Sediment Removal from Deep Reservoir Dams by Suction and Jet Flow

Enlèvement des sédiments des barrages de réservoirs profonds par aspiration et écoulement à jet

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Abstract. One method of sediment removal from dam reservoirs is the use of submerged pumps and suction mixes of sediment and water. This method is usually considered for shallow rivers but we want to adopt this method for large dams. In this research, a system based on suction with a submerged pump structure is designed to collect fine sediments close to body of the dam from a large depth and to be transmitted by floating pipes to the margin of lake. And also, by pumping of jet fresh water flow and creating turbulence by the jet on sedimentary bed is simultaneously used to increase harvesting efficiency. The usage of simple equipment for removing fine grains near the dam body without the need for discharging of water resources is one of the essential features of this method which is suitable for arid and dry areas such as Iran. By using turbulent flow of water jet and simultaneous suction with a submerged pump, a vortices stretch is produced to suction the sediment mixture. Overall, the discharged sediment separates from water on the margin of lake to restores water to the reservoir. *Keywords*: Reservoir dams, Sediment removal, deposition, suction and jet flow.

Résumé. Une méthode d'élimination des sédiments des réservoirs de barrage est l'utilisation de pompes immergées, et de mélanges d'aspiration de sédiments et d'eau. Cette méthode est généralement envisagée pour les rivières peu profondes, mais nous souhaitons adopter cette méthode pour les grands barrages. Dans cette recherche, un système basé sur l'aspiration avec une structure de pompe immergée est conçu pour collecter des sédiments fins près du corps du barrage à une grande profondeur et pour être transmis par des tuyaux flottants jusqu'au bord du lac. De plus, le pompage du jet d'eau douce et la création de turbulences par le jet sur le lit sédimentaire sont

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utilisés simultanément pour augmenter l'efficacité de la récolte. L'utilisation d'équipements simples pour enlever les grains fins à proximité du corps du barrage sans avoir besoin de décharger les ressources en eau est l'une des caractéristiques essentielles de cette méthode qui convient aux zones arides et sèches comme l'Iran. En utilisant un jet d'eau turbulent et une aspiration simultanée avec une pompe immergée, un tronçon de tourbillons est produit pour aspirer le mélange de sédiments. Dans l'ensemble, les sédiments rejetés se séparent de l'eau au bord du lac pour restituer l'eau au réservoir. *Mots-clés* : Barrages-réservoirs, Élimination des sédiments, dépôt, succion et écoulement-jet.

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1 Introduction

Dams provide a range of economic, environmental, and social benefits, including recreation, flood control, water supply, hydroelectric power, waste management, river navigation, and wildlife habitat. Reservoirs created by dams not only suppress floods but also provide water for activities such as irrigation, human consumption, industrial use, aquaculture, and navigability. A dam can also be used to collect water or for storage of water which can be evenly distributed between locations.

Most natural river reach are approximately balanced with respect to sediment inflow and outflow. Dam construction dramatically alters this balance, creating an impounded river reach characterized by extremely low flow velocities and efficient sediment trapping. The impounded reach will accumulate sediment and lose storage capacity until a balance is again achieved, which would normally occur after the impoundment has become “filled up” with sediment and can no longer provide water storage and other benefits. Declining storage reduces and eventually eliminates the capacity for flow regulation and with it all water supply and flood control benefits, plus those hydropower, navigation, recreation, and environmental benefits that depend on releases from storage.

At any dam or reservoir where sustainable long-term use is to be achieved, it will be necessary to manage sediments as well as water. This is not a trivial challenge. Many types of sediment-related problems can occur both upstream and downstream of dams, and sediment entrainment can also interfere with the beneficial use of diverted water. Sediment can enter and obstruct intakes and greatly accelerate abrasion of hydraulic machinery, thereby decreasing its efficiency and increasing maintenance costs. Turbid density currents can carry sediments tens of kilometres along the bottom of the impoundment, eventually entering deep intakes and accumulating in front of low-level outlets.

Based on the inventory published by the International Commission on Large Dams (ICOLD, 1988) and the current rate of dam construction, as of 1996 there were about 42,000 large (over 15 m tall) dams worldwide. There are several times as many lesser structures. An overwhelming majority of these structures are designed and operated to continuously trap sediment, without specific provisions for sustained long-term use. Neither current nor projected levels of population and economic activity can be sustained if today's inventory of storage reservoirs is lost to sedimentation, and, as population and economic activity grow, reliance on the services provided by dams is increasing.

Conversion of sediment reservoirs into sustainable resources which generate long term benefits requires fundamental changes in the way they are designed and operated. It requires that the concept of a reservoir life limited by sedimentation be replaced by a concept of managing both water and sediment to sustain reservoir function. Sustainable use is achieved by applying the following basic sediment control strategies:

- Reduce sediment inflow
- Route sediments
- Sediment removal
- Provide large storage volume
- Sediment placement.

The cost and applicability of each strategy will vary from one site to another and also as a function of sediment accumulation. However, even the largest reservoirs will eventually be reduced to small reservoirs by sedimentation and, sooner or later, will require sediment management.

The amount of fresh water circulating through the hydrologic cycle is fixed, but the demand for water use has grown rapidly during the twentieth century and fresh water is becoming an increasingly scarce resource. Modern society is, above all else, a hydraulic society. Population and economic activity are increasingly tied to the diversion of fresh water to human use, particularly as agricultural expansion becomes increasingly dependent on irrigation.

When a tributary enters an impounded reach and flow velocity decreases, the sediment load begins to deposit. The bed load and coarse fraction of the suspended load are deposited immediately to form delta deposits, while fine sediments with lower settling velocities are transported deeper into the reservoir by either stratified or non-stratified flow. A reservoir on a single stream with no major tributaries and operated at a nearly constant high pool level may represent a uniformly depositional environment and represents the simplest sediment deposition pattern.

The longitudinal deposition zones in reservoirs may be divided into three main zones topset bed, fore set and bottomset as conceptually illustrated in Fig (1). Bottomset beds consist of fine sediments which are deposited beyond the delta by turbidity currents or no stratified flow in deepest area of the reservoir.

The availability of population and water for several countries is compared in Fig (2) while Iran is poor in terms of drinking water resources, since much of its area is formed by large deserts. Based on studies by Rahmanian more than 65 large dams with a total volume of around 31,000 mcm are in operation in Iran, each with a capacity >30mcm. Studies on Iranian reservoirs have shown that volume loss due to sedimentation in these impoundments has been between 0.15 and 3.94% of the initial volume per year (IWRI 2000), while average annual sedimentation in reservoirs around the world is about 1%. He investigated 10 Iranian reservoirs with varying characteristics: DEZ, SEFIDRUD, DROODZAN, JIROFT, MINAB, KARAJ, MAKOO, LATIAN, TOROGH and KARDEH Fig (3).

Dams in Iran, in addition to the need for power generation, should also facilitate the management of water supply and control. By setting up 88 large and small dams in 2007, Iran has, on average, placed nearly 2 billion cubic meters of water as available resources. In the prospect, forecasts for the construction of 588 large and small dams. The activities undertaken in this regard have led Iran to rank third in the world after China and Turkey. Considering that approximately 70 percent of Iran's water resources are surface deposited in dams, so the issue of sedimentation in reservoirs of dams is very important and that it is necessary to plan properly for decommissioning of dams.

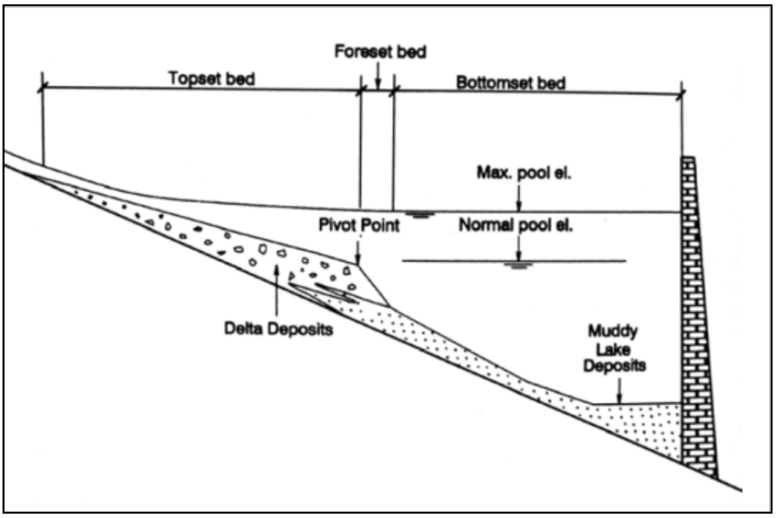

Fig. 1. Generalized depositional zones in a reservoir [1].

Country	Runoff depth, mm	Population millions 1990	Population millions 2050	Runoff per capita, m^3 1990	Runoff per capita, m^3 2050
Israel	104	4.7	8.9	461	241
Algeria	7	24.9	55.7	690	309
Egypt	59	56.3	117.4	1,046	502
Ethiopia	98	47.4	194.2	2,320	566
Morocco	573	24.3	47.9	1,151	585
Haiti	396	6.5	18.6	1,696	593
Nigeria	333	96.2	338.5	3,203	910
Pakistan	582	121.9	381.5	3,838	1,227
India	634	850.6	1639.9	2,451	1,271
Dominican Republic	410	7.1	13.2	2,813	1,519
China	293	1155.3	1606.0	2,424	1,743
Turkey	260	56.1	106.3	3,619	1,910
United Kingdom	492	57.4	61.6	2,090	1,947
Mexico	182	84.5	161.5	4,224	2,211
France	338	56.7	60.5	3,262	3,059
Germany	561	79.4	64.2	2,520	3,113
Iran	72	58.9	163.1	4,428	4,972
Japan	1448	123.5	110.0	4,428	4,972
United States	253	249.9	349.0	9,915	7,101
Russia (former U.S.S.R.)	248	280.4	318.9	19,493	17,142
Brazil	816	148.5	264.3	46,809	26,291

Source: Adapted from Engleman and Leroy (1994).

Fig. 2. Runoff per Capita for Selected Countries [1].

One of the critical reservoir dams in the table is SEFIDRUD dam in GILAN province. The SEFIDRUD reservoir was built in 1962 with a volume of 1760 cubic meters, about 250 kilometres northwest of Tehran. The SEFIDRUD is the result of a confluence between the two rivers GHEZEL OZAN and SHAHROOD. The purpose of this dam was to produce electricity as well as to supply water to rice cultivating rice.

Name of reservoir, starting year of operation – Geographical coordinates	Initial capacity (mcm)	Mean annual sedimentation (mcm)	Reservoir Length (m)	Normal water level (m.a.s.l)	Dam Height (m)	Reservoir Retention Time (days)
Dez dam – 1962 32°38′N, 48°26′E	3480	14.65	62, 442	352	188	169
Sefidrud dam –1962 37°28′N, 49°56′E	1749	45.81	28, 000	271.81	81	86
Droodzan dam – 1973 29°50′N, 51°53′E	993	3.31	16, 100	1676.5	49	372
Jiroft dam- 1991 28°51′N, 57°28′E	425	3.55	10, 300	1184	129	357
Minab dam-1983 27°9′N, 57°6′E	350	3.02	15, 943	98.5	51.5	554
Karaj dam – 1961 35°57′N, 51°5′E	205	0.509	14, 000	1765	165	160
Makoo dam –1995 39°11′N, 44°29′E	152	1.5	7566	1691	65	504
Latian dam – 1967 35°47′N, 51°39′E	95	0.75	5177	1610	78	89
Torogh dam –1988 36°16′N, 59°26′E	35	0.31	3474	1217	57	710
Kardeh dam – 1988 36°37′N, 59°39′E	33	0.33	3039	1296	46	685
Total volume(mcm)	7517					

Fig. 3. Characteristics of 10 Iranian dams included in this study [2].

Sedimentation in this dam is always a serious problem and reduces the amount of storage by 45.81 million cubic meters per year, which is equal to 2.1% annually. After about 17 years since the construction in 1980, due to a significant reduction in storage volume, the use of the dam was changed to sedimentation. Detailed and comprehensive reports are presented at all stages of sediment management in this reservoir by Ismail Tolouee (1989 and 1993).

The sediments are mainly sandy, clay and their derivatives, mainly due to the erosion of the liner of the river and canal, especially during seasonal flood events. According to a report released in 1985, more than 700 million square meters with an elevation of 20 to 30 meters of sediment accumulated at an estimated value of 106 million tons in the dam reservoir. The maximum dam height up to the bed of the river 92 has been reported, which naturally should decrease with increasing sedimentation. Therefore, we should plan for a depth of access of about 100 meters.

The weather conditions governing the region, temperature range and rainfall periods are among the determining factors. Of the other environmental constraints associated with mountainous conditions, most dams and roads have access to the dam reservoir. In this respect, the equipment must be in portable dimensions and weights in mountainous trails. Subsequently, the ability to insert sub-assemblies into the dam is a feature that is expected of the system.

2 Sediment Removal Methods

Successful sedimentation management may employ a combination of strategies, which may change over time as sedimentation becomes more advanced. The classification of "active" management techniques presented by Morris (2014) has been modified and expanded in Fig (4) to include "adaptive" strategies which do not manipulate sediment, yet which are essential management options to address reservoir sedimentation. Both active and adaptive options should be considered as integral components of the management strategy, and a combination of both approaches can represent the best overall response.

This research has been carried out to collect sediment from existing reservoir dams of Iran. So active methods and sediment deposition are considered. Meanwhile, in order to maintain existing water resources, it is not a allowed solution to flushing the sediment because of wasting of water resources through flashing. Sediment may be mechanically excavated conventional excavation when the reservoir is drawn down and submerged deposits may be removed by dredging.

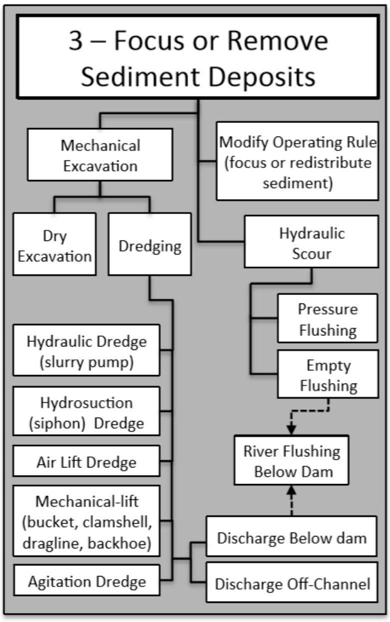

Fig. 4. Strategies for sustainable reservoir management [3].

Dredging is generally the least costly and most feasible method of excavating large volumes of sediment from reservoirs as it does not require the reservoir to be emptied, and a slurry pipeline is a clean and quite method of transporting sediment (as compared to truck traffic). Siphon or hydro-suction dredging is a special case of hydraulic dredging, in which the motive force for transporting slurry through the pipeline is provided by the head differential between the reservoir level and the foot of the dam. In this study, a combination of existing ideas was invented, which has so far been used in shallow watersheds. In other words, mechanical dredging methods are focused by using submerged pump suction. This is a customization scheme for the removal of sediments from deep reservoirs of dams without more loss of water resources.

In the table below the possibilities of the different types of dredging are shortly summarized. Due to the conditions governing the dam reservoir deposition, some of the following methods cannot, as a matter of principle, be considered as the chosen design. Sediment removal is not possible by conventional ships or dredging. On the other hand, the use of rotary shear and drilling tools cannot be considered as the main method in this plan. Although it can be proposed as auxiliary equipment along with suction and jet flow for the development of the proposed proposal.

The design of the sediment removal by bucket is a completely mechanical method outside the defined scope of this study. But the idea of sending dredger and pendant deposition tools can be considered. Because with this idea you can reach a depth of more than 100 meters on the bottom of the reservoir.

In this way, the deposition method should be a combination of a suction system and a hanging set so that access to the depth of the reservoir dam can be provided. As a replacement for costly mechanical drilling equipment, spray jets will be used. In this way, while eliminating the weaknesses of the design due to the lack of mechanical tools, the overall cost of the design is also reduced by eliminating mechanical equipment. The main equipment of the proposed design is presented and estimates of their capacity and costs are made.

3 Conceptual Design

One of the things that has to be emphasized is the introduction of the main components of the design. The main components of the decontamination system selected are as follows:

- Barge
- Sediment removal head
- Pipeline for transferring mixture of sediment and water from bed to the barge
- Pipeline for transferring mixture of sediment and water from the barge to Lake Beach.

It is necessary to present a description of the general decomposition process before describing each of the main components, in such a way that the volumes and capacities and total expenditures can be calculated.

	Bucket Dredger	Grab Dredger	Backhoe Dredger	Suction Dredger	Cutter Dredger	Trailer Dredger	Hopper Dredger
Dredging sandy materials	yes	yes	yes	yes	yes	yes	yes
Dredging clayey materials	yes	yes	yes	no	yes	yes	no
Dredging rocky materials	yes	no	yes	no	yes	no	no
anchoring wires	yes	yes	no	yes	yes	no	yes
Maximum dredging depth [m]	30	> 100	20	70	25	100	50
accurated dredging possible	yes	no	yes	no	yes	no	no
working under offshore conditions possible	no	yes	no	yes	no	yes	yes
Transport via pipeline	no	no	no	yes	yes	no	no
Dredging in situ densities possible	yes	yes	yes	no	limited	no	no

Fig. 5. Different types of dredging [4].

It is necessary to calculate capacities and costs by identifying the generalities of the system in question as well as identifying its main components. In this regard, the process by which decontamination is carried out must be described.

The capacity and specifications of the suction pump as the main component of the system determine the deposition rates. Factors such as volume, operating time, sedimentation characteristics, number of systems, efficiency factors and operating costs associated with suction pumps are examined as following.

3.1 Estimated sediment volume

One of the most important factors is the amount of sediment deposited by the dredging system during one year. The volumetric capacity determined for a degradable deposition system is a function of the initial estimated volume of sediments accumulated in the dam reservoir, which was first estimated and reported by conventional methods. Referring to the statistics on the volume of sediment accumulation in the reservoirs of the SEFIDRUD dams, annual volume of sewage treatment in the dam of 45.81 million cubic meters. Following this, the Karun 1, Dez, Aras and JIROFT dams are 25, 14, 8.3 and 6.4 million cubic meters, respectively. The rest of the dams are reported in the range of less than 5 and mostly less than 2.5 million cubic meters of annual precipitation. In this research, the target sediment volume is set at 2.5 million cubic meters. In order to increase the sedimentation removal or reduce the time period, the number of sediment remover can be increased related to the budget and investment of the projects.

3.2 Estimated time

Factors such as environmental and climatic conditions, as well as the crisis of water resources and resources, are considered in determining the deadline for sediment harvesting. In order to harvest 2.5 million cubic meters determined in a three-year period is assumed. In order to determine the useful time, 52 weeks per year should be deducted from the time spent on holidays, maintenance and equipment maintenance and improper weather conditions. For this purpose, 2 weekly annual holidays, 3 weeks for repairs and services 2 weeks are also considered due to adverse climatic and atmospheric conditions for operating the system. So, the system's net operation time will be 45 weeks. With a little more detail, each week with six working days per week, two eight-hour per day, a total of 16 hours of continuous work, are calculated for one device. So, there are 4320 hours available for sediment harvesting.

3.3 Sediment Specifications

Due to the gradual decrease of the flow rate of the input into the reservoir of dams, often fine sediment particles are displaced to the adjacent wall of the dam. Accordingly, due to the effect of fine sediment on the power plant equipment and operation, the characteristics of the sediments to be taken are proportional to the fine sediment. The concentration of sediment and water mixture is considered as a very important characteristic. Usually, the concentration of sediment grains is measured in terms of weight, volumetric and flow rates relative to the mixture, and the following relationships are presented in this regard: $C_v = U_s / U_m$. Which provides volumetric concentration with the volume ratio of the sediment on the volume of the mixture. In this research, it is assumed that the fine-grained sediments are removable, which can be removed with a mix of water by a dredger pump and transported through the pipeline from the depth of the reservoir to the site at the reservoir side. Accordingly, we assume the ratio of volumetric sediment flow rate to the mixture flow rate of 50% to be used in the final calculation stage of the required flow rate for the sediment pump. It should be noted that the discharge mass of the sediment will be about 30% of the mixture discharge.

3.4 Number of dredger unit

Due to the time limit set for the project, as well as the amount of sediment volume to be removed, the number of systems is determined. In the initial estimation that is considered in this research, there are 2 units of sediment removal unit that is used simultaneously.

3.5 System efficiency

Using the correct equipment and the proper operating conditions, the results can be obtained according to the predictions. Many factors, such as the lack of operation of the pump at its optimal point of use, the inaccuracy of the suction spigot at the site of the deposit, the instability of the sediment and bed surfaces at the reservoir depth and many other factors, can lead to a failure of the dredger system in accordance with prediction to be designed. In this research, it is assumed that using the trained personal and the accuracy of the processes, 90% of the compliance with the plans for the operation of harvesting is to be realized.

3.6 Cost

One of the important factors in deciding on the choice of equipment is the cost of supply and utilization. In this regard, it is attempting to use low capacity equipment, in order to eventually impose a lower cost on the project. The financial analysis of the system will be presented after the presentation of the detailed plan. The diagram below shows the process of deposition of sediment by a different device unit.

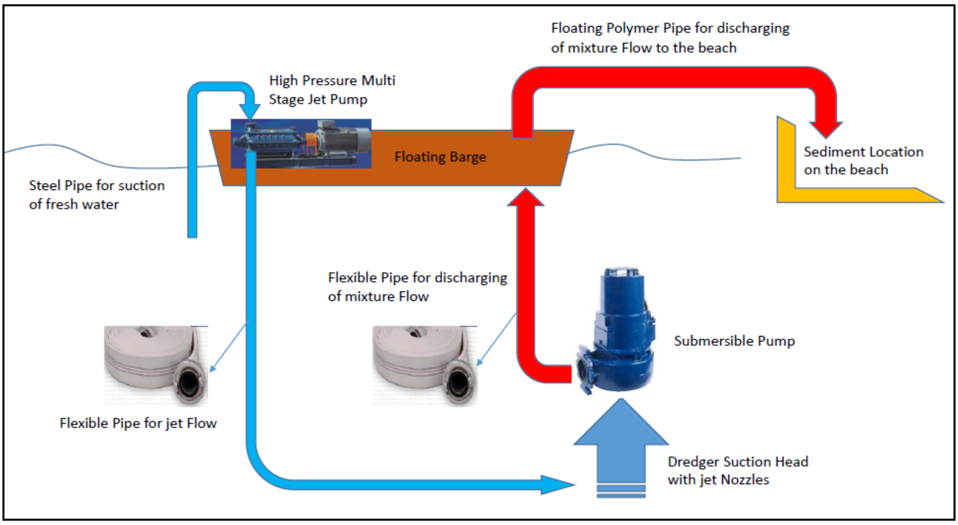

Fig. 6. Flow diagram of sediment removal by suction and jet flow [5].

4 Provided details of the equipment

The main equipment of the design is presented in accordance with the following divisions:

- Floating structures
- dredger head and Sediment Pump Assembly
- High pressure jet pump Assembly
- Transport and Drainage of Mixture Lines
- Structures and lift systems
- Energy Production and Transfer Unit
- Fuel storage and fresh water Tanks
- Barge Driver System
- Measurement and control tools
- Equipment Control and guidance cabin

In the following, some of the main issues are described in detail, and the specifications are fixed for them.

4.1 Deposition discharge equipment

Sediments taken from the reservoir bed are sent to the water level by a submersible pump. The transfer of sediments by floating tubes on the surface of the water and the directing of sediments to a suitable location is another method for discharging sediment. The pipe path can be through the outlet of the dam, bypass or over the dam. The desired and desirable method in this research is sediment drainage at the lake beach so that water return to the lake are guaranteed. Depending on the environmental conditions, the drainage ditch can be changed, but the preference for this drainage plan is adjacent to the lake.

The temporary collection location of removed sediments depends on the geographical conditions of the dam lake and its surroundings. If the exploiter is fortunate and there is a natural margin around the lake, it can use a temporary pound for the discharge of wet sediments. Also, artificial pounds and large dewatering sediment bags can be used to drain sediment into and packed them. An example of these bags can be seen in Fig 7. Thus, by penetrating the ground bed, water resources are returned to the lake and the accumulated sediments can gradually be removed from the area by trucks.

Fig. 7. Dewatering sediment bags.

4.2 Sediment dredger head

The most important equipment of the system is the sediment sampling set that is sent submerged on the surface of sedimentary bed. The design in question does not include mechanical shaking or stirring equipment. Also, due to the necessity of deposition from the depth of the bed, it is not possible to use a sweeping head system. Since it is not possible to remove the sediment near the dam wall using the floating set traction. Most often these designs are used by large naval vessels. Blowing and suction simultaneously deposition systems flow is determined as the main factor in this method. A submerged pump is used to suction the mixture of water and sediment from the relatively large depth of the reservoir and transfer to the floating level. On the other hand, the tail water is cleaned by a high-pressure pump mounted on the float. Thus, by spraying a high-speed jet, the flow of water occurs at the site of deposition, turbulence and further mixing, and the sediments dispersed from the bed are removed by flow. An example is given in the following forms.

Due to the fact that the basis of the sediment removal process in this method is based on rising eddy currents, it is essential to create a chamber for conducting mixed flow into the submerged pump suction nozzle. In this way, a cone-shaped conduit can be used to guide the flow, proportional to the large surface of the withdrawal on one side and the small spout on the other side. The uniform distribution of spray jets at the large cone base is considered to improve the mixing.

The main idea behind the deposition process is to send the head to the depth of the water to the surface of the bed. The submerged pump, which is sent with the structure in to the water depth, sends a mixture of sediment and water to the floating surface through the cone-shape suction head. The following figures provides the intended details. As shown, the pump inside the steel compartment is mounted on the welded flange to the top of the cone. The mixture of sediment and water is directed from the mouth of the cone to the suction mouth of the pump and sent to a floating vessel through a flexible pipe. The steel enclosure, while protecting the collection pump and fittings, is also used to move the set. When the head is placed on a sedimentary bed, it continues to be deposited more deeply with the continuation of the deposition until the subsoil and the deposition of the deposit is not possible.

One of the benefits of the proposed scheme is the use of water jet spraying to create a mixing and turbulence in the sediment bed. For this purpose, a high-pressure pump mounted on a floating vessel has been used. The flow of clean water into spray nozzles, high speed jets is created and prepares the surface of the substrate for harvesting. The angle of the nozzles is adjustable and adjusts to the substrate and sediment profile. The angle of installation of the jets is such that it causes the vortices flow inside the cone, and the central portion of the bed is generated by a vortex flow and the suction of the pump is pulled to the suction mouth of the pump.

4.3 Precautionary considerations

In order to control the proper operation of the pump under working pressure conditions and also to ensure no clogging in the pump and pipe path, some actions should be performed. The overall operational area defined for descaling in this research, is near the dam body, where most of trapped sediments particle are fine size. But in the inlet opening of the sucker head, a suitable mesh structure or perforated plate should be installed to prevent the entry of possible large solid objects and clogging in the pump suction path. (Fig 8).

By examining the possibility of installing of flow and pressure instruments at discharge of the submersible pump and also in pipelines located on the barge, the flow conditions are constantly monitored and checked. With permanent reading of the compartments recorded by the measurement tools, the continuation of discharge flow is ensured. Also, in case of clogging, appropriate actions such as stopping pumps operations and using by-pass pipe branches and valves on the piping system located on the barge should be done. it is possible to use the high-pressure pump stationed on the barge and inject the high-pressure flow of clean water to flashing the sucker tube. According to the Fig 8, the output path of the clean water of jet pump can be directed to the sediment discharge pipe and by creating the reverse flow while the sediment sucker pump is turned off, the accumulated sediments can be removed and flashed out. It may be necessary to do this in several times in order to finally drain the accumulated sediments from the sucker pipe.

4.4 Equipment layout on the float

Considering the equipment needed to be installed on a float, the proposed scheme is shown in the figure no. 9. As it is known, the flexible tubes, which are assembled on their own drums, make it possible to connect the pumps to the depth of operation.

5 Estimated Costs

According to the statistics, in general, in different parts of the world, 0.1 to 2.3 percent of the volume of reservoirs storing dams is occupied by sediment annually. This figure is about 0.5 to 1 percent in the Asia dam's reservoir. The cost of replacing lost volumes in America is estimated at $ 13 million annually, not including the cultural, social, and environmental costs of building new dams. Part of the costs are dependent on the deposition method, as well as the type of equipment and method of operation of the dam. Thus, based on the sedimentation method, we can calculate the profit from the renewal of the storage volume. After designing the conceptual design of the system and designing a full-scale deposition head, it is necessary to estimate the cost of supply, construction and operation of the proposed system. In this regard, costs can be divided into general categories of equipment, logistics, consumables, human resources and project costs.

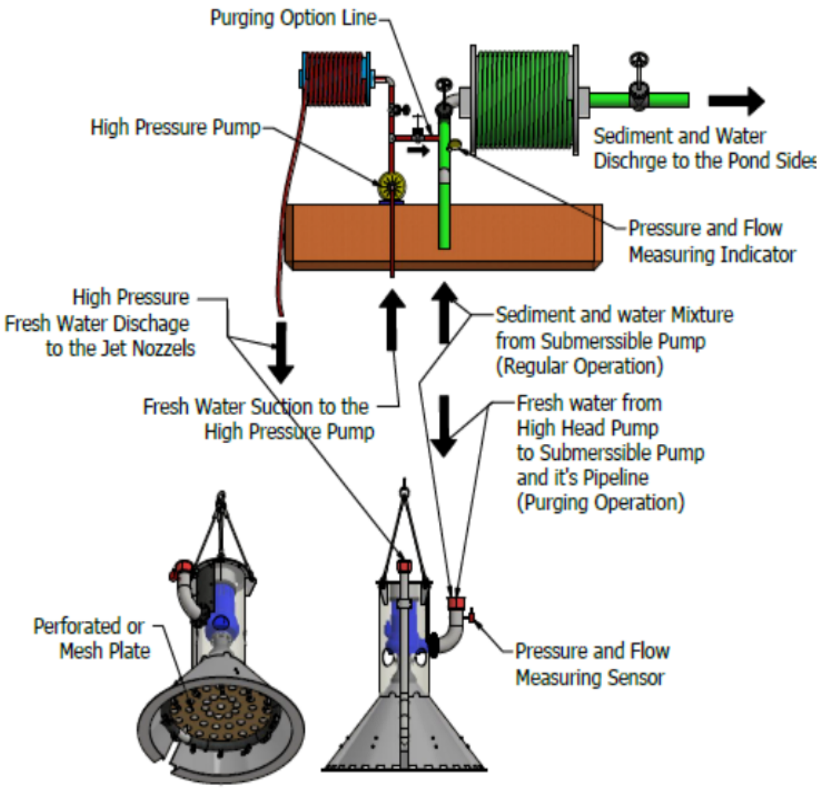

Fig. 8. Added instrument and parts [5].

5.1 Equipment cost

The main equipment used in this system includes heads, pipes and machines such as pumps, lifters, electric power generators, floats and some other equipment that will play a part in the process of the system on a daily basis. In this section, you should pay attention to the costs of supply, purchase and construction. Some of this equipment as a standard product and manufactured in factories must be purchased, and the rest should be produced after the supply of raw materials and during the manufacturing process. The cost estimate for each one is continued.

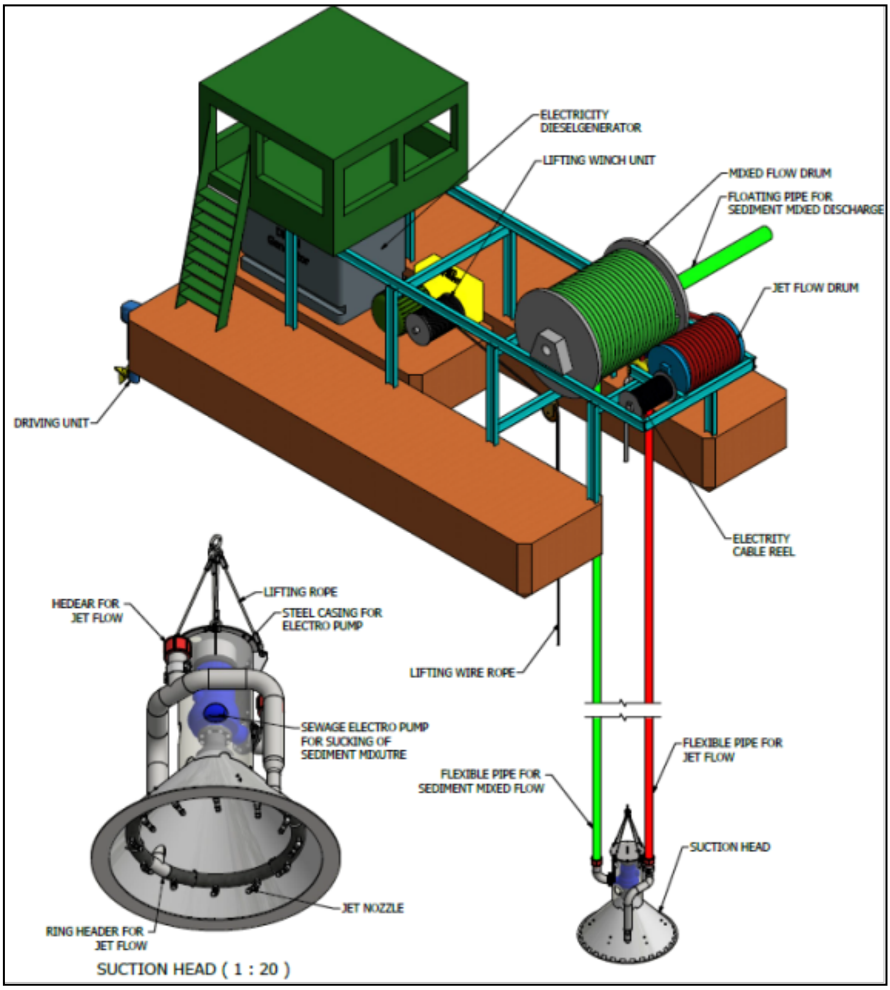

Fig. 9. General Layout of the System [5].

5.2 Operational Costs

Expenditures for decontamination operations include assembly and disassembly of equipment at site, cost of materials, and utilization of human resources, support activities as well as various project side costs. The cost of logistics is related to the use of machines and personnel for the transfer of equipment to the place, its displacement, and layout or vice versa, loading and dismantling. The period of these actions is limited to the beginning or end of the project, which in this research is generally assumed to be 15 day. It can be seen that the cost of a decontamination project for a device over a year will be $ 302,977.5. If more devices are used, a portion of the calculated costs will increase to the number added. But obviously, with the proper project management, this incremental cost factor can be reduced. It is worth noting that the specified execution cost is equivalent to 420,000 cubic meters of sediment, and therefore, for the removal of each cubic meter of sediment, it costs about $ 0.7, which is a low-cost and worthwhile method in this regard. If sufficient barriers are not anticipated for stop returning the discharged sediments to the dam lake, the increase in this cost will also be imposed again. Using dewatering bags and artificially valley and also rapid unloading of deposited sediments can be very effective and useful in controlling and limiting this additional cost.

6 Project features

The factors that make this method superior and preferable to overcoming the barriers of other systems are: Low weight, Easy Handling, Low cost, Easy operation, Supplies of commonly used materials and equipment in the industry, Low water losses, Access to the depth of the substrate, No need for a powered-deposition floating vessel. Sediment removal from the most critical position of the dam and desirable system performance are the most feature of the system. The sediment discharge system is a unique design which consists of a jet spray system as well as a cone hood, is fully innovative and designed in a process of brain storming and creative design.

7 Summarize the results

Decomposition in deep reservoir dams of Iran was analyzed using suction and flow blowing method. Focusing on this constructive system, it was introduced in a way that by providing funds or investors, as well as attracting the views of water resource managers as potential customers, a set of equipment was developed to solve one of the country's greatest problems. The result of this research is the conceptual design of a system that is capable of constructing and using. In addition, a partial design of one of the main parts of the system along with a list of its materials is presented. Eventually, operating costs and equipment supplies are estimated.

The author does not consider the research to be sufficient ultimate solution, and is keen on the enthusiasts of this field to work on the completion and restoration of the studies carried out. It is hoped that the proposed strategy will provide an opportunity for the emergence and use of the solution and will be effective in solving the country's drought problems.

Table 1. Equipment Cost Estimation [5].

Row	Equipment	Qty.	Unit	Unit Price ($)	Total Price ($)
1	Submersible Pump	1	No.	5,000.0	5,000.0
2	High Pressure Pump	1	No.	7,000.0	7,000.0
3	Winch	1	No.	5,000.0	5,000.0
4	Electrical Diesel Generator	1	No.	10,000.0	10,000.0
5	Flexible Pipe	200	m	5.0	1,000.0
6	Polymer Pipe	200	m	25.0	5,000.0
7	Electrical Wire	120	m	25.0	3,000.0
8	Driving Motors	2	No.	4,000.0	8,000.0
9	Head Structure	1000	kg	2.5	2,500.0
10	Barge Structure	25000	kg	2.5	62,500.0
11	Steel Structure	3000	kg	2.5	7,500.0
12	Others Structure	1000	kg	2.5	2,500.0
13	Extra Costs				35,700.0
					154,700.0

Table 2. Operational Cost Estimation [5].

Row	Subject	Qty.	Unit	Unit Price ($)	Total Price per day ($)	Effective day	Total Price per one year ($)
1	Assembly & Disassembly	5	person	150.0	750.0	15	11,250.0
2	Mobile Crane	8	hour	250.0	2,000.0	15	30,000.0
3	Truck Trailer	24	hour	150.0	3,600.0	4	14,400.0
4	Gasoline	856	Liter	0.6	513.6	270	138,672.0
5	Labor	2	person	64.0	128.0	270	34,560.0
6	Others	1	day	50.0	50.0	270	13,500.0
7	Extra Prices						60,595.50
Summary					7,041.6		302,977.5

References

1. G.L. Morris, & J. Fan, Reservoir Sedimentation Handbook, McGraw-Hill (2009).
2. M.R Rahmanian, M.A Banihas, "Sediment distribution pattern in some Iranian dams based on a new empirical reservoir shape function," in Lake and Reservoir Management, pp. 245-255 (2011)
3. G. L. Morris, Management alternatives to combat reservoir sedimentation (2015)
4. P. W.J. Vlasblom, "Designing Dredging Equipment" (2003~2006)
5. A. Kianmehr and N. M. Nouri, "Sediment Removal from Reservoir Dams by Suction and Jet Flow," Iran University of Science and Technology, Tehran (2018)