231	15.71	34.78
513.89	231	15.19	
513.88	231	15.88	
513.87	231	15.92	
513.88	231		
513.88	231		
513.90	231	16.13	
513.91	231		
513.92	231		
513.93	231	16.12	
513.96	231		
513.98	231		
513.99	231	16.68	34.80
514.00	231	16.68	34.80

Figure (4.26) Rate of seepage after initial Filling 2015, and after filiing2016

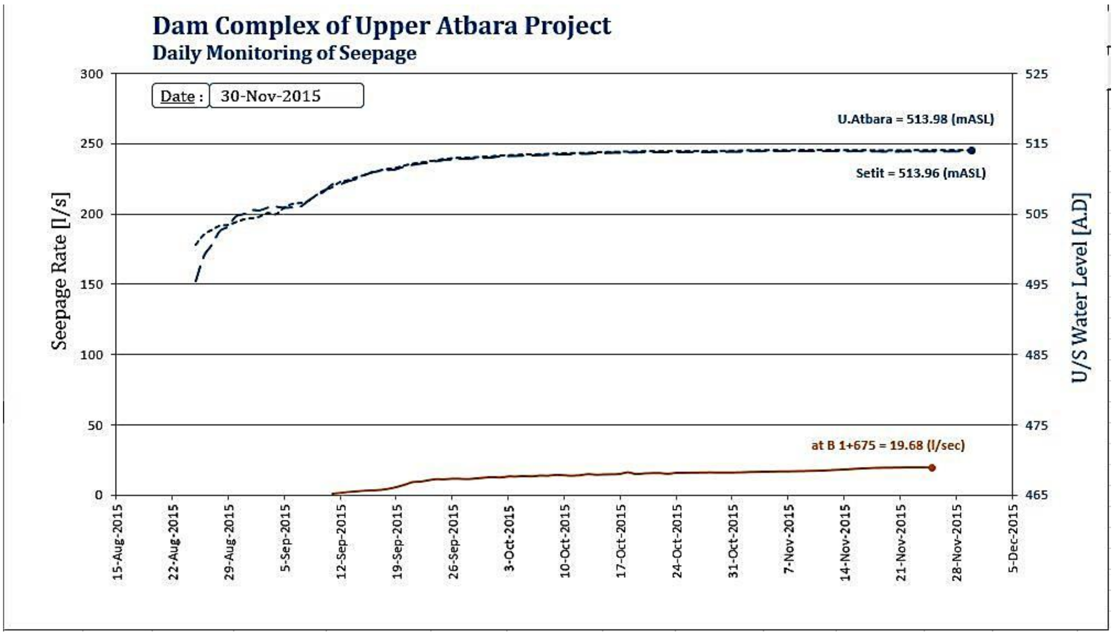


Figure (4.26) the Rate of seepage after initial impounding 2015

The rate of seepage = 0.2l/s per 100 meter

Discussion and analysis:

Comparison between the planed and Actual:

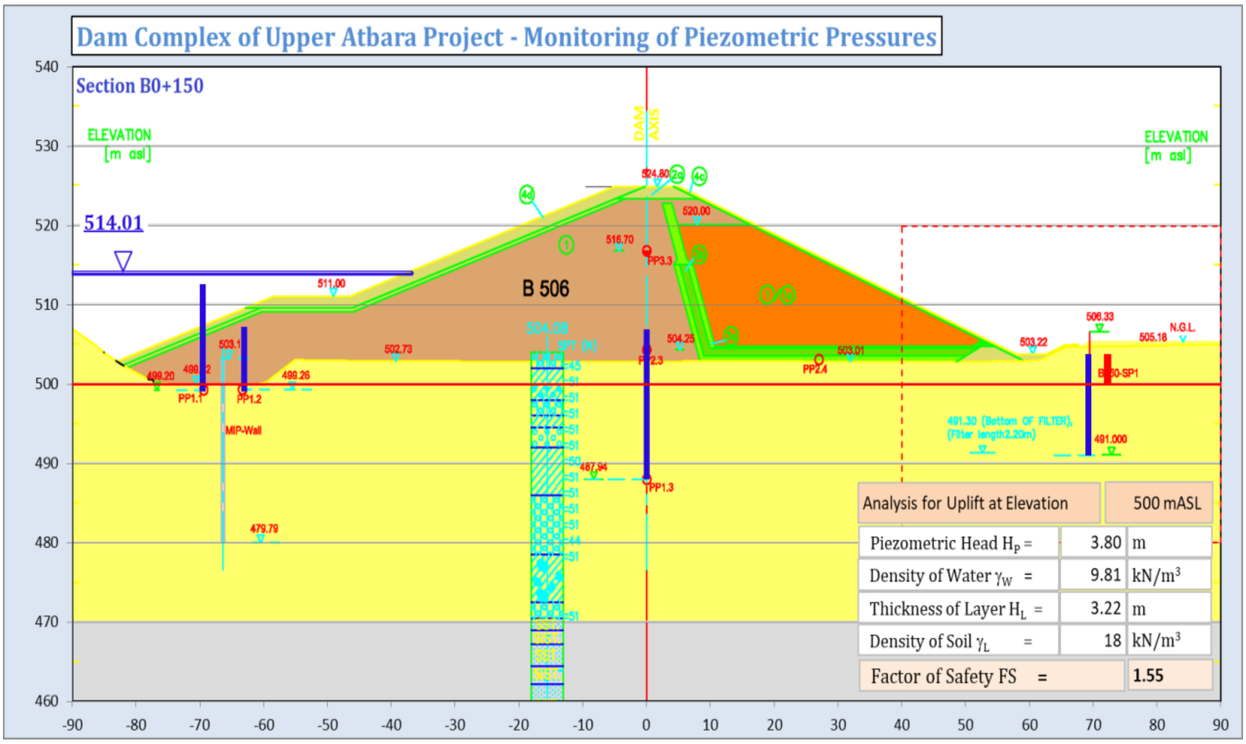
- If we compare the values of calculated by finite element model and real values after impounding (514masl), we notice that the real rate of seepage Less than the calculated = 231 mm/s per 100 meter > 19.68 mm/s per 100 meter

Note: The levels did not reach the maximum operational level

Monitoring of Uplift

Safety factor of Uplift after initial filling 2015

Figure (4.27) shows the Safety factor of Uplift after initial filling 2015



Analysis for Uplift at Elevation		500 mASL
Piezometric Head H_P =	3.80	m
Density of Water γ_W =	9.81	kN/m^3
Thickness of Layer H_L =	3.22	m
Density of Soil γ_L =	18	kN/m^3
Factor of Safety FS =		1.55

Figure (4.27) the Safety factor of Uplift after initial impounding 2015

Safety factor = 1.55
More than acceptable (1.4)
Discussion and analysis:

Comparison between the planed and Actual

- If we compare the values of acceptable uplift safety factor and real values after impounding (514masl), we notice that the real uplift safety factor more than the acceptable = 1.55> 1.4.

Note: The levels did not reach the maximum operational level

In this aspect, the researcher believes that the Actual situation of dam safety before filling with in the acceptable rang, and the plan achieved the target and followed the Engineer (LI) recommendations

CHAPTER FIVE

Conclusions and Recommendation

CHAPTER FIVE

Conclusions and Recommendation

5.1. Conclusions

Dam Complex of Upper Atbara Project (DCUAP) initial filling stage had been planned to start in the flood season (2014) to reduce to the maximum operation level (521) ASL, however, due to some constraints the construction progress of the project was delayed, consequently the impounding also delayed. the initial filling took place between (15Augest to 19 October 2015) with final elevation of 514 m ASL .since, DCUAP is part of the national water resources management system, and due to unexpected demand (for power generation) in Merowe Dam, the filling was stopped at level 514.00 m ASL on 8 November 2018, with a total accumulative storage of 1.993 million cubic meters. Inflow was released in order to satisfy the demand in Merowe Dam.

The scenarios were built according to the inflow of the rivers, the start of filling range is considered based on the sedimentation and operation study chapter7 (done by deltares) and the engineer (LI) recommendations .The triggers of the filling was the inflow magnitude and the sediment concentration in the water.

During and after filling a daily inspection program was carried out for all dam components to monitor and observe damages usually caused by the initial filling it turned out that there was no signs of failure or any damage in the embankments, foundations.

The recommendations of the Project Engineer (LI) were complied with when implementing the filling and the summary of the results is as follows:

- Water level rising rates not significantly higher than 1 m/day for levels lower than 500 masl, not more than 0.4 m/day for levels between 500 and 507masl, and in the following to limit the water rising rate to 0.2m/day for levels above 507masl< above 513 m ASL the filling rates shall be limited to 10 -20 cm.

- The Actual maximum current velocity in the Inlet/ Outlet of the channel did not exceed 78m3/s.

- Gates Opening heights significantly not less than 5 %(42.5cm) for longer time.

- Settlement before the initial impounding 2015and real values after impounding (514masl), we notice that the real settlement is very small = 0.13-0.12= .01 mm/day

- Real rate of seepage Less than the calculated = 231 mm/s per 100 meter > 21 mm/s per 100 meter

- Uplift safety factor more than the acceptable = 1.55> 1.4

The first filling stage has achieved the target objectives from the point of view of the researcher, and it became clear after the evaluation and technical analysis of many data and information (design documents, construction methods, hydrological observations, and the engineer (LI) recommendations).

5.2. Recommendations

1. The results of the assessment of the initial filling stage together with the physical models results of the spillways and the experience during the previous filling can be used to calculate gates closing and opening to ensure the rate of filling and the releases of future impounding according to the inflow.
2. Khashm el-Girba Dam (KEG) flushing is doable to be planned and coordinated in the same time if the filling of DCUAP reservoir because amount of water expected to be released from DCUAP in the period of 16-25 August (954.59 Mm3) is More than 103 Mm3 (the storage required in KEG reservoir to reach 467 m ASL).
3. The normal filling of the KEG reservoir might also start as normal (the lowest calculated release is 1296 Mm3), however it may takes longer time than before to reach the maximum level. This may not be an issue as the downstream demand of KEG Dam is already fulfilled.
4. The effects of initial filling on concrete structures are recommended to be studied separately in the future.

References

References

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6. http://damfailures.org/lessons-learned/the-first-filling-of-a-reservoir-should -be-planned-controlled-and-monitored (30/7/2017).
7. Heloise Yang, Matt Haynes, Stephen Winze read, and Kevin Okada (1999) Ref.htm.
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APPENDIX

Appendix

Section (A)

A- 1TABIES

Mathematical model

- **A.1.1. Program of Filling of DCUAP Reservoir From [16-Aug to 4 Oct-2015] (Dry Condition)**

Upper Atbara Reservoir						
#	Date	Inflow	Res. P. W.L	Res. Con	DS	Outflow
		(Mm3)	(masl)	(Mm3)	(M.m3)	(Mm3)
		A	B	C	D	E
Stage 1 - 150 cm	16-Aug-15	70.81	488.20	30.97	30.97	39.84
	17-Aug-15	58.18	489.70	43.22	12.25	45.93
	18-Aug-15	82.16	491.20	58.74	15.52	66.63
	19-Aug-15	151.19	492.70	79.13	20.39	130.80
	20-Aug-15	94.05	494.20	104.46	25.34	68.71
	21-Aug-15	68.81	495.70	134.88	30.42	38.39
Stage 2 - 120 cm	22-Aug-15	69.60	496.90	164.18	29.30	40.30
	23-Aug-15	63.98	498.10	198.26	34.08	29.90
	24-Aug-15	49.52	499.30	237.12	38.86	10.66
	25-Aug-15	53.27	500.50	281.08	43.95	9.32
	26-Aug-15	68.51	501.70	331.32	50.25	18.26
	27-Aug-15	77.18	502.90	387.87	56.55	20.64
Stage 2 - 100 cm	28-Aug-15	53.27	503.80	434.42	46.55	6.72
	29-Aug-15	122.68	505.00	502.00	67.58	55.10
	30-Aug-15	84.21	506.00	563.25	61.25	22.96
	31-Aug-15	62.77	507.00	630.58	67.33	-4.56
Stage 3 - 70 cm	1-Sep-15	47.16	507.70	681.34	50.75	-3.59
	2-Sep-15	57.66	508.40	736.42	55.08	2.58
	3-Sep-15	73.89	509.10	793.93	57.51	16.38
	4-Sep-15	65.31	509.80	850.51	56.57	8.74
	5-Sep-15	49.76	510.50	910.59	60.08	-10.33
Stage 6 - 45 cm	6-Sep-15	44.81	510.95	951.60	41.02	3.79
	7-Sep-15	53.85	511.40	994.32	42.71	11.14
	8-Sep-15	50.46	511.85	1038.72	44.41	6.05
	9-Sep-15	61.30	512.30	1084.82	46.10	15.20
	10-Sep-15	48.52	512.75	1132.62	47.79	0.73
	11-Sep-15	46.56	513.20	1182.10	49.49	-2.92
	12-Sep-15	53.93	513.65	1233.29	51.18	2.75
	13-Sep-15	66.56	514.10	1286.16	52.88	13.68

	14-Sep-15	63.61	514.55	1340.73	54.57	9.04
	15-Sep-15	60.94	515.00	1397.00	56.27	4.68
	16-Sep-15	99.93	515.45	1448.89	51.89	48.04
	17-Sep-15	64.74	515.90	1503.69	54.80	9.94
	18-Sep-15	67.92	516.35	1561.40	57.71	10.21
	19-Sep-15	81.14	516.80	1622.02	60.62	20.52
	20-Sep-15	73.16	517.25	1685.55	63.53	9.64
Stage 6 - 20 cm	**21-Sep-15**	54.59	517.45	1714.72	29.17	25.42
	22-Sep-15	44.31	517.65	1744.47	29.74	14.56
	23-Sep-15	36.09	517.85	1774.78	30.32	5.77
	24-Sep-15	44.24	518.05	1805.68	30.89	13.34
	25-Sep-15	43.60	518.25	1837.14	31.47	12.13
	26-Sep-15	43.25	518.45	1869.19	32.04	11.20
	27-Sep-15	32.32	518.65	1901.80	32.62	-0.30
	28-Sep-15	38.34	518.85	1935.00	33.19	5.15
	29-Sep-15	31.31	519.05	1968.76	33.77	-2.46
Stage 7 - 10 cm	**30-Sep-15**	28.79	519.15	1985.86	17.10	11.70
	1-Oct-15	21.63	519.25	2003.10	17.24	4.39
	2-Oct-15	21.43	519.35	2020.49	17.39	4.04
	3-Oct-15	19.26	519.45	2038.02	17.53	1.73
	4-Oct-15	16.33	519.55	2055.69	17.67	-1.35
	5-Oct-15	15.56	519.65	2073.51	17.82	-2.26
	6-Oct-15	14.91	519.75	2091.47	17.96	-3.05
	7-Oct-15	20.00	519.85	2109.57	18.10	1.90
	8-Oct-15	15.49	519.95	2127.82	18.25	-2.75
	9-Oct-15	14.01	520.05	2147.21	19.39	-5.38
	10-Oct-15	13.18	520.15	2167.71	20.50	-7.32
	11-Oct-15	12.47	520.25	2188.31	20.60	-8.13
	12-Oct-15	11.76	520.35	2209.00	20.70	-8.94
	13-Oct-15	11.06	520.45	2229.80	20.80	-9.74
	14-Oct-15	10.12	520.55	2250.70	20.90	-10.78
	15-Oct-15	9.35	520.65	2271.70	21.00	-11.65
	16-Oct-15	8.59	520.75	2292.81	21.10	-12.51
	17-Oct-15	8.38	520.85	2314.01	21.20	-12.82
	18-Oct-15	8.26	520.95	2335.31	21.30	-13.05
	19-Oct-15	8.42	521.05	2356.44	21.13	-12.71

Setit Reservoir						
#	Date	Inflow	Res. P.W.L	Res. Con	DS	Outflow
		(Mm3)	(masl)	(Mm3)	(M.m3)	(Mm3)
		F	G	H	I	J
	16-Aug-15	43.91				43.91
Stage 1 - 150 cm	**17-Aug-15**	52.63	489.00	4.40	4.40	48.23
	18-Aug-15	40.26	490.50	8.67	4.27	35.99
	19-Aug-15	71.65	492.00	15.46	6.79	64.87
	20-Aug-15	81.04	493.50	24.90	9.44	71.60
	21-Aug-15	67.40	495.00	37.00	12.10	55.31
Stage2 - 120 cm	**22-Aug-15**	43.91	496.20	48.51	11.51	32.40
	23-Aug-15	58.89	497.40	62.75	14.24	44.64
	24-Aug-15	33.24	498.60	79.73	16.98	16.26
	25-Aug-15	37.22	499.80	99.45	19.72	17.51
	26-Aug-15	37.62	501.00	122.14	22.69	14.93
	27-Aug-15	61.92	502.20	148.98	26.84	35.08
	28-Aug-15	39.44	503.40	180.03	31.05	8.38
	29-Aug-15	179.28	504.60	215.30	35.27	144.01
	30-Aug-15	94.59	505.80	255.24	39.94	54.65
	31-Aug-15	64.76	507.00	301.50	46.26	18.50
Stage 3 - 70 cm	**1-Sep-15**	49.68	507.70	331.48	29.98	19.71
	2-Sep-15	99.56	508.40	364.73	33.25	66.31
	3-Sep-15	104.71	509.10	399.80	35.07	69.64
	4-Sep-15	61.08	509.80	434.03	34.23	26.85
	5-Sep-15	96.10	510.50	470.53	36.51	59.60
Stage 6 - 45 cm	**6-Sep-15**	55.96	510.95	495.53	25.00	30.96
	7-Sep-15	53.64	511.40	521.58	26.05	27.59
	8-Sep-15	31.27	511.85	548.69	27.11	4.17
	9-Sep-15	54.92	512.30	576.85	28.16	26.76
	10-Sep-15	49.92	512.75	606.07	29.22	20.71
	11-Sep-15	48.25	513.20	636.35	30.27	17.98
	12-Sep-15	40.06	513.65	667.68	31.33	8.73
	13-Sep-15	43.91	514.10	700.06	32.39	11.53
	14-Sep-15	53.64	514.55	733.50	33.44	20.20
	15-Sep-15	60.80	515.00	768.00	34.50	26.31
	16-Sep-15	50.41	515.45	800.94	32.94	17.47
	17-Sep-15	43.91	515.90	835.43	34.49	9.42
	18-Sep-15	68.00	516.35	871.47	36.04	31.96
	19-Sep-15	63.05	516.80	909.06	37.59	25.46
	20-Sep-15	60.53	517.25	948.19	39.14	21.39
e 6 - 20	**21-Sep-15**	29.22	517.45	966.08	17.89	11.33

	22-Sep-15	25.40	517.65	984.28	18.20	7.21
	23-Sep-15	25.40	517.85	1002.78	18.50	6.90
	24-Sep-15	23.92	518.05	1021.59	18.81	5.11
	25-Sep-15	29.90	518.25	1040.70	19.11	10.78
	26-Sep-15	36.63	518.45	1060.12	19.42	17.21
	27-Sep-15	30.75	518.65	1079.85	19.73	11.03
	28-Sep-15	28.72	518.85	1099.88	20.03	8.69
	29-Sep-15	32.87	519.05	1120.22	20.34	12.54
Stage 7 - 10 cm	**30-Sep-15**	25.40	519.15	1130.50	10.28	15.12
	1-Oct-15	18.95	519.25	1140.86	10.36	8.59
	2-Oct-15	16.25	519.35	1151.30	10.44	5.81
	3-Oct-15	16.03	519.45	1161.81	10.51	5.51
	4-Oct-15	15.70	519.55	1172.40	10.59	5.11
	5-Oct-15	13.05	519.65	1183.07	10.67	2.38
	6-Oct-15	12.57	519.75	1193.81	10.74	1.83
	7-Oct-15	13.63	519.85	1204.63	10.82	2.81
	8-Oct-15	12.39	519.95	1215.52	10.90	1.49
	9-Oct-15	12.95	520.05	1226.93	11.40	1.55
	10-Oct-15	11.75	520.15	1238.82	11.90	-0.14
	11-Oct-15	11.06	520.25	1250.77	11.95	-0.89
	12-Oct-15	8.20	520.35	1262.77	12.00	-3.80
	13-Oct-15	7.02	520.45	1274.82	12.05	-5.03
	14-Oct-15	6.59	520.55	1286.92	12.10	-5.51
	15-Oct-15	6.65	520.65	1299.07	12.15	-5.50
	16-Oct-15	9.59	520.75	1311.27	12.20	-2.61
	17-Oct-15	17.74	520.85	1323.52	12.25	5.49
	18-Oct-15	16.81	520.95	1335.83	12.30	4.51
	19-Oct-15	13.05	521.05	1348.05	12.22	0.82

•A.1.2. Setit Spillway capacity

#	**Parameter**	**U.A Spillway**	**Setit Spillway**								
1	B.O n	4	6								
2	S.O n	1	2								
3	B.O w	8	8		B.O Dis.Cap=Cd*n*w*h*√(2gh)						
4	B.O h	8.5	8.5								
5	S.O w	15	15								
6	Sill elev.	482	485								
7	Roof elev.	490.5	493.5								
8	Weir crest elev.	507	507		S.O Dis.Cap=Cd*n*w*√(2gh^3)						
9	Reservoir elev.	521	521								
10	B.O Dis.Coff (Cd)	0.866	0.883								
11	S.O Dis.Coff (Cd)	0.497	0.487								
12	B.O Dis.Cap	4321.63	6973.57								
13	S.O Dis.Cap	1729.77									
14	Total Dis.Cap	6051.40	6973.57		Total Dis.Cap=B.O Dis.Cap + S.O Dis.Cap						
			13024.98								
		373.3887452									
		149.4524178									
Setit (We.)					**Setit B.O**				**Setit Total**		
H	Q					Q (n-1)	Q (n)		H	Q (n-1)	Q (n)
485	0				485	0			485	0.00	0.00
494	0				494	940.3166	1128.379975		494	940.32	1128.38
495	0				495	1628.676	1954.411447		495	1628.68	1954.41
496	0				496	2102.612	2523.134329		496	2102.61	2523.13
497	0				497	2487.844	2985.412799		497	2487.84	2985.41
498	0				498	2820.95	3385.139926		498	2820.95	3385.14
499	0				499	3118.677	3742.412999		499	3118.68	3742.41
500	0				500	3390.36	4068.431859		500	3390.36	4068.43
501	0				501	3641.831	4370.196852		501	3641.83	4370.20
502	0				502	3877.025	4652.429824		502	3877.02	4652.43
503	0				503	4098.745	4918.494282		503	4098.75	4918.49
504	0				504	4309.072	5170.886649		504	4309.07	5170.89
505	0				505	4509.6	5411.520256		505	4509.60	5411.52
506	0				506	4701.583	5641.899876		506	4701.58	5641.90
507	0				507	4886.029	5863.234342		507	4886.03	5863.23
508	64.71421947				508	5063.76	6076.512132		508	5128.47	6141.23
509	183.0394537				509	5235.462	6282.553814		509	5418.50	6465.59
510	336.2649483				510	5401.708	6482.049457		510	5737.97	6818.31
511	517.7137558				511	5562.988	6675.585959		511	6080.70	7193.30
512	723.5269693				512	5719.723	6863.667433		512	6443.25	7587.19
513	951.1009009				513	5872.276	7046.730687		513	6823.38	7997.83
514	1198.524117				514	6020.964	7225.157168		514	7219.49	8423.68
515	1464.31563				515	6166.069	7399.28232		515	7630.38	8863.60
516	1747.283926				516	6307.836	7569.402987		516	8055.12	9316.69
517	2046.443305				517	6446.486	7735.783368		517	8492.93	9782.23
518	2360.960631				518	6582.217	7898.659827		518	8943.18	10259.62
519	2690.119586				519	6715.204	8058.244833		519	9405.32	10748.36
520	3033.295675				520	6845.609	8214.730217		520	9878.90	11248.03
521	3389.938122				521	6973.575	8368.289865		521	10363.51	11758.23
522	3759.556414				522	7099.235	8519.081993		522	10858.79	12278.64
523	4141.710046				523	7222.709	8667.251049		523	11364.42	12808.96
524	4536.00056				524	7344.108	8812.929336		524	11880.11	13348.93

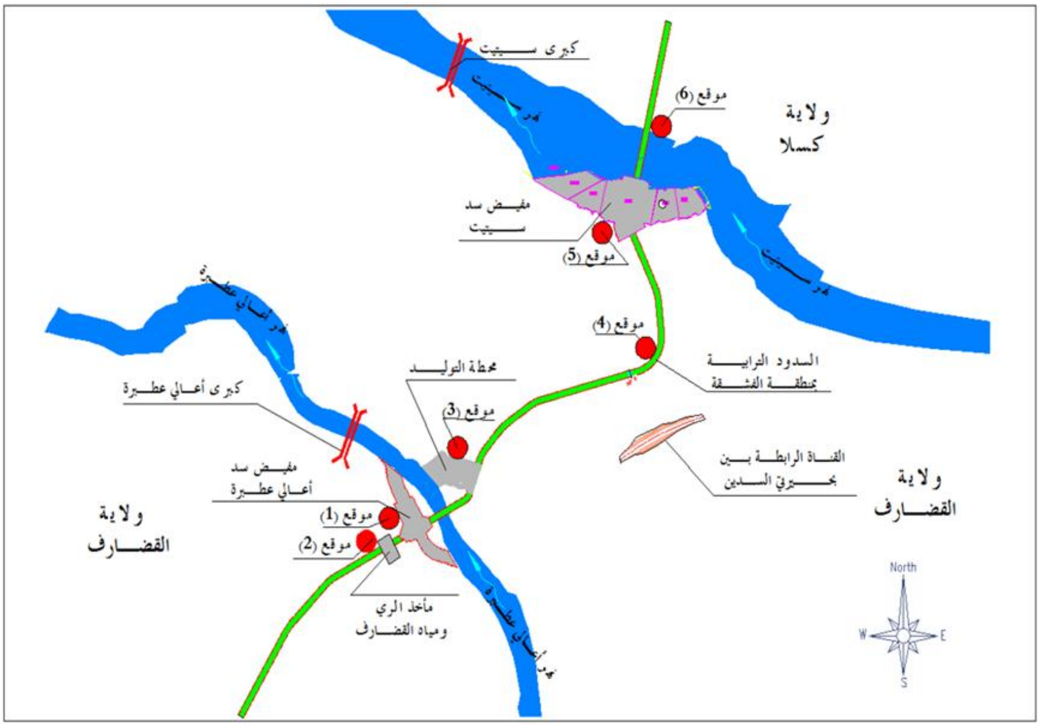
•A.1.2. Upper Atbara Spillway capacity

#	Parameter	U.A Spillway	Setit Spillway								
1	B.O n	4	6								
2	S.O n	1	2								
3	B.O w	8	8		B.O Dis.Cap=Cd*n*w*h*√(2gh)						
4	B.O h	8.5	8.5								
5	S.O w	15	15								
6	Sill elev.	482	485								
7	Roof elev.	490.5	493.5								
8	Weir crest elev.	507	507		S.O Dis.Cap=Cd*n*w*√(2gh³)						
9	Reservoir elev.	521	521								
10	B.O Dis.Coff (Cd)	0.866	0.883								
11	S.O Dis.Coff (Cd)	0.497	0.487								
12	B.O Dis.Cap	4321.63	6973.57								
13	S.O Dis.Cap	1729.77	3389.94								
14	Total Dis.Cap	6051.40	10363.51		Total Dis.Cap=B.O Dis.Cap + S.O Dis.Cap						
			16414.92								
A (We.)			**U.A (BO.)**					**UA Total**			
H	**Q**		**H**	**Q (n-1)**	**Q (n)**			**H**	**Q (n-1)**	**Q (n)**	
482	0		482	0	0			482	0.00	0.00	
491	0		491	553.3279	737.7705236			491	553.33	737.77	
492	0		492	958.392	1277.856031			492	958.39	1277.86	
493	0		493	1237.279	1649.705043			493	1237.28	1649.71	
494	0		494	1463.968	1951.95733			494	1463.97	1951.96	
495	0		495	1659.984	2213.311571			495	1659.98	2213.31	
496	0		496	1835.181	2446.908008			496	1835.18	2446.91	
497	0		497	1995.052	2660.069452			497	1995.05	2660.07	
498	0		498	2143.03	2857.372951			498	2143.03	2857.37	
499	0		499	2281.429	3041.905796			499	2281.43	3041.91	
500	0		500	2411.9	3215.867156			500	2411.90	3215.87	
501	0		501	2535.667	3380.88927			501	2535.67	3380.89	
502	0		502	2653.667	3538.223134			502	2653.67	3538.22	
503	0		503	2766.639	3688.852618			503	2766.64	3688.85	
504	0		504	2875.176	3833.568094			504	2875.18	3833.57	
505	0		505	2979.762	3973.01586			505	2979.76	3973.02	
506	0		506	3080.799	4107.732429			506	3080.80	4107.73	
507	0		507	3178.627	4238.168992			507	3178.63	4238.17	
508	33.02152677		508	3273.532	4364.709279			508	3306.55	4397.73	
509	93.39898203		509	3365.762	4487.682897			509	3459.16	4581.08	
510	171.5848863		510	3455.532	4607.375443			510	3627.12	4778.96	
511	264.1722142		511	3543.027	4724.036322			511	3807.20	4988.21	
512	369.1918929		512	3628.414	4837.884854			512	3997.61	5207.08	
513	485.3153467		513	3711.836	4949.115128			513	4197.15	5434.43	
514	611.5672343		514	3793.425	5057.899884			514	4404.99	5669.47	
515	747.1918562		515	3873.295	5164.393665			515	4620.49	5911.59	
516	891.5812229		516	3951.552	5268.735391			516	4843.13	6160.32	
517	1044.232364		517	4028.288	5371.050485			517	5072.52	6415.28	
518	1204.720157		518	4103.589	5471.452641			518	5308.31	6676.17	
519	1372.679091		519	4177.534	5570.045305			519	5550.21	6942.72	
520	1547.790504		520	4250.192	5666.922921			520	5797.98	7214.71	
521	1729.773354		521	4321.629	5762.171993			521	6051.40	7491.95	
522	1918.377349		522	4391.904	5855.871991			522	6310.28	7774.25	
523	2113.377714		523	4461.072	5948.096121			523	6574.45	8061.47	
524	2314.571128		524	4529.184	6038.912001			524	6843.76	8353.48	

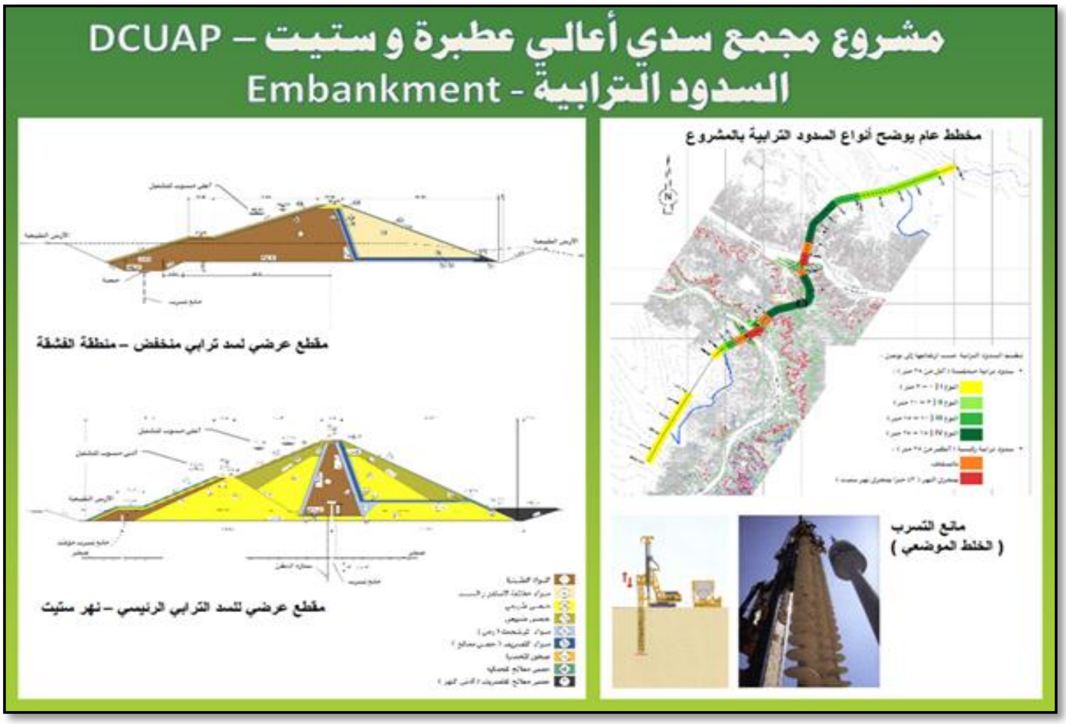
Section (b)

B -1 PROJECT DROWING

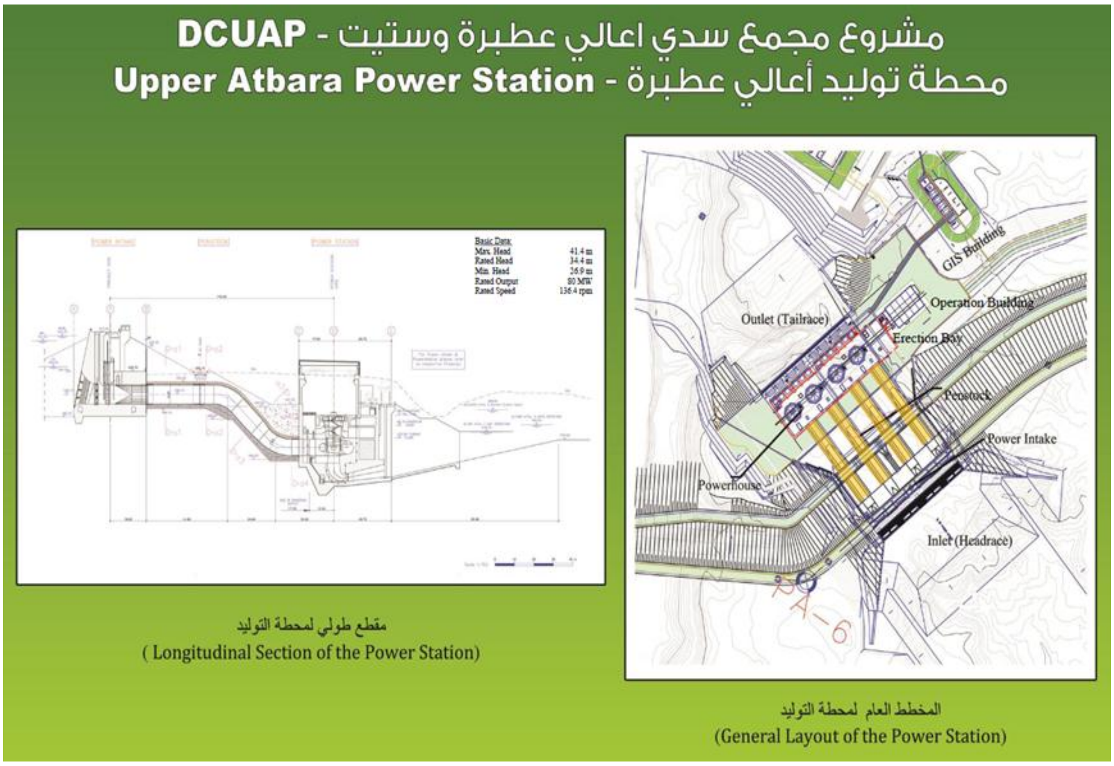
B.1.1. general layout of dam complex of upper Atbara project



B.1.2. general layout + cross section of embankment of dam complex of upper Atbara project



B.1.3. general layout + cross section of upper Atbara power station



DCUAP - مشروع مجمع سدي اعالي عطبرة وستيت

Upper Atbara Power Station - محطة توليد أعالي عطبرة

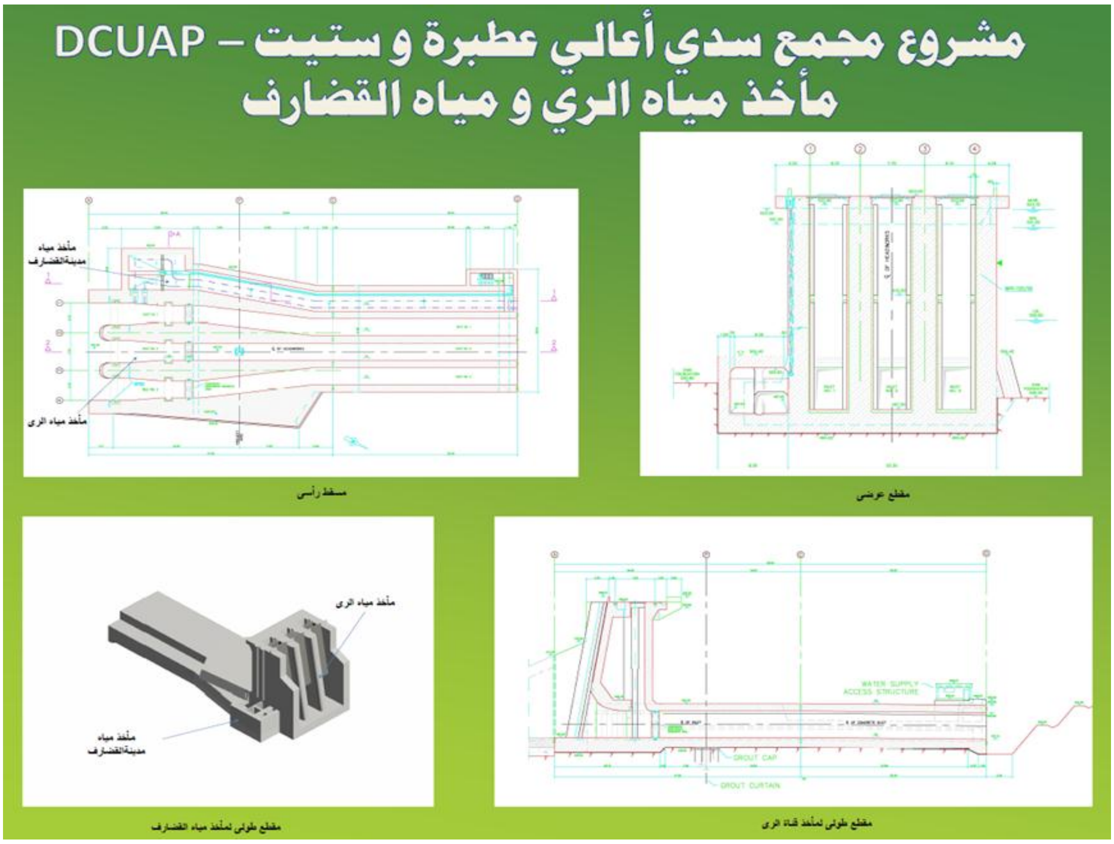
مقطع طولي لمحطة التوليد

(Longitudinal Section of the Power Station)

المخطط العام لمحطة التوليد

(General Layout of the Power Station)

B.1.3. general layout + cross section of upper Atbara power station



DCUAP – مشروع مجمع سدي أعالي عطبرة و ستيت

مأخذ مياه الري و مياه القضارف

مسقط رأسى

مقطع عرضى

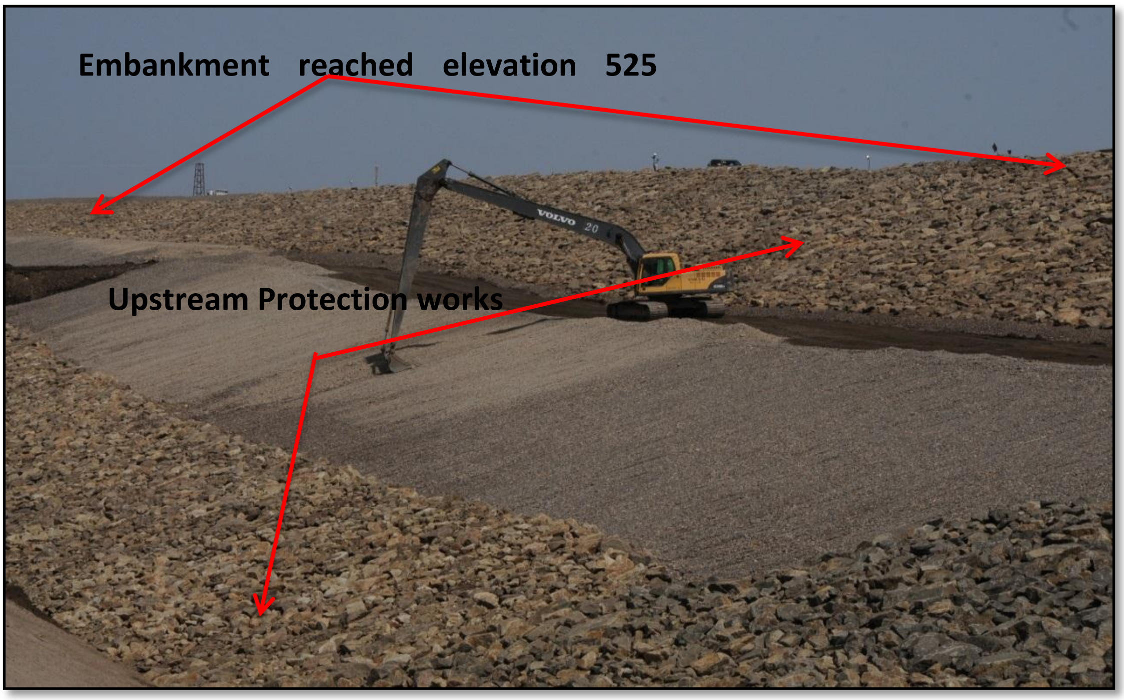
مقطع طولى لمأخذ مياه القضارف

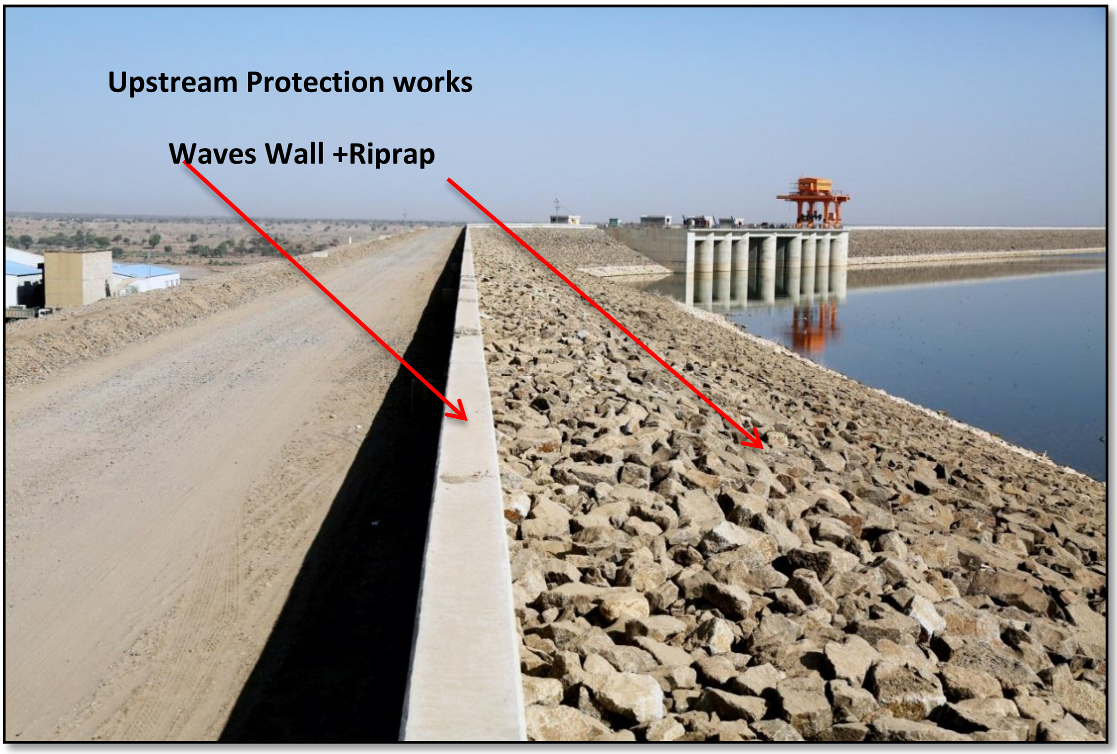
مقطع طولى لمأخذ قناة الرى

Section (C)

C -1 PHOTO SHOWING THE PROGRESS OF THE PROJECT BEFOR / DURING /AFTER THE INISIAL FILLING 2015

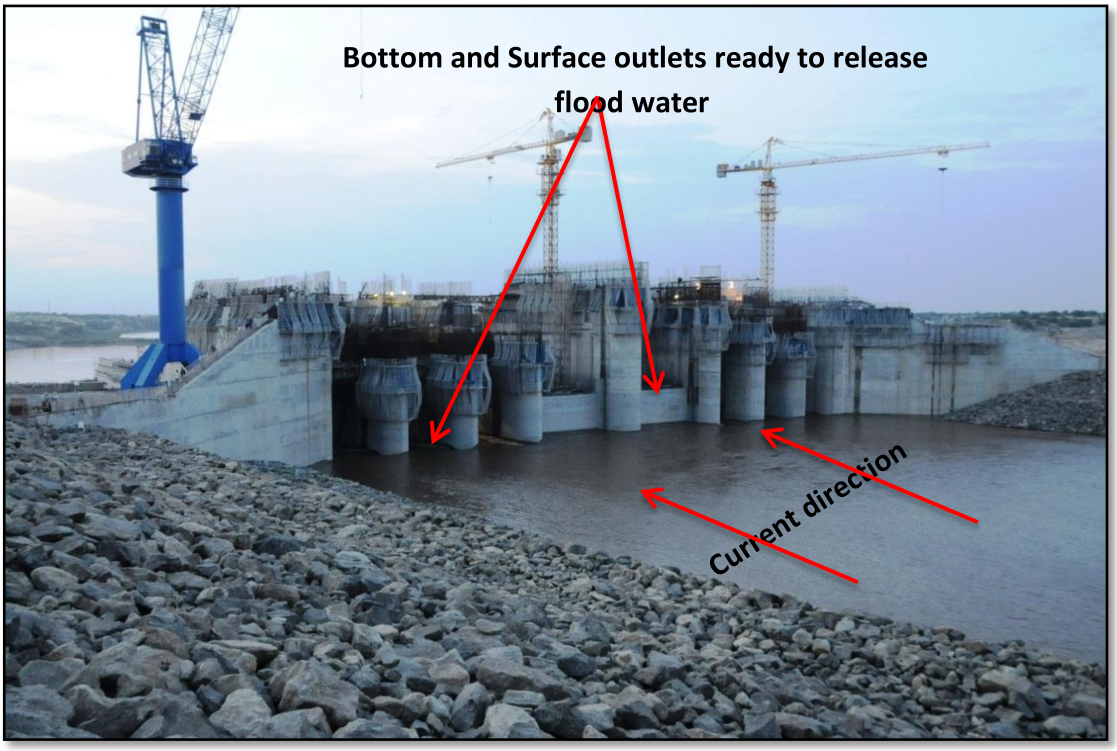
C.1.1. the embankment



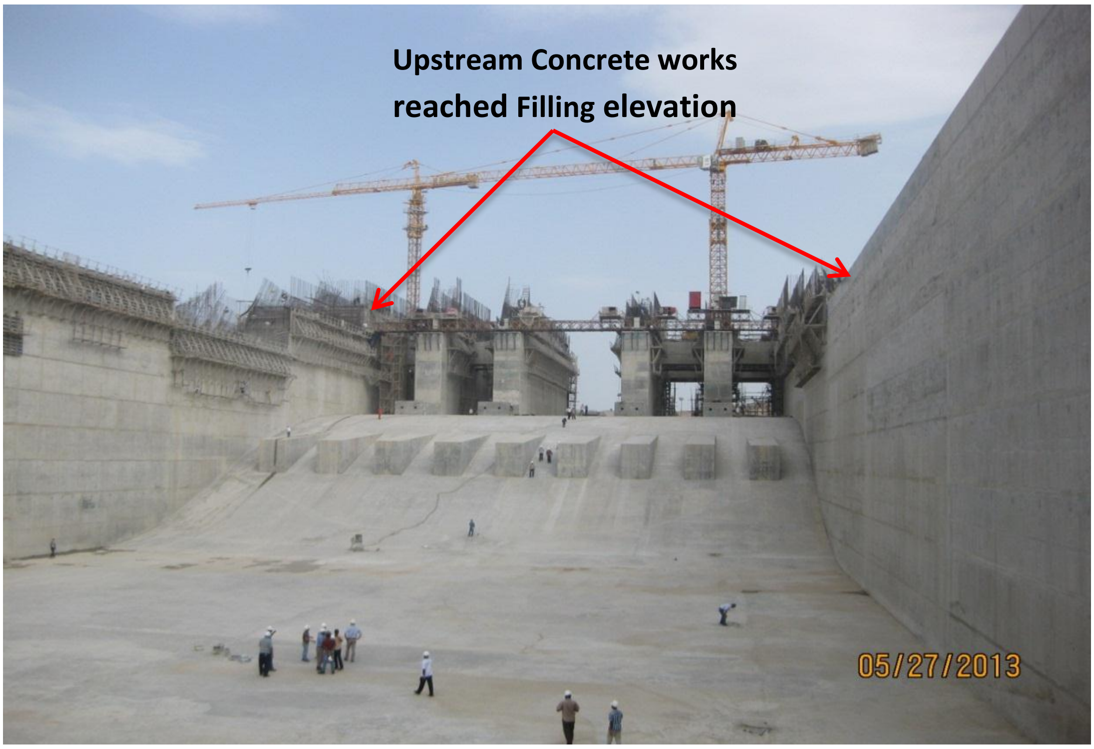


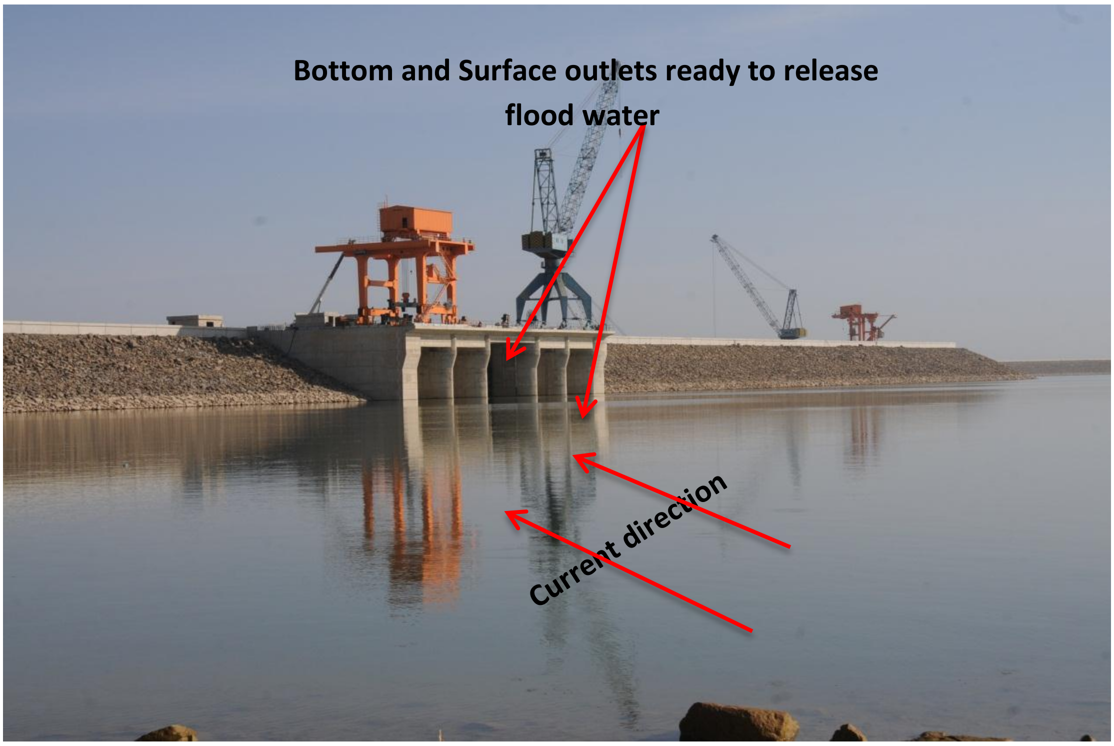
C.1.2. Setit and upper Atbara Spillways

C.1.2. 1 Setit Spillway



C.1.2. 2 Upper atbara Spillway





C.1.3. upper Atbara Power station

C.1.3.1 Power intake