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# Suggested Scenarios of Initial Filling for the Badush Reservoir, Iraq

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**Keywords:**
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**Abstract**: This study developed hypotheses based on the geometric analysis of the Badush Dam reservoir to simulate the initial filling and operation of the dam reservoir. A mathematical equation was developed to estimate the daily demand for water behind the dam, and then build an EXCEL program for calculating the input demand, output discharges, and the storage difference for the dam reservoir. Conditions and parameters for continuous/rapid filling and others for gradual filling of the reservoir were arranged in the program. The daily input discharges records, demand, and output discharges produced for the two wet and dry years selected from the records released from Mosul dam to implement the scenarios of rapid and gradual filling of Badush reservoir. The results showed that the reservoir could be filled within 20 or 130 days, according to the continuous (rapid) filling program in the wet or dry years, respectively, and the possibility of filling the reservoir within 133 or 258 days, according to the gradual filling program in the same two wet or dry years, respectively. The operation was more flexible in the dry year than the wet because the wet years may have high daily discharge releases from Mosul Dam, which requires careful monitoring of the Badush reservoir levels. After all, it may rise in a critical period and needs quick intervention by the operator. In rapid filling, it was noted that the daily increase during the days of storage in a wet year was about 1-2 m/day while no more than 1 m/day for the dry year. Regarding the gradual filling, the daily increase during the days of storage in the wet year varied between 1-3 m/day on some days that do not coincide with the peak flood wave. In the second stage, which lasted only two days, the level rose between 3-4 m/day. The third stage, which lasted only one day and coincided with the peak flood, was accompanied by a sharper increase in the level, reaching 7 m/day. The daily level increased from a few centimeters to 2 m/day through the gradual filling in the dry year.

# السيناريوهات المقترحة للملئ الأولي لخزان سد بادوش، العراق

**مها شاهر بدوي، صبار عبدالله صالح، محمد راشد عبود**
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**الخلاصة**
في الدراسة الحالية، تم تطوير فرضيات مبنية على التحليل الجيومتري لخزان سد بادوش، لمحاكاة الملء الأولي وتشغيل خزان السد. تم بناء معادلة رياضية لتقدير الطلب اليومي على المياه خلف السد مع استخدام برنامج أكسل لحساب الطلب على التصاريف الداخلة والتصاريف الخارجة وفرق الخزين لخزان السد. تضمن البرنامج معادلات رياضية أخرى لتحديد منسوب المياه في الخزان بدلالة الحجم التراكمي للمياه داخل الخزان. تم ترتيب الشروط والمعايير الخاصة بالملء المستمر/السريع وغيرها للملء التدريجي للخزان في البرنامج .كما تم اختيار سجلات التصاريف الداخلة اليومية والطلب والتصاريف الخارجة (المحددة وفقًا للتصاريف االداخلة والطلب في منطقة المؤخر) التي تم اختيارها لسنتين رطبة وجافة من سجلات الإطلاق لسد الموصل لتنفيذ سيناريوهات الاملاء السريع والتدريجي لخزان سد بادوش. بينت النتائج أنه يمكن ملء الخزان خلال فترة ٢٠ يوماً أو ١٣٠ يوماً حسب برنامج الملء المستمر (السريع) في السنوات الرطبة أو الجافة على التوالي، وإمكانية ملء الخزان خلال فترة ١٣٣ يوماً أو ٢٥٨ يومًا، وفقًا لبرنامج الملء التدريجي في نفس السنتين الرطبة أو الجافة على التوالي. كانت عملة الاملاء أكثر مرونة في السنة الجافة لأن السنوات الرطبة قد يكون لها إطلاقات تصاريف يومية كبيرة من سد الموصل، الأمر الذي يحتاج إلى مراقبة دقيقة للمناسيب في خزان بادوش، لأنها قد ترتفع في فترة حرجة وتحتاج إلى تدخل سريع من قبل المشغل .لوحظ عند الملء السريع/المستمر أن الزيادة اليومية في المنسوب خلال أيام التخزين في السنة الرطبة تبلغ حوالي ١-٢ م/يوم، بينما لا تزيد عن ١ م/يوم للسنة الجافة. أما فيما يتعلق بالملء التدريجي فإن الزيادة اليومية في المنسوب خلال أيام التخزين في السنة الرطبة تتراوح بين ١-٣ م/يوم في بعض الأيام التي لا تتزامن مع ذروة موجة الفيضان، ولكن المرحلة الثانية والتي استمرت ٢ يوم فإن المنسوب ارتفع ما بين ٣-٤ م/يوم. وفي المرحلة الثالثة التي استمرت يومًا واحدًا فقط فقد تزامنت مع ذروة الفيضان، وامتازت بارتفاع حاد في المنسوب وصل إلى ٧ م/يوم، لكن عند الملء التدريجي في السنة الجافة تراوحت الزيادة اليومية في المنسوب بين بضعة سنتيمترات إلى ٢ م/يوم.

**الكلمات الدالة:** سد بادوش، السد التنظيمي، خزان، التعبئة الأولية.

**1.INTRODUCTION**

Badush Dam on the Tigris River is located in Nineveh Governorate, northern Iraq, about 40 kilometers south of Mosul Dam and about 16 kilometers northwest of Mosul City. The regulatory dam is located on the river between Mosul and Badush dams. Fig. 1 shows the geographic location of the studied dams.

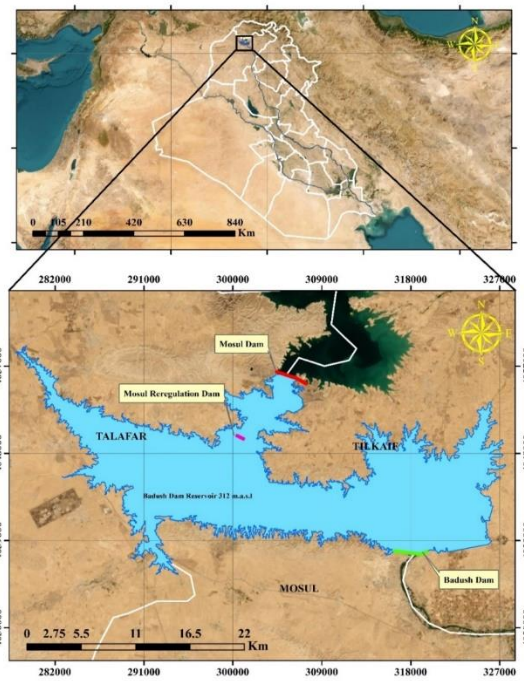


**Fig. 1** Geographic Location of Badush Dam.

The dam reservoir's preliminary filling is the first dam's performance check. Therefore, the reservoir's initial filling must be planned, controlled, and closely monitored to reduce the risk of collapse. A carefully accomplished initial fill is essential to the dam's coming performance. About two-thirds of breakdowns and half of all dam failures occur upon initial filling or in the reservoir's early operation stages [1]. For dam safety, having more control and time for suitable observation of the reservoir's initial filling is important. The water level rise rate in the reservoir must be controlled to allow the dam to adapt to the forces it will face as the water level rises behind it [2]. The dam reservoir filling program must consider all the downstream demands to cover the irrigation and electricity generation needs and maintenance [3]. The geological layers in the Badush reservoir area are mainly represented by the lower member of the Fatha Formation, which most often contains gypsum of various kinds in addition to limestone, the quaternary deposits, and limited areas of the Euphrates Formation [4]. The initial filling of the Badush reservoir submerges some of these geological outcrops. Gypsum and limestone rock diversity may lead to problems related to the site's geological and geotechnical background during the initial filling. Reservoir routing calculates the inputs, outputs, storage variation, and their change with time. One of the traditional definitions of reservoir routing is a mathematical procedure to calculate the changes over time in the volume and behavior of the flood wave movement through the reservoir from the wave entry to the reservoir and then to the dam [5]. There are many traditional routing methodologies, and all of them agree that the goal of routing is to develop a hydrograph of the flow in a section of the river based on the data of another upstream section of the target section. Many applications depend on flow routing, including flood control, protection emergency plans, and the storage dams' design. The most common type of reservoir and channel routing is the Muskingum method [6, 7]. The most important data required in reservoir routing is the relationship between the inward flow with the volume and level of water inside the reservoir and the relationship between the outflow volume and level. As for the channel routing, the flow hydrograph is predicted in several segments on the reach, depending on the inflow and outflow between upstream and downstream sections. In this study, a new methodology was developed for reservoir routing for the main storage dam (Mosul Dam), the protection dam (Badush Dam), and the river reach between Mosul and Badush Dams. Also, the rapid and gradual filling conditions of Badush reservoir will be discussed according to the data of actual incoming and outgoing discharges from Mosul Dam and the Regulatory Dam for two elected years (dry and wet) from the discharge records. These conditions will be discussed to preserve the dam stability and not cause problems due to the variation in the geotechnical characteristics of rocks in the foundation zone and the variation in the pore water pressure and the effective pressure in this zone due to saturation [8, 9]. The current study aims to develop a program to fill the Badush reservoir to its maximum operational level. The program sets for filling with one of two options. In the first option, the filling is continuous without pause, while the second option is gradual filling programmed so that the filling stops after each rise in the level of up to 5 meters and filling back after a pause of 60 days. The program was designed to test the hypothetical filling in dry or wet water years conditions as a preparatory step for the real dam filling achieved.

## 2.METHODOLOGY

New methodologies were developed in the present study for reservoir routing for the main storage dam (Mosul Dam), the protection dam (Badush Dam), and the river reach between them, in addition to the regulation dam in the mid of this reach. These methodologies were based on geometric analysis, inflow, and outflow data under Badush Dam reservoir filling conditions or normal operating conditions. According to the rapid filling methods, Fig. 2, or gradual filling, Fig. 3. The last five years (2016-2021) were selected to apply the hypothetical filling and breakdown of Mosul Dam, and this period followed the operation of the Ilisu Dam in the southwest of Turkey. The incoming flow rates from the Mosul dam to the Badush Dam site in the mentioned years ranged between 150 to 3500 $m^3$/sec, while the discharges released when the future operation of the Badush dam are suggested to be ranged between 150 to 3300 $m^3$/sec within the period of a hypothetical filling.

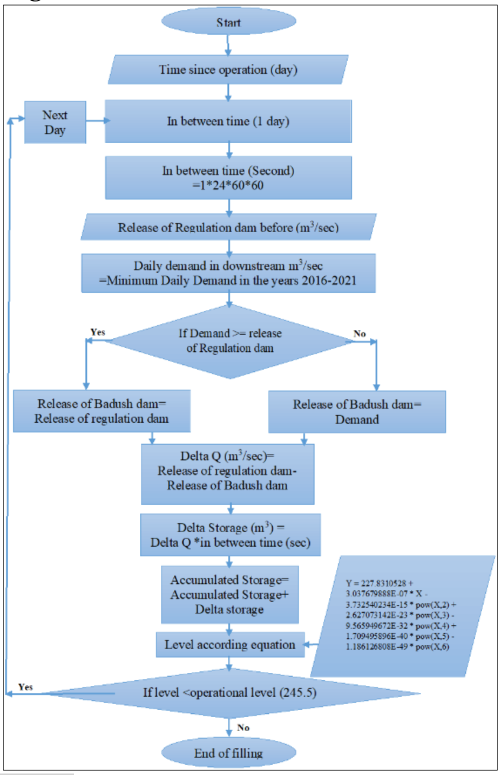


**Fig. 2** Rapid Filling Flowchart (X: Volume ($m^3$), Y: Level (m (a.s.l.)).

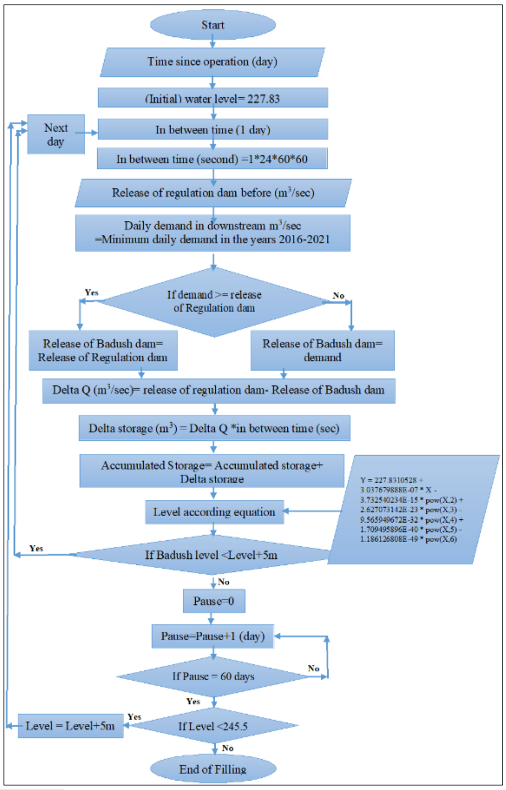


**Fig. 3** Gradual Filling Flowchart (X: Volume ($m^3$), Y: Level (m (a.s.l.)).

Time interval between two filling cycles= 60 days, the level interval between two filling cycles= 5 meters).

## 3.RESULTS AND DISCUSSION

An Excel program was prepared for the routing of normal operations. A set of assumptions and sequential steps below in the case of normal operation was considered, which are not arbitrary. Each hypothesis has its scientific support, and each step has its priority, as the variable value calculated depends on the variable value from the previous step.

### *3.1. Assumptions of Routing in Normal Filling and Operation Conditions*

***First Hypothesis***: Mosul Dam operates according to the normal operating contexts, and the maximum operational level is 330 m (a.s.l.) as a precaution in the event of unexpected flood waves, considering the maximum operational level set by the International Authority for Large Dams, in coordination with the American Engineers Team, is 319 m(a.s.l.)

***Second Hypothesis:*** The downstream's daily demand was assumed to be equal to the lowest released daily discharge from the regulatory dam from 2016 to 2021, except for 2018, when releases could not be obtained. Fig. 4 shows the daily demand releases compared to the mentioned years' releases. To establish a firm relationship between the demand and the sequence of the days of the year and explain the variation in the demand over the entire year, a mathematical equation was derived based on the correlation between the two variables, as in Eq. (1) and Fig. 5. The time limits of the equation range from 1-366 days. It is noted from the mentioned figure that the demand in the downstream Tigris River basin reaches its peak between mid-May and mid-October, which is the period of irrigation in which evaporation is most intense. In contrast, the demand gradually decreases in the other months.

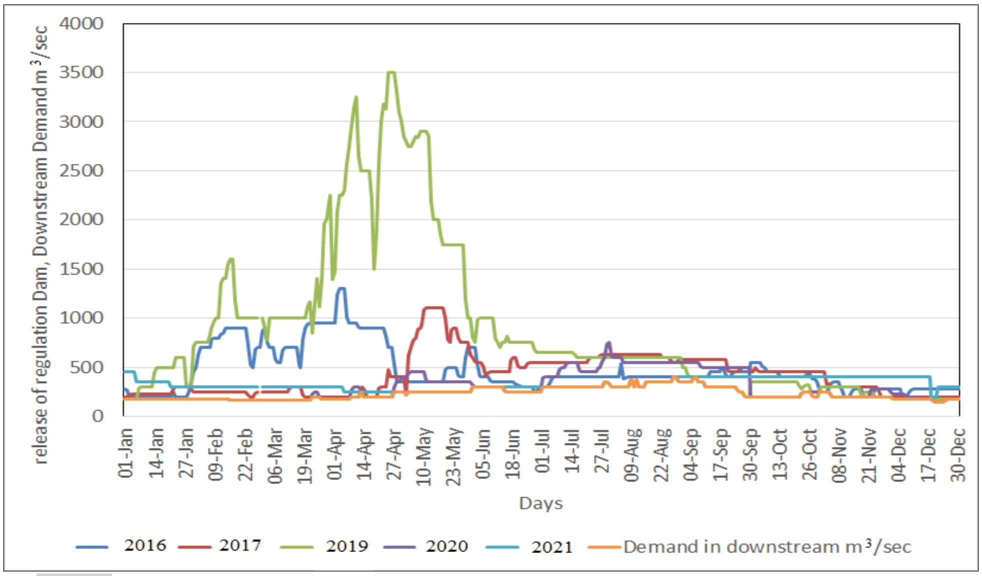


**Fig. 4** Required Daily Downstream Releases from Badush Dam Compared to the Daily Releases from the Regulatory Dam in the Five Selected Years.

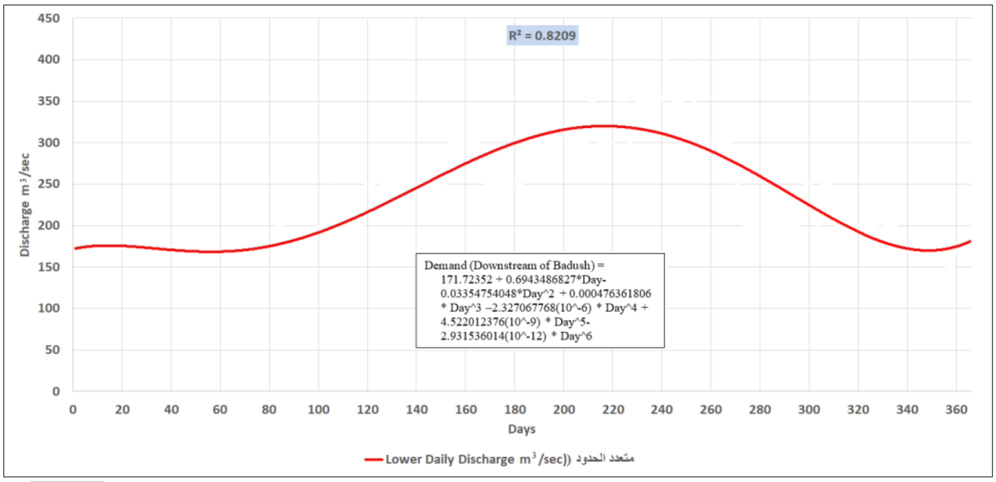


**Fig. 5** The Daily Demand Downstream of Badush Dam Derived from the Data of the Lowest Daily Releases from the Regulatory Dam in the Selected Years.

The downstream of Badush dam demand can be expressed as:

$$\text{Demand (Downstream of Badush)} = 171.72 + 0.69 \times \text{Day} - 0.036 \times \text{Day}^2 + 0.00048 \times \text{Day}^3 - 2.327(10^{-6}) \times \text{Day}^4 + 4.52(10^{-9}) \times \text{Day}^5 - 2.93(10^{-12}) \times \text{Day}^6 \quad \textbf{(1)}$$

***Third Hypothesis**:* The last five years (2016-2021) were elected to apply the hypothetical filling and breakdown hypothesis of the Mosul Dam, and this period followed the Ilisu Dam operation in Turkey. This dam was operated during these years and necessitated a new operational method on Mosul Dam, which encouraged the choice of the mentioned years for routing the reservoir to be within the period in which the dam lost a large part of the resources supplied.

***Fourth Hypothesis**:* The releases from the Badush Dam gates during the filling period is one of two options: when the demand downstream is greater than the releases from the regulatory dam. Then all input discharges are released, and no quantity is stored. However, if the releases from the regulatory dam were greater than the demand, the releases of the Badush dam would equal this demand, and the remaining releases of the regulatory dam would be stored in the Badush Dam reservoir as a change in storage Δs. The storage continues until the normal operating level of the reservoir is achieved, which is 245.5 m (a.s.l.).

***Fifth Hypothesis**:* The reservoir filling, according to the traditional engineering conditions, must be gradual, i.e., in stages separated by time intervals, during which the dam facilities are examined to ensure no problems resulting from the dam body saturation. However, since Badush Dam was designed to be a protection dam, and its operational reservoir represents only a very small percentage (2%) of the total capacity prepared for the breakdown event, the filling can occur in one of two ways. The first is that the filling occurs in one rapid or continuous phase, assuming that operational filling represents the first stage of preparation for full filling according to the hypothesis of a breakdown that may not happen. The second is the gradual reservoir filling according to the method used in traditional storage dams. Each of the two methods has its methodology and its calculation program.

***Sixth Hypothesis**:* The releases from Mosul Dam continue in the same conditions because there are no losses between the Mosul Dam gates and the regulatory dam gates up to Badush Dam. The losses are added to the Mosul Dam's releases by the Mosul Dam operators.

***Seventh Hypothesis***: The releases from Badush Dam are sufficient to operate the power station and the downstream irrigation demand, assuming the discharge flow from the regulatory dam achieves a constant level raising in Badush Dam to the normal design operational level.

***Eighth Hypothesis**:* Residential areas below the maximum operational level have been evacuated to alternative locations before storage.

### *3.2.Routing Program to Fill and Operate the Reservoir*

To estimate the minimum and maximum durations to fill the reservoir and then return to normal operation, it is proposed to fill the reservoir in two cases:

First: The filling should be in a wet year according to the records of releases from Mosul Dam, and the wet year (2019) was chosen for this purpose. In such a wet year, a rapid filling program can be implemented. This filling method has geotechnical caveats, as it may be accompanied by settlement within the foundations' zone, and more severe repercussions may occur, such as dam breakdown. A gradual filling program can also be implemented in stages, as it is paused between one stage and another for a specific period [10]. Second: The filling in a dry water year, and 2020 was chosen for this purpose. Implementing the rapid filling scenarios in dry years may be difficult due to the low release of the Mosul dam compared with wet years. However, the gradual filling scenario is easier to implement. As shown in Table 1, the program was prepared to fill and operate Badush Dam. This table consists of several steps to enter the initial discharge data, convert the time units, and calculate the incoming and outgoing volumes stored in the reservoir. Also, Table 1 shows the setting conditions for determining the amount of water stored based on the volume of releases to achieve the maximum storage to reach the normal operation level of 245.5 (m a.s.l.) to preserve the operational conditions of the regulatory dam. Fig .6 shows the boundaries of the submerged at the initial filling and operation.

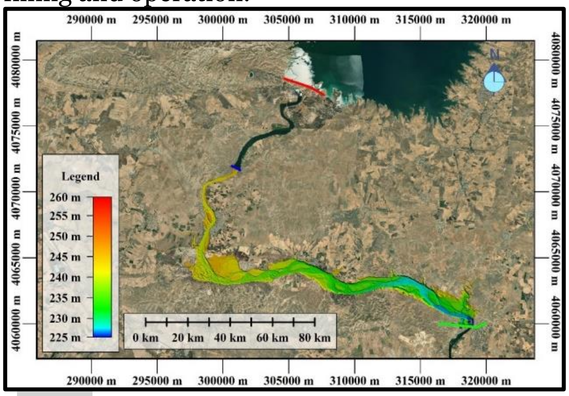


**Fig. 6** Extensions of the Immersion Areas at the Initial Filling and Badush Dam at a Level of 245.5 m (a.s.l.).

**Table 1** A Program in Microsoft Excel for Routing the Reservoir Filling of Badush Dam Based on the Operational Conditions of Mosul and Regulatory Dams, i.e., In the Case of Gradual Filling.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 Jan 2019 | 0 | 0 | 0 | 175 | 172.4 | IF(column 7 >=column 6 then column 8= column 6; else column 8= column 7 | Delta relies Q (m³/sec)= column 6 – column 8, | Delta storage (m³) = column 9 * column 5 | Acclimated storage (m³) = column 10+ column 11 | The water level in Badush dam according to the mathematical model in equation 2. If level <245.5 m(a.s.l) then continue else stop |
| 2 | 2 Jan 2019 | 1 | 1 | 86400 | 175 | 173.0 | | | | | |
| | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | | | | | |
| | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | | | | | |
| | ↓ | ↓ | ↓ | ↓ | ↓ | ↓ | | | | | |
| 25 | 25 Jan 2019 | 24 | 1 | 86400 | ↓ | ↓ | | | | | |

1 Day
2 Date of beginning the operation
3 Time since starting the operation (days)
4 In between time (days)
5 In between time in (seconds)
6 Release from Regulation dam before operation of Badush dam (m³/sec)
7 Demand in downstream (m³/sec) according to equation 1
8 Release from Badush dam after operation (m³/sec)
9 Delta releases Q (m³/sec)
10 Delta storage (m³)
11 Accumulated storages in Badush reservoir (m³)
12 Water level in Badush reservoir (m (a.s.l)) according to the mathematical equation 2 (polynomial- degree 6) derived from geometric data of the reservoir, the boundary of the equation is the levels of the dam 226.5- 245.5 m (a.s.l).
↓ = Complete the calculations on the same methodology

$$\text{Level in Badush Reservoir} = 227.83 + 3.04E\text{-}07 \times Vol - 3.73E\text{-}15 \times Vol^2 + 2.63E\text{-}23 \times Vol^3 - 9.57E\text{-}32 \times Vol^4 + 1.71E\text{-}40 \times Vol^5 - 1.19E\text{-}49 \times Vol^6 \quad (2)$$

X= Volume in Badush reservoir (m³)
Y= Level in Badush reservoir m (a.s.l.)
The limits of Eq. (2) ranged between the levels 226.5 to 245.5 m (a.s.l.), which are the operational limits of Badush Dam before the collapse occurred Fig. 7.

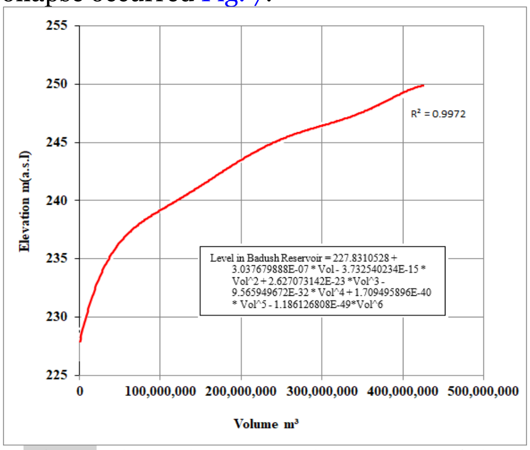


**Fig. 7** The Volume-Level Equation of the Badush Dam Reservoir.

The program mentioned above was applied for four scenarios to predict the rapid and gradual filling cases using the data of two wet and dry years, as in below:

***a-Continuous/Rapid Filling in a Wet Year***

The EXCEL program was applied to simulate the reservoir's fill, based on the inputs of the water year 2019, characterized by the maximum amount of releases from Mosul Dam compared to other water years in the record. The calculations reflect the possibility of filling the reservoir with a maximum volume of 264875073 m³ corresponding to the level 245.5 m, with a period of 20 days. It is noted here that the daily increase in the level during the days of storage was about one to two meters per day; however, this increase is only sometimes stable in the wet years. If the filling coincides with the peak of a flood wave, a sharp increase may occur, i.e., several meters in one day, and this is undesirable because it may lead to a lack of stability in the dam. Therefore, the peaks of the flood waves should be avoided for the initial filling. On the other hand, the rapid filling in a wet year sometimes mitigates the high discharges to avoid floods downstream [11, 12]. The filling calculations are shown in Table 2.

***b-Continuous/Rapid Filling with A Dry Year***

The routing program was applied to fill the reservoir in a dry year. Therefore, 2020 was chosen, with the lowest amount of release from Mosul and Regulatory Dams compared to other recorded dry years. After completing the calculations, it became clear that the reservoir could be filled within 130 days, with a maximum volume of 264875073 m³, when the corresponding level was about 245.5 m. There are some days of no storage difference (ΔS=0) because the releases from the regulatory dam were less than demand; thus, the releases from Badush Dam were equal to those from the regulatory dam. It is noted here that the daily increase in the level during storage days was limited to a few centimeters to less than a meter on most days and may reach one meter on very limited days. This means the increasing storage was more stable and less dangerous to the dam's stability than the wet flood years. The filling program is continuous and automatically gradual due to days of no storage difference or close to zero storage. The filling calculations are listed in Table 3.

***c-Gradual Filling in a Wet Water Year***

The program was applied to simulate the reservoir filling, based on the inputs of the water year 2019; However, the filling was gradual to avoid or diagnose and manage the risks during the filling [13]. The reservoir was filled in the first stage to a level of 235.74 m (a.s.l.), the storage was paused for 60 days, and then the storage continued for the second stage until another 5 meters depth was added. The third and final stage ended when the maximum operational level reached 245.5 m (a.s.l.). It was found that the reservoir could be filled within 133 days to its maximum volume. The level of daily increase during the days of storage fluctuated and was sharp, and the level increasing varied between one and three meters per day on some days that did not coincide with the flood wave peak. In the second storage stage, which lasted only two days, the level rose between three to four meters per day. However, the third stage lasted only one day and was accompanied by a level sharper increase, reaching 7 meters. This is an unencouraging indicator regarding the dam stability, as this daily increase level was above the maximum scheduled level of 245.5 m (a.s.l.), which required careful monitoring by the dam's operator to open the release gates when the specified level was reached before the end of that day because continued storage may affect the reservoir stability. The reason for the sharp increase may threaten the existing regulatory dam upstream from Badush Dam, so the peaks of the flood waves must be avoided from the initial filling. The calculations are included in Table 4.

***d-Gradual Filling in a Dry Water Year***

The EXCEL program was applied to simulate the gradual filling of the reservoir based on the inputs of the same year, i.e., 2020, as the reservoir was filled in the first stage to a level of 235 meters (the filling was stopped on the first day it exceeded aforementioned cumulative storage level). After each storage stage, the storage was paused for 60 days. Then the storage was continued for the second stage until another 5 meters of depth was added, while the third and final stage ended when the level reached the maximum operational level of 245.5. The calculations reflect that the reservoir can be filled within 258 days to the maximum volume of 264,875,073 m³; the corresponding level was about 245.5. The level of daily increase during the days of storage was more stable and less severe and ranged from a few centimeters on most days of storage to one meter per day on limited days, and there was no sharp increase in the days of storage. These observations are encouraging indicators of the dam's stability, as this gradual and stable increase allowed monitoring of the dam's behavior against storage and the foundations' zone saturation during the gradual filling. Also, the results showed periods of unintended zero storage because the demand downstream was higher than the regulatory dam releases. Thus $\Delta S = 0$. Therefore, the storage was less severe and less dangerous to the dam. The calculations are listed in Table 5.

**Table 2** Results of the Reservoir Routing Calculations at the Initial (Hypothetical) Continuous Filling in a Wet Water Year, i.e., 2019.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 01/01/2019 | 0 | 0 | 0 | 175 | 172.4 | 172 | 2.6 | 0 | 0 | 227.83 |
| 2 | 02/01/2019 | 1 | 1 | 86400 | 175 | 173.0 | 173 | 2.0 | 174372 | 174372 | 227.88 |
| 3 | 03/01/2019 | 2 | 1 | 86400 | 175 | 173.5 | 174 | 1.5 | 128104 | 302477 | 227.92 |
| 4 | 04/01/2019 | 3 | 1 | 86400 | 175 | 174.0 | 174 | 1.0 | 86914 | 389391 | 227.95 |
| 5 | 05/01/2019 | 4 | 1 | 86400 | 175 | 174.4 | 174 | 0.6 | 50572 | 439962 | 227.96 |
| 6 | 06/01/2019 | 5 | 1 | 86400 | 175 | 174.8 | 175 | 0.2 | 18851 | 458814 | 227.97 |
| 7 | 07/01/2019 | 6 | 1 | 86400 | 290 | 175.1 | 175 | 114.9 | 9927532 | 1038634 | 230.61 |
| 8 | 08/01/2019 | 7 | 1 | 86400 | 300 | 175.4 | 175 | 124.6 | 1076839 | 21154742 | 232.82 |
| 9 | 09/01/2019 | 8 | 1 | 86400 | 300 | 175.6 | 176 | 124.4 | 1074923 | 3190397 | 234.48 |
| 10 | 10/01/2019 | 9 | 1 | 86400 | 300 | 175.8 | 176 | 124.2 | 1073383 | 42637811 | 235.74 |
| 11 | 11/01/2019 | 10 | 1 | 86400 | 300 | 175.9 | 176 | 124.1 | 1072199 | 5335981 | 236.70 |
| 12 | 12/01/2019 | 11 | 1 | 86400 | 300 | 176.0 | 176 | 124.0 | 1071352 | 6407333 | 237.45 |
| 13 | 13/01/2019 | 12 | 1 | 86400 | 300 | 176.1 | 176 | 123.9 | 1070821 | 74781553 | 238.05 |
| 14 | 14/01/2019 | 13 | 1 | 86400 | 442 | 176.1 | 176 | 265.9 | 2297469 | 97756243 | 239.09 |
| 15 | 15/01/2019 | 14 | 1 | 86400 | 500 | 176.1 | 176 | 323.9 | 2798635 | 12574259 | 240.23 |
| 16 | 16/01/2019 | 15 | 1 | 86400 | 500 | 176.0 | 176 | 324.0 | 2798942 | 15373202 | 241.45 |
| 17 | 17/01/2019 | 16 | 1 | 86400 | 500 | 176.0 | 176 | 324.0 | 2799493 | 18172695 | 242.71 |
| 18 | 18/01/2019 | 17 | 1 | 86400 | 500 | 175.9 | 176 | 324.1 | 2800269 | 2097296 | 243.90 |
| 19 | 19/01/2019 | 18 | 1 | 86400 | 500 | 175.8 | 176 | 324.2 | 2801255 | 2377422 | 244.91 |
| 20 | 20/01/2019 | 19 | 1 | 86400 | 500 | 175.6 | 176 | 324.4 | 2802433 | 2657665 | 245.70 |

1 Day
2 Date of beginning the operation
3 Time since starting the operation (days)
4 In between time (days)
5 In between time in (seconds)
6 Release from Regulation dam before operation of Badush dam (m³/sec)
7 Demand in downstream (m³/sec) according to Eq. (1).
8 Release from Badush dam after operation (m³/sec)
9 Delta relieses Q (m³/sec)
10 Delta storage (m³)
11 Accumulated storage in Badush reservoir (m³)
12 Water level in Badush reservoir m (a.s.l) according to the mathematical Eq. (2) (polynomial- degree 6) which derived from geometric data of the reservoir, the boundary of the equation is the levels of the dam 226.5- 245.5 m (a.s.l).

**Table 3** Results of the Reservoir Routing Calculations when (Hypothetical) Continuous Initial Filling in a Dry Water Year, i.e., 2020 as an Example.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1/1/2020 | 0 | 0 | 0 | 175 | 172.4 | 172 | 2.6 | 0 | 0 | 227.83 |
| 2 | 2/1/2020 | 1 | 1 | 86400 | 175 | 173.0 | 173 | 2.0 | 174372 | 174372 | 227.88 |
| 3 | 3/1/2020 | 2 | 1 | 86400 | 175 | 173.5 | 174 | 1.5 | 128104 | 302477 | 227.92 |
| 4 | 4/1/2020 | 3 | 1 | 86400 | 175 | 174.0 | 174 | 1.0 | 86914 | 389391 | 227.95 |
| 5 | 5/1/2020 | 4 | 1 | 86400 | 175 | 174.4 | 174 | 0.6 | 50572 | 439962 | 227.96 |
| 6 | 6/1/2020 | 5 | 1 | 86400 | 175 | 174.8 | 175 | 0.2 | 18851 | 458814 | 227.97 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to the releases from the regulation dam and storage were undone. | | | | | | | | | | | |
| 24 | 24/1/2020 | 23 | 1 | 86400 | 175 | 174.9 | 175 | 0.1 | 7507 | 466321 | 227.97 |
| 25 | 25/1/2020 | 24 | 1 | 86400 | 175 | 174.7 | 175 | 0.3 | 26558 | 492879 | 227.98 |
| 26 | 26/1/2020 | 25 | 1 | 86400 | 175 | 174.5 | 174 | 0.5 | 46622 | 539501 | 227.99 |
| 27 | 27/1/2020 | 26 | 1 | 86400 | 175 | 174.2 | 174 | 0.8 | 67560 | 607061 | 228.01 |
| 28 | 28/1/2020 | 27 | 1 | 86400 | 175 | 174.0 | 174 | 1.0 | 89236 | 696297 | 228.04 |
| 29 | 29/1/2020 | 28 | 1 | 86400 | 175 | 173.7 | 174 | 1.3 | 111520 | 807818 | 228.07 |
| 30 | 30/1/2020 | 29 | 1 | 86400 | 175 | 173.4 | 173 | 1.6 | 134284 | 942102 | 228.11 |
| 31 | 31/1/2020 | 30 | 1 | 86400 | 175 | 173.2 | 173 | 1.8 | 157403 | 1099505 | 228.16 |
| 32 | 1/2/2020 | 31 | 1 | 86400 | 175 | 172.9 | 173 | 2.1 | 180758 | 1280263 | 228.21 |
| 33 | 2/2/2020 | 32 | 1 | 86400 | 175 | 172.6 | 173 | 2.4 | 204229 | 1484492 | 228.27 |
| 34 | 3/2/2020 | 33 | 1 | 86400 | 175 | 172.4 | 172 | 2.6 | 227705 | 1712197 | 228.34 |
| 35 | 4/2/2020 | 34 | 1 | 86400 | 175 | 172.1 | 172 | 2.9 | 251073 | 1963270 | 228.41 |
| 36 | 5/2/2020 | 35 | 1 | 86400 | 175 | 171.8 | 172 | 3.2 | 274228 | 2237498 | 228.49 |
| 37 | 6/2/2020 | 36 | 1 | 86400 | 175 | 171.6 | 172 | 3.4 | 297065 | 2534563 | 228.58 |
| 38 | 7/2/2020 | 37 | 1 | 86400 | 175 | 171.3 | 171 | 3.7 | 319484 | 2854047 | 228.67 |
| 39 | 8/2/2020 | 38 | 1 | 86400 | 175 | 171.0 | 171 | 4.0 | 341387 | 3195434 | 228.76 |
| 40 | 9/2/2020 | 39 | 1 | 86400 | 175 | 170.8 | 171 | 4.2 | 362680 | 3558115 | 228.87 |
| 41 | 10/2/2020 | 40 | 1 | 86400 | 175 | 170.6 | 171 | 4.4 | 383273 | 3941387 | 228.97 |
| 42 | 11/2/2020 | 41 | 1 | 86400 | 175 | 170.3 | 170 | 4.7 | 403076 | 4344464 | 229.08 |
| 43 | 12/2/2020 | 42 | 1 | 86400 | 175 | 170.1 | 170 | 4.9 | 422006 | 4766470 | 229.20 |
| 44 | 13/2/2020 | 43 | 1 | 86400 | 175 | 169.9 | 170 | 5.1 | 439980 | 5206450 | 229.32 |
| 45 | 14/2/2020 | 44 | 1 | 86400 | 175 | 169.7 | 170 | 5.3 | 456920 | 5663370 | 229.44 |
| 46 | 15/2/2020 | 45 | 1 | 86400 | 175 | 169.5 | 170 | 5.5 | 472749 | 6136119 | 229.56 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to the releases from the regulation dam and storage were undone. | | | | | | | | | | | |
| 83 | 23/3/2020 | 82 | 1 | 86400 | 225 | 177.0 | 177 | 48.0 | 4143902 | 10280022 | 230.59 |
| 84 | 24/3/2020 | 83 | 1 | 86400 | 250 | 177.7 | 178 | 72.3 | 6246493 | 16526515 | 231.94 |
| 85 | 25/3/2020 | 84 | 1 | 86400 | 250 | 178.4 | 178 | 71.6 | 6186909 | 22713423 | 233.09 |
| 86 | 26/3/2020 | 85 | 1 | 86400 | 197 | 179.1 | 179 | 17.9 | 1545960 | 24259384 | 233.35 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to the releases from the regulation dam and storage were undone. | | | | | | | | | | | |
| 100 | 9/4/2020 | 99 | 1 | 86400 | 270 | 191.6 | 192 | 78.4 | 6771462 | 31030845 | 234.36 |
| 101 | 10/4/2020 | 100 | 1 | 86400 | 300 | 192.7 | 193 | 107.3 | 9271615 | 40302461 | 235.50 |
| 102 | 11/4/2020 | 101 | 1 | 86400 | 300 | 193.8 | 194 | 106.2 | 9177977 | 49480437 | 236.38 |
| 103 | 12/4/2020 | 102 | 1 | 86400 | 300 | 194.9 | 195 | 105.1 | 9082578 | 58563016 | 237.08 |
| 104 | 13/4/2020 | 103 | 1 | 86400 | 269 | 196.0 | 196 | 73.0 | 6307055 | 64870070 | 237.49 |
| 105 | 14/4/2020 | 104 | 1 | 86400 | 216 | 197.1 | 197 | 18.9 | 1629041 | 66499111 | 237.59 |
| 106 | 15/4/2020 | 105 | 1 | 86400 | 200 | 198.3 | 198 | 1.7 | 146172 | 66645283 | 237.60 |
| 107 | 16/4/2020 | 106 | 1 | 86400 | 200 | 199.5 | 199 | 0.5 | 44087 | 66689370 | 237.60 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to the releases from the regulation dam and storage were undone. | | | | | | | | | | | |
| 119 | 28/4/2020 | 118 | 1 | 86400 | 303 | 215.0 | 215 | 88.0 | 7606656 | 74296026 | 238.02 |
| 120 | 29/4/2020 | 119 | 1 | 86400 | 350 | 216.3 | 216 | 133.7 | 11548066 | 85844092 | 238.58 |
| 121 | 30/4/2020 | 120 | 1 | 86400 | 350 | 217.7 | 218 | 132.3 | 11427656 | 97271748 | 239.07 |
| 122 | 1/5/2020 | 121 | 1 | 86400 | 390 | 219.1 | 219 | 170.9 | 14762272 | 112034020 | 239.67 |
| 123 | 2/5/2020 | 122 | 1 | 86400 | 400 | 220.6 | 221 | 179.4 | 15503963 | 127537983 | 240.31 |
| 124 | 3/5/2020 | 123 | 1 | 86400 | 400 | 222.0 | 222 | 178.0 | 15380777 | 142918761 | 240.97 |
| 125 | 4/5/2020 | 124 | 1 | 86400 | 439 | 223.4 | 223 | 215.6 | 18626362 | 161545123 | 241.80 |
| 126 | 5/5/2020 | 125 | 1 | 86400 | 450 | 224.9 | 225 | 225.1 | 19451968 | 180997091 | 242.68 |
| 127 | 6/5/2020 | 126 | 1 | 86400 | 450 | 226.3 | 226 | 223.7 | 19326444 | 200323536 | 243.52 |
| 128 | 7/5/2020 | 127 | 1 | 86400 | 450 | 227.8 | 228 | 222.2 | 19200240 | 219523776 | 244.28 |
| 129 | 8/5/2020 | 128 | 1 | 86400 | 450 | 229.2 | 229 | 220.8 | 19073407 | 238597183 | 244.94 |
| 130 | 9/5/2020 | 129 | 1 | 86400 | 450 | 230.7 | 231 | 219.3 | 18945994 | 257543176 | 245.49 |

1 Day 2 Date of beginning the operation
3 Time since starting the operation (days) 4 In between time (days)
5 In between time in (seconds) 6 Release from Regulation dam before operation of Badush dam ($m^3$/sec)
7 Demand in downstream ($m^3$/sec) according to Eq. (1) 8 Release from Badush dam after operation ($m^3$/sec)
9 Delta relies Q ($m^3$/sec) 10 Delta storage ($m^3$)
11 Accumulated storage in Badush reservoir ($m^3$)
12 Water level in Badush reservoir m (a.s.l.) according to the mathematical Eq. (2) (polynomial- degree 6) derived from geometric data of the reservoir, the boundary of the equation is the levels of the dam 226.5- 245.5 m (a.s.l.).

**Table 4** Results of the Reservoir Routing Calculations at the (Hypothetical) Gradual Initial Fill in a Wet Water Year, i.e., 2019.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 01/01/2019 | 0 | 0 | 0 | 175 | 172.4 | 172 | 2.6 | 0 | 0 | 227.83 |
| **2** | 02/01/2019 | 1 | 1 | 86400 | 175 | 173.0 | 173 | 2.0 | 174372 | 174372 | 227.88 |
| **3** | 03/01/2019 | 2 | 1 | 86400 | 175 | 173.5 | 174 | 1.5 | 128104 | 302477 | 227.92 |
| **4** | 04/01/2019 | 3 | 1 | 86400 | 175 | 174.0 | 174 | 1.0 | 86914 | 389391 | 227.95 |
| **5** | 05/01/2019 | 4 | 1 | 86400 | 175 | 174.4 | 174 | 0.6 | 50572 | 439962 | 227.96 |
| **6** | 06/01/2019 | 5 | 1 | 86400 | 175 | 174.8 | 175 | 0.2 | 18851 | 458814 | 227.97 |
| **7** | 07/01/2019 | 6 | 1 | 86400 | 290 | 175.1 | 175 | 114.9 | 9927532 | 10386345 | 230.61 |
| **8** | 08/01/2019 | 7 | 1 | 86400 | 300 | 175.4 | 175 | 124.6 | 10768397 | 21154742 | 232.82 |
| **9** | 09/01/2019 | 8 | 1 | 86400 | 300 | 175.6 | 176 | 124.4 | 10749234 | 31903976 | 234.48 |
| **10** | 10/01/2019 | 9 | 1 | 86400 | 300 | 175.8 | 176 | 124.2 | 10733835 | 42637811 | 235.74 |
| Pause for 60 days without filling so that Badush Dam releases were equal to the releases of the Regulation Dam. | | | | | | | | | | | |
| **71** | 12/03/2019 | 70 | 1 | 86400 | 1000 | 171.1 | 171 | 828.9 | 71621041 | 114258852 | 239.76 |
| **72** | 13/03/2019 | 71 | 1 | 86400 | 1000 | 171.4 | 171 | 828.6 | 71590064 | 185848916 | 242.89 |
| Pause for 60 days without filling so that Badush Dam releases were equal to the releases of the Regulation Dam and ΔS=0. | | | | | | | | | | | |
| **133** | 13/05/2019 | 132 | 1 | 86400 | 2850 | 235.2 | 235 | 2614.8 | 225920788 | 411769704 | 249.61* |

1 Day
2 Date from the beginning of the operation
3 Time since starting the operation (days)
4 In between time (days)
5 In between time in (seconds)
6 Release from Regulation dam before operation of Badush dam ($m^3$/sec)
7 Demand in downstream ($m^3$/sec) according to Eq. (1)
8 Release from Badush dam after operation ($m^3$/sec)
9 Delta relies on Q ($m^3$/sec)
10 Delta storage ($m^3$)
11 Accumulated storage in Badush reservoir ($m^3$)
12 Water level in Badush reservoir m (a.s.l.) according to Eq. (2) (polynomial- degree 6) derived from geometric data of the reservoir, the boundary of the equation is the levels of the dam 226.5- 245.5 m (a.s.l.).
*Here, continuing to fill for a full day increased the level above the specified level of 245.5 m (a.s.l.), which required continuous monitoring by the operator to stop filling at this level and to release all discharges coming from the regulatory dam

**Table 5** Results of the Reservoir Routing Calculations when the (Hypothetical) Continuous/Gradual Initial Filling in a Dry Water Year, i.e., 2020.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1/1/2020 | 0 | 0 | 0 | 175 | 172.4 | 172.4 | 2.6 | 0.0 | 0 | 227.83 |
| 2 | 2/1/2020 | 1 | 1 | 86400 | 175 | 173.0 | 173.0 | 2.0 | 174372.4 | 174,372 | 227.88 |
| 3 | 3/1/2020 | 2 | 1 | 86400 | 175 | 173.5 | 173.5 | 1.5 | 128104.2 | 302,477 | 227.92 |
| 4 | 4/1/2020 | 3 | 1 | 86400 | 175 | 174.0 | 174.0 | 1.0 | 86914.1 | 389,391 | 227.95 |
| 5 | 5/1/2020 | 4 | 1 | 86400 | 175 | 174.4 | 174.4 | 0.6 | 50571.7 | 439,962 | 227.96 |
| 6 | 6/1/2020 | 5 | 1 | 86400 | 175 | 174.8 | 174.8 | 0.2 | 18851.3 | 458,814 | 227.97 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to those, from the regulation dam, and storage was undone. | | | | | | | | | | | |
| 24 | 24/1/2020 | 23 | 1 | 86400 | 175 | 174.9 | 174.9 | 0.1 | 7507.1 | 466,321 | 227.97 |
| 25 | 25/1/2020 | 24 | 1 | 86400 | 175 | 174.7 | 174.7 | 0.3 | 26558.4 | 492,879 | 227.98 |
| 26 | 26/1/2020 | 25 | 1 | 86400 | 175 | 174.5 | 174.5 | 0.5 | 46622.2 | 539,501 | 227.99 |
| 27 | 27/1/2020 | 26 | 1 | 86400 | 175 | 174.2 | 174.2 | 0.8 | 67559.8 | 607,061 | 228.01 |
| 28 | 28/1/2020 | 27 | 1 | 86400 | 175 | 174.0 | 174.0 | 1.0 | 89236.3 | 696,297 | 228.04 |
| 29 | 29/1/2020 | 28 | 1 | 86400 | 175 | 173.7 | 173.7 | 1.3 | 111520.3 | 807,818 | 228.07 |
| 30 | 30/1/2020 | 29 | 1 | 86400 | 175 | 173.4 | 173.4 | 1.6 | 134284.1 | 942,102 | 228.11 |
| 31 | 31/1/2020 | 30 | 1 | 86400 | 175 | 173.2 | 173.2 | 1.8 | 157403.4 | 1,099,50 | 228.16 |
| 32 | 1/2/2020 | 31 | 1 | 86400 | 175 | 172.9 | 172.9 | 2.1 | 180757.6 | 1,280,26 | 228.21 |
| 33 | 2/2/2020 | 32 | 1 | 86400 | 175 | 172.6 | 172.6 | 2.4 | 204229. | 1,484,49 | 228.27 |
| 34 | 3/2/2020 | 33 | 1 | 86400 | 175 | 172.4 | 172.4 | 2.6 | 227704.7 | 1,712,197 | 228.34 |
| 35 | 4/2/2020 | 34 | 1 | 86400 | 175 | 172.1 | 172.1 | 2.9 | 251073.3 | 1,963,27 | 228.41 |
| 36 | 5/2/2020 | 35 | 1 | 86400 | 175 | 171.8 | 171.8 | 3.2 | 274228.1 | 2,237,49 | 228.49 |
| 37 | 6/2/2020 | 36 | 1 | 86400 | 175 | 171.6 | 171.6 | 3.4 | 297065.1 | 2,534,56 | 228.58 |
| 38 | 7/2/2020 | 37 | 1 | 86400 | 175 | 171.3 | 171.3 | 3.7 | 319483. | 2,854,04 | 228.67 |
| 39 | 8/2/2020 | 38 | 1 | 86400 | 175 | 171.0 | 171.0 | 4.0 | 341387.0 | 3,195,43 | 228.76 |
| 40 | 9/2/2020 | 39 | 1 | 86400 | 175 | 170.8 | 170.8 | 4.2 | 362680. | 3,558,115 | 228.87 |
| 41 | 10/2/2020 | 40 | 1 | 86400 | 175 | 170.6 | 170.6 | 4.4 | 383272.7 | 3,941,38 | 228.97 |
| 42 | 11/2/2020 | 41 | 1 | 86400 | 175 | 170.3 | 170.3 | 4.7 | 403076. | 4,344,46 | 229.08 |
| 43 | 12/2/2020 | 42 | 1 | 86400 | 175 | 170.1 | 170.1 | 4.9 | 422006. | 4,766,47 | 229.20 |
| 44 | 13/2/2020 | 43 | 1 | 86400 | 175 | 169.9 | 169.9 | 5.1 | 439980. | 5,206,45 | 229.32 |
| 45 | 14/2/2020 | 44 | 1 | 86400 | 175 | 169.7 | 169.7 | 5.3 | 456920. | 5,663,37 | 229.44 |
| 46 | 15/2/2020 | 45 | 1 | 86400 | 175 | 169.5 | 169.5 | 5.5 | 472749.2 | 6,136,119 | 229.56 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to those from the regulation dam, and storage was undone. | | | | | | | | | | | |
| 83 | 23/3/2020 | 82 | 1 | 86400 | 225 | 177.0 | 177.0 | 48.0 | 4143902 | 10,280,0 | 230.59 |
| 84 | 24/3/2020 | 83 | 1 | 86400 | 250 | 177.7 | 177.7 | 72.3 | 6246493 | 16,526,51 | 231.94 |
| 85 | 25/3/2020 | 84 | 1 | 86400 | 250 | 178.4 | 178.4 | 71.6 | 6186908 | 22,713,4 | 233.09 |
| 86 | 26/3/2020 | 85 | 1 | 86400 | 197 | 179.1 | 179.1 | 17.9 | 1545960. | 24,259,3 | 233.35 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to those from the regulation dam, and storage was undone. | | | | | | | | | | | |
| 100 | 9/4/2020 | 99 | 1 | 86400 | 270 | 191.6 | 191.6 | 78.4 | 6771461. | 31,030,8 | 234.36 |
| 101 | 10/4/2020 | 100 | 1 | 86400 | 300 | 192.7 | 192.7 | 107.3 | 9271615. | 40,302,4 | 235.50 |
| Pause for 60 days without filling so that Badush Dam releases were equal to the releases of the Regulation Dam and ΔS=0. | | | | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 162 | 10/6/2020 | 161 | 1 | 86400 | 300 | 277.9 | 277.9 | 22.1 | 1913431. | 42,215,8 | 235.70 |
| 163 | 11/6/2020 | 162 | 1 | 86400 | 300 | 279.2 | 279.2 | 20.8 | 1796016. | 44,011,9 | 235.88 |
| 164 | 12/6/2020 | 163 | 1 | 86400 | 300 | 280.6 | 280.6 | 19.4 | 1679773. | 45,691,6 | 236.04 |
| 165 | 13/6/2020 | 164 | 1 | 86400 | 300 | 281.9 | 281.9 | 18.1 | 1564749. | 47,256,4 | 236.18 |
| 166 | 14/6/2020 | 165 | 1 | 86400 | 300 | 283.2 | 283.2 | 16.8 | 1450991. | 48,707,4 | 236.31 |
| This period was not a period of pause in storage. The storage did not occur because the releases from the regulation dam were less than the demand. Therefore, the releases from Badush Dam were equal to those from the regulation dam, and storage was undone. | | | | | | | | | | | |
| 184 | 2/7/2020 | 183 | 1 | 86400 | 388 | 303.8 | 303.8 | 84.2 | 7274826 | 55,982,2 | 236.90 |
| 185 | 3/7/2020 | 184 | 1 | 86400 | 400 | 304.7 | 304.7 | 95.3 | 8230358 | 64,212,6 | 237.45 |
| 186 | 4/7/2020 | 185 | 1 | 86400 | 400 | 305.7 | 305.7 | 94.3 | 8151201. | 72,363,8 | 237.92 |
| 187 | 5/7/2020 | 186 | 1 | 86400 | 400 | 306.5 | 306.5 | 93.5 | 8074192 | 80,438,0 | 238.33 |
| 188 | 6/7/2020 | 187 | 1 | 86400 | 400 | 307.4 | 307.4 | 92.6 | 7999365 | 88,437,3 | 238.69 |
| 189 | 7/7/2020 | 188 | 1 | 86400 | 400 | 308.3 | 308.3 | 91.7 | 7926753. | 96,364,1 | 239.03 |
| 190 | 8/7/2020 | 189 | 1 | 86400 | 400 | 309.1 | 309.1 | 90.9 | 7856392 | 104,220, | 239.35 |
| 191 | 9/7/2020 | 190 | 1 | 86400 | 479 | 309.9 | 309.9 | 169.1 | 14613911 | 118,834, | 239.95 |
| 192 | 10/7/2020 | 191 | 1 | 86400 | 500 | 310.6 | 310.6 | 189.4 | 1636254 | 135,196, | 240.63 |
| Pause for 60 days without filling so that Badush Dam releases were equal to the releases of the Regulation Dam and ΔS=0. | | | | | | | | | | | |
| 253 | 9/9/2020 | 252 | 1 | 86400 | 510 | 298.7 | 298.7 | 211.3 | 1826063 | 153,457, | 241.44 |
| 254 | 10/9/2020 | 253 | 1 | 86400 | 500 | 297.5 | 297.5 | 202.5 | 1749654 | 170,954, | 242.23 |
| 255 | 11/9/2020 | 254 | 1 | 86400 | 500 | 296.3 | 296.3 | 203.7 | 1759875 | 188,552, | 243.01 |
| 256 | 12/9/2020 | 255 | 1 | 86400 | 500 | 295.1 | 295.1 | 204.9 | 1770324 | 206,256, | 243.77 |
| 257 | 13/9/2020 | 256 | 1 | 86400 | 500 | 293.9 | 293.9 | 206.1 | 1780997 | 224,066, | 244.45 |
| 258 | 14/9/2020 | 257 | 1 | 86400 | 500 | 292.6 | 292.6 | 207.4 | 1791889 8.8 | 241,985, 024 | 245.05 |

1 Day
2 Date of beginning the operation
3 Time since starting the operation (days)
4 In between time (days)
5 In between time in (seconds)
6 Release from Regulation dam before operation of Badush dam ($m^3$/sec)
7 Demand in downstream ($m^3$/sec) according to Eq. (1)
8 Release from Badush dam after operation ($m^3$/sec)
9 Delta relies on Q ($m^3$/sec)
10 Delta storage ($m^3$)
11 Accumulated storage in Badush reservoir ($m^3$)
12 Water level in Badush reservoir m (a.s.l.) according to Eq. (2) (polynomial- degree 6) derived from geometric data of the reservoir, the boundary of the equation is the levels of the dam 226.5- 245.5 m (a.s.l.).

Based on the previous, it can be concluded that the period of continuous filling ranged between 20 days in the wet watery year and 130 days in the dry watery year, considering the conditions of the watery year when the filling occurred and then returned to normal operation. As for the period of gradual storage, it will range between 133 days in the wet water year and 258 days in the dry water year, taking into account the conditions of the water year during which the filling takes place, and then it returns to normal operation.

## 4.CONCLUSIONS

The Badush reservoir can be filled in a wet or dry water year without affecting the demand-supply. In the chosen wet year, the results showed the possibility of filling the reservoir in three weeks in the case of continuous filling. This period increases to more than four months in the case of gradual filling. In a dry year, the continuous filling may take more than four months, while the gradual filling may take 8-9 months because the filling stops for many days when the demand downstream is more than the Mosul Dam releases. The operator can fill in the wet water year due to the abundance of water and the desire to not affect the downstream demand. The operational flexibility was more in the dry year because the wet years may have high daily discharge releases from Mosul Dam, which required careful monitoring of the levels inside the Badush reservoir. The levels may rise quickly, requiring quick intervention by the operator. It was noted that the gradual filling in the wet year might achieve a sharp rise in the level on some days that coincide with the peak of the flood wave, which required continuous monitoring and extreme caution.

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