Irrigated Areas Power and Sediment Interaction Case Study Sinnar Dam

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ABSTRACT:

This research covers the Al-Jazeera and Al-Manaqil projects, which are irrigated from the Sennar reservoir. Previous studies covered hydraulic calculations and techniques for removing weeds and silt accumulations from existing canals and drains.The research followed the descriptive analytical approach and the survey method by collecting important data on the network of canals and existing drains, to cover the main problems of weed spread, silt accumulation and soil analyzes. The aim of the research was to demonstrate the interaction between silt drainage and energy, and to determine the effect of operating the reservoir on the plans of Al-Jazeera, Al-Suki, Al-Rahad, and Northwest Sennar sugar factories. The importance of the research was to reveal the presence of many problems in the methods of water management at the field level and their relationship to the consumption and regularity of the electrical supply, in addition to the design and maintenance of agricultural courses, in addition to business management, including capacity-building, which is the heart that drives development with the selected scientists included .One of the results of the research is that the rehabilitation of the agricultural project contributes to its development and the availability of equipment and mechanisms that include the application of advanced technology and modern technologies, including statistics sciences mixed with modern technology in modern models and information applied in geographical systems. This method leads the way to solve problems and achieve goals.

Key words: Energy and silt interaction, irrigated areas, Sennar Dam.

مستخلص:

يغطى هذا البحث مشروعى الجزيرة والمناقل الذى يروى من خزان سنار، الدراسات السابقة غطت الحسابات الهيدروليكية وتقانات ازالة الحشائش وتراكمات الطمى من القنوات والمصارف القائمة.اتبع البحث المنهج الوصفي التحليلي والمنهج المسحي من خلال جمع البيانات الهامة عن شبكة القنوات والمصارف القائمة، لتغطية المشاكل الرئيسية عن كل من انتشار الحشائش وتراكمات الأطماءوتحليلات التربة.وهدف البحث لبيان التفاعل بين تصريف الأطماء والطاقة، وتحديد تأثير تشغيل الخزان على مخططات معمل سكر الجزيرة والسوكيوالرهد وشمال غرب سنار.تمثلت أهمية البحث في الكشف عن وجود العديد من المشكلاتفي أساليب ادارة المياه على مستوى الحقول وما لها من علاقة باستهلاك وانتظام المداد الكهربائي بالضافةالى التصميم والصيانة الدورات الزراعية اضافة لإدارة الأعمال بما تتضمنه من بناء القدرات الذى يعتبر القلب المحرك للتطور مع من يضمهم من العلماء المختارين.من نتائج البحث أن تأهيل المشروع الزراعي يساهمفى تطويره توفرالمعدات والآلياتالتتشمل تطبيق التقانة المتقدمةوالتقانات الحديثة بما فى ذلك علوم الإحصاء مخلوطة مع التقانة الحديثةفى النماذج والمعلومات الحديثة المطبقة فى النظم الجغرافية.هذا الأسلوب عبد الطريق لتقود لحل المشاكل وتحقيق الأهداف.

الكلمات المفتاحية: تفاعل الطاقة والأطماء، المساحات المروية، خزان سنار.

Background:

Dams are mainly constructed for water harvesting. Dams and reservoirs are constructed in rivers for flood control, hydropower generation, irrigation, navigation, water supply, fishing and recreation. Among multipurpose dams, hydropower and irrigation dams are predominant. Environmental impacts and long-term morphological changes of the natural water course due to human intervention are inevitable. In the last three decades dams reservoirs were faced with the problem of sediment accumulation associated with aggradation and degradation affecting their main purposes and delaying their objectives. Recently sedimentation became a major problem that faced dams construction. Sediment at control therefore was given first priority in design consideration especially in models designs and dams implementations.Sedimentation is one of the major problems which endangers the performance and sustainability of reservoirs. It reduces the effective flood control volume. It poses hazards to navigation, changes water stage and underground water conditions. It also affects the operation of low-level outlets gates and valves, reduces stability, water quality and recreational benefits(Antila, H, 1997).

Sedimentation is a complex hydro-morphological process and is difficult to predict. It has been underestimated in the past and was perceived as a minor problem which could be controlled by sacrificing a certain volume of the reservoir for accumulation of the sediment (dead zone). However, nowadays it is of paramount importance to take design and implementation of sediment control measures into consideration in the planning, design, operation and maintenance phases of the reservoirs. It was revealed that sediment has a profound effects on the dam performance .This is clearly revealed in it effects on the relation between discharge and irrigated area; discharge and power concussion; as well as discharge and downstream scour or degradation.The current state of the art in combating this problem of reservoir sedimentation ranges from, measures which used to reduce sediment influx into reservoirs by bypassing, trapping or by watershed management, to measures which use artificial methods (dredging) or utilize natural forces (flushing and sluicing) to clear or release incoming sediment along with the flow. The application of one measure or the other depends on many factors such as the geometry of the reservoir, operational rules, characteristics of the sediment its distribution, and the possibility of the measure. The mostly practiced techniques are sediment flushing and sluicing which is the dredging limited to clearing of blocked hydropower intakes or sediment removal (Loman1994) . However, with exception of few cases, these methods are either claimed to be inefficient or cost prohibitive. For example the cost of restoring lost storage by conventional dredging, without the additional cost of providing disposal areas and containment facilities, varies from $2 to $3 per cubic meter (Mahmood, 1987) . It is well known that sedimentation has often greatly reduced and endangered the live storage of many existing reservoirs coupled with the limitations of the existing sediment control measures.

Objective:

General Objective:

Assess sediment impact on irrigation canals networks with optimal consumptive use of irrigation water and power consumption.

Specific objectives:

1. Indicate the interaction among discharge sediment and power.
2. Determine impact of the Reservoir operation on the schemes of the Gezira, Suki, Rahad, and North West Sennar Sugar Factory.
3. Indicate the erosion occurring during flood season.
4. Suggest some recommendations to measures that can be taken to reduce the amount of deposited sediment.

Area of the study:

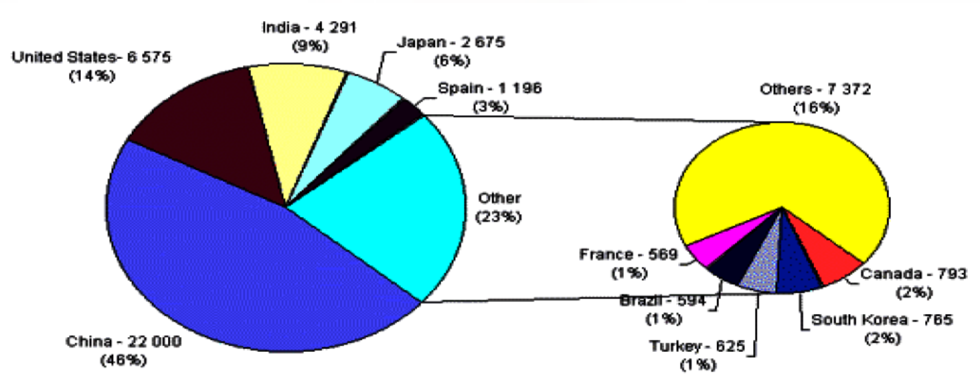
The area of study is the Gezira scheme inside the Gezira State which lies in the core of the Sudan.The Gezira State is connected with the other states of the Sudan by highways, waterways, as well as air plains, both national and international. The climate is poor Savanna, with temperatures ranging from 18 in winter to 45 in summer, and rainfall average of 250 mm annually.

Literature Review:

Dams:

Dams have been accepted as a means of meeting the need for water. Energy services are the long-term, strategic investments with ability to deliver multiple benefits. The benefits are typical of all large public infrastructure projects, while other benefits are unique to dams and specific to particular projects. Regional development, job creation, and fostering of an industry base with export capability are most often cited as additional considerations for building large dams. Other important purposes include creating income from export earnings. Application is either through direct sales of electricity or by selling cash crops or processed products from electricity-intensive industry. Clearly, dams can play an important role in meeting people's needs (WCD, 2000) . Hydropower accounts for more than 90% of the total electricity supply in 24 countries, such as Brazil and Norway(Abdel-Haleem, Ibrahim, 2009).

Half of the world's large dams are built exclusively for irrigation, and dams are estimated to contribute 12 to 16% of world food production. In addition, in at least 75 countries large dams have been built to control floods. For many nations, dams remain the largest single investment project in the country. These hydropower, irrigation, water supply and flood control services were widely seen as sufficient to justify the significant investments made in dams, and other benefits were often cited as well. These included the impact of economic properties on a region due to multiple crops, rural electrification and the expansion of physical and social infrastructure such as roads and schools. The benefits were seen as self-evident, when balanced with the construction and operational costs in economic and financial terms . These benefits were seen to justify dams as the most competitive option (WCD, 2000). Figure (1) is WCD estimates, based on ICOLD.



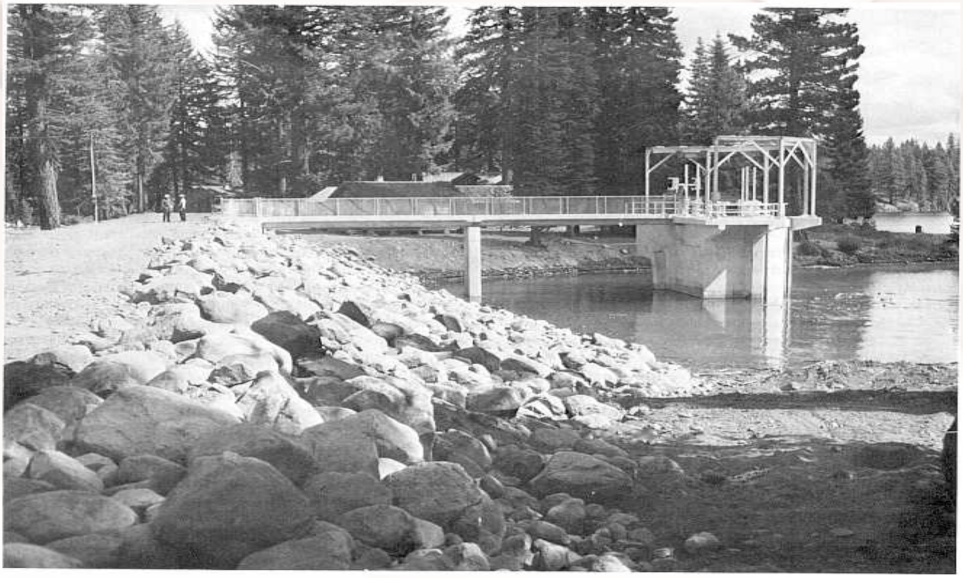
FigNo.(1): WCD Estimates, Based on ICOLD

There are 45 000 large dams in the world today. A large dam is defined as a dam with a height of 15 m or more from the foundation, or a height of 5 m or more but with a reservoir volume of more than 3 millions cubic meters. Dam construction is one of few attractive options of many nations and investors in the last decades. Their contribution to economic growth cannot be denied, but the impacts were also recognized on environment and human beings(WCD, 2000).

Classification of Dams Types:

Dams may be classified into a number of different categories, depending upon the purpose of the classification. For the purposes of this study, it is convenient to consider three broad classifications.Dams are classified according to their use, their hydraulic design, or the material of which they are constructed(Braga, 2002).

Storage dams are constructed to impound water during periods of surplus supply for use during periods of deficient supply. These periods may be seasonal, annual, or longer. Many small dams impound the spring runoff for use in the dry summer season. Storage dams may be further classified according to the purpose of the storage, such as water supply, recreation, fish and wildlife, hydroelectric power generation, irrigation, etc. The specific purpose or purposes to be served by a storage dam often influence the design of the structure and may establish criteria such as the amount of reservoir fluctuation expected or the amount of reservoir seepage permitted. shows a small earth fill storage dam, and figure (2) shows a concrete gravity structure serving both diversion and storage purposes.



Diversion dams are ordinarily constructed to provide head for carrying water into ditches, canals, or other conveyance systems. They are used for irrigation developments, for diversion from a live stream to an off-channel-location storage reservoir, for municipal and industrial uses, or for any combination of the above. Detention dams are constructed to retard flood runoff and minimize the effect of sudden floods.Detention dams consist of two main types. In one type, the water is temporarily stored and released through an outlet structure at a rate that does not exceed the carrying capacity of the channel downstream. In the other type, the water is held as long as possible and allowed to seep into pervious banks or into the foundation. The latter type is sometimes called a water-spreading dam or dike because its main purpose is to recharge the underground water supply. Some detention dams are constructed to trap sediments; these are often called debris dams. Although it is less common on small projects than on large developments. Dams are often constructed to serve more than one purpose. Where multiple purposes are involved, a reservoir allocation is usually made to each distinct use. A common multipurpose project combines storage, flood control, and recreational uses(Mahgoub, 2013).

Forces on Gravity Dam:

1. Gravity (weight of dam):

$$W = V \times \gamma ---(2.1)$$

Where:-

$V = Volume \quad ft^3$

$\gamma =$ Specific weight of material $\frac{Lb}{ft^3}$

2. Hydrostatic pressure:-

$$H_h = \frac{\gamma h_2}{2} ---(2.2) \rightarrow (Horizental \text{ component})$$

Where:-

h = Depth of water at the section (ft)

$\gamma =$ Specific weight of material $\frac{Lb}{ft^3}$

$$H_V = \frac{\gamma V}{h} ---(2.3) \rightarrow (Vertical \text{ component})$$

f^3 Where:-

V = Volume of the dam at that point

3. Uplift Pressure:-

Dams are subjected to uplift force (U) under their bases. The uplift acts upward.

$$U = \frac{1}{2}\gamma_\omega hB ---(2.4)$$

Where:-

B = The width of the base of the dam.

$\gamma_\omega =$ Specific weight of water.

4. Wave Pressure:

The upper part of the dam (above the water level) is subjected to the impact of waves. The maximum wave pressure P_V per unit width is:-

$$P_V = 2.4\gamma_\omega h_w ---(2.5)$$

Where:-

h_w = The wave height

5. Body Force:-

Body force P_{em} acts horizontally at the center of gravity and is calculated as:

$$P_{em} = \alpha \text{ W-------- } (2.6)$$

Where:-

α = Earthquake coefficient ,taken as 0.2 for practical reasons.

W = Weight of the dam.

6. Ice pressure:

Pressure created by thermal expansion exerts thrust against upstream face of the dam. This is not applicable in arid regions.

Hydropower Characteristics:

The water of rivers and streams flows down from places of higher elevations to those with lower elevations, and loose their potential energy and gain kinetic energy. (Peter F., March, 1999, pp.55-47). (Mosonyi, Emil (1991).

The main components of a hydropower system are power plants, water reservoirs and the water channels between, which form a network-type system. The reservoirs in the hydropower system can be divided into two categories; seasonal reservoirs and plant reservoirs. (Vilkko, M. 1999). (Antila, H. (1997).

The water channel can represent the main water route between reservoirs and power plants or the spillage route of a power plant. Each main water route consists of one or more parallel water channels. In real life, the time delays depend on the volume of water running along the water route. (P. M. Anderson, 1977). D. B. Arnautovic and D. M. Skataric, September 1991).

Hydropower generation is based on the potential energy of water. This potential energy is converted into mechanical energy by a hydro turbine. The mechanical energy is converted further to electrical energy by a generator.

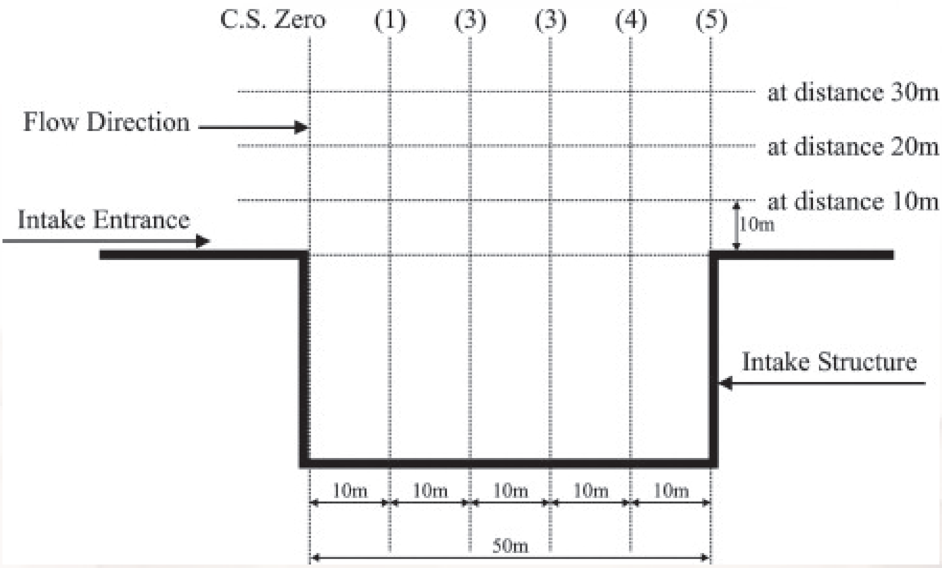
Methodology Materials and equipment's used

Road Map:

Methodology is the road map using materials and equipment's to analyze the problems. The problems are intakes reduced hydropower. Furthermore the problems are clearly coupled with sediment transportation, knitted with decreasing cultivated areas, as well as complexity in operation, and river bank erosion .

New Tebbin Power Plant (NTPP) was investigated as a case study, in the Hydraulics Research Institute (HRI) experimental hall, the National Water Research Center (NWRC). Figure (3) present the bed level deformations measurements and the location of velocity cross-sections measurements , respectively.

In strategic perspective and options assessment of Blue Nile multipurpose development eastern Nile water resource modeling using Mike Basin,AsegdewGashaw ,researcher in AAU/Intern, ENTRO indicated that there are a number of dams planed in the upper Blue Nile (Abay) river basin. He considered the reservoirs:- Karadobi , Bekoabo,Mendia, Gerd, TekezeEthiopia; Rosaries, Sennar, Merewe, Jebel Aluia , Kashim El GibraSudan;and HAD Egypt.



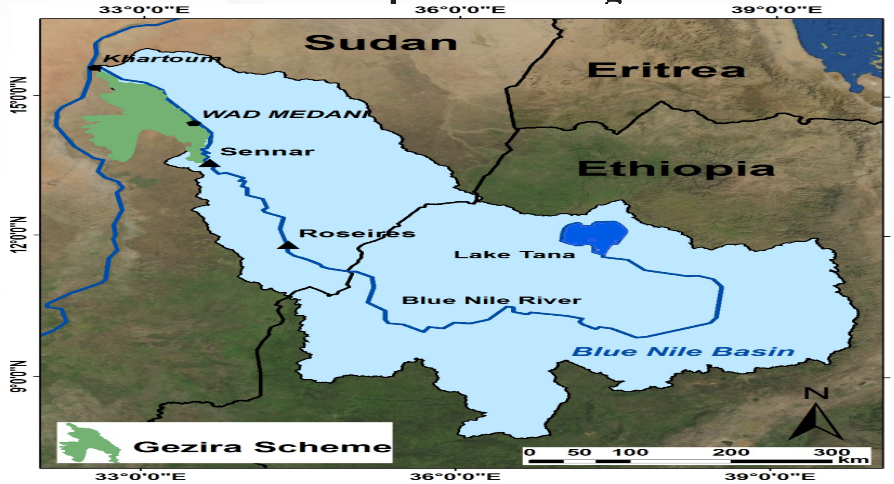
FigNo.(3): Location of the Bed Level Deformations Measure-

ments

Upstream Downstream Aggradation Degradation :

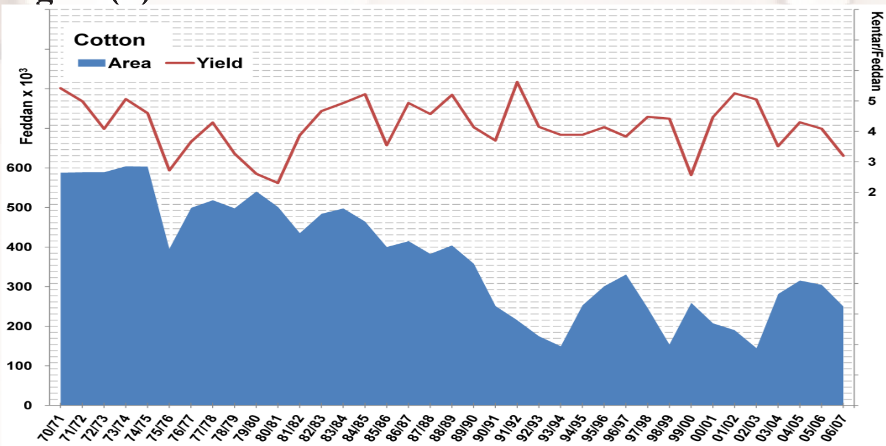
Black, Richard (2009-09-21),indicated That the mass balance between sediment being transported and sediment in the bed can be estimated by change in elevation.. Aggradational environments are often undergoing slow subsidence which balances the increase in land surface elevation due to aggradation. In another example, the quantity of sediment entering a river channel may increase when climate becomes drier. The drier conditions cause river flow to decrease at the same time as sediment is being supplied in greater quantities, resulting in the river becoming choked with sediment.

Sediment Assessment And Optimized Irrigation Water:



Islam Al Zayed1et.al.in an analysis of irrigation efficiency using comparative performance indicators, conducted a case study of Gezira Scheme, Sudan.Indicated that previous researchers revealed that Gezira Scheme was wasting irrigation water, there was always poor distribution and inadequate irrigation management .With the objective to assess the irrigation performance for Gezira Scheme, they relied on their argument that irrigation indicators improve irrigation management. figure (4) and figure (5) represent the area of study of the Gezira Scheme boundaries.

FigNo.(4):Area Of The Gezira Scheme Boundaries



FigNo.(5): Cotton Production

Rouseires Dam Operation And Maintenance Difficulties:

The dam in 1966 initial capacity of 3.024 km3 at level 480 m to be used for irrigation water supply as first priority, and hydropower generation comes as the second priority . Figure (6) is the location of the Rosaries Dam and Eddiem Station within Blue NileRiver,and figure (7) is the longitudinal profile of the Blue NileRiver from Rosaries Dam to KhartoumCity.

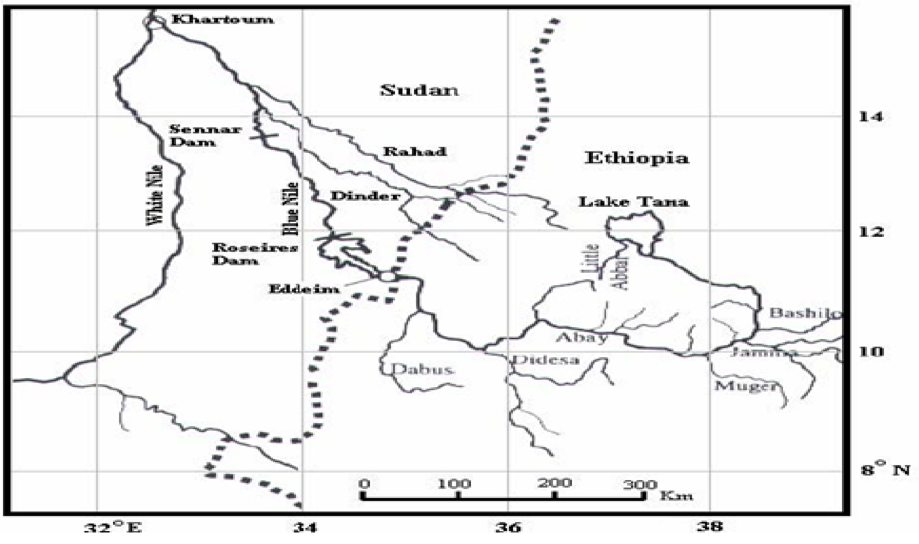


Fig. No. (6): Location In Blue Nile River

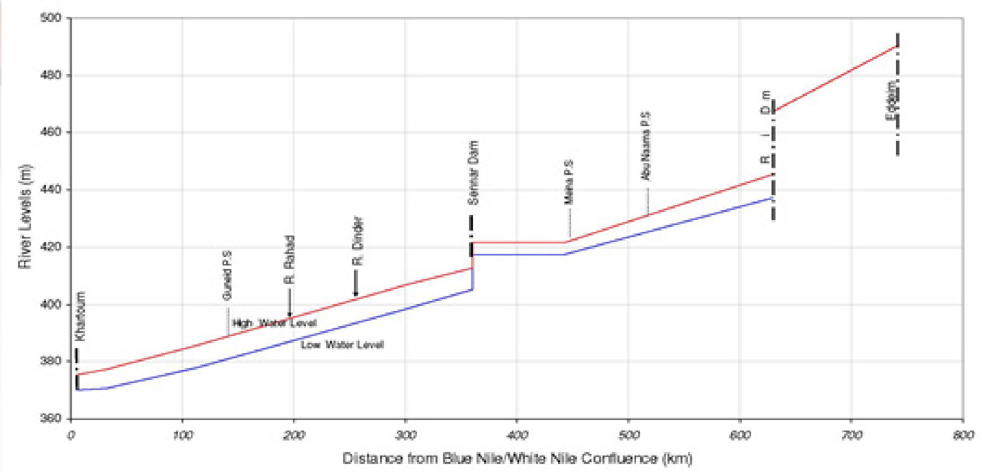


Fig. No. (7): Blue NileRiver Longitudinal Profile From Rosaries Dam To Khartoum City

Dam heightening was accompanied with extension in earth embankment bringing the total length of the dam to about 25 km. A special operation strategy was applied to reduce the siltation (UNESCO Chair in Water Resources, 2011). The main inflow to the reservoir is monitored at Eddiem Gauging Station 102 kms south-east of Rosaries dam on the Ethiopian Sudanese border.

Water is stored in Sennar reservoir for the following purposes:

1. Frequent use to supplement the natural flow of the Blue Nile.

a) Satisfy requirements of irrigation from reaches upstream or downstream Sennar Dam.

b) Maintain through Sinnar dam power station so far as may be possible the flows of water requisite for the generation of power. For this purposes, the flow passed downstream from Sinnar Dam in the irrigation season should normally be not less than 8 million m3 per day.

c) Maintain minimum flow of the river to Gunaid of 5 millions m^3/day

When possible with at least 3.5 millions m^3/day .

2. Ensure command of the Gezira and Managil canals by gravity,throughout the irrigation season,as well as other times when required.

3. Maintain suitable heads for power generation from Sennar Dam,as far as possible.

In order to restrict the deposit of sediment in the reservoirs during the period of high flood in July and August, at this time no more water is kept stored in Sennar and Roseires reservoirs no more than is necessary. The programs of filling are designed accordingly on stored water during the period of shortage. The rate of lowering of either reservoir should at no time exceed certain limits, defined in their respective "operation manuals", intended to avoid the risk of slips in the embankment sections of the dams (MOIWRS, 1968).

Data collection and analysis:

Hydraulic Models Theory:

Generally hydraulic models are of two types. Those designed to solve a special hydraulic problem as for example a definite reach of a known river, and those designed for research for establishing hydraulic laws applicable to special problems within the field of river engineering. The first type produces qualitative results only applicable to known prototype river, while the second type produces quantitative results applicable to any prototype involving the same special problem with the same hydraulic laws. Unfortunately, the former cannot be applied, because a large hydraulic laboratory is needed which is not available. Similarly the latter cannot be applied because of lack of sophisticated equipment's usually needed in such case. However simple conceptual mathematical models using the standing computers strong SPSS techniques can be applied.

SPSS Theory And Application:

Mathematical models were developed to predict the effects of hydrological and morphological events. Field data for such events are very difficult to obtain. Hence data is vitally needed to verify these mathematical models.

Use of Dimensional Analysis:

Physical laws are expressed in terms of certain characteristic parameters governing the behavior of the phenomenon completely.

These parameters will produce quantitative properties of the phenomenon.

A property (A), of any phenomenon can be expressed in terms of all or some of the (n), characteristic parameters of the phenomenon, in a functional relation of the form:-

$$A = \int_A (x_1, x_2, x_3 \ldots\ldots x_n) \text{-------} (4.1)$$

By definition various properties $A_1, A_2, A_3, A_4, \ldots\ldots\ldots A_n$ of the same phenomenon, are various functions of the (n) characteristic parameters of the phenomenon. It is not necessary that all the (n) characteristic parameters of the phenomenon are functions of every property of the phenomenon. These characteristic parameters are each expressible in terms of the basic dimensions Mass M ,Length L , Time T ……etc. It is well known that correct expression of a natural law satisfies dimensional homogeneity. The dimensional parameters are used to form the so called "Complete set of dimensionless products." According to Buckingham π theorem, which is based on dimensional homogeneity, the (n) dimensional parameters will have a general equation expressed as a function of (n -m) ,dimensionless π terms, where (m) being the basic dimensions in terms of which the (n) parameters are given. Each dimensionless π term will have

$(m+1)$ parameters of which only one need be changed(REF). The dimensionless version of equation (4.1) is:-

$$\pi_A = \int_A \left(\pi_1, \pi_2, \pi_3 \ldots\ldots \pi_{(n-m)} \right) --- (4.2)$$

The parameters involved can be classified into three main categories.

a) Geometrical Parameters;-

I. Width of the channel upstream the dam B

II. Agricultural area downstream A

III. Channel bed slope i

b) Flow Parameters:

I. Upstream approaching velocity V

II. Channel Water depth upstream the dam D

III. Sour depth downstream d_S

IV. Acceleration of gravity g

V. Density of water ρ

VI. Dynamic viscosity of water μ

VII. Discharge Q

VIII. Power Generated Pow

c) Sediment Parameters:

I. Medium grain of sediment d_{50}

II. Standard deviation σ

III. Sub wtsed

σ, and γ_{Sub} can be defined as follows:-

$$\sigma = \frac{1}{2}\left(\frac{d_{84}}{d_{60}} + \frac{d_{50}}{d_{16}}\right) --- (4.3)$$

$$\gamma_{Sub} = g\left(\rho_s - \rho_\omega\right) --- (4.4)$$

Where:

d_{84} = Grain size of which 84 % is finer.

d_{60} = Grain size of which 60 % is finer

d_{50} = Grain size of which 50 % is finer.

d_{16} = Grain size of which 16 % is finer.

ρ_s = Density of sediment material.

ρ_ω = Density of water.

Furthermore, in any study involving flow around any obstruction, the effects of both shear stress and fall velocity are not to be ignored. These two parameters are usually used to compute dimensions of physical models. The shear stress can be expressed as:-

$$\tau = \int\left(\rho g D S\right) --- (4.5)$$

Similarly the fall velocity can be expressed as :-

$$W_s = \int\left(d_{50}, g, \mu, \gamma_{sub}, C_D\right) --- (4.6)$$

Also expressed as :-

$$W_s = \sqrt{\frac{4(s-1)gd}{3C_D}}$$

Where:-

C_D = Drag coefficient.

The slope of the channel i , the standard deviation σ ,are dimensionless. To obtain dimensionless groups from the remaining parameters, the dimension of each parameter (M, L, T) are displayed in matrix form .Each column consists of the exponent in the dimensional expression for the corresponding parameter as given in the matrix form table (1).

Table No.(1): Matrix Form of Dimensional Parameters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	B	A	V	D	d_s	g	ρ	μ	Q	P	d_{50}	Q_s	γ_s	τ	W_s
M	0	0	0	0	0	0	1	1	0	1	0	1	1	1	0
L	1	2	1	1	1	1	-3	-1	3	2	1	1	-2	-1	1
T	0	0	-1	0	0	-2	0	-1	-1	-3	0	-3	-2	-2	-1

The above matrix is (3×15) matrix of rank (3).The number of the dimensionless groups is the number of the parameters (n),minus the rank of the matrix $(r=3)$.The number of the dimensionless π terms is $(15-3=12)$.It is necessary to obey the matrix rule to insure that the above (3×15) matrix has rank (3).The matrix has a determinant of (3), columns and (3) rows. If the determent has an extension value greater than zero, the rule of the matrix to be (3),will be satisfied. Choosing $\gamma_s, \tau, and\ W_s$ as the selected determinant its value is calculated as follows as given in table (4.2),of the determinant taken from the matrix form of table (4.1).

Table No.(2): Determinant Taken From The Matrix Table (1).

1	1	0
-2	-1	1
-2	-2	-1

$$\Delta = 1\times[(-1\times-1)-(-2\times1)] = 1\times[(1)-(-2)] = 3$$

From the matrix showing the parameters, the homogenous linear equations, whose coefficiets, are number of the rows of the matrix can

$$k_7 + k_8 + k_{10} + k_{12} + k_{13} + k_{14} = 0 --- (4.7) --- [M] --- (a)$$

$$k_1 + 2k_2 + k_3 + k_4 + k_5 + k_6 - 3k_7 - k_8 + 3k_9 + 2k_{10} + k_{11} + k_{12} - 2k_{13} - k_{14} + k_{15} = 0 --- (4.8) --- [L] --- (b)$$

$$-k_3 - 2k_6 - k_8 - k_9 - 3k_{10} - 3k_{12} - 2k_{13} - 2k_{14} - k_{15} = 0 --- (4.9) --- [T] --- (c)$$

Again choosing $\gamma_s, \tau, and\ W_s$ as the repeating variables, and. solving for their coefficients $(k_{13}, k_{14}, and\ k_{15})$ in terms of the other $ks(k_1\ to\ \mathrm{k}_{12})$:-

Gave the solution:-

$$K_{13} = K_1 + 2K_2 + K_4 + K_5 - K_6 + K_8 + 2K_9 + 2K_{10} + K_{11} + K_{12}$$

$$k_{14} = -k_1 - 2k_2 - k_4 - k_5 + k_6 - k_7 - 2k_8 - 2k_9 - 3k_{10} - k_{11} - 2k_{12}$$

$$k_{15} = -k_3 - 2k_6 + 2k_7 + k_8 - k_9 - k_{10} - k_{12}$$

Substituting these values in the matrix give the solution in table (4.3).

Hence as shown in table (4.3) ,the twelve (12), dimensionless groups are calculated as given below:-

$$\pi_1 = \frac{B\,\gamma_s}{\tau} \qquad \pi_2 = \frac{A\,\gamma_s^2}{\tau^2} \qquad \pi_3 = \frac{V}{W_s} \qquad \pi_4 = \frac{D\,\gamma_s}{\tau}$$

$$\pi_5 = \frac{\mathrm{d_s}\gamma_s}{\tau} \qquad \pi_6 = \frac{\mathrm{g}\tau}{\gamma_s \mathrm{W_s^2}} \qquad \pi_7 = \frac{\rho W_s^2}{\tau} \qquad \pi_8 = \frac{\mu\gamma_\mathrm{s}}{\tau^2}\mathrm{W_s}$$

$$\pi_9 = \frac{\mathrm{Q}\,\gamma_s^2}{\tau^2 W_s} \qquad \pi_{10} = \frac{\mathrm{P}\,\gamma_s^2}{\tau^3 \mathrm{W_s}} \qquad \pi_{11} = \frac{d_{50}\gamma_s}{\tau} \qquad \pi_{12} = \frac{Q_s\gamma_s}{\tau^2 \mathrm{W_s}}$$

Furthermore adding the slope of the channel i ,and the standard deviation σ , which are dimensionless? The total number of the the dimensionless groups will be fourteen (14).

$\pi_{13} = i \qquad \pi_{14} = \sigma$

These equations can be put in the form of equation (4.2):-

$$\pi_0 = \int_A \left(\frac{B\gamma_s}{\tau}, \frac{A\gamma_s^2}{\tau^2}, \frac{V}{W_s}, \frac{D\gamma_s}{\tau}, \frac{d_s\gamma_s}{\tau}, \frac{g\tau}{\gamma_s W_s^2}, \frac{\rho W_s^2}{\tau}, \frac{\mu\gamma_s W_s}{\tau^2}, \frac{Q\gamma_s^2}{\tau^2 W_s}, \frac{P\gamma_s^2}{\tau^3 W_s}, \frac{d_{50}\gamma_s}{\tau}, \frac{Q_s\gamma_s}{\tau^2 W_s}, i, \sigma \right) --- (4.7)$$

The above is the method of calculating a complete set of dimensionless groups of any given set of parameters. Use of standard products can be used instead of calculations. For π to be dimensionless the exponents of M,L,and T must be equal to zero as in the equations of the ks.Theseks equations possess an infinite number of solutions. Any values can be assigned to $k_1, k_2, k_3.....k_{12}$ and the equations solved for the remaining unknowns. This produces an arbitrary trivial solution, however, it can be anticipated that a complete set of dimensionless groups is always obtained. Such solution is known as linear combination of solutions of ks . To obtain solutions which are linearly independent on each other, the fundamental system of solutions has to be obtained. The 13th, 14th and 15th columns in the matrix of solutions are the coefficients in the equations of $k_{13}, k_{14}, and, k_{15}$. The first twelve (12) columns of the matrix of solutions, consist of zero values except the ones in the principle diagonal. Alternatively the solution can be written by inspection of the ks equations. Examination of the determinant on the right hand side of the matrix indicates that its rank is 3 This constitute a fundamental system of $(n-r)$ solutions. Each raw is a set of dimensionless group. The first variable B occurs only in π_1 ,the second variable A occurs only in π_2 ,and so on.

The resulting equation is the equation developed in order to solve the problems of the study and fulfill the objectives as well.

Table No.(3): Dimensionless π Parameters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	B	A	V	D	d_S	g	ρ	μ	Q	P	d_{50}	Q_s	γ_s	τ	W_s
π_1	1	0	0	0	0	0	0	0	0	0	0	0	1	-1	0
π_2	0	1	0	0	0	0	0	0	0	0	0	0	2	-2	0
π_3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	-1
π_4	0	0	0	1	0	0	0	0	0	0	0	0	1	-1	0
π_5	0	0	0	0	1	0	0	0	0	0	0	0	1	-1	0
π_6	0	0	0	0	0	1	0	0	0	0	0	0	-1	1	-2
π_7	0	0	0	0	0	0	1	0	0	0	0	0	0	-1	2
π_8	0	0	0	0	0	0	0	1	0	0	0	0	1	-2	1
π_9	0	0	0	0	0	0	0	0	1	0	0	0	2	-2	-1
π_{10}	0	0	0	0	0	0	0	0	0	1	0	0	2	-3	-1
π_{11}	0	0	0	0	0	0	0	0	0	0	1	0	1	-1	0
π_{12}	0	0	0	0	0	0	0	0	0	0	0	1	1	-2	-1

Significance Of Dimensionless Groups;-

In practice some dimensionless groups are more useful than others. Transformation may bring about an equation:-

$\pi = \int(\pi_1, \pi_2, \pi_3 .....\pi_n)$; into a more tractable form .This transformation should as much as possible satisfy the researcher desire in obtaining dimensionless groups that are possible to be controlled, while keeping others constant. This can be achieved if in the dimensional matrix, the dependent variable is set first, followed by that which can be regulated easily, followed by the next easiest to regulate and so on. This is difficult because often a few of the variables can not be regulated. When a variable has a negligible influence of the phenomenon under study the dimensionless group containing the variable can be discarded. However if that variable is repeated in more than one dimensionless group it is necessary to change to another complete set of dimensionless groups. The new dimensionless groups must be independent on each others, and equal in number to the original set of groups. From a given set of dimensionless groups as equation (4.7);it is possible to form various complete sets of dimensionless groups. Accordingly equation (4.7); is transformed to the form:-

$$\frac{Q\gamma_s^2}{\tau^2 W_s}, = \int_A \left(\frac{P\gamma_s^2}{\tau^3 W_s}, \frac{Q_s\gamma_s}{\tau^2 W_s}, \frac{A\,\gamma_s^2}{\tau^2}, \frac{B\gamma_s}{\tau}, \frac{V}{W_s}, \frac{D\gamma_s}{\tau}, \frac{d_s\gamma_s}{\tau}, \frac{g\tau}{\gamma_s W_s^2}, \frac{\rho W_s^2}{\tau}, \frac{\mu\gamma_s W_s}{\tau^2}, \frac{d_{50}\gamma_s}{\tau}, i, \sigma \right) --- (4.8)$$

The dimensionless groups $\frac{B}{D}, i\frac{A\tau^4 W^4}{\gamma_s^6}$ define the geometry of the system. The groups $\frac{V}{W_s}, \frac{d_s\gamma_s}{\tau}, \frac{Q\gamma_s^2}{\tau^2 W_s}$;define flow characteristic and pattern within the system.

The group $\frac{d_{50}\gamma_s}{\tau}\ \frac{Q_s\gamma_s}{\tau^2 W_s}$ define sediment motion,

While the group $\frac{P\gamma_s^2}{\tau^3 W_s}$ defines the power generation .

Consequently equation (4.8) can be written in any form similar to that of equation (4.2).

Hence for example putting, $\frac{A\tau^4W^4}{\gamma_s^6}$, or, $\frac{Q_s\gamma_s}{\tau^2W_s}$,or, $\frac{P\gamma_s^2}{\tau^3W_s}$,as the subject equation (4.8) becomes;-

$$\frac{A\gamma_s^2}{\tau^2} = \int_A \left(\frac{P\gamma_s^2}{\tau^3W_s}, \frac{Q_s\gamma_s}{\tau^2W_s}, \frac{Q\gamma_s^2}{\tau^2W_s}, \frac{B\gamma_s}{\tau}, \frac{V}{W_s}, \frac{D\gamma_s}{\tau}, \frac{d_s\gamma_s}{\tau}, \frac{g\tau}{\gamma_sW_s^2}, \frac{\rho W_s^2}{\tau}, \frac{\mu\gamma_sW_s}{\tau^2}, \frac{d_{50}\gamma_s}{\tau}, i, \sigma \right) --- (4.9)$$

$$\frac{Q_s\gamma_s}{\tau^2W_s} = \int_A \left(\frac{P\gamma_s^2}{\tau^3W_s}, \frac{Q\gamma_s^2}{\tau^2W_s}, \frac{A\gamma_s^2}{\tau^2}, \frac{B\gamma_s}{\tau}, \frac{V}{W_s}, \frac{D\gamma_s}{\tau}, \frac{d_s\gamma_s}{\tau}, \frac{g\tau}{\gamma_sW_s^2}, \frac{\rho W_s^2}{\tau}, \frac{\mu\gamma_sW_s}{\tau^2}, \frac{d_{50}\gamma_s}{\tau}, i, \sigma \right) --- (4.10)$$

$$\frac{P\gamma_s^2}{\tau^3W_s} = \int_A \left(\frac{Q\gamma_s^2}{\tau^2W_s}, \frac{Q_s\gamma_s}{\tau^2W_s}, \frac{A\gamma_s^2}{\tau^2}, \frac{B\gamma_s}{\tau}, \frac{V}{W_s}, \frac{D\gamma_s}{\tau}, \frac{d_s\gamma_s}{\tau}, \frac{g\tau}{\gamma_sW_s^2}, \frac{\rho W_s^2}{\tau}, \frac{\mu\gamma_sW_s}{\tau^2}, \frac{d_{50}\gamma_s}{\tau}, i, \sigma \right) --- (4.11)$$

Also equations (4.8),itself as well as equations (4.9) to (4.11) can be reduced discarding the ineffective groups.

This gives the following equations:-

$$\frac{Q\gamma_s^2}{\tau^2W_s}, = \int \left(\frac{P\gamma_s^2}{\tau^3W_s}, \frac{Q_s\gamma_s}{\tau^2W_s}, \frac{A\gamma_s^2}{\tau^2} \right) --- (4.12)$$

$$\frac{A\gamma_s^2}{\tau^2} = \int \left(\frac{P\gamma_s^2}{\tau^3W_s}, \frac{Q_s\gamma_s}{\tau^2W_s}, \frac{Q\gamma_s^2}{\tau^2W_s} \right) --- (4.13)$$

$$\frac{P\gamma_s^2}{\tau^3W_s} = \int \left(, \frac{Q_s\gamma_s}{\tau^2W_s}, \frac{A\gamma_s^2}{\tau^2}, \frac{Q\gamma_s^2}{\tau^2W_s} \right) --- (4.14)$$

$$\frac{Q_s\gamma_s}{\tau^2W_s} = \int \left(\frac{P\gamma_s^2}{\tau^3W_s}, \frac{Q\gamma_s^2}{\tau^2W_s}, \frac{A\gamma_s^2}{\tau^2} \right) --- (4.15)$$

Tabulation of Measured and Computed Data:

The measured cultivated areas were collected from the records of the past years respective fields of the schemes. Total year Cultivated Area in all Gezira,Managil,and Sugar (Sennar Guneid),are recorded in a table.Theyare;Wheat , Sorghum, ground nut ,Cotton, and Sugar, are as in table (4.4) in all the schemes downstream Sennar dam.

Table No.(4): The Area For The Five Crops Downstream Dam

Year	Discharge Q $\times 10^9 m^3$ (*milliard*)	*Power* $P_{watt} \times 10^6$	Sediment Q_s $m^3 \times 10^6$	*Area* $\times 10^6 m^2$
2005	46.5	2.248	32.31	4564
2006	61.1	1.055	32.04	4794
2007	61.2	2.323	15.75	3420
2008	57.9	1.870	32.31	3559
2009	37.8	2.360	24.56	3999
2010	56.2	1.608	34.71	4017
2011	47.7	1.109	33.91	5466
2012	51.9	2.864	26.97	4044
2013	57.5	3.169	17.09	3488
2014	64.0	2.828	21.16	4298
2015	42.5	3.412	17.09	3608

The discharge (Q) is also measured in $m^3/\sec$ (m^3/year), together with the water depth and width $(D \text{ and } B)$ upstream the dam in m (average year) , as well as the scour depth downstream the dam below the water surface d_s in m (average day or month or year,which is not available) .The other measured parameters are d_{50} , in m (average day or month or year) , the fall velocity w_s,in $m/\sec$,the power generation in GWH $\left(\left(\frac{kgr.m^2}{\sec^3}\right)\right)$,and the sediment in $\frac{kgr\ m}{\sec^3}$.The computed parameters are the velocity in $m/\sec$,the wetted parameter P in m ,the hydraulic radius R in m ,shear velocity V_* in $m/\sec$, τ = shear stress in $\frac{kgr}{m.\sec^2}$ .Taking all averages in day or month or year.

It is important to note here that the values of the parameters $\gamma_s, \tau,$ and W_s Where not easily obtainable. A visit to the responsible personnel in the old Ministry of Irrigation, among whom were the past resident engineers of Sennar and RoseiresDamas, gave the following values.

$$\gamma_s = \frac{1500 \ \text{kgr}}{\text{m}^2 \sec^2}; \quad \tau = \frac{0.52 \ \text{kgr}}{\text{m} \sec^2}, and \quad W_s = 0.22 \ \text{m/sec}$$

Being the only available data for the time being the researcher used them in the present study, which may attribute to some errors. However, being very important parameters the researcher recommended their availability in future studies, including their variation in consequecative years. Furthermore the sediment data consisted of suspended sediment only. As it is well known that the bed load as a proportion of the suspended is in the range from 5 % to 25 %,it was increased by an amount of 20%,in table (4.5),which will also be a source of error.The data of the sediment is multipied by the specific gravity of 2.67 to convert the unit to cubic meteres instead of tons in table (45)..

The values of the important dimensionless quantities of equation (4.12) to (4.15) are shown in table (5) as total of the year.

Table No.(5):Measured And Computed Data

Year	$\frac{Q\gamma_s^2}{\tau^2 W_s}\times10^{20}$	$\frac{P\gamma_s^2}{\tau^3 W_s}\times10^{15}$	$\frac{Q_s\gamma_s}{\tau^2 W_s}\times10^{10}$	$\frac{A\ \gamma_s^2}{\tau^2}\times10^{15}$
2005	1.76	1.64	0.81	37.98
2006	2.31	0.77	0.81	39.89
2007	2.31	1.69	0.40	28.46
2008	2.19	1.36	0.81	29.61
2009	1.43	1.72	0.62	33.28
2010	2.13	1.17	0.88	33.43
2011	1.80	0.81	0.86	45.48
2012	1.96	2.08	0.68	33.65
2013	2.17	2.31	0.43	29.02
2014	2.42	2.06	0.53	35.76
2015	1.61	2.48	0.43	30.02

Conclusions:

1. Depletion has been reported world-wide in drought prone areas. In the Sudan yearly losses attained the range from 0.3% to 1.67%.
2. AlthoughSudan irrigated agriculture produces about 50 % of the total crop production,yet it is associated with painstaking of removing sediments from the irrigation network system and reservoirs.
3. Based on the results obtained in this research, it could be admitted that Sennar Reservoir lost a great part of its capacity due to the sedimentation problems.
4. Data from 2005 to 2015 was used to calibrate the hydrodynamic and morphodynamic model of the Sennar Reservoir, and the calibration results showed good agreements to observed data.

Recommendations:

1. Complexity in reservoir operation and maintenance coupled with downstream the dam river bank erosion, sediment deposition, insufficient irrigation water for the agricultural schemes, with problems in power generation; require urgent mitigation.
2. The assessment of the impact of sediment on irrigation water and optimization of use and consumption of water for irrigation suggested in this research are recommended.
3. Further research is required to evaluate the extend of direct and indirect impact of sedimentation on existing reservoirs where real data are available. This will bring about the understanding, through case studies.
4. Further research is required using modern sophisticated model to investigate the Sennar sedimentation problems
5. Dams and reservoirs data about soil,shear,waterdepth.. are essential tools used in reseach.It is therefore highly recommended to establish a data base recoding all relevant reseach parameters.

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