ISSN:2372-0743 print
ISSN:2373-2989 on line
International Journal of Ground Sediment & Water
Vol. 06
2017

Research Paper

A Comparison between the Amount of Reservoir Sediment Load Prediction during Design Period and the Operational Period

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Abstract: Sedimentation of dams in Iran is an important issue. Often the sedimentation prediction is done in different ways in dams' design. Sometimes due to lack of data of sedimentation, the calculations lead to false results. To compare the predictions made as to whether the design is correct or not a method called Bathymetry is being used to determine the amount of sediment deposited in the reservoir in a certain period of time. The comparison between the above methods can determine whether the rate of deposition matches the anticipated design time or not? Therefore, in this paper, deposition rate obtained through Bathymetry was compared to the amount of anticipated deposition at design time in Karaj and Latian dams. So we used 40 to 45 years of operation period, which is done by echo sounder system, with the gained results during designing of Karaj dam and Latian dam. Furthermore, sedimentation rate and volume reduction percentage are evaluated in these two dams and the results were analyzed for determining sedimentation rate and also to study whether the total sediment volume during the reservoir useful life coincides calculations during designing. In the end, it showed that the Area Increment Method for the mentioned dams was not an appropriate and adequate method to distribute sediments. The data obtained by sedimentation through Bathymetry findings can be a model for other dams in Iran and worldwide.

Key words: Sediment Estimation, Sedimentation Prediction, Sediment Deposition, Area Increment Method

Introduction

Limitation of drinking water on the earth and increasing demand of water in spite of its non-uniformity distribution, led to the emerging science of dam engineering (Heydari, Othman et al. 2013, Heydari, Othman et al. 2015), but one of the major problems regarding with storage facility, taking water, water distribution and transport of surface water is load transportation, sedimentation and the losses resulting from it (Sadeghian, Heydari et al. 2014). The natural hydrologic administration and hydraulic properties will be varied after construction reservoir dams on the rivers and Due to the slow rate of water inflow to the reservoir, much of the load is deposited while carrying. Sedimentation was reduced storage volumes of reservoirs and the useful life of dams will be reduced (Yang 1996, Sahay 2011). According to the present data, reservoirs annually lose 0.5 to 1 percent of their initial storage volume around the world (Liu, Minami et al. 2004, Othman, Sadeghian et al. 2013). Dam reservoirs of Iran annually lose 1.15 percent of their initial storage volume (Zare Bidaki 2006). The reservoir storage volume reduction due to sedimentation causes to reduce water storage capacity, reduce power of electricity production, damage to hydroelectric facilities, degradation of water quality, loss of flood control capacity and other problems. In addition, sedimentation causes to increase evaporation of water from the reservoir level for a given storage capacity (due to increasing reservoir level), flooded and forming swamp the area upstream of the dam, increasing power of erosion of the river downstream of the dam, reducing of the reservoir flood control volume. Increasing depth of sediment behind the dam, has reduced its stability and undesirable effects would have an operation of water living facilities, valves and flush downstream level (Yang 1996). If we add them frequent and rare proper places to construct new reservoirs and large cost of dam construction, it would be inevitable to control sedimentation in the current reservoirs. Therefore, the importance and complexity requires that it will be done comprehensive studies in this regard for every dam, because the lack of information on the deposition in the reservoir dam and predicting of its control methods, will cause to decrease the useful life of the dam and a huge waste of national resources (Seyedian 2006).

Solutions proposed for estimating reservoir sedimentation during operation, mostly requires Field operations and high costs and time consuming, so, it is necessary to investigate Phenomenon of sediment accumulation in reservoirs with appropriate strategies considering of time and cost and it is very important to predict of reservoir sedimentation and providing administrative commands to control of dam reservoirs from the point of view of long-term operation (Shakeri Darian 2006). Several methods such as mathematical models or empirical methods are used in order to estimate or predicting the status of sedimentation during the commission of reservoir (Seyedian 2006). Although, several mathematical models have been developed for distribution deposited in repositories, (Toniolo and Parker 2003), however, experimental methods are still widely used in practical engineering (Salas and Shin 1999). There are several experimental methods for distribution of a certain volume of sediments in reservoir dams that in all these methods, the level curve data - height and volume - initial height of the tank is used to calculate the sediment distribution. Trigonometric methods, area increment method and area reduction method are more important and applicable among the methods of site distribution. Area increment methods and area reduction methods have proposed by Cristofano (Cristofano 1953) and Borland & Miller (Borland and Miller 1958), respectively. The area reduction method was modified by Lara in 1962 (Khodhal 2009). This model depends on the mode of operation, Sediment particle size, the reservoir shape and volume of sediment deposited in the reservoir. However, the shape of the reservoir is considered as the main criterion to develop empirical design curves and for using on sediment distribution (Rahmanian 2011).

So far, many studies have been done on optimal reservoir operation such as (Sadeghian, Heydari et al. , Ahmadianfar, Adib et al. 2015, Heydari, Othman et al. 2015, Heydari, Othman et al. 2016, Ahmadianfar, Samadi-Koucheksaraee et al. 2017) and distribution of sediments in dam reservoirs with empirical methods in Iran which the results show the superiority of lower-level models and some results showed the more accuracy of area increment method. Mosavi (1996) Examined the way of sedimentation of 14 small dam reservoirs in Chaharmahal and Bakhtiari. The results showed that both methods of increasing and decreasing of level are also used for distribution of sediment in small dams. These two methods are less accurate in low numbers of reservoir and more accuracy in high numbers of reservoir.

In a study to estimate Sedimentation process in Dez Dam Reservoir, Shabanlo (2003) have estimated the sediment will enter into the reservoir until 2021 and also have determined the way of distribution of sediments in the reservoir through area increment method and area reduction method and regression analysis. The results showed less error for area reduction model while using Borland and Miller. In another study on the mentioned reservoir dam, coefficient experimental methods for area reduction method were precisely calculated based on hydrographic in 2003 (Emami 2006). Mousavi (2006) studied sediment distribution in Zayandehrud reservoir dam by using the mentioned models. Distribution of sediment deposited in the dam in comparing with predicted sediment distribution models showed that area increment model is most consistent with the distribution of sediments way. Additionally, Mousavi et al. (2008) have evaluated the error rate of current Experimental methods regarding to area increment and area reduction for predicting reservoir sediment distribution about Dez, Doroodzan and Shahid Abbaspour dams. By using area increment method and area reduction method, comparison of actual sediment distribution with the predicted sediment distribution showed that the maximum error occurs behind the dam in determining of depth of sediment and error rate decreases with increasing level. For Doroodzan dam whose sediment volume is very low, area reduction method error is greater comparing with area increment method, but for Dez and Shahid Abbaspour dams whose sediment volume is very high; both methods are almost the same error (Mousavi 2008). In a similar study, Hasirchian et al. studied sediment distribution way in Shahid Rajai reservoir dam by using experimental methods. The results showed that area increment method can better calculate Sediment distribution in reservoir dam comparing with area reduction method (Hasirchian 2010). In other research, the way of deposition of sediments in Karaj dam reservoir was studied with all modified three experimental trigonometric method, area increment method and area reduction method. The obtained results showed that the trigonometric method has been more accurate to estimate the spatial distribution of sediments in the reservoir of the dam despite being older (Khodhal 2009).

Materials and Methods

Case study:

The case study details are shown briefly in tables 1.

Table 1 Location details

	Latian	Amirkabir
Latitude	35.7898	35.9564
Longitude	51.6785	51.089
Usage	• Electricity production, • Tehran drinking water, • Varamin plain agricultural water	• Electricity production, • Tehran drinking water, • Agricultural irrigation Karaj Plains • and spring flood control
River	Jajrud River	Karaj River

Area Increment Method:

This method is based on the premise that the sedimentation volume is fixed for per unit height of the reservoir. In other words, assumed load surface and load volume were constant at all height and yet it is evenly distributed over than zero altitude (Safamehr 2011). This method is applicable for reservoirs that sediment discharge of the reservoir is not too much than reservoir capacity. Major errors will occur when big changes occur in the altitude sea level or ratio of entering sediment to the volume reservoir is large. The general rule was provided by the U.S. Bureau of Land Development mentions the point that this method can be used in a situation that a hundred years of accumulated sediment is less than 15% of the total capacity of the reservoir.

Sediment distribution is obtained from VS = A0 (H-H0) + V0 where:

Vs: volume of sediment which must be distributed in reservoir (Cubic meters).

H0: the new zero level in the reservoir (m).

A0: Reservoir Area in height H0 (m)

V0: volume of Sediment between old zero and the zero level of new bed (m3).

H: maximum difference in water altitude from the reservoir bed to dam normal level (m).

Process or distribution of the total volume of given sediment Vs is done by trial and error method which the details are as follows:

i) Assume h0 and find corresponding v0 and a0.

ii) Check whether vs given by VS=A0 (H-H0) + V0 equation agree with the given value. If not repeat with a new value of h0.

iii) Sediment area at any level is a0.establishes water surface area at any level as (original area –a0).

iv) Over depth Δh0 incremental sediment volume = a0.Δh0. Hence reservoir capacity after sedimentation at any level h\` above new zero = (original volume –v0- a0h\`) (Subramanya 1994).

For example, to calculate about Latian dam from the beginning to 1989 by using area increment method, we do as follows:

Volume from 1967 to 1989= Vs = 95 -73 = 22 MCM = 22000000 M3

We have at 1548 levels:

$22000000 \stackrel{?}{=} 330000(78 - 16) + 1600000$

$22000000 \neq 21440000$

It is not correct

We have at 1549 levels:

$22000000 \stackrel{?}{=} 350000(78 - 17) + 1700000$

$22000000 \neq 23050000$

It is not correct

We have at 1548.4 levels:

$22000000 \stackrel{?}{=} 332000(78 - 16.6) + 1615200$

$22000000 = 22000000$

It is correct

As a result, new zero of the reservoir is selected at 1548.4 levels in 1989.

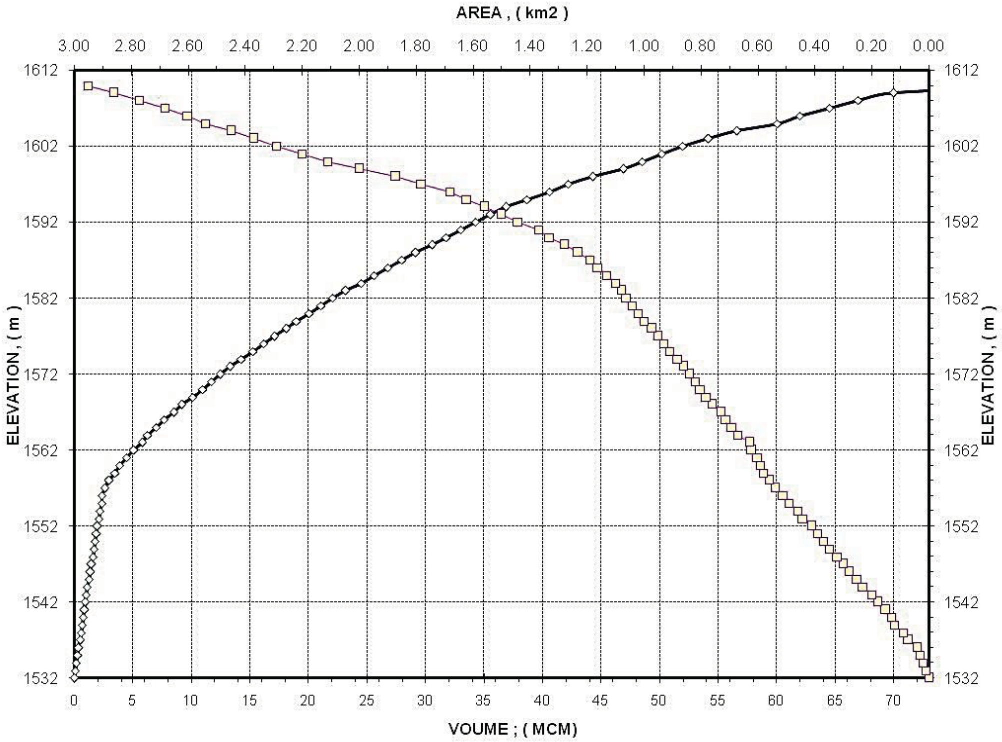

Figure 1 Area volume elevation – Latian dam

Calculation Methods for Sedimentation in Reservoir

Total deposits from the base year to until the desired year the normal level

= Water volume in desired year – water volume in base year

Percent reduction in volume reservoir compared to the initial volume at normal level =100×

Annual percent reduction in volume reservoir compared to the initial volume at normal level =100×

Rate reduction in annual volume reservoir compared to the initial volume at normal level=

Results and Discussion

When designing the Latian reservoir dam, the annual input of sediment into the reservoir dam has been predicated and estimated approximately 720000 tons equivalent to 554000 cubic meters per year during the 50 year life of the dam, but it has reached annual average 485000 cubic meters per year from 1967 to 2006 which the dam reservoir is totally filled by 19400000 cubic meters of sediment during 40 years of useful life. At present, 554000 cubic meters per year during the 50 year life of the dam, but it has reached annual average 485000 cubic meters per year from 1967 to 2006 which the dam reservoir is totally filled by 19400000 cubic meters of sediment during 40 years of useful life. At present, designed sediments of the reservoir must be reached to approximately 22160000 cubic meters during 40 years, but now we see comparing with the initial estimate, it has been reduced sediment volume amounts to 2760000 cubic meters now and the result is very ideal which the deposition rate is less than the initial estimate by designing company during 40 years. It also shows that consulting company despite the short period statistical course could provide a good estimation of the annual volume inflow sediment to the reservoir dam. (Figure 2-Figure 5)

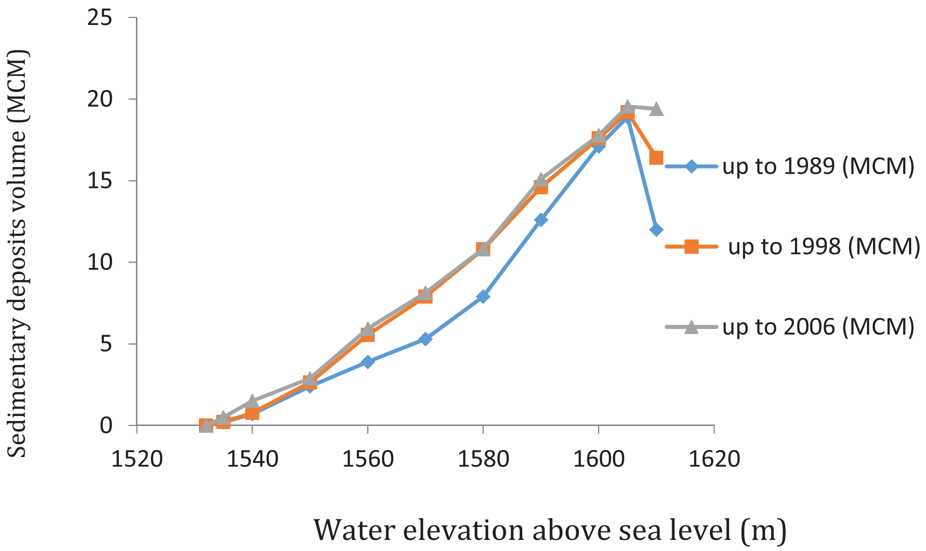

Figure 2 Volume of reservoir sedimentation at Latian dam in different years and levels

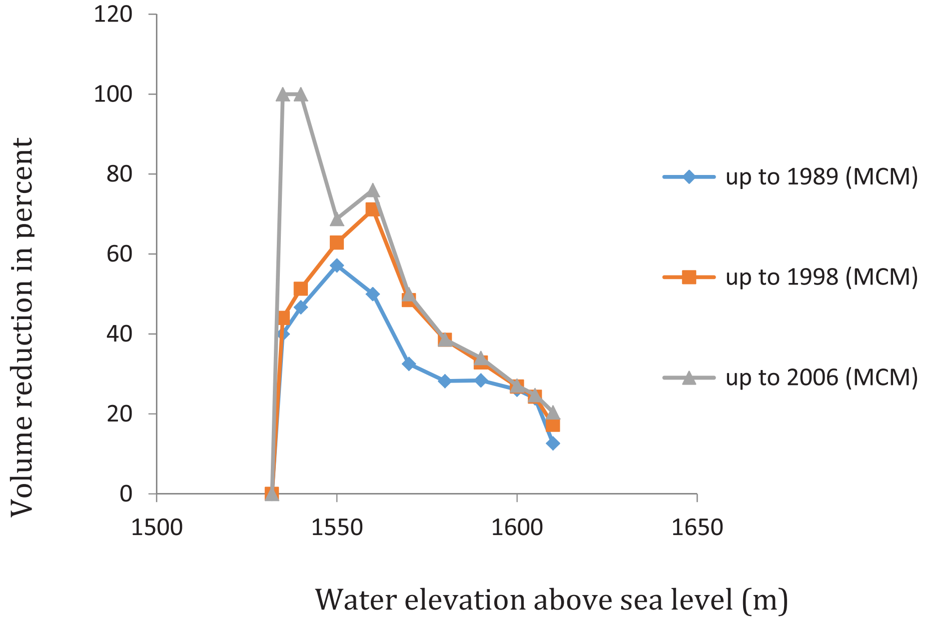

Figure 3 The percent reduction of Latian reservoir in comparison to the initial volume of the reservoir

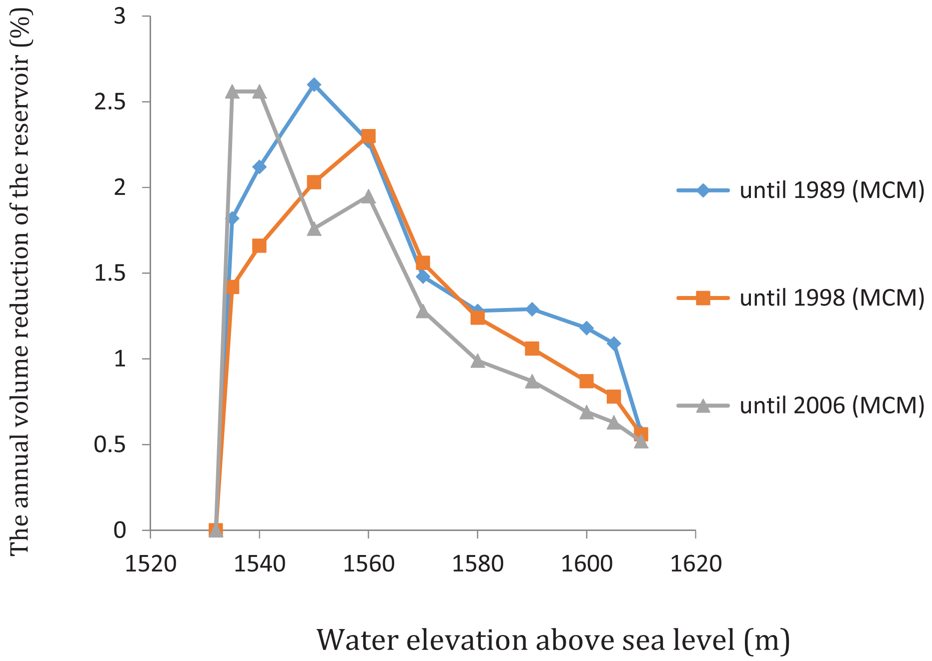

Figure 4 The annual reduction of the Latian reservoir volume to the initial volume of the reservoir in percent

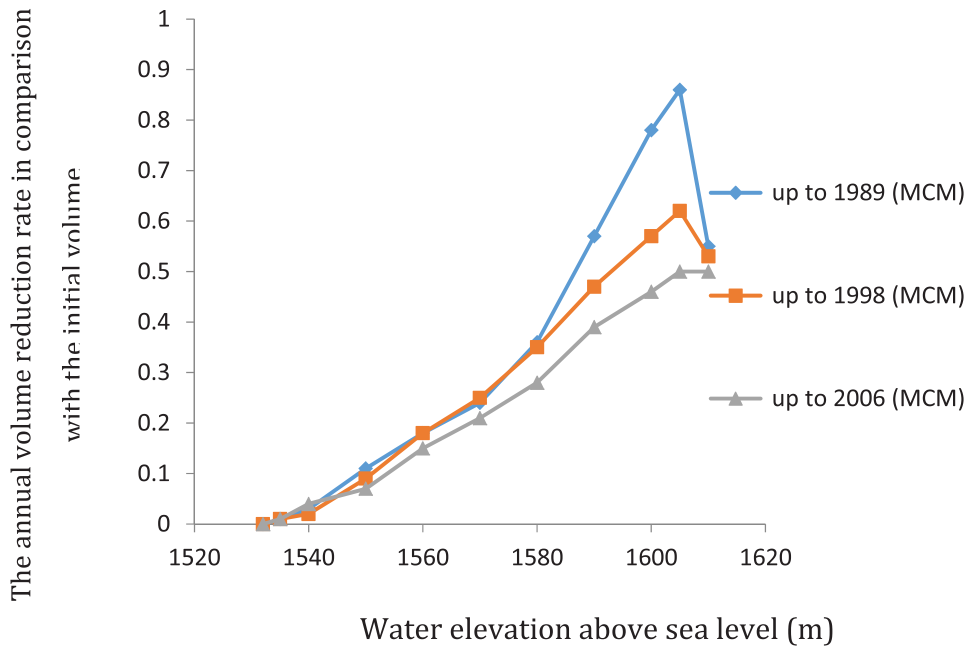

Figure 5 The annual volume reduction rate in comparison with the initial volume of the Latian reservoir

When designing Amirkabir dam reservoir (in dam design), annual input of sediment into the reservoir dam has been predicated approximately 370000 cubic meters per year during the 50 year life of the dam, but it has reached an annual average of 490000 cubic meters per year from 1961 to 2008 which the dam reservoir is totally filled with 21.8 million cubic meters of sediment during 45 years of useful life. At present, designed sediments of the reservoir must be reached at approximately 16650000 cubic meters during the 45 years which it has been estimated so far, it is observed increasing sediment Approximately 5150000 cubic meters comparing with the initial estimation. So, for now, about 88.8% of the total volume of water in the dam lake remains comparing with initial volume (100%) and as a result, reservoir sedimentation rates is about 11.2% from the first year reservoir commissioned during 45 years which the amount is at the ideal conditions This amount of sedimentation rates compared to other dams in the world is considered ideal, and the reasons could be proper implementation of the watershed in Karaj River basin, timely monitoring sediment discharge valve, controlling of river slope and so forth.

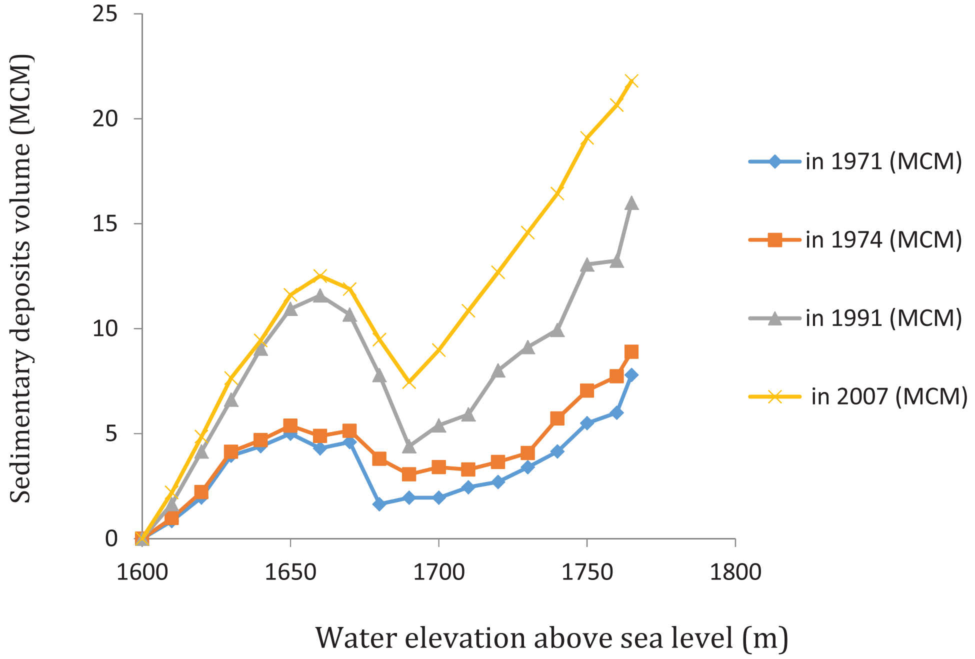

Figure 6 Volume of reservoir sedimentation at Amirkabir dam in different years and levels

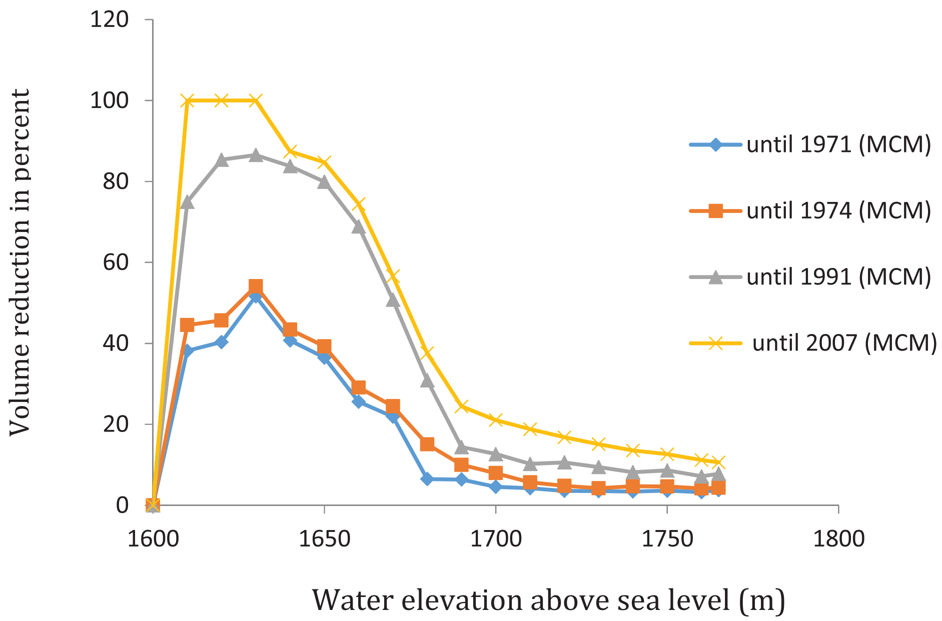

Figure 7 The percent reduction of Amirkabir reservoir in comparison to the initial volume of the reservoir

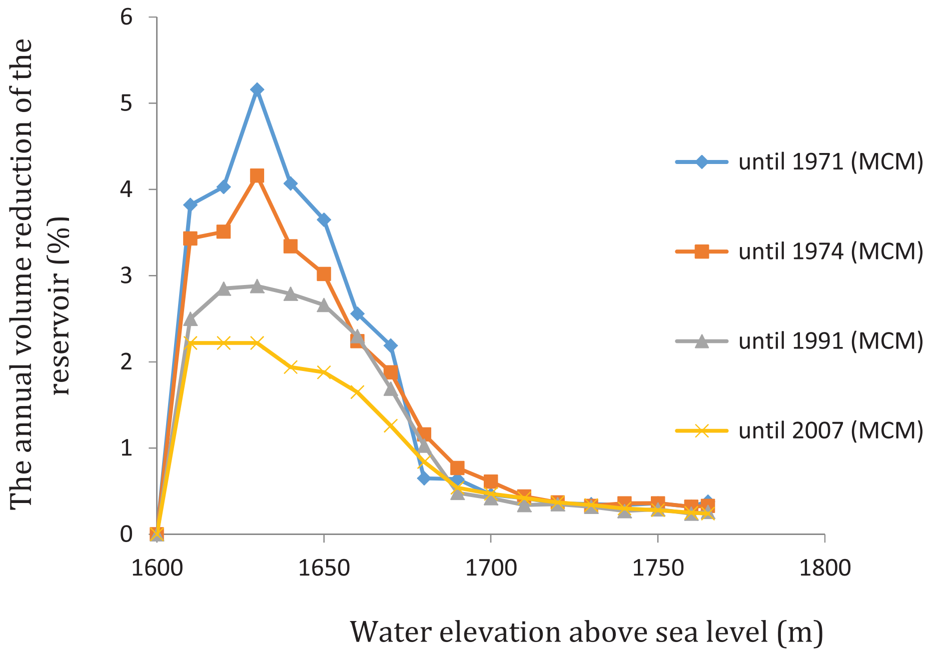

Figure 8 The annual reduction of the Amirkabir reservoir volume to the initial volume of the reservoir in percent

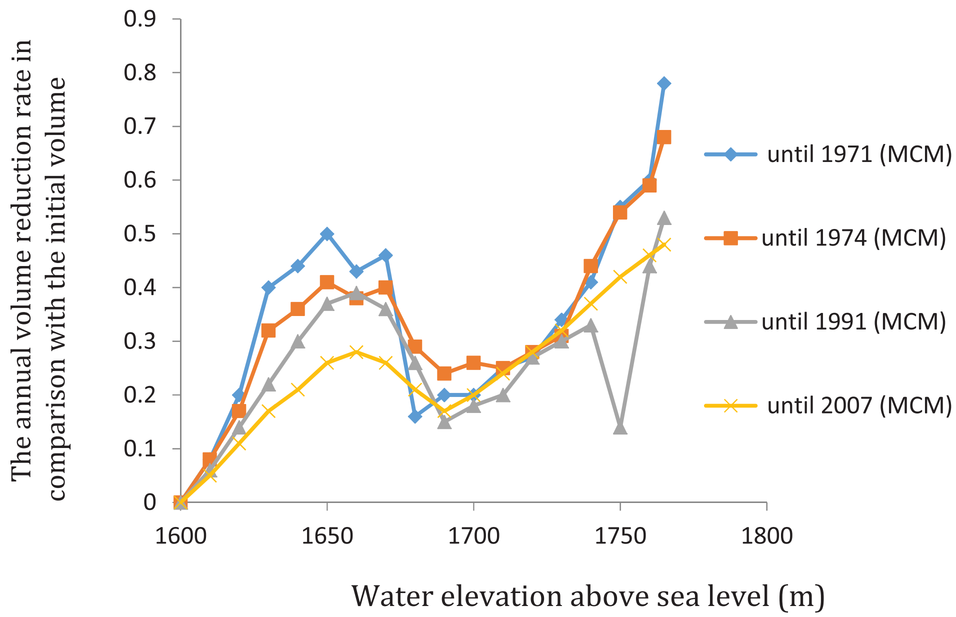

Figure 9 The annual volume reduction rate in comparison with the initial volume of the Amirkabir reservoir

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It can be concluded that Initial predictions are based on limited data available and therefore early predictions of the input volume of the reservoir can be defected, so it is recommended to use long statistical periods, furthermore, different reliability coefficients will be calculated on the input volume of the reservoirs.

Conclusion

Latian Dam: It can be understood from area increment method calculations that this method has many errors comparing with the results of reservoir hydrographic and according to a calculation was performed using the method, reservoir new zero was obtained at 1552 levels in 2006, however, the reservoir zero is at 1540 levels according to the results and hydrographic stochastic, therefore, it can be concluded area increment method is not a reliable method for finding desired reservoir zero and sediment distribution for the mentioned dam.

Table 2 The relationship between the bathymetry result of deposition rate in Latian dam

Bathymetry years	Reservoir storage at normal water level (1610m) (MCM)	Sediment volume in normal water level (MCM)	Sedimentation rate than the initial volume	Sedimentation rate than the remaining volume
1967	95	0	0	0
1989	83	12	0.126	0.144
1998	78.6	16.4	0.172	0.208
2006	75.5	19.4	0.204	0.26

Amirkabir Dam: As you know there is a difference between area increment methods in comparing with hydrographic results of dam reservoir. The calculations of area increment method showed that zero dam reservoir is at level 1650, on the other hand the hydrographic results obtained from data was performed on the dam showed the zero dam reservoir is at level 1635.

Table 3 The relationship between the Bathymetry result with the deposition rate in Amirkabir dam

Bathymetry years	Reservoir storage at normal water level (1765m) (MCM)	Sediment volume in normal water level (MCM)	Sedimentation rate than the initial volume	Sedimentation rate than the remaining volume
1961	205	0	0	0
1971	197.2	7.8	0.038	0.039
1974	196.1	8.9	0.043	0.045
1991	189	16	0.078	0.084
2007	183.2	21.8	0.112	0.118

The area increment method has 12 meter and 15 meter error respectively in Latian and Amirkabir dams than the zero of the reservoir obtained from hydrographic results. So, it can be concluded that the area increment method is not also a very accurate method regarding the dam in order to spread the load of the mentioned reservoir.

References:

Ahmadianfar, I., A. Adib and M. Salarijazi (2015). "Optimizing multireservoir operation: Hybrid of bat algorithm and differential evolution." Journal of Water Resources Planning and Management 142(2): 05015010.

Ahmadianfar, I., A. Samadi-Koucheksaraee and O. Bozorg-Haddad (2017). "Extracting Optimal Policies of Hydropower Multi-Reservoir Systems Utilizing Enhanced Differential Evolution Algorithm." Water Resources Management: 1-23.

Borland, W. M. and C. R. Miller (1958). "Distribution of sediment in large reservoirs." Journal of the Hydraulics Division 84(2): 1-18.

Cristofano, E. A. (1953). "Area increment method for distributing sediment in a reservoir." US Bureau of Reclamation, Albuquerque, New Mexico.

Emami, S. A., Mahjoub, H., Jabari, E., & Alaghe Mandan, M. (2006). Evaluation of deposition in the Dez reservoir based on Empirical Area Reduction method and the calibration of results based on reservoir Hydrography results. Seventh International Seminar on River Engineering, Shahid Chamran University., Iran.

Hasirchian, M., Meshkati, J., Emadi, A., & Taghavi, J. (2010). Investigate the distribution of sediment in the Shahid Rajai dam reservoir (Tange Soleiman) with Area Reduction and Area Increment Method. The Fifth National Congress of Civil Engineering, Ferdowsi University of Mashhad, Mashhad, Iran. .

Heydari, M., F. Othman and M. Noori (2013). "A review of the Environmental Impact of Large Dams in Iran." International Journal of Advancements Civil Structural and Environmental Engineering, IJACSE 1(1): 4.

Heydari, M., F. Othman and M. Noori (2016). "OPTIMAL OPERATION OF MULTIPLE AND MULTI PURPOSE RESERVOIRS SYSTEMS USING NON-DOMINATED SORTING GENETIC ALGORITHM (NSGA-II)." FEB-FRESENIUS ENVIRONMENTAL BULLETIN:

2935.
Heydari, M., F. Othman and K. Qaderi (2015). "Developing optimal reservoir operation for multiple and multipurpose reservoirs using mathematical programming." Mathematical Problems in Engineering 2015.
Heydari, M., F. Othman, K. Qaderi, M. Noori and A. Pasa (2015). "Introduction to Linear Programming as a popular tool in optimal reservior operation, a review." American Eurasian Network for Scientific Information 9(3): 1-11.
Khodhal, N., & Ghiasi, R. (2009). Accuracy comparison of experimental methods (Area Reduction method, Area Increment Method and trigonometric levels) to estimate the deposition of sediments in the Karaj dam reservoir using survey data deposition. . The Second National Conference on Dams. , Iran.
Liu, J., S. Minami, H. Otsuki, B. Liu and K. Ashida (2004). "Environmental impacts of coordinated sediment flushing." Journal of Hydraulic Research 42(5): 461-472.
Mosavi, S. F., & Samadi Brojeni , H. (1996). "Evaluation of Sediment distribution in Small Dam Reservoirs in Chaharmahal Bakhtiari province. ." Water and Wastewater (Iran) 2(18): 4-13.
Mousavi, F., Mohammadzadeh Habili, J., & Haidarpour, M. (2008). "Evaluation of error in area reduction and area increment methods for predicting distribution of sediment in Dez, Doroodzan and Shahid Abbaspour reservoirs." Agricultural Sciences and Natural Resources 46 (twelfth year).
Mousavi, S. F., Heydarpour, M., & Shabanlo, S. (2006). "Evaluation of reservoir sedimentation in Zayandeh rood reservoir by area increment and area reduction methods. ." Water and Wastewater (Iran) 57: 7.
Othman, F., M. S. Sadeghian, F. Ebrahimi and M. Heydari (2013). "A Study on Sedimentation in Sefidroud Dam by using Depth Evaluation and Comparing the Results with USBR and FAO methods." International Proceedings of Chemical, Biological and Environmental Engineering 51(9): 43-48.
Rahmanian, M. R., & Banihashemi, M. A. (2011). "Sediment distribution pattern in some Iranian dams based on a new empirical reservoir shape function." Lake and Reservoir Management 27(3): 245-255. .
Sadeghian, M. S., M. Heydari, M. Noori, F. Ebrahimi and A. ShahiriParsa (2014). "Evaluating the Suspended Sediment of Mahabad Dam Using Statistical Methods." Journal of river engineering 2(7): 10.
Sadeghian, M. S., M. Heydari, F. Othman and S. Yeganeh "A STATISTICAL REVIEW OF THE MOST CITED ISI PAPERS IN THE FIELD OF RESERVOIR OPERATION."
Safamehr, M. (2011). "Study of Sediments Water Resources System of Zayanderud Dam through Area increment and Area reduction Methods, Isfahan Province, Iran." Procedia Earth and Planetary Science 4: 29-38. .
Sahay, R. R. (2011). "Life forecasting of Getalsud Reservoir in India based on its sedimentation behaviour." Lakes & Reservoirs: Research & Management 16(4): 287-292.
Salas, J. D. and H.-S. Shin (1999). "Uncertainty analysis of reservoir sedimentation." Journal of Hydraulic Engineering 125(4): 339-350.
Seyedian, S. M., & Shafaei Bajestan, M. (2006). Evaluation of reservoir sedimentation in the Vashmgir reservoir using a GSTARS 3 mathematical model. The Seventh International

Seminar in River Engineering, Shahid Chamran University. .

Shabanlo, S., Mousavi, S. F., & Heydarpour, M. (2003). Evaluation of input sediment to the Dez reservoir and its distribution so far and estimates of future conditions in the reservoir. The Sixth International Seminar on River Engineering, Shahid Chamran University

Shakeri Darian, A. N., M; Ahmadi, H. (2006). Selecting, planning and applying the appropriate mathematical model for estimating reservoir sedimentation The Seventh International Congress on Civil Engineering, Tarbiat Modarres University, School of Civil Engineering. .

Subramanya, K. (1994). Engineering hydrology, Tata McGraw-Hill Education.

Toniolo, H. and G. Parker (2003). 1D numerical modeling of reservoir sedimentation. IAHR Symposium on River, Coastal and Morphodynamics, Barcelona, spain.

Yang, C. T. (1996). Sediment transport: theory and practice, McGraw-hill New York.

Zare Bidaki, R. M., M. (2006). Review and analysis on hydrological methods of controlling sedimentation in reservoirs. The first regional conference on utilization of water resources and river basins Karoon (Opportunities and Challenges), Shahrekord University.

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