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Evaluation of dike-type causeway impacts on the flow and salinity regimes in Urmia Lake, Iran

Mostafa Zeinoddini [a], Mohammad Ali Tofighi [b,*], Fereydun Vafaee [a,c]

[a] K.N.T.University of Technology, Iran, Faculty of Civil Eng.KNToosi University of Technology (KNTU),ValiAsr-Mirdamad Cross, Tehran, 19697, Iran
[b] Sharif University of Technology, Iran, Faculty of Civil Eng. Sharif University of Technology (SUT), Azadi Av, Tehran, Iran
[c] Soil Conservation and Watershed Management Research Institute (SCWMRI), Iran, Coastal Department, (SCWMRI), P.O.Box 13445-1136, Tehran, Iran

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ABSTRACT

Urmia Lake, located in a closed basin in north-west Iran, is the largest lake (5000–6000 km^2) in the Middle East. It is very saline with total dissolved salts reaching 200 g/l compared with a normal seawater salinity of about 35 g/l. The construction of a causeway, which was initiated in 1979 but then abandoned until the early 2000s, is near completion and will provide road access between the western and eastern provinces. The causeway has an opening 1.25 km long and divides Urmia Lake into a northern and southern basin and restricts water exchange. The flow and salinity regimes are affected by the presence of this new causeway, and there are concerns over the well being of the Artemia population. This study investigates the effects of the construction of the causeway on flow and salinity regimes, considers remedial actions, and examines the effects of climatic variability on salinity and flow. Flow and salinity regimes were numerically simulated by using a commercially available two and three-dimensional (2D and 3D) MIKE model. The validity of the numerical model was assessed through sensitivity analysis of the model and comparing the simulated results against field measurements; the 3D model provided the higher correlation between simulated and actual data. Wind input was the main climatic and hydrologic factor influencing flow regime while river discharge, evaporation and rainfall were the key parameters affecting salinity distribution in the lake models. The 3D model was subsequently used to predict lake conditions in typical dry, wet and normal climates, to examine the environmental impacts from the new causeway, and to evaluate possible improvements that some remedial measures may provide.

Introduction

Urmia Lake is one of the largest salt lakes in the world and is located in a closed basin in north-west Iran (37 °4′–38 °17′ N and 45 °–46 °E). The lake has a semi-rectangular shape, a maximum length of 135 km, and a surface area between 5000 and 6000 km^2 (Shabestari, 2003). A general map of Urmia Lake is presented in Fig. 1 and shows its bathymetry (Sadra, 2003) based on a water datum of 1275 m above the Persian Gulf Mean Sea Level (MSL). The mean water level varies seasonally (yearly) by about 1 m, with greater variations in water level occurring over longer time spans. For the 1930–2007 period, the extreme low of 1273.5 m occurred in 2002 and the extreme high of 1278.4 m in 1994. From 1979 to 1992, a 15.4 km dike-type causeway was gradually constructed to cross the lake width at its narrowest part (Fig. 1) and to provide road access between the western and eastern provinces. This rubble mound embankment was built by direct dumping of the quarry run materials, concurrently, from the eastern and western shores with a 1.25 km long opening left in the causeway to provide for connection between the northern and southern parts of the lake. In the early 2000s, construction was accelerated to build a bridge to span this opening and thus complete the causeway. Thus this east–west running dike-type causeway essentially divides the lake into northern and southern parts with a single opening allowing limited water flow between the two basins.

Several rivers flow into Urmia Lake (Fig. 1) and, with an average annual inflow of about 4.6 billion m^3, are the main source of water to the lake. Some rivers flow over saline soils, picking up dissolved salts which are discharged with their flow into the lake; salinity is 6 g/l around some river mouths. Evaporation rates are high averaging 1200 mm/year for a 50 year record. As a result, the lake is highly saline with salinity averaging 225 g/l but may reach 280 g/l when the lake water level declines during dry years. Salinity is approximately 60% higher in the northern basin of the lake because of higher evaporation rates and lower water river inflows than in the southern basin. Salinity and lake level have declined over the past 20 years although salinity did increase over 2003–2004 with favorable climatic conditions (Eimanifar and Mohebbi, 2007). Construction of the causeway may also have contributed to a higher salinity in the north and lower salinity in the south by reducing the normal exchange of water between the northern and southern parts of the lake.

* Corresponding author.
E-mail addresses: Zeinoddini@kntu.ac.ir (M. Zeinoddini), Tofighi@civil.sharif.edu (M.A. Tofighi), fvafai@kntu.ac.ir (F. Vafaee).

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Urmia Lake is registered under RAMSAR Convention as an area of international importance for birds. The brine shrimp *Artemia urmiana* is one of the few organisms inhabiting the lake and can tolerate a salinity range of range of 40 to 250 g/l although may be stressed by the higher salinities (Csvas, 1996). The increasing salinity in the northern basin of the lake, if acerbated by the causeway, may have an adverse impact on the *Artemia* populations if their salinity tolerance range is exceeded. Various remedial actions have been considered to reduce the salinity of the northern basin. One option is to construct additional openings in the causeway to improve water exchange between and mixing within the north and south basins. This would be an expensive and technically demanding solution as relatively long overpass rail/road bridges would have to be built on top of each new opening. Moreover, the causeway bed is very loose and, after about 30 years, is still subsiding. This subsiding substructure would have adverse effects on a rigid bridge structure and on its long-term performance. Another option being considered is moving the mouth of the Nazloochi River so that it discharges into the northern basin. Therefore, additional openings and/or relocating the Nazloochi River mouth would only be considered feasible if comprehensive hydrodynamic modeling studies proved them to be essential measures to reducing the increased salinity of the northern basin.

Several attempts have been made to quantify Urmia Lake hydrodynamics. Ab-Niroo (1995) used a 2D model and concluded that the natural mixing of the waters between the north and south parts of the lake was reduced because of the construction of the causeway. Alikhani (1997) used the HEC-5 program and a water balance approach to model water level fluctuations; the results were verified using field measurements. Modaresi (2002) used a critical meteorological approach to quantify water exchange through the causeway opening and the widening of the opening required to obtain the desired water exchange. Abrari (2003) used 2D hydrodynamics modeling to investigate water circulation patterns (simulated data were compared to field monitoring data generated by freely travelling buoys released into the lake) and concluded that flow patterns in the lake were controlled by the wind regime. Sadra (2003) employed a 2D depth-averaged hydrodynamic model to investigate design improvements in the causeway and for the design of a bridge to span the existing opening; they also performed one-year simulations of the flow and salinity circulation in the lake. They recommended that a

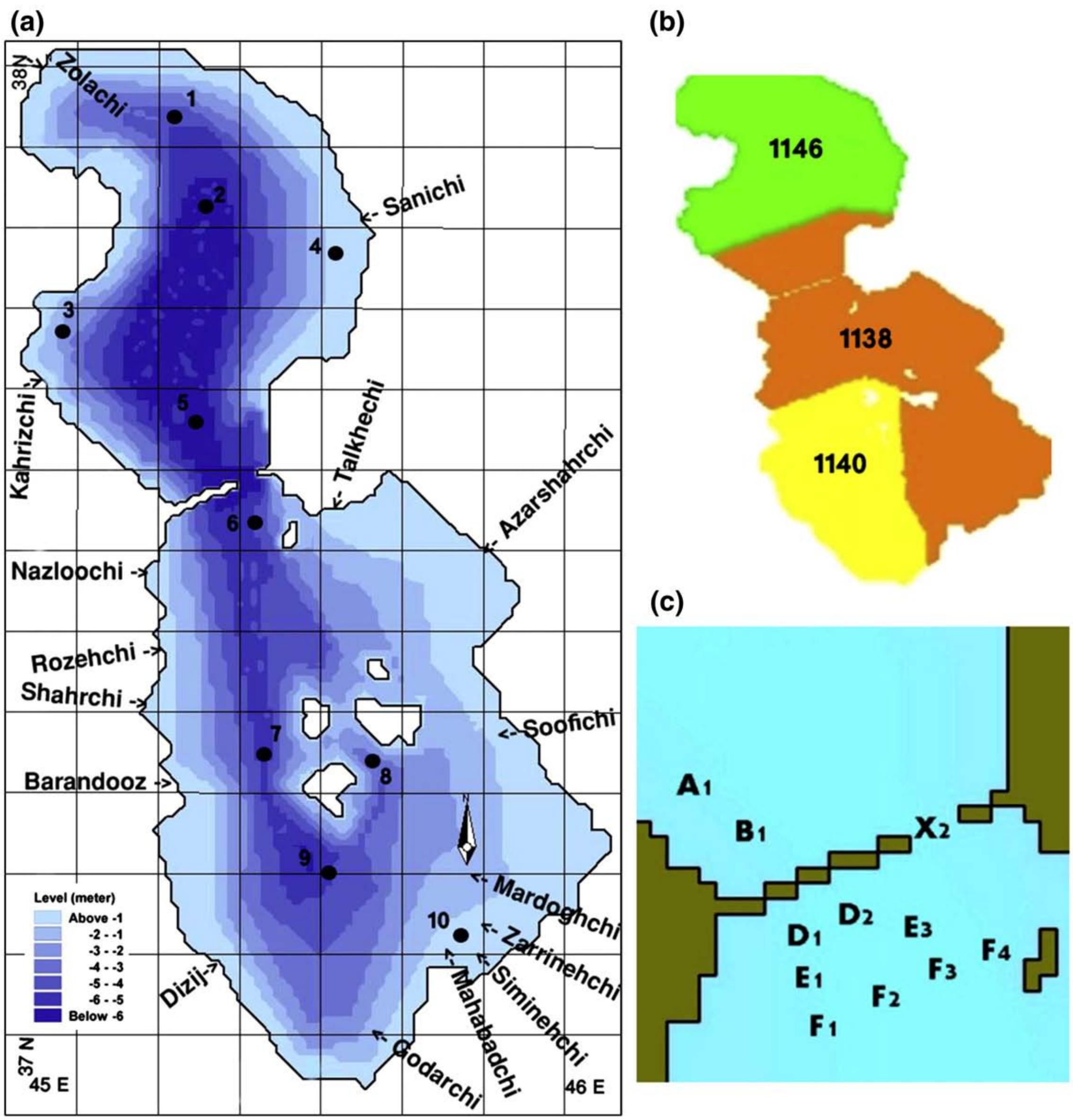

Fig. 1. (a) A general map of Urmia Lake, its bathymetry, the crossing dike and the major river entries; (b) distribution of salinity in May 1987 (see also Table 4); (c) measurement stations (see also Table 1).