The State of the Sediments in the Sennar dam

AMANI OSMAN AHMED

Prof. Dr. Abbas Abd Alla Ibrahim

Assoc Prof.Dr. Hamad Mohamed Abu El Hassan

Abstract :

The study dealt with the state of sediments in Sennar tank. It aimed to assess the condition of the sediments in the Sennar tank, determine the effect of the sediments on the efficiency of the operation of the Sennar tank, and then learn how to remove the sediments from the Sennar tank.The importance of the study was the importance of the impact of studying the state of sediments in tank's , their impact on their work, the importance of scientifically removing them, or erecting tank's in a way that prevents the formation of sediments repeatedly at short intervals.The study followed the descriptive, analytical and exploratory approach. Among the most important results of the study, although the irrigated agriculture in Sudan produces about 50% of the total crop production, it is painstakingly related to the removal of sediments from the irrigation network system and reservoirs, based on the results obtained in this research, it can be noted that the reservoir Sennar has lost a large part of its energy due to sedimentation problems.

Keywords: State – the Sediments- theSennar Dam- lrrigation

المستخلص:

تناولت الدراسة حالة الرواسب في خزان سنار. وهدفت إلى تقييم حالة الرواسب في خزان سنار ، وتحديد تأثير الرواسب على كفاءة تشغيل خزان سنار ، ومن ثم معرفة كيفية إزالة الرواسب من خزان سنار.تمثلت أهمية الدراسة أهمية تأثير دراسة حالة الرواسب في السدود، وتأثيرها على عملها، وأهمية إزالتها بصورة علمية، أو إقامة السدود بطريقة تمنع تكون الرواسب بصورة متكررة على فترات قريبة.اتبعت الدراسة المنهج الوصفي والتحليلي والاستكشافي. من أهم

نتائج الدراسة ، على الرغم من أن الزراعة المروية في السودان تنتج حوالي 50٪ من إجمالي إنتاج المحاصيل ، إلا أنها مرتبطة بشق الأنفس بإزالة الرواسب من نظام شبكة الري والخزانات ، بناءً على النتائج التي تم الحصول عليها في هذا البحث ، يمكن علمًا بأن خزان سنار فقد جزءًا كبيرًا من طاقته بسبب مشاكل الترسيب.

الكلمات المفتاحية: ولاية الرواسب، خزان سنار، الري

Introduction:

It was revealed that sediment has a profound effects on the tank 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. Attention of researchers is must therefore be focused on the subject of reservoir sedimentation area in water resources engineering.

Objective:

1. To assess the condition of sediments in Sennar tank.
2. To determine the effect of sediments on the operating efficiency of Sennar tank.
3. To learn how to remove sediments in Sennar tank.

Literature Review:

Definition of a tank:

A tank is an engineering construction erected over a valley or depression with the aim of impounding water. tank's generally serve the primary purpose of holding water, while other structures such as ditches are used to prevent water from flowing into specific areas of the land. The tallest tank in the world is the 300-meter-high Norktank in Tajikistan.

Efforts have been combined to raise the level of water resources and provide what would ensure life on the surface of the earth through the construction of tank projects and making maximum use of them.

Clearly, tank's 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.

Classification of tank's Types:

tank's 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.tank's are classified according to their use, their hydraulic design, or the material of which they are constructed.

Storage tank's 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 tank's impound the spring runoff for use in the dry summer season. Storage tank's 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 tank 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.

tank's may also be classified as overflow or no overflow tank's . Overflow tank's are designed to carry discharge over their crests or through spillways along the crest. Concrete is the most common material used for this type of tank's . Non overflow tank's are those designed not to be overtopped. This type of design extends the choice of materials to include earth fill and rock fill tank's . Often the two types are combined to form a composite structure consisting , for example,of an overflow concrete gravity tank with earth fills dikes.

Diversion tank's 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.

Forces on Gravity tank:

1. Gravity (weight of tank):

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

Where:-

$$V = Volume \quad \text{ft}^3$$

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

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 $\frac{\text{Lb}}{\text{ft}^3}$

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

f^3 Where:-

V = Volume of the tank at that point

3. Uplift Pressure:-

tank's are subjected to uplift force (U) under their bases. The uplift acts upward.

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

Where:-

B = The width of the base of the tank.

γ_ω = Specific weight of water.

4. Wave Pressure:-

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

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

h_w Where:-

= The wave height

5. Body Force:-

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

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

α Where:-

= Earthquake coefficient ,taken as 0.2 for practical reasons.

W = Weight of the tank.

6. Ice pressure:

Pressure created by thermal expansion exerts thrust against upstream face of the tank. 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.

Sennar Reservoir:

A rocky hydroelectric tank located in Sennar State in Sudan above the Blue Nile, one of the largest tributaries of the Nile, 300 km from Khartoum. It was established in 1926 to irrigate agricultural lands in the Gezira project and to supply Khartoum with electricity. It is the oldest water tank built in Sudan.

Site selection studies were completed in 1914 AD, and the first part of the reservoir was constructed by Messrs S. Perssn& Son Ltd in partnership with the Sudanese Construction Company, and the work was completed in 1925 AD by MessrsAlessandrini&Perssn Company. The design and engineering supervision was undertaken by the English engineer Stephen "Roy" Sherlock.

The length of the tank from the east bank to the west bank is 3025 meters (9,925 feet) and its maximum height is 40 meters (130 feet).

The lake has a capacity of about 390 million cubic meters of water and extends more than five kilometers to the south.

The tank provides flow-irrigation water for the Al-Jazeera and Al-Manaqil project and raises the water level needed for irrigation projects by pumps in the Blue Nile in the lands in front and behind the tank.

The water of the reservoir is also used to irrigate agricultural projects represented in the Blue Nile agricultural companies, the Al-Suki project, the extension of Al-Manaqil, the West Sennar sugar and the Al-Rahad project.

Storage is also used to generate hydraulic electric power, whose productivity is estimated at about 14 megawatts and covers more than 80% of the state's consumption and covers the slight deficit of the national electricity network in Sudan (before the completion of the heightening of the Roseirestank in 2013).

Sennar tank and Reservoir:

As shown in figure (1)., Stephen "Roy" Sherlock, The tank is 3025 meters long, with a maximum height of 40 meters. It provides water for crop irrigation in the Al Gezira region (Prowde, 1926). Once completed, the tank was constructed on the Blue Nile River at Sennar Town some 300 kilometers south Khartoum the capital of Sudan. Construction works began in 1920 and completed on 1925/1926.Its main objective was to provide irrigation water for the

Gezira agricultural scheme to irrigate cotton and other crops. It provided irrigation water for about 60 percent of the country`s agricultural production. The tank extended over about 3.10m, i.e. over 3 km (3,025 meters) in length, and of a maximum height of 40-45m (tank Implementation Unit, 2012).

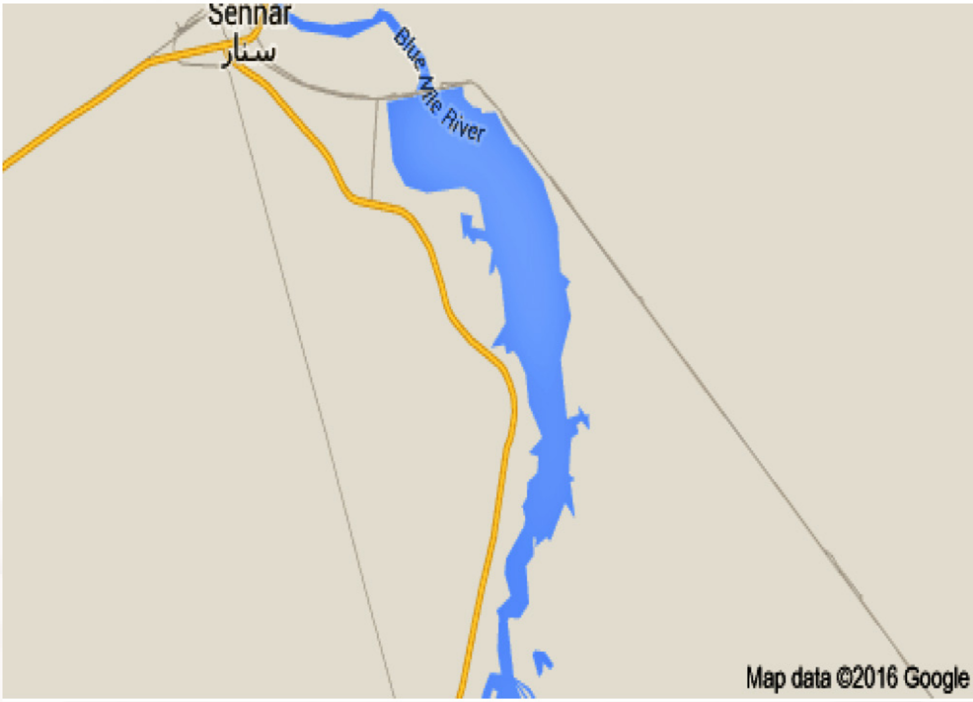
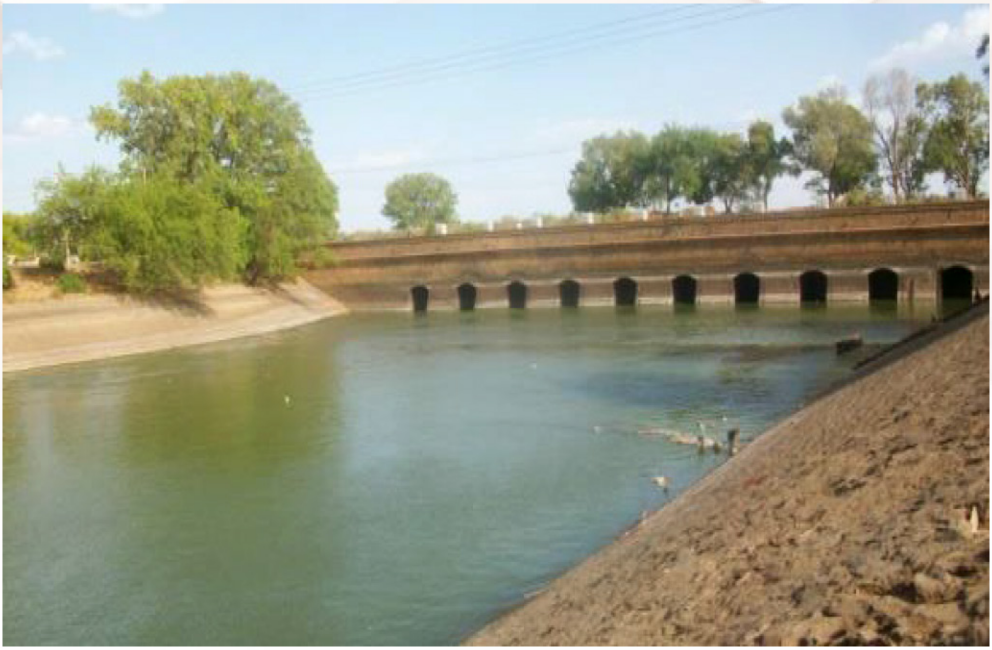


Fig. No. (1): Sinnar tank Location In Blue Nile River



Gezira main Canal was constructed with Sinnar tank in 1925, water is supplied from the reservoir through 14 gates. Figure (2) shows head works of Gezira main Canal at sinnartank.

Fig.No.(2): Head Works Of Gezira Main Canal At Sennar tank

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 tank.

b. Maintain through Sinnar tank 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 tank 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 gavity,thoughout the irrigation season,as well as other times when required.

3.Maintain suitable heads for power generation from Sennar tank,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 tank's (MOIWRS, 1968).

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 can not be applied, because a large hydraulic laboratory is needed which is not available. Similarly the latter can not be applied because of lack of sophisticated equipments usually needed in such case. However simple conceptual mathematical models using the standing computers strong SPSS techniques can be applied.

Theoretical approaches in the design of River engineering constructions are usually preferred for economical reasons. If the whole design or part of it can not be predicted by theory, it is accordingly advisable to study the performance of the whole or part of the prototype by means of a hydraulic model. A hydraulic model is a precisian device for experimental investigation of a hydro mechanical phenomenon. It is common practice to construct hydraulic model research to verify or modify the design of a hydraulic structure. In study of complex flow phenomenon, for which theory is either not available or incomplete, resort must be made to hydraulic models. In this case the model research becomes more an art than a science. It has contributed significantly in the design of hydraulic structures, training of rivers and basic hydraulic research.

Discussions:

Previous investigators have not conducted similar investigations. They conducted experimental works about discharge sediment and power. Investigator have not conducted work about cultivated areas of the different crops in schemes. Some of them conducted studies about discharge sediment and power generation, but obtained quantitative and qualitative results of certain and specific areas that can not be applied in this study.

The previous investigators have covered important studies but it was selective and not covering the parts studied by the researcher. However it was all covered in the literature review so that the study would not be incomplete. The procedures adopted by the researcher mainly rely on basic and advanced knowledge about dimensional analysis and theory of models backed with SPSS supported by the advancing knowledge of the computer analysis. Consequently it is very difficult if not impossible to apply the developed empirical equations (4.32) to (4.35) to any of the previous investigators. Equations (4.32) to (4.35) are, therefore applied to the data taken from Sennar tank only.

Discharge Aspects Relations:

the maximum demand for cotton was (1430 mm),and the water available was higher than the demand, due to inadequate rainfall moisture utilization and harvesting to reduce the need of supplemental irrigation, indicating that Gezira Scheme has low productivity.

In the present study the discharge relation with the other aspects was considered . The results to the four dimensionless groups developed by the researcher are shown in tables (1), (2), (3),and (4),respectively.

Tables No.(1): Discharge Aspects Relations $\frac{Q\gamma_s^2}{\tau^2 W_s} \times 10^{20}$

Year	Actual	Predicted	Error
2005	1.76	1.196	0.564
2006	2.31	1.198	1.112
2007	2.31	1.199	1.111
2008	2.19	1.198	0.992
2009	1.43	1.197	0.233
2010	2.13	1.198	0.932
2011	1.8	1.197	0.603
2012	1.96	1.196	0.764
2013	2.17	1.198	0.972
2014	2.42	1.197	1.223
2015	1.61	1.197	0.413

Power Aspects Relations:

This is to be conducted considering the power relation with the other aspects. The relevant equation is (4.33).

Tables No.(2): Power Aspects Relations $\frac{P\gamma_s^2}{\tau^3 W_s} \times 10^{15}$

Year	Actual	Predicted	Error
2005	1.64	1.413	0.227
2006	0.77	1.415	-0.645
2007	1.69	1.414	0.276
2008	1.36	1.415	-0.055
2009	1.72	1.414	0.306
2010	1.17	1.415	-0.245

Year	Actual	Predicted	Error
2011	0.81	1.415	-0.605
2012	2.08	1.412	0.668
2013	2.31	1.412	0.898
2014	2.06	1.411	0.649
2015	2.48	1.413	1.067

Sediment Aspects Relations:

Quantification of water uses along the Blue Nile River network using hydrodynamic model conducted by Yasir revealed that Basin area is about 330,000 km2.It required study of the water distribution along the entire Blue Nile River system.He Develop Hydrodynamic model using Sobek River to study the sediment transport.The methodology adopted consisted of a certain Mode schematization.He found that the model slightly overestimated the water level during the high flows . The model slightly overestimated the water level during the high flows. The model slightly underestimated the water level during the low flows.

In this study the power relation with the other aspects was conducted The relevant equation is (4.34)

Table No.(3):Sediment Aspects Relations $\frac{Q_s \gamma_s}{\tau^2 W_s} \times 10^{10}$

Year	Actual	Predicted	Error
2005	0.81	0.799	0.011
2006	0.81	0.808	0.002
2007	0.4	0.792	-0.392
2008	0.81	0.796	0.014

Year	Actual	Predicted	Error
2009	0.62	0.797	-0.177
2010	0.88	0.800	0.080
2011	0.86	0.811	0.049
2012	0.68	0.793	-0.113
2013	0.43	0.788	-0.358
2014	0.53	0.793	-0.263
2015	0.43	0.790	-0.360

Cultivated Area Aspects Relations:

This is to be conducted considering the power relation with the other aspects. The relevant equation is (4.35).

Table No.(4):Cultivated Area Aspects Relations $\frac{A\,\gamma_s^2}{\tau^2}\times 10^{15}$

Year	Actual	Predicted	Error
2005	37.98	13.07	24.91
2006	39.89	13.00	26.89
2007	28.46	13.11	15.35
2008	29.61	13.04	16.57
2009	33.28	13.12	20.16
2010	33.43	13.03	20.40
2011	45.48	13.02	32.46
2012	33.65	13.09	20.56
2013	29.02	13.13	15.89
2014	35.76	13.10	22.66
2015	30.02	13.16	16.86

Blockage and Power:

It can be stated that using groins and dredging as suggested and conducted by Abdel-Fattah (2004) is a partial solution for reduction of sedimentation problems at intake structures.

It can also be stated that using vanes which are similar to groins conducted by AbdelHaleem (2009) is a partial solution for reduction of sedimentation problems at intake structures. However it is better than that of Abdel-Fattah (2004), because it solved more than 50% of the sediment problem.

Using experimental results suggested by Hassanpour and Ayoubzadeh (2008), they revealed that implementing submerged vanes at 20° to 25°to the direction of the intake improved the flow into the intake reducing the sediment entering the intake. However no full solution was obtained, and when the intake angle was made 15°the inflow into the intake was reduced with increased sediment, resulting in an incomplete solution.

Similar results of field observations and laboratories experiments were obtained by Hossain et al. (2004), Odgaard (2005), SadjediSabegh (2004) and Tan Soon-Keat et al. (2005).

SayedMahgoub 2013 work using movable bed model, conducted a comprehensive model test to cover the different river flow conditions and operation modes of the power plant in sixteen (16) experiments. Introducing double rows of submerged vanes mounted vertically at an angle of 60° to the main flow direction, his work resulted in preventing sediment intrusion. Mahgoub 2013 research work is recommended to be applied in RoseiresDam,however to be applied at Sennar tank is questionable.

River Aggradation Degradation and Scour:

Black, Richard (2009-09-21) indicated that reduced aggradation contributes to increased flooding in rivers deltas. It is used in geology for the increase in land elevation, typically in a river system, due to the deposition of sediment. It occurs in areas in which the supply of sediment is greater than the amount of material that the system is able to transport, estimated as change in elevation.

In the net **Engineering112** (6): 497. doi:10.1061/(ASCE)0733-9429(1986)112:6(497),revealed that in geology, degradation refers to the lowering of a fluvial surface, such as a stream bed or floodplain, through processes Degradation is characteristic of channel networks in which either bedrock erosion is taking place, or in systems that are sediment-starved and are therefore entraining more material than is being deposited.

Hydraulic Engineering Circular No. 18Manual (HEC-18) included several techniques of estimating scour depth. Empirical scour equations for live bed scour, clear water scour, and local scour at piers and abutments. The total scour depth was determined by adding three scour components which included the long-term aggradation and degradation of the river bed, general scour at the bridge and local scour at the piers or abutments. The equations in HEC-18 over-predict scour depth for a number of hydraulic and geologic conditions. Most of the HEC-18 relationships are based on laboratory flume studies conducted with sand-sized sediments streams frequently contained much more scour resistant materials such as compact silt, stiff clay, and shale. In this research the data obtained was downstream the tank. It indicated that there was fluctuation in the water levels with fluctuation of scour and deposition downstream the tank.

SennarDam Operation And Maintenance Difficulties:

Srnnartank, completed in 1925 for irrigation as first priority, and hydropower generation as a second priority.The storage capacity has considerably been affected by siltation and is now about 30 percent less. A special operation strategy, maintaining low reservoir level and high flow velocities during the passage of the flood, is applied to reduce the siltation (UNESCO Chair in Water Resources, 2011).

Operation of reservoir depended on rules set for mainly water balance of the system among other factors, which are rarely revised during the life time of the reservoirs and Sennar is not an exception (MOIWRS, 1968).

Sennar tank, about 320 km south-east of Khartoum, in operation since 1926,Roseires tank, about 270 km upstream of Sennar tank, in operation since 1966

Currently four main irrigation schemes are supplied with water from the Blue Nile between Roseirestank and Sennar tank: These are:EsSuki Irrigation Scheme,Gezira and Managil Irrigation Schemes,NW Sennar Irrigation Scheme and,Meina Irrigation Pump Station. Between Sennar tank and Khartoum, located nearby to the confluence with the White Nile, the following irrigation schemes are supplied with Blue Nile water: El Waha Irrigation Scheme Guneid Irrigation Scheme Irrigation Pumps Schemes. Two further rivers flow into the Blue Nile in this section.

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. Although Sudan 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 morph dynamic 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 tank 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. tank's 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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