ISLAMIC REPUBLIC OF IRAN
MINISTRY OF ENERGY (MOE)
WATER RESOURCE MANAGEMENT COMPANY (WRMC)

DATA COLLECTION SURVEY ON HYDROLOGICAL CYCLE OF LAKE URMIA BASIN IN THE ISLAMIC REPUBLIC OF IRAN

FINAL REPORT

FEBRUARY 2016

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CTI ENGINEERING INTERNATIONAL CO., LTD
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Source (Urmia Lake Basin): United Nations Environment Programme (UNEP)

LOCATION MAP

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ACRONYMS AND ABBREVIATIONS

CIWP	:	Conservation of Iranian Wetlands Project
C/P	:	Counterpart
DEM	:	Digital Elevation Model
DF/R	:	Draft Final Report
DHI	:	Danish Hydraulic Institute
DOE	:	Department of Environment
FAO	:	Food and Agriculture Organization
F/R	:	Final Report
GOI	:	Government of Iran
GOJ	:	Government of Japan
IC/R	:	Inception Report
IDW	:	Inverse Distance Weighted
IMO	:	Iranian Meteorological Organization
IWRM	:	Integrated Water Resources Management
JICA	:	Japan International Cooperation Agency
JST	:	JICA Survey Team
LURC	:	Lake Urmia Restoration Committee
M/M	:	Man-month
MOE	:	Ministry of Energy
MOH	:	Ministry of Health
MOJA	:	Ministry of Jihad-e Agriculture
M/P	:	Master Plan
O&M	:	Operation and Maintenance
PWRI	:	Public Works Research Institute
SC	:	Steering Committee
TOR	:	Terms of Reference
TRWR	:	Total Renewable Water Resources
UNDP	:	United Nations Development Plan
UNEP	:	United Nations Environment Programme
USGS	:	United States Geological Survey
WRMC	:	Water Resources Management Compan
RCUWM	:	The Regional Centre on Urban Water Management
SRTM	:	Shuttle Radar Topography Mission

CHAPTER 1. INTRODUCTION

1.1 BACKGROUND

The Islamic Republic of Iran (hereinafter referred to as "Iran") is located in an arid area. The average annual rainfall is 228mm and the Total Renewable Water Resources (TRWR) per capita is 1,978m^3/year (Source: FAO AQUASTAT 2008). Recently, water demand has been increasing due to the economic growth in agricultural and industrial sectors and the increase in population, which has led to surface water and groundwater development.

Lake Urmia is located in the northwestern part of Iran. As of June 1995 when the highest water level was recorded, with its water level of 1,278.4m, area of 5,700km^2 and pondage of 36,760MCM, the lake used to be ranked as the 6th largest inland saline lake in the world. The area of the lake, however, has gradually shrunk concurrently with the decrease in water inflow since Year 2000. As of November 2014, the water level, area and pondage of Lake Urmia were below 1,270.4m, 1,860km^2 and 2,199MCM, respectively. The principal cause of decline of the lake surface area has been reportedly attributed to chronic drought and the increase in quantity of water intake for agriculture brought by water resources development in the Lake Urmia Basin. However, it is not clear as to what extent these factors contribute to the decline of lake surface area.

To cope with the decline of Lake Urmia surface area, Iran established the "Conservation of Iranian Wetlands Project (CIWP)" (2006-2012) under the support of UNDP and GEF in 2006. In 2010, the master plan for restoration of Lake Urmia was endorsed by the Iranian Government. Since then, however, no practical measure has been taken until Mr. Hassan Rouhani, who made a public commitment on the restoration of Lake Urmia, assumed the presidency in August 2013. President Rouhani hammered out measures and called for assistance from international communities. In 2014, the Lake Urmia Restoration Committee (LURC), directly controlled by the President, was established. In March, an international roundtable meeting on Lake Urmia restoration was held, followed by approval of 14 countermeasure projects proposed by LURC in June 2014(After that, 10 more projects were added, and the total number of countermeasure projects resulted in 24).

Japan supported the Iranian water resources sector through "The Study on Integrated Water Resources Management for Sefidrud River Basin in the Islamic Republic of Iran" from 2007 to 2010. In the study, formulated was the Master Plan (hereinafter referred to as "M/P") of Integrated Water Resources Management for Sefidrud River Basin, a part of which is adjacent to Lake Urmia. To follow up the M/P, implementation of the project "Capacity Building Project for Implementation of Integrated Water Resources Management in the Islamic Republic of Iran" is examined by JICA. The area of capacity building project will cover both Lake Urmia Basin and Sefidrud River Basin.

In November 2013, during Japanese Foreign Minister Fumio Kishida's visit to Iran, the Iranian counterpart requested Japan for assistance on the implementation of the Lake Urmia restoration countermeasure projects. A similar request was made when Iranian Vice President Dr. Masoumeh Ebtekar visited Japan in April 2014. In response to the requests, GOJ requested JICA to execute the data collection survey (hereinafter referred to as "the Survey").

1.2 PROJECT SURVEY OBJECTIVES

The objectives of the Survey are as follows:

(1) To establish an integrated hydrological cycle model for the Lake Urmia Basin based on the available data collected and provided by GOI, and other existing data.

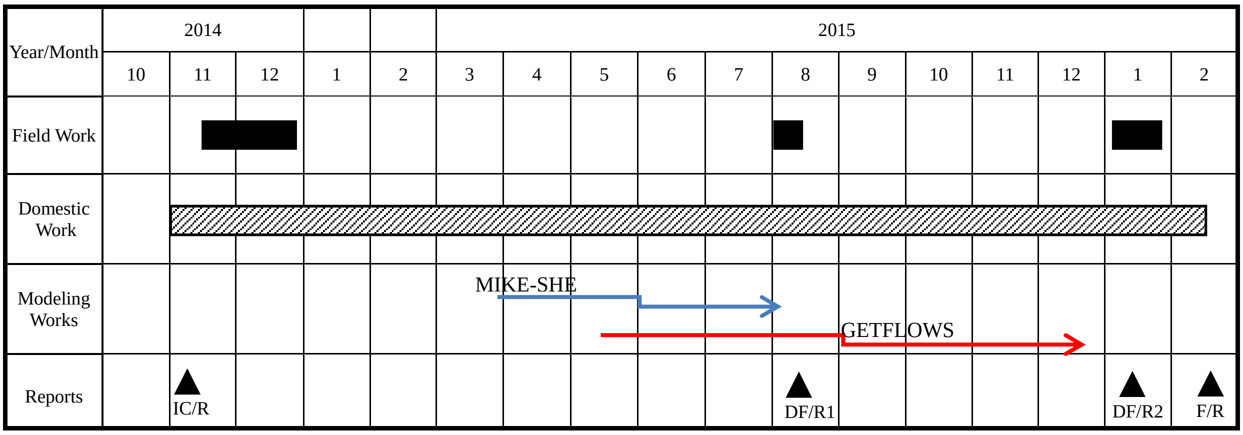
(2) To evaluate the prospective countermeasure projects for Lake Urmia restoration to be implemented by GOI, in a quantitative manner.

1.3 SURVEY AREA

The Survey Area covers the Lake Urmia Basin (West Azerbaijan Province, East Azerbaijan Province and Kurdistan Province).

1.4 TENTATIVE OVERALL SURVEY SCHEDULE

The Survey is tentatively scheduled for a period of about sixteen (16) months as shown in Figure 1.4.1.



Legend：IC/R: Inception Report;DF/R: Draft Final Report;F/R: Final Report

Figure 1.4.1 Overall Project Schedule

1.5 STAFFING PLAN

The composition of the JICA Survey Team (hereinafter referred to as "JST") is as shown in the following table.

Table 1.5.1 Composition of the JICA Survey Team (JST)

Name	Designation / Field of Specialty
Toshihiro GOTO	Team Leader / Water Resources Management 1
Takashi FURUKAWA	Water ResourcesManagement 2
Yosuke MIURA	Simulation Model
Kiyoshi YAMADA	Geology
Hitoshi NAGATA	Meteorology/Hydrology

1.6 WORKING SYSTEM

Due to the involvement of multiple organizations on the Iranian side and to ensure a smooth cooperation and partnership and enhancement of local capacity building, the following counterpart structure has been established on the Iranian side:

- Overall supervision: Dr Bahram Taheri, the Senior Environment, Safety and Health Advisor of Minister of Energy and member of the Kalantari Commission's Steering Committee will administer the overall supervision on this project in the Iranian side.
- Focal Person: Mr Sayyari, Deputy Manager in Planning & Development of Water Resources Management Company (WRMC)

Counterpart Organization

➢ Main Partner:
  - ✓ Water Resources Management Company (WRMC), Ministry of Energy (MOE)

➢ Co-Partners:
  - ✓ National Committee for Saving Lake Urmia and its affiliate regional research partners
  - ✓ Water Research Institute (WRI),MOE
  - ✓ Regional Center on Urban Water Management (RCUWM)

- ✓ The proposed organizaional framework are summarized below.

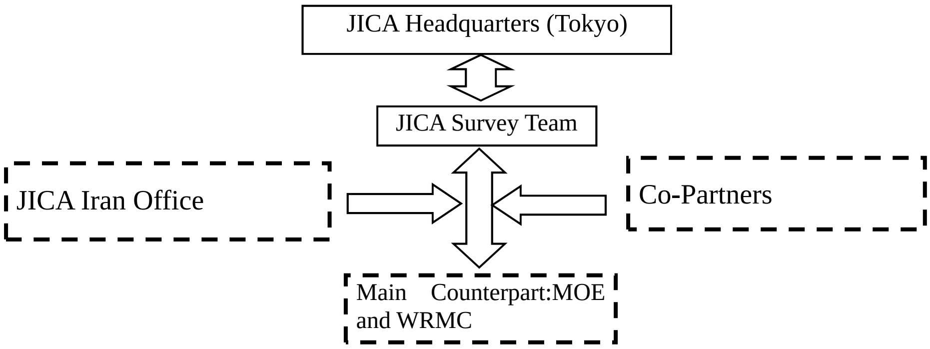


Figure 1.6.1 Organizational Framework of the Survey

CHAPTER 2. NATURAL CONDITION

2.1 LAKE URMIA

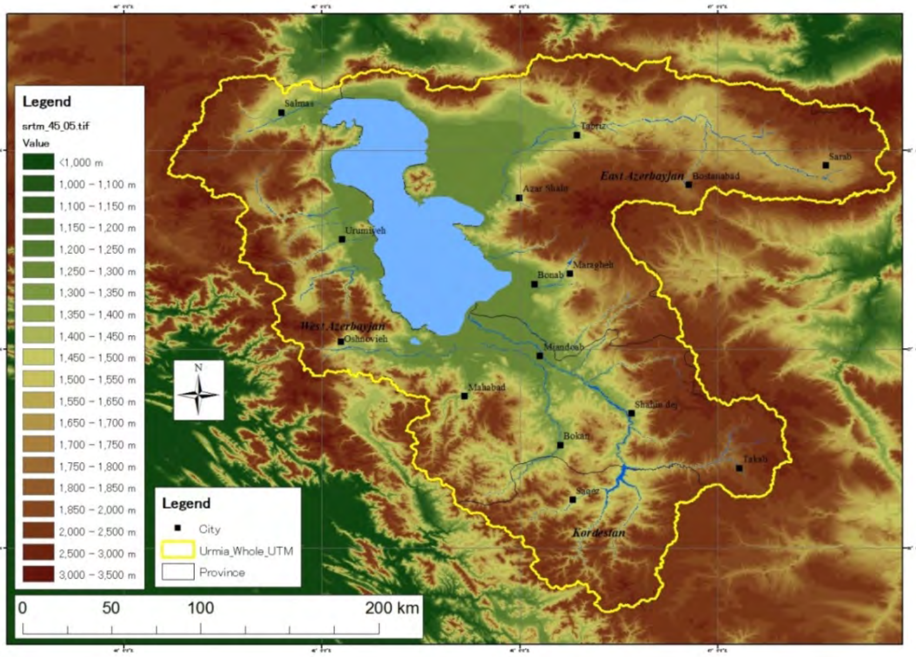
2.1.1 GENERAL INFORMATION ON LAKE URMIA

The location of Lake Urmia Basin is shown in Figure 2.1.1, and the general information on Lake Urmia is summarized in Table 2.1.1. The Lake Urmia Basin is located in the North-West of the Islamic Republic of Iran, bounded by the Zagros Mountains that neighbor with the Aras River Basin to the North and the Sabalan Mountains that neighbor with the Zaab River Basin to the South.

The Lake Urmia Basin is located between 35˚40'N and 38˚30'N Latitude, 44˚13'E and 47˚54'E Longitude. The lake basin area is 52,000km^2, which is 3.15% of that of the whole country, and the volume of surface water in the lake basin dominates 7%[1], and thus positioned as one of the six (6) large river basins in the Islamic Republic of Iran. Elevation of the lake basin varies between 1,267m and 3,746m above sea level. Climate in the lake basin is classified into cold semi-arid (Köppen: BSk), in which average annual precipitation is approximately 400mm and average potential evapotranspiration ranges between 530mm and 680mm.

Total population is approximately 3.7 million with 57.6% dominated by East Azerbaijan Province holding 1.5 million population in the provincial capital of Tabliz, 38.6% dominated by West Azerbaijan Province holding 0.67 million in the provincial capital of Urmia, and the remaining 3.8% by Kurdestan Province(as shown in Table 2.1.2).

As mentioned in Chapter 1, In June 1995 the water level of 1,278.41m, area of 5,722km^2 and storage of 36,757MCM were recorded as such. However, as of November 2014, the water level, area and storage of Lake Urmia were 1,270.42m, 1,901km^2 and 2,199MCM, respectively. Recently, a variety of environmental degradation has occurred such as dry-up of inflow of rivers, degradation of neighboring area which is ex-swamp area, drifting sand blown up by wind which was originally lake deposition, and other environmental issues.



Source: DEM; SRTM
Basin boundary, Lake boundary and river channel provided by WRMC

Figure 2.1.1 Location of the Lake Urmia Basin

[1] http://www.researchgate.net/profile/Martine_Rebetez/publication/229086658_Observed_climate_variability_and_change_in_Urmia_Lake_Basin_Iran/links/0fcfd5003c557c5e6f000000.pdf

Table 2.1.1 General Information on Lake Urmia

Item	Description
Location*1	Latitude : 35˚40’N - 38˚30’N Longitude : 44˚13’E - 47˚54’E
Basin Area*1	51,876 km^2
Topographical Distribution*2	Mountainous : 33,736km^2 (63.3%) Plain : 12,664km^2 (23%) Lake : 5,362km^2 (13.7%) (as of Dec, 2013)
Administration*2	East Azerbaijan Province (24,888km^2, 48%) West Azerbaijan Province (20,832km^2, 40%) Kurdestan Province (6,042km^2. 12%)
Population (as of 2011)*3	East Azerbaijan Province (2,143 thousand people, 57.6%) West Azerbaijan Province (1,437 thousand people, 38.6%) Kurdestan Province (142 thousand people, 3.8%)
Season	Spring :March – May Summer :June – August Autumn :September – November Winter :December - February
Air Temperature*4	-6 - 31.2˚C (Urmia)
Average Air Temperature*4	10.9˚C
Average Annual Precipitation*2	401 mm
Potential Annual Evapotranspiration*2	530～680mm
Climate*1	Cold Semi-Arid, Steppe Climate (Köppen: BSk)
Lake Area*2	1,861 km^2 (as of Nov., 2014)
Lake Water Volume*2	2,151 MCM (as of Nov., 2014)

*1: Source: “Study on Updating National Water Master Plan in the Basins of Urmia” (MOE, Nov., 2013)
*2: Calculated by the JICA Survey Team by means of the data provided by WRMC
*3: Source: “Statistical Centre of Iran” (http://www.amar.org.ir/Default.aspx?tabid=133)
*4: Source: “World Weather Service” (http://worldweather.wmo.int/en/city.html?cityId=1454)

Table 2.1.2 Summary of Population in Administrations (as of 2011)

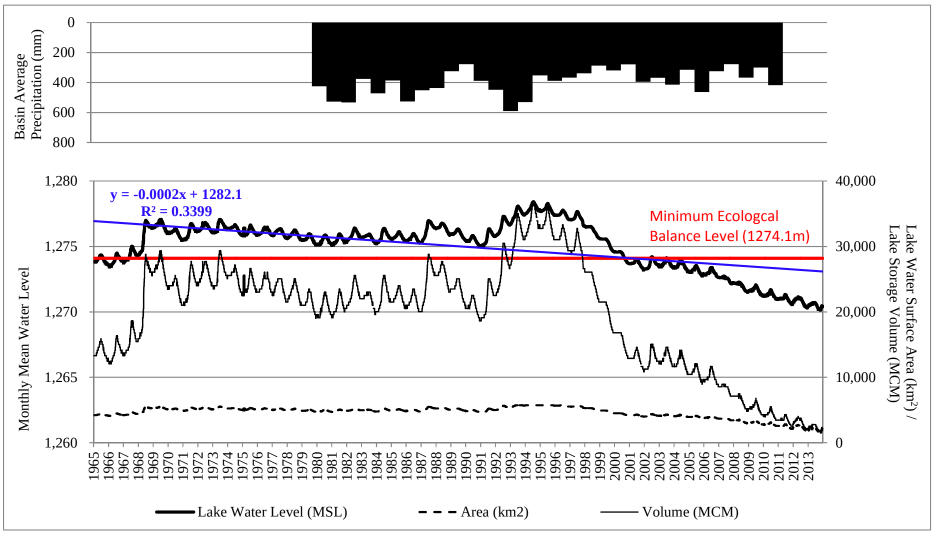
Province	Families	Female	Male	Total	Percentage(%)
East Azerbaijan	646,013	1,062,091	1,080,948	2,143,039	57.6
West Azerbaijan	403,844	714,712	722,430	1,437,142	38.6
Kurdestan	37,776	71,107	70,925	142,032	3.8
Total	1,087,633	1,847,910	1,874,303	3,722,213	100.0

*Source: ”Statistical Centre of Iran” (http://www.amar.org.ir/Default.aspx?tabid=133)
*Refer to Annex2.1 for breakdown

2.1.2 HISTORICAL TREND OF HYDROLOGICAL STATUS OF LAKE URMIA

(1) Historical Trend until the Present

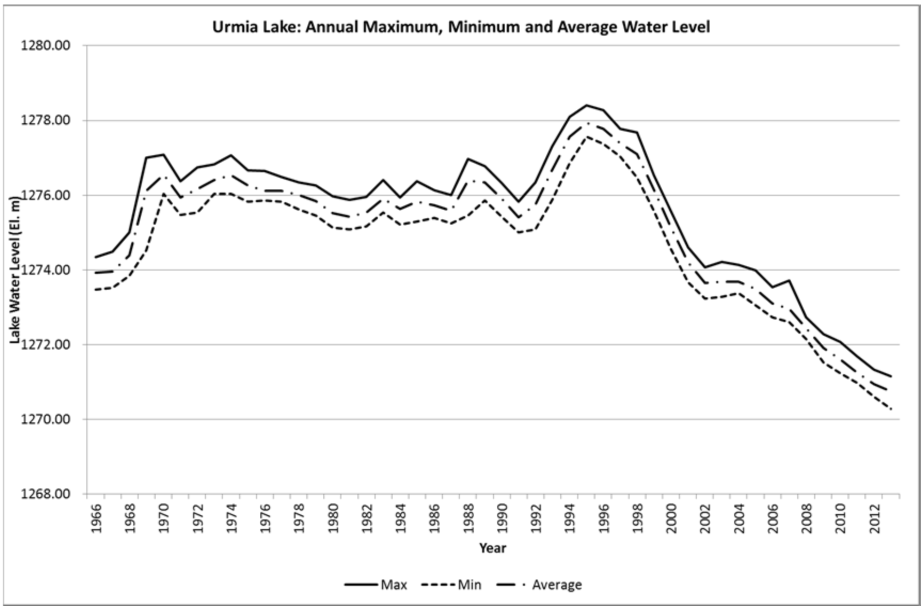
Figure 2.1.2 illustrates the historical fluctuation of annual basin average precipitation, lake water level with linear correlation, lake water area, and lake water volume. Lake water volume was calculated based on the relationship among lake water level, lake water area and lake water volume, which was obtained from the bathymetry survey result provided by WRMC (as shown in Figure 2.1.4 and Annex 2.2 for their calculated values). Daily water level changes of Lake Urmia from late November 1965 to late November 2013 are described in Subsection 2.1.2. Figure 2.1.3 shows the historical changes of annual maximum water level, annual minimum water level, and annual average water level of the Lake. The lowering tendency of lake water level observed from the 1960's up to the present has been recognized..



*Prepared by JICA Survey Team based on data provided by WRMC

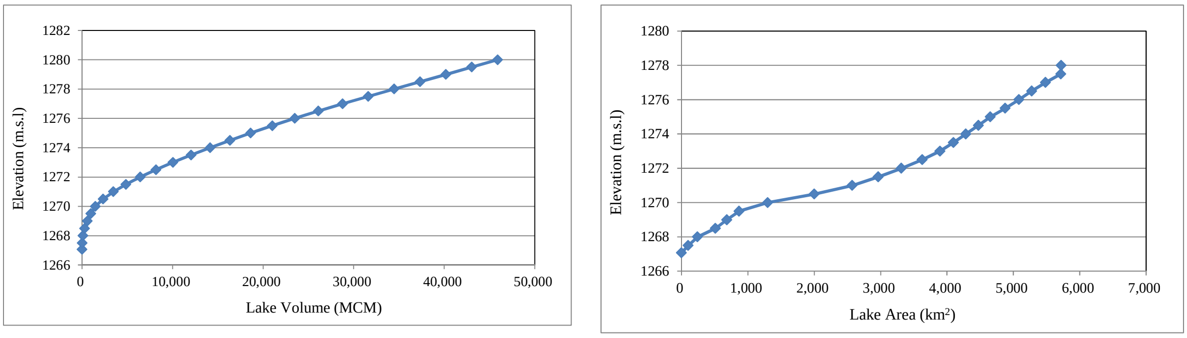
*Due to insufficient observed data and limitation of data provided by WRMC, basin average precipitation was calculated from 1980 to2011.

Figure 2.1.2 Historical Fluctuation of Water Level, Lake Area and Water Volume of Lake Urmia



*Prepared by JICA Survey Team based on data provided by WRMC

Figure 2.1.3 Historical Changes of Annual Maximum, Minimum and Average Water Level of Lake Urmia



*Prepared by JICA Survey Team based on bathymetry survey result conducted by Iran Water Research Institute in 2010
*Refer to Annex2.2 for their calculated values

Figure 2.1.4 Relationships between Lake Water Level - Lake Water Volume (H-V), and Lake Water Level - Lake Surface Area (H-A)

(2) Hydrological Condition Lake Urmia in Decades

To grasp the historical trend of these hydrological conditions, averages of lake water level, lake water area, and lake water volume in five (5) decades (1960's, 1970's, 1980's, 1990's and 2000's) and average values of whole observation period (1965-2014) are as summarized shown in Table 2.1.3. From Figure 2.1.3, the historical trend can be roughly classified into two periods: (1) "period of stabilization (1960's-1990's)" and (2) "period of lowering (1990's)".

Drastic changes in water environment was found between these two periods. In the period of stabilization, though temporal lowering of lake water level occurred, it had fluctuated at high water levels between MSL + 1,275 and MSL + 1,276m. The highest water level with MSL + 1,278.41m (5,722km^2, 36,757MCM) was recorded on June 11, 1995. Subsequently, water level declined to below the Minimum Ecological Balance Level (1,274.1m) on July 30, 2001.This trend was established by LURC. The lowest water level at 1,270.14m (1,441km^2, 1,644MCM) was recorded on September 24, 2014. The differences of water level between the highest and lowest water levels, is -8.27m with 4,281km^2 (-75%) of lake area and -35,113MCM (-96%) of lake water volume, that are considerable for water environment. Recorded as of November 2014, Lake Urmia had 1,270.42m of lake surface elevation, 1,901km^2 of water area and 2,199MCM of water volume. The differences of hydrological conditions between the highest and the present values are -7.99m, -3,821km^2 (-67%) and -34,558MCM (-94%), respectively.

Table 2.1.3 Summary of Average Water Condition of the Lake Urmia in Decades

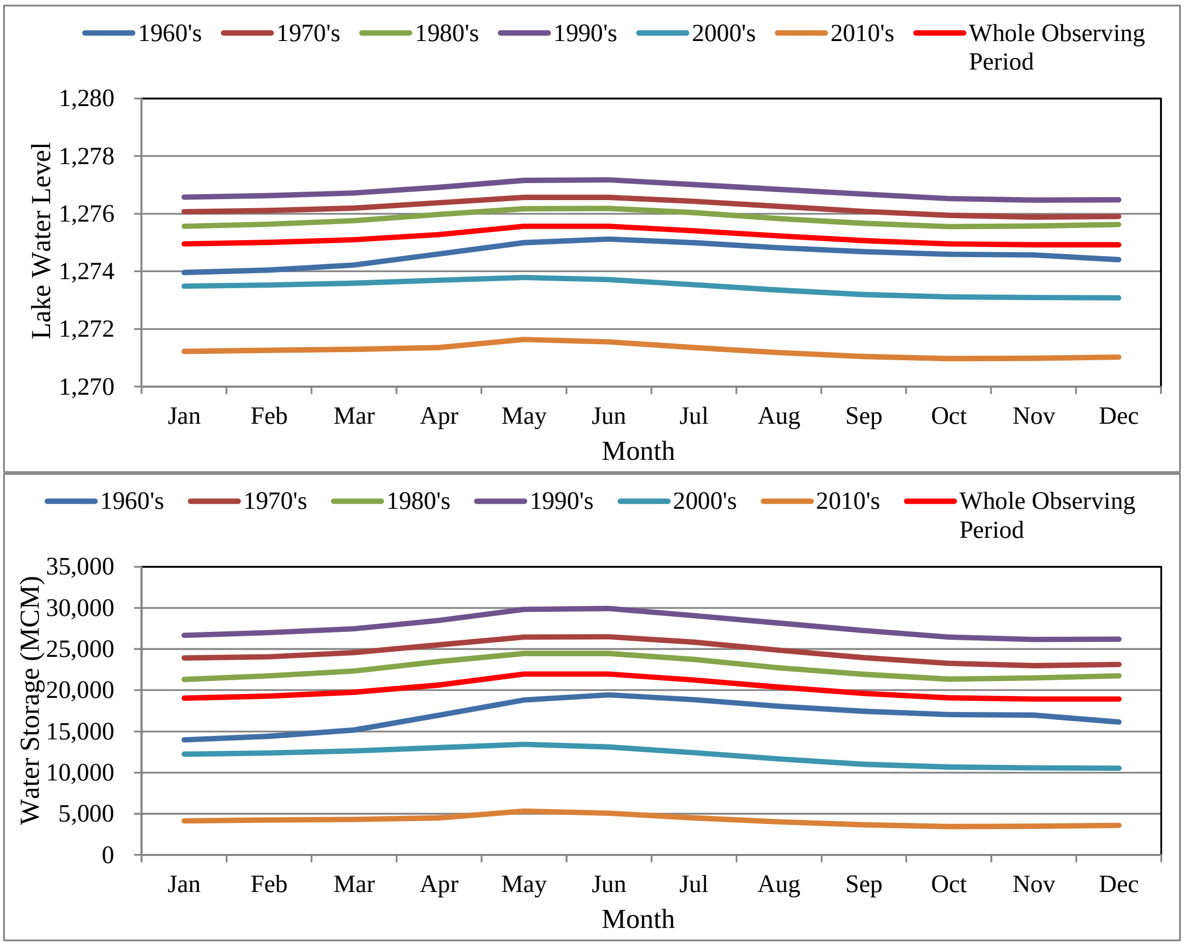
Period	Average Lake Water Level (MSL)	Average Lake Water Area (km^2)	Average Lake Water Volume (MCM)	Average Annual Precipitation (mm)
1960's (1965-1969)	1,274.6	4,516	16,921	-
1970's (1970-1979)	1,276.2	5,164	24,583	-
1980's (1980-1989)	1,275.8	5,001	22,565	436
1990's (1990-1999)	1,276.8	5,365	27,718	403
2000's (2000-2009)	1,273.4	4,034	11,972	367
2010's (2010-2014)	1,271.0	2,521	3,640	
Whole Observation Period	**1,275.0**	**4,622**	**19,497**	**401**

*Prepared by JICA Survey Team based on data provided by WRMC

(3) Historical Trend of Monthly Fluctuation of Hydrological Condition in Decades

Figure 2.1.5 shows the historical trend of monthly averages of lake water level and water volume in the five decades described above while Table 2.1.4 and Table 2.1.5 summarize their values with variation. Focusing on their annual fluctuation pattern, there are similar fluctuation patterns among the five decades, that is, water level and water volume are minimum between November and January and maximum between June and July with increase in inflow by snowmelt water.

Comparing the average lake water levels among the periods, declination of lake water level has been recognized with periods. The differences in water level and water volume between January and June are 1.16 and 5,466MCM in the 1960's and 0.33 and 974MCM in the 2000's, respectively. Restoration of lake water mainly caused by increase in the snowmelt water has also declined.



*Prepared by JICA Survey Team based on data provided by WRMC

Figure 2.1.5 Monthly Averages of Water Level and Water Storage for Decades

Table 2.1.4 Monthly Average of Water Level with Differences for Decades

Water Level (Unit:MSL)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960's	1273.96	1274.04	1274.22	1274.60	1274.99	1275.12	1275.00	1274.82	1274.69	1274.59	1274.57	1274.40
(1960-1969)	-	0.08	0.26	0.64	1.03	1.16	1.04	0.86	0.73	0.64	0.62	0.45
1970's	1276.06	1276.11	1276.20	1276.38	1276.56	1276.57	1276.44	1276.26	1276.08	1275.94	1275.89	1275.91
(1970-1979)	-	0.04	0.13	0.31	0.50	0.50	0.37	0.19	0.02	-0.12	-0.18	-0.16
1980's	1275.56	1275.63	1275.75	1275.97	1276.18	1276.18	1276.04	1275.83	1275.67	1275.55	1275.58	1275.63
(1980-1989)	-	0.07	0.19	0.41	0.62	0.62	0.47	0.27	0.11	-0.01	0.02	0.07
1990's	1276.57	1276.63	1276.72	1276.92	1277.15	1277.18	1277.01	1276.85	1276.67	1276.53	1276.47	1276.49
(1990-1999)	-	0.06	0.15	0.34	0.58	0.60	0.44	0.27	0.10	-0.05	-0.10	-0.09
2000's	1273.49	1273.53	1273.59	1273.69	1273.78	1273.71	1273.54	1273.35	1273.20	1273.11	1273.09	1273.08
(2000-2009)	-	0.04	0.10	0.20	0.30	0.22	0.05	-0.13	-0.29	-0.37	-0.40	-0.41
2010's	1271.22	1271.26	1271.29	1271.36	1271.63	1271.55	1271.36	1271.18	1271.05	1270.98	1270.98	1271.03
(2010-2014)	-	0.04	0.07	0.14	0.42	0.33	0.14	-0.04	-0.17	-0.24	-0.24	-0.19
Whole Observing	1274.95	1275.00	1275.10	1275.28	1275.57	1275.56	1275.41	1275.23	1275.07	1274.95	1274.92	1274.92
Period	-	0.05	0.15	0.33	0.62	0.61	0.46	0.28	0.12	0.00	-0.02	-0.03

*Prepared by JICA Survey Team based on data provided by WRMC

Table 2.1.5 Monthly Average of Water Volume with Differences for Decades

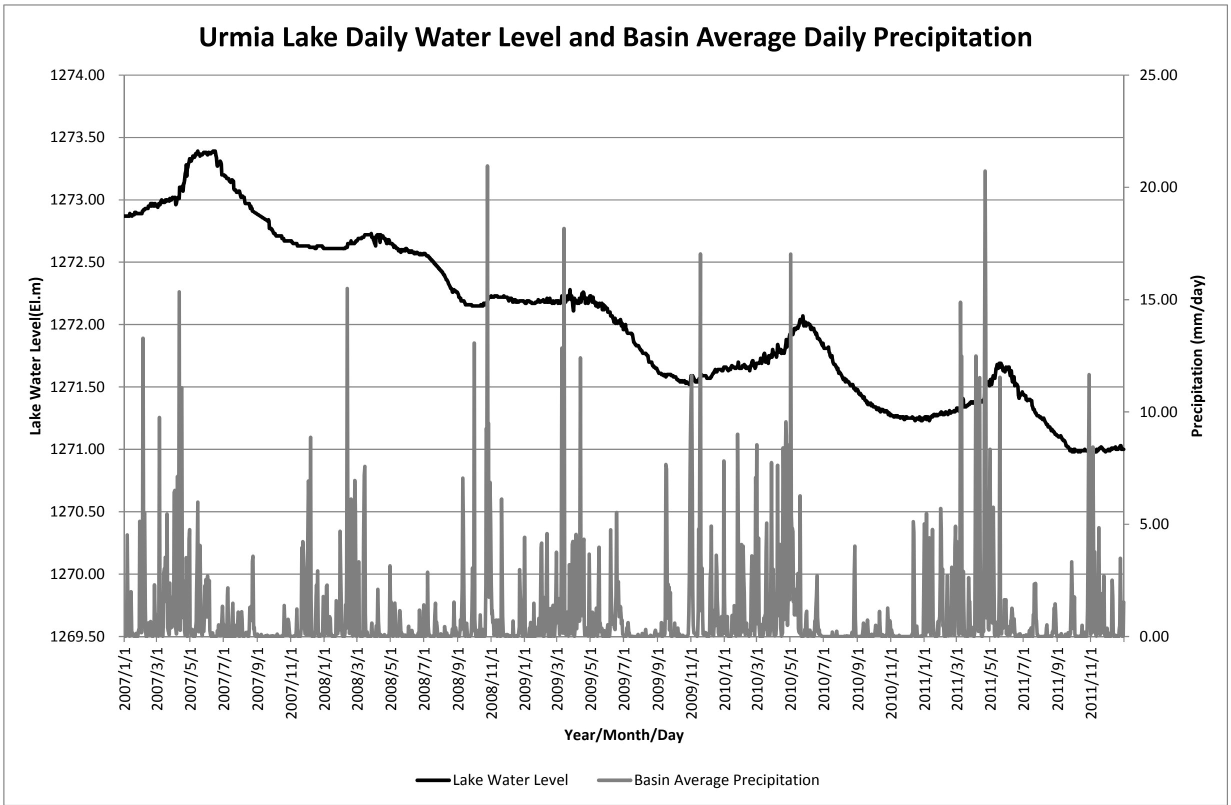
Water Storage (Unit:MCM)

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960's	13,961	14,390	15,161	16,966	18,825	19,427	18,849	18,052	17,457	17,055	16,956	16,150
(1960-1969)	-	429	1,201	3,005	4,865	5,466	4,888	4,091	3,496	3,095	2,995	2,189
1970's	23,914	24,054	24,571	25,505	26,459	26,470	25,823	24,871	23,963	23,257	22,993	23,111
(1970-1979)	-	140	657	1,591	2,545	2,556	1,909	956	49	-657	-922	-803
1980's	21,325	21,745	22,312	23,470	24,468	24,473	23,733	22,738	21,924	21,360	21,478	21,755
(1980-1989)	-	421	987	2,146	3,144	3,148	2,408	1,413	599	35	153	430
1990's	26,657	26,993	27,470	28,492	29,826	29,938	29,054	28,156	27,234	26,446	26,149	26,204
(1990-1999)	-	336	813	1,835	3,168	3,281	2,397	1,499	576	-211	-509	-453
2000's	12,233	12,371	12,635	13,034	13,432	13,104	12,401	11,644	11,017	10,666	10,577	10,545
(2000-2009)	-	138	402	801	1,199	871	168	-590	-1,216	-1,567	-1,657	-1,688
2010's	4,116	4,224	4,309	4,506	5,309	5,062	4,500	4,016	3,666	3,438	3,495	3,594
(2010-2014)	-	108	193	390	1,193	947	384	-100	-450	-678	-621	-522
Whole Observing	19,033	19,293	19,745	20,644	21,980	21,973	21,255	20,390	19,621	19,060	18,942	18,910
Period	-	260	712	1,611	2,947	2,940	2,222	1,357	588	27	-91	-123

*Prepared by JICA Survey Team based on data provided by WRMC

(4) Correspondence between Precipitation and Fluctuation of Lake Water Level

Figure 2.1.6 shows the daily water level changes of the Urmia Lake, together with the basin average daily precipitation of the Urmia Basin from Year 2007 to 2011. Peaks of lakewater level occur one to two months after the peak of precipitation. Hence, it can be established that the response of lakewater level to the precipitation is relatively fast.



*Prepared by JICA Survey Team based on data provided by WRMC

Figure 2.1.6 Daily Water Levels of Lake Urmia and Basin Average Precipitation (2007 to 2011)

2.1.3 WATER QUALITY OF LAKE URMIA

Basically, the element of water output from the lake is only evaporation from water surface because Lake Urmia is located at the end point of inland rivers. From generation of the lake to the present, inflow materials from rivers have been stored into the lake. According to UNEP, salinization of lake water has accelerated with the decrease of inflow from rivers. Recent salinity concentration of lake water has reached 300g/L, which is eight (8) times higher than that of sea water[2], while salinity level of drinking water is below 0.5g/L.

(1) Hydrogeological Structure around Lake Bed from from the Viewpoint of Lake Deposit

Since there is no other outlet from the lake, surfacewater and groundwater flow into the lake and then evaporate in a natural water circulation system considered peculiar to this basin. All the materials carried from the catchment area by rivers or gravity are deposited as sediment of very fine, medium, coarse materials as well as gravel and rubble. Upstream areas with 3,000 to 4,000meter-high mountains produce coarser deposits while downstream areas have finer sediment. Upon evaporation, solutes such as salts accumulate in the lake. Concentration of salinity is almost in saturation of about 300g/L and salts are precipitated at the bottom and in the shore of the lake. During the JICA Survey Team's visit, thick deposits were seen at about 0.5m or more around the western abutment of Kalantari Bridge on the causeway. Calcium are accumulated in lake clay deposits as marl which is calcium rich due to adsorption. Travertine is also a Calcium chemical deposit that has been transported by groundwater. Furthermore, travertine ridge is found at the top of the fissure in the lake deposits by seismic analysis at the central part of the lake[3].

This fissure may have been caused by regional stress and tectonic movement; however, travertine ridge at the top indicates presence of higher pressure at the depths of the lake that transports the Ca rich water upwards to the bottom of the lake.

(2) Lake Urmia and Development of Closed System

Lake Urmia has a unique closed system in lake water and also in lake deposits. Salinity of lakewater accumulates by evaporation from lake surface water and homogeneity of concentration is achieved in lakewater. Salinity in the closed system is almost saturated and partly precipitated. Quaternary deposits of more than 200m in thickness, especially the top tens of meters which are very soft clay, are deposited at the lake bottom[4]. According to the geological cross section at the central part of Lake Urmia, unconsolidated materials are mainly clay, silt, marl and partly sand and clay. Clayey deposits contain much amount of remnants of Artemia which was the sole lifeform in the hypersaline lake. The closed system of the lake has a peculiar biosphere and the biological history of Artemia is estimated to be more than 200 thousand years according to the study of drilled core material[5,6]. Alluvial and Quaternary deposits around the lake is caused by the function of rivers and gravity. The Quaternary lake deposits are created by the function of the lake itself, such as circular flow, re-sedimentation and relation with biosphere[7],[8].

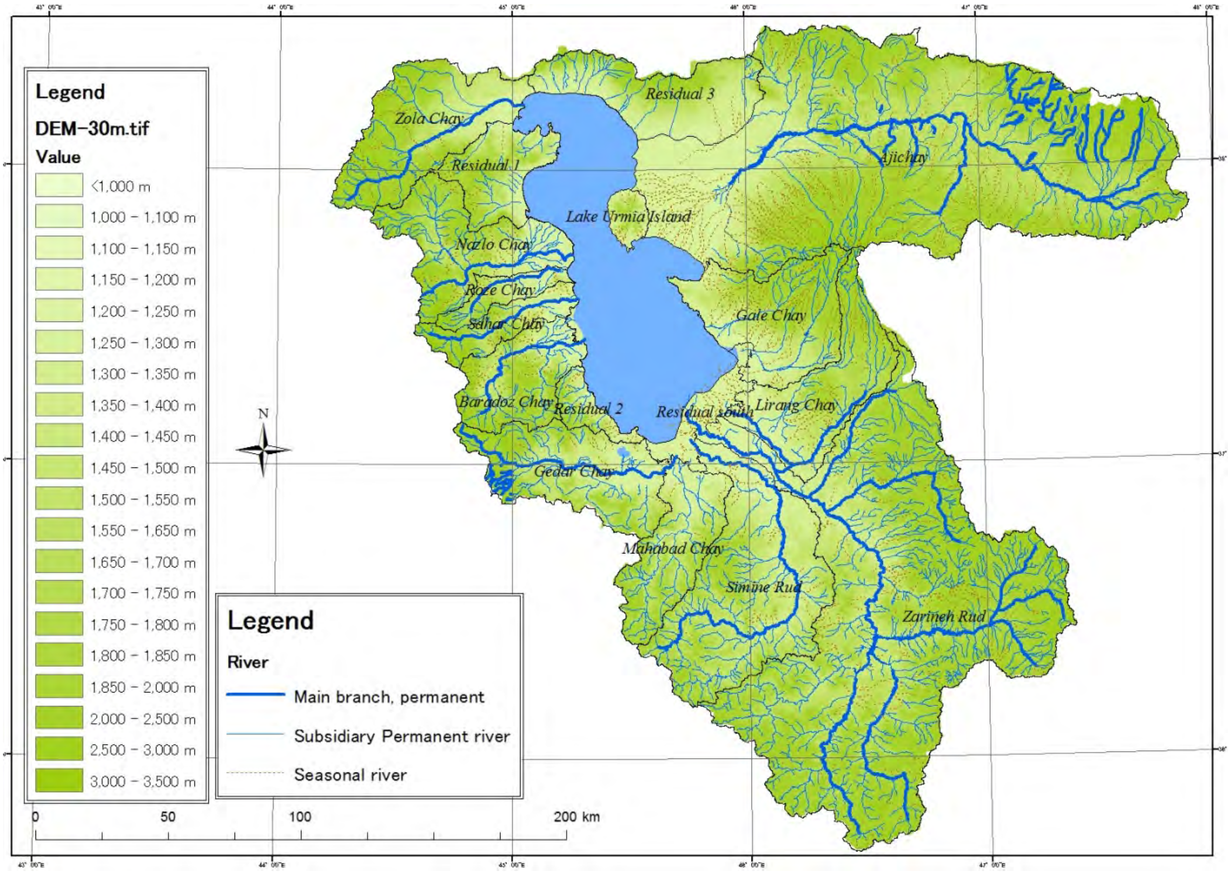
2.2 INFLOW RIVERS

2.2.1 RIVER MORPHOLOGY

As described in 2.1.1, climate in the lake basin is classified as cold semi-arid that indicates low potentials of water resources in the area. Inflow rivers into the Lake Urmia Basin are classified into (i) permanent

2 http://na.unep.net/geas/getuneppagewitharticleidscript.php?article_id=79
3Mohammad MOHAJJEL etc., Quaternary travertine ridges in the Lake Urmia area: active extension in NW Iran, Turkish Journal of Earth Sciences Research Article (2014)
4Mohammadi, A. etc., Investigation of sedimentary controls on Urmia lake using sedimentological characteristics of floor deposits (three100m Cores), The 1st International Applied Geological Congress, Department of Geology, Islamic Azad University – Mashad Branch,Iran, 26-28 April 2010
5Jacques-Louis A Long Pleistocene pollen record from the Urmia Lake, NW Iran (abstract XVII INQUA Congress 2007)
6MortezaDjamail etc., A 200,000-year record of the brine shrimp Artemia (Crustacea :Anostraca) remains in Lake Urmia, NW Iran IJAS Vol. l1, No. 1, 2010
7Samad Alipour Hydrogeochemistry of seasonal variation of Urmia Salt Lake, Iran Saline Systems, 2006; 2:9
8Mohammadi, A. etc., Investigation of sedimentary controls on Urmia lake using sedimentological characteristics of floor deposits (three 100m Cores), The 1st International Applied Geological Congress, Department of Geology, Islamic Azad University – Mashad Branch, Iran, 26-28 April 2010

rivers which have waters flowing into the lake without drying-up throughout the year; and (ii) seasonal rivers derived only from snowmelt water during spring (see Figure 2.2.1). Thirty (30) percent of the length of river channels in the Lake Urmia Basin is seasonal river (as shown in Table 2.2.1). According to the horizontal map, river that goes downstream on to the main river channel are also defined as seasonal rivers. This indicates that the morphological condition of rivers changes in every season.



*Prepared by JICA Survey Team based on data provided by WRMC

Figure 2.2.1 Distribution of River Channels

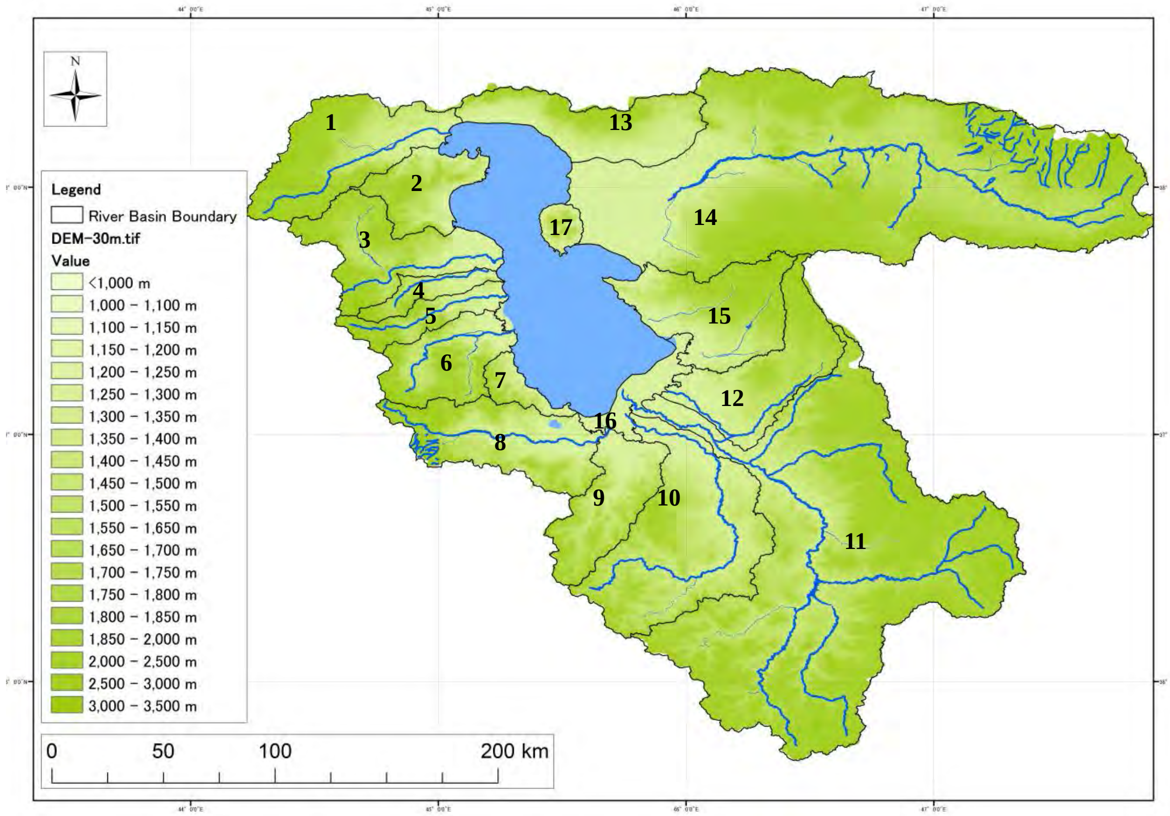
Table 2.2.1 Length of River Channels

Type	Length (km)	Ratio (%)
Main Channel（Permanent）	2,255	13.3
Branch Channel（Permanent）	9,722	57.4
Seasonal River	4,957	29.3
Total	16,934	100.0

*Prepared by JICA Survey Team based on data provided by WRMC

2.2.2 INFLOW RIVER AND CATCHMENT AREA

Figure 2.2.2 shows the horizontal map of main channels and their catchment areas in the Lake Urmia Basin which were summarized in Table 2.2.2. The Lake Urmia Basin has twelve (12) main channels flowing into the lake. Aji Chay River (No. 14 in Figure 2.2.2) has the largest catchment area of 12,717 km^2 which is 24.6% of the whole lake basin area, and Zarineh Rud River (No. 11) has the second largest area with 11,838 km^2 which is 22.9%. These two (2) river basins cover almost half (48%) of the whole lake basin.



*Provided by WRMC, only main channels (temporal rivers) were illustrated.

Figure 2.2.2 Inflow Rivers and Catchment Area

Table 2.2.2 Summary of River Cathment Areas

No.	Basin Name	Area (km²)	Percentage (%)	River Length (km)	River Slope	Administration
1	Zola Chay	2,258	4.4	85	0.012	Khoy,Urmia,Salmas,Shabestar
2	Residual 1	1,060	2.1	-	-	Urmia,Salmas,Shabestar
3	NazloChay	1,880	3.6	75	0.005	Urmia,Salmas,Shabestar
4	RozeChay	458	0.9	45	0.008	Urmia,Shabestar
5	Sahar Chay	712	1.4	65	0.016	Urmia,Shabestar
6	BaradozChay	1,362	2.6	60	0.012	Urmia,Oshnaviyeh
7	Residual 2	375	0.7	-	-	Mahabad,Miyandoab,Naqadeh,Urmia
8	GedarChay	2,091	4.0	105	0.015	Mahabad,Miyandoab,Naqadeh,Urmia,Oshnaviyeh,Piranshahr
9	MahabadChay	1,507	2.9	80	0.005	Mahabad,Miyandoab,Naqadeh,Piranshahr,Sardasht
10	SiminehRud	3,783	7.3	180	0.002	Baneh,Bonab,Bukan,Mahabad,Miyandoab,Saqqez,Sardasht, Shahindezh
11	ZarinehRud	11,838	22.9	190	0.006	Baneh,Bijar,Bonab,Bukan,Divandarreh,Hashtrud,Mahneshan, Marivan,Miyandoab,Saqqez,Shahindezh,Takab
12	LilangChay	1,936	3.7	75	0.005	Bonab,BostanAbad,Hashtrud,Maraqeh,Tabriz
13	Residual 3	1,840	3.6	-	-	Khoy,Marand,Shabestar
14	Ajichay	12,717	24.6	280	0.003	Ahar,Ardebil,BostanAbad,Heris,Marand,Mianeh,Neer,Sarab,Shabestar,Tabriz
15	Gale Chay	2,094	4.0	50	0.030	Bonab,BostanAbad,Hashtrud,Maraqeh,Tabriz
16	Residual south	551	1.1	-	-	Bonab,Mahabad,Maraqeh,Miyandoab
17	Lake Urmia Island	260	0.5	-	-	Shabestar,Tabriz
-	Lake Urmia (water body)	4,986	9.6	-	-	-
	Total	51,707	100.0	-	-	-

*Prepared by JICA Survey Team based on data provided by WRMC
*Residual area and “Urmia Island” has been prepared by JICA Survey Team for calculation of average precipitation over catchment area and for *development of hydrological circulation model.

2.3 TOPOGRAPHY

Lake Urmia is situated in a closed basin with a lake surface water level of about 1,270m surrounded by mountainous areas with elevations ranging from 1,270m to 4,000m. The lake basin area is 52,000km^2 whose percentages of topologies are 63.3%, 23%, and 13.7%, respectively. The lake basin is enclosed by Zagros Mountains neighboring with the Aras River Basin to the North and Sabalan and Sahand Mountains neighboring with the Zaab River Basin to the South. Salaban Mountain located at 60km North-East of the Urmia Lake Basin and Sahand Mountain at 40km South-Southwest are two well-known volcanos, of nine (9) volcanos, whose top elevations are 4,740m and 3,707m, respectively. According to the DEM data provided by WRMC, the lowest and highest elevations of the lake basin are 1,267m (deepest point of Lake Urmia) and 3,746m (adjacent to Salaban Mountain), respectively.

2.4 LAND USE

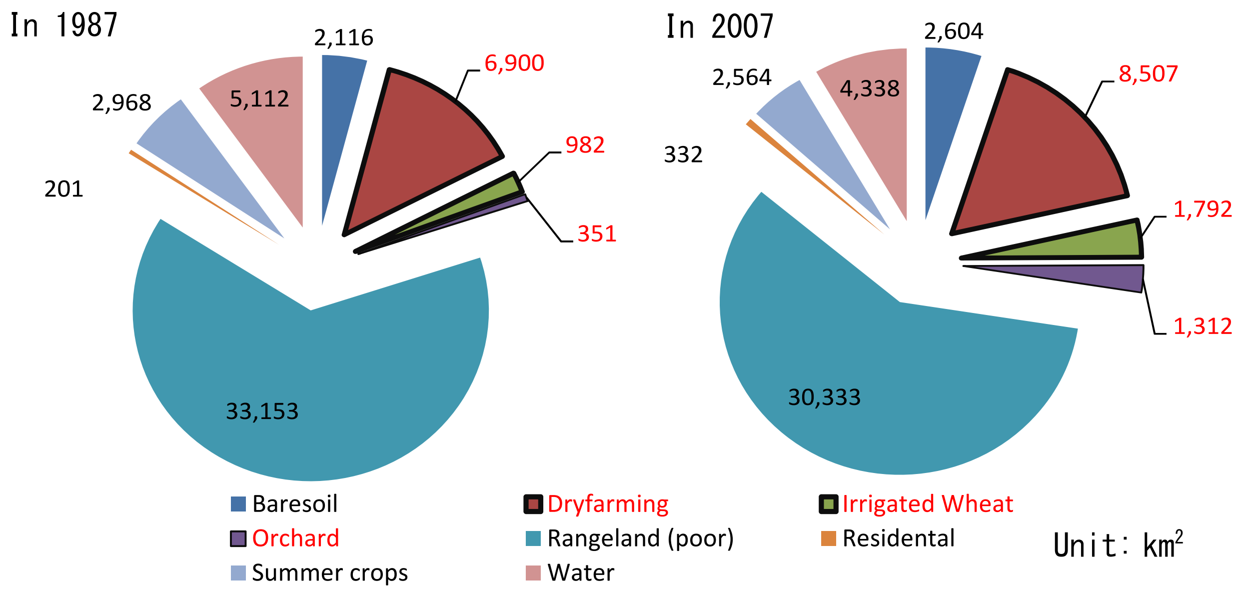
2.4.1 TEMPORAL CHANGE OF LAND USE IN THE LAKE URMIA BASIN

Based on the land use data in two periods (1987 and 2007) provided by WRMC, the changes of land use condition in twenty years were analyzed using Landsat satellite images.

Comparison of land use areas between 1987 and 2007 are shown in Figure 2.4.1 and are summarized in Table 2.4.1. Table 2.6.8 focuses on agricultural land (Dry farming, Irrigated wheat and Orchard). Figure 2.4.2 and Figure 2.4.3 illustrate distributions of land use in the two periods. While land use area for each sub-basin was calculated in Annex 2.3.

Agricultural land area has increased by approximately forty percent in twenty years. Looking at the distribution of land use for the entire lake basin, the area of Rangeland is the largest for both periods, with 64% in 1987 and 59% in 2007, respectively. The area of Dry farming is the second largest, 13% in 1987 and 16% in 2007.

As for the change in agricultural land, whose water use holds dominant part, there was an increase of 23% in Dry farming in twenty years, 82% for Irrigated Wheat and 374% for Orchard, respectively. Though the increase in area of Orchard in 2007 is approximately four times as that in 1987, the percentage itself of the area in the lake basin is 3%.



*Prepared by JICA Survey Team based on data provided by WRMC

Figure 2.4.1 Comparison of Land Use Area between 1987 and 2007

Table 2.4.1 Summary of Differences of Land Use Area in the Whole Lake Basin

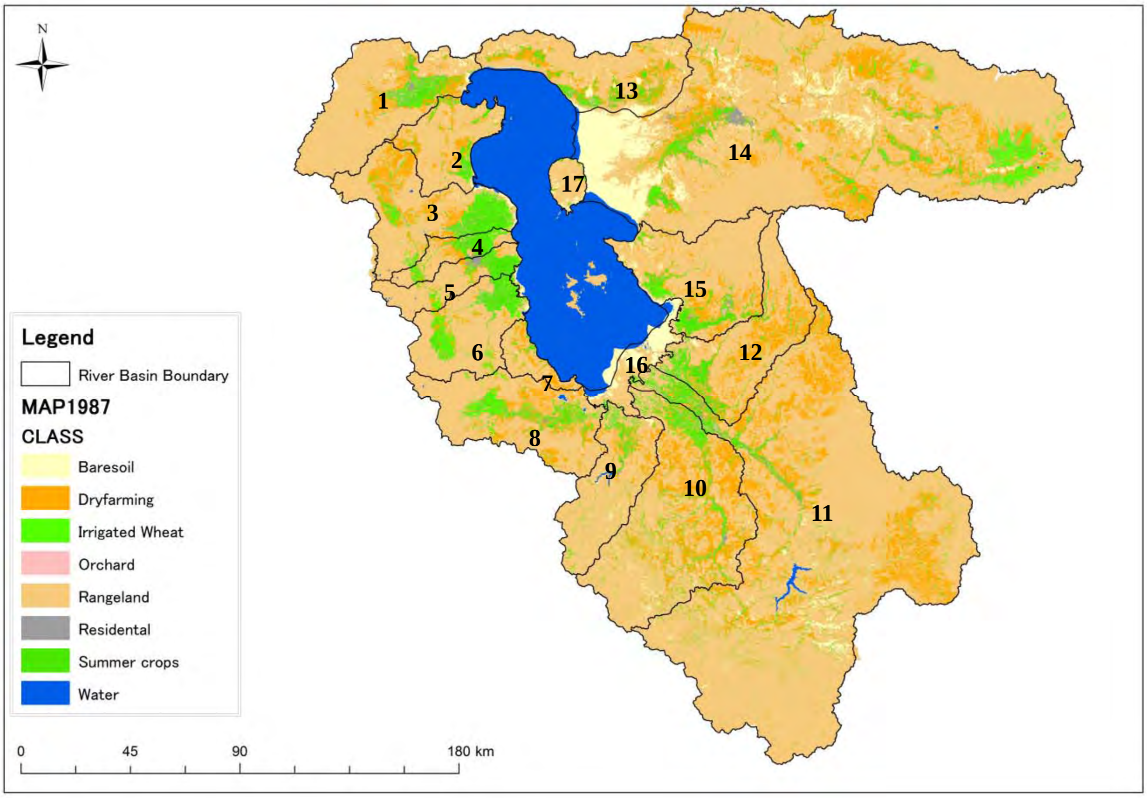
	Bare Soil	Dry Farming	Irrigated Wheat	Orchard	Rangeland	Residential	Summer crops	Water	Total
In 1987 (km^2)	2,116	6,900	982	351	33,153	201	2,968	5,112	51,783
(Percentage in the Basin)	4%	13%	2%	1%	64%	0.39%	6%	10%	-
In 2007 (km^2)	2,604	8,507	1,792	1,312	30,333	332	2,564	4,338	51,783
(Percentage in the Basin)	5%	16%	3%	3%	59%	0.6%	5%	8%	-
Difference (km^2)	488	1,607	810	961	-2,820	131	-404	-774	-
(Increasing Rate)	123%	123%	182%	374%	91%	165%	86%	85%	-

*Prepared by JICA Survey Team based on data provided by WRMC

Table 2.4.2 Differences of Agricultural Land Area in the Entire Lake Basin

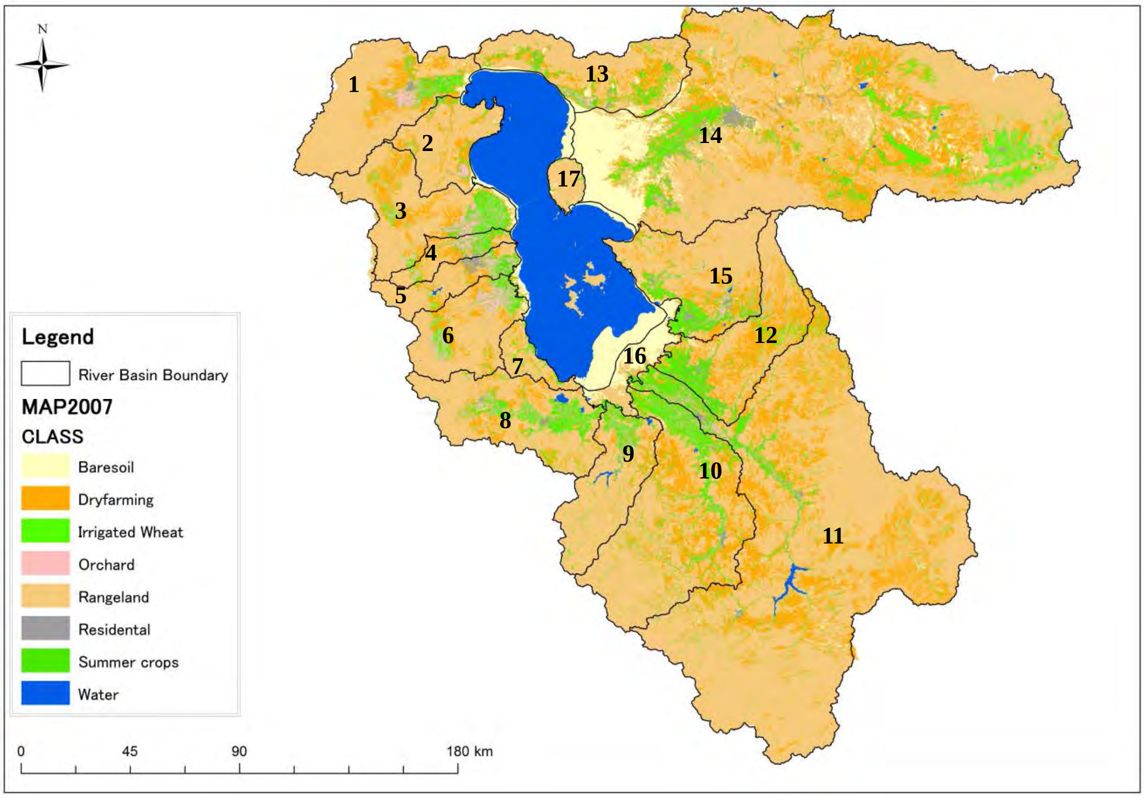
	Dry Farming	Irrigated Wheat	Orchard	Total
In 1987 (km^2)	6,900	982	351	8,223
(Percentage in the Basin)	(13%)	(2%)	(1%)	(16%)
In 2007 (km^2)	8,507	1,792	1,311	11,586
(Percentage in the Basin)	(16%)	(3%)	(3%)	(22%)
Difference (km^2)	1,607	811	960	3,363
(Increasing Rate)	(123%)	(182%)	(374%)	(141%)

*Prepared by JICA Survey Team based on data provided by WRMC



Source: WRMC

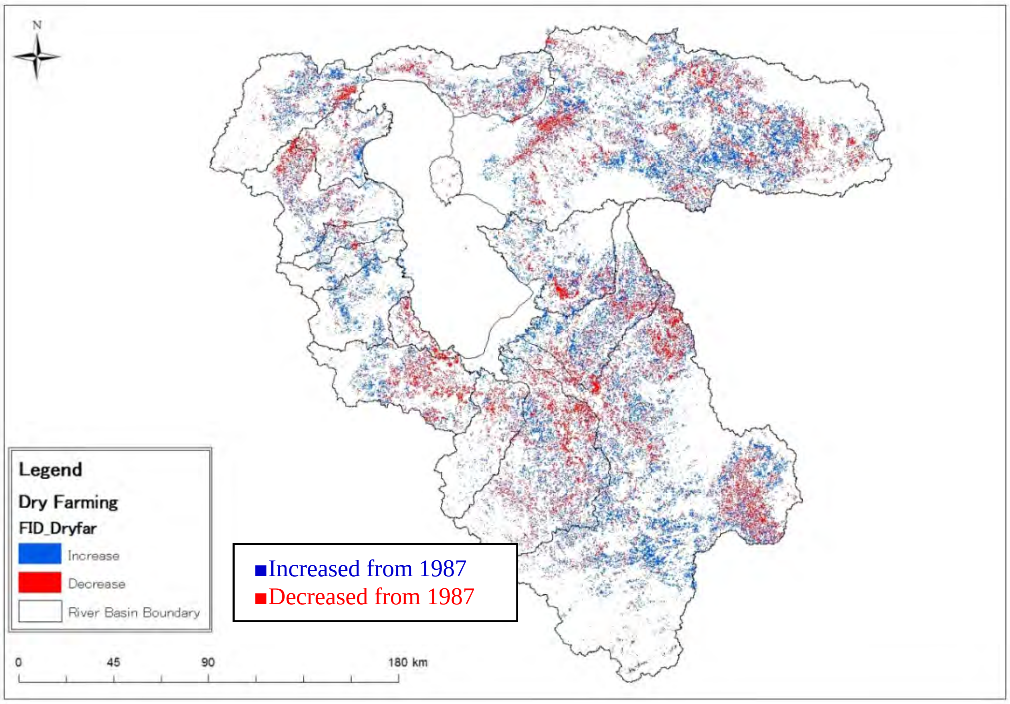
Figure 2.4.2 Land Use Distribution in 1987



Source: WRMC

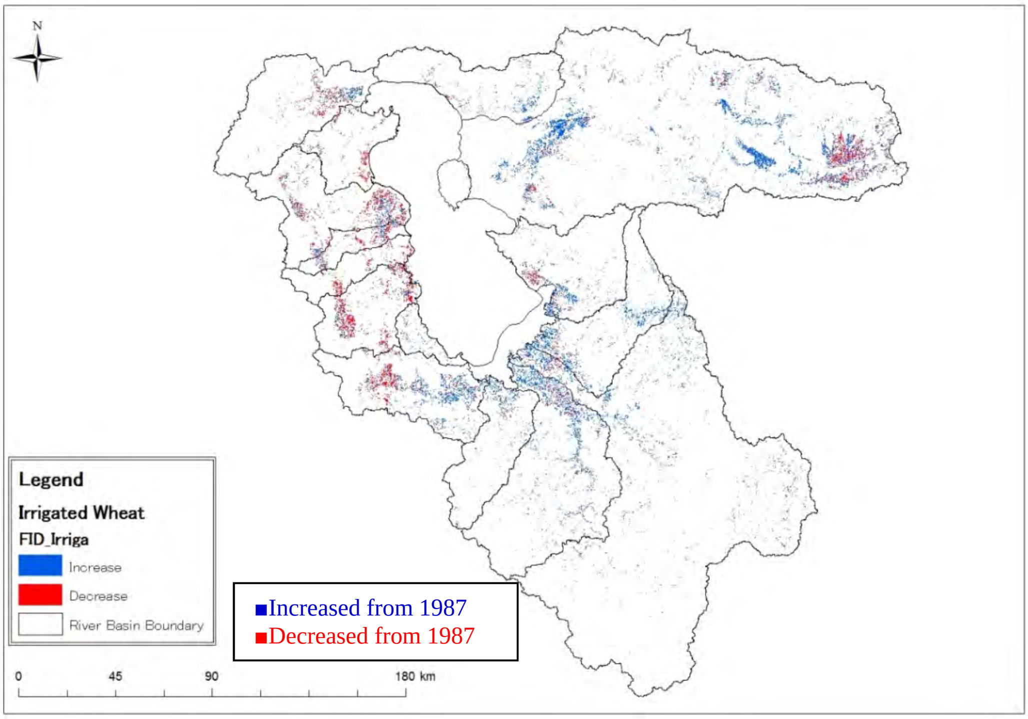
Figure 2.4.3 Land Use Distribution in 2007

For detection analysis, increased and decreased parts of land for agriculture (Dry farming, Irrigated Wheat and Orchard) were extracted and illustrated in Figure 2.4.4, Figure 2.4.5 and Figure 2.4.6, respectively. It was recognized that Irrigated wheat and Orchard have increased mainly at plain areas and neighboring areas along rivers.



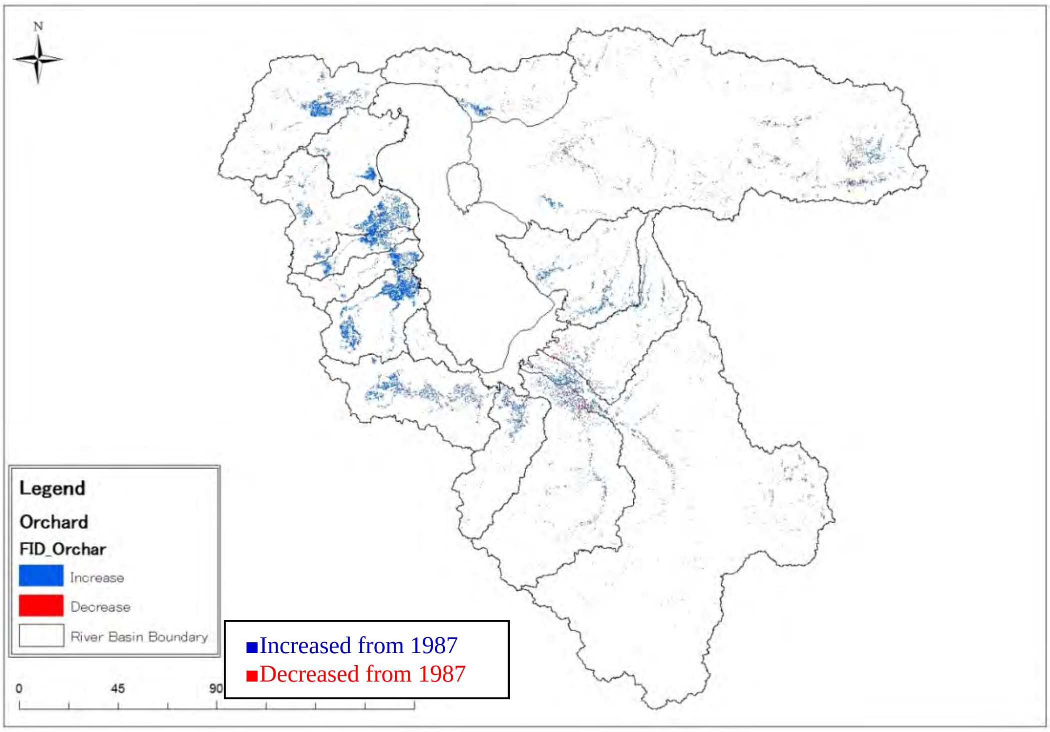
*Prepared by JICA Survey Team based on data provided by WRMC

Figure 2.4.4 Spatial Change in Area of Dry Farming from 1987 to 2007



*Prepared by JICA Survey Team on data provided by WRMC

Figure 2.4.5 Spatial Change in Area of Irrigated Wheat from 1987 to 2007



*Prepared by JICA Survey Team on data provided by WRMC

Figure 2.4.6 Spatial Changes in Area of Orchard from 1987 to 2007

2.4.2 ESTIMATION OF WATER REQUIREMENT FOR IRRIGATED AREA AND ORCHARD

Water requirements for the areas of irrigated wheat and orchard in the Lake Urmia Basin were estimated. The annual water requirements were obtained by firstly calculating annual unit water requirments (annual water requirement per irrigated area) based on the collected report and secondery multiplying the unit annual water requirment with the irrigated wheat and orchard that were analyzed above. As a result, Table 2.4.3 shows the calculated water rewuirement in the Lake Urmia Basin in 1987 and 2007, respectively.

Referring to “Master Plan Report on Agricultural Water in the Lake Urmia Basin (herein called as the “M/P report”)” provided by WRMC, as described in Chapter 4, annual water requirement and area of irrigated wheat were 6,632MCM (29 – 43% of irrigation effciency) and 356,420ha, respectively. 1,861 mm of annual unit water requirement for irrigated wheat was calculated. Based on this annual water requirements in the basin in 1987 and 2007 were calculated as 1,827MCM and 3,334MC, respectively. The difference between two periods is 1,507MCM, which had increased 1.8 times from 1987.

As for the orchard area which was described as “Irrigated Garden” in the “M/P report”, by means of 155,506 ha of annual irrigated area and 2,187MCM of anuual water requirement, calculated annual water unit was 1,893mm. Applying this value, 665MCM in 1987 and 2,484MCM in 2007 were calculated, respectively. The difference between two periods is 1,820MCM which ha increased 3.7 times in the two decades.

In total, annual water requirenment in the basin in 1987 and 2007 were approximately 2,500MCM and 5,800MCM, respectevely. Irrigated water had increased 2.3 times between the period.

For referrence, daily irrigated water requirements were calculated. In the M/P report, applied irrigattion pattern was not clearly confirmed. Therefore nine months for irrigation period was applied based on the variation pattern of monthly net water requirement. Daily water requirememt for both land types were 6.9mm for irrigated wheat and 7mm for orchard, respectively. According to FAO[9] daily water needs for agriculture is approximately 10/mm in dryland. This secures validity of the unit water requirement applied in this secrion for both land types.

Table 2.4.3 Annual Water Requirements of Irrigated Wheat and Orchard Areas of Lake Urmia Basin in 1987 and 2007

	Area (ha)	Annual Water Requirement (MCM/Year)	Annual unit Water Requirement (mm/m^2/Year)	Daily Water Requirement (mm/Day)	
Irrigated Wheat	356,420	6,632	1,861	6.9	
Orchard	115,506	2,187	1,893	7.0	
	Area in 1987 (ha)	Area in 2007 (ha)	Annual Water Requirement in 1987 (MCM/Year)	Annual Water Requirement in 2007 (MCM/Year)	Difference (MCM)
Irrigated Wheat	98,200	179,200	1,827	3,334	1,507
Orchard	35,100	131,200	665	2,484	1,820
Total			2,492	5,819	3,327

9 FAO Training Manual no.3 “IRRIGATION WATER MANAGEMENT”

2.5 HYDROGEOLOGY AND GEOLOGICAL STRUCTURE

The geological structure of Iran is summarized by Mansour Ghormani in his book "The Economic Geology of Iran" showing several types (as shown in Table 2.5.1). One of the definitions is by Nogole-Sadat (1993), in which Lake Urmia is in the Central Metamorphic Zone, the area around the lake is in Quaternary depressions and the eastern part is in the Central Magmatic Zone where volcanic extrusive rocks prevail[10]. Lake Urmia is situated in a closed basin with a lake surface water level of about 1270m surrounded by mountainous areas with elevations ranging from 1270m to 4000m. Lake Urmia and its vicinities are in the geological sink area called graben where volcanic rocks caused by eruptions are widely distributed, specifically on the eastern part of the lake geologically ranging from Tertiary to Quaternary Era. Western and southern parts of the lake are mainly covered by pre-Cambrian, Palaeozoic, and Mesozoic formations. Travertine, chemical deposits from fissures, seeping from the depth of basement is distributed in this area. Rock facies are shown for Geological Ages.

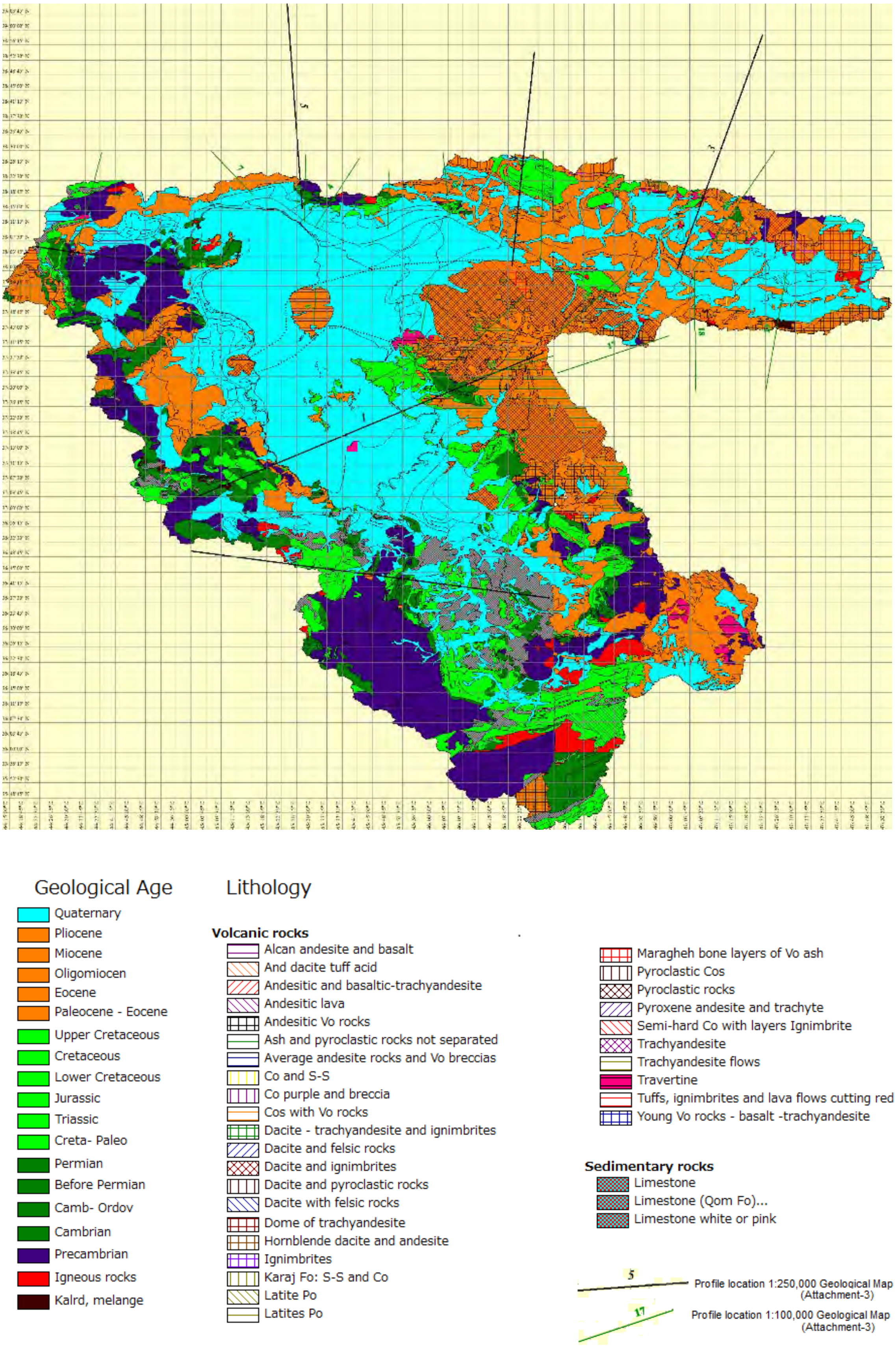
Table 2.5.1 Regional Geology related in Iran

Geological Age	Sedimentary Rocks	Igneous Rocks	Metamorphic rocks
Quaternary	Alluvium, Terrace, Talus, Lake deposits, Limestone, Travertine	Andesite, Basalt	
Pliocene		Dacite, Felsic rocks	
Miocene	Marl, Sandy red marl, Chalk	Pyroclastic rocks, Andesite	
Oligocene	Sandstone, Shale, Marl, Limestone		
Eocene	Sandstone, Conglomerate,	Green TUFF, Andesite	
Paleocene to Eocene		Andesite, Diorite	
Cretaceous	Limestone, Shale, Sandstone, Marl	Diorite, Basalt	
Lower Cretaceous	Limestone, Dolomite		
Jurassic	Green shale, Limestone with chert		
Triassic	Dolomite, Limestone		
Cretaceous to Palaeocene		Granodiorite, Granite	
Permian	Limestone, Dolomite		Schist
Cambrian Ordovician	Dolomite black Dolomite, Limestone		
Cambrian	Sandstone		
Precambrian	Shale, Slate, Dolomite	Rhyolite, Granite,	Gneiss, Phyllite

*Prepared by JICA Survey Team

According to the focal mechanism analysis of seismicity, wide areas from the Caspian Sea to Western Iran are in the reverse fault stress field with overwhelming horizontal compressive stress; however, the lake and its surrounding area is in the normal fault stress field with prevailing vertical stress[11]. This stress field still continues and it is reported that NW-SE fissures develop on the eastern side of the lake[12]. Active faults running north of Lake Urmia and then through the eastern area of the city of Tabriz may have closed the ancient river flowing into the Caspian Sea several thousands of years ago (as for age of lake deposits, [13,14] to make the closed catchment area[15].

[10] Mansour Ghorbani: The Economic Geology of Iran (2013)
[11] World Stress Map, Helmholtz Center Potsdam - GFZ German Research Center for Geosciences
[12] Mohammad MOHAJJEL, etc.: Quaternary travertine ridges in the Lake Urmia area: active extension in NW Iran, Turkish Journal of Earth Sciences Research Article (2014)
[13] Jacques-Louis: A Long Pleistocene Pollen Record from the Urmia Lake, NW Iran (abstract XVII INQUA Congress 2007)
[14] Morteza Djamail, etc.: A 200,000-year record of the brine shrimp Artemia (Crustacea: Anostraca) remains in Lake Urmia, NW Iran IJAS Vol. l1, No.1, 2010
[15] Manuel Berberian: Earthquakes and Coseismic Surface Faulting on the Iranian Plateau, 1st Edition (2014)



*Source: Iran Geological Service

Figure 2.5.1 Geological Map and Faults

According to the USGS Earthquake Hazards Program 264, earthquakes happened from October 1, 1985 to February 21, 2015 between longitude 44°E and 48°E latitudes 35.5°N and 40°N. Maximum magnitude is M6.4.

251 Epicenters with Magnitude values are shown in the following drawing. It is remarkable that there are no epicenters within the lake or its vicinities. This is already pointed out by stress field of normal faulting with prevailing vertical stress for lake and its vicinities. Many earthquakes happened in the outside area which show reverse faulting with prevailing horizontal stress. The north rim of the lake has many epicenters syndicating unstable stress field and active tectonic movement. Quaternary active faults separate outside and inside areas and change of stress is solved by the faulting systems. Groundwater level and pressure in the aquifers in the north rim area and lake water may be related to stressfield, active fault, and tectonic movement.

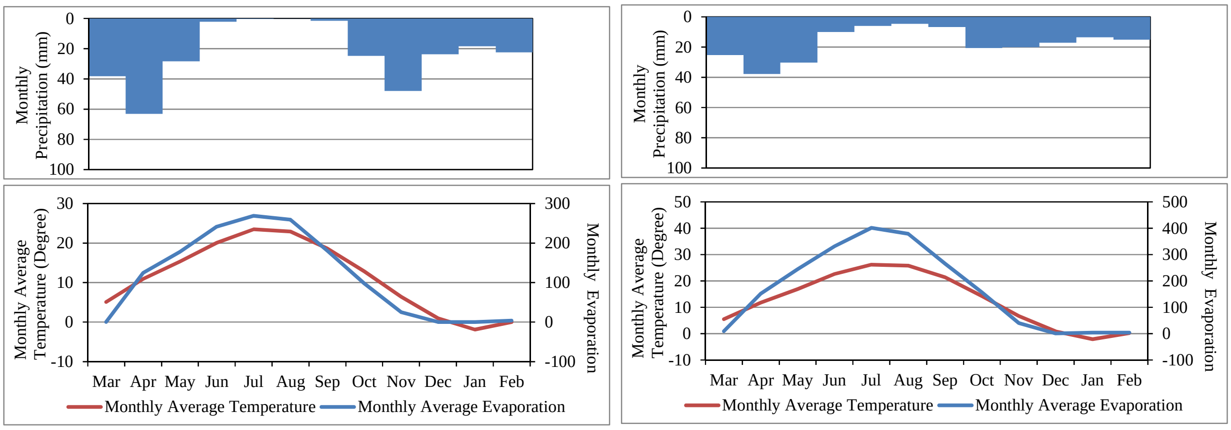
2.6 HYDROMETEOROLOGY

2.6.1 GENERAL CLIMATE CONDITION IN LAKE URMIA BASIN

(1) Average and Variation Trend of Precipitation, Air Temperature and Evaporation in

In order to grasp the typical climatological characteristics of the Lake Urmia Basin, monthly precipitation, monthly mean air temperature, and monthly pan evaporation in Urmia and Tabriz are shown in Figure 2.6.1 and Table 2.6.1, while their variation trend are illustrated in Figure 2.6.2. All of these data were summarized in Annex 2.4.

Differences of temperature in Urmia and Tabriz are 30 - 40˚C, ranging from -8 to 27˚C and -10 to 31˚C, respectively. Annual evaporation fluctuates, within the range of 1,158 - 1,525mm (average: 1,362mm) in Urmia and 1,271 – 2,244mm (average: 1,965mm) in Tabriz. Annual precipitation also ranges between 90 - 630mm (average: 274mm) and 89 - 324mm (average: 274mm). None of noticeable changes in climate condition until the present are recognized in the both places.



*Precipitation: WRMC; Air Temperature and Evaporation: IMO

*Calculation period is as illustrated in Figure 2.6.2.

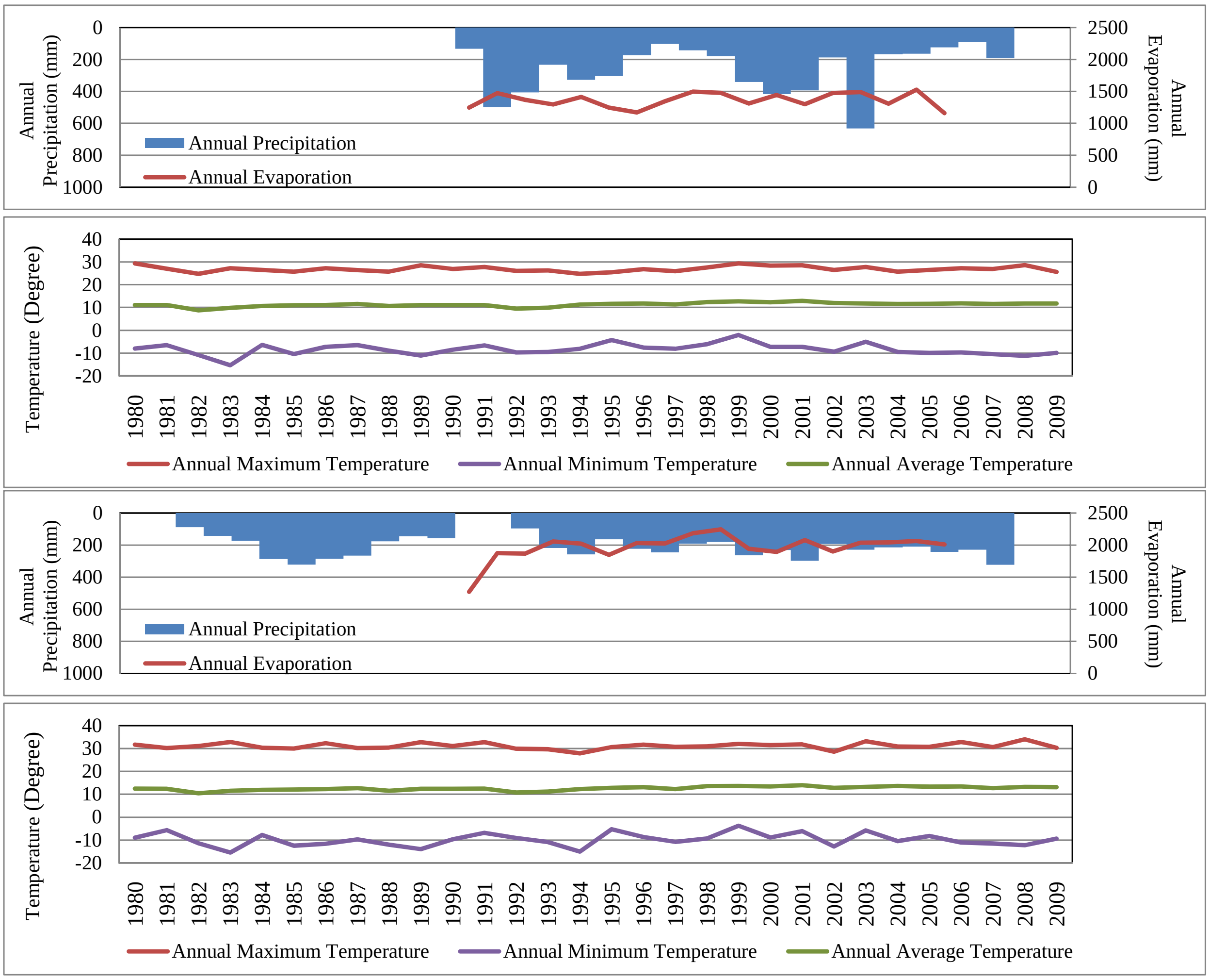
Figure 2.6.1 Monthly Average Precipitation, Air Temperature and Evaporation in Urmia and Tabriz

Table 2.6.1 Average Precipitation, Air Temperature and Evaporation in Urmia and Tabriz

Item / City	Annual Precipitation	Annual Pan Evaporation	Annual Maximum Temperature	Annual Minimum Temperature	Annual Average Temperature
Urmia	274mm	1,363mm	27˚C	-8 ˚C	11 ˚C
Tabriz	212mm	1,966mm	31˚C	-10 ˚C	13 ˚C

*Precipitation: WRMC; Air Temperature and Evaporation: IMO

*Calculation period is as illustrated in Figure 2.6.2.



Precipitation: WRMC; Air Temperature and Evaporation: IMO

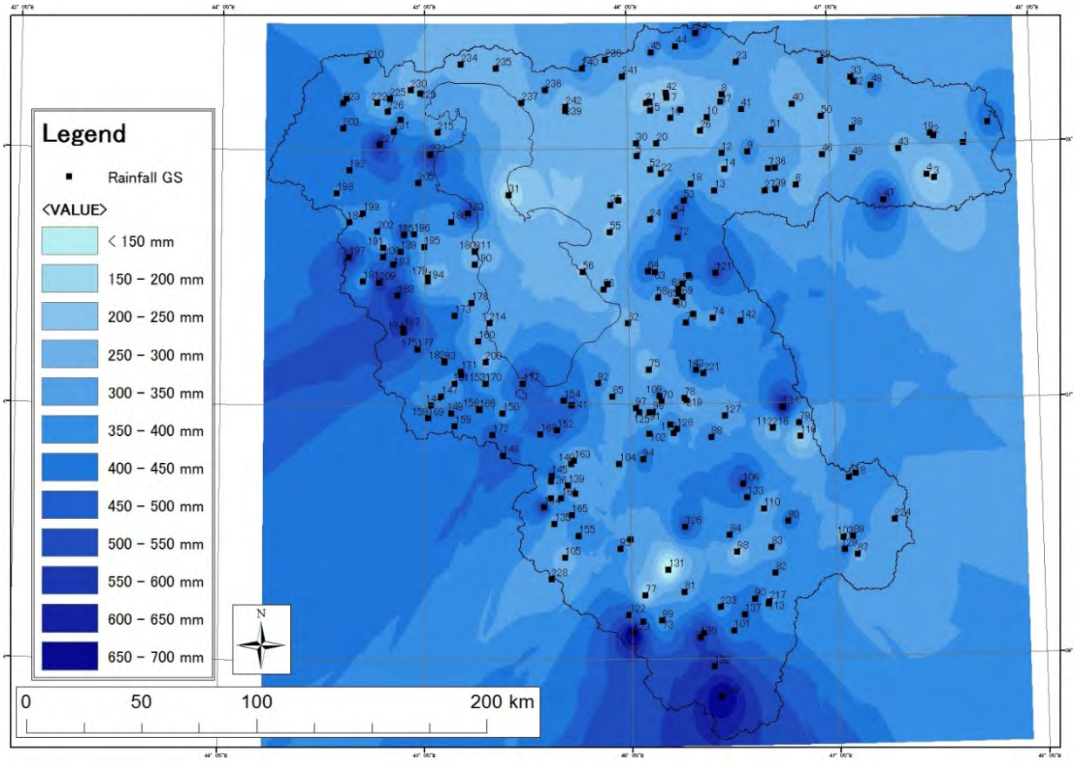
Figure 2.6.2 Variation Trend of Annual Maximum/Minimum/Average Temperature, Precipitation and Pan Evaporation in Urmia (up) and Tabriz (bottom)

2.6.2 HYDRO-METEOROLOGICAL CONDITION IN THE LAKE URMIA BASIN

(1) Spatial Characteristics of Precipitation and Relationship between Annual Precipitation and Elevation

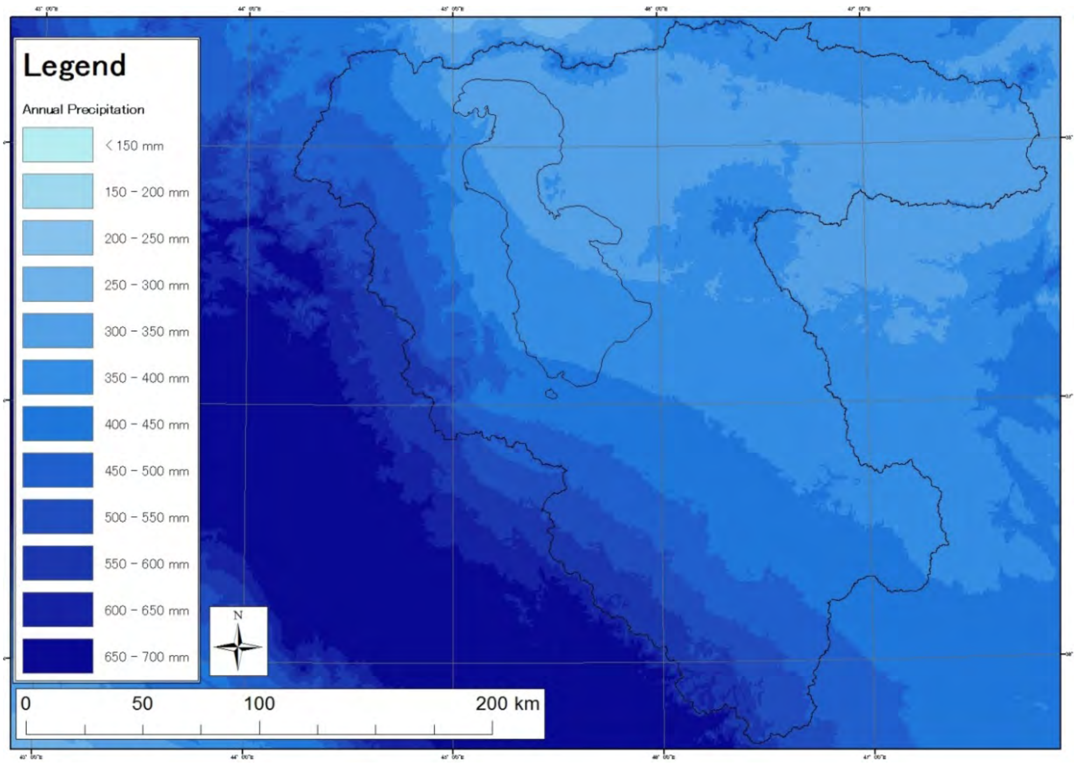
To evaluate spatial characteristics of annual precipitation in the Lake Urmia Basin, contour map of annual precipitation was prepared by means of daily precipitation as shown in Figure 2.6.3 and Annex 2.5 their calculated values at all rainfall stations. The IDW method was applied for spatial interpolation.. In the Lake Urmia Basin with spatial variation whose annual precipitation ranges between 200mm and 800mm, precipitation tends to occur more in the western and southwestern parts of the basin, gradually lessening in the northeastern part. Precipitation also tends to occur more in East Azerbaijan Province than in West Azerbaijan Province. Besides, the spatial distribution issued in WOLDCLIM (http://www.worldclim.org/) shows a similar precipitation trend (see Figure 2.6.4), which is a set of global climate layers (climate grids) with a spatial resolution of about one (1) square kilometer.

Figure 2.4.4 and Figure 2.4.5 shows the relationships between elevations of rainfall gauging stations and their annual precipitation. Though linear relationship is barely seen on points with low precipitation, there is a wide variation which makes it difficult to establish a clear relationship. Thus, in the Survey all of the collected daily data are used without altitude collection to secure the accuracy of the model.



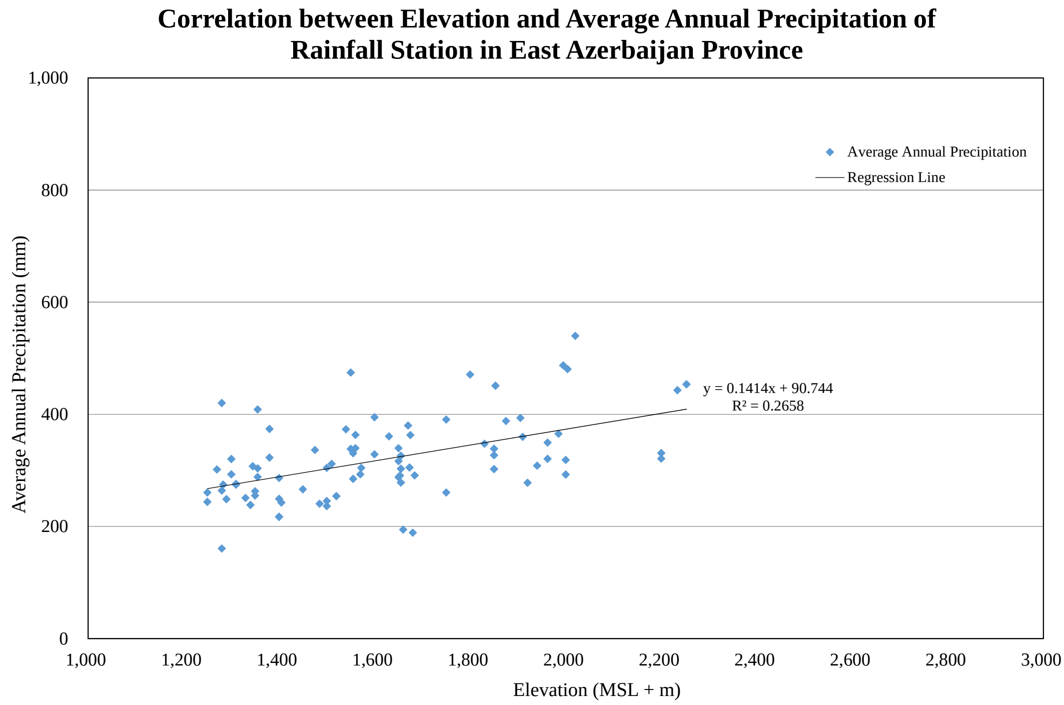
*Prepared by JICA Survey Team based on data provided by WRMC
*Numbers in figure correspond that in "No" in Annex 2.5.
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Figure 2.6.3 Contour Map of Annual Precipitation



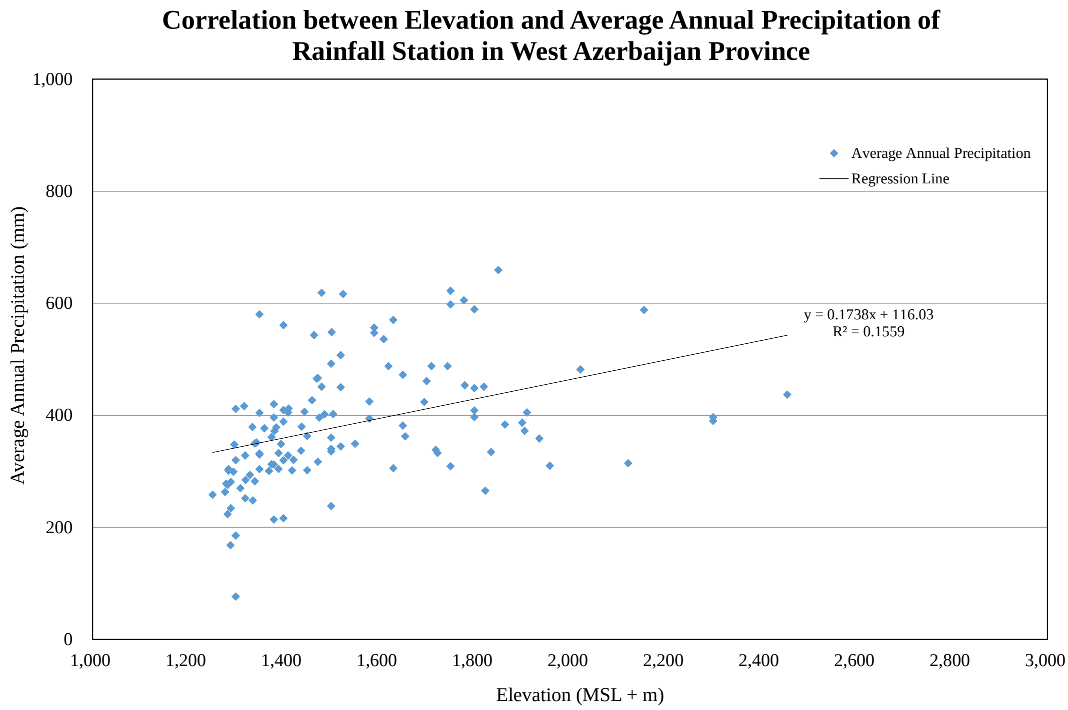
*Source: WORLDCLIM(http://www.worldclim.org/)

Figure 2.6.4 Distribution of Annual Precipitation by WORLDCLIM



*Prepared by JICA Survey Team based on data from WRMC
*Aggression period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Figure 2.6.5 Relationship between Elevation of Rainfall Gauging Station and Annual Precipitation (East Azerbaijan Province)



*Prepared by JICA Survey Team based on data from WRMC
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Figure 2.6.6 Relationship between Elevation of Rainfall Gauging Station and Annual Precipitation (West Azerbaijan Province)

(2) Annual Pattern of Precipitation and Discharge for Monthly Basis

In order to evaluate precipitation runoff characteristics in the Lake Urmia Basin by means of daily precipitation and discharge, monthly basin precipitation and monthly average discharge at the discharge gauging stations neighboring at the end points of inflow rivers were calculated (see Table 2.6.2 for typical basin, Figure 2.6.7 for the selected discharge gauging stations and Annex 2.6 for all calculated data). The hyeto-hydrograph were illustrated in Figure 2.6.8. To remove the influence of discharge interception by the dams constructed at upstream, monthly average discharge was calculated basically during the period before the dams were constructed. However, for those dams that were constructed before the calculation periods, monthly discharge of some rivers was calculated including the influence of the interception by dams.

Most of the precipitation occurs from snowfall that melts and runoffs in spring causing peak discharge to occur between April and May due to melting water. The discharge rapidly decreases by June and onwards. The annual patterns of rainfall and discharge described above were recognized at every station, in spite of the influence of dams. As for the cause of declining of discharge from spring to summer, it is presumed that water restoration by dam at upstream for water usage reduces the base flow due to low groundwater recharge caused by limited vegetation in mountainous area. Average monthly precipitations vary between 40 and 70mm during winter season and less than 10mm during winter season. Though it was confirmed that dozens of cubic meter per second of discharge reach near the end points of inflow rivers during spring season, only less than 10 m^3/s reaches during summer season (less than 1 m^3/s in some inflow rivers).

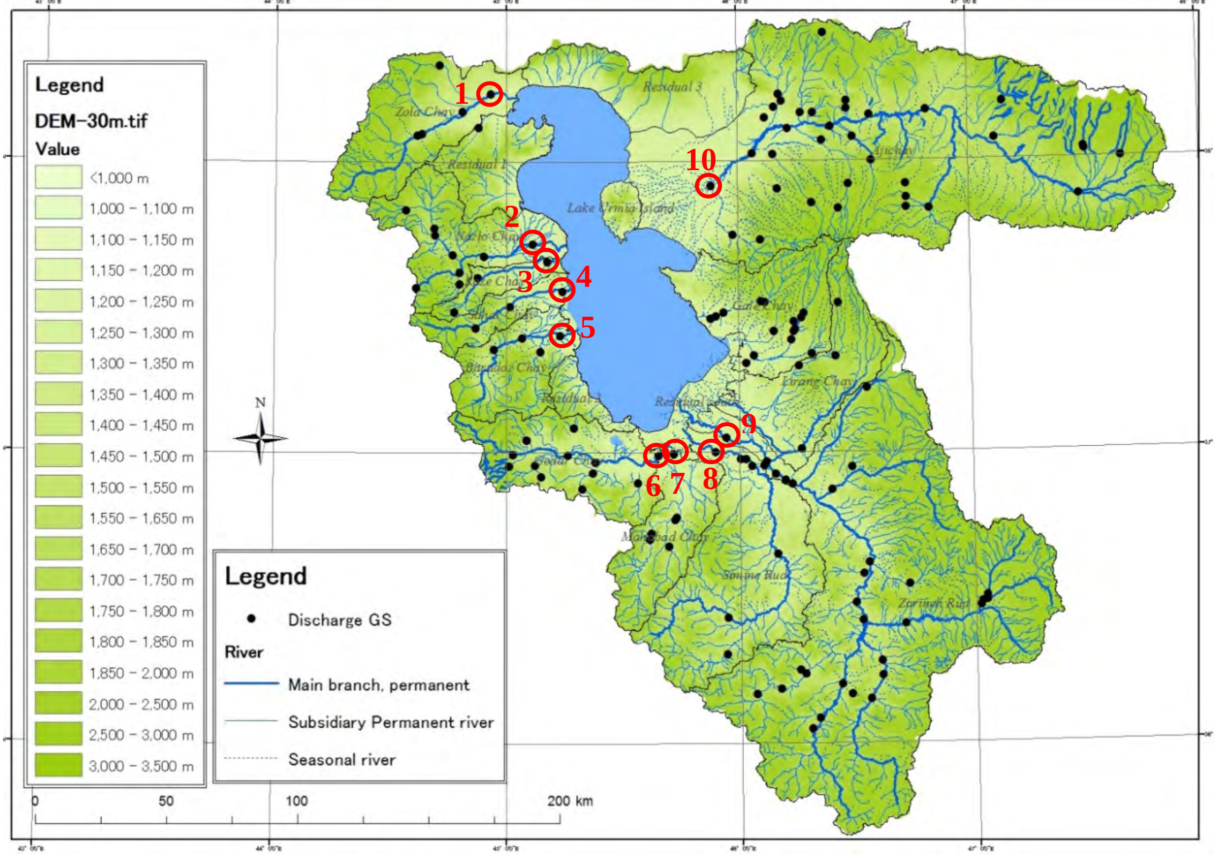
Thus, inflow rivers in the Lake Urmia Basin have two common characteristics, (i) drastic increase in discharge caused by storage function due to accumulation of snow and (ii) drastic change of river discharge for the seasons.

Table 2.6.2 Monthly Basin Precipitation and Monthly Average Discharge at End Point of the Basins of Inflow Rivers (No disturbance by Dams)

Basin	Zola chay		Nazlo Chay	
Basin Area (km2)	2,258		1,880	
	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)
Mar	51.84	2.48	62.10	7.77
Apr	72.50	6.83	77.35	26.36
May	70.08	6.19	60.90	31.80
Jun	25.73	2.38	17.54	12.28
Jul	13.96	2.02	7.61	3.65
Aug	5.30	0.97	3.81	0.49
Sep	6.12	0.48	3.71	0.36
Oct	35.46	0.65	34.89	1.74
Nov	49.01	0.97	63.28	3.90
Dec	29.86	1.11	42.54	3.63
Jan	28.21	1.20	42.84	3.35
Feb	32.83	1.32	41.64	3.79

Basin	Baradoz Chay		Gedar Chay		**Average**	
Basin Area (km2)	1,362		2,091		-	
	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	**Monthly Avegare Precipitation (mm)**	**Monthly Average Discharge (m^3/s)**
Mar	67.31	9.53	70.10	17.91	**62.84**	**9.42**
Apr	85.13	21.03	68.86	45.57	**75.96**	**24.95**
May	53.21	24.36	61.69	49.10	**61.47**	**27.86**
Jun	12.81	10.33	10.47	14.37	**16.64**	**9.84**
Jul	3.87	3.32	1.27	1.81	**6.68**	**2.70**
Aug	3.60	0.95	0.55	0.17	**3.31**	**0.65**
Sep	4.05	0.36	0.98	0.18	**3.72**	**0.35**
Oct	38.16	2.09	45.83	2.36	**38.59**	**1.71**
Nov	61.90	5.47	75.38	6.59	**62.39**	**4.23**
Dec	45.22	5.08	53.91	8.46	**42.88**	**4.57**
Jan	45.45	4.80	43.62	6.74	**40.03**	**4.02**
Feb	49.95	5.23	61.75	8.04	**46.54**	**4.59**

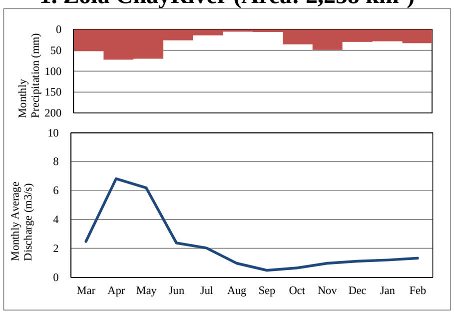
*Prepared by JICA Survey Team based on data from WRMC
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)



*Numbers correspond that in Figure 2.6.8

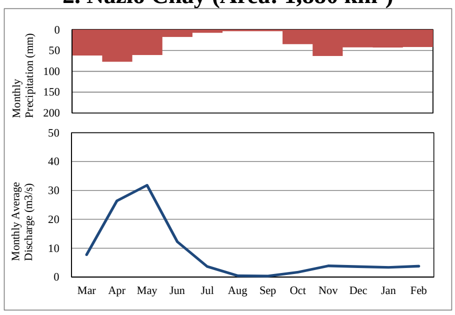
Figure 2.6.7 Selected Discharge GS Neighboring the End Points of Inflow Rivers

1. Zola ChayRiver (Area: 2,258 km²)



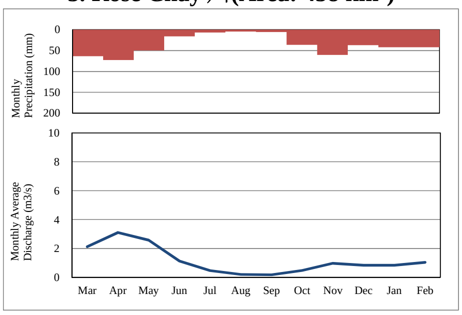
(Cal. Period：1980－2007, Not affected by dam)

2. Nazlo Chay (Area: 1,880 km²)



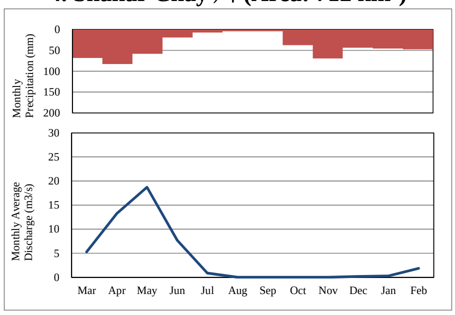
(Cal. Period：1980－2007, Not affected by dam)

3. Rose Chay 川(Area: 458 km²)



(Cal. Period：1980－2011, Not affected by dam)

4. Shahar Chay 川 (Area: 712 km²)

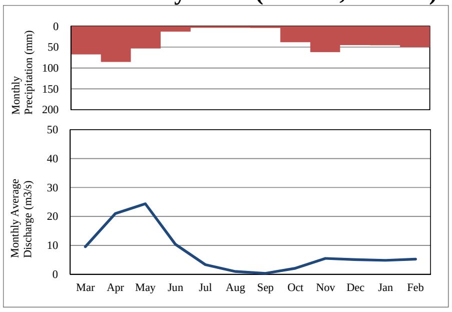


(Cal. Period：1980－2005, Not affected by dam)

*Prepared by JICA Survey Team based on data from WRMC

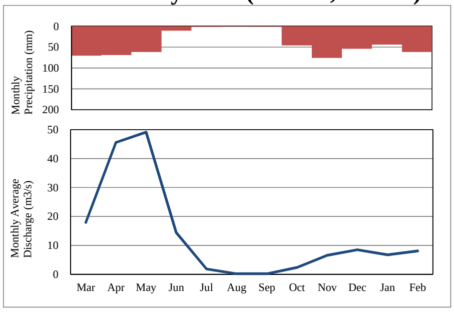
Figure 2.6.8 Monthly Hyeto-Hydrograph Neighboring the End Points of Inflow Rivers (1/2)

5. Baradoz Chay River (Area: 1,362 km^2)



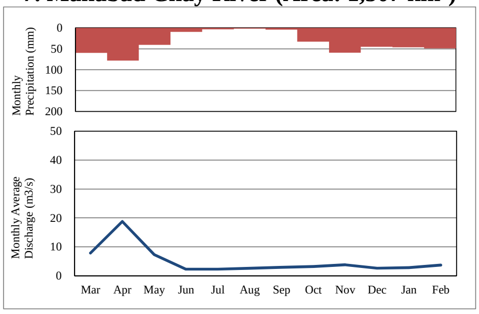
(Cal. Period：1980－2011, Not affected by dam)

6. Gedar ChayRiver (Area: 2,091km^2)



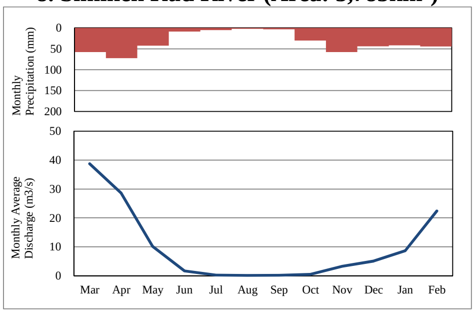
(Cal. Period：1980－1987, Not affected by dam)

7. Mahabad Chay River (Area: 1,507 km^2)



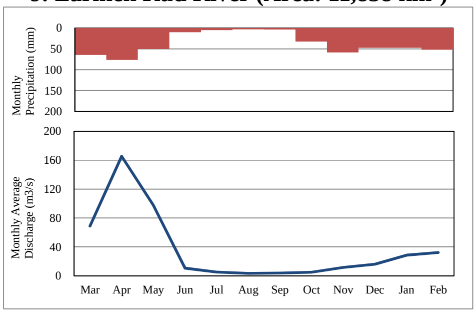
(Cal. Period：1980－2011, Affected by dam)

8. Simineh Rud River (Area: 3,783km^2)



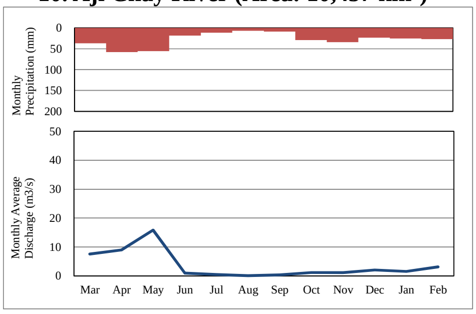
(Cal. Period：1980－2011, Affected by dam)

9. Zarineh Rud River (Area: 11,838 km^2)



(Cal. Period：1980－2011, Affected by dam)

10. Aji Chay River (Area: 10,457 km^2)*



(Cal. Period：1980－2011, Affected by dam**)**

*Prepared by JICA Survey Team based on data from WRMC

Figure 2.6.8 Monthly Hyeto-Hydrograph Neighboring the End Points of Inflow Rivers (2/2)

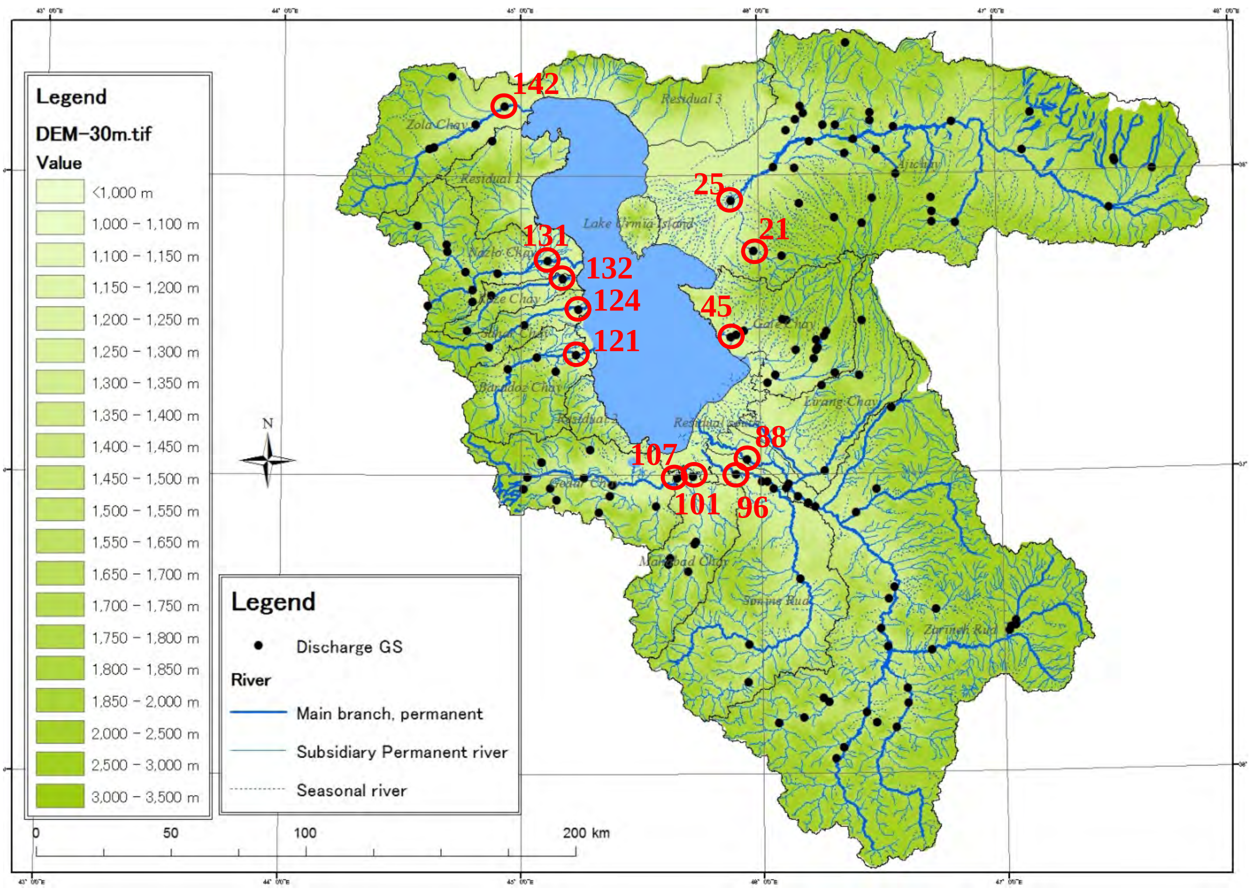
(3) Calculation of Runoff Ratio

Based on the daily precipitation data provided by WRMC, annual runoff ratio were calculated at the neighboring end points of the inflow river basins. For calculation, the effects of dam operations on river discharge were considered. In the Project, operation data at twelve dams were provided, out of the fourty four dams which have been constructed until December 2014. Table 2.6.3 shows the calculation result. Annual runoff ratio considering dam opration effects ranges between 0.06 and 0.35 (0.2 in average), and 0.03 and 0.7 (0.3 in average) for excluding their effects, respectively. As for the hydrological station with high runoff ratio (Kashitaban 0.7), which 0.13 of annual runoff ratio with influence of dam operation was calculated, it is considered that large discharge of dam operation could be recorded. Excluding this station, average runoff ratio of the Lake Urmia Basin is 0.24. This indicates approximately 20 – 30% of annual precipitaion would be converted to river discharge as runoff phenonmenon.

Table 2.6.3 Annual Runoff Ratio at Ending Point of Inflow River Basins

No**	Basin Name	Discharge GS	Code	Catchment Area (km^2)	Annual Runoff Ratio (Affected by dam)	Annual Runoff Ratio (Not affected by dam)
142	Zola chay	Yalghuz aghaj	36-011	2,258	0.06	0.14
131	Nazlo Chay	Abajalu sofla	35-033	1,880	0.27	No Dam data
132	Rose Chay	Guyjali aslan	35-037	458	0.17	No Dam data
124	Shahar Chay	Kashtiban	35-013	712	0.13	0.70
121	Baradoz Chay	Babarud	35-007	1,362	0.35	No Dam data
107	Gedar Chay	Pol bahramlu santu	34-021	2,091	0.30	0.30
101	Mahabad Chay	Gard yaghub	34-009	1,507	0.23	0.44
96	Simineh Rud	Pol bukan	33-985	3,783	0.19	No Dam data
88	Zarineh	Nezam abad	33-917	11,838	0.20	0.23
45	Gale Chay R Up	Shishvan	32-021	698	0.16	0.28
21	Aji Chay Low2	Azarshahr	31-039	702	0.12	No Dam data
25	Aji Chay	Sarin dizaj	31-085	10,905	0.03	No Dam data
				Average.	0.18	0.35

*Prepared by JICA Survey Team based on data from WRMC
**"No" responds that in Figure 3.1.3 in Chapter 3



*Number refers Table 2.6.3

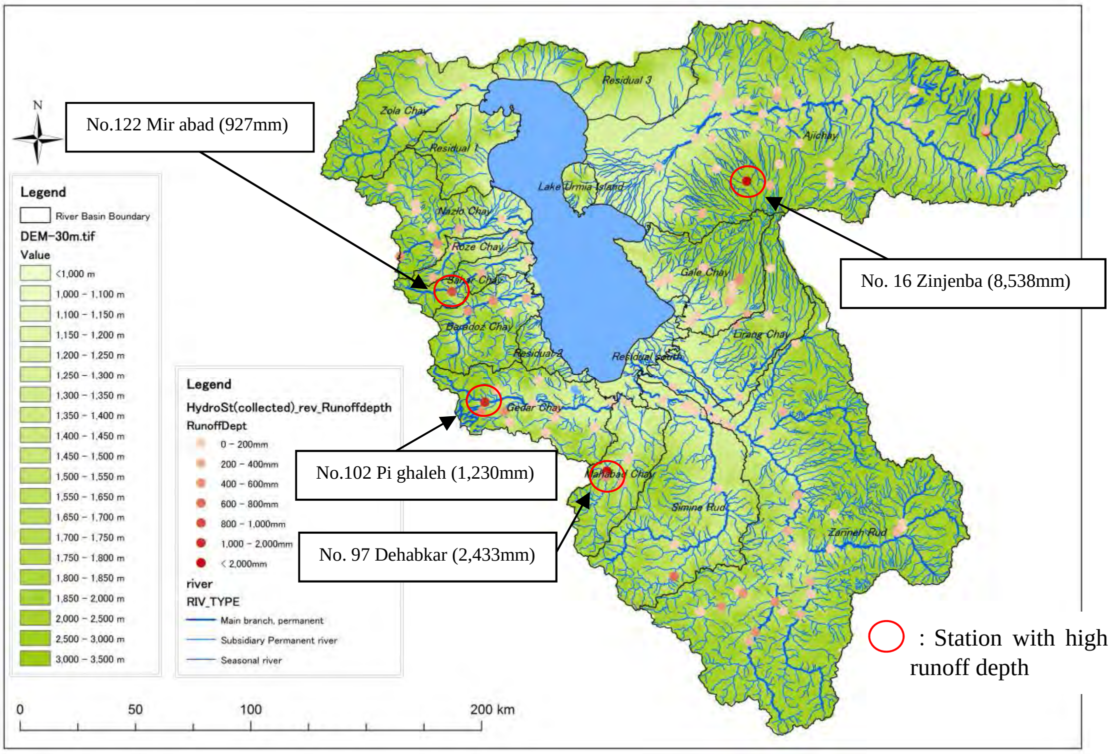
Figure 2.6.9 End Points of Inflow Rivers where Annual Runoff Ratio

(4) Spatial Distribution of Runoff Depth

In order to preliminarily check the accuracies and adequacies of discharge data for input to the hydrological model described in Chapter 5, rough comparison of calculated runoff depth was carried out. Though most of discharge data at discharge gauging stations appear to have adequate quality for input into the model, considerably large runoff depth data were found at some stations. This may possibly be caused by (i) wrong information or misunderstanding on location provided by WRMC and (ii) low reliability of rating curve due to lack of regular checking or monitoring. These gauging stations (see Figure 2.6.10, Figure 2.6.11 and Table 2.6.5) would be recommended to rechek the situation of hydrological monitoring such as information on location of station and applied rating curve.

In order to spatially compare discharge volumes of inflow rivers, average runoff depth at discharge gauging stations were calculated by dividing the annual discharge with the catchment area located upstream of the gauging stations, as shown in Figure 2.6.10 and are summarized in Table 2.6.4. Calculated values of all stations were tabulated in Annex 2.7.

The resultsof the calculations show that runoff depth varies both for river basin and their location such as up/downstream, whose values are distributed within the range of 80-700m with an average of 300mm (excluding residual catchment area). They also range between 0 - 200mm in the lower river basin and 400 – 600mm in the upper river basin, respectively.



*Prepared by JICA Survey Team based on data provided by WRMC
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Figure 2.6.10 Distribution of Runoff Depth at Discharge Gauging Stations

Table 2.6.4 Summary of Runoff Depth of Inflow River Basins

Basin Name	Area (km^2)	Runoff Depth (mm)	Basin Name	Area (km^2)	Runoff Depth (mm)
Zola Chay	2,258	79.3	Mahabad Chay	1,507	699.6
Residual 1	1,060	23.1	Simine Rud	3,783	250.6
Nazlo Chay	1,880	216.7	Zarineh Rud	11,838	259.8
Roze Chay	458	103.4	Gale Chay	2,094	190.2
Sahar Chay	712	472.7	Lirang Chay	1,936	156.6
Baradoz Chay	1,362	407.6	Ajichay	12,717	419.9
Gedar Chay	2,091	349.1	Ave.		318.6

*Prepared by JICA Survey Team based on data provided by WRMC

Table 2.6.5 Hydrological Station with High Average Runoff Depth

No.*	Station Name	River Basin	Catchment Area (km^2)	Average Runoff Depth (mm)	Supposable Reason
16	Zinjenba	Aji Chay	43	8,538	Daily discharge more than 2,000m^3/s has been recorded though the station is located at upstream.
97	Dehabkar	Mahabad Chay	56	2,433	Considering the catchment area, observed discharge is rather large.
102	Pi ghaleh	Gedar Chay	225	1,230	
122	Mir abad	Shahar Chay	175	927	

*Number refers Figure 3.1.3 of Chapter 3

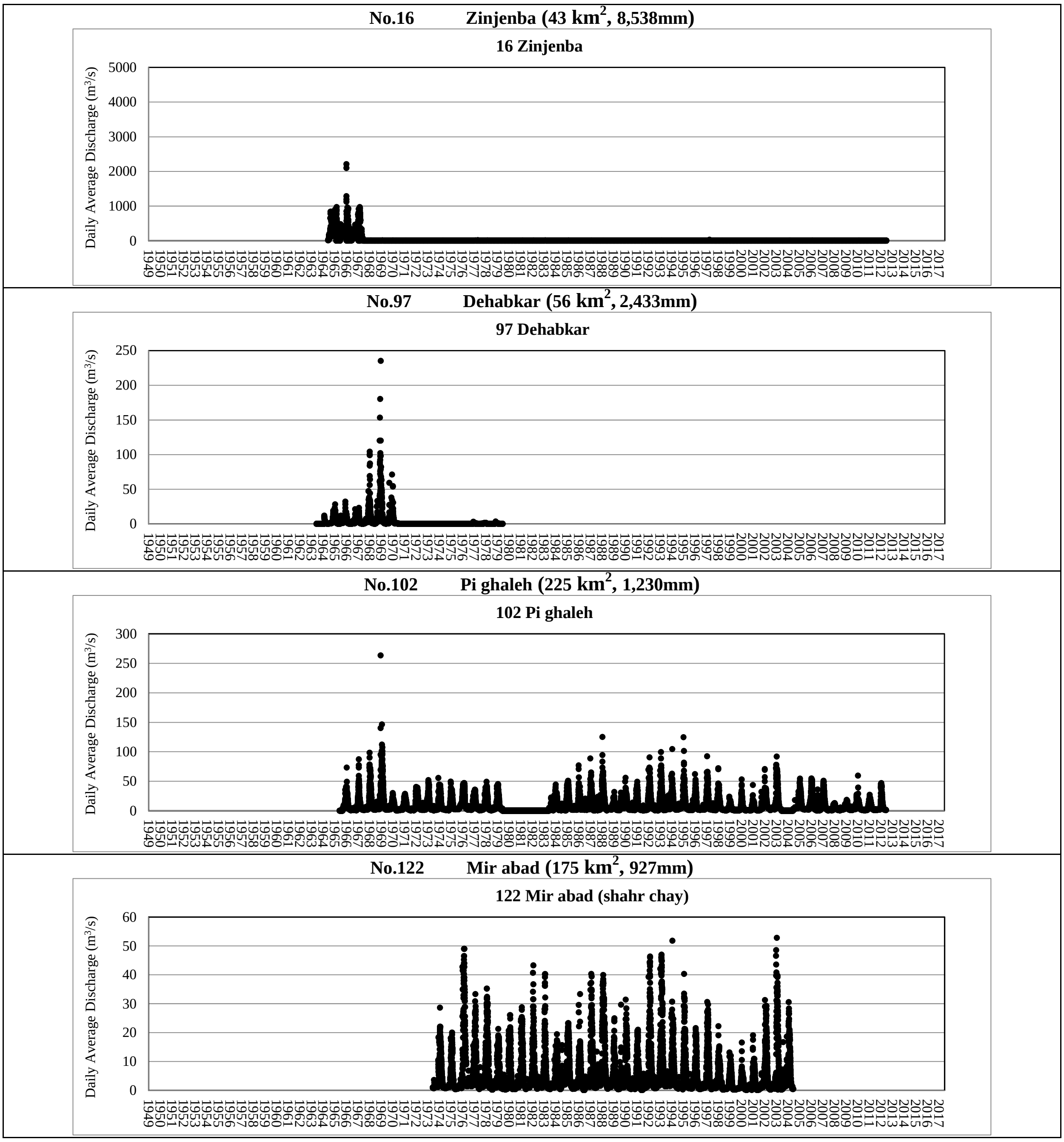


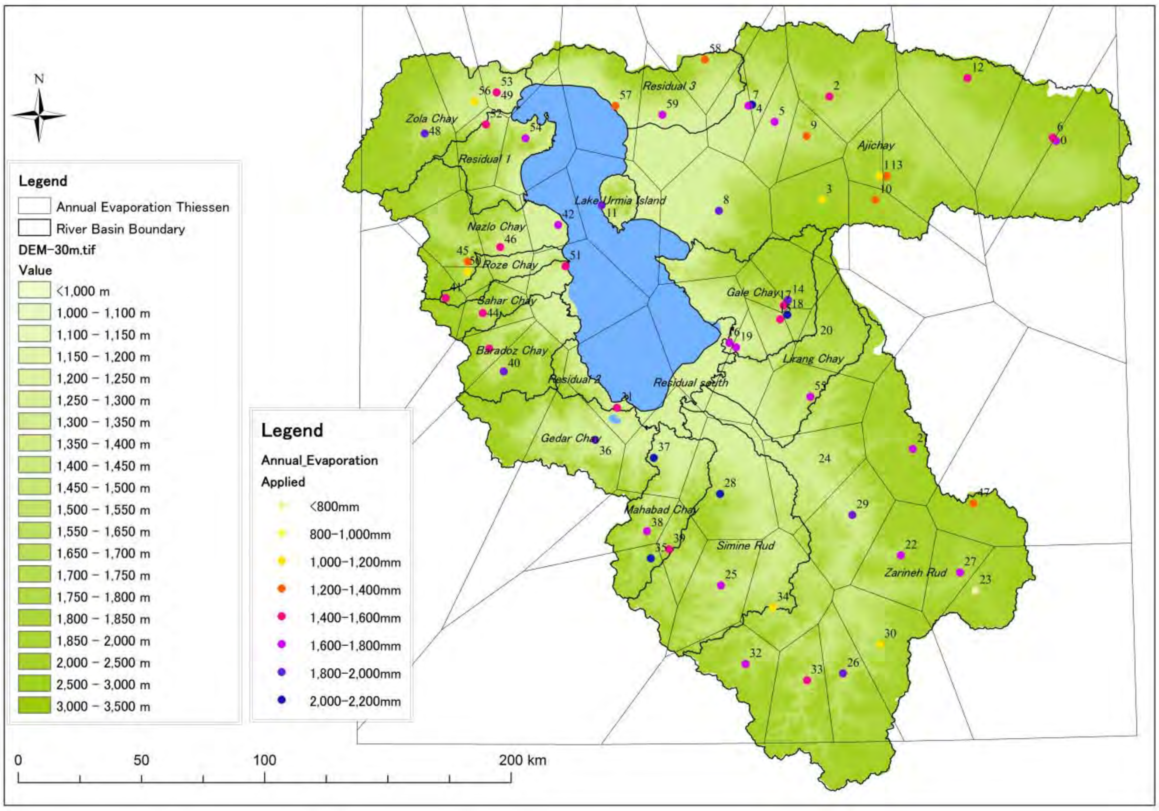
Figure 2.6.11 Hydrogaph of Daily Discharge at Discharge Gauging Stations with High Runoff Depth

2.6.3 ESTIMATION OF BASIN AVERAGE EVAPORATION AND EVAPORATION FROM LAKE SURFACE

As described above, the Lake Urmia Basin having a unique closed system in lake water, the only factors of water balance are land evapotranspiration and evaporation from the surface of the lake. In this section, both factors were preliminarily estimated. As for land evapotranspiration, for its reference, basin average evaporation was estimated. The results by the methods will be referred to in the establishment of simulation model. Incidentally, the PAN evaporation data is collected from WRMC and IMO. The former organization supplies monthly PAN evaporation data for 61 stations and the latter one daily data for 10 stations.

(1) Esimation of Basin Average Evaporation using Monthly Data of WRMC

Based on the monthly pan evaporations provided by WRMC, annual basin average evaporation was calculated, where the Thiesen Method was applied for basin average estimation. Figure 2.6.12 shows the distribution of annual pan evaporation at meteorological stations while Annex 2.8 shows the calculated Thiesen coefficients. The calculated annual basin evaporation is 1,643mm.



*Prepared by JICA Survey Team based on the data provided from WRMC
*Numbers in figure correspond that in “No” in Annex 2.8

Figure 2.6.12 Annual Evaporation and Thiesen Delineation in the Lake Urmia Basin

(2) Estimation of Reference Land Evapotranspiration

Annual evapotranspiration amount in the three stations (MARAGHEH, SAGHEZ and TABRIZ), is calcurated by the Hamon mthod based on monthly data provided by WRMC. The data of three station has the smaller number of gaps compared with with other stations. The calculated results are summerized in Table 2.6.6, 0.36 of average ratio through the years. From the results, it can be said that the amount of evapotranspiration in the basin as input to the model is basically around 30% of the pan evaporation amount.

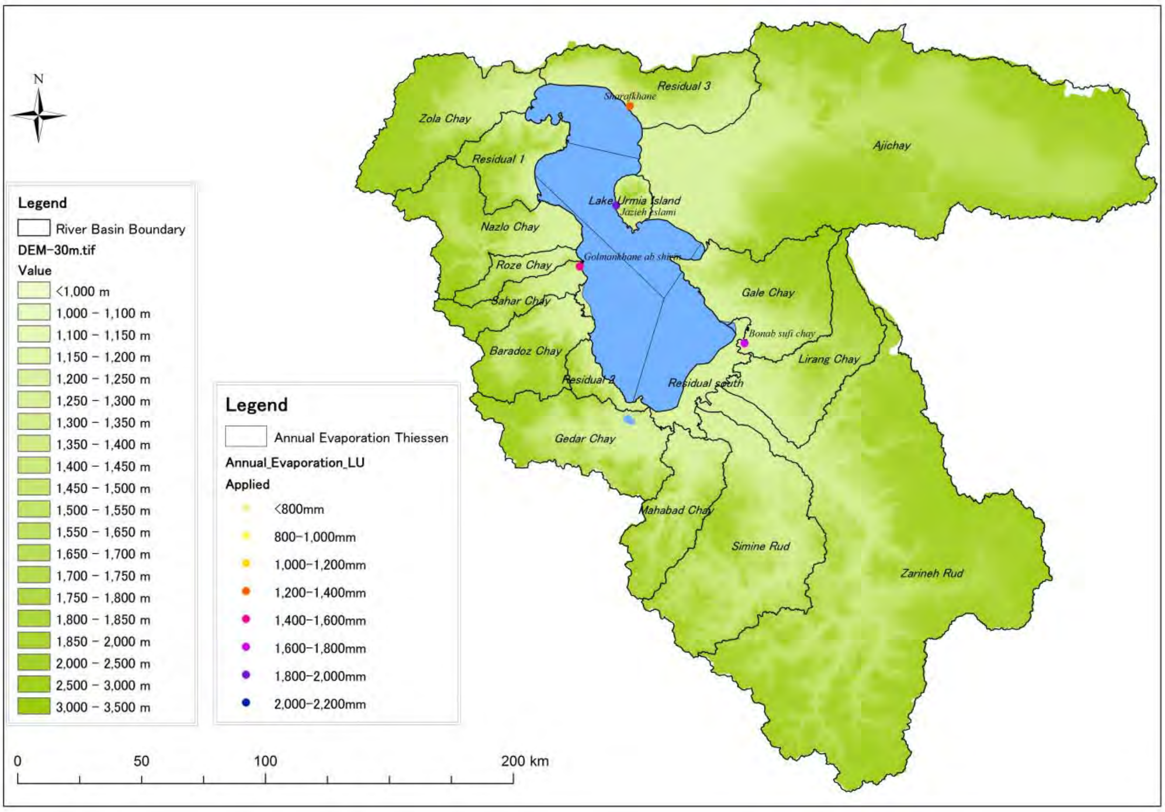
Table 2.6.6 Correcting Calculation Result of Evapotranspiration (based on WRMC data)

Station	MARAGHEH			SAGHEZ			TABRIZ		
Items / Year	(1) Annual PAN Evaporation (mm)	(2) Annual Potential Evapotran-spiraiotn (mm)	Ratio (1)/(2)	(1) Annual PAN Evaporation (mm)	(2) Annual Potential Evapotran-spiraiotn (mm)	Ratio (1)/(2)	(1) Annual PAN Evaporation (mm)	(2) Annual Potential Evapotran-spiraiotn (mm)	Ratio (1)/(2)
1992	1,623.0	601.24	0.37	1,031.7	527.83	0.51	1,270.7	622.59	0.49
1993	2,059.3	640.01	0.31	1,405.7	576.50	0.41	1,876.0	652.49	0.35
1994	2,012.5	671.22	0.33	1,329.0	604.17	0.45	1,865.5	675.31	0.36
1995	1,764.2	678.43	0.38	1,378.2	597.38	0.43	2,054.9	695.44	0.34
1996	1,963.3	692.12	0.35	1,798.6	630.14	0.35	2,020.5	711.55	0.35
1997	1,969.6	671.81	0.34	1,754.3	579.99	0.33	1,848.3	688.63	0.37
1998	2,073.4	729.43	0.35	1,728.3	618.82	0.36	2,034.2	742.02	0.36
1999	2,128.1	727.12	0.34	2,085.2	660.94	0.32	2,025.5	730.99	0.36
2000	2,087.3	730.80	0.35	2,164.6	651.19	0.30	2,182.8	745.13	0.34
2001	2,163.8	737.34	0.34	2,215.3	659.14	0.30	2,244.3	742.41	0.33
2002	1,474.7	714.46	0.48	2,016.9	619.90	0.31	1,941.0	703.52	0.36
2003	1,692.8	715.86	0.42	1,705.5	621.48	0.36	1,892.6	717.58	0.38
2004	1,933.5	708.05	0.37	1,821.9	617.10	0.34	2,076.8	732.73	0.35
2005	2,014.1	723.55	0.36	1,850.6	628.72	0.34	1,899.1	732.89	0.39
2006	2,136.1	747.39	0.35	1,823.4	639.11	0.35	2,036.7	759.12	0.37
2007	1,909.7	717.08	0.38	1,893.3	621.69	0.33	2,040.8	715.24	0.35
2008	2,165.2	753.62	0.35	2,283.0	671.43	0.29	2,063.7	745.01	0.36
2009	1,929.5	706.22	0.37	1,849.6	616.95	0.33	2,010.1	695.12	0.35
Ave.	**1,950**	**703.7**	**0.36**	**1,785**	**619.0**	**0.36**	**1,966**	**711.5**	**0.36**

(3) Estimation of Evaporation from Lake Surface

Based on the monthly pan evaporation at stations adjacent to Lake Urmia, average evaporation from the lake surface was estimated by the Thiesen Method. Figure 2.6.13 shows the extracted annual pan evaporation at the stations adjacent to Lake Urmia and Table 2.6.7 shows the calculated Thiesen coefficients. The calculated average annual evaporation in the lake area is 1,611mm. For preliminary estimation of evaporation from lake surface, an adequate "correlation factors" was required which is to be multiplied to the calculated average evaporation. According to Mehdi Mazaheri, et al.,[16], evaporation from the lake surface was obtained by multiplying with the evaporation value of 0.6. By referring to the research results, the estimated evaporation from the lake surface is 1,611× 0.6 = 967mm. Linsley, et al.[17], mentioned that evaporation from lake surface can be estimated with the coefficient factor ranging 0.6 – 0.7. Applying this, the evaporation can be estimated within a range of 967 – 1,127mm.

[16] "Two-Dimensional Modeling of Urmia Lake Hydrodynamics" (Mehdi Mazaheri, et al.) (Presented in "Workshop on Integrated River Basin Modeling, Emphasizing on Lake Urmia Basin" in Dec. 2014)
[17] "HYDROLOGY FOR ENGINEER -Third edition-" (Ray K. Linsley, Jr., et al.)



Prepared by JICA Survey Team based on the data provided from WRMC

Figure 2.6.13 Thiesen Delineation in the Lake Area

Table 2.6.7 Annual Evaporation at Meteorological Stations and Thiesen Coefficient around Lake Urmia

No.	Longitude	Latitude	Code	St_Name	Elevation	Annual Evapotranspiration (mm)	Area (km2)	Thiessen Coef.
1	46	37.316667	32-013	Bonabsufichay	1,283	1,697	1,139	0.229
2	45.25	37.6	35-082	Golmankhane ab shirin	1,252	1,515	1,418	0.284
3	45.483333	38.183333	38-002	Sharafkhane	1,280	1,256	878	0.176
4	45.418056	37.821944	31-046	Jazieheslami	1,280	1,836	1,551	0.311
Ave.						1,611	4,986	-

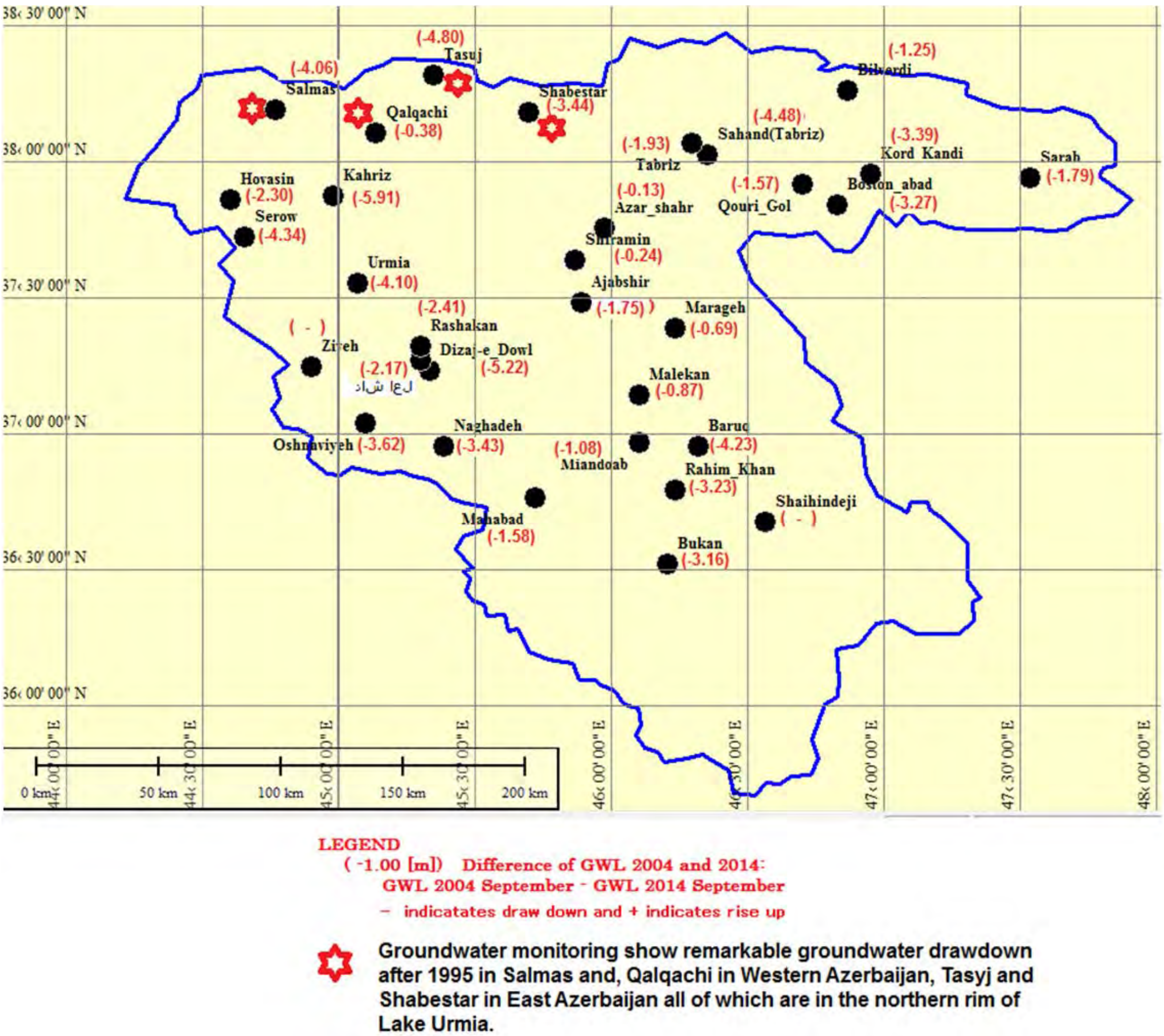
*Prepared by JICA Survey Team based on the data provided from WRMC

2.6.4 GROUNDWATER

(1) Groundwater Change Trend

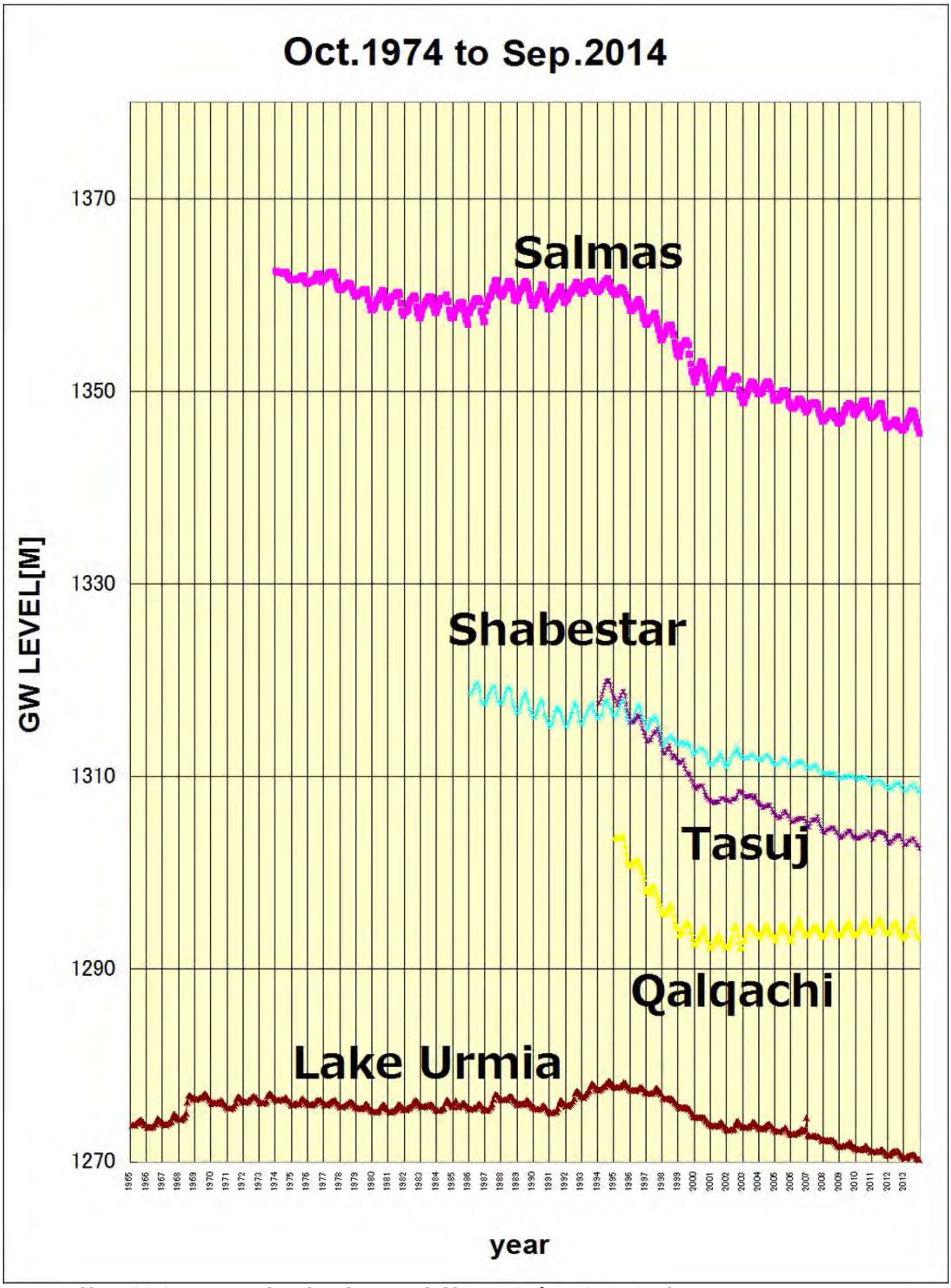
The historical data on groundwater level that were provided by WRC of East/West Azerbaijan Provinces were arranged as presented in Figure 2.6.14 and Figure 2.6.15. Drawdown of groundwater in 10 years from 2004 to 2014 for aquifers is about 3.2m in West Azerbaijan and 2.1m in East Azerbaijan. In Salmas, drawdown is 16.85m in 40 years, in Sahand (Tabriz) in East Azerbaijan, drawdown is 11.28m in 30 years and in Tasuj, drawdown is 15.09m in 20 years. According to the long monitoring, remarkable drawdowns after 1995 are observed in Salmas and Qalqachi in West Azerbaijan and in Tasji and Shabestar in East Azerbaijan. These aquifers are located at the northern rim of Lake Urmia.

Comparing with the fluctuation of groundwater level of the Norhern part of the Lake Urmia Basin, that in other parts are relatively small. This may be because the river flow is dominant factor that affects ground water recharge in the area. In the Lake Urmia Basin, there may be spatial patterns for groundwater fluctuation, one is governed by river water level with abundant water, and the other by that of lake water.



*Prepared by JICA Survey Team based on data provided by WRC of East/West Azerbaujan Provinces

Figure 2.6.14 Groundwater Variation in 10 years and Groundwater Change (2004–2014)



*Prepared by JICA Survey Team based on data provided by WRC of East/West Azerbaujan Provinces

Figure 2.6.15 Groundwater Variation in 10 years and Groundwater Change (2004–2014)

Table 2.6.8 and Table 2.6.9 show average groundwater level and its drawdown from September to October in the last forty (40) years for West Azebaijan, and thirty (30) years for East Azerbaijan. At the northern part of Lake Urmia, drastic decline of groundwater level has been recognized after year 1995, specifically for Salmas of West Azerbaijan and Tasuji and Shabestar of East Azerbaijan.

Table 2.6.8 Groundwater Level and Drawdown DDN in West Azerbaijan (m)

Location	Groundwater Level between September and October (m)					Drawdown (m)			
	2014	2004	1994	1984	1974	2014 -2004	2014 -1994	2014 -1984	2014 -1974
Salmas	1345.66	1349.72	1360.38	1358.20	1362.51	4.06	14.72	12.54	16.85
Qalqachi	1293.25	1293.63	*1303.58			0.38	9.95		
Kahriz	1268.27	1274.18				5.91			
Urmia	1294.67	1298.77	1299.95	1299.03		4.10	5.28	4.36	
Serow	1564.76	1569.10				4.34			
Hovasin	1773.49	1775.79				2.30			
Ziveh	1515.28								
Rashakan	1275.74	1278.15				2.41			
داشآغل	1278.63	1280.80				2.17			
Dizaj-e Dowl	1283.90	1289.12				5.22			
Naghadeh	1297.34	1300.77				3.43			
Oshnaviyeh	1401.90	1405.52				3.62			
Mahabad	1285.57	1287.15				1.58			
Miandoab	1286.27	1287.35				1.08			
Baruq	1328.67	1332.90				4.23			
Rahim Khan	1312.07	1315.30				3.23			
Bukan	1356.44	1359.60	1361.70			3.16	5.26		
Shaihindeji	1335.01								
Average(m)						3.20			

*Prepared by JICA Survey Team based on data provided by WRC of East/West Azerbaujan Provinces

Table 2.6.9 Groundwater Level and Drawdown DDN in East Azerbaijan (m)

地点	Groundwater Level between September and October (m)					Drawdown (m)			
	2014	2004	1994	1984	1974	2014 -2004	2014 -1994	2014 -1984	2014 -1974
Maragheh	1301.61	1302.30	1303.07	1303.32		0.69	1.46	1.71	
Ajabshir	1290.43	1292.18	1296.61	1296.42		1.75	6.18	5.99	
Azar shahr	1316.00	1316.13	1319.04	1317.56		0.13	3.04	1.56	
Tabriz	1311.60	1313.53	1315.37			1.93	3.77		
Sahand (Tabriz)	1637.46	1641.94	1644.00	1648.74		4.48	6.54	11.28	
Bilverdi	1566.43	1567.68	1568.83			1.25	2.4		
Sarab	1684.48	1686.27	1686.88			1.79	2.4		
Shabestar	1308.32	1311.76	1316.16			3.44	7.84		
Tasuj	1302.50	1307.30	1317.59			4.8	15.09		
Malekan	1284.41	1285.28				0.87			
Shiramin	1282.92	1283.16				0.24			
QouriGol	1922.68	1924.25				1.57			
Boston Abad	1802.44	1805.71				3.27			
KordKandi	1654.06	1657.45				3.39			
Average [m						2.11			

*Prepared by JICA Survey Team based on data provided by WRC of East/West Azerbaujan Provinces

(2) Seasonal Fluctuation of Groundwater Level

Pattern for low water coincides in both groundwater and lake water. Pattern for high water of groundwater shows about one (1) month earlier than lakewater, which indicates time for groundwater movement.

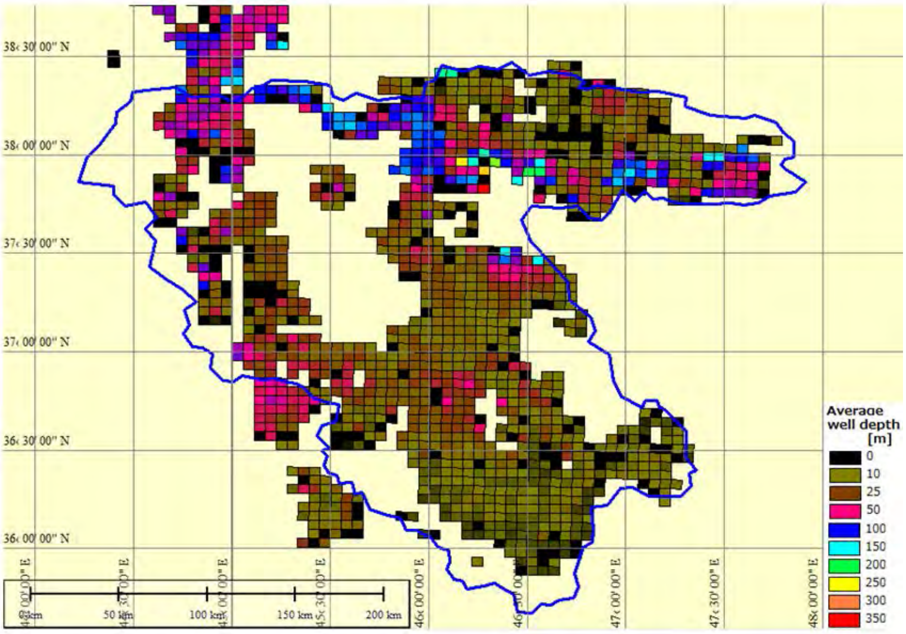
Table 2.6.10 Months with Highest and Lowest Groundwater Level

	High Water Level					Low Water Level				
	Salmas	Qalqachi	Shabestar	Tasuj	Lake Urmia	Salmas	Qalqachi	Shabestar	Tasuj	Lake Urmia
1986	4		4		5	9		9		9
1987	6		4,5		6	10		10		10
1988	4		4		4	9		9		9
1989	4		4		5	9		9		9
1990	4		4		5	9		9		9
1991	6		6		6	10		10,11		10
1992	6		5		6	10		10		10
1993	4		6		5	10		11		11
1994	5	5	6		6	9	10	10		10
1995	3	4	4	4	5	9	9	9	9	9
1996	4	4	4	3	6	9	9	10	9	9
1997	4	2	4	6	5	9	9	9	9	9
1998	4	4	4	3	4	9	9	11	9	9
1999	3	4	1	1	10	9	9	9	9	9
2000	3	5	3	3	3,4	9	9	9	9	9
2001	5	3	5	6	5	11	10,9	9	12	9
2002	4	4	5	6	5	9	9	10	1	11
2003	4	4	5	3,4	5	10	10	9	9	12
2004	4	3	4	5	5	9	11	9	9	9
2005	4	4	5	5	5	9	9	9	9	9
2006	4	4	5	5	5	9	10	9	9	10
2007	4	4	4	5	3	9	9	9	9	9
2008	4	4	4	4	3,4	9	10,9	9	9	9
2009	5	4	6	5	5	10	9	10	10	9
2010	4,5	5	3	7	5	9	10	9	12	9
2011	4	4	4	3	5	9	10	9	9	9
2012	3	3	4	5,6	3,4	9	9	9	11	9
2013	4	4	4	4	4	9	9	9	9	9

*Prepared by JICA Survey Team based on data provided by WRC of East/West Azerbaujan Provinces

(3) Groundwater Depth

Based on location of wells and drilling test results, average depth of wells in 5km×5km grid are prepared and are shown in Figure 2.6.16. Average well depth along Section No. S1 (see Figure 2.6.17) is shown in pink color in Figure 2.6.18. This area marked with pink indicates available freshwater territory. Average well depth along Section No. S2 is shown in pink color in Figure 2.6.19. This area marked with pink likewise indicates available freshwater territory.



*Prepared by JICA Survey Team based on data provided by WRC of East/West Azerbaujan Provinces

Figure 2.6.16 Depths of Wells in the Lake Urmia Basin

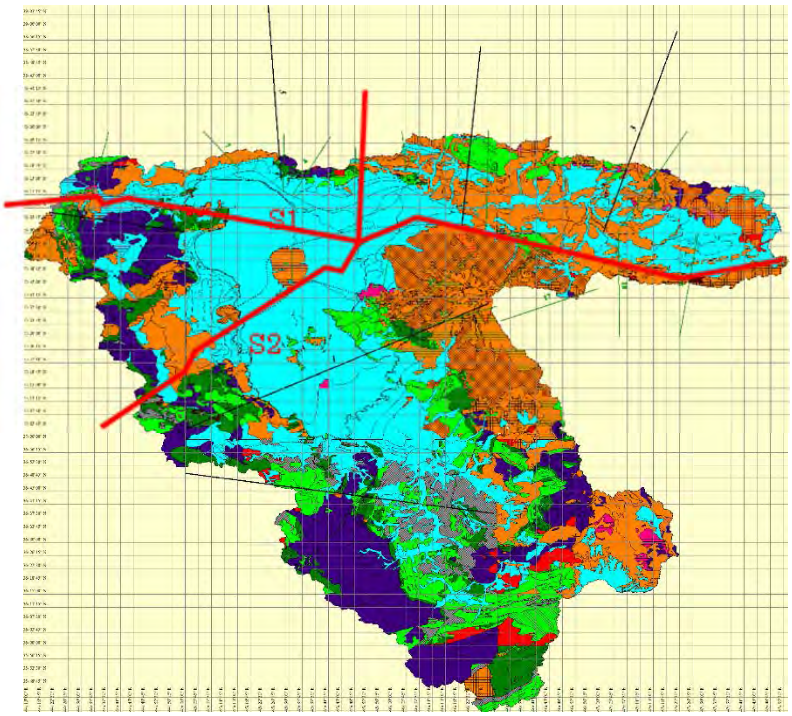
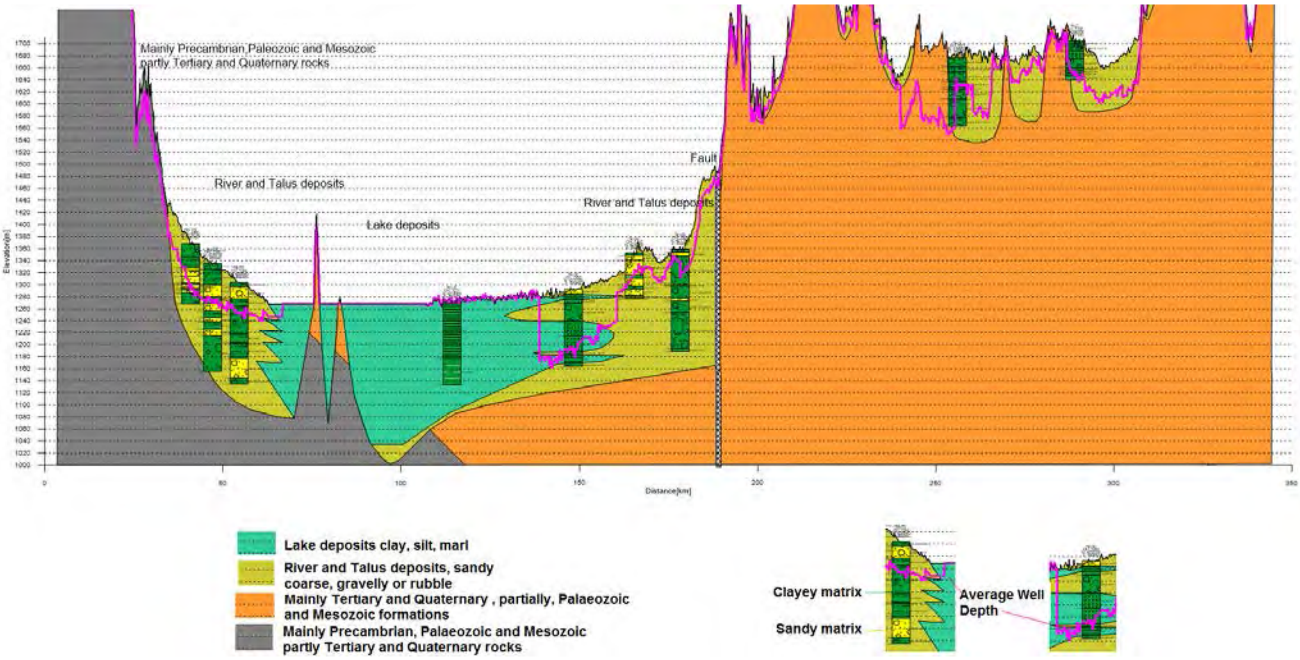
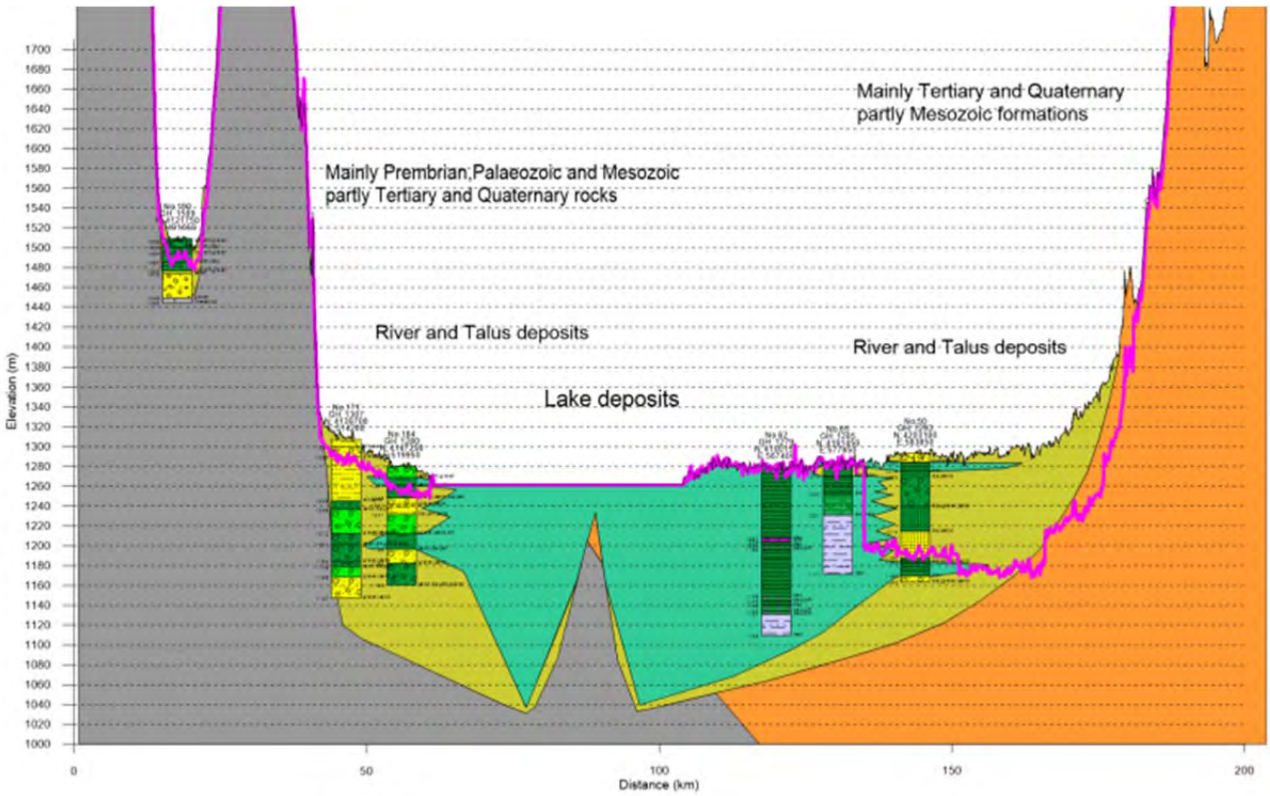


Figure 2.6.17 Cross Section Line for Longitudinal Profile



*Prepared by JICA Survey Team based on data from Iran Geological Service

Figure 2.6.18 Well Depth in Longitudinal Plan of Section No. 1

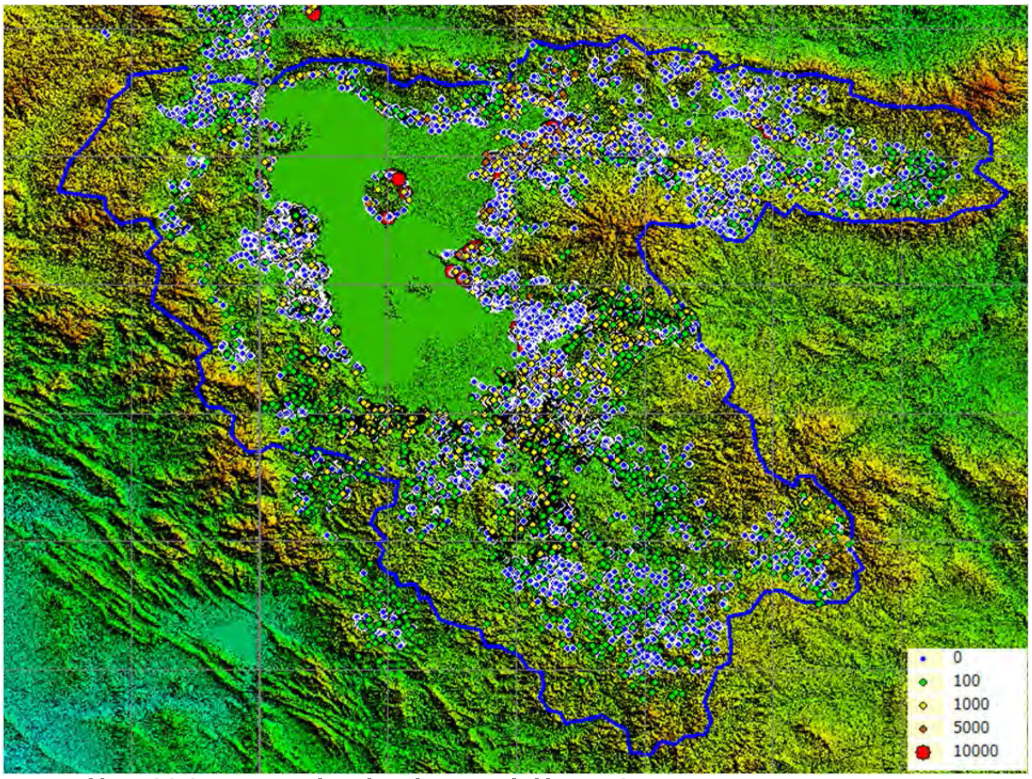


*Prepared by JICA Survey Team based on data from Iran Geological Service

Figure 2.6.19 Well Depth in Longitudinal Plan of Section No. 2

(4) Electric Conductivity

According to WRMC, authorized agencies permitted 93,276 wells where electric conductivity (EC) was measured upon installation (see Figure 2.6.20). Some of the wells were confirmed to have high salinity of more than 10,000 μS/cm of EC. During the recent site investigation, it was found that the salinity of wells is increasing (for reference, average EC of seawater and tap water ranges from 45,000 to 50,000 μS/cm and 100 to 200 μS/cm, respectively). According to WMC of East and West Azerbaijan provinces, salinization of well water occurs at the villages neighboring Bonab in East Azerbaijan and Kahriz in West Azerbaijan.



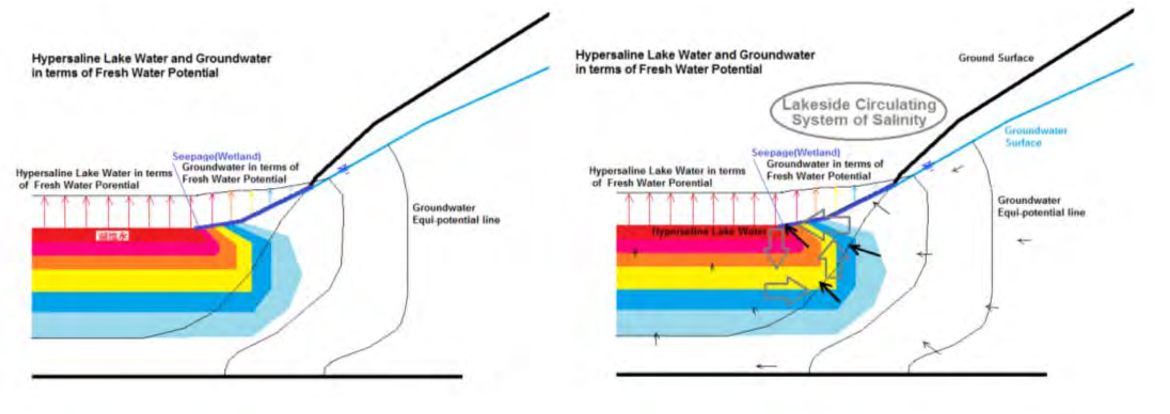
*Prepared by JICA Survey Team based on data provided by WRC

Figure 2.6.20 Electric Conductivity of Groundwater(Unit: μS/cm)

(5) Salinity Distribution/Diffusion and Potential of High Saline Water Lake

The final destination of surface water is Lake Urmia which is the place of storage for surface water. Salts in water are transported to Lake Urmia, concentrated by evaporation of water and become homogeneous through circular flow within the lake. Groundwater has the same final destination but only a small part is allowed to directly flow out into the bottom of the lake due to high salinity and thick clayey lake deposits. It is to be noted that the upward flow vector at the depths of the lake has sealed salinity within the lakewater and lake deposits. Lakeside adjacent to the lake becomes seepage surface. The lakeside seepage creates wetland for ecological zone. The seepage zone is worthy in circulating salinity starting from lakewater, once dispersing and diffusing in groundwater movement and then flowing out to the seepage. The diminishing seepage zone may lead to stoppage of circulation and to prevailing dispersion and diffusion. The two storage places for groundwater and surface water (lake water) have the extensive mutual relationship as discussed above.

Figure 2.6.21 shows the potential relationship between the hyper-saline lake and groundwater and its seepage (wetland). The potential of lakewater in terms of freshwater source depends on the vertical distribution of salinity under the lakewaterwith the potential value itself varying in geological and historical time. As discussed above, the estimated potential value is about 1,295m. It is to be noted that horizontally, groundwater potential is also affected by salinity distribution near the lakeside, because it should have higher potential (in terms of freshwater potential) than lakeside seepage, complemented by salinity and its high density.



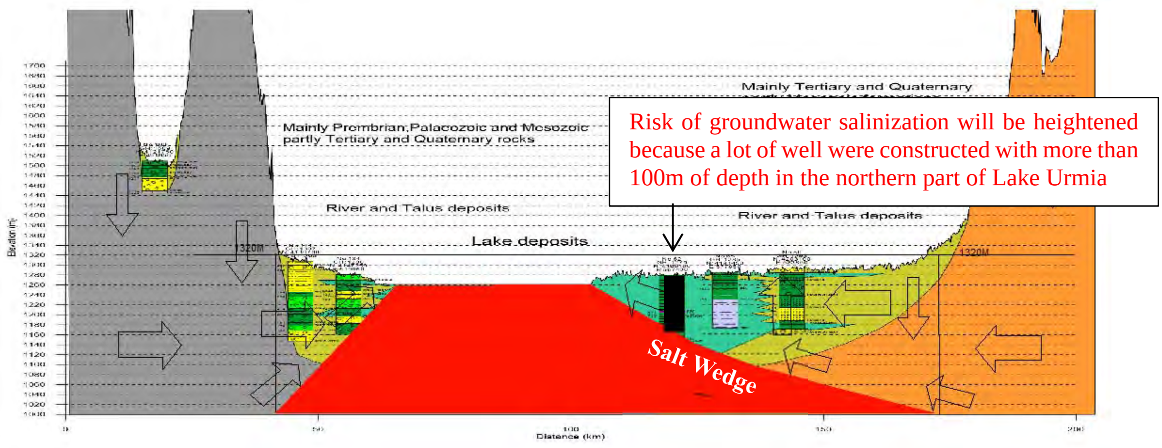
*Prepared by JICA Survey Team

Figure 2.6.21 Scheme of Salinity Distribution

Figure 2.6.22 illustrates boundary of salt water intrusion (Salt Wedge) into the surrounding groundwater with linearly attenuating C-curve. Though this is the most serious case for groundwater salinization, vertical upward vector is still working.

If vertical velocity is zero, concentration is constant. In a two-dimensional case, Ghyben-Herzberg relation is applied and rigid Salt Wedge is located at the bottom. Inside the wedge, static salty water potential governs and there is no water movement. In this case no seepage happens at the lake bottom and all the groundwater flow is focused onto the lakeside seepage (wetlands).As such, there is high possibility of occurrence of groundwater salinization in the futurre, especially at the north part of Lake Urmia where a number of wells were constructed with more than 100m of depth.

In Lake Urmia Basin, information on groundwater salinization based on amonitoring systemwas quite limited. Because of this limitation, the module of water quality calculation was not considered in the hydrological model that was applied in the Survey which was conducted to simulate the phenomenon of density current.



*Prepared by JICA Survey Team

Figure 2.6.22 Possible Salinity Dstribution around Lake Bed in the Future

CHAPTER 3. WATER USE STRUCTURES

3.1 HYDRO-METEOROLOGICAL MONITORING NETWORK

Table 3.1.1 and Table 3.1.2 summarize rainfall gauging stations and discharge gauging stations, respectively. While Figure 3.1.2 and Figure 3.1.3 show their locations their inventory lists are tabulated in Annex 3.1.

In the Lake Urmia Basin, based on the provided precipitation and discharge data, it was confirmed that there were 242 rainfall gauging stations and 136 discharge gauging stations administered by WRC, a subsidiary organization of WRMC. These gauging stations record daily hydrological data. Discharge data is converted from water level observed at 7 a.m. by means of the relationship between water level and discharge (H-Q rating curve). According to an interview with a staff of WRC, revision of H-Q rating curves has not been conducted regularly.

As for condition of stations whether they are working or not, a number of stations appear to be operational as of 2013 judging from the stations having observed data. One hundred fifty-three (153) rainfall stations out of 242 were confirmed to be operational with sixty three (63) percent of working ratio, and eighty-four (84) discharge gauging stations out of 136 with sixty-two (62) percent. Annex 3.1 shows the inventory and condition of rainfall and discharge gauging stations. This may be caused by (i) termination of monitoring upon completion of project, (ii) lack of budget for maintenance.

The commanded area of a functional rainfall gauging station ranges between 150 to 450km^2, with an average of 271.8 km^2. For reference, in “Technical Criteria for River Works” published by The Japanese Ministry of Land, Infrastructure, Transport and Tourism, it was defined that the required commanded area of rainfall gauging station is less than 50km^2. To further improve the accuracy of monitoring of rainfall, monitoring network is better to be dense. As such, it is recommended that regular maintenance of monitoring stations should include repair of stations and parts when they malfunction.

Figure 3.1.1 Discharge Gauging Stations (Akhola, Downstream of AjiChay River)

Table 3.1.1 Summary of Rainfall Gauging Stations in the Lake Urmia Basin

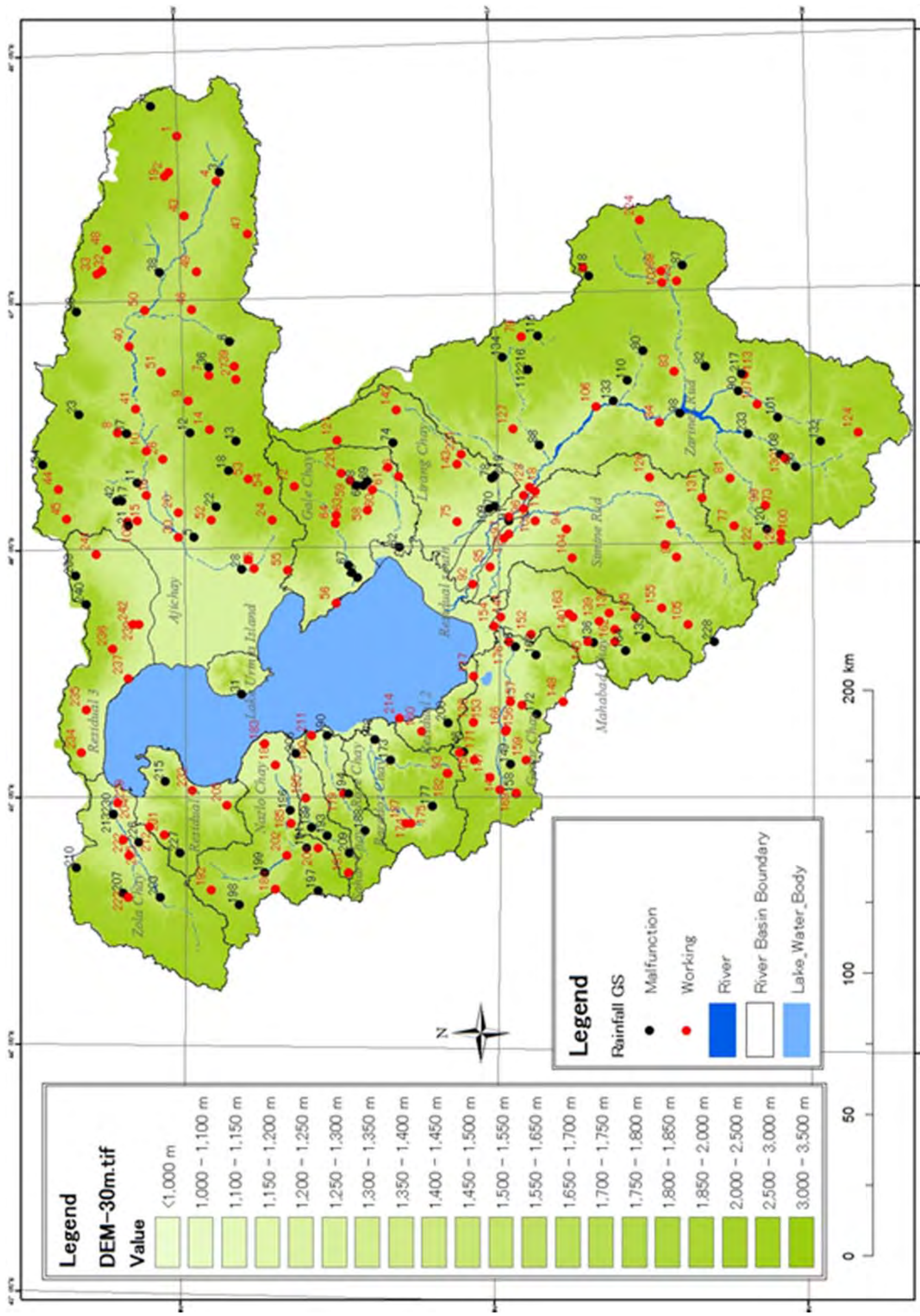
Basin Name	Catchment Area km^2)	Number of All Rainfall GS	Number of Working Rainfall GS	Commanded Area of All Rainfall GS (km^2)	Commanded Area of Working Rainfall GS (km^2)
Aji Chay	12,716.7	56	37	227.1	343.7
Baradoz Chay	1,361.7	8	5	170.2	272.3
Gale Chay	2,093.6	17	10	123.2	209.4
Gedar Chay	2,091.0	20	14	104.5	149.4
Lilang Chay	1,936.3	10	5	193.6	387.3
Mahabad Chay	1,507.0	14	11	107.6	137.0
Nazlo Chay	1,880.1	12	7	156.7	268.6
Rose Chay	457.8	6	2	76.3	228.9
Sahar Chay	711.7	6	3	118.6	237.2
Simineh Rud	3,782.7	13	12	291.0	315.2
Zarineh Rud	11,837.9	49	28	241.6	422.8
Zola Chay	2,258.4	11	5	205.3	451.7
Residual 1	1,060.4	6	4	176.7	265.1
Residual 2	375.1	4	3	93.8	125.0
Residual 3	1,840.0	9	7	204.4	262.9
Residual south	551.2	0	0	-	-
Lake Urmia Island	259.8	1	0	259.8	-
Urmia Lake	4,976.0	0	0	-	-
Whole Lake Basin	**51,697.2**	**242**	**153**	**171.9 (Average)**	**271.8 (Average)**

*Prepared by JST based on data provided by WRMC

Table 3.1.2 Summary of Discharge Gauging Stations in the Lake Urmia Basin

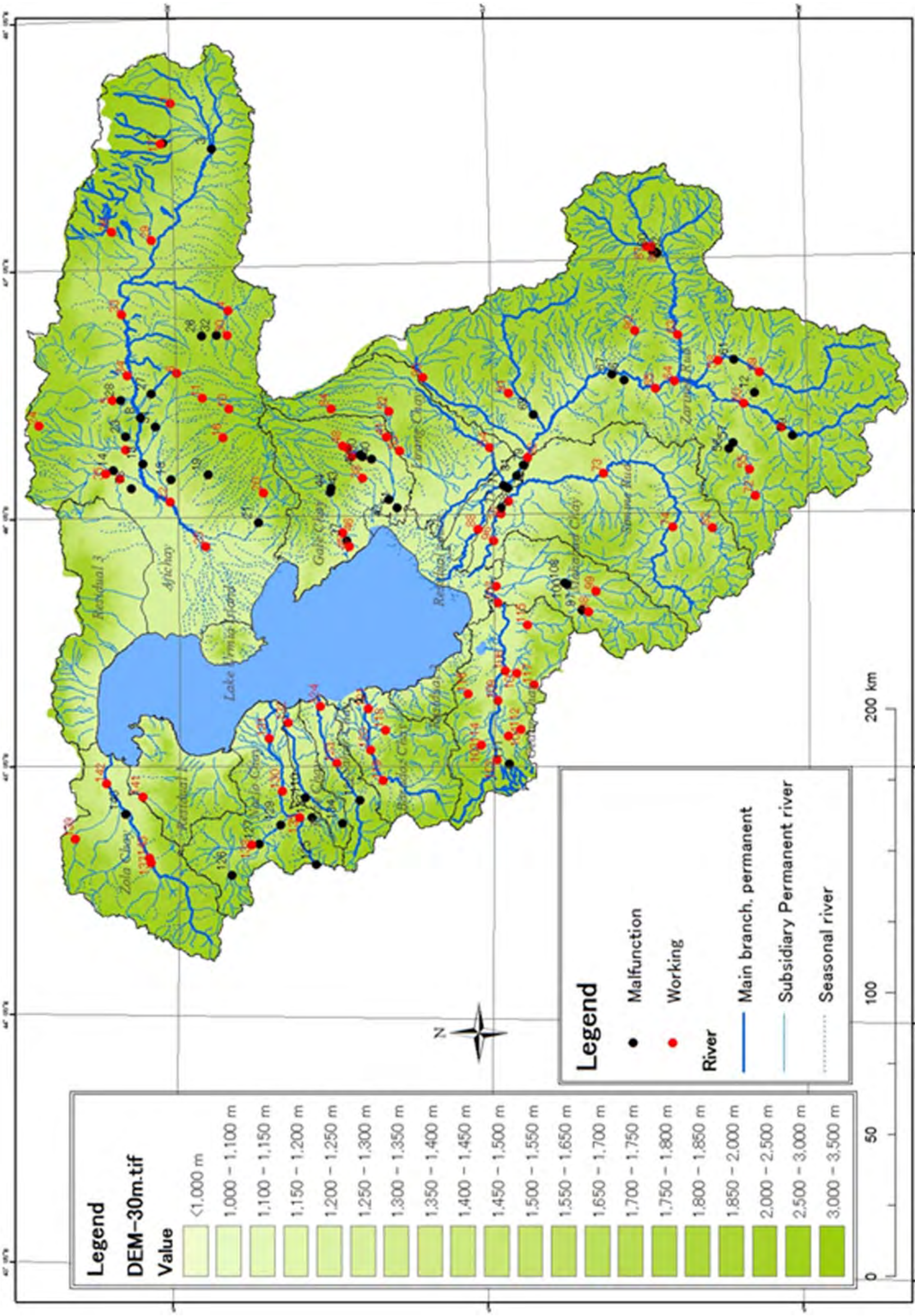
Basin Name	Catchment Area (km^2)	Number of All Discharge GS	Number of Working Discharge GS
Aji Chay	12,716.7	35	20
Baradoz Chay	1,361.7	4	4
Gale Chay	2,093.6	15	7
Gedar Chay	2,091.0	13	12
Lilang Chay	1,936.3	4	4
Mahabad Chay	1,507.0	6	3
Nazlo Chay	1,880.1	9	4
Rose Chay	457.8	3	1
Sahar Chay	711.7	3	2
Simineh Rud	3,782.7	7	6
Zarineh Rud	11,837.9	31	16
Zola Chay	2,258.4	5	4
Residual 1	1,060.4	1	1
Residual 2	375.1	0	0
Residual 3	1,840.0	0	0
Residual south	551.2	0	0
Lake Urmia Island	259.8	0	0
Urmia Lake	4,976.0	0	0
Whole Lake Basin	**51,697.2**	**136**	**84**

*Prepared by JST based on data provided by WRMC



*Prepared by JST based on data provided by WRMC
*Numbers correspond “No” in Annex 3.1

Figure 3.1.2 Locations of Rainfall Gauging Station



*Prepared by JST based on data from WRMC
*Numbers correspond "No" in Annex 3.1

Figure 3.1.3 Locations of Discharge Gauging Station

3.2 DAM AND WEIR

3.2.1 GENERAL VIEW OF DAMS AND WEIRS

This section of the report gives the descriptions of the dams and weirs in the Lake Urmia Basin as confirmed through a site reconnaissance conducted during the Survey in Iran from the middle of November to the middle of December 2014, as well as from the information obtained from the West Azerbaijan Regional Water Corporation and the East Azerbaijan Regional Water Corporation.

The construction of dams in the Lake Urmia Basin started with the construction of Mahabad Dam in the Mahabad River in 1971.At present, a total of 44 dams were constructed which include Bukan Dam (Shahid Kazemi Bukan-Zarineh Dam). The biggest portion of intake and water supplied by these dams is utilized for irrigation of agriculture. Intake and water supply for drinking water and industrial water are also provided by these dams.

The dams are managed mainly by the Regional Water Corporation of each province under the Water Resources Management Company (WRMC) of the Ministry of Energy (MOE). There are also other dams managed by the electric companies and drinking water supply companies of the cities (Note: This is based on the information from WRMC. However, information about management agency of each dam could not be collected yet.) .Furthermore, about 30 new dams are being proposed or studied. Figure 3.2.1 to Figure 3.2.4 show photos of some of the damssuch as Bukan Dam, Shahr Chay Dam, Mahabad Dam and the under-constructed Shahid Madani Dam, all of which were visited during the Survey. In terms of storage volume, Bukan Dam, Shahrchay Dam and Mahabad Dam have the 1st, 2nd and 3rd largest storage volume among the existing dams.

Dam Body of Bukan Dam

Reservoir of Bukan Dam

Downstream View from Bukan

Release of Environmental Flow (about $3m^3/s$) from Bukan Dam

Note: Main purposes of Bukan Dam are drinking water supply, agricultural water supply, environmental flow, and flood control.
Photos were taken by the JICA Survey Team in the beginning of December 2014.

Figure 3.2.1 Condition of Bukan Dam (Catchment Area 6,890km^2, Storage Volume 486MCM) in the Zarineh Rud River Basin

Dam Body and Reservoir of Sharchay Dam

Reservoir and the Mountains of Water Source of Sharchay Dam

Note: Main purposes of Sharchay Dam are drinking water supply and agricultural water supply.
Photos were taken by the JICA Survey Team in the end of November 2014.

Figure 3.2.2 Condition of Shahr Chay Dam in the Shahr Chay River Basin (Catchment Area 330km^{2,}, Storage Volume 213MCM)

Dam Body of Mahabad Dam

Reservoir and Intake Tower of Mahabad Dam

Downstream View from Mahabad Dam

Note: Main purposes of Mahabad Dam are drinking water supply and agricultural water supply.
Photos were taken by the JICA Survey Team in the beginning of December 2014.

Figure 3.2.3 Condition of Mahabad Dam (Catchment Area 806km^2, Storage Volume 190MCM) in the Mahabad River Basin

Dam Body of Shahid Madani Dam

Reservoir Area and Intake Tower (Left Side) of Shahid Madani Dam

Downstream View from Shahid Madani Dam

Note: Main purposes of Shahid Madani Dam are agricultural water supply and flood control.
Photos were taken by the JICA Survey Team in the beginning of December 2014.

Figure 3.2.4 Condition of the Under-Constructed Shahid Madani Dam (Catchment Area 7,723km^2, Storage Volume 280MCM in the Aji Chay River Basin

In terms of weir, many relatively old weirs exist and new weirs have been constructed in the recent years. The relatively old weirs supply irrigation water to the irrigation areas, where irrigation is conducted in the traditional way. The old weirs as well as their gate operations are managed by farmers Among the traditional water intakes, there are instances when the rivers are closed by sand bags or sediment and soil during the dry season and water is taken from the rivers (information from the East Azerbaijan Regional Water Corporation). The new weirs were constructed and managed by the Regional Water Corporation of the provinces. Figure 3.2.5 and Figure 3.2.6 show photos of some of the weirs visited during the Survey.

Note: Water is taken from the left and right banks, and irrigation water is supplied to total 200 to 300ha. There are many weirs like this weirwhich supply irrigation water to 7,000ha (information from the East Azerbaijan Regional Water Corporation).
Photos were taken by the JICA Survey Team in the beginning of December 2014.

Figure 3.2.5 Relatively Old Intake Weirs for Agriculture and Irrigation Canal in the Aji Chay River

Note: The original plan was to supply irrigation water to 40,000ha, however, the plan was changed to supply irrigation water to 25,000ha only. By December 2014, main irrigation canals for 7,000 to 10,000ha have been completed, but new canals will not be constructed any more (information from the East Azerbaijan Regional Water Corporation).
Photos were taken by the JICA Survey Team in the beginning of December 2014.

Figure 3.2.6 Under-Constructed Intake Weir for Agriculture in the Aji Chay River (Downstream Side)

3.2.2 INVENTORY OF DAMS AND WEIRS

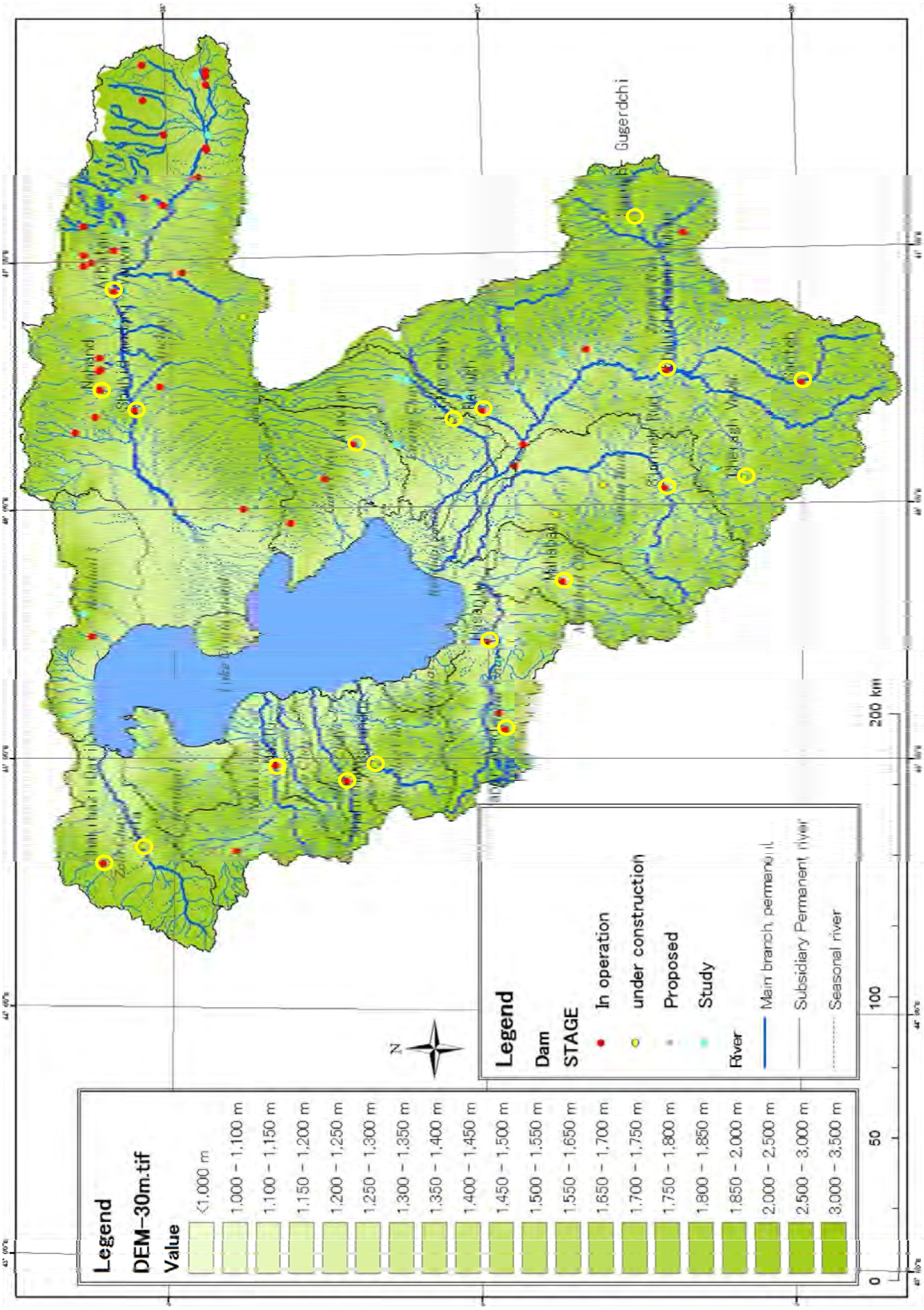
Inventory of the dams and weir(s) in the Urmia Basin is shown in Table 3.2.1 (for the dams with storage volume of more than 10MCM) and in Annex 3.2 (all dams and weir(s)). Figure 3.2.7 shows the Location Map. As for the weir(s), only Noruzlu Diversion Weir in the Zarineh Rud River is included in the Inventory and the Location Map. Information about most of the weirs have not been collected yet by this Survey. In addition, the Inventory and the Location Map include the existing under-operated dams and weirs, under-constructed dams, proposed dams and the dams under study.

Table 3.2.1 Inventory of Dams in the Urmia Basin (Dams of Storage Volume more than 10MCM)

No.	Dam Name	River Name	Basin Name	Province	Purpose	Constructed Year (Western)	Constructed Year (Iranian)	Storage Vol. (MCM)	Catchment Area (km2)
A. Under-operated Dams									
1	Shahid Kazemi Bukan-Zarineh Rud	Zarineh Rud	Zarineh Rud	West Azerbayjan	AW, EL	1972	1350	486.00	6,890.00
2	Shahrchay	Shahr Chay	Shahr Chay	West Azerbayjan	DW, IW, AW	2006	1384	213.00	330.00
3	Mahabad	Mahabad Chay	Mahabad Chay	West Azerbayjan	DW, IW, AW, EL	1971	1349	190.00	806.00
4	Barugh	Ghorichay (Barugh)	Zarineh Rud	West Azerbayjan				100.00	
5	Hasanlu	Out of Gedar Chay Bed	Gedar Chay	West Azerbayjan	AW	2001	1379	94.00	35.00
6	Zola	Zola Chay	Zola Chay	West Azerbayjan	DW, IW, AW, EL	2010	1388	72.00	945.00
7	Alavian	Sofi Chay	Sofi Chay	East Azerbayjan	DW, IW, AW, EL	1996	1374	57.00	314.00
8	Ghale Chay Ajabshir	Ghaleh Chay	Gale Chay	East Azerbayjan	DW, IW, AW, EL	2007	1385	38.80	250.00
9	Sarough- Gougerdchay	Sarough Chay (Ghare Ghieh)	Zarineh Rud	West Azerbayjan	DW, IW, AW	2010	1388	35.00	332.00
10	Arbatan	Out of Zarangh Bed	Aji Chay	East Azerbayjan				25.00	
11	Shakrbazi-Darik (Darek Salmas)	Darik Chay	Darik Chay	West Azerbayjan	AW	2009	1387	22.00	
12	Nahand	Nahand Chay	Aji Chay	East Azerbayjan	DW, IW	1997	1375	21.10	216.00
B. Under-constructed Dams									
1	Simineh Rud -Bukan	Simineh Rud	Simineh Rud	West Azerbayjan	DW, IW, AW, EL, FC, AR	2012	1390	312.00	1,441.00
2	Shahid Madani-Vanyar	Aji Chay	Aji Chay	East Azerbayjan	AW	2010	1388	280.00	7,723.00
3	Nazlu	Nazlu Chay	Nazlu Chay	West Azerbayjan	DW, IW, AW, EL	2011	1389	145.00	1,715.00
4	Oshnavie-Chapar Abad	Godar Chay (Kanirash)	Gedar Chay	West Azerbayjan	DW, IW, AW, EL	2012	1390	122.00	361.00
5	Baranduz	Baranduz Chay	Baranduz Chay	West Azerbayjan	DW, IW, AW, FC, AR	2014	1392	84.00	594.00
6	Cheragh Veys	Cham Khan (Saghez Branch) Zarineh Rud	Zarineh Rud	Kurdistan	DW, IW, AW	2013	1391	68.60	363.00
7	Lilan Chay	Lilan Chay	Zarineh Rud	East Azerbayjan	AW, EL, FC, AR	2012	1390	35.50	571.00
C. Proposed Dams									
1	Ahmad	Moghanjigh Chay	Lirang Chay	East Azerbayjan	AW			14.00	
D. Under-studied Dams									
1	Mardagh Chay - Ghare Naz	Mardagh Chay	Sofi Chay	East Azerbayjan	AW			110.60	390.00
2	Ajorlu	Ajorlu	Zarineh Rud	West Azerbayjan				93.00	
3	Santeh	Khor Khore	Zarineh Rud	Kurdistan	AW, EL, FC, AR			67.08	884.00
4	Godarchay- naghade	Godar Chay	Gedar Chay	West Azerbayjan	AW, EL			49.00	
5	Atmian Sarab	Atmian Chay	Aji Chay	East Azerbayjan	AW			25.00	
6	Sayanjagh	Kharaju Chay	Zarineh Rud	East Azerbayjan				18.50	
7	Khaje Chay	Sarajuy	Lirang Chay	East Azerbayjan	AW			18.00	
8	Asgar Abad	Aji Chay	Aji Chay	East Azerbayjan				16.50	
9	Khanum Goli	Jushato Sofla	Zarineh Rud	West Azerbayjan				16.00	
10	Markhaz	Markhaz	Zarineh Rud	Kurdistan	AW, FC, AR			14.44	58.00
11	Sinikh Chay Dam	Sinikh Chay (Aji Chay)	Aji Chay	East Azerbayjan				13.00	
12	Kardkan- Ghapltan	Kardkand	Zarineh Rud	Kurdistan				11.50	
13	Kharaju Chay	Kharaju Chay	Zarineh Rud	East Azerbayjan	AW			10.50	188.00

Data source: Ministry of Energy, Water Resources Management Company (WRMC).
Note: Purpose: DW_drinking water supply, IW_industrial water supply, AW_agricultural water supply, EL_electric power generation, AR_artificial recharge, FC_flood control and EN_environment.

Among the existing dams, Bukan Dam (Shahid Kazemi Bukan-Zarineh Dam) located in the Zarineh Rud River Basin has the biggest storage volume of 486MCM and a big catchment area of 6,890km^2.Zarineh Rud River Basin is one of the major river basins occupying the southeasr part of the Lake Urmia Basin. Shahrchay Dam in the Shahr Chay River Basin which is located in the western side and central part of the Lake Urmia Basin, has the second biggest storage volume of 213MCM and catchment area at the dam site of 330km^2. Mahabad Damwhich is located in the Mahabad Chay River Basin in the southwest part of the Lake Urmia Basin has the third biggest storage volume of 190MCM and big catchment area of 806km^2.



*Prepared by JST based on data from WRMC
*Named only for the dams with more than 10MCM of water storage

Figure 3.2.7 Location of Dams constructed, under construction and Proposed

Table 3.2.2 shows the total number of dams, total storage volume, and average storage volume per dam (=total storage volume/ number of dams) in each river basin in the Lake Urmia Basin. There are 44 under-operated dams with a total storage volume of 1,413MCM. There area 11 under-constructed dams with a total storage volume of 1,053MCM.

In terms of the characteristics of the under-operated dams by river basin, total storage volume of Zarineh Rud River Basin located in the southeastern part of the Lake Urmia Basin, is the biggest with 625MCM and an average storage volume per dam of 104MCM. Total storage volume of the Shahr Chay River located in the western side and central part of the Lake Urmia Basin, is the second biggest with 213MCM by only one dam. Total storage volume of the Mahabad Chay River Basin located in the southwestern part of the Lake Urmia Basin, is the third biggest with 190MCM by only one dam.

The Aji Chay River Basin which is one of the major river basins located in the northeastern part of the Lake Urmia Basin, has 26 dams. However, its total storage volume is small at 99MCM and average storage volume per dam is also small at 4MCM.

Table 3.2.2 Number of Dams and Storage Volume by River Basins

Basin Name	Number of Dams	Province	Total Storage Volume (MCM)	Average Storage Volume (MCM/ Number of Dams)
A. Under-operated Dams				
Aji Chay	26	East Azerbayjan	99.43	3.82
Baranduz Chay	1	West Azerbayjan	0.35	0.35
Darik Chay	1	West Azerbayjan	22.00	22.00
Gale Chay	1	East Azerbayjan	0.25	0.25
Gedar Chay	2	West Azerbayjan	94.13	47.07
Mahabad Chay	1	West Azerbayjan	190.00	190.00
Nazlu Chay	1	West Azerbayjan	0.50	0.50
Residual 4	1	East Azerbayjan	0.67	0.67
Shahr Chay	1	West Azerbayjan	213.00	213.00
Sofi Chay	1	East Azerbayjan	57.00	57.00
Gale Chay	1	East Azerbayjan	38.80	38.80
Zarineh Rud	6	West Azerbayjan	625.06	104.18
Zola Chay	1	West Azerbayjan	72.00	72.00
合計	44		1413.19	32.12
B. Under-constructed Dams				
Aji Chay	2	East Azerbayjan	282.50	141.25
Baranduz Chay	1	West Azerbayjan	84.00	84.00
Gedar Chay	1	West Azerbayjan	122.00	122.00
Nazlu Chay	1	West Azerbayjan	145.00	145.00
Simineh Rud	2	West Azerbayjan	313.60	156.80
Zarineh Rud	4	West Azerbayjan	106.50	26.63
合計	11		1053.60	95.78
C. Proposed Dams				
Lirang Chay	1	East Azerbayjan	14.00	14.00
Residual 4	1	East Azerbayjan	6.00	6.00
合計	2		20.00	10.00
D. Under-studied Dams				
Aji Chay	8	East Azerbayjan	58.18	7.27
Baranduz Chay	1	West Azerbayjan	0.00	0.00
Gedar Chay	1	West Azerbayjan	49.00	49.00
Lirang Chay	2	Ardebil and East Azerbayjan	18.68	9.34
Nazlu Chay	1	West Azerbayjan	0.00	0.00
Residual 1	1	West Azerbayjan	8.60	8.60
Residual 4	2	East Azerbayjan	9.20	4.60
Simineh Rud	3	West Azerbayjan	15.30	5.10
Sofi Chay	2	East Azerbayjan	111.50	55.75
Zarineh Rud	7	West Azerbayjan, East Azerbayjan and Kurdistan	231.02	33.00
合計	28		501.48	17.91

Data source: Ministry of Energy, Water Resources Management Company (WRMC).

3.2.3 CONDITION OF DAM OPERATION

(1) Dams with Collected Operation Data

Only the operation data of 12 dams that were downloaded from the webpage of the Water Resources Management Campany (WRMC) of the Ministry of Energy (MOE) were collected in the Survey. Table 3.2.3 shows the dams and their data period.

The total storage volume of these 12 dams is 1,203MCM which is 85% of the total storage volume of 1,413MCM of the 44 existing dams. In addition, the total catchment area of these 12 dams with collected operation data is 10,078km2; This is 94% of the total catchment area of 19 existing dams with information on catchment areas among the 44 existing dams. It is idealistic that daily operation data of all of the dams can be collected. However, the 12 dams with collected operation data represent majority of the dams in terms of total storage volume and total catchment area. Hence, it is considered that the data about the 12 dams can be utilized in the further analysis for estimating intake water quantity and water supply quantity from surface water.

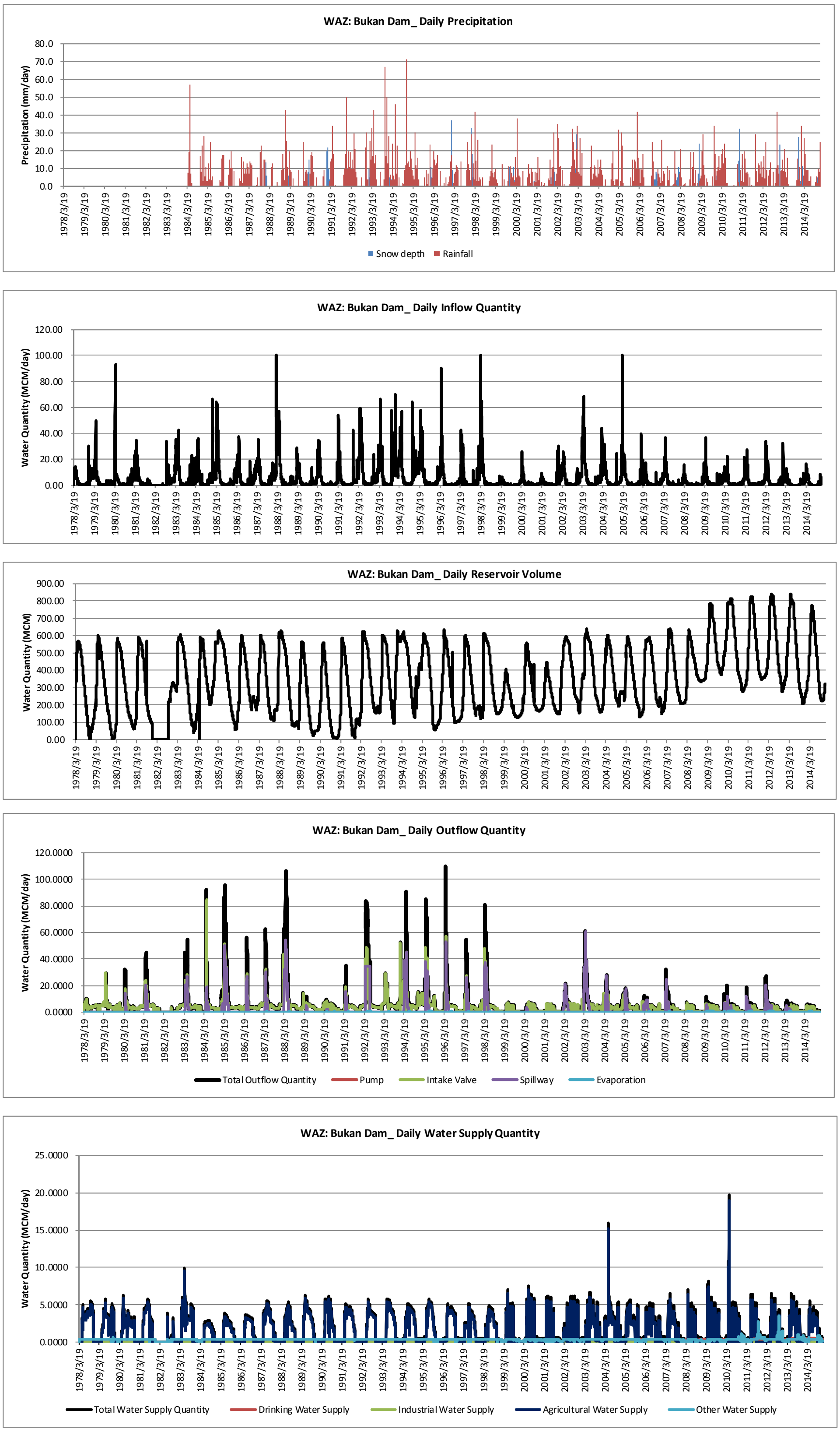
Table 3.2.3 Dams with Collected Daily Operation Data

No.	Dam	River Basin	Province	Duration of Daily Data （Year/Month）	Kind of Data
A-13	Kardkandi	Aji Chay	East Azerbaijan	2011/3～2014/12	Temperature, precipitation, reservoir water level, reservoir water area, inflow water quantity, outflow water quanity (evaporation, leakage, pump intake, drainage, electricity generation, sediment discharge, intake valve, spillout and water supply quanity (drinking water supply, industrial water supply and agricultural water supply, and other water supply)
A-19	Nahand	Aji Chay	East Azerbaijan	2000/3～2014/12	ditto
A-23	Tajyar Sarab	Aji Chay	East Azerbaijan	2009/4～2014/12	ditto
A-28	Shakrbazi-Darik (Darek Salmas)	Darik Chay	West Azerbaijan	2012/6～2014/12	ditto
A-31	Hasanlu	Gedar Chay	West Azerbaijan	2002/3～2014/12	ditto
A-32	Mahabad	Mahabad Chay	West Azerbaijan	1971/3～2014/12	ditto
A-35	Shahrchay	Shahr Chay	West Azerbaijan	2006/5～2014/12	ditto
A-36	Alavian	Sofi Chay	East Azerbaijan	1997/9～2014/12	ditto
A-37	Ghale Chay Ajabshir	Gale Chay	East Azerbaijan	2009/4～2014/12	ditto
A-42	Sarough-Gougerdchay	Zarineh Rud	West Azerbaijan	2012/6～2014/12	ditto
A-43	Shahid Kazemi Bukan- Zarineh Rud (Bukan Dam)	Zarineh Rud	West Azerbaijan	1978/3～2014/12	ditto
A-44	Zola	Zola Chay	West Azerbaijan	2011/9～2014/12	ditto

Note: 1) The number corresponds to the number in Annex 3.2
Data source: Web-page of WRMC: http://dams.wrm.ir
Based on the data of WRMC, the JICA Survey Team made this table.

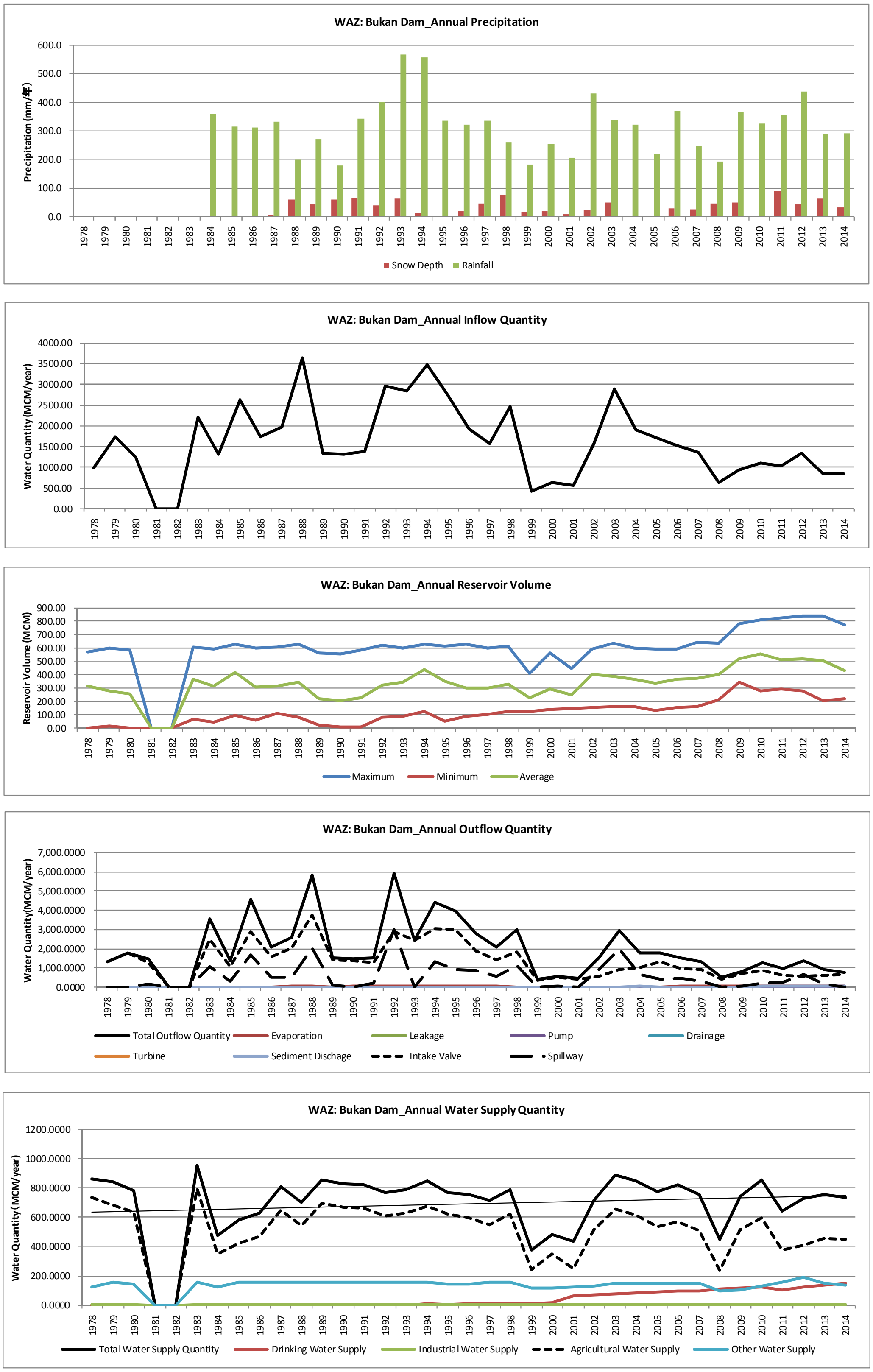
(2) Condition of Operation of Dams

As example of the condition of historical dam operations, Figure 3.2.8 and Figure 3.2.9 show the daily and annual operation of Bukan Dam. In addition, Figure 3.2.10 and Figure 3.2.11 show conditions of daily and annual operation of the 12 dams. Total storage volume and total water supply quantity have been increased rapidly fromYear 1997 to 1998. Total water quantity of the 12 dams were utilized for estimating water use quantity described in the Section 4.4. Furthermore, the operation data of each dam is utilized in the simulation model described in the Chapter 5.



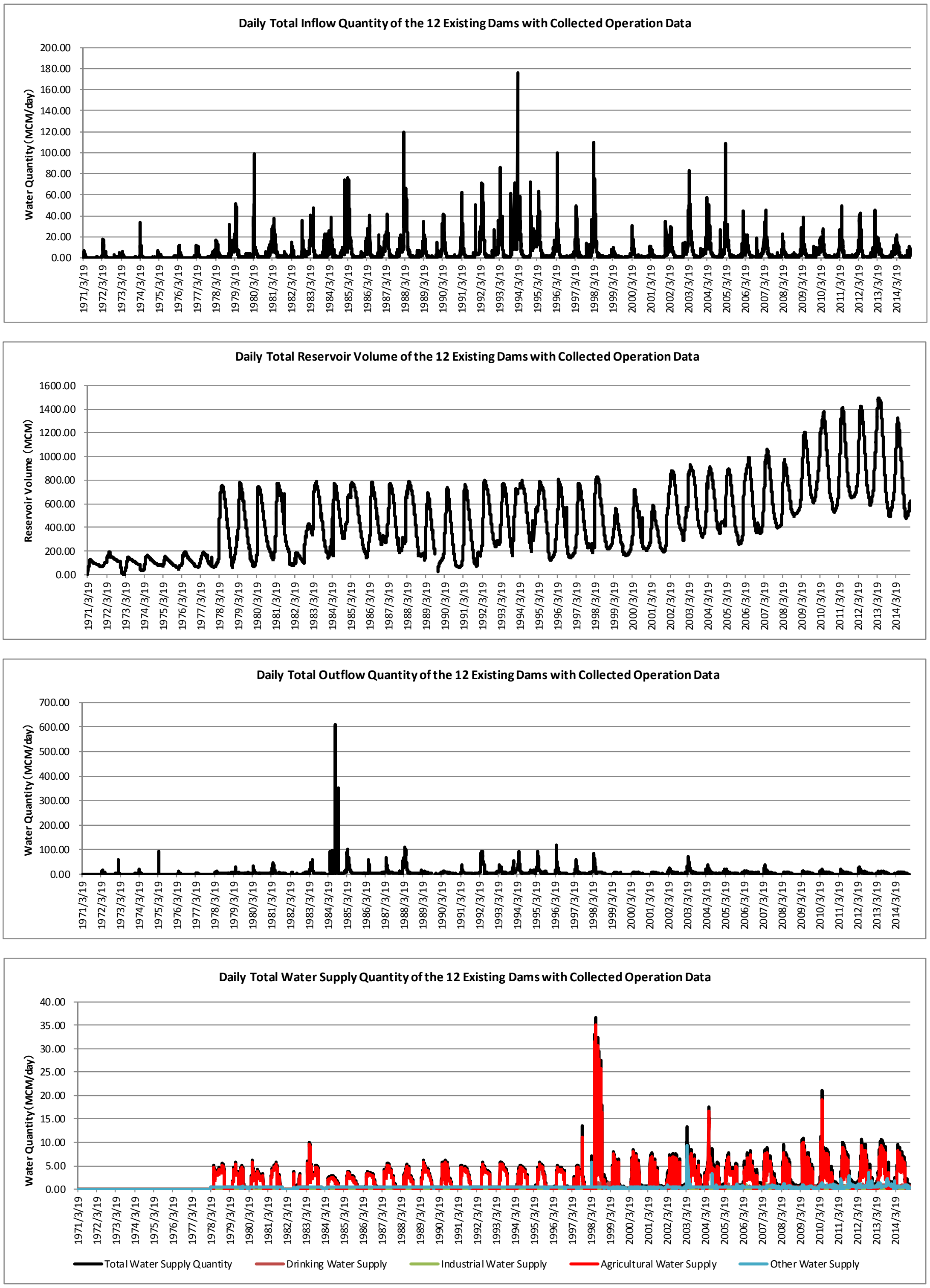
*Prepared by JST based on data provided by WRMC

Figure 3.2.8 Condition of Historical Daily Reservoir Operation of Bukan Dam



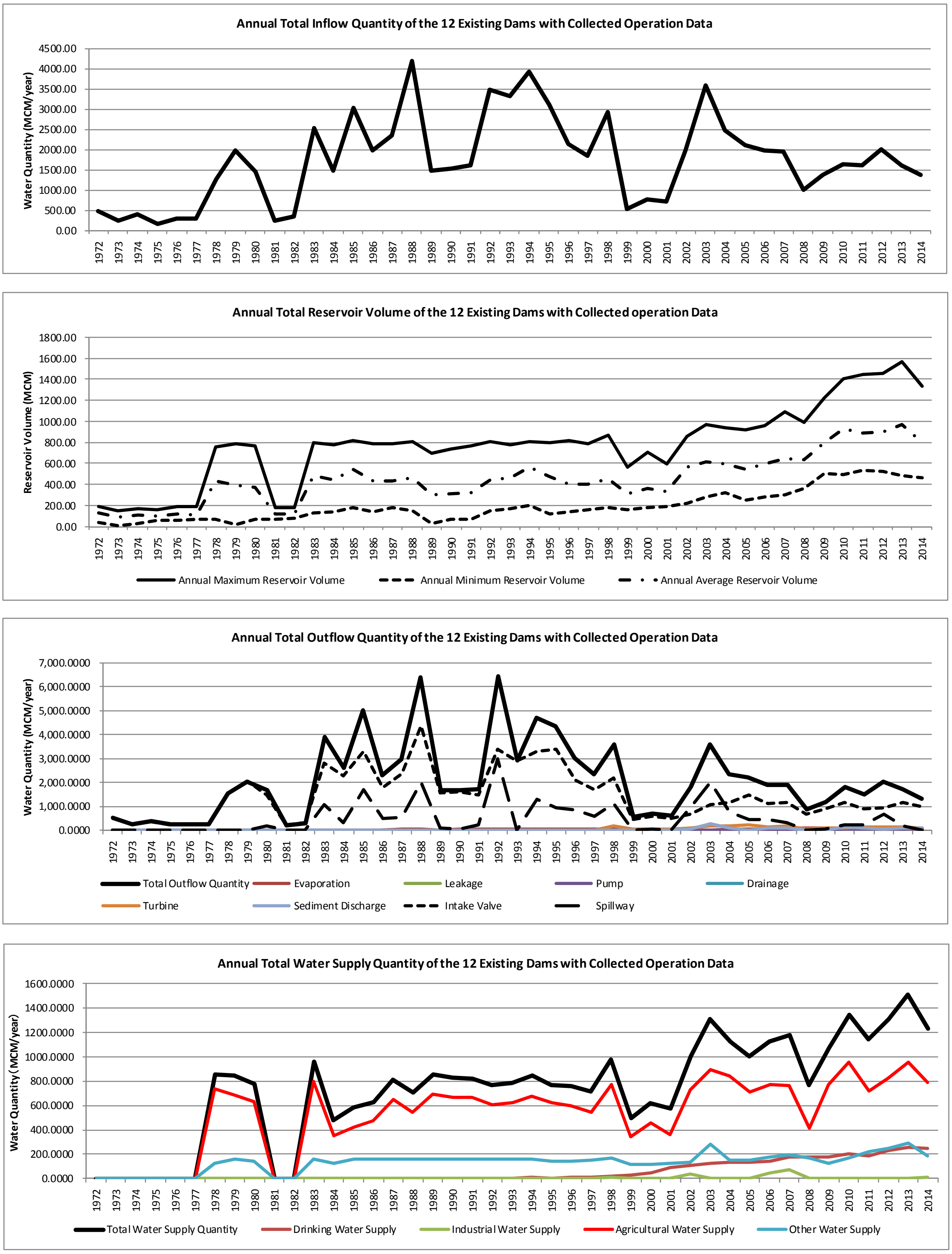
*Prepared by JST based on data provided by WRMC

Figure 3.2.9 Condition of Historical Annual Reservoir Operation of Bukan Dam



*Prepared by JST based on data provided by WRMC

Figure 3.2.10 Condition of Historical Total Daily Operation Quantity of the 12 Existing Dams with Collected Operation Data



*Prepared by JST based on data provided by WRMC

Figure 3.2.11 Condition of Historical Total Annual Operation Quantity of the 12 Existing Dams with Collected Operation Data

3.3 AGRICULTURAL FACILITIES RELATED TO WATER USE

As for the agricultural facilities, dams and weirs were described in Subsections 3.2.1 and 3.2.2, and irrigation canals, drainage canals and diversion facilities and other facilities in the irrigation systems, which receive agricultural water supply from the dams and weirs (Examples: Figure 3.3.1 and Figure 3.3.2). However, information related to these facilities collected by the Survey is very small.

In addition to the operation data of the dams, operation data of weirs are important to grasp correctly the intake water quantity and water supply quantity to the irrigation area etc. along the rivers. In the meantime, by using the collected operation data of the 12 dams, intake water quantity and water supply quantity from the whole Lake Urmia Basin can be estimated. However, in the future, it is preferable to collect data and conduct monitoring of intake and water supply quantity from the weirs to calculate more accurately intake and water supply quantity from surface water and to conduct simulation.

The following shows the conditions of the irrigation canals visited during the Survey. Both canals are managed by the East Azerbaijan Regional Water Corporation, but there are similar ones in the West Azerbaijan Province as well.

Figure 3.3.1 Irrigation Canal and Diversion Facility of the Under-developed Irrigation System in the Southern Area of Tabriz (in the Aji Chay River Basin)

Figure 3.3.2 Irrigation Canal in the Right Bank Area of the Zarineh Rud River, which receives Agricultural Water Supply from Bukan Dam

In addition to the list of dams, there is a list of irrigation and drainage networks in Table 2.2 of the "Studies on Updating National Water Master Plan in Basins of Aras, Urmia, Talesh-Anzali Wetland, Great Sefidroud, Sefidroud-Haraz, Haraz-Ghareh Sou, Gorganroud and Atrak: Fourth Volume, Report on Surface Water Resources (Quantitative and Qualitative) Urmia Watershed, November 2012" of the Ministry of Energy. Based on the said table, conditions of the irrigation and drainage systems are as itemized below. It is noted that there is no description about size of the irrigation areas.

1) Existing (Under-operation) and Under-construction
   East Azerbaijan Province: 39 systems
   West Azerbaijan Province: 5 systems
   Kurdistan Province: 1 system
2) Under-administration
   East Azerbaijan Province: 4 systems
3) Under-study
   East Azerbaijan Province: 5 systems

3.4 WELLS

In the Urmia Lake Basin, wells are managed by WMCs of the East and West Azerbaijan provinces. Users of wells regularly obtain permission for water use. Figure 3.4.1 shows changes in annual permitted uptake water, Figure 3.4.2 shows the present status of percentages of permitted uptake water amount from well for the purposes, and Figure 3.4.3 shows the spatial distribution of permitted wells in the present condition. An approximate 89,000 wells have already been constructed from which 1,600MCM of uptake water is permitted mainly for agricultural water use a ninety (90) percent Wells are distributed with high density in plain areas.

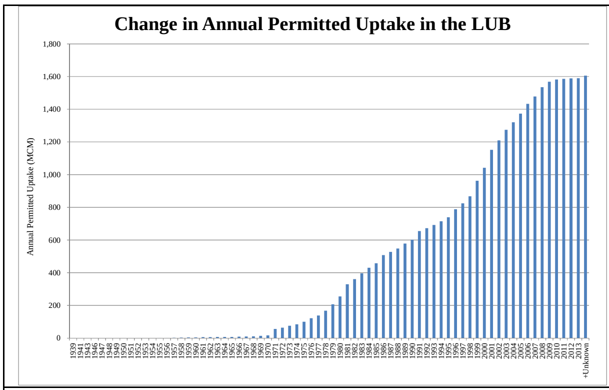


Figure 3.4.1 Changes in Annual Permitted Uptake Water in the Lake Urmia Basin

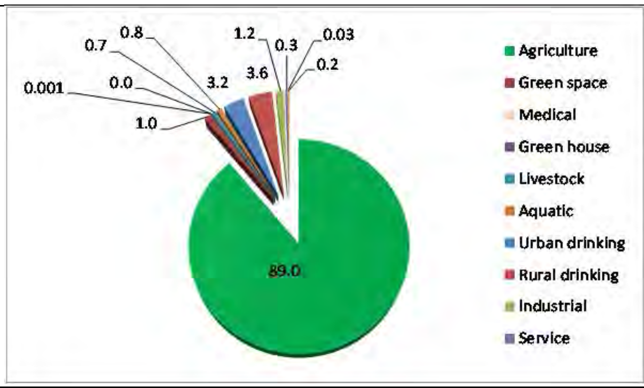


Figure 3.4.2 Percentages of Permitted Uptake Water Amount from Wells for Purposes in the Lake Urmia Basin

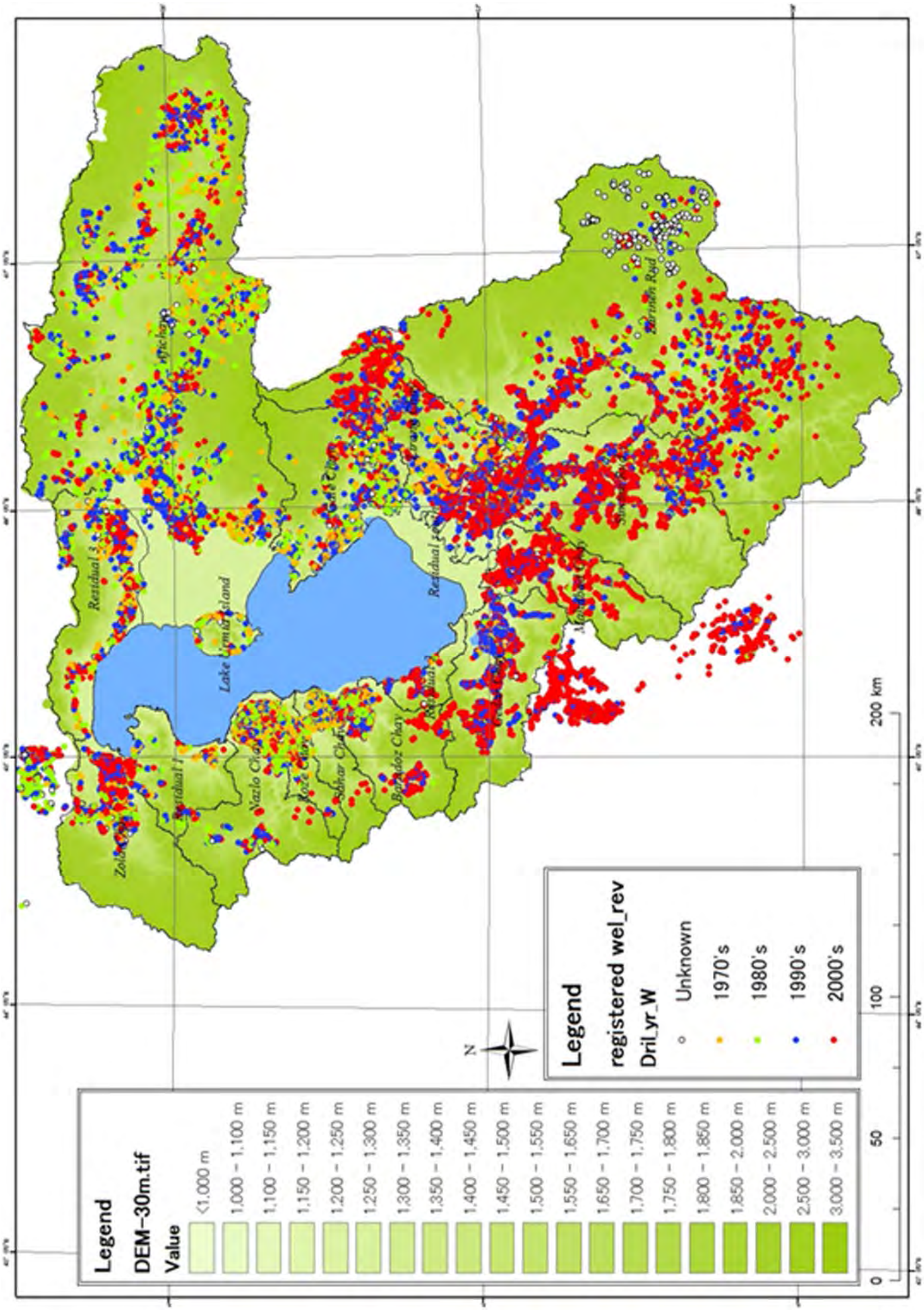
*Prepared by JST based on data from WRMC

Table 3.4.1 Permitted Uptake Water Amount and Percentages for Purposes

Unit: MCM

	Agriculture	Green space	Medical	Green house	Livestock	Aquatic	Urban drinking	Rural drinking	Industrial	Service	Packed water	Other	Total
Ajichay	300.3	14.1	0.0	0.1	3.1	0.6	33.5	22.5	8.0	2.2	0.0	1.5	386.0
Baradoz Chay	63.4	0.0	0.0	0.0	0.9	4.9	0.0	1.2	4.3	0.1	0.0	0.1	74.9
Gale Chay	112.9	1.1	0.0	0.0	1.6	1.0	2.9	3.9	1.3	0.4	0.0	0.1	125.2
Gedar Chay	103.4	0.1	0.0	0.1	0.3	1.1	0.1	1.6	0.3	0.0	0.0	0.0	107.1
Lake Urmia Island	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	3.9
Lirang Chay	83.7	0.0	0.0	0.0	0.4	0.2	0.8	1.9	0.4	0.2	0.0	0.1	87.7
Mahabad Chay	16.9	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.1	0.0	0.0	0.0	17.5
Nazlo Chay	86.7	0.0	0.0	0.0	0.5	1.2	0.2	0.7	0.4	0.0	0.0	0.1	89.8
Residual 1	32.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.2	33.4
Residual 2	7.5	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	7.9
Residual 3	79.0	0.4	0.0	0.0	0.6	0.2	3.8	4.2	1.0	0.2	0.0	0.3	89.7
Residual south	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Roze Chay	27.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	28.6
Sahar Chay	18.7	0.0	0.0	0.0	0.1	0.1	0.1	1.3	0.2	0.0	0.0	0.1	20.8
Simine Rud	230.0	0.3	0.0	0.1	1.2	0.0	2.1	6.7	2.0	0.5	0.3	0.2	243.4
Zarineh Rud	129.2	0.5	0.0	0.2	2.1	2.6	4.2	5.3	1.0	0.9	0.2	0.5	146.9
Zola Chay	129.7	0.3	0.0	0.0	0.1	0.0	2.7	6.0	0.4	0.0	0.0	0.3	139.4
Total	1,425.6	16.8	0.0	0.6	11.2	12.3	50.6	57.3	19.6	4.5	0.5	3.6	1,602.5
Percentage	89.0	1.0	0.001	0.0	0.7	0.8	3.2	3.6	1.2	0.3	0.03	0.2	100.0

*Prepared by JST based on data from WMC



*Prepared by JS based on data provided from WMC

Figure 3.4.3 Distribution of Well Permited by WMC (Colored by Constructed Period)

CHAPTER 4. STUDY ON ROUGH WATER BALNCE OF LAKE URMIA

In this Chapter, in order to understand thoroughly the mechanism of degradation of water level in Lake Urmia and to study the preliminary direction for improvements, rough water balance was included in the study by considering water use quantity of surface water and groundwater. Furthermore, the purpose of conducting basic analysis is to provide useful data for the detailed water balance analysis by MIKE SHE while the study of the rough water balance is to provide useful information for securing accuracy of the MIKE SHE Model.

4.1 BASIC DATA AND INFORMATION COLLECTED

From November 2014 to February 205, the period when the JICA Survey Team conducted a field survey, basic data/information that were necessary for development of the distributed hydrological models were collected through WRMC as shown in Table 4.1.1. Though most of the data requested by the JICA Survey Team were provided, the data owned by the other relevant organizations (e.g. statistical data, detailed information on irrigation scheme which can be input into the model, water demand) were not collected. Alternatively, water demand was estimated by means of the collected data on water supply and water requirement for each irrigation unit reported in the existing report.

Table 4.1.1 Status of Collection of Basic Data/Information (as of Feburuary 2015)

No.	Clasisifcation	Item	Unit /Format	Provided by	Status
1	Meterological data	Precipitation, Pan evaporation, Aire Temperature, Relative humidity Information on Gauging Station	Daily (daily/monthly for evaporation)	WRMC, IMO	Collected
2	Hydrological data	River discharge, lake water level	Daily	WRMC	Collected
3	Geological data	Surface geology, longitudinal profile, drilling test result	TIFF, CAD	WMC, Iranian Geological Service	Collected
4	Topological data	Elevation, Bathymetry data, River network/cross section, topological map	DEM、SHP	WRMC, Water Research Authority	Collected (Cross sectios were modeled by JST)
5	Land use	Land use ro two period for lake water level: (i) stabilization period and (ii) declining period	SHP	WRMC	Collected for land use data of 1987 and 2007
6	Natural condition	Information on lake basin, environment	Report, etc.	WRMC	Report of M/P of Lake Urmia Basin was collected
7	Dam	Outflow, water supply for sectors, Information on dams	Daily	WRMC	Partly collected for primary dam General information waas collected
		Operation rule	Report, etc.	-	Not collected
8	Water intake facility	Water intake amount (planned, observed), Water intake pattern, Information on commanded area, etc.	Report, etc.	-	Not collected
9	Groundwater	Water intake amount, groundwater level	Water intake: monthly	WMC	Collected
10	Water demand	Water demand for sectors	Report, etc.	-	Not collected

11	Statistical data	Population, Irrigated area, cropping area, Industry production, etc.	Yearly	Statistical Centre of Iran	Collected only for population in 2011
12	Irrigation	Water requirement, cropping pattern, irrigation requirement, information on irrigation scheme	Report, etc.	WRMC	Referred to irrigated water demand for irrigation units were collected

4.1.1 Similar Studies by Relevant Organizations

In the "Workshop on Integrated River Basin Modeling, Emphasizing on Lake Urmia Basin" held by Tabiat Modares University on 17 November 2014 case studies conducted by Iranian researchers on the Lake Urmia Basin were introduced. Included in the case studies introduced was on modeling for the Lake Urmia Basin which targeted water balance of the lake water using inflow into the lake as boundary condition (e.g. hydraulic model using MIKE FLOOD for evaluating the fluctuation of lake water level, water balance analysis of lake water under the physical conditions for maintaining lake water lake level such as transfer of whole water at north side into the south side). None of the studies were confirmed to be similar to this Survey by the JICA Study Team in the Workshop, which aimed to evaluate water cycle and water balance including groundwater flow in the basin scale. The schedule of the Workshop is presented below.

Workshop on Integrated River Basin Modeling,
Emphasizing on Lake Urmia Basin
Tarbiat Modares University, 17-Nov-2014
(*Time table of the presentations)*

Time	Topic	Speaker
8:00-8:30	Registration	
8:30-8:45	Recitation of Quran and National Anthem	
8:45-9:05	Welcome speech and objective of the workshop	Dr. S. Morid
9:05-9:15	Last Status of Lake Urmia	Dr. N. Agh
9:15-9:30	Speech by the secretary of the working group on Lake Urmia Restoration Program	Dr. I. Kalantari
9:30-10:00	Modeling of changes in irrigation system and cropping pattern on saving water in favor of Lake Urmia (A case study on Zarinehrud Subbasin)	Dr. M. Delavar
10:00-10:30	System of water accounting	Dr. A. Bagheri
10:30-11:00	Break	
11:00-11:30	Introduction to JICA's upcoming study on the hydrologic cycle of Lake Urmia	Mr. Toshihiro Goto
11:30-12:00	Modeling the effects of climate variability and human activities on Lake Urmia Lake	Mr. A. Farokhnia
12:00-12:30	Two-Dimensional modeling of Lake Urmia hydrodynamics	Dr. M. Mazaheri
12:30-13:00	Modeling of partial rehabilitation of Lake Urmia to maintain its ecosystem services	Mr. A. Shokri
13:00-14:30	Lunch Break	
14:30-15:00	Comparative analysis of the Lake Urmia and the Lake Van Water level time series	Dr. Sh. Jalili
15:00-15:30	Hydrological and Hydrogeological Properties of Lake Van	Dr. H. Aydin
15:30-16:00	Monitoring Lake Urmia from space: spatial variability and precipitation trends	Dr. A. Aghkouchak (Video conf.)
16:00-16:15	Van Basin in a glance	
16:15-17:30	Concluding Discussion	

4.1.2 Outlook on Water Cycle of Lake Urmia Basin by the LURC

According to the public hearing as part of the survey with C/P, LURC has denied connection between the lakewater and groundwater. Based on the result of isotope analysis for the waters near the lakebed and groundwater conducted by the Iran Water Research Institute, one of the members of the LURC, there has not been correlation on stable isotope ratio between lakewater and groundwater. However, adverse opinion was also issued inside the LURC because the isotope analysis is not sufficient to warrant acceptance by LURC. . To make the mechanism of water cycle in Lake Urmia Basin clearer, JST attempted to conduct hydrological analysis using the hydroligical model which includes behaviour on groundwater.

4.2 EMPLOYED HYDROLOGICAL AND CLIMATOLOGICAL DATA

JST basically employed the hydrological data and climatological data provided by WRMC as much as possible. The data were arranged and analyzed as they were provided; although, both data sets have a lot of missing values. Average precipitation was calculated and applied in the analysis. For discharge data, as described in Chapter 2, accuracy of data was roughly checked by comparing runoff depthwhere the data with compoundable accuracy was employed.

4.3 METHOD AND PROCEDURE FOR THE STUDY ON ROUGH WATER BALANCE OF THE LAKE URMIA

The method of studying the rough water balance of the Lake Urmia is described below and also in Table 4.3.1 and Figure 4.3.1.

1) In the first part of the study on rough water balance of the Lake Urmia, natural surface water quantity was calculated from the precipitation volume in the Lake Urmia Basin by assuming annual runoff rate. In addition, by assuming groundwater recharge height, groundwater recharge rate was set as the rate of groundwater recharge height to annual precipitation volume; from this the natural groundwater quantity was calculated. In case that uptaking groundwater quantity is smaller than groundwater recharge quantity, groundwater recharge quantity becomes the same as the natural groundwater quantity. However, in case that uptaking groundwater quantity is bigger than groundwater recharge quantity, groundwater is also abstracted from groundwater storage. In this case, it is considered that natural groundwater quantity becomes groundwater recharge quantity plus supplemented water quantity from groundwater storage.

2) Water supply quantity was calculated as the water use quantity from surface water and groundwater.

3) Evaporation quantity from the Lake Area was calculated as the only one big outflow water quantity from the Lake Area. It is noted that the Lake Area is the water surface area plus dried-up Lake Bed of the Lake.

4) Total quantity of the Natural surface water quantity and the Natural groundwater quantity minus Total water supply quantity from surface water and groundwater becomes Inflow water quantity to the Lake Area. Then, the Inflow water quantity plus Precipitation volume in the Lake Area minus Evaporation quantity becomes Water balance of the Lake Area.

5) On the other hand, storage water volume corresponding to annual average water level of the Lake can be calculated based on the H-V curve of the Lake Urmia. In case that storage volume of certain year becomes smaller than previous year's storage volume, water level of the Lake of that year becomes lower than the water level of the previous year. In case that storage volume of certain year becomes bigger than previous year's storage volume, water level of the Lake of that year becomes higher than the water level of the previous year. Therefore, it is considered that this difference of storage volume becomes equivalent to the water balance quantity of the Lake Area as the difference between inflow water quantity to the Lake Area and outflow water quanity from the Lake Area.

6) Therefore, it is necessary to find the scenario where the historical annual water balance calculated in 4) fits the historical annual difference of storage volume of the Lake calculated in 5). In order to do this, for the various cases by changing evaporation from water surface of the Lake, combinations of Natural surface water quantity and Natural groundwater quantity, which fit to the 4) and 5), were calculated by try and error method. Then, water balances of the Lake Area were calculated as the combinations of Natural surface water quantity, Natural groundwater quantity and Evaporation from Lake Area.

Table 4.3.1 Steps of Analysis on Annual Water Balance of the Lake Urmia

Analysis Step	Contents of Analysis	Remarks
Step 1: To grasp precipitation volume of the Lake Urmia Basin	● Calculation of the historical change of annual precipitation volume of the whole Lake Urmia River Basin based on the annual precipitation (see Figure 4.4.2 of Sub-section 4.5.1).	● None
Step 2: To grasp precipitation volume of the Lake Urmia Area	● Calculation of precipitation volume of the Lake Urmia Area.	● None
Step 3: To grasp historical annual difference of storage volume of the Urmia Lake	● Calculation of historical change of the storage volume of the Lake Urmia based on the historical change of annual average water level and the updated H-A-V curve of the Lake based on the bathymetric survey data in the Year 2010 (see Figure 4.4.4 of Subsection 4.5.2). ● Calculation of historical annual differece of storage volume based on the historical change of annual storage volume (see Figure 4.4.5 of Subsection 4.5.2).	● Since the updated most recent bathymetric data was made in Year 2010, accuracy of applying the H-A-V curve seem to be good for about 10 years around 2010. ● Accuracy of applying the above H-A-V curve to 1980s and 1990s seems to be lower than the accuracy for applying it to around recent 10 years due to possibility of different conditions of sediment and salt deposition on the bottom of the Lake.
Step 4: To estimate water use (water supply) quantity of surface water and groundwater in the Lake Urmia Basin	● Estimation of historical annual water supply quantity of surface water of the whole Basin based on the historical data of water supply quantity of surface water from the 12 existing dams, from which the operation data could be collected, as well as on the recent water supply quantity from surface water written in the MOE's Master Plan Report (see Subsection 4.6.4, Annex 4.1 and Figure 4.5.3). ● Estimation of historical change of total uptaking quantity of groundwater in the whole Basin based on the historical permitted uptaking quantity of groundwater in the whole Basin, as well as MOE's Master Plan Report (see Subsection 4.6.4, Annex 4.1 and Figure 4.5.3).	● Modified Water Supply Quantity from Surface Water / Water Supply Quantity of the 12 Dams = 1.72 (considering return flows to the rivers.) ● Modified Uptaking Quantity from Groundwater / Permitted Uptaking Quantity from Groundwater = 1.11 (considering return flows to the springs and aquiducts).
Step 5: To estimate evaporation from Lake Urmia Area	● Estimation of historical change of water surface area and dry-up area based on the annual average Lake water level, as well as the updated	● According to the "Two-Dimensional Modeling of Urmia Lake Hydrodynamics" by Mehdi Mazaheri, Saeed Morid, Ashkan Shokri of

Analysis Step	Contents of Analysis	Remarks
	most recent H-A-V curve (see Figure 4.4.4 of Subsection 4.5.2). ● Calculation of evaporation quantity by changing the evaporation from water surface from 1,000mm/year to 1,900mm with 100mm/year interval. Evaporation from the dry-up lake bed areas is assumed to be the same as annual precipitation (see Figure 4.4.6 of Subsection 4.5.3).	Tarbiat from Tarbiat Modares University, evaporation from the Lake surface area is 1,100mm/year, which is 0.60 times of pan evaporation. ● It can be estimated that the evaporation from water surface of the Lake based on the data of pan evaporation of WRMC is within the range of about 950mm to 1350mm/year.
Step 6 To estimate natural surface water quantity of land area	● Study on the cases of changing evaporation from water surface of the Urmia Lake from 1,000mm to 1,900mm with 100mm interval, combinations of natural surface water quantity of land area with natural groundwater quantity as groundwater recharge quantity plus supplemented water quantity from groundwater storage, which relatively fit the annual difference of storage volume of the Lake. ● Historical change of annual natural surface water quantity of land area was calculated by Precipitation volume multiplied by annual runoff rates. The annual runoff rates was set for the above each case (see Table 4.6.1). ● Base flow is calculated at 14% of the natural surface water quantity of land area.	● Base flow was calculated from the base portion of the hydrographs as proportional to the annual water quantity based on the annual hydrographs of the discharge gauging stations which are not affected by the dams.
Step 7: To estimate natural groundwater quantity (groundwater recharge quantity and supplemented water quantity from groundwater storage)	● Through trial and error calculation of water balance including surface water as well, natural groundwater quantity, whch is groundwater recharge quantity plus supplemented water quantity from groundwater storage, were calculated. ● In case the uptaking groundwater quantity is small and groundwater level is maintained, water use quantity from groundwater becomes part of the groundwater recharge quantity. However, in case the uptaking groundwater quantity is more than the groundwater recharge quantity, water of the groundwater storage is also abstracted as the supplemented water quantity from groundwater storage. ● The natural groundwater qantity was set for each case of evaporation from water surface of the Urmia Lake changing from 1,000mm/year to 1,900mm/year with 100mm interval (see Table 4.6.1).	● For reference, groundwater recharge quantity (height) of the Sefidrud Study of JICA is set at 32mm/year. ● Groundwater recharge quantity is set for 350mm/year of the basin average precipitation of recent years as well as for 450mm/year of the basin average precipitation in 1980's.

Analysis Step	Contents of Analysis	Remarks
Step 8: To estimate natural surface water quantity and natural groundwater quantity (groundwater recharge quantity and supplemented water quantity from groundwater storage)	● As the total water quantity of natural surface water quantity of land area and natural groundwater quantity, (Natural surface water quantity) + (Natural groundwater quantity: Groundwater recharge quantity + Supplemented water quantity from groundwater storage) – (Base flow) was calculated (see Table 4.6.2). ● As the Base flow is the water quantity coming out of groundwater to surface water, same water quantity is included in both surface water and groundwater. Hence, when summing up the natural surface water quantity of land area and natural groundwater quantity, instead of summing them up as they are, it becomes conservative total water quantity by deducting duplicated portion of Base Flow following the above equation.	● Same as the above table.
Step 9: To calculate water balance of the Lake Area	● As described in Step 4, historical water balance was calculated for alternative cases through (Natural surface water quantity and natural groundwater quantity) + (Precipitation volume in the Lake Area) – (Water supply quantity from surface water and groundwater) – (Evaporation from the Lake area) (see Table 4.6.2). The alternative cases are set by changing evaporation from 1,000mm to 1,900mm with 100mm interval. ● Since the relationship between lake water level and accumulated water balance seems to be high, the coefficient of correlashion between them was studied (see Figure 4.6.4).	● The calculated water balance of the Lake was compared with the tendency of the historical change of the annual difference of storage volume of the Lake Urmia. Due to the H-A-V curve of the Lake, it is supposed that the accuracy of annual difference of storage volume in these 10 years is relatively high.

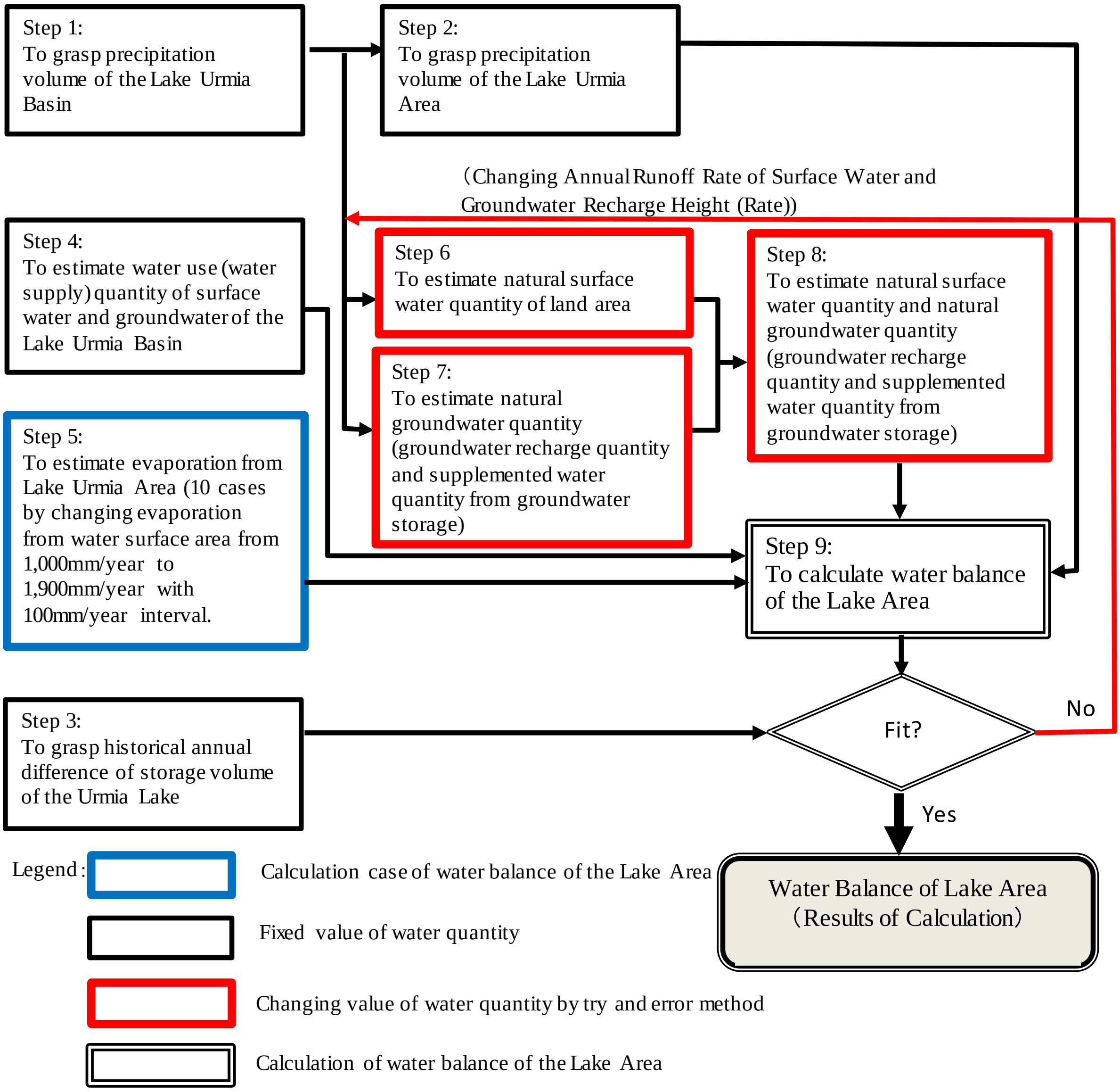


Figure 4.3.1 Procedure of Studying Rough Annual Water Balance of the Lake Urmia Area

4.4 PRELIMINARY STUDY ON WATER RESOURCES AMOUNT

The water resources configuration in the whole Lake Urmia Basin is composed of (1) Surface water resources amount, and (2) Groundwater resources amount. The Groundwater resources amount is composed of groundwater recharge and groundwater storage.

Assuming that Urmia Lake is a large reservoir, annual natural surface water quantity and annual natural groundwater quantitywhich should have flowed into the Lake under natural conditions, have been analyzed on the preliminary level. It has been noted that evaporation from the Lake area was considered in the analysis. The results are described in Section 4.5 as the preliminary analysis of water balance.

In this section, as basis of the above preliminary analysis, the following items are described: precipitation volume, water surface area and storage volume of Lake Urmia itself, and evaporation from the Lake Area.

4.4.1 Precipitation Volume

Historical precipitation volume of the whole Urmia Basin was calculated using the annual average precipitation of each river basin comprising the Urmia Basin multiplied by the catchment area of each river basin. Table 4.4.1 and Annex 4.2 show the historical changes of basin average annual precipitation from year 1980 to 2011 calculated by the Thiessen Method. Figure 4.4.1 shows a graph of basin average annual precipitation of the whole Lake Urmia Basin. Furthermore, Table 4.4.2 and Annex 4.3 show the precipitation calculated as volume of each river basin, as well as that of the whole Urmia Basin.

Table 4.4.1 Basin Average Annual Precipitation of the Urmia Basin (Above table based on western calender and below table based on Iranian calender)

(Unit: mm/year)

Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,717	1,362	2,094	2,091	260	1,507	1,880	1,060	375	1,840	551	458	712	3,783	1,936	11,838	2,258	4,976	51,697
Average 1980 to 2011	328.05	470.66	373.11	455.25	362.03	429.68	445.66	411.91	367.68	332.47	425.17	435.78	455.49	411.26	394.21	456.13	410.60	362.03	396.87
Average 1980 to 1989	329.20	522.93	386.54	481.73	582.60	466.75	515.62	457.59	365.18	317.64	478.67	489.43	508.29	420.68	401.47	516.38	502.12	582.60	447.02
Average 1990 to 1999	325.58	454.15	373.24	476.63	350.73	434.83	432.27	426.99	374.00	359.89	427.06	456.36	510.33	424.63	407.42	452.38	405.36	350.73	397.89
Average 2000 to 2011	329.15	440.85	361.81	415.38	187.64	394.51	398.51	361.28	364.51	321.97	379.02	373.92	365.79	392.26	377.16	409.05	338.70	187.64	354.22

(Unit: mm/year)

Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,717	1,362	2,094	2,091	260	1,507	1,880	1,060	375	1,840	551	458	712	3,783	1,936	11,838	2,258	4,976	51,697
Average 1980 to 2011	325.23	474.35	372.72	456.57	362.64	430.69	446.90	412.43	370.10	329.95	427.29	438.10	459.56	412.13	394.83	451.61	410.90	375.58	396.79
Average 1980 to 1989	325.41	526.45	390.15	477.64	573.85	465.67	514.78	457.57	367.50	318.00	480.67	490.25	513.08	419.15	406.13	508.28	503.12	446.35	431.32
Average 1990 to 1999	326.33	457.52	370.90	476.17	350.34	437.84	435.14	427.64	376.81	360.41	423.83	457.35	509.38	422.15	404.16	443.59	403.96	385.77	399.25
Average 2000 to 2011	324.08	442.28	358.53	419.59	181.80	392.40	395.88	357.57	366.37	313.11	381.89	373.19	365.61	396.66	376.09	407.40	333.37	301.96	363.18

*JICA Survey Team prepared these tables based on the data from WRMC.

Table 4.4.2 Annual Precipitation calculated as Volume of the Whole Urmia Basin (Above table based on western calender and below table based on Iranian calendar)

(Unit: MCM/year)

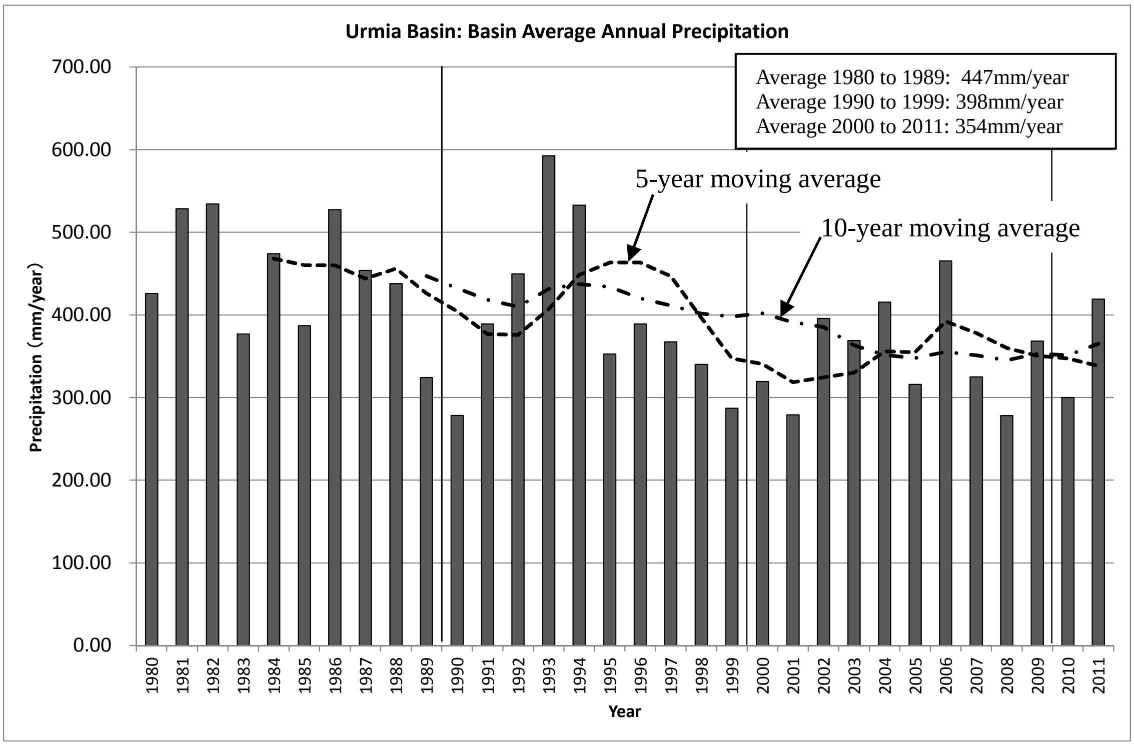
Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,716.73	1,361.68	2,093.59	2,090.98	259.77	1,506.97	1,880.14	1,060.38	375.08	1,839.96	551.17	457.76	711.69	3,782.74	1,936.28	11,837.88	2,258.39	4,976.00	51,697.17
Average 1980 to 2011	4,171.70	640.88	781.14	951.92	94.04	647.52	837.90	436.78	137.91	611.72	234.34	199.48	324.17	1,555.68	763.31	5,399.62	927.29	1,801.48	20,516.89
Average 1980 to 1989	4,186.30	712.06	809.26	1,007.28	151.34	703.37	969.43	485.22	136.97	584.45	263.83	224.04	361.74	1,591.32	777.36	6,112.89	1,133.98	2,899.03	23,109.89
Average 1990 to 1999	4,140.29	618.41	781.40	996.62	91.11	655.27	812.73	452.77	140.28	662.18	235.38	208.91	363.20	1,606.25	788.88	5,355.16	915.46	1,745.25	20,569.54
Average 2000 to 2011	4,185.70	600.30	757.48	868.54	48.74	594.51	749.26	383.10	136.72	592.40	208.90	171.17	260.33	1,483.83	730.29	4,842.29	764.91	933.72	18,312.18

(Unit: MCM/year)

Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,717	1,362	2,094	2,091	260	1,507	1,880	1,060	375	1,840	551	458	712	3,783	1,936	11,838	2,258	4,976	51,697
Average 1980 to 2011	4,135.92	645.91	780.32	954.67	94.20	649.04	840.23	437.33	138.82	607.09	235.51	200.54	327.06	1,558.99	764.51	5,346.13	927.98	1,868.86	20,513.13
Average 1980 to 1989	4,138.13	716.85	816.81	998.73	149.07	701.75	967.85	485.20	137.84	585.11	264.93	224.42	365.15	1,585.53	786.38	6,016.91	1,136.24	2,221.05	22,297.95
Average 1990 to 1999	4,149.89	623.00	776.51	995.65	91.01	659.82	818.12	453.46	141.33	663.14	233.60	209.36	362.52	1,596.86	782.57	5,251.12	912.30	1,919.60	20,639.88
Average 2000 to 2011	4,121.20	602.25	750.62	877.36	47.23	591.33	744.32	379.16	137.42	576.11	210.49	170.83	260.20	1,500.44	728.21	4,822.71	752.89	1,502.57	18,775.33

*JICA Survey Team prepared these tables based on the data from WRMC.

From Figure 4.4.1, it can be seen that the annual basin average precipitation of the whole Lake Urmia Basin was around 450mm/year in 1980s, 400mm/year in 1990s, and has decreased to 350mm/year after Year 2000. In terms of precipitation volume, from Figure 4.4.2, it can be seen that annual precipitation volume of the whole Lake Urmia Basin was about 23,110MCM in 1980s with a tendency to becoming smaller than 18,300MCM after Year 2000 (18% reduction).



*JICA Survey Team prepared this figure based on the data from WRMC's data.

Figure 4.4.1 Historical Change of Basin Average Annual Precipitation in the Whole Lake Urmia Basin

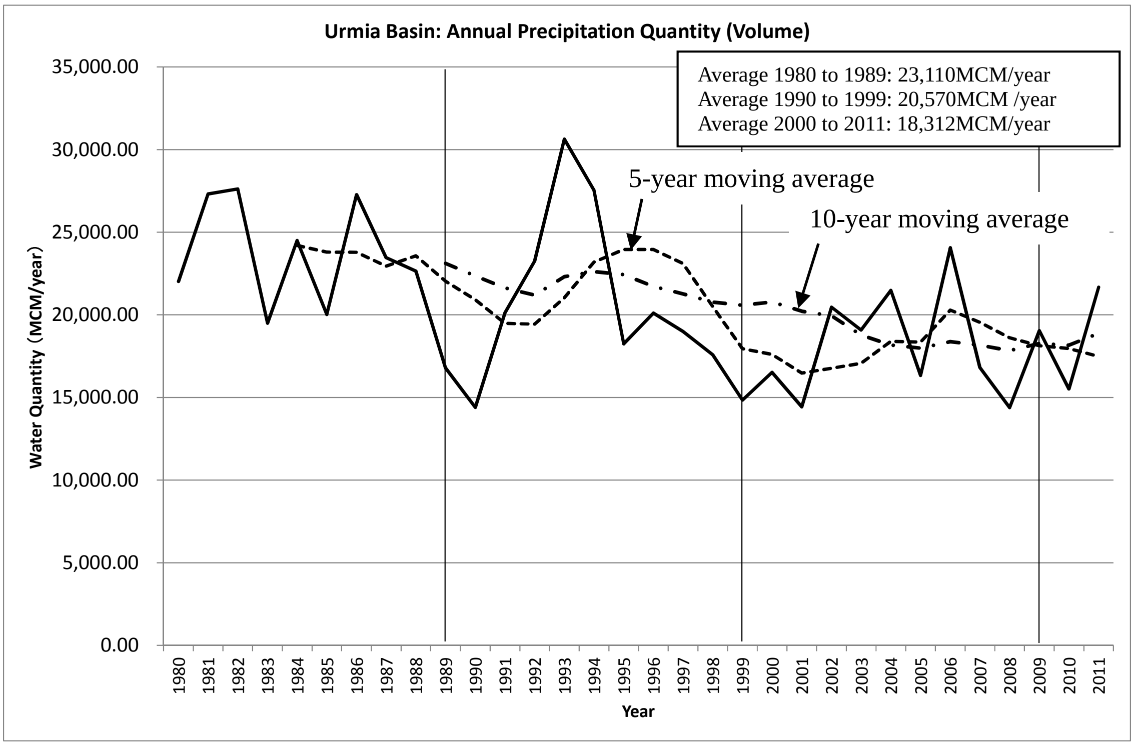


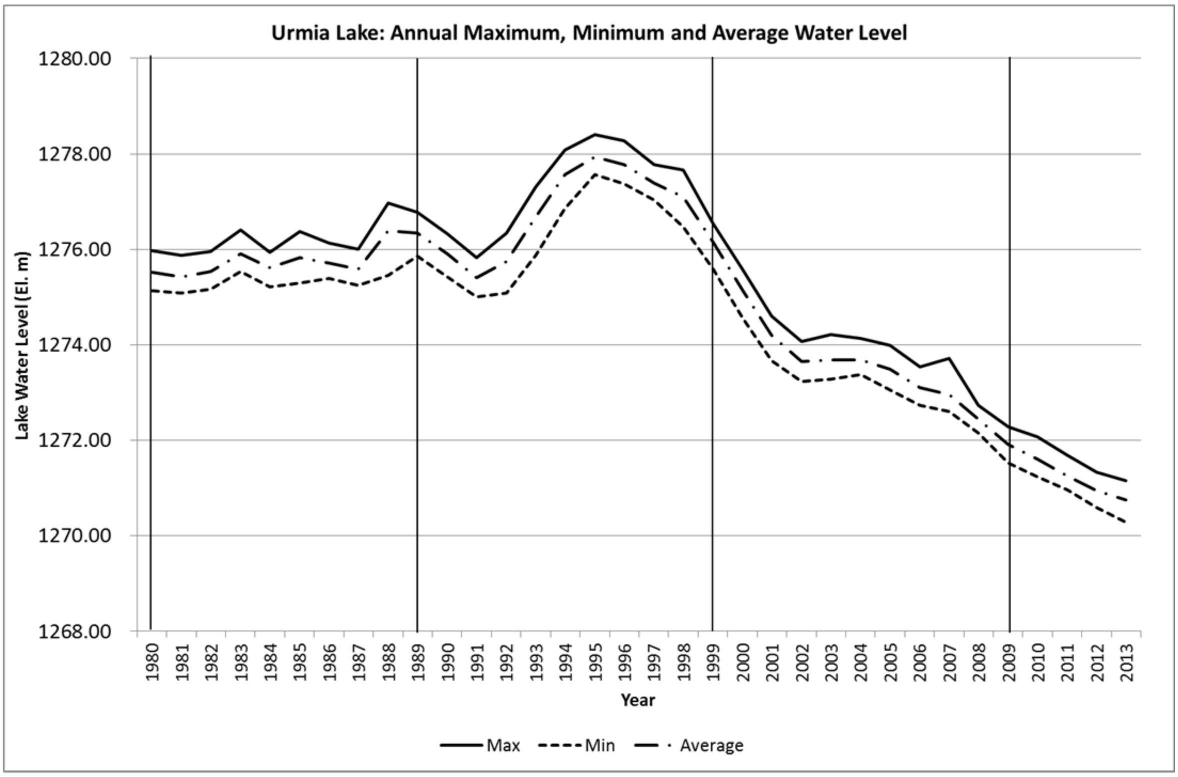
Figure 4.4.2 Historical Change of Basin Average Precipitation Volume in the Whole Lake Urmia Basin

4.4.2 Storage Volume, Water Surface Area and Dry-up Area of the Lake Urmia

As the basic information for the preliminary study on water balance which will be described in Section 4.4, Storage Volume, the water surface area, and dry-up area of Lake Urmia were studied based on the most updated lake water level – Water surface area – Storage volume curve (H-A-V curve). The most updated H-A-V curve was prepared by the JICA Survey Team based on the bathymetric data made by the Iran Water Research Institute in 2010 (see Subsection 2.1.2).

(1) Changes of Water Level of Lake Urmia

Daily water level changes of Lake Urmia from late November 1965 to late November 2013 are described in Subsection 2.1.2. Figure 4.4.3 shows the historical changes of annual maximum water level, annual minimum water level, and annual average water level of the Lake after Year 1980.

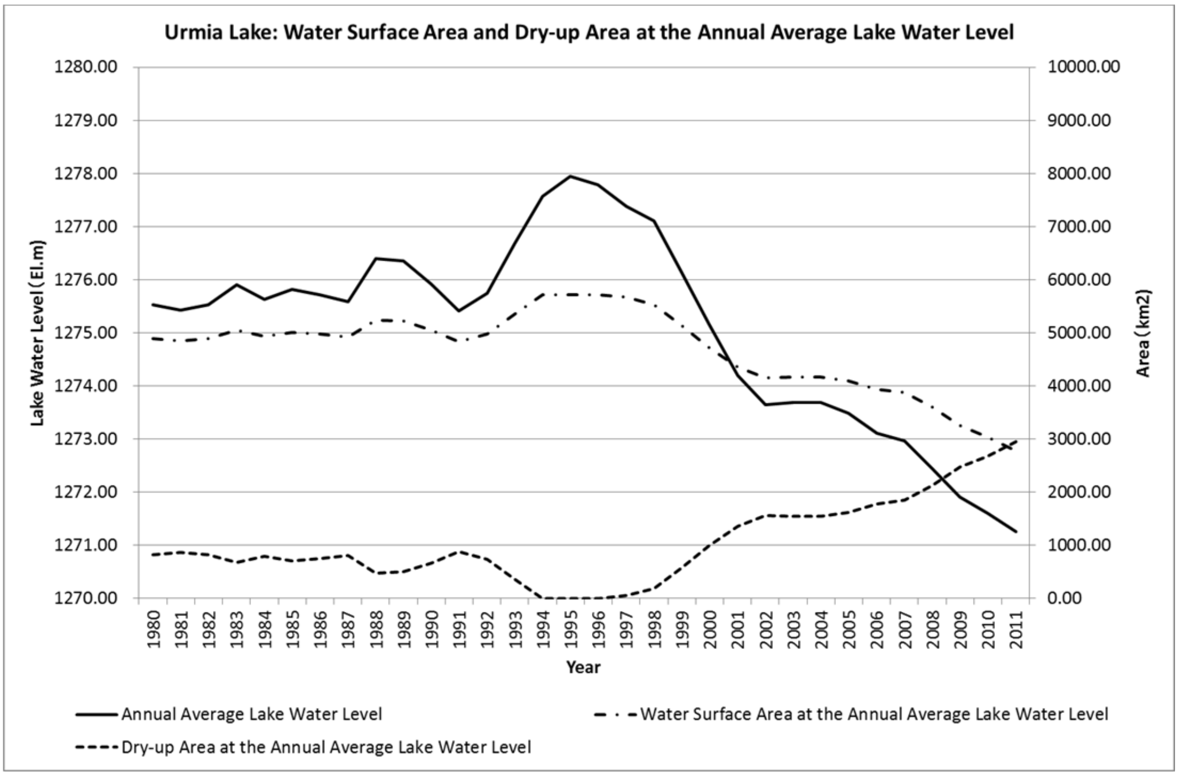


*JICA Survey Team prepared this figure based on the data from WRMC's data.

Figure 4.4.3 Historical Change of Annual Maximum, Minimum and Average Water Level of Lake Urmia

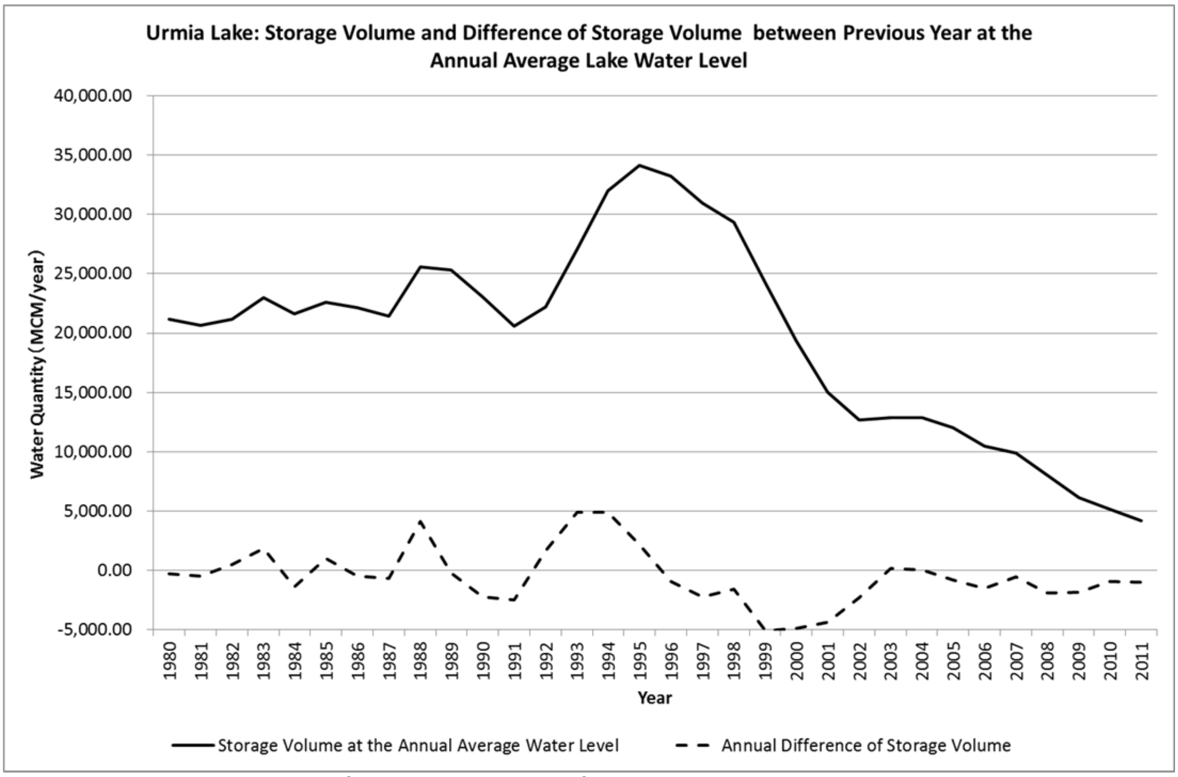
(2) Storage Volume, Water Surface Area and Dry-up Area of Lake Urmia

In the preliminary analysis of water balance of the Urmia Lake described in Section 4.6, since the basin average precipitation can be calculated from 1980 to 2011, historical changes of annual storage volume and water surface area, which correspond to the annual average lake water levels, were also calculated from 1980 to 2011 based on the most updated H-A-V curve. Since the most updated H-A-V curve reflects the topographic conditions of the Lake before and after 2010, the applicability of the H-A-V curve seems to be relatively good in 10 years. However, applicability to 1980's and 1990's seems to be smallerbecause the conditions of sediment and salt deposition on the bottom of the Lake may be different from the conditions in recent years. Figure 4.4.3 shows the historical changes of storage volume, water surface area, and dry-up area at the annual average lake water levels. In addition, based on this table, Figure 4.4.4 shows the historical annual changes of water surface area and dry-up area while Figure 4.4.3 shows the historical changes of the difference in storage volume between years. Corresponding to the sudden decrease of annual average lake water level after 1995, there was a decrease in water surface area and storage volume.



*JICA Survey Team prepared this figure based on the data from WRMC's data.

Figure 4.4.4 Historical Changes of Water Surface Area and Dry-up Area of the Urmia Lake at the Annual Average Water Level of the Lake



*JICA Survey Team prepared this figure based on the data from WRMC's data.

Figure 4.4.5 Historical Change of Storage Volume at the Annual Average Water Level of the Urmia Lake and Annual Difference of Storage Volume from the Storage Volume of Previous Years

Table 4.4.3 Historical Annual Changes of Water Surface Area, Dry-up Area and Storage Volume of the Urmia Lake

Year	Annual Average Lake Water Level	Water Surface Area corresponding to the Annual Average Water Level	Dry-up Area corresponding to the Annual Average Water Level	Storage Volume corresponding to the Annual Average Water Level	Difference of Storage Volume
	(El.m)	(km2)	(km2)	(MCM)	(MCM)
1980	1275.53	4890.10	831.25	21,141.45	-304.67
1981	1275.43	4848.05	873.30	20,679.33	-462.12
1982	1275.53	4891.41	829.94	21,157.20	477.87
1983	1275.90	5045.22	676.13	23,012.89	1,855.69
1984	1275.63	4931.15	790.20	21,636.64	-1,376.26
1985	1275.82	5013.15	708.20	22,625.98	989.35
1986	1275.72	4970.97	750.38	22,117.12	-508.87
1987	1275.58	4913.94	807.41	21,429.03	-688.09
1988	1276.40	5237.35	484.00	25,549.56	4,120.53
1989	1276.35	5219.55	501.80	25,309.19	-240.37
1990	1275.91	5049.20	672.15	23,060.97	-2,248.23
1991	1275.41	4837.91	883.44	20,571.66	-2,489.31
1992	1275.74	4980.08	741.27	22,226.96	1,655.31
1993	1276.69	5355.69	365.67	27,091.43	4,864.47
1994	1277.57	5718.82	2.53	31,994.09	4,902.67
1995	1277.94	5721.35	0.00	34,141.03	2,146.93
1996	1277.78	5720.25	1.10	33,207.26	-933.77
1997	1277.39	5665.71	55.64	30,962.32	-2,244.94
1998	1277.10	5533.93	187.42	29,346.07	-1,616.25
1999	1276.14	5140.11	581.24	24,236.60	-5,109.47
2000	1275.15	4722.76	998.59	19,349.03	-4,887.57
2001	1274.19	4359.68	1361.67	14,993.73	-4,355.30
2002	1273.65	4153.58	1567.77	12,661.06	-2,332.67
2003	1273.69	4169.57	1551.78	12,838.95	177.89
2004	1273.69	4170.20	1551.15	12,845.95	7.00
2005	1273.49	4095.47	1625.88	12,019.01	-826.93
2006	1273.11	3940.24	1781.11	10,484.56	-1,534.46
2007	1272.96	3875.30	1846.05	9,902.26	-582.30
2008	1272.45	3597.09	2124.26	8,001.22	-1,901.04
2009	1271.91	3250.36	2470.99	6,134.05	-1,867.17
2010	1271.60	3037.40	2683.95	5,181.09	-952.97
2011	1271.26	2774.33	2947.02	4,177.38	-1,003.71

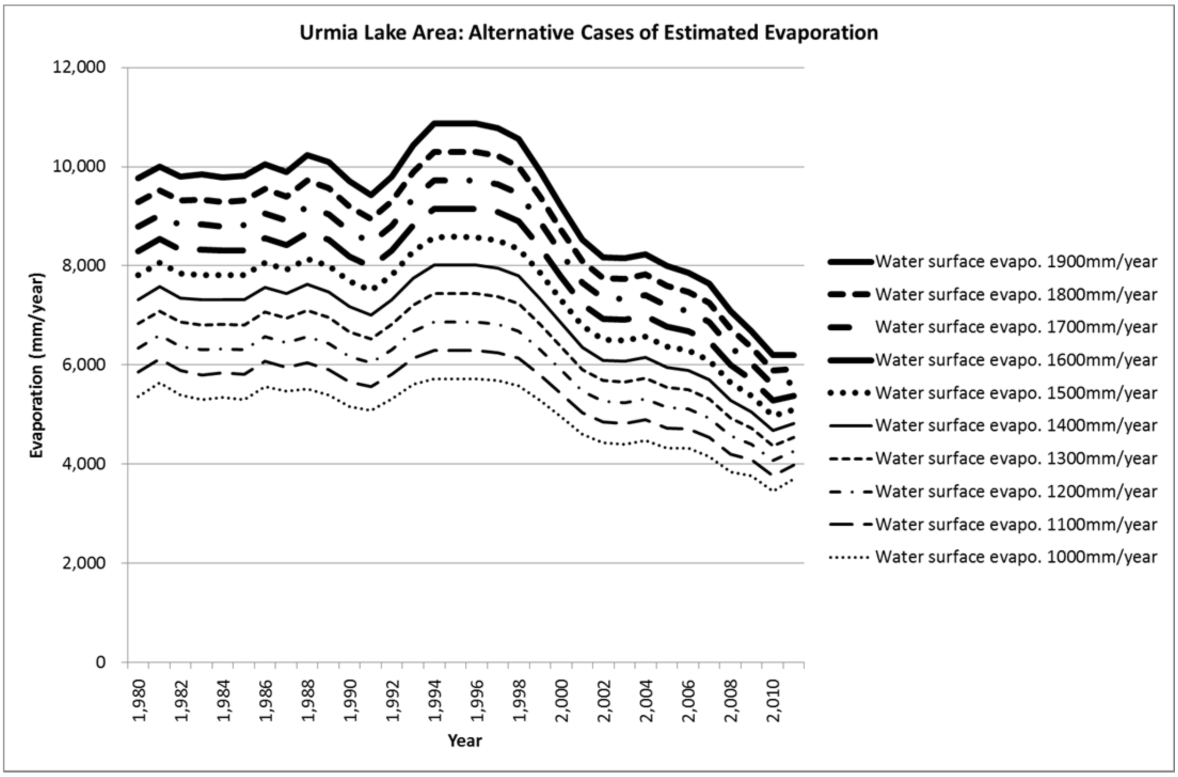
*JICA Survey Team prepared above table based on the data from WRMC.

4.4.3 Estimation of Annual Evaporation Quantity from the Lake Urmia Area

Annual evaporation of the Lake Urmia Area is the total of evaporation from water surface and evaporation from dried-up lake bed. For water balance of the Lake Area, evaporation is the only one outflow from the Lake Area that hugely affects annual water level change of the Lake.

There is no observed data on the evaporation from water surface. Hence, referring to the values of pan evaporation, the total evaporation from water surface and dried-up lake bed were estimated by changing the evaporation from water surface from 1,000mm/year to 1,900mm/year with 100mm/year interval. It has been noted that evaporation from the dried-up lake bed is set as the same as the annual precipitation of that area. It is assumed that if the annual precipitation amount is evaporated from the dried-up area evaporation will not occur anymore from that area. Figure 4.4.6 shows the estimated annual evaporation from the Lake Area.

For reference, according to the “Two-Dimensional Modeling of Urmia Lake Hydrodynamics” by Mehdi Mazaheri, Saeed Morid, Ashkan Shokri of Tarbiat from Tarbiat Modares University, evaporation from the Lake surface area is 1,100mm/year, which is 0.60 times of pan evaporation.



*JICA Survey Team prepared this figure based on the data from WRMC’s data.

Figure 4.4.6 Estimated Evaporation of the Urmia Lake (Calculation by Changing Evaporation from Water Surface Area)

4.5 ESTIMATION OF WATER USE CONDITION

4.5.1 Collected Data related to Water Use Quantity

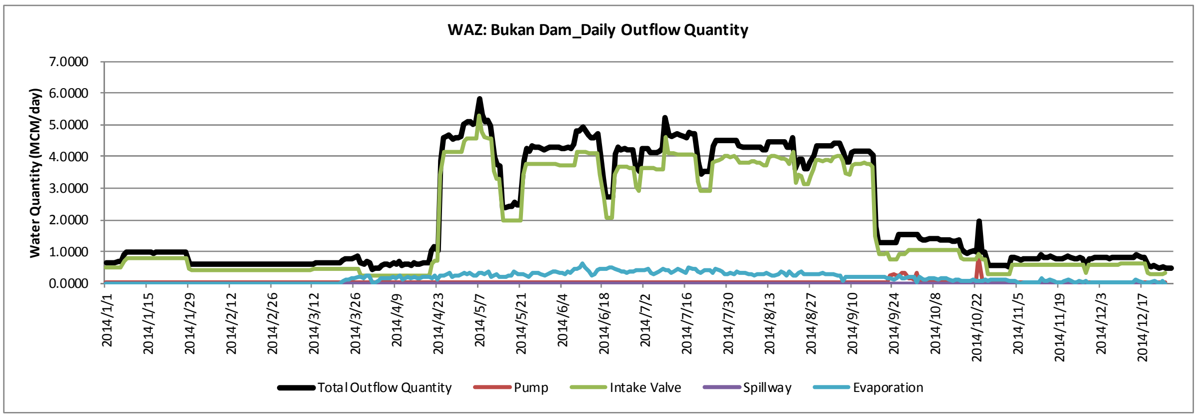
1) In relation to water use quantity, several data were collected by the Survey. In terms of surface water use quantity, historical data of outflow quantity, and water supply quantity are available from the 12 existing dams (see Figure 3.2.8 to Figure 3.2.11). In the data of outflow quantity, evaporation from reservoir water surface, leakage from reservoir, discharge from intake valve, intake by pumps, and discharge from spillway etc. are included. In the data on water supply quantity, drinking water supply, industrial water supply, agricultural water supply, and other water supply are included. Hence, for water use quantity, water supply quantity is the data of water quantity sent to irrigation areas etc. from the dams. By using the water quantity (water supply quantity) sent to the irrigation areas etc. water is consumed. In analyzing water balance of surfacewater using the data of water supply quantity, water supply quantity from surface water in the whole Lake Urmia Basin was estimated.

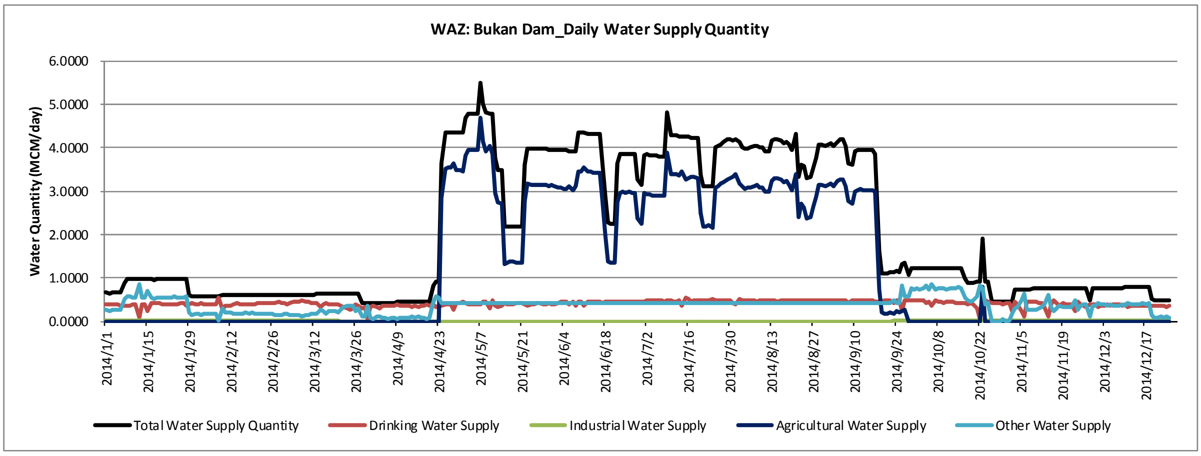
2) In terms of groundwater use quantity, historical data of permitted annual quantity for uptaking groundwater from the permitted groundwater wells in the whole Lake Urmia Basin were also collected (see Section 3.4). Uptaking groundwater quantity as water supply quantity from groundwater in the whole Lake Urmia Basin was estimated based on the permitted uptaking groundwater quantity.

4.5.2 Water Supply Pattern from the Dams

As for the above item 1) the data of water supply from the 12 existing dams were collected as described in Subsection 3.2.3. Using these data and to determine the seasonal variations including water supply, the daily operation data of Bukan Dam for 5 years between 2010 and 2014 and the total water quantity of the 12 existing dams were collected. The data are as shown in Annex 4.4 and Annex 4.5. In addition, as typical examples of outflow quantity including discharge quantity from the dams and water supply quantity, conditions of 2014 are shown in Figure 4.5.1 and Figure 4.5.2 respectively.

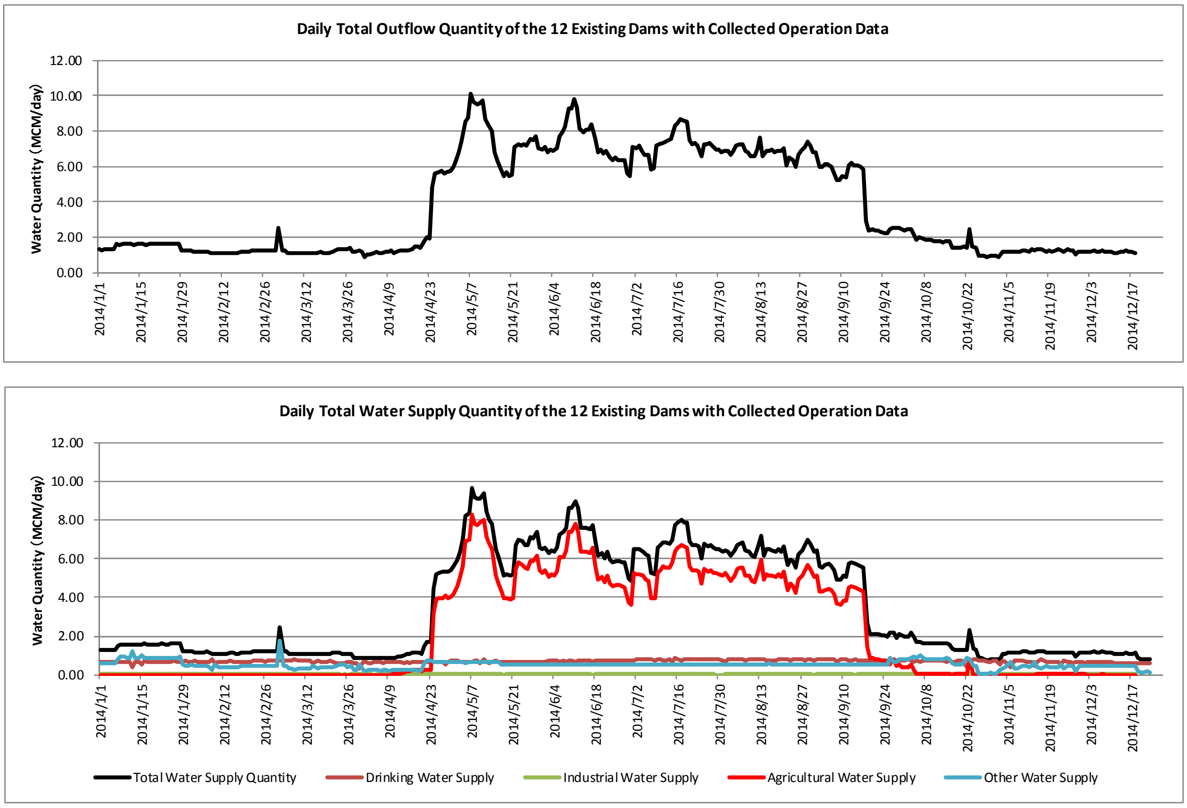
From Figure 4.5.1 and Figure 4.5.2, it can be gleaned that most of the water supply quantity is agricultural water supply. Furthermore, the agricultural water supply peaks from end of April to middle of September. Inflow to the dams starts increasing from around January, peaks at around April, and decreases in the end of June. Storage volumes of the dams start increasing from January, peaks from April to May, and decreases at the end of October. As for the outflow from the dams, in addition to the seasonal variation of water supply, water spills out around April when inflow becomes big due to snow melt.





*JICA Survey Team prepared this figure based on the data from WRMC's data.

Figure 4.5.1 Daily Outflow and Water Supply Quantity of Bukan Dam in Year 2014



*JICA Survey Team prepared this figure based on the data from WRMC's data

Figure 4.5.2 Total Daily Operation of Water Quantity of the 12 Existing Dams with Collected Operation Data in terms of Total Outflow Quantity and Total Water Supply Quantity

4.5.3 Master Plan Reports of the Ministry of Energy

(1) Master Plan of Agriculture

In the first half of the Master Plan Report of the Ministry of Energy (Ministry of Energy, Water and Wastewater Macro-Planning Office; Studies on Updating National Water Master Plan in Basins of Aras, Urmia, Talesh-Anzali Wetland, Greater Sefidrood, Sefidrood-Haraz, Haraz-Ghareh Sou, Gorganrood and Atrak, Agriculture Studies, Urmia Watershed, June 2013), focus was on the analysis of the present condition of agricultural water supply and future water quantity, irrigation areas, efficiency of irrigation, water demand quantity, intake water quantity, return flow quantity by drainage, and water se quantity (consumption). Meanwhile, the other half of the Report describes the cropping patterns and necessary water quantities for several irrigation schemes based on the data presented on the first part pf the report. Table 4.5.1 shows useful information for the analysis of water balance in the Basin.

Table 4.5.1 Present Condition of Agricultural Water Supply in the Master Plan Report on Agricultural Water Supply

No.	Item	Contents
1	Agricultural lands in the Lake Urmia Basin	Existing in 25 plain areas
2	Irrigated agricultural area	Total 511,926ha composed of: Croplands: 356,420ha (70%) Garden: 155,506ha (30%)
3	Intake water for irrigation areas	Surface water: about 60%, and Groundwater: about 40%.
4	Irrigation water supply	For agriculture: 37% For horticulture: 45%
5	Efficiency for irrigation	Agricultural area: 29%~43% Horticultural area: 30%~53%
6	Water demand in irrigated agricultural lands (by purpose)	Total 6,632MCM/year composed of: Agricultural lands: 4,445MCM/year (67%) Horticultural lands: 2,187MCM/year (33%)
7	Water demand in irrigated agricultural lands (by area)	West Azerbaijan Province: 3,518MCM/year (53%) East Azerbaijan Province: 2,935MCM/year (44%) Kurdistan Province: 179MCM/year (3%)
8	Intake water quantity for agriculture	Total 4,222MCM/year composed of: Surface water: 2,499MCM/year (59%) Groundwater: 1,723MCM/year (41%)
9	Estimated return flow quantity (Note: Water quantity returning to the rivers, etc. by drainage, etc.)	Total 300MCM/year composed of: Return flow from agricultural drainage: 254MCM/year Return flow from fountains and aqueducts: 46MCM/year
10	Agricultural water consumption (demand)	3,921MCM/year（=4,222-300）composed of: Supplied from surface water: 2,245MCMyear (57%) Supplied from groundwater: 1,676MCM (43%)

Data source: Ministry of Energy

(2) Master Plan of Groundwater

The Master Plan Report on Groundwater of the Ministry of Energy (Ministry of Energy, Water and Wastewater Macro-Planning Office; Studies on Updating National Water Master Plan in Basins of Aras, Urmia, Talesh-Anzali Wetland, Greater Sefidrood, Sefidrood-Haraz, Haraz-Ghareh Sou, Gorganrood and Atrak, Fifth Volume, Report on Groundwater Studies, Urmia Watershed, September 2012) describes the present condition of aquifers and groundwater level, water quality of groundwater, groundwater source and used water quantity and groundwater recharge quantity in terms of the present condition of groundwater. In addition, as countermeasures for sustainable management and development of groundwater, the Report discusses the reduction of up-taking groundwater, water transfer from the neighboring river basins, transfer of water to the area of groundwater aquifer and artificial groundwater recharge. Useful information for analyzing the present water balance in the Basin is shown in Table 4.5.2.

Table 4.5.2 Present Condition of Groundwater Quantity in the Master Plan Report on Groundwater

No.	Item	Contents
1	Reduction of groundwater storage volume in the recent years from 2001 to 2006 in the Lake Urmia Basin	About 32MCM/year
2	Aquifer	Existing in the plains of Tabriz, Salmas, Urmia, Miandoab, Boukan, and Shahindej (Saein Ghale)
3	Groundwater	Under the ground: 2m to 130m Groundwater level: 1,260m to 1,850m
4	Irrigation water supply	For agriculture: 37% For horticulture: 45%
5	Annual maximum groundwater up-taking quantity	Total 2,174.5MCM/year composed of: Wells: 1,842.3MCM/year (85%) Springs: 174.9MCM/year Aqueducts: 157.3MCM/year
6	Groundwater recharge	Study on groundwater recharge quantity in the study area: (5,137km^2) for groundwater balance. 5,137km^2 is 45% of the plain areas of 11,408km^2. Groundwater recharge quantity by precipitation: 26.3mm/year

Data source: Ministry of Energy

(3) Master Plan of Drinking Water

In the Master Plan Report on Drinking Water of the Ministry of Energy (Ministry of Energy, The Deputy of Water and Wastewater, Water and Wastewater Macro-Planning Office; Studies on National Water Comprehensive Plan at Aras, Urmia, Talesh-Anzali Wetlands, Sefidrud, Sefidrud-Haraz, Haraz-Gharasu, Gorganroud and Atrek River, Volume VII, Reporting the Uses and Needs of Urban and Rural Drinking Water and Wastewater Produced in the Base Year 2007at Urmia Catchment), there are descriptions about intake water quantity, water use quantity, unaccounted-for water quantity, return flow through sewerage and others, in relation to the present condition of drinking water. Useful information for analyzing the present water balance in the Basin is shown in Table 4.5.3.

Table 4.5.3 Present Condition of Drinking Water Quantity in the Master Plan Report on Drinking Water

No.	Item	Contents
1	Population in Lake Urmia Basin	Total 4,963,002 persons composed of: Population of urban areas: 3,426,026 persons Population of rural areas: 1,536,976 persons (Based on the census of population in 2007)
2	Intake Raw Water Quantity for Drinking Water for the Urban Areas	Total 293,973,000m^3/year (224 liter/day/person) composed of: Groundwater: 152,669,000m^3/year (52%) Surface water: 141,303,000m^3/year (48%) (There are descriptions about intake water quantity of groundwater and surface water by city.)
3	Quantity of water use for urban drinking water	Total: 280,369,000m^3/year (There are descriptions about used water quantity by city.)
4	Unaccounted-for quantity of the Cities	Total: 57,170,000m^3/year (There are descriptions about unaccounted-for water quantity by city.)
5	Coverage ratio for drinking water supply to urban population	West Azerbaijan Province: 99.7% East Azerbaijan Province: 99% Kurdistan Province: 99.8%
6	Coverage ratio of sewerage system among the urban population	West Azerbaijan Province: 49% East Azerbaijan Province: 44.7% Kurdistan Province: 96.1%
7	Wastewater Treatment Plants	8 places, where, 3 plants for activated sludge method, and 3 places of lagoons and 2 places of others.
8.	Quantity of urban sewage	230,488,000m^3/year (78% of drinking water supply)

Data source: Ministry of Energy

(4) Master Plan of Industrial Water Supply

In the Master Plan Report on Industrial and Mining Water Supply of the Ministry of Energy (unknown title) there is a presentation of condition of industrial and mining water supply which includes descriptions about the major industries, water use quantity, and return flow as industrial wastewater. Useful information for analyzing the present water balance in the Basin is shown in Table 4.5.4.

Table 4.5.4 Present Condition of Industrial Water Supply Quantity in the Master Plan Report on Industrial Water Supply

No.	Item	Contents
1	Industrial Water Use Quantity	Total 11.526MCM/year composed of: West Azerbaijan Province: 4.792MCM/year East Azerbaijan Province: 4.802MCM/year Kurdistan Province: 1.932MCM/year
2	Water Use Quantity of Major Industries, Power Plants, Airports and Big Mines	Total: 29.747MCM/year
3	Water Use Quantity by Livestock Farms and Poultry Farms	Total 13.26MCM/year composed of: West Azerbaijan Province: 1.86MCM/year East Azerbaijan Province: 8.7MCM/year Kurdistan Province: 2.6MCM/year
4	Water Use Quantity by Mining	0.028MCM/year
5	Total Industrial Water Use Quantity	Total 54.694MCM/year composed of: Groundwater: 54.694MCM/year (100%) Surface water: (0%)
6	Return Flow by Industrial Wastewater	Total: 33.375MCM/year

Data source: Ministry of Energy

4.5.4 Estimation of Water Use Quantity

(1) Conditions for the Estimation of Water Use Quantity of Surface Water

1) Use of surface water is conducted through intake of water directly from the dams or once discharged into the river from the dams, and then taken from the weirs in the downstream reaches for water supply. Water supply for drinking water, industrial water, agricultural water and others are conducted from the dams.
2) Water intake and supply of agricultural water from the weirs are also conducted. Furthermore, there are cases where rivers are closed by farmers using sand bags during dry season as such, water is taken from the weir and supplied where necessary.
3) The data on surface water intake and supply which were collected by the Survey are the only downloaded daily data of the 12 existing dams from the webpage: http://dams.wrm.ir of the Water Resources Management Company (WRMC). Among the data, the one of Mahabad Dam has the longest duration from March 1971 to February 2014 (see Subsections 3.2.3). These dam data which are related to surface water intake and supply quantity, are the only collected historical data.
4) As for other information, the Master Plan's Reports on agricultural water supply, drinking water supply, and industrial water supply are good references on water use (see Subsection 4.5.2).
5) In terms of water intake and supply quantity of the 12 existing dams, historical daily changes of water quantity of each water use category, as well as total water use quantity, are calculated. Based on this, annual total intake and water supply quantity were also computed. In order to compare with the water supply quantity in the Master Plan Reports, the average of annual total water intake and supply quantity were calculated after Year 2010which resulted to 1,305MCM/year.
6) From the Master Plan Report of MOE, water intake and supply quantity of each water use category are extracted. Then, by taking into account the return flow,recent total water intake and supply quantity were calculated at 2,242.3MCM/year. This value is considered as the actual water intake and supply quantity in the whole basin.
7) Based on the proportion of the above items 6) and 5) at 1.72, quantity of total water intake and supply from the 12 existing dams have increased. It is noted that although 1.72 is the adjustment ratio for increasing water intake and supply based on the recent water intake quantity, this factor is applied to all periods as provisional solution. Table 4.5.5 shows the method of calculating the adjustment value as well as the modified water intake and supply quantity of surface water. Figure 4.5.3 shows the estimated quantity of historical water intake and supply of the whole Urmia Lake Basin, which is based on the water intake and supply of the 12 existing dams.

(2) Estimation of Water Use Quantity (Up-taking Quantity) of Groundwater

1) The collected data on water use quantity of groundwater is the permitted annual quantity of uptaking groundwater in the whole Basin. These data are the historical annual permitted uptaking water quantities of groundwater for each of the wells in the Urmia Lake Basin. Hence, these data are the only data collected and used to study the historical water use quantity (uptaking water quantity) of groundwater.
2) Based on the Master Plan of Groundwater in the Report of the Ministry of Energy (see Subsection 4.5.2), uptaking water quantity of groundwater in recent years was extracted.
3) Based on the proportion of the above items 1) and 2) at 1.11, the historical uptaking water quantity of groundwater was calculated (see Table 4.5.5). It is noted that although 1.11 is the adjustment ratio and is calculated from the recent groundwater uptaking quantity and permitted uptaking water quantity, as a provisional solution, it is applied on the same period of the surface water use estimation (see Figure 4.5.3).

Table 4.5.5 Adjustment Ratio of Water Intake and Supply Quantity of Surface Water and Groundwater

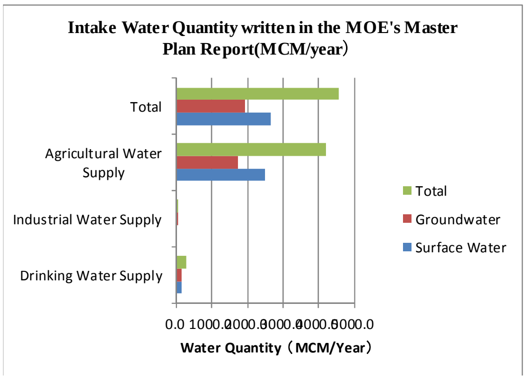
Water Supply Quantity written in the Master Plan Reports of the Ministry of Energy

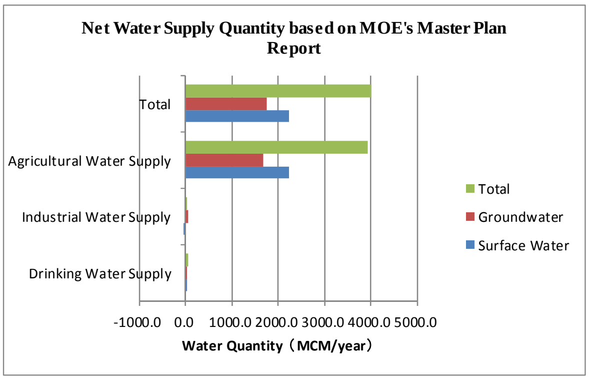
No.	Item	Water Intake			Return Flow			Net Water Supply Quantity		
		Surface Water	Groundwater	Total	Surface Water	Groundwater	Total	Surface Water	Groundwater	Total
		(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)
		(1)	(2)	(3)=(1)+(2)	(4)=(6) x 0.48	(5)=(6) x 0.52	(6)	(7)=(1)-(4)	(8)=(2)-(5)	(9)=(7)+(8)
1	Drinking Water Supply	141.3	152.7	294.0	110.6	119.9	230.5	30.7	32.8	63.5
2	Industrial Water Supply	0.0	54.7	54.7	33.4	0.0	33.4	-33.4	54.7	21.3
3	Agricultural Water Supply	2499	1723	4222	254	46	300	2245	1677	3922
	Total	2640.3	1930.4	4570.7	398.0	165.9	563.9	2242.3	1764.5	4006.8

Sources: 1) Quantity of drinking water supply: Ministry of Energy, The Deputy of Water and Wastewater, Water and Wastewater Macro-Planning Office; Studies on National Water Comprehensive Plan at Aras, Urmia, Talesh-Anzali Wetlands, Sefidrud, Sefidrud-Haraz, Haraz-Gharasu, Gorganroud and Atrek River, Volume VII, Reporting the Uses and Needs of Urban and Rural Drinking Water and Wastewater Produced in the Base Year (2007) at Urmia Catchment
2) Quantity of industrial water supply: Master Plan Report of the Ministry of Energy (title unknown)
3) Quantity of agricultural water supply: Ministry of Energy, Water and Wastewater Macro-Planning Office; Studies on Updating National Water Master Plan in Basins of Aras, Urmia, Talesh-Anzali Wetland, Greater Sefidrood, Sefidrood-Haraz, Haraz-Ghareh Sou, Gorganrood and Atrak, Agriculture Studies, Urmia

Adjustment Ratio for Estimating Water Supply Quantity based on the Collected Data of the 12 Existing Dams

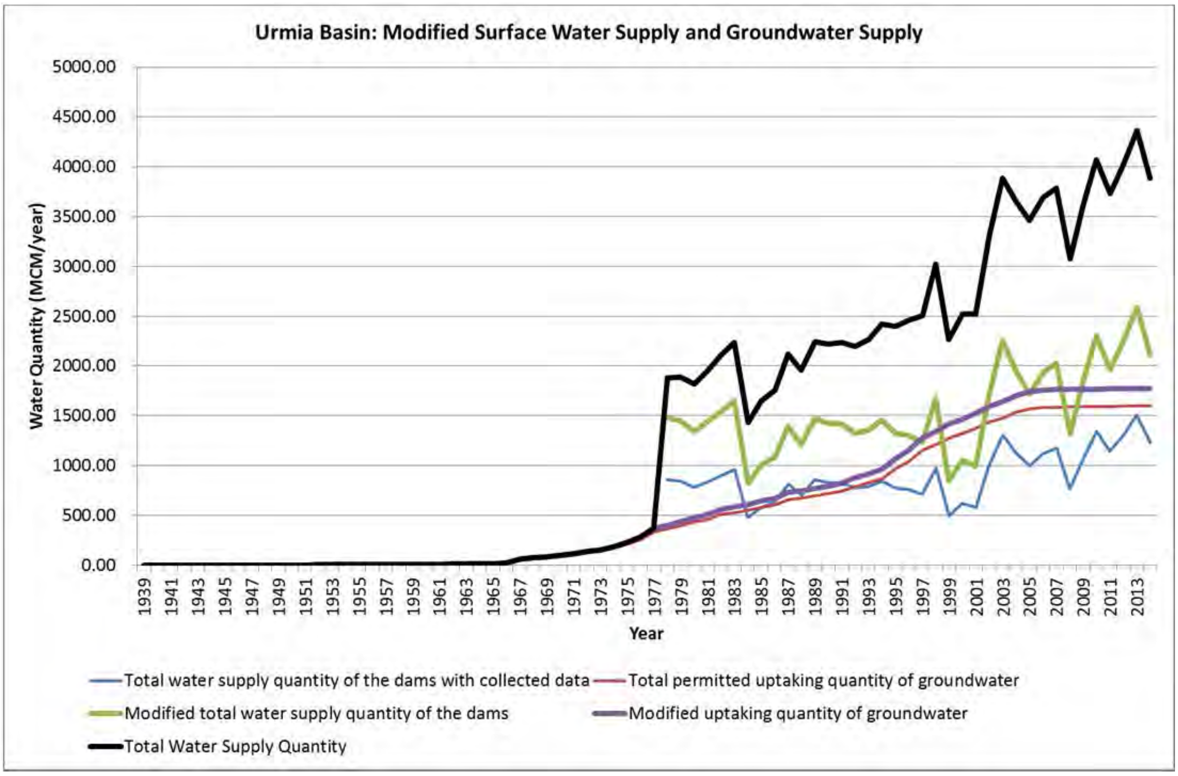
No.	Item	Estimated Water Supply Quantity of the Whole Basin			Adjustment Ratio	
		Surface Water	Groundwater	Total	Surface Water	Groundwater
		(MCM/year)	(MCM/year)	(MCM/year)		
1	Dam (Average value from Year 2010 to 2014)	1305		1305	1.72 (=2242.3/1305.0)	
2	Permitted Uptake Quantity of Groundwater (Estimated average value from Year 2010 to 2014)		1595	1595		1.11 (=1764.5/1590.0)





(3) Characteristics of Water Use Quantity

From Figure 4.5.3, it can be seen that the water use quantity (water supply quantity) of surface water had an increasing tendency since the beginning of 1980's, and the increasing tendency has accerelated around 1999. Although Mahabad Dam and Bukan Dam were the only major dams in 1970s, the construction of dams increased after 1980s and currently as many as 44 dams are under operation. The water use quantity (uptaking quantity) of groundwater has been increasing since the middle of 1960's, and the increasing tendency has accerelated around 1993. The estimated total water use quantity (water supply quantity) was also in an increasing pattern since the beginning of 1980's and had accerelated around 1995.



*JICA Survey Team prepared this figure based on the data from WRMC's data

Figure 4.5.3 Modified Annual Water Supply Quantity of Surface Water and Groundwater in the Whole Lake Urmia Basin

4.6 GRASP OF ROUGH WATER BALANCE OF THE LAKE URMIA AREA

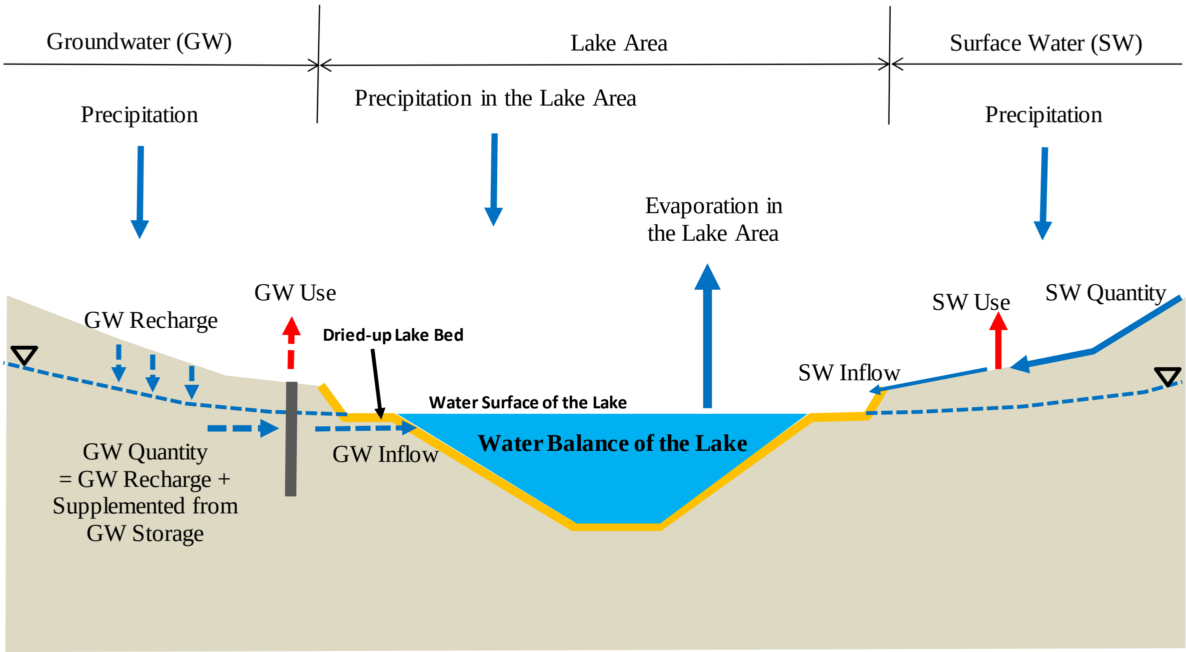
4.6.1 Annual Water Balance

(1) Study on Annual Rough Water Balance of the Urmia Lake

Figure 4.6.1 shows the concept of rough water balance of the Lake Urmia Area. In the rough water balance analysis of the Lake Area, natural surface water quantity of land area and atural groundwater quantity are the water sources. These water sources minus water supply quantity from surface water and groundwater becomes inflow water quantity into the Lake Area. Rough water balance of the Lake Area can be calculated by adding precipitation volume in the Lake Area to the inflow quantity minus evaporation quantity from the Lake Area.

Furthermore, in Table 4.6.1, for the water balance of the Lake Urmia Area, the results of the case studies by changing evaporation quantity from water surface of the Lake are summarized. For each case, combination of natural surface water quantity and natural groundwater quantity where the historical annual difference of storage volume of the Lake fits, was calculated using trial and error method. It is noted that the parameter for calculating natural surface water quantity is runoff rate, and that of natural groundwater quantity is recharge height. If recharge quantity (height) is big, recharge quantity (height) includes supplemented water quantity (height) from groundwater storage. Lastly, Table 4.6.1 shows coefficient of correlation between accumulated annual water balance of the Lake Area and annual average lake water level. Table 4.6.2 summarizes the results of water balance calculation of the Lake Area.

It is noted that the water supply quantity shown in Figure 4.6.1 is the net water supply quantity. The net water supply quantity is calculated by Water supply quantity minus Return flow. Return flow is the water quantity of returning to the rivers etc. through drainage etc., after intake and supply water for water consumption.



Notes:
1) Surface water use quantity is surface water supply quantity, which is net water use quantity by deducting un-used water quantity to rivers etc. through drainage etc. (return flow) from the water intake and sent to water consumption.
2) Groundwater use quantity is groundwater supply quantity, which is net groundwater use quantity by deducting return flow after use from the water uptaken and sent for consumption.
3) For conservative calculation, as Base flow is overlapped in Surface water quantity and Groundwater Quantity, Surface water quantity and Groundwater Quantity shown above are modified quantity by deducting 1/2 of Base flow from each water quantity.

Figure 4.6.1 Concept of Rough Water Balance Calculation for the Lake Urmia Area

In addition, special conditions for this analysis are the following. The results of the analysis of Case 8 are shown in Figure 4.6.2, Figure 4.6.3, Figure 4.6.4 and Figure 4.6.5.

- For each case, Natural surface water quantity (with runoff rate as parameter) and Natural groundwater quantity (with the parameter recharge height: recharge quantity (height) + supplemented water quantity (height) from groundwater storage) were set, so that the tendency of changes in the annual water balance of the Urmia Lake relatively fits the tendency of changes in the annual difference of storage volume of the Lake for the years around 2010 (after 2004 or 2005). For this period, it is considered that the accuracy of H-A-V curve of the Lake is relatively high (see Figure 4.6.2 and Figure 4.6.3).
- The Natural groundwater quantity for the period 1980's to 1990's with annual precipitation of 400 to 450mm and for the period after Year 2000 with about 350mm of annual precipitation are set separately.
- For the Case 6 to 8, coefficients of correlation between accumulated annual water balance of the Lake Area and annual average lake water level becomes high at more than 90%. It is considered that the accumulated minus water balance of every year affects degradation of lake water level. Hence, it seems that these cases with high coefficient of correlation explains well this phenomena. Among the cases, it is estimated that Case 8 with 94.5% of the highest coefficient of correlation possibly fits the phenomena most in explaining water balance of the Lake (see Figure 4.6.4).
- Based on the above analyses, it can be confirmed that the lowering of the lake water level is affected by Natural water quantity and Natural groundwater quantity, both of which are based on precipitation quantity, as well as evaporation from the lake Area, water supply quantity from surface water, and water supply quantity from groundwater affect. Therefore, it can be also confirmed that both surface water and groundwater are important for maintaining the Lake.

Note:

Case 8:
1) Evaporation from water surface of the Lake: 1,200mm/year
2) Runoff rate of surface water: 28% (Before Year 1991: Annual average precipitation 447mm/year x 0.28 =125mm/year. After Year 2000: Annual average precipitation 354mm/year x 0.28=99mm/year)
3) Groundwater recharge rate before Year 1991 is 7% (447mm x 0.07=31mm/year). After Year 2000, it is 14% (354mm x 0.14=50mm).

Table 4.6.1 Cases for Annual Water Balance Calculation of the Urmia Lake and their Results

Case	Annual Evaporation Quantity from Water Surface	Duration	Annual Runoff Rate (Height) of Surface Water	Rate (Height) of Groundwater Flow (Groundwater Recharge + Supplement from Groundwater Storage)	Coefficient of Correlation between Annual Average Lake Water Level and Accumulated Annual Water Balance	Possibility of Fitting in the Changing of Annual Difference of Storage Volume of the Lake
Case 1	1,900mm	Before 1999 After 2000	43% (192mm) 43% (152mm)	7% (31mm) 15% (53mm)	81.6%	
Case 2	1,800mm	Before 1999 After 2000	41% (183mm 41% (145mm)	7% (31mm) 15% (53mm)	83.7%	
Case 3	1,700mm	Before 1999 After 2000	38% (170mm) 38% (134mm)	7% (31mm) 15% (53mm)	84.2%	
Case 4	1,600mm	Before 1999 After 2000	36% (162mm) 36% (126,mm)	7% (31mm) 15% (53mm)	86.7%	
Case 5	1,500mm	Before 1999 After 2000	33% (147mm) 33% (117mm)	7% (31mm) 15% (53mm)	87.3%	
Case 6	1,400mm	Before 1999 After 2000	31% (138mm) 31% (110mm)	7% (31mm) 15% (53mm)	90.3%	Third
Case 7	1,300mm	Before 1999 After 2000	30% (134mm) 30% (106mm)	7% (31mm) 14% (50mm)	94.1%	Second
Case 8	1,200mm	Before 1999 After 2000	28% (125mm) 28% (99mm)	7% (31mm) 14% (50mm)	94.5%	First
Case 9	1,100mm	Before 1999 After 2000	26% (116mm) 26% (92mm)	7% (31mm) 14% (50mm)	88.5%	
Case 10	1,000mm	Before 1999 After 2000	24% (107mm) 24% (85mm)	7% (31mm) 13% (46mm)	88.5%	

Note:
1) Annual Precipitation: About 400 to 450mm for the period before Year 1999. Among this, in the above table, 447mm of annual average precipitation in 1980s is used, when the water level of the Urmia Lake was stable. Annual average precipitation of 354mm is used after Year 2000.
2) (Water Balance of the Lake Area) = (Natural Surface Water Quantity) + (Natural Groundwater Quantity: Groundwater Recharge Quantity + Supplemented Water Quantity from Groundwater Storage) – (Base Flow of the Rivers) + (Precipitation in the Lake Area) – (Evaporation from the Lake Area) – (Water Supply Quantity from Surface Water and Groundwater)
3) (Base Flow of the Rivers) = (Natural Surface Water Quantity) x 14%

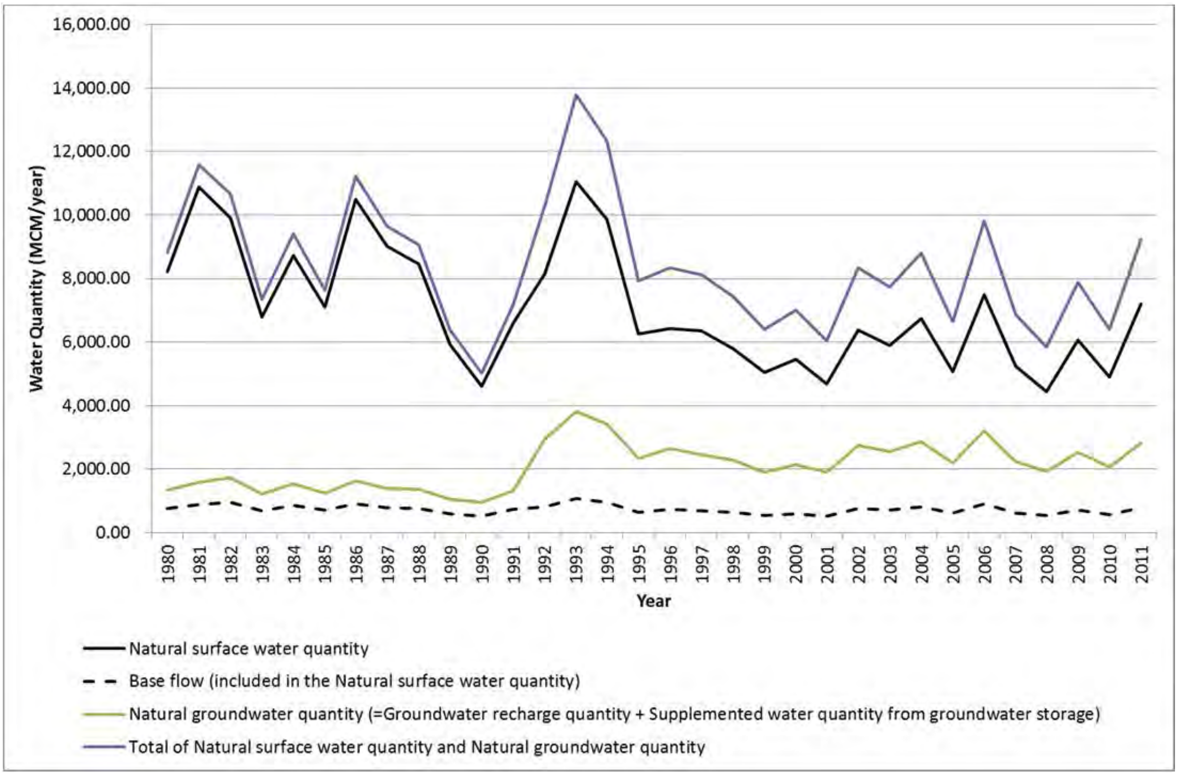


Figure 4.6.2 Surface Water Quantity, Groundwater Quantity and Total of Both Quantities of the Urmia Basin (Case of 1,200mm/year of Annual Evaporation from Lake Water Surface)

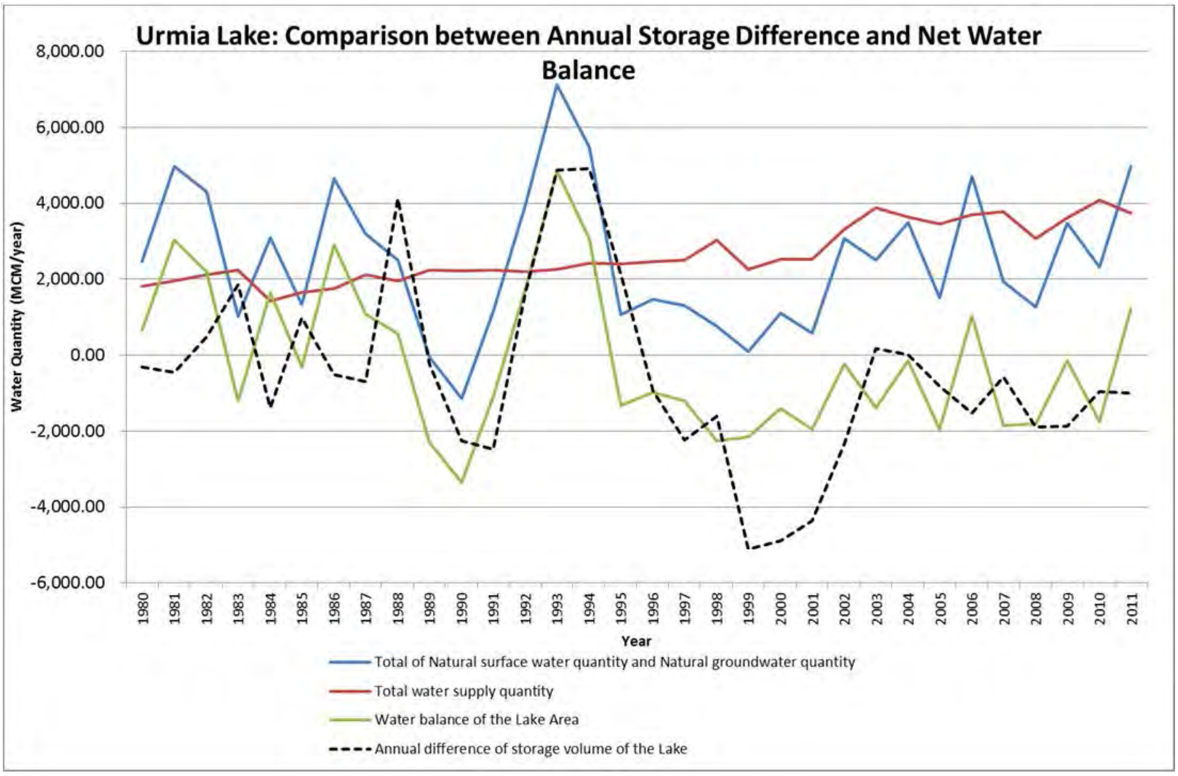


Figure 4.6.3 Annual Water Balance of the Lake Urmia (Case of 1,200mm/year of Annual Evaporation from Lake Water Surface)

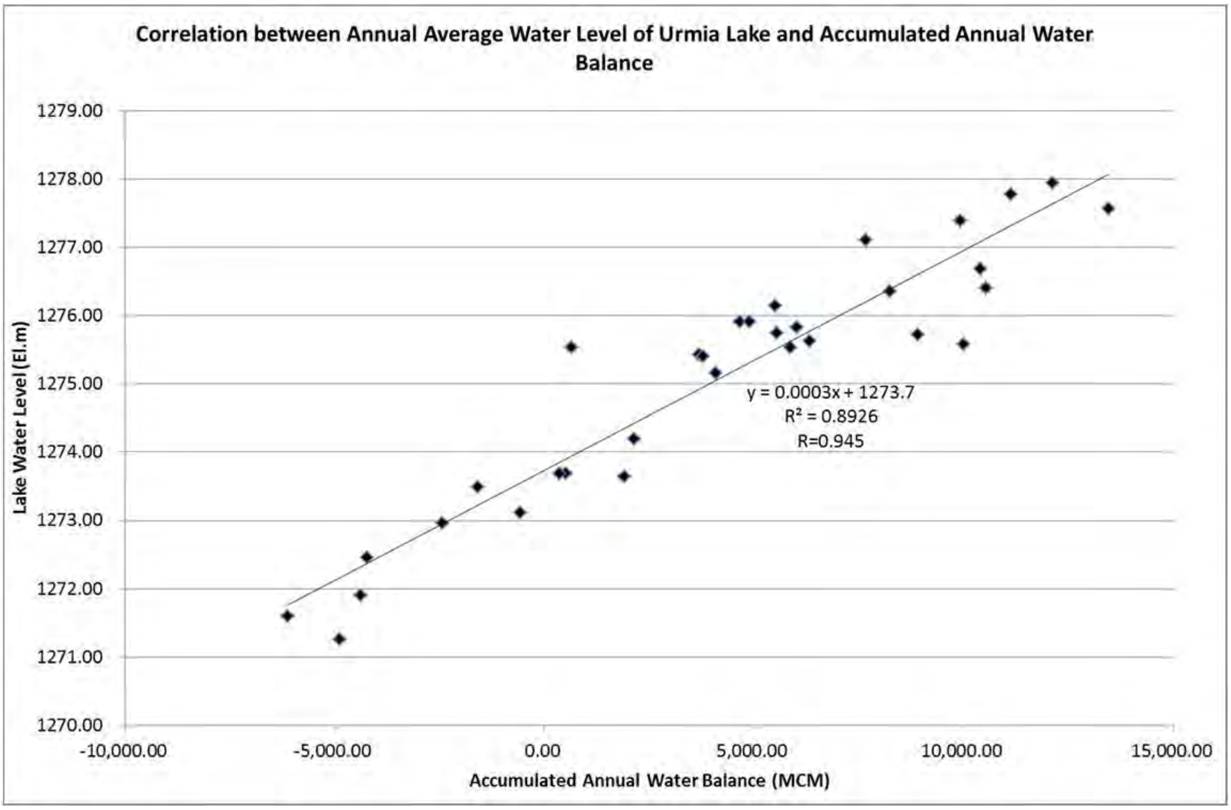


Figure 4.6.4 Correlation between Annual Average Lake Water Level and Accumulated Annual Water Balance of the Lake (Case of 1,200mm/year of Annual Evaporation from Lake Water Surface)

Table 4.6.2 Results of Annual Water Balance Calculation of the Urmia Lake (Case of 1,200mm/year of Annual Evaporation from Lake Water Surface

Year	Precipitation Volume (whole Lake Urmia Basin)	Precipitation Volume (Lake Area)	Natural Surface Water Quantity of Land Area	Natural Groundwater Quantity	Base Flow (included in the Natural surface water quantity)	Total of Natural Surface Quantity and Natural Groundwater Quantity of Land Area	Evaporation from Lake Urmia	Modified Water Supply Quantity from Surface Water	Modified Groundwater Uptaking Quantity	Total Water Supply Quantity	Water Balance of the lake area	Accumulated Water Balance of the Lake Area	Annual Difference of Storage Volume of the Lake
	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)	(MCM/year)
1980	22,022.02	2,858.71	5,365.73	1,341.43	751.20	5,955.96	6,345.68	1,340.78	477.55	1,818.33	650.66	650.66	-304.67
1981	27,317.44	4,494.02	6,390.56	1,597.64	894.68	7,093.52	6,606.37	1,442.51	508.79	1,951.30	3,029.86	3,680.53	-462.12
1982	27,616.83	3,032.18	6,883.70	1,720.93	963.72	7,640.91	6,375.42	1,544.25	563.55	2,107.80	2,189.86	5,870.38	477.87
1983	19,494.25	1,859.83	4,937.64	1,234.41	691.27	5,480.78	6,306.97	1,645.98	586.27	2,232.25	-1,198.62	4,671.76	1,855.69
1984	24,503.19	2,610.16	6,130.05	1,532.51	858.21	6,804.35	6,331.88	821.50	608.66	1,430.16	1,652.48	6,324.24	-1,376.26
1985	20,012.74	2,071.26	5,023.61	1,255.90	703.31	5,576.21	6,310.57	1,002.95	642.60	1,645.55	-308.65	6,015.59	989.35
1986	27,266.06	3,987.72	6,517.94	1,629.48	912.51	7,234.91	6,566.51	1,086.16	668.92	1,755.08	2,901.03	8,916.62	-508.87
1987	23,454.03	3,417.87	5,610.13	1,402.53	785.42	6,227.24	6,451.31	1,391.03	727.80	2,118.83	1,074.96	9,991.58	-688.09
1988	22,641.13	2,960.42	5,510.60	1,377.65	771.48	6,116.76	6,572.77	1,209.83	746.21	1,956.04	548.38	10,539.96	4,120.53
1989	16,771.16	1,698.16	4,220.44	1,055.11	590.86	4,684.69	6,434.71	1,473.66	769.12	2,242.78	-2,294.64	8,245.32	-240.37
1990	14,394.89	811.93	3,803.23	950.81	532.45	4,221.58	6,168.72	1,424.46	794.25	2,218.71	-3,353.91	4,891.41	-2,248.23
1991	20,111.90	1,351.28	5,252.97	1,313.24	735.42	5,830.80	6,045.40	1,416.62	820.48	2,237.10	-1,100.42	3,790.99	-2,489.31
1992	23,254.39	2,281.40	5,872.44	2,936.22	822.14	7,986.51	6,315.95	1,324.71	875.38	2,200.09	1,751.87	5,542.86	1,655.31
1993	30,636.20	3,443.29	7,614.01	3,807.01	1,065.96	10,355.06	6,679.86	1,353.19	915.41	2,268.61	4,849.89	10,392.74	4,864.47
1994	27,537.55	2,998.24	6,871.01	3,435.50	961.94	9,344.57	6,864.11	1,454.51	963.07	2,417.57	3,061.13	13,453.88	4,902.67
1995	18,237.69	1,587.59	4,662.03	2,331.01	652.68	6,340.36	6,865.62	1,326.94	1,068.75	2,395.69	-1,333.36	12,120.51	2,146.93
1996	20,108.01	1,095.52	5,323.50	2,661.75	745.29	7,239.96	6,864.54	1,299.96	1,156.46	2,456.42	-985.49	11,135.02	-933.77
1997	18,991.44	1,428.56	4,917.61	2,458.80	688.46	6,687.94	6,814.83	1,229.69	1,278.44	2,508.13	-1,206.46	9,928.57	-2,244.94
1998	17,581.75	1,225.94	4,579.63	2,289.81	641.15	6,228.29	6,686.90	1,679.14	1,342.66	3,021.80	-2,254.47	7,674.10	-1,616.25
1999	14,841.59	1,228.77	3,811.59	1,905.79	533.62	5,183.76	6,311.67	849.69	1,414.08	2,263.77	-2,162.90	5,511.20	-5,109.47
2000	16,513.72	1,163.34	4,298.11	2,149.05	601.73	5,845.43	5,900.77	1,058.35	1,465.68	2,524.03	-1,416.04	4,095.16	-4,887.57
2001	14,424.94	895.28	3,788.30	1,894.15	530.36	5,152.09	5,476.61	996.20	1,523.97	2,520.17	-1,949.40	2,145.76	-4,355.30
2002	20,458.41	894.98	5,477.76	2,738.88	766.89	7,449.75	5,266.27	1,725.68	1,591.13	3,316.81	-238.34	1,907.41	-2,332.67
2003	19,077.34	763.82	5,127.79	2,563.89	717.89	6,973.79	5,241.68	2,247.07	1,640.80	3,887.87	-1,391.95	515.46	177.89
2004	21,478.09	1,012.62	5,730.33	2,865.17	802.25	7,793.25	5,319.90	1,941.16	1,703.87	3,645.03	-159.06	356.40	7.00
2005	16,330.65	686.69	4,380.31	2,190.15	613.24	5,957.22	5,138.94	1,720.20	1,740.71	3,460.91	-1,955.94	-1,599.54	-826.93
2006	24,057.21	1,062.38	6,438.55	3,219.28	901.40	8,756.43	5,108.56	1,933.16	1,755.85	3,689.00	1,021.25	-578.29	-1,534.46
2007	16,805.86	751.38	4,495.26	2,247.63	629.34	6,113.55	4,929.11	2,023.39	1,760.94	3,784.33	-1,848.52	-2,426.82	-582.30
2008	14,380.08	582.19	3,863.41	1,931.70	540.88	5,254.24	4,565.05	1,313.74	1,763.67	3,077.40	-1,806.02	-4,232.84	-1,901.04
2009	19,039.56	1,025.06	5,044.06	2,522.03	706.17	6,859.92	4,409.46	1,851.52	1,765.41	3,616.93	-141.41	-4,374.25	-1,867.17
2010	15,508.46	787.45	4,121.88	2,060.94	577.06	5,605.76	4,069.62	2,305.60	1,767.16	4,072.76	-1,749.17	-6,123.42	-952.97
2011	21,671.90	1,579.43	5,625.89	2,812.95	787.62	7,651.21	4,264.61	1,962.97	1,768.90	3,731.87	1,234.17	-4,889.25	-1,003.71
Average all	20,516.89	1,801.48	5,240.31	2,107.29	733.64	6,613.96	5,925.32	1,481.14	1,161.77	2,642.91	-152.79		-539.65
Average from Year 1980 to Year 1989	23,109.89	2,899.03	5,659.04	1,414.76	792.27	6,281.53	6,430.22	1,295.87	629.95	1,925.81	824.53		386.31
Average from Year 1990 to Year 1999	20,569.54	1,745.25	5,270.80	2,409.00	737.91	6,941.88	6,561.76	1,335.89	1,062.90	2,398.79	-273.41		-107.26
Average from Year 2000 to Year 2011	18,312.18	933.72	4,865.97	2,432.99	681.24	6,617.72	4,974.21	1,756.59	1,687.34	3,443.93	-866.70		-1,671.60

Notes:
1) Base flow = Natural surface water quantity of land area x 14%
2) Total of Natural surface water quantity and Natural groundwater quantity = Natural surface water quantity + Natural groundwater quantity - Base flow
3) Water balance of the Lake Area = Total of Natural surface water quantity and Natural groundwater quantity + Precipitation volume in the Lake Area - Evaporation from the Lake Area - Total water supply quantity

(2) Rough Estimation of Annual Water Balance

Figure 4.6.5 shows average rough annual water balance of the Lake Urmia from Year 1980 to 1989 for the period of stable high water level of the Lake before Year 1995. Figure 4.6.6 shows average rough annual water balance of the Lake from Year 2000 to 2011for the period of lowering lake water level after Year 1995.

In terms of mechanism of water balance of the Urmia Basin as well as the Urmia Lake before Year 1990 when the water level of the Urmia Lake was stable and the precipitation quantity was big and water supply quantity was small, water balance was positive. Furthermore, it can be estimated that uptaking water quantity from groundwater was within the groundwater recharge quantity. However, among the rivers with dams, it was estimated that there are rivers in very unbalanced condition of water quantity like the Zarineh Rud River with Bukan Dam. For example, the Zarineh Rud River had almost no water in the most downstream reach of the river due to significant water use.

After Year 1995, especially after Year 2000, when the water level of the Urmia Lake had a lowering tendency, annual precipitation quantity has decreased to 80%. On the other hand, the water supply quantity is estimated to increase by 1.8 times. Among the water supply quantities, water supply quantity from surface water had increased by 1.4 times and that from groundwater has increased by 2.7 times. These phenomenon can be considered as reasons behind the water balance becoming negative. Even before Year 1990, there were rivers with very small water quantity in the most downstream reaches due to intaking water through dams, etc. As for the groundwater, it can be estimated that uptaking of groundwater has been conducted more than groundwater recharge quantity. Due to this condition, according to the water balance calculation, it can be estimated that supplementing water from groundwater storage has occurred. This might be related to the lowering tendency of groundwater level.

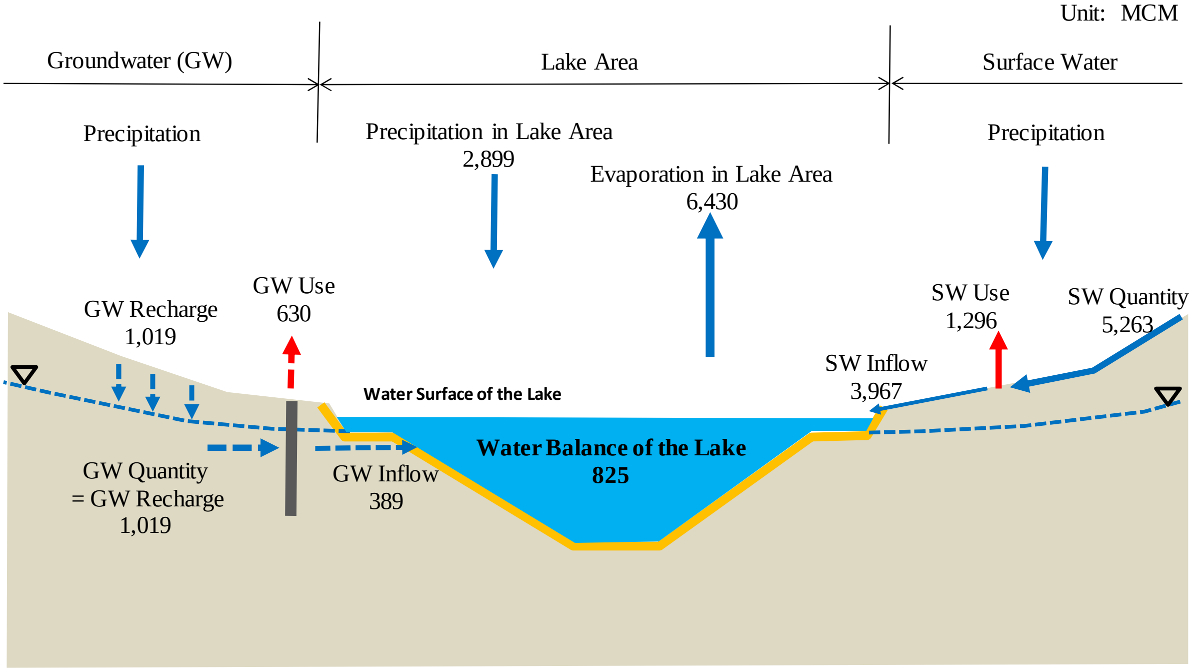


Figure 4.6.5 Rough Annual Water Balance of the Lake Urmia Area during the Period of Stable Water Level of the Lake (Before Beginning of 1990s)

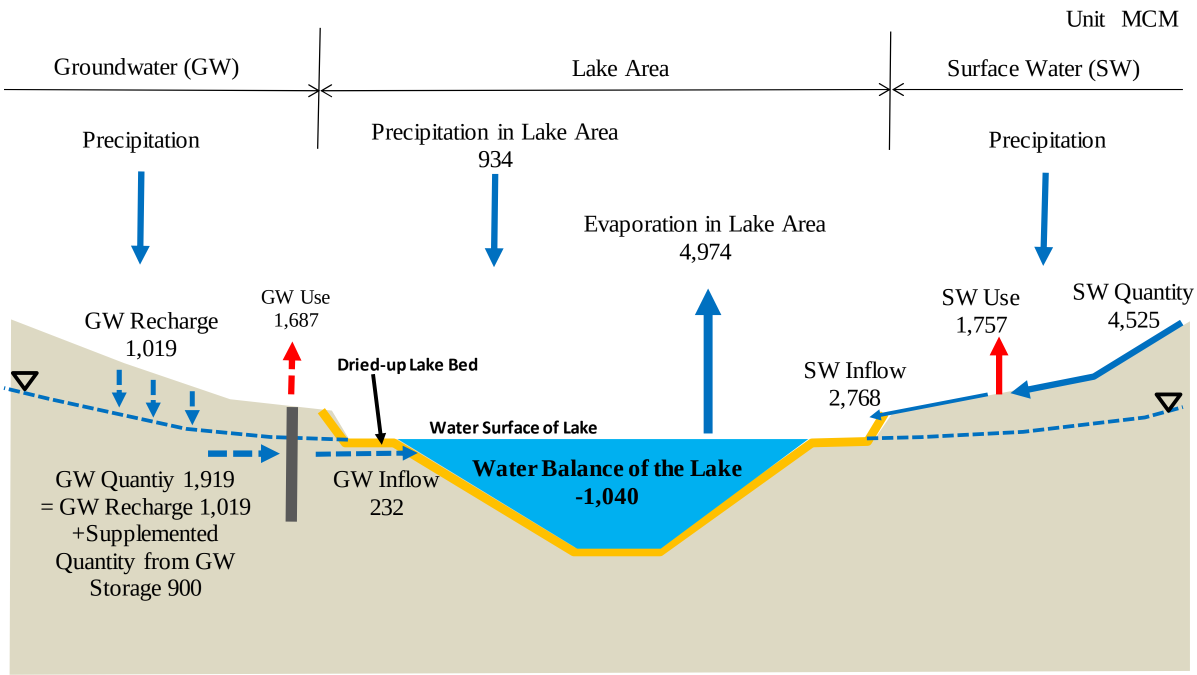


Figure 4.6.6 Rough Annual Water Balance of the Lake Urmia Area during the Period of Lowering Water Level of the Lake (After 1995 Especially After 2000)

(3) Consideration on the Results of the Study on Rough Water Balance

The rough water balance was studied for the primary purpose of understanding the mechanism of lowering water level of the Lake Urmia. As a result, rough water balance could be determined, and it can be utilized as a basic information for developing detailed water balance simulation model(s).

- It was difficult to estimate water quantity from groundwater to the Lake, but it can be estimated that annual average lake water level and accumulated annual water balance have high coefficient of correlation at more than 90% (see Figure 4.6.4).
- In this condition, annual runoff rate from the rivers was estimated at the order of 0.2. It could be possible to confirm from the distribution type of simulation model that the annual runoff rate becomes similar to this order (see Table 4.6.1).
- It was clarified that water balance can be achieved by the evaporation calculated as 60% to 70% of PAN evaporation. Iranian side's research indicate 1,100mm of evaporation. As the JICA Study estimates 1,200mm, it was possible to keep cosisntency between the two. Distiribution model also used this evaporation (see Table 4.6.1).
- Based on this rough water balance calclation, it can be estimated that inflow from groundwater is equal to several hundred MCM. This quantity is also considered for the simulation model (see Figure 4.6.5 and Figure 4.6.6).
- Since the annual water balance is the sum of surface water balance and groundwater balance, decreasing tendency of annual precipitation volume, evaporation from the Lake Area and rapid increase of surface and groundwater use relate to the water balance. Therefore, among the various countermeausres to maintain annual water balance, the countermeasure for reducing water use quantity from surface water and groundwater to the same level as the water use quantity during the period of stable lake water level is one of the most basic measures (see Figure 4.4.3 and Figure 4.5.3).
- It could be established that both of surface water and groundwater affect lake water level. Hence, in order to study water balance in detail with better accuracy, it is preferable to develop simulation model(s), which can simulate both of surface water and groundwater.

CHAPTER 5. ESTABLISHMENT OF DISTRIBUTED HYDROLOGICAL MODEL

5.1 NECESSITY OF DISTRIBUTED HYDROLOGICAL MODEL AND THE DESRIPTION OF APPLIED MODEL

To determine the contributing factor of lowering the lake water level of Lake Urmia and to evaluate the measures to recover the lake water level, it is required to clarify the hydrological water cycle of Lake Urmia Basin. Since the observation data of river flow or ground water level are partly insufficient to understand water flow, runoff model analysis is required for the evaluation. When more detailed actual condition has to be determined, the distributed hydrological model is adequate, in which the Urmia Basin is divided specially and governing equations for runoff phenomenon are incorporated.

On this circumstance, MIKE-SHE and GETFLOWS were employed in this study to establish the distributed hydrological model. Based on the characteristics of each model, MIKE-SHE was used to evaluate the project effect to Urmia Lake as the quick solution model (overall water movement relating to the water level variance of Urmia Lake is studied). As for GETFLOWS, water movement is analyzed more physically than MIKE-SHE. Thus it is intended to be used to well understand the hydrological cycle of Lake Urmia Basin including lowering of the lake water level.

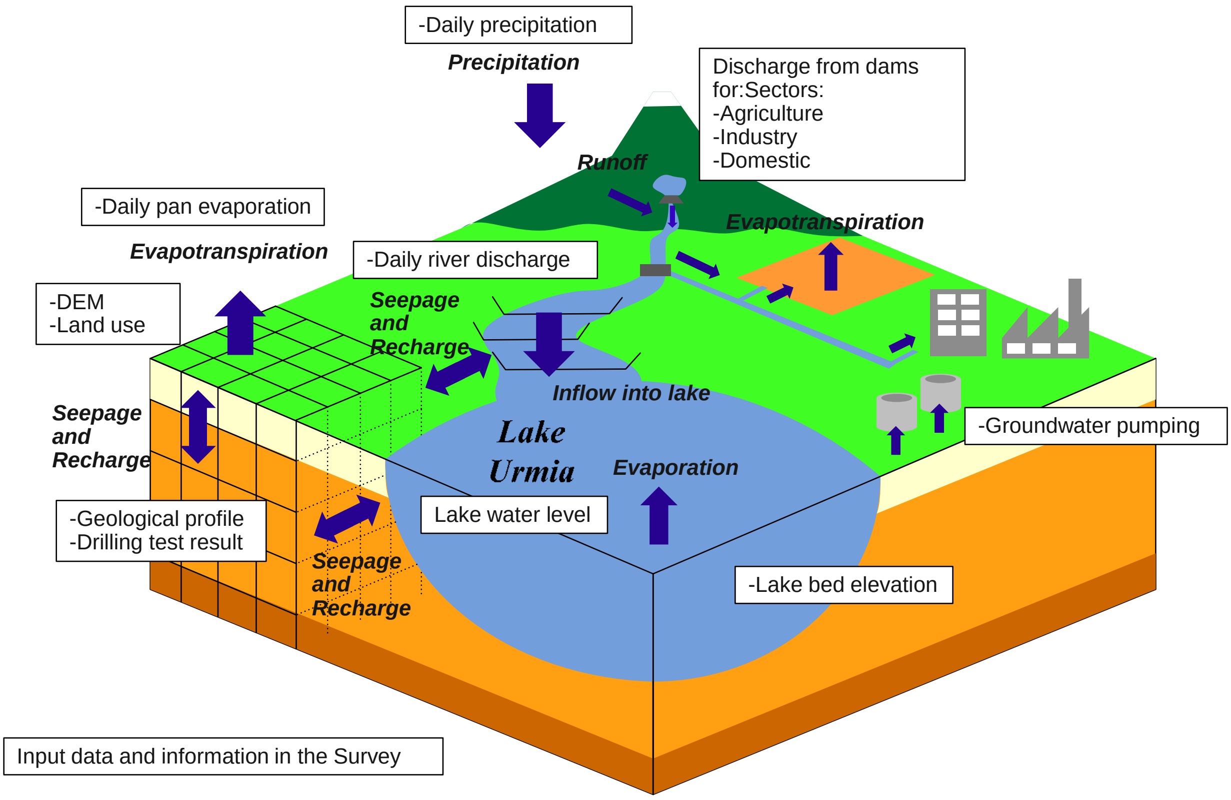
Among the various distributed hydrological models, MIKE-SHE and SHETRAN are the globally most-used, while GETFLOWS is the most common in Japan. In this study, MIKE-SHE and GETFLOWS were selected to be deployed from the following viewpoints:

- MIKE-SHE is the globally used model. It has GUI for model establishment, can deploy versatile GIS data, namely shp files, and convert automatically to model input data. Thus, a model can be established in a relatively short time.
- SHETRAN is one of the free models, but applicable area is limited. In SHETRAN, modeled area is several thousand kilometers horizontally, and vertically 100 meters. The number of the grids are 50x50 at the maximum. Therefore, SHETRAN is not adopted.
- GETFLOWS is a model in which multi-phase and multi-component fluid is calculated as surface and subsurface fully-coupled fluid flow. Since it does not have the GUI, and it calculates surface and subsurface fully-coupled fluid flow, model establishment or calculation time can be relatively long. It is because, when surface and subsurface water flow with different flow velocity is analyzed, the surface flow condition define the overall calculation time.

5.2 BASIC CONCEPT OF DISTRIBUTED HYDROLOGICAL MODEL BY MIKE-SHE

To clarify the mechanism of the contributing factor of lowering the lake water level of Lake Urmia, the distributed hydrological model (hereinafter called as "the model") was established on the basis of collected information and examination results discussed in the previous chapters. In the Survey, MIKE SHE (released by DHI), which has user-friendly interface and versatile modules and has been used successfully abroad, was employed as the quick solution model for the evaluation of water cycles. Figure 5.2.1 shows conceptual diagrams of the model and applied input data and information.

MIKE-SHE is a mesh based model, in which the entire basin is divided horizontally into orthogonal meshes, and vertically into multiple columnar soil layers. Each divided block is given with observation values including precipitation, and parameter values including permeability coefficient to analyze water flow among the entire basin. Furthermore, optional tools are prepared for the process of pre- and post-calculation, digitizing of paper-based information, interpolation of data, graph drawing and animations of the results, etc. The source code, however, is not open to the public.



*JICA Survey Team

Figure 5.2.1 Conceptual Diagram of Distributed Hydrological Model and Input Data and Information

5.2.1 Structure of MIKE-SHE

MIKE-SHE consists of (i) precipitation, evapotranspiration, and snowmelt; (ii) land use (transpiration from plants and irrigation); (iii) surface and river flow; (iv) unsaturated flow; and (v) saturated flow, which express almost the complete process of water circulation. Not only each process can be individually calculated, but also the calculation is carried out with selected time steps to meet the most appropriate time scale for each process. Furthermore, all calculated results are updated at certain common time points. Thus, calculation can effectively be carried out even for long-term calculation. The water circulation process is modeled as follows.

(1) Precipitation, Evapotranspiration, and Snowmelt

Precipitation is handled as input data. When unsaturated flow is activated, evapotranspiration is handled as “evapotranspiration”. It is handled as “evaporation” when unsaturated flow is inactivated. When unsaturated flow is activated, actual transpiration is calculated by multiplying crop index with input base evapotranspiration by setting leaf area index (LAI) and root depth for land use parameters.

Snowmelt is calculated by degree-day method. In addition to input precipitation and temperature, rain/snow determination temperature and snowmelt coefficient are referred.

(2) Landuse

For land use, when unsaturated flow is activated, leaf area index (LAI) and root depth can be set according to the vegetation. LAI and root depth can also be applied as time series data.

In addition, for impermeable areas such as urban area, runoff coefficient and storage volume can be set. Furthermore, irrigation can also be considered, by setting supply and demand volume in temporary and spatially distributed manner for irrigation area.

(3) Surface Flow and River Flow

Surface flow and river flow are described with diffusion wave model which is a simplified St. Venant Equation, and continuous equation (For river flow, dynamic wave model is also applicable.). Surface flow is two-dimensional (2-D), and river flow is one-dimensional (1-D). In surface flow analysis, the process of flowing toward river channels with water evaporation and seepage is incorporated. In most cases, area of river channels is much smaller than the area of the entire basin; river channels are handled as lines embedded along the grid edges.

(4) Unsaturated Flow

Since recharge of groundwater and exchange of surface and groundwater occur within an unsaturated layer, the calculation of unsaturated flow is the critical part of the model. Water flow in an unsaturated soil layer is expressed by one-dimensional (1-D) Richards Equation. In addition, for the surface layer where roots grow, water absorption to roots from the soil is also incorporated.

(5) Saturated Flow (Subsurface water Flow)

Subsurface water flow calculation is the significant part which has a great influence to the water circulation process. Two-dimensional (2-D) model is applied for single aquifer, whereas three-dimensional (3-D) model is for multiple aquifers. For complete three-dimensional (3-D) flow, the aquifer is divided three-dimensionally. When the flow is approximated to two-dimensional (2-D) (or quasi three-dimensional (quasi-3-D)), the aquifer is divided according to the geological structure. When deploying quasi-three-dimensional (quasi-3-D) model, quasi-horizontal flow is assumed. Thus the vertical variation of water head is not considered. In the groundwater analytical model, water exchange between unsaturated aquifer and river flow, water uptake and pouring at wells, water drainage through embedded pipes, etc., are modeled. Heterogeneity of the aquifer and anisotropy of permeability coefficient are also able to be incorporated.

5.2.2 The Governing Equation of MIKE-SHE

MIKE-SHE consists of basin model (land surface layer, unsaturated layer, and underground layer), and river model. Modeled area is divided into grids to calculate horizontal and vertical water flow, as well as water exchange with river channels (one-dimensional (1-D) unsteady flow model). The governing equations for basin model (land surface layer, unsaturated layer, and underground layer) and river model are shown below.

① Land surface layer model: Two-dimentional (2-D) horizontal diffusion wave model
② Unsaturated layer model: One-dimentional (1-D) Richards Equasions
③ Underground layer model: Two-dimentional (2-D) horizontal /three-dimentional (3-D) groundwater flow model
④ River channel model: One-dimentional (1-D) dynamic wave/ diffusion wave/ kinematic wave model

(1) Surface Layer Model

In the surface layer model, surface flow is described by two-dimensional (2-D) horizontal diffusion wave model, which is the simplified St. Venant Equation, and continuity equation. The governing equations for surface layer model are shown below. When precipitation is larger than the permeability of unsaturated layer, surface flow emerges and thus evaporation and seepage along the flowing process through river channels are considered.

① Continuity Equation

$$\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}(uh)+\frac{\partial}{\partial y}(vh)=i \qquad (5.1.1)$$

② Equations of Motion in x direction

$$S_{fx}+\frac{\partial}{\partial x}(Z_g+h)=0 \qquad (5.1.2)$$

$$S_{fx}=\frac{u^2}{K_x^2 h^{4/3}} \qquad (5.1.3)$$

③ Equations of Motion in y direction

$$S_{fy}+\frac{\partial}{\partial y}(Z_g+h)=0 \qquad (5.1.4)$$

$$S_{fy}=\frac{v^2}{K_y^2 h^{4/3}} \qquad (5.1.5)$$

where, Z_g : ground elevation (m)

h : water depth(m)

u, v : water velocity in x, y directions (m/s)

i : inflow per unit area [precipitation – seepage] (m/s)

S_{fx}, S_{fy} : friction slopes in x, y directions

K_x, K_y : roughness coefficients in x, y directions ($m^{-1/3}s$)

The water level for the next time step is calculated based on the water balance with the 4 surrounding grids as shown in Figure 5.2.2. Outflow between grids are calculated by the equation (5.1.10).

$$\frac{\partial}{\partial x}(uh) \cong \frac{1}{\Delta x}\left\{(uh)_{east} - (uh)_{west}\right\} \tag{5.1.6}$$

$$\frac{\partial}{\partial y}(vh) \cong \frac{1}{\Delta y}\left\{(vh)_{north} - (vh)_{south}\right\} \tag{5.1.7}$$

$$\Delta h = h(t + \Delta t) - h(t) = \frac{I + \Sigma Q \Delta t}{\Delta x^2} \tag{5.1.8}$$

where,

$$I = i\Delta x^2, \quad \Sigma Q = Q_N + Q_S + Q_E + Q_W \tag{5.1.9}$$

Additionally, for x direction,

$$Q = \frac{K\Delta x}{\Delta x^{1/2}}(Z_U - Z_D)^{1/2} h_u^{5/3} \tag{5.1.10}$$

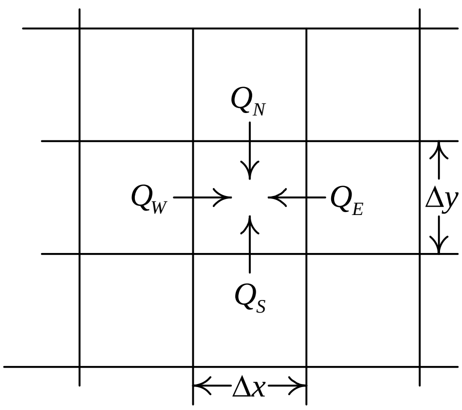


Figure 5.2.2 Water Balance for the Control Volume

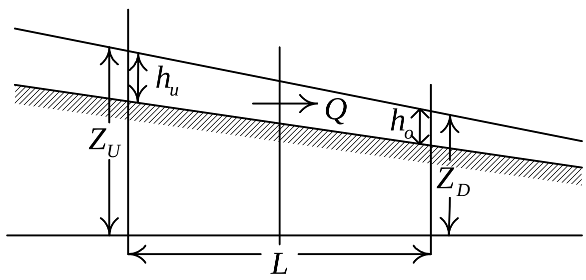


Figure 5.2.3 Outflow between Grids

(2) Unsaturated Layer Model

Water flow in the unsaturated layer is expressed by one-dimensional (1-D) Richards Equation. The governing equation is shown below. In addition, for surface layer where roots grow, water absorption to roots from the soil is also incorporated.

$$C\frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial \psi}{\partial z}\right) + \frac{\partial K}{\partial z} - S \qquad (5.1.11)$$

$$C = \frac{\partial \theta}{\partial \psi} \qquad (5.1.12)$$

where, θ : volumetric water content ratio

ψ : absorption pressure (cmH_2O)

K : permeability coefficient for unsaturated layer (m/s)

S : absorption volume to roots (l/s)

C : specific water content volume

(3) Underground Layer Model

Water flow in the underground layer is expressed by two-dimensional (2-D) horizontal or three-dimensional (3-D) groundwater flow model. Two-dimensional (2-D) model is applied to single-layered aquifers, where three-dimensional (3-D) model is applied for multi-layered aquifers.

Since both shallow and deep groundwater flow are the calculation targets in the modeled basin, three-dimensional (3-D) groundwater flow model is applied. In aquifers, water recharge from unsaturated layer, outflow to river channels, seepage from river channels, and water uptake are incorporated.

The governing equations for three-dimensional (3-D) groundwater flow model are shown below.

The governing equation of three-dimensional (3-D) groundwater flow model is shown below.

$$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z}) - Q = S\frac{\partial h}{\partial t} \qquad (5.1.13)$$

where, K_{xx}, K_{yy}, K_{zz} : permeability coefficient in x, y, z directions (m/s)

S : specific storage coefficient

h : water head in the aquifer (m)

Q : groundwater flow per unit area (such as water recharge, water uptake etc.) (m/s)

In MIKE-SHE, groundwater flow model is solved by difference method. In this method, partial differential equations are approximated with difference equations which are specially and temporally discretized. For a micro control volume stretching from the top to the bottom of an aquifer, 4 inflows (outflows) from (to) surrounding micro grids and water uptake (recharge) from the upper grid are assumed. By applying Continuity Equation and Darcy's Equation and considering the water balance, Continuity Equation (5.1.14) is derived. Continuity Equation of a grid means the outflow (inflow) between control volumes is equal to the temporal change of the storage in the grid. This infinite difference approximation based on water balance leads to the equation below.

$$q_{p,i-1} + q_{p,i+1} + q_{p,j-1} + q_{p,j+1} + q_{p,k-1} + q_{p,k+1} - q_{out} = \frac{\Delta w}{\Delta t} \qquad (5.1.14)$$

where; q_p : inflow to domains i, j, k 、 q_{out} : outflow from the domains、 Δw : storage volume

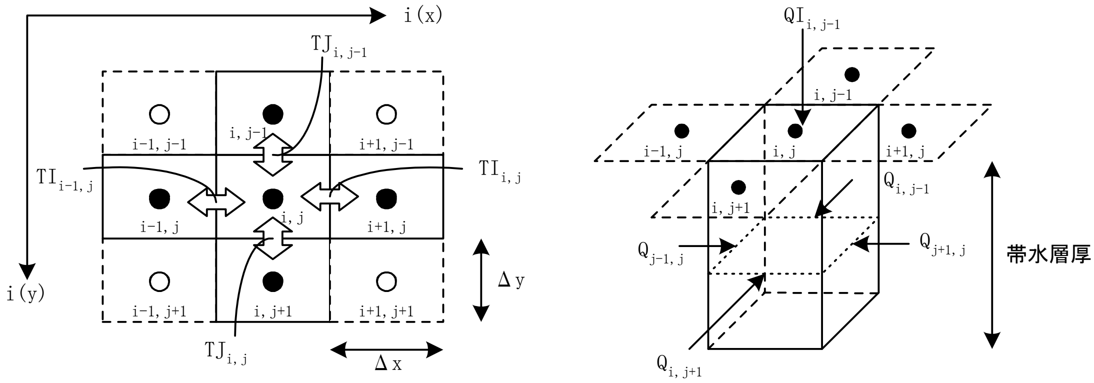


Figure 5.2.4 Water Balance at a Control Volume

(4) River Channel Model

River channel model can be selected from one-dimensional (1-D) dynamic wave/diffusive wave/ kinematic wave models. The governing equations for river channel model are shown below.

① Continuity Equation

$$\frac{\partial A}{\partial t} + \frac{\partial}{\partial x}(Au) = q_L \qquad (5.1.19)$$

② Equations of Motion

$$S_f + \frac{\partial}{\partial x}(Z_o + h) = 0 \qquad (5.1.20)$$

$$S_f = \frac{u^2}{K^2 h^{4/3}} \qquad (5.1.21)$$

$$Au = K\left(-\frac{\partial Z}{\partial x}\right)^{1/2} A h^{2/3} \qquad (5.1.22)$$

where, A : cross-sectional area (m^2)

u	:	velocity (m/s)
q_L	:	inflow per unit length (m^2/s)
S_f	:	friction slope
Z_o	:	river bed elevation (m)
h	:	water depth (m)
K	:	roughness coefficient ($m^{-1/3}s$)

5.2.3 MODEL SETTING (MIKE-SHE)

The basic ideas of model setting are summarized in Table 5.2.1. Details for the items are described after this subsection.

Table 5.2.1 Summary of Model Setting (MIKE-SHE)

Classification	Item	Description
Modeled Area		Surface water basin boundary: Boundary of the Lake Urmia Basin provided by WRMC Groundwater basin boundary: Ditto
Mesh size		2-km-mesh was employed, considering required resolution for modeling topographic and land use conditions, and calculation time.
Calculation period		9 years (1999 – 2007)
Meteorological condition	Lake surface evaporation	Lake surface evaporation was estimated based on daily pan evaporation (10 gauging stations) observed by IMO with Thiessen method. 60% of the observed pan evaporation was applied for initial condition and then calibrated, based on the research outcome of Tarbiat Modares University of Iran.
	Land evapotranspiration	Evapotranspiration was estimated based on the daily pan evaporation and water balance in dam catchment area. The values were also calibrated in the process of model establishment in reference to the ratio to pan evaporation.
	Precipitation	The average precipitation in each sub-basin (50 basins) was applied. The average precipitation was calculated using the observed precipitation data (242 stations) by the Thiessen method. The potential influence of missing data was removed by preparation of Thiessen polygon by the day without the missing values.
Geological condition	Subsurface geological structure	Based on the results of analysis, layers with geological features such as Quaternary layer, Tertiary, Mesozoic, Paleozoic, Precambrian, igneous rocks, and mélange were considered. The parameters corresponding to these types of geology were given in each prepared mesh.
	Parameters of the layer (permeability coefficient, etc.)	In reference to the guidelines (draft) published by the Ministry of Land, Infrastructure, Transport and Tourism, Japan, the values corresponding to actual geological parameters were applied.
Topography	Ground surface elevation	2-km-mesh of ground elevation data was prepared by MIKE-SHE based on the 90m-DEM provided by WRMC.
	Lake bed elevation	Meshed lake bed elevation data was created by MIKE-SHE based on the DEM data obtained from 2010 bathymetry survey result of Lake Urmia.
Land use	Surface roughness	Based on the land use data provided by WRMC, the dominant land use type in each mesh was selected with the area. Roughness coefficient in each land use (from 0.06 to 0.05) was placed into the grid, in reference to the manual for flood simulation published by the Public Work Research Institute.
Natural conditions	River network	Main river channel in each basin was modeled based on the collected river channel data. Rectangle-shaped cross sections on the channels were prepared with elevations of river beds referred to the elevation of the 90m-DEM.
Water use structure	Dam	According to information on the dam provided by the WRMC, only those labeled "In Operation" (40 dams) were modeled, while those labeled as "Under Construction" (14 dams) were not modeled. Dams on the main river channels were modeled in MIKE11 module. As for the other dams to be modeled on un-modeled river channels, dam lakes were modeled by lowering elevation grid (dam weir were not modeled). The discharge was placed into the modeled river channel.
Ground water	Initial condition	In MIKE-SHE, meteorological data from 1993 to 1999 (precipitation, lake surface evaporation, and land evapotranspiration) were placed into the model. The calculation results by MIKE-SHE when the lake water levels at some points had high similarities with the observed data in 1999 were applied for the initial condition.
Water use	River water intake	According to the analysis in Chapter 4, amount of actual water supply for the sectors were estimated as 1.72 times more than that of collected discharge data from dams. The estimated water amount was subtracted from river discharge.
	Groundwater intake	The water amount of wells permitted by WRMC in the grid of 2-km-mesh were summed up and was found to be 1.1 times more than collected amount. (1.1 was the ratio of the water demand described in 2013 Master Plan to the permitted amount between 2012 and 2014) Seasonal proportion of groundwater uptake was referred to that of river water intake amount.

(1) Modeled Area

The main objectives of modeling in the Survey were (i) to analyze the behavior of surface water and groundwater around Lake Urmia, and (ii) to simulate the change in lake surface area and lake water level. Therefore, the target area was determined as the Lake Urmia Basin for the following reasons:

- Although it was not determined whether the boundary of groundwater basin matches that of surface water, according to interview with experts in Iran, no interaction of groundwater outside the boundary of Lake Urmia has occured. As such, the behavior of groundwater outside the basin boundary was not considered in modeling.
- It was not necessary to model the water cycle outside the basin since there was no interchange of water with other neighboring basins.

(2) Mesh Size

The target area was modeled with 2-km-mesh based on the following reasons.

- In the Survey, it was required to simulate the lake surface area and lake water level that were affected by the change of water withdrawal from surface/ground waters. Therefore, it was necessary to model the target area with sufficient resolution to simulate change of the lake water surface of Lake Urmia.
- The resolution was required so that spatial distribution of elevation and land use are represented as clear as possible (See Annex 5.2).
- The balance between resolution and calculation time was considered. The established model with 2-km-mesh required approximately 1 day for 5-year simulation.

(3) Verification Period

To determine the verification period of the established model, the validity of observed lake water level was examined and used for model verification. Based on the following viewpoints, calibration period of the water cycle model was determined to be 9 years from 1999 to 2007:

- The verification period was required to contain the period (i) when the lake water level had lowered and (ii) when the lake water level of Minimum Ecological Balance Level (1,274.1m) was included.
- In the Survey, daily pan evaporation data between 1992 and 2009 had been collected.
- As described in Chapter 4, since most of the recent bathymetric data updated was prepared in 2010, accuracy of applying the H-A-V curve seem to be good for about 10 years around 2010.
- Based on the quality check of the observed data, the period confirmed that validity of observed lake water level was secured.

The validity of examination results are explained as below.

The abnormal values of the Lake’s water level data are identified as (i) rapid variation and (ii) different trend of water level change from the normal, whose occurrence affects water balance of the lake. Water balance in periods other than normal years was compared with that in normal period. From October 1 to October 14, 1998, rapid lowering in the Lake's water level was observed (See Figure 5.2.5). Furthermore, in 2008 the lowering of lake water level from May to July was different from that of other years (See Figure 5.2.6).

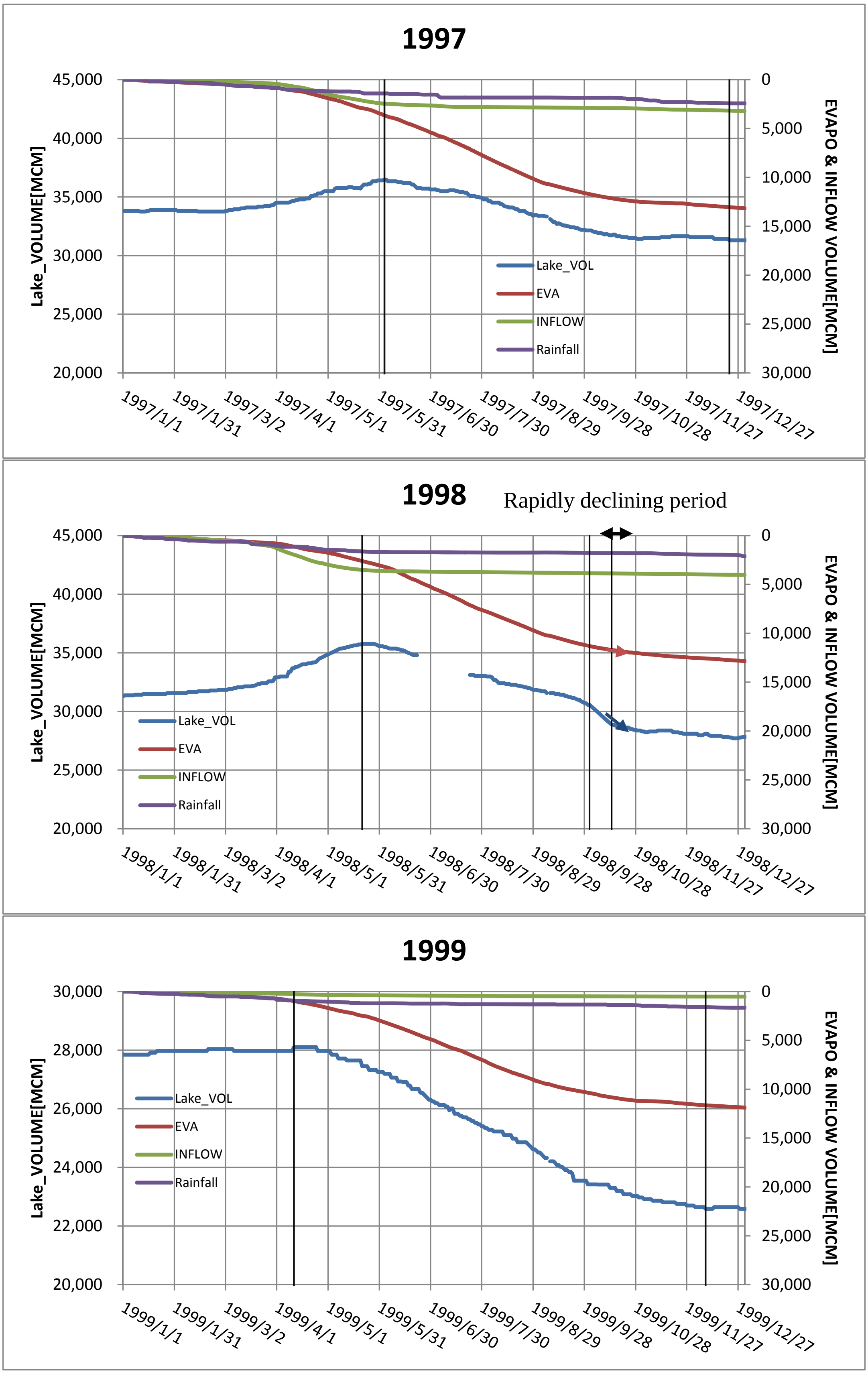


Figure 5.2.5 Variation of the Lake Water Volume (1997-1999)

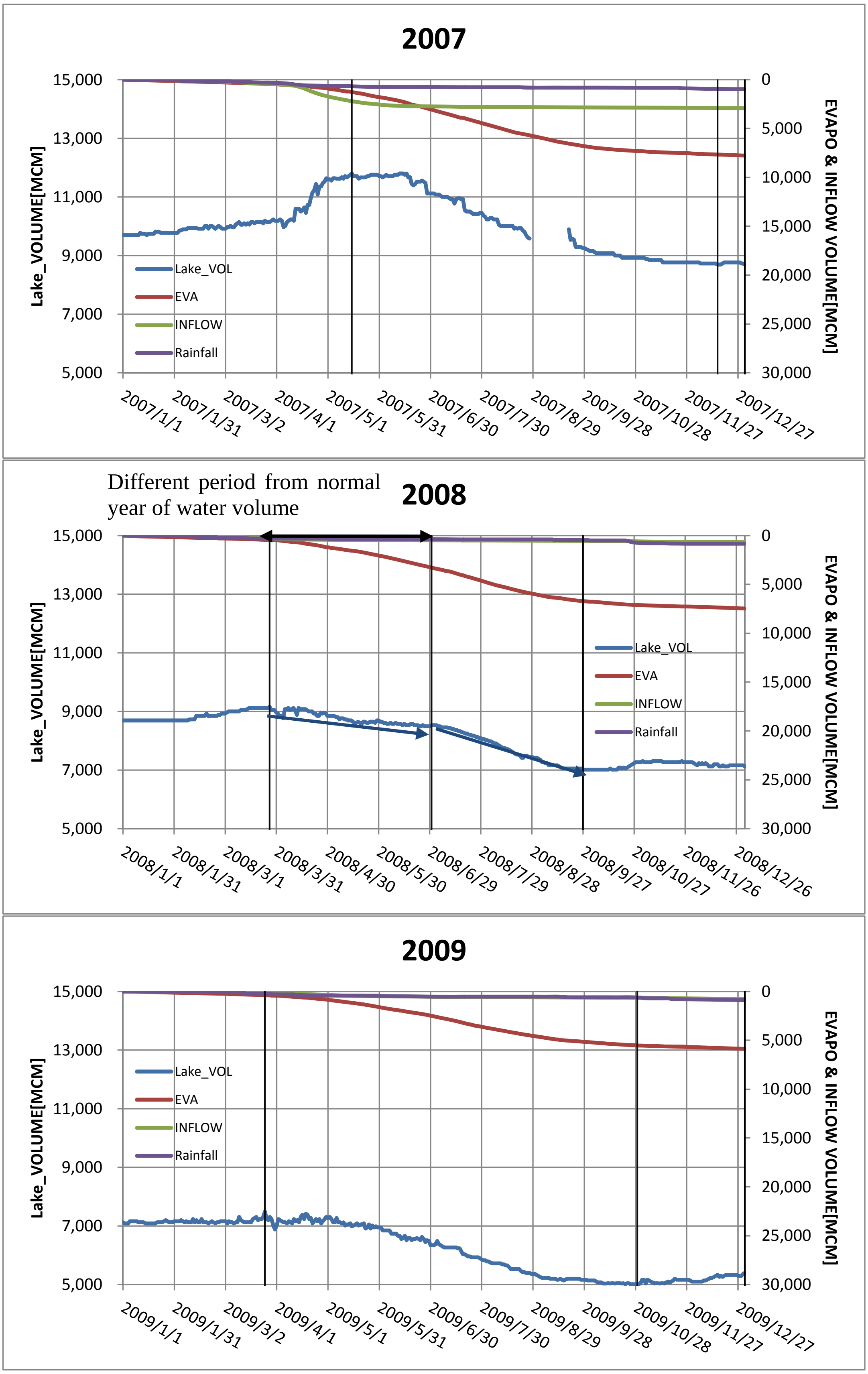


Figure 5.2.6 Variation of the Lake Water Volume (2007 – 2009)

For the water balance of the lake, three (3) items were taken into account as listed in Table5.2.2, which were categorized into "Inflow/Outflow elements". The "Outflow element" in Lake Urmia is only evaporation from the lake surface due to the closed inland river systems. Therefore, on yearly basis, the water amount which is the subtracted amount of "Inflow element" from the difference of lake water volume matches that of evaporation from the lake surface, theoretically.

In order to adjust the water balance of the lake, the necessary pan evaporation rate was calculated and evaluated. The evaluation period was the period from the peak water level to the low water level of the lake for 1 year. In order to adjust the water balance of the lake, the necessary pan evaporation rate was calculated using the formula shown below (See Table5.2.3 and Table5.2.4).

The pan evaporation rate = (the amount of changes in lake's water amount - river inflow - precipitation) / pan evaporation from the lake surface

Table5.2.2 Items used in the balance of the lake

Water balance elements	Items
Inflow element	・Precipitation (lake surface) ・River inflow (observed value)
Outflow element	・The amount of evaporation from the lake surface (pan evaporation)

Table5.2.3 Pan evaporation rate (From 1997 to 1999)

Year	Period	① Lake_VOL	② Evapo_VOL	③ INFLOW_VOL	④ Rainfall_VOL	Evapo_Rate (①-③-④)/②
1998	Peak→10/1	-5202.5	8694.7	327.4	148.6	0.653
	10/1→10/14	-1690.0	387.2	25.5	5.8	4.445
1997	Peak→Bottom	-5180.0	9388.1	706.3	993.9	0.733
1999	Peak→Bottom	-5515.5	10660.4	246.2	635.7	0.600

Table5.2.4 Pan evaporation rate (From 2007 to 2009)

Year	Period	① Lake_VOL	② Evapo_VOL	③ INFLOW_VOL	④ Rainfall_VOL	Evapo_Rate (①-③-④)/②
2008	Peak→7/1	-624.0	2837.8	163.8	70.7	0.303
	7/1→Bottom	-1519.0	3422.8	71.7	83.7	0.489
2007	Peak→Bottom	-3108.4	6387.8	698.9	255.4	0.636
2009	Peak→Bottom	-2501.5	5139.6	460.8	365.9	0.648

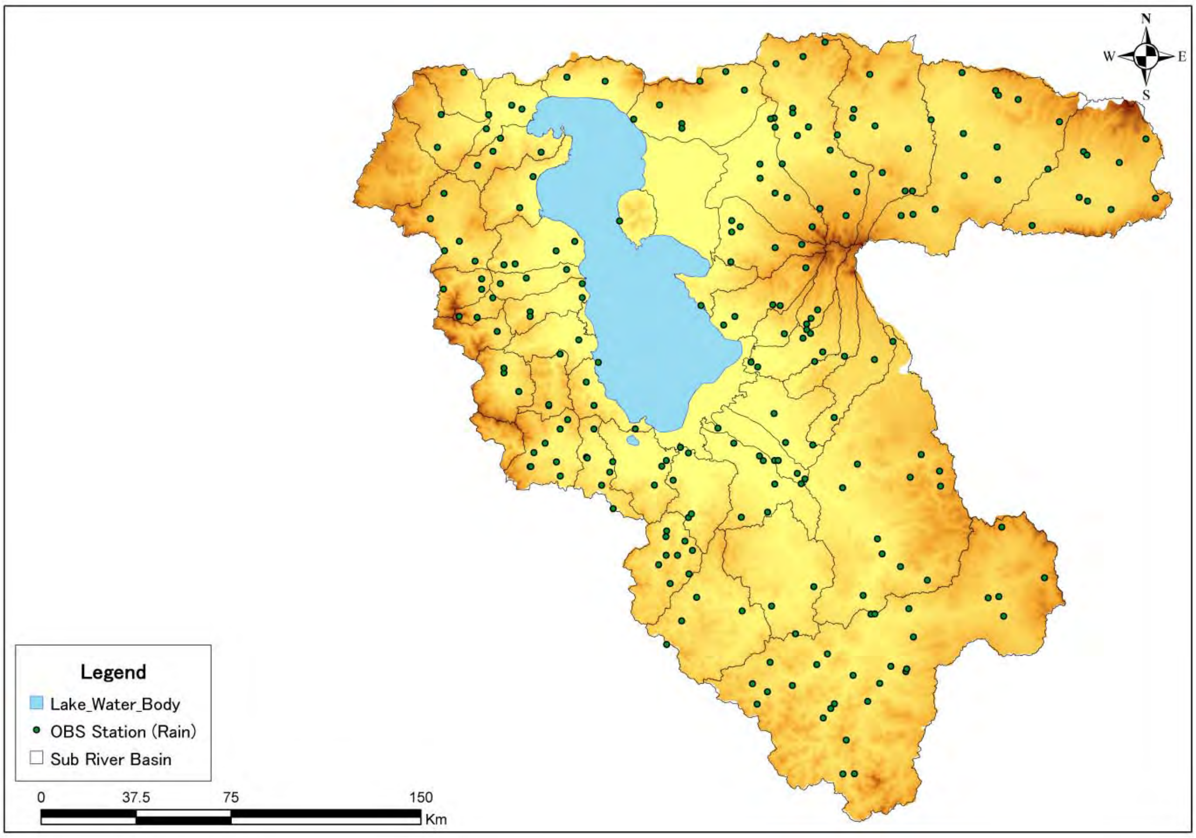
In the period when the Lake's water level declined sharply in 1998, the rate to the pan evaporation was about 4.5 times. However, when compared to the other years, the pan evaporation rate in 2008 was smaller. The difficult lowering of the Lake's water level is expressed in the model.

(4) Meteorological Condition

(a) Precipitation

The precipitation data observed at 242 rainfall gauging stations (as shown in Figure 5.2.7) were given into the model as the data sets of average precipitation which was calculated by Thiessen Method. This is because, as described in Subsection 2.6.2, altitude correlation of precipitation data has not been carried out since no clear linear relationship has been recognized between precipitaion and the elevation of their gauging stations. Therefore, as much precipitation data as possible was applied so as to increase the accuracy of input data in terms of spatial interpolation.

MIKE-SHE requires time series data set with spatial distribution for the input. Also, the time series data has a lot of missing values so that the data sets were prepared by means of the Thiessen Method day by day. The data set of precipitation was given to 50 sub-basins (See Figure 5.2.7) which were processed day by day, separately with the MIKE SHE module. Also, the snow melting was considered by the degree-day method.



* Prepared by JICA Survey Team based on the data provided by WRMC

Figure 5.2.7 Location of Rainfall Gauging Station

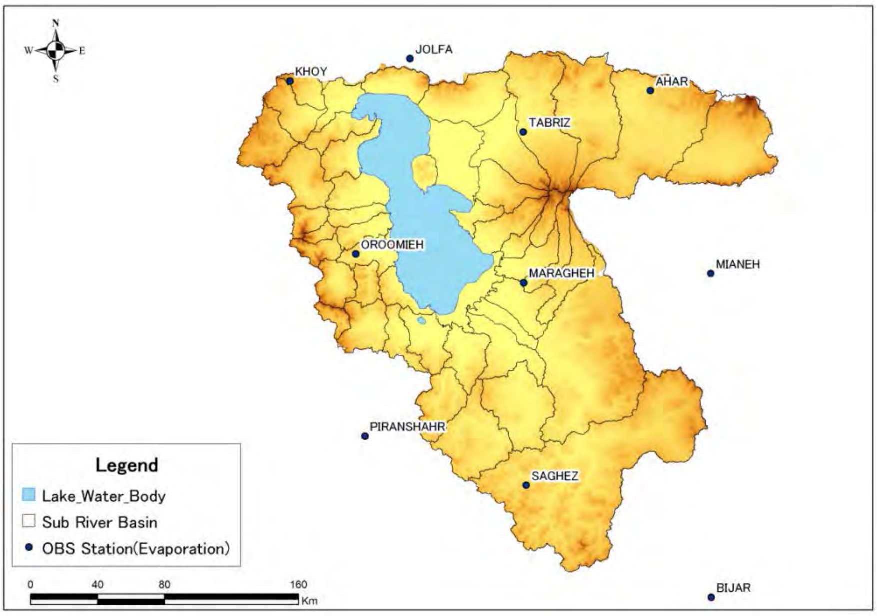
(b) Lake Surface Evaporation

For lake surface evaporation amount, 60% of the pan evaporation with Thiessen Method was given to the calculation mesh corresponding to Lake Urmia as initial value. Sixty percent (60%) was set as the initial value according to the research document of Tabiat Moares University in Iran, in which lake surface evaporation is set at 60% of pan evaporation. When calibrating the model, 75% of the pan evaporation which is the result of the study on rough water balance of Lake Urmia was also made as reference.

(c) Estimation of Reference Land Evapotranspiration

Land evapotranspiration can be estimated in accordance with conditions of climatolgy, land use type and cropping. In order to prepare the precise time series data of land evapotranspiration, basic data and information such as meteorological data (e.g. air temperature, relative humidity, net radiation), land use type and cropping pattern are required. In the Survey, the collected data applicable for the estimation was only daily pan evaporation. Furthermore, little information on cropping condition has been collected. However, it is pointed out that the evapotranspiration cannot be ignored, Winter wheat that are considered typical crops was set into the model. In the Survey, reference land evapotranspiration, as described in Subsection 2.6.3, was estimated by parametrically-calibrating daily pan evaporation with a scale factor.

The applied daily pan evaporation data were that observed by IMO at 10 gauging stations (as shown in Figure5.2.8 and Table 5.2.5). The collected data (See Annex 5.1) are available during the period from 1992 to 2009. The Thiessen Method was employed for the model input.



Note: Prepared by JICA Survey Team based on the data provided by IMO

Figure5.2.8 Location of Pan Evaporation Gauging Stations

Table 5.2.5 Calculated Annual Pan Evaporation

Station name	Pan Evaporation in 2007 (mm)
AHAR	1458.1
BIJAR	1727.8
JOLFA	2321.2
KHOY	1310.1
MARAGHEH	1909.7
MIANEH	1935.8
OROOMIEH	1308
PIRANSHAHR	1335.6
SAGHEZ	1893.3
TABRIZ	2040.8

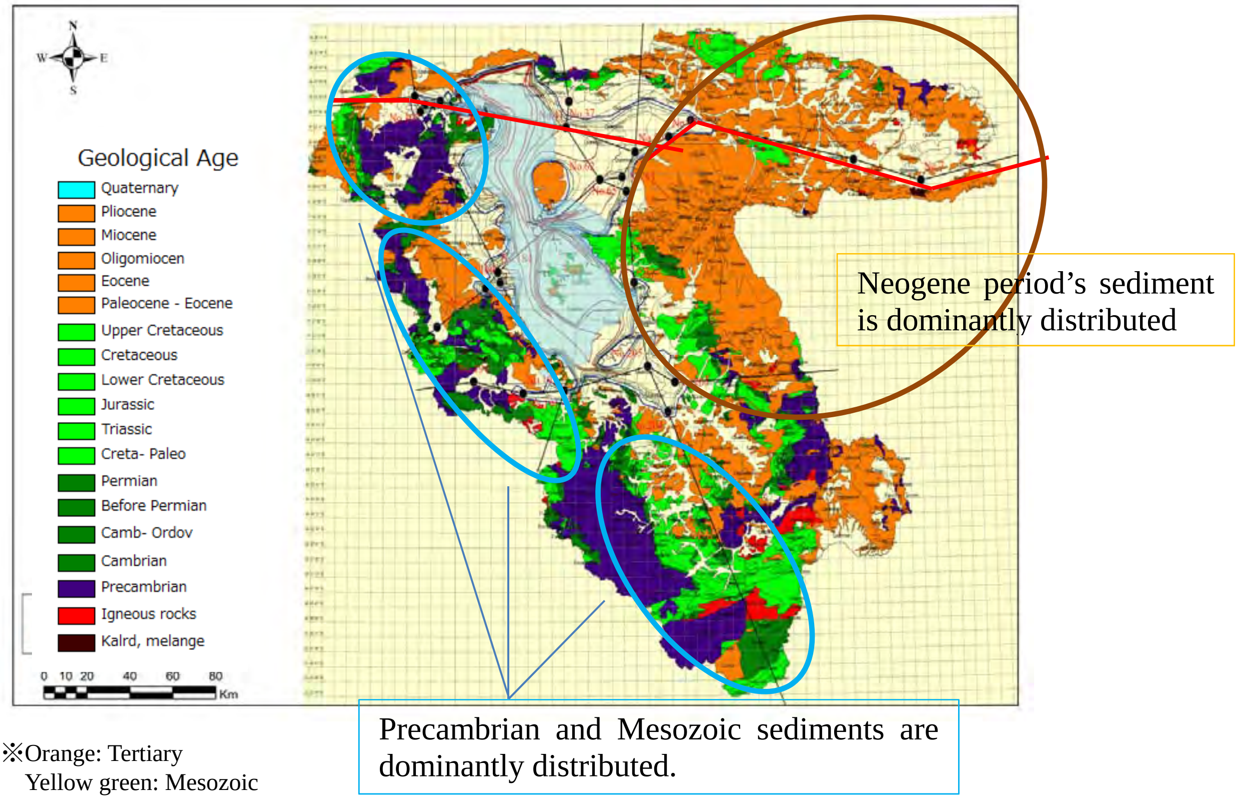
Note: Prepared by JICA Survey Team based on the data provided by IMO
-The year of 2007 had average precipitation trend
-According to the collected data from IMO, all the observed values in winter season were 0. While the values larger than 0 were observed in winter season in the collected monthly pan evaporation data from WRMC. So the tabulated values were interpolated in winter season (refer to subsection 5.2.4(1)).

(5) Geological Condition

(a) Modeling of Geological Structure

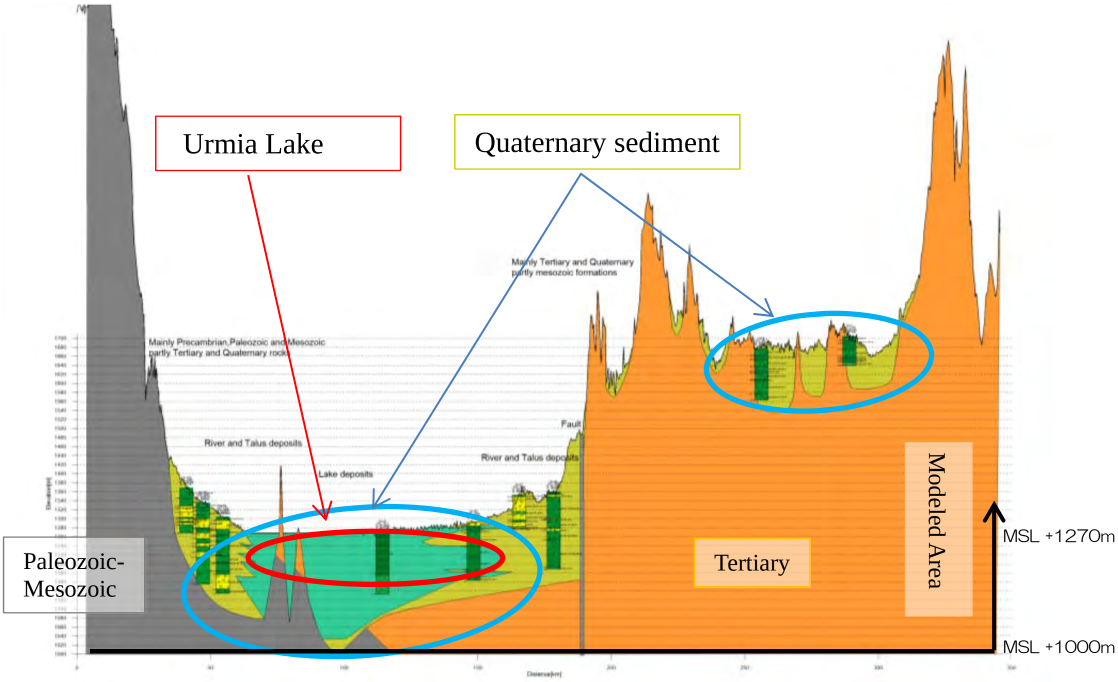
The geological structure of Urmia Lake Basin consists of the old strata of the Pre Mesozoic (Pre Cambrian to Mesozoic) in the southwest region of the main basin and old strata of the Tertiary in the eastern region. Moreover, relatively new geology of Quaternary was found in the areas along the river valleys and the lake. Location of these geological features are shown below in horizontal and longitudinal view. (See Figure5.2.9 and Figure 5.2.10)

Since these geological features were established in different era, parameters such as permeability coefficient can differ significantly. Therefore, geological features of different age groups are modeled to have different parameters.



※Orange: Tertiary
Yellow green: Mesozoic
Green: Paleozoic
Purple: Pre-Cambrian
Yellow grid : Quaternary period

Figure5.2.9 Geological Planar map of the Lake Urmia Basin



*In this figure, columnar diagram indicates that the boring survey was done at that point
*The left side of the figure is the West, the right side is the East.

Figure 5.2.10 Geological Cross Sectional View of the Lake Urmia Basin

(b) Concept of Geological Parameter Setting

In this model, it was necessary to set the geologic parameters as shown below. (See Table5.2.6)

Table5.2.6 Geological Parameters

Classification	Item
Geological features	Conductivity
	Specific yield
	Specific storage

When calculating groundwater flow, permeability coefficient was to be determined based on geological features. In the Lake Urmia Basin, it is considered that the quaternary deposits exists on top of the paleogene, mesozoic and paleozoic layers. Further, weathered rocks and fresh rocks constitute the geological foundation besides the above deposits. The geological parameter was set for each type of deposit.

The initial setting for each deposi was set with reference to the standards issued by the Ministry of Construction (currently Ministry of Land, Infrastructure, Transport and Tourism, Japan) as shown in Table5.2.7.

Table5.2.7 Parameters Applied for Initial Setting

Soil type	Horizontal conductivity (m/s)	vertical conductivity (m/s)	specific yield	specific storage (1/m)
Quaternary	1.00×10^{-4}	1.00×10^{-7}	0.2	0.001
Paleogene	3.00×10^{-7}	3.00×10^{-7}	0.2	0.002
Mesozoic	1.00×10^{-7}	1.00×10^{-7}	0.2	0.001
Paleozoic	1.00×10^{-7}	1.00×10^{-7}	0.2	0.001
Precambrian	1.00×10^{-7}	1.00×10^{-7}	0.2	0.001
IngeousRock	2.00×10^{-6}	2.00×10^{-6}	0.2	0.005
Karld-melange	1.00×10^{-6}	1.00×10^{-6}	0.2	0.001

*Prepared by JICA Survey Team

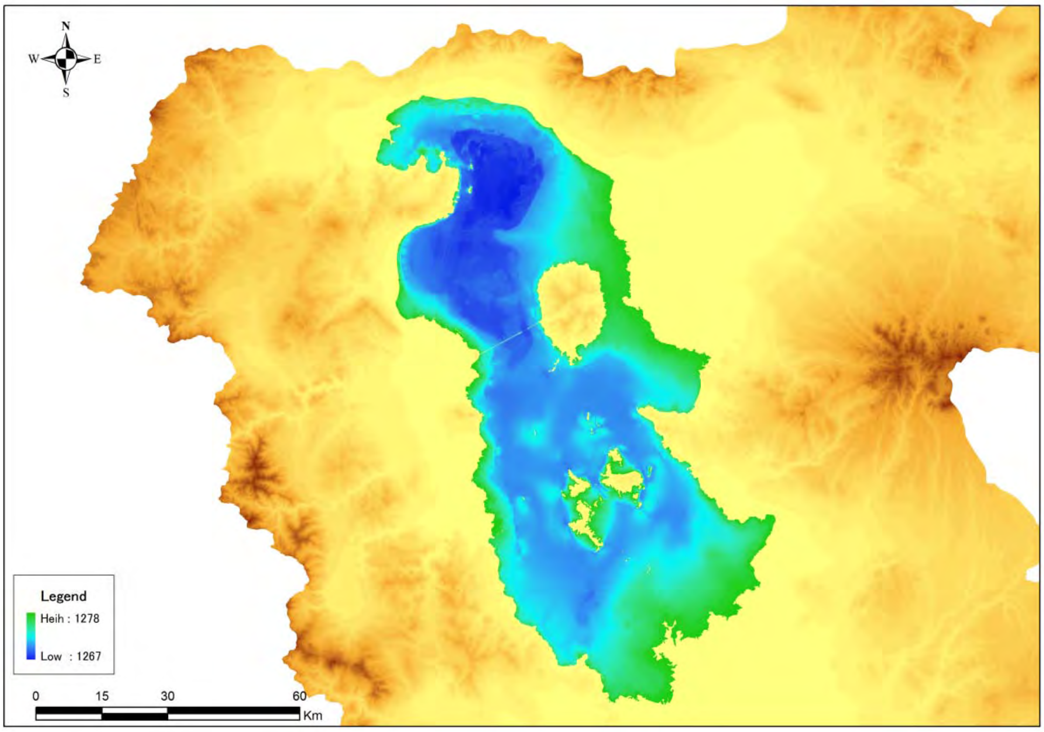
(6) Topographic Condition

(a) Ground Surface Elevation

Ground surface elevation data of 2km mesh was prepared from the 90m-DEM data provided by WRMC and established using the MIKE SHE module.

(b) Lake Bed Elevation

The lake bed elevation data was prepared from DEM data established from bathymetry survey results of Lake Urmia. The 2km mesh of lake bed elevation data was created using MIKE SHE (See Figure5.2.11) .



Source : Iran Water Research Authority

Figure5.2.11 Lake Bed Elevation

(7) Land Use

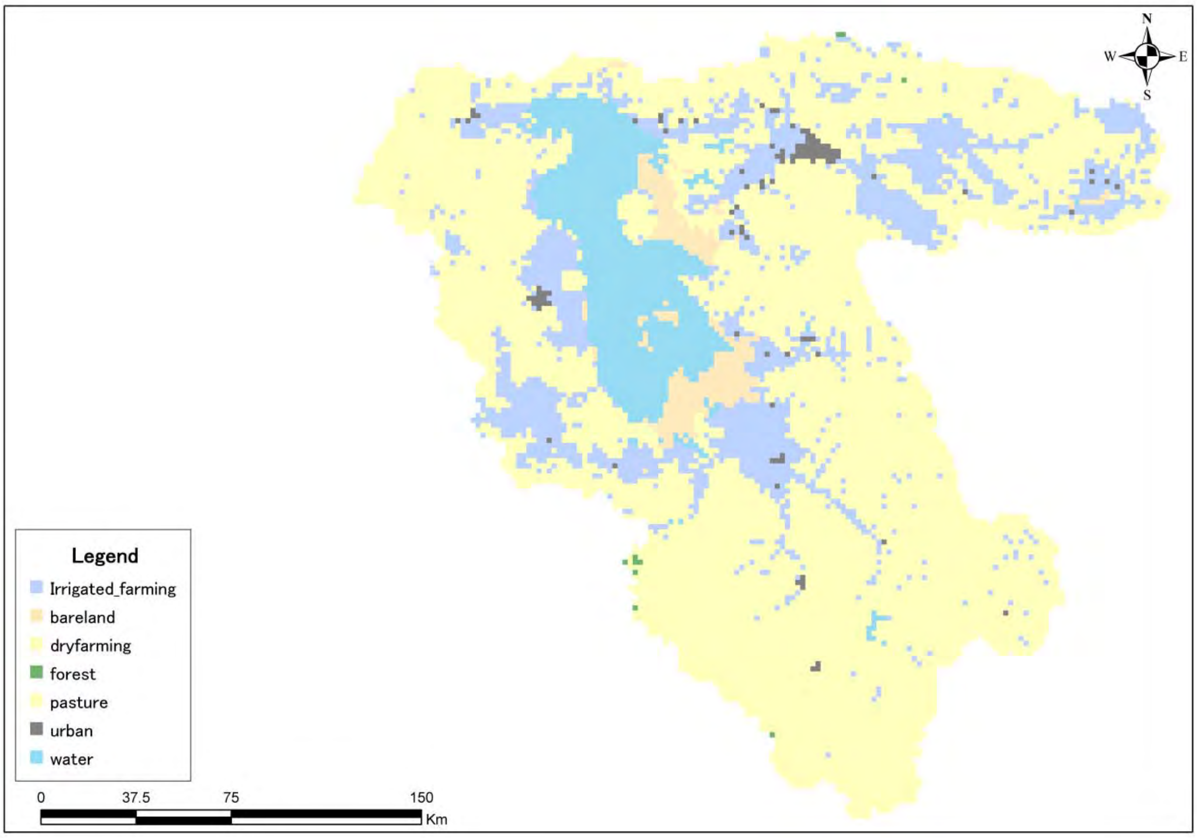
Based on the data on land use provided by WRMC, 2km-mesh data of land use was prepared (See Figure5.2.12). In calculating surface flow, roughness coefficient was one of the important factors determined for each land use type. The roughness coefficients were set based on the commonly used value of roughness coefficients for different land uses listed in the "Inundation Simulation Manual (draft)" published by the Public Works Research Institute (under jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism, Japan).

The roughness coefficients for the types of land use in the Lake Urmia Basin are as tabulated in Table5.2.8.

Table5.2.8 Roughness Coefficient for Land Use Type

Land use of the Lake Urmia Basin	Land use described in the flood simulation manual	Roughness Coefficient
Irrigated wheat	Building, farmland A_1	0.06
Baresoil	Others A_3	0.05
Dry farming	Others A_3	0.05
Orchard	Others A_3	0.05
Rangeland	Others A_3	0.05
Residental	Building, farmland A_1	0.06
Water	(None)	-

Source: PWRI



Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.12 Land use (processed by 2-km-mesh)

(8) River Channel

(a) Concept of River Channel Modeling

Distribution of river network and basin boundaries within the Lake Urmia Basin are shown in Figure5.2.13. Although river channels are densely distributed in the basin, some of them only seasonally exist and these are quite small. In consideration of this situation, river channels were modeled by following the ideas below. The water flow in un-modeled river channels which actually exist was modeled as surface runoff flowing on the ground surface or as a seepage into the ground which contributes to groundwater recharge.

The modeled river channel network is shown in Figure5.2.14 and Table5.2.9.

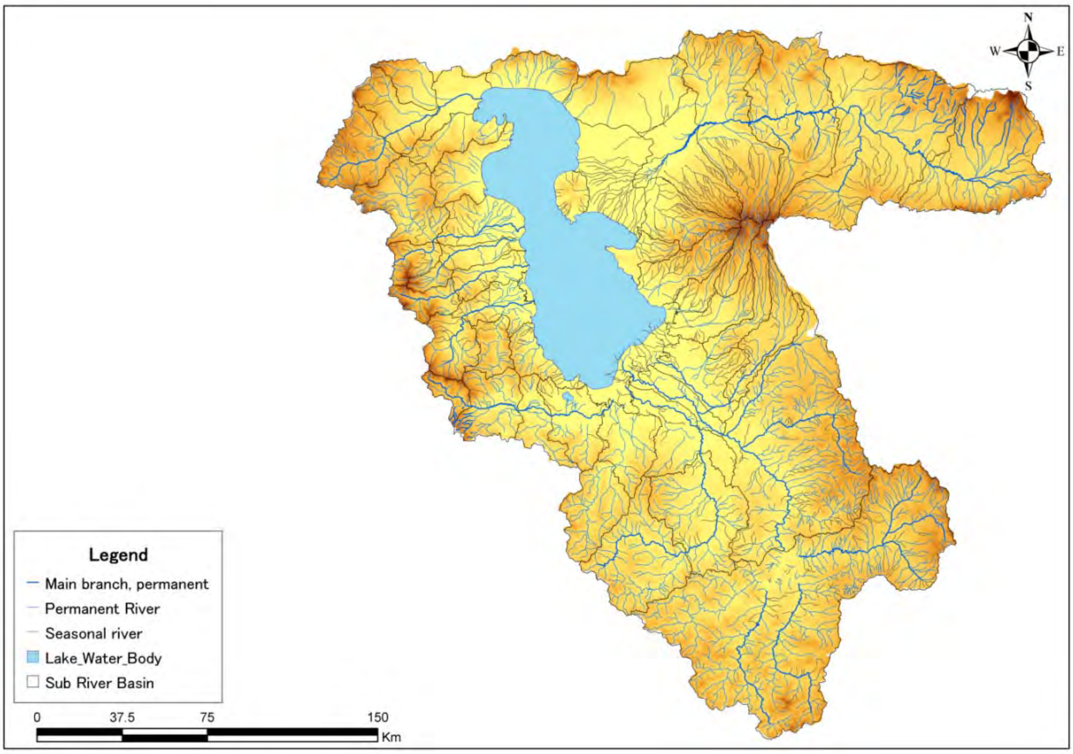
- Main river channels in the river basin were modeled (Main Branch)*

  Based on the information provided by WRMC, the river channel defined as “Main Branch” was selected for modeling. As for the river basins which do not have main river channels, the longest river network was selected.

- River channels on which dam (s) exist were modeled

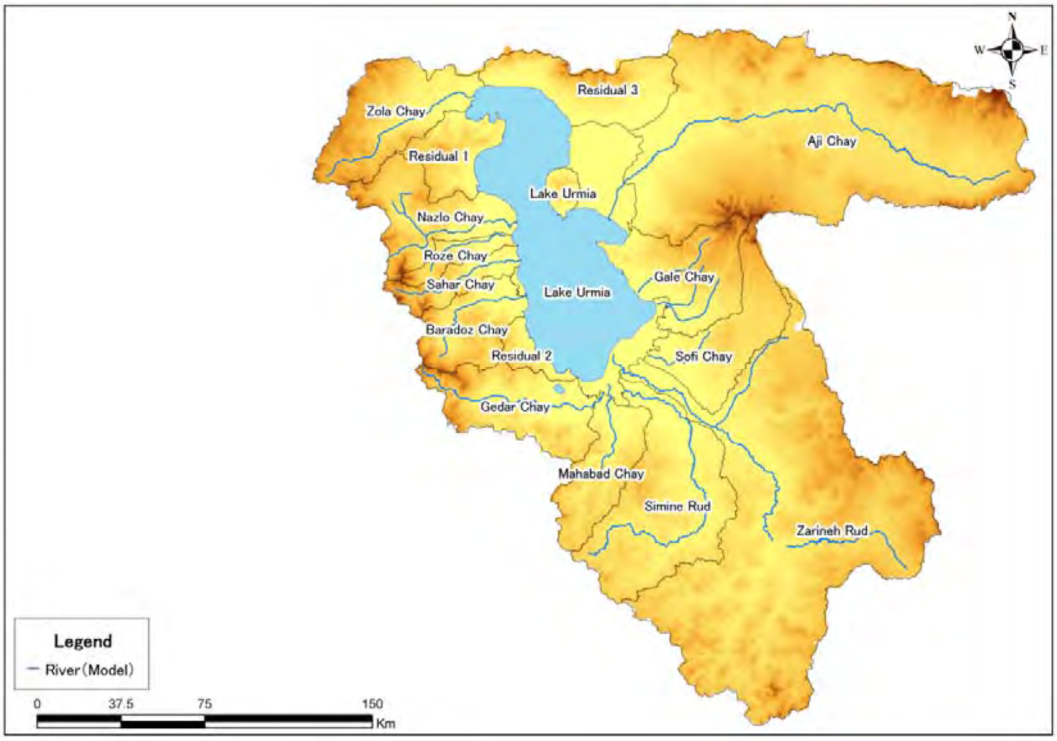
  As for dams located in neighboring main river channel, though they were not modeled, outflow data of the dams was input on the main rivers, directly.

*Among the collected river channel data, "Main Branch, Permanent" is described



*Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.13 Distribution of Basin Boundaries and River Channel Network



Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.14 Modeled River Channel Network

Table5.2.9 Summary of Modeled River Channel

No.	River Name	River Model Length (km)	Area (km^2)
1	Zola Chay	4.6	2,260.10
2	Ajichay	8.2	11,608.40
3	Nazlo Chay	36.8	1,881.60
4	Roze Chay	18.2	458.1
5	Sahar Chay	5.5	712.3
6	Gale Chay R	7.7	699.4
7	Baradoz Chay	7.5	1,362.80
8	Gale Chay L2	4.8	235.2
9	Gale Chay L1	2.9	860.8
10	Sofi Chay	5.7	1,937.20
11	Zarineh Rud	16	11,841.20
12	Mahabad Chay	7.3	1,508.00
13	Gedar Chay	3.7	2,092.60
14	Simine Rud	12.5	3,785.00

Note: Prepared by JICA Survey Team based on the data provided by WRMC

(b) Modeling of Cross Section

The cross-sections of the river channels were modeled based on the following concepts (See Table5.2.10).

Table5.2.10 Concept of Modeling of River Channel and Cross-Section

Item	Concept of modeling
Modeled river channels	Modeled for main river channel in each basin (14 river channels)
Cross-sectional shape	Cross sections were modeled based on DEM as rectangle with 100m wide, which were processed by GIS software.
Cross-section interval	1km
Roughness coefficient	0.03 was applied for all stretches. The natural river and riverbed were considered to be gravel and rocks.

(9) Modeled Dams in Verification of the Model

(a) Concept of Dam Modeling

The condition of the dams in the Lake Urmia Basin is classified into 4 phases: “In Operation”, “Proposed”, “Under Study” and “Under Construction”. In the established model, in order to evaluate current condition in the Lake Urmia Basin, only the dams which are in the phase of “in operation” were modeled. When evaluating the future conditions in the model, the current conditions in the dams were basically applied because information on construction schedules were not collected in the Survey.

(b) Dam Operation Rules

Collected information on dam operation rules in Lake Urmia Basin was quite limited. Thus, dam outflow was determined as the policies and are described below. Another factor considered was that the dam outflow varies with influences of weather conditions for the year and the water use.The following dam operation rules were applied both for model calibration and future evaluation.

- For both the dams and the period that discharge data are available, the observed outflow data were basically employed.
- For dams where outflow data were not collected or for the period when the outflow data were not collected or missing, the outflow data was estimated based on the observed data of Mahabad Dam whose data on outflow and storage are available.

For the dams which do not have observed data sufficient to be used as input data into the model, the data of storage volume were collected with relatively better quality. Therefore, the outflow data of the dams were calculated based on the relationship of the observed data between outflow and dam storage in Mahabad Dam. Mahabad Dam data was selected from the viewpoints descibed below.

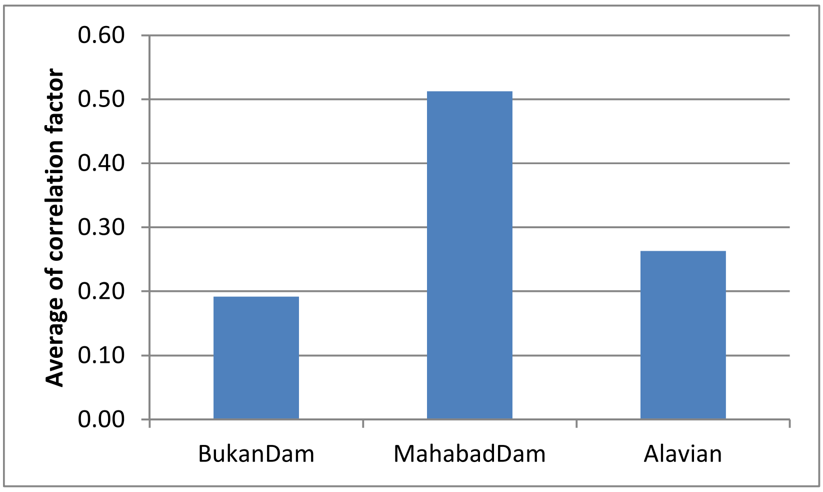
- Only Bukan Dam, Mahabad Dam, and Alavian Dam have the outflow as well as storage volume data from 1999 that can be applied for the simulation.
- Comparing the Dam Outflow/Storage Ratio calculated among the three dams, the variation trend of the observed data of Mahabad Dam was apparently similar to that of other dams which do not have sufficient observed data for the simulation (as shown in Table5.2.11).

The outflow data used as the input data is shown in Figure5.2.16 and Figure5.2.17.

Table5.2.11 Dam Outflow / Storage Ratio

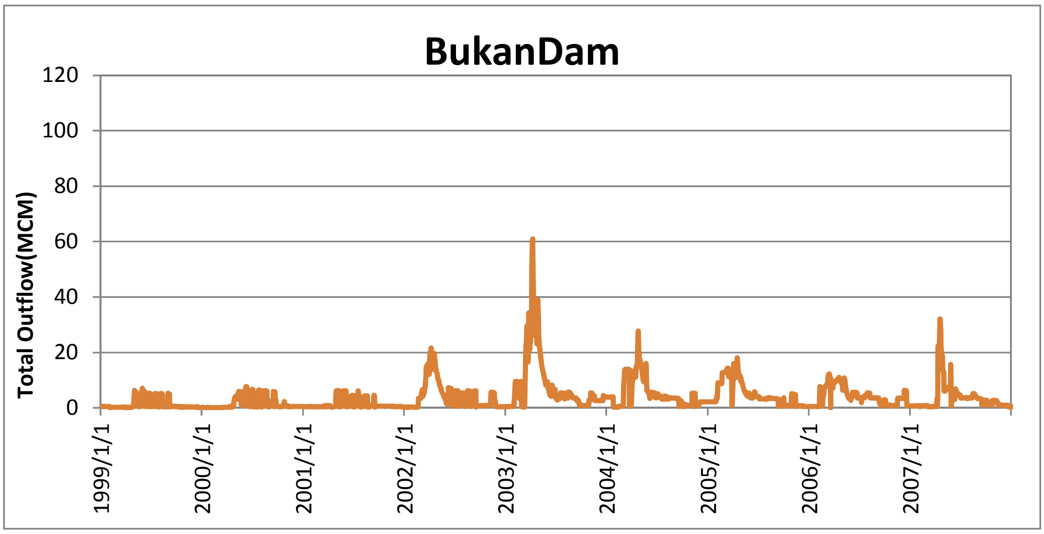
	2010	2011	2012	2013	2014	Average	max	min
Bukan Dam	2.61	2.00	2.82	1.90	1.64	2.19	2.82	1.64
Mahabad Dam	0.87	0.84	1.03	1.05	0.71	0.90	1.05	0.71
Alavian Dam	1.93	1.74	1.59	1.69	1.14	1.62	1.93	1.14
Saroogh Dam				0.39	0.38	0.39	0.39	0.38
Hasanlu Dam	0.49	0.58	0.82	1.16	0.72	0.75	1.16	0.49
Ghaleh Chay	1.47	1.09	1.05	1.09	0.75	1.09	1.47	0.75
Shahr Chay Dam	0.66	0.74	0.82	0.92	0.67	0.76	0.92	0.66
Kord Kandi Dam			0.05	0.00	0.60	0.22	0.60	0.00
Tajyar Sarab	0.04	0.24	0.66	0.39	0.48	0.36	0.66	0.04
Zola Dam			0.57	1.64	0.54	0.91	1.64	0.54
Nahand Dam	1.09	1.03	1.18	1.37	0.92	1.12	1.37	0.92
DarikSalmas Dam				0.65	0.46	0.56	0.65	0.46

Note: Prepared by JICA Survey Team based on the data provided by WRMC



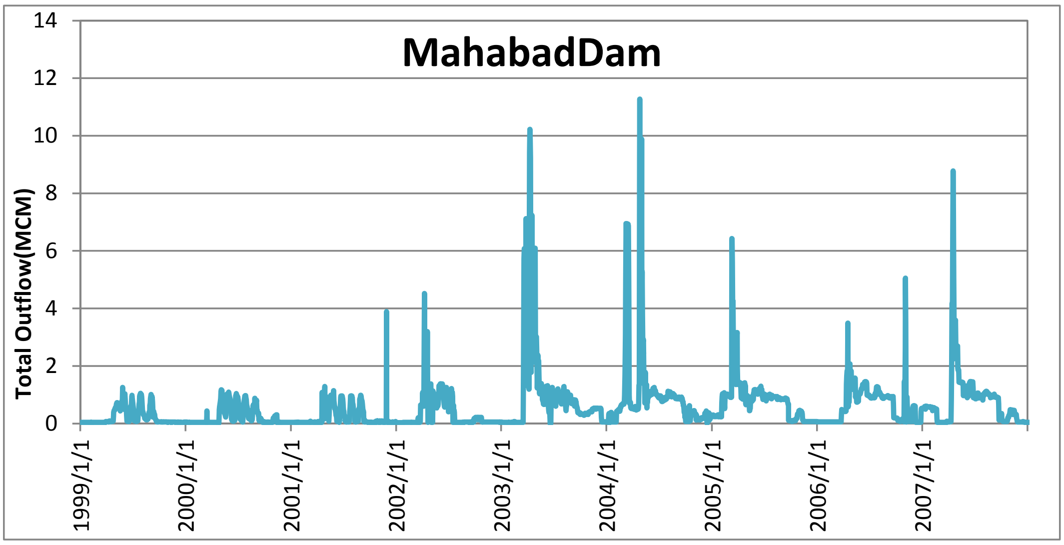
Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.15 Average of Correlation Factor of Dam Outflow / Storage



Note Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.16 Prepared Outflow for the Model in Bukan Dam



Note: Prepared by JICA Survey Team based on the data provided by WRMC

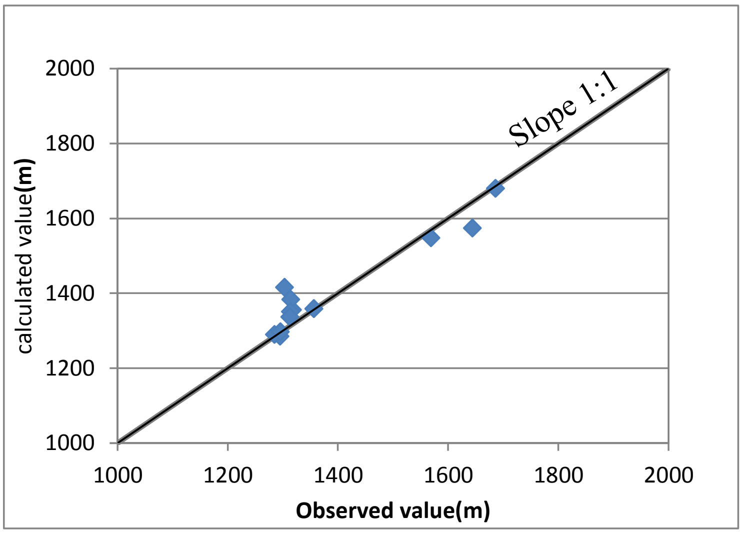
Figure5.2.17 Prepared Outflow for the Model in Mahabad Dam

(10) Setting of Initial Condition

For the initial condition used at the start of calculation time, it was preferred that calculated values of lake water level and groundwater level agree with those of observed data. The observed data of the lake water level were gathered since collected observed groundwater level was limited. In case that spatial distribution of groundwater level is prepared using only observed data, low accuracy shall be obtained for initial condition for model simulation, and there will be a high possibility of instability of model calculation. Instead, the initial condition was prepared based on calculation by MIKE-SHE.

In order to obtain the initial condition of the model starting from January 1, 1999, calculation was carried out under the climatological and hydrological condition from 1993 to 1999 (by inputting data of precipitation, lake surface evaporation, and land evapotranspiration). Calculated value of the lake water level (1,276.52m) that matches the observed lake water level on January 1, 1999 (1,276.49m) was selected for the initial condition of the model simulation.

The calculated and observed data of groundwater level on the same date were compared as shown in Figure5.2.18. It was confirmed that the calculated groundwater level well matches that of observed in 1999.



Note:Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.18 Comparison of Groundwater Level between Calculated and Observed

(11) Water Use

(a) Water Intake from the River

Information on the locations of water intake points from the river were not collected in the Survey. In the established model, water intake amount have been withdrawn from river channels as irrigated water and given to the farmland to be part of the model as recharge into groundwater. The process is as described below.

- ➢ Locations of intake points were determined on the river channel neighboring the grid classified as "irrigated farming" in the processed land use data.
- ➢ Water intake amount was evenly allocated throughout the mesh area where the land use is set as irrigated farming.

As for water intake volume, as described in Chapter 4, with reference to the M/P of the Ministry of Energy, the amount of intake water, which multiplied 1.72 with the collected water volume data for water supply, was input into the model.

In order to confirm the adequacy of the increasing rate of "1.72", the volume ratio of the estimated water intake to the total water supply from Bukan Dam were calculated from 1999 to 2010 as shown in Table5.2.12 In spite of variation of the calculated values for the said years, the estimated variation values only range between 1.4 and 2.7. This indicates that the increasing rate was necessary for increasing the accuracy of the model.

Table5.2.12 Ratio of Estimated Water Intake to Observed Water Supply

	① River Discharge (MCM)	② Dam Outflow (MCM)	③ Dam Inflow (MCM)	④ Dam Catchment Area (km2)	⑤ Specific Discharge in Dam Catchment Area (②/③) (MCM/km2)	⑥ Catchment Area in Dam Outside (km2)	⑦ Discharge Rate of Dam Outside (④×⑤) (MCM)	⑧ Estimated Intake (②+⑦-①) (MCM)	⑨ Water Supply (MCM)	⑩ Ratio of intake (⑧/⑨)
1999	164.3	405.4	419.5	6,890	0.061	4,400	267.9	508.9	375.8	1.4
2000	153.8	568.8	637.5	6,890	0.093	4,400	407.1	822.1	483.9	1.7
2001	50.0	454.6	554.8	6,890	0.081	4,400	354.3	758.9	438.9	1.7
2002	804.5	1,543.1	1,579.8	6,890	0.229	4,400	1,008.9	1,747.4	717.9	2.4
2003	2,417.3	2,940.5	2,901.5	6,890	0.421	4,400	1,852.9	2,376.1	885.2	2.7
2004	1,199.2	1,778.9	1,909.0	6,890	0.277	4,400	1,219.1	1,798.8	850.0	2.1
2005	794.3	1,801.2	1,706.8	6,890	0.248	4,400	1,090.0	2,096.9	777.2	2.7
2006	816.3	1,511.7	1,518.3	6,890	0.220	4,400	969.6	1,664.9	818.8	2.0
2007	1,140.8	1,318.9	1,368.0	6,890	0.199	4,400	873.6	1,051.7	754.2	1.4
2008	50.0	512.7	645.2	6,890	0.094	4,400	412.0	874.7	450.3	1.9
2009	44.9	821.9	940.4	6,890	0.136	4,400	600.5	1,377.5	739.6	1.9
2010	688.4	1,269.1	1,101.1	6,890	0.160	4,400	703.2	1,283.8	851.7	1.5

Note: Prepared by JICA Survey Team based on the data provided by WRMC

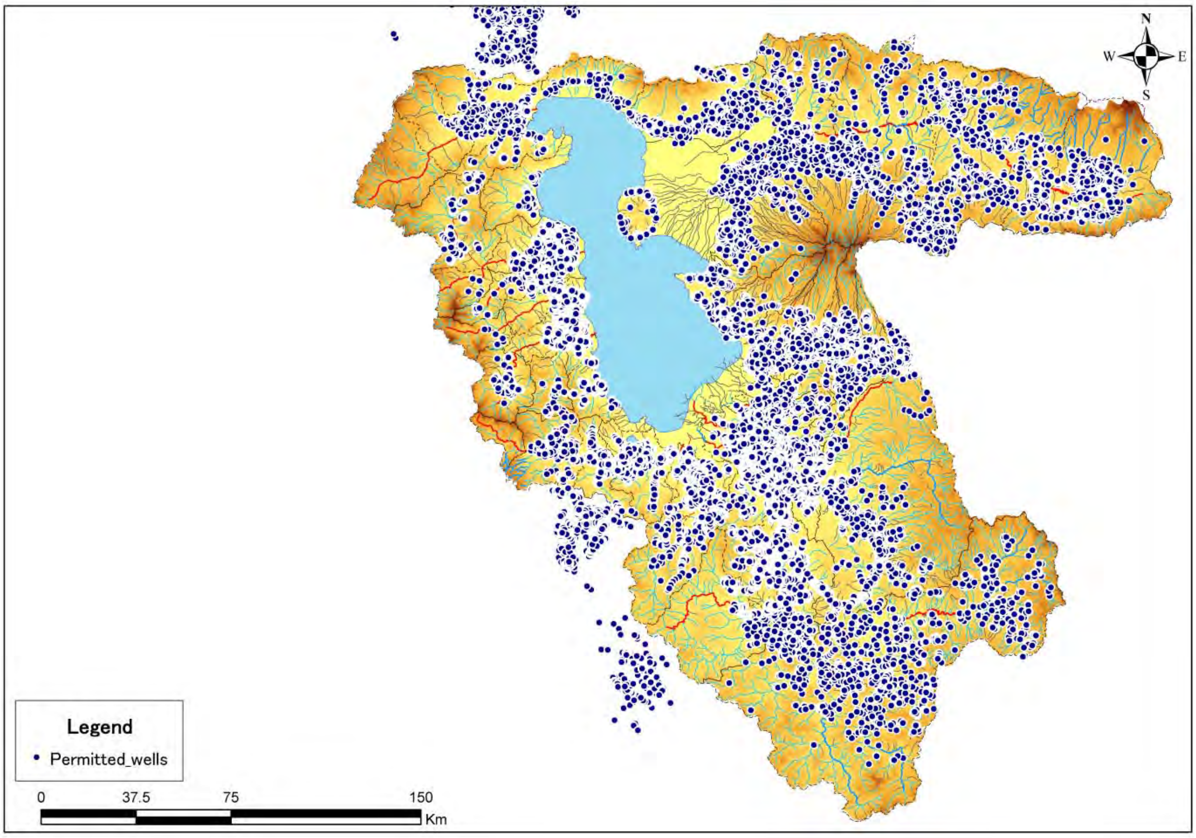
(b) Water Uptake from Groundwater

The locations of the 89,000 wells permitted by WRMC are shown in Figure5.2.19. The amount of water uptake from wells were referred from the data provided by WRMC while the approach of water intake from the river, with reference to the M/P of the Ministry of Energy, at an increasing rate of 1.1 was obtained by dividing water uptake volume of the M/P with the total water uptake volume permitted by WRMC. The calculated water uptake volume was extracted from the layer of groundwater for each mesh. The schedule of water uptake for agriculture was determined based on the M/P as shown in Table5.2.13. For other sectors, monthly water uptake data was estimated by dividing the annual water extraction data by 12.

Table5.2.13 Seasonal Ratio of Monthly Agricultural Water Intake

	Water Requirement (10^3 m^3)	Seasonal ratio
Jan	7,073	0.11%
Feb	24,987	0.38%
Mar	80,994	1.22%
Apr	405,070	6.11%
May	747,626	11.27%
Jun	1,439,579	21.70%
Jul	1,319,512	19.89%
Aug	1,135,134	17.11%
Sep	830,176	12.52%
Oct	330,185	4.98%
Nov	308,433	4.65%
Dec	3,718	0.06%

Note: Prepared by JICA Survey Team based on the data provided by WRMC



Note: Prepared by JICA Survey Team based on the data provided by WRMC

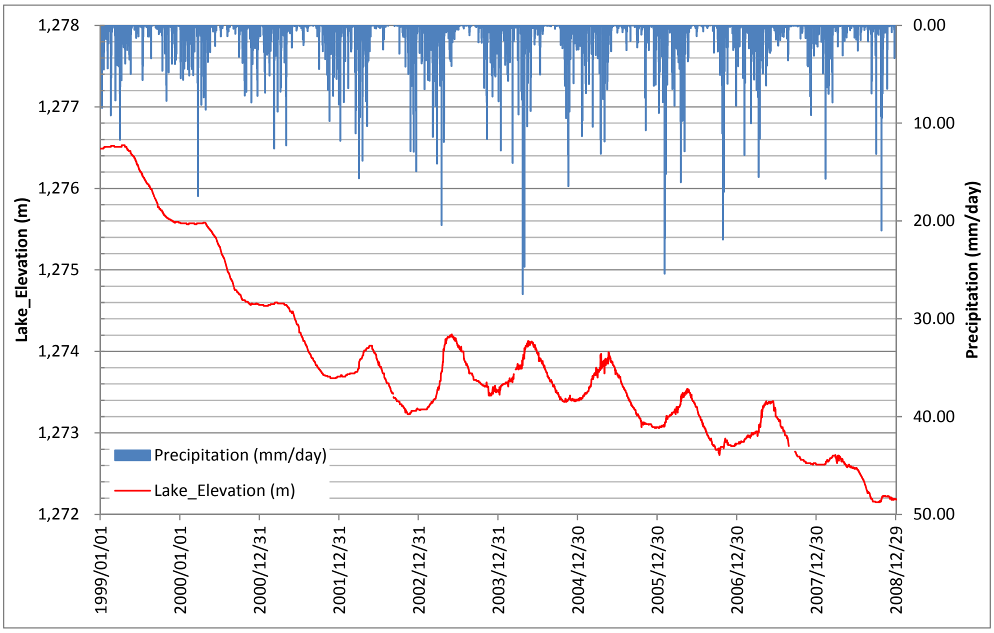
Figure5.2.19 Location of Permitted Well

5.2.4 ANALYSIS (CALIBRATION) OF PARAMETERS

Since one of the objective of the Survey was to simulate the actual situation of changing water level of Lake Urmia, it was decided that the parameters with particular strong influence on the lake water level are extracted to be able to conduct the calibration. After extracting the values corresponding to the parameters, their calibrations were conducted on the selected items and locations.

(1) Selected Parameters for Calibration

In order to use the primal parameters for the calibration, the changing situation of the lake water level was confirmed. The changing situation of the lake water level is shown in Figure5.2.20.



*Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.20 Changing Situation of Lake Water Level

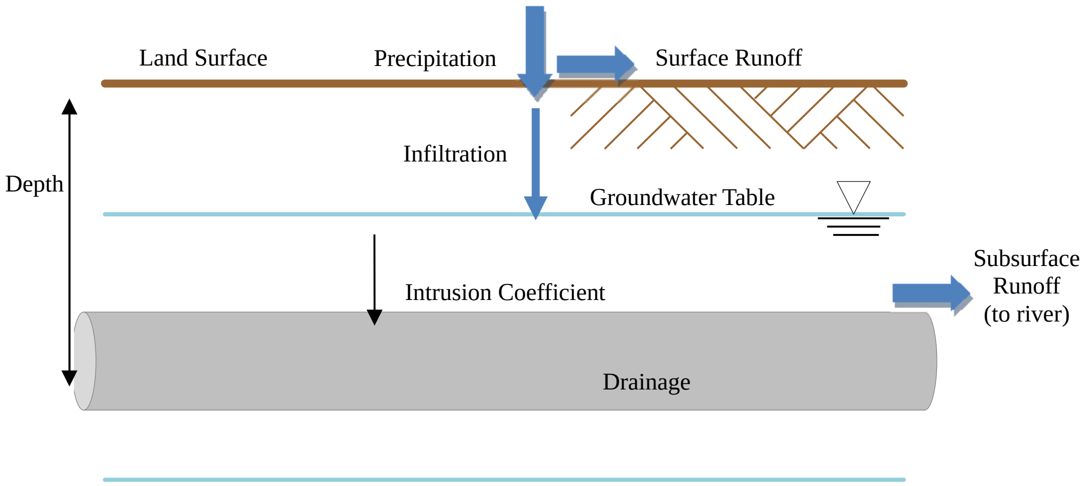
The changing situation of the lake water level shows the followings characteristics.

- As shown in Figure5.2.20, the response corresponding to precipitation occurrence is that of lake water level rises. Water inflow from rivers and groundwater appear to govern the fluctuation of the lake water. Therefore precipitation-runoff characteristic is the most important factor.
- During the period when lake water level declines within the year (from May to October), precipitation is low and there is an influence of evaporation from the lake water surface.

Since the river discharges and evaporation from the lake surface happens and causes change of the lake water level, the values based on parameter were extracted as shown in Table5.2.14, after which, sensitivity analysis for each parameter was conducted.

Table5.2.14 Parameters Affecting Lake Water Level in the Model

Parameters	Assumed contribution to lake water level
Evaporation from Lake surface	Parameter that is considered to contribute directly to changes in lake water level.
Evapotranspiration of land area	Parameter that is considered to have the maximum contribution to the annual river discharge volume.
Drainage module (See Figure5.2.21)	Parameter that is considered to contribute to the subsurface runoff and to affect the river discharge volume and hydrograph
Permeability coefficient of surface geology	Parameters that are considered to contribute to the base flow of the rivers and infiltration into groundwater.



*Prepared by JICA Survey Team

Figure5.2.21 Schematic Figure of Drainage Component

The drainage module is set in the model as an underground pipe that drains water permeating from the ground surface. If the area of drainage module is set, water flows along the surface gradient of the ground into the downstream drainage, and finally to the river. As a runoff component, drainage has a function for representing the subsurface runoff.

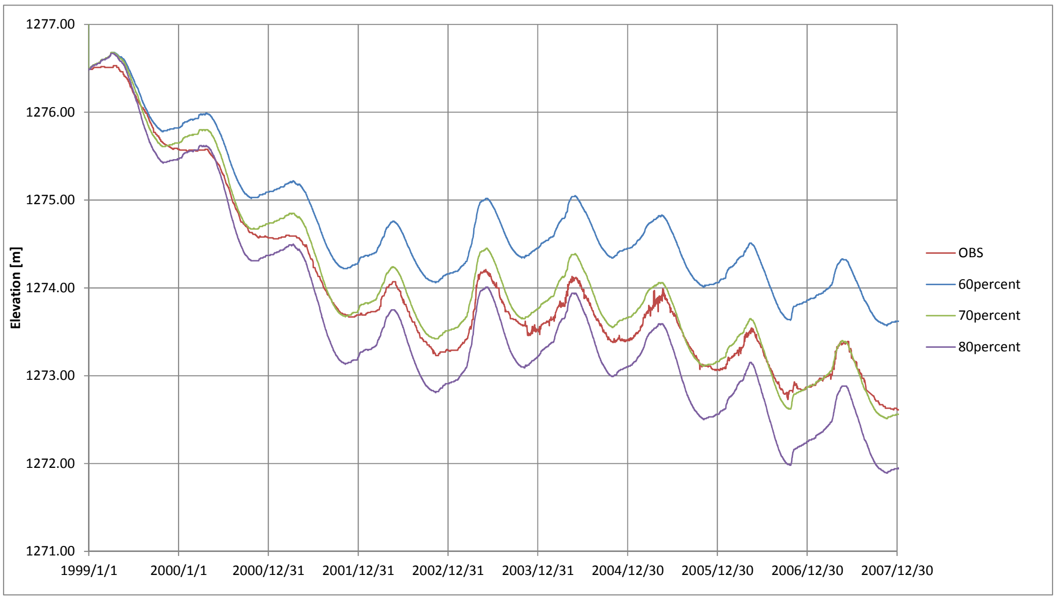
The drainage module has two parameters. One is the depth at which the drainage is located. The duration of the rainfall to permeate into the drainage depends on its depth. As a result, the speed or time for the rainfall to flow out to the river also depends on the depth. Another parameter is the intrusion coefficient which is the parameter that indicates the ease of intrusion of water into drainage. Higher numbers of intrusion coefficient show that it is easier to intrude. Volume of the intrusion depends on the intrusion coefficient, which results in the variation of inflows on the modeled rivers.

For the extracted values for the parameters "Lake surface evaporation", "Evapotranspiration of land area", "Drainage", and "Permeability coefficient of surface geology", sensitivity analysis was conducted. As a result, very important parameters were extracted to be able to study and calculate the rough standard values.

(a) Evaporation from Lake Surface

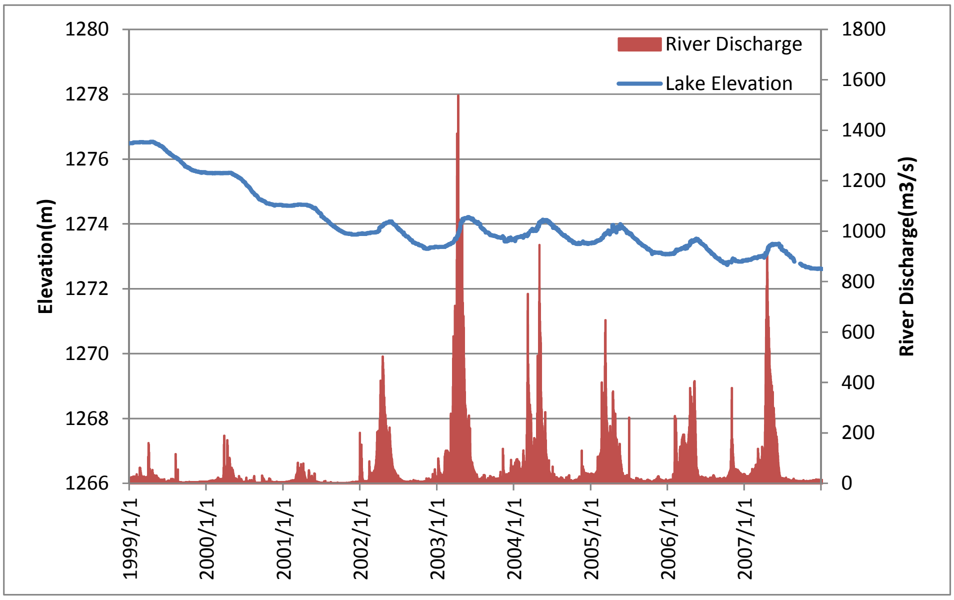
In setting the “evaporation from lake surface”, sensitivity analysis was carried out for understanding the influence of percentage of pan evaporation to the lake water level. Surface water of Lake Urmia was modeled in 2km-mesh using MIKE-21, as in the case of MIKE-SHE and the observed discharge of the main rivers were given as boundary condition. Since MIKE-21, a program used to simulate horizontal water flow, is suitable for the examination of evaporation from lake surface, it can incorporate evaporation from the lake surface in the module. Calculation period was 9 years from 1999 to 2007, which is the same period as the calibration process.

Three (3) simulation cases of sensitivity analysis were carried out on 60%, 70%, and 80% of pan evaporation referring to the initial 60% and 75% of pan evaporation examination described in Chapter 4, basic analysis. The results of the calculated lake water level are shown in Figure5.2.22.



Note: Prepared by JICA Survey Team

Figure5.2.22 Result of Sensitivity Analysis (Effect of Evaporation from Lake Surface)



Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.23 Relation of Lake Water Level and River Inflow

From the result of the above analysis shown in Figure5.2.22, since evaporation from the lake surface hugely affects lake water level, it was selected as one of the parameters and calibrated. In addition, evaporation from lake surface of 70 percent of pan evaporation roughly comes close to the observed lake water level.

According to Figure5.2.23 and Figure5.2.22, it was recognized that there were inflows from the rivers in winter season (December to March) from 1999 to 2001. However, the observed lake water level (OBS) had not risen, while the calculated lake water level had risen due to inflow from the river. This could be caused by the influence of evaporation in winter season. In case that the data collected from IMO with 0 values in winter were applied for the input of the model, the model simulated no evaporation in winter from the lake surface. Since saturated saline water is frozen at 22oC, Lake Urmia with saltwater is not frozen even in winter. Hence, the series of results indicate that there had been evaporation from the lake surface even in winter.

In order to establish the evaporation amount from lake surface in winter, the collected data was verified as to whether there is a record of pan evaporation value in winter. As a result, as shown in the data below, there are observed pan evaporation data in the Lake Urmia Basin even in winter. Referring to this report, the evaporation amount in winter was set.

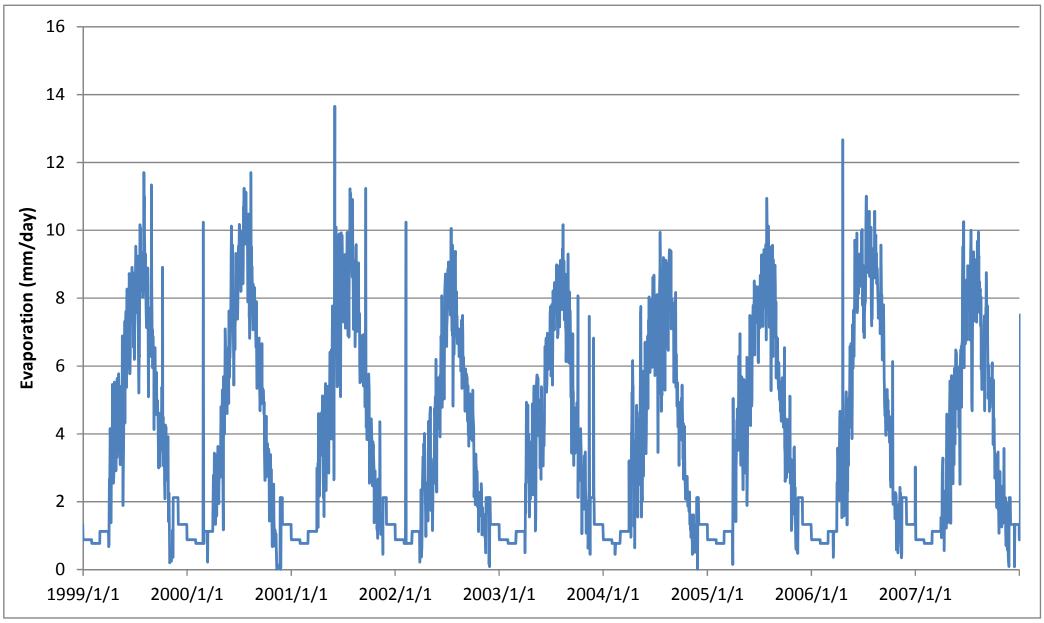
	Temperature ˚C(1)			Precipitation (2)	Humidity (3)	Pan Evaporation (3)
	Max	Min.	Ave.	mm	%	mm
Jan	2.9	-7.9	-2.7	23.2	73	39
Feb	4.8	-5.9	-0.5	28.2	69	31
Mar.	9.5	-0.5	4.8	37.8	63	50
Apr.	16.7	3.2	10.2	48.0	55	104
May	22.2	6.5	14.6	46.9	50	171
Jun.	27.9	9.5	18.3	8.7	40	250
Jul.	31.4	11.9	21.8	1.6	39	320
Aug.	32.1	11.6	22.0	0.4	37	306
Sep.	28.1	8.0	18.1	0.3	37	260
Oct.	21.7	4.3	13.2	15.8	52	180
Nov.	12.0	-0.8	5.7	27.2	54	91
Dec.	6.3	-3.8	1.0	28.7	70	59
Ann.Ave.	18.0	2.6	10.6	267		1,861

1-Naghadeh station 2-Bahramlou station 3-Mahabad station

Source: Integrated Water Resources Management for the Lake Uromiyeh Basin (Module 3: Water for Ecosystems)

Although monthly evaporation amount at Mahabad point is described in the report above, the specific year for the data was not written. Since this report was issued in 2005, it was safe to assume that the data were before 2005. Furthermore, it was described in the report that the data were average values.

Considering that the evaporation values in the report are monthly data, they were converted into daily data by dividing the values with the number of days in each month. These daily data were applied to interpolate missing values. The initial values of evaporation from lake surface, which include supplemented values of evaporation in winter season, are shown in Figure5.2.24.



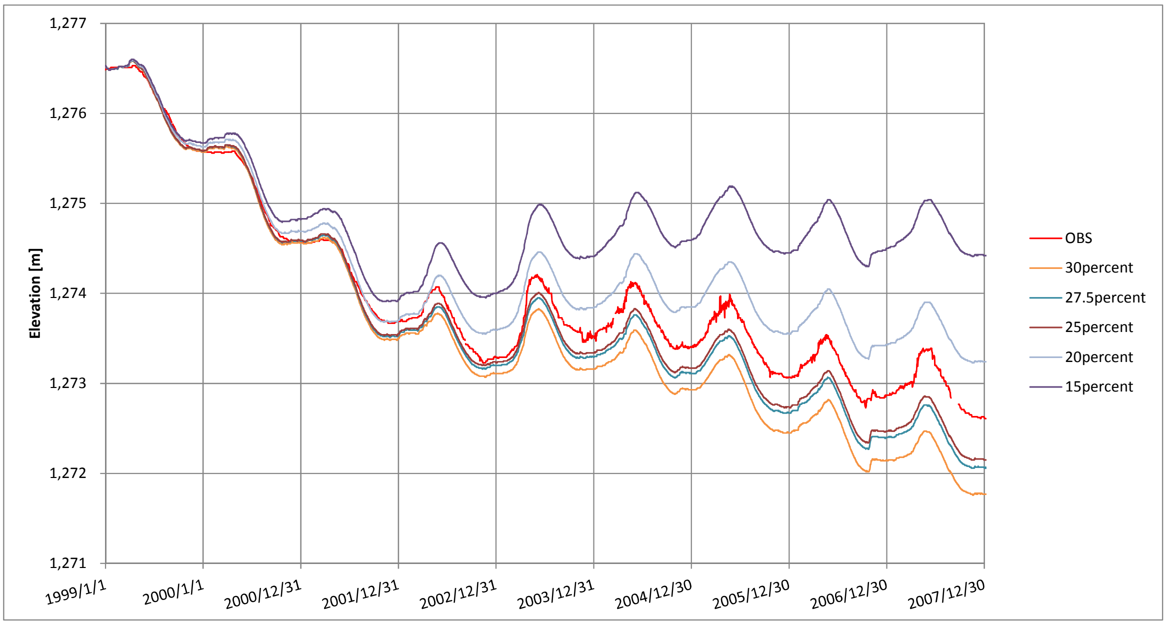
*Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.24 Input Value of Evaporation from Lake Surface to the Model

(b) Evapotranspiration of Land Area

In setting evapotranspiration of land area, sensitivity analysis was carried out by giving proportion to pan evaporation as parameters. The sensitivity analysis was carried out for the 9 years of calibration from 1999 to 2007 by using MIKE-HE.

Five (5) cases of sensitivity analysis were conducted for certain scale factors of evaporation which are 30%, 27.5%, 25%, 20%, and 15% of pan evaporation. Calculated lake water level for each case is shown in Figure5.2.25. Other parameters are set as fixed values of 67%for evaporation from lake surface, 0.7(m) for drainage depth, 10 x 10^{-6} (1/s) for intrusion coefficient and 10 x 10^{-6} (m/s) for permeability coefficient of surface geology.



*Prepared by JICA Survey Team

Figure5.2.25 Results of Sensitivity Analysis of Evapotranspiration of Land Area

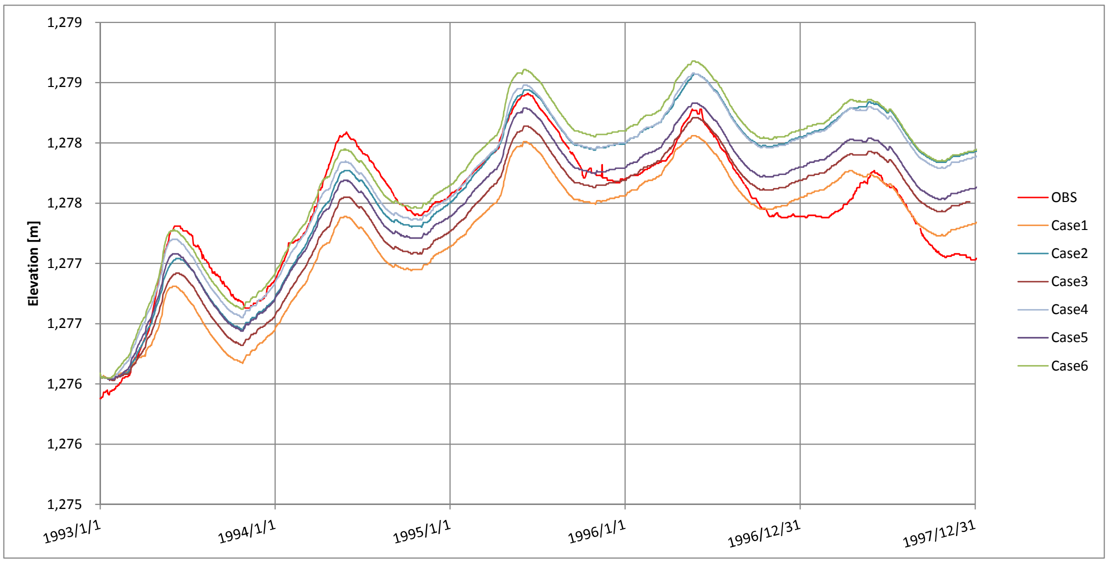
From the results of the sensitivity analysis, it was found that evapotranspiration of land area has huge effect on the lake water level, evapotranspiration was selected as one of the parameters and was calibrated. It is considered that evapo-transpiration can be set within 20 to 25 percent of pan evaporation as one of the reference values.

(c) Drainage Module

From the view point of considering the effects of flood events, the sensitivity analysis on drainage component was conducted for the period from 1993 to 1997, when many flood events occurred. The cases of sensitivity analysis were shown in Table5.2.15, and the calculated results of lake water level are shown in Figure5.2.26. Other parameters were determined as fixed values of 70% for evaporation from the lake surface, 30% for evapotranspiration of land area, and 10 x 10^{-6} (m/s) for coefficient of permeability of surface geology.

Table5.2.15 Calculation Cases of Sensitivity Analysis (Drainage)

Case	Level(m)	Intrusion Coefficient(1/s)
Case1	-0.70	1.0 x 10^{-6}
Case2	-0.90	1.0 x 10^{-7}
Case3	-0.85	1.0 x 10^{-7}
Case4	-0.80	5.0 x 10^{-7}
Case5	-0.80	2.5 x 10^{-7}
Case6	-0.80	1.0 x 10^{-6}



*Prepared by JICA Survey Team

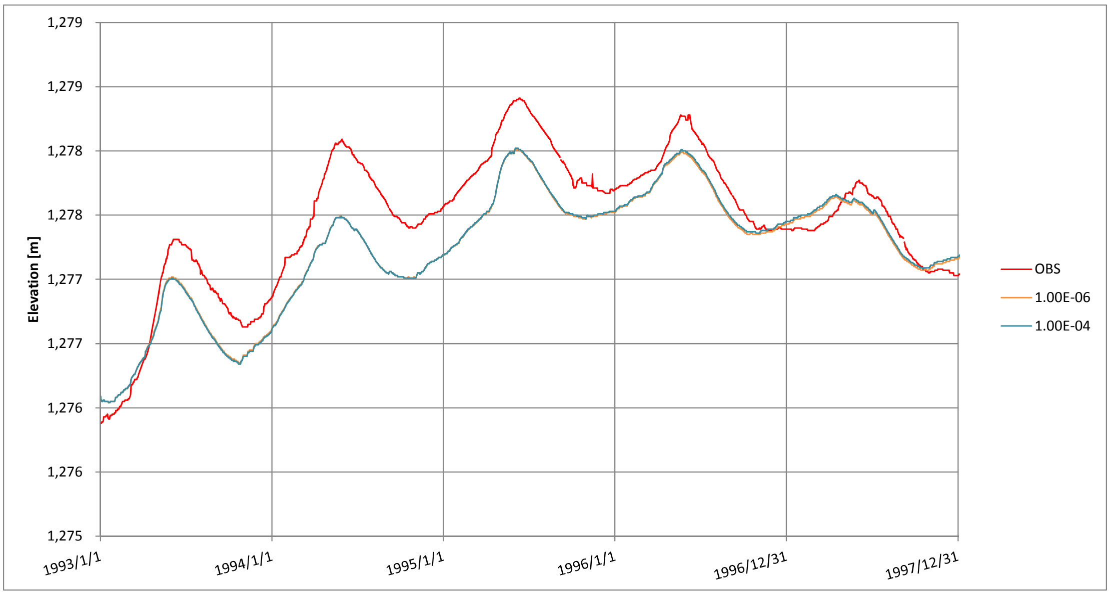
Figure5.2.26 Result of Sensitivity Analysis for Drainage Component

From the results of sensitivity analysis, it was found that parameters of drainage component have a high impact on the lake water level. Therefore, the parameter "Drainage Component" was selected as one of the parameters of the Model..

(d) Permeability of Surface Geology

From the view point of considering the effects of flood events, the sensitivity analysis on permeability of surface geology was conducted during the period from 1993 to 1997.

Two (2) cases of sensitivity analyses were conducted which included the case of 1.00 x 10^{-6} (m/s) of default value and the case of 1.00 x 10^{-4} (m/s) for high permeability. The results of the calculation of lake water level is shown in Figure5.2.27. Other parameters are set as fixed values of 70% for evaporation from lake surface, 30% for evapo-transpiration of land area, 0.7 (m) for Drainage depth, and 10 x 10^{-6} (1/s) for intrusion coefficient.



*Prepared by JICA Survey Team

Figure5.2.27 Results of the Sensitivity Analysis of Permeability of Surface Geology

From the results of the sensitivity analysis, the effect of permeability of surface geology on the lake water level is considered small. Standard value of 1.00x 10^{-6} (m/s) was applied in the verification.

(e) Procedures of Model Calibration

From the results described above, three (3) parameters namely; "Evaporation from lake surface", "Evapo-transpiration of land area" , and "Drainage" were selected as important parameters for calibration of the Model. The calibration flow is shown in Figure5.2.28.

Since river flow has huge impact on the lake water level, for calibrationit is decided that the accuracy of river discharge (runoff quantity) should first be ensured ahead of the accuracy of lake water level. For this purpose, in order to ensure the accuracy of runoff quantity, "Evapo-transpiration of land area" was firstly calibrated, and then "Drainage". In the case that sufficient accuracy was not obtained, Calibration was conducted for "Evapo-transpiration of land area" or "Drainage" again. After ensuring accuracy of runoff quantitively, as the next step, in order to ensure the accuracy of lake water level, "Evaporation from lake surface" were adjusted by calibration.

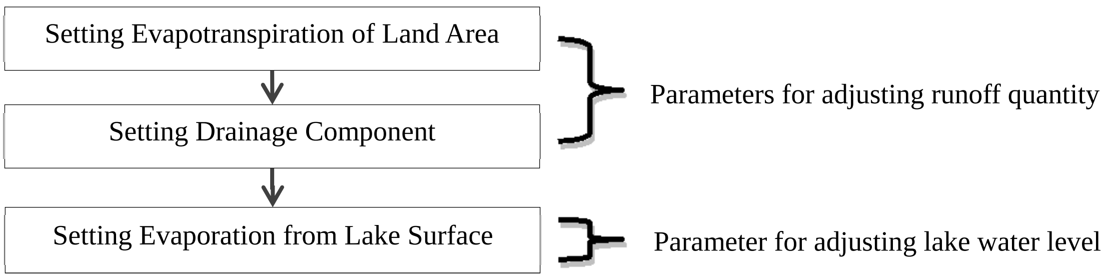


Figure5.2.28 Work Procedures of Calibration

(2) Selection of Calibration Points for River Discharge

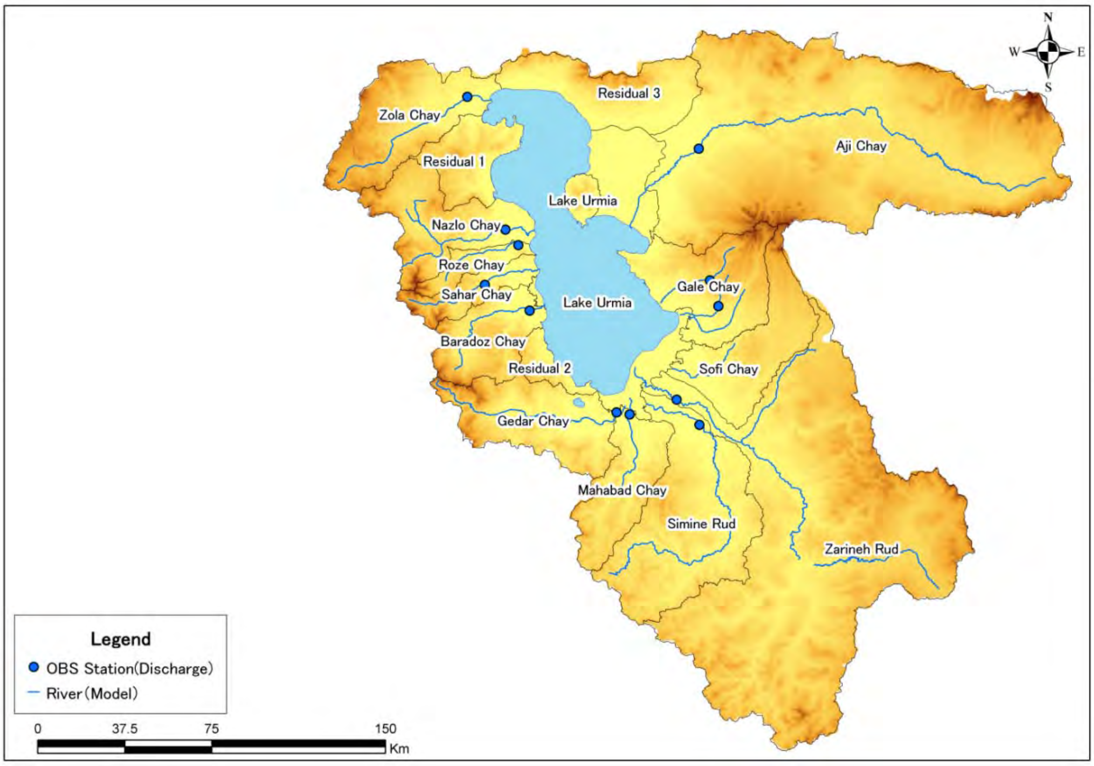
In order to confirm the validity of the model, target items and locations were selected for the calibration from the following viewpoints.

- Since the inflow from the rivers hugely affects the lake water level, annual inflow volume was evaluated as runoff rates.
- Basically, the lowest discharge observing stations were selected as the evaluation points from the in the major rivers that were modeled. In case that the stations do not have the data sufficient for the caliblation, neighboring stations at upstream of the stations were selected. Considering the availability of data for the modeled rivers, the selected observing stations for calbration are shown in Table5.2.16 and Figure5.2.29. It is noted that although there were no appropriate stations for calbration in the Gale Chay L1 and Sofi Chay river basins, as these river basins occupy only 7% of the entire basin area, in these two river basin, calibration points were not established because it was judged that they do not affect the accuracy of the model.

Table5.2.16 Locations for Calibration in the Modeled Rivers

River name	Station name	Catchment area (km^2)	Station area (km^2)
Zola Chay	Chehrigh olia	2,260.1	2,204.0
Ajichay	Akhola	11,608.4	9,752.0
Nazlo Chay	Abajalu sofla	1,881.6	1,631.6
Roze Chay	Guyjali aslan	458.1	428.1
Sahar Chay	Band urmia	712.3	418.0
Gale Chay R	Yengjeh	699.4	249.0
Baradoz Chay	Babarud	1,362.8	1,160.0
Gale Chay L2	Khorma zard	235.2	89.0
Gale Chay L1	-	860.8	756.0
Sofi Chay	-	1,937.2	1,937.2
Zarineh Rud	Nezam abad	11,841.2	11,578.0
Mahabad Chay	Gard yaghub	1,508.0	1,508.0
Gedar Chay	Pol bahramlu santu	2,092.6	2,090.0
Simine Rud	Miandoab	3,785.0	3,363.0

Note: Prepared by JICA Survey Team based on the data provided by WRMC



Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.29 Location Map of Calibration Sites in the Modeled Rivers

In addition, runoff rates were calculated from the observed river discharge at the selected sites and basin average rainfall at upstream of observing stations. The results are shown in Table5.2.17 and Figure 5.2.30.

Table5.2.17 Runoff Rates at the Calibration Sites（from 1999 to 2007）

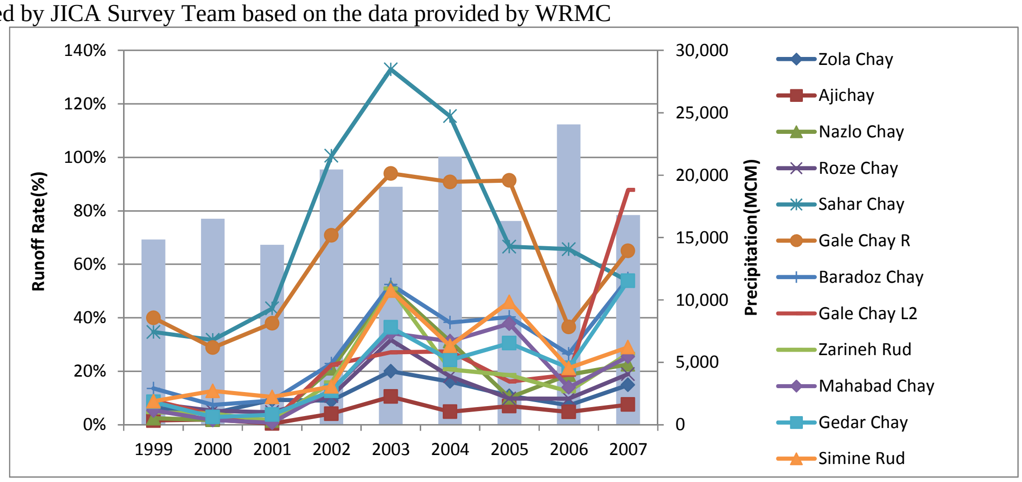
	1999			2000			2001		
	Rain (MCM)	River Flow (MCM)	Runoff Rate	Rain (MCM)	River Flow (MCM)	Runoff Rate	Rain (MCM)	River Flow (MCM)	Runoff Rate
Zola Chay	659.99	41.39	0.06	843.65	36.62	0.04	571.50	53.10	0.09
Ajichay	2731.93	43.39	0.02	3012.30	58.54	0.02	2626.80	10.84	0.00
Nazlo Chay	556.20	13.50	0.02	690.00	12.33	0.02	604.83	9.43	0.02
Roze Chay	150.43	12.06	0.08	169.19	8.78	0.05	130.85	6.17	0.05
Sahar Chay	151.67	52.63	0.35	173.53	55.11	0.32	126.39	54.93	0.43
Gale Chay R	63.84	25.52	0.40	75.83	21.87	0.29	79.54	30.19	0.38
Baradoz Chay	345.91	46.85	0.14	441.15	32.59	0.07	405.14	36.54	0.09
Gale Chay L2	22.82	2.08	0.09	27.10	0.98	0.04	28.43	0.30	0.01
Zarineh Rud	3533.26	164.26	0.05	3662.93	153.84	0.04	3332.38	49.99	0.02
Mahabad Chay	406.33	21.69	0.05	533.73	9.32	0.02	468.10	3.35	0.01
Gedar Chay	616.49	52.65	0.09	735.87	21.44	0.03	659.42	24.98	0.04
Simine Rud	762.56	66.90	0.09	1000.80	126.76	0.13	974.77	101.48	0.10

*Prepared by JICA Survey Team based on the data provided by WRMC

	2002			2003			2004		
	Rain (MCM)	River Flow (MCM)	Runoff Rate	Rain (MCM)	River Flow (MCM)	Runoff Rate	Rain (MCM)	River Flow (MCM)	Runoff Rate
Zola Chay	875.61	79.16	0.09	772.41	154.55	0.20	778.06	125.72	0.16
Ajichay	3619.84	150.76	0.04	3208.12	337.39	0.11	3623.06	177.03	0.05
Nazlo Chay	718.48	151.09	0.21	708.93	364.56	0.51	711.10	222.19	0.31
Roze Chay	179.87	19.29	0.11	179.43	56.98	0.32	159.83	28.92	0.18
Sahar Chay	180.57	181.67	1.01	178.46	237.12	1.33	153.01	176.58	1.15
Gale Chay R	101.90	72.16	0.71	93.73	88.06	0.94	106.26	96.51	0.91
Baradoz Chay	614.43	140.64	0.23	653.65	343.03	0.52	637.15	243.67	0.38
Gale Chay L2	36.42	8.16	0.22	33.50	9.07	0.27	37.98	10.43	0.27
Zarineh Rud	5086.56	804.54	0.16	4746.98	2417.34	0.51	5794.21	1199.21	0.21
Mahabad Chay	651.65	85.15	0.13	682.67	233.93	0.34	656.49	204.90	0.31
Gedar Chay	1034.19	130.78	0.13	1053.95	383.90	0.36	1096.35	265.35	0.24
Simine Rud	1564.10	223.71	0.14	1365.58	685.21	0.50	1717.45	507.23	0.30

	2005			2006			2007		
	Rain (MCM)	River Flow (MCM)	Runoff Rate	Rain (MCM)	River Flow (MCM)	Runoff Rate	Rain (MCM)	River Flow (MCM)	Runoff Rate
Zola Chay	549.77	59.55	0.11	912.19	66.20	0.07	670.66	99.87	0.15
Ajichay	3238.25	226.06	0.07	3672.31	175.79	0.05	3181.49	240.17	0.08
Nazlo Chay	556.07	56.72	0.10	854.35	159.80	0.19	624.33	140.90	0.23
Roze Chay	138.45	13.59	0.10	217.32	21.18	0.10	143.01	27.12	0.19
Sahar Chay	145.47	96.91	0.67	211.28	138.70	0.66	131.31	70.54	0.54
Gale Chay R	76.34	69.75	0.91	119.03	43.49	0.37	87.11	56.64	0.65
Baradoz Chay	413.01	166.39	0.40	761.84	201.98	0.27	419.27	229.12	0.55
Gale Chay L2	27.29	4.41	0.16	42.55	7.96	0.19	31.14	27.32	0.88
Zarineh Rud	4282.12	794.26	0.19	6534.62	816.32	0.12	4295.90	1140.84	0.27
Mahabad Chay	450.39	170.15	0.38	802.99	111.97	0.14	503.66	128.34	0.25
Gedar Chay	699.94	213.75	0.31	1373.76	292.86	0.21	788.87	424.70	0.54
Simine Rud	1219.22	560.79	0.46	1898.65	402.76	0.21	1198.57	347.65	0.29

*Prepared by JICA Survey Team based on the data provided by WRMC



*Prepared by JICA Survey Team based on the data provided by WRMC

Figure 5.2.30 Runoff Rates at the Calibration Site and Average Precipitation in the Whole Basin (from 1999 to 2007)

As shown in the historical change in Table5.2.17 and Figure 5.2.30, the following items are understood.

- Years from 1999 to 2001 were under drought condition. The annual runoff rate of each river for those years is lower than that of other years.

- The runoff rate of each river is relatively high in 2003. It seems that following the drought period until 2001, big amount of water were stored in the dams in 2002 and were discharged in 2003 causing an estimated runoff rates that was high in 2003.

To simulate water levels of the lake adequately, river discharge is one of the most important factors. However, in simulating volume of river discharge based on the limited information, there has been a difficulty of the modeling of the rivers which have high runoff rates more than one in hydrological environment of semi-arid region. To ensure the accuracy of the Model, runoff rate of each river was checked. The results are shown below.

- Runoff rates of the Sahar Chay River are constantly in high values. It is mostly over 0.4 and is over 1.0 in the years 2002 and 2003. There is a possibility that observed values of river discharge are abnormal values, or observation of precipitation in mountainous area is insufficient.
- Due to similar reasons, it is also difficult to ensure accuracy for the Gale Chay River and Baradoz Chay River.

To ensure accuracy of the lake water level, it is considered that the rivers with big river discharge and large catchment area are important. Hence, rivers with large catchment area and huge observed river discharge among the modeled rivers are selected to mainly ensure accuracy of river discharge. Catchment areas of the modeled rivers and the observed discharge in 2006 are shown in Table5.2.18.

Table5.2.18 Catchment Areas and Observed Discharge of the Modeled Rivers

River name	Basin area			Discharge_2007		
	Catchment area (km2)	Rank	Percentage (%)	Discharge_2007 (MCM)	Rank	Percentage (%)
Zola Chay	2,260.1	4	5.48	99.87	8	3.40
Ajichay	11,608.4	2	28.15	240.17	4	8.19
Nazlo Chay	1,881.6	7	4.56	140.90	6	4.80
Roze Chay	458.1	13	1.11	27.12	11	0.92
Sahar Chay	712.3	11	1.73	70.54	9	2.40
Gale Chay R	699.4	12	1.70	56.64	10	1.93
Baradoz Chay	1,362.8	9	3.30	229.12	5	7.81
Gale Chay L2	235.2	14	0.57	27.32	12	0.93
Gale Chay L1	860.8	10	2.09	Missing	-	-
Sofi Chay	1,937.2	6	4.70	Missing	-	-
Zarineh Rud	11,841.2	1	28.71	1140.84	1	38.89
Mahabad Chay	1,508.0	8	3.66	128.34	7	4.38
Gedar Chay	2,092.6	5	5.07	424.70	2	14.48
Simine Rud	3,785.0	3	9.18	347.65	3	11.85

Note: Prepared by JICA Survey Team based on the data provided by WRMC

From the above, Zarineh Rud, Simine Rud, Gedar Chay, Ajichay, and Nazlo Chay Rivers are selected as important rivers[1] to secure expected accuracy of lake water level. River discharges of these rivers are considered to be important, and accuracy of the discharges will be ensured.

[1] These five (5) rivers consist of 75% of entire catchment area and river discharge.

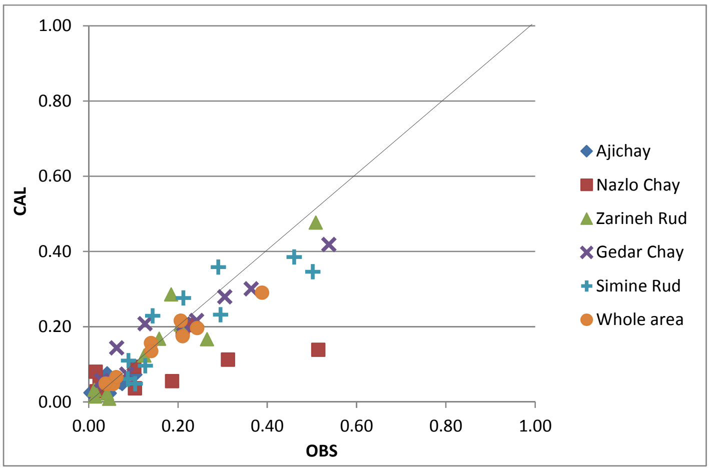
(3) Calibration Results of the Parameters

The most important factor for calibrating the Model was the lake water level. To reproduce the lake water level, it is necessary to ensure reproduction of river discharge. To reproduce the river discharge, the annual volume of inflow to the lake is important. Thus, a study on comparison of the observed and the calculated runoff rates was conducted. Furthermore, once the re-productivity of river discharge is ensured, the observed and calculated water levels of the lake are compared.

River discharge was refined by adjusting "Evapotranspiration of land area" and "Drainage" described above for ensuring reproduction. As for the Evapotranspiration of land area, based on the sensitivity analysis (See Figure5.2.25), it was set at 0.25, which has high consistency with the observation for years 1999 to 2001. Adjustment of Drainage is carried out afterward. Values of Drainage are set from a river basin to another, because it is difficult to ensure expected accuracy for river discharge of each river with one common value for Drainage.

The overall tendency in the initial setting was that the calculated discharge was smaller than the observed discharge. Therefore, in order to increase runoff quantity, adjustments such as deepening the height of Drainage was conducted to make bigger the Intrusion coefficient.

As the results of the ensuring reproducing river discharge, comparisons of observed and calculated river discharge are shown in Figure5.2.31 and Table5.2.19. In the years 1999 to 2001 under drought condition, the accuracy of the calculated values varies from basin to basin. In 2002 and 2003, the period after the drought, the calculated runoff rates are higher than the observed values in 2002, and there was a tendency that the calculated runoff rates are lower than the observed values in 2003. In spite of the possibility of release of discharge by dams, the study shows that the Model mostly ensure reproducing river discharges.



*Prepared by JICA Survey Team

Figure5.2.31 Results of Calibration (River Discharge and Runoff Rates)

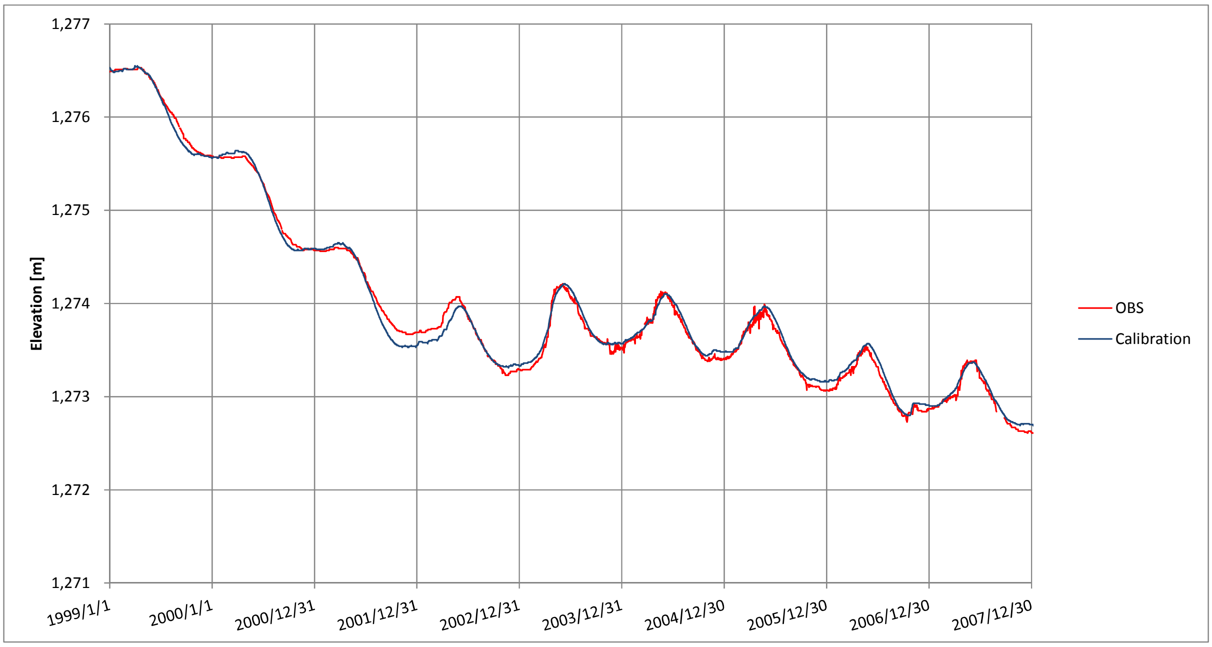
Table5.2.19 Results of Calibration (River Discharge and Runoff Rates)

Runoff Rate	Ajichay		Nazlo Chay		Zarineh Rud		Gedar Chay		Simine Rud		Whole area	
	OBS	CAL	OBS	CAL	OBS	CAL	OBS	CAL	OBS	CAL	OBS	CAL
1999	0.02	0.03	0.02	0.05	0.05	0.01	0.09	0.07	0.09	0.06	0.05	0.05
2000	0.02	0.02	0.02	0.03	0.04	0.02	0.03	0.06	0.13	0.10	0.05	0.05
2001	0.00	0.03	0.02	0.08	0.02	0.01	0.04	0.05	0.10	0.05	0.04	0.05
2002	0.04	0.08	0.21	0.19	0.16	0.17	0.13	0.21	0.14	0.23	0.14	0.16
2003	0.11	0.07	0.51	0.14	0.51	0.48	0.36	0.30	0.50	0.35	0.39	0.29
2004	0.05	0.05	0.31	0.11	0.21	0.21	0.24	0.22	0.30	0.23	0.21	0.18
2005	0.07	0.05	0.10	0.09	0.19	0.29	0.31	0.28	0.46	0.39	0.21	0.22
2006	0.05	0.02	0.19	0.06	0.12	0.12	0.21	0.21	0.21	0.28	0.14	0.14
2007	0.08	0.05	0.23	0.20	0.27	0.17	0.54	0.42	0.29	0.36	0.24	0.20

*Prepared by JICA Survey Team
*OBS:observed values, CAL:calculated values with the model

After ensuring the accuracy of river discharges, evaporation from the lake surface was adjusted to ensure the accuracy of the lake water level. Although the initial value for evaporation from the lake surface is set at 70% of pan evaporation, it is lowered to 67% since the calculated water level tends to be much lower in summer to winter seasons than the observed water level when the water level was becoming lower.

Comparison of the observed and calculated lake water level is shown in Figure5.2.32. Figure5.2.32 shows a slight difference in decreasing tendency from summer to winter season from 1999 to 2001 and the rest of the years. However, the calculated lake water level is mostly consistent with the observed values. It is accepted that the Model ensures expected accuracy to be obtained in the study using various measures and their outcomes to recover the lake water level to the target level set at 1,274.1m.



Note:Prepared by JICA Survey Team

Figure5.2.32 Calibration Result (Lake Water Level)

Final values of the parameters in this analysis are shown in Table5.2.20. It is noted that drainage values are set for each river basin to ensure reproduction of each river discharge. However, they are not shown in the table since they are not important in a physical sense.

Table5.2.20 Final Values for Parameters

Evaporation from Lake surface	Evapotranspiration of land area	Permeability coefficient of surface geology (m/s)
67% of pan evaporation	25% of pan evaporation	$1.00x\ 10^{-6}$

The calibrated model has high accuracy because the lake water level and river discharge (runoff rate) were matched between the observed data and calculated. Furthermore, additional refinement can be expected if following conditions are considered.

- Setting evapo-transration in winter season in detail (As average values are given to the evapo-transpiration in winter season which is from December to March, annual difference of evapo-transpiration could not be reflected.)
- Incorporating pattern of water use . It has to be considered that there is a possibility of different pattern of water use from 1999 to 2001 under droughtconditionswhen the actual water use condition is not known)
- Incorporating actual discharge quantity from the dams. After the drought from 1999 to 2001, there is a possibility that the stored water in the dams in 2002 was released in 2003. Based on this analysis, model input data of discharge from the dams and water supply quantity were partly supplemented.

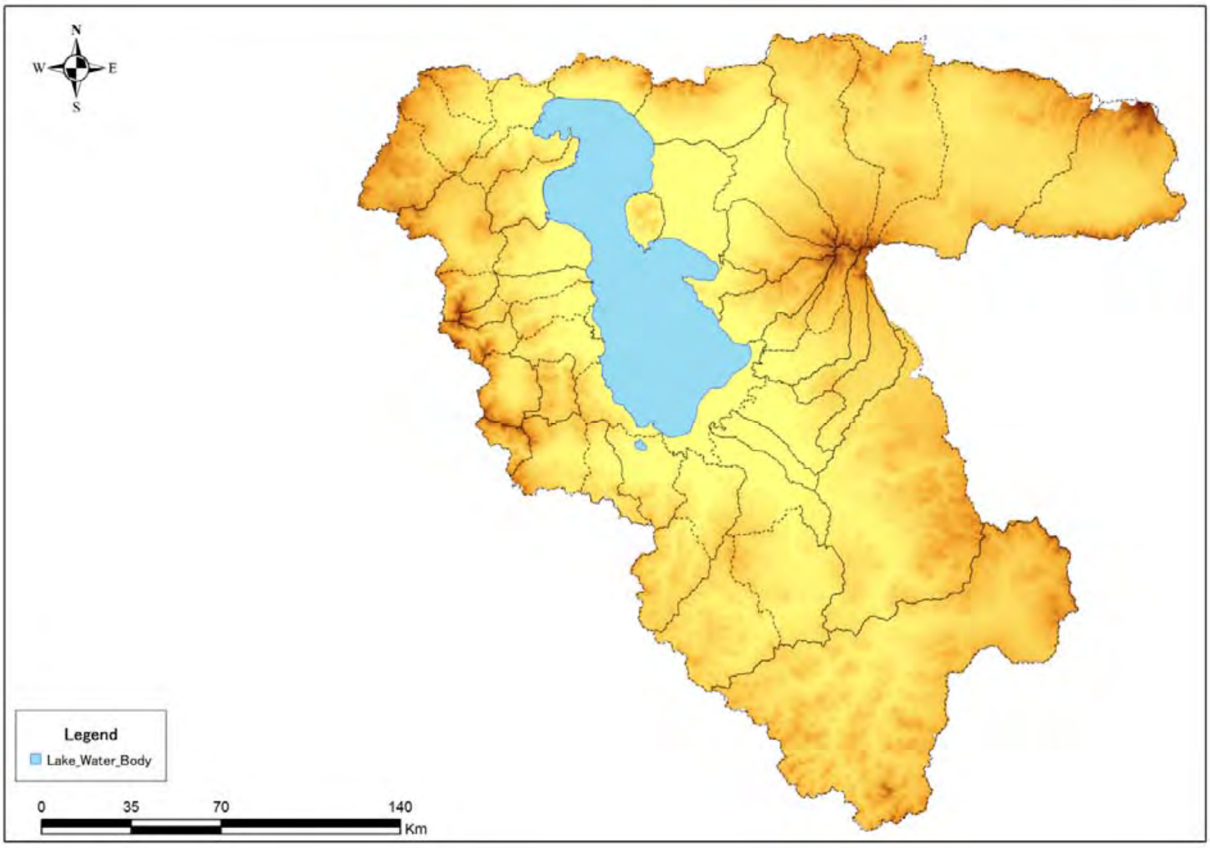
- Clarification of the conditions of water intake from the rivers such as the locations of water intake, return flow, and intake water quantity at each intake point, were incorporated into the model.

5.2.5 EVALUATION OF WATER BALANCE BY MODEL SIMULATION

Based on the results of the calibration described above, it was confirmed that the established model was appropriately verified. By means of the simulation result carried out, water balance of Lake Urmia was evaluated. In this subsection, water balance evaluation in the basin scale was not conducted because the difficulties of evaluation were recognized, especially in terms of indivisibilities of hydrological outputs of the simulation model.

- Land evaporation extracted in the model includes the evaporation from the supplied water to irrigated area by taking water from the rivers or groundwater.
- Runoff volume to the rivers include that of the return flows of the intake water.
- There are interaction of water between the rivers and groundwater.

Target area for evaluating the water balance of Lake Urmia was fixed as shown in Figure5.2.33.



*Prepared by JICA Survey Team based on the data provided by WRMC

Figure5.2.33 Target Area for Evaluation of Water Balance

(1) Water Balance from 1999 to 2007 (Calibration Period)

The Water balance during the period (1999 - 2007) when the model was sufficiently verified was evaluated. Calculated water balances of Lake Urmia for the years are tabulated in Table5.2.21.

Table5.2.21 Water Balance of Lake Urmia

	① Rainfall (MCM)	② River inflow (MCM)	③ Groundwater inflow (MCM)	④ Evaporation (MCM)	Water balance (MCM) ①+②+③-④
1999	1356.8	613.4	163.5	6,550.2	-4,416.5
2000	1472.6	658.2	159.8	6,638.5	-4,347.8
2001	1237.5	570.4	157.5	6,487.4	-4,522.0
2002	1791.3	2,657.9	157.7	5,481.3	-874.4
2003	1698.4	4,448.7	153.7	5,957.2	343.6
2004	1764.0	3,077.1	151.0	5,900.1	-908.0
2005	1272.9	2,859.1	147.5	6,195.1	-1,915.7
2006	2217.7	2,696.6	143.8	6,392.2	-1,334.2
2007	1196.6	2,763.8	142.1	5,761.9	-1,659.4

*Prepared by JICA Survey Team

Based on the calculation results, the water balance every year except in 2003 when it showed negative values and the decline of water level at the same time. It was confirmed that inflow volumes and runoff rates in 2003 calculated in Section 5.3 were larger than that in other years.

The above-mentioned phenomenon could have been caused by (i) the increase of discharge from dams in 2002 when dam water were stored after the droughts in 1999 to 2001; and (ii) the increase in surface and subsurface flows which were attributed to the increase of moisture content in soil caused by high precipitation in 2002. Assuming that the increase in runoff rates were caused by moisture content in underground soil, it would be natural that the runoff rates in 2004 show similar values or more compared to those of 2003. Hence, the reason for the positive water balance of 2003 could be the increase in outflow of water stored in the dams in 2002.

In order to examine the explanation described above, details about Bukan Dam, the biggest dam in the Lake Urmia Basin, was examined. Bukan Dam's annual inflow and outflow obtained from simulation result were compared as shown in Table5.2.22. Since it was confirmed that outflow from Bukan Dam was larger than its inflow in 2003, the main factor for the positive water balance in 2003 could be the influence of the increase in outflow from dams.

Table5.2.22 Comparison between Inflow and Outflow in Simulation Result in Bukan Dam

Year	① Inflow (MCM)	② Outflow (MCM)	① -②
2002	1579.811	1543.069	36.742
2003	2901.514	2940.52	-39.006
2004	1908.959	1778.925	130.034

*Prepared by JICA Survey Team

To analyze the impacts of inflow and outflow on the variation of (i) the lake water level, (ii) the amount of water use, (iii) inflow rate (the rate of river inflow volume to river runoff), and (iv) water use rate were calculated based on simulation result (See Table5.2.23). Inflow rate was the ratio of inflow volume to the runoff volume. Water use rate was that of the estimated water use to the runoff volume. Based on the calculation result, water use increased while the inflow rate decreased during the period 2004 2007 except for the drought years 1999-2001 and the period affected by dam storage in 2002 and 2003. Assuming that land use in the Lake Urmia Basin had slightly changed, this could have been caused predominantly by the increase in infiltrated water from the rivers into groundwater which were attributed to the lowering groundwater potential due to the increase in groundwater extraction. There is, however, the possibility of change in storage conditions of the dam storages.

Table5.2.23 Proportion of Inflow from the Rivers and Water Use (Based on Simulation Result)

	① River inflow to Lake (MCM)	② River runoff (MCM)	③ Estimated Water use ②-①	Inflow rate ①/②	Water use rate ③/②
1999	613.4	847.4	234.0	0.72	0.28
2000	658.2	1,104.3	446.0	0.60	0.40
2001	570.4	1,098.8	528.3	0.52	0.48
2002	2,657.9	4,476.9	1,819.0	0.59	0.41
2003	4,448.7	6,527.4	2,078.7	0.68	0.32
2004	3,077.1	4,796.8	1,719.7	0.64	0.36
2005	2,859.1	4,545.4	1,686.3	0.63	0.37
2006	2,696.6	4,741.9	2,045.2	0.57	0.43
2007	2,763.8	4,983.2	2,219.4	0.55	0.45

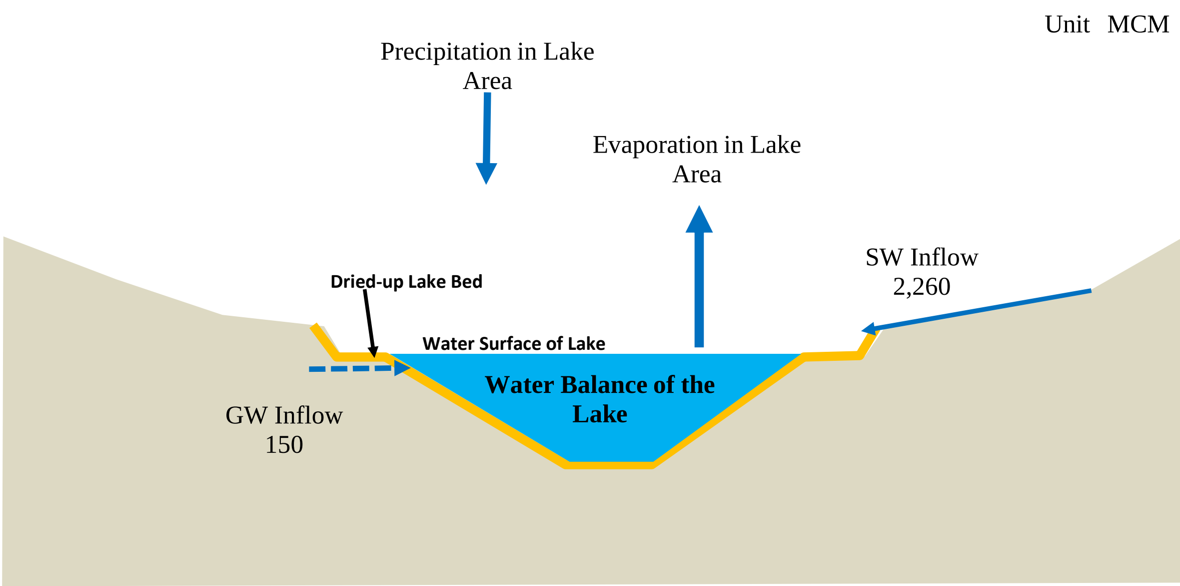
Note: Prepared by JICA Survey Team

Based on the above analyses, the temporal trend of water balance of Lake Urmia from Year 1999 to 2007 was evaluated as shown in Table5.2.24. Average water balance condition from Year 1999 to 2007 is also shown in Figure5.2.34.

Table5.2.24 Temporal Trend of Estimated Water Balance of Lake Urmia

Year/Period	Trend of Water Balance
1999～2001	Since this period was drought year, the precipitation in this period was smaller than normal years and runoff rates were less than 10%. The lake water level had decreased because the inflow from the rivers was small.
2002	Although more precipitation occurred than that in between 1999 and 2001, as the inflow rates were smaller than that of other years, The storage volume of the dams or intake water volume from the rivers had increased.
2003	The water level of Lake Urmia had recovered due to the increase in the runoff rate by releasing the stored water from the dams in 2002.
2004～2007	Precipitation in 2004 was higher than that of 2003, but the lake water level had not recovered. In 2005, as the precipitation was lower than normal years, the lake water level had decreased. In 2006, although the precipitation was relatively high, as the evaporation from the lake surface was larger than that of other years, It was assumed that the lake water level had not recovered in 2007 due to low precipitation. From 2003 to 2007, as the river flow had gradually reduced, the water use rate had increased accordingly. Although the difference of storage condition of dams, it could be caused by the increase in intake from the rivers and infiltrated water from the rivers to groundwater which were associated with the groundwater level lowering due to the groundwater use.

Note: Prepared by JICA Survey Team



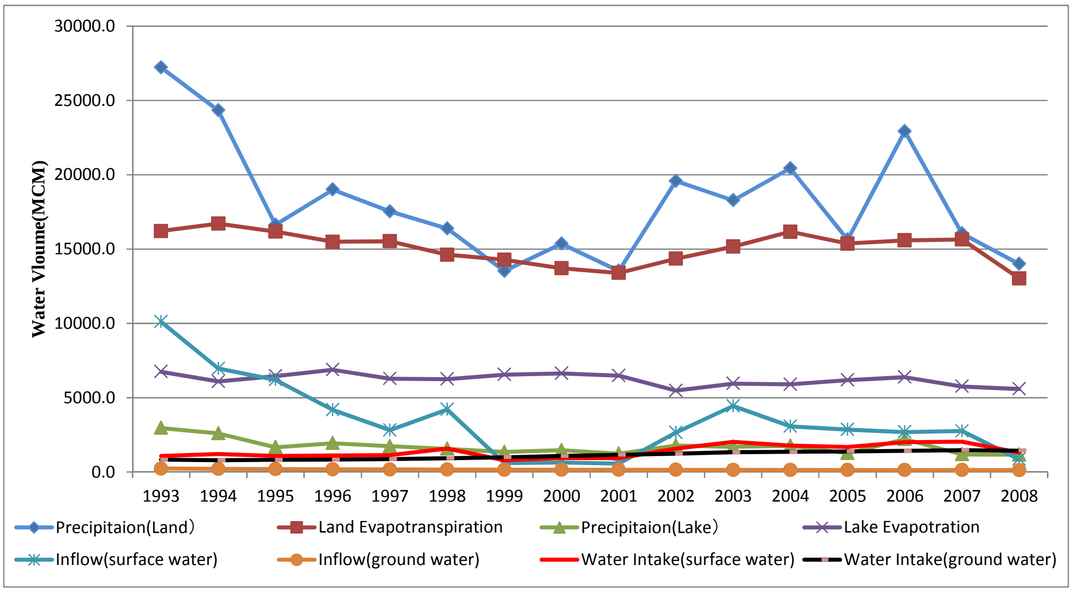
Source: JICA Survey Team

Figure5.2.34 Water Balance by the Simulation Model (Average among the period from 1999 to 2007)

(2) Water Balance Analysis (from 1993 to 2008)

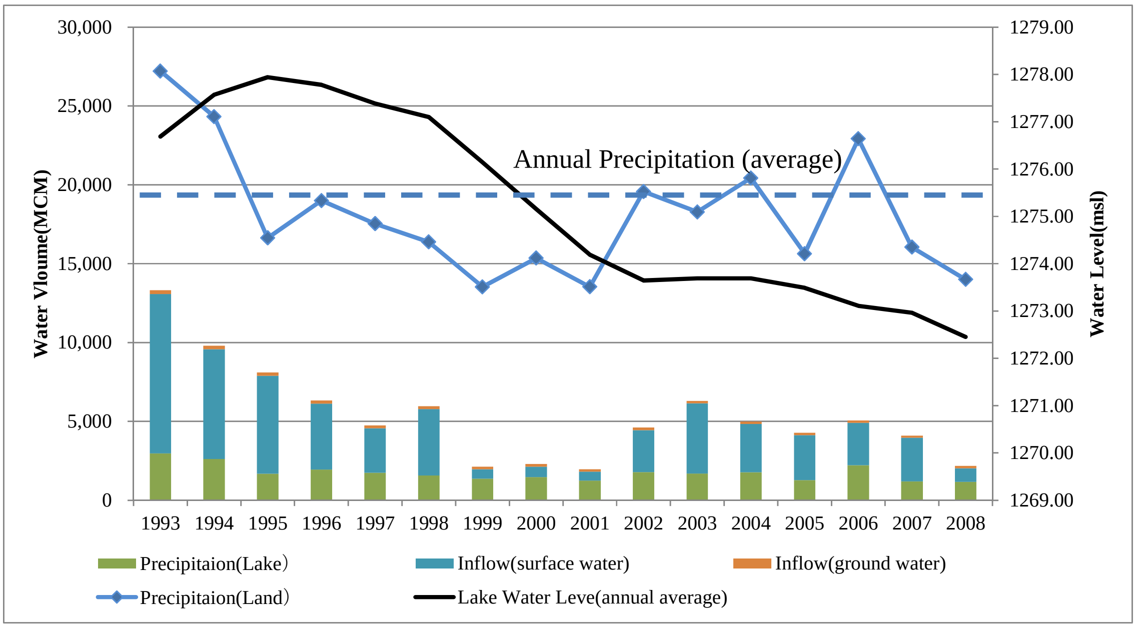
In order to analyze the factors causing the lowering of the lake water level a water balance simulation was carried out. The simulation period was from 1993 to 2008 because this period had enough meteorological and hydrological data. Based on the simulation result, annual water amount of precipitation (land and lake surface), evaporation (land and lake surface), inflow to the lake (river flow and groundwater) and water extraction (surface water and groundwater) were calculated.

Figure 5.2.35 shows the calculated overall annual volume and Figure 5.2.36 shows the incremental factors for the water balance of the lake. On the other hand, Figure 5.2.37 shows the decremental factors for it.



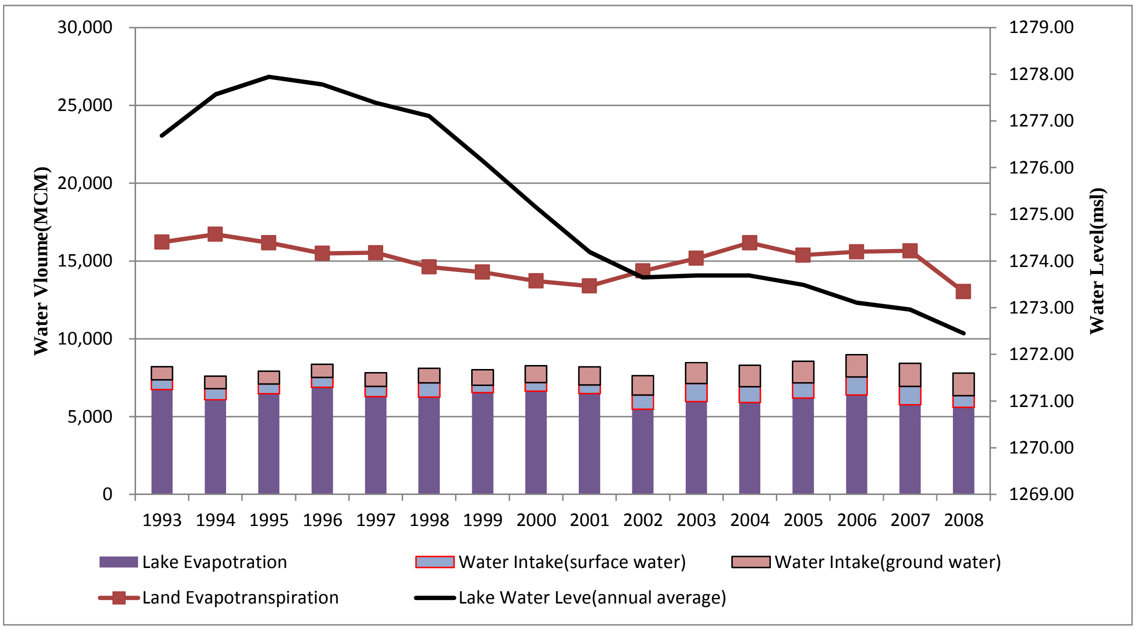
Source: JICA Survey Team

Figure 5.2.35 Water Balance Analysis



Source: JICA Survey Team

Figure 5.2.36 Water Volume (Incremental factors)



Source: JICA Survey Team

Figure 5.2.37 Water Volume (Decrementing Factors)

According to Figure 5.2.36 the fluctuation of precipitation was large and the inflow (surface water) was proportional to it. In addition, in response to the decrease of annual precipitation from 1994 (below annual average level), the lake water level had lowered. Although water extraction of surface water and groundwater has increased mildly as shown in Figure 5.2.37, the fluctuation of water extraction is smaller than that of inflow of surface water.

Thus, it could be said that the incremental factors of the water balance contribute mainly to the recovery of the lake water level... In considering the order of hydrological cycle, the decrease of land precipitation is thought to be the fundamental factor for the decrease of the lake water level.

On the assumption that the annual precipitation is below the annual average level, it could be difficult to recover the river flow to the same as it was before the drought period from 1999 to 2001 by regulation of water extraction as countermeasure to preserve river flow.

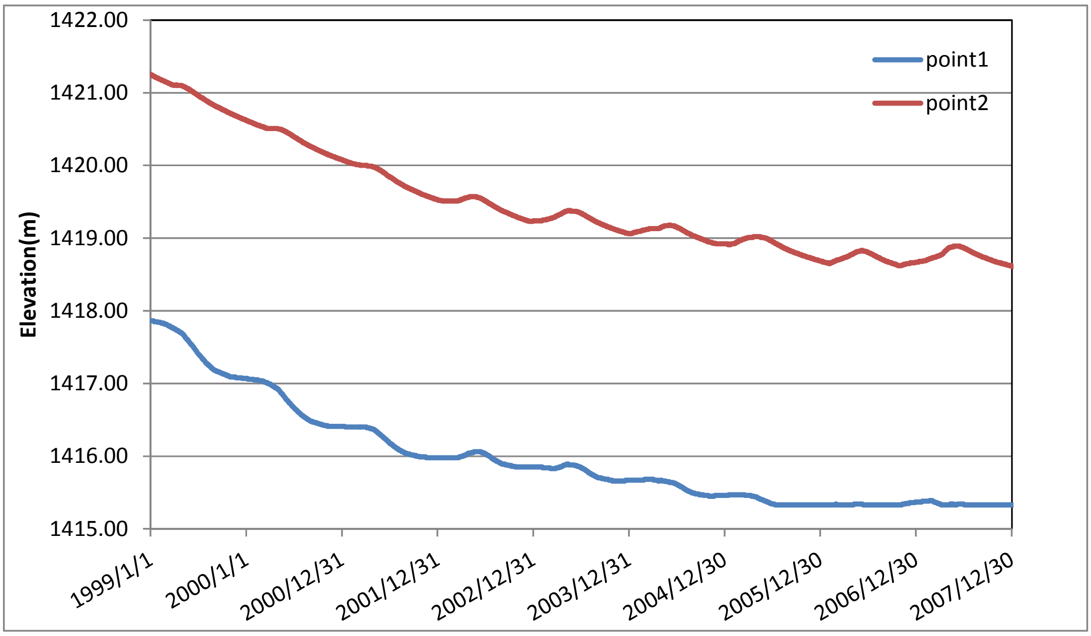
The precipitation in 2006 is the same as that of 1994 as shown in Figure 5.2.36. However, as the lake water level in 1994 recovered it decreased in 2006. This was due to the difference between the surface water inflow in 1994 and that of 2006. The amount of surface water in 1994 was about twice as much as that of 2006.

According to the analysis on the decrementing factors of water balance, it is found that there is not a great difference in evaporation amount, but the water extraction from surface water and groundwater in 2006 was larger than that of 1994.

The main factor for the difference of surface water inflow depends on the fluctuation of (i) inflow from the basin to the river, and (ii) infiltration from rivers to ground. Both factors are influenced by ground water level. In proportion to the lowering of ground water level, what could occur are a decrease of river base flow and a decrease of intermediate flow caused by the increase of seepage flow in vertical direction. In addition, subsoil flow from rivers could increase due to lowering of ground water level.

In Chapter 2, time-series data of observed groundwater level is described. According to this data, the groundwater level has lowered as much as over 10 meters between 1994 and 2014 at a certain observation point. Furthermore, from the results of water balance analysis, it is expected that ground water level tends to decrease (See Figure 5.2.38).

According to the above analysis, it could be said that the lowering of the lake water level is mainly due to the decrease of surface water inflow along with the decrease of precipitation. Furthermore, it is thought that the reason why the lake water level has not recovered even by recent rainfall can be caused by the decrease of ground water level.



Point1: Northwest part of the Lake Urmia Basin
Point2: Southwest part of the Lake Urmia Basin

Figure 5.2.38 Estimated Groundwater Level

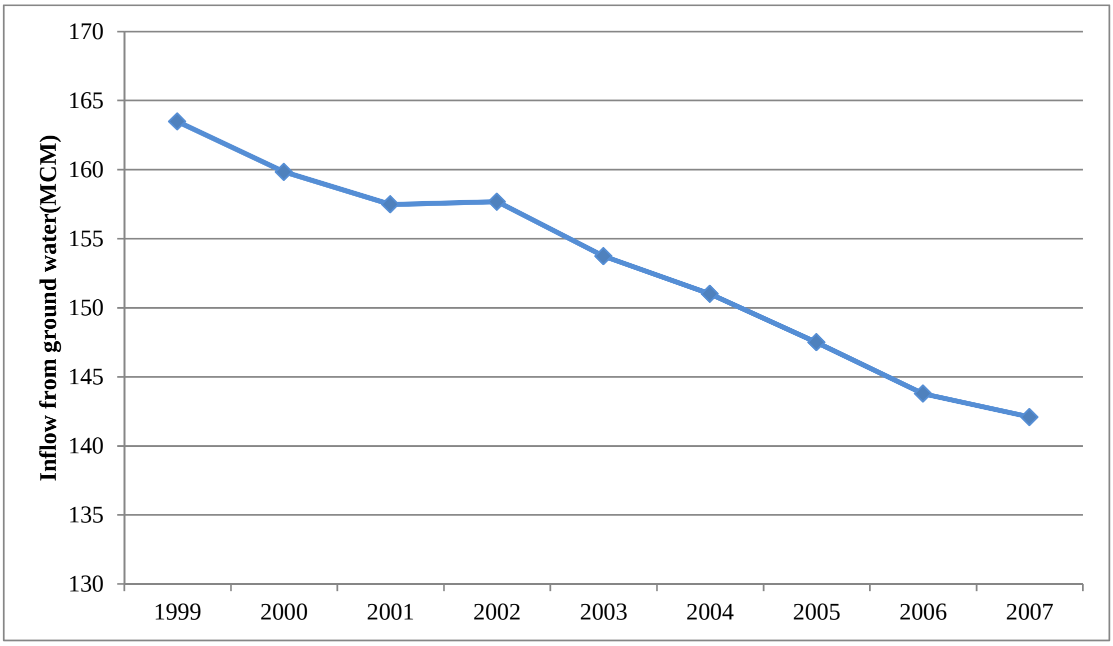
(3) Findings

According to the result of water balance analysis on the Lake Urmia Basin, the reasons behind the decrease of lake water level are listed as follows,

- The rapid decline of the lake water level from 1995 is mainly caused by the decrease of surface water inflow along with the decrease of precipitation (See Figure 5.2.36).
- Even though annual precipitation from 2002 to 2006 was at average level, the lake water level still decreased. It can be assumed that (i) decrease of surface water inflow is caused by the decrease of recharge from groundwater to the rivers and (ii) increase of seepage flow from rivers to the ground (See Figure 5.2.36 and Figure 5.2.38).

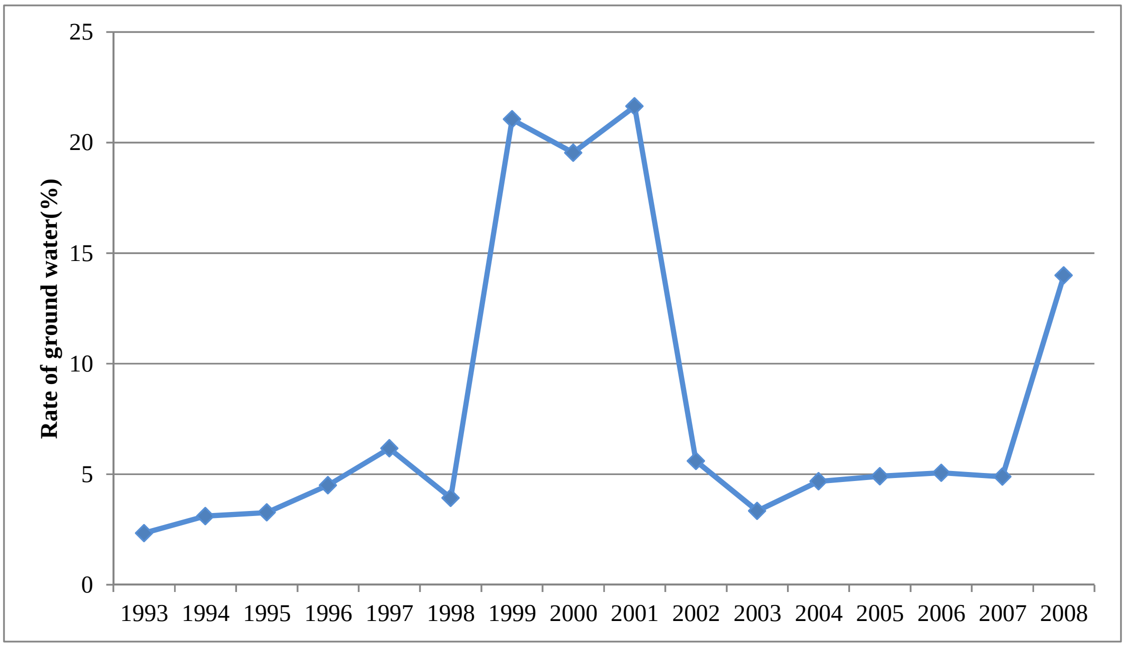
From the findings mentioned above, recommendations to avoid the decrease of the lake water level are listed as follows:

- Even though inflow from the rivers to the lake depends on meteorological conditions, it is important to secure the amount of river inflow in order to recover the lake water level. Therefore, the reduction of extracting water from the rivers and setting-up of criteria for proper water use are required.
- According to the results of water balance analysis, it is found that inflow from groundwater to the lake has decreased (See Figure 5.2.39). Although inflow from groundwater is smaller than that from the rivers, inflow from groundwater is important as water supply source during drought period. If extraction of groundwater increases continously, it will induce not only decrease of inflow to the lake, but also lowering of groundwater level in inland, which would cause decrease of river baseflow flowing into the lake.
- It can be considered that decrease of groundwater level will cause an intrusion of salt water to Lake Urmia since sea water density is higher than that of fresh water. It can also induce decrease of lake water level and a water salinity of wells. This would further cause over- extraction from the rivers. Hence, proper utilization of ground water is required which can induce an increase of base flows and a decrease of seepage flow from the rivers to the underground. And, finally a securement of amount of river inflow to Lake Urmia. In addition, there is a possibility that the recovery of groundwater will contribute to conservation of the wetlands in the surrounding areas of the lake.
- It is thought that one of the reasons why the lake water level recovered in year 2013 was the release of water from dams. In order to keep the balance between water utilization and the lake water level considering changes of precipitation and rainfall pattern due to climate changes, appropriate dam operations will be required. In the future, proper dam operations should be installed for stable water supply to the river and the avoidance of over-extraction from the ground water. The healthy hydrologic cycle shall be reconstructed considering human activities.



Source: JICA Survey Team

Figure 5.2.39 Estimated Annual Inflow from Groundwater into the Lake



Source: by JICA Survey Team

Figure 5.2.40 Estimated Annual Inflow Rate from Groundwater into the Lake

5.3 ESTABLISHMENT OF DISTRIBUTED HYDROLOGICAL MODEL BY GETFLOWS

In MIKE-SHE, surface and subsurface water flow is connected with different time steps when calculation. On the other hand, in integrated hydrological simulator "GETFLOWS (General-purpose Terrestrial Fluid-FLOW Simulator)", multi-phase and multi-component fluid is calculated as surface and subsurface fully-coupled fluid flow. Thus, it is possible to analyze closer conditions to the actual phenomenon. Especially, in the simulation of non-static runoff resulted from precipitation and evaporation, water condition in the unsaturated layer, change of subsurface air pressure (change of suction) have a great influence on surface or subsurface runoff. For this reason, GETFLOWS is effective model to analyze the hydrological structure.

In Japan, there are a lot of studies with GETFLOWS in areas where they have groundwater challenges, including Kumamoto, the winner of "Water for Life" UN-Water Best Practices Award in 2013, Kiso River Basin, and Hadano City, where groundwater is widely used. Globally, it is employed in the Yellow River Basin in China and throughout the state of Sri Lanka.

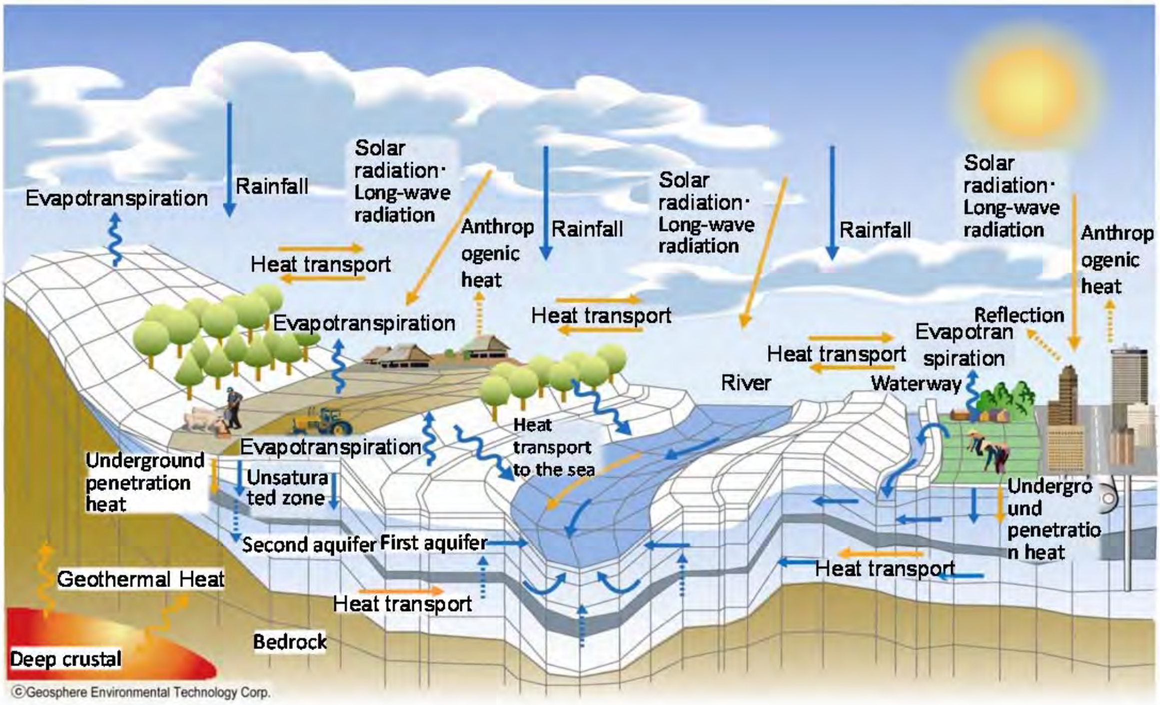


Figure 5.3.1 Conceptual Diagram of GETFLOWS

5.3.1 Theory of GETFLOWS

Governing equations and the method of fully-coupled surface and subsurface water are shown below.

(1) Fluid Theory of Surface Flow

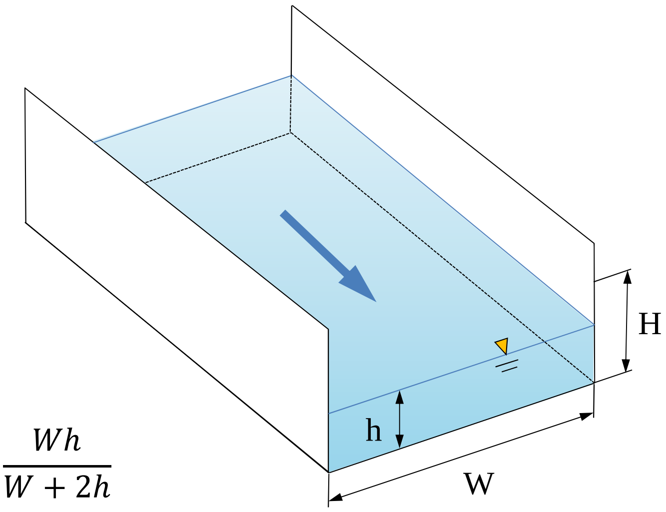
Surface water flow through rivers and mountainous surface is modeled as open channel flow. Considering the behavior of a water body (water body between cross-sections A and B) flowing through an open channel of a uniform slope as shown in Figure 5.3.2, where water depth is much smaller than the width of the channel, it can be approximated as vertically averaged shallow flow. Acceleration of the water body is defined by geographical slope and the gradient of water depth. By adding friction between the river bed and inflow and outflow from/to outside the system, the equation of motion is expressed as below.

$$\beta \frac{1}{g}\frac{\partial v_x}{\partial t} = \frac{\partial \xi}{\partial x} - \frac{\partial h}{\partial x}\cos^2\theta_x - \frac{\partial h_{fx}}{\partial x} - \frac{\alpha}{2g}\frac{\partial v^2}{\partial t} - \frac{P_r v_x}{gh} \qquad (1)$$

Where,

θ_x, θ_y	: geographical slope for each flowing direction [－]
h	: water depth [L]
h_{fx}, h_{fy}	: friction loss in each flowing direction [－]
v_x, v_y	: flow velocity in each flowing direction averaged over depth [LT^{-1}]
ξ	: height of open channel [L]
α	: energy corrective coefficient [－]
β	: momentum corrective coefficient [－]
P_r	: precipitation [LT^{-1}]
g	: gravitational acceleration [LT^{-2}]
t	: time [T]
x, y	: distance in flowing direction component [L]

The first term on the right side in the above equation is acceleration (a term for gravity), the second term is acceleration by water depth gradient (a term for pressure), the third term is resistance force by friction (a term for friction), the fourth term is the balance of momentum (a term for velocity), the fifth term is momentum loss by precipitation. Left side is the velocity change of water flow which occurs as the result of above mentioned external forces.



$$R = \frac{A}{S} = \frac{Wh}{W + 2h}$$

Figure 5.3.2 Diagram of Open Channel Flow

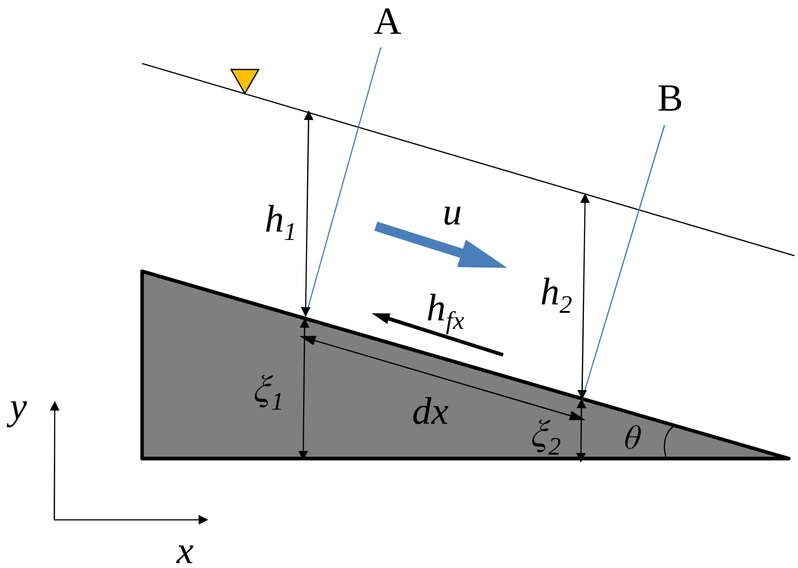


Figure 5.3.3 Movement of Water Body in an Open Channel

(a) Continuous Equation

Where channel width is non-constant, an equation for mass conservation of water body is expressed as below for each flow directional component in 2-dimentional horizontal surface.

$$\frac{\partial \rho v_x A_x}{\partial x} + \frac{\partial \rho A_x}{\partial t} = 0$$
$$\frac{\partial \rho v_y A_y}{\partial x} + \frac{\partial \rho A_y}{\partial t} = 0 \qquad (2)$$

Where, ρ is water density, A_j is the cross-sectional area in j direction (j=x,y) (L^2). Especially, when channel width W_j is constant, A_j is equals to $W_j h$, and above equations are transformed as below.

$$\frac{\partial (v_x h)}{\partial x} + \frac{\partial h}{\partial t} = 0$$
$$\frac{\partial (v_y h)}{\partial x} + \frac{\partial h}{\partial t} = 0 \qquad (3)$$

(b) Mean Velocity Equation

Through experiments in open channels, it is known that the mean velocity equation (Manning's Equation) holds, as shown below, under the condition of uniform flow, where the weight of water body in the flowing direction is balancing with friction resistance along wetted perimeter.

$$v = \frac{R^{2/3}}{n}\sqrt{\frac{\partial \xi}{\partial x}} = \frac{R^{2/3}}{n}\sqrt{i_g} \qquad (4)$$

Where, R is the hydraulic radius which represents hydraulic water depth, which is defined with channel cross-sectional area (A) and wetted perimeter (S) as shown in Figure 5.3.2. i_g is the slope of the channel bed in the flowing direction. n is the Manning's Roughness Coefficient which is given to each calculation mesh according to the shape or material of the river bed, ground vegetation (forest, grass field, farmland etc.), artificial coverage (pavement etc.). The dimension of Manning's Roughness Coefficient is $L^{-1/3}T$, which is $m^{-1/3}s$ in SI units.

(2) Fluid Theory of Underground Flow

The governing equations of two-phase flow of water and gas are expressed as below by applying Generalized Darcy's Law.

$$\nabla \cdot \left(\rho_w \frac{Kk_{rw}}{\mu_w} \nabla \Psi_w \right) - \rho_{ws} q_{ws} = \frac{\partial}{\partial t}\left(\rho_w \phi S_w \right)$$
$$\nabla \cdot \left(\rho_g \frac{Kk_{rg}}{\mu_g} \nabla \Psi_g \right) - \rho_{gs} q_{gs} = \frac{\partial}{\partial t}\left(\rho_g \phi S_g \right) \quad (5)$$

Above equations express the mass conservation law applied to water and gas among porous medium. The first term in the left side of each equation is flow term (a term for advection), the second term is production term, and the right side is a term for storage. Symbols in the equations are described as below.

K : absolute permeability(m^2)
S_p : saturation rate of fluid phase p(=w,g) (-)
ρ_p : viscosity coefficient of fluid phase p(=w,g) ($Pa \cdot s$)
μ_p : density of fluid phase p(=w,g) (kg/m^3)
Ψ_p : potential of fluid phase p(=w,g) (Pa)
ϕ : porosity (－)
t : time (s)
q_{ps} : production and depletion of fluid phase p(=w,g) ($m^3/m^3/s$)

The product of absolute permeability and relative permeability in the above equations has directionality. Both isotropic and anisotropic grounds are considered as well. Potential of water and gas phase in the above equations are expressed in the equations below.

$$\Psi_w = P_g - P_{cw} + \rho_w gZ$$
$$\Psi_g = P_g + \rho_g gZ \quad (6)$$

Where, Pg is the pressure of gas phase, Pcw is the capillary pressure; Z is the elevation (distance where up is positive). Furthermore, there is a relationship between saturation rates as expressed in the equation below.

$$S_w + S_g = 1 \quad (7)$$

Unknown variables in the above equations are the pressure of gas phase (P_g) and saturation rate of water (S_w). In the simulator in this study, both values are calculated with simultaneous complete implicit method.

(3) Full-Coupling of Surface and Subsurface Fluid

Simultaneous terrestrial flow of two-phase compressible fluid of water and gas is generalized with the governing equation below for each phase, which is a mass balance equation given with momentum conservation law for surface and subsurface fluid.

$$-\nabla M_p - \rho_p q_p = \frac{\partial \left(\rho_p \phi S_p \right)}{\partial t} \quad (8)$$

Where, Mp is the mass flux (kg/m^2/s) by flow, p(＝g:gas,w:water) is the suffix to express the fluid phase. Surface and subsurface interaction of fluid is considered by applying the above mentioned each mass conservation equations to the first flow term on the left side and solving them simultaneously and implicitly. Surface fluid is expressed by the below equation, in which above equation is applied only to water phase (p=w), and shallow water wave equation describing Manning's Open Channel is approximated to diffusional wave.

$$M_w = -\frac{\rho_w R_x^{\frac{2}{3}} W_x h}{n} \sqrt{\left| \frac{\partial h_f}{\partial x} - \frac{\partial h}{\partial x}\cos^2\theta \right|} \operatorname{sgn}\left(\frac{\partial h_f}{\partial x} - \frac{\partial h}{\partial x}\cos^2\theta \right) \qquad (9)$$

Subsurface fluid is expressed by the below equation. It is derived by equations (5) in which Darcy's Velocity Equation is applied to a two-phase (water and gas) and two-component fluid system.

$$M_p = -\frac{\rho_p K k r_p}{\mu_p} \nabla (P_p + \rho_p g Z) \qquad (10)$$

Where, K is absolute permeability(m^2), $kr_p(S_p)$ is the relative permeability (-) expressed by a non-linear function of saturation rate, μ_p is the viscosity coefficient (Pa・s), P_p is the fluid pressure (Pa), g is the gravitational acceleration (m/s^2), Z is the control elevation (m). Among the fluid pressures of each phase, Pa＝Pw+Pc(Sw) holds. Pc(Sw) describes capillary pressure (Pa) which is the function of water saturation rate. Mass flux at the surface and subsurface boundary where fluid gets out and in is evaluated by two-phase fluid curve called "quasi-capillary pressure and quasi-relative permeability". This two-phase fluid curve is an extended parameter to express the difference of the potential between free surface space and underground space in an equal manner as handled in underground medium by giving unsaturated property (relative permeability, capillary pressure). It is to analyze fluid flow between surface and subsurface space continuously, including spring, rain permeation, intrusion or outflow of the gas, with a unified description.

5.3.2 Model Setting (GETFLOWS)

Model setting in GETFLOWS is carried out in the same manner as in MIKE-SHE as shown in Table5.3.1. Even the same manner, mesh shape in GETFLOWS is different from that in MIKE-SHE. Thus the models are not completely the same. Different model setting compared to MIKE-SHE is shown inTable5.3.2. Detailed description is described later in this section.

Table5.3.1 Summary of Model Settings (GETFLOWS)

*○ represents the same settings as MIKE-SHE

Classification	Item	Description	Comparison with MIKE-SHE*
Modeled Area		Surface water basin boundary: Boundary of the Lake Urmia Basin provided by WRMC Groundwater basin boundary: Ditto	○
Mesh size		2-km-mesh was employed in much the same manner as in MIKE-SHE, but not orthogonal.	
Calculation period		5 years (1999 – 2003), considering required calculation time	
Meteorological condition	Lake surface evaporation	Based on the calibration result of MIKE-SHE, 67% of pan evaporation was referred. The values were modified in the calibration process.	○
	Land evapotranspiration	Since the potential evapotranspiration is to be applied in the model, the potential evapotranspiration by Hamon equation was applied.	○
	Precipitation	Same precipitation as in MIKE-SHE was applied.	○
Geological condition	Subsurface geological structure	Geological conditions greatly influence the runoff characteristics in GETFLOWS. Thus, the geological structure was modeled based on the combination of 4 classifications (Surface, Weathered, Deep Weathered, and foundation), and 6 geological eras (Quaternary, Tertiary, Mesozoic, Paleozoic, Pre-Cambrian, Igneous Rocks, and Mélange).	○
	Parameters of the layer (permeability coefficient, etc.)	In reference to the guidelines (draft) published by the Ministry of Land, Infrastructure, Transport and Tourism, Japan, the values corresponding to actual geological parameters were applied. The parameters were to be adjusted during the model establishment process.	
Topography	Ground surface elevation	2-km-mesh of ground elevation data was prepared based on the 90m-DEM provided by WRMC as used in MIKE-SHE.	○
	Lake bed elevation	Meshed lake bed elevation data was created based on the DEM data obtained from bathymetry survey result of Lake Urmia as used in MIKE-SHE.	○
Land use	Surface roughness	Based on the land use data provided by WRMC as used in MIKE-SHE, roughness coefficient in each land use (from 0.06 to 0.05) was placed into the grid, in reference to the manual for flood simulation published by the Public Work Research Institute.	○
Natural conditions	River network	Main river channel in each basin was modeled as in MIKE-SHE. Rectangle-shaped cross sections on the channels were prepared with elevations of river beds referred to the elevation of the 90m-DEM. Cross sections were to be adjusted, where necessary, checking the calculated surface water flow. (Resolution of pans where water retention occurs)	○
Water use structure	Dam	Dams labeled "In Operation" (40 dams) were modeled as in MIKE-SHE. Dam lakes were modeled by lowering elevation grid (dam weir were not modeled). The discharge was placed into the modeled river channel.	○
Ground water	Initial condition	Saturated condition, in which underground medium is filled with groundwater to the ground level, was created. Then meteorological data from 1992 to 1998 (precipitation, lake surface evaporation, and land evapotranspiration) were placed into the model. The calculation results when the fluctuation of the lake water level became sufficiently small were applied for the initial condition.	
Water use	River water intake	River water intake is modeled in a same manner as in MIKE-SHE.	○
	Groundwater intake	Ground water intake is modeled in a same manner as in MIKE-SHE.	○

Table5.3.2 Comparison of Model Settings between MIKE-SHE and GETFLOWS

Classification	Item	MIKE-SHE	GETFLOWS
Mesh size		2-km-mesh was employed, considering required resolution for modeling topographic and land use conditions, and calculation time.	2-km-mesh was employed in much the same manner as in MIKE-SHE, but not orthogonal.
Calculation period		9 years (1999 – 2007)	5 years (1999 – 2003)
Meteorological condition	Lake surface evaporation	Lake surface evaporation was estimated based on daily pan evaporation (10 gauging stations) observed by IMO with Thiessen method. 60% of the observed pan evaporation was applied for initial condition and then calibrated, based on the research outcome of Tarbiat Modares University of Iran.	Based on the calibration result of MIKE-SHE, 67% of pan evaporation was referred. The values were modified in the calibration process.
	Land evapotranspiration	Evapotranspiration was estimated based on the daily pan evaporation and water balance in dam catchment area. The values were also calibrated in the process of model establishment in reference to the ratio to pan evaporation.	Since the potential evapotranspiration is to be applied in the model, the potential evapotranspiration by Hamon equation was applied.
Geological condition	Subsurface geological structure	Based on the results of analysis, layers with geological features such as Quaternary layer, Tertiary, Mesozoic, Paleozoic, Precambrian, igneous rocks, and mélange were considered. The parameters corresponding to these types of geology were given in each prepared mesh.	Geological conditions greatly influence the runoff characteristics in GETFLOWS. Thus, the geological structure was modeled based on the combination of 4 classifications (Surface, Weathered, Deep Weathered, and Foundation), and 6 geological eras (Quaternary, Tertiary, Mesozoic, Paleozoic, Pre-Cambrian, Igneous Rocks, and Mélange).
	Parameters of the layer (permeability coefficient, etc.)	In reference to the guidelines (draft) published by the Ministry of Land, Infrastructure, Transport and Tourism, Japan, the values corresponding to actual geological parameters were applied.	In reference to the guidelines (draft) published by the Ministry of Land, Infrastructure, Transport and Tourism, Japan, the values corresponding to actual geological parameters were applied. The parameters were to be adjusted during the model establishment process.
Ground water	Initial condition	Meteorological data from 1993 to 1999 (precipitation, lake surface evaporation, and land evapotranspiration) were placed into the model. The calculation results by MIKE SHE when the lake water levels at some points had high similarities with the observed data in 1999 were applied for the initial condition.	Saturated condition, in which underground medium is filled with groundwater to the ground level, was created. Then meteorological data from 1992 to 1998 (precipitation, lake surface evaporation, and land evapotranspiration) were placed into the model. The calculation results when the fluctuation of the lake water level became sufficiently small were applied for the initial condition.

(1) Calculation Mesh

Mesh size in GETFLOWS is basically 2-km, as it is the reference model to MIKE-SHE model. Since the mesh does not necessarily have to be orthogonal in GETFLOWS, and can be set in a flexible way, it is set non-orthogonal. If the mesh shape is too twisted, or mesh size differs greatly, the calculation will take a long time to get conversion. Therefore, the mesh is set close to orthogonal as much as possible.

The calculation mesh is shown in Figure 5.3.4 and Figure 5.3.5.

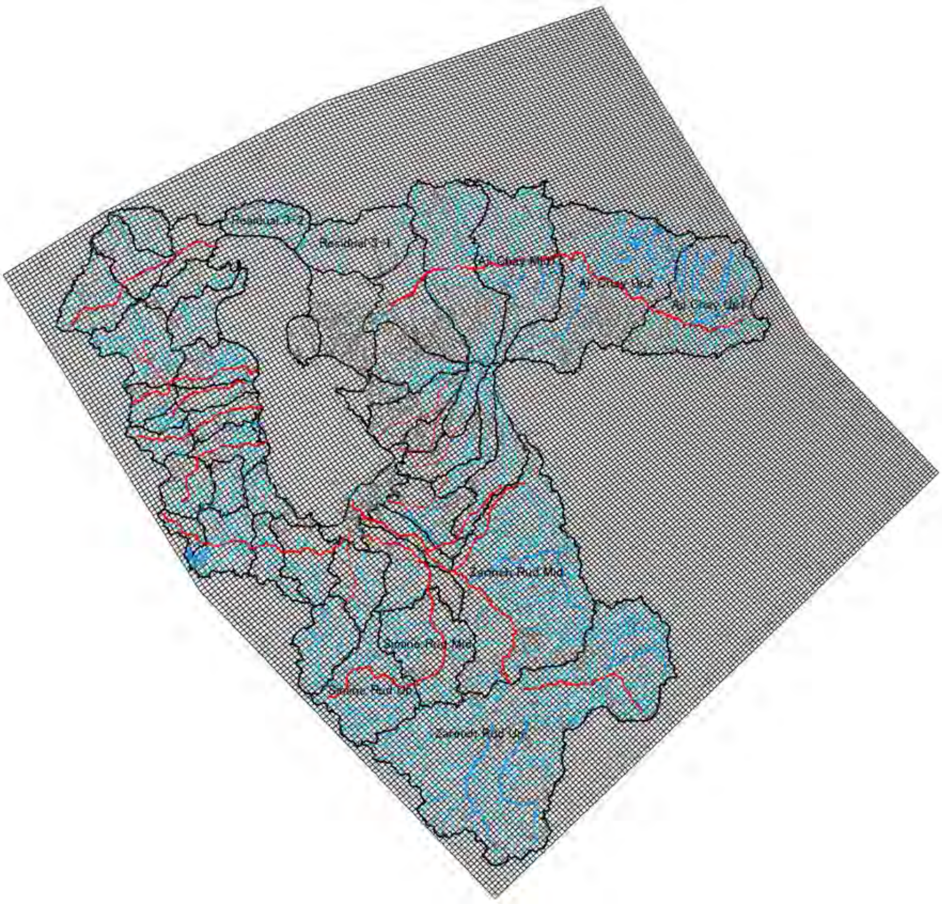


Figure 5.3.4 Calculation Mesh (GETFLOWS)

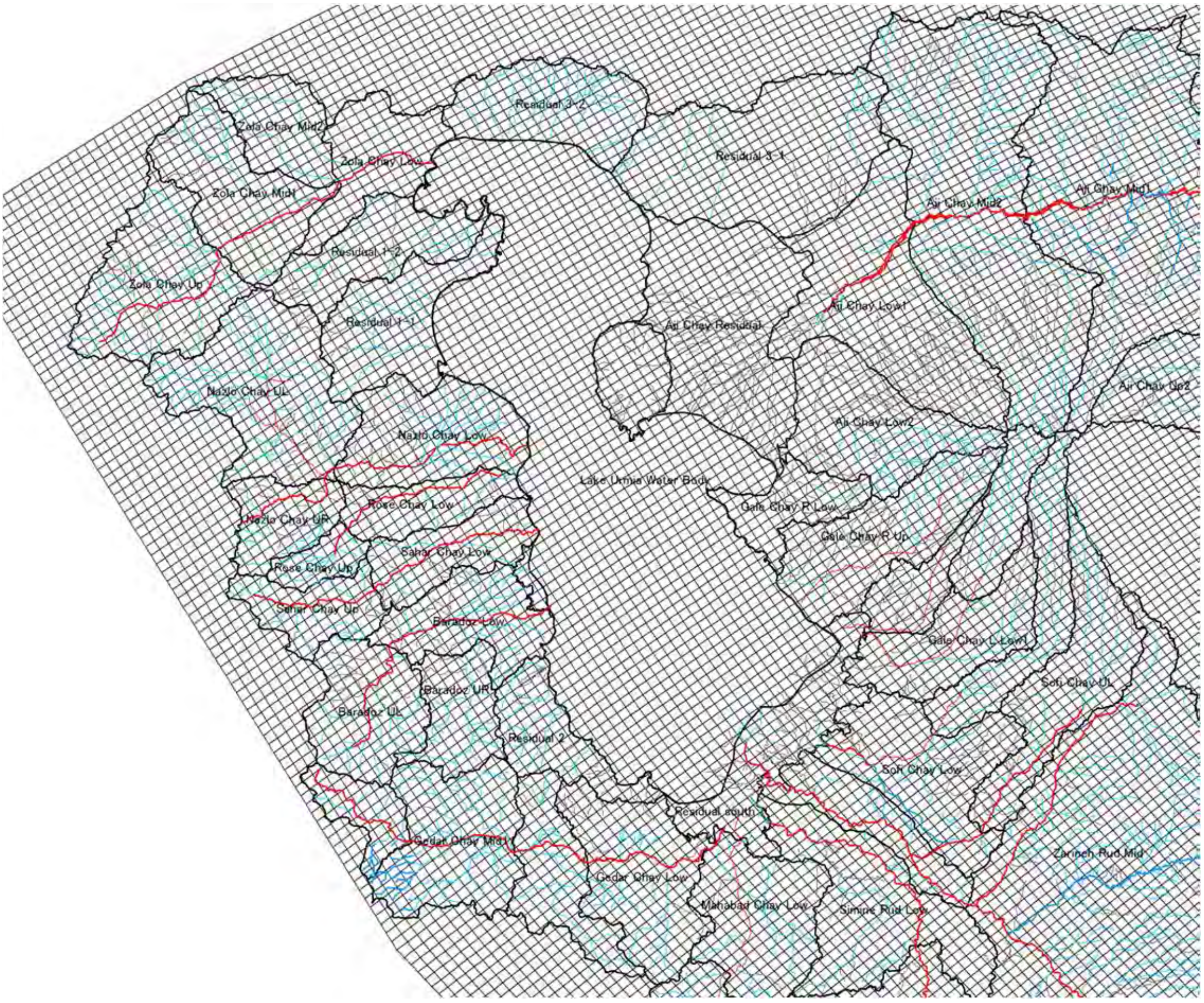


Figure 5.3.5 Enlarged Illustration of the Calculation Mesh (GETFLOWS)

(2) Verification Period and Validity Ensuring Period

In reference to the MIKE-SHE model, calibration period is to be selected among 9 years from 1999 to 2007 based on the reliability of the lake water level data as the input for the verification. In case of fully-coupled surface and subsurface analysis in GETFLOWS, 3-dimentional analysis is carried out where calculation time is dependent on the surface flow with faster velocity. On the other hand, in MIKE-SHE, surface and subsurface flow is calculated independently, with boundary conditions passed to each other. The calculation load is relatively light since the surface calculation is 2-dimentional, and the subsurface flow is calculated in a different time steps. Thus the calculation is likely to be faster in MIKE-SHE than in GETFLOWS.

Considering above conditions, the verification period in GETFLOWS is determined to be 5 years from 1999 to 2003. Another 4 years from 2004 to 2007 is selected as the period to ensure validity.

(3) Meteorological Condition

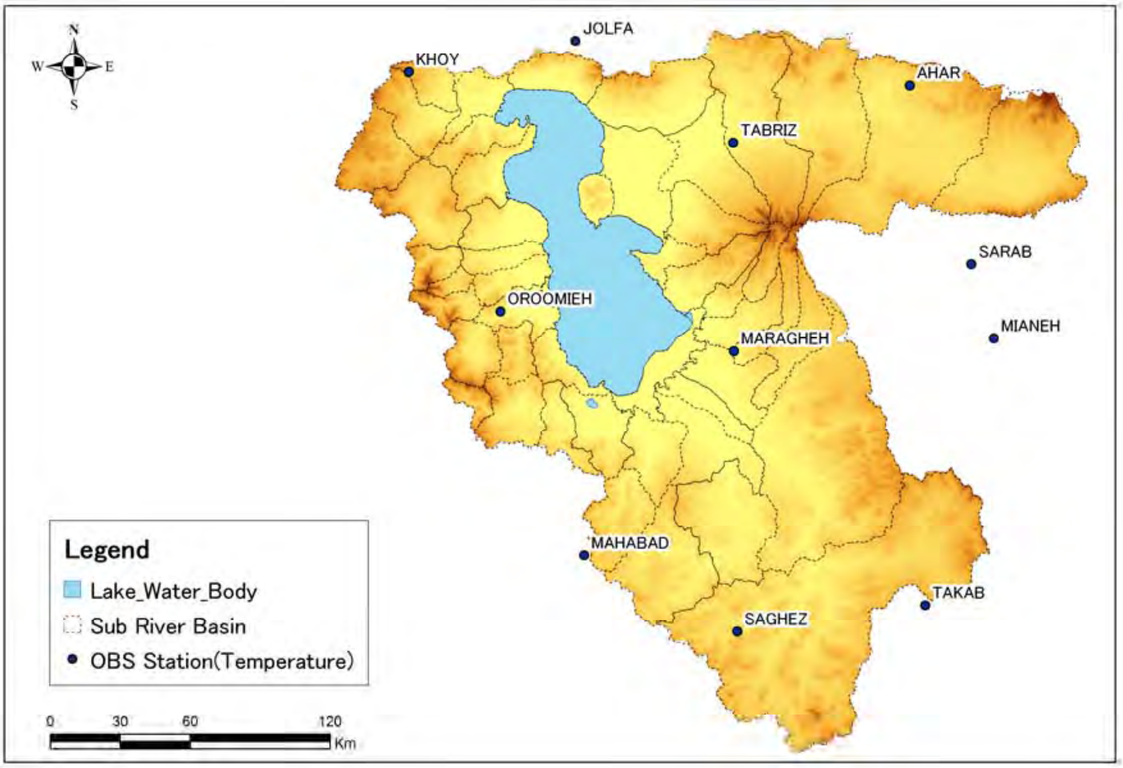
(a) Lake Surface Evaporation

Based on the calibration result of MIKE-SHE, 67% of pan evaporation was referred. The values were modified in the calibration process.

(b) Evapotranspiration

Since the potential evapotranspiration is to be applied in the GETFLOWS model, the potential evapotranspiration by Hamon equation was applied. With Hamon equation, potential evapotranspiration can be calculated from temperature. To utilize limited data effectively, Hamon equation was employed.

Land evapotranspiration applied to the model were calculated from daily average temperature at 11 observation stations obtained from IMO (Fig.5.1.8 and Table5.1.5). The input data was calculated by the Thiessen method.



Note: Prepared by JICA Survey Team based on the data provided by IMO

Figure 5.3.6 Location of Temperature Gauging Stations

Table5.3.3 Potential Evapotranspiration

Observation Station	Annual Potential Evapotranspiration in 2007 (mm)
AHAR	659.7
JOLFA	918.5
KHOY	780.6
MAHABAD	776.3
MARAGHEH	807.6
MIANEH	843.0
OROOMIEH	718.2
SAGHEZ	698.4
SARAB	591.0
TABRIZ	811.1
TAKAB	660.2

*Prepared by JICA Survey Team based on the data provided by IMO
*The year of 2007 had average precipitation trend

(4) Geological Conditions

Geological conditions greatly influence the runoff characteristics in GETFLOWS. Thus, the geological structure was modeled based on the combination of 4 vertical classifications (Surface, Weathered, Deep Weathered, and foundation), and 6 geological eras of surface layer (Quaternary, Tertiary, Mesozoic, Paleozoic, Pre-Cambrian, Igneous Rocks, and Mélange). Each classification is given with different parameters including permeability coefficient. Since vertical distribution of geological structure data was not obtained, surface layer is defined as 1m from the ground level, the foundation of weathered and deep-weathered are derived based on the ground surface slope with GIS geographical analysis. In GETFLOWS, permeability coefficient is treated as a parameter not only in subsurface but also surface layers, which is different from MIKE-SHE.

Initial setting of parameters are the same as described in 5.2.3(5). Geological condition prepared for GETFLOWS is shown in Figure 5.3.5.

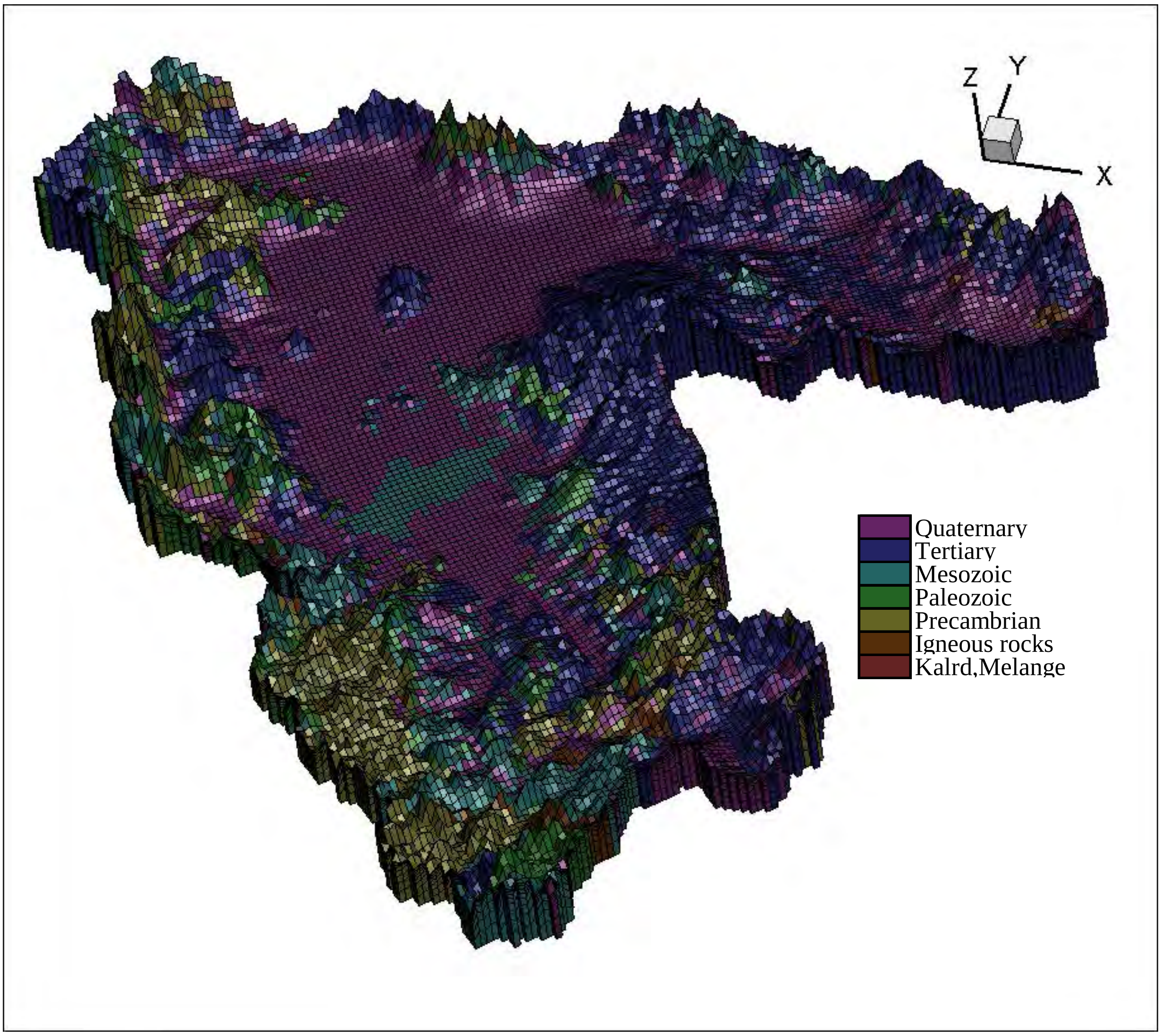


Figure 5.3.7 Geological Condition

(5) Topographic Condition

Topographic Condition is also created in the same manner as MIKE-SHE. Ground surface elevation data of 2 km-mesh was prepared from the 90m-DEM data. The lake bed elevation data was prepared from DEM data established from bathymetry survey results of Lake Urmia. Created topographic elevation is shown in Figure 5.3.8.

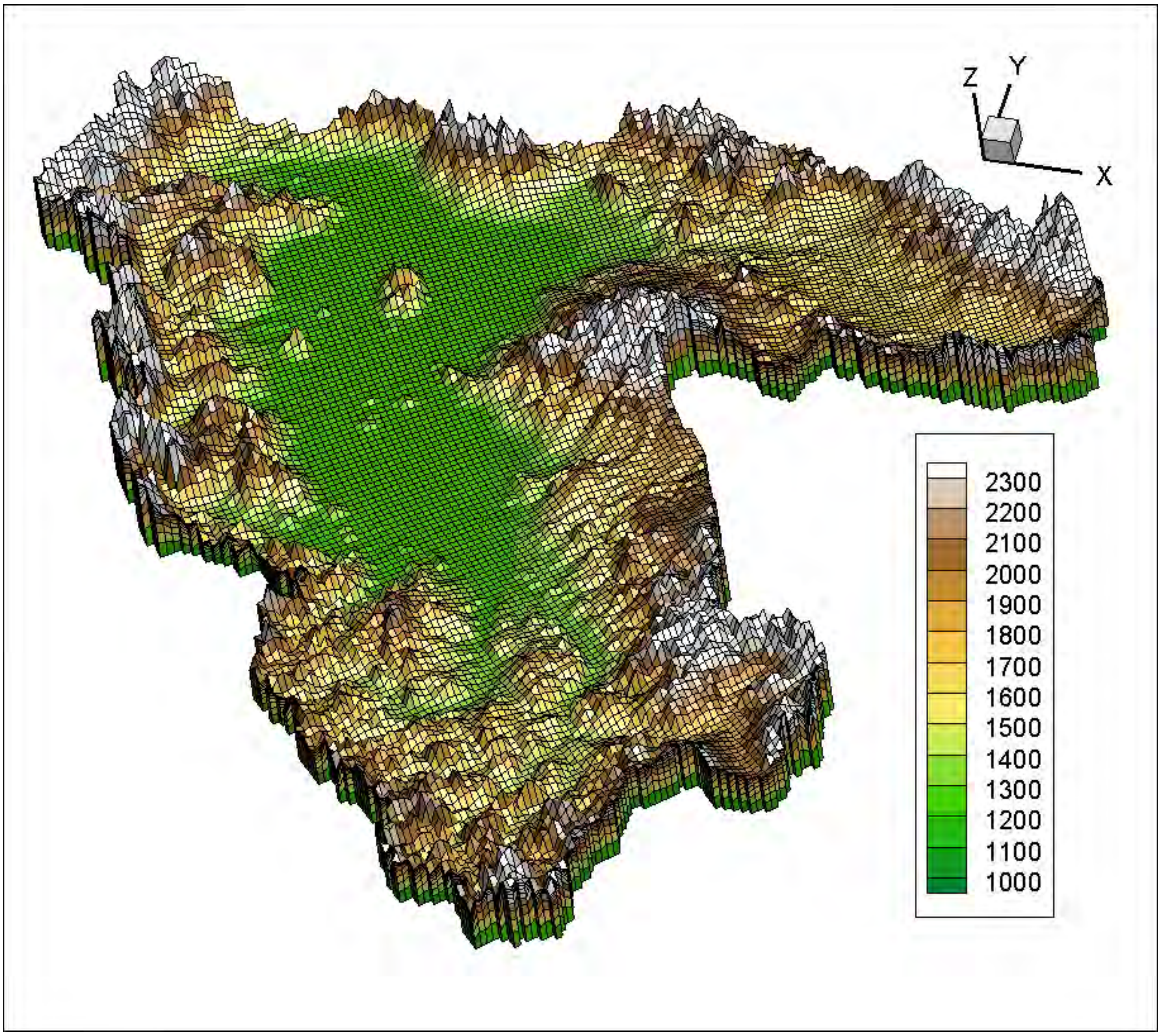


Figure 5.3.8 Topographic Elevation

(6) Setting of Initial Condition

To create the initial condition of subsurface water in GETFLOWS, a calculation was carried out to create initial settings as shown in Figure 5.3.9. Since the initial year of the calibration was set in 1999 in this study, the lake water level of 1999 was given as the initial lake water level. Then, the initial condition to fit the situation was created.

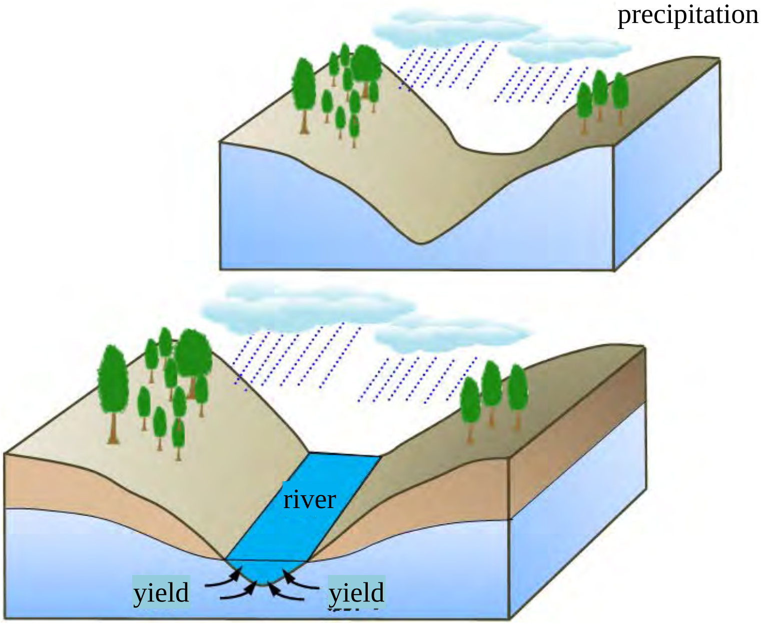
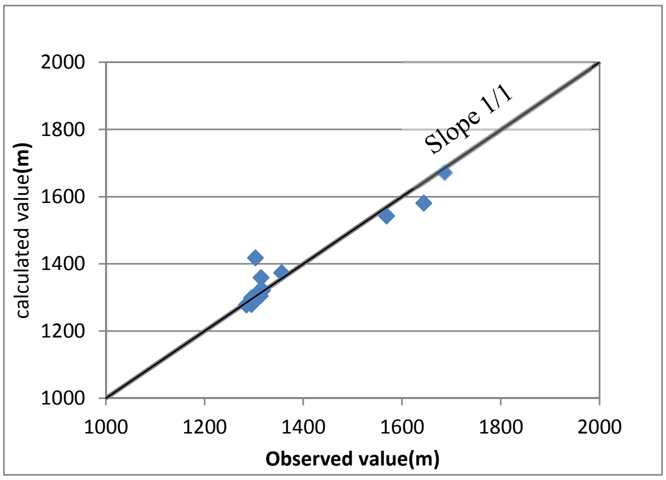


Figure 5.3.9 Diagram of Creating the Initial Conditions

i) Completely saturated condition is created with underground medium filled up with water to the ground surface, assuming no water exists on the surface layer.
ii) Starting from above condition, the basin-averaged precipitation is continuously given. Unsteady flow analysis of 2-phase flow of water and gas through geological substance is carried out.
iii) During the analysis, springs emerge in the lowland and eventually form rivers. At the same time, subsurface water level lowers and accordingly unsaturated layer develops since gas intrudes to subsurface layer at high elevated locations.
iv) Finally, the condition of groundwater and river with fully balanced surface and subsurface water is created, which go with given precipitation, topographic condition, and geographic structure.

Observed and calculated groundwater level at 12 locations in the above condition is shown inFigure 5.3.10. The calculation was finalized with a stable groundwater level, after a period of 8,000 years' calculation. Since the calculated and observed values show similarity, the initial condition obtained through the calculation is considered to express almost the actual conditions.



Note: Prepared by JICA Survey Team based on the data provided by WRMC

Figure 5.3.10 Comparison of Calculated and Observed Groundwater Level

5.3.3 Analysis (Calibration) of the Parameters

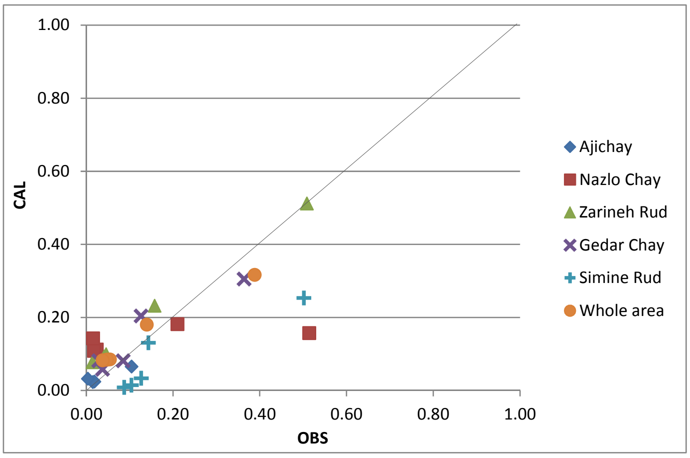
Since GETFLOWS is a program to model physical phenomenon, the parameters to express runoff are limited. The parameters in GETFLOWS are the "permeability coefficient" and the "porosity". For other parameters including lake surface evaporation and land evapotranspiration, the values are set referring to the values set in the MIKE-SHE study, although the actual values are not clarified.

Calibration points are set as the same points in the MIKE-SHE study.

(1) Calibration Result of Parameters

In the GETFLOWS study, the objective is to make clear the hydrological mechanism accompanying the lowering of the lake water level. Thus, as in MIKE-SHE, the runoff rate of river flow and lake water level is selected as the calibration items.

As the calibration result of river flow, the comparison of observed and calculated runoff rate is shown in Figure 5.3.11. In the years 1999 to 2001 under drought condition, the accuracy of the calculated values varies from basin to basin. In 2002 and 2003, the period after the drought, the calculated runoff rates are higher than the observed values in 2002, and there was a tendency that the calculated runoff rates are lower than the observed values in 2003. In spite of the possibility of release of discharge by dams, the study shows that the Model mostly ensure reproducing river discharges since the result shows the similar tendency as MIKE-SHE.



Source: JICA Survey Team

Figure 5.3.11 Calibration Result (runoff rate of river flow)

Table5.3.4 Calibration Result (runoff rate of river flow)

Runoff rate / year	Ajichay		NazloChay		ZarinehRud		GedarChay		SimineRud		Whole area	
	OBS	CAL	OBS	CAL	OBS	CAL	OBS	CAL	OBS	CAL	OBS	CAL
1999	0.02	0.02	0.02	0.11	0.05	0.10	0.09	0.08	0.09	0.01	0.05	0.08
2000	0.02	0.02	0.02	0.11	0.04	0.09	0.03	0.08	0.13	0.03	0.05	0.08
2001	0.00	0.03	0.02	0.14	0.02	0.08	0.04	0.06	0.10	0.01	0.04	0.08
2002	0.04	0.08	0.21	0.18	0.16	0.23	0.13	0.20	0.14	0.13	0.14	0.18
2003	0.11	0.07	0.51	0.16	0.51	0.51	0.36	0.30	0.50	0.25	0.39	0.32

Surce: JICA Survey Team

Note:OBS:observed values, CAL:calculated values with the model

After ensuring the accuracy of river discharges, the accuracy of lake water level is ensured. Comparison of the observed and calculated lake water level is shown in Figure 5.3.12. Figure 5.3.12 shows higher lake water levels in the calculated values than the observed ones after 1999. It is considered because of the lack of the model input data or the impact of the salt water in Urmia Lake. The challenges for these reasons are described below.

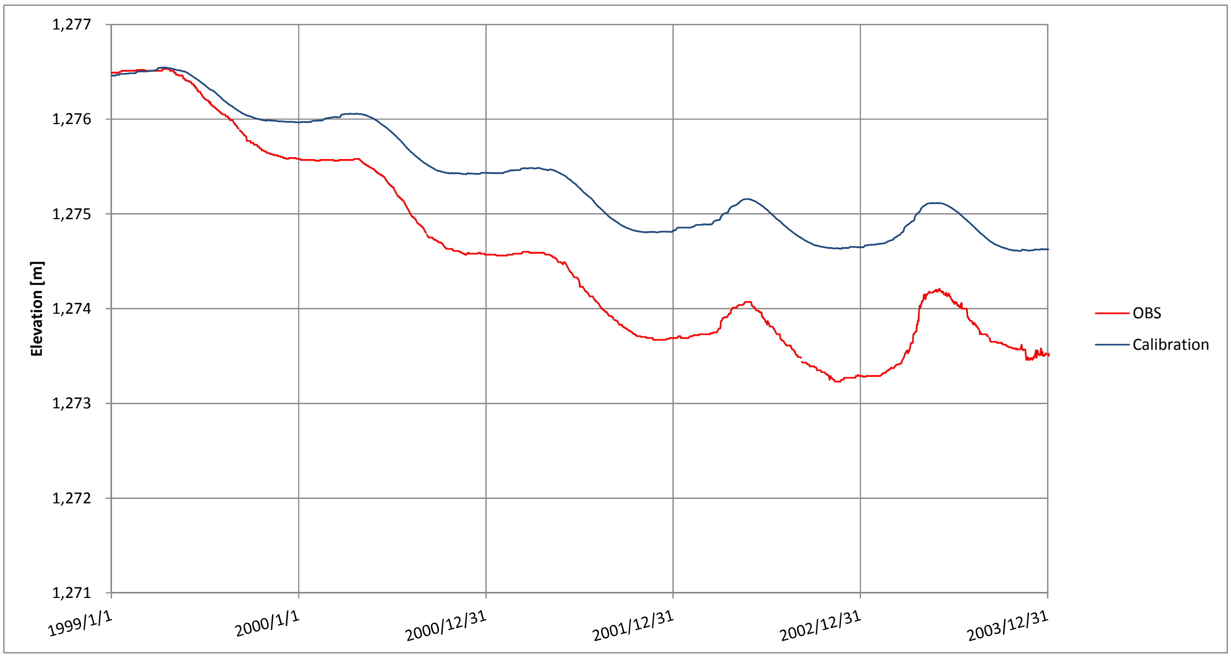
[Lack of the model input data]

Geological conditions is set as surface layer, weathered, deep weathered, and the foundation. However, the information on the foundation was not obtained. There is a possibility that the established model does not correspond to the real conditions. It is required to understand the horizontal distribution of the geological conditions, and input that information to the model. Furthermore, meteorological conditions and water use data are also needed to be more dense in timely and spatially manner, which is described in detail afterwards.

[Impact of the salt water]

Although lake water in Urmia Lake is salt water, only the calculation of fresh water is implemented in this study. Because of the difference in the density of the fresh water and salt water, there is a possibility that the actual yield volume from the lake bed is less than the calculated values. Although the permeability coefficient and the porosity of the lake bed is set as relatively small values in this study, some groundwater yields seem to exist in the calculation.

Since the runoff rates in Table5.3.4 shows only slight difference between the observed and calculated values, the groundwater yield volume is considered to be the cause of the relatively high lake water level.



*JICA Survey Team

Figure 5.3.12 Calibration Result (lake water level)

In MIKE-SHE, above two challenges are addressed by Drainage and the permeability coefficient of the geology. Drainage, as previously described, Drainage module is set in the model as an underground pipe that drains water permeating from the ground surface and eventually discharge to rivers. Thus the runoff phenomenon is expressed in the model. Furthermore, by setting relatively low values to the permeability coefficient of geology, the intrusion volume from shallow underground as well as yield volume from subsurface to lake bed are restrained. By restraining intrusion volume to underground, subsurface water discharges to rivers and lakes through Drainage.

In GETFLOWS, subsurface runoff is also expressed by permeability and porosity, the timely and spatially distribution of model input have a great influence to the accuracy of the calculation result.

The final settings of parameters in this study are shown in Table5.3.5. The final value for lake surface evaporation is set as 75% of pan evaporation.

Table5.3.5 Final Settings of Parameters in this Study

	Horizontal permeability coefficient (m/s)	Vertical permeability coefficient (m/s)	Porosity
Surface Layer	2.0E-04	2.0E-04	0.3
Quaternary (Weathered)	1.0E-04	1.0E-04	0.2
Tertiary (Weathered)	1.0E-04	1.0E-04	0.2
Mesozoic (Weathered)	5.0E-06	5.0E-06	0.2
Paleozoic (Weathered)	5.0E-06	5.0E-06	0.2
Precambrian (Weathered)	5.0E-05	5.0E-05	0.2
Igneous rocks (Weathered)	1.0E-04	1.0E-04	0.2
Mélange (Weathered)	1.0E-04	1.0E-04	0.2
Tertiary (Deep Weathered)	5.0E-05	5.0E-05	0.2
Mesozoic (Deep Weathered)	1.0E-06	1.0E-06	0.2
Paleozoic (Deep Weathered)	1.0E-06	1.0E-06	0.2
Precambrian (Deep Weathered)	1.0E-06	1.0E-06	0.2
Igneous rocks (Deep Weathered)	5.0E-05	5.0E-05	0.2
Mélange (Deep Weathered)	5.0E-05	5.0E-05	0.2
Quaternary	7.5E-08	7.5E-08	0.2
Tertiary	1.5E-08	1.5E-08	0.2
Mesozoic	1.0E-08	1.0E-08	0.2
Paleozoic	1.0E-08	1.0E-08	0.2
Precambrian	1.0E-08	1.0E-08	0.2
Igneous rocks	2.0E-07	2.0E-07	0.2
Mélange	1.0E-07	1.0E-07	0.2
River bed	2.0E-05	2.0E-05	0.2
Lake bed	3.0E-07	2.0E-07	0.05

(2) Required Data to improve model accuracy

To improve model accuracy with GETFLOWS and better understand the factor of lowering lake water level in Urmia Lake, it is found in this study that data improvement as shown in Table5.3.6 is required. Since there is several information that are unclear, as shown in Table5.3.6, the main data item that impacts model accuracy cannot be described with clear evidence. At least, data including estimated water use input values (water uptake location, and its volume) seems to have some impact on the model accuracy. Furthermore, unlike other basins, Urmia Lake is a closed basin. Thus, challenges about the water balance when calibrating the model should be easier to be found than in other basins. The existence of unclear information is considered to be the cause of the difficulty of finding the factors.

Table5.3.6 Data Required to Improve Model Accuracy

Data Item	Description	Application to the Model
Precipitation	Spatially denser distribution of precipitation data. Since river runoff rate exceeds 1.0 at several gauzing stations, and spatially distribution of precipitation may not be well captured, thus denser data is required. Detailed check of the observation data is also needed.	Model input to be prepared with denser and more precise precipitation data. It is the most important data to determin the accuracy.
Geology (Soil)	Soil thickness as surface soil layer, soil component (clay, sand, gravel, etc.)	Soil thickness to be modeled as surface layer. Thus, permeability coefficient and porosity can be set according to the soil components (clay, sand, gravel, etc.) Furthermore, unsaturated characteristics (negative pressure etc.) can also be considered, which will be an indicator for calibration and result in model accuracy improvement.
Vertical distribution of the geology	Spatial distribution (horizontal) of the surface geology data was obtained. As for vertical distribution, denser boring data is required. Especially, Quaternary geology is widely distributed in Lake Urmia Basin, where there is a possibility that various layers including aquifer (gravel layer) and aquiclude (clay layer) lay complexly on each other. Thus it is important to understand the vertical distribution of these layers. If the vertical distribution is unclear and the model expresses the condition far from the reality, the subsurface flow, ground water level would also be far from the actual condition. Furthermore, it will result in the change of surface and subsurface runoff forms (too early runoff, too much or too little river flow, etc.). Thus it will be difficult to ensure the required accuracy.	If vertical geological distribution can be created from the obtained boring data, 3-dimentional (3D) hydrological geology model can be established, which will result in model accuracy improvement.
Salinity concentratio n	In the future, it is necessary to input saline density to the model in order to understand the groundwater behavior which will be changed as the density becomes higher.	Surface and subsurface salinity concentration to be observed. After ensuring the reproducibility of the model, interaction of salt water between surface and subsurface layer according to the rainy/dry seasons and the lake water level of Urmia Lake is to be reflected in the model.
Water use data	Water intake amount and locations are necessary to make a precise model. Water intake volume was input according to the estimation. Since water intake location was unclear as well, that data needs to be improved reflecting the actual conditions considering illegal water intake.	Input data to be created based on the data close to actual conditions, and inputted to the model.

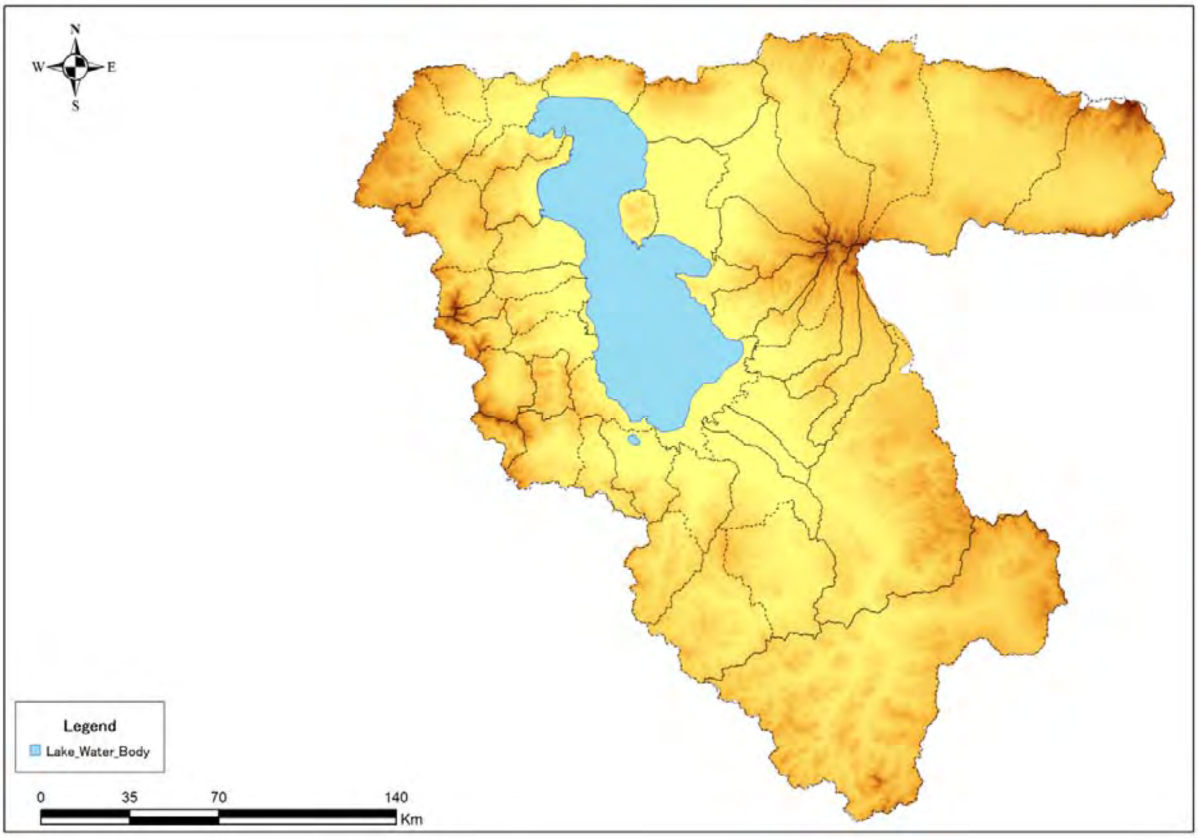
(3) Model Accuracy of GETFLOWS

As described previously, there is not a large difference between the observed and calculated river runoff in GETFLOWS. As runoff phenomenon, it is considered there is not a great difference in model accuracy between MIKE-SHE and GETFLOWS. On the other hand, calculated the lake water level is higher than the observed values in GETFLOWS, thus it is difficult to ensure expected accuracy. The contributing factor for this is considered to be the impact of water use data and salt water. To express the hydrological cycle in the basin more accurately, above data needs to be enhanced.

5.3.4 Hydrological System in Lake Urmia Basin by GETFLOWS

The hydrological system in Lake Urmia Basin is determined with the calibration result. Water balance, water flow line network, and flow velocity vector are evaluated to consider hydrological system. In addition to water balance in the Lake, water balance in each sub-basin is evaluated as the water balance in GETFLOWS.

For the evaluation of inflow and outflow of the lake by GETFLOWS, the boundary of the lake is fixed as shown in the Figure 5.3.13 as in the MIKE-SHE.



Note:Prepared by JICA Survey Team based on the data provided by WRMC

Figure 5.3.13 Boundary of the Lake Used in the Evaluation

(1) Water Balance

To consider the hydrological system in Lake Urmia Basin, the water balance during the calibration period was evaluated. Water balance of the lake is shown in Table5.3.7 and Table5.3.8. Since there exists a difference in water balance between regions in the Lake Urmia Basin, water balance in southern, western, and eastern region of the basin was evaluated. This enables to determine which region to focus on the implementation of countermeasures to restore lake water level. Among the Lake Urmia Basin, Simine Rud Basin representing the southern region, Gedar Chay Basin representing the western region, and Aji Chay Basin representing the eastern region are as shown in the tables below.

Table5.3.7 Water Balance in the Lake (Surface)

Item / Year	① Precipitation (MCM)	② Yield (MCM)	③ Inflow (MCM)	④ Evaporation (MCM)	⑤ Recharge (MCM)	Water balance (MCM) ①+②+③-④−⑤
1999	1358.5	12.1	1119.7	4731.7	8.2	-2249.6
2000	1474.3	12.0	1320.7	5167.1	11.3	-2371.5
2001	1239.0	12.9	1154.6	5054.7	11.2	-2659.4
2002	1688.4	14.2	2894.7	5158.5	24.8	-586.0
2003	1781.1	14.2	4275.4	5861.0	25.7	183.9

Source: JICA Survey Team

Table5.3.8 Water Balance in the Lake (Subsurface)

Item / Year	① Recharge (MCM)	② Inflow (MCM)	③ Evaporation (MCM)	④ Yield (MCM)	Water balance (MCM) ①+②−③-④
1999	8.2	19.6	15.6	12.1	0.1
2000	11.3	19.3	18.9	12.0	-0.3
2001	11.2	18.9	20.5	12.9	-3.2
2002	24.8	19.1	31.2	14.2	-1.5
2003	25.7	19.1	28.5	14.2	2.2

Source: JICA Survey Team

Table5.3.9 Water Balance in the Simie Rud (Surface)

Item / Year	① Precipitation (MCM)	② Yield (MCM)	③ Inflow (MCM)	④ Recharge on Farmland (MCM)	⑤ Evaporation (MCM)	⑥ Recharge (MCM)	⑦ River Intake (MCM)	Water balance (MCM) ①+②+③+④−⑤−⑥−⑦
1999	790.7	108.3	57.8	53.4	501.2	558.6	0.0	-49.7
2000	1039.3	114.5	30.9	59.7	529.4	759.8	0.0	-44.7
2001	1014.0	110.7	31.8	70.2	543.8	723.6	0.0	-40.7
2002	1462.3	135.7	-75.7	77.3	635.3	971.1	0.0	-6.7
2003	1575.7	156.1	-142.5	85.8	748.6	919.3	0.0	7.4

Source: JICA Survey Team

Table5.3.10 Water Balance in the Simie Rud (Subsurface)

Item / Year	① Recharge (MCM)	② Inflow (MCM)	③ Evaporation (MCM)	④ Yield (MCM)	⑤ Water uptake (MCM)	Water balance (MCM) ① +②−③-④−⑤
1999	558.6	22.4	548.5	108.3	3.4	-79.1
2000	759.8	20.7	633.8	114.5	4.1	28.1
2001	723.6	18.9	614.7	110.7	4.3	12.8
2002	971.1	19.4	741.0	135.7	6.1	107.6
2003	919.3	21.0	763.2	156.1	6.7	14.2

Source: JICA Survey Team

Table5.3.11 Water Balance in the Gedar Chay (Surface)

Item / Year	① Precipitation (MCM)	② Yield (MCM)	③ Inflow (MCM)	④ Recharge on Farmland (MCM)	⑤ Evaporation (MCM)	⑥ Recharge (MCM)	⑦ River Intake (MCM)	Water balance (MCM) ①+②+③+④−⑤−⑥−⑦
1999	395.0	124.6	-5.6	41.9	176.9	389.3	0.1	-10.5
2000	469.5	114.7	-11.9	48.3	141.7	488.1	0.1	-9.2
2001	426.7	114.0	-13.9	65.0	162.3	440.1	0.0	-10.6
2002	586.7	131.0	-83.2	69.0	198.2	497.6	0.1	7.5
2003	738.8	146.0	-129.2	73.9	220.9	590.4	0.3	17.9

Source: JICA Survey Team

Table5.3.12 Water Balance in the Gedar Chay (Subsurface)

Item / Year	① Recharge (MCM)	② Inflow (MCM)	③ Evaporation (MCM)	④ Yield (MCM)	⑤ Water uptake (MCM)	Water balance (MCM) ①+②−③-④−⑤
1999	389.3	5.0	338.4	124.6	7.7	-76.4
2000	488.1	4.9	355.6	114.7	7.4	15.2
2001	440.1	4.6	344.2	114.0	9.0	-22.5
2002	497.6	4.5	373.3	131.0	9.9	-12.1
2003	590.4	4.9	375.2	146.0	11.1	62.9

Source: JICA Survey Team

Table5.3.13 Water Balance in the Aji Chay (Surface)

Item / Year	① Precipitation (MCM)	② Yield (MCM)	③ Inflow (MCM)	④ Recharge on Farmland (MCM)	⑤ Evaporation (MCM)	⑥ Recharge (MCM)	⑦ River intake (MCM)	Water balance (MCM) ①+②+③+④−⑤−⑥−⑦
1999	1545.3	980.8	105.5	266.7	1122.5	2085.3	33.6	-343.0
2000	1615.7	904.7	49.9	285.9	737.0	2432.6	60.3	-373.7
2001	1334.0	843.8	27.7	303.7	742.1	2068.0	103.3	-404.2
2002	1716.2	869.1	57.4	342.3	652.5	2366.7	192.2	-226.5
2003	1862.0	940.3	143.4	345.4	497.7	2760.0	421.5	-388.2

Source: JICA Survey Team

Table5.3.14 Water Balance in the Aji Chay (Subsurface)

Item / Year	① Recharge (MCM)	② Inflow (MCM)	③ Evaporation (MCM)	④ Yield (MCM)	⑤ Water uptake (MCM)	Water balance (MCM) ①+②−③-④−⑤
1999	2085.3	6.3	1393.6	980.8	218.1	-500.9
2000	2432.6	6.1	1408.4	904.7	221.8	-96.2
2001	2068.0	6.2	1422.9	843.8	245.2	-437.7
2002	2366.7	6.2	1556.9	869.1	245.0	-298.0
2003	2760.0	6.5	1447.9	940.3	252.5	125.8

Source: JICA Survey Team

For the water balance of the Lake, 2003 is the only year with the positive value, which is similar tendency with the result of MIKE-SHE. On the other hand, for the water balance of each sub-basin, the condition is described as below.

- In Simie Rud representing the southern region, surface water balance in 2003 results in positive value, which is the same as the lake water balance. On the other hand, subsurface water balance results in positive values every year except for 1999, which is considered to be the result of large volume of yield which increases in proportion to precipitation.
- In Gedar Chay representing the western region, surface water balance results in positive values. For subsurface water balance, the value results in either positive or negative according to the balance of yield and evaporation.
- In Aji Chay representing the east region, surface water balance results in negative values from 1999 to 2003. It is because, although inflow from other basin or Lake Urmia exists as shown in the positive inflow values, there are large yields, evaporation, and river water intake exist.
- Subsurface water balance in Aji Chay is governed mostly by the yield from surface, thus, it is considered to be dependent on precipitation.

(2) Flow Velocity Vector

To understand the water flow in Lake Urmia Basin and consider the hydrological system in Lake Urmia, vertical cross-sectional diagrams of flow velocity vector were created. Drawing area of the diagram is shown in Figure 5.3.14. The diagrams are created for each season; January, April, July, and October of 1999 to 2003. Since there is not a great difference in the characteristics of the diagrams, that of 1999, the dry year and that of 2003 with positive water balance are as shown below. (Figure 5.3.15 and Figure 5.3.16)

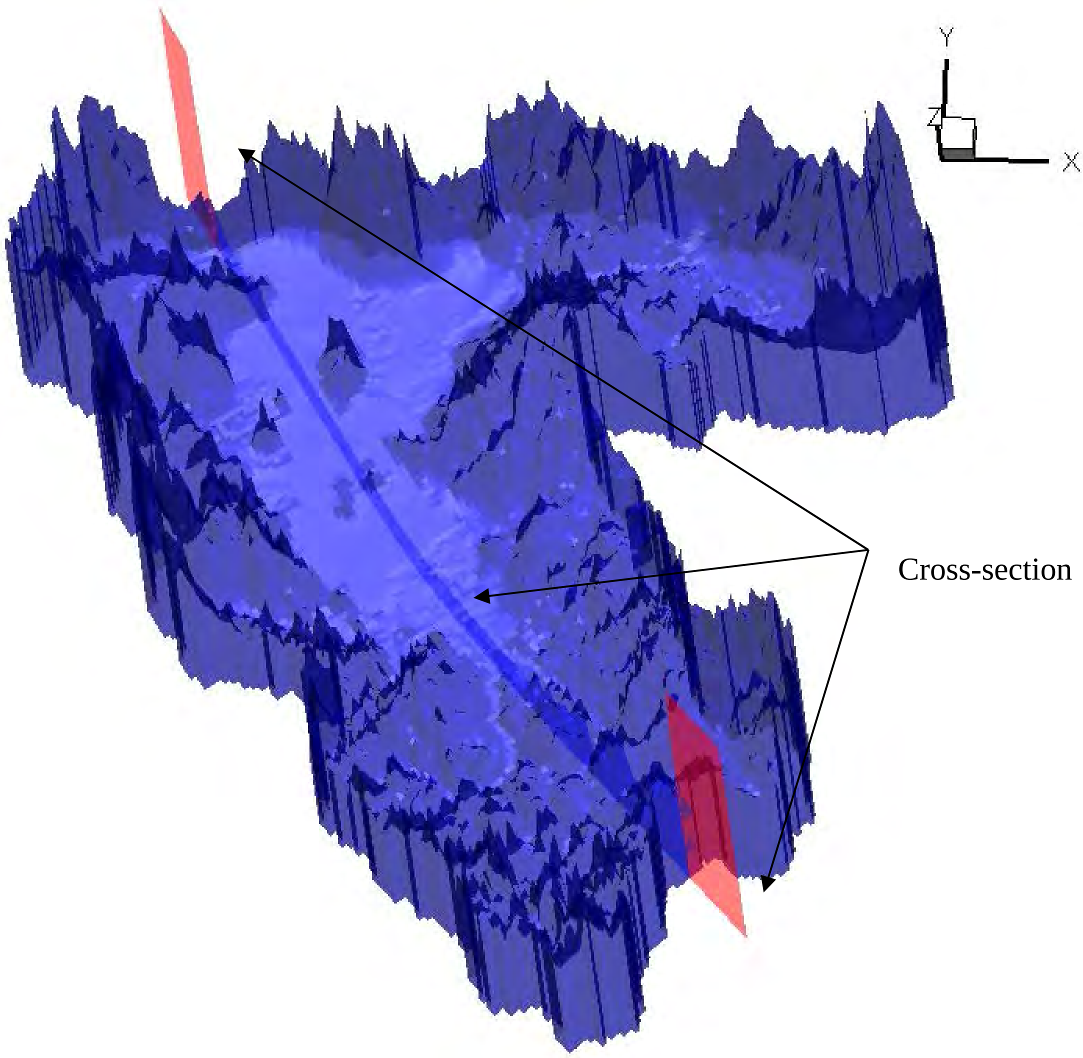


Figure 5.3.14 Drawing Area of Vertical Cross-sectional Diagram

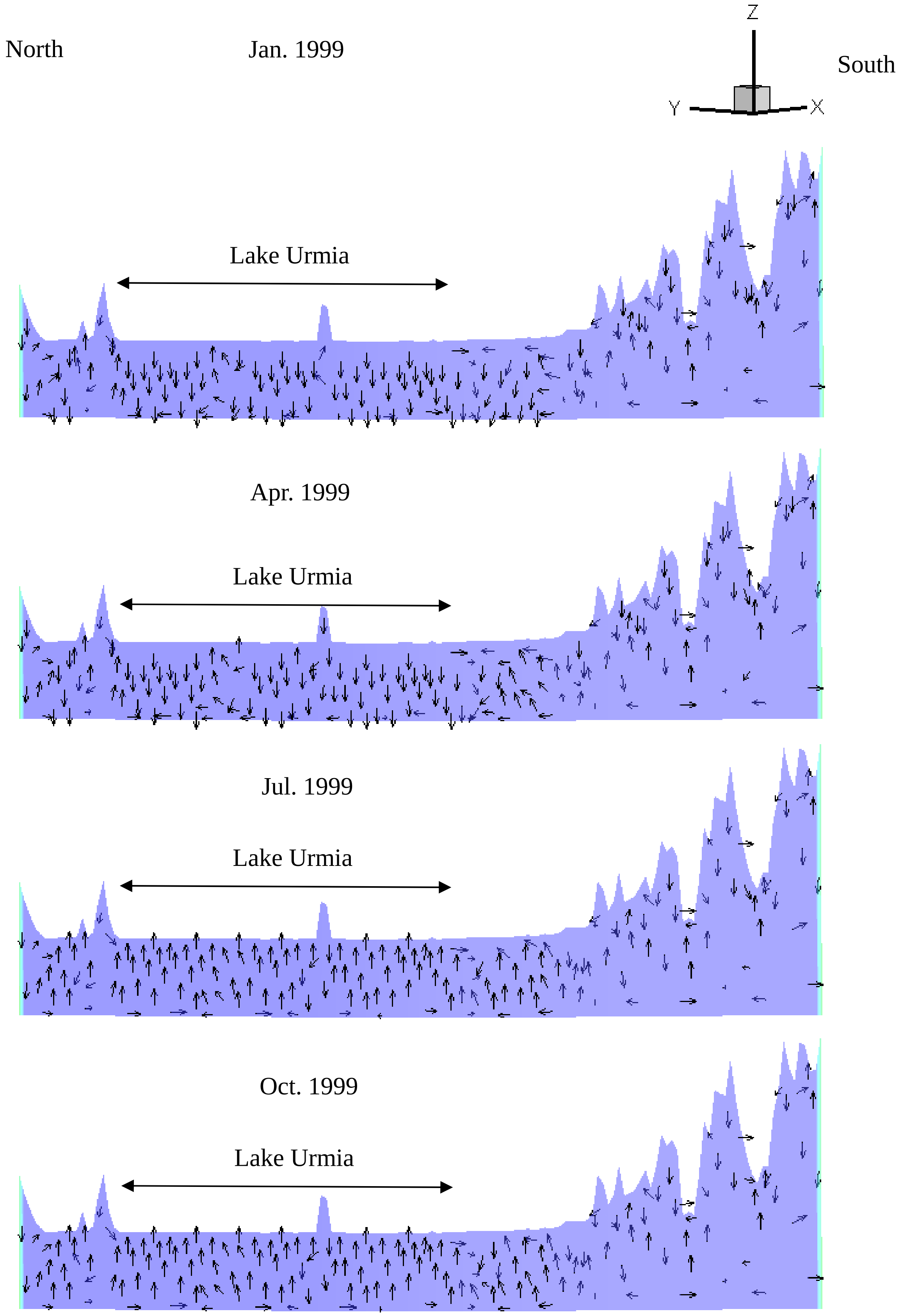


Figure 5.3.15 Diagram of Flow Velocity Vector (1999)

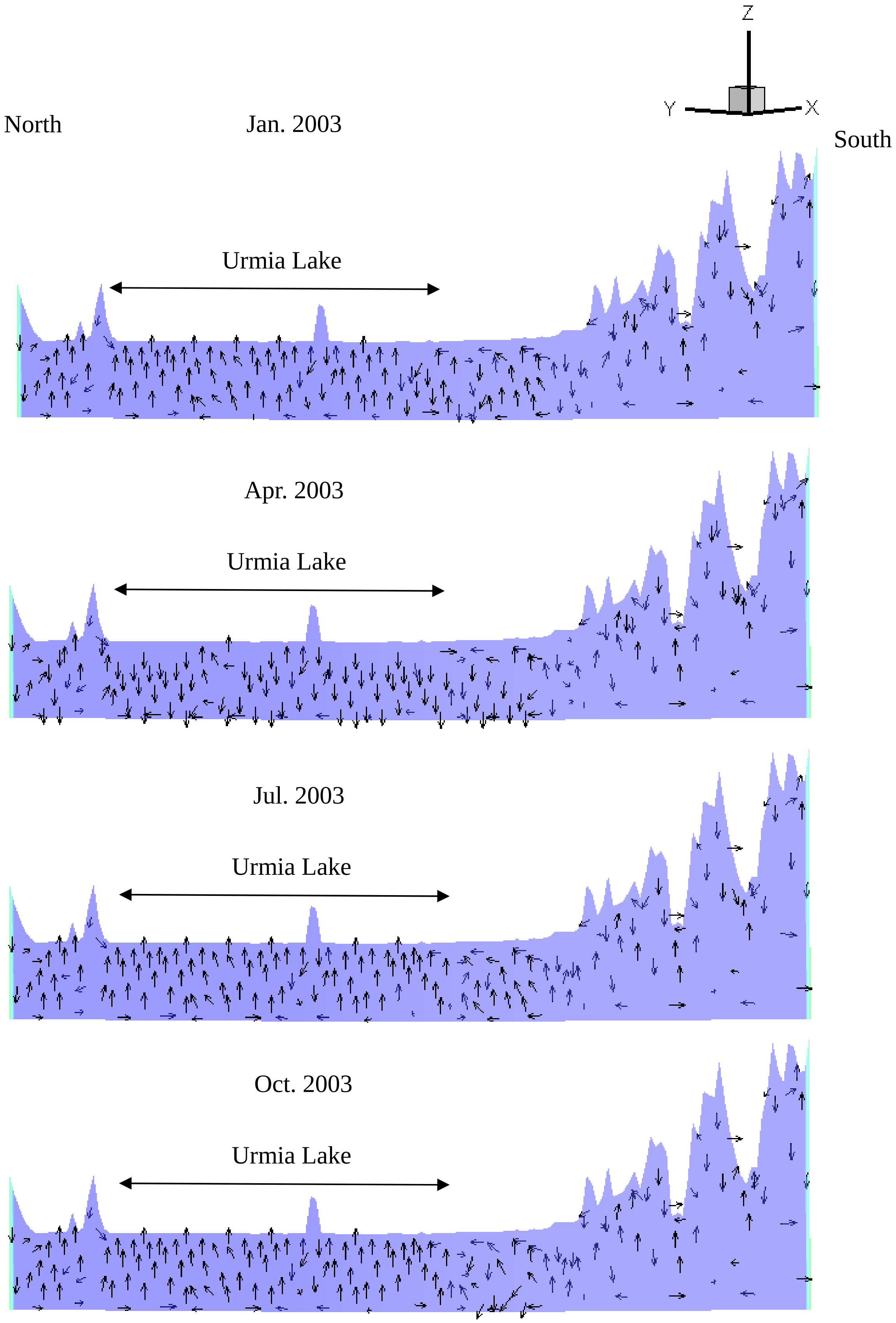


Figure 5.3.16 Diagram of Flow Velocity Vector (2003)

From the cross-sectional diagrams of flow velocity vector, it is determined as below.

- In January and April of 1999 of dry period, vertical downward water flow exist underground, while vertical upward flow exist in July and October. Downwared water flow develops during the seasons with relatively high lake water level. In July and October when lake surface evaporation exceeds and lake water level lowers, it is observed that there exists groundwater inflow from the basin.
- For 2003, the tendency is similar to 1999. As for April of flooding season, since the lake water level increases, there develop a downward water flow, while in July and October with lower lake water level, there develops an upward water flow.
- As for January, the characteristics vary depending on the previous year's precipitation.
- Since the analysis was implemented only for fresh water in this study, it is difficult to confirm if the above described phoenomenon actually exist. But supplemental flow of the groundwater when the lake water level lowers is possibly enough to occur according to the balance of lake water level and the ground water level of the basin.

(3) Hydrological System in Lake Urmia Basin by GETFLOWS

From the results of the study of Lake Urmia Basin with GETFLOWS as described above, the hydrological system in Lake Urmia Basin is briefly described, as below:

- In the west of Lake Urmia, the hydrological cycle is greatly influenced by natural factors. The water balance vary from positive to negative depending on the balance of precipitation, intrusion to subsurface, and evaporation.
- On the other hand, in the east of Lake Urmia, the hydrological cycle is influenced by artificial factors as well as natural ones. The surface water balance does not become positive as the consequence of large amount of river intake as well as intrusion to underground and evaporation.
- In the south of Lake Urmia, the hydrological cycle has both the characteristics of the west and the east of the Lake. Since the water balance varies according to the balance between precipitation, intrusion to underground, and evaporation, it can be considered as the region with strong natural influence. Surface water balance, however, is in similar condition to Lake Urmia while subsurface water balance is positive. It is considered that the region is resilient to natural change. Thus, it is considered as the important region to restore and recover the lake water level of Lake Urmia.
- From the calculation result of vertical water flow in Lake Urmia, subsurface water flow under Lake Urmia can develop according to the lake water level change accompanied by lake surface evaporation. Although the flow of saltwater is not taken into account, it is considered that there exists an influence of the balance with the groundwater level of the basin.
- When the groundwater level of the basin lowers, the saltwater of Lake Urmia further goes downward by the density difference. It results in the additional water level lowering. Furthermore, by saltwater intrusion to the basin, issues on groundwater including salination of wells around the lake can be induced.
- The groundwater may be sustained the water body of the Lake Urmia. Therefore, the preservation of groundwater of the basin is very important.

CHAPTER 6. EVALUATION OF PROJECTS

6.1 COUNTERMEASURE PROJECTS

6.1.1 SELECTION OF PROJECTS

In August 2013, President Rouhani hammered out measures and called for assistance from international communities. As of November 2014, LURC which is directly controlled by the President, was established and after that, the Government of Iran (GOI) had proposed 24 countermeasure projects for Lake Urmia restoration, of which 11 projects are envisaged to have direct relation with the hydrological conditions of the Lake Urmia watershed. In the Survey, the effects of the 11 projects were quantitatively evaluated by using the distributed hydrological models. In November 2014, the JICA Survey Team held discussions with the Ministry of Energy (MOE) of Iran and the 11 projects were confirmed, as summarized in Table 6.1.1

Table 6.1.1 Prpjects Regarding the Hydrological Matters

No. (Project No.)	Outline of Project	Issue for Modeling
1 (1)	Prohibition against any increase in uptake from water resources of the basin on one hand, and preventing any new developments especially in agricultural section on the other hand	● Estimate of present intake water
2 (2)	Preventing unauthorized removal of water from surface waters	● Estimate of unauthorized water intake
3 (3)	Stopping all dam projects which are under study or operation (except Shahid Madani and Cheraq Veis dams), all irrigation networks and water supply projects of downstream in Urmia Lake basin; saving and releasing water into Shahid Madani dam merely for the sake of Urmia Lake	● Confirmation of the meaning of “saving and releasing water into Shahid Madani dam merely for the sake of Urmia Lake”
4 (4)	Providing the required budget and funding on one hand and accelerating the process of water transmission in the project of Water Transmission from Zaab River to Urmia Lake Basin	● Amount of water transmission setting method ● Setting the schedule of water transmission
5 (6)	Organizing the wells in Urmia Lake basin; installing smart and volume meters in order to monitor withdrawals in line with increasing the amount of inflows from rivers into Urmia Lake	● Confirmation of the meaning of “organizing the wells” ● Effect assuming method for installation of meters
6 (8)	Controlling and reducing water consumption in agriculture section	● Setting the method of reduction in water consumption
7 (9)	Transferring water from Hasanlou dam to the islands and wetlands around Urmia Lake and opening the way for the inflow lines to the southern wetlands	● Amount of water transmission setting method ● Confirmation of the specification of inflow channel (longitudinal and transverse shape of channel)
8 (12)	Designing and establishing the decision-making system for the integrated and comprehensive management of Urmia Lake basin	● Effect setting method for decision-making system
9 (15)	Transferring rivers water into the body of the Lake (the water of Zarinehrood river will be transferred to Syminehrood river to reduce evaporation amount).	● Amount of water transmission setting method
10 (19)	Identifying the areas affecting the discharge of rivers running into the Lake and reinforcing them through watershed and aquifer management in order to increase the volume of water inflows into the lake	● Effect setting method for watershed and aquifer management
11 (20)	Accelerating the implementation of water transferring from Aras River in West Azerbaijan merely into Urmia Lake on the basis of approved allocation by the Ministry of Energy	● Amount of water transmission setting method ● Implementation schedule setting method

After the first field survey for the Inception Report (IC/R), the JICA Survey Team elaborated to quantify the impact of projects based on collected information through the counterpart agencies. however, among them, 5 projects were not clear to quantify direct impacts as of May 2014. Finally, the JICA Survey Team and the counterparts in GOI decided through consultation by e-mail and letters to conduct the analysis focussing on the 6 projects with clear conditions at that time.

Table 6.1.2 Quantifiable Prpject for Hydrological Model

No. (Project No.)	Outline of Project	Issue for Modeling
1 (1)	Prohibition against any increase in uptake from water resources of the basin on one hand, and preventing any new developments especially in agricultural section on the other hand	● Estimate of present intake water
3 (3)	Stopping all dam projects which are under study or operation (except Shahid Madani and Cheraq Veis dams), all irrigation networks and water supply projects of downstream in Urmia Lake basin; saving and releasing water into Shahid Madani dam merely for the sake of Urmia Lake	● Confirmation of the meaning of "saving and releasing water into Shahid Madani dam merely for the sake of Urmia Lake"
4 (4)	Providing the required budget and funding on one hand and accelerating the process of water transmission in the project of Water Transmission from Zaab River to Urmia Lake Basin	● Amount of water transmission setting method ● Setting the schedule of water transmission
6 (8)	Controlling and reducing water consumption in agriculture section	● Setting method of reduction in water consumption
9 (15)	Transferring rivers water into the body of the Lake (the water of Zarinehrood river will be transferred to Syminehrood river to reduce evaporation amount).	● Amount of water transmission setting method
11 (20)	Accelerating the implementation of water transferring from Aras River in West Azerbaijan merely into Urmia Lake on the basis of approved allocation by the Ministry of Energy	● Amount of water transmission setting method ● Implementation schedule setting method

6.1.2 EXAMINATION OF PROJECT EFFECTS

Prospective simulations using MIKE-SHE models were carried out for a 10 year period to gain trends and average amount of hydrological conditions per year such as average surface and groundwater volumes inflowing to the lake, and some project impacts. In consideration of the long computation time required for long-term simulation, sequential simulation was conducted by using the outputs of the MIKE SHE models to evaluate the effects of the projects. In sequential simulation, the surface area of the lake is estimated to correspond to the lake water level, and the volume of rainfall to the lake and evaporation from the lake are estimated in consideration of the changing lake surface area.

(1) Boundary Condition for the MIKE SHE Model

To make the conditions for the prospective-sequential analysis, conditions of year 2007 were applied as initial condition in the MIKE-SHE model, because the initial conditions should be balanced among the hydrological aspects to perform the simulation stably without error caused by lack of equivalence between the aspects in the model.

Then, as for rainfall depth, potential evaporation and evapotranspiration, which are the given conditions for 10 years prospective analysis by MIKE-SHE, the actual (observed) data of hydrological-year 2007/2008 were repeatedly given to the model. The year of given conditions was selected in consideration of average value of rainfall (354 mm) during 5 years from 2006 to 2010. The other conditions including rainfall are summarized in the following table.

Table 6.1.3 Initial Conditions for Perspective Simulation

No.	Items	Conditions
1.	Rainfall	Rainfall of 2007/2008 year which is almost equal total depth to average rainfall amount from 2006 to 2010 (Total 354mm).
2.	Potential Evaporation	Pan evaporation of 2006/2007 year is basically used. The potential evaporation of Lake Urmia surface and evapotranspiration in other land cover are 67 % and 25% of value of Pan evaporation respectively.
3.	Physical conditions	Geological, land form, groundwater level, lake water level, etc. are set based on calibration results.

(2) Grasp of Recovery Effect by Project

Based on the simulation results using the MIKE-SHE model, the effects of each project are summarized as water recovery amount as shown in Table 6.1.4. From the aspect of water recovery amount, all projects except Project No. 1 indicate the tendency of increment of lake water level. Project No. 3 has the highest value among them although it has a significant influence to the socio-economic conditions in the Lake Urmia basin compared with the others. Therefore, a combination of projects is necessary to reduce or mitigate the influence. In addition, further considerations and researches (for example, quantification of not-quantified projects at present, review of target water level, re-arrangement of preservation policy, etc.) may be needed to establish a better combination to secure the lake water.

Table 6.1.4 Approx. Water Recovery Amount by Project

(Per year)

Item No.	Projects	(a) Impact by Project	(b) Inflow w/o Project*1	(c) Inflow to lake with Project*1(a+b)	(d)*2 Average rainfall on surface of lake	(e)*2 Average evaporation on surface of lake	(f) Groundwater inflow to lake*1	(g) Water recovery amount (c+d-e+f)
1	Prohibition against any increase of water use (maintenance of status quo)	0MCM	2,300 MCM	2,300 MCM	904 MCM (LWL: 1271.05 to 1270.94)	3,375 MCM (LWL: 1271.05 to 127.94)	131 MCM	-40 MCM
3	Stop of whole water supply	2,245MCM	2,300 MCM	4,545 MCM	1520 MCM (LWL: 1271.05 to 1274.78)	5320 MCM (LWL: 1271.05 to 1274.78)	142 MCM	520 MCM
4	Water Transmission from Zaab River to Urmia Lake Basin	600MCM	2,300 MCM	2,900 MCM	1,059 MCM (LWL: 1271.05 to 1271.72)	3,954 MCM (LWL: 1271.05 to 1271.72)	130 0MCM	135 MCM
6	Controlling and reducing water consumption in agriculture section	190MCM to 890MCM	2,300 MCM	2,490～3,190MCM	1,160 MCM (LWL: 1271.05 to 1272.45)	4,330 MCM (LWL: 1271.05 to 1272.45)	135 MCM	155 MCM
9	Transferring rivers' water into the body of the Lake	127MCM	2,300 MCM	2,427 MCM	929 MCM (LWL: 1271.05 to 1271.08)	3,467 MCM (LWL: 1271.05 to 1271.08)	131 MCM	20 MCM
11	Transferring from Aras River in West Azerbaijan merely into Urmia Lake	146MCM*1	2,300 MCM	2,446 MCM	932 MCM (LWL: 1271.05 to 1271.10)	3,479 MCM (LWL: 1271.05 to 1271.10)	130 MCM	29 MCM
Maximum Effect	Including No.3,4,9,11 (in this case No.6 contain in No.3)	3,177MCM	2,300 MCM	5,477 MCM	1,293 MCM (LWL: 1271.05 to 1274.36)	4,827 MCM (LWL: 1271.05 to 1274.36)	130 MCM	2,073 MCM

*1: Calculated by MIKE-SHE model, *2: Estimated value corresponding to changing of the lake water level

6.1.3 EFFECT OF PROJECT COMBINATIONS

Based on the result of the MIKE-SHE model, the water level of Lake Urmia was simulated for future 20 or 30 years on the condition that the selected hydrological situation will continuously occur every year from the start to the end steps of the sequential simulation. The results of sequential simulation are summarized in Table 6.1.5 and Figure 6.1.1. As a result, it can be seen that only the No. 3 Project can achieve the target water level (1,274.1 m), even though all projects except No. 1 have the possibility to recover the lake water level to some extent.

Among the elements affecting the water balance, evaporation from the water surface of the lake affected the water balance very much in comparison with the others as described in Table 6.1.4. In case Project No. 1 is implemented, the evaporation volume per year has about twice the river flow and three times the rainfall. Incidentally, since the evaporation amount is changed corresponding to the water surface area of the lake, the water balance will be stable in some water levels on the condition of giving the average rainfall and evaporation potential repeatedly.

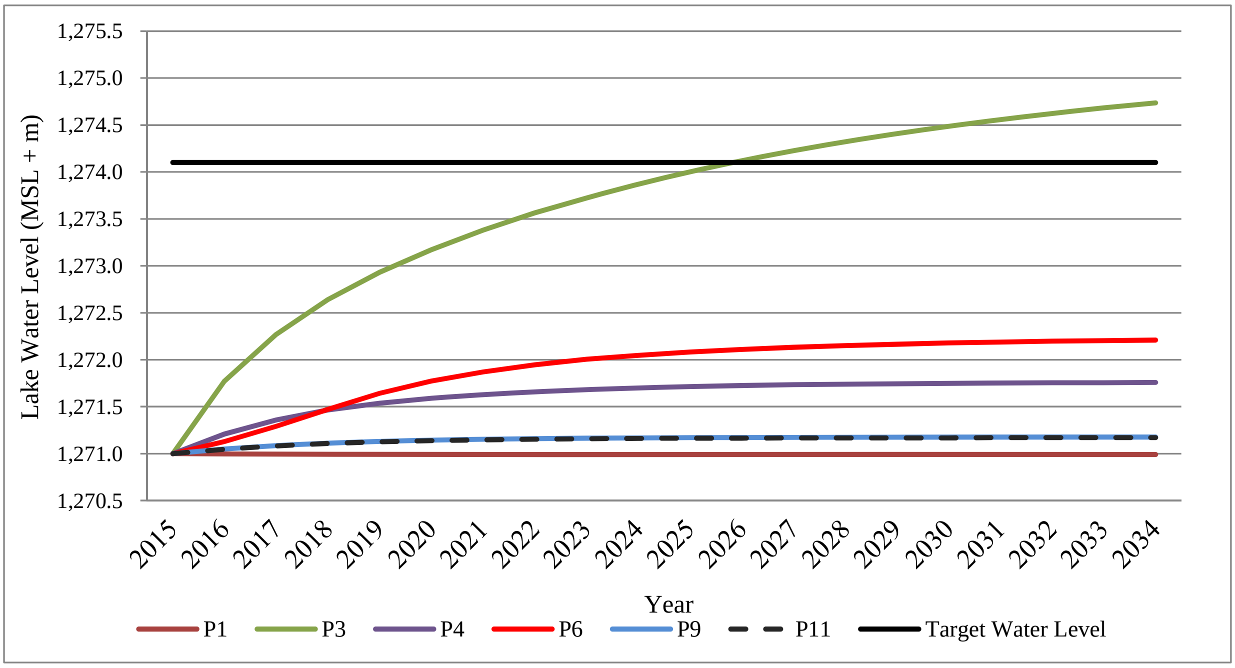


Figure 6.1.1 Effect by Individual Projects (Yearly Average Water Level)

Table 6.1.5 Attained Water Level and Recovery Speed by Individual Projects

Item No.	Items	Initial Water Level (WL)	About 1year later	About 2years later	About 5years later	About 10years later	About 20years later
1	Average WL (msl)	1271.05	1270.97	1270.96	1270.94	1270.94	1270.94
	Extent of Recovery (m)	-	-0.08	-0.09	-0.11	-0.11	-0.11
	Water Recovery Rate to Target WL (%)	-	-2.60	-3.09	-3.55	-3.61	-3.62
3	Average WL (msl)	1271.05	1271.75	1272.25	1273.16	1274.01	1274.78
	Extent of Recovery (m)	-	0.70	1.20	2.11	2.96	3.73
	Water Recovery Rate to Target WL (%)	-	23.09	39.29	69.02	96.92	124.00
4	Average WL (msl)	1271.05	1271.19	1271.33	1271.55	1271.67	1271.72
	Extent of Recovery (m)	-	0.14	0.28	0.50	0.62	0.67
	Water Recovery Rate to Target WL (%)	-	4.62	9.17	16.45	20.46	21.99
6	Average WL (msl)	1271.05	1271.10	1271.24	1271.71	1272.02	1272.16
	Extent of Recovery (m)	-	0.05	0.19	0.66	0.97	1.11
	Water Recovery Rate to Target WL (%)	-	1.71	6.35	21.61	31.94	36.25
9	Average WL (msl)	1271.05	1271.02	1271.04	1271.06	1271.08	1271.08
	Extent of Recovery (m)	-	-0.03	-0.01	0.01	0.03	0.03
	Water Recovery Rate to Target WL (%)	-	-0.93	-0.42	0.42	0.84	0.95
11	Average WL (msl)	1271.05	1271.03	1271.05	1271.08	1271.10	1271.10
	Extent of Recovery (m)	-	-0.02	0.00	0.03	0.05	0.05
	Water Recovery Rate to Target WL (%)	-	-0.72	-0.06	1.04	1.59	1.72

6.1.4 EXAMINATION OF PROJECT COMBINATIONS

Individual projects could not absolutely attain the target water level (1,274.1 m), considering the future change of hydro-meteorological conditions (especially, the condition of average rainfall and potential of evaporation). The possibilities of employing a combination of projects to attain the target water level (1,274.1 m) are thus herein analyzed. Sharing of water volume to be imposed on each project are classified into three types: water transmission, water saving, and regulation of water use. However, even at the present time, restoration projects and policies to secure the lake water are discussed and introduced by related agencies and institutions in Iran. Thus, those projects and policies should be examined in the future to establish more reasonable plans.

(1) Estimation of River Inflow Volume to Attain Target Water Level

The necessary river inflow volume per year to attain the target water level (1,274.1 m) is confirmed by the trial and error method and estimated at approx. 4,400MCM/year in the long term (50 years). Since the present river flow volume is approx. 2,300MCM/year, the necessary volume of increase is calculated at approx. 2,100MCM/year by the combination of projects. However, it takes around 50 years to reach the target water level of the lake.

In addition, the trial and error simulation is carried out in case of achieving the target water level in a time span of a decade and two decades. As a result of the simulation, it became clear that the river inflow volumes of approx. 2,050MCM and 2,450MCM/year are necessary to attain around 10 and 20-year respectively. However, in case of the project effect of over 2,100MCM/year, the water level will also rise to more than the target water level of 1,274.1 m in the future. Thus, to adjust the water level to the target, after the achievement of the target water level, the total river inflow volume should be controlled to approx. 2,100MCM/year.

Table 6.1.6 Attained Water Level and Recovery Speed by Degree of Inflow Volume

Number of years to attain the target water level	Items	Initial Water Level (WL)	About 1year later	About 2years later	About 5years later	About 10years later	About 20years later	Remarks
50years level - River inflow : Approx.4,400 MCM - Project impact: Approx1900 MCM	Average WL (msl)	1271.05	1271.67	1272.07	1272.58	1273.25	1273.81	About 50 years later, the lake water level may reach 1274.1m.
	Extent of Recovery (m)	0.00	0.62	1.02	1.53	2.20	2.76	
	Water Recovery Rate to Target WL (%)	0.00	20.29	33.40	50.23	72.21	90.50	
20years level - River inflow : Approx.4,550 MCM - Project impact: Approx.2,050 MCM	Average WL (msl)	1271.05	1271.72	1272.14	1272.58	1273.46	1274.12	Water level will rise little by little
	Extent of Recovery (m)	0.00	0.67	1.09	1.53	2.41	3.07	
	Water Recovery Rate to Target WL (%)	0.00	21.86	35.90	50.23	79.03	100.70	
10years level - River inflow : Approx.4,950 MCM - Project impact: Approx.2,450 MCM	Average WL (msl)	1271.05	1271.86	1272.38	1273.08	1274.10	1275.07	Water level will rise little by little。
	Extent of Recovery (m)	0.00	0.81	1.33	2.03	3.05	4.02	
	Water Recovery Rate to Target WL (%)	0.00	26.68	43.54	66.40	100.03	131.84	

(2) Recovery Effect in Case of Implementation of All projects

If all projects are implemented, the river inflow volume will increase to approx. 3,177MCM/year compared with Project No. 1 (status quo) and the lake water level is likely to rise to around 1,276.78m (higher than the target water level). In this case, it takes around 6 years to reach the target water level (1,274.1m).

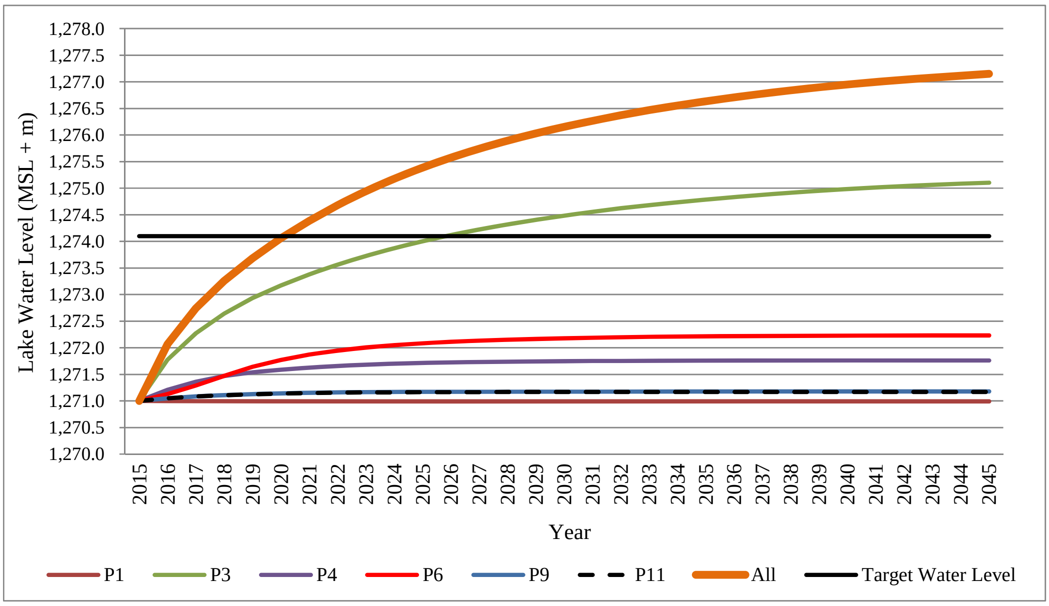


Figure 6.1.2 Project Effects (Change of Yearly Average Water Level)

Table 6.1.7 Attained Water Level and Recovery Speed by All Projects

Project Contents	(a) Initial Water Level (msl)	(b) Target Water Level (msl)	(c)=(b)-(a) Difference (m)	(d) The number of years to reach the target	(c)/(d) Recovery Speed (cm/year)
All projects (increment of flow volume with approx.3,117MCM/year)	1271.05	1274.1	3.050	About 6years (After the 6 years, water level may rise up to 1,278m)	About 50.83cm/year

(3) Selection of Projects to Attain the Target Water Level

In Item (1), it is revealed that the total river flow volume with approx. 4,400MCM/year is necessary to attain the target water level (1274.1m). Therefore, the combination of projects as summarized in Table 6.1.6 was considered so that the river flow volume can be increased to a minimum of 2,100MCM/year to add the original river flow volume with 2,300MCM/year, which means that all seven projects will lead the lake water level to the target level in about 50 years.

There are three kinds of individual projects: water saving, conveyance of water, and stop of water supply. The seven combinations of projects are described in Table 6.1.8 on the condition that Project No. 6 (the water saving) is prioritized over the others and Project No. 3 (to stop whole water supply) is prioritized last in consideration of the influence to the Lake Urmia basin, although in the future, the prioritization should be defined to find the balanced combination based on several aspects such as natural and social environment, financial effects, etc.

Table 6.1.8 Conbinations of Projects to Attain the Target Water Level

Case	Quantified Project						Maximum Impact (MCM)
	1	3 Stop of Water Supply	4 Water Conveyance	6 Water Saving*	9 Regulation of Evaporation	11 Water Conveyance	
Impact (MCM)	0	2,245	600	189 to 890	127	146	-
A	0	1,210 (90% of water supply)	-	189 to 890		-	2,245 (No.6 effect include No.3)
B	0	1,064 (79%)	-	189 to 890	-	146	2,391 (2245+146)
C	0	610 (45%)	600	189 to 890	-	-	2,845 (2245+600)
D	0	464 (34%)	600	189 to 890	-	146	2,991 (2245+600+146)
E	0	1,083 (80%)	-	189 to 890	127		2,372 (2245+127)
F	0	483 (36%)	600	189 to 890	127		2,972 (2245+600+127)
G	0	337 (25%)	600	189 to 890	127	146	3,118 (2245+600+127+146)

*Water saving (in total 40% of irrigation water) will be gradually carried out with 8%/year during 5 years

Although the results summarized in Table 6.1.8 lead to the inference that recovery of the lake level is possible by the combination of projects, from now on further examinations are needed in terms of (a) scale of project component, (b) relationship between recovery span and cost, and (c) flexibility for facilities and plans as explained in items (a) to (c) below.

In addition, quantification for projects which cannot be quantified at this moment are recommended to establish the proper combination plan from the viewpoint of IWRM. Among the projects, Project No. 7 did not seem to contribute to the recovery of lake water level; however, the necessity of the project should be considered from the aspect of natural environment.

(a) Scale of project components

The contribution rate of each project in the combination project to increment of inflow volume should be examined from several aspects. For instance, in Case A in Table 6.1.8, the balance of impact (increment of inflow to the lake) can be arranged if quantified projects are detected through further studies. Therefore, non-quantifiable projects in the Survey should be quantified to increase the variation of contribution rate for each project.

(b) Relationship between recovery span and cost

In case of implementation of all projects with full-specs (increment of approx. 3,118MCM/year), it takes a minimum of six years to reach the target water level [refer to item (2)]. However, the construction cost and O&M cost in this case might significantly affect socio-economic environment. On the other hand, in the case of increment of river flow volume with approx. 1900MCM/year (minimum level to attain the target water level), around 50 years is necessary to reach the target water level of the lake with construction cost of less than the case of all projects. Therefore, the relationship between recovery span and cost should be examined in detail in the process of establishment of combination plans. Moreover, a relatively-large pump station may be needed to transfer the water to Lake Urmia beyond the mountain ridge of watershed. Besides, the O&M cost might be several times the present construction cost and replacement of the pumping machines might be needed once in 15 years. Thus, due consideration regarding O&M cost is also important so as not to squeeze the financial environment of related agencies.

(c) Flexibility of the project facilities and plans

Combination plans to reach the target water level within 50 years have the capacity of more than 1,900MCM/year in increment of inflow amount. Thus, after reaching the target water level, the project facilities should have functions to control the inflow volume to keep it at around 1,900MCM/year which is the minimum requirement to maintain the target water level. In addition, the combination plans should be proper and understandable for stakeholders. Therefore, in the process of formulation of plans simultaneously, ingenious attempt should also be examined such as effective utilization of excess water, e.g., the excess water resulting from the control may be applied for other water demands in the Lake Urmia basin.

(4) Consideration of Climate Change Impact (As Reference)

The World Bank publishes climate change impacts on its website (http://sdwebx.worldbank.org/climateportal/index.cfm) including hydro-meteorological changes in Iran. According to the website, the average rainfall in B1 scenario may be varied in the range of about 72% to -54% (high and low case) by 2039, which was evaluated by ensemble method using 15 Global Circulation Models (GCM). To evaluate the climate change impact in the Lake Urmia basin, the rainfall time series are modified along the B1 scenario (high, median, low cases) and input to the simulation model as a boundary condition. The result of simulation for the three cases is plotted in Figure 6.1.3

The range of impacts is so wide to be involved in the planning of project combinations. Therefore, it is better to raise the precision of analyzed impacts, at least, by the establishment and use of a downscaling model. In addition, based on the result, the flexibility of project components should be considered in terms of efficient use of facilities and conveyed water for the future to avoid excess investment.

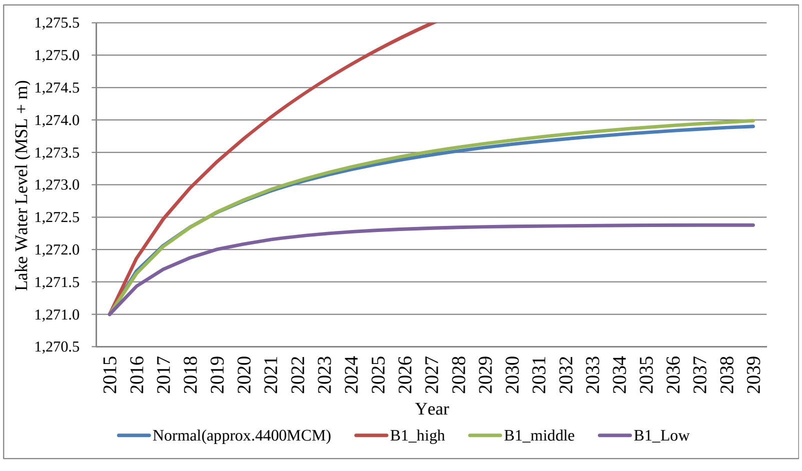


Figure 6.1.3 Climate Change Impact on Recovery of Lake Water Level

CHAPTER 7. CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

In the Survey, the distribution runoff models for Urmia Lake Basin were established by MIKE-SHE and GETFLOWS. The model by MIKE-SHE is constructed to analyze the lake water change from the aspect of confirm the whole water movement and balance and the model by GETFLOWS from the aspect of hydrological cycle based on further physical conditions including interactive behavior between surface water and groundwater. By utilization of those models, the investigations and evaluations for (1) mechanism of water level declining in Lake Urmia and (2) Proposed projects (by Iran) for Lake Urmia restoration were implemented by using above-mentioned models in Chapter 5 and 6. These results are described in 7.1.1.and 7.1.2.

Although estimated data was used compensated for lack of information in the establishment of the models, especially, the model by MIKE-SHE is constructed with good accuracy in terms of following to past water level record of Lake Urmia and actual runoff ratio for Lake Urmia Basin. However, accuracy of the model by GETFLOWS cannot reach to the same level of that by MIKE-SHE. Then, the conclusion is described based on the results by MIKE-SHE model in Section 7.1.

It can be said that the analysis and evaluation results by MIKE-SHE is reliable at the moment due to maximum use of existing data and high consistency between actual and simulation results even though there is the fact to use the estimated data as a given condition in distribution of water use. Therefore, the model by MIKE-SHE can be applied to calculate future water level trends and changes of Lake Urmia corresponding to the variation of basin mean rainfall. When setting initial conditions and inputting the assumed rainfall time series data, the model can calculate the water level of Lake Urmia corresponding to the conditions between surface water and groundwater and assess impacts on surface and groundwater condition by rainfall changes. However, some of conditions such as dams, land use and topographical conditions should be reconfigured to adjust to future scenarios or projects.

As for the GETFLOWS modeling, however, the fact revealed that the information collected until now is not enough to complete the model at the same level of MIKE-SHE although the implementation of modeling by GETFLOWS was decided as a reference at the first meeting for Inception Report in the Survey to scientifically analyze the behavior of groundwater which may be an important element influenced on the declining of water level of Lake Urmia. At that time the modeling by GETFLOWS was thought to be possible based on the past results in Japan if there are a certain level of hydrological information in the Lake Urmia basin. However, it made clear in the process of model calibration that further accurate information in water use is necessary to complete the model of GETFLOWS.

7.1.1 MECHANISM OF WATER LEVEL DECLINE

Since 1993, the inflow volume from rivers to the lake clearly has been on a declining trend. Concretely, the yearly flow volume in 2008 decreased to the tenth of that in 1993, and after 1994 the yearly volumes have not overtook that of 1993. The change of hydrological characteristics of the basin by the decrement of yearly rainfall, and the increment of water use by the changes of social environment are considered as a major factors; however, the former factor is recognized as the most influencing matter based on the result of analysis in Chapter 5. As seen in Table 5.2.36 and 5.2.37, it is very clear that the water level decline over time is following the rainfall decrement after year 1996.

After then, even when yearly basin mean rainfall (408mm in past 30 years) is occurred after 1996, the lake water level continues to decrease. The situation may be happened due to a lot of rainfall infiltration to the ground caused by the shortage of groundwater by recent sequence of dry year. The simulation results also indicate same facts that nevertheless the same amount of rainfall occurred in 1994 and 2006, the simulated water level shows the recovery of water level in 1994 and the decline in 2006 as same as past observed records. However, it is impossible to divide water flows into two portions such as the underground flow and the intermediate runoff by MIKE-SHE system. Therefore, it can be just assumed that the groundwater infiltration increases from the viewpoint of the decline of water level (see Figure 5.2.38) and the decrement of groundwater inflow to the lake but cannot explain directly about increment of infiltration portion due to the shortage of groundwater storage. The GETFLOWS model was requested to analyze the phenomenon; however, the quantification of the phenomenon cannot done precisely due to the incompletion of the GETFLOWS model as mentioned in Chapter 5.

Meanwhile, it clarified based on simulation results that the water inflow to the lake about 4,400 to 4,500MCM/year is necessary to prevent declining tendency of the water level. The simulation result of water balance in year 1993 and 2003 also indicates the fact that the water level in 2003 with the inflow volume 4,400MCM is kept the same water level of the last year though other years since 1996 indicate just declining trend. In addition, the result of predictive calculation also indicates the necessity of maintenance of about 4,400MCM/year to recover the water level of Lake Urmia (see Figure 7.1.2).

Figure 7.1.1 shows that the composition of surface inflow volume to Lake Urmia in year 1994 and 2006, which indicates that the inflow volume could be kept with about 4,500MCM without the decrement of the water level if the water intake amount had been kept in the same degree since 1994. Under the above circumstances, the major reason of water level declining caused by the decrement of inflow volume to Lake Urmia is the rainfall decrement followed by the increment of intake water volume.

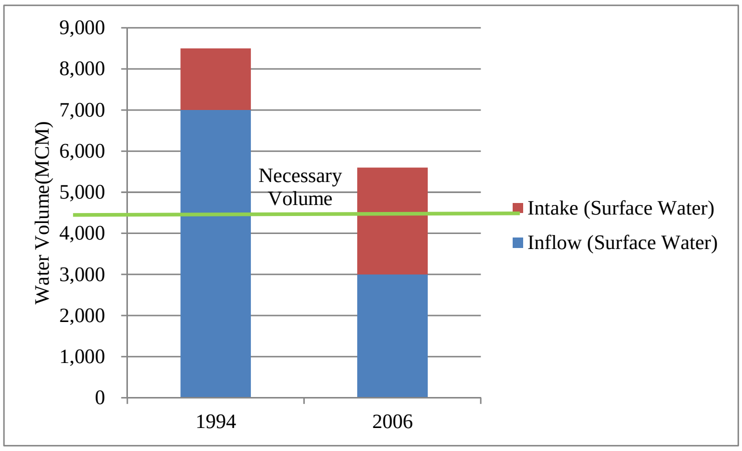


Figure 7.1.1 Change of Inflow Volume to Lake Urmia

(Comparison between 1994 and 2006 with the same rainfall amount more than 30 years average rainfall)

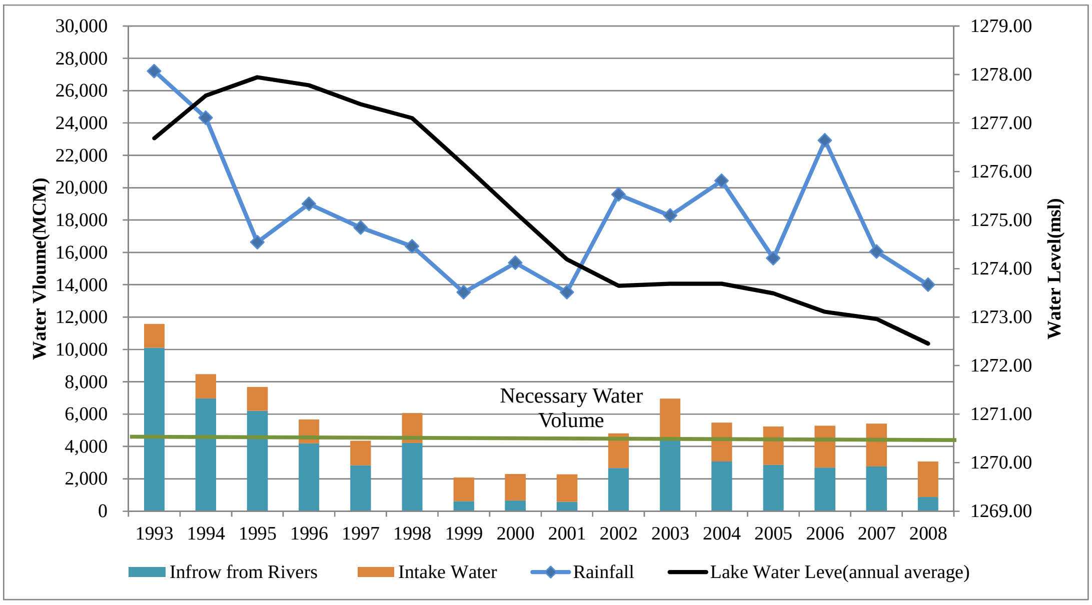


Figure 7.1.2 Change of Volumes of Inflow, Intake Waterand Rainfall, and Water Level

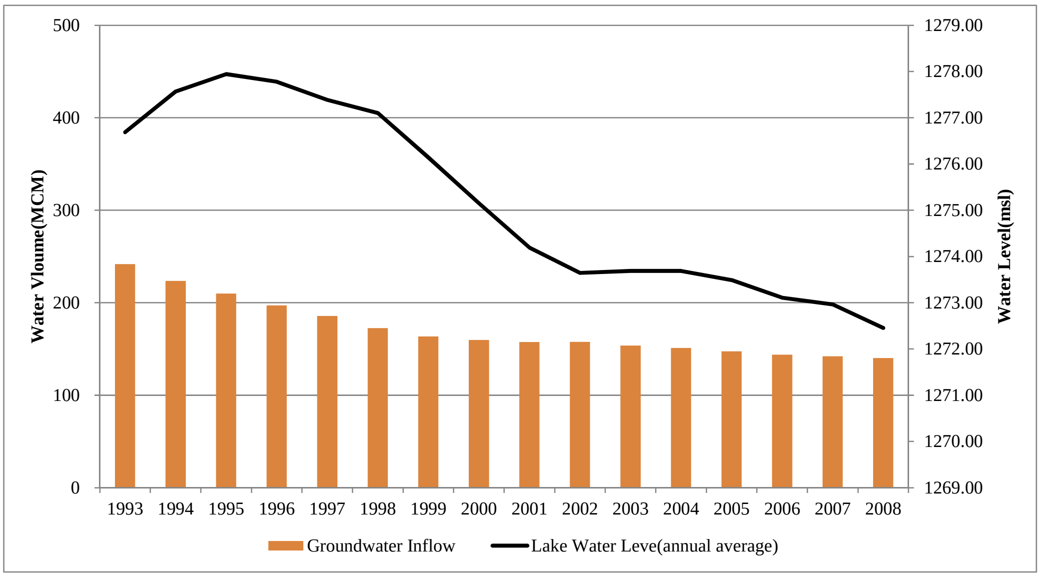


Figure 7.1.3 Change of Groundwater Inflow Volume and Lake Water Level

7.1.2 EFFECT OF PROPOSED PROJECTS AND PROJECT COMBINATIONS

Of 26 proposed projects by LURC, 6 projects which are able to quantify water volume as follows are selected to confirm the effects on recovery of the lake water level by using the distributed runoff model (Maximum volumes which can flow into the lake by the projects are in parentheses).

- Project-1: Prohibition of New Water Resources Development and Water Use (about 0MCM/year)
- Project-3: Stop of Water Use in the downstream of Existing and Planning Dam (about 2,245MCM/year)
- Project-4: Transmission of Water from the Zaar River to Lake Urmia (about 600MCM/year)
- Project-6: Water Saving in irrigation field with 8% every year and 40% in total (about 190MCM - 890MCM/year)
- Project-9: Control of evaporation amount in the downstream of the Zarinehrood River (about 127MCM/year)
- Project-11: Transmission of Water from the Aras River to Lake Urmia (about 146MCM/year)

The lake water level would reach target water level (1274.1m) by the implementation of Project-3; however, in case of individual implementation of others the water level would not reach the target level with the small recovery to some extent. While, the implementation of all 6 projects has enough effect to recover the water level to the target level with about 6 years. The combination of 5 projects except for Project-3 does not have effect to recover the water level to the target due to non-attainment of the necessary water volume increment (about 2,100MCM/year); therefore, the partial implementation of Project-3 is necessary to recover to the target level as far as additional projects are not proposed. Incidentally, if 25 % amount of water use is stopped by Project-3, the water level would be recovered to the target level in about 50 years by the implementation of 6 projects

In addition, to recover the water level for a short period, more additional inflow water should be secured corresponding to requested time scales. For example, about 4,400MCM/year is necessary to recover in around 50 years, 5,000MCM in around 10 years, which means the necessary-additional water volume by the projects about 2,1000MCM/year and about 2,700MCM/year respectively.

In case of securement of additional water volume by the 6 projects, due examination as to the balance of combination should be done from the aspects of cost-benefit relationships and impacts on natural and social conditions.

7.2 RECOMMENDATIONS

7.2.1 ACCURACY IMPROVEMENT OF THE DISTRIBUTED RUNOFF MODEL

The process of calibration of the distributed runoff model was executed by trial-and-error method with the limited information based on indicators such as daily lake water level and runoff volume from the basin. So preparations and collections of high-accurate and reliable data are very important works so that it can just take short time to adjust between simulation results and observed records in the process of calibration, and the calibration period can be more than 10 years. In the following, the necessary information and activities to rise up the accuracy of calibration results and predictive calculation by MIKE-SHE and GETFLOWS models are explained as well as considerations for the distributed runoff modeling in Lake Urmia.

(1) Necessary Information and Actions for Accuracy Improvement of Predictive Calculation

As for the calibration of MIKE-SHE model, high consistency can secure between simulation model and observed data of the lake water level although estimated data and information are included in the input data. However, intake point and water amount which are very important information to make the distributed runoff model are furnished on the condition of land use information level but not precise locations and specific water amount. Thus, the information was compensated by land-use maps and total water use amount and released discharge from dams summarized in the Master Plan Report on water resources management in the Lake Urmia basin.

Therefore, to improve the accuracy of perspective calculation by MIKE-SHE model, the estimated data should be replaced by actual information and the model should be calibrated again based on the actual information summarized in Table 7.2.1 so that the result of perspective calculation become realistic by setting proper model parameters.

On the other hand, since all of the behavior and movement of water flow are solved in accordance with the physical law in the GETFLOWS model, the existing of uncertain information mentioned above conduces to heavy difficulties of model calibration. In the Survey, although it is considered to be able to establish the model from the viewpoint of a lot of past accomplishment of modeling by GETFLOWS in Japan, problems and issues summarized in Table 7.2.1, which are detected in the process of calibration of MIKE-SHE model, disturbed and gave adverse impacts on GETFLOWS modeling works. The Survey Team thinks that the most significant problems is originate in the estimated water use data without investigation regarding irrigable water use in agriculture sector, followed by the issues as to saline density and geological structure in the basin. As for the saline density in the water, the hydrological cycle speed around the lake will be varied corresponding to the seasonal conditions if setting the density but that cannot be seen as direct reason for the 1m difference of lake water level between observed and simulated one. In addition, the collected information of geological condition is the similar situation of the past modeling cases in Japan. Therefore, the first priority to complete the calibration of GETFLOWS model is to investigate and prepare the more precise information for the water use such as intake points and water amounts.

Table 7.2.1 Necessary Information and Activities to Improve Accuracy

No.	Item		Necessary Information and Activities (Upper：In case there are information Lower：In case there are no information)
1	Intake	-Location and each Intake water amount	✓ Set proper surface and underground intake points by each water user ✓ Input of time series of intake water amount to the surface and groundwater intake points
			✓ Research on actual situation on intake water amount (including investigation for illegal water intake) ✓ Investigation of location (coordinates for GIS) ✓ Administrative regulation for illegal water use
2	Evaporation	-Daily Evaporation	✓ Utilization of daily data observed in all 61monitoring stations ✓ Input of daily evaporation data of the lake in winter season
			✓ Investigation for winter evaporation amount of the lake water which includes saline content (not freeze to some extent)
3	Dam	-Operation Rule	✓ Operation rule or released discharge (all dams but not only major dam)
			✓ Record of operation and water level of dam lakes(all dams)
4	Sedimentation Conditions	-latest Height-Area-Volume (HAV) relationship -Chang of height in typical point	✓ Input of proper HAV data corresponding to calibration and perspective simulation
			✓ Fixed point observation ✓ Periodical measurement of HAV
5	Density flow	-Saline Density	✓ Input of Saline Density
			✓ Continual monitoring of saline density in the lake and wells

(a) Intake Point and Intake Water Amount

As described in 4.5.4, the information for water use situation of surface water cannot grasp precisely due to the lack of data such as each intake point (GIS coordinates) and intake water amount. Thus, the information was compensated by yearly total amount of water use in the basin (described in the Master Plan Report) and time series data of dams' released discharge.

Furthermore, because of the 92% of water use is dominated by irrigation sector, intake points for surface water are decided referencing to irrigation areas interpreted by the land use map. As for the groundwater use, a lot of intake points of ground water are collected as GIS information and the time series data of ground water use can be estimated by using water right information and total yearly water use amount summarized in the Master Plan (See Chapter 4).

If there are clear information for the water intake, the estimations mentioned above was not necessary and realistic water allocations on the model can be done. Therefore, to improve the accuracy of calibration and perspective calculation by using the calibrated model, it is needed to input more proper information as to intake point (GIS coordinats shoud be arranged) and intake water amount (time series data is better) should be input to the model. Following that, the actural intake amount from groundwater shoud be input instead of water right amount (the locations are already arranged as GIS coordinates).

In case of no arrangement regarding mentioned-above information in the basin, investigations and monitorings shoud be conducted to confirm the actural situation of water intakes from surface water and groundwater. Although there is the yearly total amount of water use in the whole basin, the water related agencies should properly store and maintain the detaled information about water use which may be utilized as basic information for the formulation of Master Plan. Furthermore, situations of water intake sites should be confirmed and recorded by conducting invastigations including measurements of the GIS coordinates.

In addition, according to the related agencies, there may be illegal water intake or water intakes without water right in the basin. As described in 3.2.1, farmers sometimes take the water from rivers interrupting river flows by sandbags or sand filling in the dry season. Although the investigation and regulation of those illegal water uses are proposed as a project in Iran, the illegal activities should be grasped and regulated strictly in accordance with Iranian laws to improve the accuracy of distributed runoff models and perspective calculation by using the models.

(b) Depth of Evaporation

As explained in 2.6.3, although the evaporation have been measured in 71 stations and managed by WRMC and IMO, daily evaporation data at the only ten stations is collected in the Survey. The evaporation data was used for the estimation of evaporation from the lake Surface and evapotranspiration from the basin ground: therefore, the data recorded in all stations are needed to improve the model calibration accuracy.

In addition, as pointed out in 5.3.1, the observed data of above 10 stations indicates “0” data in the winter season; however, there are values other than “0” in the Master Plan repot and monthly data collected from WRMC. The all observed daily data should be arranged and input to the model instead of the daily data estimated based on divided monthly data by the number of days at the moment. Especially, since the lake saline water is not froze even in some winter seasons, the measurement of evaporation in winter seasons is very important to calculate water balance around the lake.

(c) Operation rules of dams

To conduct perspective calculation precisely, dam operation rule is essential. In the Survey, the modeling was carried out by inputting dam released discharges to river channels because the rules are not provided in the Survey. However, since the released discharge will be affected by conditions of previous hydrological year, it is difficult to directly use the data in the model for perspective calculations.

It is hard to imagine that there is no data about operation rule of each dam. However, the monitoring system should be constructed to confirm the situation of actual operations and based on monitoring results the rule curve should be established to properly use of water.

(d) Released Discharge from Dams

As explained in the previous item (e), the released discharge was used as river flows in the just downstream of dams. However, of 40 existing dams 12 major dams’ data were collected in the Survey. Therefore, the data of remaining dams were estimated by using the 12 major dams (See Chapter 4). If all released discharge data for 40 dams are input to the model, the river flow conditions will be expressed more precisely.

Therefore, the monitoring system should be set in the remaining 28 dams to observe released discharge so that the information can be input in the process of model calibration to improve the accuracy of calculation.

(e) Bathymetry Data of Lake Urmia

In the Steering Committee meeting for Draft Final Report 1, there is an opinion to consider the sedimentation conditions of the lake in the modeling. To realize the opinion for the accuracy improvement of analyze, the bathymetry survey should be conducted periodically and the result of survey should be input in consideration of the calibration or perspective simulation period. Particularly, since the evaporation is proportionate to the water surface area of Lake Urmia, the bathymetry data is very important to express closely actual hydrological phenomena in and around Lake Urmia.

(f) Saline Density

At present the inflow volume to the lake from ground water is estimated at 10 % of surface water inflow volume, and so the yearly effect in the water level of the Lake is just several millimeters. However, as presented in Figure 2.6.19 and 2.6.20, there is a possibility that the behavior of groundwater movement in and around Lake Urmia would be change corresponding to the saline density in the future.

Therefore, to improve the calculation result as to the ground water movement, it is better to monitor water quality (saline density) particularly at the monitoring wells and to input the data to the models, though unfortunately the proper data to input to the model cannot be collected in the Survey. In the future, if saline wedges are formulated in and around the lake, the saline density data will be also needed to input to the model to confirm the flow conditions of groundwater.

(2) Considerations and Necessary Activities to Establish the Distributed Runoff Models

(a) Discharge Data

As mentioned in 2.6.2 (3), some outlier data were detected at the 4 discharge measurement stations when the discharge data are converted to annual depth from annual volume. In the 4 stations, the depth of discharge was estimated at 1,000mm to 2,000mm which more than annual average rainfall in Lake Urmia. In addition, even though annual data can be seen correct in the depth, there are conditions that the outlier data more than average rainfall in the upstream basin can be detected in several years. The cause could be attributed to misunderstanding of location of discharge stations, gaps in discharge rating curves, improper location of rainfall stations, malfunctions of measurement equipment and so on. Therefore, the meta data for the stations should be re-arranged and make an inventory list for the stations including necessary information for the modeling.

(b) Rainfall

For example, yearly rainfall volumes in the upper basin of Bukan Dam in some years are smaller than the discharge volume flowing to Bukan Dam. The cause could be attributed to information shortage of rainfall at high altitude areas in the upper basin of Bukan Dam. Incidentally, there are less than 10 % of stations are allocated in the high altitude than 2,000m. Unfortunately, the rainfall correction corresponding to the altitude is not conducted in the Survey because correlations between the altitude and rainfall volume is not revealed as described in 2.6. Therefore, it is better to increase the number of rainfall station in the high altitude area to be able to investigate the rainfall amount in the area.

(c) Record of Lake Water Level

The outlier data include in the provided data of 2007 year. Such a data is very easy to detect by making graphs. The official data should be arranged by related agencies to provide water users without outlier data.

(d) Land Use Data

Regarding the land use data, 1987 and 2007 land use maps are provided in the Survey and the information of year 2007 is applied for the modelling in consideration of the calibration period from 1999 to 2007. The land use data is utilized to set the land surface roughness coefficients in the modelling. The selection of the information is considered reasonable and proper in this case because the dominant land use is rangeland area of which is not varied so much from 1987 to 2007 as described in 2.4. The result of model calibration also indicates the proper selection. However, the land use conditions should be examined in consideration of future development scenarios in the Lake Urmia basin when the perspective calculation for a long period.

(e) Detailed Check of Hydrological Data

In the Survey, it is clarified the existence of data to be judged as outlier or unexplainable data caused by the limited condition in hydrological observation conditions especially for rainfall and discharge. To maintain quality of hydrological data, the data should be cross-checked by the several methods (such as comparison of runoff depth and ratio, check of specific discharge, double mass curve, check of correlations between yearly rainfalls in the stations, water balance analysis in the upper basin of dams and so on). The suspicious data in quality are not used in the Survey; however, in the future the data of all station should be utilized because of present low density of hydrological station for the basin.

In addition, it is better to investigate the physical conditions of measurement equipment in the stations. The causes may be attributed to improper maintenance, technical problem in responsible person for maintenance, inadequate location of stations, budgetary restriction and so on.

(f) Establishment of Information Sharing System

During the Survey, mainly WRMC assist the Survey Team to collect necessary information; however, some of information are not satisfied with the distributed runoff model which needs the information of locations because the information were scattering in several related agencies. Many water related agencies are analyzing and modelling to confirm the conditions of water level of Lake Urmia at the several technical levels. To support the actions of agencies, it is better to construct the information sharing system or work flows to arrange the information for the modelling at the initiative of LURC or MOE.

(g) Data Treatment for the Modelling

The topographical data and land use data cannot be treated as time series data in the distributed runoff models established in the Survey; therefore, the simulation period should be divided setting the appropriate data to the period.

The modeling in the Survey is carried out focusing on water movement in the basin to confirm the declining of the lake water level caused by the hydrological behaviors. Therefore, the hydrological data varies from day to day with the proper representative data for land use and topographic data of the lake and its basin.

(h) Consideration of Sediment Movement in the Basin

If the distribution model is established in consideration of the process of sedimentation transportation to the lake and the changing of the topographic condition of the lake bottom, it is necessary to set a lot of data such as sediment yield, river capacity of sediment conveyance, river bed fluctuation, particle size distribution data, hypothesis of sediment movement inside the lake and so on. Judging from the conditions of data collection, if the models are constructed including both of the sediment and water movement, the uncertain elements may increase and disturb the proper model calibration with the limited condition, which make a problem to utilize the model for the decision supports.

7.2.2 DIRECTIONS OF EXAMINATION ON PROJECTS BY UTILIZATION OF THE MODEL

(1) Examination of Scenarios for Project Combination

The combination of 6 projects will lead to recover the lake water level to the target level as analyzed in Chapter 6. However, it should be considered as significant issues that the project-3 has a hevy impact to social environment and the construction and O&M costs for the project-4 and 11is considered very huge. Therefore, it is very important to examine and propose effective projects, for example, a) quantifications of new alternative project, b) examination of proper target water level, c) restriction of reservoir area in the Lake and so on. The examination of those effects of new propositions can be done by using the models as follows:.

(a) Quantification of Projects

The quantification can be done by using the models for some propositions such as projects to control evaporation from water surface, groundwater recharge projects, exchanges of cropping pattern, water saving projects and so on. While, there are the projects to be quantified in water amount before inputting the model such as establishment of water resources management organizations, install of smart meter to measure the intake water, construction of decision making system and so on.

(b) Examination of Target Water Level

If the additional inflow volume does not reach about 2,100MCM/year in case of the reduction of impact by project-3, the examination as to target water level will be necessary in the future. The models can estimate the water level corresponding to the combination projects which may have gaps by region and small basin. However, there are uncertainties in some small basins based on the accuracy level of data in the present model. Therefore, if the estimation for correct impact on the small basins and regions by the projects to explain stakeholders, the model should be calibrated again with the more reliable data (especially water use data) in accordance with the contents described in 7.2.

(c) Restrictions of Reservoir Area

LURC has an idea to restrict the reservoir area in the lake to keep the lake water level and the idea can be applied in the model by modifying the DEM data. However, as for setting of capable water storage volume of the lake in the model, the sedimentation condition should be examined as mentioned by Urmia Lake University. For the predictive simulation, the latest bathymetry data is necessary to input as topographical data in the model.

(2) Examination of Proper Intake Water Amount

The established model will be utilized to estimate proper water use amount by trial-and-errors method. However, since the input information regarding the intake points and intake water amount has an uncertainty by region, the proper water use amount can be estimated roughly at the whole basin level. To estimate more precisely, uncertain data such as illegal water intake should be clarified in terms of locations and quantity to input the model. In addition, after the removal of uncertainty, the proper setting of intake water amount and allocations can be estimated in consideration of the variation of water balance between surface water and groundwater by using the models.

7.3 POSSIBILITY OF FUTURE UTILIZATION OF THE MODEL

Although a number of projects were proposed to restore the lake water level in Iran, consensus formations are necessary among stakeholders in water related sectors to select and implement the projects. Therefore, the projects should be planned and implemented based on the concept of Integrated Water resources Management (IWRM) which basically recommends the basin-wise management. However, there are a lot of stakeholders which should be involved from planning stage in and out of the Lake Urmia basin because the proposed projects by Iran include the works of interbasin transfer of water.

In addition, in the Lake Urmia basin, the difficult and complex arrangement should be done from the aspects of the balance between surface water and groundwater, saline and raw water movement, interbasin transfer affected on both basins, and trade-off relationship between water resources development and implementation of restoration projects. Therefore, those issues and problem for restoration of the water level should be solved on the scientific basis to facilitate making consensus formation. In the circumstance, the distributed-physical runoff models will support to resolve those complex water related issues by inputting the all subjects to the model simultaneously. The scientific-based result of the model will have a big role as a part of consensus formation system between stakeholders.

In the Survey, the distributed runoff models are established by the tools of MIKE-SHE and GETFLOWS. As for the MIKE-SHE model, the adjustment can be carried out to fix the simulated water level to the observed record by controlling the debatable part (for example, degree of runoff from intermediate flows to rivers) even though the information is not enough a little bit to set boundary conditions completely as per the present conditions. As shown in Chapter 5, the simulated water level by the MIKE-SHE model has a high consistency with the observed daily water level. On the other hand, since the all hydrological phenomenon are completely solved in accordance with physical law in the GETFLOWS model, the calibration is very difficult compared with the MIKE-SHE model if there are some ambiguities in the information. However, the completed GETFLOWS model will show the good result to understand the sequence of water moving behavior more precise than the MIKE-SHE model.

In the circumstance, both of the models have a high possibility to be utilized as a support system for decision making in water related issues. Indeed, the MIKE-SHE model can be used as a part of support system to promote IWRM process without enough information in hydrological cycle in the target basin.

While, the GETFLOWS model will be utilized to solve complex issues and form the consensus between stakeholders at the advanced level when the related agencies is able to manage and understand necessary information to a satisfactory extent for the establishment of distribution models. For example, plans concerning the issues of saline water and the balance between groundwater and surface water will be applied better by the GETFLOWS model than the MIKE-SHE model.

ANNEX

Annex1.1

Minutes of Meeting on 15th October 2014: Data Collection Survey on the Hydrological Cycle of Lake Urmia Basin in the Islamic Republic of Iran agreed upon between Ministry of Energy, National Committee for Saving Lake Urmia and the Japan International Cooperation Agency

THE MINUTES OF MEETINGS

ON

THE MISSION FOR THE INCEPTION REPORT

ON

THE DATA COLLECTION SURVEY ON
THE HYDROLOGIC CYCLE OF LAKE URMIA

IN

THE ISLAMIC REPUBLIC OF IRAN

AGREED UPON BETWEEN

THE MINISTRY OF ENERGY,

NATIONAL COMMITTEE FOR SAVING URMIA

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Tehran, November 19, 2014

Bahram TAHERI, Ph.D
Advisor to the Minister
Ministry of Energy
and
Representative
National Committee for Saving Lake Urmia
Islamic Republic of Iran

Kenji NAGATA
Leader of the Survey Team
Japan International Cooperation Agency

Based on the Minutes of Meetings held between the Government of Islamic Republic of Iran (hereinafter referred to as "GOI") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") concerning the Data Collection Survey on the Hydrologic Cycle of Lake Urmia (hereinafter referred to as "the Survey") dated on October 15, 2014, JICA dispatched a mission team (hereinafter referred to as "the Team") for the Survey to the Islamic Republic of Iran from November 14 to 19, 2014.

The Team held a series of discussions with relevant organizations and conducted field visits to develop the scope and implementing arrangements of the Survey. The main points discussed during its visit are described in the Appendix 1. The scope and implementing arrangements of the Survey are described in the Appendix 2.

Appendix 1: Main Points Discussed
Appendix 2: Scope and Implementing Arrangements of the Survey

Appendix 1

THE MAIN POINTS DISCUSSED

1. Hydrological models to be adopted in the Survey

The Team proposed to develop hydrological models of Lake Urmia basin based on two different model packages, namely MIKE SHE and GETFLOWS. While MIKE SHE has advantages such as:

- user-friendly interface,
- quickness in model development, and
- experiences in handling the model in MOE and other Iranian organizations.

GETFLOWS has an advantage of physical-based expression in modeling the basin hydrologic cycle with features such as:

- seamless water flow simulation between different layers (e.g. atmosphere, surface water, unsaturated groundwater and saturated groundwater), and
- high scalability from the aspect of many fluid flow components (e.g. water, gas, non-aqueous liquid and solid), heat and mass transport in watershed.

Therefore, MIKE SHE shall be utilized as a quick solution to evaluate the proposed restoration project of Lake Urmia, while GETFLOWS utilized as a reference to validate the reliability of MIKE SHE. MOE agreed on it.

2. Data collection process

The Team requested MOE to submit the data necessary for model development by November 23, 2014. To facilitate the data collection procedures, MOE requested the Team to further discuss on the detail and priority of necessary data and to submit a more elaborated data request form. Upon the submission of the form, MOE immediately search the data in MOE or the National Committee for Saving Lake Urmia (hereinafter referred to as "the Committee") or refer to other relevant organizations. The Team agreed on it.

On the other hand, both sides agreed that, when gaps and inaccuracy are found in the data, the Team explores the possibility to fill the gap using alternative information such as satellite imageries, as noted at the 4th article of Appendix III of the Minutes of Meetings signed between MOE, the Committee and JICA on October 15, 2014.

3. Transfer of the developed model and training on the model

The Team explained that, upon the completion of the Survey, the hydrological model developed through the Survey is to be transferred to MOE and that the Team would organize a training workshop on the model. MOE mentioned that the model transferred is to be utilized in both Tehran and Lake Urmia region and that the contents of training workshop should not be limited to the operational instruction of model itself but also broader concepts related to the model, such as basic knowledge of Decision Support Systems (DSS). Both sides agreed that the Team will conduct a needs assessment on the training workshop and elaborate its contents through discussions with MOE by the end of the Survey. The training of the model shall provide enough details of GETFLOWS in comparison to MIKE SHE, which is already commonly used in Iran.

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Further capacity building of related stakeholders, including local partners, shall be implemented within the scope of JICA's upcoming technical cooperation project.

4. Detailed contents of the Lake Urmia revival projects approved by GOI

The Team requested MOE to provide the detailed contents of all the approved projects so far for the revival of Lake Urmia which had already been approved by GOI, since some of the measures included in these projects are to be interpreted into the parameter setting of the hydrological model of the Survey, and their performance for the restoration of Lake Urmia is to be evaluated using scenario analysis by the model. MOE suggested that the Team submit a more detailed questionnaire form on the all the approved projects so far so as to facilitate the communication between MOE and the Team. The Team agreed on it.

5. Organizational set-up of the Survey

MOE mentioned that the Survey is conducted under the cooperation by the Ministry of Energy, including Water Resources Management Company, the Committee and JICA, and that communication with other agencies such as Department of Environment, Ministry of Jahad-e-Agriculture is to be conducted via the Committee. The Team agreed on it.

6. Work and reporting schedule

The Team explained that, if both MIKE SHE and GETFLOWS are adopted as modeling platform of the Survey, the duration of the Survey would be longer than originally planned to complete the Survey by March 2015. In the case of adopting two models, the Team shall submit a final report for each model used: one is when model development and evaluation of existing projects are completed based on MIKE SHE around March 2015, and the other is when model development of GETFLOWS and validation of MIKE SHE are completed around August 2015. Both sides agreed to adopt two hydrological models by extending the survey period.

7. Stakeholders involvement

Because the implementation and success of any plan for saving Lake Urmia is vitally dependent upon the public and stakeholder participation and creation of a sense of ownership in them, both sides agreed that in all stages of implementing this project, great importance will be placed on this aspect of cooperation and that both sides will think about, find and implement practical mechanisms to this effect.

END

B.T

Appendix 2

Data Collection Survey on the Hydrologic Cycle of the Lake Urmia

Scope and Implementing Arrangements

Global Environment Department, JICA

1. Purpose of the Study

An integrated hydrological cycle model for the Lake Urmia (LU) basin is established, as a main component of comprehensive Decision Support System (DSS), taking into account basin rainfall, surface runoff and groundwater flow, evapotranspiration, water quality/temperature and water utilization in the basin. Applying this numerical model, the following studies will be made; 1) Water balance of the LU basin will be clarified; 2) Priority and effectiveness of the projects that LU Restoration Committee proposed and were endorsed by the Iranian Government will be evaluated and confirmed; 3) Priority and effectiveness of combinations of the projects will be studied and proposed.

2. Iranian Counterpart Agency/ies

Due to the involvement of multiple organizations on the Iranian side and to ensure a smooth cooperation and partnership and enhancement of local capacity building, the following counterpart structure has been established on the Iranian side:

Overall supervision: Dr Bahram Taheri, the Senior Environment, Safety and Health Advisor of Minister of Energy and member of the Kalantari Commission's Steering Committee will administer the overall supervision on this project in the Iranian side.

Focal Person: Mr Sayyari, Deputy Manager in Planning & Development of Water Resources Management Company (WRMC)

(2-1) Counterpart Organizations:

Main Partner:

- Water Resources Management Company (WRMC), Ministry of Energy (MOE)

Co-Partners:

- National Committee for Saving Lake Urmia and its affiliate regional research partners
- Water Research Institute (WRI),MOE
- Regional Center on Urban Water Management (RCUWM)

Iranian experts from the main partner and co-partner organizations will assist the JICA team with the available local expertise and will enhance the local capacity building and empowerment within the lake's basin and the partner organizations.

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3. Outputs

(3-1) **An integrated hydrological cycle model** for the Lake Urmia (LU) basin is established taking into account basin rainfall, surface runoff and groundwater flow, evapotranspiration, water quality, temperature and water utilization in the basin.

(3-2) Under conditions of relevant scenarios of water resources utilization in the LU basin, impacts by Climate Change (mainly future changes of precipitation, temperature and snow) to LU as well as main rivers, groundwater and marshes are studied through model simulations.

(3-3) **Effectiveness of the projects** that LU Restoration Committee proposed and was endorsed by the Iranian Government is evaluated through model simulations.

(3-4) Based on results of the above model simulations, **priority and effective combinations of the projects** to restore LU are recommended.

4. Activities[1]

(1) Integrated hydrological cycle modeling

(1-1) Data and information of topography, geology, vegetation, etc. are collected modeled, evaluated, validated and pre-processed.
(1-2) Integrated hydrological data such as rainfall, groundwater level, evaporation and runoff as well as water use data are collected.
(1-3) An integrated hydrological cycle model is numerically developed and calibrated through trial simulations with actual hydrological and water use data, and is finally established.

(2) Impacts by Climate Change

(2-1) On the basis of agricultural and domestic water uses in the basin, three (3) relevant scenarios of water use in the LU basin are configured.
(2-2) On the basis of past and future precipitation and temperature changes in the basin, three (3) relevant scenarios of basin precipitation are configured.
(2-3) Pairing a relevant water use scenario and relevant basin precipitation scenario, hydrological cycle of the basin is simulated.
(2-4) Analyzing and evaluating simulation results, impacts on Lake Urmia, main rivers, ground water and marshes are studied. Then, effective policy directions to restore Lake Urmia are proposed.

(3) Effectiveness of the projects

(3-1) The contents of the projects proposed by the Iranian Government are reviewed, clarified and identified.
(3-2) Assuming specifications of main projects, hydrological cycle situations after the project implementation are simulated.
(3-3) Based on the simulation results, effectiveness to restore Lake Urmia as well as negative impacts by the main projects are evaluated.

(4) Priority and effective combinations of the projects

(4-1) Based on all of the above simulation results, priority and effective combinations of the projects are studied, and preferable project implementation plans are proposed.

[1] It is possible that due to the complexity of data collection and verification, completion of items 3-3 and 4-3 need extra time.

(4-2) Model simulations are carried out according to the proposed implementation plans, and it is confirmed whether or not the water level of Lake Urmia can be restored.
(4-3) Recommendations to the project implementation to restore Lake Urmia are made.

5. Inputs

(5-1) Inputs from JICA

1) JICA dispatches experts in the following fields:

a) Water resources management
b) Meteorology, Hydrology and Water Uses
c) Hydrogeology
d) Simulation model

2) Provision of data needed through the study for areas of gap in the Iranian side, including remote sensing data.

3) Holding a workshop at the end of the current phase of study.

(5-2) Inputs from the Iranian Counterpart Agency/ies

4) The Iranian counterpart agency(ies) assign(s) the following counterpart personnel:

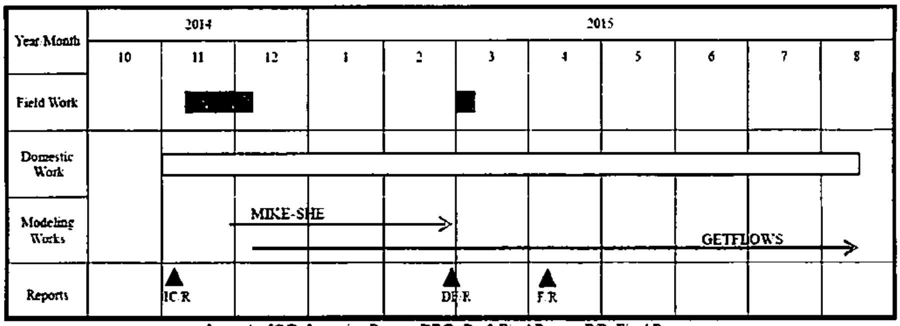
a) Leader/Water resources management
b) Meteorology, Hydrology and Water Uses
c) Simulation modeler

5) Provision of existing data and information such as topography, geology, vegetation hydrology, meteorology, water utilizations, etc.

6) Coordination with the internal departments of the MOE, Steering and Technical Committees of the kalantari commission, MOE, Ministry of Jahad-e Agriculture (MOJA), DOE, and related provincial offices.

7) Conducting site surveys with JICA Team

6. Schedule



Legend : IC/R: Inception Report; DF/R: Draft Final Report; F/R: Final Report

END

Annex1.2
Discussion Records between Water Resources Management Company(WRMC) and JICA Mission that was held on 4th August 2015

Japan International Cooperation Agency

August 4th 2015

Discussion Records between Water Resources Management Company (WRMC) and JICA Mission

Summary of Discussions

1 **Data Collection Survey on Hydrological Cycle of Lake Urmia Basin**

1.1 JICA's Consultant Team (hereinafter referred to as "the Consultant") prepared the Draft Final Report 1 based on MIKE-SHE modelling works (hereinafter referred to as "DF/R1"), and submitted (10) copies and PDF soft copies of the report alongside the data of DF/R1 to WRMC. The Stakeholder Meeting on DF/R1 attended by Dr. Taheri as the joint representative of the MOE and the Kalantaeri Commission and chaired by Mr. Majid Sayyari, Deputy, Planning and Economic Affairs, Water Resources Management Company was held on August 3rd, 2015 in attendance with the participants from the different related organizations (hereinafter referred to as "the Participants"), where the Consultant explained the contents of DF/R1.

1.2 Comments, if any, on the DF/R1 will be collected by MOE/WRMC from the counterpart organizations/Participants and be forwarded to the Consultant through WRMC and JICA Iran Office until the end of August. Necessary modifications by incorporation of the comments will be delivered ten days before the next meeting for the Draft Final Report 2 adding the results of GETFLOWS modelling works (hereinafter referred to as "DF/R2"),.

1.3 Consultant will follow a jointly devised framework to guarantee a more meaningful cooperation of the stakeholders' participation in simulation of scenarios and preparation of the DF/R2. This framework will be drafted and enacted between the Consultant and MOE/WRMC through email communication.

1.4 As a current schedule, the stakeholder meeting for DF/R2 will be held in November 2015, where the Consultant will explain and discuss the contents of DF/R2 with the stakeholder body of the project, and will organize a training workshop with certification on the GETFLOWS software in comparison to MIKE-SHE.

1.5 The Consultant will transfer each license of MIKE-SHE and GETFLOWS software to WRMC as well as all the relevant technical documents, manuals...etc.

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1.6 Consultant will provide copies of the DF/R2, at least one week in advance of its trip to Iran, so that comments from the professional members within the organizational and regional stakeholders could be incorporated into the final report and so that this back and forth communication will enhance the level of discussions between the Consultant and MOE/WRMC during the final presentation.

1.7 WRMC requested the support service of the two software namely, MIKE-SHE and GETFLOWS for one year for MIKE-SHE and two years for GETFLOWS starting from the completion of the training.

1.8 Consultant will prepare and gradually transfer GETFLOWS software technical documentation in English language to Dr. Taheri and together and satisfactorily (in terms of quantity and quality) complete the needed documents and finalize the framework and the material for GETFLOWS training session between now and the time for the training session.

1.9 MOE/WRMC requested JICA to extend and expand this internationally important project to save Lake Urmia.

2 Project for Capacity Development on Integrated Water Resources Management

2.1 JICA Mission (hereinafter referred to as "the Mission") and WRMC discussed the schedule for starting the "Technical Cooperation Project for Capacity Development on Integrated Water Resources Management" by JICA (hereinafter referred to as "the Project") as below,

- ✓ Detailed Planning Survey of the Project (hereinafter referred to as "the Survey") will be dispatched by December 2015.
- ✓ After the Survey, necessary administrative procedures such as agreement of Record of Discussion between both sides and procurement of the project team will require approximately 6 months.

2.2 WRMC will provide the latest organizational information such as its structure, responsibilities, the number of staff as well as budgets with particular focus on the deputy of conservation and IWRM offices which will be the important counterpart units. The organization set up to proceed IWRM is a precondition of the Project.

3 Others

3.1 WRMC requested information and references of legislation and/or guidelines in Japan regarding water resources with particular focus on Integrated Water Resources Management.

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3.2 In order to install a monitoring system at the Intelligent Office in Zanjan Province, WRMC requested technical advice and assistance from JICA is started by December 2015.

3.3 Country focus training separated from the Project was requested by WRMC. The Mission will consider it.

3.4 MOE/WRMC expects assistance to Afghanistan's Ministry of Energy and Water, and will update JICA to consider its support based on item the Ⅷ in the Minutes of Meeting on November 11th 2013.

Appendix. 1 Mission Schedule

Participants

WRMC	JICA
Mr. Majid Sayyari	Mr. Katsuji Miyata
m. sayyari	宮田克二
Ms. Maryam Movahedinia	Mr. Kenji Nagata
	Mr. Shinya Goto

Witness by

MOE

Dr. Bahram Taheri

Bahram Taheri

B.T.

Japan International Cooperation Agency

Appendix 1

Schedule of Workshop for Dam control in Zanjan and DF/R1 mission of Lake Urmia data collection survey

No	Date		MLIT and JICA, Mr. Shinya Goto			JICA, Mr.Katsuji Miyata and Mr. Kenji Nagata		
1	7/25	Sat	10:00 15:00	Teheran to Zanjan	Zanjan			
			15:30 18:30	Work Shop 1st day(Zanjan WC)				
2	7/26	Sun	9:00 12:00	Site visiting(Taham dam, hydrogy station)	Zanjan			
			14:30 16:00	Work Shop 2nd day(Zanjan WC)				
3	7/27	Mon	8:00 20:00	Zanjan to Ulmia, Site visiting(Hasanloo dam, Zarine rood drainage network, Channel…etc)	Ulmia			
4	7/28	Tue	8:45 9:45	Meeting(Urmia WC)	Ulmia			
			10:00 14:00	Site visiting (Brandooz Dam, Lake Urmia)				
5	7/29	Wed	AM	Ulmia to Teheran(air plane)	Teheran			
			PM	Meeting (JICA Iran Office)				
6	7/30	Thu	All	Report writing	Teheran			
7	7/31	Fri	All	Report writing	Teheran	22:00	Tokyo/Narita Departure (EK319)	–
8	8/1	Sat	9:00	Meeting with WRMC(Mr.Sayyari) JICA Iran, Mr.Yukihira	Teheran	03:40 7:45 10:25	Dubai arrival Dubai Departure (EK971) Teheran Arrival	Teheran
			PM	Meeting with WRMC(Mr.Sayyari)		PM	Meeting with WRMC(Mr.Sayyari)	
9	8/2	Sun	AM		Teheran	AM		Teheran
			14:00	Meeting with MOE (Dr.Taheri) for GETFLOWS		14:00	Meeting with MOE (Dr.Taheri) for GETFLOWS	
10	8/3	Mon	AM	Steering Committee for Draft Final Report 1 (MIKE-SHE Model)	Teheran	AM	Steering Committee for Draft Final Report 1 (MIKE-SHE Model)	Teheran
				Courtesy call to Director of WRMC, Mr Hajrasooliha			Courtesy call to Director of WRMC, Mr Hajrasooliha	
			PM	Discussion for M/M		PM	Discussion for M/M	
11	8/4	Tue	AM	Sigining the M/M	–	AM	Sigining the M/M	Teheran

Annex 2.1
Population in Administrations (as of 2011)

Province	District	Family	Female	Male	Population
East Azarbaijan	Azar	11,827	19,616	20,302	39,918
East Azarbaijan	Osku	5,553	8,543	8,440	16,983
East Azarbaijan	Ilkhchi	4,735	7,546	7,685	15,231
East Azarbaijan	Basmenj	3,283	5,380	5,810	11,190
East Azarbaijan	Forgiveness	1,677	3,218	2,880	6,098
East Azarbaijan	Bostanabad	4,940	8,693	9,261	17,954
East Azarbaijan	Therefore	23,174	39,640	40,254	79,894
East Azarbaijan	Therefore NEW	1,401	2,319	2,052	4,371
East Azarbaijan	Tabriz	455,494	739,445	755,553	1,494,998
East Azarbaijan	Tasuj	2,288	3,708	3,662	7,370
East Azarbaijan	Khamenei	812	1,299	1,242	2,541
East Azarbaijan	Khdajv (Kharaju, Azarshahr)	430	836	748	1,584
East Azarbaijan	Khosroshahr	3,789	6,327	6,120	12,447
East Azarbaijan	Eunuch	1,154	1,891	1,910	3,801
East Azarbaijan	Duzduzan	897	1,858	1,957	3,815
East Azarbaijan	Zarnaq	1,548	2,804	2,909	5,713
East Azarbaijan	Mirage	13,353	22,250	22,596	44,846
East Azarbaijan	Sardrud	8,076	13,051	13,805	26,856
East Azarbaijan	Sahand	7,342	11,809	12,895	24,704
East Azarbaijan	Cis	1,586	2,769	2,733	5,502
East Azarbaijan	Shabestar	4,824	7,869	7,794	15,663
East Azarbaijan	Sharabian	1,322	2,363	2,374	4,737
East Azarbaijan	Sharafkhane	1,133	1,858	1,727	3,585
East Azarbaijan	Shendabad	2,474	4,508	4,526	9,034
East Azarbaijan	Sufis	2,830	4,590	4,536	9,126
East Azarbaijan	Ajabshir	7,758	13,261	13,019	26,280
East Azarbaijan	Kolvanaq	1,827	3,434	3,358	6,792
East Azarbaijan	Kennan pitcher	917	1,666	1,608	3,274
East Azarbaijan	Gugan	3,564	5,594	5,801	11,395
East Azarbaijan	Leylan	1,858	3,026	3,149	6,175
East Azarbaijan	Maragheh	47,552	81,046	81,229	162,275
East Azarbaijan	Malekan	7,284	12,502	12,810	25,312
East Azarbaijan	Mamaghan	3,606	7,172	6,187	13,359
East Azarbaijan	Kind	1,728	3,011	3,084	6,095
East Azarbaijan	Harris	2,704	5,057	4,766	9,823
East Azarbaijan	Vayqan	1,273	2,132	2,166	4,298
West Azarbaijan	Urmia	197,749	333,363	334,136	667,499
West Azarbaijan	Oshnavieh	8,149	16,367	16,356	32,723
West Azarbaijan	Baroogh	1,142	1,970	2,148	4,118
West Azarbaijan	Bukan	43,269	84,765	85,835	170,600
West Azarbaijan	Tekab	11,749	22,466	21,574	44,040
West Azarbaijan	Chahar Borj	2,496	4,241	4,440	8,681
West Azarbaijan	Khalifan, Erbil	128	227	735	962
West Azarbaijan	Cedar	331	749	781	1,530
West Azarbaijan	Salmâs	23,751	42,575	45,621	88,196
West Azarbaijan	Silvaneh	396	741	749	1,490
West Azarbaijan	Symynh	274	597	576	1,173
West Azarbaijan	Shahin fortress	10,782	19,473	18,923	38,396
West Azarbaijan	Qushchi	844	1,260	1,266	2,526
West Azarbaijan	Farmers	1,154	1,922	1,982	3,904
West Azarbaijan	Mohammadyari	2,423	4,224	4,380	8,604
West Azarbaijan	Mahmoodabad	1,835	3,372	3,308	6,680
West Azarbaijan	Mahabad	38,393	73,642	73,626	147,268
West Azarbaijan	Mentioned	35,066	60,198	62,883	123,081
West Azarbaijan	Nalus	669	1,362	1,576	2,938
West Azarbaijan	Tinsel	21,283	37,690	37,860	75,550
West Azarbaijan	N.	1,961	3,508	3,675	7,183
Kurdistan	Turpentine	37,262	69,882	69,856	139,738
Kurdistan	Master	514	1,225	1,069	2,294
Total		1,087,633	1,847,910	1,874,303	3,722,213

Source: “Statistical Centre of Iran” (http://www.amar.org.ir/Default.aspx?tabid=133)

Annex 2.2
Relationship among Lake Water Level, Water Surface Area and Water Volume

Elevation (MSL +m)	Lake Surface Area (m^2)	Volume (m^3)
1267.1	0	0
1267.5	103,144,984	17,077,233
1268.0	242,911,566	104,220,623
1268.5	514,055,744	286,207,922
1269.0	683,223,550	586,065,090
1269.5	869,296,825	981,072,280
1270.0	1,300,367,520	1,475,107,642
1270.5	2,001,396,972	2,319,996,414
1271.0	2,574,263,090	3,464,022,059
1271.5	2,965,144,322	4,857,746,051
1272.0	3,314,654,364	6,421,741,397
1272.5	3,627,369,647	8,170,557,169
1273.0	3,895,863,619	10,045,895,927
1273.5	4,098,865,924	12,052,549,045
1274.0	4,286,941,138	14,144,350,527
1274.5	4,475,197,260	16,342,643,359
1275.0	4,654,026,379	18,619,245,345
1275.5	4,879,320,642	21,011,342,474
1276.0	5,085,325,023	23,496,769,116
1276.5	5,277,725,478	26,094,794,146
1277.0	5,487,511,407	28,776,678,310
1277.5	5,718,363,239	31,608,124,868
1278.0	5,721,737,605	34,468,613,553

Annex 2.3
Differences of Land Use Area for River Basin between 1987 and 2007

■Land Use in 1987 Unit:km^2

Classification	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	ake Urmia Islan	Lirang Chay	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Zarineh Rud	Zola Chay	Lake Urmia	Whole Basin
Baresoil	1,296.1	4.9	43.2	4.0	30.5	11.4	18.1	22.6	11.9	2.3	103.2	216.1	0.6	1.6	51.9	183.3	44.7	0.0	2,046.6
Dryfarming	1,859.1	65.4	253.6	310.2	4.4	492.3	122.1	313.9	146.3	73.9	276.6	0.1	56.3	43.3	856.0	1,800.2	219.6	0.0	6,893.3
Irrigated Wheat	311.8	114.0	37.3	95.6	1.2	16.1	12.7	97.2	32.6	4.3	10.2	0.6	40.8	35.7	57.0	65.3	45.7	0.0	978.2
Orchard	74.4	26.4	15.4	28.4	0.1	21.2	12.9	19.7	4.9	1.3	12.0	1.2	8.4	6.7	34.3	59.6	24.3	0.0	351.1
Rangeland	8,483.8	949.4	1,538.8	1,464.6	212.9	1,191.7	1,227.9	1,160.1	790.8	276.1	1,245.2	270.4	233.5	487.0	2,462.6	9,206.3	1,725.1	0.0	32,926.2
Residental	80.6	1.2	11.4	5.0	0.6	5.3	3.0	4.6	3.9	0.1	11.9		5.7	17.3	10.6	20.3	18.9	0.0	200.4
Summer crops	489.2	193.6	184.9	173.4	6.6	197.5	100.6	242.9	62.0	14.6	157.1	12.3	111.6	114.5	309.3	447.5	146.2	0.0	2,963.7
Water	88.2	4.5	9.0	7.1	3.5	0.2	8.4	17.6	8.0	2.4	16.2	50.4	0.8	3.8	0.1	40.2	6.5	4,986.0	5,253.1
Total	12,683.3	1,359.5	2,093.6	2,088.3	259.8	1,935.7	1,505.8	1,878.6	1,060.4	375.1	1,832.4	551.2	457.8	710.0	3,781.8	11,822.7	2,231.0	4,986.0	51,613

■Land Use in 2007 Unit:km^2

Classification	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	ake Urmia Islan	Lirang Chay	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Zarineh Rud	Zola Chay	Lake Urmia	Whole Basin
Baresoil	1,278.4	8.2	33.1	5.8	19.1	12.5	7.8	41.8	21.2	4.3	107.0	303.0	2.6	6.0	10.7	37.7	35.2	0.0	1,934.4
Dryfarming	2,407.5	191.2	347.2	265.5	2.7	623.6	117.5	334.5	170.1	42.5	326.2	16.1	95.3	88.0	865.3	2,297.9	294.7	0.0	8,485.7
Irrigated Wheat	708.0	68.7	76.5	146.0	1.3	102.7	41.7	83.6	13.6	13.6	50.6	5.8	27.6	14.6	185.8	202.8	45.8	0.0	1,788.8
Orchard	171.3	178.1	73.6	116.3	0.9	60.2	53.2	152.4	32.7	4.3	37.4	1.3	66.9	55.9	79.5	133.4	94.0	0.0	1,311.4
Rangeland	7,520.0	836.6	1,340.3	1,350.8	229.6	894.5	1,148.4	1,122.7	784.8	290.7	1,147.2	203.2	197.7	446.4	2,281.8	8,663.8	1,650.7	0.0	30,109.3
Residental	137.8	1.4	22.4	11.0	0.1	11.2	7.6	5.3	3.5	0.1	16.7	0.1	10.4	31.2	19.8	32.9	20.2	0.0	331.6
Summer crops	443.9	74.6	194.2	175.4	5.8	230.6	116.3	138.3	34.1	19.5	147.3	19.0	57.2	63.5	336.9	410.7	90.2	0.0	2,557.4
Water	16.3	0.5	6.3	17.5	0.2	0.3	13.3	0.1	0.4	0.1	0.2	2.7	0.0	4.4	2.1	43.6	0.1	4,986.0	5,094.0
Total	12,683.3	1,359.3	2,093.6	2,088.3	259.8	1,935.7	1,505.8	1,878.6	1,060.4	375.1	1,832.4	551.2	457.8	710.0	3,781.8	11,822.7	2,231.0	4,986.0	51,613

■Difference Unit:km^2

Classification	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	ake Urmia Islan	Lirang Chay	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Zarineh Rud	Zola Chay	Lake Urmia	Whole Basin
Baresoil	-17.7	3.3	-10.2	1.7	-11.4	1.1	-10.3	19.1	9.3	2.0	3.8	86.9	2.0	4.4	-41.2	-145.7	-9.5	0.0	-112.3
Dryfarming	548.4	125.8	93.6	-44.7	-1.6	131.3	-4.6	20.6	23.8	-31.4	49.5	15.9	39.0	44.7	9.3	497.7	75.1	0.0	1,592.4
Irrigated Wheat	396.2	-45.3	39.2	50.4	0.1	86.6	29.0	-13.6	-19.0	9.3	40.4	5.2	-13.2	-21.1	128.9	137.5	0.1	0.0	810.5
Orchard	96.9	151.7	58.2	87.9	0.8	39.1	40.3	132.7	27.8	3.0	25.4	0.1	58.5	49.2	45.2	73.8	69.7	0.0	960.4
Rangeland	-963.7	-112.8	-198.4	-113.8	16.6	-297.2	-79.5	-37.4	-6.0	14.6	-98.0	-67.1	-35.8	-40.5	-180.8	-542.6	-74.4	0.0	-2,816.9
Residental	57.2	0.2	11.0	6.0	-0.4	5.9	4.5	0.7	-0.5	0.0	4.8	0.1	4.7	13.9	9.2	12.6	1.4	0.0	131.2
Summer crops	-45.3	-119.0	9.3	2.0	-0.7	33.2	15.7	-104.7	-27.9	4.9	-9.8	6.7	-54.4	-51.1	27.6	-36.8	-56.0	0.0	-406.3
Water	-71.9	-4.0	-2.7	10.4	-3.3	0.0	4.9	-17.5	-7.7	-2.4	-16.0	-47.7	-0.8	0.5	1.9	3.5	-6.4	0.0	-159.1

■Indrease Ratio Unit:%

Classification	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	ake Urmia Islan	Lirang Chay	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Zarineh Rud	Zola Chay	Lake Urmia	Whole Basin
Baresoil	98.6	166.9	76.5	142.9	62.7	109.9	43.2	184.5	178.8	186.9	103.7	140.2	422.4	372.3	20.6	20.6	78.7	-	94.5
Dryfarming	129.5	292.3	136.9	85.6	62.4	126.7	96.2	106.6	116.3	57.5	117.9	11,428.8	169.3	203.3	101.1	127.6	134.2	-	123.1
Irrigated Wheat	227.1	60.3	205.1	152.7	105.5	637.5	329.0	86.0	41.7	314.1	495.7	961.2	67.6	40.9	326.2	310.4	100.2	-	182.9
Orchard	230.2	674.8	479.1	409.7	940.8	284.5	412.2	773.6	671.4	334.1	312.6	105.8	800.5	829.6	231.7	223.9	387.0	-	373.5
Rangeland	88.6	88.1	87.1	92.2	107.8	75.1	93.5	96.8	99.2	105.3	92.1	75.2	84.7	91.7	92.7	94.1	95.7	-	91.4
Residental	170.9	114.0	196.3	221.9	22.4	212.4	248.5	116.0	88.2	75.5	139.9	-	181.7	180.4	187.0	161.9	107.2	-	165.5
Summer crops	90.7	38.5	105.0	101.2	88.9	116.8	115.6	56.9	55.0	133.3	93.8	154.2	51.3	55.4	108.9	91.8	61.7	-	86.3
Water	18.5	10.4	70.0	247.6	6.7	118.3	158.3	0.6	4.7	2.1	1.0	5.4	1.1	113.6	1,619.2	108.6	1.9	100.0	97.0

*Prepared by JICA Survey Team based on data provided by WRMC

Annex 2.4
Averages of Monthly Precipitation, Monthly Mean Air Temperature and Monthly Pan Evaporation in Urmia and Tabriz

City	Urmia					Tabriz				
Item	Annual Precipitation	Annual Evaporation	Annual Maximum Temperature	Annual Minimum Temperature	Annual Average Temperature	Annual Precipitation	Annual Evaporation	Annual Maximum Temperature	Annual Minimum Temperature	Annual Average Temperature
Unit	mm	mm	Degree	Degree	Degree	mm	mm	Degree	Degree	Degree
1980			29.4	-8	11.1			31.7	-8.9	12.5
1981			27	-6.5	11.1			30.2	-5.7	12.3
1982			24.8	-10.9	8.8	89		31	-11.4	10.5
1983			27.2	-15.3	9.8	143.2		32.9	-15.4	11.5
1984			26.5	-6.4	10.7	172.4		30.3	-7.8	11.9
1985			25.8	-10.4	11.0	286		30	-12.4	12.1
1986			27.2	-7.3	11.2	321.5		32.3	-11.6	12.2
1987			26.4	-6.5	11.5	285.6		30.2	-9.7	12.7
1988			25.8	-8.9	10.6	265.1		30.4	-12	11.5
1989			28.5	-11.1	11.1	175.8		32.7	-13.9	12.4
1990			26.9	-8.5	11.1	143.9		31	-9.7	12.4
1991			27.8	-6.6	11.1	157		32.7	-6.8	12.5
1992	134	1244.4	26.1	-9.7	9.5		1270.7	29.9	-9.1	10.8
1993	499	1474	26.3	-9.5	9.9		1876	29.7	-10.9	11.2
1994	406	1365	24.8	-8.1	11.3	95.5	1865.5	27.9	-15	12.3
1995	233	1294	25.4	-4.3	11.6	218.9	2054.9	30.6	-5.2	12.8
1996	328	1411.7	26.8	-7.6	11.7	258	2020.5	31.7	-8.6	13.1
1997	304.5	1246.7	26	-8.1	11.3	164.5	1848.3	30.7	-10.8	12.2
1998	172.5	1170.5	27.6	-6.1	12.4	222.5	2034.2	30.9	-9.3	13.6
1999	104	1345.8	29.4	-2	12.7	245.9	2025.5	32	-3.7	13.6
2000	143.5	1494.5	28.4	-7.2	12.3	191.2	2182.8	31.5	-8.8	13.4
2001	178.5	1475.4	28.5	-7.2	13.0	180.9	2244.3	31.8	-6.1	14.0
2002	340.5	1309.4	26.5	-9.4	12.0	263.4	1941	28.6	-12.8	12.8
2003	416.5	1442.7	27.8	-5	11.7	230.5	1892.6	33.2	-5.8	13.3
2004	393.5	1298.3	25.8	-9.5	11.5	297.6	2076.8	30.8	-10.4	13.6
2005	188	1473.3	26.5	-9.9	11.6	193.5	1899.1	30.7	-8.2	13.4
2006	631.5	1489.2	27.2	-9.7	11.9	229.9	2036.7	32.9	-11.1	13.4
2007	166.5	1308	26.9	-10.4	11.6	214.7	2040.8	30.6	-11.5	12.7
2008	163.5	1525.2	28.6	-11.2	11.7	209.6	2063.7	34	-12.2	13.2
2009	124.5	1157.6	25.6	-9.9	11.7	243.1	2012.2	30.3	-9.4	13.1
2010	90.5					228.7				
2011	190					323.6				
Ave.	274	1363	27	-8	11	212	1966	31	-10	13

*Source: Precipitaion:WRMC, Air Temparature and Pan Evaporation: IMO
*Prepared by JICA Survey Team based on data provided by WRMC

Annex 2.5

Average Annual Precipitation at Rainfall Gauging Station

No	Code	St. Name	Lon (Degree)	Lat (Degree)	Elevation (MSL +m)	Average Anuual Precipitation (mm)	No	Code	St. Name	Lon (Degree)	Lat (Degree)	Elevation (MSL +m)	Average Anuual Precipitation (mm)
1	31-001	Sahzab	47.664444	38	1850	302	123	33-203	Kileh shin	46.011667	36.101944	1743	790
2	31-003	Sarab asbaghran(mir ku)	47.52	38.03	2000	293	124	33-205	Bastam	46.43333	35.85	1704	727
3	31-004	Sarab	47.516667	37.866667	1680	189	125	33-308	Fgazal ghabr	46.05	36.96666	1723	333
4	31-005	Saransar	47.48	37.88	1660	194	126	33-334	Ghalghanlu	46.26666	36.516666	2022	482
5	31-006	Khosroshah	46.05	37.97	1310	276	127	33-335	Fguzlu olia	46.46666	36.95	1750	309
6	31-007	Bostanabad	46.833333	37.85	1750	260	128	33-336	Heydar abad	46.233333	36.9	2300	397
7	31-009	Ghurigol	46.7	37.916667	1850	327	129	33-337	Zareh shuran	47.04	36.42	1800	448
8	31-011	Nahand	46.475278	38.209444	1570	293	130	33-345	Pol badamlu	46.333333	36.083333	2155	588
9	31-013	Saiid abad	46.599167	37.983333	1875	388	131	33-347	Hasanlu dam	46.183333	36.35	1300	76
10	31-015	Vanyar	46.4	38.12	1450	266	132	33-508	Ghamishleh	46.4	35.97	1850	601
11	31-017	Anakhatun	46.27	38.15	1400	249	133	33-526	Ghoz karpi	46.57	36.63	1350	404
12	31-018	Basmanj	46.47	37.98	-	322	134	33-528	Tazeh kand ajorlu	46.75	36.98	1850	659
13	31-019	Lighavan	46.433333	37.833333	2200	331	135	33-530	Noruz lu dam	45.633333	36.533333	1330	293
14	31-021	Harvi	46.483333	37.916667	1920	278	136	33-917	Nezam abad	45.616667	36.7	1283	276
15	31-022	Sahlan	46.116667	38.183333	1350	255	137	33-919	Santeh	46.55	36.17	1434	463
16	31-025	Pol davazdah dahaneh	46.22	38.12	1345	307	138	33-921	Mahmud abad	45.733333	36.65	1500	340
17	31-027	Pardil (Abshur)	46.2	38.2	1400	217	139	33-923	Jan agha	45.7	36.683333	1421	320
18	31-031	Zinjenab	46.316667	37.859444	2200	321	140	33-925	Vchalkhmaz	45.716667	36.766667	1390	332
19	31-032	Mirkuh haji	47.504722	38.042222	1830	348	141	33-973	Pol gheshlagh	45.718611	36.996389	1472	466
20	31-033	Pol sar dorud	46.15	38.02	1400	286	142	33-975	Golestan sofla	46.55	37.32	1750	390
21	31-034	Tazeh kand (khosro shahr)	46.1	38.18	-	160	143	33-979	Sari gheshlagh	46.33	37.13	-	448
22	31-035	Esfanjan	46.17	37.9	1650	288	144	33-987	Ahmad abad saghez	45.033333	37	1719	338
23	31-036	Afshord	46.55	38.333333	2000	318	145	34-001	Dehabkar	45.62	36.72	1400	561
24	31-037	Ghermezigol	46.113889	37.722222	1673	305	146	34-002	Afan	45.183333	37.116667	1630	570
25	31-039	Unknown	45.958056	37.798333	1340	238	147	34-003	Kuter	45.083333	37.033333	1380	396
26	31-041	Tabriz	46.366667	38.066667	1500	236	148	34-004	Giah darvan	45.383333	36.8	1744	488
27	31-042	Amanlu	46.68	37.83	-	307	149	34-005	Bitas	45.133333	36.966667	1444	406
29	31-044	Asb khoran	46.966667	38.333333	1940	308	150	34-007	Pol sorkh mahabad	45.383333	36.966667	1344	351
30	31-045	Akholeh	46.05	38.02	1310	274	151	34-009	Gard yaghub	45.15	37.083333	1280	278
31	31-046	Jazireh eslami	45.418056	37.821944	1280	160	152	34-011	Pi ghaleh	45.65	36.9	1500	492
32	31-053	Haris	47.128333	38.25	1962	349	153	34-012	Durbeh	45.3	37.083333	1905	372
33	31-056	Barazin	47.116667	38.266667	1962	320	154	34-013	Oshnavieh	45.683333	37.016667	1480	451
34	31-059	Gomnanj	46.35	38.45	1800	471	155	34-014	Masu	45.75	36.483333	1355	409
35	31-098	Gugan	45.92	37.78	1250	261	156	34-015	Chapar abad	45.266667	36.983333	1470	465
36	31-101	Arshtnab	46.733333	37.916667	1850	338	158	34-019	Naghadeh	45.016667	36.95	1340	350
37	31-107	Dam location- nahand chay	46.47	38.18	1572	304	159	34-020	Gard kashan	45.15	36.916667	1695	423
38	31-109	Mehrban- Chekeh chay	47.116667	38.066667	1510	311	160	34-021	Pol bahramlu	45.266667	37.25	1285	304
39	31-113	Diznab	46.733333	37.833333	1910	360	161	34-022	Yuneslu	45.666667	36.633333	1500	360
40	31-117	Markid	46.822778	38.168333	1520	254	162	34-023	Dashkhaneh	45.616667	36.633333	1278	263
41	31-119	Khajeh	46.57	38.15	1500	305	163	34-025	Yarghu	45.73	36.78	1340	282
42	31-527	Pardil	46.2	38.216667	1400	217	164	34-028	Gagesh olia	45.583333	36.6	1778	605
43	31-923	Ghazal gachi	47.343333	37.983333	1684	291	165	34-029	Pieh jik	45.716667	36.566667	1375	361
44	31-925	Alucheh malek	46.25	38.4	1905	393	166	34-031	Jashiran	45.27	36.98	1380	420
45	31-926	Kahal	46.127222	38.375833	1675	363	168	34-039	Sufian	45.566667	36.883333	1520	450
46	31-964	Kordkandi	46.966667	37.966667	1655	278	169	34-042	Dorud sheykhan	45.02	36.95	-	526
47	31-970	Ghueshchi	47.265833	37.784444	2020	540	170	34-045	Nari	45.3	37.083333	1472	317
48	31-971	Khoshknab	47.216667	38.233333	1985	365	171	34-049	Cheshmeh dul eslam abad	45.18	37.13	1900	387
49	31-972	Dozduzan	47.116667	37.95	1655	303	172	34-053	Khatun asti	45.333333	36.883333	1710	487
50	31-973	Bakhshayesh	46.966667	38.116667	1653	291	173	34-055	Siah ghol	45.15	37.35	1700	461
51	31-974	Tarkeh dari	46.716667	38.066667	1655	326	174	34-057	Ziveh	44.9	37.283333	1610	536
52	31-976	Osku	46.116667	37.916667	1500	245	175	34-059	Kamam	44.966667	37.216667	1820	451
53	31-977	Kandovan	46.281111	37.795278	2004	481	177	34-112	Mehmandar	44.966667	37.216667	1350	332
54	31-978	Gombarf	46.233333	37.733333	1995	487	178	34-912	Mohammad shah sofla	45.233333	37.4	1390	304
55	31-979	Shiramin	45.915	37.673889	1485	241	179	34-915	Eslam abad	45.016667	37.5	1380	214
56	32-001	Bandar rahmanlu	45.78	37.52	1250	244	180	34-918	Bayazd abad	45.25	37.6	1500	238
57	32-003	Ajab shir	45.9	37.47	-	289	181	35-001	Ghasemlu	44.7	37.483333	1395	349
58	32-005	Khorma zard	46.15	37.416667	1560	339	182	35-002	Aghbolagh	45.1	37.17	1780	454
59	32-007	Tazeh kand (alavian dam)	46.27	37.47	1600	329	183	35-003	Hashem abad bi bakran	45.216667	37.75	1464	543
60	32-009	Maragheh	46.233333	37.4	1475	336	184	35-005	Dizaj	44.633333	37.716667	1335	379
61	32-011	Chakan	46.32	37.35	1550	338	185	35-006	Zhar abad	44.9	37.666667	1590	556
62	32-013	Bonab (Sufi chay)	46	37.316667	1283	275	186	35-007	Babarud	45.133333	37.716667	1297	348
63	32-015	Yengjeh	46.133333	37.516667	1670	380	187	35-008	Sagregan	44.9	37.3	1480	619
64	32-019	Tajragh	46.1	37.52	1550	474	188	35-009	Mir abad	44.87	37.43	1525	616
65	32-020	Gheshlagh Maragheh	46.25	37.43	-	318	189	35-011	Band orumieh	44.883333	37.6	1411	412
66	32-021	Shishvan	45.88	37.45	1270	301	190	35-013	Kashtiban	45.25	37.55	1285	301
68	32-023	Esfastanj	46.25	37.45	1560	363	191	35-015	Golmankhaneh abshur	44.8	37.616667	1320	252
69	32-031	Alavian dam	46.266667	37.416667	1555	331	192	35-016	Ghurmik	44.63	37.92	-	434
70	32-047	Shirin kandi	46.16	37.01	1300	293	193	35-017	Talin	44.85	37.55	1590	547
71	32-861	Gharkh belagh	47.786944	38.080833	2234	443	194	35-018	Gachi	45.016667	37.483333	1958	310
72	32-962	Hargalan	46.25	37.65	2253	454	195	35-019	Zinalu	45	37.62	1380	312
73	33-000	Saghez organization	46.15	36.15	1600	233	196	35-020	Ghareh lor	44.95	37.67	1350	330
74	33-001	Moghanjagh	46.416667	37.333333	1650	340	197	35-021	Marmisho	44.63	37.58	1750	598
75	33-002	Malekan	46.1	37.133333	1350	263	198	35-023	Barduk	44.57	37.83	1800	397
76	33-003	Gheshlagh amir	46.283333	37.316667	1540	373	199	35-025	Golkani	44.7	37.75	1580	394
77	33-004	Kandelan	46.07	36.25	1550	162	200	35-026	Mush abad	45.3	37.166667	1310	270
78	33-005	Shirin kandi- lilan	46.27	37.02	1380	323	201	35-027	Marz sarv	47.1	36.716667	1650	381
79	33-006	Miadoab dolat abad	46.83	36.92	1410	328	202	35-029	Ni chalan	44.77	37.68	1550	349
80	33-007	Ghabaghlu	46.766667	36.533333	1580	424	203	35-031	Tapik	44.6	38.083333	1410	405
81	33-008	Dash alucheh	46.2596	36.2616	-	337	204	35-033	Abajalu sofla	44.933333	38.233333	1290	281
82	33-009	Pol saghez	46.700833	36.332778	1504	402	205	35-035	Kahriz	44.97	37.87	1910	405
83	33-010	Baba ghazi	46.683333	36.433333	1450	302	207	35-039	Kalhur	44.616667	38.2	1500	336
84	33-011	Dareh panbeh dan	46.483333	36.483333	1400	389	208	35-041	Movana	44.8	37.58	1650	472
85	33-012	Tazeh kand- lelklu	45.92	37.03	1295	299	209	35-043	Chaman	44.78	37.48	1800	589
87	33-014	Takab	47.1	36.4	-	265	210	35-045	Karim abad	44.716667	38.35	1486	402
88	33-015	Pol anian	46.4	36.866667	1438	380	211	35-082	Golmankhaneh Abshirin	45.25	37.6	1252	258
89	33-016	Feyz abad- takab	47.08	36.47	1800	409	212	35-086	orumieh research center	44.883333	38.116667	1385	378
90	33-017	Karim abad	46.6	36.23	1480	457	213	35-100	Orumieh camp	44.933333	38.233333	1381	372
91	33-018	Baghcheh misheh	46.1	36.966667	1936	358	214	35-201	Bandar rashkan	45.32	37.32	-	291
92	33-020	Rahim abad	45.85	37.083333	1864	383	215	35-207	Dalu darband	45.066667	38.066667	1630	305
93	33-021	Safakhaneh	45.1	37.166667	1475	396	216	35-334	Ghalghanlu	46.7	36.9	2122	314
94	33-022	Ghushkhaneh sofla	46.066667	36.783333	2455	437	217	35-335	Ghuzlu olia	46.67	36.22	1821	297
95	33-023	Sari ghamish	45.95	36.433333	1380	374	218	35-337	Zareh shuran	47.0667	36.7	2300	390
96	33-027	Chublucheh	46.116667	36.966667	1370	301	219	35-340	Hasanlu dam	46.28	37.01	1400	216
97	33-029	Miandoab	46.033333	36.983333	1300	320	220	35-961	Ashan	46.3	37.5	1853	451
98	33-031	Ghareh papgh	46.516667	36.416667	1283	223	221	36-001	Chehrigh olia	46.366667	37.116667	1655	362
99	33-033	Saghez organization	46.15	36.15	1600	362	222	36-002	Salmas	44.7667	38.1833	1823	265
101	33-035	Dashband bukan	46.496389	36.106667	1318	416	223	36-003	Nazar abad	44.6	38.183333	1620	488
102	33-036	Gezel gonabd	46.1	36.883333	1450	363	224	36-005	ourban	47.283333	36.533333	1835	334
103	33-039	Tazeh kand- miandoab	47.033333	36.466667	1290	234	225	36-006	Sedghian	44.83	38.2	1360	377
104	33-040	Shahid kazemi dam	45.95	36.766667	1437	336	226	36-007	Pol darish	44.82	38.15	1350	304
105	33-041	Zanjir abad	45.683333	36.4	1290	249	227	36-008	Bazhargah	44.78	38.02	1750	622
106	33-042	Rostaman	46.55	36.683333	1501	548	228	36-009	Tamar	45.616667	36.316667	1418	302
107	33-043	Malek kandi	46.12	38.15	1300	320	229	36-010	Kangarlu	44.98	38.22	1320	328
108	33-044	Gheshlagh pol	46.35	36.1	1300	530	230	36-011	Yalghuz aghaj	44.93333	38.23333	1300	185
109	33-045	Pol mamdil	46.15	37.03	1280	420	231	36-014	Shurgol	44.85	38.07	1460	427
110	33-046	Kalb reza khan	46.65	36.583333	1321	285	232	36-050	Ghueshchi	45.03	37.98	1350	580
111	33-047	Gheshlagh	46.2	36.92	1300	412	233	36-222	Ghareh bagh	46.433333	36.2	1520	344
112	33-048	Rahim khan	46.7	36.9	1336	248	234	37-981	Tupchi	45.183333	38.333333	1555	285
113	33-049	Alasghol	46.665278	36.210556	1400	409	235	37-983	Tasuj	45.355	38.318889	1355	288
114	33-050	Manuchehr sanjagh	46	36.47	1400	319	236	38-001	Daryan	45.6	38.233333	1630	361
116	33-052	Talkhab	46.8333	36.8666	1289	168	237	38-002	Sharafkhaneh	45.483333	38.183333	1280	264
117	33-055	Kavlan	45.48333	37.083333	1520	507	238	38-006	Benis- shanjan	45.9	38.35	1650	316
118	33-058	Saiin dej	46.21666	36.88333	1375	313	239	38-008	Alishah	45.7	38.15	1330	251
120	33-071	Mirdeh	46.05722	36.14555	1623	444	240	38-010	Shurdaragh	45.783333	38.316667	1600	395
121	33-081	Kord deh	46.4325	37.51111	-	542	241	38-982	Sufian	45.983333	38.283333	1355	303
122	33-201	Vazmaleh	45.991944	36.174444	1814	497	242	38-984	Shabestar	45.7	38.166667	1405	242

*Prepared by JICA Survey Team based on data provided by WRMC
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Annex 2.6
Monthly Basin Precipitation and Monthly Average Discharge at End Point of the Basins of Inflow Rivers

Basin	Zola chay		Nazlo Chay		Rose Chay		Shahar Chay		Baradoz Chay	
Basin Area (km2)	2,258		1,880		458		712		1,362	
Code	-	36-011	-	35-033	-	35-037	-	35-013	-	35-007
Discharge GS		Yalghuz aghaj		Abajalu sofla		Guyjali aslan		Kashtiban		Babarud
Agression Period	1980-2007		1980-2007		1980-2011		1980-2005		1980-2011	
Influence of Dam	Excluded		Excluded		Excluded		Excluded		Excluded	
	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)
Mar	51.84	2.48	62.10	7.77	63.32	2.13	67.89	5.28	67.31	9.53
Apr	72.50	6.83	77.35	26.36	72.67	3.11	82.84	13.26	85.13	21.03
May	70.08	6.19	60.90	31.80	49.59	2.58	57.97	18.70	53.21	24.36
Jun	25.73	2.38	17.54	12.28	15.87	1.13	18.73	7.68	12.81	10.33
Jul	13.96	2.02	7.61	3.65	6.78	0.47	6.81	0.87	3.87	3.32
Aug	5.30	0.97	3.81	0.49	4.06	0.20	3.97	0.00	3.60	0.95
Sep	6.12	0.48	3.71	0.36	5.73	0.18	4.22	0.00	4.05	0.36
Oct	35.46	0.65	34.89	1.74	36.19	0.48	37.16	0.00	38.16	2.09
Nov	49.01	0.97	63.28	3.90	60.57	0.98	69.07	0.02	61.90	5.47
Dec	29.86	1.11	42.54	3.63	37.24	0.84	43.50	0.16	45.22	5.08
Jan	28.21	1.20	42.84	3.35	41.78	0.84	45.50	0.30	45.45	4.80
Feb	32.83	1.32	41.64	3.79	41.98	1.03	47.46	1.87	49.95	5.23
Basin	Gedar Chay		Mahabad Chay		Simineh Rud		Zarineh Rud		Aji Chay	
Basin Area (km2)	2,091		1,507		3,783		11,838		10,457	
Code	-	34-021	-	34-009	-	33-985	-	33-917	-	31-085
Discharge GS	Pol bahramlu santu			Gard yaghub		Pol bukan		Nezam abad		Sarin dizaj
Agression Period	1980-1987		1980-2011		1980-2011		1980-2011		1980-2011	
Influence of Dam	Excluded		Included		Included		Included		Included	
	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)	Monthly Avegare Precipitation (mm)	Monthly Average Discharge (m^3/s)
Mar	70.10	17.91	59.99	7.85	58.15	38.75	64.76	68.77	37.05	7.56
Apr	68.86	45.57	78.08	18.77	72.08	28.58	76.55	165.39	57.95	8.98
May	61.69	49.10	40.36	7.30	42.62	10.13	50.57	97.80	55.68	15.85
Jun	10.47	14.37	9.16	2.31	8.51	1.67	10.14	10.59	18.88	0.97
Jul	1.27	1.81	3.22	2.28	5.20	0.23	5.07	5.15	11.59	0.47
Aug	0.55	0.17	1.69	2.59	2.32	0.10	3.21	3.55	7.25	0.10
Sep	0.98	0.18	4.01	2.91	3.47	0.19	3.79	4.05	8.92	0.41
Oct	45.83	2.36	33.03	3.23	30.38	0.51	32.53	4.98	29.25	1.21
Nov	75.38	6.59	59.41	3.80	57.96	3.29	58.24	11.83	34.34	1.13
Dec	53.91	8.46	45.43	2.61	44.08	5.09	47.51	16.07	23.38	2.08
Jan	43.62	6.74	46.30	2.84	41.95	8.65	47.38	28.58	25.39	1.56
Feb	61.75	8.04	48.99	3.67	44.55	22.39	52.21	32.26	26.99	3.14

*Prepared by JICA Survey Team based on data provided by WRMC
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Annex 2.7
Average Runoff Depth at Discharge Gauging Stations

No	Station Name	Basin Name	Average Discharge (MCM)	Catchment Area (km^2)	Runoff Depth (mm)	No	Station Name	Basin Name	Average Discharge (MCM)	Catchment Area (km^2)	Runoff Depth (mm)
1	Sahzab	Ajichay	27.4	73	375	62	Pol sarugh	Zarineh Rud	209.2	1026	204
2	Sarab Asbaghran	Ajichay	47.8	45	1063	63	Safakhaneh	Zarineh Rud	283.4	2219	128
3	Saransar	Ajichay	137.4	1700	81	65	Sarighamish	Zarineh Rud	1584.8	7160	221
4	Bostan abad	Ajichay	46.4	575	81	67	Ghozkarpi	Zarineh Rud	1834.9	7973	230
5	Nahand	Ajichay	40.0	216	185	69	Chublucheh	Zarineh Rud	142.1	900	158
6	Saiid abad	Ajichay	9.0	224	40	71	Miandoab (zarrineh rud)	Zarineh Rud	1964.4	11400	172
9	Anakhatun	Ajichay	27.3	396	69	73	Dashband bukan	Simine Rud	449.8	2431	185
10	Lighavan	Ajichay	24.6	76	324	75	Miandoab (simineh rud)	Simine Rud	499.7	3368	148
11	Harvi	Ajichay	19.4	186	104	76	Tazeh kand)Miandoab	Simine Rud	125.6	3512	36
13	Pol davazdah dahaneh	Ajichay	559.2	9167	61	80	Alasghol	Zarineh Rud	243.6	1026	237
14	Pardil	Ajichay	72.5	456	159	82	Kavlan	Simine Rud	63.3	100	633
15	Pol sanikh	Ajichay	24.9	498	50	87	Alasghol right branch	Zarineh Rud	103.7	650	160
16	Zinjenba	Ajichay	367.1	43	8538	89	Santeh	Zarineh Rud	272.7	766	356
17	Mirkuh haji	Ajichay	51.1	128	399	90	Mahmud abad (ghureh chay)	Zarineh Rud	64.5	384	168
18	Mir kuh	Ajichay	3.8	109	35	91	Jan agha	Zarineh Rud	111.5	467	239
19	Esfanjan	Ajichay	7.4	111	67	92	Chalkhmaz	Zarineh Rud	31.4	631	50
20	Ghermezigol	Ajichay	34.9	103	338	93	Pol gheshlagh	Zarineh Rud	475.4	1105	430
21	Azarshahr	Ajichay	33.8	290	116	97	Dehabkar	Mahabad Chay	136.2	56	2433
22	Akhola	Ajichay	263.9	9752	27	99	Bitas	Mahabad Chay	45.9	203	226
24	Komanj	Ajichay	8.7	97	89	101	Gard yaghub	Mahabad Chay	147.0	1635	90
25	Sarin dizaj	Ajichay	113.5	10622	11	102	Pi ghaleh	Gedar Chay	276.7	225	1230
27	Tavighun	Ajichay	13.3	288	46	103	Oshnavieh (golaz chay)	Gedar Chay	44.0	103	428
28	Dam location	Ajichay	47.8	205	233	104	Chapar abad	Gedar Chay	24.6	43	572
29	Mehrban	Ajichay	30.9	391	79	105	Balghchi	Gedar Chay	20.6	230	90
30	Diznab	Ajichay	16.9	113	150	106	Naghadeh	Gedar Chay	339.2	1565	217
31	Baranj	Ajichay	7.9	484	16	107	Pol bahramlu santu	Gedar Chay	349.5	2090	167
32	Gorgan (Sabri chay)	Ajichay	3.1	49	63	108	Yarghu	Mahabad Chay	5.5	110	50
33	Markid	Ajichay	181.1	5619	32	111	Dorud	Gedar Chay	36.8	63	584
34	Khajeh	Ajichay	16.0	398	40	115	Mohammad shah sofla	Gedar Chay	13.8	203	68
35	Pardil	Ajichay	32.3	459	70	116	Eslam abad (cheshmeh do)	Gedar Chay	4.3	108	40
36	Harz varz	Ajichay	13.8	187	74	117	Bayziad abad	Gedar Chay	9.6	100	96
37	Ajab shir	Gale Chay	68.9	431	160	119	Hashem abad bibakran	Baradoz Chay	228.3	382	598
38	Khorma zard	Gale Chay	9.2	89	104	120	Dizaj (orumieh)	Baradoz Chay	254.6	618	412
39	Tazeh kand	Gale Chay	118.8	263	452	121	Babarud	Baradoz Chay	247.3	1160	213
40	Marafgheh	Gale Chay	99.6	280	356	122	Mir abad (shahr chay)	Sahar Chay	162.3	175	927
41	Chakan	Gale Chay	21.1	104	203	123	Band urmia	Sahar Chay	156.6	418	375
42	Bonab (sufi chay)	Gale Chay	52.3	756	69	124	Kashtiban	Sahar Chay	77.9	670	116
43	Yengjeh	Gale Chay	63.8	249	256	125	Marmisho	Nazlo Chay	149.3	296	504
45	Shishvan	Gale Chay	45.1	534	84	127	Golkani	Nazlo Chay	61.2	635	96
46	Khanian	Gale Chay	2.8	137	21	129	Ni chalan	Nazlo Chay	170.8	1003	170
47	Esfastanj	Gale Chay	6.4	56	114	130	Tapik	Nazlo Chay	373.1	1715	218
48	Kahik darsi	Gale Chay	17.3	42	413	131	Abajalu sofla	Nazlo Chay	230.4	1965	117
51	Bonab)gapi chay(	Gale Chay	29.8	597	50	132	Guyjali aslan	Roze Chay	34.2	331	103
52	Moghanjigh	Lirang Chay	20.7	108	192	133	Movana	Nazlo Chay	5.0	62	81
53	Gheshlagh amir	Lirang Chay	76.0	377	202	135	Karim abad (arzin)	Nazlo Chay	216.5	506	428
54	Shirin kand	Lirang Chay	53.0	691	77	137	Chehrigh olia	Zola Chay	114.4	819	140
55	Ghabghablu	Zarineh Rud	295.9	660	448	138	Nazar abad (darik chay)	Nazlo Chay	28.5	240	119
57	Pol saghez	Zarineh Rud	339.6	782	434	139	Urban	Zola Chay	13.5	114	118
58	Dareh panbeh dan	Zarineh Rud	282.9	1046	270	140	Pol darish	Zola Chay	48.0	1400	34
59	Pol hasan salaran	Zarineh Rud	401.9	1106	363	141	Tamar (orumieh)	Residual 1	5.0	218	23
60	Pol anian (pol saheb)	Zarineh Rud	593.4	1221	486	142	Yalghuz aghaj	Zola Chay	54.9	2204	25
61	Karim abad (kherkhereh)	Zarineh Rud	256.4	1419	181						

*Prepared by JST based on data provided by WRMC
*Calculation period: 1980-2011 (Annual precipitation with 70% of collection rate were employed.)

Annex 2.8
Annual Evaporation at Meteorological Stations and Thiesen Coefficient

No.	Longitude (Degree)	Latitude (Degree)	Code	Station Name	Elevation	Annual Evaporation	Area (km2)	Thiessen Coefficient
0	47.52	38.03	31-003	Sarab asbaghran (mir kuh)	2000	1676	1478.39	0.029
1	46.7	37.916667	31-009	Ghurigol	1850	1158	352.09	0.007
2	46.475278	38.209444	31-011	Nahand	1570	1401	1542.26	0.030
3	46.433333	37.833333	31-019	Lighavan	2200	1012	927.16	0.018
4	46.116667	38.183333	31-022	Sahlan	1350	2079	441.66	0.009
5	46.22	38.12	31-025	Pol davazdah dahaneh	1345	1741	539.34	0.011
6	47.504722	38.042222	31-032	Mir kuh haji	1830	1482	1194.19	0.023
7	46.1	38.18	31-034	Taze kand (khosro shah)	-	1698	506.44	0.010
8	45.958056	37.798333	31-039	Azar shahr	1340	1865	1931.43	0.038
9	46.366667	38.066667	31-041	Tabriz	1500	1320	482.30	0.009
10	46.68	37.83	31-042	Amanlu	-	1218	425.35	0.008
11	45.418056	37.821944	31-046	Jazieh eslami	1280	1836	1485.48	0.029
12	47.116667	38.266667	31-056	Berazin	1962	1401	1606.94	0.032
13	46.733333	37.916667	31-101	Arshtnab	1850	1220	1137.20	0.022
14	46.27	37.47	32-007	Taze kand (ALavian dam)	1600	1959	616.39	0.012
15	46.233333	37.4	32-009	Maragheh	1475	1539	301.81	0.006
16	46	37.316667	32-013	Bonab sufi chay	1283	1697	1387.72	0.027
17	46.25	37.45	32-023	Esfastanj	1560	1562	209.14	0.004
18	46.266667	37.416667	32-031	Alavian dam	1555	2001	92.91	0.002
19	46.03	37.3	32-035	Bonab (Gapi chay)	-	1727	655.54	0.013
20	46.416667	37.333333	33-001	Moghanj	1650	2279	1013.09	0.020
21	46.83	36.92	33-006	Dolat abad (miandoab)	1410	1656	1064.03	0.021
22	46.766667	36.533333	33-007	Ghabghablu	1580	1779	967.86	0.019
23	47.1	36.4	33-014	Takab	-	806	683.72	0.013
24	46.4	36.866667	33-015	Pol anian Pol saheb	1438	2279	1151.63	0.023
25	45.95	36.433333	33-023	Sarighamish	1380	1608	1015.37	0.020
26	46.496389	36.106667	33-035	Dashband bukan	1318	1874	950.91	0.019
27	47.033333	36.466667	33-039	Taze kand miandoab	1290	1625	594.27	0.012
28	45.95	36.766667	33-040	Shahid kazemi dam	1437	2123	1484.70	0.029
29	46.55	36.683333	33-042	Rostaman	1501	1941	1109.34	0.022
30	46.665278	36.210556	33-049	Alasghol	1400	1163	995.68	0.020
31	45.483333	37.083333	33-055	Kavlan'	1520	1493	1510.93	0.030
32	46.057222	36.145556	33-071	Mirdeh	1623	1698	890.66	0.017
33	46.333333	36.083333	33-345	Pol badamlu	2155	1581	960.28	0.019
34	46.183333	36.35	33-347	Hasanlu dam	1300	1090	1162.05	0.023
35	45.633333	36.533333	33-530	Noruz lu dam	1330	2198	597.95	0.012
36	45.383333	36.966667	34-007	Pol sorkh mahabad	1344	1979	985.19	0.019
37	45.65	36.9	34-011	Pi ghale	1500	2009	994.45	0.019
39	45.616667	36.633333	34-023	Dashkhane	1278	1699	437.51	0.009
40	45.716667	36.566667	34-029	Pieh jik	1375	1540	447.74	0.009
41	44.966667	37.216667	34-112	Mehmandar	1350	1862	1423.42	0.028
42	44.7	37.483333	35-001	Ghasemlu	1395	1402	368.87	0.007
43	45.216667	37.75	35-003	Hashem abad bi bakran	1464	1719	595.47	0.012
44	44.9	37.3	35-008	Sagregan	1480	1431	292.93	0.006
45	44.87	37.43	35-009	Mir abad (shahr chay)	1525	1403	463.64	0.009
46	44.8	37.616667	35-015	Golmankhane abshur	1320	1236	546.66	0.011
47	44.95	37.67	35-020	Ghare lor	1350	1471	787.05	0.015
48	47.1	36.716667	35-027	Marz sav	1650	1368	639.60	0.013
49	44.6	38.083333	35-031	Tapik	1410	1966	1892.94	0.037
51	44.8	37.58	35-041	Movana	1650	1155	155.36	0.003
52	45.25	37.6	35-082	Golmankhane ab shirin	1252	1515	1340.88	0.026
53	44.883333	38.116667	35-086	Urmia research center	1385	1551	496.89	0.010
54	44.933333	38.233333	35-100	Armieh camp	1381	1595	445.10	0.009
55	45.066667	38.066667	35-207	Dalu	1630	1783	1008.16	0.020
56	46.366667	37.116667	36-001	Chehrigh olia	1655	1709	1070.88	0.021
57	44.83	38.2	36-006	Sadghian	1360	1164	448.64	0.009
58	45.483333	38.183333	38-002	Sharafkhane	1280	1256	1207.58	0.024
59	45.9	38.35	38-006	Shanjan	1650	1391	467.85	0.009
60	45.7	38.15	38-008	Alishah	1330	1764	1024.68	0.020

*Prepared by JST based on data provided by WRMC
*Calculation period: 1980-2011 (Annual evaporation with 70% of collection rate were employed.)

Annex 3.1
Inventory Lists of Daily Precipitation and Discharge

Inventory of Daily Precipitatoin (1/2)

No	Station Name	Code	Longitude (Degree)	Latitude (Degree)	Elevevation (m)	Province	Basin Name	Working Status	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	Sahzab	31-001	47.6644	38.0000	1850	East Azerbayjan	Aji Chay	Working	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
2	Sarab asbaghran(mir ku)	31-003	47.5200	38.0300	2000	East Azerbayjan	Aji Chay	Working													18	66	64	70	67	69	66	59	61	76	72	81	88	81	75	63	62	51	56	64	57	57	53	61	84	79	81	80	88	92	86	90	94	93	87	92	86	85	65
3	Sarab	31-004	47.5167	37.8667	1680	East Azerbayjan	Aji Chay	Malfunction					19	72	84	88	83	80	81	90	89	71	50	25	88	90	95	79	65	76	65	64						21	76	56																			
4	Saransar	31-005	47.4800	37.8800	1660	East Azerbayjan	Aji Chay	Working																					21	69	45	27	97	92	85	70	79	69	87	82	77	68	77	92	90	88	87	86	93	90	87	85	89	92	84	87	88	91	68
5	Khosroshah	31-006	46.0500	37.9700	1310	East Azerbayjan	Aji Chay	Malfunction													16	59	56	64	69	58	58	70	80	71	62	58	58	58	56	47	53	48	56	52	36	40	27															
6	Bostanabad	31-007	46.8333	37.8500	1750	East Azerbayjan	Aji Chay	Malfunction					23	85	85	89	88	85	82	83	75	68	59																							19	46											
7	Ghurigol	31-009	46.7000	37.9167	1850	East Azerbayjan	Aji Chay	Working											17	65	69	52	55	69	63	47	25	62	61	55	52	48	55	55	73	72	75	76	78	96	82	89	99	97	92	82	70	79	93	90	89	92	95	93	82	89	87	97	70
8	Nahand	31-011	46.4753	38.2094	1570	East Azerbayjan	Aji Chay	Working											27	98	97	68	21	77	79	52														23	82	76	54		17	65	52	24	87	98	100	100	100	100	100	100	100	100	100	72
9	Saiid abad	31-013	46.5992	37.9833	1875	East Azerbayjan	Aji Chay	Working											19	70	65	57	63	48	50	35	22	79	79	72	56	67	79	72	81	57	42			23	82	59			16	59	37	22	89	100	100	100	100	100	100	100	84	52	72
10	Vanyar	31-015	46.4000	38.1200	1450	East Azerbayjan	Aji Chay	Working						25	91	86	89	83	83	72	81	76	88	80	68	77	72	82	75	71	68	75	86	70	72	72	75	66	84	81	85	76	80	81	76	78	77	86	99	97	94	91	93	95	86	96	94	97	70
11	Anakhatun	31-017	46.2700	38.1500	1400	East Azerbayjan	Aji Chay	Malfunction					24	86	92	88	70	68	68	61	72	66	77	73	76	89	90	83	79	79	60	69	73	74	77	52	53	60	55	69	72	55	38															
12	Basmanj	31-018	46.4700	37.9800	-	East Azerbayjan	Aji Chay	Malfunction											23	80	50							19	72	70	67	71	85	76	83	77	70	42	22	82	79	71	66	71	54	24	61											
13	Lighavan	31-019	46.4333	37.8333	2200	East Azerbayjan	Aji Chay	Malfunction						26	90	79	82	84	89	64																																						
14	Harvi	31-021	46.4833	37.9167	1920	East Azerbayjan	Aji Chay	Working						25	91	88	61	27	73									26	95	98	99	97	96	98	98	95	93	87	84	90	97	95	96	97	89	87	84	89	98	100	100	100	100	100	100	100	73	27	72
15	Sahlan	31-022	46.1167	38.1833	1350	East Azerbayjan	Aji Chay	Working											21	78	71	51	48	52	44	51	53	56	53	46	53	62	63	64	71	61	54	61	79	72	79	67	61	72	70	61	60	77	84	85	91	91	93	97	91	93	90	94	70
16	Pol davazdah dahaneh	31-025	46.2200	38.1200	1345	East Azerbayjan	Aji Chay	Working											23	87	83	68	77	42	20	52		17	65	68	69	68	68	66	67	57	60	65	72	71	68	67	63	74	73	60	62	73	89	100	100	100	100	100	100	100	73	27	72
17	Pardil (Abshur)	31-027	46.2000	38.2000	1400	East Azerbayjan	Aji Chay	Malfunction							26	87	70	72	59																																								
18	Zinjenab	31-031	46.3167	37.8594	2200	East Azerbayjan	Aji Chay	Malfunction									24	88	86	83	85	71	75	48	30	21							25	88	76	82	75	72	74	79	80	78	81	65	71	73	62	54	72	64									
19	Mirkuh haji	31-032	47.5047	38.0422	1830	East Azerbayjan	Aji Chay	Working					25	89	92	85	75	73	84	84	90	67	69	76	68	67	78	80	79	73	78	87	85	72	67	56	70	67	81	89	90	90	94	91	81	72	74	89	90	80	81	89	92	93	89	87	83	76	64
20	Pol sar dorud	31-033	46.1500	38.0200	1400	East Azerbayjan	Aji Chay	Working											25	92	88	76	82	83	98	64			26	88	78	87	89	88	90	90	91	90	85	57	26	90	81	82	78	65	79	85	100	100	100	100	100	100	100	100	73	27	72
21	Tazeh kand (khosro shahr)	31-034	46.1000	38.1800	-	East Azerbayjan	Aji Chay	Malfunction											20	81	81	70	85	48																																	
22	Esfanjan	31-035	46.1700	37.9000	1650	East Azerbayjan	Aji Chay	Malfunction																						23	79	67	60	64	64	70	56	55	31																			
23	Afshord	31-036	46.5500	38.3333	2000	East Azerbayjan	Aji Chay	Malfunction					24	61		21	76	81	85	83	87	67	66	68	50														25	67																	
24	Ghermezigol	31-037	46.1139	37.7222	1673	East Azerbayjan	Aji Chay	Working																											18	67	71	65	62	66	62	69	60	52	41	32	52	68	70	54	62	51	67	74	66	80	87	74	57
25	Unknown	31-039	45.9581	37.7983	1340	East Azerbayjan	Aji Chay	Working					18	61	61	68	53	45	48	70	79	67	90	81	88	88	90	82	70	83	84	77	84	82	73	56	57	63	76	85	78	77	72	71	63	48	48	69	84	91	89	84	84	78	70	80	76	71	54
26	Tabriz	31-041	46.3667	38.0667	1500	East Azerbayjan	Aji Chay	Working											15	68	84	74	81	67	76	78	83	93	84	86	84	76	87	88	91	84	79	79	96	94	94	88	70	87	74	42	64	84	91	100	100	100	100	100	100	100	73	27	72
27	Amanlu	31-042	46.6800	37.8300	-	East Azerbayjan	Aji Chay	Working							26	93	66	27	73	26	91	86	79	30						23	83	84	92	95	91	92	82	84	53			25	92	90	88	94	82	79	92	93	93	95	94	87	96	93	97	97	94	68
28	Teymurlu	31-043	45.9200	37.8200	1270	East Azerbayjan	Aji Chay	Malfunction																													18	49				21	77	56		22	54											
29	Asb khoran	31-044	46.9667	38.3333	1940	East Azerbayjan	Aji Chay	Malfunction																																			14	40			22	56										
30	Akholeh	31-045	46.0500	38.0200	1310	East Azerbayjan	Aji Chay	Working																														18	66	69	61	66	63	60	53	48	52	53	68	68	73	70	77	88	76	77	83	61	54
31	Jazireh eslami	31-046	45.4181	37.8219	1280	East Azerbayjan	Lake Urmia Island	Malfunction																						17	69	85	89	78	72	69	45		19	71	68	62	61	77	58															
32	Haris	31-053	47.1283	38.2500	1962	East Azerbayjan	Aji Chay	Working																											22	79	71	61	64	58	52	17	63	61	48	49	43	56	84	100	100	100	100	100	100	100	73	27	72
33	Barazin	31-056	47.1167	38.2667	1962	East Azerbayjan	Aji Chay	Working																																							23	82	91	85	87	88	93	95	92	97	98	99	70
34	Gomnanj	31-059	46.3500	38.4500	1800	East Azerbayjan	Aji Chay	Malfunction																																			22	58															
35	Gugan	31-098	45.9200	37.7800	1250	East Azerbayjan	Aji Chay	Working																																		24	89	94	94	68	25	89	94	96	100	98	96	98	98	100	99	97	70
36	Arshtnab	31-101	46.7333	37.9167	1850	East Azerbayjan	Aji Chay	Malfunction																																			25	88	61														
37	Dam location- nahand chay	31-107	46.4700	38.1800	1572	East Azerbayjan	Aji Chay	Malfunction																						22	79	74	70	94	97	93	88	84	79	87	84	87	88	86	89	81	81	72	83	93	100	100	100	73						
38	Mehrban- Chekeh chay	31-109	47.1167	38.0667	1510	East Azerbayjan	Aji Chay	Malfunction																												19	65	69	78	85	76	75	69	56	45															
39	Diznab	31-113	46.7333	37.8333	1910	East Azerbayjan	Aji Chay	Working																													13	62	89	87	87	86	78	86	80	70	60	77	93	89	84	84	90	91	79	82	87	93	72
40	Markid	31-117	46.8228	38.1683	1520	East Azerbayjan	Aji Chay	Working																												15	58	49	16	58	63	61	51	51	42	56	46	52	69	68	81	74	83	96	83	84	82	88	63
41	Khajeh	31-119	46.5700	38.1500	1500	East Azerbayjan	Aji Chay	Working																																						20	67	70	80	73	74	70	64	64	60	73	75	67	54
42	Pardil	31-527	46.2000	38.2167	1400	East Azerbayjan	Aji Chay	Malfunction																													19	50	23	85	73	60	40	19	52															
43	Ghazal gachi	31-923	47.3433	37.9833	1684	East Azerbayjan	Aji Chay	Working																																									21	78	82	85	85	92	89	97	89	73	49
44	Alucheh malek	31-925	46.2500	38.4000	1905	East Azerbayjan	Aji Chay	Working																																						25	87	82	85	94	84	85	92	89	84	88	91	91	65
45	Kahal	31-926	46.1272	38.3758	1675	East Azerbayjan	Aji Chay	Working																																						18	63	68	74	80	78	78	87	85	87	91	87	87	66
46	Kordkandi	31-964	46.9667	37.9667	1655	East Azerbayjan	Aji Chay	Working																																						20	71	82	93	84	73	70	80	76	80	85	80	69	56
47	Ghueshchi	31-970	47.2658	37.7844	2020	East Azerbayjan	Aji Chay	Working																																						16	62	75	91	81	73	79	82	90	77	85	86	87	67
48	Khoshknab	31-971	47.2167	38.2333	1985	East Azerbayjan	Aji Chay	Working																																						24	81	73	88	83	86	83	89	90	75	65	63	72	60
49	Dozduzan	31-972	47.1167	37.9500	1655	East Azerbayjan	Aji Chay	Working																																						20	69	78	91	93	92	95	96	95	96	95	96	95	72
50	Bakhshayesh	31-973	46.9667	38.1167	1653	East Azerbayjan	Aji Chay	Working																																						16	62	68	87	85	80	85	85	86	77	77	80	78	58
51	Tarkeh dari	31-974	46.7167	38.0667	1655	East Azerbayjan	Aji Chay	Working																																						21	77	80	87	84	87	89	82	92	86	92	97	96	67
52	Osku	31-976	46.1167	37.9167	1500	East Azerbayjan	Aji Chay	Working																																							22	77	82	86	80	69	76	70	70	87	81	75	66
53	Kandovan	31-977	46.2811	37.7953	2004	East Azerbayjan	Aji Chay	Working																																						20	73	81	87	84	84	84	85	95	93	97	96	93	66
54	Gombarf	31-978	46.2333	37.7333	1995	East Azerbayjan	Aji Chay	Working																																						21	78	90	97	96	96	93	91	89	80	89	80	88	64
55	Shiramin	31-979	45.9150	37.6739	1485	East Azerbayjan	Aji Chay	Working																																						20	77	90	96	92	89	92	94	92	92	94	90	98	66
56	Bandar rahmanlu	32-001	45.7800	37.5200	1250	East Azerbayjan	Gale Chay	Working																																						13	50	69	77	76	83	79	82	81	70	77	79	85	63
57	Ajab shir	32-003	45.9000	37.4700	-	East Azerbayjan	Gale Chay	Malfunction											16	58	63	63	77	81	68	58	70	81	75	68	35																											
58	Khorma zard	32-005	46.1500	37.4167	1560	East Azerbayjan	Gale Chay	Working					25	89	90	77	66	70	62	59	43	20	68	56	59	47	42	54	27	29															20	70	66	73	82	75	86	80	79	83	72	81	89	92	64
59	Tazeh kand (alavian dam)	32-007	46.2700	37.4700	1600	East Azerbayjan	Gale Chay	Working																	16	58	59	65	51	65	58	63	58	62	68	53	52	48	73	74	77	76	67	60	55	53	59	66	92	91	82	82	81	80	72	81	85	79	64
60	Maragheh	32-009	46.2333	37.4000	1475	East Azerbayjan	Gale Chay	Working													18	68	75	75	62								20	76	80	67	72	86	81	75	82	84	86	89	81	61	79	72	63	30	7	5	27	100	100	100	73	27	72
61	Chakan	32-011	46.3200	37.3500	1550	East Azerbayjan	Gale Chay	Working					22	84	93	94	85	87	87	88	83	73	84	75	63	71	74	90	85	77	54	24	85	84	93	71	67	77	88	88	95	98	98	95	89	73	85	90	95	99	95	89	91	90	85	87	87	91	68
62	Bonab (Sufi chay)	32-013	46.0000	37.3167	1283	East Azerbayjan	Gale Chay	Malfunction											19	74	76	66	55	58	50	48	44	70	78	89	86	73	79	72	84	77	69	64	81	86	78	68	70	73	59													
63	Yengjeh	32-015	46.1333	37.5167	1670	East Azerbayjan	Gale Chay	Working						23	88	89	57	52	59			21	56								6	20	38	77	66	73	57	51	52	73	78	64	60	61	68	64	78	81	82	91	100	100	100	100	100	100	100	73	27	72
64	Tajragh	32-019	46.1000	37.5200	1550	East Azerbayjan	Gale Chay	Working																						10	46	75	79	77	84	76	84	85	85	85	96	94	88	92	59	20	49	22	83	87	85	80	85	81	68	81	90	89	59
65	Gheshlagh Maragheh	32-020	46.2500	37.4300	-	East Azerbayjan	Gale Chay	Working						25	92	93	88	81	83	80	85	72	83	86	86	84	84	88	88	70																	23	56											
66	Shishvan	32-021	45.8800	37.4500	1270	East Azerbayjan	Gale Chay	Malfunction											21	79	80	82	92	91	85	66			25	90	86	59																											
67	Khanian	32-022	45.9300	37.4800	1317	East Azerbayjan	Gale Chay	Malfunction																						23	81	72	76	81	81	67	69	70	77	75	63	59	58	42															
68	Esfastanj	32-023	46.2500	37.4500	1560	East Azerbayjan	Gale Chay	Malfunction																																				19	50														
69	Alavian dam	32-031	46.2667	37.4167	1555	East Azerbayjan	Gale Chay	Malfunction						24	85	59												20	75	81	77	78	91	86	89	76	73	70	88	59	25	92	93	90	66															
70	Shirin kandi	32-047	46.1600	37.0100	1300	East Azerbayjan	Sofi Chay	Working																																							20	77	88	100	100	100	73						
71	Gharkh belagh	32-861	47.7869	38.0808	2234	East Azerbayjan	Aji Chay	Malfunction																																									25	84	77	83	74	76	50				
72	Hargalan	32-962	46.2500	37.6500	2253	East Azerbayjan	Gale Chay	Working																																							26	92	93	90	85	92	70	53	89	92	94	87	66
73	Saghez organization	33-000	46.1500	36.1500	1600	Kordestan	Zarineh Rud	Working																																						19	65	73	93	93	95	88	88	86	75	79	84	81	64
74	Moghanjagh	33-001	46.4167	37.3333	1650	East Azerbayjan	Sofi Chay	Malfunction																																													27	73					
75	Malekan	33-002	46.1000	37.1333	1350	East Azerbayjan	Sofi Chay	Working																			18	66	71	82	67	68	69	83	95	87	82	76	86	81	81	83	72	58	59	46	55	64	82	100	100	100	100	100	100	100	73	27	72
76	Gheshlagh amir	33-003	46.2833	37.3167	1540	East Azerbayjan	Gale Chay	Working																																							15	60	84	92	89	82	88	91	82	83	87	87	61
77	Kandelan	33-004	46.0700	36.2500	1550	Kordestan	Zarineh Rud	Working										9	43	66	70	63	56	74	75	72	91	92	82	72	53	62	67	74	67	52	50	66	64	78	74	75	72	59	40	51	70	84	73	70	78	83	77	58	73	82	72	59
78	Shirin kandi- lilan	33-005	46.2700	37.0200	1380	East Azerbayjan	Sofi Chay	Malfunction																20	70	68	75	73	80	88	75	59																										
79	Miadoab dolat abad	33-006	46.8300	36.9200	1410	West Azerbayjan	Zarineh Rud	Working											23	78	78	86	73	81	77	71	78	84	80	80	64	68	80	92	79	87	80	67	76	88	84	76	89	84	75	75	58	63	56	54						20	77	87	77	54
80	Ghabaghlu	33-007	46.7667	36.5333	1580	West Azerbayjan	Zarineh Rud	Malfunction						21	80	90	72	68	55																																						
81	Dash alucheh	33-008	46.2596	36.2616	-	Kordestan	Zarineh Rud	Working								15	61	89	92	87	90	88	97	89	73	75	72	73	67	62	60	60	65	92	89	87	82	71	83	81	88	87	90	83	74	69	95	94	95	100	100	100	100	100	100	100	100	100	72
82	Pol saghez	33-009	46.7008	36.3328	1504	West Azerbayjan	Zarineh Rud	Malfunction																																									26	81	38								
83	Baba ghazi	33-010	46.6833	36.4333	1450	West Azerbayjan	Zarineh Rud	Working					24	86	87	84	79	83	93	89	88	87	92	92	61	24	84	77	60	41			25	95	84	58	45	24	86	83	80	90	82	83	78	76	89	96	98	91	91	91	92	95	78	78	82	100	72
84	Dareh panbeh dan	33-011	46.4833	36.4833	1400	West Azerbayjan	Zarineh Rud	Working																																							17	62	55	8	3	24	80	85	69	72	84	100	72
85	Tazeh kand- lelklu	33-012	45.9200	37.0300	1295	West Azerbayjan	Simine Rud	Working										27	95	88	90	82	90	88	85	80	81	80	75	75	41		20	76	81	51						18	73	79	78	58	79	76	83	79	80	72	76	79	69	80	88	100	72
86	Pol hasan salaran	33-013	46.3000	36.0500	1500	Kordestan	Zarineh Rud	Malfunction								23	83	87	86	78	82	80	83	79	70	61	72	88	86	92	77	76	83	52																								
87	Takab	33-014	47.1000	36.4000	-	West Azerbayjan	Zarineh Rud	Malfunction																16	59	58	51	62	66	70	60	67	42																								
88	Pol anian	33-015	46.4000	36.8667	1438	West Azerbayjan	Zarineh Rud	Malfunction																					25	65		24	88	77	73	64	54									25	85	80	94	73								
89	Feyz abad- takab	33-016	47.0800	36.4700	1800	West Azerbayjan	Zarineh Rud	Working										27	93	90	90	86	83	80	42	17	57	61	75	73	61	81	82	83	79	65	73	67	75	84	84	90	92	80	70	60	80	86	91	100	100	100	100	100	100	100	100	100	72
90	Karim abad	33-017	46.6000	36.2300	1480	Kordestan	Zarineh Rud	Malfunction						25	93	95	85	88	93	88	79	70	84	75	50	21	76	76	52	20	76	81	64																								
91	Baghcheh misheh	33-018	46.1000	36.9667	1936	West Azerbayjan	Zarineh Rud	Malfunction										20	74	75	58	53	69	77	53	56	47	62	52	58	45	65	56	81	83	76	71	68	84	78	81	93	87	64												
92	Rahim abad	33-020	45.8500	37.0833	1864	West Azerbayjan	Zarineh Rud	Working						25	93	94	81	83	92	85	84	81	81	80	74	71	66	83	90	94	87	82	74	84	86	81	81	84	84	85	78	88	82	78	77	60	71	74	81	82	75	74	75	81	64	73	86	100	72
93	Safakhaneh	33-021	45.1000	37.1667	1475	West Azerbayjan	Baradoz Chay	Working																	23	75	60	73	85	71	61	85	93	89	77	61	67	62	84	93	86	84	71	73	79	70	77	75	81	72	58	62	59	75	58	66	67	100	72
94	Ghushkhaneh sofla	33-022	46.0667	36.7833	2455	West Azerbayjan	Simine Rud	Working										26	90	76	75	71	79	78	69	65	67	75	69	75	71	81	86	78	89	75	76	76	81	87	84	90	90	79	84	65	81	84	90	96	90	88	87	89	79	82	90	100	72
95	Sari ghamish	33-023	45.9500	36.4333	1380	East Azerbayjan	Simine Rud	Working																																							18	72	87	86	89	81	86	90	84	85	95	100	72
96	Chublucheh	33-027	46.1167	36.9667	1370	West Azerbayjan	Zarineh Rud	Working					27	93	89	85	82	74	84	76	85	81	85	84	43	13	55	79	73	62	64	67	77	78	86	65	58	58	82	82	74	77	70	67	70	51	76	74	80	82	76	68	68	82	69	73	90	100	72
97	Miandoab	33-029	46.0333	36.9833	1300	West Azerbayjan	Simine Rud	Working									20	78	80	80	82	74	73	77	75	72	78	88	52	16	59	64	67	71	78	63	59	58	73	80	92	89	80	76	70	54	67	76	81	85	76	68	61	70	67	70	77	100	72
98	Ghareh papgh	33-031	46.5167	36.4167	1283	West Azerbayjan	Zarineh Rud	Malfunction							25	64																																										
99	Saghez organization	33-033	46.1500	36.1500	1600	Kordestan	Zarineh Rud	Working												22	70	55	65	67	33									16	57	67	72	52	64	67	74	60	53	70	67	57	58	64	78	73	75	77	67	56	35	64	71	100	72
100	Aghbolagh hamedani	33-034	46.0400	36.1000	-	Kordestan	Zarineh Rud	Working																																								27	73					23	83	93	96	92	66
101	Dashband bukan	33-035	46.4964	36.1067	1318	West Azerbayjan	Zarineh Rud	Malfunction																																									27	73								
102	Gezel gonabd	33-036	46.1000	36.8833	1450	West Azerbayjan	Simine Rud	Working					21	75	75	82	82	85	89	75	74	73	62	32	68	64	72	80	79	77	78	78	83	77	80	70	70	68	78	87	92	91	86	81	76	62	78	79	86	100	100	100	100	100	100	100	100	100	72
103	Tazeh kand- miandoab	33-039	47.0333	36.4667	1290	West Azerbayjan	Zarineh Rud	Working																																				19	73	74	49	54	73	78	85	88	73	75	65	50	54	72	100	72
104	Shahid kazemi dam	33-040	45.9500	36.7667	1437	West Azerbayjan	Simine Rud	Working														24	61	22	79	77	73	65	65	49	49	74	62	56	76	61	60	33	18	67	67	70	65	57	46	40	46	60	79	100	100	100	100	100	100	100	100	100	72
105	Zanjir abad	33-041	45.6833	36.4000	1290	East Azerbayjan	Simine Rud	Working																								24	83	80	86	72	75	90	88	90	93	91	83	85	74	89	91	91	100	100	100	100	100	100	100	100	100	72
106	Rostaman	33-042	46.5500	36.6833	1501	West Azerbayjan	Zarineh Rud	Working												24	80	68	69	63	51	60	70	70	48	20	73	70	72	80	80	67	65	58	68	61	59	55	54	65	58	43	43	46	72	83	64	51	59	73	42	61	82	100	72
107	Malek kandi	33-043	46.1200	38.1500	1300	East Azerbayjan	Aji Chay	Working						24	90	86	68	79	84	70	77	77	74	76	63	67	78	94	93	92	91	68		25	90	87	87	76	77	76	79	78	67	66	64	71	75	69	84	88	84	80	81	91	79	84	85	100	72
108	Gheshlagh pol	33-044	46.3500	36.1000	1300	Kordestan	Zarineh Rud	Malfunction					21	79	90	95	80	80	68	78	77	61	66	76	85	75	76	90	96	85	75	79	78	63	79	46	65	64	27	94	86	87	81	73	66	40	34											
109	Pol mamdil	33-045	46.1500	37.0300	1280	East Azerbayjan	Sofi Chay	Malfunction																								25	87	84	85	82	75	85	84	87	64				24	63											
110	Kalb reza khan	33-046	46.6500	36.5833	1321	West Azerbayjan	Zarineh Rud	Malfunction					22	77	75	84	74	57																																							
111	Gheshlagh	33-047	46.2000	36.9200	1300	West Azerbayjan	Zarineh Rud	Working																											17	61	62	83	80	84	84	74	75	65	41	50	65	77	92	88	73	67	72	42	61	81	100	72
112	Rahim khan	33-048	46.7000	36.9000	1336	West Azerbayjan	Zarineh Rud	Malfunction												22	75	63	69	67	43															24	89	64															
113	Alasghol	33-049	46.6653	36.2106	1400	West Azerbayjan	Zarineh Rud	Working																											19	65	61	70	58	64	61	55	62	47	58	75	65	82	81	86	77	76	83	73	72	79	100	72
114	Manuchehr sanjagh	33-050	46.0000	36.4700	1400	West Azerbayjan	Simine Rud	Working																	19	67	74	79	82	74	79	81	76	78	69	62	70	67	48	55	52	40	61	85	79	80	91	93	97	90	81	81	82	84	91	95	100	72
115	Taghi abad	33-051	46.1500	36.9200	-	West Azerbayjan	Zarineh Rud	Working																											18	65	67	81	76	75	76	79	79	74	59	69	73	82	88	77	74	73	71	62	68	82	100	72
116	Talkhab	33-052	46.8333	36.8666	1289	West Azerbayjan	Zarineh Rud	Malfunction																																										2	7							
117	Kavlan	33-055	45.4833	37.0833	1520	West Azerbayjan	Residual 2	Working																											17	56	53	68	69	67	80	75	76	67	40	49	52	54	55	56	58	59	56	37	48	65	100	72
118	Saiin dej	33-058	46.2167	36.8833	1375	West Azerbayjan	Zarineh Rud	Working																																	22	80	81	75	39	59	49	55	100	100	100	100	100	100	100	100	100	72
119	Garmik	33-060	46.0800	36.4500	-	East Azerbayjan	Simine Rud	Working																	26	88	78	79	87	74	65	70	68	61	31	57	81	84	81	72	75	66	62	67	54	75	82	93	92	89	89	90	91	83	82	83	100	72
120	Mirdeh	33-071	46.0572	36.1456	1623	Kordestan	Zarineh Rud	Malfunction						21	56																																												
121	Kord deh	33-081	46.4325	37.5111	-	East Azerbayjan	Sofi Chay	Working																																										27	100	100	100	100	100	100	100	100	100	72

*Prepared by JST based on data provided by WRMC
*Numers for years are collection rate of daily data

Inventory of Daily Precipitatoin (2/2)

No	Station Name	Code	Longitude (Degree)	Latitude (Degree)	Elevevation (m)	Province	Basin Name	Working Status	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
122	Vazmaleh	33-201	45.9919	36.1744	1814	Kordestan	Zarineh Rud	Working																									
123	Kileh shin	33-203	46.0117	36.1019	1743	Kordestan	Zarineh Rud	Working																									
124	Bastam	33-205	46.4333	35.8500	1704	Kordestan	Zarineh Rud	Working																									
125	Fgazal ghabr	33-308	46.0500	36.9667	1723	West Azerbyajan	Simine Rud	Working																									
126	Ghalghanlu	33-334	46.2667	36.5167	2022	West Azerbyajan	Simine Rud	Working																									
127	Fguzlu olia	33-335	46.4667	36.9500	1750	West Azerbyajan	Zarineh Rud	Working																									
128	Heydar abad	33-336	46.2333	36.9000	2300	West Azerbyajan	Zarineh Rud	Working																									
129	Zareh shuran	33-337	47.0400	36.4200	1800	West Azerbyajan	Zarineh Rud	Working																									
130	Pol badamlu	33-345	46.3333	36.0833	2155	West Azerbyajan	Zarineh Rud	Working																									
131	Hasanlu dam	33-347	46.1833	36.3500	1300	West Azerbyajan	Zarineh Rud	Working																									
132	Ghamishleh	33-508	46.4000	35.9700	1850	Kordestan	Zarineh Rud	Malfunction																									
133	Ghoz karpi	33-526	46.5700	36.6300	1350	West Azerbyajan	Zarineh Rud	Malfunction							27	94	92	93	96	97	92	87	92	94	88	93	87	93	89	81	85	88	70
134	Tazeh kand ajorlu	33-528	46.7500	36.9800	1850	West Azerbyajan	Zarineh Rud	Malfunction					25	87	87	92	80	79	86	83	86	54	24	87	84	76	45						
135	Noruz lu dam	33-530	45.6333	36.5333	1330	West Azerbyajan	Mahabad Chay	Malfunction								22	79	84	87	86	81	75	82	62	41	67	70	40					
136	Nezam abad	33-917	45.6167	36.7000	1283	West Azerbyajan	Mahabad Chay	Malfunction																									
137	Santeh	33-919	46.5500	36.1700	1434	Kordestan	Zarineh Rud	Working																									
138	Mahmud abad	33-921	45.7333	36.6500	1500	West Azerbyajan	Mahabad Chay	Working																									
139	Jan agha	33-923	45.7000	36.6833	1421	West Azerbyajan	Mahabad Chay	Working																									
140	Vchalkhmaz	33-925	45.7167	36.7667	1390	West Azerbyajan	Mahabad Chay	Working																									
141	Pol gheshlagh	33-973	45.7186	36.9964	1472	West Azerbyajan	Mahabad Chay	Working																									
142	Golestan sofla	33-975	46.5500	37.3200	1750	East Azerbayjan	Sofi Chay	Working																									
143	Sari gheshlagh	33-979	46.3300	37.1300	-	East Azerbayjan	Sofi Chay	Working																									
144	Ahmad abad saghez	33-987	45.0333	37.0000	1719	West Azerbyajan	Gedar Chay	Working																									
145	Dehabkar	34-001	45.6200	36.7200	1400	West Azerbyajan	Mahabad Chay	Working																									
146	Afan	34-002	45.1833	37.1167	1630	West Azerbyajan	Gedar Chay	Malfunction					24	88	96	91	85	78	92	87	81	74	85	86	87	89	85	93	68	25	64		
147	Kuter	34-003	45.0833	37.0333	1380	West Azerbyajan	Gedar Chay	Working					22	57	25	88	82	67	76	74	79	69	69	71	92	81	75	67					
148	Giah darvan	34-004	45.3833	36.8000	1744	West Azerbyajan	Gedar Chay	Working									22	79	76	70	68	61	67	69	74	63	69	74	80	77	52	65	81
149	Bitas	34-005	45.1333	36.9667	1444	West Azerbyajan	Gedar Chay	Malfunction					24	82	83	95	89	93	94	90	87	93	87	84	88	84	81	78	67	78	77	79	82
150	Pol sorkh mahabad	34-007	45.3833	36.9667	1344	West Azerbyajan	Gedar Chay	Working					24	81	64	63	67	71	73	85	88	73	53	69	71	54	57	66	38	18	66	76	74
151	Gard yaghub	34-009	45.1500	37.0833	1280	West Azerbyajan	Gedar Chay	Working					25	93	95	88	84	86	89	79	85	84	88	90	90	85	81	91	86	79	95	89	93
152	Pi ghaleh	34-011	45.6500	36.9000	1500	West Azerbyajan	Mahabad Chay	Working						23	84	83	78	62	71	69	73	67	79	68	57	49	65	87	54				
153	Durbeh	34-012	45.3000	37.0833	1905	West Azerbyajan	Gedar Chay	Working					19	78	90	92	83	76	85	89	91	91	93	92	95	87	81	80	80	75	78	83	85
154	Oshnavieh	34-013	45.6833	37.0167	1480	West Azerbyajan	Mahabad Chay	Working																		12	51	72	68	75	69	64	64
155	Masu	34-014	45.7500	36.4833	1355	East Azerbayjan	Simine Rud	Working					26	95	95	93	84	77	77	78	82	78	82	83	72	73	83	81	96	91	86	53	19
156	Chapar abad	34-015	45.2667	36.9833	1470	West Azerbyajan	Gedar Chay	Working																		20	52						
157	Balghchi	34-017	45.3700	36.9300	1350	West Azerbyajan	Gedar Chay	Working					23	76	66	76	66	69	64	68	61	51	58	65	61	51	40	55	64	64	61	67	70
158	Naghadeh	34-019	45.0167	36.9500	1340	West Azerbyajan	Gedar Chay	Malfunction																		9	21	24	62				
159	Gard kashan	34-020	45.1500	36.9167	1695	West Azerbyajan	Gedar Chay	Working					21	74	79	86	77	83	88	88	79	71	75	78	70	43	45	85	56	23	75	57	72
160	Pol bahramlu	34-021	45.2667	37.2500	1285	West Azerbyajan	Residual 2	Working																									
161	Yuneslu	34-022	45.6667	36.6333	1500	West Azerbyajan	Mahabad Chay	Working					21	76	77	75	61	54	70	63	53	52	65	61	50	53	42	60	71	72	48	49	66
162	Dashkhaneh	34-023	45.6167	36.6333	1278	West Azerbyajan	Mahabad Chay	Working																									
163	Yarghu	34-025	45.7300	36.7800	1340	West Azerbyajan	Mahabad Chay	Working									14	55	60	59	82	77	75	42									
164	Gagesh olia	34-028	45.5833	36.6000	1778	West Azerbyajan	Mahabad Chay	Malfunction													24	63		25	64	24	88	65					
165	Pieh jik	34-029	45.7167	36.5667	1375	West Azerbyajan	Mahabad Chay	Working																									
166	Jashiran	34-031	45.2700	36.9800	1380	West Azerbyajan	Gedar Chay	Working												25	87	79	81	77	77	72	55	73	78	75	73	64	67
167	Dorud	34-037	45.6000	36.9500	1650	West Azerbyajan	Gedar Chay	Malfunction																									
168	Sufian	34-039	45.5667	36.8833	1520	West Azerbyajan	Gedar Chay	Malfunction																									
169	Dorud sheykhan	34-042	45.0200	36.9500	-	West Azerbyajan	Gedar Chay	Working																									
170	Nari	34-045	45.3000	37.0833	1472	West Azerbyajan	Gedar Chay	Working																									
171	Cheshmeh dul eslam abad	34-049	45.1800	37.1300	1900	West Azerbyajan	Gedar Chay	Working																									
172	Khatun asti	34-053	45.3333	36.8833	1710	West Azerbyajan	Gedar Chay	Malfunction																									
173	Siah ghol	34-055	45.1500	37.3500	1700	West Azerbyajan	Baradoz Chay	Malfunction																									
174	Ziveh	34-057	44.9000	37.2833	1610	West Azerbyajan	Baradoz Chay	Working																									
175	Kamam	34-059	44.9667	37.2167	1820	West Azerbyajan	Baradoz Chay	Working																									
176	Mohammad yar	34-100	45.6200	36.9700	-	West Azerbyajan	Gedar Chay	Working																									
177	Mehmandar	34-112	44.9667	37.2167	1350	West Azerbyajan	Baradoz Chay	Malfunction																					12	30			
178	Mohammad shah sofla	34-912	45.2333	37.4000	1390	West Azerbyajan	Baradoz Chay	Malfunction									19	73	61	23	59	23	81	73	60	42	37						
179	Eslamabad	34-915	45.0167	37.5000	1380	West Azerbyajan	Sahar Chay	Working																									
180	Bayazd abad	34-918	45.2500	37.6000	1500	West Azerbyajan	Sahar Chay	Working																									
181	Ghasemlu	35-001	44.7000	37.4833	1395	West Azerbyajan	Rose Chay	Working																	20	52							
182	Aghbolagh	35-002	45.1000	37.1700	1780	West Azerbyajan	Baradoz Chay	Working							27	93	87	84	87	83	83	72	69	63	60	42	49	60	79	79	64	64	75
183	Hashem abad bi bakran	35-003	45.2167	37.7500	1464	West Azerbyajan	Nazlo Chay	Working						25	90	93	88	84	88	84	77	69	83	85	66	45	27	85	61		23	83	81
184	Diziaj	35-005	44.6333	37.7167	1335	West Azerbyajan	Nazlo Chay	Working									25	93	70	25	87	83	87	79	81	81	83	80	87	82	89	79	85
185	Zhar abad	35-006	44.9000	37.6667	1590	West Azerbyajan	Nazlo Chay	Working					22	81	90	84	78	70	82	79	57	21	77	77	59	51	52	57	75	68	65	51	67
186	Babarud	35-007	45.1333	37.7167	1297	West Azerbyajan	Nazlo Chay	Working							25	92	91	87	89	91	87	79	88	87	73	69	82	90	84	83	70	76	88
187	Sagregan	35-008	44.9000	37.3000	1480	West Azerbyajan	Baradoz Chay	Working					17	66	84	73	73	73	83	77	52	20	66	60	56	36	52	56	59	56	55	59	56
188	Mir abad	35-009	44.8700	37.4300	1525	West Azerbyajan	Sahar Chay	Malfunction					20	76	90	94	92	94	98	93	89	84	87	84	59				23	84	88	75	83
189	Band orumieh	35-011	44.8833	37.6000	1411	West Azerbyajan	Rose Chay	Malfunction					27	100	97	94	91	90	96	94	91	65	25	91	95	68	24	89	66	26	90	84	97
190	Kashtiban	35-013	45.2500	37.5500	1285	West Azerbyajan	Sahar Chay	Malfunction					21	79	88	80	74	84	93	82	87	73	83	78	77	85	82	78	81	87	86	82	89
191	Golmankhaneh abshur	35-015	44.8000	37.6167	1320	West Azerbyajan	Nazlo Chay	Malfunction												27	87	71	86	82	57								
192	Ghurmik	35-016	44.6300	37.9200	-	West Azerbyajan	Nazlo Chay	Working										25	87	83	72	70	82	62	46	81	83	74	71	69	74	47	20
193	Talin	35-017	44.8500	37.5500	1590	West Azerbyajan	Rose Chay	Malfunction						27	92	77	83	90	86	86	80	62	64	68	68	70	64	76	74	56	62	44	
194	Gachi	35-018	45.0167	37.4833	1958	West Azerbyajan	Sahar Chay	Malfunction										24	86	84	78	65	56										
195	Zinalu	35-019	45.0000	37.6200	1380	West Azerbyajan	Rose Chay	Working								24	87	85	87	74	71	67	76	62	67	64	48	63	63	67	60	65	60
196	Ghareh lor	35-020	44.9500	37.6700	1350	West Azerbyajan	Nazlo Chay	Malfunction										20	73	79	82	72	84	86	76	73	78	77	59				
197	Marmisho	35-021	44.6300	37.5800	1750	West Azerbyajan	Nazlo Chay	Malfunction										21	77	71	62	56	78	84	78	78	77	79	87	86	92	83	89
198	Banfuk	35-023	44.5700	37.8300	1800	West Azerbyajan	Nazlo Chay	Malfunction											23	85	83	72	89	92	84	78	81	72	43				
199	Golkani	35-025	44.7000	37.7500	1580	West Azerbyajan	Nazlo Chay	Malfunction							21	70	56	59	68	66	71	59	70	67	51	34	44	49					
200	Mush abad	35-026	45.3000	37.1667	1310	West Azerbyajan	Residual 2	Malfunction									19	76	91	87	86	83	86	79	75	73	72	81	77	79	75	72	65
201	Marz sarv	35-027	47.1000	36.7167	1650	West Azerbyajan	Zarineh Rud	Working						25	86	85	89	84	87	85	79	69	76	76	79	77	79	80	76	75	72	69	66
202	Ni chalan	35-029	44.7700	37.6800	1550	West Azerbyajan	Nazlo Chay	Working									16	70	88	86	85	79	86	78	74	61	19	68	71	62	54	23	83
203	Tapik	35-031	44.6000	38.0833	1410	West Azerbyajan	Zola Chay	Malfunction						27	92	79	81	81	88	77	82	70	84	79	77	59	54	61	67	76	55		
204	Abajalu sofla	35-033	44.9333	38.2333	1290	West Azerbyajan	Zola Chay	Working					21	81	92	88	81	59		22	70	51	68	74	75	64	55	65	66	66	56	55	82
205	Kahriz	35-035	44.9700	37.8700	1910	West Azerbyajan	Residual 1	Working							22	80	80	78	85	83	80	65	73	71	66	59	68	71	77	78	78	74	82
206	Pol ozbak	35-037	45.1800	37.6500	1285	West Azerbyajan	Rose Chay	Malfunction									24	87	83	73	65	59	70	72	65	68	64	77	70	61			
207	Kalhur	35-039	44.6167	38.2000	1500	West Azerbyajan	Zola Chay	Malfunction																						14	49	43	65
208	Movana	35-041	44.8000	37.5800	1650	West Azerbyajan	Nazlo Chay	Working									24	62				18	62	64	55	44	46	47	51	56	57	45	54
209	Chaman	35-043	44.7800	37.4800	1800	West Azerbyajan	Rose Chay	Malfunction													22	81	82	55	10	41	55	85	94	88	72	70	78
210	Karim abad	35-045	44.7167	38.3500	1486	West Azerbyajan	Zola Chay	Malfunction																		17	70	81	62	62	68	79	55
211	Golmankhaneh Abshirin	35-082	45.2500	37.6000	1252	West Azerbyajan	Sahar Chay	Working																		22	81	79	66	68	58	59	66
212	orumieh research center	35-086	44.8833	38.1167	1385	West Azerbyajan	Residual 1	Working																									
213	Orumieh camp	35-100	44.9333	38.2333	1381	West Azerbyajan	Zola Chay	Malfunction																									
214	Bandar rashkan	35-201	45.3200	37.3200	-	West Azerbyajan	Residual 2	Working						27	98	92	93	93	66	27	89	80	94	92	73	36	45	73	83	88	58		
215	Dalu darband	35-207	45.0667	38.0667	1630	West Azerbyajan	Residual 1	Malfunction																			19	70	74	68	68	63	67
216	Ghalghanlu	35-334	46.7000	36.9000	2122	West Azerbyajan	Zarineh Rud	Malfunction																									
217	Ghuzlu olia	35-335	46.6700	36.2200	1821	Kordestan	Zarineh Rud	Malfunction																									
218	Zareh shuran	35-337	47.0667	36.7000	2300	West Azerbyajan	Zarineh Rud	Malfunction																									
219	Hasanlu dam	35-340	46.2800	37.0100	1400	West Azerbyajan	Lilang Chay	Malfunction																									
220	Ashan	35-961	46.3000	37.5000	1853	East Azerbayjan	Gale Chay	Working																									
221	Chehrigh olia	36-001	46.3667	37.1167	1655	West Azerbyajan	Lilang Chay	Working																									
222	Salmas	36-002	44.7667	38.1833	1823	West Azerbyajan	Zola Chay	Working						26	94	92	86	91	97	96	92	85	79	79	80	87	79	83	73	71	71	88	92
223	Nazar abad	36-003	44.6000	38.1833	1620	West Azerbyajan	Zola Chay	Working																8	48	76	45	90	91	79	75	71	80
224	ourban	36-005	47.2833	36.5333	1835	West Azerbyajan	Zarineh Rud	Working									19	73	84	79	84	88	92	77	93	91	83	87	91	89	83	74	73
225	Sedghian	36-006	44.8300	38.2000	1360	West Azerbyajan	Zola Chay	Working									18	62	55	61	52	58	58	47	70	73	53	66	50	20	69	63	75
226	Pol darish	36-007	44.8200	38.1500	1350	West Azerbyajan	Zola Chay	Malfunction						26	93	88	82	88	81	66	76	73	80	47									
227	Bazhargah	36-008	44.7800	38.0200	1750	West Azerbyajan	Residual 1	Malfunction									17	72	87	77	72	66	63	53	56	52	58	59	58	39	26		
228	Tamar	36-009	45.6167	36.3167	1418	West Azerbyajan	Simine Rud	Malfunction						27	96	87	79	81	83	73	80	67	72	75	64	69	65	80	37				
229	Kangarlu	36-010	44.9800	38.2200	1320	West Azerbyajan	Zola Chay	Working									15	58	67	56	53	45	45	25	26	34	40	44	62	54	37	27	38
230	Yalghuz aghaj	36-011	44.9333	38.2333	1300	West Azerbyajan	Zola Chay	Malfunction						23	81	79	67	76	75	59	64	53	56	50	44	46	50	73	54				
231	Shurgol	36-014	44.8500	38.0700	1460	West Azerbyajan	Residual 1	Working																18	71	75	67	67	64	63	52	59	72
232	Ghueshchi	36-050	45.0300	37.9800	1350	West Azerbyajan	Residual 1	Working																									
233	Ghareh bagh	36-222	46.4333	36.2000	1520	West Azerbyajan	Zarineh Rud	Malfunction						27	91	73	57	49	60	52	51	55	66	47	35	24							
234	Tupchi	37-981	45.1833	38.3333	1555	East Azerbayjan	Residual 3	Working																									
235	Tasuj	37-983	45.3550	38.3189	1355	East Azerbayjan	Residual 3	Working																									
236	Daryan	38-001	45.6000	38.2333	1630	East Azerbayjan	Residual 3	Working																									
237	Sharafkhaneh	38-002	45.4833	38.1833	1280	East Azerbayjan	Residual 3	Working											18	73	84	67	77	78	71	71	81	75	88	78	80	79	76
238	Benis- shanjan	38-006	45.9000	38.3500	1650	East Azerbayjan	Residual 3	Malfunction						24	90	93	84	91	89	87	87	75	80	76	71	42		22	79	79	80	85	88
239	Alishah	38-008	45.7000	38.1500	1330	East Azerbayjan	Residual 3	Working									24	86	88	87	82	73	80	61	75	50			26	68	25	88	88
240	Shurdaragh	38-010	45.7833	38.3167	1600	East Azerbayjan	Residual 3	Malfunction									22	85	94	95	91	82	85	81	94	68		26	88	81	86	93	89
241	Sufian	38-982	45.9833	38.2833	1355	East Azerbayjan	Residual 3	Working																									
242	Shabestar	38-984	45.7000	38.1667	1405	East Azerbayjan	Residual 3	Working																									

No	Station Name	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
122	Vazmaleh																26	95	92	86	88	94	87	91	84	90	70
123	Kileh shin																27	100	100	95	82	81	73	82	91	89	61
124	Bastam																27	100	100	99	93	90	85	81	87	94	69
125	Fgazal ghabr																	27	100	99	95	95	90	88	93	90	64
126	Ghalghanlu																26	87	78	80	82	81	66	77	83	100	72
127	Fguzlu olia																24	85	86	82	79	76	65	71	76	100	72
128	Heydar abad																24	82	78	75	66	58	47	67	74	100	72
129	Zareh shuran															20	76	85	86	83	94	92	90	88	66	30	72
130	Pol badamlu																23	79	74	82	100	100	100	100	100	100	72
131	Hasanlu dam																	27	100	100	100	100	100	100	100	100	72
132	Ghamishleh																		28	71	27	73					
133	Ghoz karpi																										
134	Tazeh kand ajorlu																										
135	Noruz lu dam				18	66	47	23	59																		
136	Nezam abad																						8	18			
137	Santeh	25	81	61	60	64	72	81	63	61	57	79	69	48	57	64	71	77	79	71	72	76	57	66	81	100	72
138	Mahmud abad		10	44	61	65	90	91	84	90	93	92	92	88	93	85	94	94	93	92	93	91	81	81	93	100	72
139	Jan agha							23	83	87	84	78	81	64	66	73	80	88	80	81	79	79	71	82	83	100	72
140	Vchalkhmaz				18	68	75	54	19	65	54	56	64	45	57	56	86	86	81	77	75	82	67	71	83	100	72
141	Pol gheshlagh							24	87	87	79	72	72	56	70	69	76	85	74	73	79	83	67	74	85	100	72
142	Golestan sofla										19	77	77	50	26	93	93	87	81	81	83	84	69	79	91	100	72
143	Sari gheshlagh													19	48		22	77	74	73	76	75	75	79	78	75	61
144	Ahmad abad saghez																23	82	78	72	60	37	70	69	61	67	52
145	Dehabkar													23	81	73	58	21	74	72	73	80	68	79	91	100	72
146	Afan																										
147	Kuter			20	72	78	86	81	87	88	81	83	80	79	83	85	93	95	89	88	91	95	88	90	100	100	72
148	Giah darvan	80	72	52	52	55	77	76	88	90	75	75	72	68	77	74	82	90	85	81	77	92	84	83	93	100	72
149	Bitas	69	87	79	84	75	81	81	80	93	91	87	78	59	72	78	85	89	82	79	76	78	60	38			
150	Pol sorkh mahabad	72	87	69	75	69	78	78	82	75	78	82	78	66	74	78	80	74	74	73	69	84	72	76	93	100	72
151	Gard yaghub	92	96	96	95	92	93	90	92	96	92	90	87	80	84	87	95	100	100	100	100	100	100	100	100	100	72
152	Pi ghaleh	4	15	32	58	52	74	78	75	79	72	78	79	65	73	82	93	92	84	82	85	81	65	78	90	100	72
153	Durbeh	78	88	78	75	78	92	91	88	82	90	85	83	75	80	85	90	100	100	100	100	100	100	100	100	100	72
154	Oshnavieh	32	20	45	67	70	81	83	83	81	87	84	75	71	57	59	71	74	73	72	73	84	60	72	86	100	72
155	Masu	76	90	77	85	82	96	93	92	93	94	87	81	74	73	75	54			27	100	100	100	100	100	100	72
156	Chapar abad	18	66	65	66	67	74	75	57	67	79	81	77	61	73	75	82	76	70	73	72	72	58	64	77	100	72
157	Balghchi	76	76	66	72	70	83	68	74	74	76	66	65	62	63	59	70	73	77	71	73	78	57	57	72	100	72
158	Naghadeh																										
159	Gard kashan	87	86	70	62	62	77	75	91	84	75	84	77	59	65	76	82	88	87	82	84	85	80	80	86	100	72
160	Pol bahramlu		4	34	74	73	91	79	74	78	76	83	84	67	74	76	88	87	86	73	76	76	72	82	88	100	72
161	Yuneslu	63	79	62	63	58	70	75	60	62	58	63	56	36	39	45	62	62	69	61	54	61	41	47	63	100	72
162	Dashkhaneh			16	59	64	78	78	77	78	71	74	65	52	60	67	64	70	73	70	75	72	56	59	77	100	72
163	Yarghu	3	11	31	58	53	81	94	84	82	83	83	78	52	54	65	81	100	100	100	100	100	100	100	100	100	72
164	Gagesh olia																										
165	Pieh jik				19	49		25	85	72	68	68	78	68	75	76	80	84	81	82	87	88	90	93	98	100	72
166	Jashiran	24	22	80	77	63	83	90	78	76	78	69	62	45	55	58	84	100	100	100	100	100	100	100	100	100	72
167	Dorud																18	69	70	45							
168	Sufian													24	63	21	56										
169	Dorud sheykhan		2	28	71	76	93	87	91	90	95	91	92	64	25	89	90	90	90	81	86	76	66	81	98	100	72
170	Nari			18	64	66	83	88	81	88	84	75	84	76	67	72	73	76	79	72	67	79	66	59	65	100	72
171	Cheshmeh dul eslam abad			22	67	41	47	60	40	24	89	83	45	37	43	64	72	73	75	55	66	71	65	56	72	100	72
172	Khatun asti																18	70	74	38							
173	Siah ghol										24	86	83	68	81	84	88	89	90	79	72	61					
174	Ziveh										17	70	75	61	79	83	88	84	80	74	79	87	65	78	83	100	72
175	Kamam										22	81	72	54	72	77	92	91	88	83	83	91	81	78	90	100	72
176	Mohammad yar										21	79	81	67	76	73	84	90	84	78	78	79	71	78	88	100	72
177	Mehmandar																										
178	Mohammad shah sofla																										
179	Eslamabad						21	74	71	73	72	77	61	39	53	53	69	81	69	73	75	65	39	45	76	100	72
180	Bayazd abad		2	22	56	48	69	60	53	57	57	63	60	53	51	63	50		15	60	69	68	46	58	74	100	72
181	Ghasemlu	6	20	35	69	60	66	62	56	61	51	61	57	30	45	48	52			14	59	58	34	36	53	100	72
182	Aghbolagh	80	89	82	74	56	65	79	88	84	83	81	69	59	68	77	87	100	100	100	100	100	100	100	100	100	72
183	Hashem abad bi bakran	78	89	78	89	85	93	89	85	88	93	80	67	57	66	81	87	93	89	91	92	94	86	88	98	100	72
184	Diziaj	78	82	70	70	69	86	95	91	95	93	84	83	76	90	90	96	100	100	100	100	73	28	100	100	100	72
185	Zhar abad	65	80	65	52	56	70	75	71	62	64	61	59	55	54	64	68	61	64	56	62	72	58	69	88	100	72
186	Babarud	84	85	77	73	58	67	90	69	26	90	82	77	65	77	91	95	89	94	87	79	84	76	86	86	100	72
187	Sagregan	67	69	74	72	59	75	77	75	79	76	76	64	54	62	61	77	80	81	81	78	88	75	85	91	100	72
188	Mir abad	77	79	48																							
189	Band orumieh	92	92	88	87	81	89	94	93	93	91	93	89	78	85	93	93	100	100	100	73						
190	Kashtiban	80	90	84	84	76	83	82	89	95	83	86	81	59	71	81	82	86	89	81	84	95	83	88	65		
191	Golmankhaneh abshur																										
192	Ghurmik	72	66	62	75	57	79	89	83	84	79	73	52	16	51	43	80	100	100	100	100	100	100	100	73	27	72
193	Talin																										
194	Gachi																										
195	Zinalu	67	64	59	65	57	64	70	65	69	62	58	59	52	47	44	56	65	51	39	46	50	33	79	88	100	72
196	Ghareh lor																										
197	Marmisho	87	88	85	84	69	84	92	79	85	83	76	75	42													
198	Banfuk																										
199	Golkani																										
200	Mush abad	24																									
201	Marz sarv	65	73	62	66	62	70	77	84	83	71	72	65	60	56	71	82	63	69	66	72	73	55	71	86	100	72
202	Ni chalan	83	75	68	75	66	85	87	88	92	85	84	73	67	80	91	93	100	100	100	100	100	100	100	100	100	72
203	Tapik																										
204	Abajalu sofla	78	63	51	62	50	60	67	65	60	40	49	65	66	63	78	77	100	100	100	100	100	100	100	100	100	72
205	Kahriz	80	79	75	79	57	75	85	85	77	66	68	61	58	50	68	82	100	100	100	100	100	100	100	100	100	72
206	Pol ozbak																										
207	Kalhur	48																									
208	Movana	66	75	62	59	49	67	69	78	70	61	69	66	49	59	65	81	92	84	82	70	72	57	70	88	100	72
209	Chaman	74	72	63	65	59	46																				
210	Karim abad																										
211	Golmankhaneh Abshirin	63	67	48	60	68	86	79	40			25	86	75	76	85	87	85	91	88	76	85	78	75	90	100	72
212	orumieh research center												15	40	20	69	80	100	100	100	100	100	100	100	74	30	72
213	Orumieh camp				21	79	84	83	87	97	86	81	82	61	72	81	87	100	100	100	100	100	100	100	73		
214	Bandar rashkan	24	84	84	90	77	85	88	91	92	87	90	81	67	74	83	91	100	100	100	100	100	100	100	100	100	72
215	Dalu darband	63	86	78	70	63	75	75	68	70	59	72	59	55	66	65	80	76	76	57	19						
216	Ghalghanlu														26	91	64										
217	Ghuzlu olia														21	79	64										
218	Zareh shuran														19	72	59										
219	Hasanlu dam														19	72	58										
220	Ashan																			27	73	27	100	100	100	100	72
221	Chehrigh olia													21	70	68	75	74	73	76	79	80	75	75	79	79	68
222	Salmas	93	97	91	89	84	91	92	90	87	92	91	89	78	84	87	98	100	100	100	100	100	100	100	100	100	72
223	Nazar abad	77	75	56	54	70	78	82	78	84	85	88	84	69	61	62	79	89	84	80	73	84	71	83	93	100	72
224	ourban	48	58	38	39	51	65	71	59	60	55	57	57	59	57	67	87	83	87	76	67	73	59	80	90	100	72
225	Sedghian	68	55	33	47	46	58	70	54	47	59	75	67	66	55	61	74	78	72	69	66	63	57	79	84	100	72
226	Pol darish																										
227	Bazhargah																										
228	Tamar																										
229	Kangarlu	37	40	32	43	41	56	61	58	63	54	54	58	56	54	59	79	75	62	65	63	56	45	74	81	100	72
230	Yalghuz aghaj																										
231	Shurgol	68	57	42	39	49	76	77	68	56	51	54	44	39	40	53	75	100	100	100	100	100	100	100	100	100	72
232	Ghueshchi																			27	100	73				27	72
233	Ghareh bagh																										
234	Tupchi																					27	69			27	72
235	Tasuj													21	76	80	95	89	79	73	80	86	83	88	91	84	63
236	Daryan														19	67	81	81	84	78	79	95	86	88	89	78	62
237	Sharafkhaneh	88	83	72	77	72	83	82	84	81	81	83	70	50	62	70	91	94	90	91	91	94	81	88	87	82	63
238	Benis- shanjan	86	80	65	66	45	21	83	84	77	78	82	59	17	62	70	90	100	100	100	100	100	100	100	73		
239	Alishah	92	85	78	85	63	30	41	76	76	58	49	11	39	46	64	91	100	100	100	100	100	100	100	73	27	72
240	Shurdaragh	94	89	84	86	81	86	88	64			19	51														
241	Sufian					23	89	93	85	89	90	91	73	57	23	74	81	88	82	63	69	63	61	73	79	76	55
242	Shabestar													17	61	70	80	79	88	89	91	88	85	84	83	71	56

*Prepared by JST based on data provided by WRMC

*Numers for years are collection rate of daily data

Inventory of Daily Discharge

No	Station Name	Basin Name	River Name	Code	Longitude (Degree)	Latitude (Degree)	Elevation (m)	Province	Working Status	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	Sahzab	Ajichay	Aghmiun chay	31-001	47.665	38.000	1900	East azarbayjan	Working																												27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	28	100	100	100	72
2	Sarab Asbaghran	Ajichay	Tajyar	31-003	47.506	38.028	2000	East azarbayjan	Malfunction							27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73						27	72		27	73									
3	Saransar	Ajichay	Ajichay	31-005	47.479	37.873	1660	East azarbayjan	Malfunction																												27	100	100	100	100	73		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72																
4	Bostan abad	Ajichay	Ojan chay	31-007	46.831	37.834	1750	East azarbayjan	Working																										27	100	100	100	100	100	100	73			27	100	100	100	100	100	100	100	100	100	73			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
5	Nahand	Ajichay	Nahand chay	31-011	46.478	38.206	1596	East azarbayjan	Working																								27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
6	Saiid abad	Ajichay	Saiid abad	31-013	46.582	37.999	1850	East azarbayjan	Working																								27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
8	Vanyar	Ajichay	Ajichay	31-015	46.405	38.115	1450	East azarbayjan	Malfunction			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	
9	Anakhatun	Ajichay	Gomnab chay	31-017	46.277	38.165	1400	East azarbayjan	Working																												27	100	100	73							27	100	100	100	100	100	100	100	73		27	100	72		27	100	100	100	100	100	100	100	100	100	100	100	100	100	72
10	Lighavan	Ajichay	Lighavan	31-019	46.436	37.836	2150	East azarbayjan	Working							27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73			27	73		27	100	100	73		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
11	Harvi	Ajichay	Lighavan	31-021	46.481	37.919	1920	East azarbayjan	Working																								27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
12	Pol mansur (Tabriz)	Zarineh Rud	Mehranrud	31-023	46.469	36.166	1450	Kordestan	Malfunction																													27	100	73																																					
13	Pol davazdah dahaneh	Ajichay	Ajichay	31-025	46.221	38.112	1345	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	100	100	100	73																																						
14	Pardil	Ajichay	Abshur	31-027	46.195	38.205	1400	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	100	100	100	100	73									27	100	100	100	100	100	73	27	73					27	73			27	71									
15	Pol sanikh	Ajichay	Sanikh chay	31-029	46.163	38.185	1352	East azarbayjan	Working																			27	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	73		27	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
16	Zinjenba	Ajichay	Sardorud	31-031	46.321	37.855	2100	East azarbayjan	Working																		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
17	Mirkuh haji	Ajichay	Tajyar sarab	31-032	47.504	38.036	1830	East azarbayjan	Working																																															27	100	100	100	100	100	73	28	100	100	100	100	100	100	73	28	100	100	100	72
18	Mir kuh	Ajichay	Sardorud	31-033	46.157	38.022	1400	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	73																																									
19	Esfanjan	Ajichay	Onsor rud	31-035	46.173	37.905	1650	East azarbayjan	Malfunction																			27	100	100	100	73			27	100	100	100	100	73																																				
20	Ghermezigol	Ajichay	Gambar chay	31-037	46.100	37.730	1800	East azarbayjan	Working																27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
21	Azarshahr	Ajichay	Azarshahr chay	31-039	45.980	37.747	1425	East azarbayjan	Malfunction																27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	73	27	72															
22	Akhola	Ajichay	Ajichay	31-045	46.068	38.026	1310	East azarbayjan	Working																																					27	73	27	73	27	100	100	73		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
23	Pol dalalzan	Ajichay	Mehranrud	31-047	46.330	38.164	-	East azarbayjan	Malfunction																			27	100	73																																														
24	Komanj	Ajichay	Komanj chay	31-059	46.378	38.439	1800	East azarbayjan	Working																																																27	98	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
25	Sarin dizaj	Ajichay	Ajichay	31-085	45.887	37.915	1500	East azarbayjan	Working																																																						27	73	27	100	100	100	100	100	100	100	100	100	72
26	Arshtnab	Ajichay		31-101	46.729	37.919	1850	East azarbayjan	Malfunction																												27	100	100	100	100	100	100	100	100	73																														
27	Tavighun	Ajichay	Saiid abad	31-105	46.501	38.080	1550	East azarbayjan	Malfunction																																													27	100	100	73																		
28	Dam location	Ajichay	Nahand chay	31-107	46.476	38.180	1572	East azarbayjan	Malfunction																																												27	100	100	100	73																					
29	Mehrban	Ajichay	Mehrban (Chekeh chay)	31-109	47.119	38.071	1510	East azarbayjan	Working																																																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
30	Diznab	Ajichay	Ojan chay	31-113	46.733	37.837	1910	East azarbayjan	Working																																													27	100	100	73	27	100	100	100	100	73	27	100	100	100	100	100	73	28	100	100	100	100	100	100	100	72
31	Baranj	Ajichay	Mehranrud	31-115	46.368	38.069	1460	East azarbayjan	Malfunction																																												27	100	100	73	27	100	100	73																		
32	Gorgan (Sabri chay)	Ajichay	Sabri chay	31-116	46.732	37.872	1870	East azarbayjan	Malfunction																																												27	100	100	100	73																					
33	Markid	Ajichay	Ajichay	31-117	46.822	38.172	1520	East azarbayjan	Working																																															27	100	100	98	93	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
34	Khajeh	Ajichay	Pajchay	31-119	46.576	38.155	1500	East azarbayjan	Working																																															27	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
35	Pardil	Ajichay	Sanikh chay	31-527	46.182	38.229	1400	East azarbayjan	Working																																																27	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	72
36	Harz varz	Ajichay	Harzuraz chay	31-529	47.154	38.198	1830	East azarbayjan	Working																																																	27	100	72	1	30	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
37	Ajab shir	Gale Chay	Ghaleh chay	32-003	45.905	37.468	1290	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73																																		
38	Khorma zard	Gale Chay	Mahpari	32-005	46.155	37.414	1530	East azarbayjan	Working																														27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
39	Tazeh kand	Gale Chay	Sufi chay	32-007	46.272	37.462	1610	East azarbayjan	Working																											27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73			27	73	27	100	100	100	100	100	100	100	100	100	100	100	100	72
40	Marafgheh	Gale Chay	Sufi chay	32-009	46.227	37.385	1440	East azarbayjan	Malfunction												27	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73		27	100	73																				
41	Chakan	Gale Chay	Chakan	32-011	46.315	37.336	1570	East azarbayjan	Working																												27	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	84	49	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
42	Bonab (sufi chay)	Gale Chay	Sufi chay	32-013	46.065	37.332	1260	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	100	100	100	73								27	100	100	100	100	100	100	100	100	100	100	100	72															
43	Yengjeh	Gale Chay	Ghaleh chay	32-015	46.115	37.514	1670	East azarbayjan	Malfunction																																					27	100	100	100	100	100	100	100	100	100	73		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73		
44	Tajragh	Gale Chay	Ghaleh chay	32-019	46.099	37.516	1550	East azarbayjan	Malfunction																																			27	100	73																													
45	Shishvan	Gale Chay	Ghaleh chay	32-021	45.881	37.460	1270	East azarbayjan	Working																																						27	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
46	Khanian	Gale Chay	Ghaleh chay	32-022	45.936	37.480	1275	East azarbayjan	Working																																													27	100	100	100	72				28	100	73	27	100	100	100	100	100	100	100	100	100	72
47	Esfastanj	Gale Chay	Estasfanj	32-023	46.240	37.447	1500	East azarbayjan	Working																																			27	100	100	73	27	100	100	73	27	100	100	100	100	100	73	28	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
48	Kahik darsi	Gale Chay	Esparan	32-025	46.283	37.475	1865	East azarbayjan	Working																																					27	100	100	100	100	100	100	100	100	100	100	100	93	79	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
49	Ghareh burgheh	Gale Chay	Nahr basteh ju	32-029	46.247	37.421	1550	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73																													
50	Alavian dam	Gale Chay	Nahr hazer abad	32-031	46.240	37.413	1550	East azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73																													
51	Bonab)gapi chay(	Gale Chay	Gapi chay	32-035	46.034	37.306	-	East azarbayjan	Malfunction																							27	100	100	100	100	100	73																																						
52	Moghanjigh	Lirang Chay	Moghanjigh	33-001	46.418	37.328	1565	East azarbayjan	Working																														27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
53	Gheshlagh amir	Lirang Chay	Mardagh chay	33-003	46.266	37.328	1520	East azarbayjan	Working																												27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
54	Shirin kand	Lirang Chay	Lilan chay	33-005	46.269	37.010	1365	East azarbayjan	Working																											27	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	72
55	Ghabghablu	Zarineh Rud	Saghez chay	33-007	46.170	36.186	1520	Kordestan	Working																							27	100	100	100	100	100	100	100	100	100	73					27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
56	Dash alucheh	Zarineh Rud	Saghez chay	33-008	46.252	36.251	-	Kordestan	Malfunction																							27	73																																											
57	Pol saghez	Zarineh Rud	Saghez chay	33-009	46.276	36.237	1480	Kordestan	Malfunction										27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73																																					
58	Dareh panbeh dan	Zarineh Rud	Saghez chay	33-011	46.600	36.280	1650	Kordestan	Working																												27	100	100	100	100	73								27	100	100	100	100	100	100	73		28	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
59	Pol hasan salaran	Zarineh Rud	Jighato chay	33-013	46.302	36.047	1500	Kordestan	Malfunction																													27	73	27	100	73								27	73																								
60	Pol anian (pol saheb)	Zarineh Rud	Jighato chay	33-015	46.430	36.203	1460	Kordestan	Working																												27	100	100	100	100	73						27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
61	Karim abad (kherkhereh)	Zarineh Rud	Kherkhereh chay	33-017	46.602	36.230	1480	Kordestan	Malfunction																												27	100	100	100	100	73							27	100	100	73																							
62	Pol sarugh	Zarineh Rud	Sarugh chay	33-019	47.024	36.467	1700	West azarbayjan	Malfunction																													27	100	100	100	73				27	100	100	73																									
63	Safakhaneh	Zarineh Rud	Sarugh chay	33-021	46.701	36.406	1475	West azarbayjan	Working																											27	100	100	100	100	100	73								27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
64	Ghushkhaneh sofla	Zarineh Rud	Zarineh rud	33-022	46.520	36.420	1283	West azarbayjan	Working																																																							27	100	100	100	100	100	100	100	100	100	72	27	100	100	72
65	Sarighamish	Zarineh Rud	Zarineh chay	33-023	46.494	36.480	1380	West azarbayjan	Working									27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73						27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
66	Shahindej	Zarineh Rud	Zarineh chay	33-024	46.529	36.581	-	West azarbayjan	Malfunction				27	100	100	100	100	73																																																								
67	Ghozkarpi	Zarineh Rud	Zarineh chay	33-025	46.551	36.620	1350	West azarbayjan	Malfunction										27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73																																					
68	Se rahi shahin dej	Zarineh Rud	Nahr haji behzad	33-026	46.107	36.955	0	West azarbayjan	Malfunction																		27	100	100	100	100	100	100	73																																													
69	Chublucheh	Zarineh Rud	Ajorlu	33-027	46.397	36.870	1523	West azarbayjan	Malfunction																										27	100	100	100	100	100	100	73		27	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	73							
70	Ghaleh	Zarineh Rud	Nahr taghi abad	33-028	46.107	36.955	-	West azarbayjan	Malfunction																		27	100	100	100	100	100	100	73																																													
71	Miandoab (zarrineh rud)	Zarineh Rud	Zarineh chay	33-029	46.116	36.966	1300	West azarbayjan	Malfunction																		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73		27	100	100	100	100	100	100	73																		
72	Cheragh veis	Zarineh Rud	Saghez	33-034	46.068	36.167	1527	Kordestan	Working																																																							27	100	100	72	27	100	100	72	27	100	100	72
73	Dashband bukan	Simine Rud	Simineh rud	33-035	46.160	36.649	1350	West azarbayjan	Working				27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73				27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
74	Gozal gonbad	Simine Rud	Simineh rud	33-036	45.947	36.433	1450	West azarbayjan	Working																																																		27	73	28	100	100	100	100	100	100	100	100	100	100	100	100	72
75	Miandoab (simineh rud)	Simine Rud	Simineh rud	33-037	46.056	36.951	1310	West azarbayjan	Working																		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
76	Tazeh kand)Miandoab	Simine Rud	Simineh rud	33-039	46.007	36.975	1295	West azarbayjan	Working																												27	100	100	73									27	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
77	Zanjir abad	Simine Rud	Simineh rud	33-041	46.028	36.976	1290	West azarbayjan	Malfunction																		27	100	100	100	100	100	73						27	100	100	100	73						27	100	73																										
78	Malek kandi	Ajichay	Mardugh chay	33-043	46.123	38.149	1300	East azarbayjan	Malfunction																			27	100	100	100	100	100	73																																															
79	Gheshlagh	Zarineh Rud	Nahr gharevarn	33-047	46.198	36.903	1300	West azarbayjan	Malfunction																		27	100	100	100	100	100	100	100	100	100	100	100	100	73																																									
80	Alasghol	Zarineh Rud	Sarugh chay	33-049	47.033	36.479	1700	West azarbayjan	Malfunction																																							27	100	100	100	100	100	100	100	100	73																		
81	Miandoab (taghi abad)	Zarineh Rud	Nahr miandoab	33-051	46.156	36.925	1290	West azarbayjan	Malfunction																		27	100	100	100	100	73																																																			
82	Kavlan	Simine Rud	Simineh rud	33-055	45.944	36.307	1442	West azarbayjan	Working																																																27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
84	Kordeh deh	Lirang Chay	Mardugh chay	33-081	46.432	37.512	2000	East azarbayjan	Working																																																					27	72		27	73	28	73	27	100	100	100	100	100	72
86	Alasghol left branch	Zarineh Rud	Sarugh chay	33-912	47.050	36.486	1700	West azarbayjan	Working																																											27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
87	Alasghol right branch	Zarineh Rud	Sarugh chay	33-916	47.051	36.502	1392	West azarbayjan	Working																																											27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
88	Nezam abad	Zarineh Rud	Zarineh chay	33-917	45.946	37.050	1283	West azarbayjan	Working																																														27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72	27	100	100	72
89	Santeh	Zarineh Rud	Kherkhereh chay	33-919	46.551	36.151	1434	Kordestan	Working																																							27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
90	Mahmud abad (ghureh chay)	Zarineh Rud	Ghaleh chay	33-921	46.721	36.542	1490	West azarbayjan	Working																																													27	100	100	100	72		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
91	Jan agha	Zarineh Rud	Ajorlu	33-923	46.481	36.948	1410	West azarbayjan	Working																																													27	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	72
92	Chalkhmaz	Zarineh Rud	Ghaleh chay	33-925	46.228	36.889	1350	West azarbayjan	Working																																													27	100	100	100	100	73	27	73	28	100	100	100	100	100	100	100	72		27	100	72
93	Pol gheshlagh	Zarineh Rud	Jighato chay	33-973	46.333	36.084	1436	Kordestan	Working																																										27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
95	Sari gheshlagh	Zarineh Rud	Ghaleh chay	33-979	46.550	37.218	1640	East azarbayjan	Working																																																							27	73		27	100	100	100	100	100	100	72
96	Pol bukan	Simine Rud	Simineh rud	33-985	45.644	36.905	1285	West azarbayjan	Working																																																	27	100	73	28	100	100	100	100	100	100	100	100	100	100	100	72
97	Dehabkar	Mahabad Chay	Mahabad chay	34-001	45.622	36.722	1400	West azarbayjan	Malfunction																	27	100	100	100	100	100	100	73						27	100	100	73																																			
98	Kuter	Mahabad Chay	Mahad chay	34-003	45.617	36.700	1380	West azarbayjan	Working																										27	73	27	100	100	100	100	73					27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
99	Bitas	Mahabad Chay	Mahabad chay	34-005	45.697	36.676	1424	West azarbayjan	Working																	27	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	73				27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
100	Pol sorkh (mahabad)	Mahabad Chay	Mahabad chay	34-007	45.723	36.768	1350	West azarbayjan	Malfunction										27	100	100	100	100	100	100	100	100	100	100	100	100	73																																																	
101	Gard yaghub	Mahabad Chay	Mahabad chay	34-009	45.718	36.994	1280	West azarbayjan	Working																																										27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
102	Pi ghaleh	Gedar Chay	Gadar chay	34-011	45.030	36.994	1500	West azarbayjan	Working																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	73				27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	28	100	100	100	100	100	100	100	72
103	Oshnavieh (golaz chay)	Gedar Chay	Golaz chay	34-013	45.088	37.042	1480	West azarbayjan	Working																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	73				27	100	100	100	100	100	100	73			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
104	Chapar abad	Gedar Chay	Kanirash	34-015	45.126	36.957	1470	West azarbayjan	Working																							27	100	100	100	100	100	100	100	100	100	73						27	100	100	100	73	27	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
105	Balghchi	Gedar Chay	Balekhlu chay	34-017	45.372	36.931	1350	West azarbayjan	Working																																27	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
106	Naghadeh	Gedar Chay	Gadar chay	34-019	45.382	36.966	1340	West azarbayjan	Working																			27	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
107	Pol bahramlu santu	Gedar Chay	Gadar chay	34-021	45.655	37.003	1320	West azarbayjan	Working											27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72	27	100	100	72
108	Yarghu	Mahabad Chay	Mahabad chay	34-025	45.730	36.776	1340	West azarbayjan	Malfunction																				27	73																																															
109	Pieh jik	Gedar Chay	Nahr khan	34-029	45.265	36.990	1375	West azarbayjan	Working																											27	73	27	100	100	100	73				27	100	100	73			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
110	Jashiran	Roze Chay	Rozeh chay	34-031	44.880	37.600	1500	West azarbayjan	Malfunction																			27	100	100	100	100	100	100	100	73	27	100	100	100	73				27	100	100	73																										
111	Dorud	Gedar Chay	Sheykhan chay	34-037	45.014	36.955	1650	West azarbayjan	Malfunction																																									27	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	73	28	73			
112	Sufian (sufian chay)	Gedar Chay	Sufian chay	34-039	45.152	36.917	1520	West azarbayjan	Working																																									27	100	100	100	100	100	100	100	100	100	73	28	73		27	100	100	100	100	100	100	73	27	72
114	Oshnavieh (nilvan)	Gedar Chay	Nahr nilvan	34-113	45.090	37.043	1508	West azarbayjan	Working																																					27	100	100	73			27	100	100	100	73	27	100	100	100	73		27	100	100	100	100	100	100	100	100	100	100	72
115	Mohammad shah sofla	Gedar Chay	Bayram balaghi	34-912	45.566	36.894	1390	West azarbayjan	Working																																27	73									27	100	100	100	100	100	100	100	100	100	100	73		27	100	100	100	100	100	100	100	100	100	100	72
116	Eslam abad (cheshmeh do)	Gedar Chay	Cheshmeh dul	34-915	45.293	37.083	1380	West azarbayjan	Working																																									27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
117	Bayziad abad	Gedar Chay	Balekhlu chay	34-918	45.326	36.875	1500	West azarbayjan	Working																																									27	100	100	100	100	100	100	72	27	100	73	28	100	100	100	100	100	100	100	100	100	100	100	72
118	Ghasemlu	Baradoz Chay	Balanj chay	35-001	45.149	37.346	1387	West azarbayjan	Working																											27	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
119	Hashem abad bibakran	Baradoz Chay	Baranduz chay	35-003	44.900	38.284	1464	West azarbayjan	Working																											27	100	100	100	100	100	73		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
120	Dizaj (orumieh)	Baradoz Chay	Baranduz chay	35-005	45.071	37.395	1335	West azarbayjan	Working										27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
121	Babarud	Baradoz Chay	Baranduz chay	35-007	45.235	37.402	1297	West azarbayjan	Working			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	28	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
122	Mir abad (shahr chay)	Sahar Chay	Shahr chay	35-009	44.870	37.429	1525	West azarbayjan	Malfunction																											27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72								
123	Band urmia	Sahar Chay	Shahr chay	35-011	45.016	37.502	1411	West azarbayjan	Working			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
124	Kashtiban	Sahar Chay	Shahr chay	35-013	45.245	37.553	1299	West azarbayjan	Working																		27	100	100	100	100	100	100	100	100	100	100	100	100	73																												27	100	100	100	100	100	100	100	100	100	72
125	Marmisho	Nazlo Chay	Marmisho	35-021	44.613	37.566	1780	West azarbayjan	Malfunction																																																											28	73	27	73	
126	Barduk	Nazlo Chay	Gonabd rud	35-023	44.569	37.833	1800	West azarbayjan	Malfunction																											27	73	27	100	100	73																																				
127	Golkani	Nazlo Chay	Gonabd rud	35-025	44.695	37.747	1580	West azarbayjan	Malfunction																										27	100	73	27	100	100	100	100	100	100	73	27	100	100	73																										
129	Ni chalan	Nazlo Chay	Saru chay	35-029	44.770	37.680	1550	West azarbayjan	Malfunction																											27	100	100	100	100	100	100	73	27	73																																	
130	Tapik	Nazlo Chay	Nazlu chay	35-031	44.906	37.676	1399	West azarbayjan	Working				27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73			27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
131	Abajalu sofla	Nazlo Chay	Nazlu chay	35-033	45.117	37.717	1295	West azarbayjan	Working																		27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
132	Guyjali aslan	Roze Chay	Rozeh chay	35-037	45.180	37.656	1285	West azarbayjan	Working																																						27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
133	Movana	Nazlo Chay	Dubreh chay	35-041	44.799	37.581	1650	West azarbayjan	Malfunction																																				27	100	73	27	100	100	73																												
134	Chaman	Roze Chay	Chaman	35-043	44.776	37.484	1800	West azarbayjan	Malfunction																																				27	100	73	27	100	100	73																												
135	Karim abad (arzin)	Nazlo Chay	Arzin chay	35-045	44.799	37.618	1486	West azarbayjan	Working																																				27	73					27	73	27	100	100	100	100	100	100	100	100	100	100	73	28	73	27	100	100	100	100	100	100	100	100	100	100	72
137	Chehrigh olia	Zola Chay	Zola chay	36-001	44.930	38.232	1533	West azarbayjan	Working																										27	100	100	100	100	100	100	73					27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
138	Nazar abad (darik chay)	Nazlo Chay	Darik chay	36-003	44.784	38.195	1597	West azarbayjan	Working																										27	100	100	100	100	100	100	73							27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
139	Urban	Zola Chay	Dirali chay	36-005	44.713	38.331	1680	West azarbayjan	Working																											27	100	100	100	100	100	73					27	100	100	100	100	73	27	73				27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	72
140	Pol darish	Zola Chay	Zola chay	36-007	44.811	38.173	1350	West azarbayjan	Malfunction																										27	73	27	100	100	100	100	100	100	100	100	100	100	73																														
141	Tamar (orumieh)	Residual 1	Kherkhereh chay	36-009	44.883	38.118	1418	West azarbayjan	Working																							27	100	100	100	73	27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	73	28	73	27	100	100	100	100	100	72	27	100	100	72
142	Yalghuz aghaj	Zola Chay	Zola chay	36-011	44.933	38.232	1307	West azarbayjan	Working																												27	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	73	28	100	100	100	100	100	100	100	100	100	100	100	72
143	Ajvaj	Zola Chay	Zola chay	36-013	44.637	38.096	900	West azarbayjan	Working																														27	100	73																		28	100	100	100	100	100	73	27	100	100	100	100	100	100	100	100	72

*Prepared by JST based on data provided by WRMC
*Numers for years are collection rate of daily data

Annex 3.2
Inventory of the Dams and Weirs in the Urmia Basin

No.	Dam Name	River Name	Basin Name	Province	Coordinate		Purpose	Constructed	Constructed	Current	Dam Type	Dam Height*)	Storage Vol.	Catchment Area	Collected Daily Operation Data	
					Latitude	Longitude		Year (Western)	Year (Iranian)	Status		(m)	(MCM)	(km2)	From	To
A. Under-operated Dams																
A-1	Abdol Abad Dam	Vanegh Chay	Aji Chay	East Azerbayjan	47° 44' 23.026" E	37° 52' 10.864" N				OP			0.25			
A-2	Amand Tabriz	Sinikh Chay (Aji Chay)	Aji Chay	East Azerbayjan	46° 36' 55.176" E	38° 13' 28.875" N				OP			2.20			
A-3	Amand1	Amand Watercourse	Aji Chay	East Azerbayjan	46° 34' 0.550" E	38° 13' 21.818" N	AW	1984	1362	OP	Earthfill dam with clay core		0.25			
A-4	Amand2	Amand Watercourse	Aji Chay	East Azerbayjan	46° 33' 41.079" E	38° 13' 42.202" N	AW	1986	1364	OP	Earthfill dam with clay core		0.25	1.00		
A-5	Ardalan Dam	Chaki Chay	Aji Chay	East Azerbayjan	47° 13' 20.592" E	38° 0' 49.841" N				OP			4.50			
A-6	Baftan	Abarghan Aji Chay Branch	Aji Chay	East Azerbayjan	47° 19' 57.385" E	37° 54' 9.166" N				OP			5.70			
A-7	Barugh Haris	Horayli	Aji Chay	East Azerbayjan	47° 2' 48.700" E	38° 10' 34.711" N	AW	1983	1361	OP	Earthfill dam with clay core		0.15			
A-8	Dash Esparan	Charshanbe Chay	Aji Chay	East Azerbayjan	46° 18' 54.493" E	38° 18' 19.402" N				OP			1.00			
A-9	Gavdush Abad	Out of Aji Chay Bed	Aji Chay	East Azerbayjan	47° 27' 0.000" E	37° 52' 30.000" N	AW	2000	1378	OP	Earthfill dam with clay core		2.50	0.00		
A-10	Gharkh Aghaj Dam	Sevin Chay	Aji Chay	East Azerbayjan	47° 47' 21.329" E	38° 4' 16.278" N	AW, FC, AR			OP	Non-homogeneous earthfill		3.00			
A-11	Gheysaragh	Chaki Chay	Aji Chay	East Azerbayjan	47° 15' 26.623" E	38° 4' 35.250" N	AW	2007	1385	OP	Earthfill dam with clay core		2.60	189.00		
A-12	Hasanjankuh Dam	Pislar Chay	Aji Chay	East Azerbayjan	47° 38' 44.719" E	38° 4' 24.543" N				OP			0.30			
A-13	Kardkandi	Out of Aji Chay Bed	Aji Chay	East Azerbayjan	46° 56' 58.712" E	37° 57' 32.880" N	AW	2004	1382	OP	Earthfill dam with clay core		5.18	105.00	Mar-2011	Dec-2014
A-14	Khormalu	Shahsavar Watercourse	Aji Chay	East Azerbayjan	47° 8' 45.387" E	38° 16' 4.310" N	AW	1980	1358	OP	Rockfill dam		0.35			
A-15	Maghsudlu Dam	Maghsudlu Water Course	Aji Chay	East Azerbayjan	47° 1' 48.922" E	38° 16' 3.225" N				OP			1.40			
A-16	Malek-Kiann	Saiid Abad	Aji Chay	East Azerbayjan	46° 29' 34.409" E	38° 2' 12.230" N	AW	2001	1379	OP	Earthfill dam with clay core		8.80	2.00		
A-17	Manigh Dam	Unknown (Seasonal river)	Aji Chay	East Azerbayjan	46° 59' 8.190" E	38° 16' 10.879" N				OP			0.40			
A-18	Mola yaghub	Vanegh Chay	Aji Chay	East Azerbayjan	47° 42' 9.172" E	37° 52' 14.505" N				OP			3.00			
A-19	Nahand	Nahand Chay	Aji Chay	East Azerbayjan	46° 28' 59.633" E	38° 13' 34.721" N	DW, IW	1997	1375	OP	Earthfill dam with clay core	52	21.10	216.00	Mar-2000	Dec-2014
A-20	Oghan Dam	Aji Chay	Aji Chay	East Azerbayjan	47° 26' 37.114" E	37° 52' 25.290" N				OP			1.00			
A-21	Param	Param Chay	Aji Chay	East Azerbayjan	46° 59' 52.833" E	38° 14' 37.677" N	AW	1998	1376	OP	Earthfill dam with clay core		3.30	82.00		
A-22	Sefidan ATigh	Charshanbe Chay	Aji Chay	East Azerbayjan	46° 22' 29.515" E	38° 14' 38.013" N	AW	1998	1376	OP	Earthfill dam with clay core		0.40	36.00		
A-23	Tajyar Sarab	Tajyar	Aji Chay	East Azerbayjan	47° 30' 28.555" E	38° 0' 27.627" N	AW	2004	1382	OP	Earthfill dam with clay core		3.50	130.00	Apr-2009	Dec-2014
A-24	Vanegh Olia Dam	Vanegh Chay	Aji Chay	East Azerbayjan	47° 45' 35.140" E	37° 52' 9.788" N				OP			1.00			
A-25	Yengje Azarshahr	Azarshahr Chay	Aji Chay	East Azerbayjan	45° 59' 52.199" E	37° 46' 30.156" N				OP			2.30			
A-26	Arbatan	Out of Zarangh Bed	Aji Chay	East Azerbayjan	46° 52' 55.744" E	38° 10' 46.619" N				OP			25.00			
A-27	Baranduz	Hache Su	Baranduz Chay	West Azerbayjan	46° 37' 3.806" E	36° 40' 58.294" N				OP			0.35			
A-28	Shakrbazi-Darik (Darek Salmas)	Darik Chay	Darik Chay	West Azerbayjan	44° 34' 47.275" E	38° 13' 35.834" N	AW	2009*)	1387*)	OP	Earthfill dam	39	22.00		Jun-2012	Dec-2014
A-29	Haft Cheshmeh Dam	Gale Chay	Gale Chay	East Azerbayjan	45° 56' 32.091" E	37° 37' 32.199" N				OP	Earthfill dam		0.25			
A-30	Deh Gorji Oshnavieh	Cheshme Deh Gorji	Gedar Chay	West Azerbayjan	45° 10' 48.917" E	36° 58' 6.891" N	AW	1989	1367	OP	Homogeneous Earthfill dam		0.13			
A-31	Hasanlu	Out of Gedar Chay Bed	Gedar Chay	West Azerbayjan	45° 27' 49.057" E	37° 0' 16.094" N	AW	2001	1379	OP	Homogeneous Earthfill dam	12.25	94.00	35.00	Mar-2002	Dec-2014
A-32	Mahabad	Mahabad Chay	Mahabad Chay	West Azerbayjan	45° 41' 55.252" E	36° 45' 59.719" N	DW, IW, AW, EL	1971	1349	OP	Rockfill dam with clay core	47.5	190.00	806.00	Mar-1971	Dec-2014
A-33	Kanspi	Kanspi	Nazlu Chay	West Azerbayjan	44° 37' 51.432" E	37° 47' 54.065" N	AW	2009	1387	OP	Earthfill dam with clay core		0.50	17.00		
A-34	Til	Til	Residual 4	East Azerbayjan	45° 29' 29.535" E	38° 15' 27.466" N	AW	1986	1364	OP	Earthfill dam with clay core		0.67	58.00		
A-35	Shahrchay	Shahr Chay	Shahr Chay	West Azerbayjan	44° 54' 43.787" E	37° 27' 11.543" N	DW, IW, AW	2006	1384	OP	Rockfill dam with clay core	116	213.00	330.00	May-2006	Dec-2014
A-36	Alavian	Sofi Chay	Sofi Chay	East Azerbayjan	46° 15' 6.920" E	37° 25' 40.093" N	DW, IW, AW, EL	1996	1374	OP	Earthfill dam with clay core	80	57.00	314.00	Sep-1997	Dec-2014
A-37	Ghale Chay Ajabshir	Ghaleh Chay	Gale Chay	East Azerbayjan	46° 6' 59.498" E	37° 30' 53.226" N	DW, IW, AW, EL	2007*)	1385*)	OP	Earthfill dam with clay core	79	38.80	250.00	Apr-2009	Dec-2014
A-38	Barugh	Ghorichay (Barugh)	Zarineh Rud	West Azerbayjan	46° 22' 42.171" E	37° 1' 2.935" N				OP	Earthfill dam with clay core*)	53	100.00			
A-39	Ghorichay - Miandoab	Badamlu	Zarineh Rud	West Azerbayjan	46° 9' 33.623" E	36° 54' 55.146" N				OP			3.92			
A-40	Ghushkhane	Ghushkhane	Zarineh Rud	West Azerbayjan	47° 4' 16.709" E	36° 21' 56.486" N	DW, IW	2004	1382	OP	Earthfill dam		0.14			
A-41	Noruzlu Diversion Dam	Zarineh Rud	Zarineh Rud	West Azerbayjan	46° 14' 33.005" E	36° 53' 2.661" N				OP			0.00			
A-42	Sarough- Gougerdchay	Sarough Chay (Ghare Ghieh)	Zarineh Rud	West Azerbayjan	47° 7' 48.646" E	36° 31' 17.925" N	DW, IW, AW	2010	1388	OP	Rockfill dam with clay core	70	35.00	332.00	Jun-2012	Dec-2014
A-43	Shahid Kazemi Bukan- Zarineh Rud	Zarineh Rud	Zarineh Rud	West Azerbayjan	46° 31' 44.453" E	36° 25' 35.020" N	AW, EL	1972	1350	OP	Earthfill dam with clay core	50	486.00	6,890.00	Mar-1978	Dec-2014
A-44	Zola	Zola Chay	Zola Chay	West Azerbayjan	44° 38' 55.251" E	38° 6' 6.239" N	DW, IW, AW, EL	2010	1388	OP	Rockfill dam with clay core	53	72.00	945.00	Sep-2011	Dec-2014

*Prepared by JST based on data provided by WRMC

No.	Dam Name	River Name	Basin Name	Province	Coordinate		Purpose	Constructed	Constructed	Current	Dam Type	Dam Height*)	Storage Vol.	Catchment Area	Collected Daily Operation Data	
					Latitude	Longitude		Year (Western)	Year (Iranian)	Status		(m)	(MCM)	(km2)	From	To
B. Under-constructed Dams																
B-1	Choghan-Joghan	Asb Abad Chay	Aji Chay	East Azerbayjan	46° 46' 7.899" E	37° 46' 15.759" N	AW	2010	1388	UC	Earthfill dam with clay core		2.50	45.00		
B-2	Shahid Madani-Vanyar	Aji Chay	Aji Chay	East Azerbayjan	46° 23' 56.923" E	38° 7' 6.334" N	AW	2010	1388	UC	Rockfill dam with clay core	93	280.00	7,723.00		
B-3	Baranduz	Baranduz Chay	Baranduz Chay	West Azerbayjan	44° 58' 31.817" E	37° 22' 1.902" N	DW, IW, AW, FC, AR	2014	1392	UC	Earthfill dam with clay core/ or Earthfill*)	46.5	84.00	594.00		
B-4	Oshnavie-Chapar Abad	Godar Chay (Kanirash)	Gedar Chay	West Azerbayjan	45° 7' 2.079" E	36° 56' 54.891" N	DW, IW, AW, EL	2012	1390	UC	Earthfill dam with clay core	46.1	122.00	361.00		
B-5	Nazlu	Nazlu Chay	Nazlu Chay	West Azerbayjan	44° 58' 23.175" E	37° 40' 33.532" N	DW, IW, AW, EL	2011	1389	UC	Earthfill dam with clay core	97	145.00	1,715.00		
B-6	Khorasane Dam	Sardar Abad	Simineh Rud	West Azerbayjan	46° 4' 57.091" E	36° 37' 56.174" N				UC			1.60			
B-7	Simineh Rud -Bukan	Simineh Rud	Simineh Rud	West Azerbayjan	46° 3' 53.518" E	36° 26' 17.825" N	DW, IW, AW, EL, FC, AR	2012	1390	UC	Earthfill dam with clay core	37	312.00	1,441.00		
B-8	Ahmad Abad Sofla	Ahmad Abad	Zarineh Rud	West Azerbayjan	47° 7' 57.195" E	36° 36' 55.230" N				UC			1.80			
B-9	Cheragh Veys	Cham Khan (Saghez Branch) Zarineh Rud	Zarineh Rud	Kurdistan	46° 6' 4.886" E	36° 11' 0.599" N	DW, IW, AW	2013	1391	UC	Rockfill dam with clay core	69	68.60	363.00		
B-10	Lilan Chay	Lilan Chay	Zarineh Rud	East Azerbayjan	46° 20' 26.325" E	37° 6' 34.893" N	AW, EL, FC, AR	2012	1390	UC	Earthfill dam with clay core	70	35.50	571.00		
B-11	Sanjagh	Bajvand (Ghourichay)	Zarineh Rud	West Azerbayjan	45° 58' 1.537" E	36° 46' 57.574" N	AW	2010	1388	UC	Homogeneous Earthfill dam/ or Earthfill with clay core*)	57.5	0.60	57.00		
C. Proposed Dams																
C-1	Ahmad	Moghanjigh Chay	Lirang Chay	East Azerbayjan	46° 25' 18.265" E	37° 19' 45.737" N	AW			PR	Earthfill dam		14.00			
C-2	Kabutar ALi	Daryan Chay	Residual 4	East Azerbayjan	45° 37' 0.000" E	38° 14' 0.000" N				PR	Rockfill dam		6.00			
D. Under-studied Dams																
D-1	Abraghan Dam	Abarghan Chay	Aji Chay	East Azerbayjan	47° 12' 58.108" E	37° 51' 59.081" N				ST			0.78			
D-2	Agh Dagh	Aji Chay	Aji Chay	East Azerbayjan	47° 30' 0.000" E	37° 52' 0.000" N				ST	Diversion and reservoir		0.00	1,570.00		
D-3	Asgar Abad	Aji Chay	Aji Chay	East Azerbayjan	47° 44' 30.083" E	37° 54' 3.292" N				ST			16.50			
D-4	Atmian Sarab	Atmian Chay	Aji Chay	East Azerbayjan	47° 16' 6.565" E	38° 9' 14.542" N	AW			ST	Earthfill dam		25.00			
D-5	Gharaje Dam	Gharje Water Course	Aji Chay	East Azerbayjan	46° 45' 56.485" E	38° 14' 22.987" N	AW, FC, AR			ST	Non-homogeneous earthfill		0.40			
D-6	Haris Harzorez Dam	Out of Harzurez Bed	Aji Chay	East Azerbayjan	47° 7' 14.320" E	38° 9' 35.959" N				ST			2.00			
D-7	Sinikh Chay Dam	Sinikh Chay (Aji Chay)	Aji Chay	East Azerbayjan	46° 45' 1.157" E	38° 9' 58.389" N				ST			13.00			
D-8	Tarp	Lar Chay (Sinikh Chay)	Aji Chay	East Azerbayjan	46° 9' 40.313" E	38° 20' 58.365" N				ST			0.50			
D-9	Gur Banadak	Balanush Chay	Baranduz Chay	West Azerbayjan	45° 8' 17.906" E	37° 17' 7.610" N				ST	Diversion and reservoir		0.00	233.00		
D-10	Godarchay- naghade	Godar Chay	Gedar Chay	West Azerbayjan	45° 23' 0.795" E	36° 57' 59.934" N	AW, EL			ST	Rockfill dam		49.00			
D-11	Jamal Abad	Dibeglu	Lirang Chay	Ardebil	46° 30' 17.697" E	37° 15' 15.558" N				ST			0.68			
D-12	Khaje Chay	Sarajuy	Lirang Chay	East Azerbayjan	46° 31' 8.435" E	37° 17' 0.482" N	AW			ST	Earthfill dam		18.00			
D-13	Kalhor	Ruze Chay	Nazlu Chay	West Azerbayjan	44° 53' 15.468" E	37° 35' 53.084" N				ST	Diversion and reservoir		0.00	172.00		
D-14	Kahriz - Urmia	Kahriz Chay (Shivasan Chay)	Residual 1	West Azerbayjan	44° 58' 6.281" E	37° 52' 49.826" N	AW			ST	Earthfill dam		8.60	225.00		
D-15	Tupchi	Tupchi	Residual 4	East Azerbayjan	45° 10' 27.856" E	38° 19' 48.070" N				ST			3.20			
D-16	Zilber Dam	Zilber Chay	Residual 4	East Azerbayjan	45° 35' 2.385" E	38° 16' 59.230" N				ST			6.00			
D-17	Gol Tape Mahabad	Gol Taprh (Simineh Rud)	Simineh Rud	West Azerbayjan	45° 49' 25.189" E	36° 29' 25.015" N				ST			7.00			
D-18	Sardar Abad	Sardar Abad	Simineh Rud	West Azerbayjan	45° 56' 29.809" E	36° 35' 29.864" N				ST			8.30			
D-19	Shahrikand	Simineh Rud	Simineh Rud	West Azerbayjan	46° 3' 38.404" E	36° 25' 51.162" N				ST	Divesrion and reservoir		0.00	1,456.00		
D-20	Dush	Choan Chay	Sofi Chay	East Azerbayjan	46° 8' 11.776" E	37° 23' 6.781" N				ST			0.90			
D-21	Mardagh Chay - Ghare Naz	Mardagh Chay	Sofi Chay	East Azerbayjan	46° 15' 5.909" E	37° 17' 11.118" N	AW			ST	Earthfill dam with clay core	118	110.60	390.00		
D-22	Ajorlu	Ajorlu	Zarineh Rud	West Azerbayjan	46° 28' 9.498" E	36° 54' 51.834" N				ST	Earthfill with clay core*)	60	93.00			
D-23	Kardkan- Ghapltan	Kardkand	Zarineh Rud	Kurdistan	46° 43' 7.907" E	36° 14' 43.128" N				ST			11.50			
D-24	Khanum Goli	Jushato Sofla	Zarineh Rud	West Azerbayjan	46° 36' 6.869" E	36° 45' 44.942" N				ST	Concrete gravity	57	16.00			
D-25	Kharaju Chay	Kharaju Chay	Zarineh Rud	East Azerbayjan	46° 30' 3.378" E	37° 15' 0.186" N	AW			ST	Rockfill and earthfill dam	39	10.50	188.00		
D-26	Markhaz	Markhaz	Zarineh Rud	Kurdistan	46° 8' 27.383" E	36° 17' 0.351" N	AW, FC, AR			ST	Homogeneous earthfill dam		14.44	58.00		
D-27	Santeh	Khor Khore	Zarineh Rud	Kurdistan	46° 28' 21.272" E	35° 59' 58.946" N	AW, EL, FC, AR			ST	Homogeneous Earthfill dam/ or Earthfill with clay core*)	55	67.08	884.00		
D-28	Sayanjagh	Kharaju Chay	Zarineh Rud	East Azerbayjan	46° 26' 15.759" E	37° 3' 52.334" N				ST			18.50			

Data source: Ministry of Energy, Water Resources Management Company (WRMC) except the data indicated with *) as written in the Note 3).

Note: 1) Current Status: OP_under operation, UC_under construction, PR_Proposed and ST_under study.

2) Purpose: DW_drinking water supply, IW_industrial water supply, AW_agricultural water supply, EL_electric power generation, AR_artificial recharge, FC_flood control and EN_environment.

3) *) are based on the Ministry of Energy, Water and Wastewater Department, Water and Wastewater Macro-Planning Office; "Studies on Updating National Water Master Plan in Basins of Aras, Urmia, Talesh-Anzali Wetland, Great Sefidroud-Haraz, Haraz-Ghareh Sou, Gorganroud and Atrak, Fourth Volume: Report on Surface Water Resources (Quantitative and Qualitative) Urmia Watershed, Table 2.1".

4) It is not confirmed whether the under-constructed dam with construction year of less than 2014 are already under-operation or not. So, they are written in the group of under-constructed dams in the above table.

*Prepared by JST based on data provided by WRMC

Annex 4.1
Status of Collection of Basic Data/Information

Category	Item		Organization	Unit	Format	Status
1-Climatology	Gneral information of meteorological station (e.g. location and type)		WRMC	-	SHP	Collected
	Rainfall (mm)		WRMC	Daily	Excel	Collected
				Montly	Excel	Collected
	Gneral information of climatological stations (e.g. location and type)		IMO	-	-	Collected
	Air temperature (Degree)				Text	Collected
	Evaporation (mm) (additional request)			Daily	Text	Collected
	Sunshine hour (hours)			Daily	Text	Collected
	Average wind velocity (m/s)			Daily	Text	Collected
	Relative humidity (%)			Daily	Text	Collected
2-Hydrology		River discharge	WRMC	Daily	Excel	Collected
				Montly	Excel	Collected
				Peak	Excel	Collected
	Lake Urmia	Lake water level	WRMC	Daily	Excel	Collected
3-Geology	Surface geology		WRMC	-	SHP	Collected
	Subsurface geology	Geological Profile Geological Histogram	WRMC Iran Geological Service	-	PDF	Collected
4-Topology	Land elevation (DEM)		WRMC	-	TIFF	Collected
	Lake bed elevation (DEM) or bathymetry data		Iran Water Authority	-		Collected
	Lake H-V		WRMC			Collected
	River cross section	Surveyed result (Horizontal, Cross Section and Longitudinal)	WRMC	-	CAD	Collected (but might not be applied)
	Topological map 1/250,000		WRMC	-	-CAD -Scanned	Collected
	Topological map 1/50,000			-	Scanned	Collected
	Topological map 1/25,000			-	SHP	Collected
5-Land use	Classification for landuse			-	SHP	Collected
	Information on land use change (information based on satelite image would be appreciated)		WRMC		SHP	Collected (shape files of landuse pattern in 1987 and 2007)
6-Natural condition	River, Lake, etc		WRMC	-	SHP	
7-Dam	Information and operation of dam	Observed data（Inflow, outflow, water level of dam lake and storage volume）	WRMC	Daily	Excel	12 dams were collected, other data will be estimated based on existing data
		Operation rule		-	Report	Not collected, to be estimated based on observed data
		Physical Conditions (Locations, Dam name, Reservoir Volume(Gross, Effective and dead), Water levels(Natural water level, low water level and Flood control level), Purpose of Dam, Dam type(earth, rock fill or concrete), Stage(Operation, Construction or planning), Dam Height, Basin area, Water demand and its purpose), H-V curve, Discharge Capacities)		-	Excel and SHP	Collected and Checking
8-Intake facility	Intake water (surface water)	Location of intake point (weir or head work) on maps or GIS	WRMC	-	SHP	Not collected, to be estimated based on discharge from dam for water supply
		Water amount permitted by water right (or Planned water intake amount)		Daily	Excel / Report	
		Actual water intake amount		Daily	Excel	
		Information of service area for water supply (location, area and annual schedule)		-	Report	
		Location of drainage point		-	Report	
		Distribution and drainage channel networks (GIS or Map data)			SHP	
9-Groundwater	Information and operation of groundwater	Location of observation well	WRMC WRC of EAZ and WAZ	-	SHP	Collected
		Record of water level as long as possible		Daily	Excel	Collected (changes in salinity in plain areas)
		Record of groundwater use amount (village/district level)		Daily	Excel	Collected
		Pumping test result		-	Excel	Collected
		Drilling test result		-	Excel / CAD	Collected
		Groundwater level contour		-	SHP	Not collected
		Distribution of salinization		-	Excel	Collected (changes in salinity in plain areas)
10-Water Demand	Calculated Water Demand and actual water use amount	Irrigation sector	WRMC	Monthly	Excel / Report	Not collected, to be estimated based on dam discharge for water supply
		Industrial sector		Monthly		
		Commerce sector		Monthly		
		Domestic water sector		Monthly		
11-Statistic	Statistical data	Population change	Iran Statistical Center	Yearly	Excel / Report	Not colleted
		Change in industrial production		Yearly	Excel / Report	
		Change in cropping area		Yearly	Excel / Report	
12-Irrigation	General conditions	General information of irrigation schemes -Location -Area -Administrator -Types and number of working staff and equipment	WRMC	-	Excel / Report	Not collected, to be estimated based on dam discharge for water supply
	Actual schemes	-Water source (groundwater or surface water) -Field water requirement by area and crop -Irrigation efficiency (conveyance and application efficiencies) -Cropping type (double cropping, etc.) -Cropping pattern (monthly level) -Irrigation schedule (Scheme and field levels)	WRMC	-	Excel	Collected (only basic information)

Annex 4.2
Annual Precipitation calculated as Volume of the Whole Urmia Basin

Basin Average Annual Precipitation of the Urmia Basin
(Above table based on western calender, and below table based on Iranian calender)

(Unit: MCM/year)

Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,717	1,362	2,094	2,091	260	1,507	1,880	1,060	375	1,840	551	458	712	3,783	1,936	11,838	2,258	4,976	51,697
1980	358.61	372.05	362.23	471.70	574.50	389.30	515.62	577.46	364.28	331.22	350.48	457.90	423.84	383.46	385.67	455.40	440.74	574.50	425.98
1981	404.80	570.43	481.59	544.18	903.14	589.72	569.16	554.87	445.58	432.62	418.72	634.00	590.60	502.39	432.17	527.84	478.62	903.14	528.41
1982	391.90	518.58	477.54	577.10	609.36	667.33	697.48	671.11	410.76	351.13	495.54	635.21	563.87	497.98	441.06	615.39	758.72	609.36	534.20
1983	232.97	375.16	275.22	409.32	373.76	472.97	408.10	314.03	260.95	202.94	459.67	401.27	417.75	397.67	354.04	539.06	461.38	373.76	377.09
1984	331.75	544.55	377.09	494.59	524.55	451.18	504.72	402.17	378.54	338.92	592.51	483.19	512.19	494.72	434.26	618.65	533.10	524.55	473.98
1985	275.48	470.86	305.58	370.09	416.25	404.08	417.45	441.80	312.53	262.66	508.16	358.78	401.76	380.34	368.05	509.21	399.82	416.25	387.11
1986	370.41	782.81	426.37	548.15	801.39	514.25	709.94	527.09	441.40	363.70	589.45	566.07	618.11	456.38	474.38	540.11	747.92	801.39	527.42
1987	317.16	586.09	421.07	540.12	686.87	428.83	459.59	351.83	373.94	322.74	526.74	483.95	518.58	358.87	455.32	538.63	399.27	686.87	453.68
1988	328.56	582.66	404.57	468.85	594.94	371.03	484.60	407.79	333.01	334.22	488.99	475.36	552.35	414.20	381.24	496.54	452.29	594.94	437.96
1989	280.33	426.10	334.17	393.15	341.27	378.76	389.51	327.76	330.79	236.28	356.48	398.61	483.83	320.79	288.52	323.01	349.34	341.27	324.41
1990	222.27	307.42	280.40	344.05	163.17	336.52	330.82	286.57	298.69	204.33	292.47	337.35	382.88	313.27	303.71	337.56	314.76	163.17	278.45
1991	296.45	429.83	374.28	550.67	271.56	531.07	326.94	342.47	382.10	331.28	459.61	387.39	472.27	441.36	456.85	487.41	344.51	271.56	389.03
1992	385.20	526.73	411.58	550.34	458.48	449.31	560.47	527.21	492.50	387.77	469.07	556.09	635.67	439.39	436.11	467.76	455.37	458.48	449.82
1993	420.67	660.44	500.07	701.42	691.98	663.40	578.67	605.20	476.80	424.63	608.86	610.93	704.59	721.78	546.72	705.42	577.80	691.98	592.61
1994	390.48	610.35	454.79	565.41	602.54	522.30	587.80	600.83	461.01	462.35	514.22	638.95	710.78	576.76	501.44	620.32	584.97	602.54	532.67
1995	278.94	378.95	366.34	429.39	319.05	397.80	426.05	412.20	327.47	334.25	383.72	428.02	443.71	362.68	394.01	382.34	389.49	319.05	352.78
1996	357.86	433.03	403.60	473.57	220.16	402.42	491.13	486.50	393.26	434.28	454.66	493.03	546.99	381.37	430.78	408.70	445.87	220.16	388.96
1997	304.64	472.18	321.82	462.41	287.09	432.93	364.94	341.92	315.28	368.24	411.73	418.52	477.08	445.88	345.12	426.22	299.00	287.09	367.36
1998	319.14	424.38	363.04	394.07	246.37	338.93	314.95	353.36	320.52	350.33	386.46	341.90	366.53	333.26	356.35	378.01	342.37	246.37	340.09
1999	280.15	298.19	256.41	294.97	246.94	273.59	340.94	313.65	272.37	301.44	289.76	351.44	362.81	230.51	303.11	310.01	299.42	246.94	287.09
2000	308.72	380.28	304.56	352.08	233.79	353.94	422.90	357.37	342.88	312.40	326.24	395.24	415.12	297.63	340.20	317.28	382.83	233.79	319.43
2001	269.44	349.23	319.39	315.51	179.92	310.14	370.72	310.51	248.68	269.66	315.55	305.67	302.37	289.65	288.38	287.29	259.28	179.92	279.03
2002	370.90	529.67	408.68	494.92	179.86	432.40	440.39	392.49	381.72	374.68	458.99	420.18	431.95	465.21	427.50	441.16	397.29	179.86	395.74
2003	329.01	563.51	376.42	504.26	153.50	451.87	432.89	439.89	419.08	327.44	414.16	418.68	426.94	406.20	417.96	413.75	350.48	153.50	369.02
2004	371.50	549.23	427.39	524.54	203.50	436.22	437.44	377.51	497.55	299.85	491.91	373.78	366.08	510.70	474.87	505.08	353.02	203.50	415.46
2005	332.33	356.07	306.61	334.91	138.00	298.69	340.82	263.38	268.42	276.74	327.56	323.42	348.05	362.40	342.34	371.81	249.44	138.00	315.89
2006	376.53	656.78	478.02	657.24	213.50	532.52	523.59	440.05	630.75	393.11	512.06	507.69	505.45	564.77	491.35	572.03	413.88	213.50	465.35
2007	326.31	361.19	349.91	377.34	151.00	334.05	382.65	318.27	272.31	291.65	315.69	334.02	314.15	356.33	339.65	372.52	304.32	151.00	325.08
2008	258.92	363.34	258.40	360.46	117.00	291.95	338.51	317.69	361.66	234.69	278.24	319.43	274.38	327.17	261.94	320.14	299.03	117.00	278.16
2009	313.01	411.34	359.18	346.71	206.00	383.04	375.71	368.65	321.76	337.84	411.86	392.32	362.33	435.18	380.81	479.45	355.55	206.00	368.29
2010	290.94	319.96	288.23	295.43	158.25	481.41	278.78	285.03	283.20	320.27	303.48	300.26	276.40	300.87	298.93	352.92	300.95	158.25	299.99
2011	402.18	449.62	464.90	421.12	317.41	427.86	437.77	464.55	346.06	425.25	392.46	396.35	366.26	391.05	462.02	475.19	398.26	317.41	419.21
Average all	328.05	470.66	373.11	455.25	362.03	429.68	445.66	411.91	367.68	332.47	425.17	435.78	455.49	411.26	394.21	456.13	410.60	362.03	396.87
Average 1980 to 1989	329.20	522.93	386.54	481.73	582.60	466.75	515.62	457.59	365.18	317.64	478.67	489.43	508.29	420.68	401.47	516.38	502.12	582.60	447.02
Average 1990 to 1999	325.58	454.15	373.24	476.63	350.73	434.83	432.27	426.99	374.00	359.89	427.06	456.36	510.33	424.63	407.42	452.38	405.36	350.73	397.89
Average 2000 to 2011	329.15	440.85	361.81	415.38	187.64	394.51	398.51	361.28	364.51	321.97	379.02	373.92	365.79	392.26	377.16	409.05	338.70	187.64	354.22

(Unit: MCM/year)

Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,717	1,362	2,094	2,091	260	1,507	1,880	1,060	375	1,840	551	458	712	3,783	1,936	11,838	2,258	4,976	51,697
1980	326.96	413.62	403.30	478.32	641.01	457.62	528.08	581.42	398.71	342.91	366.16	489.18	482.23	415.00	432.85	463.88	444.23	444.71	419.67
1981	389.86	548.20	476.76	525.54	800.79	553.31	553.57	521.66	411.38	367.59	457.24	609.54	556.06	467.43	397.89	501.96	467.82	518.52	470.27
1982	369.97	499.24	431.32	553.90	568.59	668.93	681.83	640.10	394.41	354.44	458.83	605.04	528.67	469.98	431.27	616.84	735.38	478.20	507.26
1983	259.44	401.96	302.87	380.69	392.18	420.22	395.26	348.57	258.66	243.91	408.73	394.47	421.19	383.55	354.30	485.40	473.80	319.16	365.92
1984	347.64	630.25	391.23	588.25	618.03	527.89	554.47	417.04	447.04	324.59	754.14	508.58	554.68	569.54	470.90	724.66	572.15	496.08	521.93
1985	250.83	412.34	278.73	302.76	350.66	344.25	432.65	491.93	263.25	272.02	427.96	388.57	415.91	313.15	338.93	393.49	465.56	320.78	335.96
1986	360.81	781.69	434.96	563.08	803.36	505.29	667.35	475.04	457.08	344.02	562.05	530.93	590.76	450.44	486.37	567.57	660.91	553.36	500.17
1987	350.20	681.87	494.01	612.59	812.88	452.85	516.17	388.00	416.45	358.73	612.66	548.56	614.37	411.10	500.52	563.67	414.22	570.22	479.42
1988	297.24	490.87	353.63	392.34	423.90	341.89	446.60	388.65	280.29	272.39	412.39	408.01	451.01	410.29	328.26	457.10	443.08	403.28	383.65
1989	301.13	404.42	334.66	378.91	327.10	384.50	371.79	323.26	347.72	299.42	346.57	419.57	515.87	301.01	320.01	308.20	354.06	359.22	328.92
1990	214.64	343.58	291.75	396.48	188.99	403.76	323.30	281.25	313.89	194.95	336.48	316.21	364.16	339.16	321.30	352.95	344.89	262.84	298.60
1991	305.62	442.07	349.11	537.22	227.12	484.12	329.78	365.00	362.22	316.00	425.44	397.76	488.39	403.60	413.53	459.17	280.70	329.32	380.20
1992	419.85	529.03	453.28	601.21	591.46	478.78	620.02	578.22	535.05	416.37	509.56	596.55	662.24	482.48	479.21	505.34	560.15	548.15	495.95
1993	402.37	668.09	490.89	657.15	634.66	656.33	584.74	615.14	454.06	421.68	611.90	631.58	720.46	742.32	536.06	716.67	519.77	568.32	575.49
1994	363.60	527.51	434.34	537.73	544.65	482.23	522.31	521.09	416.84	454.70	449.16	583.12	640.07	513.30	478.58	531.68	549.11	469.50	473.53
1995	294.34	464.09	403.59	476.19	340.72	434.90	519.68	517.06	373.75	358.78	478.93	511.40	549.89	419.60	428.88	436.34	485.52	384.65	401.73
1996	379.17	427.10	377.56	472.84	172.33	403.35	441.01	419.07	372.96	414.65	399.94	454.35	510.38	370.20	408.59	370.49	372.65	363.76	387.49
1997	309.92	517.09	345.68	483.87	319.49	449.99	365.77	353.47	358.93	365.31	473.51	412.16	448.73	455.16	373.41	454.29	280.44	375.72	388.91
1998	273.23	329.84	341.16	303.64	227.28	278.36	285.51	315.82	274.19	336.59	315.38	306.57	334.43	274.91	335.58	333.41	326.45	279.91	303.00
1999	300.59	326.82	221.65	295.33	256.70	306.62	359.27	310.32	306.21	325.10	237.98	363.79	375.07	220.73	266.46	275.52	319.94	275.55	287.56
2000	290.97	358.55	290.96	333.96	210.78	296.37	417.96	368.06	295.24	283.83	317.00	369.15	383.58	286.53	332.44	311.36	383.77	266.57	310.07
2001	270.42	410.29	361.50	387.76	171.58	365.37	400.92	357.49	287.23	256.71	370.48	338.29	336.80	343.25	316.46	333.47	272.79	292.92	317.32
2002	380.92	540.93	412.33	484.30	147.59	446.74	401.69	353.17	397.12	391.63	479.18	395.89	417.78	483.49	441.69	447.85	372.40	336.45	414.16
2003	318.26	528.52	357.03	509.92	157.00	459.07	420.69	398.61	431.32	299.52	411.15	378.39	372.82	394.62	417.24	425.28	348.38	331.05	380.56
2004	384.30	542.08	433.28	520.62	216.50	396.87	452.14	386.00	467.97	309.31	499.39	400.45	420.59	530.74	471.62	521.05	336.13	361.63	438.80
2005	377.17	450.99	371.74	406.82	143.50	356.66	386.96	309.42	366.67	344.05	373.70	400.09	413.32	404.08	406.90	428.40	321.28	310.01	382.60
2006	332.36	518.33	409.60	541.31	211.50	448.07	457.08	393.81	499.15	334.73	414.95	414.97	384.56	461.37	405.68	442.50	363.70	375.23	403.93
2007	314.34	424.15	338.67	419.15	144.50	359.10	406.80	338.62	353.37	294.98	330.89	356.94	349.58	407.82	344.88	409.94	326.84	249.32	351.57
2008	257.05	322.33	250.66	308.63	120.00	258.20	317.75	324.78	287.76	231.43	267.15	325.35	274.89	279.42	243.46	294.33	272.12	217.07	270.28
2009	333.18	393.58	376.90	342.79	197.00	394.98	367.07	353.80	309.23	371.88	407.38	370.91	337.06	425.84	403.73	472.96	358.10	271.79	378.69
2010	305.87	375.34	341.20	360.29	279.86	534.96	325.66	349.51	334.99	326.16	329.57	354.60	330.71	346.05	352.84	394.22	311.60	309.55	346.99
Average all	325.23	474.35	372.72	456.57	362.64	430.69	446.90	412.43	370.10	329.95	427.29	438.10	459.56	412.13	394.83	451.61	410.90	375.58	396.79
Average 1980 to 1989	325.41	526.45	390.15	477.64	573.85	465.67	514.78	457.57	367.50	318.00	480.67	490.25	513.08	419.15	406.13	508.28	503.12	446.35	431.32
Average 1990 to 1999	326.33	457.52	370.90	476.17	350.34	437.84	435.14	427.64	376.81	360.41	423.83	457.35	509.38	422.15	404.16	443.59	403.96	385.77	399.25
Average 2000 to 2011	324.08	442.28	358.53	419.59	181.80	392.40	395.88	357.57	366.37	313.11	381.89	373.19	365.61	396.66	376.09	407.40	333.37	301.96	363.18

*JICA Survey Team prepared these tables based on the data from WRMC.

Annex 4.2
Annual Precipitation calculated as Volume of the Whole Urmia Basin

Annual Precipitation calculated as Volume of the Whole Urmia Basin
(Above table based on western calender, and below table based on Iranian calender)

(Unit: MCM/year)

Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,716.73	1,361.68	2,093.59	2,090.98	259.77	1,506.97	1,880.14	1,060.38	375.08	1,839.96	551.17	457.76	711.69	3,782.74	1,936.28	11,837.88	2,258.39	4,976.00	51,697.17
1980	4,560.31	506.61	758.36	986.31	149.24	586.66	969.44	612.33	136.63	609.43	193.18	209.61	301.64	1,450.51	746.76	5,390.92	995.35	2,858.71	22,022.02
1981	5,147.69	776.74	1,008.24	1,137.86	234.60	888.69	1,070.09	588.37	167.13	796.00	230.79	290.22	420.32	1,900.42	836.80	6,248.51	1,080.91	4,494.02	27,317.44
1982	4,983.63	706.14	999.77	1,206.71	158.29	1,005.64	1,311.37	711.63	154.07	646.06	273.13	290.77	401.30	1,883.73	854.01	7,284.91	1,713.48	3,032.18	27,616.83
1983	2,962.61	510.85	576.20	855.88	97.09	712.76	767.29	332.99	97.88	373.39	253.36	183.69	297.31	1,504.28	685.52	6,381.38	1,041.97	1,859.83	19,494.25
1984	4,218.74	741.51	789.48	1,034.18	136.26	679.91	948.95	426.45	141.98	623.61	326.58	221.18	364.52	1,871.41	840.84	7,323.47	1,203.95	2,610.16	24,503.19
1985	3,503.25	641.16	639.76	773.85	108.13	608.93	784.86	468.47	117.22	483.29	280.08	164.24	285.93	1,438.72	712.65	6,027.98	902.95	2,071.26	20,012.74
1986	4,710.39	1,065.93	892.64	1,146.16	208.17	774.96	1,334.78	558.92	165.56	669.19	324.89	259.13	439.90	1,726.35	918.53	6,393.73	1,689.10	3,987.72	27,266.06
1987	4,033.19	798.07	881.54	1,129.38	178.43	646.23	864.10	373.08	140.26	593.83	290.33	221.54	369.07	1,357.53	881.63	6,376.27	901.70	3,417.87	23,454.03
1988	4,178.25	793.39	847.00	980.35	154.55	559.13	911.11	432.41	124.91	614.96	269.52	217.60	393.10	1,566.79	738.20	5,878.00	1,021.44	2,960.42	22,641.13
1989	3,564.89	580.21	699.62	822.08	88.65	570.77	732.33	347.55	124.07	434.75	196.48	182.47	344.34	1,213.47	558.65	3,823.74	788.95	1,698.16	16,771.16
1990	2,826.51	418.61	587.05	719.39	42.39	507.12	621.99	303.88	112.03	375.96	161.20	154.43	272.49	1,185.02	588.06	3,995.97	710.85	811.93	14,394.89
1991	3,769.93	585.29	783.59	1,151.44	70.54	800.30	614.69	363.15	143.32	609.54	253.32	177.33	336.11	1,669.54	884.59	5,769.87	778.04	1,351.28	20,111.90
1992	4,898.46	717.24	861.69	1,150.74	119.10	677.10	1,053.76	559.04	184.73	713.47	258.54	254.56	452.40	1,662.10	844.42	5,537.26	1,028.40	2,281.40	23,254.39
1993	5,349.50	899.30	1,046.94	1,466.66	179.75	999.72	1,087.98	641.74	178.84	781.30	335.59	279.66	501.45	2,730.29	1,058.59	8,350.69	1,304.90	3,443.29	30,636.20
1994	4,965.58	831.10	952.15	1,182.25	156.52	787.09	1,105.15	637.11	172.92	850.70	283.42	292.49	505.85	2,181.74	970.93	7,343.22	1,321.09	2,998.24	27,537.55
1995	3,547.15	516.01	766.97	897.85	82.88	599.48	801.04	437.09	122.83	615.01	211.50	195.93	315.78	1,371.93	762.91	4,526.12	879.62	1,587.59	18,237.69
1996	4,550.83	589.64	844.98	990.23	57.19	606.43	923.39	515.88	147.50	799.05	250.60	225.69	389.28	1,442.63	834.10	4,838.12	1,006.95	1,095.52	20,108.01
1997	3,874.03	642.96	673.75	966.89	74.58	652.42	686.14	362.56	118.25	677.54	226.93	191.58	339.53	1,686.63	668.25	5,045.56	675.26	1,428.56	18,991.44
1998	4,058.36	577.87	760.06	823.99	64.00	510.76	592.15	374.69	120.22	644.60	213.01	156.51	260.86	1,260.64	690.00	4,474.88	773.21	1,225.94	17,581.75
1999	3,562.55	406.04	536.82	616.78	64.15	412.29	641.01	332.59	102.16	554.63	159.71	160.88	258.21	871.96	586.91	3,669.92	676.21	1,228.77	14,841.59
2000	3,925.95	517.82	637.63	736.18	60.73	533.38	795.11	378.95	128.61	574.81	179.81	180.93	295.44	1,125.86	658.72	3,755.89	864.57	1,163.34	16,513.72
2001	3,426.41	475.54	668.67	659.72	46.74	467.37	697.00	329.26	93.27	496.16	173.92	139.93	215.19	1,095.68	558.38	3,400.88	585.55	895.28	14,424.94
2002	4,716.69	721.24	855.61	1,034.86	46.72	651.61	828.00	416.19	143.18	689.39	252.98	192.34	307.42	1,759.75	827.77	5,222.43	897.24	894.98	20,458.41
2003	4,183.88	767.32	788.07	1,054.40	39.87	680.95	813.90	466.45	157.19	602.48	228.27	191.66	303.85	1,536.53	809.28	4,897.91	791.51	763.82	19,077.34
2004	4,724.26	747.88	894.77	1,096.81	52.86	657.36	822.44	400.31	186.62	551.71	271.13	171.10	260.53	1,931.85	919.49	5,979.09	797.27	1,012.62	21,478.09
2005	4,226.17	484.85	641.92	700.29	35.85	450.11	640.79	279.28	100.68	509.20	180.54	148.05	247.70	1,370.87	662.86	4,401.46	563.34	686.69	16,330.65
2006	4,788.18	894.33	1,000.79	1,374.27	55.46	802.49	984.41	466.62	236.58	723.30	282.23	232.40	359.72	2,136.38	951.39	6,771.57	934.70	1,062.38	24,057.21
2007	4,149.63	491.83	732.58	789.01	39.22	503.40	719.43	337.49	102.14	536.62	174.00	152.90	223.58	1,347.91	657.66	4,409.81	687.28	751.38	16,805.86
2008	3,292.56	494.75	540.99	753.72	30.39	439.96	636.45	336.87	135.65	431.82	153.36	146.22	195.27	1,237.61	507.19	3,789.75	675.33	582.19	14,380.08
2009	3,980.50	560.11	751.98	724.96	53.51	577.23	706.39	390.91	120.69	621.62	227.01	179.59	257.87	1,646.19	737.35	5,675.64	802.97	1,025.06	19,039.56
2010	3,699.85	435.68	603.43	617.73	41.11	725.47	524.14	302.24	106.22	589.29	167.27	137.45	196.71	1,138.11	578.80	4,177.81	679.67	787.45	15,508.46
2011	5,114.37	612.24	973.30	880.55	82.45	644.77	823.07	492.60	129.80	782.44	216.31	181.43	260.66	1,479.22	894.61	5,625.21	899.43	1,579.43	21,671.90
Average all	4,171.70	640.88	781.14	951.92	94.04	647.52	837.90	436.78	137.91	611.72	234.34	199.48	324.17	1,555.68	763.31	5,399.62	927.29	1,801.48	20,516.89
Average 1980 to 1989	4,186.30	712.06	809.26	1,007.28	151.34	703.37	969.43	485.22	136.97	584.45	263.83	224.04	361.74	1,591.32	777.36	6,112.89	1,133.98	2,899.03	23,109.89
Average 1990 to 1999	4,140.29	618.41	781.40	996.62	91.11	655.27	812.73	452.77	140.28	662.18	235.38	208.91	363.20	1,606.25	788.88	5,355.16	915.46	1,745.25	20,569.54
Average 2000 to 2011	4,185.70	600.30	757.48	868.54	48.74	594.51	749.26	383.10	136.72	592.40	208.90	171.17	260.33	1,483.83	730.29	4,842.29	764.91	933.72	18,312.18

(Unit: MCM/year)

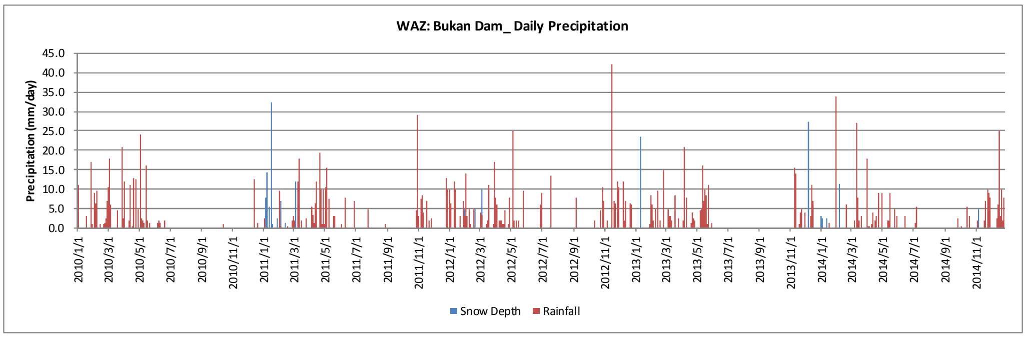
Basin / Year	Ajichay	Baradoz Chay	Gale Chay	Gedar Chay	Lake Urmia Island	Mahabad Chay	Nazlo Chay	Residual 1	Residual 2	Residual 3	Residual south	Roze Chay	Sahar Chay	Simine Rud	Sofi Chay	Zarineh Rud	Zola Chay	Urmia Lake	Urmia Basin
Catchment Area (km^2)	12,717	1,362	2,094	2,091	260	1,507	1,880	1,060	375	1,840	551	458	712	3,783	1,936	11,838	2,258	4,976	51,697
1980	4,157.88	563.22	844.35	1,000.16	166.51	689.61	992.87	616.53	149.55	630.93	201.82	223.93	343.20	1,569.84	838.12	5,491.30	1,003.24	2,212.88	21,695.95
1981	4,957.71	746.48	998.13	1,098.90	208.02	833.82	1,040.78	553.16	154.30	676.36	252.02	279.02	395.74	1,768.16	770.42	5,942.13	1,056.52	2,580.16	24,311.81
1982	4,704.87	679.81	903.00	1,158.20	147.70	1,008.06	1,281.94	678.75	147.93	652.16	252.90	276.97	376.25	1,777.83	835.05	7,302.05	1,660.77	2,379.52	26,223.76
1983	3,299.24	547.33	634.08	796.01	101.87	633.25	743.15	369.62	97.02	448.78	225.28	180.58	299.76	1,450.88	686.02	5,746.08	1,070.02	1,588.14	18,917.13
1984	4,420.87	858.20	819.07	1,230.01	160.54	795.50	1,042.48	442.22	167.68	597.24	415.66	232.81	394.76	2,154.40	911.79	8,578.47	1,292.14	2,468.49	26,982.33
1985	3,189.78	561.47	583.54	633.07	91.09	518.77	813.44	521.63	98.74	500.51	235.88	177.87	296.00	1,184.55	656.26	4,658.06	1,051.42	1,596.20	17,368.28
1986	4,588.30	1,064.41	910.63	1,177.38	208.69	761.46	1,254.71	503.73	171.44	632.99	309.79	243.04	420.44	1,703.88	941.76	6,718.86	1,492.59	2,753.52	25,857.59
1987	4,453.42	928.49	1,034.26	1,280.91	211.16	682.42	970.46	411.42	156.20	660.04	337.68	251.11	437.24	1,555.08	969.15	6,672.61	935.47	2,837.41	24,784.55
1988	3,779.89	668.40	740.36	820.38	110.11	515.21	839.66	412.12	105.13	501.18	227.30	186.77	320.98	1,552.02	635.61	5,411.10	1,000.66	2,006.72	19,833.62
1989	3,829.36	550.69	700.63	792.29	84.97	579.42	699.02	342.78	130.42	550.92	191.02	192.06	367.14	1,138.63	619.63	3,648.42	799.60	1,787.48	17,004.49
1990	2,729.48	467.85	610.81	829.03	49.09	608.46	607.85	298.23	117.73	358.70	185.46	144.75	259.17	1,282.97	622.12	4,178.13	778.89	1,307.89	15,436.62
1991	3,886.43	601.95	730.90	1,123.31	59.00	729.56	620.04	387.04	135.86	581.42	234.49	182.08	347.58	1,526.71	800.72	5,435.58	633.94	1,638.70	19,655.31
1992	5,339.07	720.37	948.98	1,257.12	153.64	721.50	1,165.73	613.13	200.69	766.11	280.86	273.08	471.31	1,825.09	927.89	5,982.19	1,265.04	2,727.59	25,639.38
1993	5,116.88	909.73	1,027.72	1,374.09	164.86	989.06	1,099.39	652.28	170.31	775.87	337.26	289.11	512.74	2,807.99	1,037.97	8,483.87	1,173.85	2,827.96	29,750.95
1994	4,623.80	718.30	909.33	1,124.37	141.48	726.70	982.01	552.55	156.35	836.63	247.57	266.93	455.53	1,941.68	926.66	6,293.96	1,240.10	2,336.23	24,480.19
1995	3,743.09	631.94	844.95	995.71	88.51	655.38	977.06	548.28	140.19	660.13	263.97	234.10	391.35	1,587.24	830.43	5,165.30	1,096.50	1,914.02	20,768.16
1996	4,821.79	581.57	790.46	988.70	44.77	607.83	829.16	444.38	139.89	762.94	220.44	207.99	363.23	1,400.37	791.14	4,385.82	841.58	1,810.07	20,032.12
1997	3,941.22	704.11	723.71	1,011.76	82.99	678.12	687.71	374.81	134.63	672.15	260.99	188.67	319.35	1,721.73	723.03	5,377.87	633.35	1,869.58	20,105.79
1998	3,474.62	449.14	714.24	634.90	59.04	419.48	536.79	334.89	102.84	619.31	173.83	140.34	238.01	1,039.90	649.78	3,946.91	737.24	1,392.83	15,664.10
1999	3,822.55	445.02	464.04	617.52	66.68	462.06	675.48	329.06	114.85	598.18	131.17	166.53	266.93	834.95	515.95	3,261.52	722.56	1,371.14	14,866.19
2000	3,700.14	488.23	609.15	698.30	54.75	446.62	785.83	390.29	110.74	522.24	174.72	168.98	272.99	1,083.88	643.70	3,685.88	866.70	1,326.45	16,029.58
2001	3,438.91	558.69	756.82	810.79	44.57	550.59	753.79	379.08	107.73	472.33	204.20	154.86	239.69	1,298.41	612.76	3,947.56	616.06	1,457.57	16,404.43
2002	4,844.12	736.57	863.24	1,012.65	38.34	673.22	755.24	374.50	148.95	720.58	264.11	181.22	297.33	1,828.92	855.24	5,301.62	841.02	1,674.18	21,411.06
2003	4,047.27	719.68	747.48	1,066.24	40.78	691.80	790.95	422.68	161.78	551.11	226.62	173.21	265.33	1,492.74	807.89	5,034.47	786.79	1,647.30	19,674.13
2004	4,887.04	738.15	907.12	1,088.61	56.24	598.06	850.09	409.30	175.53	569.11	275.25	183.31	299.33	2,007.63	913.19	6,168.13	759.12	1,799.47	22,684.69
2005	4,796.38	614.10	778.27	850.64	37.28	537.47	727.53	328.10	137.53	633.03	205.97	183.15	294.16	1,528.55	787.87	5,071.37	725.57	1,542.61	19,779.56
2006	4,226.56	705.80	857.53	1,131.87	54.94	675.22	859.38	417.59	187.22	615.90	228.71	189.96	273.69	1,745.22	785.50	5,238.21	821.38	1,867.14	20,881.80
2007	3,997.44	577.56	709.04	876.43	37.54	541.16	764.83	359.07	132.54	542.74	182.38	163.39	248.79	1,542.68	667.78	4,852.83	738.12	1,240.62	18,174.96
2008	3,268.82	438.91	524.77	645.33	31.17	389.09	597.41	344.39	107.93	425.83	147.25	148.93	195.64	1,056.98	471.41	3,484.22	614.56	1,080.14	13,972.80
2009	4,236.91	535.93	789.07	716.77	51.17	595.22	690.13	375.16	115.99	684.25	224.54	169.79	239.88	1,610.86	781.74	5,598.86	808.72	1,352.43	19,577.40
2010	3,889.65	511.10	714.33	753.37	72.70	806.16	612.29	370.62	125.65	600.12	181.65	162.32	235.36	1,309.01	683.20	4,666.70	703.72	1,540.32	17,938.27
Average all	4,135.92	645.91	780.32	954.67	94.20	649.04	840.23	437.33	138.82	607.09	235.51	200.54	327.06	1,558.99	764.51	5,346.13	927.98	1,868.86	20,513.13
Average 1980 to 1989	4,138.13	716.85	816.81	998.73	149.07	701.75	967.85	485.20	137.84	585.11	264.93	224.42	365.15	1,585.53	786.38	6,016.91	1,136.24	2,221.05	22,297.95
Average 1990 to 1999	4,149.89	623.00	776.51	995.65	91.01	659.82	818.12	453.46	141.33	663.14	233.60	209.36	362.52	1,596.86	782.57	5,251.12	912.30	1,919.60	20,639.88
Average 2000 to 2011	4,121.20	602.25	750.62	877.36	47.23	591.33	744.32	379.16	137.42	576.11	210.49	170.83	260.20	1,500.44	728.21	4,822.71	752.89	1,502.57	18,775.33

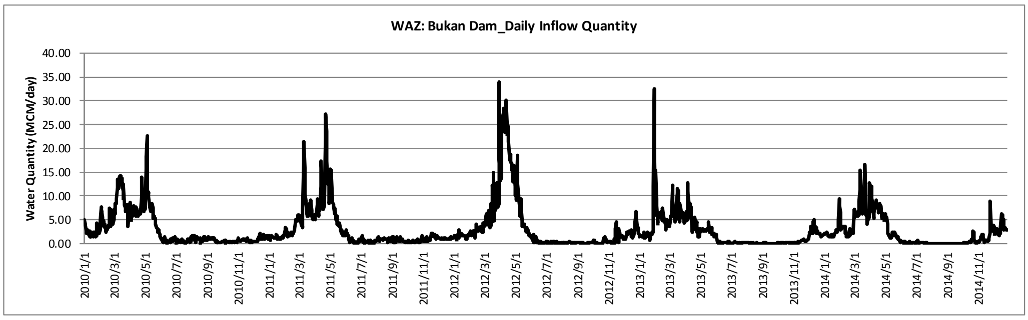
*JICA Survey Team prepared these tables based on the data from WRMC.

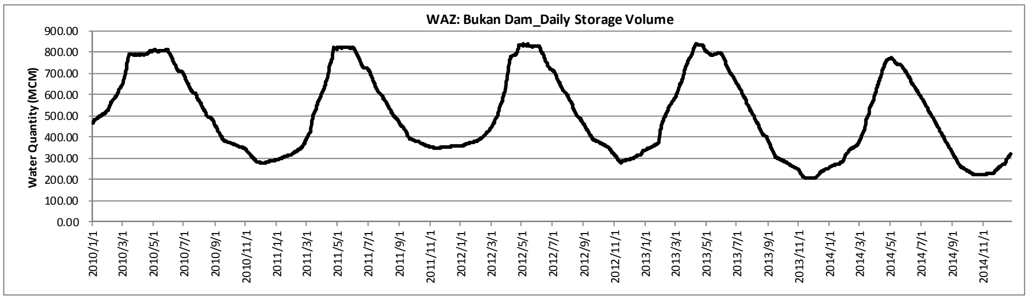
Annex 4.4
Modified Water Supply Quantity of Surface Water and Groundwater in the Whole Urmia Basin

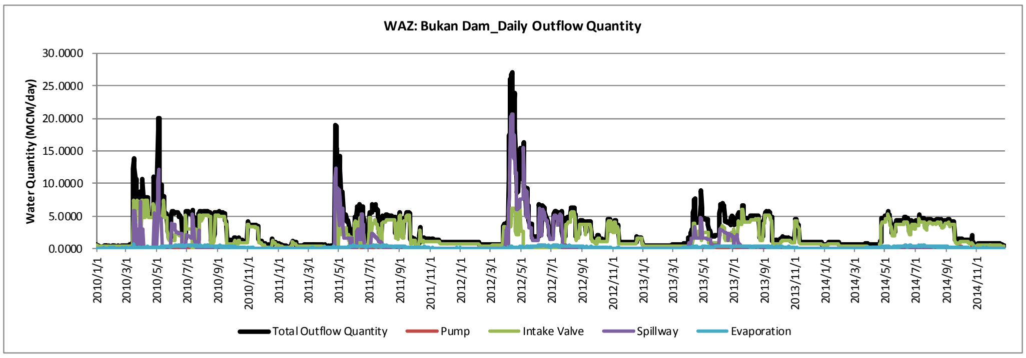
Year	Total Water Supply Quantity of the Dams with Collected Data	Total Quantity of Groundwater Uptaking Permission	Adjustment Ratio		Modified Total Water Supply Quantity from Dams	Modified Total Groundwater Uptaking Quantity	Total Water Supply Quantity
			Supply from Surface Water	Supply from Groundwater			
	(MCM/year)	(MCM/year)			(MCM/year)	(MCM/year)	(MCM/year)
	(1)	(2)	(3)	(4)	(5)=(1) x (3)	(6) = (2) x (4)	(6) = (2) x (4)
1939		0.03	1.72	1.11		0.04	0.04
1940		0.13	1.72	1.11		0.14	0.14
1941		0.35	1.72	1.11		0.39	0.39
1942		0.59	1.72	1.11		0.65	0.65
1943		0.60	1.72	1.11		0.66	0.66
1944		0.61	1.72	1.11		0.68	0.68
1945		0.65	1.72	1.11		0.72	0.72
1946		0.67	1.72	1.11		0.74	0.74
1947		0.90	1.72	1.11		1.00	1.00
1948		0.93	1.72	1.11		1.03	1.03
1949		0.96	1.72	1.11		1.06	1.06
1950		1.00	1.72	1.11		1.11	1.11
1951		1.02	1.72	1.11		1.13	1.13
1952		2.10	1.72	1.11		2.33	2.33
1953		2.38	1.72	1.11		2.64	2.64
1954		3.21	1.72	1.11		3.57	3.57
1955		4.26	1.72	1.11		4.73	4.73
1956		4.35	1.72	1.11		4.83	4.83
1957		6.22	1.72	1.11		6.90	6.90
1958		6.38	1.72	1.11		7.08	7.08
1959		7.14	1.72	1.11		7.93	7.93
1960		7.38	1.72	1.11		8.19	8.19
1961		7.52	1.72	1.11		8.34	8.34
1962		9.28	1.72	1.11		10.31	10.31
1963		9.95	1.72	1.11		11.04	11.04
1964		11.90	1.72	1.11		13.21	13.21
1965		14.62	1.72	1.11		16.23	16.23
1966		17.85	1.72	1.11		19.81	19.81
1967		56.64	1.72	1.11		62.87	62.87
1968		64.72	1.72	1.11		71.84	71.84
1969		76.26	1.72	1.11		84.65	84.65
1970		85.16	1.72	1.11		94.53	94.53
1971		100.61	1.72	1.11		111.68	111.68
1972		121.47	1.72	1.11		134.83	134.83
1973		138.81	1.72	1.11		154.08	154.08
1974		168.19	1.72	1.11		186.69	186.69
1975		207.54	1.72	1.11		230.37	230.37
1976		255.24	1.72	1.11		283.32	283.32
1977		329.93	1.72	1.11		366.22	366.22
1978	859.01	360.73	1.72	1.11	1477.50	400.41	1877.91
1979	842.93	396.82	1.72	1.11	1449.85	440.47	1890.32
1980	779.52	430.23	1.72	1.11	1340.78	477.55	1818.33
1981	*838.67*	458.37	1.72	1.11	*1442.51*	508.79	*1951.30*
1982	*897.82*	507.71	1.72	1.11	*1544.25*	563.55	*2107.80*
1983	956.97	528.17	1.72	1.11	1645.98	586.27	2232.25
1984	477.61	548.35	1.72	1.11	821.50	608.66	1430.16
1985	583.11	578.92	1.72	1.11	1002.95	642.60	1645.55
1986	631.49	602.63	1.72	1.11	1086.16	668.92	1755.08
1987	808.74	655.67	1.72	1.11	1391.03	727.80	2118.83
1988	703.39	672.26	1.72	1.11	1209.83	746.21	1956.04
1989	856.78	692.90	1.72	1.11	1473.66	769.12	2242.78
1990	828.18	715.54	1.72	1.11	1424.46	794.25	2218.71
1991	823.62	739.17	1.72	1.11	1416.62	820.48	2237.10
1992	770.18	788.63	1.72	1.11	1324.71	875.38	2200.09
1993	786.74	824.70	1.72	1.11	1353.19	915.41	2268.61
1994	845.64	867.63	1.72	1.11	1454.51	963.07	2417.57
1995	771.48	962.84	1.72	1.11	1326.94	1068.75	2395.69
1996	755.79	1041.85	1.72	1.11	1299.96	1156.46	2456.42
1997	714.94	1151.75	1.72	1.11	1229.69	1278.44	2508.13
1998	976.24	1209.60	1.72	1.11	1679.14	1342.66	3021.80
1999	494.01	1273.94	1.72	1.11	849.69	1414.08	2263.77
2000	615.32	1320.43	1.72	1.11	1058.35	1465.68	2524.03
2001	579.19	1372.94	1.72	1.11	996.20	1523.97	2520.17
2002	1003.30	1433.45	1.72	1.11	1725.68	1591.13	3316.81
2003	1306.44	1478.20	1.72	1.11	2247.07	1640.80	3887.87
2004	1128.58	1535.02	1.72	1.11	1941.16	1703.87	3645.03
2005	1000.12	1568.21	1.72	1.11	1720.20	1740.71	3460.91
2006	1123.93	1581.84	1.72	1.11	1933.16	1755.85	3689.00
2007	1176.39	1586.43	1.72	1.11	2023.39	1760.94	3784.33
2008	763.80	1588.89	1.72	1.11	1313.74	1763.67	3077.40
2009	1076.46	1590.46	1.72	1.11	1851.52	1765.41	3616.93
2010	1340.47	*1592.03*	1.72	1.11	2305.60	*1767.16*	4072.76
2011	1141.26	*1593.61*	1.72	1.11	1962.97	*1768.90*	3731.87
2012	1305.87	*1595.18*	1.72	1.11	2246.09	*1770.65*	4016.74
2013	1506.94	*1596.75*	1.72	1.11	2591.94	*1772.40*	4364.34
2014	1229.62	*1598.33*	1.72	1.11	2114.94	*1774.14*	3889.08
Note:	Italic values are estimated groundwater supply quantity based on the trend from 2008 to 2009.						

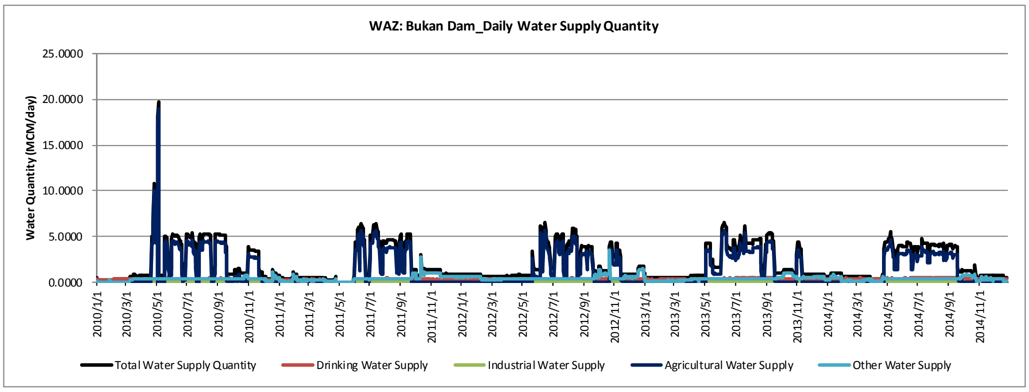
Annex 4.5
Conditions of Daily Operation of Bukan Dam from Year 2010 to 2014


WAZ: Bukan Dam_ Daily Precipitation
Precipitation (mm/day)
Snow Depth
Rainfall

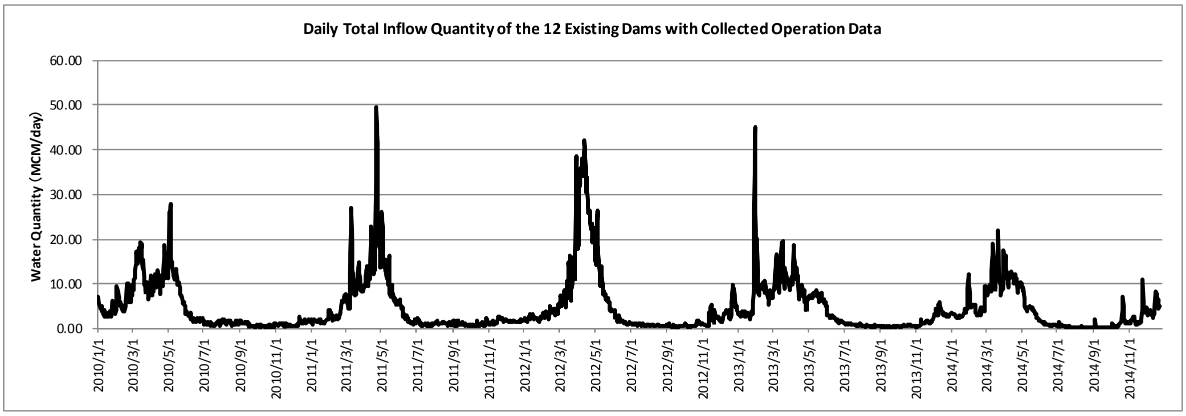

WAZ: Bukan Dam_Daily Inflow Quantity
Water Quantity (MCM/day)

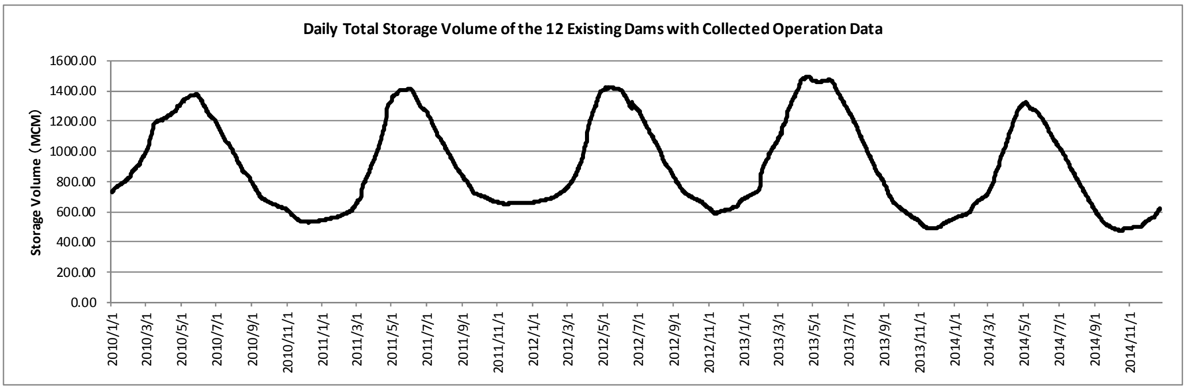

WAZ: Bukan Dam_Daily Storage Volume
Water Quantity (MCM)

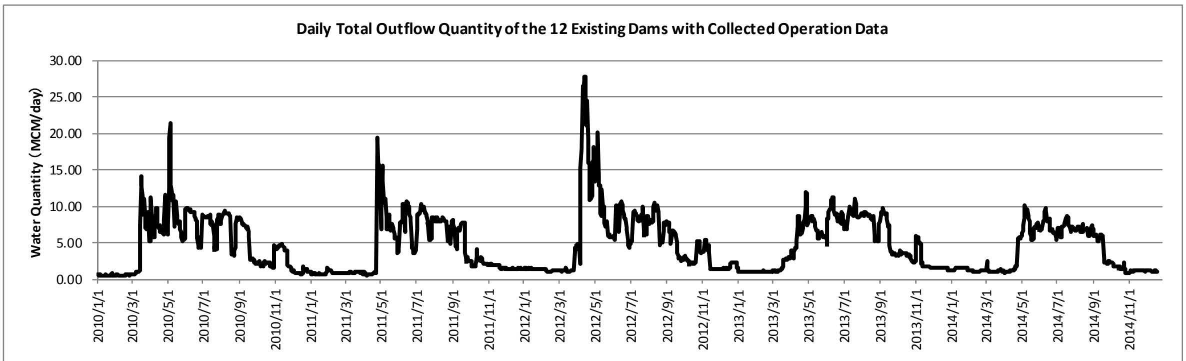

WAZ: Bukan Dam_Daily Outflow Quantity
Water Quantity (MCM/day)
Total Outflow Quantity
Pump
Intake Valve
Spillway
Evaporation

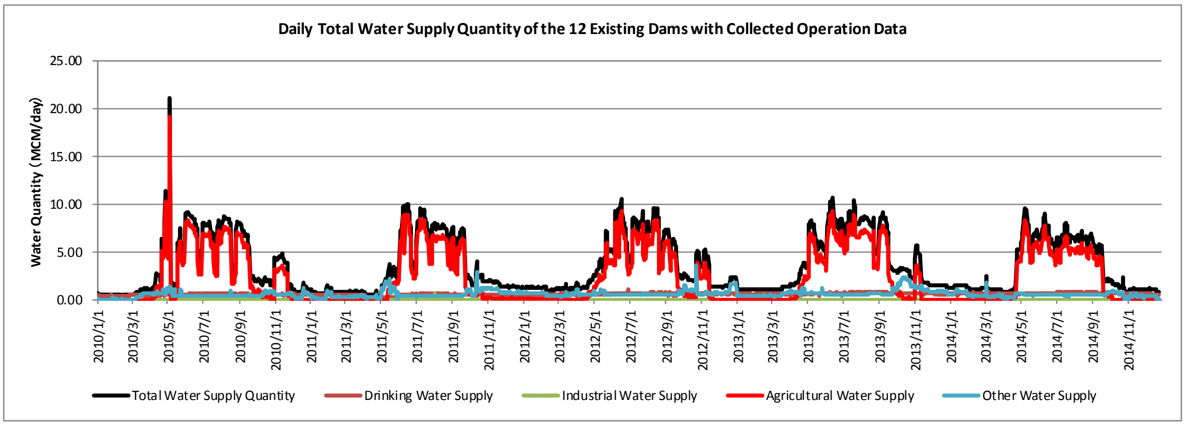

WAZ: Bukan Dam_Daily Water Supply Quantity
Water Quantity (MCM/day)
Total Water Supply Quantity
Drinking Water Supply
Industrial Water Supply
Agricultural Water Supply
Other Water Supply

Annex 4.6
Total Daily Operation of Water Quantity of the 12 Existing Dams with Collected Operation Data

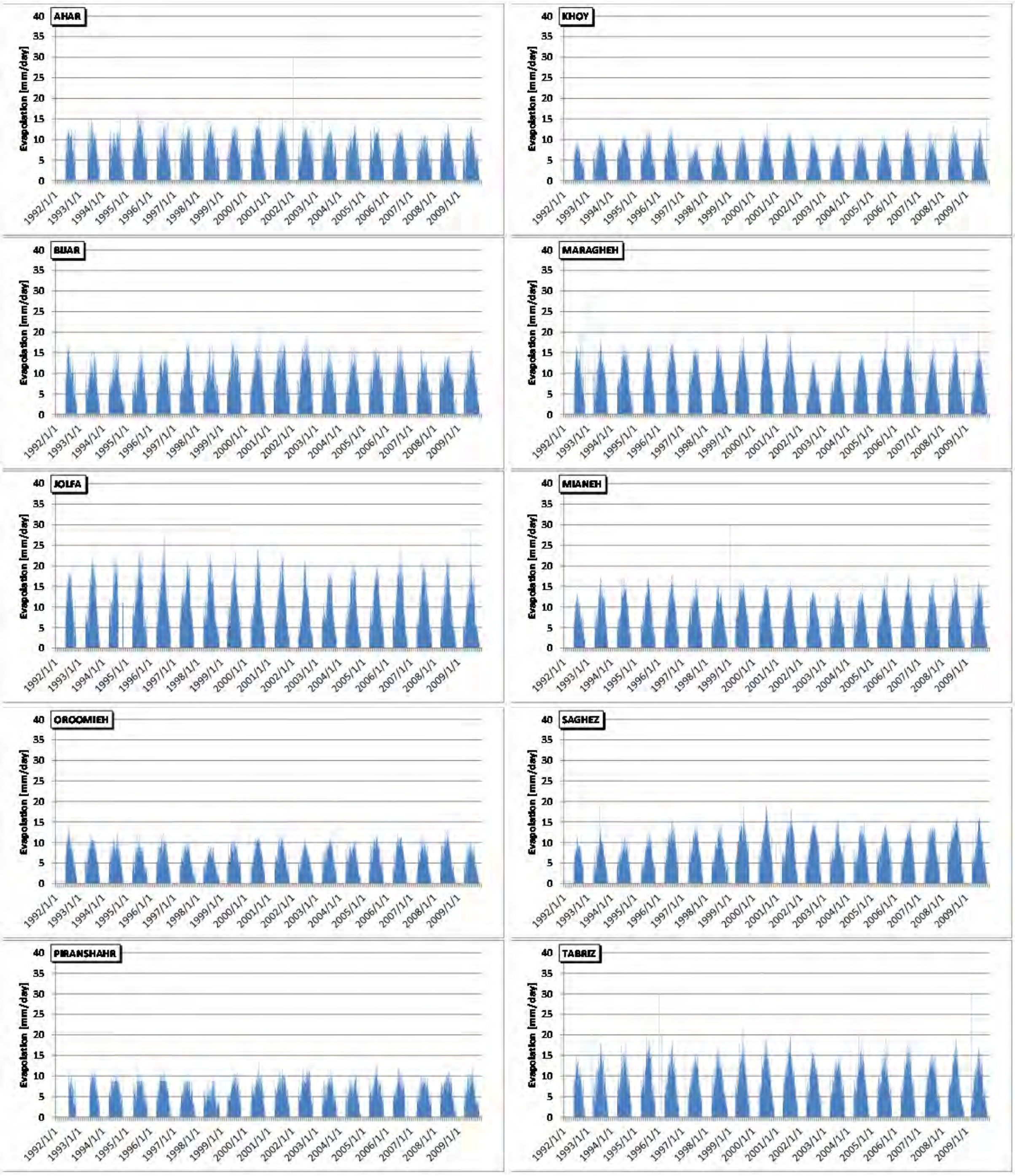

Daily Total Inflow Quantity of the 12 Existing Dams with Collected Operation Data
Water Quantity (MCM/day)


Daily Total Storage Volume of the 12 Existing Dams with Collected Operation Data
Storage Volume (MCM)


Daily Total Outflow Quantity of the 12 Existing Dams with Collected Operation Data
Water Quantity (MCM/day)

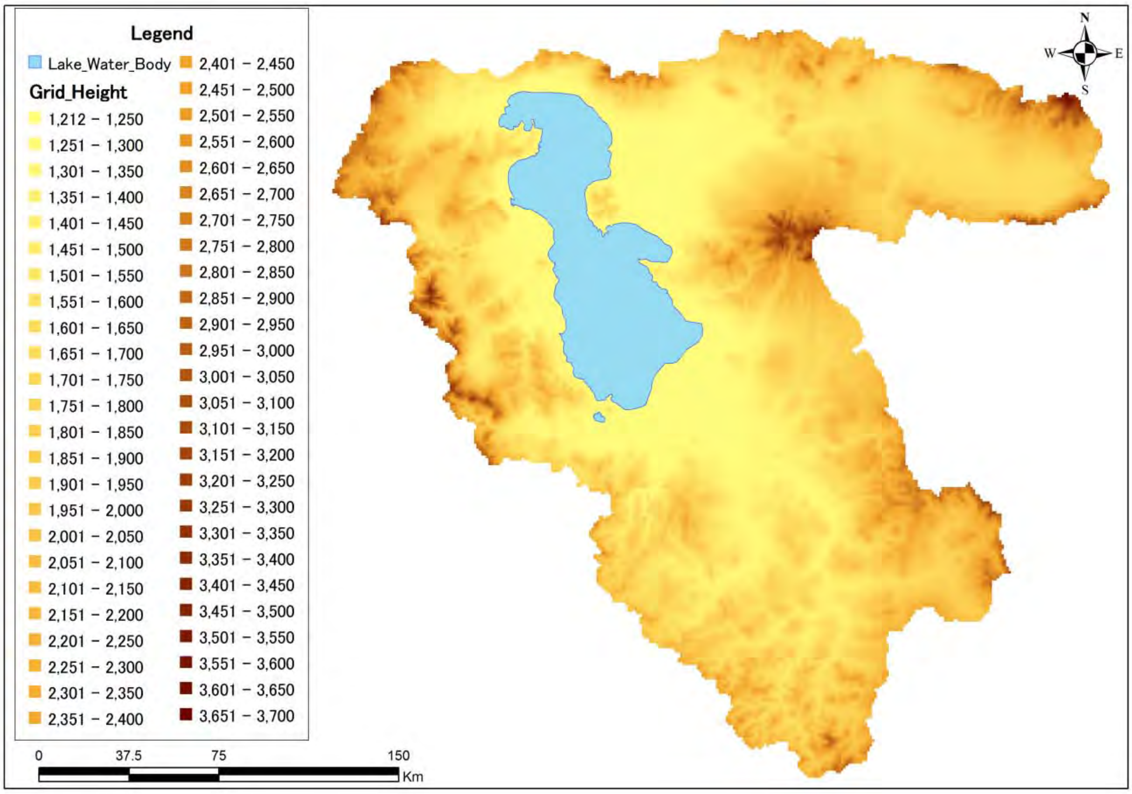

Daily Total Water Supply Quantity of the 12 Existing Dams with Collected Operation Data
Water Quantity (MCM/day)
Total Water Supply Quantity
Drinking Water Supply
Industrial Water Supply
Agricultural Water Supply
Other Water Supply

Annex 5.1
Observed Pan Evaporation

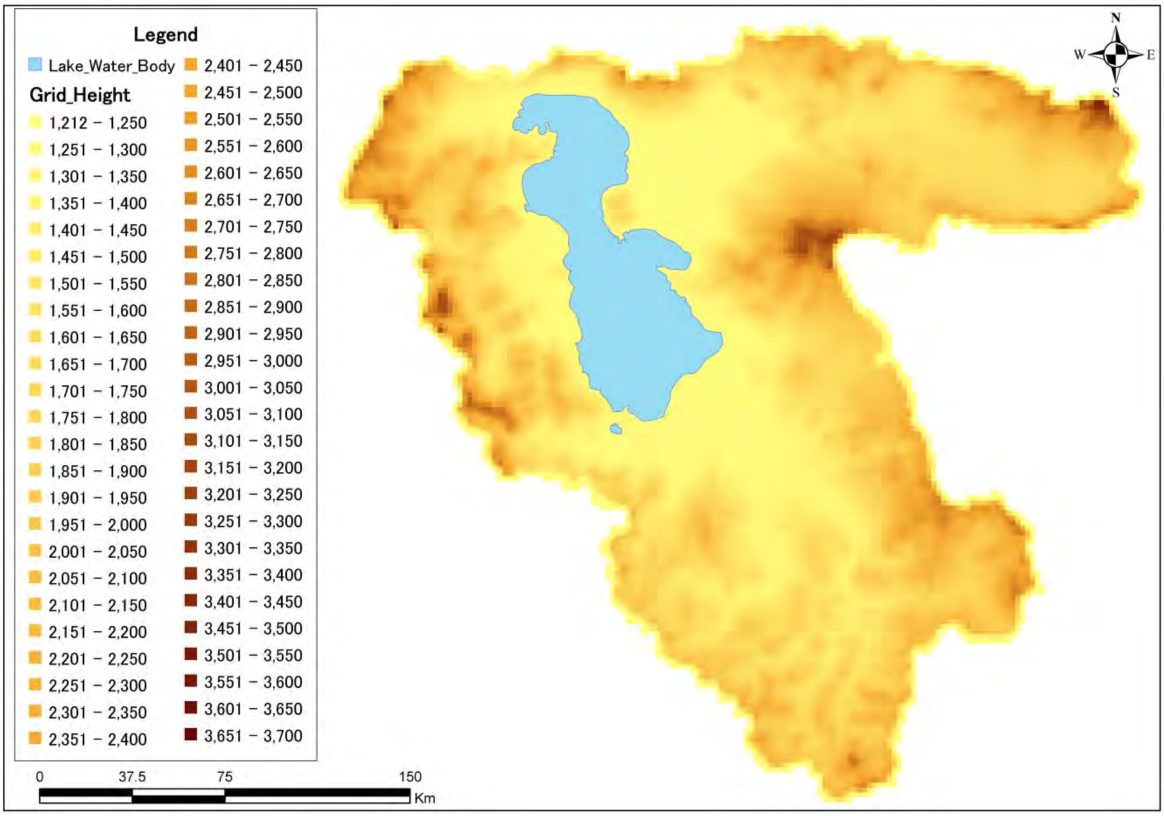

AHAR
KHOY
BIJAR
MARAGHEH
JOLFA
MIANEH
OROOMIEH
SAGHEZ
PIRANSHAHR
TABRIZ
Evapolation [mm/day]
0
5
10
15
20
25
30
35
40
1992/1/1
1993/1/1
1994/1/1
1995/1/1
1996/1/1
1997/1/1
1998/1/1
1999/1/1
2000/1/1
2001/1/1
2002/1/1
2003/1/1
2004/1/1
2005/1/1
2006/1/1
2007/1/1
2008/1/1
2009/1/1

Source: IMO

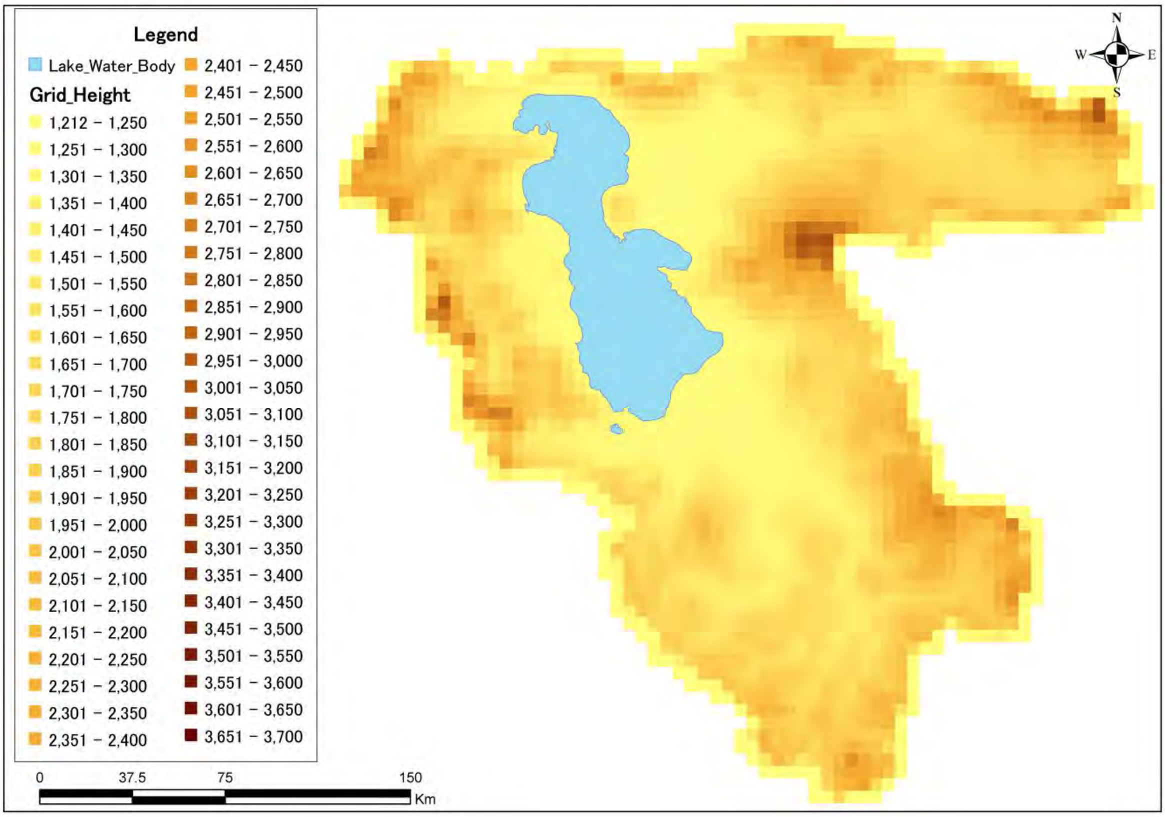
Annex 5.2
Comparison of Resolution for Mesh Sizes



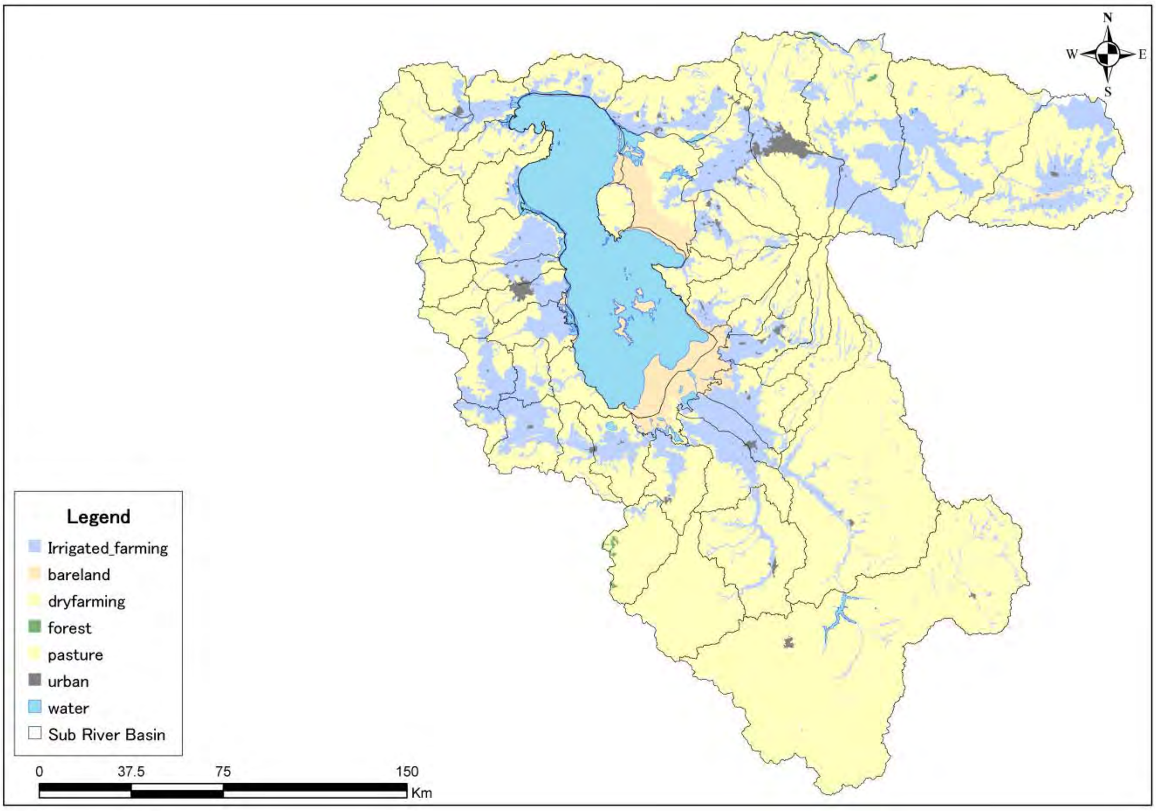
1km mesh DEM



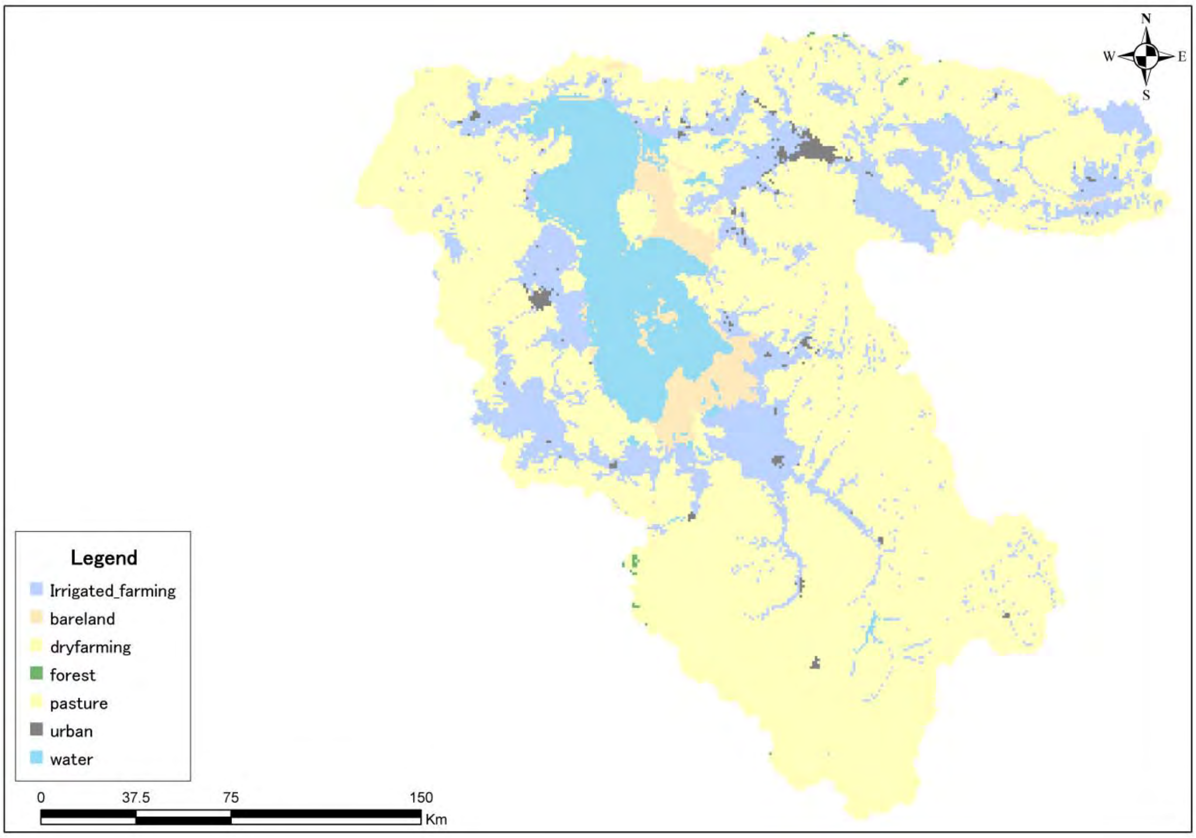
2km mesh DEM



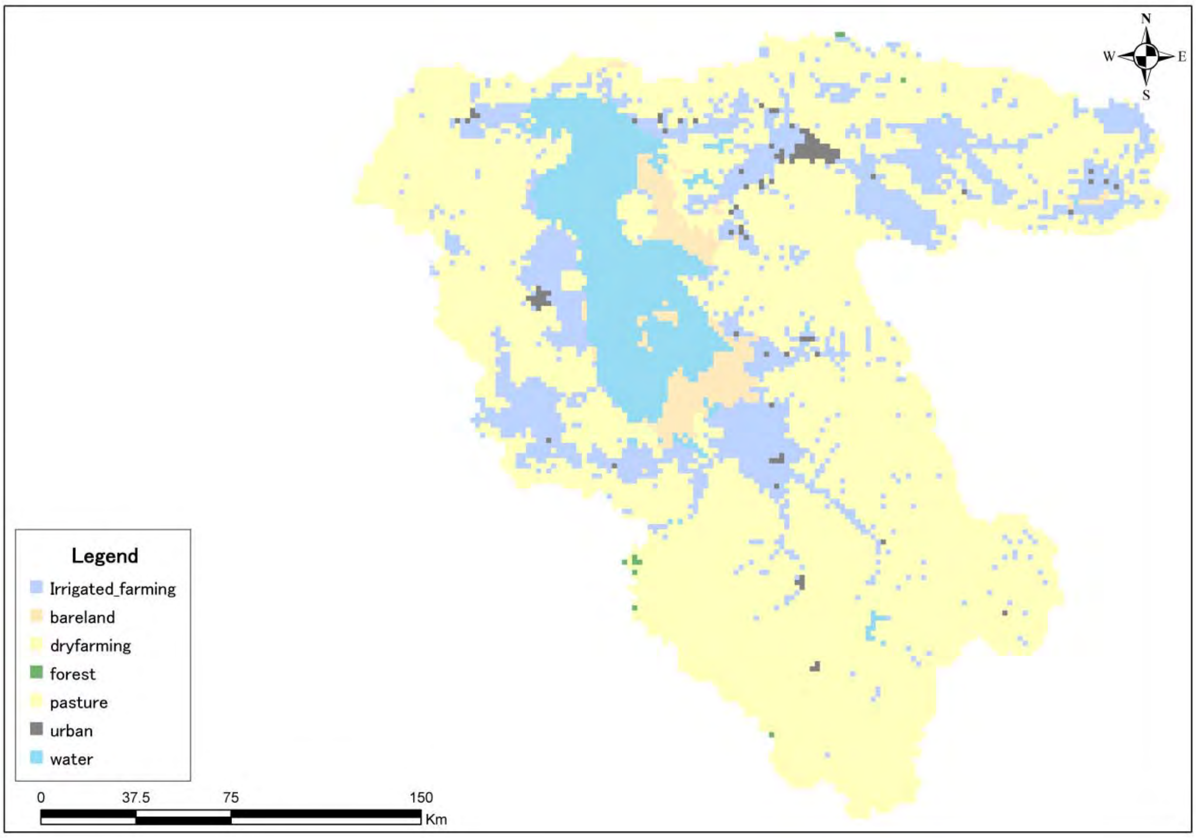
5km mesh DEM



Prepared Polygon of Land Use



1km mesh Land Use



2km mesh Land Use

Annex 6.1
Countermeasure Projects Proposed by LURC (as of November 2014)

Source: LURC(November, 2014)

Approved Solutions …

13. Studying the effects of Shahid Kalantari causeway on Urmia Lake ecosystem and suggesting the corrective solutions
14. Assessing the feasibility of industrial utilization of Urmia Lake salts and minerals in compliance with environmental considerations
15. Transferring rivers' water into the body of the Lake
16. Identifying the centers producing atmospheric pollutants (dirt and dust) and consolidating them
17. Studying and implementing the ecologic conservation of Urmia Lake National Park with the priority of its southern area
18. Conducting the necessary coordination with the judiciary in order to accelerate and pave the way for determining the conditions of wells without license especially those affecting the surface water
19. Identifying the areas affecting the discharge of rivers running into the Lake and reinforcing them through watershed and aquifer management in order to increase the volume of water inflows into the Lake.

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Approved Solutions…

20. Accelerating the implementation of water transferring from Aras River in West Azerbaijan merely into Urmia Lake on the basis of approved allocation by the Ministry of Energy
21. Establishing a future center for Urmia Lake by DOE
22. Pathology of health, hygiene, social and environmental effects due to the lake drying up and accordingly preparing and implementing a program in order to prevent and reduce the risk of possible effects
23. Preparing the program to enhance the opportunities for employment and alternative livelihood by the relevant agencies
24. The feasibility of using modern technologies for Urmia Lake Restoration

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Source: LURC(November, 2014)