Tikrit Journal of Pure Science (2023) 28 (6):112-121
Doi:

TJPS

Tikrit Journal of Pure Science
ISSN: 1813 – 1662 (Print) --- E-ISSN: 2415 – 1726 (Online)

Journal Homepage: http://tjps.tu.edu.iq/index.php/j

Spatial analysis for geometric parameters of Badush dam reservoir, Mosul, Northern Iraq

[1*]Maha Shaher Badowi, [2]Sabbar Abdullah Saleh, [3]Mohammad Rashid Abood
[1,2,3] Department of Applied Geology, College of Science, Tikrit University, Iraq.

Keywords: Geometric property; Badush; Dam; Reservoir; Breakdown.

ARTICLE INFO.

Article history:

- **-Received:** 10 May 2023
- **-Received in revised form:** 04 July 2023
- **-Accepted:** 05 July 2023
- **-Final Proofreading:** 24 Dec. 2023
- **-Available online:** 25 Dec. 2023

Corresponding Author*:
Maha Shaher Badowi
mahageo88@gmail.com

ABSTRACT

The Iraqi government planned to complete the building of partially constructed Badush dam to protect against the collapse of Mosul Dam on Tigris River northwest of Mosul. The study aimed to derive the ge1ometric parameters that compatible with the levels ranged 226.5-312 m (a.s.l.) such as reservoir volume, reservoir area, reservoir submerged area, perimeter, and average depth of the water column, which values ranges are 68039-12354976139 m^3, 130074-407943574 m^2, 130078-410538707 m^2, 2.32-594.27 km, and 0.52-30.29 m respectively. These parameters were analyzed against the raising of the level, the spatial analysis of the geometric criteria and its relations with the levels of Badush reservoir showed that the relations between the volume of the positive bodies (islands), the undulated areas above water level which indicate the islands, and the planer areas (projections) of the islands with the level, fluctuates between increase and decrease with an increase in the level, as for the volume of reservoir, the submerged undulated area, the exposed planer area of the water pond, and the average water column depth they increased with the level increasing, unlike the thickness of the islands with the level, which fluctuates in increase and decrease with the level, the geometric analysis of the reservoir showed that Badush Dam is able to absorb the flood wave resulting from the collapse of Mosul Dam, at a level much lower than the level suggested in the preliminary studies that were adopted in the designs, because a large part of the water of Mosul Dam reservoir will remain in the same reservoir when the level is balanced after the collapse. between the two reservoirs, and that the results of this analysis represent a database that will be used in subsequent modifications in the designs.

Tikrit Journal of Pure Science (2023) 28 (6):112-121
Doi:

TJPS

التحليل المكاني للعناصر الجيومترية لخزان سد بادوش، الموصل، شمال العراق

[1] مها شاهر بدوي، [2] صبار عبد الله صالح، [3] محمد راشد عبود

[3،2،1] قسم علوم الارض التطبيقية، كلية العلوم، جامعة تكريت، تكريت، العراق

الملخص

تعمل الحكومة العراقية لاستكمال بناء سد بادوش المنفذ جزئياً للحماية من انهيار سد الموصل على نهر دجلة شمال غرب الموصل، تهدف الدراسة إلى استخلاص العناصر الجومترية المناظرة للمناسيب التي تراوحت بين 226.5 و 312 م وبفاصلة 0.5 متر، ومن هذه العناصر حجم الخزان، ومساحة الخزان، ومساحة المنغمرات في الخزان، والمحيط ، ومتوسط عمق العمود المائي والتي تراوحت قيمها بين 68039 -12354976139 م^3، 407943574-130074 م^2 ، 410538707-130078 م، 594.27-2.32 كم، و 30.29-0.52 م على التوالي. تم تحليل تغاير هذه العناصر مقابل ارتفاع المنسوب، وبين التحليل المكاني للعناصر الجيومترية وعلاقتها بمناسيب خزان بادوش ان تذبذب العلاقات بين حجم الأجسام الموجبة (الجزر)، ومساحاتها المتموجة فوق مستوى الماء ومساقطها المستوية، ومعدل سماكاتها، بين زيادة ونقصان مع ارتفاع المنسوب، على العكس منه بالنسبة للعناصر السالبة كحجم الخزان، والمساحة المغمورة (غير المستوية)، والمساحة المستوية المكشوفة للخزان، ومتوسط عمق عمود الماء والتي تزداد زيادة طردية مستمرة مع زيادة المنسوب، كما اظهر التحليل الجيومتري للخزان ان سد بادوش قادر على استيعاب الموجة الفيضانية الناتجة عن انهيار سد الموصل، عند منسوب اقل بكثير من المنسوب المقترح في الدراسات الاولية التي اعتمدت في التصاميم، لان جزء كبير من مياه خزان سد الموصل ستبقى في نفس الخزان بعد توازن المنسوب بعد الانهيار بين الخزانين، وان نتائج هذا التحليل تمثل قاعدة بيانات تعتمد في التعديلات اللاحقة في التصاميم.

1. Introduction:

Within the management plan for Tigris River basin, Badush dam was proposed to construct (currently partially constructed) as a protection dam against the collapse of Mosul dam due to engineering or structural problems. and to reduce its destructive effects on residential areas as well as damage to agricultural lands, and to utilize them in dry seasons, generate electric power, tourism, ward off flood risks, fish farming, and irrigation purposes.

Spatial analysis of geometric characteristics for the reservoir is very significant to know the relations between the geometric parameters and level of water in the reservoir, moreover to analyze the geometric criteria such as negative volume (storage volume) m^3, positive planer area (area of island projection) m^2, negative planer areas (area of water body) m^2, undulated surface areas of positive bodies (islands) m^2, and negative surface area (submerged areas) m^2, of dam reservoir [1]. Badush dam located in northern Iraq, within Nineveh Governorate, on Tigris River about 40 kilometers south of Mosul Dam and about 16 kilometers northwest of Mosul, between the UTM coordinates 280000 – 327000 East, and 4030000 – 4060000 North, while the regulation dam located between the two mentioned dams, figure 1.

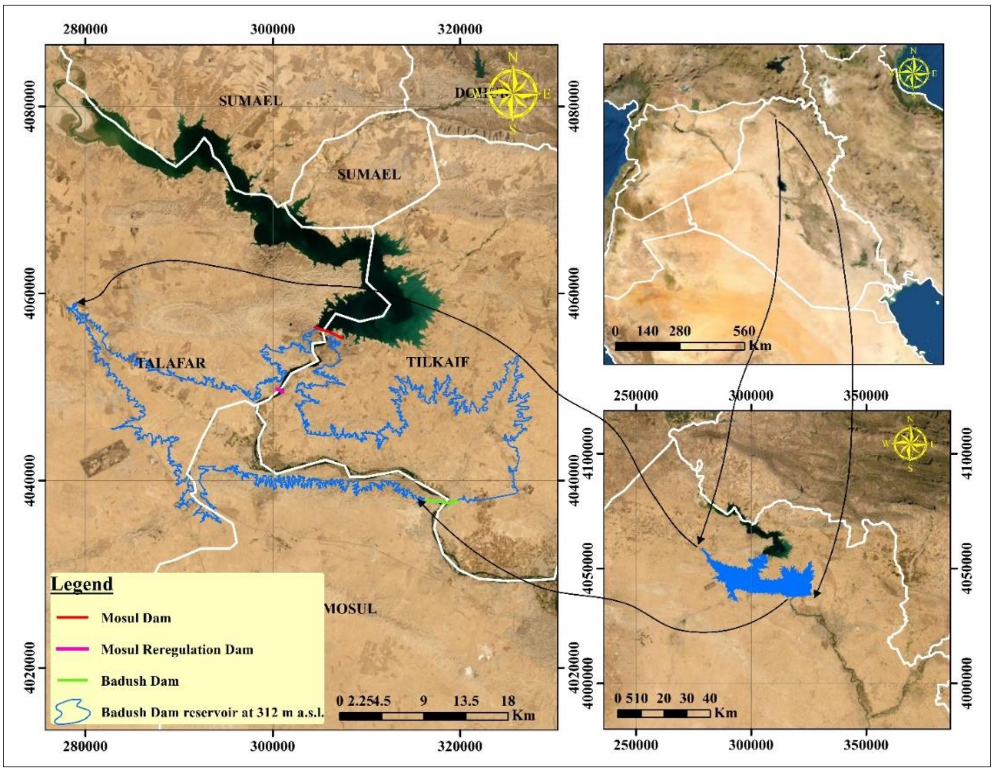

Fig. 1. Location of the three dams in the study area.

The outcropped geological formations in the area periods from Paleocene to Recent ages. The lithostratigraphic sequence of the bedrock layers is composed of Mukdadiya Formation of Lower Pliocene, Injana Formation of Upper Miocene, the Fat'ha formation (Middle Miocene), Euphrates Formation of Lower Miocene, Jeribe Formation of Middle Miocene, Jaddala Formation of Early Eocene-Late Eocene and Sinjar Formation of Paleocene-Early Eocene distributed between the reservoir and watershed.

The Euphrates Formation (Lower Miocene) was first described by [2]. The formation is composed of dolomitic, fossiliferous, and oolitic limestone with green marls at the top [3]. The thickness of the formation is from (26-50) m. It is exposed at the core of the Alan anticline; with highly karstified rocks [4]. Recent alluvial deposits (river terrace deposits and alluvial deposits silt, silty clay, sand, gravel pebbles and cobbles) cover the major portion of the reservoir area, thickness of these sediments vary from several centimeters to more than ten meters [5].

Fat'ha Formation outcrops on the surface on both sides along Tigris River between the dam site and the reservoir, the formation is divided into Lower and Upper Members and forms the majority of the Alan anticline and surrounding areas [4].

Lower Fat'ha: It consists of marl, marly limestone, limestone, and gypsum, usually these rocks have variable thicknesses in sedimentary cycles [6].

Upper Fat'ha: It consists of successions of limestone, mudstone, silt stone, and thin layered gypsum [6]. These rocks have high hazard on the reservoir and dam.

Injana Formation is a series of interbedding of sandstone, siltstone, sand (the sandstones and sands are medium to fine grained) and claaystone. These sediments fill the synclinal foredeep which lies close to Sinjar, Bashiqa, and Ain Alsafra anticlines. Injana outcrops appear in the ultimate northwest and northeast parts of the reservoir in the lower synclinal parts of the structure [5].

Tectonically and structurally, Badush Dam and reservoir areas represent a part of the Unstable Shelf, Foothill Zone, and Mosul Butmah subzone. Allan anticline is the most outstanding structure in the reservoir area. It is an asymmetric double-plunge anticline. Its southern limb is inclined by 22° and the northern limb is inclined by 10°, and the length of the anticline is about 26 km and the width is approximately 4 km [7]. The dam site is located at the eastern end of the anticline, which refer to the left shoulder of Badush Dam.

There are several indications that Badush Dam site is not suitable for long-term storage, all of these indications are based on the geological background of the site, however, the site is suitable as a protection dam with low storage at low levels.

The geometry of Badush reservoir may affects the behavior of flash flood's discharge resulting from Mosul dam breakdown. The section of Badush reservoir also effects the flood peak discharge, this conclusion was also indicated by [8], who studied the reservoir's geometry impact on the peak discharge of dam-failure flash flood. The results showed that shape factor and failure ratio have a significant impact on the out-flow hydrograph. [9], studied the geological and geometric study of the proposed Fat'ha dam reservoir as a blocking dam for the proposed Makhoul dam in Al-Fat'ha area north of Baiji. The study included determining the geological outcrops that submerge at each level and the extent of their impact on the dam and reservoir facilities; the geometrical parameters such as reservoir volume, reservoir surface area, perimeter, submersed area and depth of water column; derived and then analyzing their relations with the levels and with each other and the changing of the reservoir shape; in addition to determining the optimum level of the dam when Makhoul dam collapse, and identifying the affected areas.

The present study aimed to derive the reservoir volume, reservoir area, perimeter, reservoir submerged area, and depth of the water column, as geometric parameters and analyzing their relations with the levels and with each other and the changes of reservoir shape with the changes of level, The geometric parameters corresponding to the levels were derived from the lowest level 226.5 m (a.s.l.) to the highest emergency flood level 312 m (a.s.l.), with an interval of 0.5 meters.

2. Methodology

Several geospatial software were used to extract the geometric relations of the reservoir of the study area, and calculate the geometric parameters that can be summarized by the following:

1. The software Arc.GIS 10.3, Global Mapper.18, and Surfer.16. used for processing the (DEM) and then extract and export the data, then mapping the reservoir extensions.
2. The Global Mapper.18 used to select and deduct the study area within the borders of Badush reservoir at level of (312) m (a.s.l). that the highest peak flood of the reservoir when Mosul dam breakdown, and export the deducted area as a (Global Mapper Package File).
3. The digital elevation model (10*10 m) used to extract the geometric element for majority of the studied area, except for small parts in the southeast of the area where (30*30 m DEM used. The model of the reservoir was extracted at (172) selected levels, from (226.5) to (312) m (a.s.l) by an interval (0.5) m, then it was exported as Global mapper package file and re-exported as maps in JPG format at one scale for the visual comparison between the extent of the reservoir at each level. it was noted that the extensions in the area of the reservoir increase with the increase in the level, showing a change in the shape of the reservoir at each level.

4. Generate contour lines for the heights of the earth's surface to determine the predicted geometric parameters for the selected levels using the command (Generate Contour) in the Global Mapper.18, with contour interval (0.5) m, from the lowest level (226.5) m at the dam site, to the level of (312) m above sea level), that represents the highest level of peak flood of the dam reservoir when the breakdown of Mosul dam.
5. The deducted data was exported by the Global Mapper.18 as (SURFER Grid File) format and by the SURFER (Grid-Volume), to generate a Grid Volume Report, then enter the file name in Upper Surface field and the reservoir's hypothetical water surface in the Lower Surface field.
6. Extracting the volumetric and areal geometric parameters using (SURFER.16) program, where the positive volume, negative volume, positive surface area, negative surface area, positive planer area and negative planer area were calculated for 172 different levels, so the table of the derived geometric elements is too large and cannot be presented in this paper, but it can be replaced by graphic figures that show the relationship of the geometric elements to the level.
7. The relations of the various geometric parameters and the hypothetical levels of water in the reservoir are plotted by (Excel).

3.Result and Discussion

3.1. The extensions of the reservoir.

The studies of spatial analyses of geometric parameters are locally and globally very few, but there are few recent studies that are use this methodology, such as the study of [9], which included the spatial analyses of geometric parameters for dam reservoir, as well as the blocking dam, and other local studies, such as the studies of [10]; [11]; [12]; and [13]; on Makhoul Dam reservoir, Al-Wind dam reservoir, and Bekhma Dam reservoirs respectively, as hydro-geometric studies to select the optimal level, routing of these dams reservoirs, or analysis of immersed geological formations.

The model of the studied reservoir was extracted at (172) selected levels, from (226.5 m) to (312 m) above sea level with an interval of (0.5) m. As for the extensions of the reservoir, they increase with the increase of the level. Through a visual comparison of the hypothetical levels chosen at a specific unified scale. As for the growth of the reservoir from the lowest level to the flood level (312) m (a.s.l), downstream to Mosul Dam as in figures (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12) and (13). it was concluded that the growth of Badush reservoir at the highest operational level (245.5) m (a.s.l) reaches the downstream of Mosul Reregulation Dam.

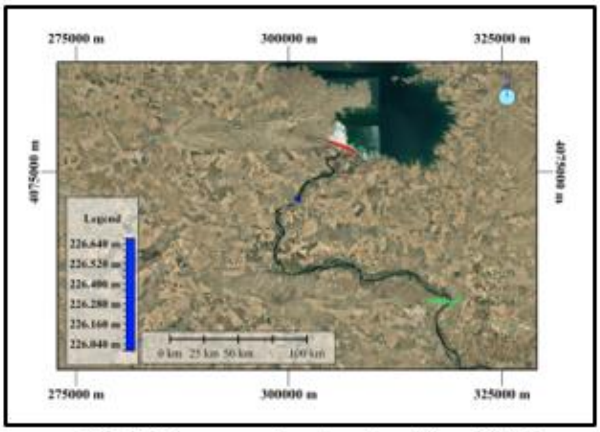

Fig. 2. The reservoir extension at level 226.5 m.

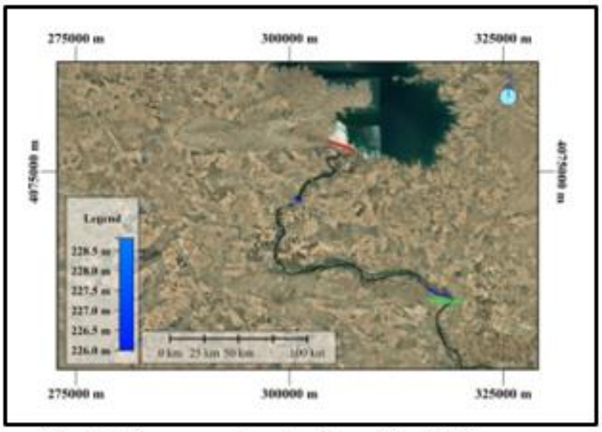

Fig. 3. The reservoir extension at level 228 m.

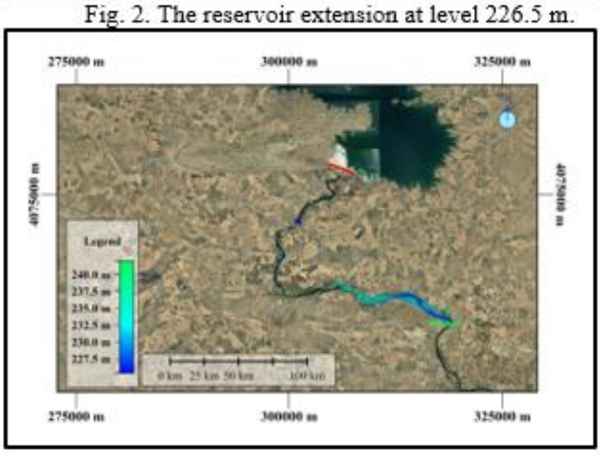

Fig. 4. The reservoir extension at level 235 m.

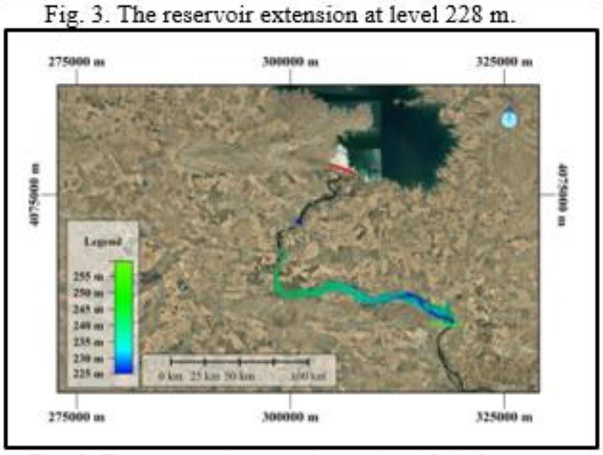

Fig. 5. The reservoir extension at level 241.5 m.

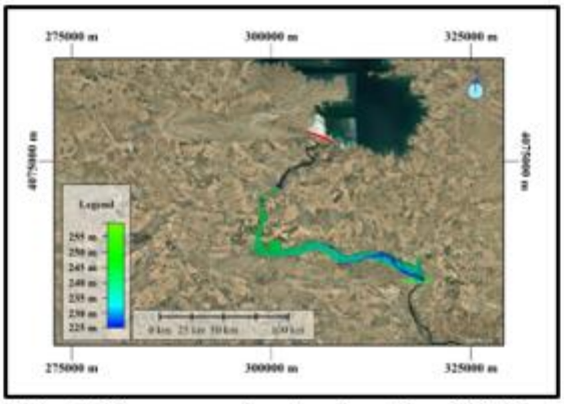

Fig. 6. The reservoir extension at level 245 m.

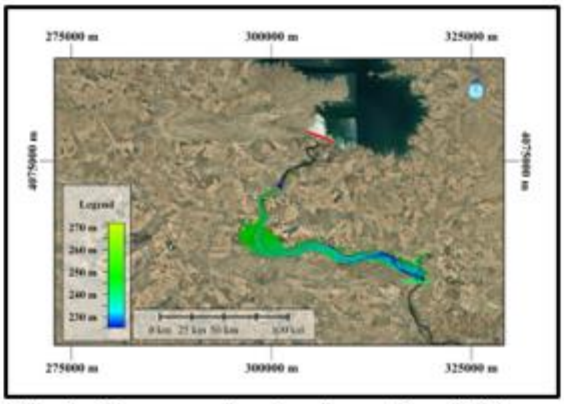

Fig. 7. The reservoir extension at level 250 m.

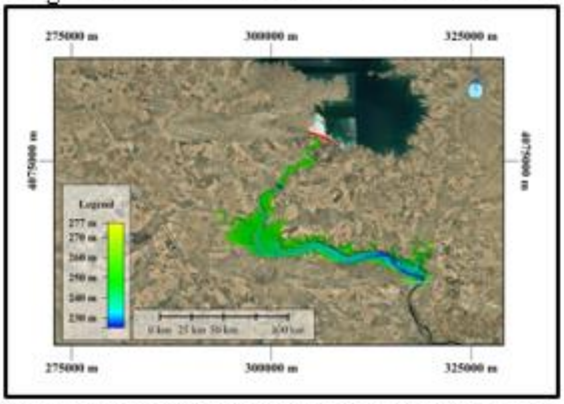

Fig. 8. The reservoir extension at level 261.5 m.

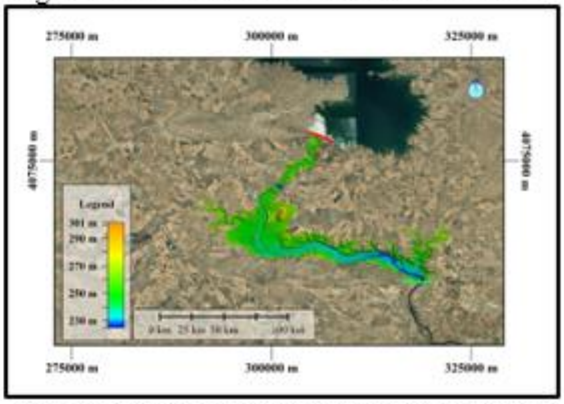

Fig. 9. The reservoir extension at level 270 m.

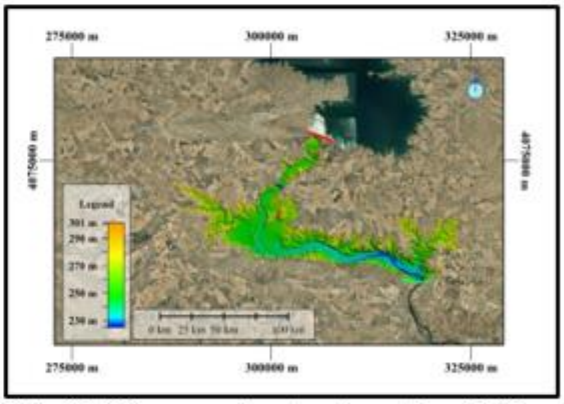

Fig. 10. The reservoir extension at level 280 m.

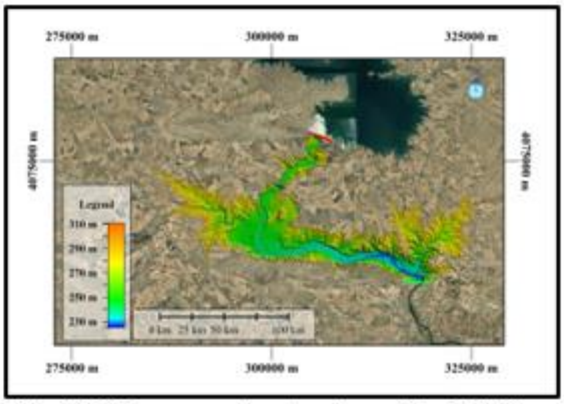

Fig. 11. The reservoir extension at level 290 m.

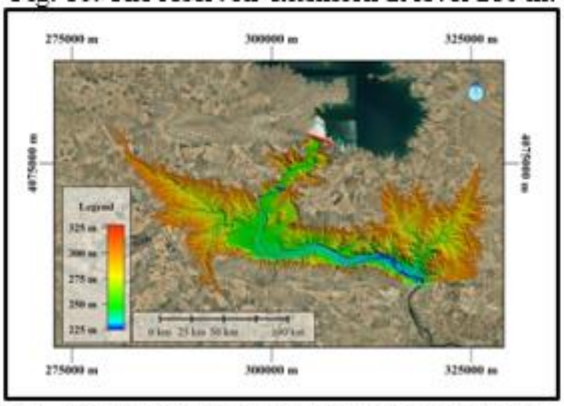

Fig. 12. The reservoir extension at level 309 m.

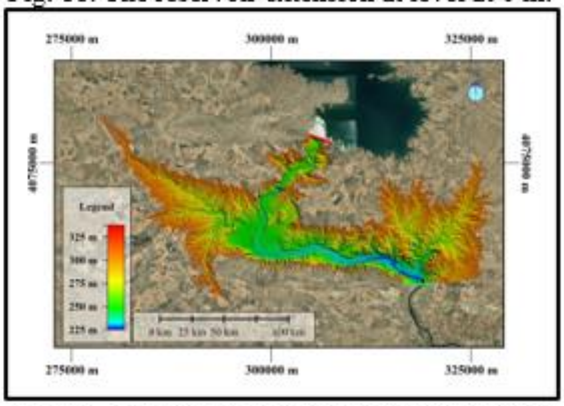

Fig. 13. The reservoir extension at level 312 m.

3.2. The relation between water level in the reservoir and the volume of islands (positive).

The relation between the water level in the reservoir on the X-axis and the volumetric geometrical parameters on the Y-axis was drawn. Through the first of these relations, a variation occurred between the positive volume and the water level. Which showed this relation vibrate between increasing and decreasing positive volume with an increased water level. From the level of 226.5 m to the level of 246.5 m, the increase will fluctuate. Then a high increase happens at the level of 247 m, where the positive volume is about (3711497 m^3). The reason for this is that the reservoir begins to progressively approaching to the level of 262 m, where the positive volume is about (962374 m^3), and then the highest increase is obtained at the level of 268 m, the positive volume to be about 24098446 m^3as a result of adding new islands. The addition of new land to the reservoir body is an important determinant factor in the future land uses, especially the areas of islands that will appear at these levels as shown in figure 14.

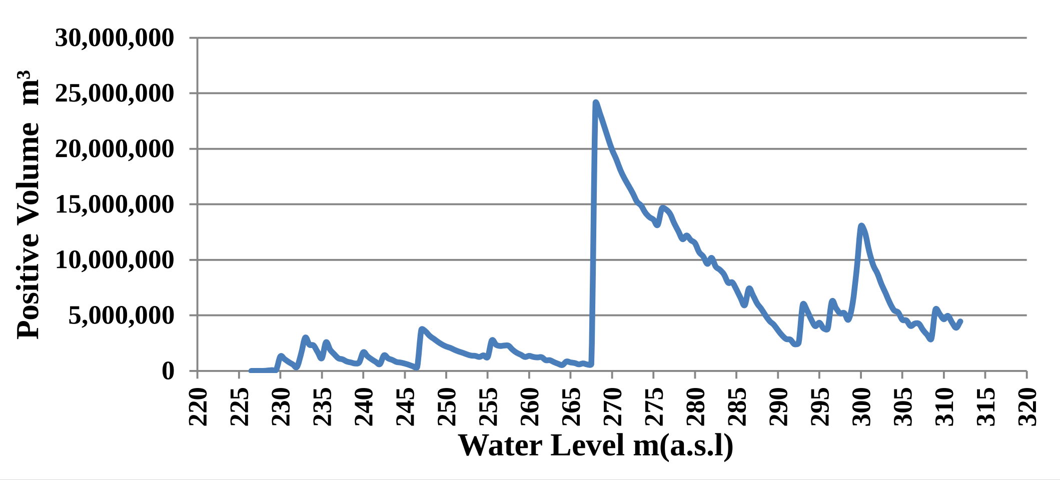

Fig. 14. Relation between water level and positive volume (island Volume) of reservoir.

3.3. The relation of water level in the reservoir with capacity of reservoir (negative volume).

The relation between the selected water level in the reservoir was plotted on the x-axis, against the negative volume on the y-axis, it was noticed an increase in the negative volume with the increase in the water level, The increasing curve behavior affected by the extension of the reservoir from the initial riverbed to the strip of flood plain surround the river channel and then the extension of the reservoirs from surround flood plain to the area of river terraces in the latest period, as in figure 15, this relation represent the main requirement to derive the mathematical models needed for the scenarios of Badush reservoir filling, Mosul dam breakdown and the response of Badush dam and reservoir, and the behavior of groundwater in reservoir banks.

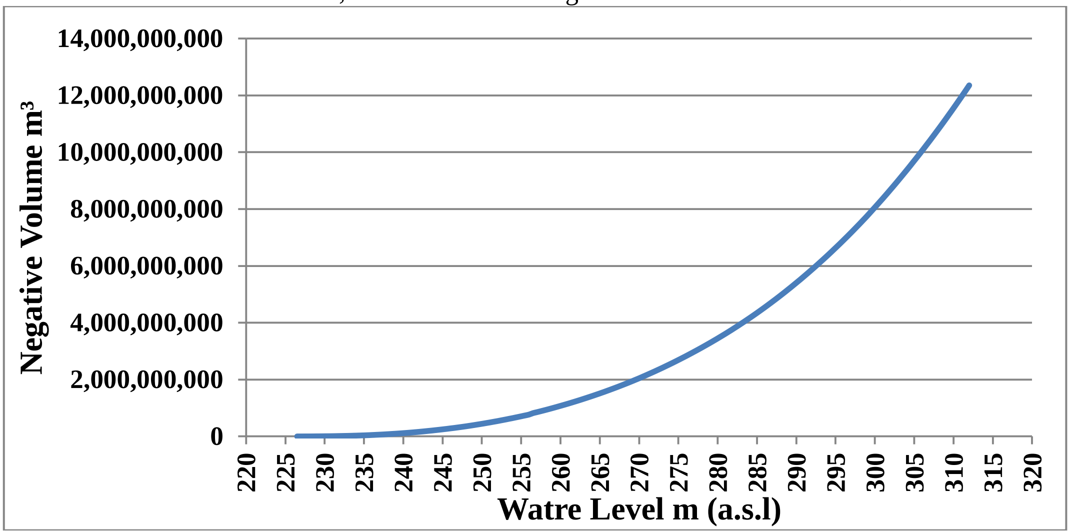

Fig. 15. The relation between the negative Volume (storage Volume) and the water level of reservoir.

3.4. The relation between water level in the reservoir with undulated surface areas of islands.

The positive surface area, which indicates the non-planar area of the exposed islands within the borders of the reservoir, begins with an increase where the level (232.5- 233 m) and a second increase where the level (246.5-247 m) and a third increase where the level (267.5- 268 m) due to the extension of the reservoir from the initial reach of the river, it increases directly at this level and then begins to progressively decreases, as in figure 16.

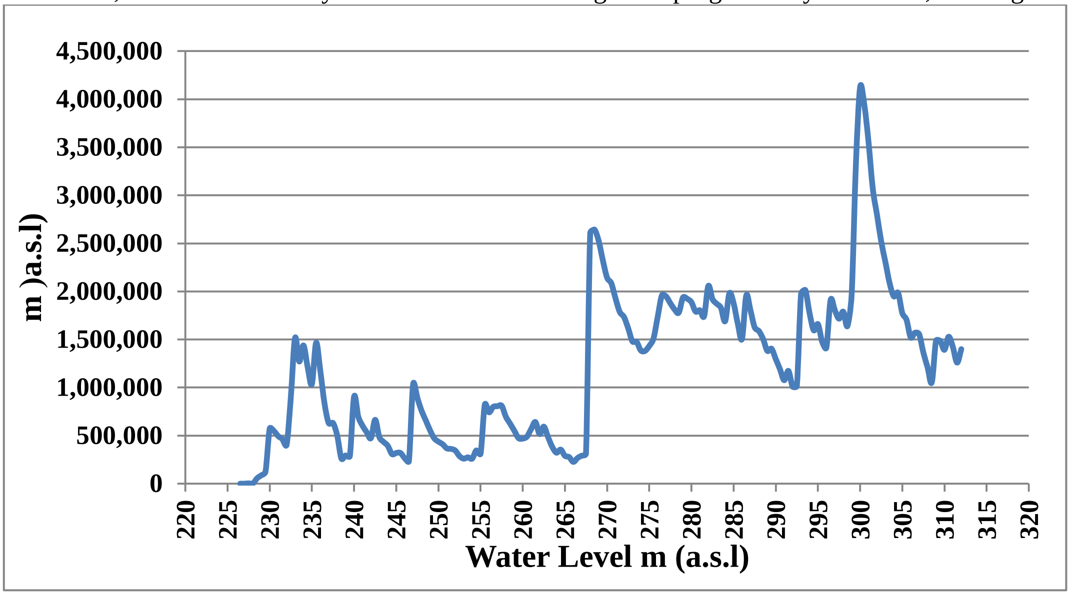

Fig. 16. The relation between the positive surface areas with the water level of reservoir.

3.5. The relation of water level in the reservoir with undulated reservoir area (negative).

The negative surface area, which indicates the uneven immersed area in figure 17, increased continuously and with the increase in the level.

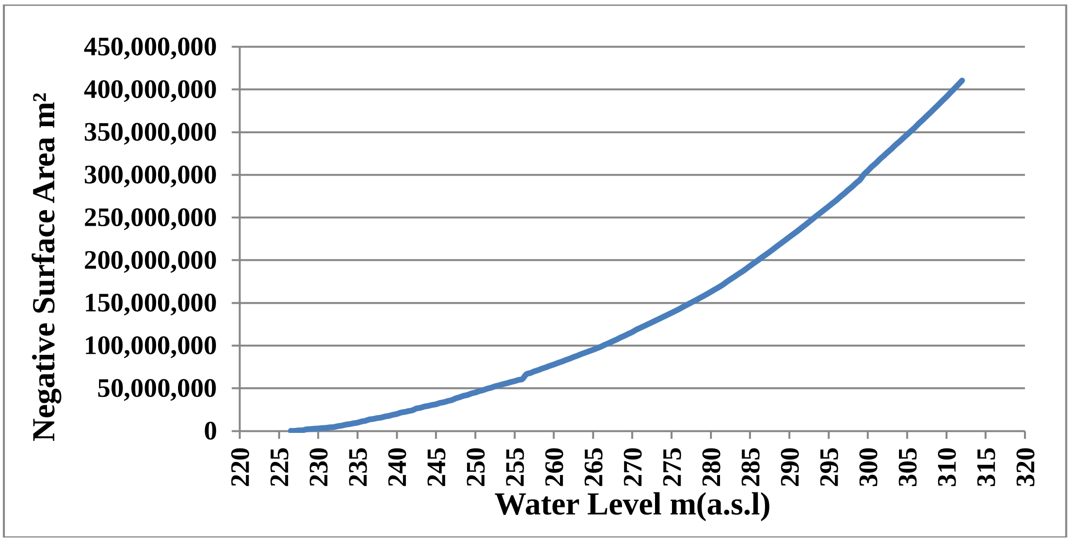

Fig. 17. The relation between the negative surface areas and the water level of reservoir.

3.6. The relation of water level in the reservoir with planar areas of islands (positive).

The positive planar area, which indicates the (the projection of the island), behaves similarly to the positive surface area, as it is relatively three stages the first in level (232.5-233 m), while the second in the level (267.5-268 m) and in the third stage of the level (299.5-300 m), as the borders of Badush reservoir are remain within the initial studied reach of Tigris river within the area, but the area extended directly due to the appearance of new islands, which makes the islands appear and disappear with the increase in the level due to the joining of new lands to the reservoir body, as in figure 18, these results can be used as data base to build the programs and scenarios of reservoir filling and its response against the breakdown of Mosul dam.

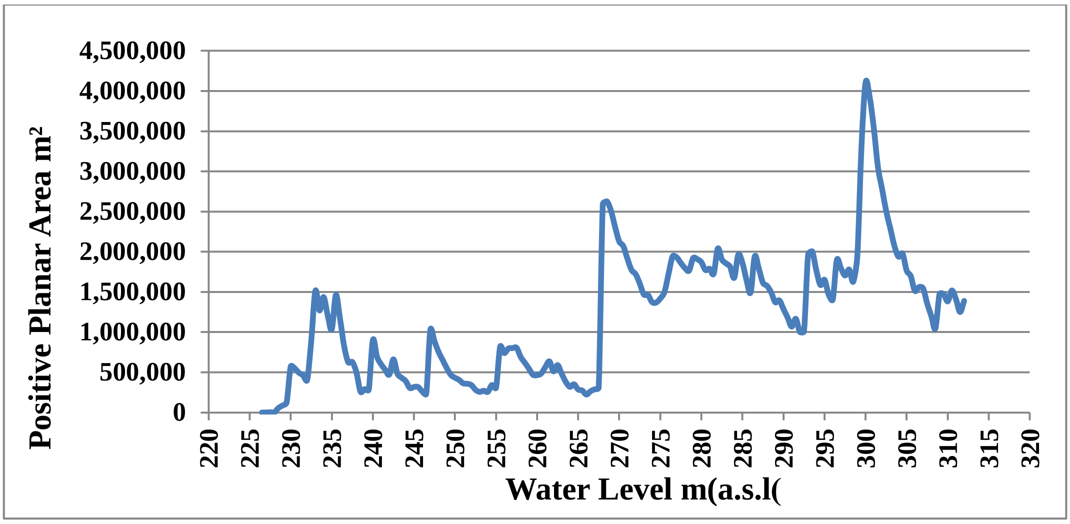

Fig. 18. The relation between the positive planar areas and the water level of reservoir.

3.7. The relation of the water level in the reservoir with water body planar areas (negative).

The negative planer area, which indicates the exposed area of water body, it is behaves identically to the negative surface area, it is notice that the planer area of water body (negative) continuously increases, and does not fluctuate when the increase of the level as in figure 19.

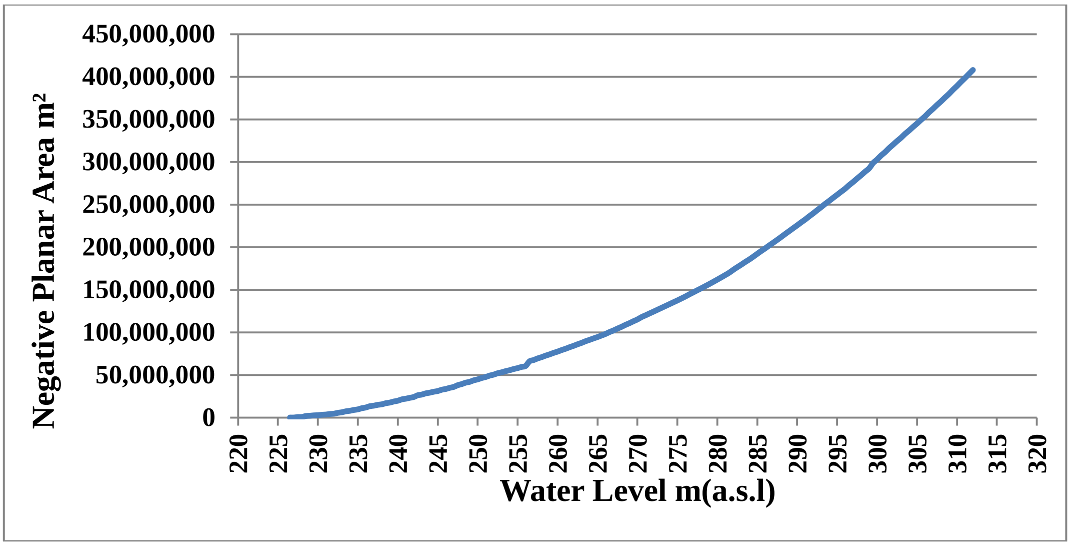

Fig. 19. The relation between the negative planar areas and the water level of reservoir.

3.8. Relation of the level in the reservoir with the average reservoir depth.

The average depths at selected levels were calculated by dividing the reservoir volume on the planer area of the reservoir at each of the selected levels, according to the relation between water level in the reservoir against the average reservoir depth, it was concluded that the depth increased when the increase of extension and level of the curve is semi-linear, where (0.523 m) at the level 226.5 m and continues to increase with the increase in the level to reach (9.877 m) at the operational level and (30.285 m) at the flood level as in figure 20.

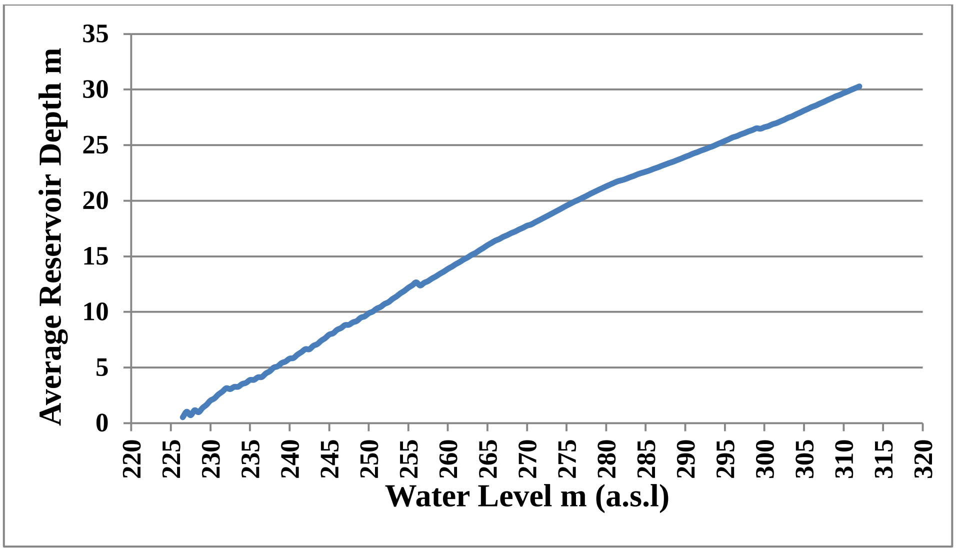

Fig. 20. The relation between the reservoir average depth and the water level of reservoir.

3.9. Relation of the level in the reservoir with the average islands thickness.

Regarding to the relations of the level and the average thickness of islands, it is concluded that the average height above the water level is fluctuated with the thickness of islands. It is equal to (0.58 m) at the level (226.5m) above sea level, and then increases to reach (10.38) m at the level (273) m, which indicates the largest average height of the islands within the borders of Badush Dam reservoir, which is partially appears, then progressively decreases to reach (2.395) at the level (292) to continue to fluctuate to the level of (312) as shown in figure 21.

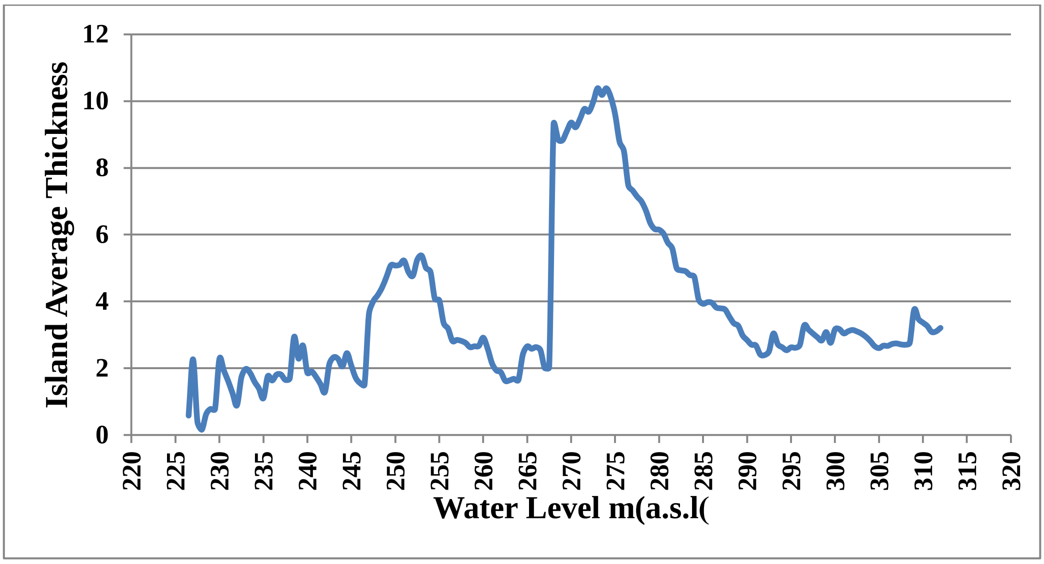

Fig. 21. The relation between the average islands thickness and the water level of reservoir.

4. Conclusions:

The current study is the first attempt to analyze Badush Dam reservoir, using digital elevation model data, which were not present during the traditional preliminary surveys conducted four decades ago. It was found that the results of the analysis could be a solid database that could be used to develop the designs of the dam, as it gave a visualization of the growth of the volume of reservoirs and immersion areas, and a vision of the status of the islands and their extensions and their appearance and disappearance at different levels. This database will be essential for suggest scenarios of filling the reservoir and the behavior of the reservoir towards a possible failure of the Mosul Dam upstream of the Badush Dam.

Spatial distribution analysis and the relations of geometric parameters with the level of Badush Dam reservoir reflect proportional relationship between volume of the positive bodies above water levels (islands), the undulated area of the islands, and the planer area (projections) of the islands with the level, fluctuates between increase and decrease with an increase in the level, as for the volume of reservoir, the submerged undulated area, the exposed planer area of the water body, and the average depth they increased with the increase of the level, unlike the thickness of the islands with the level, which fluctuates in increase and decrease with the level, the

geometric analysis of the reservoir showed that Badush Dam is able to absorb the flood wave resulting from the collapse of Mosul Dam, at a level much lower than the level suggested in the preliminary studies that were adopted in the designs, because a large part of the water of Mosul Dam reservoir will remain in the same reservoir when the level is balanced between the two reservoirs after the collapse, and that the results of this analysis represent a database that will be used in subsequent modifications in the designs.
The spatial analysis of the level showed that when the reservoir reaches the highest operational level, the storage effect reaches near the regulatory dam gates, which requires caution, and lowering the normal operational level of the Badush reservoir.

References:

[1] Saleh, S.A., Ali, B.R. and Ahmed, M.A. (2021) Study of Geometric Parameters for the Proposed Protecting Dam Reservoir in Al-Fat'ha Area, Iraq, E3S Web of Conferences, 2nd International Conference on Geotechnical Engineering – Iraq (ICGE 2021), 318, 01009, pp.1-13. https://doi.org/10.1051/e3sconf/202131801009.
[2] Bellen, W. A. et al. (1959) Laxique Stratigraphy International Asia Fascicule 10 a – Iraq, Center National Dela Researches Scientifics. Paris.
[3] Ctyroky, P. and Karim, S. A. (1971) 'Stratigraphy and Paleontology of the Oligocene and Miocene strata near Anah, Euphrates Valley. NIMCO Report No. CZ 140, SOM', Library, Baghdad.
[4] Sissakian, V. et al. (2018) Geological and Geotechnical Study of Badush Dam, Iraq,
[5] Ministry of water Resources (2008) Badush dam project, internal report.
[6] Jassim, S. Z. and Goff, J. C. (2006) Geology of Iraq. DOLIN, sro, distributed by Geological Society of London.
[7] AL-Daghastani, H. S. and Ghanem, B. G. (2018) Comparison Between Visual and Digital Interpretation of Lineament Features in Allan Anticline Northern Iraq, Iraqi National Journal of Geosciences, 18(1), pp.1-18.
[8] Tahershamsi, A., Hooshyaripor, F. and Razi, S. (2018) Reservoir's geometry impact of three dimensions on peak discharge of dam-failure ash ood, Scientia Iranica, 4(25), pp.1-12.
[9] Albayati, B. A. R. A. (2019) Geological and geometric study of the proposed aperture dam reservoir as a blocking dam for the proposed Makhoul dam, Al Fateh area north of Baiji. University of Tikrit.
[10] Saleh, L. M. (2014) Makhoul Reservoir Dam Hydro geometric study of select the optimum level. Ph.D. Thesis, Tikrit University, Iraq.
[11] Nida, G.Sh. Saleh, S.A. (2017) Flood Routing of Tigris River in Baiji Station and Makhoul Dam Reservoir under Supposed Operation of the Dam, Tikrit Journal of Pure Science, 22(1), pp.115-127.
[12] Saleh, S.A., Abdul Qadir, I.T., Ibrahim, A.M. and Hussain, H.M., (2018) Geometric Investigation of Al-Wind Dam Reservoir Northeastern Iraq, using Digital Elevation Models and Spatial Analyses System. Tikrit Journal of Pure Science, 23(3), pp.75-86. https://doi.org/10.25130/tjps.v23i3.503.
[13] Abdula, N., Omary, F., and Al-Kaisy, S. (2022) Analysis of immersed geological formations for Bekhmeh dam reservoir/ Erbil. Tikrit Journal of Pure Science. 27, pp. 50-76. https://doi.org/10.25130/tjps.v27i1.82.