EFFECT OF OPERATION PROCEDURES IN SEDIMENT TRANSPORT IN A TRANSBASIN CANAL SYSYTEM

Aleji Davar, [1] P.E., M. ASCE

Ahmad Barari [2]

ABSTRACT

The purpose of this paper is to discuss problems associated with performance of earth canals, designed for non-scouring and non-silting flow, and suggest operational procedures to minimize the sedimentation problem for transbasin projects, where adequate facilities for removal of suspended solids may not be available at the headworks. Remarks are based on observations of site characteristics, and analysis of field data for the Moghan Irrigation Project, as a part of the Mill and Moghan Project constructed jointly between Iran and the Republic of Azerbaijan (a former Soviet Union republic).

SCOPE OF MILL AND MOGHAN IRRIGATION PROJECT

The Mill and Moghan Irrigation Project is a major water development project in the Aras River basin. The Aras River runs from west to east along the northern international boundary of Iran, from Ararat Mountains in Turkey to Kur River in Azerbaijan and finally to the Caspian Sea, a distance of approximately 1000 kilometers (km). The Aras River basin (approximately 124,000 square kilometers) is shown in Figure 1.

Along its route, various watersheds, primarily from the mountains in the northwest of Iran, and the Caucus Mountains, drain to the Aras, creating a water conveyance system across a multitude of basins. This multipurpose project supplies irrigation water to Moghan Plane in Iran and Mill Plane in the Republic of Azerbaijan. The construction of the project was started in 1960s at the peak of water development projects in the world, and was completed in early 1970s.

PRIMARY ELEMENTS OF THE PROJECT

The joint project consisted of a 42-meter high earth-type storage dam with impermeable core, reservoir capacity of 1,350,000 hectare-meters (hm), and two powerplants with 44 MW electricity generating capacity. These facilities are located near the Azerbaijani City of Nakhjevan. Approximately 250 km

1) Consulting Engineer, DAVAR ENGINEERING, P. O. Box 1906, San Luis Obispo, California 93406, USA.

2) Deputy Director, East Azerbaijan Regional Water Authority, 29th Bahman Blvd., Tabriz, East Azerbaijan 51564, Iran.

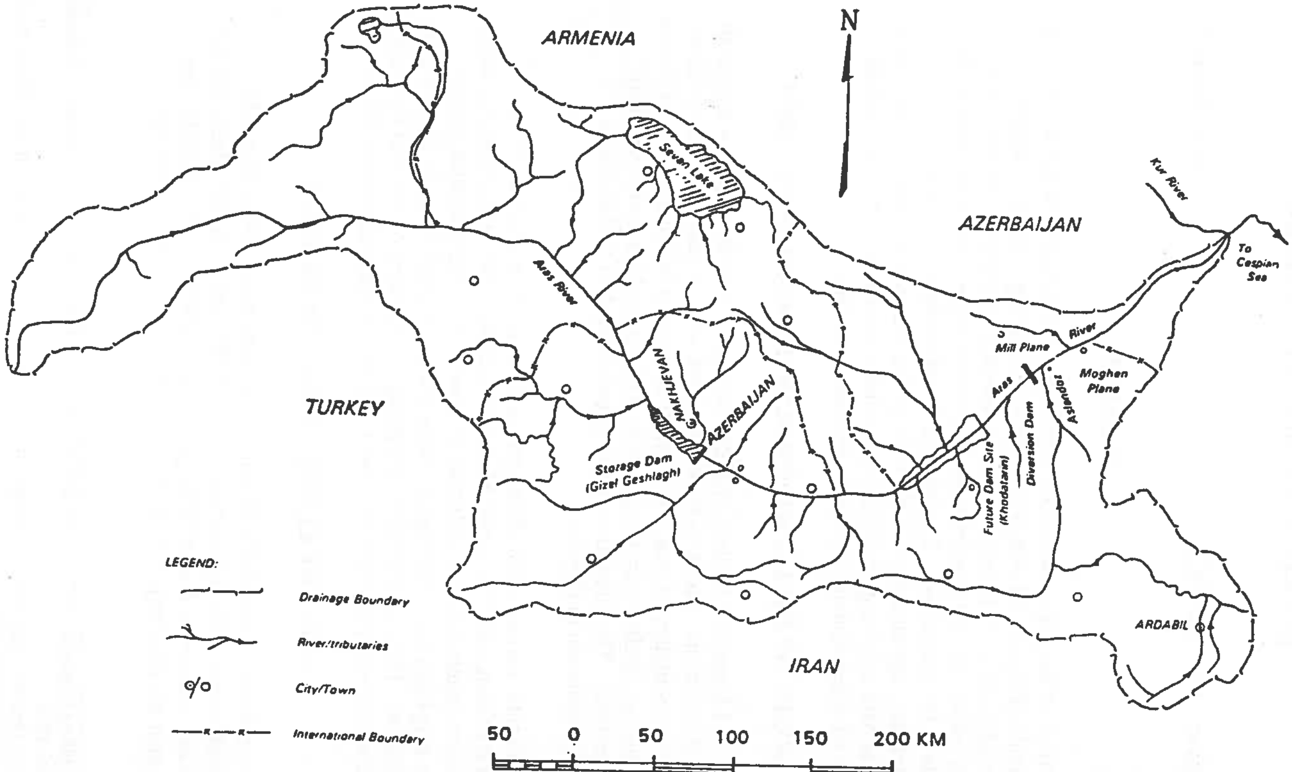

Figure 1: Aras River Basin (local dam project sites not shown)

downstream along the Aras River at Aslandoz (Iran), a diversion dam (earth-type) diverts water to the canal systems on both sides of Aras and, therefore, conveys water to farm lands in Iran and in the Republic of Azerbaijan.

On the Iranian side at the present time, the head structure at the diversion dam includes a sedimentation facility designed to trap suspended solids larger than 0.15 mm in diameter. Then, the water flows in a primary canal system (approximately 150 km) and secondary canals (approximately 250 km). The design capacity of the main canal at upper reaches is 80 cubic meters per second (CMS).

The land under irrigation in Moghan Plane on the Iranian side is approximately 90,000 hectares (ha) and the primary canal system is shown in Figure 2. From a historical perspective it should be mentioned that prior to the water project under consideration there was an existing canal system, namely A-canal and T-canal in the area which was supplying water to approximately 18,000 ha of the land. However, by construction of the main canal under the project described above, these two previously constructed canals, which were seriously affected by sedimentation, became an extension of the main canal system of Moghan Project, and their intake facilities at Aras River that consisted of temporary earth dikes, were abandoned.

SEDIMENT LOAD IN ARAS RIVER

The sediment load upstream from the storage dam is primarily removed by the sediment pool of the reservoir. The sediment rating curve at a gauging station (Khazanghah) on the downstream side of the storage dam is shown in Figure 3. Based on average flow in this reach, the sediment load in the river below the storage dam is estimated to be 1.4 million metric tons per year. Downstream from the storage dam a number of tributaries join the Aras River as shown in Figure 1. These intermediate tributaries from abutting watersheds add a very significant amount of sediment load to the Aras River. The sediment rating curve for Aras River at a gauging station at Khodafarin, approximately 200 km downstream from the storage dam, is shown in Figure 4 (based on average sediment loads) and Figure 5 (based on high sediment loads). The relationship between water discharge and suspended sediment given in figures 3 through 5 are based on limited data and pertains to an intermediate region of Aras River Basin between the gauging stations mentioned above.
Reportedly, approximately 13 percent of the total sediment in the Aras River may be assumed bed load. Regarding the suspended sediment, approximately 10 percent consist of particles larger than 0.15 mm that may be trapped in the sedimentation chambers at diversion dam.

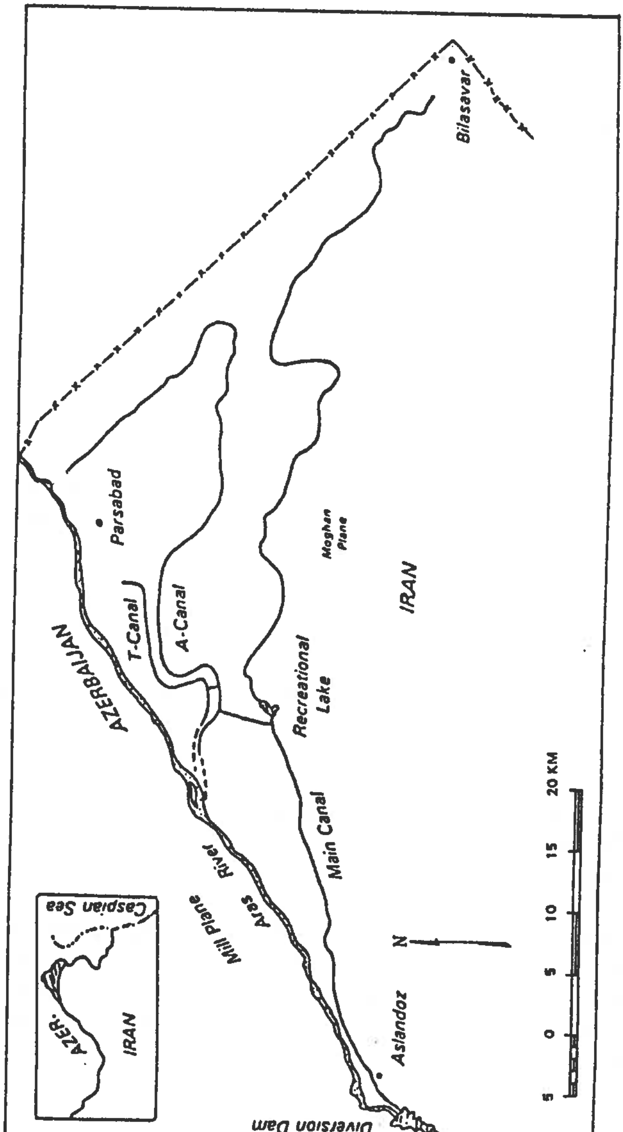

Figure 2: Moghan Irrigation Project

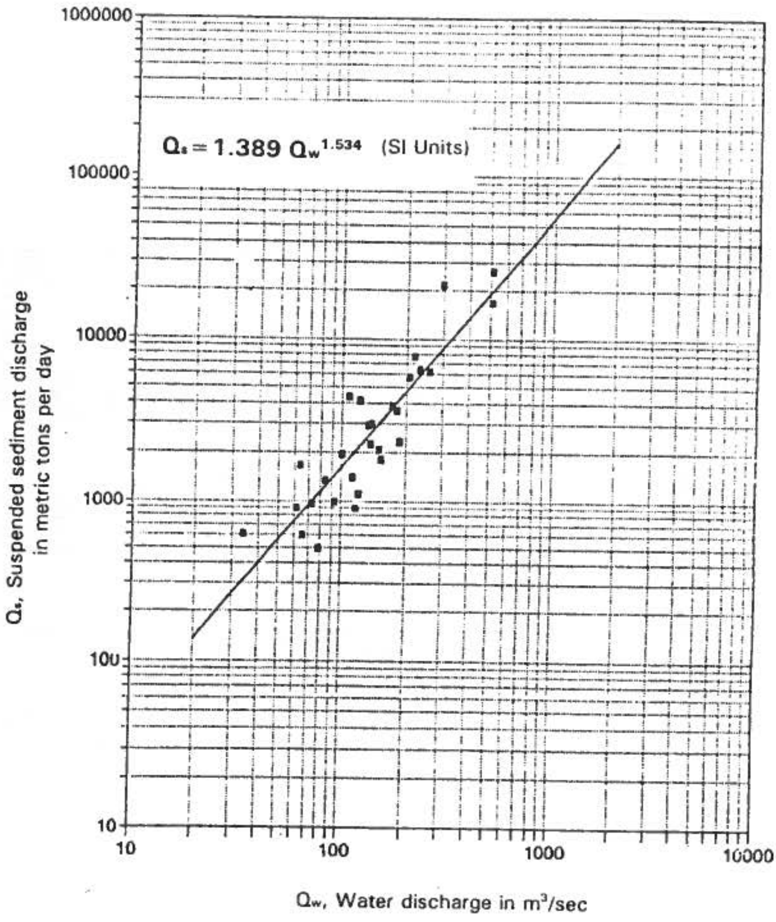

Figure 3: Sediment Rating Curve for Aras River at Khazanghah Gauging Station (Downstream of Storage Dam at Gizel Geshlagh)

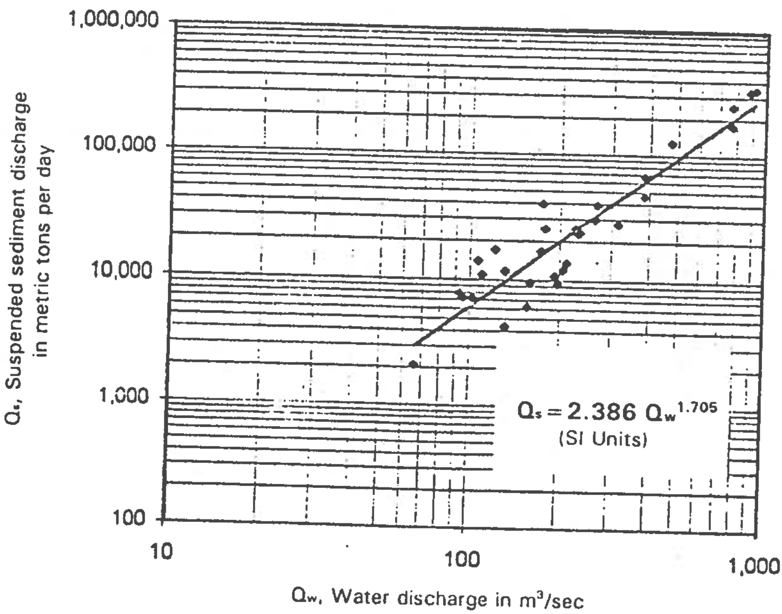

Figure 4: Sediment Rating Curve for Aras River at Khodafarin Gauging Station (Based on Average Sediment Loads)

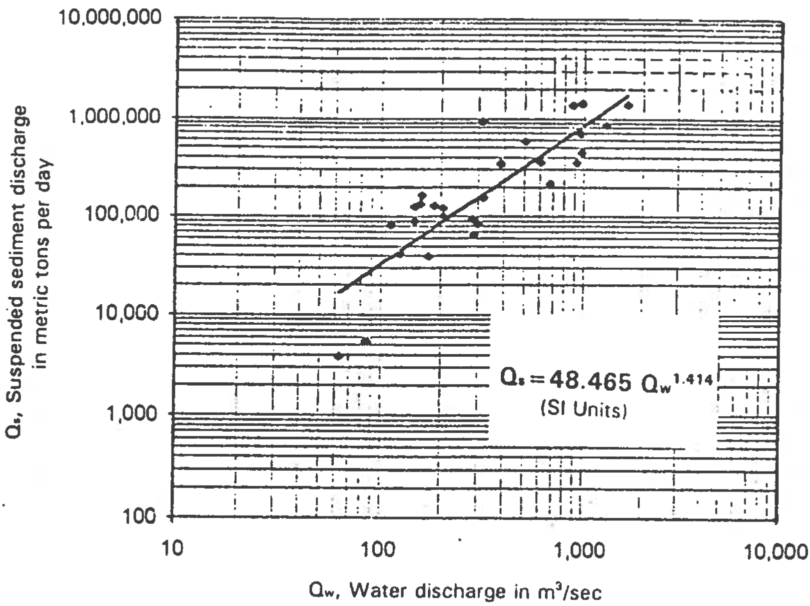

Figure 5: Sediment Rating Curve for Aras River at Khodafarin Gauging Station (Based on High Sediment Loads)

DISCUSSION OF DESIGN CRITERIA

For the purpose of sediment removal, the head structure at the diversion dam includes a sedimentation facility with 4 chambers, each chamber with 5 galleries, 120 meters (m) long, 5 m wide and 3 m deep. Three of the chambers may be in operation while the 4^{th} chamber is being flushed. Based on limited field data available, approximately 10 percent of the suspended load is particles larger than 0.15 mm (larger than fine sand) that may be trapped in the sedimentation basin under proper operational procedure. The canal design was based on tractive-force method (pioneered by U. S. Bureau of Reclamation), and the sediment capacity of the system was determined to be adequate under normal flow conditions. It is imperative to realize that in tractive force method the allowable tractive force is a function of median grain size (D50) of soil or canal material, and therefore, the maximum velocity of flow is restrained by the geometric design of a canal (to prevent scouring). However, it provides no provisions for minimum velocity of flow (to avoid silting). In fact the tractive-force method is meant for clear water or moderately sediment-laden water, in canals with uniform flow, at normal depth.

OPERATING PRACTICE

Following completion of the water project described in this article, development of land remained incomplete and therefore, the system was operated at reduced capacity (approximately ½ capacity at most). This condition, in conjunction with the effect of check structures along the canal system designed to maintain the water surface elevation at desired levels, caused serious reduction in velocity of flow and accelerated silting process. The upper reaches of the main canal behaved, to some degree, as a regime canal and the sediment deposits were carried downstream by fluctuations in the position of regulating gates at the check structures. However, the lower reaches of the main canal, and A-canal as well as the secondary canals branching off from A-canal, with fixed check structures such as Duckbill-type weirs developed serious sediment problems. Admittedly, inadequate maintenance for an extended period of time compounded the problem, and approximately 1/3 of canal capacity was lost in the first 25 years of operation. Allowing excessive sediment in to the canal system is prone to cause problems. However, under the condition described above, the silting could be minimized by incorporating requisite criteria in the design of check structures and operating procedures to maintain adequate velocity of flow in the canals during water delivery.

CONSIDERATION OF CORRECTIVE MEASURES

As shown in Figure 1, the project encompasses watersheds across international boundaries. Therefore, soil conservation methods in the numerous watersheds seemed to be ineffective due to lack of control over the vast area contributing to the system. Construction of check dams below certain watersheds with high erosion was also considered. Furthermore, addition of a desilting structure on the main canal at a certain strategic location was considered to supplement the function of sedimentation facility at diversion dam. Construction of sedimentation basins at the headwork of some of secondary canals prone to silting were also considered by means of enlarging the depth and width of required length of canal (depending on maximum flow capacities). Improvements in the practice of mechanical removal of sediment were also considered.

Because a storage dam with adequate sediment pool is planned for construction at Khodafarin, approximately 50 km upstream from the existing diversion dam, other costly alternatives for sediment control were deemed unwarranted.

Maintaining a pre-determined minimum velocity of flow in the canals would be a viable means to minimize silting problem. This can be achieved by proper maintenance of the system including tertiary canals, and implementation of a water delivery plan based on hydraulic characteristics of the canal system. Needless to say, this method would require precise planning and management.

CONCLUSIONS

For canals with sediment laden water source, the maximum (non-scouring) velocity and minimum (non-silting) velocity shall be determined for every reach of the canal and incorporated in the design. The tractive-force method should be used for canals with clear water source, or canals with adequate sediment removal facilities at the headwork. This method provides an upper limit for velocity of flow to prevent scouring. There is no provision in the method to prevent sediment deposition in the canal. Use of this method may work for canals with moderately sediment laden water, providing that the flow in the canal shall be uniform (normal depth flow). In case of check structures designed to maintain the water surface at desired elevations, a threshold velocity (lower limit of velocity) shall be determined and implemented in the operational plan to avoid deposit of sediment in the canal system. Social aspects such as water and transportation needs of communities in the immediate vicinity of the project and access restrictions should be seriously considered in the design phase. Operation and maintenance manuals should be prepared during the first year of the project operation and updated periodically thereafter.

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