Assessing the Effects of Alluvial Transport in the Kızılırmak River on Dams with Local, Photogrammetric and Remote Sensing Methods

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Abstract: Naturally transported sand, clay, and gravel-like blocks by rivers cause a decrease in water flow and flow velocity. Additionally, uncontrolled disposal of waste materials into the riverbed increases adverse effects and endangers natural life. Over time, the alluvium generated by natural and external factors in river and creek beds leads to flood risks that pose a significant threat to life and property. These sediments, known as alluvium, accumulate in favorable locations in valleys and form alluvial beds with spread movement to broader areas. In Turkey, interventions in river branches and creek beds, as well as insufficient preventive measures, have kept floods a hot topic. To eliminate these issues, it is crucial for every organization to take comprehensive measures and increase environmental awareness by addressing similar areas in large projections. The Kızılırmak River, originating from the Kızıldag slopes in the İmranlı district of Sivas province and passing through the Çorum province before reaching the Black Sea at Bafra Cape, also harbors alluvial risks and adverse effects. It holds significant importance for energy production with 12 dams and hydroelectric power plants (HES) on the river. Additionally, the Pirinçli Hydroelectric Power Plant, with a transmission structure of 13,756 meters between Dodurga district of Çorum province and Güvercinlik and Kumbaba Villages, plays a vital role in electricity production in the region. The Pirinçli HES is located downstream of the Obruk Dam constructed by the State Hydraulic Works (D.S.I.) on the Kızılırmak River. It is known that a significant portion of the sediment accumulation between Güvercinlik Dam and Kumbaba Dam occurred before the construction of the Obruk Dam. Hence, preventing risks that could lead to environmental adversities is of paramount importance. In this study, a combined fieldwork was conducted using different methods to determine the areas where sediments accumulated and the alluvial material being transported cuts off the flow velocity of the Kızılırmak River and causes accumulations between the Güvercinlik Dam and Kumbaba Dam. For this purpose, terrestrial measurements, photogrammetric and remote sensing methods were combined and evaluated together to ensure the integrity of the obtained data.

Keywords: Drone photogrammetry, Risk assessment, HEPP, Environmental threats, Remote sensing

Introduction

Blocks such as sand, clay and pebbles carried naturally by streams cause the flow of water and the flow rate to decrease. In addition, waste materials left uncontrolled in the river bed increase the negativities and endanger the natural life. Flood risks caused by these alluviums, which arise from natural and external factors that form in river and stream beds over time, greatly threaten the safety of life and property. These sediments, called alluviums and accumulated in suitable places over time, occupy the ground floor in most of the valleys and form alluvial deposits by spreading to larger areas. Coastal erosion that occurs in waterways as a result of the
construction of structures in coastal areas near estuaries, which are the source of sediment supply, can negatively affect the lives of local residents (Tak et al., 2020). In order to evaluate risks in rivers, a detailed analysis is required whether changes in the flow regime are associated with sudden climate changes. It is important to record hydrogeomorphological basin changes because these processes can occur very quickly and lead to flood events that affect the entire living environment (Salandra et al., 2022).

Floods in Turkey, which occur as a result of interventions in river branches and stream beds and inadequate precautions, always remain hot on the agenda. In order to eliminate the negative effects experienced, it is of great importance for each organization to consider similar areas in wide projections, to always take precautions and to increase environmental awareness. In this context, river bed composition needs to be regularly monitored and updated due to various factors. For this purpose, to extract river bed features precisely, UAV-based orthophoto maps are created using photogrammetric techniques. (Liu, 2023).

The Kızılırmak River, which originates from the foothills of Kızıldağ in the İmranlı district of Sivas Province, passes through the borders of Çorum province and reaches the Black Sea from the Bafra cape, also contains alluvial risks and negativities. It has an important place with its energy production with 12 dams and HEPPs on the river. Obruk Dam in Dodurga district of Çorum province and Pirinçli Hydroelectric Power Plant (HEPP), which has a 13756 m long transmission structure located between Güvercinlik and Kumbaba Villages, plays an important role in the region in terms of electricity production. Pirinçli HEPP is located downstream of the Obruk Dam built by DSI on the Kızılırmak River. It is known that the majority of the conflicts between Güvercinlik Dam and Kumbaba Dam took place before the construction of the Obruk Dam. In this case, it is of great importance to prevent risks that may lead to environmental negativities.

Objective

Detection of areas where the sediment accumulated between Güvercinlik Dam and Kumbaba Dam and the alluvial material being transported interrupt the flow rate of the Kızılırmak River and cause accumulations. In this study, a composite fieldwork was conducted using varied methods to determine the areas where sediments accumulated and the alluvial material being transported cuts off the flow velocity of the Kızılırmak River and causes accumulations between the Güvercinlik Dam and Kumbaba Dam. For this purpose, terrestrial measurements, photogrammetric and remote sensing methods were combined and evaluated together to ensure the integrity of the obtained data.

![Figure 1. Location of the study area](image-url)
Study Area and Assessment of Current Situation

The length between Güvercinlik Weir, built next to Pirinçli HEPP, and Kumbaba Weir is around 13 km. In the examinations carried out on this area along the river flow, it was observed that the excessive alluvial material formed in places especially filled the stream beds and blocked the water flow. While the existing Kızılırmak River capacity (Obruk Dam Maximum production capacity) is on average 400 m³/sec, it is estimated that it cannot even carry 100 m³/sec of water due to the fullness of alluvial material. The study area, which was created for the purpose of measuring and determining the depths of the areas where this flow obstacle is concentrated in its current state, is on the Kızılırmak River line in Dodurga District of Corum Province; In the geographical coordinates of 40.51°29.24′N, 34.51°27.98′E Güvercinlik Weir and 40.55°22.04′N, 34.50°52.13′E Kumbaba Weir, it covers the Güvercinlik and Kumbaba settlement areas and the river areas on the tail water side of the Pirinçli HEPP power plant pointed at the satellite image (Figure 1).

Method

Terrestrial, Photogrammetric and Remote Sensing

Various methods were used in field studies and the integrity of the data obtained was ensured. For this purpose, terrestrial measurements were evaluated using photogrammetric and remote sensing methods. The work program including all methods is shown in the flow chart (Figure 2).

Figure 2. Flow chart of the work schedule
Drone Mapping

The length of the Kızılrmak River between Güvercinlik and Kumbaba dams is 13 km, and it's width varies between 30-70 m. Orthophoto map production of the study area was made with the 3D drone mapping method as DSM_ortho (Figure 3). 11 planned flights were made for the 13 km area. 27 GCPs (Ground Control Points) were established and coordinate measurements were carried out on a 3D plane, in the TUSAGA Active system. In addition, the study was designed to form a basis for the cadastral map of the region.

River Bottom Measurements

River depth measurements were obtained as DCP (Depth Control Points) in the form of a test point every 50 meters. Test measurements were carried out at 236 DCPs each measuring point for 0+050 to 13+000 is coordinated in three dimensions (Table 1). Measurements were started by taking the Pirinçli HEPP power plant tailwater and completed at the Kumbaba Dam. The depth was measured as 2.40 m at the initial point and 1.20 m at the ultimate point (Figure 4).
In the study, which was carried out to identify risky areas where the alluvial material accumulated and sedimented between the Güvercinlik and Kumbaba dams of the Kızılırmak River disruption of the flow rate and the water level was high. The km-depth/measurements obtained as 50 m intervals at DCPs which are considered as test points including 150 cm depths. Distribution of Depth Control Points of test points measured every 50 m is graphed (Figure 5).

![Distribution of DCPs](image)

**Figure 5. Distribution of the depth control points**

Drone images of the lowest and highest depth obtained from the model created for the study area (Figure 6).

![Drone Images](image)

**Figure 6. Lowest and highest depths among the dams**

Images of sand islands formed by alluvial materials in the region are shown as examples of risk areas (Figure 7).

![Images of Sand Islands](image)

**Figure 7. Risky areas with high potential for impact on the environment**
Results and Discussion

Data Analysis and Evaluations

The lowest depth between the dams measured as 20 cm with 3 test points are at the 5th km. The highest depth measured 4 m with 10 test points where it exceeded the limit were determined at 1.5 and 3 km and at 10, 11 and 12 km The scatter plot of the measurements are generated (Figure 8).

![Figure 8. Scatter plot of the measurements generated](image)

![Figure 9. Risky areas on the depth measurement line](image)
Depth values taken from depth measurements every 500 m, as well as risky areas where the depth falls to 50 cm or less are marked on the measurement line. As a result of the analysis carried out by processing and evaluating the data, areas that occurred in the six test regions and could pose a risk were identified (Figure 9). Orthophoto mosaics were created from images superimposed with depth measurements to define hydromorphological units marked risky areas on the ortophoto image and satellite image compared (Figure 10).

Figure 10. Mosaic image (Visible/infrared drone footage focusing on potential risk areas)

Conclusion

Of the depth measurements made at 341 points, 236 have a depth of 150 cm. It is seen that there are excessive alluvial accumulations in these areas. It has been observed that the values obtained from depth measurements between the dams are not distributed homogeneously in the anomaly graph, areas with high depth are located side by side with areas with low depth. These areas are considered to be particularly high risk. Considering that the average amount of water that Obruk Dam will release at its maximum production is 400 m³/sec, it is obvious that the river bed between Güvercinlik and Kumbaba Dams cannot carry this amount of water and that it will cause floods along with the connected streams on the side branches and threaten the safety of life and property. It is known that the alluvial material that forms the current situation was transported to the region before the construction of the Obruk Dam. Since the transports that may come from Obruk Dam will be detained/blocked by the existing dams.
**Recommendations**

When the study is evaluated in terms of its rich data, integrity of its methods and environmental quality It is anticipated that this planned work will be permanent in the long term.

**Scientific Ethics Declaration**

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

**Acknowledgements or Notes**

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 16-19, 2023.

**References**


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