CHAPTER 3 APPLICABILITY CHECK ON BASIC INFORMATION COLLECTED

3.1 Outline of Collected Data

The JICA Survey Team which conducted the previous survey had made a proposal on the data/information required for the improvement of the Hydrological Cycle Model that was constructed. The data/information for each sub-target area (south, west and east) of the Urmia Lake Basin were provided to the Survey Team.

Table 3.1.1 shows the data/information list. Based on the data/information provided, the Survey Team updated the hydrological cycle model in a stepwise manner and evaluated the restoration measures for Urmia Lake. The undertakings followed by the Survey Team to execute the works for improvement of the hydrological cycle model have been determined and agreed upon, as mentioned in the Minutes of Meeting (MM) among JICA, MOE and ULRP in February 2017.

Table 3.1.1 Data/Information Collected from ULRP

No.	Classification	Details	Approach for Application to Hydrological Cycle Model
1	Intake point and water amount	➢ Location of water intake point (such as weir) and intake water amount provided to Modern/ Semi-Modern irrigation scheme ➢ Location of intake facilities for traditional irrigation scheme and its intake amount installed along main river in the Urmia Lake Basin ➢ Location of well and water intake amount ➢ Information on illegal water intake	➢ Observed data (time series data) is to be input into the model at specified points ➢ Location of wells are input into the model, at which time series data of groundwater abstraction is to be input.
2	Evaporation and Evapotranspiration	➢ Estimated evapotranspiration using satellite image analysis calculated by Iranian side ➢ Estimated evapotranspiration using climatological data calculated by Iranian side (time series data for long period is desirable) *This data is to be provided by the Iranian side ➢ Land use map distinguishable between agricultural area and others	➢ Based on land use classification, the following time series of water demands are to be input into the model: (1) Agricultural water demand with irrigation loss for agricultural land (2) Aerial evapotranspiration for non-agricultural land
		➢ Evaporation from lake water surface (Pan evaporation at the climatological station adjacent to the Urmia Lake)	➢ Observed evaporation is to be applied with modification for estimation of that from lake surface
3	Dam	➢ Hydrological data at primary dams -Discharge for sectors -Inflow discharge into dam -Inventory list of dams	➢ Discharge from dams are to be input as upper boundary condition of river channel model
4	Topology of Lake bed	➢ Bathymetry survey result (Data surveyed in 2013 and in 2015 at the latest)	➢ Topological data of lakebed is to be combined with land topological data
5	Additional hydrological data	➢ Hydrological data updated since the previous survey -Daily rainfall -Daily discharge -Daily lake water level -Daily groundwater level *In the previous survey, data observed between 1980 and 2011 was collected.	➢ Daily rainfall data is to be converted into sub-basin average rainfall by the Thiessen method ➢ Remaining three data are to be utilized for verification of the calibrated hydrological cycle model
6	Geological information	➢ The data/information found in the formulation survey for detailed plan of the Survey -Information on geology and aquifer -Depth of geological layer -Hydrogeological parameter (e.g. hydraulic conductivity, specific storage coefficient, soil porosity)	➢ Geological conceptual model developed by URLP with outsourcing is to be provided to the JICA Survey Team

3.2 Applicability Check on Collected Data

Detailed check of collected data was carried out immediately after their provision by ULRP. The check focused on the applicability of data for the improvement of the hydrological cycle model from the viewpoint of period and accuracy. The check results were shared with the Iranian Counterparts (C/P). In case of qualitative/quantitative insufficiencies of the collected data for improving the model, the Survey Team and PRMU-ULRP discussed and determined the appropriate countermeasure such as additional data and alternative approaches. These data checks were conducted before the hydrological cycle model was constructed for each target area (southern, western and eastern parts).

In hydrological cycle modeling, the quantity and quality of collected data will greatly affect the accuracy of the constructed model. With the status of data collection, ULRP and the Survey Team discussed about the verification period and limitation of the model.

The data listed in the first field works were mainly collected for the calibration and validation periods , and the quality of data was checked and analyzed as shown in Table 3.2.1. The accuracy of data necessary for the modeling, especially, hydrometeorology, water utilization, topography, geology, land use, river network, topography of lake bed, location of measuring station, river cross sections, location, function and scale of water facilities were checked and analyzed. If the collected data had inaccurate or missing data, the Survey Team discussed them with the Iranian counterparts and asked the data distributors for a modified data, or, the Survey Team interpolated the data by itself.

Since the information on water use was not enough in quality or quantity for building a practical model, the amount of evapotranspiration from irrigating area were estimated by satellite imaging and the estimated data were input into the hydrological cycle model instead. In this case, the data of evapotranspiration estimated by the METRIC method was supposed to be provided from the Iranian side. As the result of checking of the calculation process by METRIC method, it turned out that technical advice to Iran side was necessary.

Table 3.2.1 Checkpoints of Collected Data

Items	Checkpoints
Intake Point and Quantity of Water Intake	Check the validity of quantity of water intake by comparing irrigation schemes, intake points and relevant plans on GIS
Evapotranspiration and Pan Evaporation	Check the calculation process of evapotranspiration *Since the amount of pan evaporation has an error of about 30%, the data will be used as checking order of magnitude.
Dam Operation	Check the amount of water supply for each water-use sector by comparing planned values and actual values *1.4 times of annual water supply from the dams was input as the amount of water use in the previous survey.
Topography of Urmia Lake bed	Topography of Urmia Lakebed will be integrated to the whole topography data. Although the topographic survey data in 2010 have been collected, the topography of Urmia Lakebed has already changed by sedimentation so that the relation between storage and water level has also changed. Therefore, the latest survey data shall be obtained as much as possible.
Additional Hydrological Data	In addition to the collected hydrological data (from 1980 to 2013) in the previous survey, outlier detection and check of secular change of hydrological characteristics in Urmia Lake basin shall be conducted over the whole period.
Subsurface Structure	Estimate distribution of main confined aquifer from the points of boring survey and the location of groundwater measurement and depth of screen.

3.2.1 Intake Point and Quantity

GIS database of water intake location and water intake quantity has been collected. This GIS data is the result of survey on water use between 2008 and 2013. For each of the six water intake methods (Well, Creek, Motor Pump, Qanat, Spring, Waterway), information such as latitude, longitude, specifications, purpose of water use, water intake, etc., of the intake point is stored in the database. However, this data does not cover the whole survey area, and the investigation period is from 2008 to 2013, so that it is difficult to organize a time series. In order to improve the accuracy of the hydrological cycle model, it is important to grasp the water intake amount.

In the Survey the total amount of water intake including illegal water discharge were calculated from the estimation of evapotranspiration by the satellite image produced by the METRIC method. Therefore, the GIS database of this water intake amount is treated as reference data. For reference, the water intake point for each water use purpose in the six water intake methods is shown in Figure 3.2.1, and the water intake and average discharge for each is shown in Table 3.2.2. Agricultural use is the most frequent, and the water use characteristics of the basin are expressed.

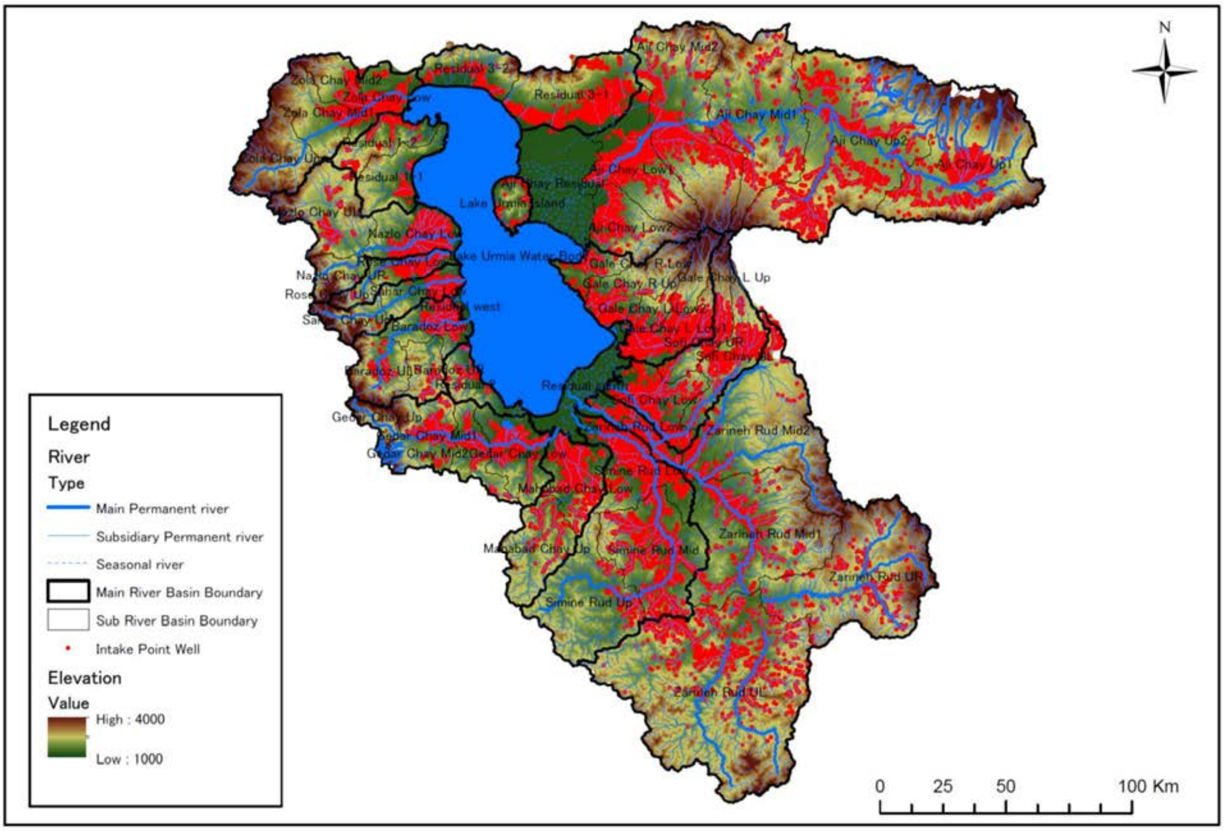


Figure 3.2.1 Locations of Intake Point (Well) (1/6)

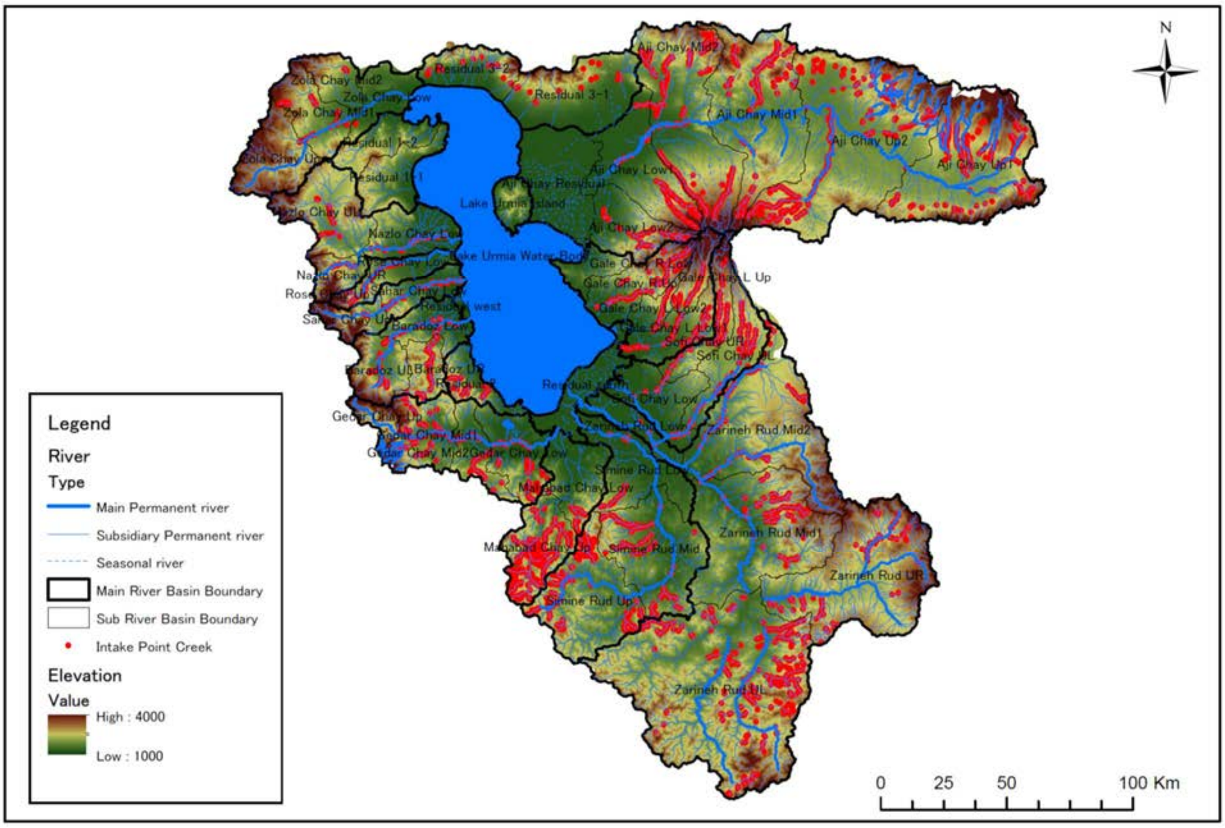


Figure 3.2.1 Locations of Intake Point (Creek) (2/6)

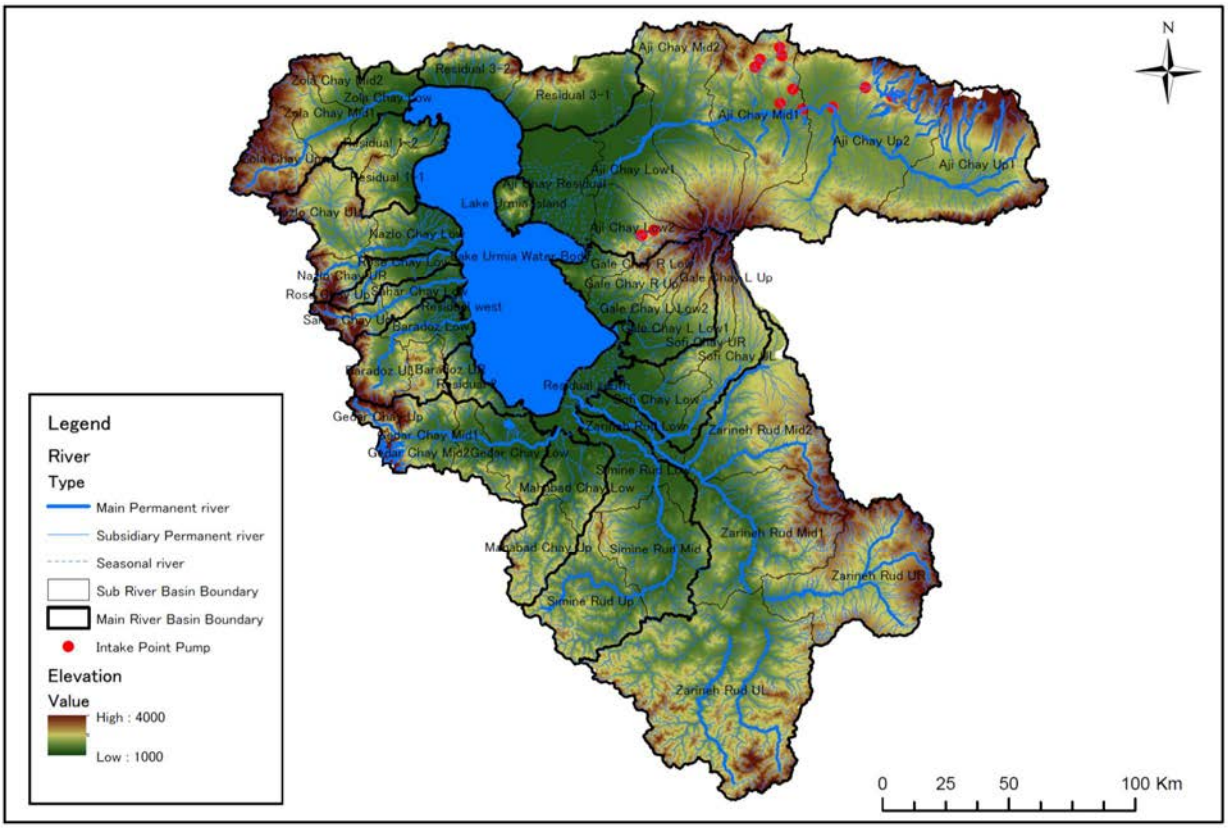


Figure 3.2.1 Location of Intake Point (Motor Pump) (3/6)

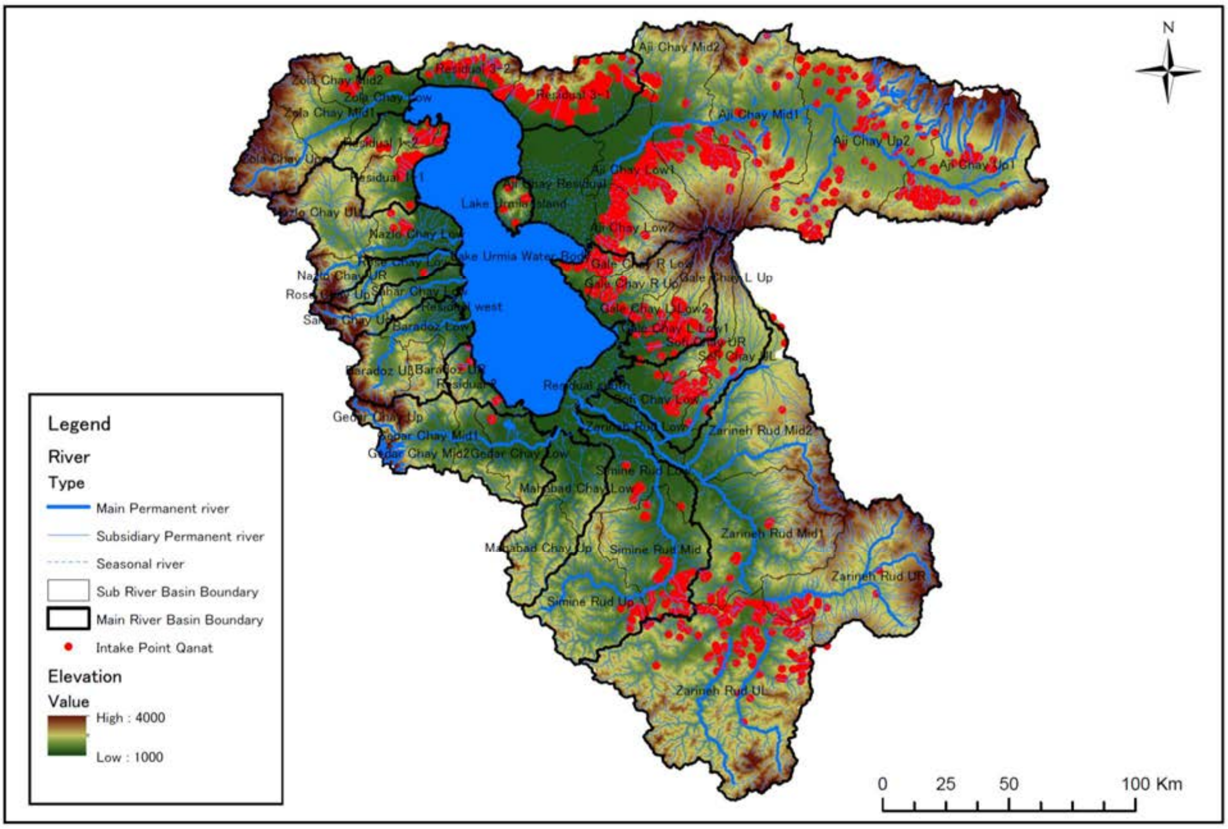


Figure 3.2.1 Location of Intake Point (Qanat) (4/6)

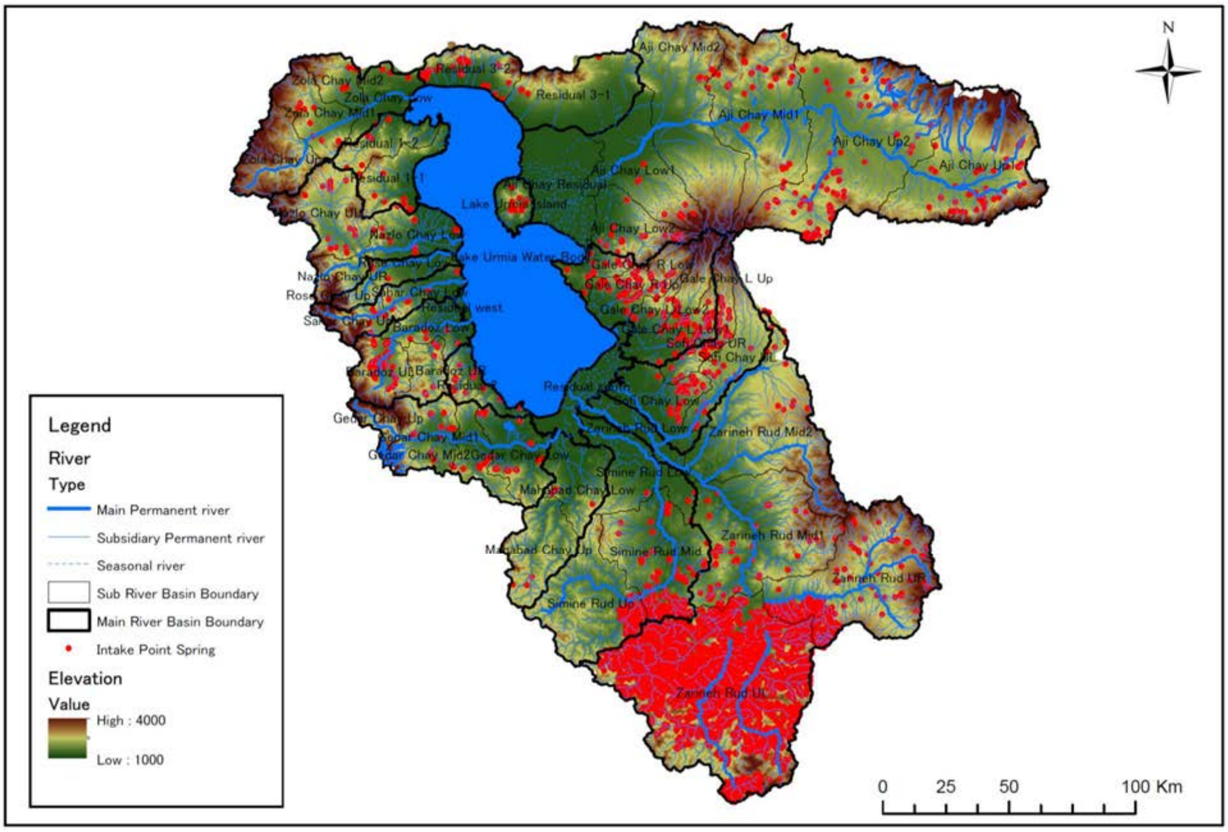


Figure 3.2.1 Location of Intake Point (Spring) (5/6)

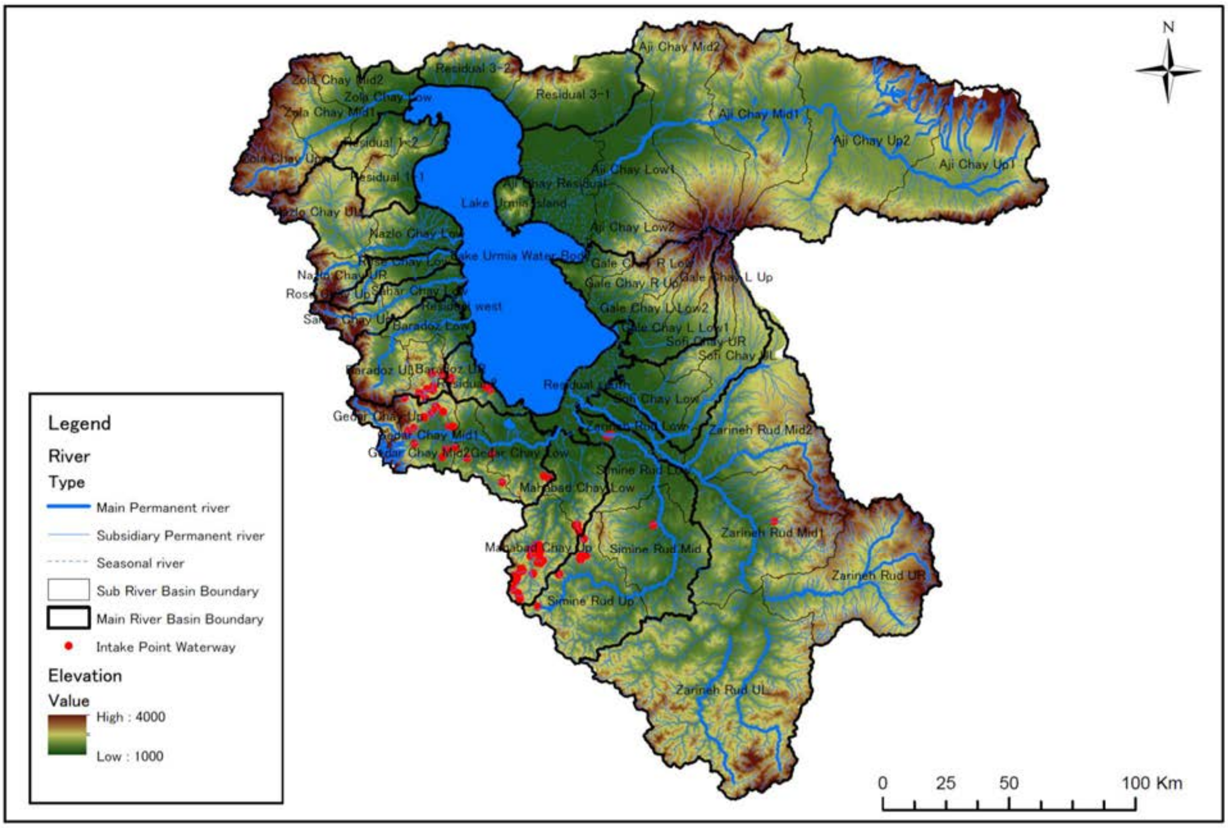


Figure 3.2.1 Location of Intake Point (Waterway) (6/6)

Table 3.2.2 Number of Intake Point Each for River Basin (Well) (1/4)

No	Basin. Name	Agricultural		Aquaculture		green House		Green Spaces		Industry		Livestock and poultry		Medical plants		Packaging		Rural Drinking		Services		Urban Drinking		Total	
		Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number	Intake Volume (MCM/year)	Number
1	Zola Chay Low	40.61	274	0.00	0	0.00	1	0.00	0	0.23	4	0.03	11	0.00	0	0.00	0	2.22	12	0.00	2	0.00	0	43.10	304
2	Zola Chay Mid2	16.15	71	0.00	0	0.00	0	0.14	3	0.02	6	0.03	11	0.00	0	0.00	0	1.85	10	0.02	4	2.64	16	20.84	121
3	Zola Chay Mid1	34.18	169	0.00	0	0.00	0	0.00	0	0.02	3	0.01	3	0.00	0	0.00	0	1.46	8	0.00	2	0.06	2	35.72	187
4	Zola Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
5	Residual 1-2	15.74	69	0.00	0	0.00	0	0.00	0	0.04	1	0.00	1	0.00	0	0.00	0	0.41	3	0.00	0	0.00	0	16.19	74
6	Residual 1-1	14.76	72	0.00	0	0.00	0	0.00	0	0.00	2	0.00	2	0.00	0	0.00	0	0.34	4	0.00	0	0.05	1	15.15	81
7	Nazlo Chay Low	62.19	4,658	0.18	4	0.00	3	0.02	6	0.41	32	0.33	104	0.00	0	0.00	0	0.35	67	0.01	5	0.16	1	63.64	4,880
8	Nazlo Chay UL	9.36	239	0.84	3	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.13	23	0.00	0	0.06	3	10.40	268
9	Nazlo Chay UR	0.18	5	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.15	1	0.00	0	0.00	0	0.33	6
10	Rose Chay Low	25.32	1,466	0.00	2	0.01	2	0.02	2	0.06	64	0.00	23	0.00	0	0.00	0	0.35	77	0.01	5	0.00	2	25.77	1,643
11	Rose Chay Up	0.38	12	0.00	0	0.00	0	0.00	0	0.04	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.42	14
12	Sahar Chay Low	15.05	3,663	0.03	3	0.00	0	0.00	3	0.16	37	0.06	19	0.00	0	0.00	0	0.63	40	0.01	9	0.14	2	16.08	3,776
13	Sahar Chay Up	0.16	2	0.00	0	0.00	0	0.00	0	0.00	1	0.00	0	0.00	0	0.00	0	0.10	1	0.00	0	0.00	2	0.26	6
14	Baradoz Low	32.93	3,131	3.05	25	0.03	3	0.17	1	2.71	73	0.64	70	0.00	0	0.00	0	0.73	60	0.06	6	0.00	0	40.33	3,369
15	Baradoz UR	3.96	148	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.00	0	0.00	0	3.96	150
16	Baradoz UL	2.85	191	1.43	3	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.05	30	0.00	0	0.00	0	4.33	224
17	Residual 2	4.24	269	0.25	8	0.00	0	0.00	0	0.00	3	0.02	4	0.00	0	0.00	0	0.00	0	0.00	1	0.00	0	4.51	285
18	Gedar Chay Low	26.89	1,228	0.25	1	0.06	3	0.04	2	0.03	2	0.12	19	0.00	0	0.00	0	0.42	2	0.00	0	0.00	0	27.82	1,257
19	Gedar Chay Mid2	17.13	630	0.64	2	0.00	1	0.00	0	0.00	0	0.01	3	0.00	0	0.00	0	0.66	2	0.00	0	0.00	0	18.45	638
20	Gedar Chay Mid1	39.69	856	0.00	0	0.00	1	0.00	0	0.27	7	0.07	7	0.00	0	0.00	0	0.60	12	0.00	0	0.14	2	40.77	885
21	Gedar Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
22	Mahabad Chay Low	14.81	2,329	0.00	1	0.00	1	0.00	3	0.14	19	0.03	26	0.00	0	0.00	0	0.23	11	0.00	0	0.00	1	15.21	2,391
23	Mahabad Chay Up	1.56	157	0.00	0	0.00	0	0.00	0	0.00	2	0.01	3	0.00	0	0.00	0	0.06	9	0.00	0	0.00	0	1.63	171
24	Simine Rud Low	101.29	3,946	0.00	1	0.00	1	0.02	1	0.37	13	0.31	1	0.00	0	0.07	9	2.08	43	0.00	2	1.55	19	105.70	4,036
25	Simine Rud Mid	45.85	2,231	0.00	1	0.09	2	0.16	22	0.97	48	0.34	43	0.01	1	0.00	0	1.51	43	0.21	36	0.25	4	49.39	2,431
26	Simine Rud Up	2.81	164	0.00	0	0.00	0	0.00	0	0.00	0	0.02	1	0.00	0	0.00	0	0.39	13	0.00	0	0.00	0	3.21	178
27	Zarineh Rud Low	22.59	1,549	1.80	5	0.14	3	0.27	9	0.04	2	0.14	2	0.00	0	0.08	20	0.14	3	0.03	13	1.77	6	27.00	1,612
28	Zarineh Rud Mid1	39.60	1,813	0.74	3	0.00	0	0.14	2	0.26	15	0.49	36	0.00	0	0.00	0	1.43	21	0.27	5	1.05	3	43.99	1,898
29	Zarineh Rud Mid2	23.98	1,138	0.00	1	0.05	1	0.00	0	0.02	1	0.06	9	0.00	0	0.00	0	0.10	11	0.00	3	0.25	1	24.47	1,165
30	Zarineh Rud UR	3.15	377	0.00	0	0.00	0	0.00	0	0.02	5	0.03	6	0.00	0	0.00	0	0.18	10	0.02	2	0.00	0	3.40	400
31	Zarineh Rud UL	13.81	1,127	0.00	0	0.02	1	0.00	0	0.56	14	0.94	61	0.00	0	0.01	1	3.40	143	0.61	17	0.08	4	19.44	1,368
32	Sofi Chay Low	23.56	4,563	0.06	1	0.00	0	0.03	3	0.28	29	0.13	29	0.00	0	0.00	0	0.79	17	0.13	23	0.61	10	25.60	4,675
33	Sofi Chay UR	28.04	1,852	0.12	2	0.00	0	0.00	0	0.00	0	0.07	15	0.00	0	0.00	0	0.11	2	0.01	1	0.00	0	28.34	1,872
34	Sofi Chay UL	9.23	1,033	0.00	0	0.00	0	0.00	0	0.04	4	0.01	2	0.00	0	0.00	0	0.34	8	0.02	3	0.00	0	9.63	1,050
35	Gale Chay L Low2	0.42	169	0.00	0	0.00	0	0.04	2	0.18	18	0.05	5	0.00	0	0.00	0	0.01	1	0.00	4	0.00	0	0.71	199
36	Gale Chay L Low1	52.01	5,630	0.85	5	0.00	1	0.55	24	0.39	37	0.71	64	0.00	0	0.00	0	1.18	25	0.12	8	0.74	12	56.55	5,806
37	Gale Chay L Up	0.91	145	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.00	0	0.00	0	0.91	146
38	Gale Chay R Up	22.96	784	0.00	0	0.00	0	0.49	7	0.24	17	0.03	14	0.00	0	0.00	0	2.00	27	0.00	1	2.08	12	27.81	862
39	Gale Chay R Low	3.59	265	0.00	0	0.00	0	0.00	1	0.01	1	0.01	2	0.00	0	0.00	0	0.03	5	0.01	1	0.06	1	3.72	276
40	Aji Chay Low2	22.31	671	0.00	0	0.00	0	0.57	11	0.10	120	0.69	84	0.00	0	0.00	0	1.73	16	0.02	6	0.89	12	26.31	920
41	Aji Chay Low1	80.01	1,023	0.00	0	0.02	3	0.94	23	1.41	235	0.64	43	0.00	0	0.00	0	3.47	29	0.46	55	5.10	15	92.04	1,426
42	Aji Chay Mid2	28.75	1,084	0.03	1	0.02	3	8.89	141	2.09	458	0.26	64	0.00	0	0.00	0	4.81	28	0.72	110	7.15	46	52.72	1,935
43	Aji Chay Mid1	3.54	326	0.04	3	0.03	4	0.18	10	1.36	44	0.62	19	0.00	1	0.00	0	1.62	7	0.09	15	9.03	16	16.52	445
44	Aji Chay Up2	60.68	1,632	0.00	1	0.01	2	0.09	6	0.37	17	0.14	19	0.00	0	0.00	0	4.36	39	0.10	5	2.52	12	68.26	1,733
45	Aji Chay Up1	95.36	850	0.35	2	0.00	0	0.04	7	0.52	10	0.11	22	0.00	0	0.00	0	4.05	39	0.03	6	4.68	9	105.13	945
46	Aji Chay Residual	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
91	Residual 3-1	64.16	777	0.23	2	0.00	1	0.42	11	0.91	28	0.48	35	0.00	0	0.00	0	4.17	20	0.12	8	3.01	11	73.51	893
92	Residual 3-2	15.03	118	0.00	0	0.00	1	0.01	1	0.04	1	0.04	2	0.00	0	0.00	0	0.16	2	0.00	0	0.87	3	16.16	128
93	Lake Urmia Island	3.78	232	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.16	1	0.00	1	0.00	0	3.94	234
94	Lake Urmia Water Body	0.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1
95	Residual south	0.27	10	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.27	10
96	Residual west	0.05	25	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	6	0.00	0	0.00	0	0.05	31
	Total	**1,145.87**	**53,174**	**10.90**	**80**	**0.51**	**38**	**13.27**	**301**	**14.32**	**1,375**	**7.67**	**884**	**0.01**	**2**	**0.16**	**30**	**48.96**	**934**	**3.08**	**359**	**44.94**	**228**	**1,289.68**	**57,405**

Table 3.2.2 Number of Intake Point Each for River Basin (Left table: Creek, Right table: Motor Pump) (2/4)

No	Basin. Name	Agricultural		Aquaculture		Domestic		Industry		Others		Total	
		Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number
1	Zola Chay Low	46.53	47	0.00	0	0.00	0	0.00	0	0.00	0	9.31	47
2	Zola Chay Mid2	22.16	22	0.00	0	0.00	0	0.00	0	0.00	0	4.43	22
3	Zola Chay Mid1	43.90	44	0.00	0	0.00	0	0.00	0	0.00	0	8.78	44
4	Zola Chay Up	39.26	39	0.00	0	0.00	0	0.00	0	0.00	0	7.85	39
5	Residual 1-2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
6	Residual 1-1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
7	Nazlo Chay Low	656.60	657	0.00	0	0.00	0	0.00	0	0.00	0	131.32	657
8	Nazlo Chay UL	68.74	69	0.00	0	0.00	0	0.00	0	0.00	0	13.75	69
9	Nazlo Chay UR	50.91	51	0.00	0	0.00	0	0.00	0	0.00	0	10.18	51
10	Rose Chay Low	84.03	70	0.00	0	0.00	0	0.00	0	0.00	0	16.81	70
11	Rose Chay Up	57.73	58	0.00	0	0.00	0	0.00	0	0.00	0	11.55	58
12	Sahar Chay Low	159.71	160	0.00	0	280.00	280	0.00	0	0.00	0	87.94	440
13	Sahar Chay Up	133.25	133	0.00	0	0.00	0	0.00	0	0.00	0	26.65	133
14	Baradoz Low	486.71	487	0.00	0	0.00	0	0.00	0	0.00	0	97.34	487
15	Baradoz UR	40.28	40	0.00	0	0.00	0	0.00	0	0.00	0	8.06	40
16	Baradoz UL	70.36	70	0.00	0	0.00	0	0.00	0	0.00	0	14.07	70
17	Residual 2	19.06	19	0.00	0	0.00	0	0.00	0	0.00	0	3.81	19
18	Gedar Chay Low	46.53	80	0.00	0	0.00	0	0.00	0	0.00	0	9.31	80
19	Gedar Chay Mid2	61.60	62	38.81	39	0.00	0	0.00	0	0.00	0	20.08	100
20	Gedar Chay Mid1	139.26	139	121.23	121	0.00	0	151.70	152	0.00	0	82.44	412
21	Gedar Chay Up	21.60	22	0.00	0	0.00	0	0.00	0	0.00	0	4.32	22
22	Mahabad Chay Low	18.17	23	0.00	0	0.00	0	0.00	0	0.00	0	3.63	23
23	Mahabad Chay Up	13.27	445	0.00	0	0.00	0	0.00	0	0.00	0	2.65	445
24	Simine Rud Low	16.40	12	0.00	0	0.00	0	0.00	0	0.00	0	3.28	12
25	Simine Rud Mid	33.66	34	0.00	0	0.00	0	0.00	0	0.00	0	6.73	34
26	Simine Rud Up	23.70	121	0.00	0	0.00	0	0.00	0	0.00	0	4.74	121
27	Zarineh Rud Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
28	Zarineh Rud Mid1	51.60	52	0.00	0	0.00	0	0.00	0	0.00	0	10.32	52
29	Zarineh Rud Mid2	38.06	62	0.00	0	0.00	0	0.00	0	0.00	0	7.61	62
30	Zarineh Rud UR	13.87	14	16.00	16	0.00	0	0.00	0	0.00	0	5.97	30
31	Zarineh Rud UL	5.85	53	0.00	0	0.00	0	0.00	0	0.00	0	1.17	53
32	Sofi Chay Low	71.79	14	0.00	0	0.00	0	0.00	0	0.00	0	14.36	14
33	Sofi Chay UR	49.87	78	0.00	0	0.00	0	0.00	0	0.00	0	9.97	78
34	Sofi Chay UL	24.79	75	0.00	0	0.00	0	0.00	0	0.00	0	4.96	75
35	Gale Chay L Low2	39.07	27	0.00	0	0.00	0	0.00	0	0.00	0	7.81	27
36	Gale Chay L Low1	54.16	70	0.00	0	0.00	0	0.00	0	0.00	0	10.83	70
37	Gale Chay L Up	10.41	79	0.00	0	0.00	0	0.00	0	0.00	0	2.08	79
38	Gale Chay R Up	26.04	140	0.00	0	0.00	0	0.00	0	0.00	0	5.21	140
39	Gale Chay R Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
40	Aji Chay Low2	27.62	90	0.00	0	0.00	0	0.00	0	300.00	1	65.52	91
41	Aji Chay Low1	19.33	133	0.00	0	0.00	0	0.00	0	0.00	0	3.87	133
42	Aji Chay Mid2	17.97	338	0.00	0	0.00	0	0.00	0	0.00	1	3.59	339
43	Aji Chay Mid1	11.34	165	0.00	0	0.00	0	0.00	0	0.00	0	2.27	165
44	Aji Chay Up2	20.51	351	0.00	0	0.00	0	0.00	0	30.00	2	10.10	353
45	Aji Chay Up1	50.47	244	0.00	0	0.00	0	0.00	0	0.00	0	10.09	244
46	Aji Chay Residual	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
91	Residual 3-1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
92	Residual 3-2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
93	Lake Urmia Island	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
94	Lake Urmia Water Body	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
95	Residual south	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
96	Residual west	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
	Total	-	**4,888**	-	**176**	-	**280**	-	**152**	-	**4**	-	**5,499**

No	Basin. Name	Agricultural		Total	
		Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number
1	Zola Chay Low	0.00	0	0.00	0
2	Zola Chay Mid2	0.00	0	0.00	0
3	Zola Chay Mid1	0.00	0	0.00	0
4	Zola Chay Up	0.00	0	0.00	0
5	Residual 1-2	0.00	0	0.00	0
6	Residual 1-1	0.00	0	0.00	0
7	Nazlo Chay Low	0.00	0	0.00	0
8	Nazlo Chay UL	0.00	0	0.00	0
9	Nazlo Chay UR	0.00	0	0.00	0
10	Rose Chay Low	0.00	0	0.00	0
11	Rose Chay Up	0.00	0	0.00	0
12	Sahar Chay Low	0.00	0	0.00	0
13	Sahar Chay Up	0.00	0	0.00	0
14	Baradoz Low	0.00	0	0.00	0
15	Baradoz UR	0.00	0	0.00	0
16	Baradoz UL	0.00	0	0.00	0
17	Residual 2	0.00	0	0.00	0
18	Gedar Chay Low	0.00	0	0.00	0
19	Gedar Chay Mid2	0.00	0	0.00	0
20	Gedar Chay Mid1	0.00	0	0.00	0
21	Gedar Chay Up	0.00	0	0.00	0
22	Mahabad Chay Low	0.00	0	0.00	0
23	Mahabad Chay Up	0.00	0	0.00	0
24	Simine Rud Low	0.00	0	0.00	0
25	Simine Rud Mid	0.00	0	0.00	0
26	Simine Rud Up	0.00	0	0.00	0
27	Zarineh Rud Low	0.00	0	0.00	0
28	Zarineh Rud Mid1	0.00	0	0.00	0
29	Zarineh Rud Mid2	0.00	0	0.00	0
30	Zarineh Rud UR	0.00	0	0.00	0
31	Zarineh Rud UL	0.00	0	0.00	0
32	Sofi Chay Low	0.00	0	0.00	0
33	Sofi Chay UR	0.00	0	0.00	0
34	Sofi Chay UL	0.00	0	0.00	0
35	Gale Chay L Low2	0.00	0	0.00	0
36	Gale Chay L Low1	0.00	0	0.00	0
37	Gale Chay L Up	0.00	0	0.00	0
38	Gale Chay R Up	0.00	0	0.00	0
39	Gale Chay R Low	0.00	0	0.00	0
40	Aji Chay Low2	11.00	11	11.00	11
41	Aji Chay Low1	0.00	0	0.00	0
42	Aji Chay Mid2	0.00	0	0.00	0
43	Aji Chay Mid1	5.86	6	5.86	6
44	Aji Chay Up2	3.00	3	3.00	3
45	Aji Chay Up1	0.00	0	0.00	0
46	Aji Chay Residual	0.00	0	0.00	0
91	Residual 3-1	0.00	0	0.00	0
92	Residual 3-2	0.00	0	0.00	0
93	Lake Urmia Island	0.00	0	0.00	0
94	Lake Urmia Water Body	0.00	0	0.00	0
95	Residual south	0.00	0	0.00	0
96	Residual west	0.00	0	0.00	0
	Total	-	**20**	-	**20**

Table 3.2.2 Number of Intake Point Each for River Basin (Left table: Waterway, Right table: Qanat) (3/4)

No	Basin. Name	Agricultural		Total	
		Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number
1	Zola Chay Low	0.00	0	0.00	0
2	Zola Chay Mid2	0.00	0	0.00	0
3	Zola Chay Mid1	0.00	0	0.00	0
4	Zola Chay Up	0.00	0	0.00	0
5	Residual 1-2	0.00	0	0.00	0
6	Residual 1-1	0.00	0	0.00	0
7	Nazlo Chay Low	0.00	0	0.00	0
8	Nazlo Chay UL	0.00	0	0.00	0
9	Nazlo Chay UR	0.00	0	0.00	0
10	Rose Chay Low	0.00	0	0.00	0
11	Rose Chay Up	0.00	0	0.00	0
12	Sahar Chay Low	0.00	0	0.00	0
13	Sahar Chay Up	0.00	0	0.00	0
14	Baradoz Low	0.00	0	0.00	0
15	Baradoz UR	1.14	11	1.14	11
16	Baradoz UL	0.00	0	0.00	0
17	Residual 2	0.60	6	0.60	6
18	Gedar Chay Low	1.50	3	1.50	3
19	Gedar Chay Mid2	2.03	2	2.03	2
20	Gedar Chay Mid1	26.49	11	26.49	11
21	Gedar Chay Up	0.00	0	0.00	0
22	Mahabad Chay Low	0.39	7	0.39	7
23	Mahabad Chay Up	0.31	23	0.31	23
24	Simine Rud Low	0.83	2	0.83	2
25	Simine Rud Mid	0.58	1	0.58	1
26	Simine Rud Up	0.27	5	0.27	5
27	Zarineh Rud Low	0.00	0	0.00	0
28	Zarineh Rud Mid1	28.94	1	28.94	1
29	Zarineh Rud Mid2	0.00	0	0.00	0
30	Zarineh Rud UR	0.00	0	0.00	0
31	Zarineh Rud UL	0.00	0	0.00	0
32	Sofi Chay Low	0.00	0	0.00	0
33	Sofi Chay UR	0.00	0	0.00	0
34	Sofi Chay UL	0.00	0	0.00	0
35	Gale Chay L Low2	0.00	0	0.00	0
36	Gale Chay L Low1	0.00	0	0.00	0
37	Gale Chay L Up	0.00	0	0.00	0
38	Gale Chay R Up	0.00	0	0.00	0
39	Gale Chay R Low	0.00	0	0.00	0
40	Aji Chay Low2	0.00	0	0.00	0
41	Aji Chay Low1	0.00	0	0.00	0
42	Aji Chay Mid2	0.00	0	0.00	0
43	Aji Chay Mid1	0.00	0	0.00	0
44	Aji Chay Up2	0.00	0	0.00	0
45	Aji Chay Up1	0.00	0	0.00	0
46	Aji Chay Residual	0.00	0	0.00	0
91	Residual 3-1	0.00	0	0.00	0
92	Residual 3-2	0.00	0	0.00	0
93	Lake Urmia Island	0.00	0	0.00	0
94	Lake Urmia Water Body	0.00	0	0.00	0
95	Residual south	0.00	0	0.00	0
96	Residual west	0.00	0	0.00	0
	Total	**63.07**	**72**	**63.07**	**72**

No	Basin. Name	Agricultural		Green Spaces		Industry		Livestock and poultry		Rural Drinking		services		Urban Drinking		Others		Total	
		Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number
1	Zola Chay Low	1.25	4	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.16	4
2	Zola Chay Mid2	2.94	5	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	1.50	1	0.56	6
3	Zola Chay Mid1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
4	Zola Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
5	Residual 1-2	1.08	20	0.00	0	0.00	0	0.00	0	1.30	1	0.00	0	0.00	0	0.10	2	0.31	23
6	Residual 1-1	1.56	27	0.00	0	0.00	0	0.00	0	0.50	1	0.00	0	0.00	0	1.35	2	0.43	30
7	Nazlo Chay Low	16.38	4	0.00	0	0.00	0	0.30	1	1.20	1	0.00	0	0.00	0	0.30	1	2.27	7
8	Nazlo Chay UL	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
9	Nazlo Chay UR	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
10	Rose Chay Low	6.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.75	1
11	Rose Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
12	Sahar Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
13	Sahar Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
14	Baradoz Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
15	Baradoz UR	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
16	Baradoz UL	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
17	Residual 2	6.00	1	0.00	0	0.00	0	0.00	0	7.00	1	0.00	0	0.00	0	0.00	0	1.63	2
18	Gedar Chay Low	1.50	3	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.19	3
19	Gedar Chay Mid2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
20	Gedar Chay Mid1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
21	Gedar Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
22	Mahabad Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
23	Mahabad Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
24	Simine Rud Low	2.18	7	0.00	0	0.00	0	0.00	0	0.25	1	0.00	0	0.00	0	0.00	0	0.30	8
25	Simine Rud Mid	2.41	17	0.00	0	0.00	0	0.00	0	0.32	5	0.00	0	0.00	0	0.28	3	0.38	25
26	Simine Rud Up	0.40	11	0.00	0	0.00	0	0.00	0	0.30	2	0.00	0	0.00	0	0.00	0	0.09	13
27	Zarineh Rud Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
28	Zarineh Rud Mid1	2.23	21	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.28	21
29	Zarineh Rud Mid2	0.40	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.05	1
30	Zarineh Rud UR	3.00	35	0.00	0	0.00	0	0.00	0	2.00	8	0.00	0	0.00	0	0.00	0	0.63	43
31	Zarineh Rud UL	0.45	105	0.00	0	0.00	0	0.21	7	0.42	17	0.00	0	0.00	0	0.00	0	0.14	129
32	Sofi Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
33	Sofi Chay UR	5.50	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.69	2
34	Sofi Chay UL	5.00	8	0.00	0	0.00	0	0.00	0	1.75	2	0.00	0	0.00	0	0.00	0	0.84	10
35	Gale Chay L Low2	1.35	4	0.00	0	0.00	0	0.00	0	0.53	3	0.00	0	0.00	0	0.00	0	0.24	7
36	Gale Chay L Low1	5.91	24	0.00	0	0.00	0	0.35	2	2.67	3	0.00	0	0.20	1	0.00	0	1.14	30
37	Gale Chay L Up	1.28	5	0.00	0	0.00	0	0.00	0	0.02	2	0.00	0	0.00	0	0.00	0	0.16	7
38	Gale Chay R Up	2.76	8	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.35	8
39	Gale Chay R Low	1.31	15	0.00	0	0.00	0	0.00	0	0.30	1	0.30	1	0.00	0	0.00	0	0.24	17
40	Aji Chay Low2	3.89	143	0.00	1	0.00	0	0.00	0	1.38	4	0.00	0	0.00	0	0.00	0	0.66	148
41	Aji Chay Low1	3.46	201	0.00	0	0.00	0	0.00	0	0.00	0	1.50	1	0.00	0	0.00	0	0.62	202
42	Aji Chay Mid2	8.90	76	8.33	3	0.00	0	0.00	0	0.00	0	0.00	0	13.83	6	0.00	0	3.88	85
43	Aji Chay Mid1	2.48	10	0.00	0	0.00	0	1.50	1	1.00	1	0.00	0	0.00	0	0.00	0	0.62	12
44	Aji Chay Up2	3.87	26	0.00	0	0.00	0	0.00	0	1.06	8	0.00	0	0.00	1	0.00	0	0.62	35
45	Aji Chay Up1	1.43	57	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.18	57
46	Aji Chay Residual	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
91	Residual 3-1	3.21	150	0.00	0	1.50	1	0.00	0	1.50	1	0.00	0	4.65	2	0.00	0	1.36	154
92	Residual 3-2	3.25	50	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.41	50
93	Lake Urmia Island	0.66	7	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.08	7
94	Lake Urmia Water Body	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
95	Residual south	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
96	Residual west	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
	Total	-	**1,048**	-	**4**	-	**1**	-	**11**	-	**62**	-	**2**	-	**10**	-	**9**	-	**1,147**

Table 3.2.2 Number of Intake Point Each for River Basin (Spring) (4/4)

No	Basin. Name	Agricultural		Aquaculture		greenhouse		Industry		Livestock and poultry		Packaging		Rural Drinking		Services		Urban Drinking		Total	
		Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number	Average Discharge (m3/s)	Number
1	Zola Chay Low	0.50	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	7.00	1	0.00	0	0.00	0	0.83	3
2	Zola Chay Mid2	0.50	1	0.00	0	0.00	0	0.00	1	0.00	0	0.00	0	1.50	4	0.00	0	0.00	0	0.22	6
3	Zola Chay Mid1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
4	Zola Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
5	Residual 1-2	2.50	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	3.50	3	0.00	0	0.00	0	0.67	5
6	Residual 1-1	1.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	8.00	5	0.70	5	0.00	0	1.08	11
7	Nazlo Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	12.00	3	1.50	2	0.00	0	1.50	5
8	Nazlo Chay UL	2.67	6	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	6.67	6	0.00	0	0.00	0	1.04	12
9	Nazlo Chay UR	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
10	Rose Chay Low	4.83	3	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.54	3
11	Rose Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
12	Sahar Chay Low	0.75	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	24.13	4	0.00	0	0.00	0	2.76	6
13	Sahar Chay Up	4.77	3	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	16.75	4	0.00	0	0.00	0	2.39	7
14	Baradoz Low	4.25	2	0.00	0	0.00	0	0.00	0	1.00	1	0.00	0	14.00	3	0.50	5	0.00	0	2.19	11
15	Baradoz UR	5.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	21.33	3	0.00	0	0.00	0	2.93	4
16	Baradoz UL	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
17	Residual 2	2.50	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	22.58	8	0.00	0	0.00	0	2.79	10
18	Gedar Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	8.76	17	0.00	0	0.00	0	0.97	17
19	Gedar Chay Mid2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	5.33	6	0.00	0	0.00	0	0.59	6
20	Gedar Chay Mid1	2.88	4	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	12.90	10	0.00	0	0.00	0	1.75	14
21	Gedar Chay Up	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
22	Mahabad Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	3.83	3	0.00	0	0.00	0	0.43	3
23	Mahabad Chay Up	2.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	5.50	2	0.00	0	0.00	0	0.83	3
24	Simine Rud Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	26.17	6	0.00	0	0.00	0	2.91	6
25	Simine Rud Mid	13.81	194	0.00	0	0.00	0	0.00	0	0.14	14	0.00	0	4.46	42	0.00	0	0.00	0	2.05	250
26	Simine Rud Up	0.17	240	0.00	0	0.20	1	0.00	0	0.11	27	0.00	0	0.15	16	0.10	1	0.00	0	0.08	285
27	Zarineh Rud Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
28	Zarineh Rud Mid1	3.10	5	0.00	0	0.00	0	7.00	1	10.00	1	0.00	0	5.06	55	2.00	1	0.20	1	3.04	64
29	Zarineh Rud Mid2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
30	Zarineh Rud UR	5.42	306	0.10	1	0.00	0	40.00	1	8.00	9	0.00	0	11.07	43	2.50	1	0.00	0	7.45	361
31	Zarineh Rud UL	0.20	4,001	0.00	0	0.00	0	0.20	4	0.20	435	0.00	0	0.30	377	0.17	3	0.54	15	0.18	4,835
32	Sofi Chay Low	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
33	Sofi Chay UR	3.39	19	0.00	0	0.00	0	0.30	1	0.00	0	0.00	0	2.28	4	0.25	2	0.00	0	0.69	26
34	Sofi Chay UL	2.00	4	0.00	0	0.00	0	0.00	0	0.50	1	0.00	0	0.00	0	0.00	0	0.00	0	0.28	5
35	Gale Chay L Low2	4.65	4	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	4.00	1	0.00	0	0.00	0	0.96	5
36	Gale Chay L Low1	1.78	16	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	1.20	3	1.05	2	0.00	0	0.45	21
37	Gale Chay L Up	1.15	2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	1.50	2	0.00	0	0.00	0	0.29	4
38	Gale Chay R Up	4.19	36	0.00	0	0.00	0	0.00	0	0.00	1	0.00	0	1.23	9	0.00	0	0.00	0	0.60	46
39	Gale Chay R Low	12.46	8	0.00	0	0.00	0	0.00	0	0.15	4	0.00	0	1.00	1	0.00	0	0.00	0	1.51	13
40	Aji Chay Low2	0.39	9	0.00	0	0.00	0	0.00	0	0.10	1	0.00	0	0.20	2	0.00	0	0.00	0	0.08	12
41	Aji Chay Low1	1.00	1	0.00	0	0.00	0	0.00	0	0.00	0	0.70	1	0.40	6	0.00	0	0.00	0	0.23	8
42	Aji Chay Mid2	23.00	1	0.00	0	0.00	0	0.00	0	0.50	1	0.00	0	1.25	2	0.88	4	0.00	0	2.85	8
43	Aji Chay Mid1	0.78	5	0.00	0	0.00	0	0.00	0	0.70	1	0.00	0	1.67	3	0.00	0	0.00	0	0.35	9
44	Aji Chay Up2	1.91	34	0.00	0	0.00	0	0.00	0	0.70	1	0.00	0	1.33	6	0.40	1	0.00	0	0.48	42
45	Aji Chay Up1	4.48	23	0.00	0	0.00	0	0.00	0	0.97	3	0.00	0	0.47	3	3.07	3	0.00	0	1.00	32
46	Aji Chay Residual	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
91	Residual 3-1	2.50	1	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.28	1
92	Residual 3-2	2.25	23	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	5.00	2	0.00	0	0.00	0	0.81	25
93	Lake Urmia Island	0.50	4	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.06	4
94	Lake Urmia Water Body	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
95	Residual south	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
96	Residual west	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
	Total	**123.29**	**4,966**	**0.10**	**1**	**0.20**	**1**	**47.50**	**8**	**23.07**	**500**	**0.70**	**1**	**242.52**	**665**	**13.11**	**30**	**0.74**	**16**	**50.14**	**6,188**

3.2.3 Dam Operation

Dam data was provided with dam specification, dam operation data, and dam operation rule. The dam specifications are the same as the previous survey in 2014, and Figure 3.2.2 shows the dam location in the Urmia Lake Basin. Currently 44 dams including large and small are in operation and 41 dams are under construction or under consideration.

Table 3.2.3 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 Urmia Lake Basin. There are 44 under-operated dams with a total storage volume of 1,413MCM. There are 11 under-constructed dams with a total storage volume of 1,053MCM.

In terms of characteristics of the under-operated dams by river basin, total storage volume of Zarine Rud River Basin located in the southeastern part of the Urmia Lake 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 Urmia Lake 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 Urmia Lake 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 Urmia Lake Basin, has 26 dams. However, its total storage volume is small at 99MCM and average storage volume per dam is also small at 4MCM.

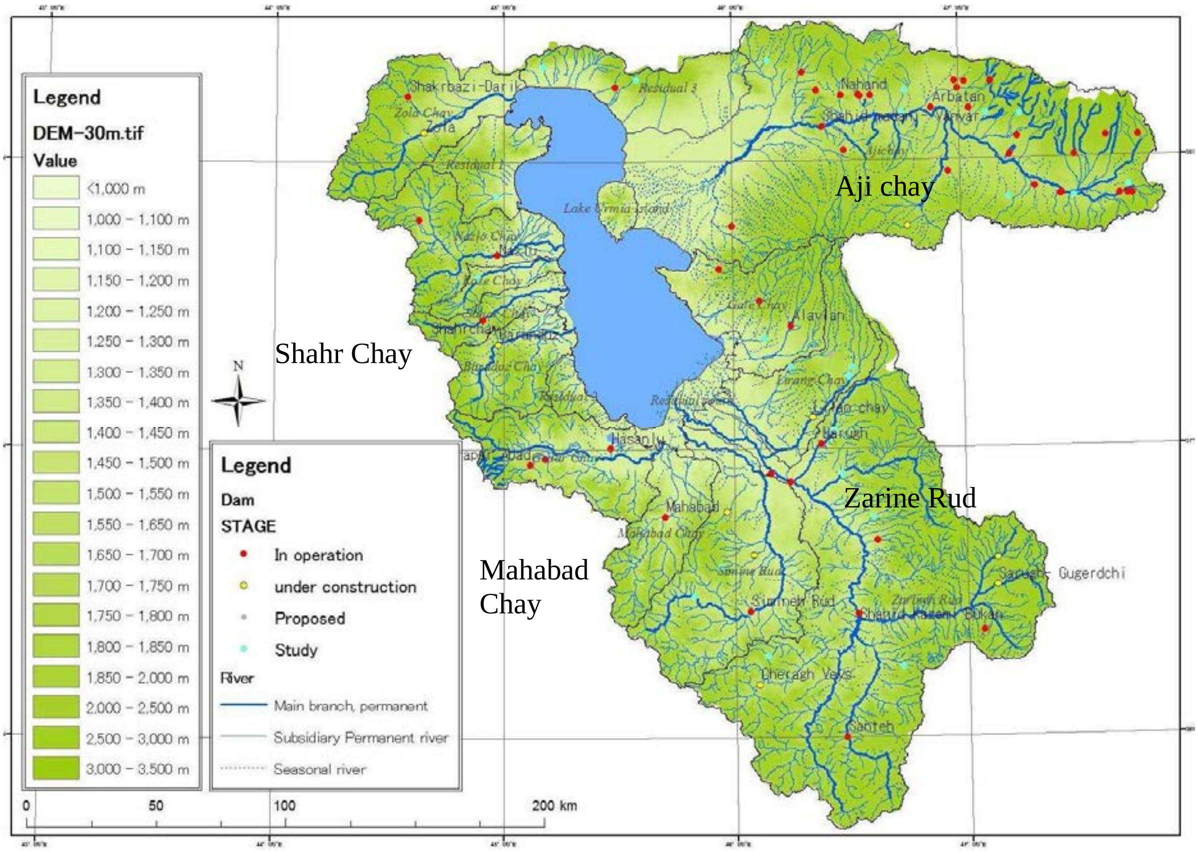


Figure 3.2.2 Location of Dams

Table 3.2.3 Number of Dams and Storage Volume by River Basin

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 Azerbaijan	99.43	3.82
Baranduz Chay	1	West Azerbaijan	0.35	0.35
Darik Chay	1	West Azerbaijan	22.00	22.00
Gale Chay	1	East Azerbaijan	0.25	0.25
Gader Chay	2	West Azerbaijan	94.13	47.07
Mahabad Chay	1	West Azerbaijan	190.00	190.00
Nazlu Chay	1	West Azerbaijan	0.50	0.50
Residual 4	1	East Azerbaijan	0.67	0.67
Shahr Chay	1	West Azerbaijan	213.00	213.00
Sofi Chay	1	East Azerbaijan	57.00	57.00
Gale Chay	1	East Azerbaijan	38.80	38.80
Zarine Rud	6	West Azerbaijan	625.06	104.18
Zola Chay	1	West Azerbaijan	72.00	72.00
Total	44		1413.19	32.12
B. Under-constructed Dams				
Aji Chay	2	East Azerbaijan	282.50	141.25
Baranduz Chay	1	West Azerbaijan	84.00	84.00
Gader Chay	1	West Azerbaijan	122.00	122.00
Nazle Chay	1	West Azerbaijan	145.00	145.00
Simine Rud	2	West Azerbaijan	313.00	156.80
Zarine Rud	4	West Azerbaijan	106.50	26.63
Total	11		1053.60	95.78
C. Proposed Dams				
Lirang Chay	1	East Azerbaijan	14.00	14.00
Residual 4	1	East Azerbaijan	6.00	6.00
Total	2		20.00	10.00
D.Under-studied Damas				
Aji Chay	8	East Azerbaijan	58.18	7.27
Baranduz Chay	1	West Azerbaijan	0.00	0.00
Gader Chay	1	West Azerbaijan	49.00	49.00
Lirang Chay	2	Ardebil and East Azerbaijan	18.68	9.34
Nazle Chay	1	West Azerbaijan	0.00	0.00
Residual 1	1	West Azerbaijan	8.60	8.60
Residual 4	2	East Azerbaijan	9.20	4.60
Simine Rud	3	West Azerbaijan	15.30	5.10
Sofi Chay	2	East Azerbaijan	111.50	55.75
Zarine Rud	7	West Azerbaijan, West Azerbaijan and Kurdistan	231.02	33.00
Total	28		501.48	17.91

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

Only the operation data of 12 dams downloaded from the webpage of the Water Resources Management Company (IWRM Co.) of the Ministry of Energy (MOE) were collected in the Survey. Table 3.2.4 show 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 10,078km^2, which is 94% of the total catchment area of 19 existing dams with information on catchment area 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 a majority of the dams in terms of total storage volume and total catchment area. Hence, it is considered that the data on the 12 dams can be utilized in the further analysis for estimating intake water quantity and water supply quantity from surface water.

The dam indicated by the red frame in Table 3.2.4 is main dam considered in the hydrological model. As example of the condition of historical dam operations, Figure 3.2.3 show the daily and annual operation of five dams. In addition, Table 3.2.5 show the predictive dam operation rule conditions in 2015 and 2016 of five dams.

In the comparison between the actual value of the dam inflow discharge and the inflow discharge prediction of the operation rule in 2015, the predicted value is set using a rough minimum value of the actual historical values so far and is a realistic value. Consumption of dam outflow discharge is organized according to purpose, which is a useful data for verification of the hydrological cycle model, and data quality is also sufficient .

Table 3.2.4 Dams with Collected Daily Operation Data

No.	Dam	River Basin	Province	Duration of Daily Data (Year/Month)	Kind of Data
1	Kardkandi	Aji Chay	East Azerbaijan	2011/3～2014/12	Temperature, precipitation, reservoir water level, reservoir water area, inflow water quantity, outflow water quantity (evaporation, leakage, pump intake, drainage, electricity generation, sediment discharge, intake valve, spillover and water supply quantity (drinking water supply, industrial water supply and agricultural water supply, and other water supply)
2	Nahand	Aji Chay	East Azerbaijan	2000/3～2014/12	ditto
3	Tajyar Sarab	Aji Chay	East Azerbaijan	2009/4～2014/12	ditto
4	Shakrbazi-Darik (Darek Salmas)	Darik Chay	West Azerbaijan	2012/6～2014/12	ditto
5	Hasanlu	Gadar Chay	West Azerbaijan	2002/3～2014/12	ditto
6	Mahabad	Mahabad Chay	West Azerbaijan	1971/3～2014/12	ditto
7	Shahrchay	Shahr Chay	West Azerbaijan	2006/5～2014/12	ditto
8	Alavian	Sofi Chay	East Azerbaijan	1997/9～2014/12	ditto
9	Ghale Chay Ajabshir	Gale Chay	East Azerbaijan	2009/4～2014/12	ditto
10	Saruq-Gougerdchay	Zarine Rud	West Azerbaijan	2012/6～2014/12	ditto
11	Shahid Kazemi Bukan- Zarine Rud (Bukan Dam)	Zarine Rud	West Azerbaijan	1978/3～2014/12	ditto
12	Zola	Zola Chay	West Azerbaijan	2011/9～2014/12	ditto

Table 3.2.5 Predictive Dam Operation Rule (Hasanlu Dam) (1/5)

Predictive values in the form of the program 2015-2016 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservoir		
Mehr	0.1	0.0	0.1	0.0	0.0	4.2	0.1	0.6	4.9	0.0	0.0	1.1	0.0	6.0	41.3
aban	1.2	0.0	1.2	0.0	0.0	0.0	0.1	0.7	0.8	0.0	0.0	0.0	0.0	0.8	41.7
Azar	1.3	0.0	1.3	0.0	0.0	0.0	0.1	0.6	0.7	0.0	0.0	0.0	0.0	0.7	42.3
Day	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.7	0.0	0.0	0.0	0.0	0.7	41.6
Bahman	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.2	41.4
Esfand	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.2	41.2
Farvardin	2.0	0.0	2.0	0.0	0.0	1.5	0.1	0.5	2.1	0.0	0.0	1.2	0.0	3.3	39.9
Ordibehesht	6.0	0.0	6.0	0.0	0.0	3.0	0.1	0.5	3.6	0.0	0.0	2.0	0.0	5.6	40.3
Khordad	1.7	0.0	1.7	0.0	0.0	6.0	0.1	0.5	6.6	0.0	0.0	2.1	0.0	8.7	33.3
Tir	0.0	0.0	0.0	0.0	0.0	7.0	0.1	0.5	7.6	0.0	0.0	2.8	0.0	10.4	22.9
Mordad	0.0	0.0	0.0	0.0	0.0	6.5	0.1	0.5	7.1	0.0	0.0	1.5	0.0	8.6	14.3
Shahrivar	0.0	0.0	0.0	0.0	0.0	6.0	0.1	0.5	6.6	0.0	0.0	0.7	0.0	7.3	7.0
Annual	**12.3**	**0.0**	**12.3**	**0.0**	**0.0**	**34.2**	**1.2**	**5.7**	**41.1**	**0.0**	**0.0**	**11.4**	**0.0**	**52.5**	

Predictive values in the form of the program2016-2017 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservoir		
Mehr	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.5	0.8	0.0	0.0	0.8	0.0	1.7	24.6
aban	1.0	0.0	1.0	0.0	0.0	0.0	0.1	0.6	0.7	0.0	0.0	0.4	0.0	1.1	24.5
Azar	3.0	0.0	3.0	0.0	0.0	0.0	0.1	0.6	0.7	0.0	0.0	0.1	0.0	0.8	26.7
Day	11.0	0.0	11.0	0.0	0.0	0.0	0.1	0.6	0.7	0.0	0.0	0.0	0.0	0.7	37.0
Bahman	18.0	0.0	18.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.2	54.8
Esfand	6.1	0.0	6.1	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.5	0.0	0.7	60.2
Farvardin	0.0	0.0	0.0	0.0	0.0	2.5	0.1	0.5	3.1	0.0	0.0	1.2	0.0	4.3	55.9
Ordibehesht	0.0	0.0	0.0	0.0	0.0	5.5	0.1	0.5	6.1	0.0	0.0	1.5	0.0	7.6	48.4
Khordad	0.0	0.0	0.0	0.0	0.0	9.8	0.1	0.5	10.4	0.0	0.0	1.8	0.0	12.2	36.2
Tir	0.0	0.0	0.0	0.0	0.0	7.0	0.1	0.5	7.6	0.0	0.0	2.0	0.0	9.6	26.6
Mordad	0.0	0.0	0.0	0.0	0.0	5.0	0.1	0.5	5.6	0.0	0.0	2.0	0.0	7.6	18.9
Shahrivar	0.0	0.0	0.0	0.0	0.0	1.0	0.1	0.5	1.6	0.0	0.0	2.3	0.0	3.9	15.0
Annual	**39.1**	**0.0**	**39.1**	**0.0**	**0.0**	**31.0**	**1.2**	**5.6**	**37.8**	**0.0**	**0.0**	**12.6**	**0.0**	**50.4**	

Table 3.2.5 Predictive Dam Operation Rule (Mahabad Dam) (2/5)

Predictive values in the form of the program 2015-2016 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservoir		
Mehr	0.5	0.0	0.5	1.6	0.0	0.0	0.1	0.0	1.6	0.0	0.0	0.6	0.0	2.2	43.1
aban	4.0	0.0	4.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.3	0.0	2.2	44.9
Azar	12.0	0.0	12.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.2	0.0	2.1	54.9
Day	8.0	0.0	8.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.2	0.0	2.1	60.8
Bahman	24.0	0.0	24.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.3	0.0	2.2	82.7
Esfand	23.0	0.0	23.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.5	0.0	2.3	103.4
Farvardin	38.0	0.0	38.0	1.7	0.0	0.0	0.3	0.0	2.0	0.0	0.0	0.9	0.0	2.9	138.5
Ordibehesht	16.5	0.0	16.5	1.7	0.0	9.0	0.3	0.0	11.0	0.0	0.0	1.3	0.0	12.3	142.7
Khordad	2.6	0.0	2.6	1.7	0.0	22.5	0.3	0.0	24.5	0.0	0.0	1.5	0.0	26.0	119.4
Tir	0.1	0.0	0.1	1.7	0.0	22.5	0.3	0.0	24.5	0.0	0.0	1.8	0.0	26.3	93.2
Mordad	0.2	0.0	0.2	1.7	0.0	23.0	0.3	0.0	25.0	0.0	0.0	1.7	0.0	26.7	66.8
Shahrivar	0.1	0.0	0.1	1.7	0.0	18.0	0.3	0.0	20.0	0.0	0.0	1.0	0.0	21.0	45.9
Annual	**129.0**	**0.0**	**129.0**	**19.8**	**0.0**	**95.0**	**2.8**	**0.0**	**117.6**	**0.0**	**0.1**	**10.2**	**0.0**	**127.9**	

Predictive values in the form of the program2016-2017 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservoir		
Mehr	0.3	0.0	0.3	1.6	0.0	0.0	0.1	12.6	14.2	0.0	0.0	0.9	0.0	15.1	82.5
aban	5.0	0.0	5.0	1.6	0.0	1.0	0.1	17.7	20.4	0.0	0.0	0.4	0.0	20.8	66.7
Azar	7.0	0.0	7.0	1.6	0.0	0.0	0.1	14.3	16.0	0.0	0.0	0.2	0.0	16.2	57.5
Day	15.0	0.0	15.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.2	0.0	2.0	70.5
Bahman	22.0	0.0	22.0	1.6	0.0	0.0	0.3	0.0	1.9	0.0	0.0	0.4	0.0	2.2	90.3
Esfand	32.0	0.0	32.0	1.6	0.0	0.0	0.3	1.5	3.4	0.0	0.0	0.8	0.0	4.1	118.2
Farvardin	33.5	0.0	33.5	1.7	0.0	6.0	0.3	0.0	8.0	0.0	0.0	1.0	0.0	9.0	142.7
Ordibehesht	11.0	0.0	11.0	1.7	0.0	15.0	0.3	0.0	17.0	0.0	0.0	1.3	0.0	18.3	135.4
Khordad	2.5	0.0	2.5	1.7	0.0	18.0	0.3	0.0	20.0	0.0	0.0	1.5	0.0	21.5	116.4
Tir	0.5	0.0	0.5	1.7	0.0	19.1	0.3	0.0	21.1	0.0	0.0	2.0	0.0	23.1	93.8
Mordad	0.1	0.0	0.1	1.7	0.0	19.0	0.3	0.0	21.0	0.0	0.0	3.1	0.0	24.1	69.8
Shahrivar	0.1	0.0	0.1	1.7	0.0	17.0	0.3	0.0	19.0	0.0	0.0	1.8	0.0	20.7	49.2
Annual	**129.0**	**0.0**	**129.0**	**19.8**	**0.0**	**95.1**	**2.5**	**46.1**	**163.4**	**0.0**	**0.2**	**13.5**	**0.0**	**177.1**	

Table 3.2.5 Predictive Dam Operation Rule (Shahrchay Dam) (3/5)

Predictive values in the form of the program 2015-2016 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservior		
Mehr	3.4	0.0	3.4	4.7	0.0	4.1	0.0	0.3	9.1	0.0	0.0	0.1	0.0	9.2	104.5
aban	4.0	0.0	4.0	4.5	0.0	2.0	0.0	0.5	7.0	0.0	0.0	0.5	0.0	7.5	101.1
Azar	5.6	0.0	5.6	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.3	0.0	6.1	100.5
Day	3.5	0.0	3.5	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.3	0.0	6.1	98.0
Bahman	3.5	0.0	3.5	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.3	0.0	6.1	95.3
Esfand	6.0	0.0	6.0	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.3	0.0	6.1	95.2
Farvardin	19.5	0.0	19.5	5.0	0.0	0.0	0.0	1.3	6.3	0.0	0.0	0.5	0.0	6.8	107.9
Ordibehesht	32.0	0.0	32.0	5.0	0.0	5.0	0.0	0.5	10.5	0.0	0.0	0.8	0.0	11.3	128.5
Khordad	22.0	0.0	22.0	5.0	0.0	10.0	0.0	0.5	15.5	0.0	0.0	1.3	0.0	16.8	133.7
Tir	8.5	0.0	8.5	5.0	0.0	12.0	0.0	0.5	17.5	0.0	0.0	1.7	0.0	19.2	123.0
Mordad	7.0	0.0	7.0	5.0	0.0	10.0	0.0	0.5	15.5	0.0	0.0	1.8	0.0	17.3	112.7
Shahrivar	5.0	0.0	5.0	5.0	0.0	9.0	0.0	0.5	14.5	0.0	0.0	1.0	0.0	15.5	102.2
Annual	**120.0**	**0.0**	**120.0**	**57.2**	**0.0**	**52.1**	**0.0**	**9.8**	**119.1**	**0.0**	**0.0**	**9.0**	**0.0**	**128.1**	

Predictive values in the form of the program2016-2017 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservior		
Mehr	4.3	0.0	4.3	4.7	0.0	0.6	0.0	0.4	5.6	0.0	0.0	1.1	0.0	6.7	153.5
aban	4.0	0.0	4.0	4.5	0.0	0.0	0.0	0.2	4.7	0.0	0.0	0.6	0.0	5.3	152.2
Azar	3.8	0.0	3.8	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.2	0.0	6.0	150.0
Day	4.0	0.0	4.0	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.2	0.0	6.0	148.0
Bahman	5.0	0.0	5.0	4.5	0.0	0.0	0.0	1.3	5.8	0.0	0.0	0.2	0.0	6.0	147.0
Esfand	11.0	0.0	11.0	4.5	0.0	0.0	0.0	43.3	47.8	0.0	0.0	0.4	0.0	48.2	109.8
Farvardin	17.0	0.0	17.0	5.0	0.0	0.0	0.0	1.3	6.3	0.0	0.0	0.6	0.0	6.9	119.9
Ordibehesht	32.0	0.0	32.0	5.0	0.0	6.0	0.0	0.5	11.5	0.0	0.0	0.8	0.0	12.3	139.6
Khordad	23.0	0.0	23.0	5.0	0.0	13.0	0.0	0.5	18.5	0.0	0.0	1.2	0.0	19.7	142.9
Tir	8.7	0.0	8.7	5.0	0.0	15.0	0.0	0.5	20.5	0.0	0.0	1.7	0.0	22.2	129.4
Mordad	3.8	0.0	3.8	5.0	0.0	15.0	0.0	0.5	20.5	0.0	0.0	1.8	0.0	22.3	110.9
Shahrivar	3.6	0.0	3.6	5.0	0.0	13.5	0.0	0.5	19.0	0.0	0.0	1.9	0.0	20.9	93.6
Annual	**120.2**	**0.0**	**120.2**	**57.2**	**0.0**	**63.1**	**0.0**	**51.6**	**171.8**	**0.0**	**0.0**	**10.6**	**0.0**	**182.5**	

Table 3.2.5 Predictive Dam Operation Rule (Alavian Dam) (4/5)

Predictive values in the form of the program 2015-2016 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservior		
Mehr	1.9	0.0	1.9	1.1	0.0	0.0	0.5	0.5	2.0	0.0	0.0	0.1	0.0	2.1	9.4
aban	4.0	0.0	4.0	1.4	0.0	0.0	0.5	0.6	2.5	0.0	0.0	0.0	0.0	2.5	10.9
Azar	2.5	0.0	2.5	1.4	0.0	0.0	0.5	0.6	2.5	0.0	0.0	0.0	0.0	2.5	11.0
Day	2.0	0.0	2.0	1.4	0.0	0.0	0.5	0.6	2.5	0.0	0.0	0.0	0.0	2.5	10.5
Bahman	4.0	0.0	4.0	1.4	0.0	0.0	0.5	0.6	2.5	0.0	0.0	0.0	0.0	2.5	12.0
Esfand	6.0	0.0	6.0	1.4	0.0	0.0	0.5	0.6	2.5	0.0	0.0	0.2	0.0	2.7	15.4
Farvardin	14.0	0.0	14.0	1.4	0.0	0.5	0.6	0.6	3.1	0.0	0.0	0.3	0.0	3.4	26.0
Ordibehesht	20.0	0.0	20.0	1.4	0.0	8.0	0.6	0.6	10.6	0.0	0.0	0.5	0.0	11.1	35.0
Khordad	10.0	0.0	10.0	1.4	0.0	10.0	0.6	0.6	12.6	0.0	0.0	0.6	0.0	13.2	31.8
Tir	2.0	0.0	2.0	1.4	0.0	6.0	0.6	0.6	8.6	0.0	0.0	0.5	0.0	9.1	24.8
Mordad	0.5	0.0	0.5	1.4	0.0	5.5	0.6	0.6	8.1	0.0	0.0	0.5	0.0	8.6	16.7
Shahrivar	0.5	0.0	0.5	1.4	0.0	3.0	0.6	0.6	5.6	0.0	0.0	0.1	0.0	5.7	11.6
Annual	**67.4**	**0.0**	**67.4**	**16.5**	**0.0**	**33.0**	**6.6**	**6.5**	**62.6**	**0.0**	**0.0**	**2.9**	**0.0**	**65.5**	

Predictive values in the form of the program2016-2017 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservior		
Mehr	1.5	0.0	1.5	1.1	0.0	0.0	0.5	0.7	2.2	0.0	0.0	0.2	0.0	2.4	20.1
aban	3.0	0.0	3.0	1.4	0.0	0.0	0.5	0.7	2.6	0.0	0.0	0.1	0.0	2.7	20.4
Azar	3.0	0.0	3.0	1.4	0.0	0.0	0.5	0.5	2.4	0.0	0.0	0.0	0.0	2.4	21.0
Day	4.0	0.0	4.0	1.4	0.0	0.0	0.5	0.5	2.4	0.0	0.0	0.0	0.0	2.4	22.6
Bahman	5.0	0.0	5.0	1.4	0.0	0.0	0.5	0.5	2.4	0.0	0.0	0.0	0.0	2.4	25.2
Esfand	11.0	0.0	11.0	1.3	0.0	0.0	0.5	0.6	2.4	0.0	0.0	0.1	0.0	2.5	33.8
Farvardin	17.0	0.0	17.0	1.4	0.0	0.0	0.5	0.6	2.5	0.0	0.0	0.2	0.0	2.7	48.1
Ordibehesht	19.2	0.0	19.2	1.4	0.0	12.0	0.5	0.6	14.5	0.0	0.0	0.4	0.0	14.9	52.5
Khordad	10.0	0.0	10.0	1.4	0.0	14.0	0.5	0.6	16.5	0.0	0.0	0.6	0.0	17.1	45.4
Tir	2.5	0.0	2.5	1.4	0.0	12.0	0.5	0.6	14.5	0.0	0.0	0.5	0.0	15.0	33.0
Mordad	1.0	0.0	1.0	1.4	0.0	12.0	0.5	0.6	14.5	0.0	0.0	0.5	0.0	15.0	19.0
Shahrivar	0.5	0.0	0.5	1.4	0.0	6.0	0.5	0.6	8.5	0.0	0.0	0.2	0.0	8.6	10.9
Annual	**77.7**	**0.0**	**77.7**	**16.4**	**0.0**	**56.0**	**6.0**	**6.7**	**85.1**	**0.0**	**0.0**	**2.7**	**0.0**	**87.8**	

Table 3.2.5 Predictive Dam Operation Rule (Bukan Dam) (5/5)

Predictive values in the form of the program 2015-2016 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservior		
Mehr	9.0	0.0	9.0	11.5	0.0	1.9	0.5	18.5	32.4	0.0	0.0	4.1	0.0	36.4	248.4
aban	25.0	0.0	25.0	11.7	0.0	28.5	0.5	10.0	50.7	0.0	0.0	2.0	0.0	52.7	220.7
Azar	98.5	0.0	98.5	11.1	0.0	0.0	0.5	9.0	20.6	0.0	0.0	1.2	0.0	21.8	297.4
Day	79.0	0.0	79.0	12.5	0.0	0.0	0.5	5.0	18.0	0.0	0.0	0.7	0.0	18.7	357.8
Bahman	148.0	11.0	159.0	12.6	0.0	0.0	0.5	62.0	75.1	0.0	0.0	0.0	0.0	75.1	441.7
Esfand	111.0	0.0	111.0	13.4	0.0	0.0	0.5	61.0	74.9	0.0	0.0	0.0	0.0	74.9	477.8
Farvardin	248.0	0.0	248.0	11.6	0.0	8.6	0.0	11.0	31.2	0.0	0.0	5.0	0.0	36.2	689.6
Ordibehesht	79.0	0.0	79.0	13.2	0.0	57.9	0.0	13.0	84.1	0.0	0.0	10.0	0.0	94.1	674.6
Khordad	11.0	0.0	11.0	14.3	0.0	74.1	0.0	13.5	101.9	0.0	0.0	13.0	0.0	114.9	570.7
Tir	1.5	0.0	1.5	14.7	0.0	77.9	0.0	13.5	106.1	0.0	0.0	11.1	0.0	117.2	454.9
Mordad	0.0	0.0	0.0	15.4	0.0	84.5	0.0	13.5	113.4	0.0	0.0	9.5	0.0	122.9	332.1
Shahrivar	0.0	0.0	0.0	15.1	0.0	66.4	0.0	13.5	95.1	0.0	0.0	7.0	0.0	102.1	230.0
Annual	**810.0**	**11.0**	**821.0**	**156.9**	**0.0**	**399.8**	**3.0**	**243.5**	**803.3**	**0.0**	**0.0**	**63.6**	**0.0**	**866.8**	

Predictive values in the form of the program2016-2017 (MCM)

Month	Inflow			Consumption/Outflow						Others/Outflow				Total outflow and consumption	Reservior Capacity at the end of month
	Prediction of the entrance to the dam from Catchment	Prediction of inter-basin transfer of water	Inflow (MCM)	Domestic	Domestic quality	Agriculture	Industry	Others (Flow stability)	Total consumption	Output from the power plant (discharge from the power plant over the dam)	Leakage (including leakage and drainage over dam consumption)	Evaporation	Other exploitation from the reservior		
Mehr	3.1	0.0	3.1	11.5	0.0	2.0	0.5	18.1	32.1	0.0	0.0	6.8	0.0	38.9	294.4
aban	15.0	0.0	15.0	11.7	0.0	21.6	0.5	14.8	48.6	0.0	0.0	2.9	0.0	51.5	257.9
Azar	50.0	0.0	50.0	11.1	0.0	0.0	0.5	6.4	18.0	0.0	0.0	1.0	0.0	19.0	288.9
Day	75.0	0.0	75.0	12.5	0.0	0.0	0.5	3.8	16.8	0.0	0.0	0.0	0.0	16.8	347.2
Bahman	145.0	0.0	145.0	12.6	0.0	0.0	0.5	61.0	74.1	0.0	0.0	0.0	0.0	74.1	418.1
Esfand	227.0	0.0	227.0	13.4	0.0	0.0	0.5	135.0	148.9	0.0	0.0	3.8	0.0	152.7	492.4
Farvardin	210.0	0.0	210.0	11.6	0.0	8.5	0.0	10.0	30.1	0.0	0.0	4.4	0.0	34.4	668.0
Ordibehesht	90.0	0.0	90.0	13.2	0.0	50.5	0.0	13.5	77.2	0.0	0.0	9.4	0.0	86.6	671.4
Khordad	12.0	0.0	12.0	14.3	0.0	76.1	0.0	13.5	103.9	0.0	0.0	12.8	0.0	116.8	566.6
Tir	7.0	0.0	7.0	14.7	0.0	78.0	0.0	13.5	106.2	0.0	0.0	11.9	0.0	118.1	455.6
Mordad	3.0	0.0	3.0	15.4	0.0	82.3	0.0	13.5	111.2	0.0	0.0	10.3	0.0	121.4	337.2
Shahrivar	1.0	0.0	1.0	15.1	0.0	61.1	0.0	13.5	89.7	0.0	0.0	8.9	0.0	98.7	239.5
Annual	**838.1**	**0.0**	**838.1**	**156.9**	**0.0**	**380.1**	**3.0**	**316.6**	**856.6**	**0.0**	**0.0**	**72.2**	**0.0**	**928.8**	

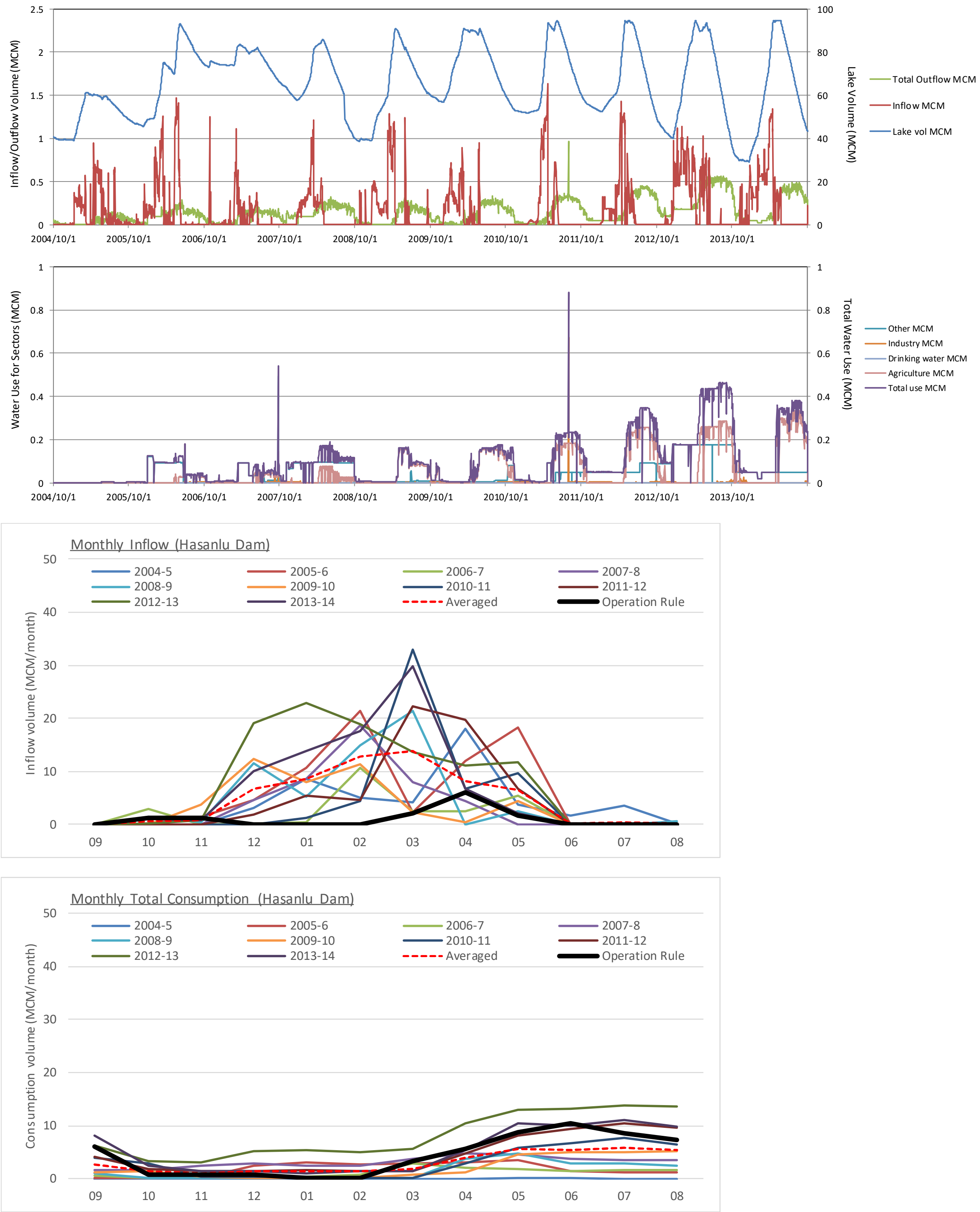
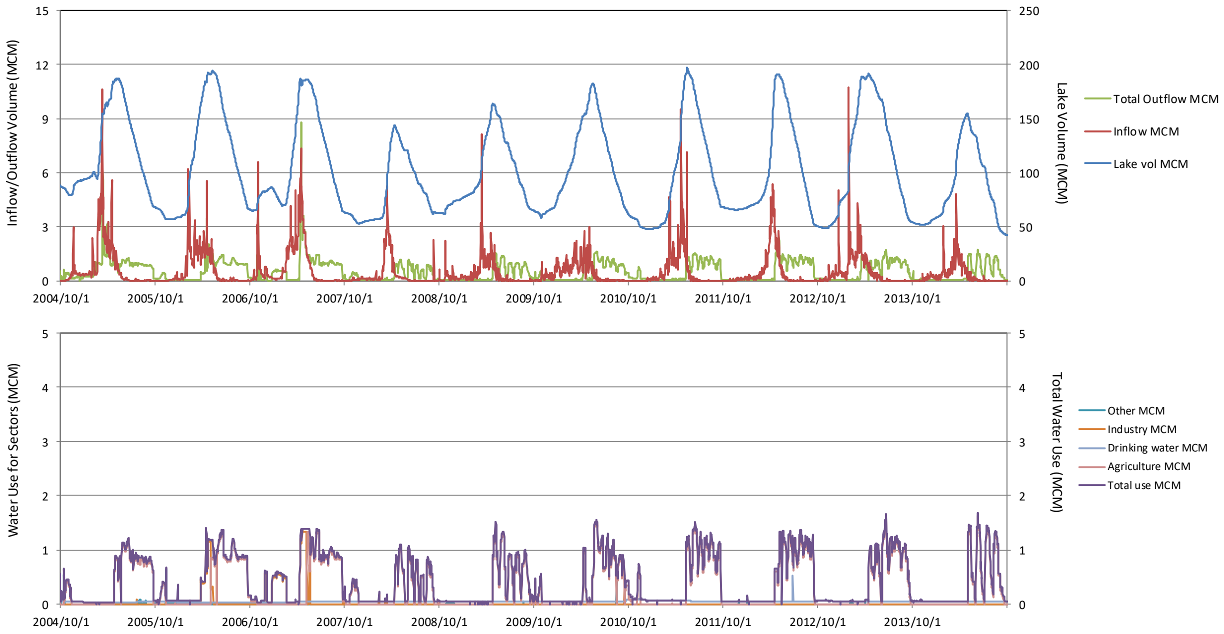
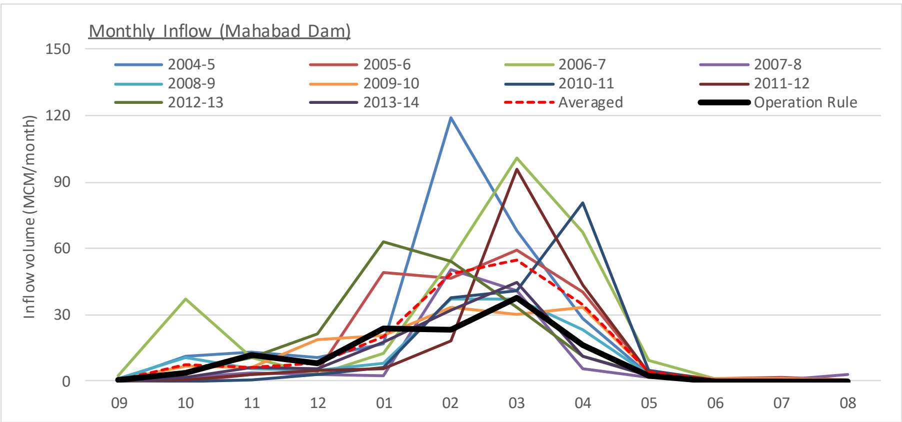


Figure 3.2.3 Historical Dam Operations and Predictive Operation Rule (Hasanlu Dam) (1/5)





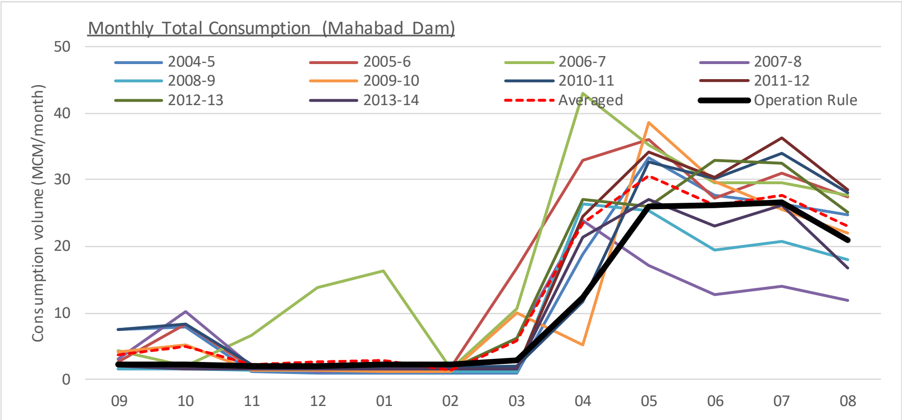
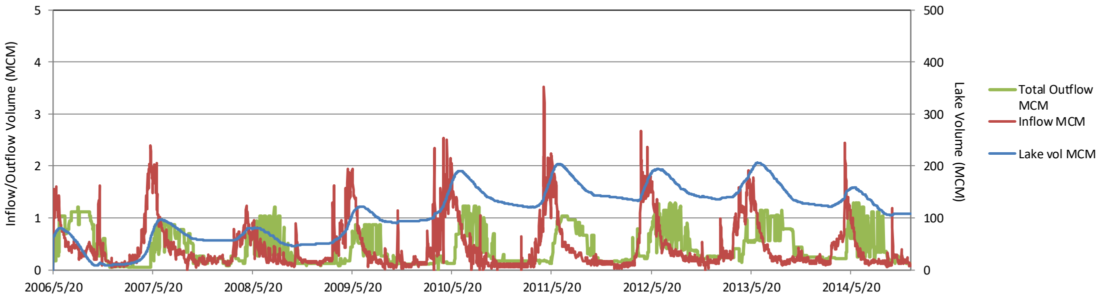
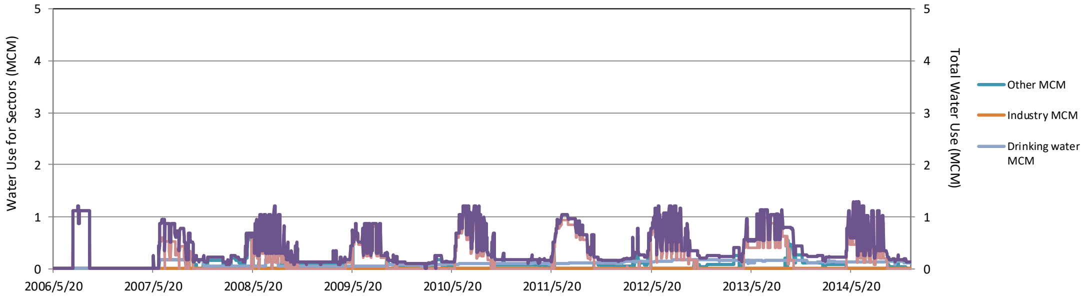
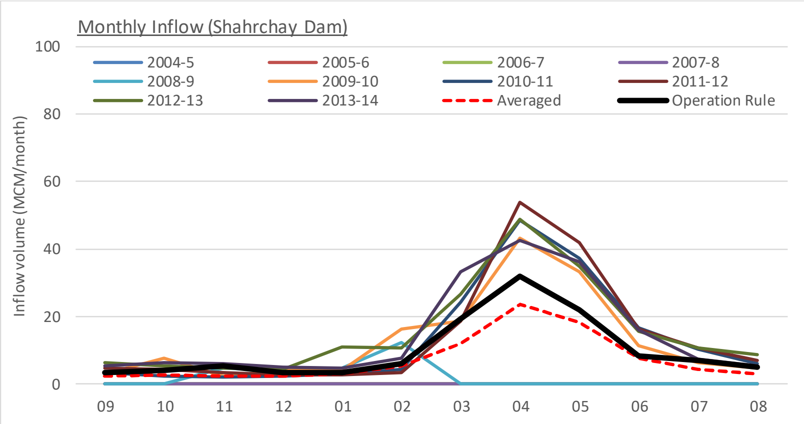


Figure 3.2.3 Historical Dam Operations and Predictive Operation Rule (Mahabad Dam) (2/5)







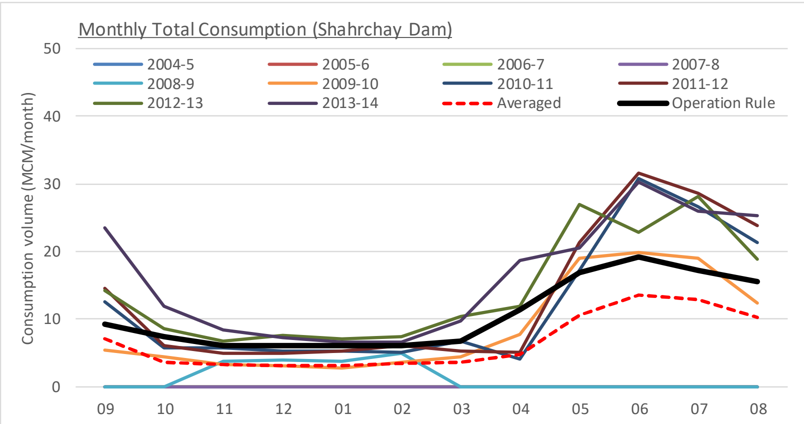


Figure 3.2.3 Historical Dam Operations and Predictive Operation Rule (Shahrchay Dam) (3/5)

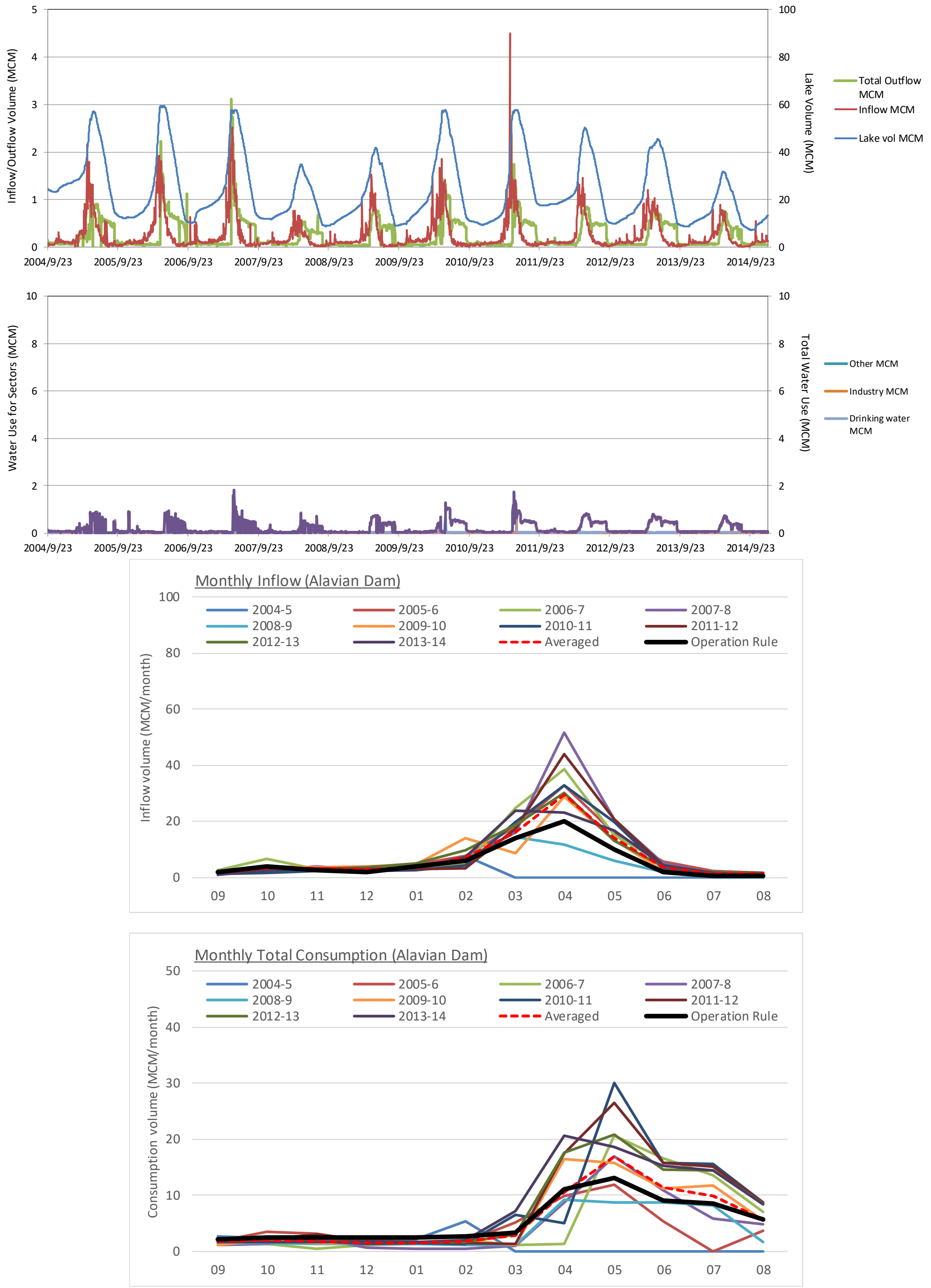


Figure 3.2.3 Historical Dam Operations and Predictive Operation Rule (Alavian Dam) (4/5)

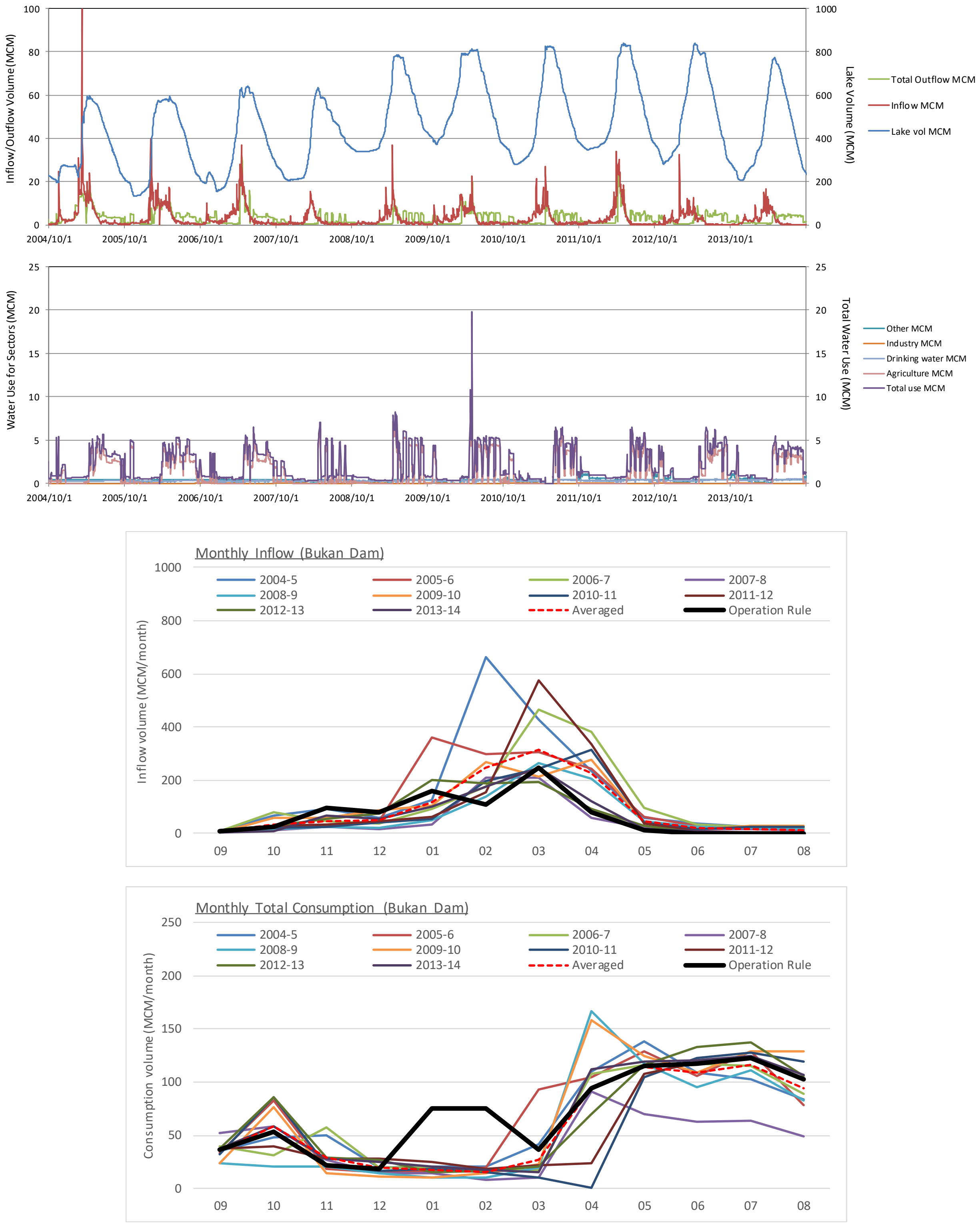


Figure 3.2.3 Historical Dam Operations and Predictive Operation Rule (Bukan Dam) (5/5)

3.2.4 Topography of Urmia Lake

The bathymetry data of Urmia Lake Basin was provided with surveyed data in 2013 in the previous survey. In the Survey, surveyed data in 2015 was provided. The new bathymetry data should contribute to the improvement of accuracy of the hydrological cycle model. The details are given in Chapter 4.

3.2.5 Additional Hydrological Data

(1) Rainfall and Discharge Gauging Station

Table 3.2.6 gives a summary of rainfall gauging stations and discharge gauging stations, while Figure 3.2.5 and Figure 3.2.6 show their locations.

The verification and calibration period of the hydrological cycle model was decided as 14 from 1999 to 2014. The reason is that basic hydrological data authorized by ULRP is up to 2014. The hydrological data quality within the verification and calibration period was checked by the Survey Team.

In the Urmia Lake 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 RWC, a subsidiary organization of IWRM Co. 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 RWC, 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 sixty-three (163) 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.

The command area of a functional rainfall gauging station ranges between 150 and 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 is defined that the required command 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 3.2.4 Discharge Gauging Station (Akhola, Downstream of Aji Chay River)

Table 3.2.6 Summary of Rainfall Gauging Stations in the Urmia Lake Basin

Basin Name	Catchment Area km^2)	Number of All Rainfall GS	Number of All Discharge GS
Aji Chay	12,716.7	42	35
Baradoz Chay	1,361.7	6	4
Gale Chay	2,093.6	9	15
Gadar Chay	2,091.0	16	13
Lilang Chay	1,936.3	6	4
Mahabad Chay	1,507.0	10	6
Nazlo Chay	1,880.1	6	9
Rose Chay	457.8	1	3
Sahar Chay	711.7	3	3
Simine Rud	3,782.7	10	7
Zarine Rud	11,837.9	34	31
Zola Chay	2,258.4	7	5
Residual 1	1,060.4	2	1
Residual 2	375.1	3	0
Residual 3	1,840.0	8	0
Residual south	551.2	0	0
Urmia Lake Island	259.8	0	0
Urmia Lake	4,976.0	0	0
Total	**51,697.2**	**163**	**136**

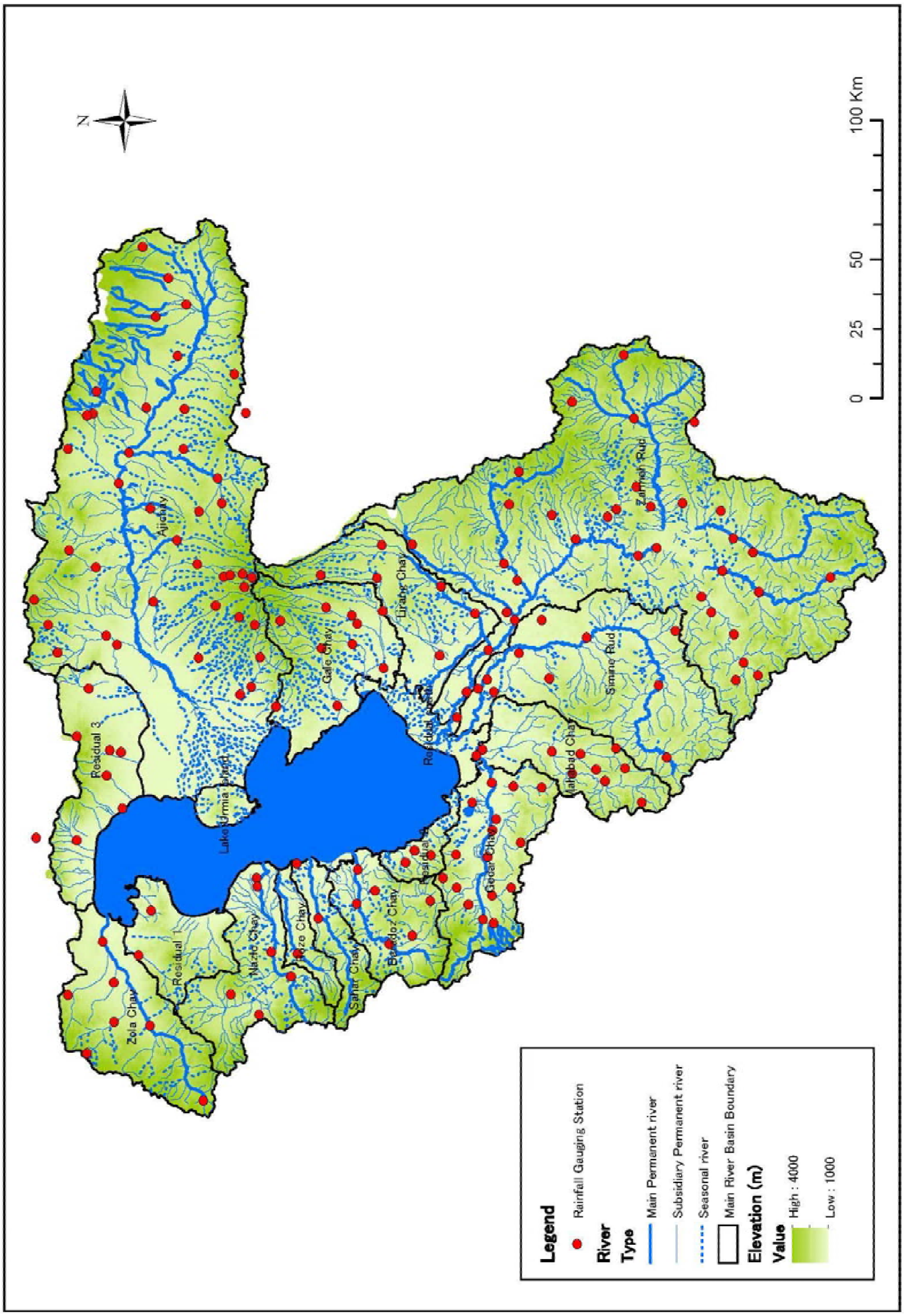


Figure 3.2.5 Locations of Rainfall Gauging Station

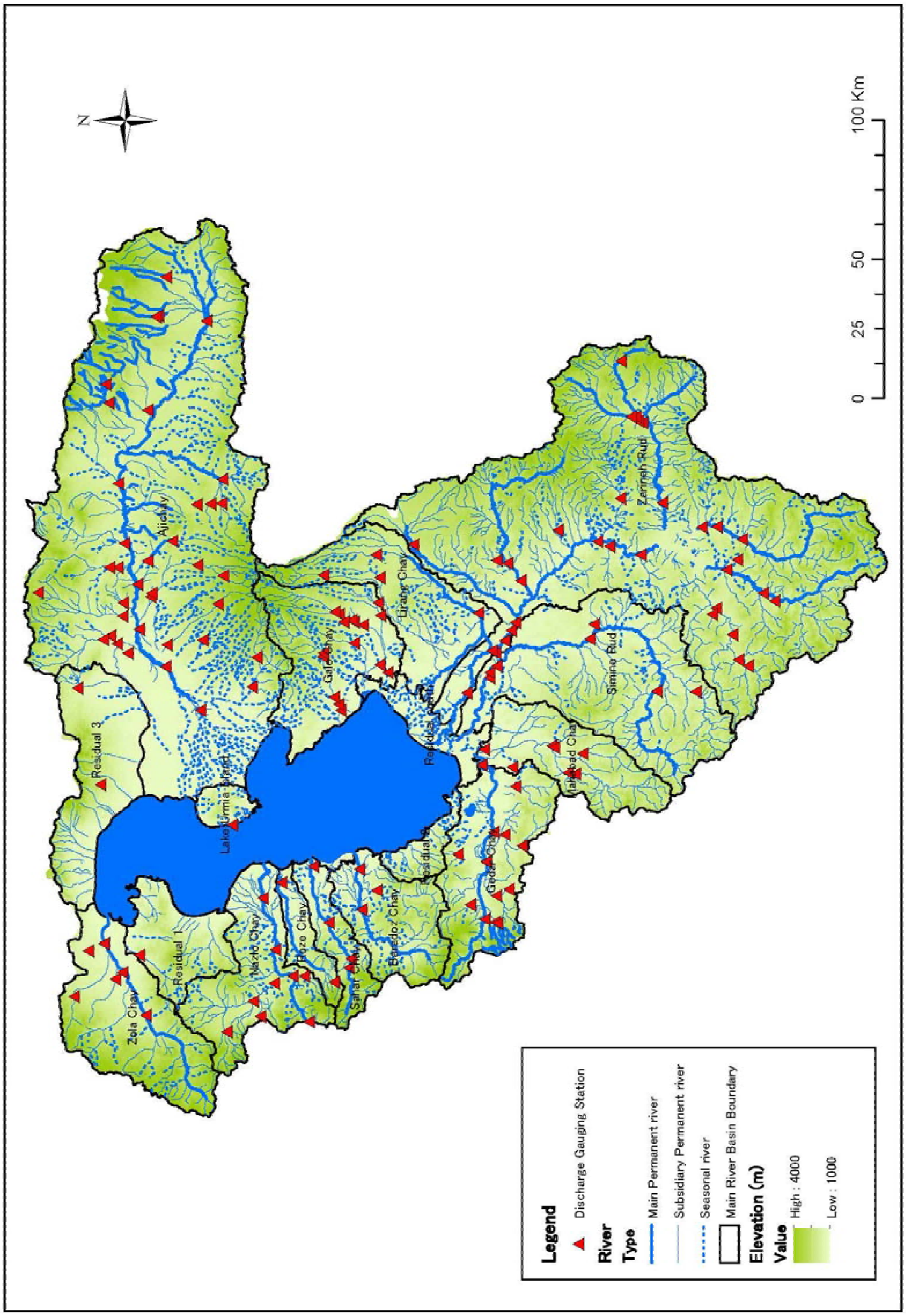


Figure 3.2.6 Locations of Discharge Gauging Station

(2) Spatial Distributed Precipitation

IMO made the spatial distribution data of rainfall in Urmia Lake basin by GIS method. The accuracy was verified by comparing the spatial distribution calculated by GIS with the ground rainfall observation data, and the error is statistically small, and it seems that the accuracy is relatively high.

The monthly data from 1379 (A.D. 2000) to 1395 (A.D. 2016) of Persian were collected. Using this data, the relationship between rainfall and elevation in the Urmia Lake basin was confirmed and used as a reference value for altitude correction of the hydrological cycle model.

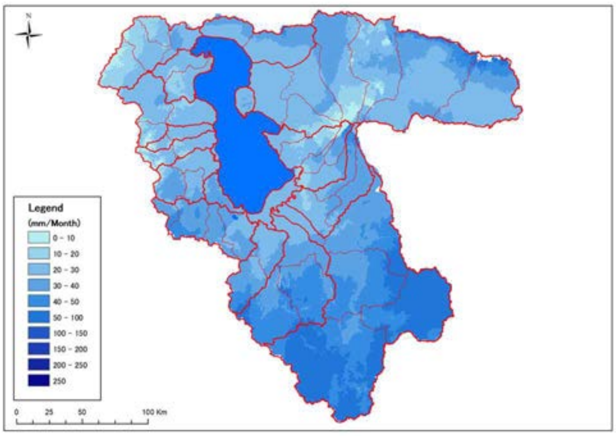


Figure 3.2.7 Spatial Monthly Precipitation of IMO (A.D. 2013)

(3) Applicability Check for Rainfall Data

The basin mean rainfall calculated by the Thiessen method using ground observation data was compared with the spatial rainfall. Except for some missing IMOs, there was acceptable agreement in most years. The example river shown in Figure 3.2.8 has a large difference in elevation in the river system, but the influence of elevation is very small.

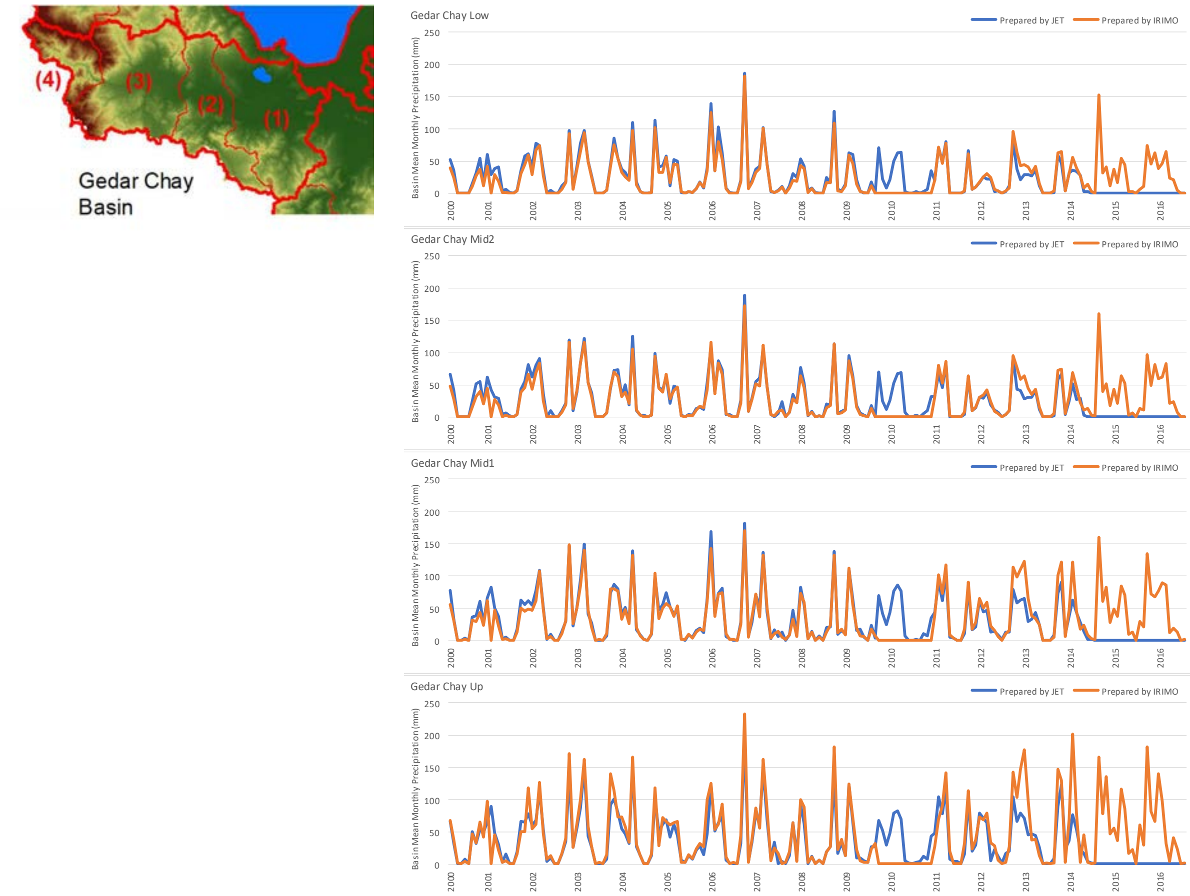


Figure 3.2.8 Comparison between Spatial Precipitation and Basin Mean Rainfall calculated by Thiessen Method

(4) Applicability Check for Discharge Data

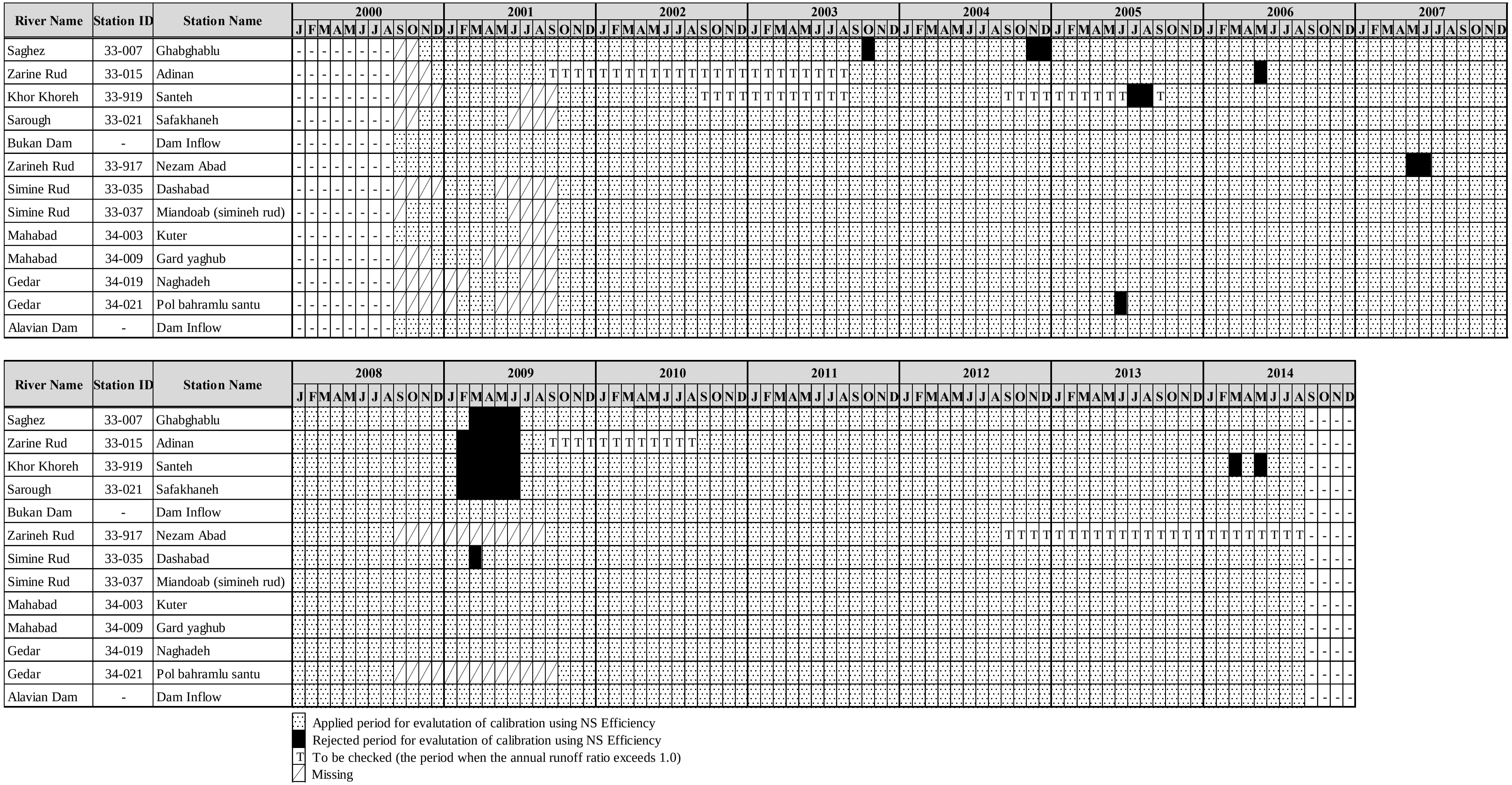
In order to qualify collected discharge data, daily discharge data at calibration points in all parts of Urmia Lake Basin were checked and graded from aspects of time series variation (hyeto-hydrograph) and runoff volume (annual runoff ratio). Summary of check is shown in below and check results at every calibration points are referred in Appendix 3-1.

3.2.6 Preliminary Check of Hydrological Data at Calibration Points for Southern Part

(1) Check of Hydrological Data with Daily Trend

In order to qualify collected hydrological data, daily discharge data at calibration points in southern part of Urmia Lake Basin were checked and graded from aspects of time series variation (hyeto-hydrograph) and runoff volume (annual runoff ratio). Summary of check is shown in Table 3.2.7 and check results at every calibration point are referred in Appendix 3-1. It was found at some calibration points that daily data seem to be linearly-interpolated for gap-filling (e.g. 2009 in Figure 3.2.9). In the evaluation of simulation results, these periods with suspicious trends were omitted for evaluation of calibration accuracy.

Table 3.2.7 Summary of Check of Hydrological Data at Calibration Points (Southern Part)



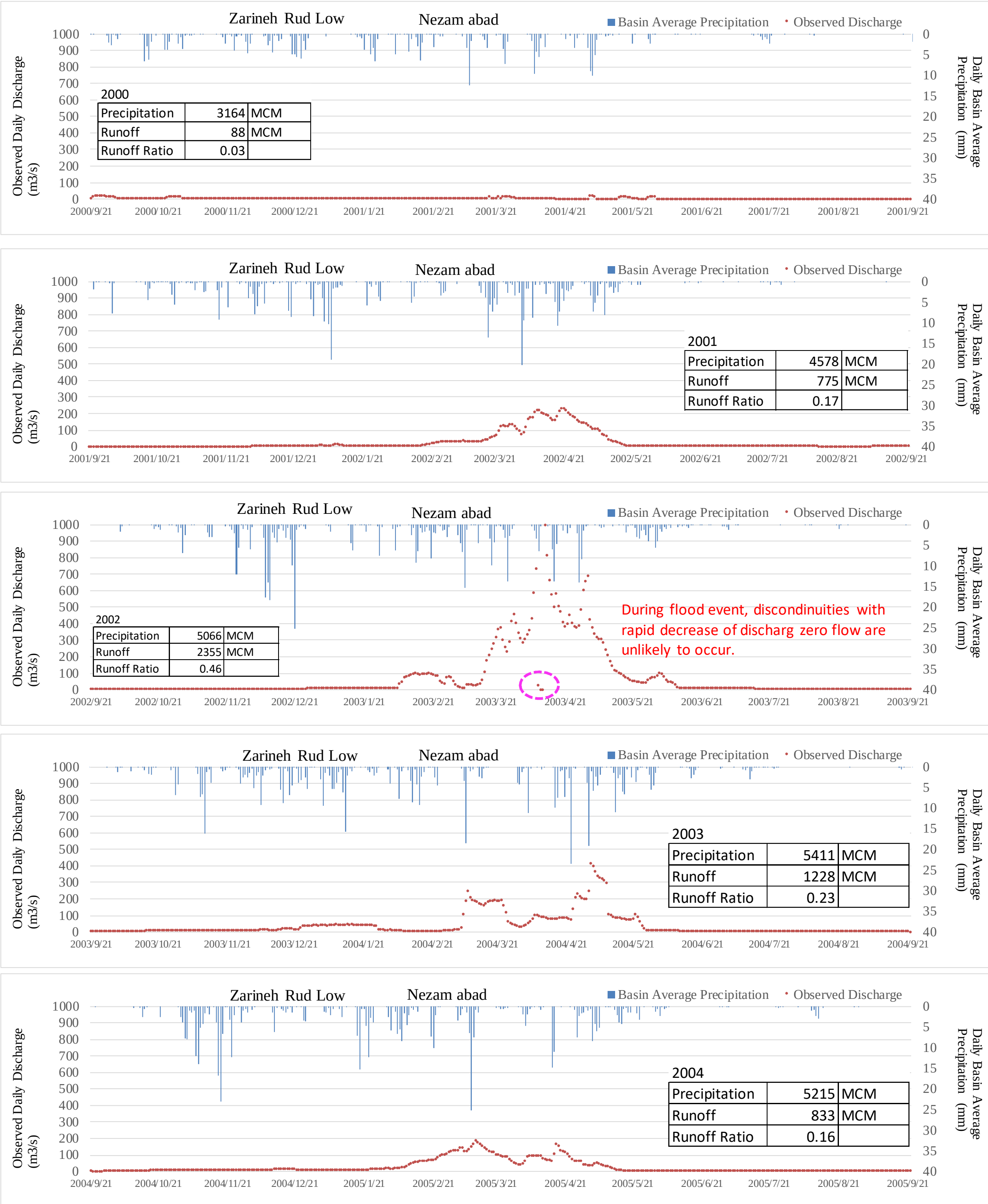
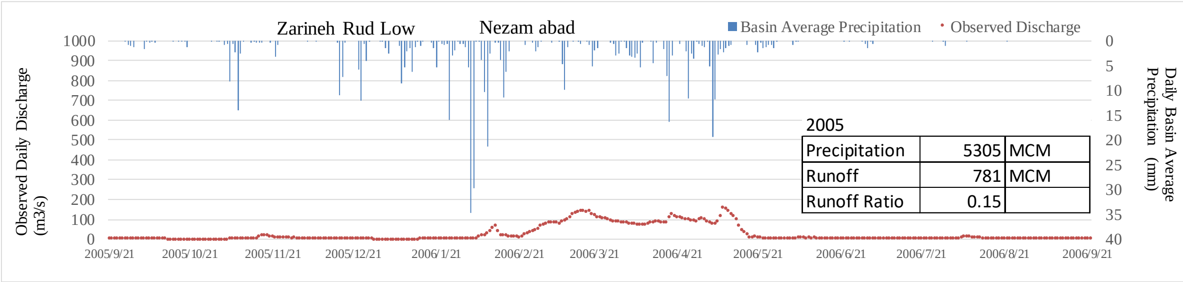
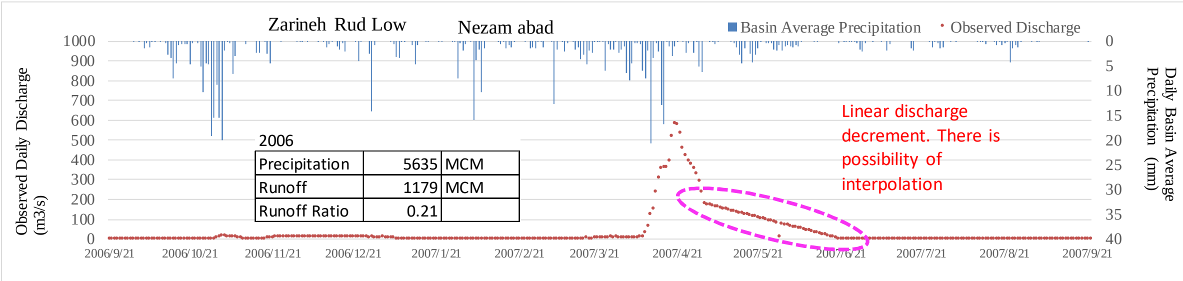
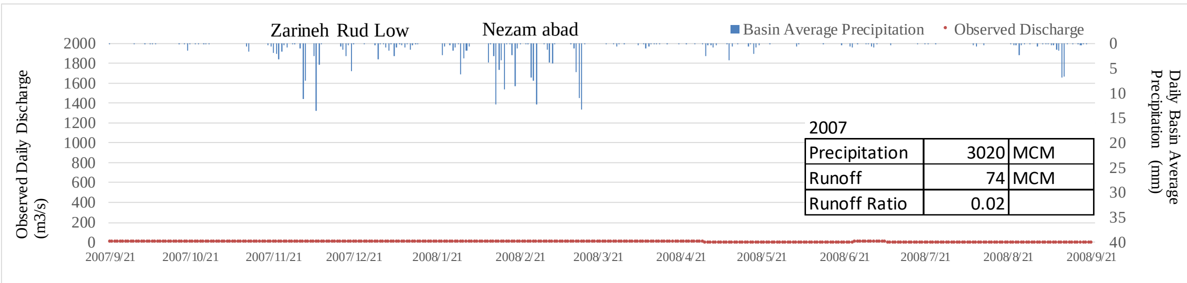
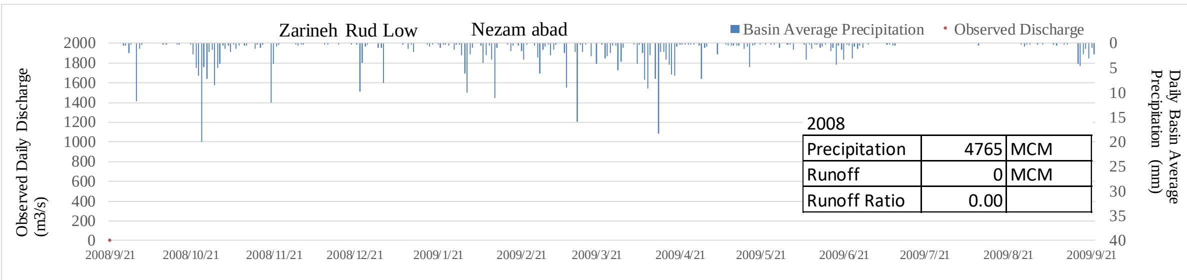


Figure 3.2.9 Example of Hydrological Data Check (Case of Nezam Abad) (1/3)









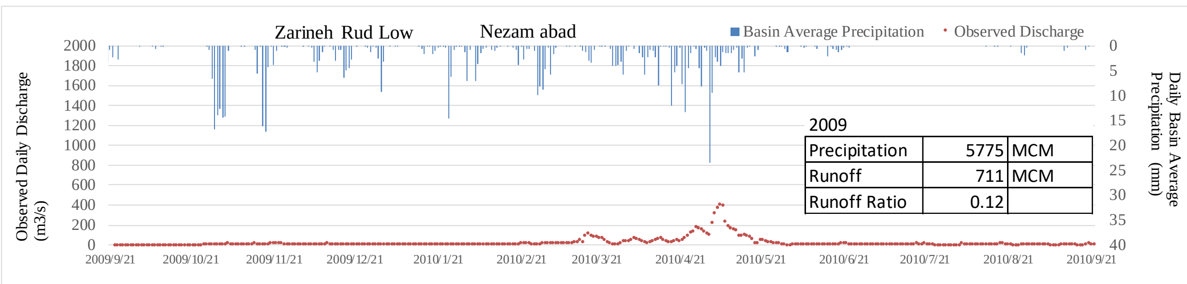


Figure 3.2.9 Example of Hydrological Data Check (Case of Nezam Abad) (2/3)

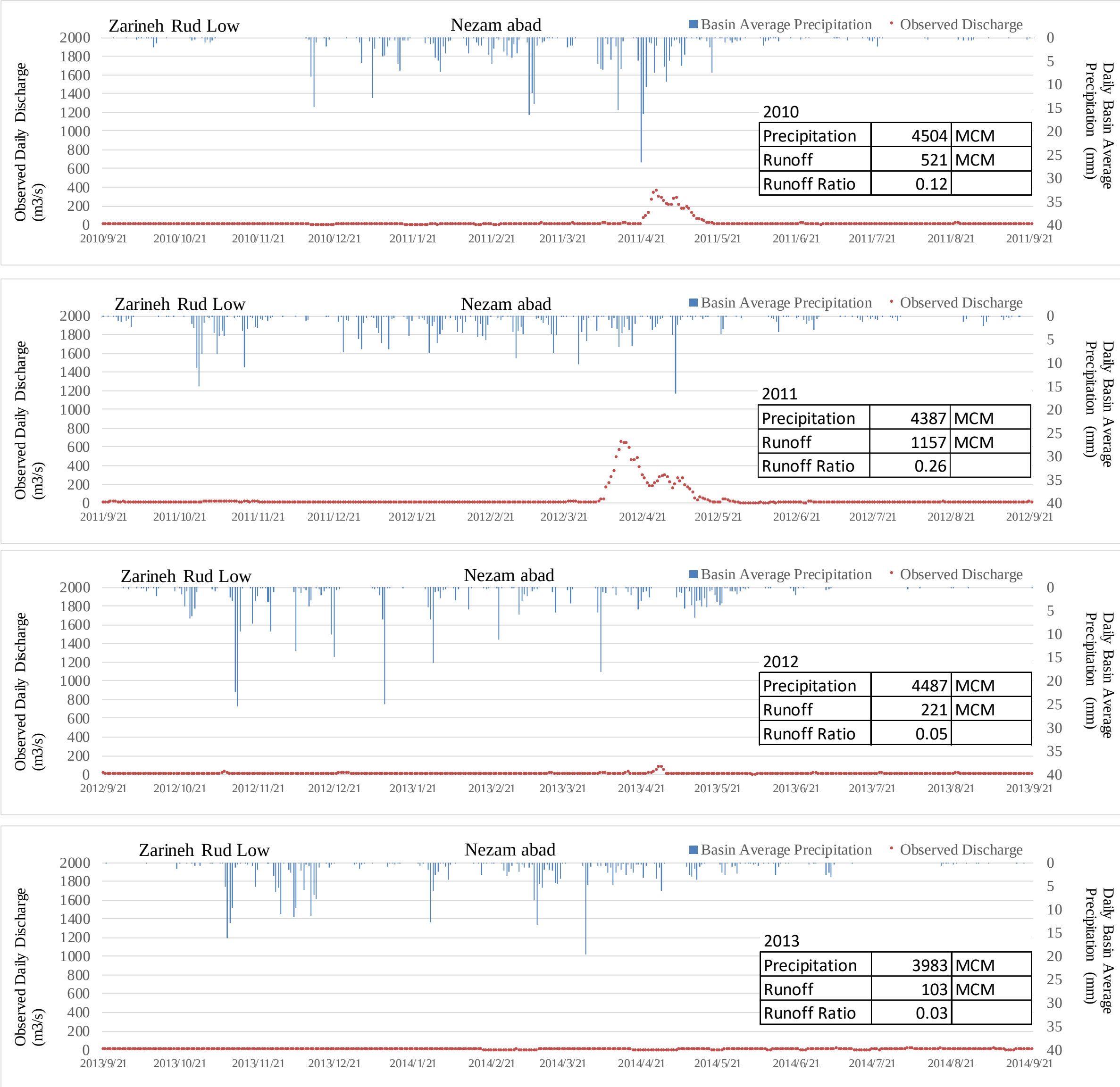
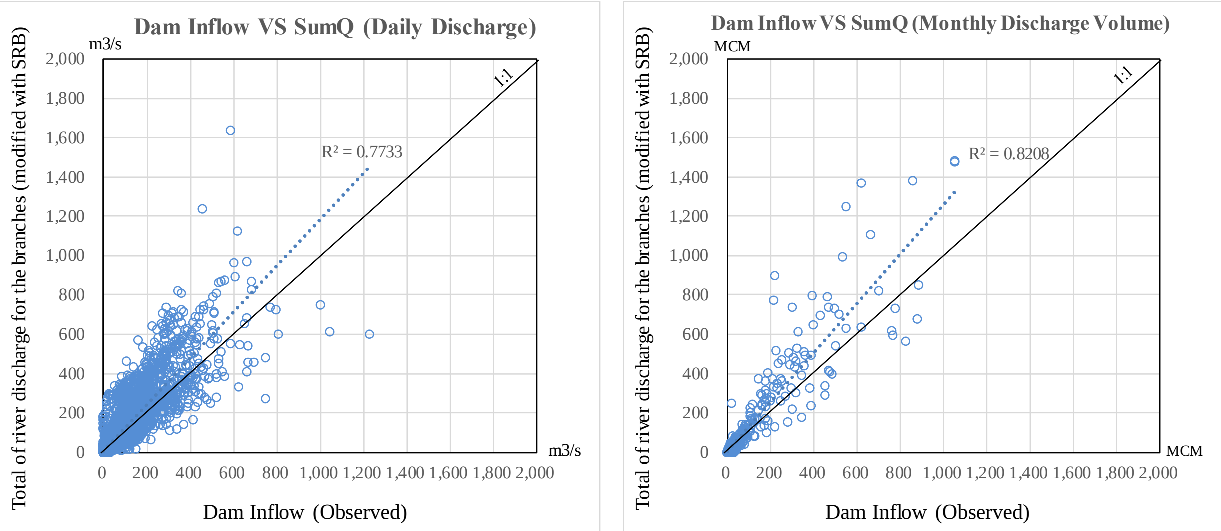


Figure 3.2.9 Example of Hydrological Data Check (Case of Nezam Abad) (3/3)

(2) Check of Dam Inflow Data at Bukan Dam

Dam inflow discharge was checked by comparison to dam inflow data and sum of the river discharge of its branches (Saghez, Zarine Rud, Khor Khoreh and Saruq Chay), that are modified with their catchment area at hydrological station to their sub-river basin area. Plots in Figure 3.2.10 show comparison with correlation of daily discharge and monthly discharge volume. The comparison results tend that sum of modified discharge is larger than dam inflow both for daily and monthly basis. Correlations of daily and monthly basis are 0.77 and 0.82, respectively. This indicates that even observation data at one of quantified observation has limitation for accuracy, which would affect accuracy of simulation by comparing with observed data.



*Modification Rate = <Catchment Area at Sub River Basin> / <Catchment Area above Hydrological station>
Saghez (Ghabghablu): 1.804, Zarine Rud (Pol anian): 1.174, Khor Khoreh (Santeh): 2.568 and Saroq Chay (Safakhaneh): 1.083

Figure 3.2.10 Comparison of Dam Inflow Data in Bukan Dam and Sum of the Branch River Discharge Modified with Sub-River Basin Area

3.2.7 Preliminary Check of Hydrological Data at Calibration Points for Western Part

(1) Check of Hydrological Data with Daily Trend

In order to qualify collected hydrological data, daily discharge data at calibration points were checked and graded from aspects of time series variation (hyeto-hydrograph) and runoff volume (annual runoff ratio). Summary of preliminary check is shown in Table 3.2.8 and check results at every calibration points are referred in Appendix 3-1. It was found at some calibration points that daily data seem to be linearly-interpolated for gap-filling (e.g. 2005 in Figure 3.2.11. It was also found that some stations' annual runoff ratio were overestimated (exceeding 1.0).

Table 3.2.8 Summary of Check of Hydrological Data at Calibration Points (Western Part)

River Name	Station ID	Station Name	2000 (JFMAMJJASOND)	2001 (JFMAMJJASOND)	2002 (JFMAMJJASOND)	2003 (JFMAMJJASOND)	2004 (JFMAMJJASOND)	2005 (JFMAMJJASOND)	2006 (JFMAMJJASOND)	2007 (JFMAMJJASOND)
Zola Chay	36-011	Yalghuz aghaj	--------····	············	·■■········■	■■·········■	■■········■■	■■·········■	■··········■	■■······■■■■
Zola Chay	36-013	Ajvaj	--------····	············	········■■■■	■■■■■■■■■···	············	····■■■·····	············	············
Zola Chay	36-001	Chehrigh olia	--------····	············	············	·······■····	····■·TTT···	·····■······	············	············
Nazlo Chay	35-033	Abajalu sofla	--------····	············	············	··■·TT······	············	············	············	············
Nazlo Chay	35-031	Tapik	--------····	············	············	··TTTTT·····	············	············	··TTTTT·····	············
Nazlo Chay	35-045	Karim abad	--------····	············	············	····■·······	············	············	············	············
Nazlo Chay (Gonbad Chay)	36-003	Nazar abad	--------TTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT
Rose Chay	35-037	Guyjali aslan	--------····	············	············	··■·········	············	············	············	············
Sahr Chay	35-013	Kashtiban	--------····	·········///	////////////	////////■■■■	■■■■■■■■■···	········////	////////····	············
Sahr Chay	35-011	Band urmia	--------····	········TTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTT····	············	············	············
Sahr Chay	35-009	Mir abad (shahr chay)	--------····	············	········TTTT	TTTTTTTT····	·········---	------------	------------	------------
Sahr Chay	35-089	Badasor	------------	------------	------------	------------	---------···	········TTTT	TTTTTTT·····	········TTTT
Baradoz Chay	35-007	Babarud	--------····	············	············	············	············	············	············	············
Baradoz Chay	35-005	Dizaj	--------····	············	············	············	············	············	············	············
Baradoz Chay	35-003	Hashem abad bibakran	--------····	············	············	········TTTT	TTTTTTTT····	············	············	············
Baradoz Chay	35-001	Ghasemlu	--------TTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT
Sahr Chay Dam	-	Dam Inflow	--------····	············	············	············	············	············	············	············

River Name	Station ID	Station Name	2008 (JFMAMJJASOND)	2009 (JFMAMJJASOND)	2010 (JFMAMJJASOND)	2011 (JFMAMJJASOND)	2012 (JFMAMJJASOND)	2013 (JFMAMJJASOND)	2014 (JFMAMJJASOND)
Zola Chay	36-011	Yalghuz aghaj	■■··■■■■····	············	············	■■TTT·······	············	···········■	■···········
Zola Chay	36-013	Ajvaj	············	············	············	············	············	············	············
Zola Chay	36-001	Chehrigh olia	········■···	············	············	············	············	············	············
Nazlo Chay	35-033	Abajalu sofla	·■·■·······■	■■··········	············	············	············	············	············
Nazlo Chay	35-031	Tapik	············	············	············	····■■■·····	············	············	············
Nazlo Chay	35-045	Karim abad	············	············	········■■··	············	············	············	············
Nazlo Chay (Gonbad Chay)	36-003	Nazar abad	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT
Rose Chay	35-037	Guyjali aslan	············	············	············	············	············	············	············
Sahr Chay	35-013	Kashtiban	············	············	············	············	············	············	············
Sahr Chay	35-011	Band urmia	············	············	············	············	············	············	············
Sahr Chay	35-009	Mir abad (shahr chay)	------------	------------	------------	------------	------------	------------	------------
Sahr Chay	35-089	Badasor	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTT····	············	········TTTT	TTTTTTTT····	············
Baradoz Chay	35-007	Babarud	····■■■■····	············	············	············	···········■	■■··········	············
Baradoz Chay	35-005	Dizaj	············	············	············	············	············	············	············
Baradoz Chay	35-003	Hashem abad bibakran	············	············	············	············	············	············	············
Baradoz Chay	35-001	Ghasemlu	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT
Sahr Chay Dam	-	Dam Inflow	············	············	············	············	············	············	············

· Applied period for evalutation of calibration using NS Efficiency
■ Rejected period for evalutation of calibration using NS Efficiency
T To be checked (the period when the annual runoff ratio exceeds 1.0)
/ Missing

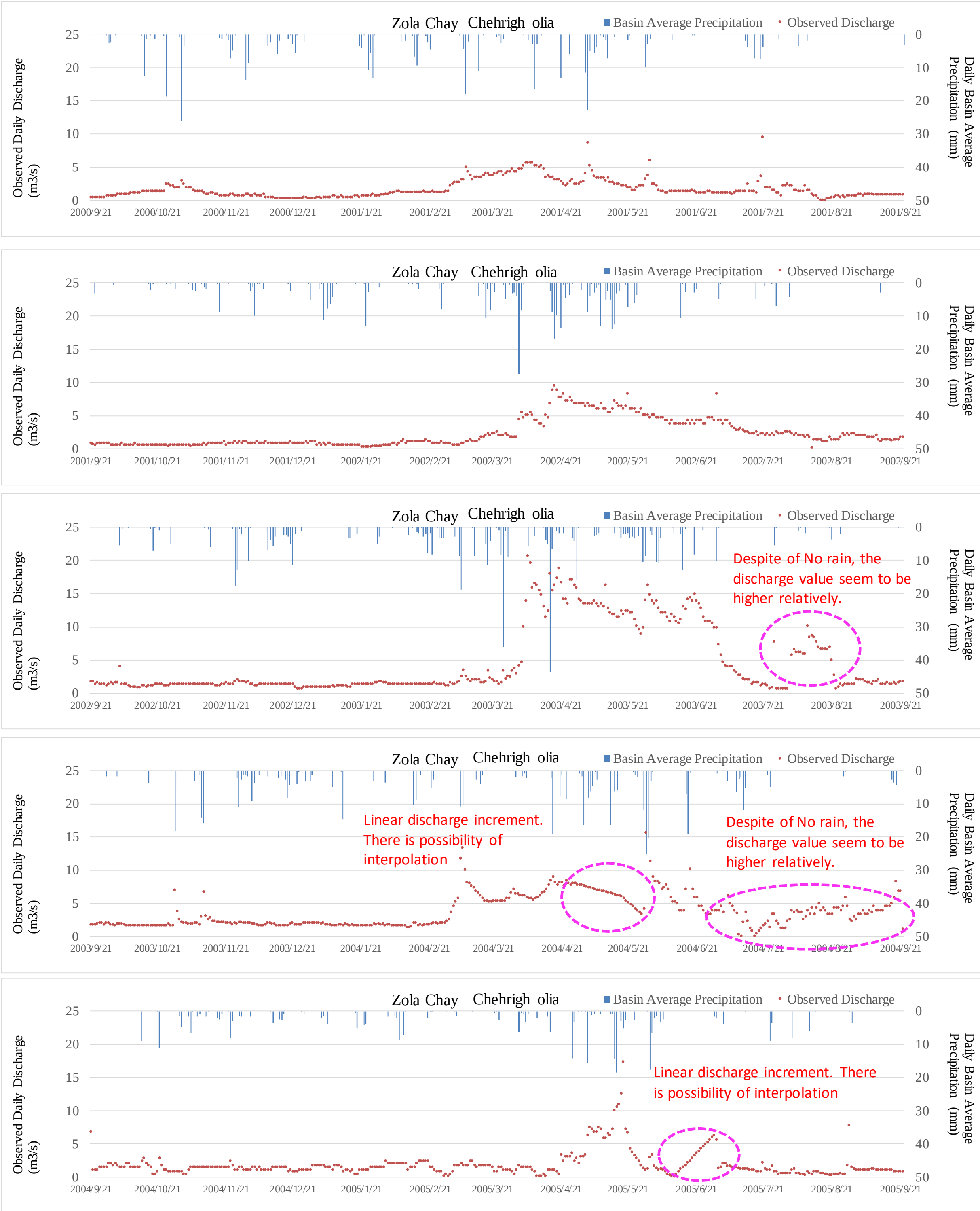


Figure 3.2.11 Example of Hydrological Data Check (Case of Chehrigh olia) (1/3)

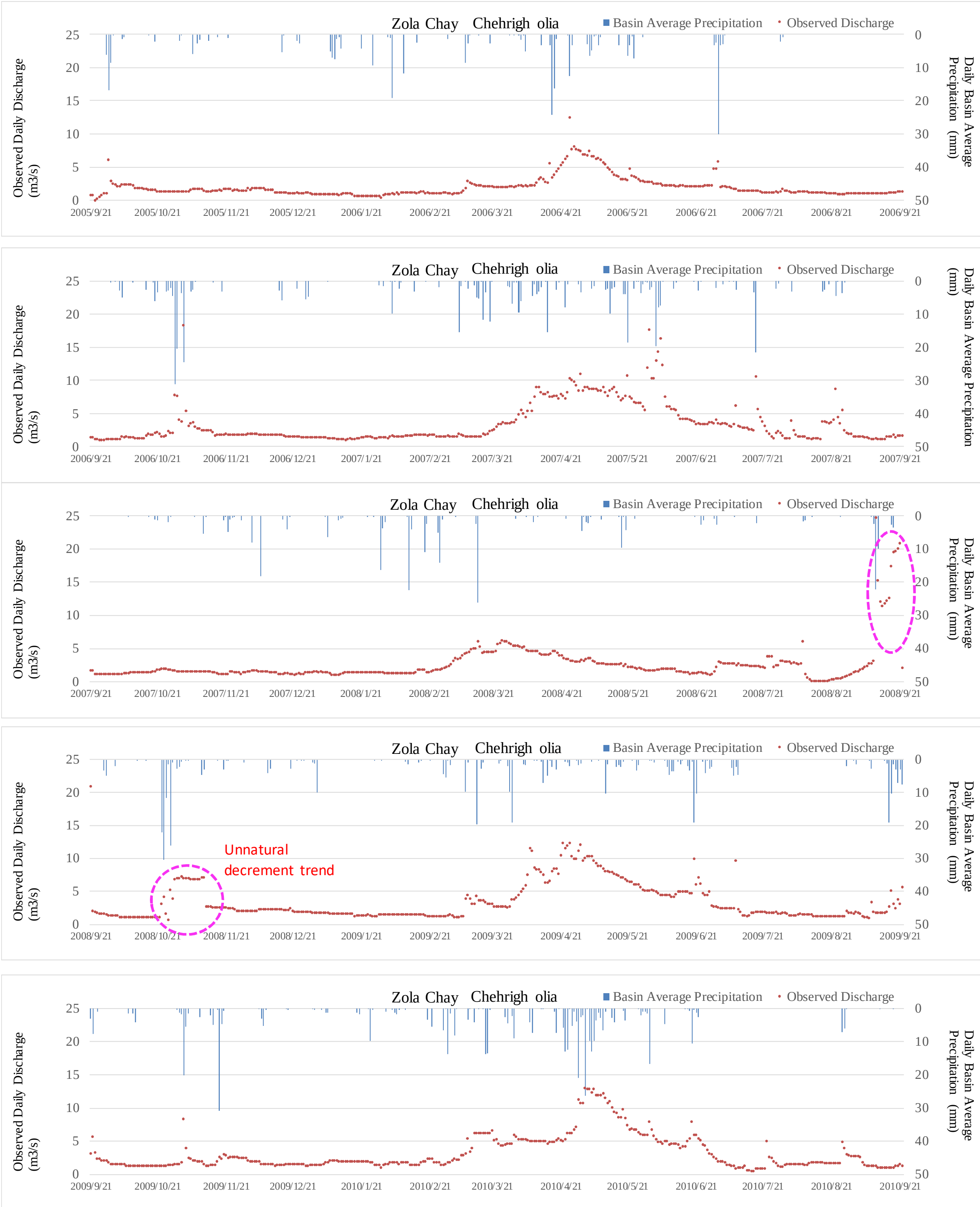


Figure 3.2.11 Example of Hydrological Data Check (Case of Chehrigh olia) (2/3)

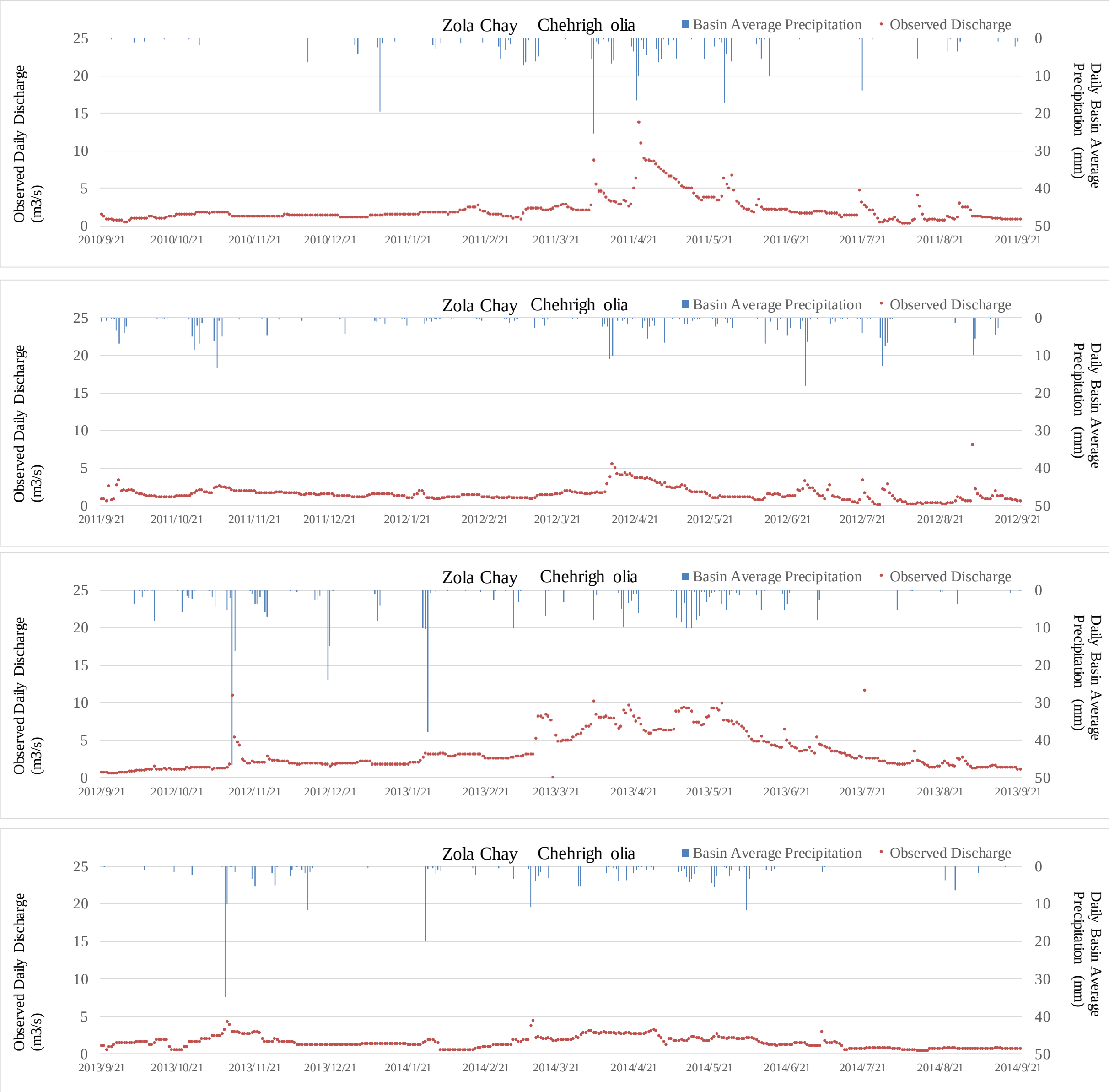


Figure 3.2.11 Example of Hydrological Data Check (Case of Chehrigh olia) (3/3)

(2) Notable Hydrological Station

For the following hydrological stations, the quality of river discharge data at calibration points were carefully checked from viewpoints of hydrological phenomena, such as presence of reverse flow between upstream and downstream, response to precipitation, volume comparison between precipitation and runoff, and so on. It appeared that these hydrologically-impossible phenomena could not be simulated by the constructed model. The periods with unreliable data quality were omitted from the data for validation process.

(a) Yalghuz Aghaj (36-011)

Yalghuz Aghaj Hydrological Station (36-011) on Zola Chay River, the closest hydrological station to the Urmia Lake, has manual observation system of float-type, according to WRC. Photos in Figure 3.2.12 show views around the hydrological station. Main material of riverbed seems to comprise of fine sand, silt clay and clay, which is vulnerable to water erosion. Without riverbed fixation work, riverbed around installed pipe seems lowered due to scouring, based on the situation that height of inlet of installed pipe is greater than 1m above the lowest height of riverbed, although the inlet should have been installed near original riverbed level. Due to this difference, water level under the inlet level cannot be observed, which possibly underestimates river discharge. Moreover, interruption of river flow by sediment could also cause water heightening due to overtopping, therefore, correct observation of river discharge was suspicious.

Figure 3.2.13 show hydrographs of observed river discharge at Yalghuz Aghaji and Chehirigh Olia (39-011) located upstream of Zola Chay Dam between September 2000 and August 2001 before construction of Zola Chay Dam was completed. Their catchment areas are 2,204 km^2 and 819 km^2, respectively. While flood events with increment and decrement trends have been formed at Chehirigh Olia during snowmelt and rainy seasons (from March to June) for both years, tiny flood patterns have been recorded at Yalghuz Aghaji, in which zero value of river discharge was recorded even in the middle of flood season. At Yalghuz Aghaj, despite different timings of flood occurrence between water years of 2008 and 2009, no flood event was recorded for March of 2010 in the season when irrigation irrigation is not scheduled. It can be said that this context also supports underestimation of river discharge at Yalguz Aghaj.

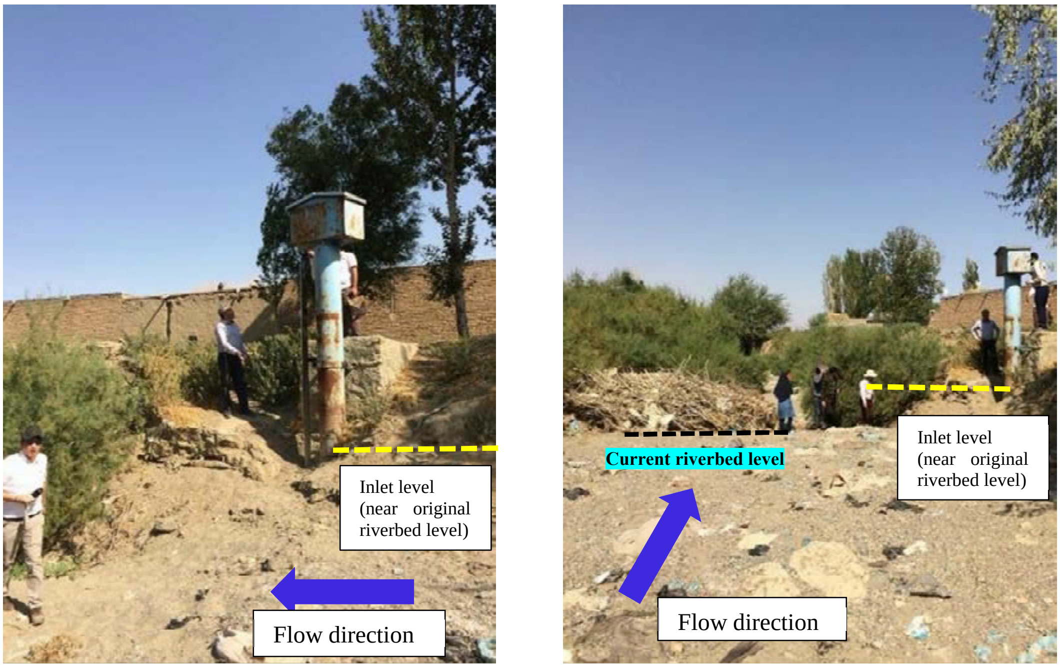
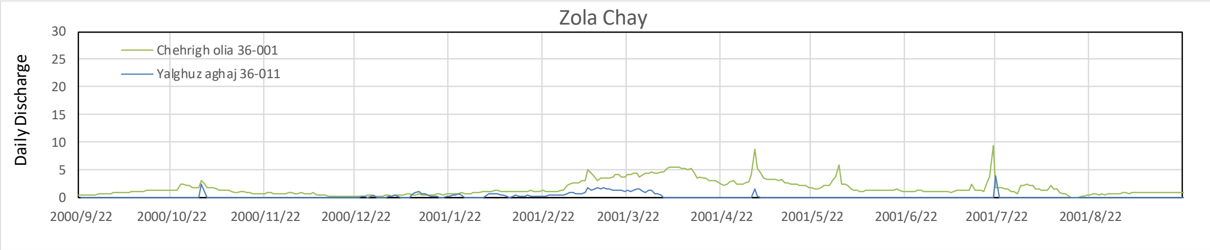


Figure 3.2.12 Views around Yalghuz Aghaj Hydrological Station (Zola Chay River)



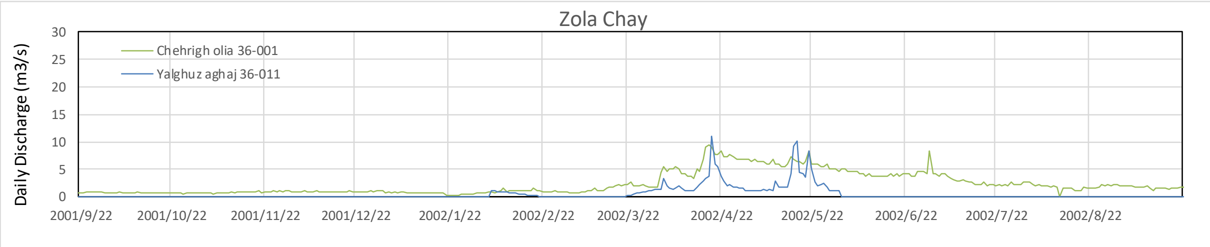


Figure 3.2.13 Hydrograph at Yalghuz Aghaji and Chehirigh Olia (top: 2008, bottom: 2009)

(b) Band Urmia (35-011)

Band Urmia Hydrological Station (35-011) on Shahr Chay River is located at approximately 10 km downstream from Shahr Chay Dam. Figure 3.2.14 shows the location and view around Band Urmia Hydrological Station. Figure 3.2.15 show the hydrograph of recorded outflow of Shahr Chay Dam and Discharge at Band Urmia. Although none of primary hydraulic structure for water use (e.g. weir) and a few square kilometers of irrigated area distributed along the river between the hydrological station and dam, hydrograph of dam outflow and observed discharge show different pattern, that are supposed to be mostly coincident. In the constructed model, dam outflow of Shahr Chay Dam is used for boundary condition of 1D hydraulic model (MIKE-11) which is given as point source.

This difference indicates that simulated river discharge at Hydrological Stations downstream of Shahr Chay Dam [e.g. Band Urmia and Kashtiban (35-013)] do not agree with the observed river discharge.

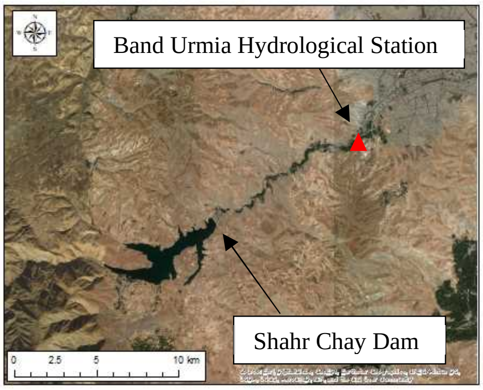


Figure 3.2.14 Location and Views around Band Urmia Hydrological Station (Shahr Chay River)

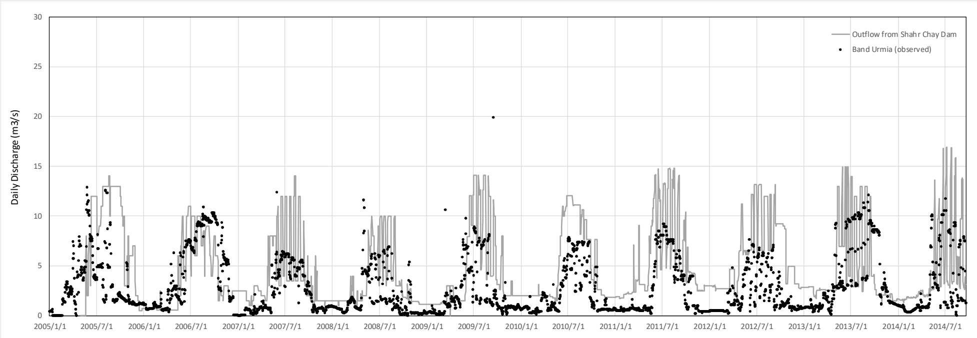


Figure 3.2.15 Hydrograph of Recorded Outflow from Shahr Chay Dam and River Discharge at Band Urmia Hydrological Station

3.2.8 Preliminary Check of Hydrological Data at Calibration Points for Eastern Part

(1) Check of Hydrological Data with Daily Trend

In order to qualify collected hydrological data, daily discharge data at calibration points in eastern part of Urmia Lake Basin were checked and graded from aspects of time series variation (hyeto-hydrograph) and runoff volume (annual runoff ratio). Summary of check is shown in Table 3.2.9 and check results at every calibration point are referred in Appendix 3-1. It was found at some calibration points that daily data seem to be linearly-interpolated for gap-filling (e.g. Anakhatun Hydrological Station in Figure 3.2.16). In the evaluation of simulation result, these periods with suspicious trends were omitted for evaluation of calibration accuracy.

Table 3.2.9 Summary of Check of Hydrological Data at Calibration Points (Eastern Part)

River Name	Station ID	Station Name	2000 (JFMAMJJASOND)	2001 (JFMAMJJASOND)	2002 (JFMAMJJASOND)	2003 (JFMAMJJASOND)	2004 (JFMAMJJASOND)	2005 (JFMAMJJASOND)	2006 (JFMAMJJASOND)	2007 (JFMAMJJASOND)
Aghmiun chay	31-001	Sahzab	--------■■■■	■■■■■■■■....	....	........■■■■	■■■■■■■■....	........TTTT	TTTTTTT.....	...TTT..////
Tajyar sarab	31-032	Mirkuh haji	--------■■■■	■■■■■■■■....	........TTTT	TTTTTTTT....	....	....	....	........////
Ajichay	31-005	Saransar	--------....	....	....	....	....	....	........////	////////////
Mehrban (Chekel	31-109	Mehrban	--------////	//...////...	....	....	....	....	....	....
Ojan chay	31-007	Bostan abad	--------....	....	....	...■........	....■.......	....	....	....
Ajichay	31-117	Markid	--------////	..../////...	//..........	....	.........../	/////....../	//..........	.........../
Nahand chay	31-011	Nahand	--------....	....	....	....	....	....	....	....
Saiid abad	31-013	Saiid abad	--------TTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT
Ajichay	31-015	Vanyar	--------....	........TTTT	TTTTTTTT....	....	..........■■	■■■........■	■■■.........	....■.......
Lighavan	31-021	Harvi	--------....	....	....	....	....	....	....	....
Gomnab chay	31-017	Anakhatun	--------/■■■	■■■■■////■■■	■■■■■■■■■■■■	■■■■■■■■■■■■	■■■.....■■■■	■■■■■■■■■■■■	■■■■■■■■■■■■	■■■■■■■■■■■■
Sardorud	31-031	Zinjenab	--------....	....	....	....	....	....	....	........TTTT
Ajichay	31-045	Akhola	--------....	////////....	....	....	....	....	....	....
Ajichay	31-085	Sarin dizaj	--------////	////////....	........////	////////....	....	....	....	....
Azar Shahr	31-037	Ghermezigol	--------....	....	........TTTT	TTTTTTTT....	....	....	....	....
Sanikh chay	31-029	Pol sanikh	--------....	....	....	....	....	....	....	........■■■■
Alavian Dam	-	Dam Inflow	--------....	....	....	....	....	....	....	....

River Name	Station ID	Station Name	2008 (JFMAMJJASOND)	2009 (JFMAMJJASOND)	2010 (JFMAMJJASOND)	2011 (JFMAMJJASOND)	2012 (JFMAMJJASOND)	2013 (JFMAMJJASOND)	2014 (JFMAMJJASOND)
Aghmiun chay	31-001	Sahzab	////////....	....■■......	....	....■■......	....	....	....
Tajyar sarab	31-032	Mirkuh haji	////////....	....	....	....	....	....	....
Ajichay	31-005	Saransar	////////////	////////////	////////////	////////////	////////////	////////////	////////----
Mehrban (Chekel	31-109	Mehrban	....	....	....	....	....	....	........----
Ojan chay	31-007	Bostan abad	....	........■■■■	■■■■■■■■....	....	....	....	........----
Ajichay	31-117	Markid	///.........	....	....	.........../	//..........	.........../	//......----
Nahand chay	31-011	Nahand	........■...	......■■■...	..■.........	.......■■...	........■■..	....	........----
Saiid abad	31-013	Saiid abad	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTTTTTT	TTTTTTTT----
Ajichay	31-015	Vanyar	....	.....■......	....■.......	..■.....////	////////////	////////////	////////----
Lighavan	31-021	Harvi	....	....	....	....	....	....	........----
Gomnab chay	31-017	Anakhatun	■■■■■■■■....	.■.........■	■■■■........	....	....	...........■	■■......----
Sardorud	31-031	Zinjenab	TTTTTTTT....	....	....	....	....	....	........----
Ajichay	31-045	Akhola	....	....	....	....	....	....	........----
Ajichay	31-085	Sarin dizaj	....	....	........■■■■	■■■■■■■■....	....	....	........----
Azar Shahr	31-037	Ghermezigol	....	....	....	....	....	....	........----
Sanikh chay	31-029	Pol sanikh	■■..........	....	....	....	....	....	........----
Alavian Dam	-	Dam Inflow	....	....	....	....	....	....	........----

(.) Applied period for evalutation of calibration using NS Efficiency
(■) Rejected period for evalutation of calibration using NS Efficiency
T To be checked (e.g. the period when the annual runoff ratio exceeds 1.0)
(/) Missing

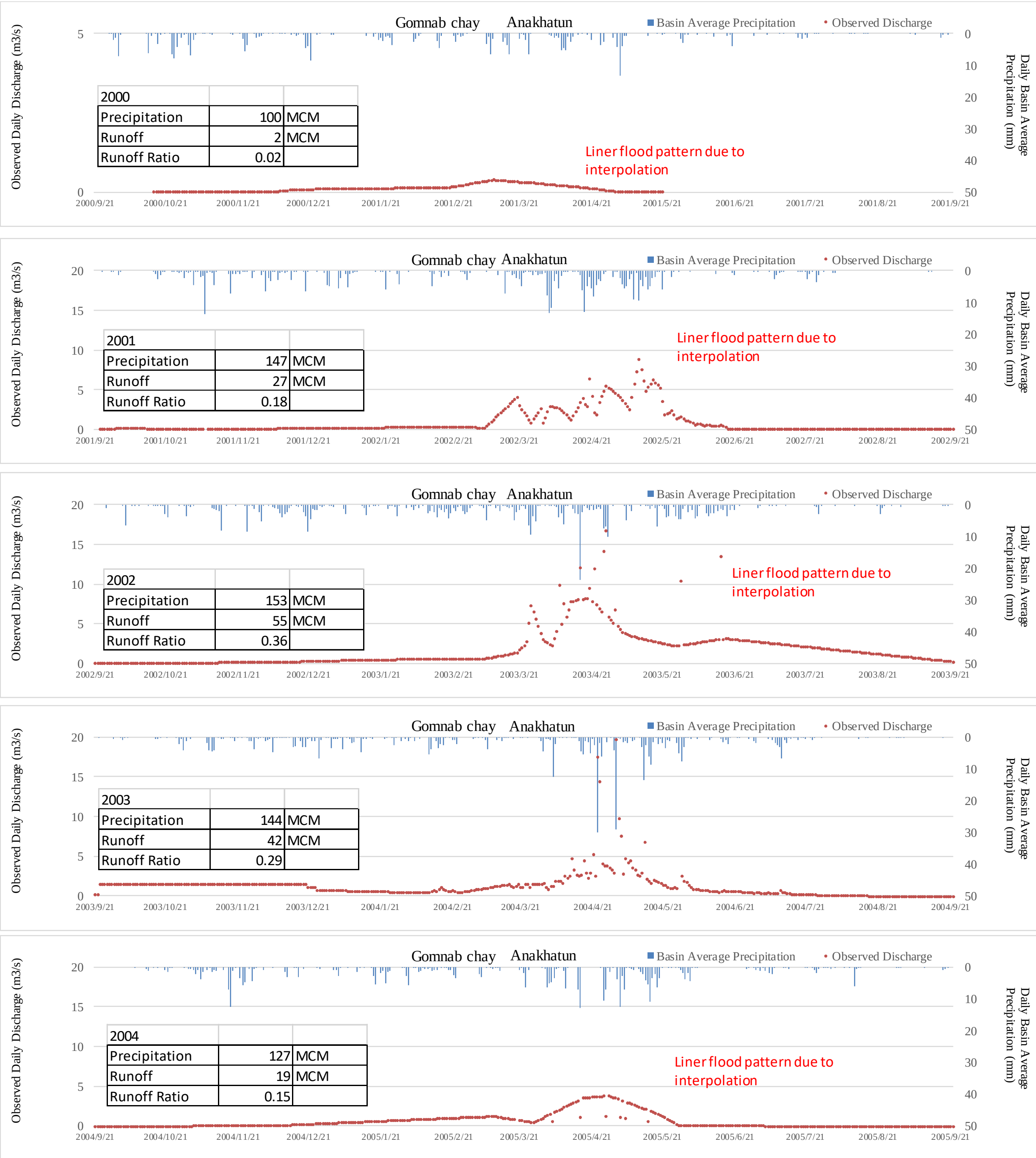


Figure 3.2.16 Example of Hydrological Data Check (Case of Anakhatun) (1/3)

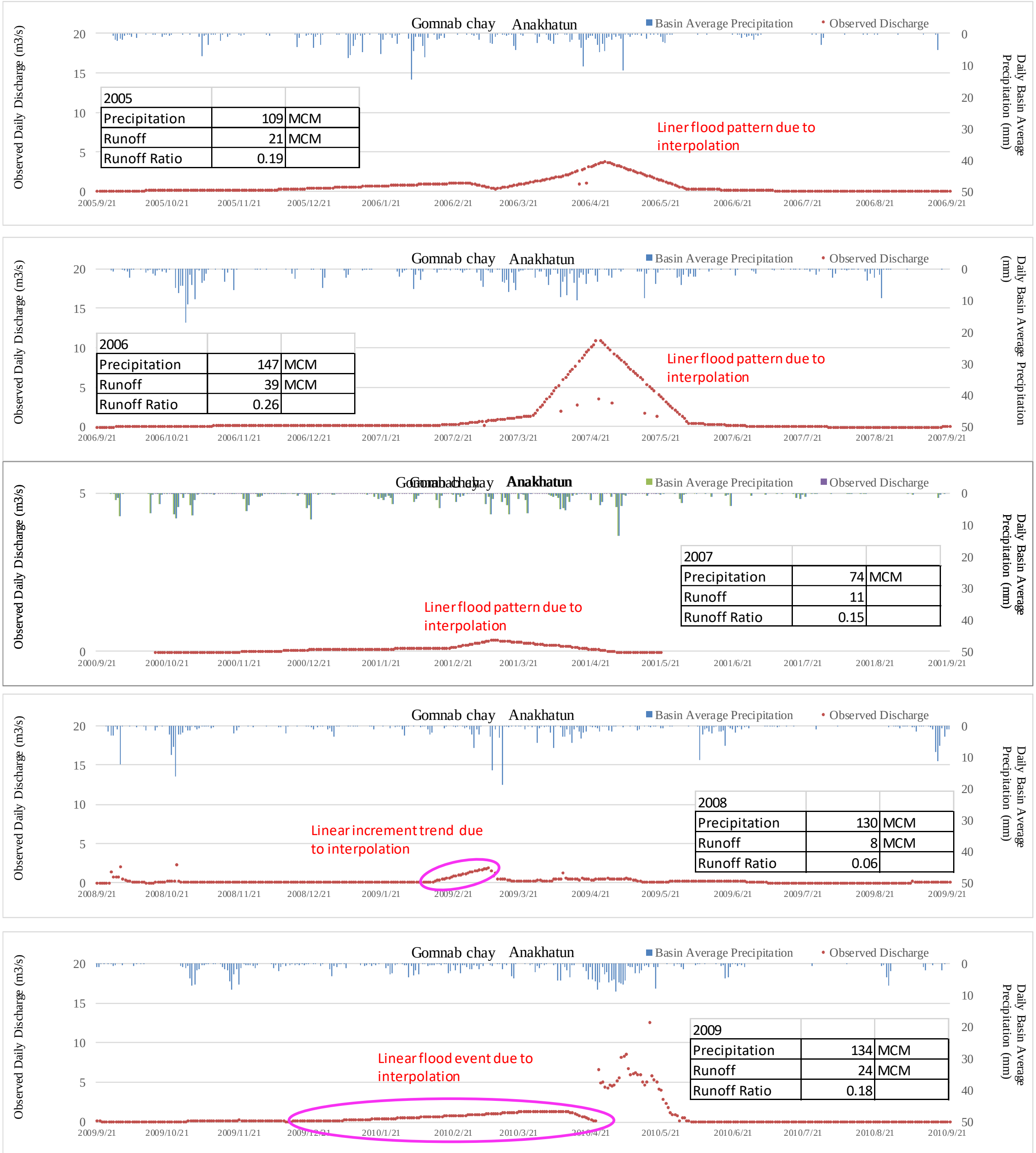


Figure 3.2.16 Example of Hydrological Data Check (Case of Anakhatun) (2/3)

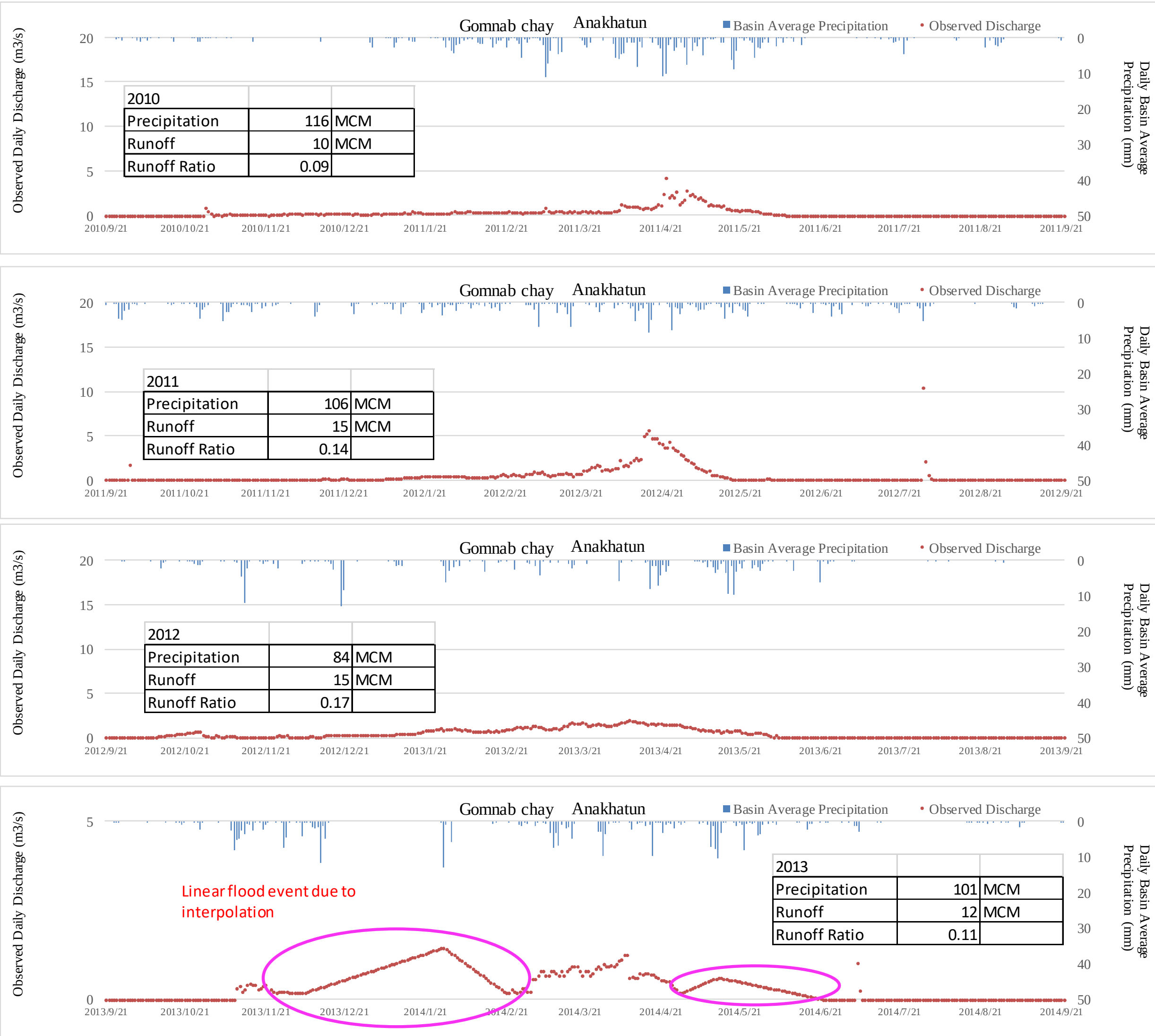


Figure 3.2.16 Example of Hydrological Data Check (Case of Anakhatun) (3/3)

(2) Notable Hydrological Station

(a) Akhola (31-045)

Akhola Hydrological Station (31-045) on Aji Chay River is located at approximately 50 km upstream from Urmia Lake, and it is one of the significant hydrological stations monitoring river discharge flowing into Urmia Lake. Figure 3.2.17 shows the landscape around Akhola Hydrological Station. The pipe equipped with gauge was installed right downstream the place where severe scouring-induced riverbed lowering occurs. As shown in Figure 3.2.17, this situation of riverbed causes the turbulence flow at measuring point which may lead to uncertainty of water level’s accuracy.

Figure 3.2.17 Akhola Hydrological Station

3.2.9 Subsurface Structure

At the meeting held at the start of the Survey, a 3D geological model was planned to be provided from ULRP. The first survey revealed that the quantity and quality of the 3D geological model data are not sufficient, and it was requested that the data be checked by dispatching geologists. In order to improve the accuracy of the 3D geological model to be provided from ULRP, additional activities by geologists were carried out in November 2017. The contents are described in detail in Chapter 4.6.1.

3.2.10 Evaporation

Pan evaporation data (64 points from 1975 to 2013) by WRM measurement were provided. Figure 3.2.18 shows the change of monthly pan evaporation and monthly rainfall at the survey point in the southern area (verification period of hydrological cycle modeling in the first year).

The pan evaporation amount in the dry season has been changing from 200 mm to 400 mm, and no value recognized as abnormal value was confirmed. However, the evapotranspiration amount used for the hydrological cycle model was calculated by the satellite image product, and the observation value of the pan evaporation amount are treated as a reference value.

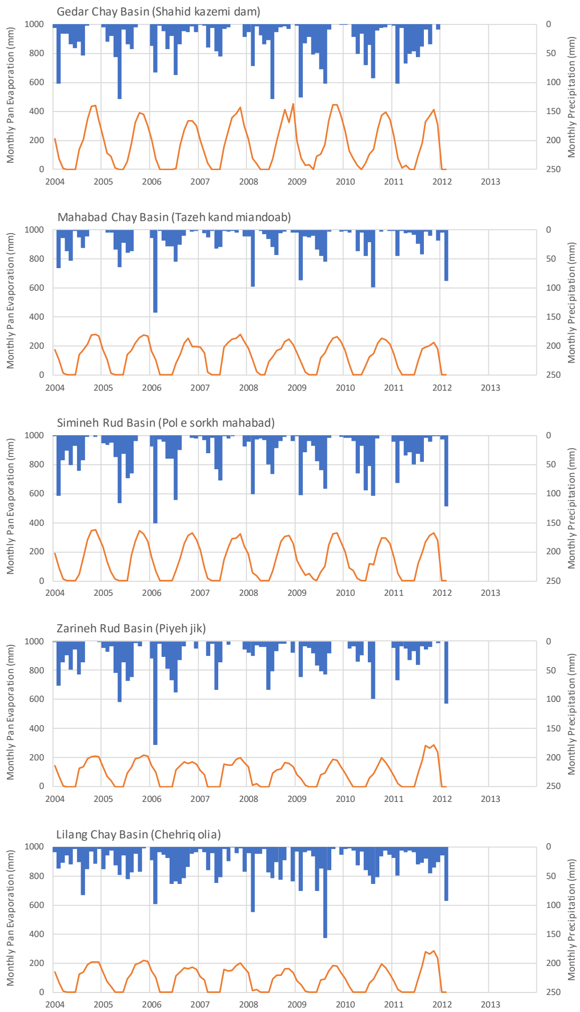


Figure 3.2.18 Precipitation and Pan Evaporation

3.2.11 Other Information (Irrigation Efficiency)

(1) Outline

Water consumption reduction measures were examined mainly in the Miandab by ULRP. The target area is shown in Figure 3.2.20. The outline is as follows.

ULRP recognizes that it is necessary to control and reduce water consumption in the agricultural sector for the restoration of Urmia Lake. According to this aim, practical contents, including supply management with emphasis on declining agricultural water use (surface water and ground water) by 40%, and preparation and implementation of efficiency enhancement programs for leftover water, 60%, have been considered. In addition to the supply management and emphasis on efficiency enhancement program, dispossession of lands inside the river bodies of Simine river and Zarine river could reduce the amount of net water in the planning area.

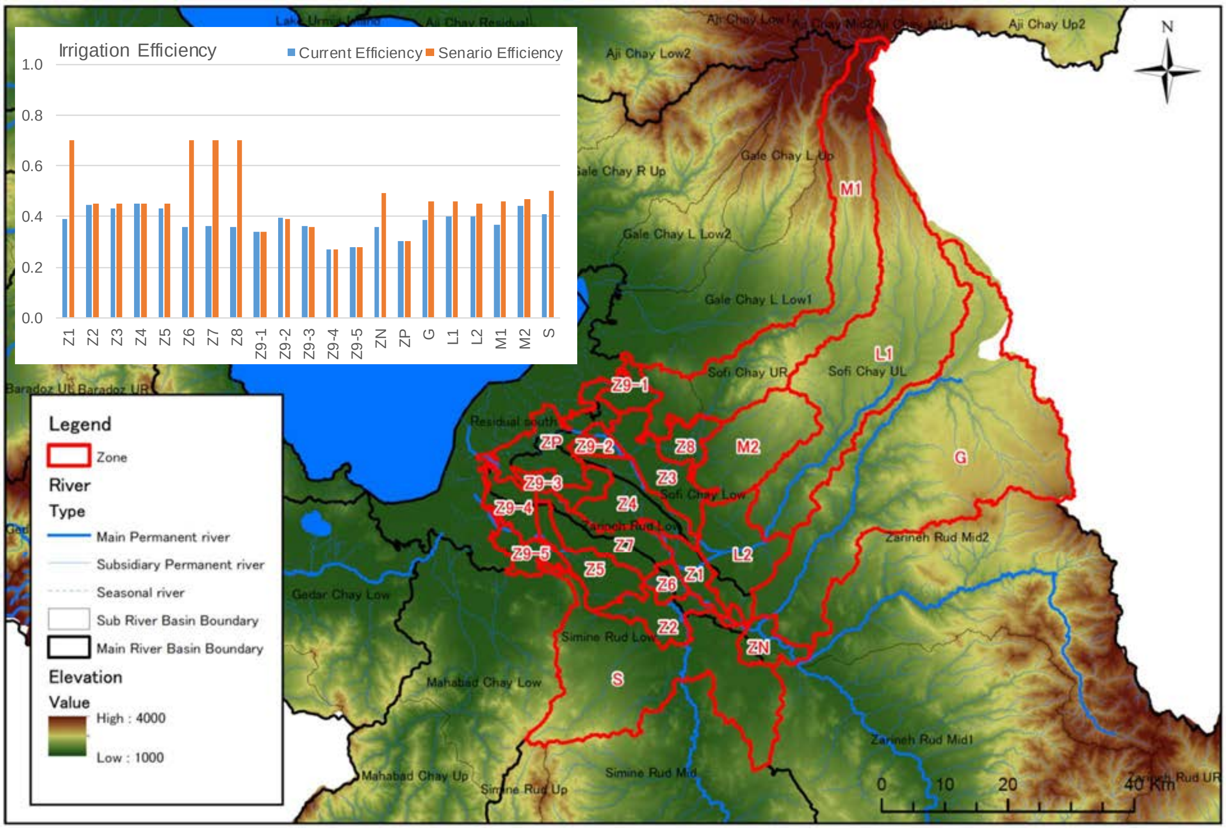
Figure 3.2.20 shows the location map of target scenario, and Figure 3.2.19 shows the division map of targeted scenario.

(2) Adopted Irrigation Efficiency for Hydrological Model

ULRP concludes that if the above water consumption reduction measures are completed in about 10 years, irrigation efficiency improvement per irrigation zone as shown in Table 3.2.10 and Figure 3.2.19 will be obtained. In the Survey, model calibration was carried out by applying current irrigation efficiencies as part of parameters of MIKE-SHE.

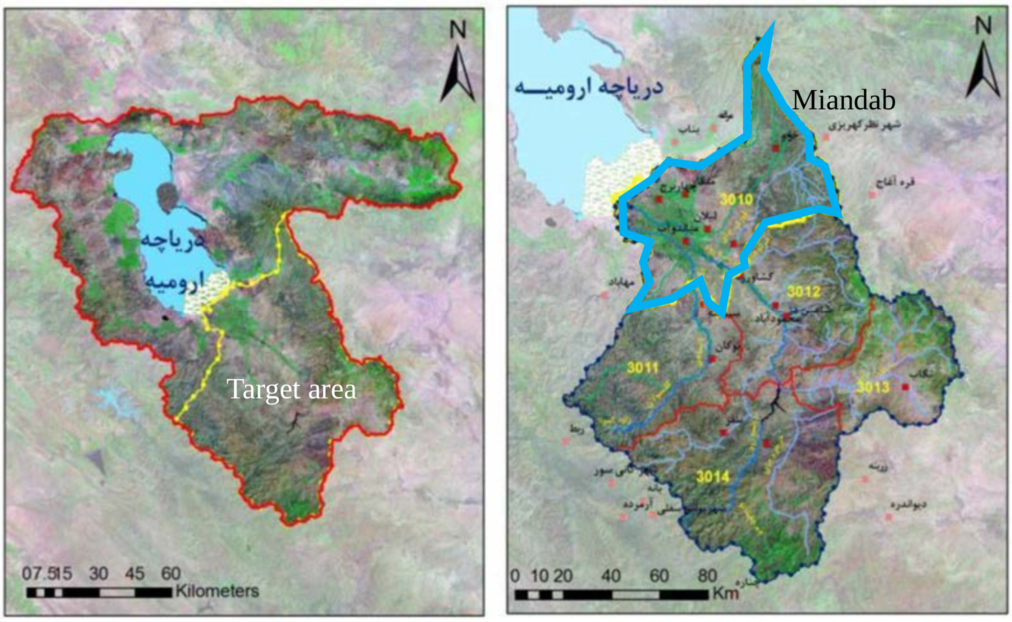
Table 3.2.10 Irrigation Efficiency Value for Each Zone

Zone	Current Efficiency	Scenario Efficiency
Z1	0.39	0.70
Z2	0.45	0.45
Z3	0.43	0.45
Z4	0.45	0.45
Z5	0.43	0.45
Z6	0.36	0.70
Z7	0.36	0.70
Z8	0.36	0.70
Z9-1	0.34	0.34
Z9-2	0.39	0.39
Z9-3	0.36	0.36
Z9-4	0.27	0.27
Z9-5	0.28	0.28
ZN	0.36	0.49
ZP	0.30	0.30
G	0.39	0.46
L1	0.40	0.46
L2	0.40	0.45
M1	0.37	0.46
M2	0.44	0.47
S	0.41	0.50



Source: Prepared by the Survey Team based on data provided by ULRP

Figure 3.2.19 Division Map and Irrigation Efficiency



Source: Implementation methods of 40% decline in agricultural water consumption in Zarinerud and Siminerud Basin (Yecom)

Figure 3.2.20 Target area for water consumption reduction measures

3.3 Application of METRIC Method to Obtain Evapotranspiration Data

In the Survey, areal evapotranspiration (ET) information of the whole Urmia Lake Basin is to be provided by the Remote Sensing Research Center (RSRC) of Sharif University of Technology. Although quantitative "verification" is not scheduled, the quality of RSRC's ET data is to be evaluated by the Survey Team. This section summarizes the current status and future improvement plans on the RSRC's ET estimation.

3.3.1 Introduction of ET Estimation Method (METRIC)

In order to estimate aerial ET for the basin scale, RSRC applies the METRIC ET estimation model.

METRIC enables the estimation of ET for large-scale area with high resolved spatial distribution that depends on the resolution of satellite images, using satellite imagery and ground-observed climatological data. Detailed descriptions of the model are found in Allen, et al. (2007 a,b)..

The METRIC-2002 (Allen, et al., 2002) selected by RSRC, which is also called as "SEBAL Idaho Implementation 2002," is an old and prototype version of the standard METRIC model (Allen, et al., 2007 a,b), where, the METRIC is a variant of SEBAL model (Bastiaanssen, et al., 1998 a,b) and is one of the widely-accepted ET estimation models in the world.

(1) Basic Methodology of METRIC

Basic concept and algorithm of the standard METRIC is as described below. Detailed descriptions of the model are found in Allen, et al. (2007 a,b). The difference between standard and the prototype versions of the model is summarized in the later part of this section. The METRIC model estimates ET by solving surface radiation and energy balance, using satellite images, digital elevation model, and ground-measured weather data as inputs. Both shortwave (i.e., visible to near-infrared) and longwave (i.e. temperature or thermal) satellite observations are required. Landsat[1] and MODIS[2] (MODerate resolution Imaging Spectroradiometer) images are popular to be used with METRIC, because these are the primary satellite images having both shortwave and thermal information. The flow chart of ET estimation by METRIC is given in Figure 3.3.1.

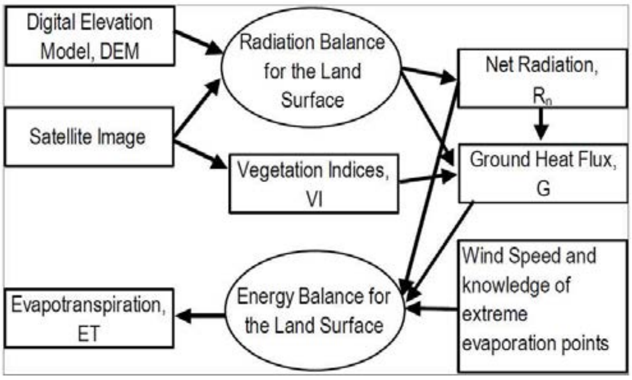


Figure 3.3.1 Schematic Diagram of the General Computational Process for Determining Evapotranspiration by the METRIC Model

First, net radiation is computed for each pixel of satellite image by solving surface radiation balance. Satellite shortwave observation provides data for solving shortwave radiation balance, while thermal observation provides data for solving longwave radiation balance. The digital elevation model provides information on elevation and topographic effects to the radiation balance. Second, latent heat flux (which is readily convertible to ET) is derived by solving the surface energy balance, where;

Latent heat flux = Net radiation – Soil heat flux – Sensible heat flux (1)

Soil heat flux is empirically estimated using the results of surface radiation balance and vegetation information. Sensible heat flux is estimated taking aerodynamic approach, by analyzing surface physical

[1] Earth observation satellite in the United States. Operation of Unit 1 started in 1972. Currently, No. 5 of launch in March 1984 and No. 7 launched in April 1999 are operated.

[2] Moderate Resolution Imaging Spectroradiometer (Radiometer in the visible and infrared range installed in Terra and Aqua which are Earth observation satellites in the United States)

(e.g., roughness), near-surface thermal, and weather conditions.

A unique feature of METRIC model is that the model incorporates strong "internal calibration" procedure, where the energy balance is calibrated at two extreme (i.e., wet and dry) locations in agriculture, according to the information given by the operator to the model. This procedure requires operators a rich knowledge of the field agricultural and ET conditions in the target area.

In METRIC, evapotranspiration flux is directly computable only for the moment of satellite image observation in clear-sky days. A term called ETrF (Reference Evapotranspiration Fraction) is employed to estimate ET for longer periods (e.g., daily, monthly, annually). ETrF is defined as the ratio of actual ET flux to reference ET flux, and computable from satellite-derived ET flux and ground-measured weather data. Once ETrF is computed, actual ET for a longer period is estimated by Equation 2, using weather data.

$$ET_{act} = ET_rF \times ET_r \quad ETact = ETrF * ETr \qquad (2)$$

Where, ETact is actual ET for a unit duration (e.g. day) for each satellite pixel. ETrF (ETr fraction) is ET related parameter determined via satellite remote sensing analysis, and ETr is "alfalfa-reference-evapotranspiration" defined by ASCE-EWRI (2005) and computed by ground-measured weather data.

(2) Points to be considered in the Application of METRIC

In general, METRIC estimation results can be regarded as reliable, compared to traditional ET estimation methods (e.g. GMS, 2015) since it enables expression of spatial distribution and detailed calculation of ground surface energy balance. However, due to limitation derived, such as limitation from topographic effect, examination of ground-measured weather data and calculation process, this method has to be applied carefully.

Primary limitations of the METRIC-2002 model are: (1) the reduced applicability to mountainous topographies; and (2) some old and inaccurate procedures in atmospheric corrections and surface emissivity computations. In the context that the standard version of METRIC model is more complicated and unapproachable because no manual has been published, in the Survey, some revisions are scheduled to the ET estimation results by RSRC, to mitigate potential degradation of the ET estimation quality caused by using the prototype model.

Also, the METRIC model (including METRIC-2002) is essentially developed for agricultural water management, and the algorithm requires the operator to have background knowledge of micrometeorology and agricultural crop water requirements, for making better decision in operation. Upon the future evaluation and revision works of the ET estimation, the Survey Team plans to support RSRC by providing advices based on these specializations.

(3) Overview of RSRC's estimated ET map

RSRC has been estimating actual ET using MODIS imagery, for the whole Urmia Lake basin, from March, 2000 to December, 2016. They apply year 2002 version of METRIC model (METRIC-2002; Allen et al., 2002) to estimate ET, with some local changes onto the model. The key specifications of the RSRC's ET maps are summarized in the following table.

Table 3.3.1 Key Specification of ET estimated by RSRC (as of November 2017)

Item	Description
Target Area	Whole Urmia Lake Basin, except the lake water surface.
Target Period	From March 2000 to December 2016
Spatial Resolution	1km (at nadir observation) or coarser, depending on the sensor angle of the selected image. Regardless of the actual spatial resolution, the ET maps are provided with 1km pixel size.
Temporal Resolution	Monthly, estimated by one-day-per-month satellite observation (RSRC has chosen best image out of several images for each month)

(4) Preliminary Findings and Evaluation of ET Estimated by RSRC (as of September 2017)

The Survey Team commenced the Survey in Tehran and the Urmia Lake basin in late August to early September 2017 for checking the status of ET estimation by RSRC. RSRC has been carefully evaluating input data (e.g., satellite data, ground-measured weather data) before use.

Initial investigation showed that the current RSRC's estimated ET data is applicable and valuable as one of the input data for basin-scale water balance, as expected. However, additional investigations and refinements are needed before use. The target due date of completion of the refinement is within 2 years. Quality evaluation is to be completed by the end of the Survey.

Through discussion with RSRC and field survey, the following were identified as issues for securing accuracy and summarized for preliminary evaluation of ET estimation result by RSRC.

The Survey Team addressed detailed recommendation to the RSRC and shared it with RSRC and ULRP in 2018. This section summarizes some primary parts of the document.

(a) Model Name

RSRC has been calling their model name as SEBAL, which is a popular ET estimation algorithm developed by Bastiaanssen, et al. (1998 a,b). Academically, the RSRC's model is closer to METRIC than SEBAL, because: (1) the model determines not sensible heat but latent heat at the cold pixel, by using ETr as a reference; and (2) the model applies not Evaporative Fraction (EF) but ETr Fraction (ETrF) for temporal extrapolation. Since RSRC uses neither the original SEBAL nor the original METRIC, calling their model as METRIC-2002 is suggested, in case the RSRC model is constructed by referring to Allen, et al. (2002), since using an appropriate name of the model would academically reduce the chance of confusion.

(b) Input data

There are two types of primary input data adopted by RSRC for the ET estimation: (1) satellite imagery (e.g. visible, near-infrared and thermal infrared observations by MODIS satellite); and (2) ground-measured meteorological data.

Both of satellite-analysis (i.e. input data, procedures, operators' decision, etc.) and the ground-measured weather data (i.e. quality of weather data and the spatial applicability of the data) will be subject to examination to evaluate the ET estimation quality. The list of evaluation items are summarized in the next section.

(c) Satellite Observation Data

As MODIS satellite images, RSRC has been using MODIS radiance and surface temperature images, after carefully evaluating input satellite data before use. They appropriately select the input satellite data, such as, using daily surface temperature product when the instantaneous surface temperature data has a problem on geo-location.

(d) Ground-measured Weather Data

In the Urmia Lake Basin, 17 climatological stations have been installed under the jurisdiction of IRIMO (Iranian Meteorological Organization). Through the investigation, it was found that RSRC applies ground-measured weather data only at Urmia Weather Station (WMO Station ID = 40712, Lat = 37o39', Lon=45o03', Elevation=1,328m) (see Figure 3.3.2). It should be checked whether weather data at one station can be a representative for the Urmia Lake Basin with approximately 52,000km^2.

This station is an appropriately designed and managed weather station, measuring a complete set of standard weather parameters including air temperature, humidity, precipitation, wind speed, solar radiation, sunshine hour, pan evaporation, and soil temperatures. Its solar radiation data (measured by pyranometer) is not accessible by RSRC, and RSRC has been using sunshine duration instead of solar radiation, which is a realistic decision.

RSRC is primarily using Urmia station data, obtained not directly by the Iranian government but via an Internet site operated by a Spanish meteorologist (Ogimet.com). The RSRC's daily weather dataset has a problem in time stamp, and it potentially has about 24-hour maximum unexpected shift of time. The

Survey Team has agreed to keep using their daily weather dataset without correcting the time-shift problem, because the impact of the problem to hydrological computation will be limited in monthly or longer timescale.

Figure 3.3.2 Urmia Weather Station

(e) Selection of Cold/Hot Pixels

METRIC incorporates a strong internal calibration procedure. The calibration is conducted using two pixels of extreme conditions, which are called "cold pixel" and "hot pixel". Typically, the operator selects two extreme pixels for each image, and assign evapotranspiration for these two pixels. In general, this process is not simple for the METRIC operators. The operators use METRIC because they want to get ET. However, to successfully get ET numbers from the model, the operator must first input ET values to the model, at least, for two specific pixels.

Agricultural pixels are recommended to be selected as the cold and the hot pixels, because ET estimation from agricultural fields have been well investigated in the long history of agricultural meteorology and irrigation science. Thus, knowledge of agricultural meteorology and irrigation science are required for successful calibration of the model.

In the context that RSRC is specialized in satellite image analysis, through interview with RSRC, RSRC has insufficient knowledge and experience in meteorological and agricultural matters. These insufficiencies may degrade the accuracy of estimated ET, especially via inappropriate selection of Cold/Hot Pixels and/or the assignment of the calibration numbers for the pixels. The current selections of the pixels by RSRC have some questions. For the cold pixel, RSRC tends to select a pixel from apple-horticultural areas, and assigns ET values according to the METRIC-2002 manual. However, the manual assumes not MODIS but Landsat (i.e., much finer resolution than MODIS) application, to large-sized agricultural fields. In such condition, operators can expect finding many thermal pixels having thermal information purely from healthy, recently irrigated agricultural fields. Applying this strategy directly to the MODIS application to Urmia (i.e., coarse resolution and small field-size), may cause overestimation of ET in wet areas.

With regard to hot pixel selection, RSRC selects a hotter pixel, and sets ET from hot pixel as zero. This may cause underestimation of ET in dry areas. METRIC standard version (Allen, et al., 2007) recommends accounting some ET from hot pixel, when the operator expects some residual soil moistures from rainfall. Soil moisture analysis has not been conducted by the current RSRC application. The investigation on cold/hot pixel selection and the assignment of values will continue in future, although the results might not be easily modified or revised, even if necessary.

(f) Limitations of the RSRC's ET Maps

The specification summarized in Section 3.3.1 shows the limitations of RSRC's ET map.

(i) Spatial Resolution

One-km (1km) to 2km spatial resolution means that ET is supplied as coarse as spatial average of 2km by 2km (even though the pixel size of the map is 1km), while sizes of the typical irrigated fields in the region are less than 100m by 100m. Two-km (2km) by 2km spatial resolution means that one pixel contains 200 different 50m by 100m fields (or bare soil grounds, houses, rangelands, roads, etc.).

Moreover, the spatial resolution of the ET map is not consistent month by month, because the resolution of input satellite image depends on the sensor angle, which changes day by day.

Grid size of MIKE-SHE is 2km, therefore, with approximately 52,000km^2 of basin area, the RSRC's ET map with 1km grid has sufficient resolution for basin-scale water balance application.

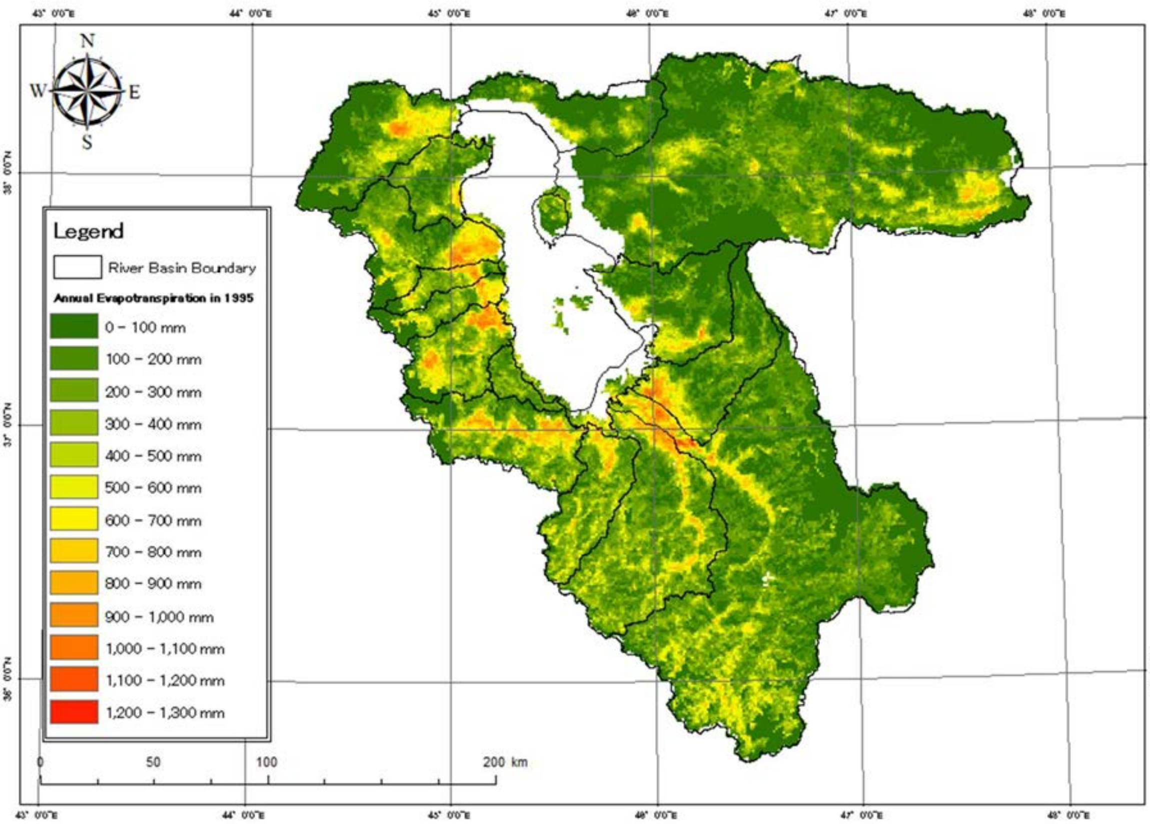


Figure 3.3.3 Resolution of ET Map (1km Grid Size)

(ii) Temporal Resolution

Figure 3.3.4 shows an example result of monthly ET of the basin, derived by RSRC. Temporal resolution of the ET map is monthly interval, but the monthly ETrF estimation is from a satellite thermal observation of one clear-sky day in the month. Generally, monthly ETrF estimated by one-day-image of the month is not accurate, because the ETrF values can vary day by day. If the adopted satellite image is taken just after a rainfall event, the ETrF of the month will reflect wet condition. On the other hand, if the image is taken just before a rainfall event, the derived ETrF will reflect dry surface condition. The uncertainty is minimum for months having constant soil wetness condition throughout the month. According to the interview to RSRC, they select a clear-sky image from near the center of the month (e.g. 15th day of the month) if possible. Also, they check rainfall event, and try selecting dates that did not have previous rainfall for a long time. Selectively choosing "dryer" days of the month and assume it as the monthly average might cause underestimation. This is a subject to be evaluated in future.

With this monthly application might be acceptable, it is important to mention that there is a significant uncertainty on estimation quality. Especially, one-image-per-month might not describe the temporal change in agriculture and irrigation status. Misuse of the ET map in future, for agricultural purpose, may cause problems.

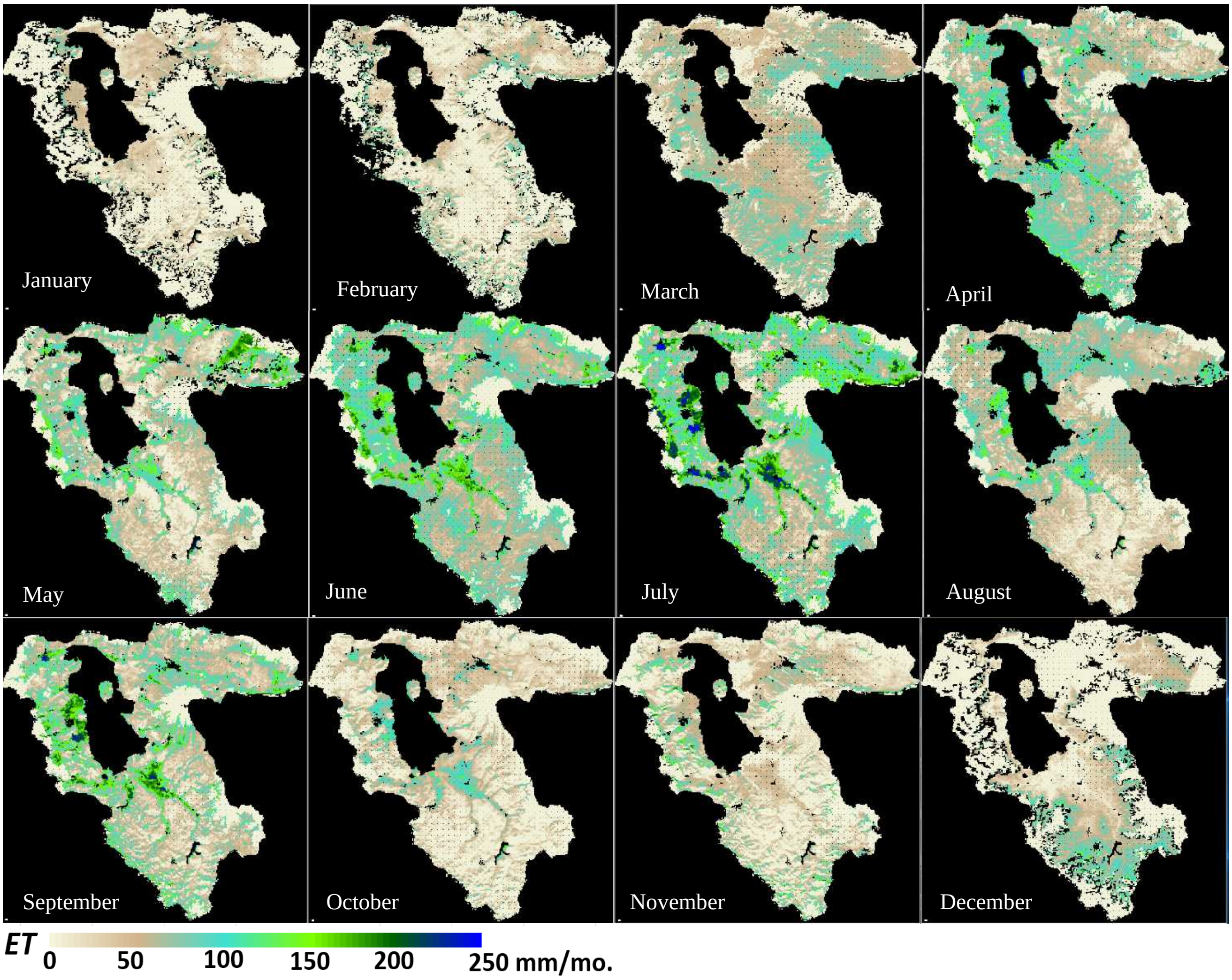


Figure 3.3.4 Example of Result by RSRC's Monthly ET in 2016: From Top to Left, January to December, 2016.

3.3.2 Accuracy Assessment of Satellite-Based Evapotranspiration Data

RSRC prepares evapotranspiration using METRIC method as input data of the hydrologica cycle model. the Survey Team has supported the estimation method for the purpose of improving the accuracy of the estimation of the evapotranspiration using METRIC method.

The evaluation results for the evapotranspiration produced by RSRC (RSRC-ET) is shown as below. The evaluation of accuracy was conducted by the Survey Team. As a conclusion, the RSRC-ET map is in a good quality as the final product for this project.

(1) Difficulty in Accuracy Assessment

Evaluating the ET estimation accuracy is not simple. Validation works, including ET measurements, are typically not scheduled, or scheduled but failed to complete, in non-academic, operational-type projects. It is because, the validation takes large amount of time, money and human resources (e.g. 2-years for measurements plus 3-years for post-analysis of data) to get limited result (e.g. obtain validation data for two or three pixels only, and overall accuracy of the whole ET map is kept remaining as uncertain), that does not fit to the scope of operational-type projects such as this project (i.e. ET estimation or academic achievement is not the primary purpose of the project but a small part of the 3-year project).

Application of SEBAL by Water Research Institute of Ministry of Energy might tell the difficulty in validation. According to them, they immediately concluded that validation of MODIS-based ET is impossible. For Landsat, they compared measured and Landsat-estimated ET only for one irrigated (alfalfa) field. Make a comparison at one alfalfa field needs lots of time and efforts, but it can provide only example accuracy at one specific field.

(2) Precipitation Amount and the Spatial Distribution

ET and precipitation are strongly related. Therefore, understanding the precipitation amount and the distribution in the Urmia Lake Basin is important to discuss about ET and the accuracy. Here, the Survey Team's understanding of precipitation in Urmia basin is explained, though ULRP (who knows about Urmia well) and RSRC (who works for Urmia basin longer, with using hydrological data) know better than the Survey Team.

(a) Ground Observation Rainfall

Figure 3.3.6 shows precipitation observed at Urmia IRIMO Station for 10 years. Average annual precipitation in recent 10 years is about 300 mm. July to September are the dry season, having almost no precipitation. In previous experiences, wheat cultivation is difficult without irrigation, in the areas having 300 mm annual precipitation. It seems no rain-fed wheat field is available around Urmia IRIMO Station, and rain-fed wheat fields spread only at hill-side which expect precipitation more than 300 mm in long-term average.

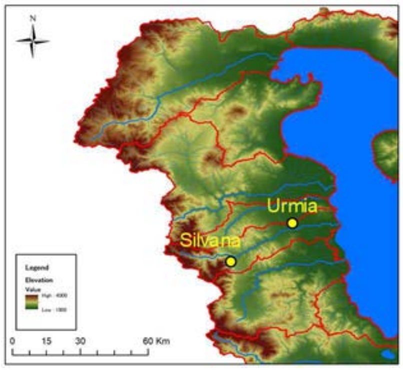


Figure 3.3.5 Location Map of Urmia IRIMO Stations

As a characteristic of precipitation measured at Urmia IRIMO Station, storm-type heavy rain is rare. The 300 mm annual precipitation is primarily by integration of small rains, occurred during October and June. In case of 2016, the largest "one day" precipitation occurred in January and was about 35 mm/day. Most precipitation was less than 10 mm/day. The soil water balance computation based on Urmia precipitation record indicates that 70% of precipitation is evaporated and only 30% is deep percolated to be groundwater recharge or drained to river. This characteristic of rainfall pattern is adequate for rain-fed agriculture (because fields can effectively use rain water) but not adequate for runoff or groundwater recharge (because most of the rainwater is evaporated).

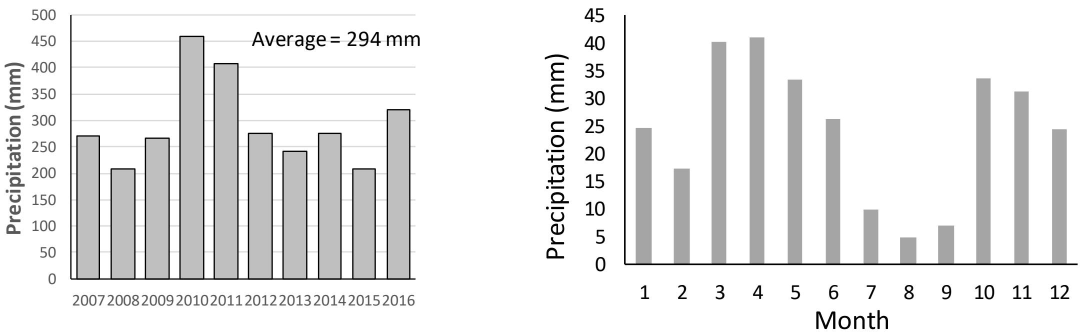


Figure 3.3.6 Precipitation observed at Urmia IRIMO Station (Left: Annual precipitation from 2007 to 2016; Right: Average monthly precipitation from 2007 to 2016)

Silvana, which is located southwest of Urmia City and the elevation is 300 m higher than Urmia (Figure 3.3.5), has annual precipitation of around 520 mm (Figure 3.3.7). According to the interview with an agricultural station in Zibeh area, precipitation is about 450 mm on average (600 mm in wet year). The field survey for the western part of the Urmia Lake Basin indicate that the 300 mm (observed at Urmia

IRIMO Station) is minimum precipitation received in the western part of the basin, and more precipitation is received at hill-side.

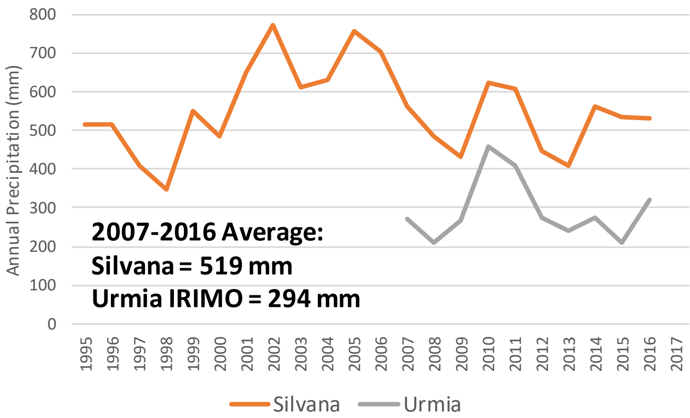


Figure 3.3.7 Precipitation Data obtained by Silvana Agricultural Office, compared to Urmia IRIMO Station.

(b) Information from Satellite Image

Landsat image implies that precipitation is even larger in mountain region near the western border. Figure 3.3.8 shows Landsat image for June 23, 2016. Red-color indicates vegetation. While vegetation becomes weak in late June in hill-side (reference value of precipitation might be 500 mm), heavy vegetation is confirmed near the border until late June, probably supported by precipitation even larger than 500 mm/year. Vegetation in mountain becomes scarce in July, and disappears in August.

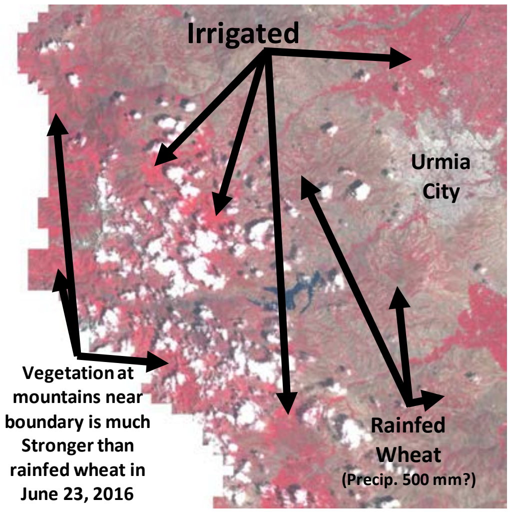


Figure 3.3.8 Landsat False Color Image for June 23, 2016, in West Part of Urmia City.

Figure 3.3.9 shows annual average precipitation from 2001-2007 by TRMM (Tropical Rainfall Measuring Mission). At least the values in Figure 3.3.9 seem reasonable if compared to the precipitation data (Urmia IRIMO Station and Silvana), information and impression obtained during the field survey.

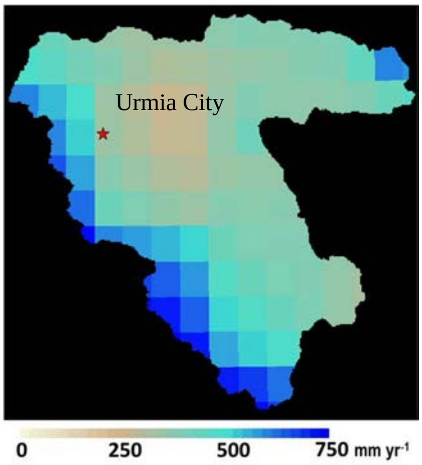


Figure 3.3.9 Annual Precipitation during 2001- 2007 by Urmia Part of Global TRMM.

(c) Reference Evapotranspiration (ETr)

Finally, Figure 3.3.10 show ETr computed using Urmia IRIMO Station data. Based on the analysis by RSRC for spatial difference of ETr, it was assumed that this ETr is applicable for entire basin. Figure 3.3.10 indicates that 1,662 mm/year is sort of maximum limit of ET from the basin (which is difficult to occur in actual condition), in terms of the weather and energy availability in Urmia Basin.

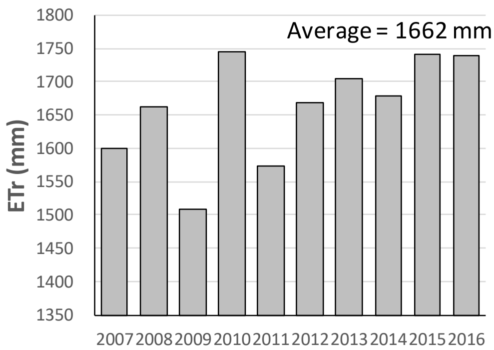


Figure 3.3.10 ETr computed using Urmia IRIMO Station Data (not by RSRC Data).

3.3.3 Strategy for Accuracy Assessment of Evapotranspiration Data

Evaluating the ET estimation accuracy has been one of the most challenging problems in satellite-based ET estimation researches (Li et al., 2009). Because of factors such as advection, the ground measured ET itself can have more than 20% (measured by eddy covariance) or up to 29% (measured by Bowen-Ratio Energy Balance) error. Moreover, ground-measured ET typically does not represent ET from the area of satellite image pixel. Therefore, large uncertainties in validation is typically inevitable even if ground-measured ET data is available.

Validation of ET maps is typically not scheduled, or scheduled but failed to complete, in non-academic, operational-type projects. It is because, the validation takes large amount of time, money and human resources (e.g. 2-years for measurements plus 3-years for post-analysis of data) to get limited result (e.g. obtain validation data for two or three pixels only, and overall accuracy of the whole ET map is kept remaining as uncertain), that does not fit to the scope of operational-type projects.

According to Water Research Institute of Ministry of Energy in Iran, who are routinely using SEBAL model to estimate ET, immediately concluded that validation of MODIS-based ET map is impossible, because no 1km-by-1km homogeneous surface is found to conduct ground-measurements.

Even though the accuracy assessment is technically challenging, providing accuracy information is necessary upon adopting the derived ET maps as a primary input of hydrological cycle model. Following strategy was taken in this project to provide accuracy information of the ET maps.

Determining the goal of the accuracy is important. In the initial stage of the project, the Survey Team proposed to achieve the error range within plus-minus 100 mm in annual timescale, in 1 standard deviation, for the entire basin (Figure 3.3.11). This is a reasonable goal when considering the timescale of the project. ET is an input of hydrological cycle model; thus, the ET maps must be passed to the hydrological cycle modeler 1 year before the end of the project. The proposed goal is to be achieved within 2 years.

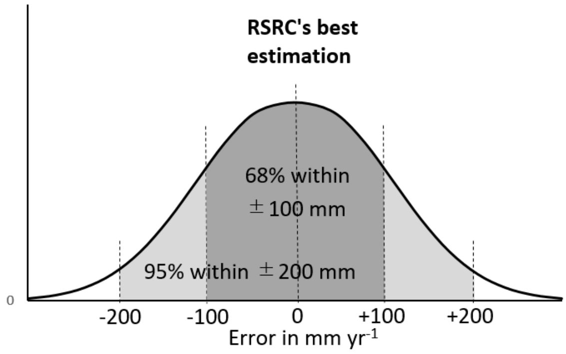


Figure 3.3.11 Accuracy Target of RSRC-ET Map, Proposed by the Survey Team

The proposed accuracy target, ±100 mm, is equivalent to the following relative accuracy.

- For irrigated agriculture, especially apple fields: Apple is the dominant irrigated crop for the region, and the largest concern in terms of sustainable water resources management in the agricultural sector in the region. Evaporation requirement of the irrigated apple fields computed by FAO's manual (Allen et al., 1998) with the local weather data, is around 1250 mm yr^{-1} (Tasumi, 2019). Example amount of water application to apple field, as interviewed to the farmers and the local agricultural officers in Balanej, western part of Urmia Lake Basin, is 1200 mm yr^{-1} of irrigation plus 450 mm yr^{-1} of precipitation equal 1650 mm yr^{-1}. The proposed error range of 100 mm yr^{-1} is equivalent to be 8% of ET requirement, or 6% of field water supply. This relative error range is regarded as high and acceptable, compared with other alternative method. The error range is much smaller than typical error range of ground-based ET measurements, which is 20%-30% (Li et al., 2009).
- For non-irrigated lands including rangelands, relative accuracy for 100 mm yr^{-1} is much larger than irrigated agriculture, because of the small ET. Assuming that annual average precipitation of the land surface of the Basin is in order of 400-500 mm yr^{-1} (analyzed by Global TRMM dataset), relative error of 100 mm yr^{-1} is equivalent to 20%-25%. ET is typically smaller than the precipitation in non-irrigated surfaces in semi-arid regions where the ground water table is deep enough. Thus, the relative error of ET can exceed 30%, which is still in competitive to the typical error range by direct ground-measurements of ET, but greater. However, the impact of error in ET can be further reduced for non-irrigated surfaces, by regulating the ET amount via water balance computation in the hydrological cycle model.

- Table 3.3.2 summarizes the characteristics of ET estimation accuracy by satellite energy balance and by water balance. The proposed strategy of application of ET map to the hydrological cycle model is, (1) rely on the accurate ET map information for irrigated agriculture, and (2) use the ET map information for initial input data of hydrological cycle model for non-irrigated surfaces, but revise the input ET values in the model by water balance, when the ET map information diverged from the water balance computation. By taking this approach, RSRC's ET maps and the hydrological cycle model make up for each other, to obtain the most reliable output by the hydrological cycle model. ULRP has welcomed this proposal made by the Survey Team.

Table 3.3.2 ET Estimation From Satellite Energy Balance and From Water Balance.

	Characteristics	ET from satellite energy balance	ET as a residual of water balance
Irrigated Agriculture	Irrigation is the dominant source of water supply	Strong: Expected error range is in order of 10% or less.	Weak: No reliable information of irrigation water application. Error range is unpredictable.
Non-irrigated surfaces	Precipitation is the dominant source of water supply	Weak: Expected error range is in order of 30% or more.	Accuracy depends on the accuracies of input data and assumptions (precipitation, river discharge, ground water flow, storage change of soil water). Error range is the integration of the erros in input data, and difficult to quantify.

The Survey Team is not willing to propose any number for target accuracy in monthly basis. The accuracy of RSRC ET in monthly timescale is evaluated using the benchmark map, and is reported in the later part of this report. Discussion can be made based on the assessment result.

The quantitative accuracy assessments of the ET map were conducted by following procedures:

(1) The Survey Team calculates monthly ET map using METRIC with Landsat, as the benchmark for the RSRC's ET map, in higher spatial and temporal resolutions. This benchmark map is provided only for one year for a limited region.

(2) The accuracy of the Survey Team's ET map (the benchmark ET map) is confirmed by comparing independent estimations of actual ET, which is estimated following FAO's manual, at some sample points for comparison.

(3) RSRC evaluates the accuracy of their MODIS-based ET, by comparing with the benchmark ET map prepared by the Survey Team assuming the benchmark ET map is more accurate

(4) In addition to the accuracy assessment by (1)-(3), ET map is compared with other ET dataset, to confirm and to discuss relative accuracy of the ET map.

(5) To add the objectivity and the reliability to the in-house accuracy assessments, the methods and the results of assessments are submitted to international scientific journals to be evaluated by anonymous professions in the world.

3.3.4 Results of Accuracy Assessment of Evapotranspiration Data

This section summarizes the key results of accuracy assessment for ET map. Refer Tasumi et al. (2019) for the details of accuracy information of benchmark ET, and Javadian et al. (2019) for the result of cross comparison.

(1) Development of Benchmark ET Map and the Accuracy

ET map by MODIS has spatial resolution of 1km or coarser. The coarse resolution prevents the accuracy evaluation. An effective approach to overcome this issue is, (1) to make a fine-resolution ET map and evaluate the accuracy of fine-resolution ET map with ground measurements or estimations, and (2) to compare coarse-resolution ET map with fine-resolution ET map.

The Survey Team has prepared a fine-resolution ET map for year 2016, for western part of the Basin, using Landsat imagery having spatial resolution of 100 m and temporal resolution of 2 weeks. This ET map is called benchmark ET map. The benchmark map is provided in monthly basis. Figure 3.3.12 shows the monthly benchmark ET map and the integrated annual ET map. The detailed information for input data, model settings and the estimation methods are found in Tasumi et al. (2019).

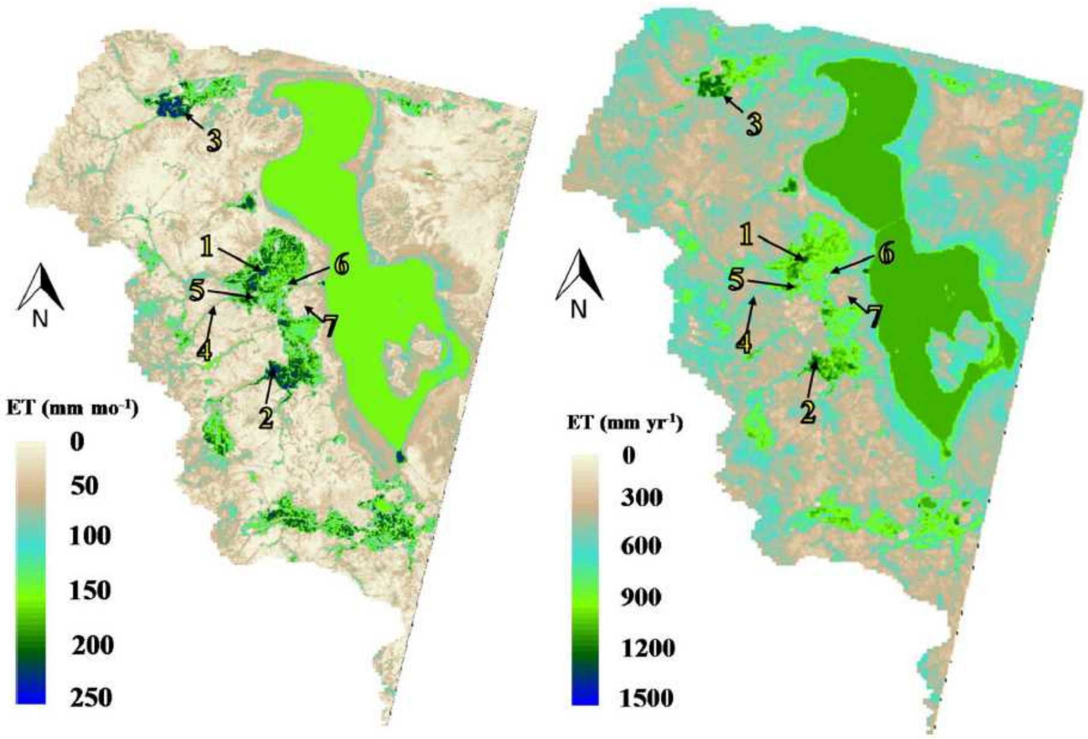


Figure 3.3.12 Monthly (example for August) and Annual Benchmark ET in 2016

The accuracy for benchmark ET maps is evaluated using FAO's standard ET (Allen et al., 1998) for apple, grape and bare soil sample fields, where the procedure for accuracy assessment is followed by Stancalie et al. (2010). Because data for irrigation water application were lacking, and size of the sample fields must be at least four times larger than one satellite pixel (100 m), ET estimation by FAO's method was possible only for three apple fields, one grape field, and three bare soil surfaces nearby Urmia weather station. Satellite-derived ET were compared with FAO's estimated ET for these sample fields, at the three different durations; the date of satellite image acquisition date, monthly, and annual. This assessment was made for three years from 2014 to 2016.

Figure 3.3.13 shows accuracy assessment for the date of satellite image acquisition. Mean bias errors (MBE) were 0.16 to 0.36 mm d^{-1}, mean absolute errors (MAE) were 0.57 to 0.72 mm d^{-1}, and the root mean squared error (RMSE) were 0.68 to 0.73 mm d^{-1}.

Monthly comparison (Figure 3.3.14) showed the MBE of 0.1 to 8.3 mm mo^{-1}, MAE of 9.0 to 16.0 mm mo^{-1}, and the RMSE of 10.8 to 20.5 mm mo^{-1}. Annual comparison (Figure 3.3.15) showed the MBE of 2 to 99 mm yr^{-1}. The ET estimation accuracy of the benchmark map is equivalent to higher than similar applications by He et al. (2017) for almond in California and Jin et al. (2018) for pistachio. The benchmark map had regarded to be in more accurate than typical field observations of ET, and well within the target accuracy suggested in this project.

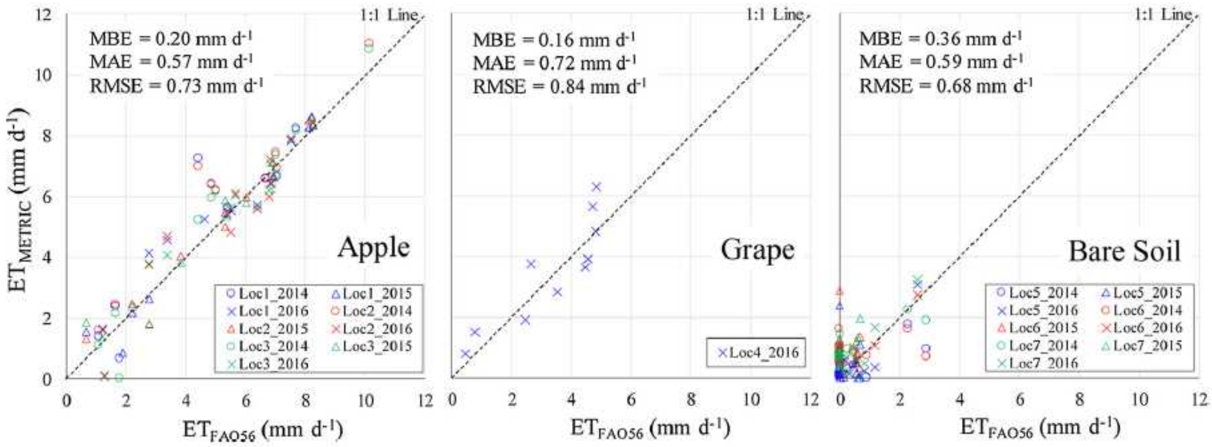


Figure 3.3.13 Comparison between FAO-56 and METRIC-estimated ET for the satellite image acquisition dates

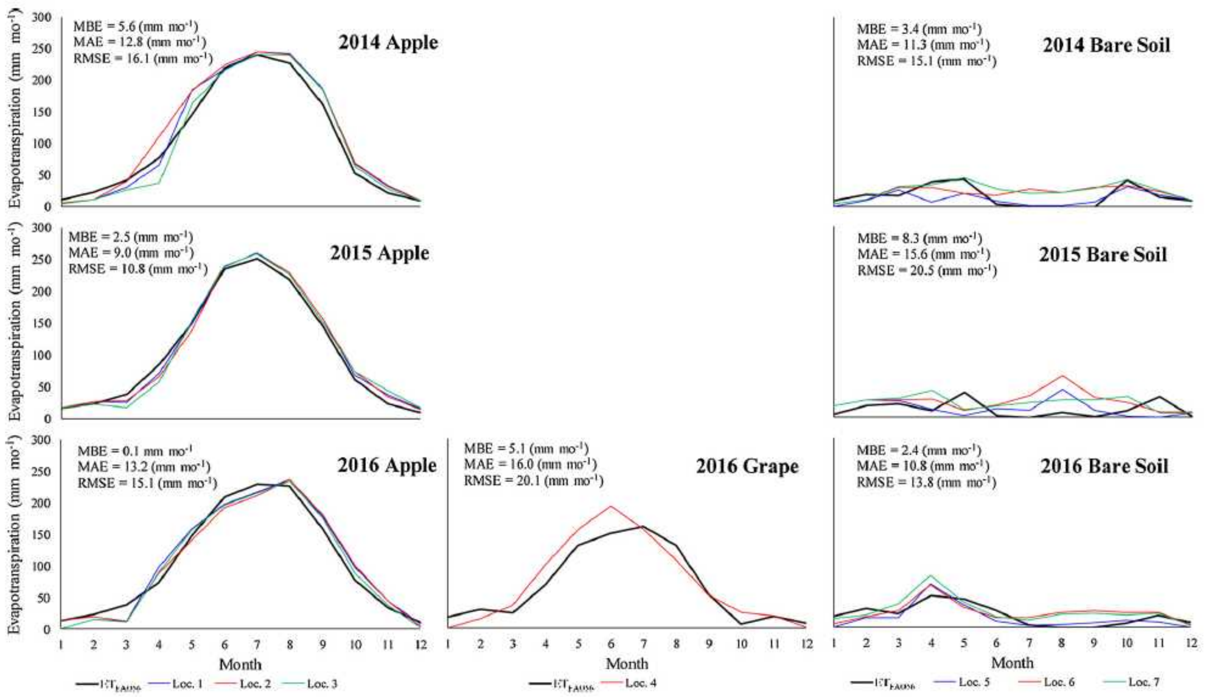


Figure 3.3.14 Estimated monthly ET with reference values for apples, grapes, and bare soil – no data was available for comparison for grape cultivated areas in 2014 and 2015.

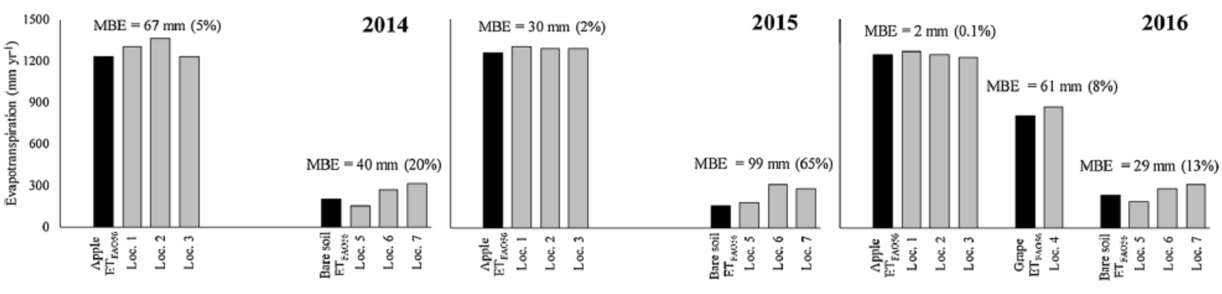


Figure 3.3.15 Estimated annual ET with reference values for apples, grapes, and bare soil

(2) Evaluation of the Accuracy of RSRC's ET Map using the Benchmark ET map

Total (or average) amount of ET for the area shown in Figure 3.3.16 was agreed between RSRC and the benchmark images. RSRC estimated 475 mm yr^{-1} in average of the whole area, which is 18 mm yr^{-1} larger than the benchmark image. This is a very good agreement. Figure 3.3.17 shows comparison of estimated average annual ET by land-use type. Although some differences are available, the difference was within ±100 mm. Although clear evidence of accuracy cannot be provided by this approach, Figure 3.3.16 and Figure 3.3.17 indicates that RSRC's ET is close to, or already achieved, the target accuracy shown in Figure 3.3.15.

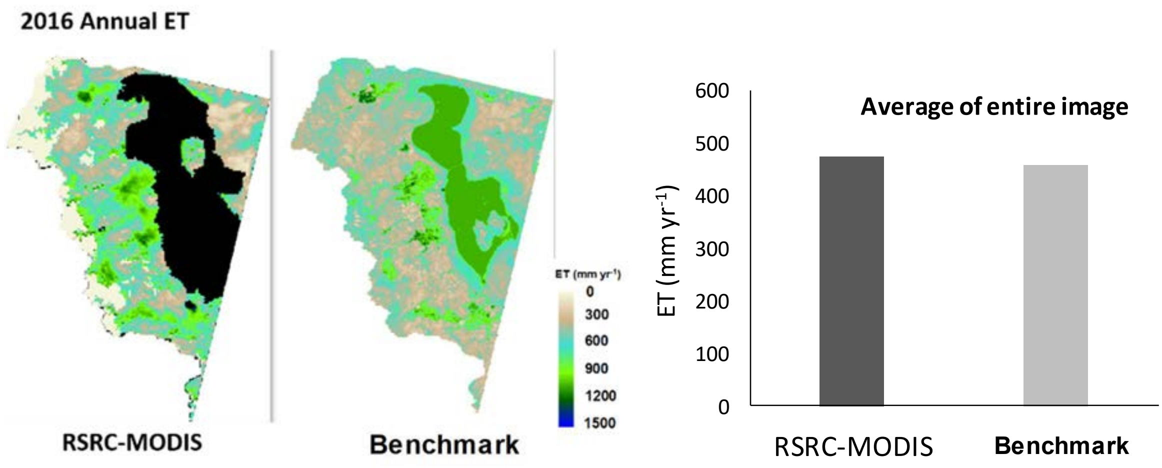


Figure 3.3.16 RC-MODIS ET and Benchmark Landsat ET (left), and Difference of Annual Average ET for Entire Image Area except Water Surface Area (right).

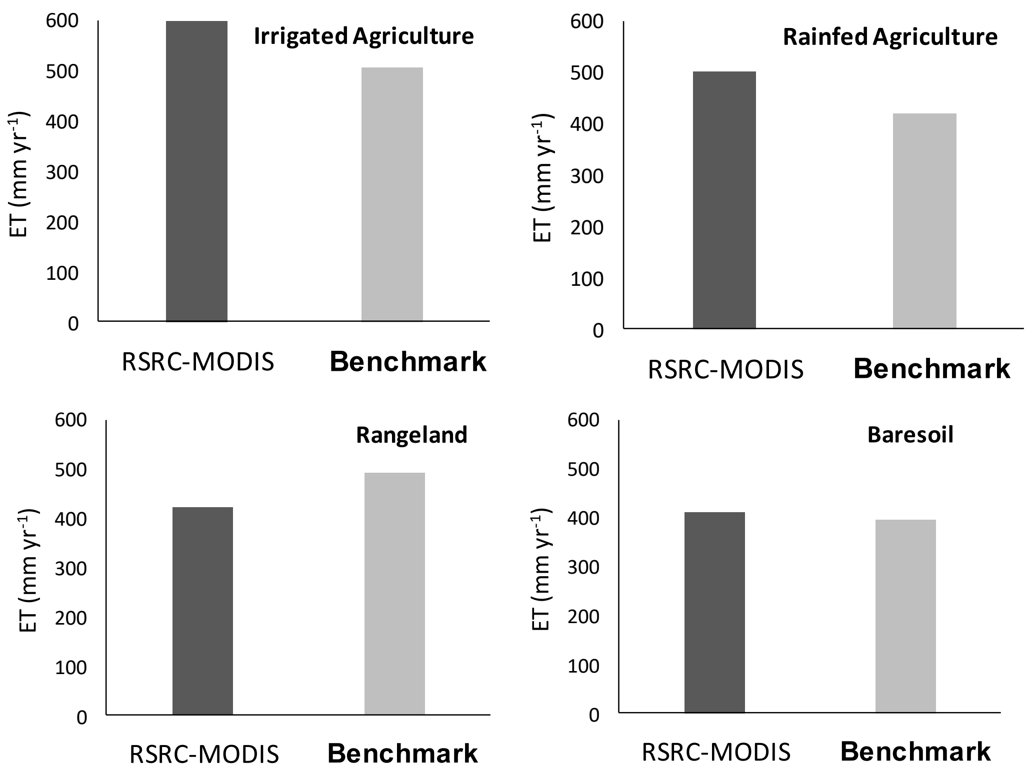


Figure 3.3.17 Comparison by Land Use

(3) Monthly ET Estimation

Figure 3.3.18 shows the comparison of monthly ET between RSRC's MODIS and the benchmark. RSRC overestimates some months, and underestimates some other months. RSRC-ET agrees with the benchmark data in some months such as February, August and November. Standard deviation of error in monthly ET was 20 mm mo^{-1}. "20 mm mo^{-1}" is regarded as a reference value in accuracy of RSRC's monthly ET. The benchmark image itself has about 20 mm mo^{-1} uncertainties, and careful evaluation implies that some part of the difference between RSRC's and the benchmark in Figure 3.3.18 is not the error of RSRC-ET but the error in the benchmark. Overall, it can be said that the accuracy of RSRC-ET would be somewhat better than the difference shown in Figure 3.3.18.

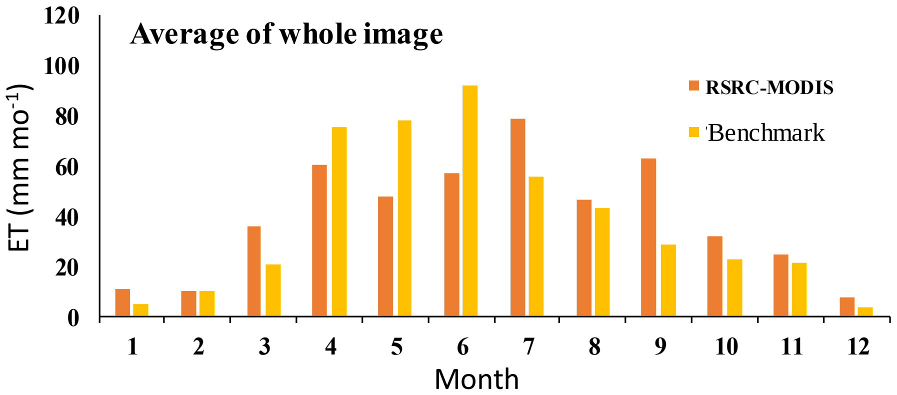


Figure 3.3.18 Comparison of monthly ET

(4) Cross comparison of RSRC's ET Map with FAO's WaPOR ET map

Javadian et al. (2019) compared RSRC's ET map with FAO's WaPOR ET map (The FAO Water Productivity Open-access portal (WaPOR)), and the accuracy of RSRC ET map is discussed through the attempts to compare the lysimeter measurements and water balance approach. As the resolutions of evaluated ET maps are too coarse to critical comparison and evaluation, several assumptions are involved in the evaluation, which are described in Javadian et al. (2019). They concluded that the RSRC- ET was more likely accurate in irrigation agriculture, and WaPOR ET was more likely accurate in no-irrigated agriculture and rangelands.

A part of the lower accuracy of RSRC-ET in rangeland might have been improved in the final version of the RSRC-ET applied in the Survey, because the RSRC further adjusted the factor for topographic impact after the data used in the paper. Rangelands tend to be in higher elevation areas and ET estimation changes by changing the factor for topographic impact.

3.3.5 Limitations

While the RSRC ET maps, used as a primary input of the hydrological cycle model in this project, is a unique and the most reliable ET information available in the region, there are some cautions and limitations on using the ET map. RSRC has been estimating actual ET using MODIS (MODerate resolution Imaging Spectroradiometer) imagery, for the whole Urmia Lake basin, from March 2000 to December 2016. The spatial and the temporal resolutions of the data processing (i.e. 1km, one day per month) was the limitation from work load. Processing a large region for 201 sequential months allowed only one image per month, unless developing an automated method for decision making procedure by operator.

The spatial resolution is sufficient for understanding general spatial distribution of the ET in the basin, but not for detailed description of ET distribution of complex terrains and land uses. The temporal resolution (using one-day per month satellite observation) is fairly sufficient to estimate annual ET, but accurate expression of ET in monthly timescale is not expected. For example, if the satellite image for the month is acquired just after a rainfall or irrigation, the model assumes as if the region was in “wet” condition for the entire month, and vice versa. In agricultural condition, field management and crop growth can dramatically change in one-month period. This limitation caused by the temporal resolution of satellite data processing is somewhat calmed in the final result of ET, because ET, with METRIC, is estimated not only by satellite image but also with daily weather data.

Another limitation of the RSRC ET map is estimation failure of ET in some high-mountainous regions spread near the border of the basin, caused by a difficulty of incorporating topographic factor to the model for some specific regions. Users should refer the accuracy information of the ET map, which is described in the later part of the section. Apparently, RSRC ET map fails to estimate ET in some high elevated mountainous areas, typically near the border of the basin (see Figure 3.3.19), and report as zero ET. The “underestimation” (or failure) is compensated by the overestimation of ET in rangelands spread in moderately high elevation of the Basin. In total, average ET values for rangeland is in a reasonable range, but these areas lose the spatial estimation of ET. Future works are needed to further improve the calibration of topographic factors in the model. In the calibration of MIKE-SHE, the ET amount in the mountainous area have been adjusted by using the correction factor in order to correctly estimate the water balance in the entire basin in case of appearance of unsolvable problems in the relationship (balance) of variables (i.e., ET, rainfall, underground water level, and surface discharge) in each basin.

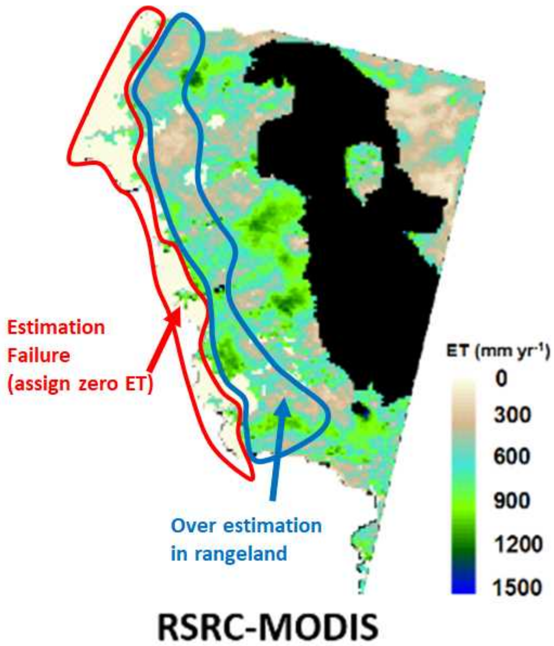


Figure 3.3.19 RSRC-ET for western part of the basin

There is a large uncertainty in METRIC-ET estimation in mountain region, especially with MODIS resolution. The benchmark ET map is also not evaluated in mountains due to lack of reliable ground measurements or estimation. Surface slope and the complicated terrain structure violates some assumptions in METRIC. Although it is difficult to propose the acceptable error in mountainous region, the Survey Team tentatively propose ±100 mm as the error range in annual timescale. There is caution on how to understand ET map in mountainous region. As shown in Figure 3.3.20, evaporative surface area is larger than pixel size in mountainous region. For example, 1km by 1km pixel in mountain area having representative slope within the pixel is 30°, has surface area not 1 km^2 but 1.33 km^2 (i.e. 33% larger surface area). If the ET from the pixel is reported as 100 mm in RSRC-ET map, it means that the actual surface evaporates 100/1.33 = 75 mm from the unit area of sloping surface. Both of RSRC-METRIC and MIKE-SHE account water based on “horizontal-projected surface area,” which is acceptable. However, it is always necessary to remind that actual surface area in mountain (for evaporation, percolation, etc.) is larger than horizontal-projected surface area.

Figure 3.3.20 Difference between Pixel-Based Computation and Actual Distance (or Area) of Evaporation Surface

Urban areas such as Urmia and Tabriz cities are small areas compared with the whole basin. Therefore, it can be regarded as a negligible level in the modeling in the Survey; however, it is recommended to improve the accuracy as the next step. The Survey Team's prediction of ET from Urmia City is about the order of 200 mm yr^{-1} based on the experiences in researches and studies, while RSRC estimates ET from Urmia City as more than 700 mm yr^{-1}. The reason of the significant over-estimation might be due to shadows of the tall buildings and/or the low emissivity of some buildings. The correction method has been suggested by Tasumi (2019), which can be incorporated in future.

While these limitations and problems remain in the ET map, there has been no alternative ET information available for the region having accuracy information. However, because the quality of ET map has been reached acceptable level for the Survey, the total performance of the hydrological cycle model has been improved by understanding the characteristics and the accuracy of the ET map, and use the information with a smart manner.

3.3.6 Utilization of ET map

(1) Application to MIKE-SHE and Issues to be Improved in Future

The elaborate revisions by RSRC with assistance from the Survey Team resulted in sufficient quality of RSRC-ET for the given condition of actual ET in the whole river basin. The ET has been highly improving from the beginning of the Survey, and it is absolutely imperative for the construction of hydrological cycle model to elucidate the unknown intake water volume to irrigation areas.

The main purpose of the calculation of the ET by METRIC is to clarify the unknown water intake amount in the irrigation acquired area. Since the accuracy of RSRC-ET in irrigation area has been secured, RSRC-ET is effectively used for the hydrological cycle model (the MIKE-SHE model). As a result of discussions with ULRP so far, it is decided to recognize the second version of RSRC-ET improved in the 2nd year of the Survey as the final version for the MIKE-SHE model. Therefore, the second version is used as input data for the hydrological cycle model of the Survey.

(2) Introducing Utilization of the ET Map to Related Policy Makers and Researchers

Informing, explaining and discussing the ET map to the several types of stakeholders are important on better utilizing the ET map in the hydrological cycle model and the project. On August 6, 2018, the Survey Team served as the lecturer of one-day evapotranspiration estimation workshop organized by ULRP (Figure 3.3.21), to explain the scientific background and the operational applications of RSRC's ET map to policy makers and researchers. ULRP obtained several positive feedbacks and interests by participants.

Figure 3.3.21 Evapotranspiration workshop organized by ULRP

<u>Reference for "Section 3.3 Application of METRIC Method to Obtain Evapotranspiration Data":</u>

Allen, R.G., Tasumi, M., Trezza, R. 2007a. Satellite based energy balance for mapping evapotranspiration with internalized calibration (METRIC) - Model. Journal of Irrigation and Drainage Engineering 133:380-394.

Allen, R.G., Tasumi, M., Morse, A., Trezza, R., Kramber, W. Lorite, I. 2007b. Satellite based energy balance for mapping evapotranspiration with internalized calibration (METRIC) - Applications. Journal of Irrigation and Drainage Engineering 133:395-406

Allen, R.G., Trezzam R., Kilic, A., Tasumi, M., Li, H. 2013. Sensitivity of Landsat-scale energy balance to aerodynamic variability in mountains and complex terrain. Journal of the American Water Resources Association, 49:3:592-604.

ASCE-EWRI, 2005. The ASCE standardized reference evapotranspiration equation. Environmental and Water Resources Institute of the ASCE Standardization of Reference Evapotranspiration Task Committee. American Society of Civil Engineers, Reston, Virginia, 216 pages.

Bastiaanssen, W.G.M., Menenti, M., Feddes, R.A., Holtslag, A.A.M. 1998a. A remote sensing surface energy balance algorithm for land (SEBAL): 1. Formulation. J. Hydrol., 212–213:198–212.

Bastiaanssen, W.G.M., Pelgrum, H., Wang, J., Ma, Y., Moreno, J., Roerink, G.J., van der Wal, T. 1998b. A remote sensing surface energy balance algorithm for land (SEBAL): 2. Validation. J. Hydrol., 212–213:213–229.

Eimanifar, A., Mohebbi, F., 2007. Urmia Lake (Northwest Iran): a brief review. Saline Syst. 3, 5. https://doi.org/10.1186/1746-1448-3-5.

Farzin, S., Ifaei, P., Farzin, N., Hassanzadeh, Y., Aalami, M.T., 2012. An investigation on changes and prediction of Urmia Lake water surface evaporation by Chaos theory. Int. J. Environ. Res. 6, 815–824.

Ghaheri, M., Baghal-Vayjooee, M.H., Naziri, J., 1999. Lake Urmia, Iran: a summary review. Int. J. Salt Lake Res. 8, 19–22.

GMS. 2015. Tracking Agricultural Water Use from Space. An online video material by NASA Goddard Media Studios (https://svs.gsfc.nasa.gov/12026) visited Oct.5, 2017.

Hassanzadeh, E., Zarghami, M., Hassanzadeh, Y., 2012. Determining the main factors in declining the Urmia Lake Level by using system dynamics modeling. Water Resour Manage 26, 129–145.

He, R., Jin, Y., Kandelous, M.M., Zaccaria, D., Sanden, B.L., Snyder, R.L., Jiang, J., Hopmans, J.W., 2017. Evapotranspiration Estimate over an almond orchard using Landsat satellite observations. Remote Sens. 9 (436). https://doi.org/10.3390/

Jägermeyr, J., Gerten, D., Heinke, J., Schaphoff, S., Kummu, M., Lucht, W., 2015. Water savings potentials of irrigation systems: global simulation of processes and linkages. Hydrol. Earth Syst. Sci. 19, 3073–3091.

Jalili, S., Kirchner, I., Livingstone, D.M., Morid, S., 2012. The influence of large-scale atmospheric circulation weather types on variations in the water level of Lake Urmia, Iran. Int. J. Climatol. 32, 1990–1996.

Jensen, M.E., Allen, R.G., Howell, T.A., Martin

Javadian, M., Behrangi, A., Gholizadeh, M., Tajrishy, M., 2019. METRIC and WaPOR estimates of evapotranspiration over the Lake Urmia Basin: comparative analysis and composite assessment. Water 2019 (11) 1647 (19 pages).

JICA, CTII, CTIE. 2016. Data Collection Survey on Hydrological Cycle of Lake Urmia Basin in the Islamic Republic of Iran. Final Report. February 2016.

Jin, Y., He, R., Marino, G., Whiting, M., Kent, E., Sanden, B.L., Culumber, M., Ferguson, L., Little, C., Grattan, S., Pau U, K.T., Lagos, L.O., Snyder, R.L., Zaccaria, D., 2018. Spatially variable evapotranspiration over salt affected pistachio orchards analyzed with satellite remote sensing estimates. Agric. For. Meteorol. 262, 178–191.

Li, Z.-L., Tang, R., Wan, Z., Bi, Y., Zhou, C., Tang, B., Yan, G., Zhang, X., 2009. A review of current methodologies for regional evapotranspiration estimation from remotely sensed data. Sensors 9, 3801–3853.

Losgedaragh, S.Z., Rahimzadegan, M., 2018. Evaluation of SEBS, SEBAL, and METRIC models in estimation of the evaporation from the freshwater lakes (Case study: amirkabir dam, Iran). J. Hydrol. 561, 523–531.

Stancalie, G., Marica, A., Toulios, L., 2010. Using earth observation data and CROPWAT model to estimate the actual crop evapotranspiration. Phys. Chem. Earth 35, 25–30.

Tasumi, M. 2019. Estimating evapotranspiration using METRIC model and Landsat data for better understandings of regional hydrology in the western Urmia Lake Basin. Agricultural Water Management 226 (2019) 105805 (11 pages).

Trezza, R., Allen, R.G., Tasumi, M. 2013. Estimation of Actual Evapotranspiration along the Middle Rio Grande of New Mexico Using MODIS and Landsat Imagery with the METRIC Model. Remote Sensing. 5:5397-5423.

Wilson, K., Goldstein, A., Falge, E., Aubinet, M., Baldocchi, D., Berbigier, P., Bernhofer, C., Ceulemans, R., Dolman, H., Field, C., Grelle, A., Ibrom, A., Law, B.E., Kowalski, A., Meyers, T., Moncrieff, J., Monson, R., Oechel, W., Tenhunen, J., Valentini, R., Verma, S. 2002. Energy balance closure at FLUXNET sites. Agricultural and Forest Meteorology. 113:223-243.

CHAPTER 4 BASIC INFORMATION FOR MODELLING URMIA LAKE BASIN

4.1 Outline of Urmia Lake

4.1.1 Outline of Urmia Lake Basin

The Urmia Lake Basin is located in the North-West part of the Islamic Republic of Iran, It is 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, as shown in Figure 4.1.1. The general information on the Lake is as summarized in Table 4.1.1.

As shown in the figure, Urmia Lake 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%, 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 Tabriz, 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. (Refer to Table 4.1.1.)

As mentioned below, in June 1995 the water level of 1,278.41m, area of 5,722km^2 and storage of 36,757MCM have been recorded. However, as of November 2014, the water level, area and storage of Urmia Lake 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.

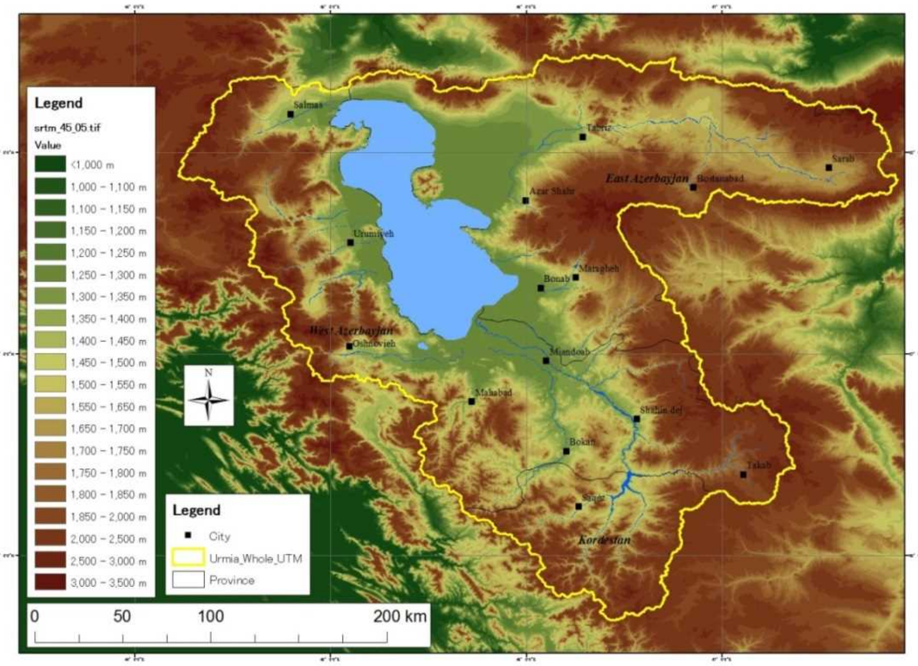


Figure 4.1.1 Area Location Map of Urmia Lake Basin

Table 4.1.1 General Information on Urmia Lake

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 IWRM Co.
*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)

4.1.2 Lake Water Level, Area and Volume

Figure 4.1.2 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, as obtained from the bathymetry survey result provided by IWRM Co.. Figure 4.1.3 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.

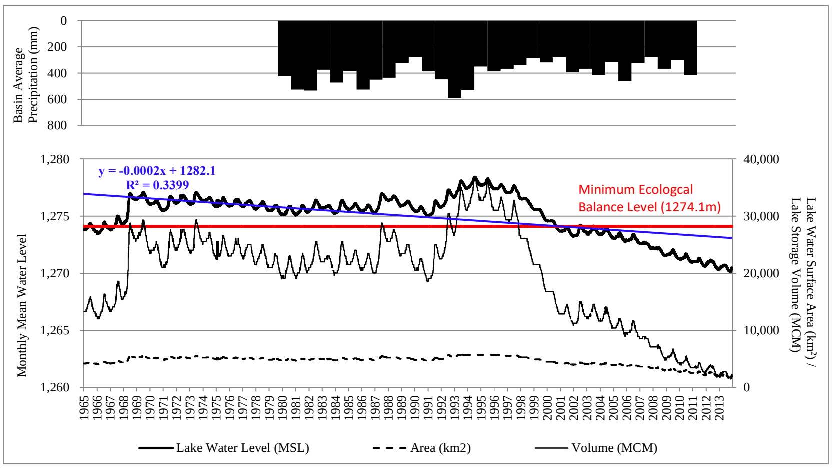


Figure 4.1.2 Historical Fluctuation of Water Level, Area and Water Volume of Urmia Lake

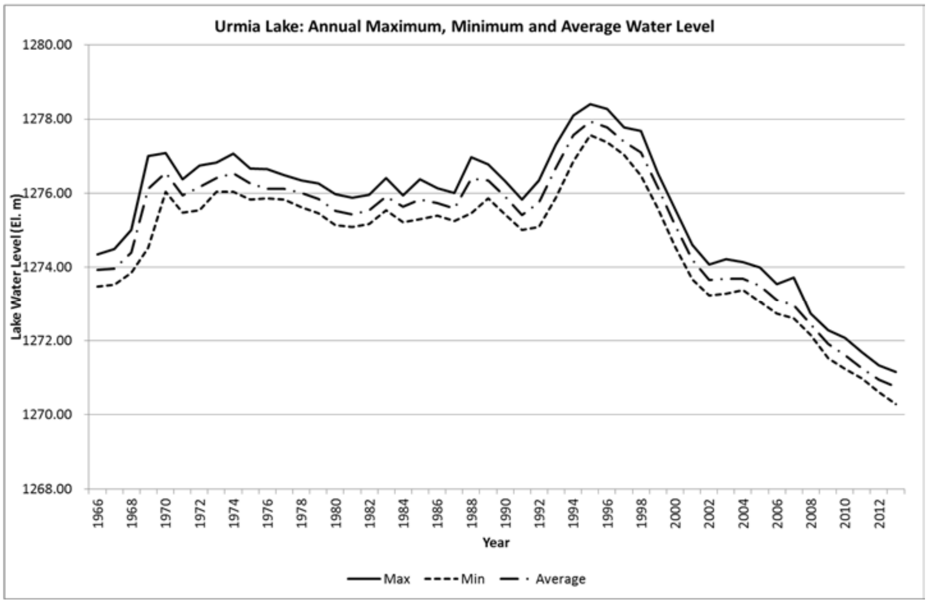


Figure 4.1.3 Historical Changes of Annual Maximum, Minimum and Average Water Level of Urmia Lake

4.2 General Climate Condition of Urmia Lake Basin

4.2.1 Average and Variation Trend of Precipitation, Air Temperature and Evaporation

In order to grasp the typical climatological characteristics of the Urmia Lake Basin, monthly precipitation, monthly mean air temperature, and monthly pan evaporation in Urmia and Tabriz are shown in Figure 4.2.1 and Table 4.2.1, while their variation trend are illustrated in Figure 4.2.2.

Differences of temperature in Urmia and Tabriz are 30 to 40˚C, ranging from -8 to 27˚C and -10 to 31˚C, respectively. Annual evaporation fluctuates, within the range of 1,158 to 1,525mm (average: 1,362mm) in Urmia and 1,271 to 2,244mm (average: 1,965mm) in Tabriz. Annual precipitation also ranges between 90 to 630mm (average: 274mm) and 89 o 324mm (average: 274mm). No noticeable change in climate condition has been recognized in both places up to the present.

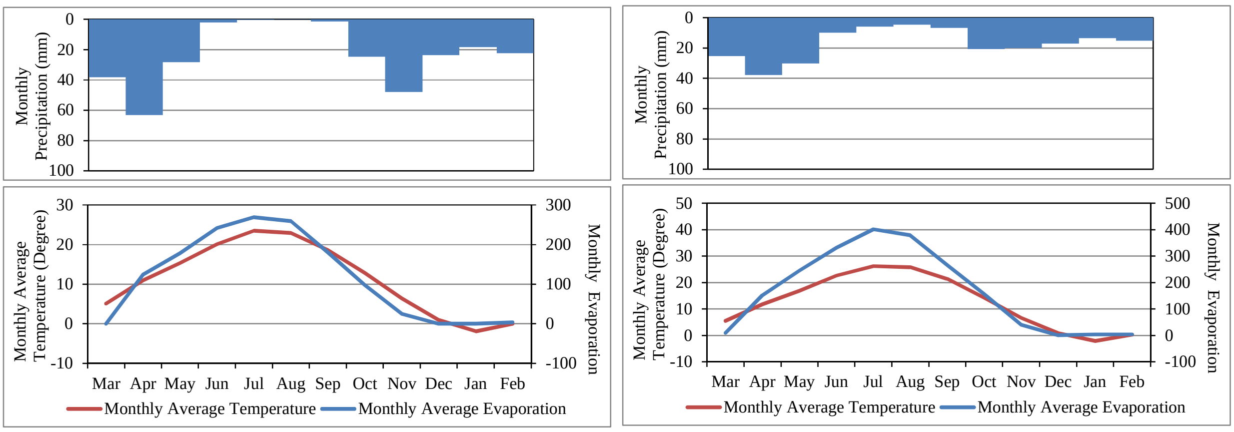


Figure 4.2.1 Monthly Average Precipitation, Air Temperature and Evaporation in Urmia (Left) and Tabriz (Right)

Table 4.2.1 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

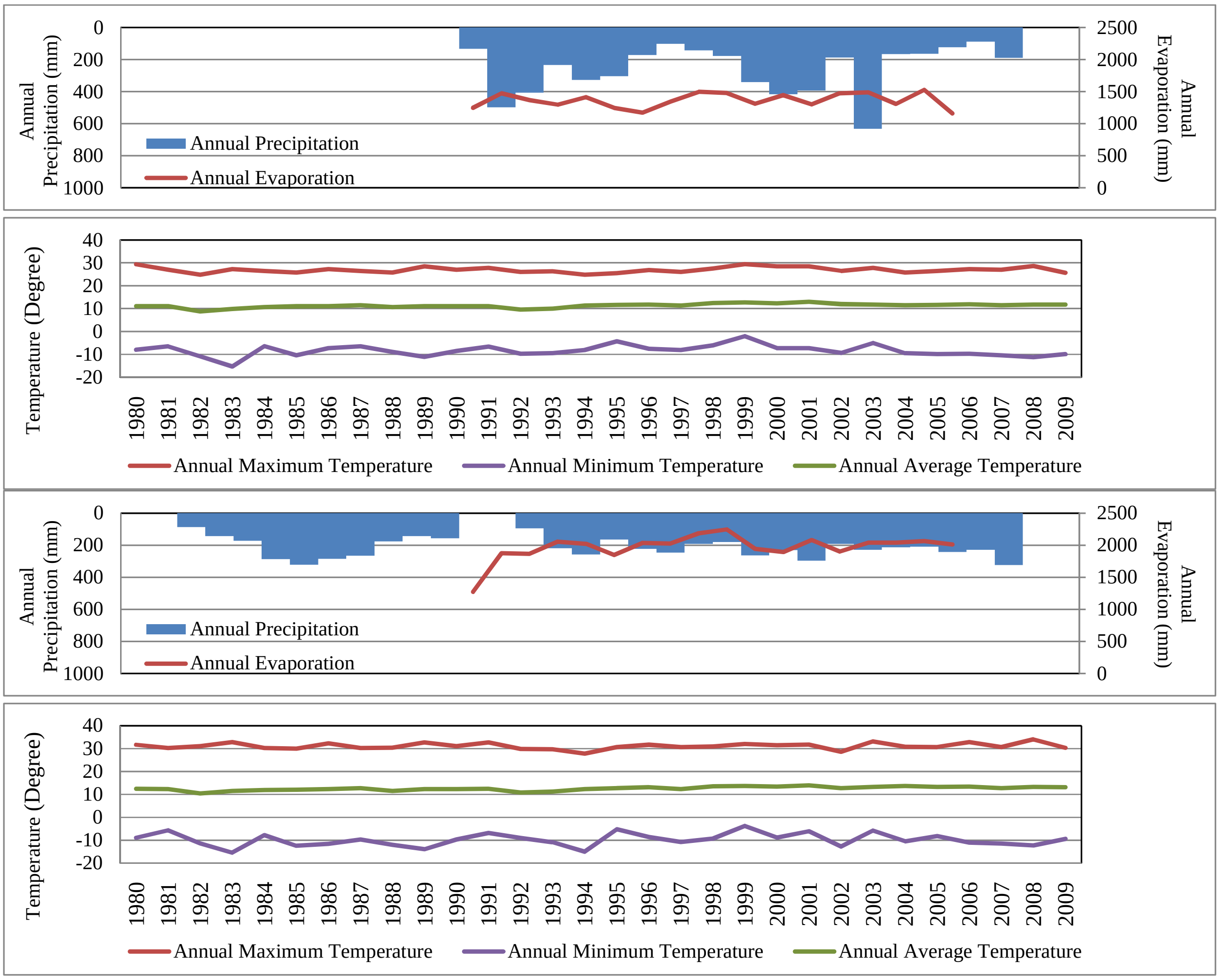
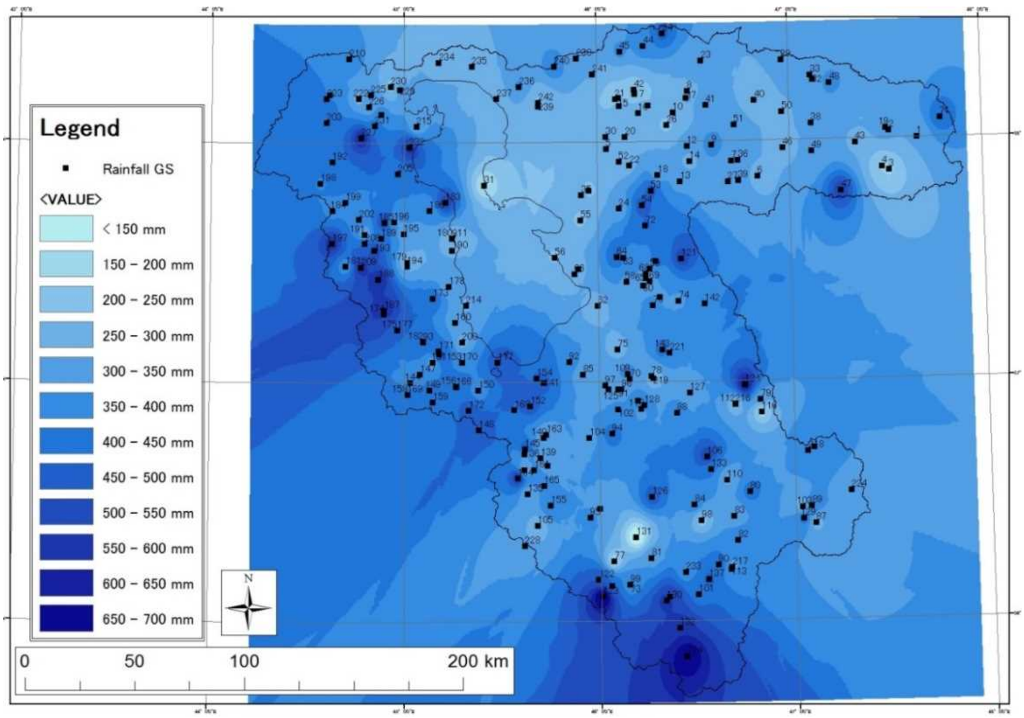


Figure 4.2.2 Variation Trend of Annual Maximum/Minimum/Average Temperature, Precipitation and Pan Evaporation in Urmia (up) and Tabriz (bottom)

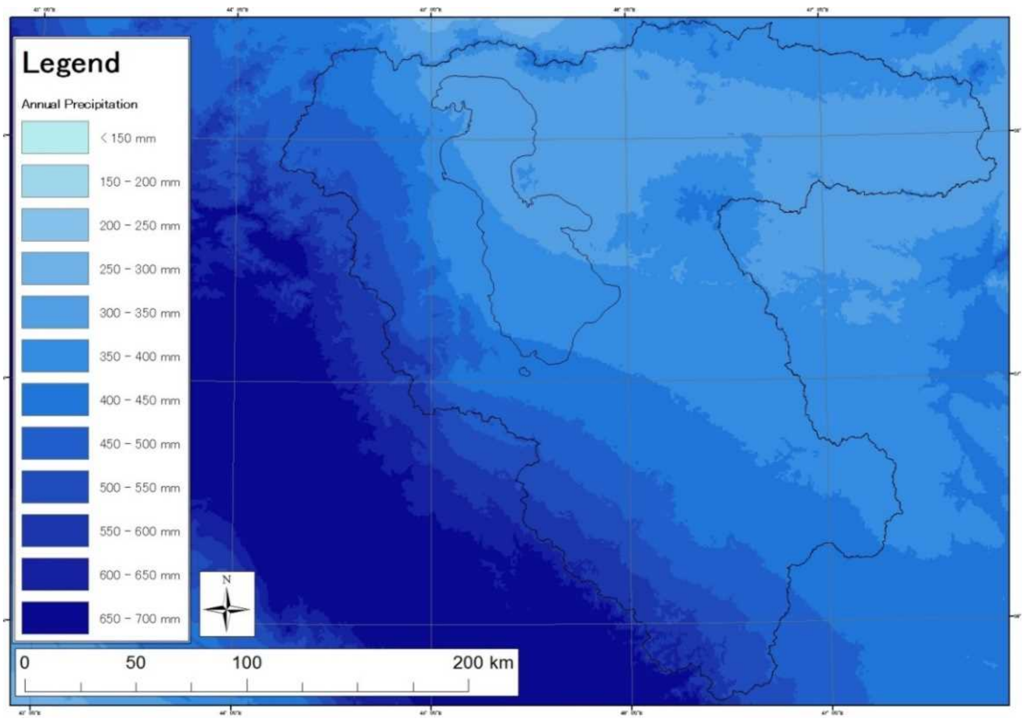
4.2.2 Spatial Characteristics of Precipitation and Relationship between Annual Precipitation and Elevation

To evaluate the spatial characteristics of annual precipitation in the Urmia Lake Basin, a contour map of annual precipitation was prepared by means of daily precipitation as shown in Figure 4.2.3, calculated values at all rainfall stations. The IDW (Inverse Distance Weighted) method was applied for spatial interpolation. In the Urmia Lake Basin where spatial variation of 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 West Azerbaijan Province than in East Azerbaijan Province. Besides, the spatial distribution issued in WOLDCLIM (http://www.worldclim.org/) shows a similar precipitation trend (see Figure 4.2.4), which is a set of global climate layers (climate grids) with a spatial resolution of about one (1) square kilometer.



*Source: prepared by the Survey Team using IRIMO data

Figure 4.2.3 Contour Map of Annual Precipitation



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

Figure 4.2.4 Distribution of Annual Precipitation by WORLDCLIM

4.2.3 Basin Mean Rainfall

The basin mean rainfall in the verification target period from 1999 to 2014 was calculated by the Thiessen method on daily basis according to the existence situation of rainfall data. A sample diagram of Thiessen division (Jan.1. 2004) is shown in Figure 4.2.5.

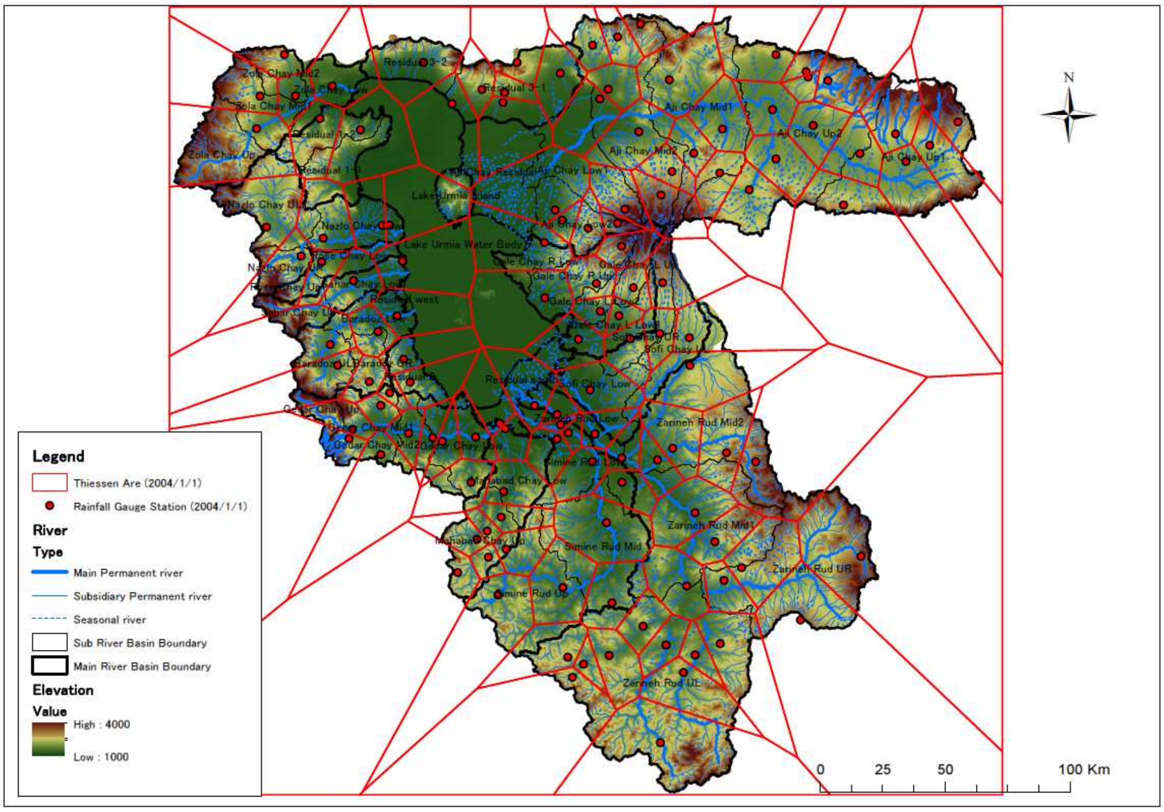


Figure 4.2.5 Reference of Thiessen Area

1999

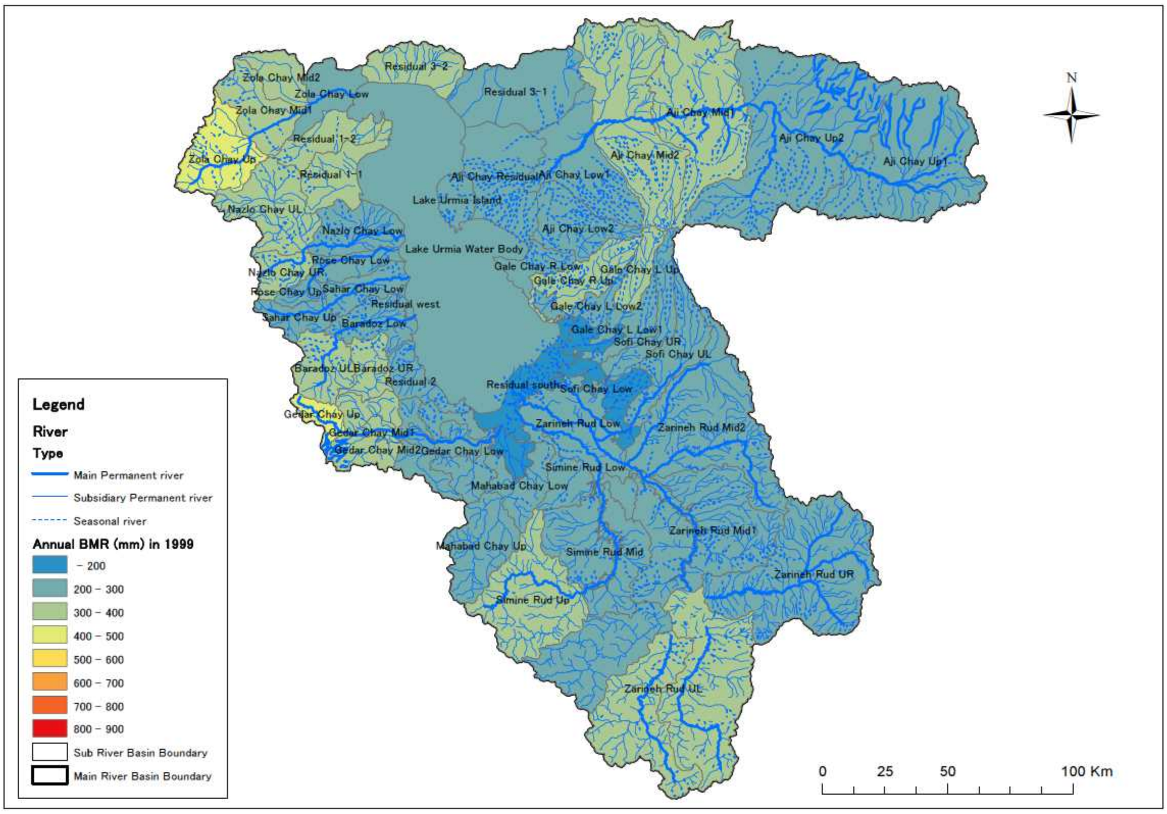
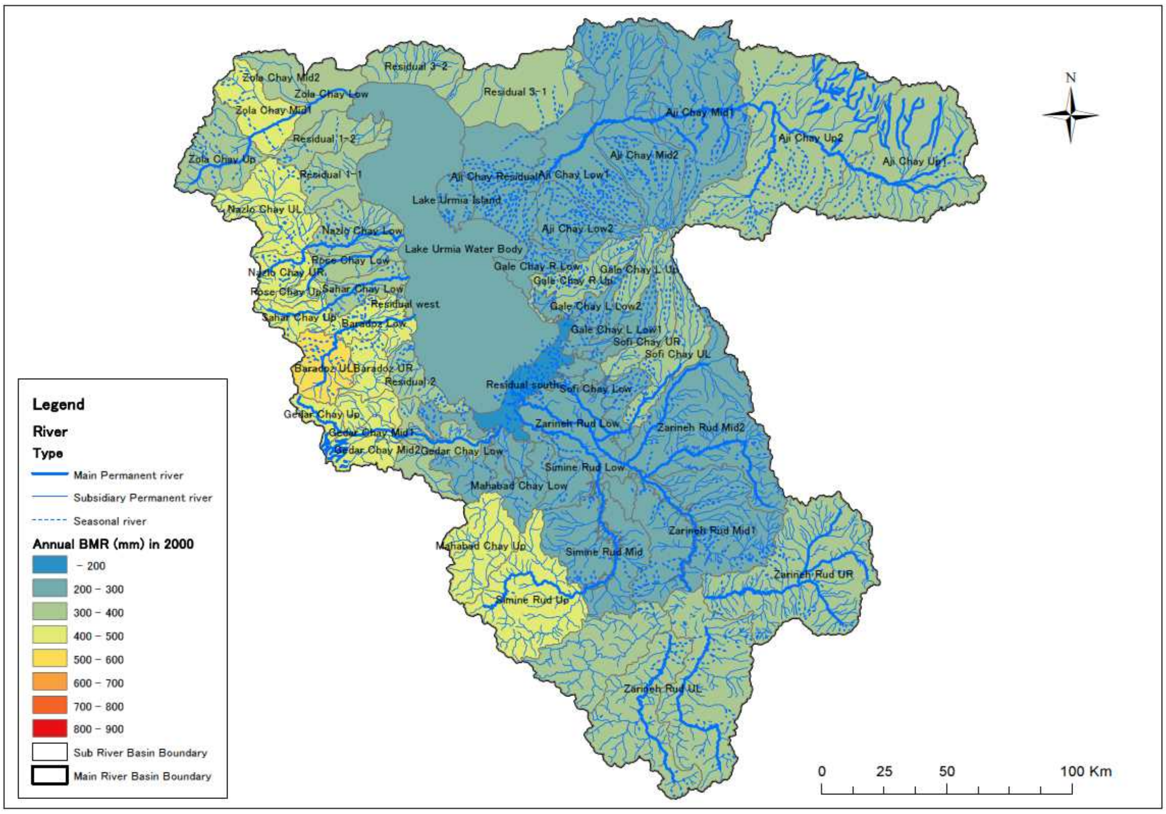


Figure 4.2.6 Annual Basin Mean Rainfall (1/8)

2000



2001

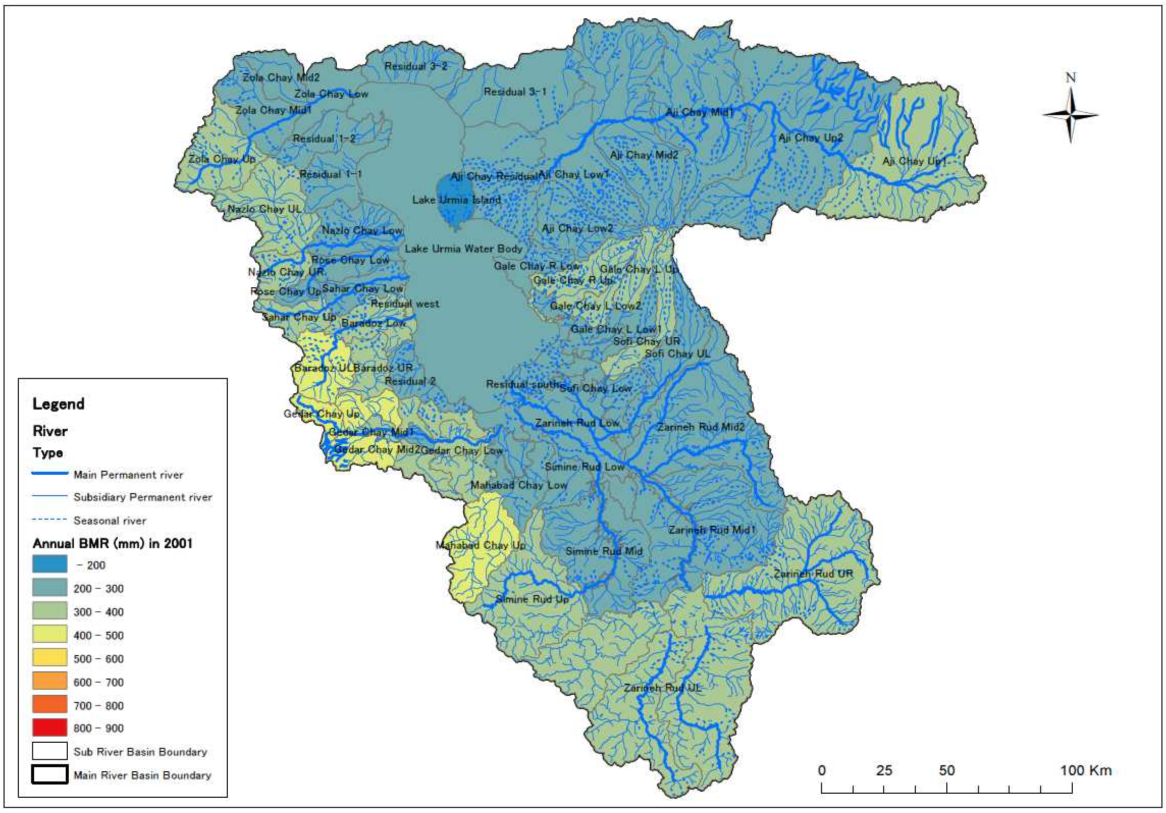
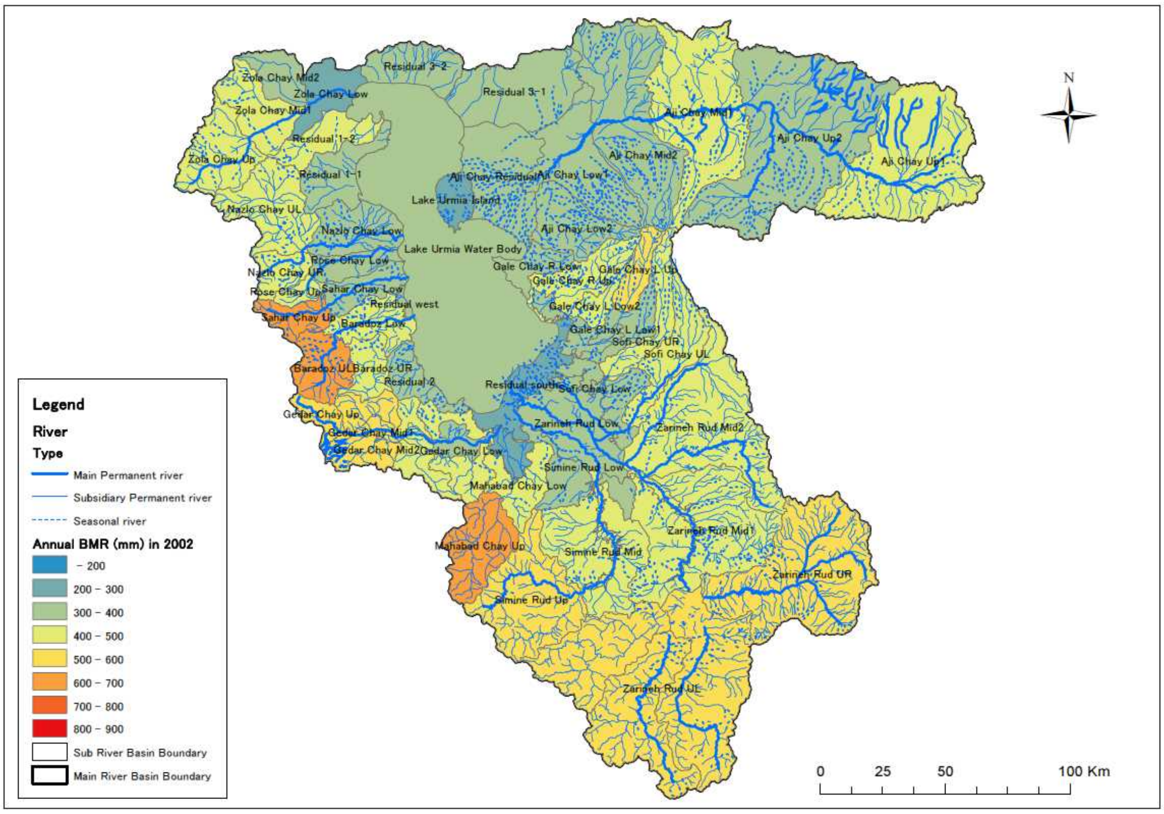


Figure 4.2.6 Annual Basin Mean Rainfall (2/8)

2002



2003

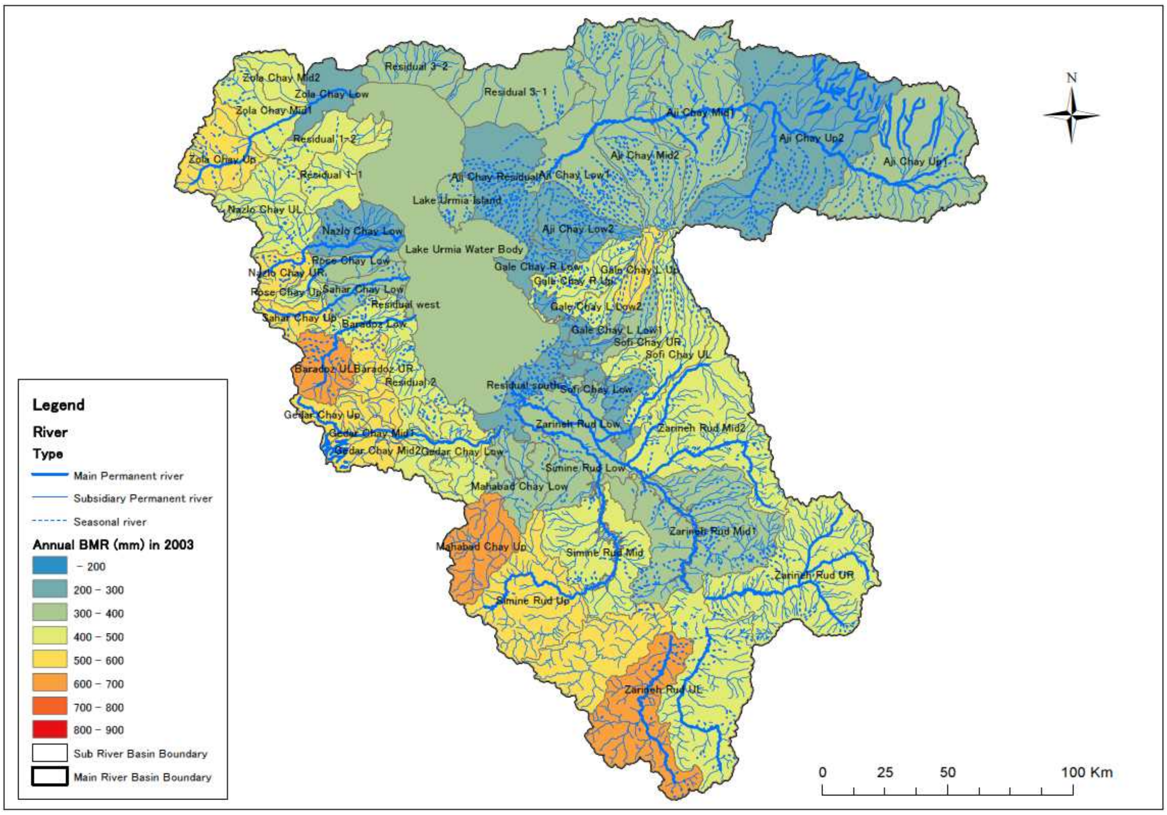
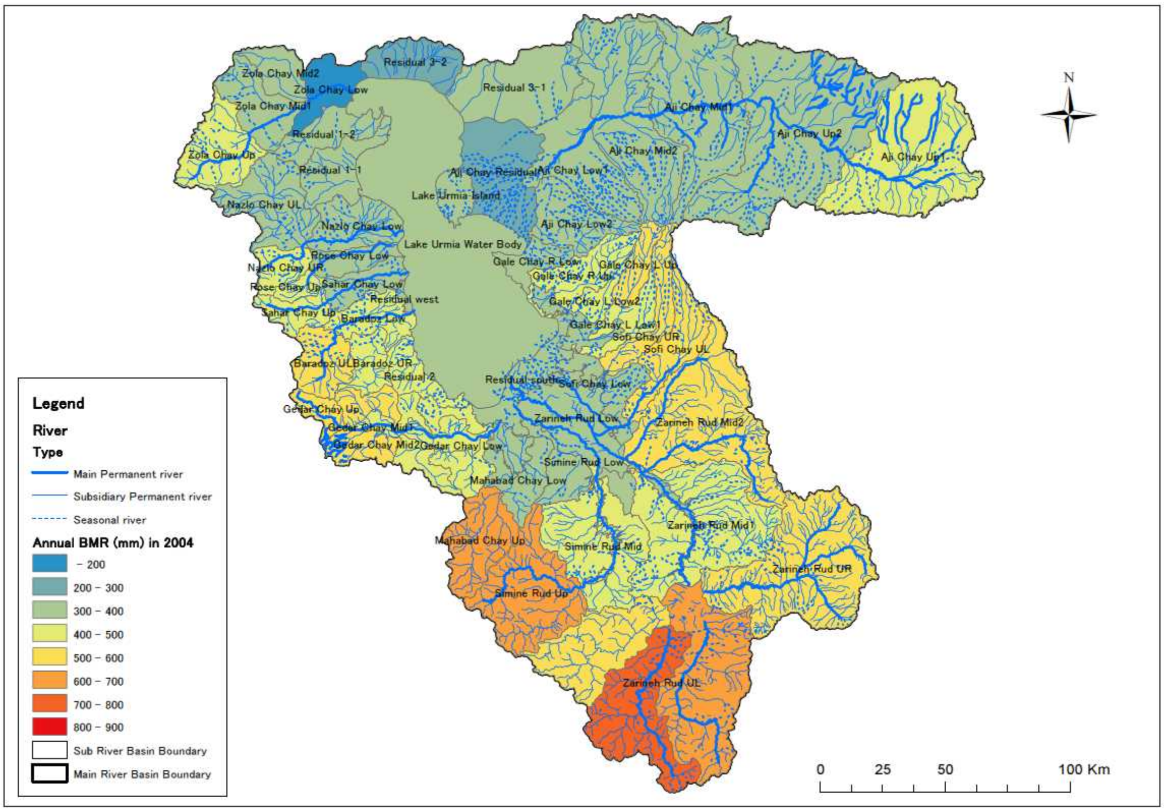


Figure 4.2.6 Annual Basin Mean Rainfall (3/8)

2004



2005

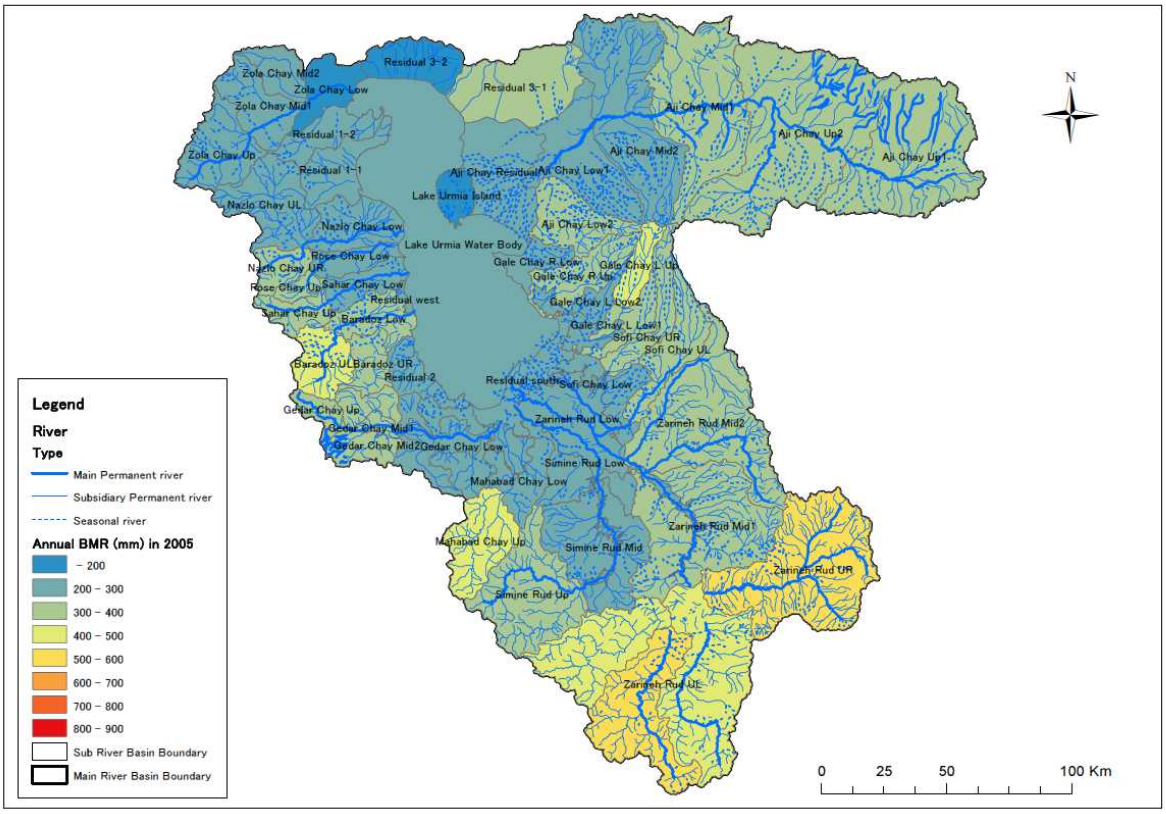
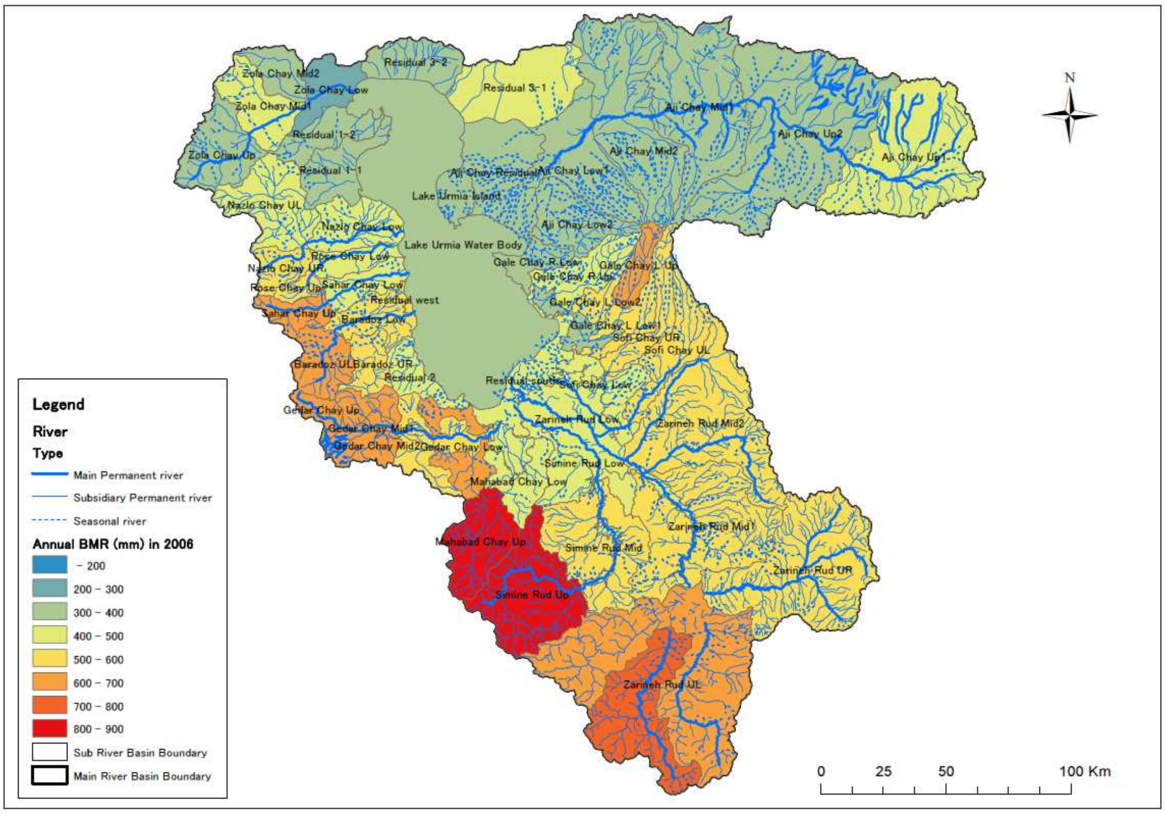


Figure 4.2.6 Annual Basin Mean Rainfall (4/8)

2006



2007

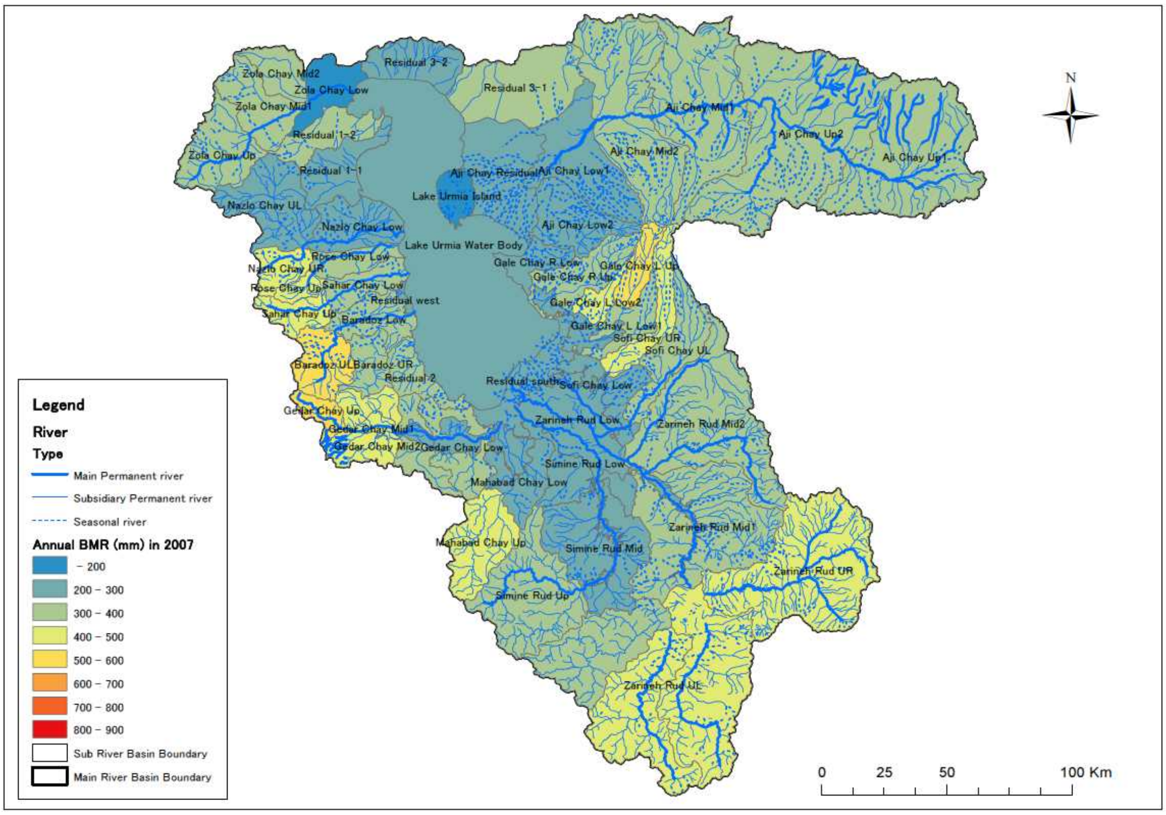
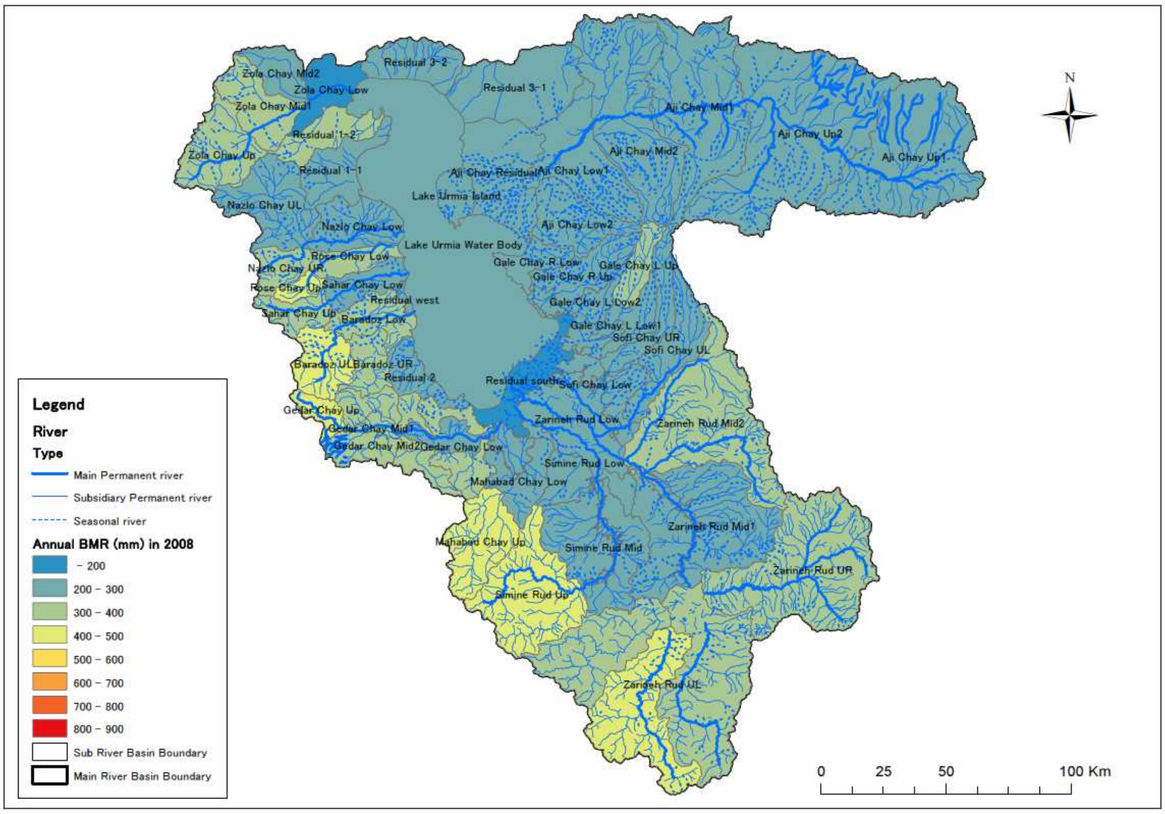


Figure 4.2.6 Annual Basin Mean Rainfall (5/8)

2008



2009

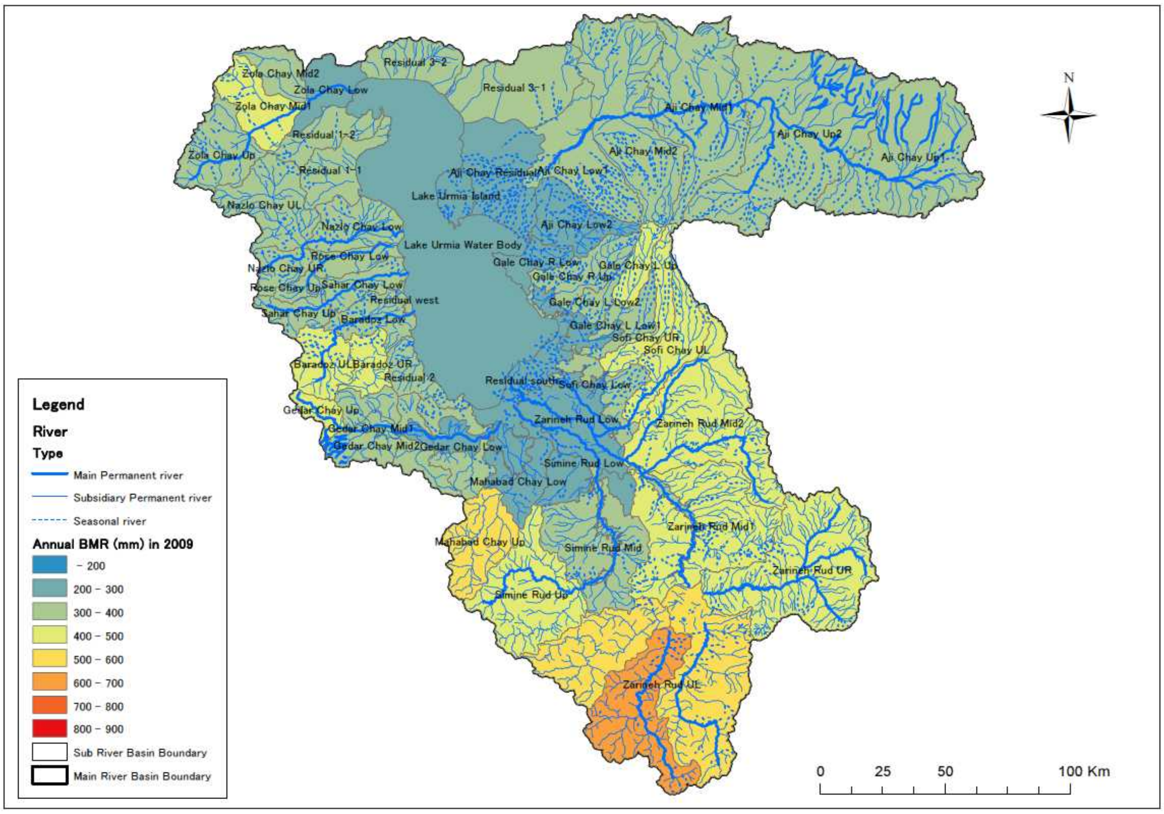
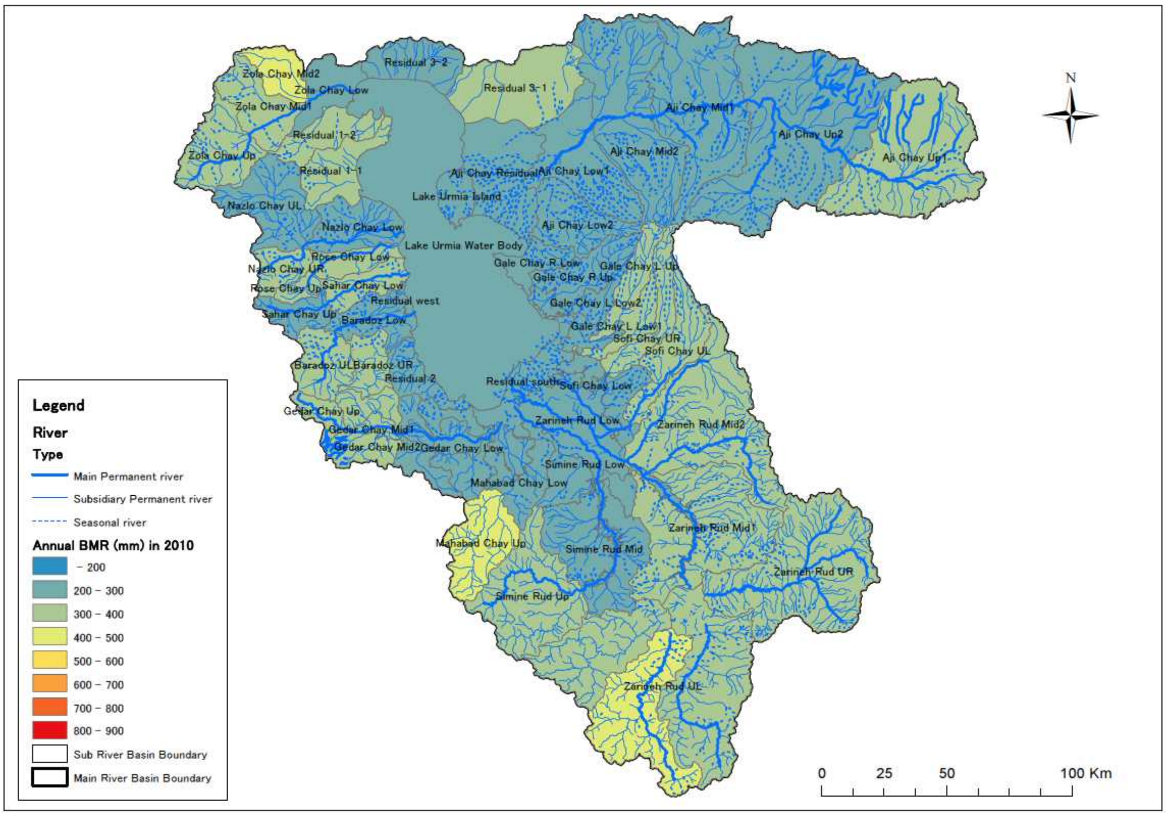


Figure 4.2.6 Annual Basin Mean Rainfall (6/8)

2010



2011

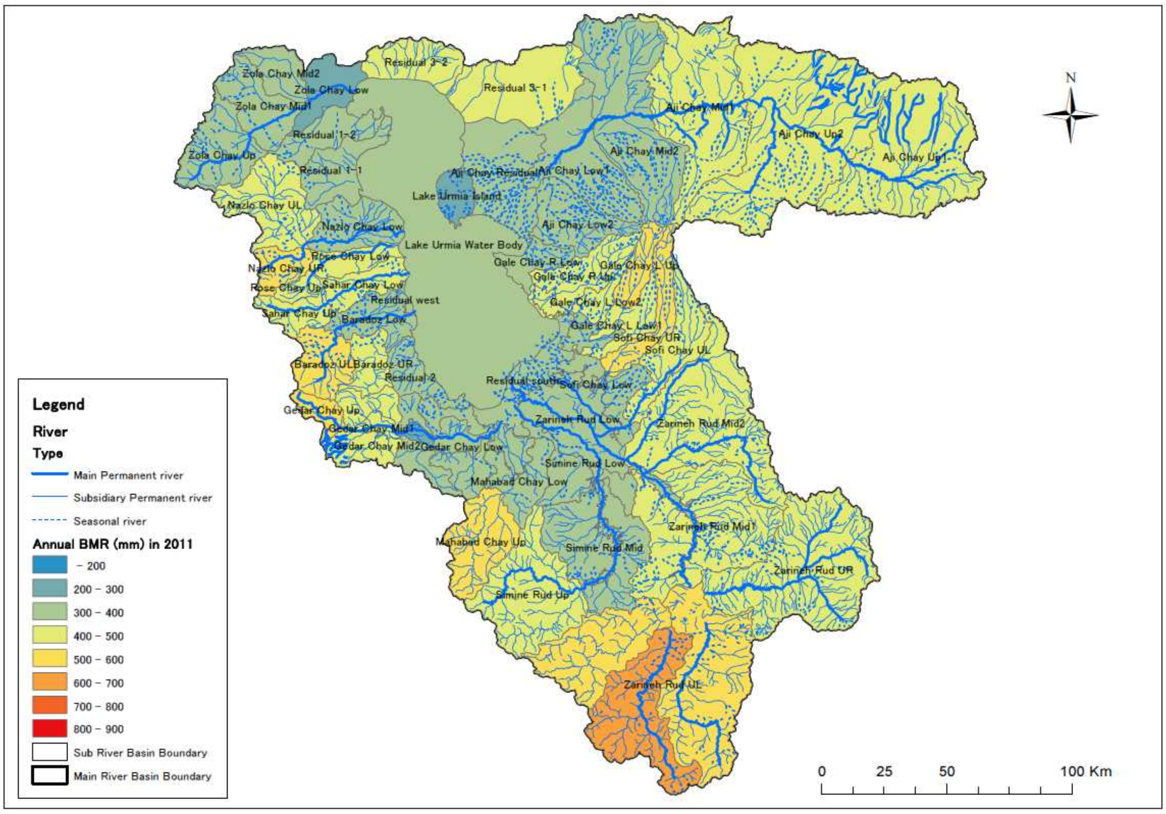
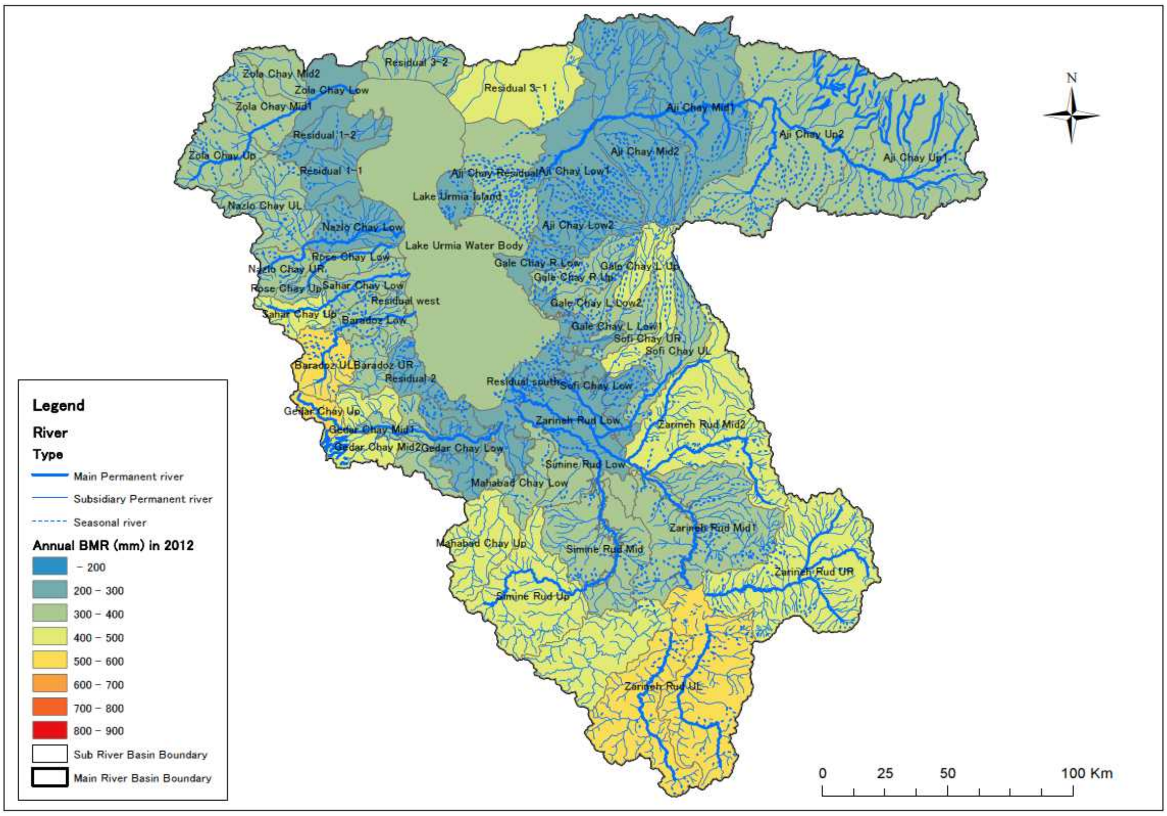


Figure 4.2.6 Annual Basin Mean Rainfall (7/8)

2012



2013

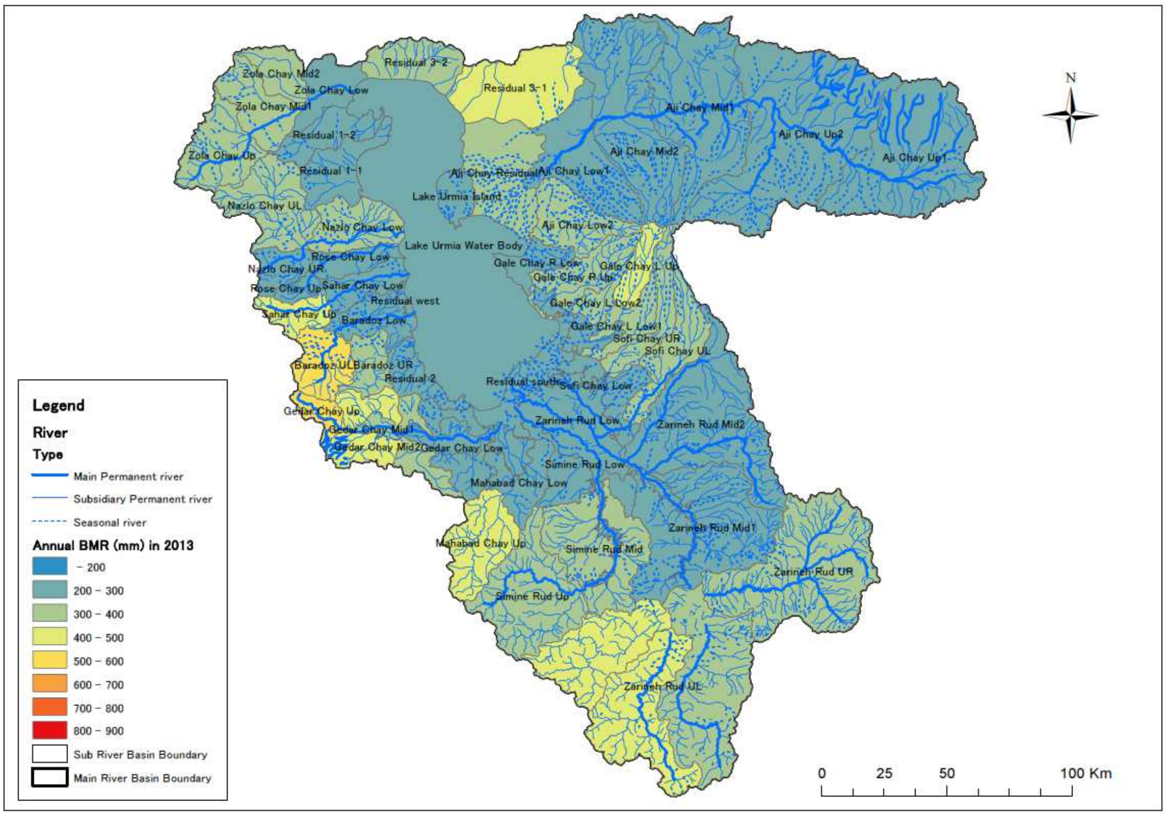
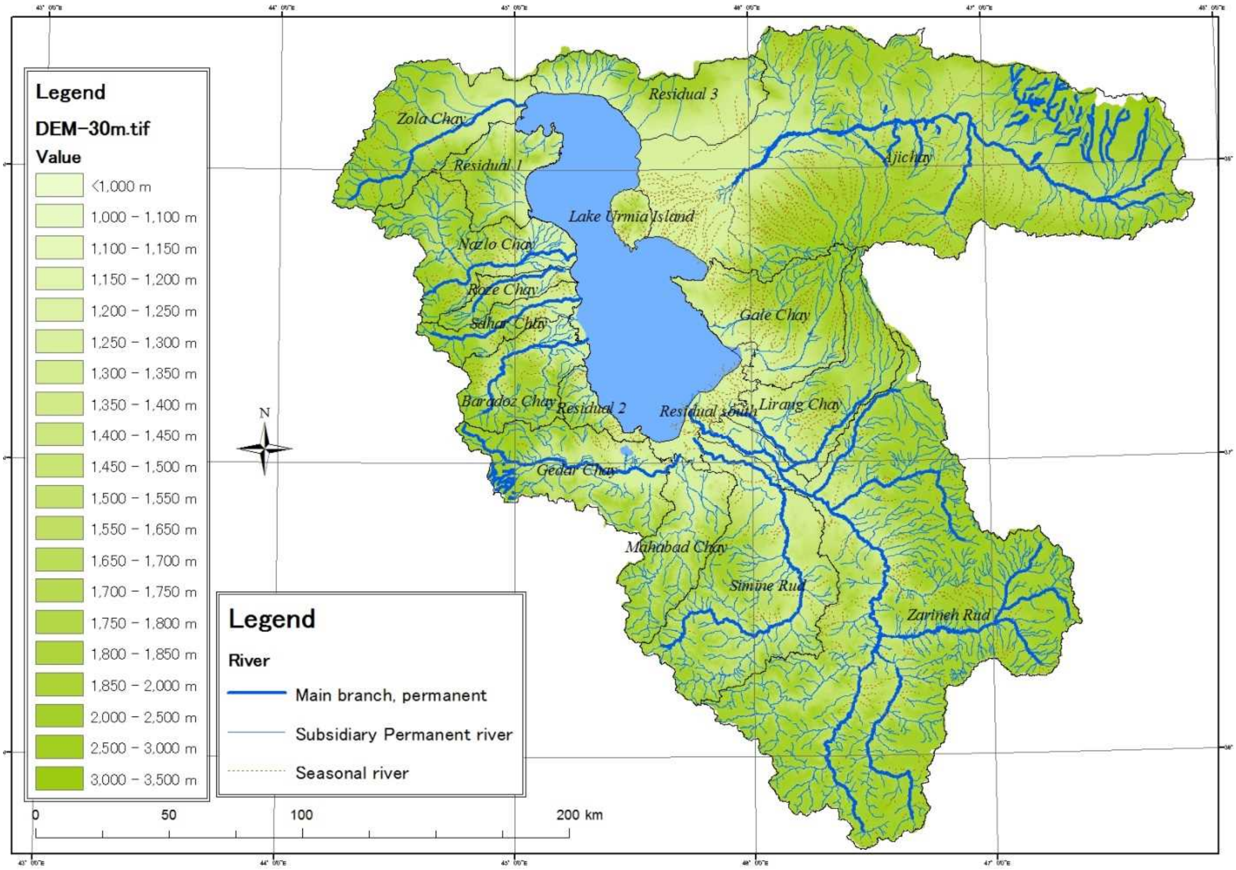


Figure 4.2.6 Annual Basin Mean Rainfall (8/8)

4.3 River

4.3.1 River System

Rivers flowing into the Urmia Lake Basin are classified into (i) permanent 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 4.3.1). Thirty (30) percent of the length of river channels in the Urmia Lake Basin is seasonal river. According to the horizontal map, river that goes downstream onto 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 IWRM Co.

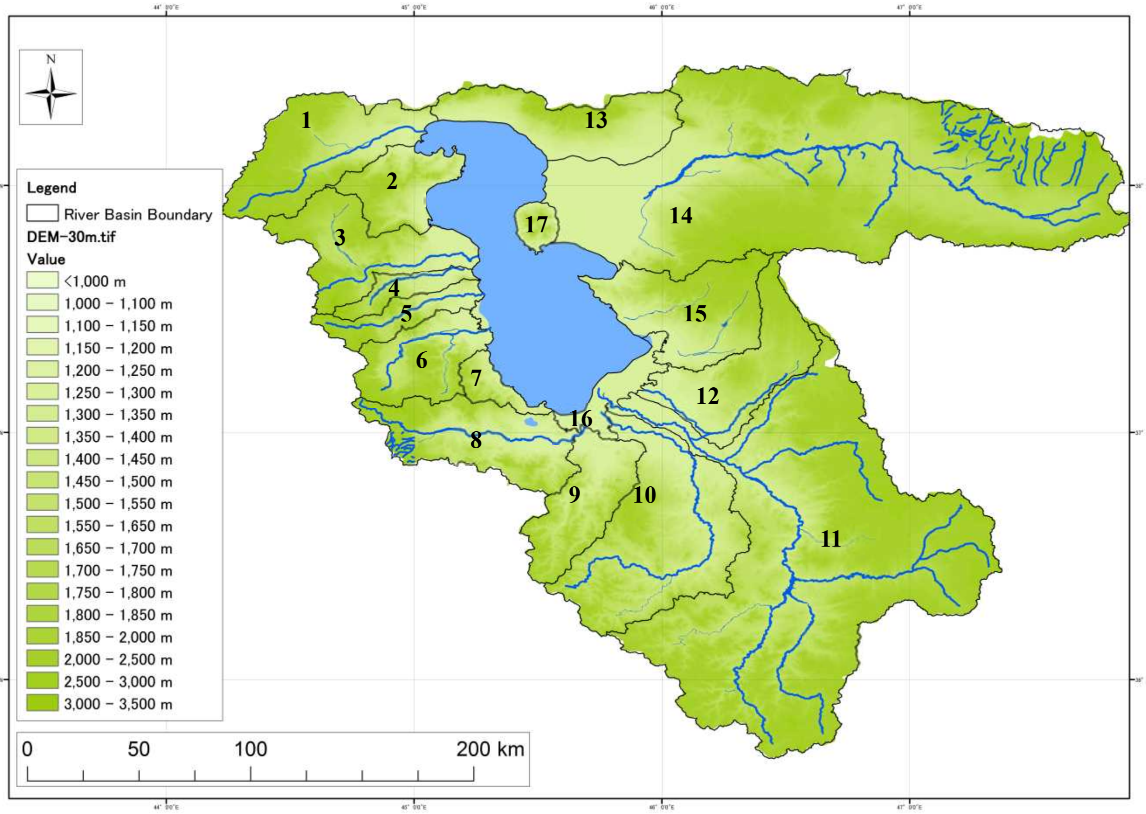
Figure 4.3.1 Distribution of River Channels

Table 4.3.1 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 IWRM Co.

Figure 4.3.2 shows the horizontal map of main channels and their catchment areas in the Urmia Lake Basin as summarized in Table 4.3.2. The Urmia Lake Basin has twelve (12) main channels flowing into the Lake. Aji Chay River (No. 14 in Figure 4.3.2) has the largest catchment area of 12,717 km^2 which is 24.6% of the whole lake basin area, and Zarine 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 IWRM Co., only main channels (temporal rivers) were illustrated.

Figure 4.3.2 Inflow Rivers and Catchment Areas

Table 4.3.2 Summary of River Cathment Areas

No.	Basin Name	Area (km^2)	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	GadarChay	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, iranshahr, Sardasht
10	SimineRud	3,783	7.3	180	0.002	Baneh, Bonab, Bukan, Mahabad, Miyandoab, Saqqez, Sardasht, Shahindezh
11	ZarineRud	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, Bostan Abad, Hashtrud, Maraqeh, Tabriz
13	Residual 3	1,840	3.6	-	-	Khoy, Marand, Shabestar
14	Ajichay	12,717	24.6	280	0.003	Ahar, Ardebil, Bostan Abad, Heris, Marand, Mianeh, Neer, Sarab, Shabestar, Tabriz
15	Gale Chay	2,094	4.0	50	0.030	Bonab, Bostan Abad, Hashtrud, Maraqeh, Tabriz
16	Residual south	551	1.1	-	-	Bonab, Mahabad, Maraqeh, Miyandoab
17	Urmia Lake Island	260	0.5	-	-	Shabestar, Tabriz
-	Urmia Lake (water body)	4,986	9.6	-	-	-
	Total	51,707	100.0	-	-	-

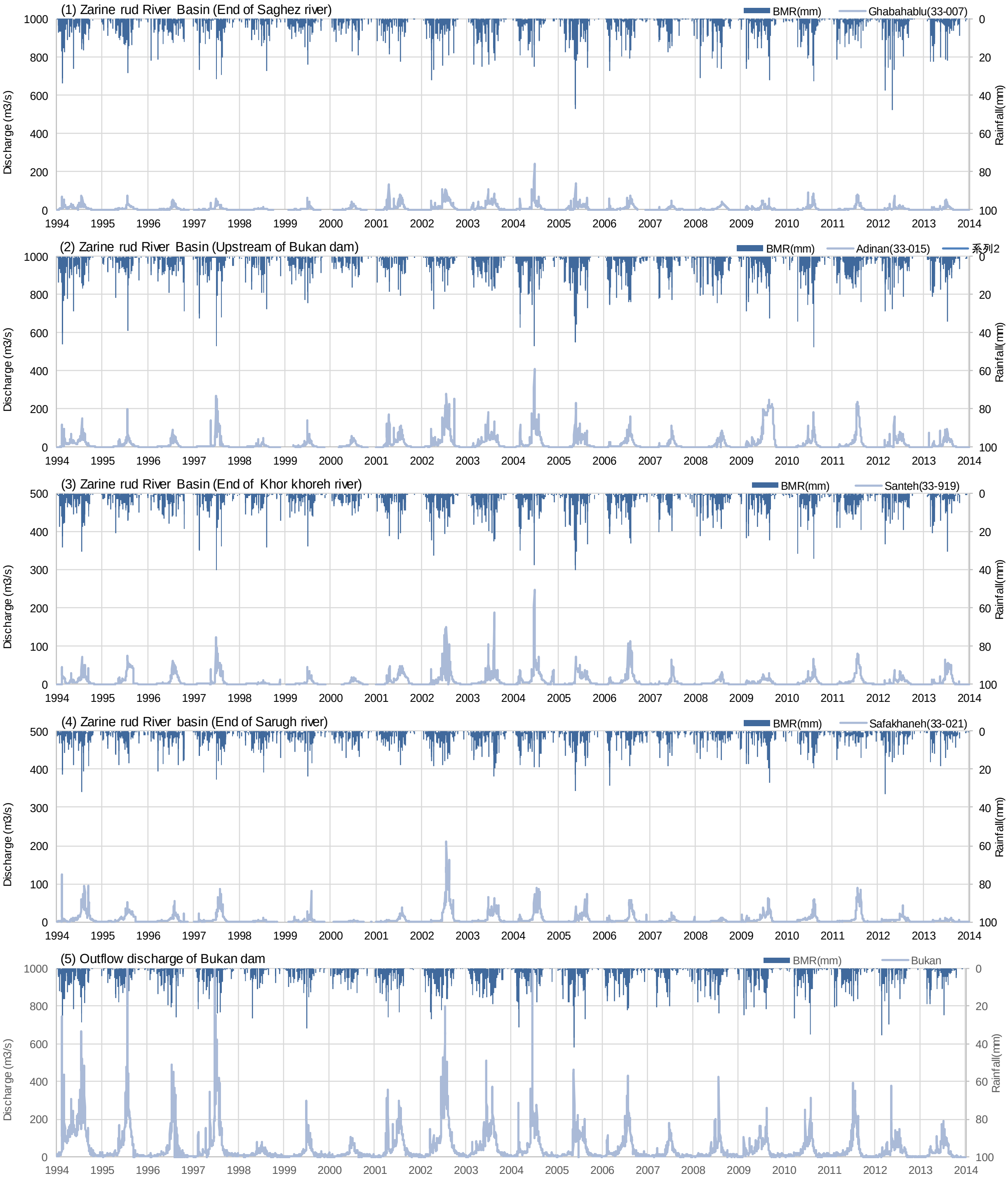
4.3.2 River Flow

(1) Annual Pattern of Precipitation and Discharge

Figure 4.3.3 show the daily precipitation and discharge observed by IWRM Co. in typical sub-basins for the evaluation of rainfall-runoff characteristics in the Urmia Lake Basin.

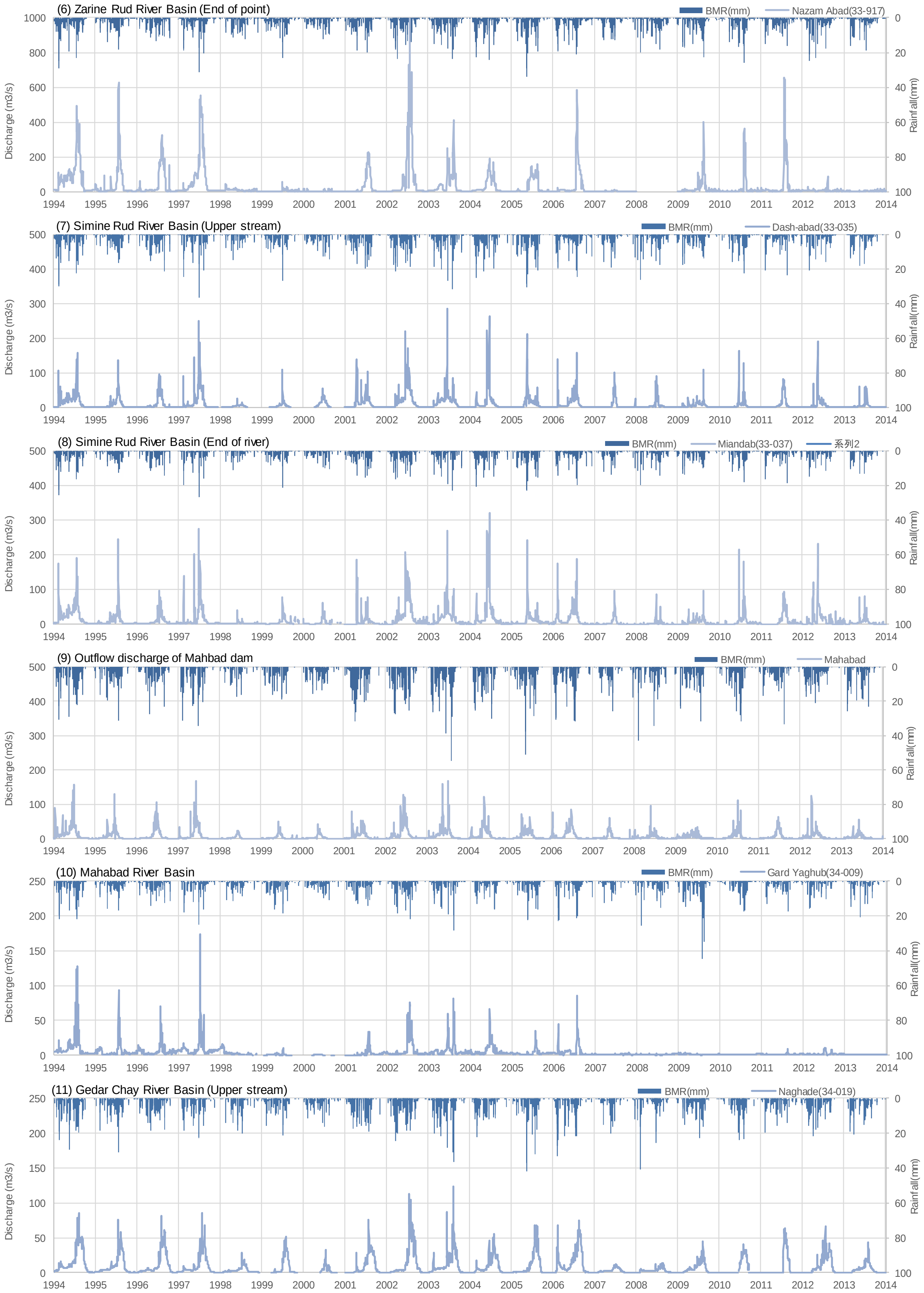
Most of the precipitation occurs from snowfall that melts and runs-off in spring causing peak discharge to occur between April and May. The discharge rapidly decreases by June onwards. As for the cause of decline of discharge from spring to summer, it is presumed that water restoration by dam at upstream for water use reduces the base flow due to low groundwater recharge caused by limited vegetation in mountainous area. Thus, the inflow-rivers in the Urmia Lake 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.

In order to qualify collected discharge data, daily discharge data at calibration points in all parts of Urmia Lake Basin were checked and graded from aspects of time series variation (hyeto-hydrograph) and runoff volume (annual runoff ratio). Details of the check results are shown in Chapter 5.



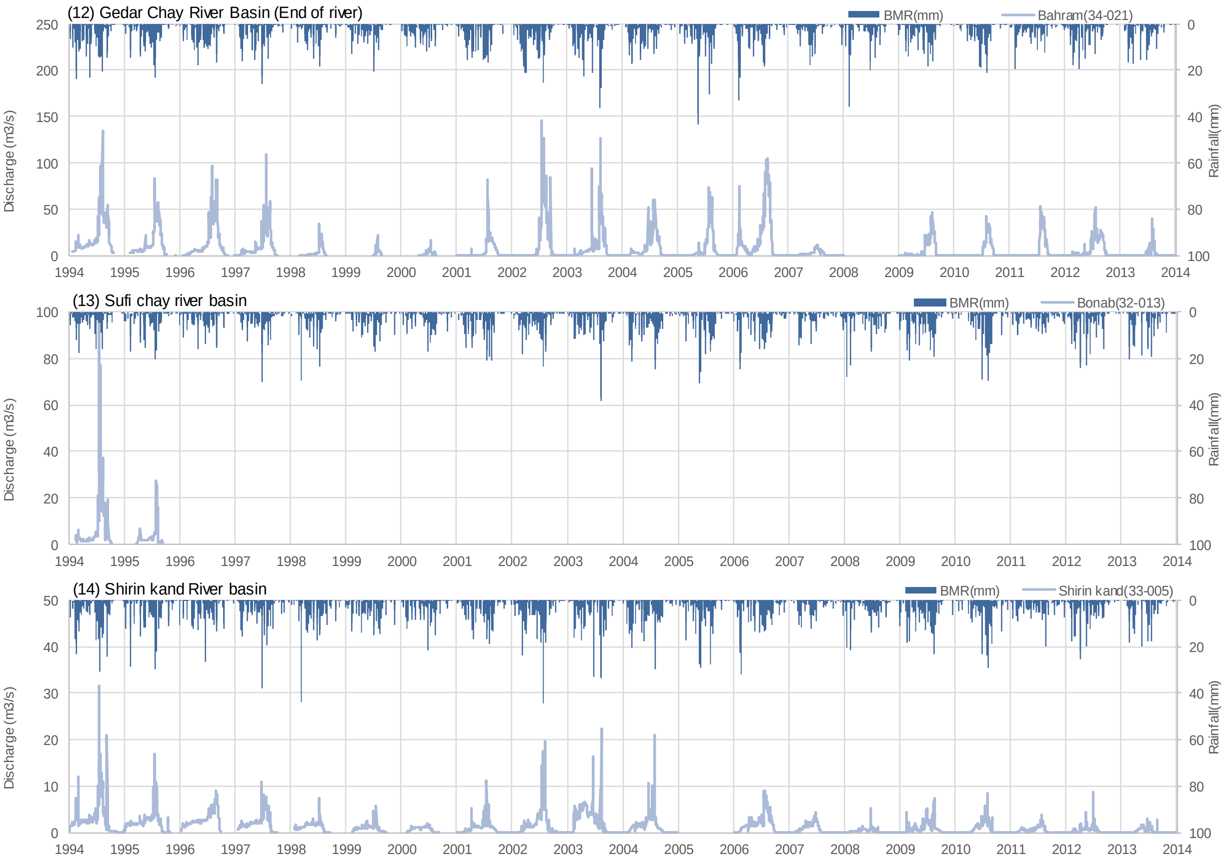
*Source: prepared by the Survey Team using IWRM Co. data

Figure 4.3.3 Daily Discharge and Daily Basin Average Precipitation (1/3)



*Source: prepared by the Survey Team using IWRM Co. data

Figure 4.3.3 Daily Discharge and Daily Basin Average Precipitation (2/3)

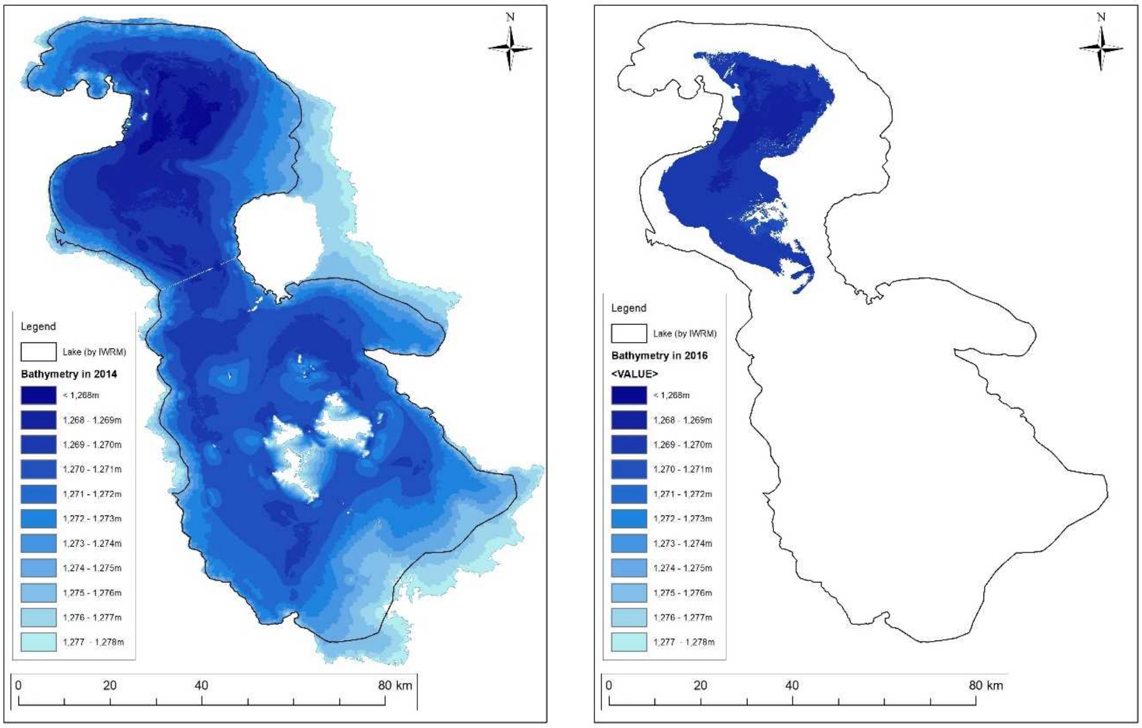


*Source: prepared by the Survey Team using IWRM Co. data

Figure 4.3.3 Daily Discharge and Daily Basin Average Precipitation (3/3)

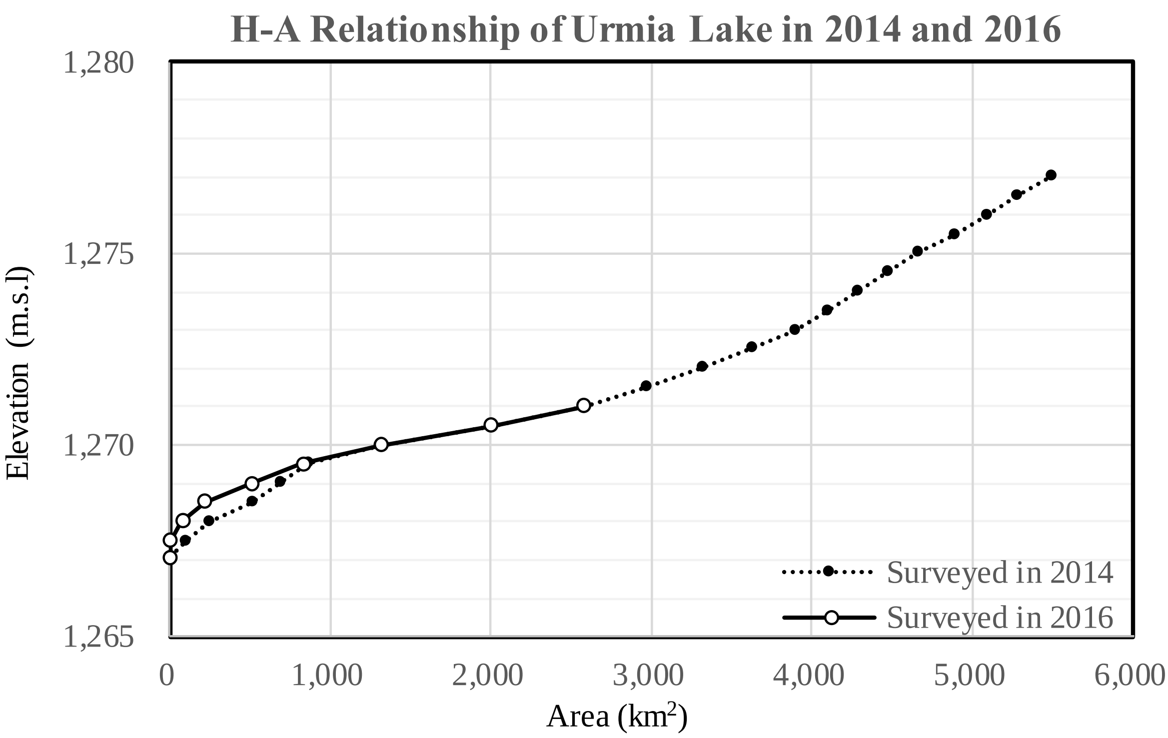
4.4 Bathymetry

Figure 4.4.1 show topographies of the lake in these years, H-A and H-V relationships and sediment depth between 2014 and 2016, respectively. Although topology of the southern part of the lake was not surveyed in 2016, maximum of 1.2m of deposition in northern part of Urmia Lake was confirmed in two years to have caused decrement of lake area and approximately 380 MCM of lake volume.



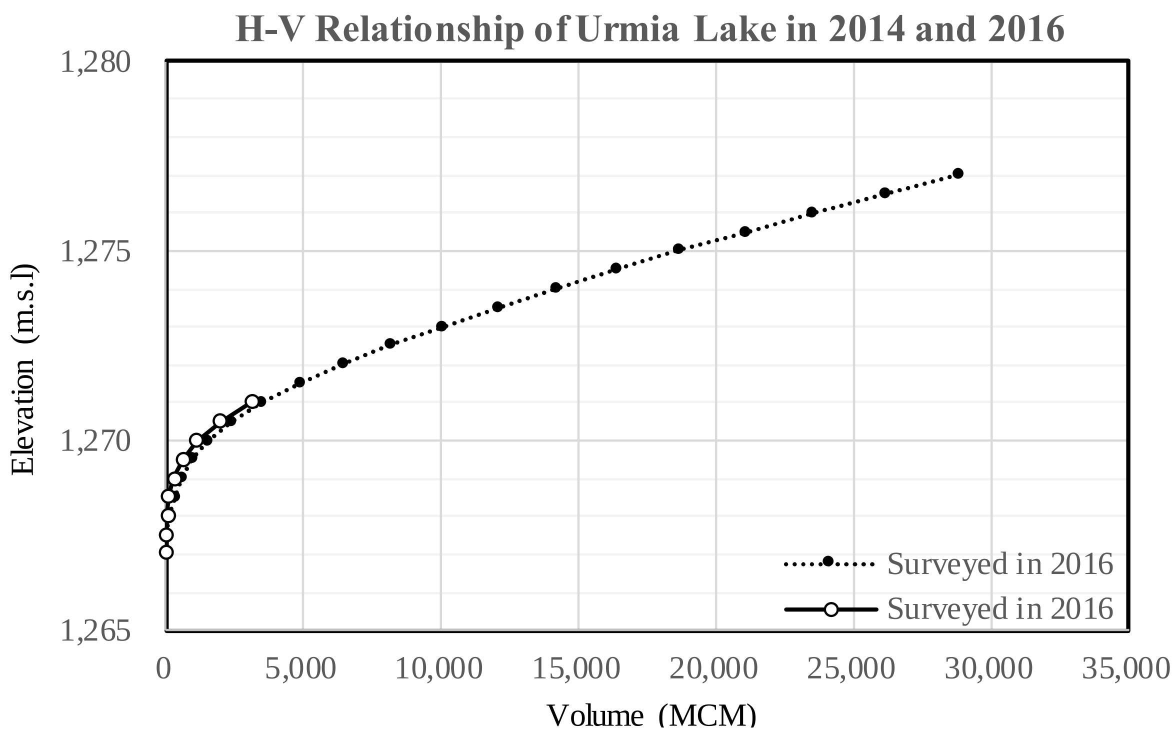
*Source: prepared by the Survey Team using collected data from ULRP

Figure 4.4.1 Topographies of Urmia Lake in 2014 and 2016



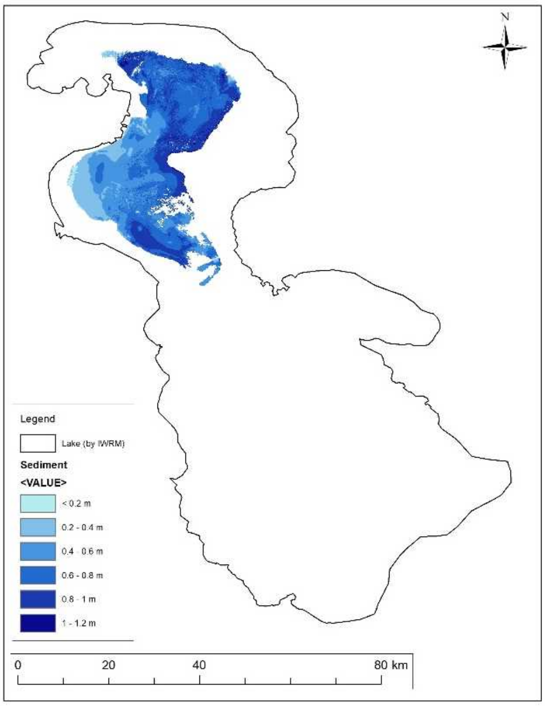
*Source: prepared by the Survey Team using collected data from ULRP

Figure 4.4.2 H-A Relationship of Urmia Lake in 2014 and 2016



*Source: prepared by the Survey Team using collected data from ULRP

Figure 4.4.3 H-V Relationship of Urmia Lake in 2014 and 2016



*Source: prepared by the Survey Team using collected data from ULRP

Figure 4.4.4 Sediment Depth of Urmia Lake from 2014 to 2016

Table 4.4.1 Bathymetry Survey Result in 2014 and 2016

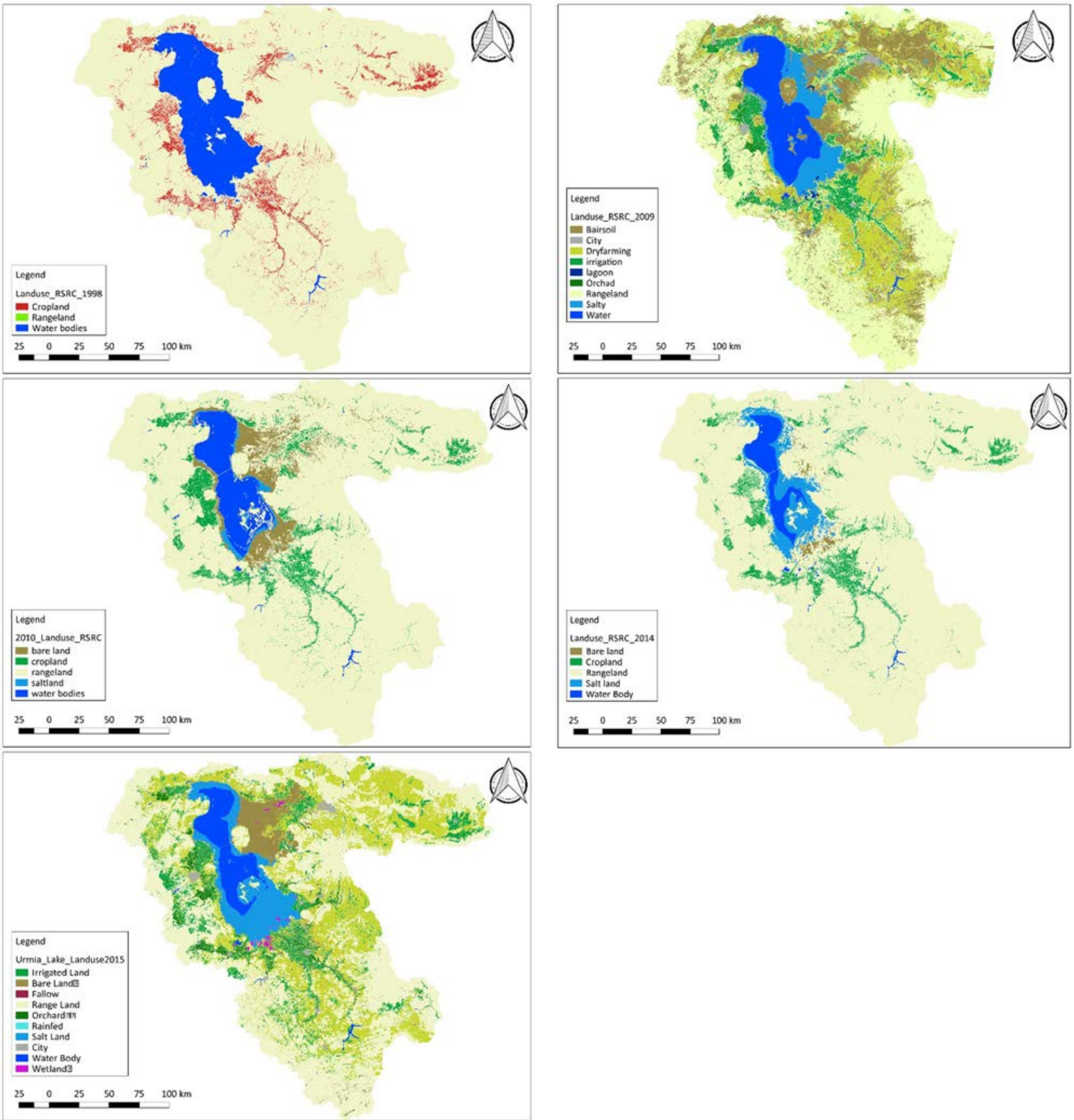
Elevation (m.s.l)	Area(km^2)			Volume(MCM)		
	2014	2016	Difference	2014	2016	Difference
1267.07	0	0	0	0	0	0
1267.5	103	0	-103	17	0	-17
1268	243	78	-165	104	12	-92
1268.5	514	214	-300	286	84	-202
1269	683	514	-169	586	257	-329
1269.5	869	829	-40	981	603	-378
1270	1,300	1,306	5	1,475	1,093	-382
1270.5	2,001	2,002	0	2,320	1,938	-382
1271	2,574	2,574	0	3,464	3,082	-382
1271.5	2,965	-	-	4,858	-	-
1272	3,315	-	-	6,422	-	-
1272.5	3,627	-	-	8,171	-	-
1273	3,896	-	-	10,046	-	-
1273.5	4,099	-	-	12,053	-	-
1274	4,287	-	-	14,144	-	-
1274.5	4,475	-	-	16,343	-	-
1275	4,654	-	-	18,619	-	-
1275.5	4,879	-	-	21,011	-	-
1276	5,085	-	-	23,497	-	-
1276.5	5,278	-	-	26,095	-	-
1277	5,488	-	-	28,777	-	-

*Source: prepared by the Survey Team using collected data from ULRP

4.5 Land Use

RSRC had conducted land use analysis using the satellite images captured in 1998, 2009, 2010, 2014 and 2015. Due to disagreement of classification of land use type and difference of percentages of land use among the years, it is difficult to grasp the change trend of land use.

Comparing land use change between 2009 and 2015 as recommended by ULRP, drastic change in land use type was recognized, especially, bare land which decreased to 75%, and rain-fed area which increased to +64%. Although there might be a possibility of land reclamation, the Survey Team and ULRP concluded that it is uncertain because different parameters were applied for both maps to identify the land use type. It was determined that the land use map in 2009 is to be applied to the hydrological cycle model because it is in the middle of the calibration period (2005 to 2014).



*Source: prepared by the Survey Team using collected data from ULRP

Figure 4.5.1 Land Use Data Provided by RSRC from 1998 to 2015

Table 4.5.1 Land Use Provided by RSRC from 1998 to 2015

1998			2009			2010			2014		
Type	Area (km²)	%	Type	Area (km²)	%	Type	Area (km²)	%	Type	Area (km²)	%
Cropland	3,875	7.5	Bare land	9,361	19.1	Bare land	2,728	5.26	Bare land	324	0.6
Rangeland	41,972	81.0	City	383	0.8	Cropland	4,307	8.31	Cropland	4,195	8.1
Water body	5,971	11.5	Dry farming	8,991	18.4	Rangeland	41,125	79.36	Rangeland	43,281	83.5
			Irrigated Area	3,868	7.9	Salt land	447	0.86	Salt land	2,291	4.4
			Lagoon	96	0.2	Water body	3,211	620	Water body	1,725	3.3
			Orchard	809	1.7						
			Rangeland	19,095	39.1						
			Saltland	2,593	5.3						
			Water body	3,695	7.6						
Sum	51,818	100	Sum	48,891	100	Sum	51,818	100	Sum	51,816	100

2015*		
Type	Area (km²)	%
Bare land	2,323	4.5
Urban	536	1.0
Rainfed	14,773	28.5
Irrigated	5,092	9.8
Fallow	81	0.2
Range land	21,944	42.3
Orchard	1,599	3.1
Salt land	3,134	6.0
Water body	2,297	4.4
Wetland	108	0.2
Sum	51,887	100

*In 2015, land use types are summarized e.g. range land (good, middle and bad) and irrigated area (agri-fall and agri-spring).

Table 4.5.2 Comparison of Land Use Change between 2009 to 2015

2009			2015			Difference	
Type	Area (km²)	%	Type	Area (km²)	%	Area (km²)	%
Bare land	9,361	19.1	Bare land	2,323	4.5	-7,038	-75.2
City	383	0.8	Urban	536	1.0	153	39.9
Dry farming	8,991	18.4	Rain fed	14,773	28.5	5,782	64.3
Irrigated Area	3,868	7.9	Irrigated	5,092	9.8	1,224	31.6
Lagoon	96	0.2	-	-	-	-	-
-	-	-	Fallow	81	0.2	-	-
Orchard	809	1.7	Orchard	1,599	3.1	790	97.7
Range land	19,095	39.1	Range land	21,944	42.3	2,849	14.9
Salt land	2,593	5.3	Salt land	3,134	6.0	541	20.9
Water body	3,695	7.6	Water body	2,297	4.4	-1,398	-37.8
-	-	-	Wetland	108	0.2	-	-
Sum	48,891	100	Sum	51,887	100		

4.6 Geology and Hydrogeology

4.6.1 Geological Structure

(1) Topography and Tectonics

The topography of Iran has a north-western and south-eastern trending regular scheme. It is the direction congruent with subduction front line of Arabian Plate (called as Zagros Fold Belt) and Persian Gulf. Persian Gulf has originated as the rift system in the past geological era.

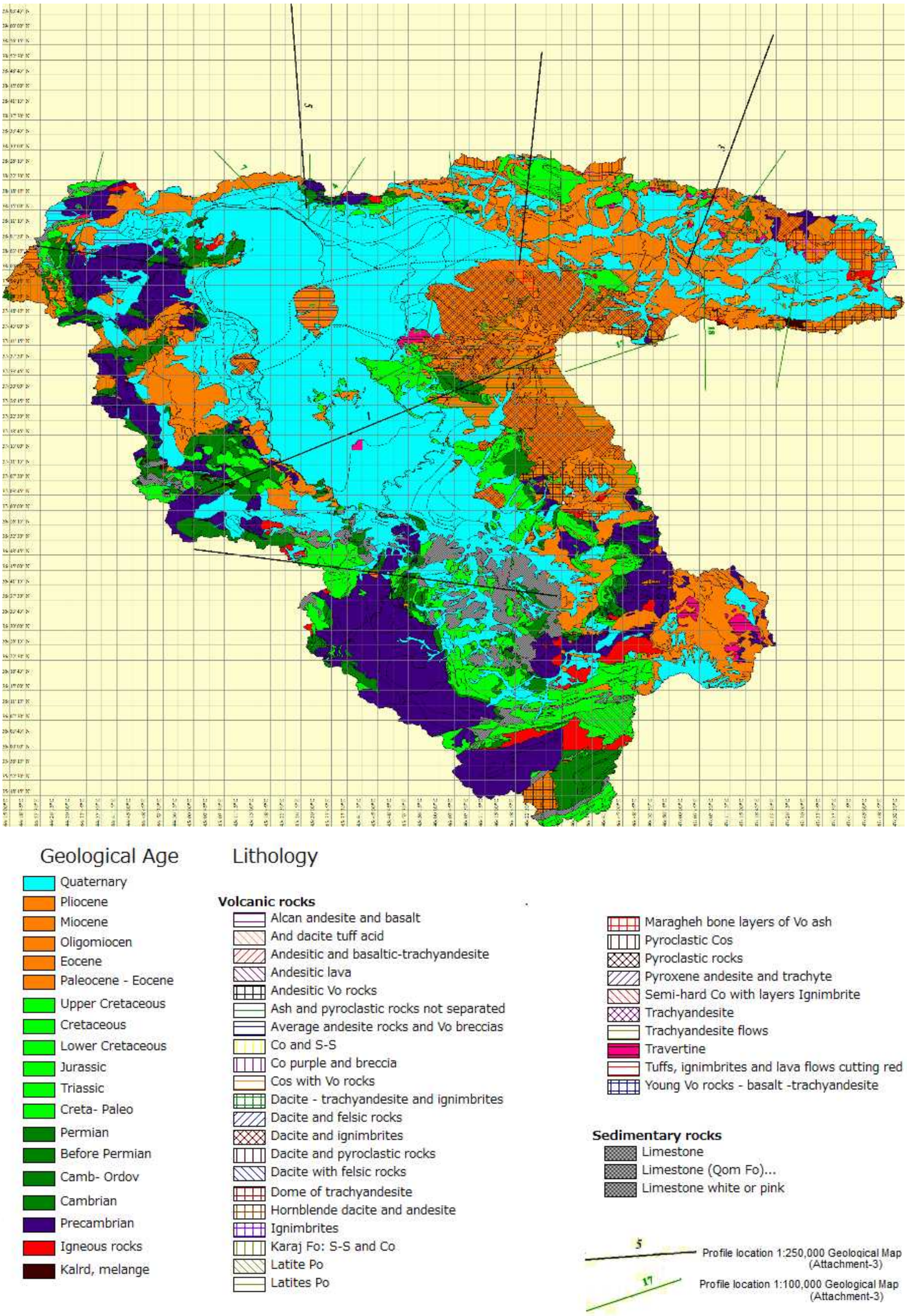
The fact that Urmia region is globally subsiding is related with the rift system occurring in the Mideast region mostly related the so-called “Back-arc basin movement”.

(2) General Geology

The oldest formation of Urmia region consist of Metamorphic rocks called Central Metamorphic Zone. This formation forms the outline of rift topography. The rift topography is covered by the younger formations consisting of sedimentary rocks and volcanic rocks in the geological era from Paleozoic to Tertiary. The youngest formation is the Tertiary volcanic rocks which distribute in the eastern part of the Urmia Lake forming the Soltanhesamch Mountain. Quaternary formation is the unconsolidated sediment which distributes in the lake area and along the river.

The previous survey elaborated a geological map shown in Figure 4.6.1 compiled from this geological information. The geological members of the Urmia Lake indicated in this map are as follows;

Alluvium	: Nonconsolidated sediment, classified as River deposit and Lake deposit
Tertiary formations	: Volcanic rocks distributed in eastern part, and Sedimentary rocks consisting mainly of calcareous rocks distributed in almost the entire area
.	
Older rocks:	: Sedimentary rocks, Metamorphic rocks and Volcanic rocks older than Mesozoic



Source: Iran Geological Service

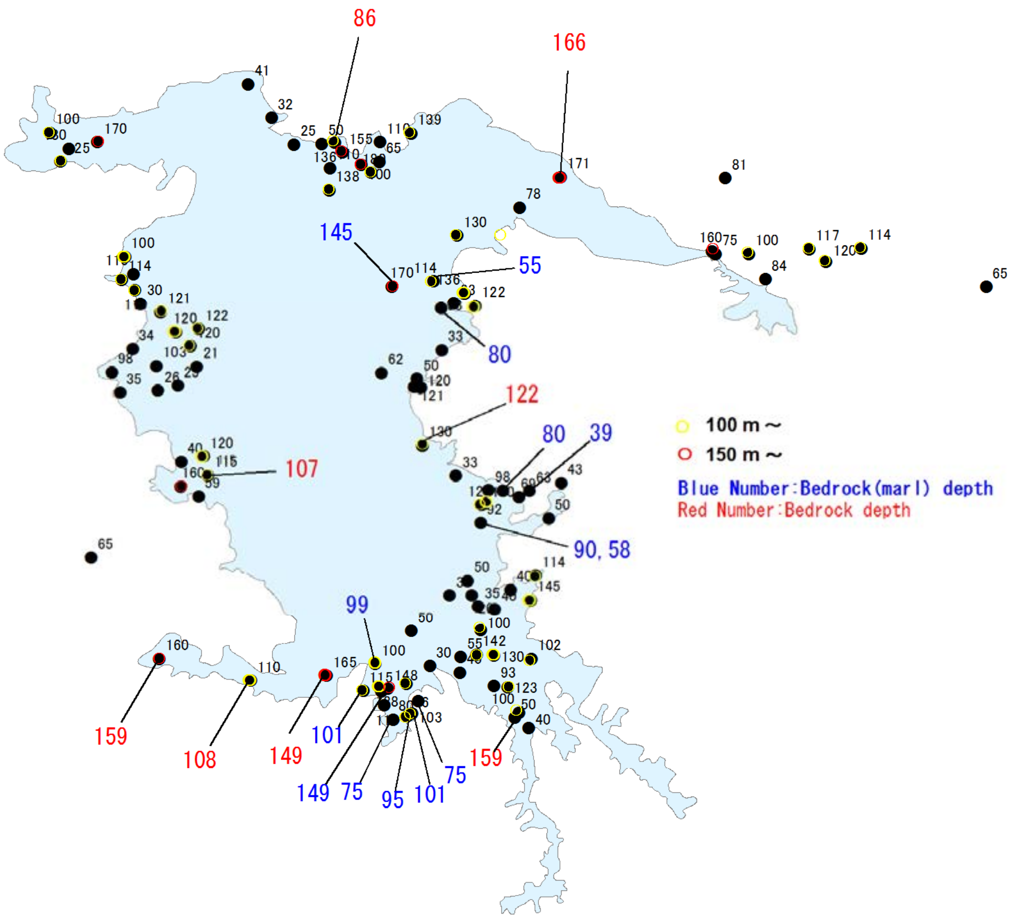
Figure 4.6.1 Geological Map and Faults

(3) Well Distribution

The wells with geological logs are summarized in Figure 4.6.2. The numbers show the drilled depth of each well. Figure 4.6.2 show drilling depths and surface depths of bed rocks consisting of Tertiary formations and older rocks. The surface depth of bed rocks is classified by the rock type such as marl and others. The well penetrated marl distributes in the south-east area and depths vary from 50 to 100 m. Wells penetrated with bedrock without marl distribute in gamut area except the Urmia City area and surface depth is 100 to 170 m.

The maximum drilling depth of each area is as follows;

- Tabriz and its western part: 155 to 210 m
- Urmia and its northern part: 120 to 170 m
- Southern area: 160 m



Note: Summarized by the Survey Team using existing well data

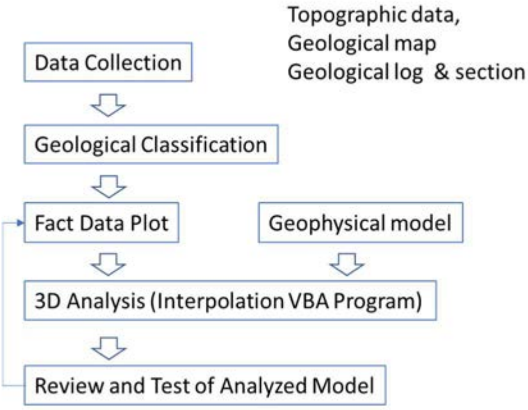
Figure 4.6.2 Well Depth Distribution

4.6.2 Geological Modeling

(1) Procedure

The flow of geological model creation is shown Figure 4.6.3. Geological data were first collected from ULRP and the previous survey. Based on these, the classification of geology used for the geological model was developed by ULRP with the support of the Survey Team. Based on this classification, the distribution of geological layers at well points and the geological cross sections were specified as "fact data."

Secondly, the boundary condition data by geological and geophysical considerations were established. Here, these boundary condition data are also called as fact data. Based on the fact data, a three-dimensional distribution model was constructed using the interpolation program. This model is called as the analyzed model. The analyzed model is reviewed and interpolated repeatedly to complete the final geological model.

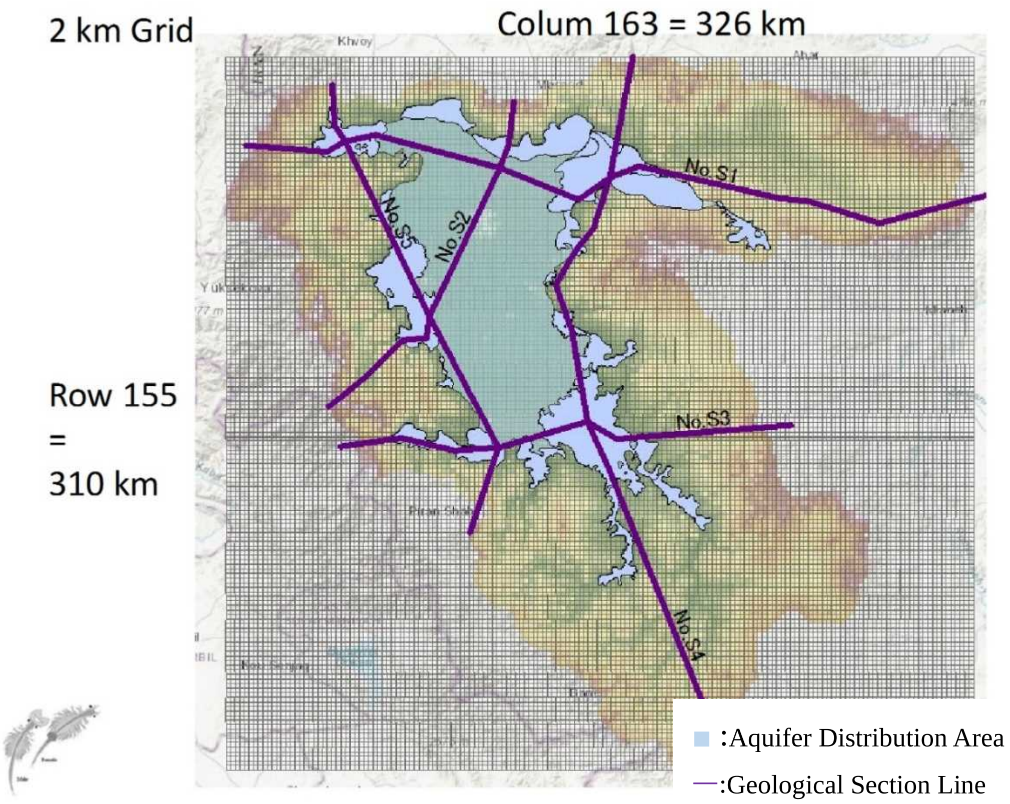


Source: the Survey Team

Figure 4.6.3 Modeling Procedure

(2) Geophysical Model

The Geophysical Model is created in GIS. This range was set to include the aquifer distribution range provided by ULRP. The model has the 2km grid as same as the hydrological cycle model.



Note: Summarized using ULRP aquifer data by the Survey Team

Figure 4.6.4 Aquifer Distribution and Geological Model Area

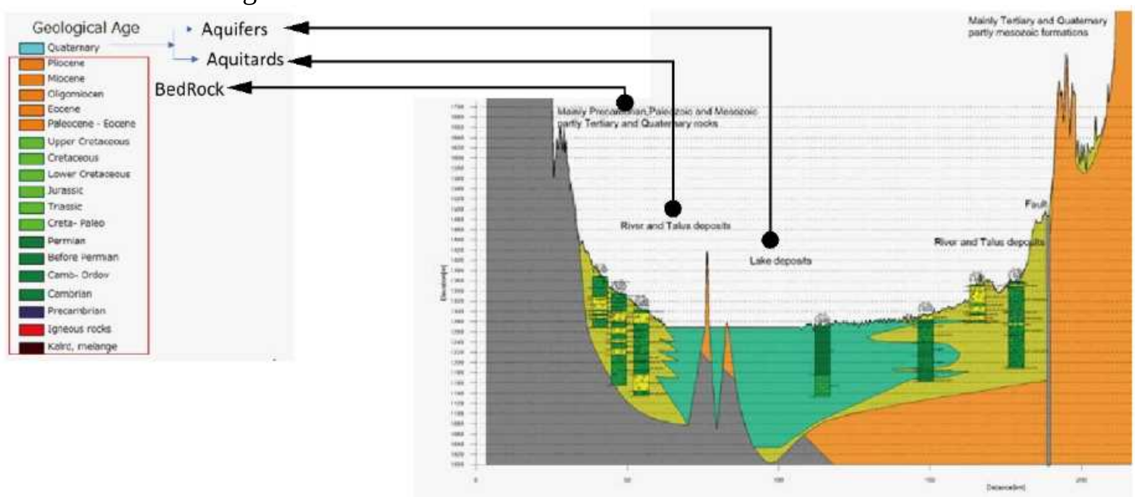
(3) Geological Classification

The geological section in the previous survey put the geological classification to use as shown in Figure 4.6.5. The classifications consist of 1- Bedrocks: mainly Tertiary, Quaternary rocks and mainly Pre-Cambrian, Paleozoic and Mesozoic; 2- Aquifer: River and Talus deposits; and 3-Aquitard: Lake deposits.

Sample of collected well data is shown in Figure 4.6.6. In the well data, classification of the layer was based only on the soil type, so that it is possible to classify the logged layers into aquifer, aquitard and bedrock. If further classification was necessary, additional data was requested.

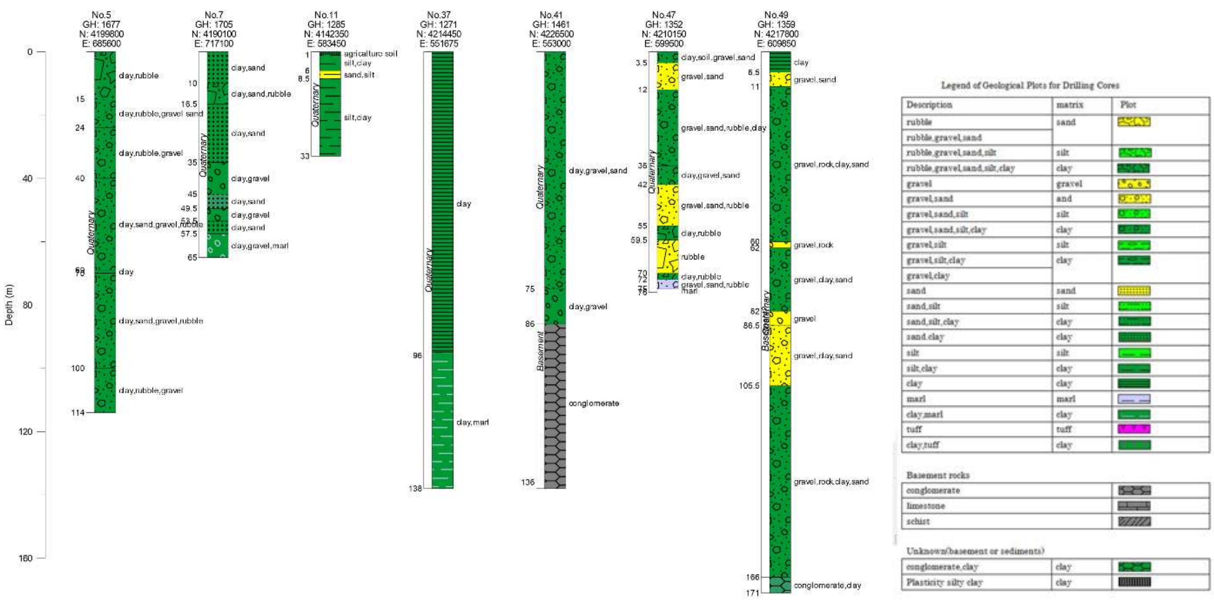
According to the IWRM Co.'s groundwater analysis report (Groundwater Studies of Shabestar-Sofian Plain, Report Code: AZP/8-1 June 2012), layers are classified into 4 units, namely; Aquifer, Lake sediment, Clay & Marl and Travertine, as shown in Figure 4.6.7. It is construable that Clay and Marl and Travertine could be unified into Bedrock; consequently, the classification in this report consist of 3 units: Aquifer, Lake Sediment and Bedrock.

According to these classifications of existing data, it is reasonable to develop the geological model for the groundwater analysis with the classification of Aquifer, Aquitard and Bedrock. Otherwise, further detailed classification might be difficult from collected data.



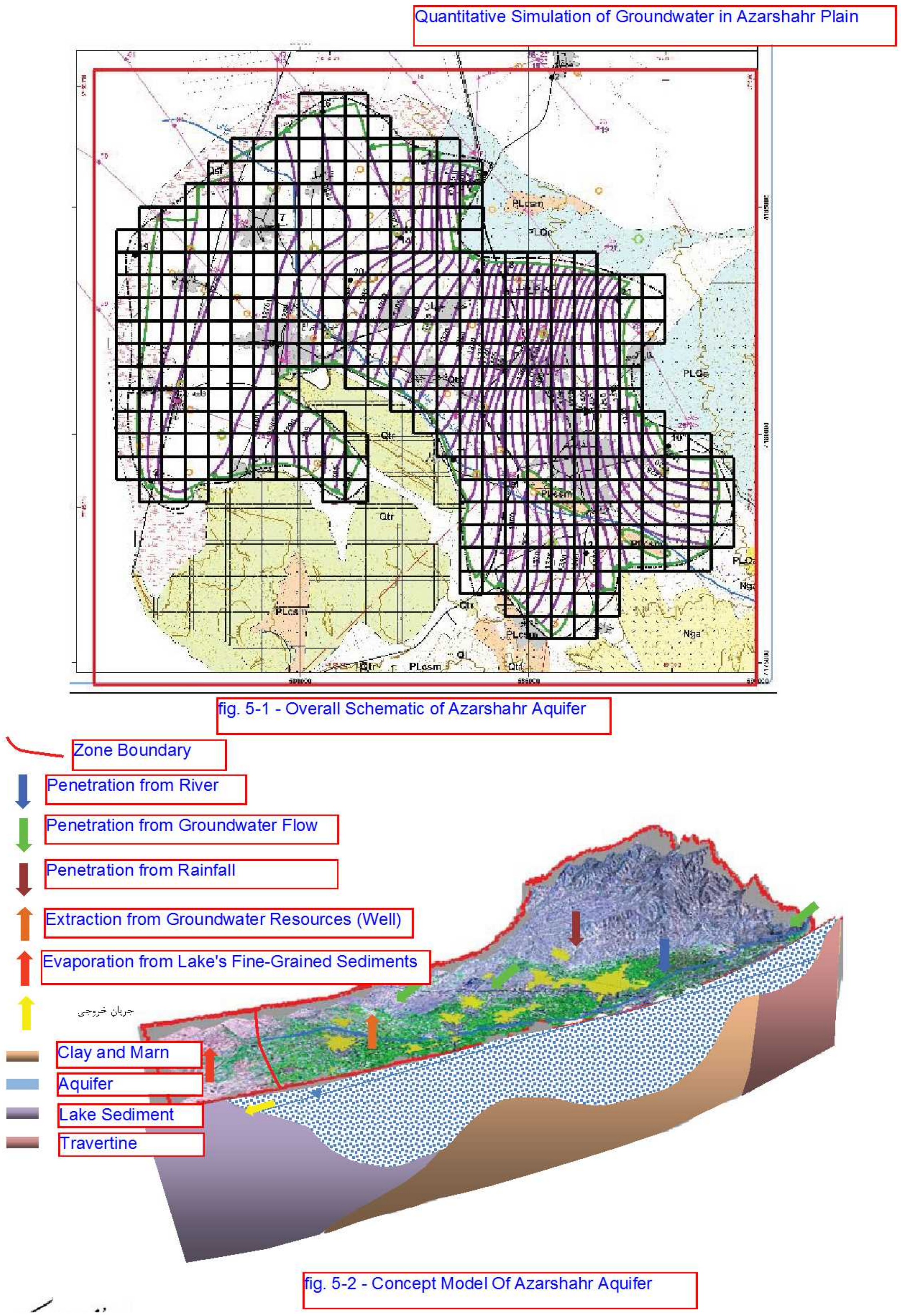
Source: the previous survey

Figure 4.6.5 Geological Section and Its Classification



Source: the previous suvey

Figure 4.6.6 Sample Columnar Section of Well Data



Source: Azarshahr-Report-kammi (Groundwater Studies of Shabestar-Sofian Plain, Report Code: AZP/8-1 June 2012), translation by JICA study team

Figure 4.6.7 Azarshahr Region Groundwater Analysis Area and Its Geological Model

4.6.3 Groundwater Level

Time series data (2010-2016) of piezometric head at 219 points in Miandoab Plain observed by the Water Authority in Western Azerbaijan Province were provided by ULRP. Out of these wells, 64 wells have strainer depths that are plotted in Figure 4.6.8. Figure 4.6.9 shows time-series fluctuation of piezometric head that were confirmed to have decrement trend of 2-5m in 10 years. Also, piezometer located near river (e.g. NO. 218) shows the annual patterns caused by infiltration from river bed.

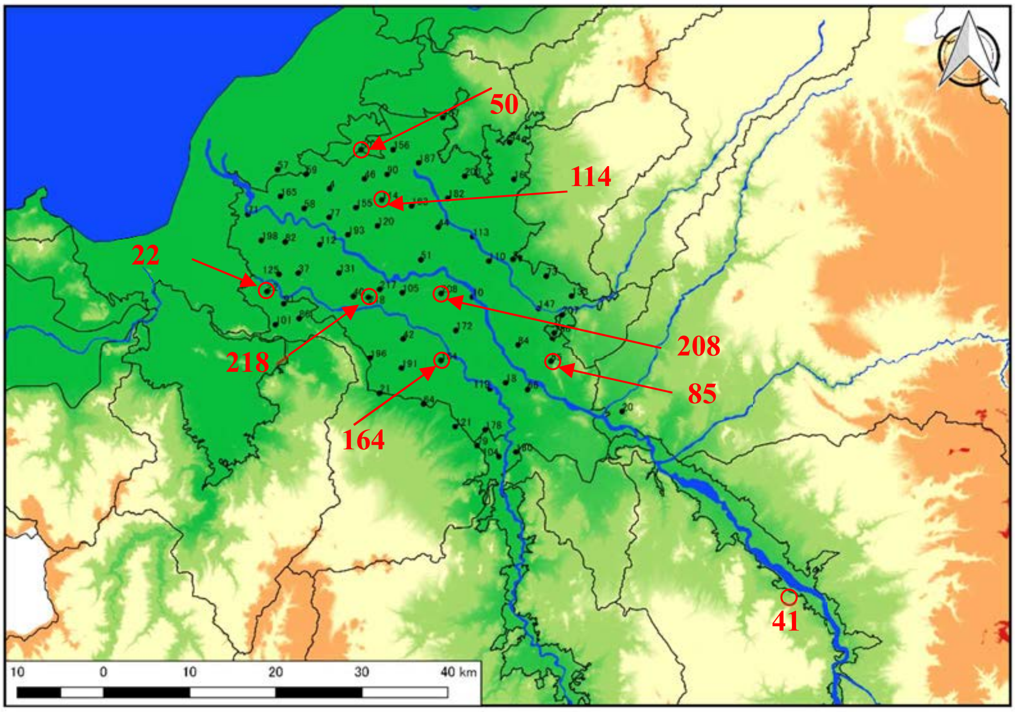


Figure 4.6.8 Distribution of Piezometer in Miandoab Plain

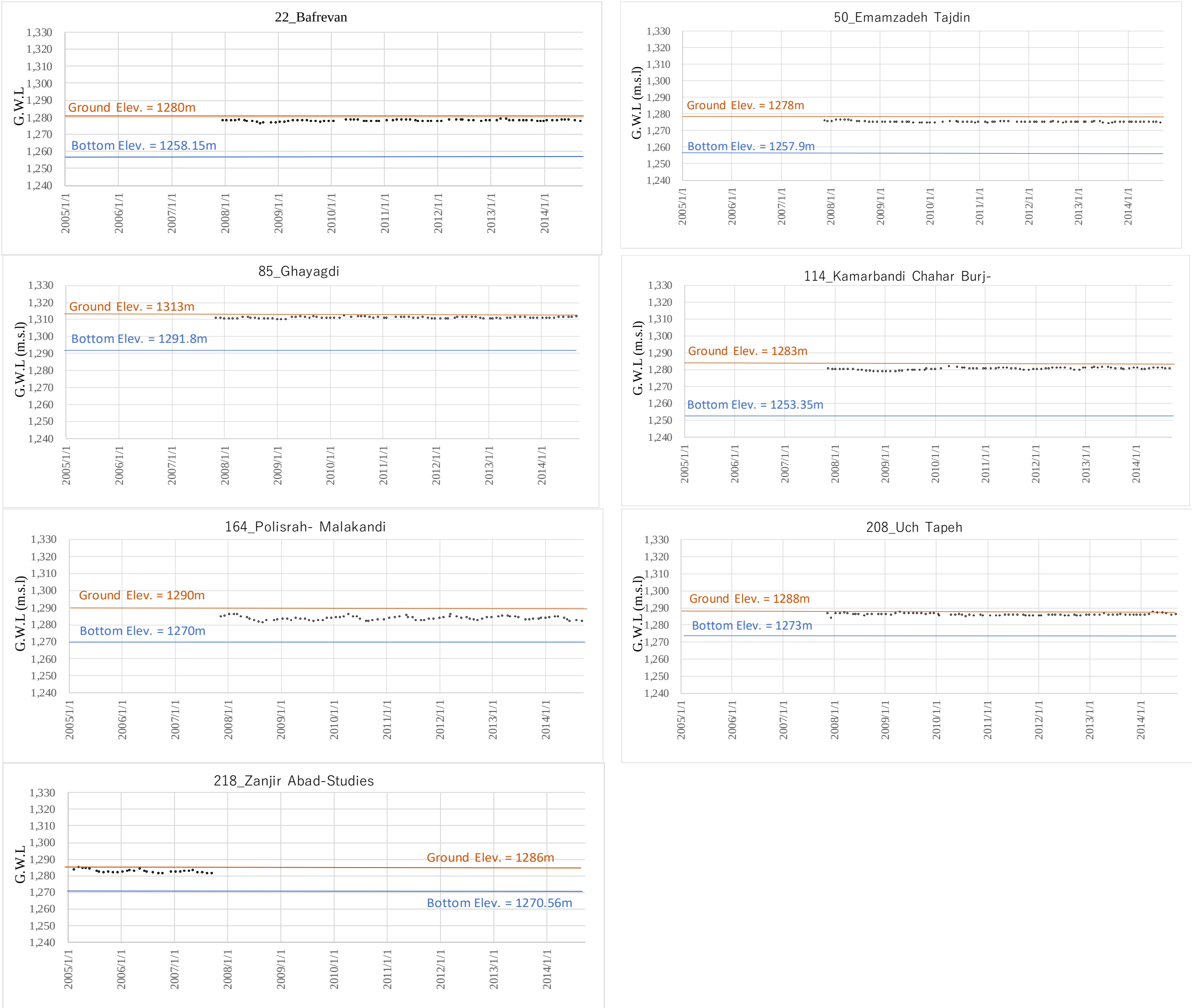


Figure 4.6.9 Temporal Change of Piezometeric Head in Miandoab Plain

4.7 Water Use Facility

4.7.1 Dam and Weir

As of November 2017, information on dams and weirs have not been updated although the Survey Team requested ULRP for their update. Figure 4.7.1 and Figure 4.7.2 show distribution of dams and weirs, and diagrams of their location.

Table 4.7.1 shows the water allocation plans of representative dam and weir in southern part of Urmia Lake Basin. These information are to be referred into the model.

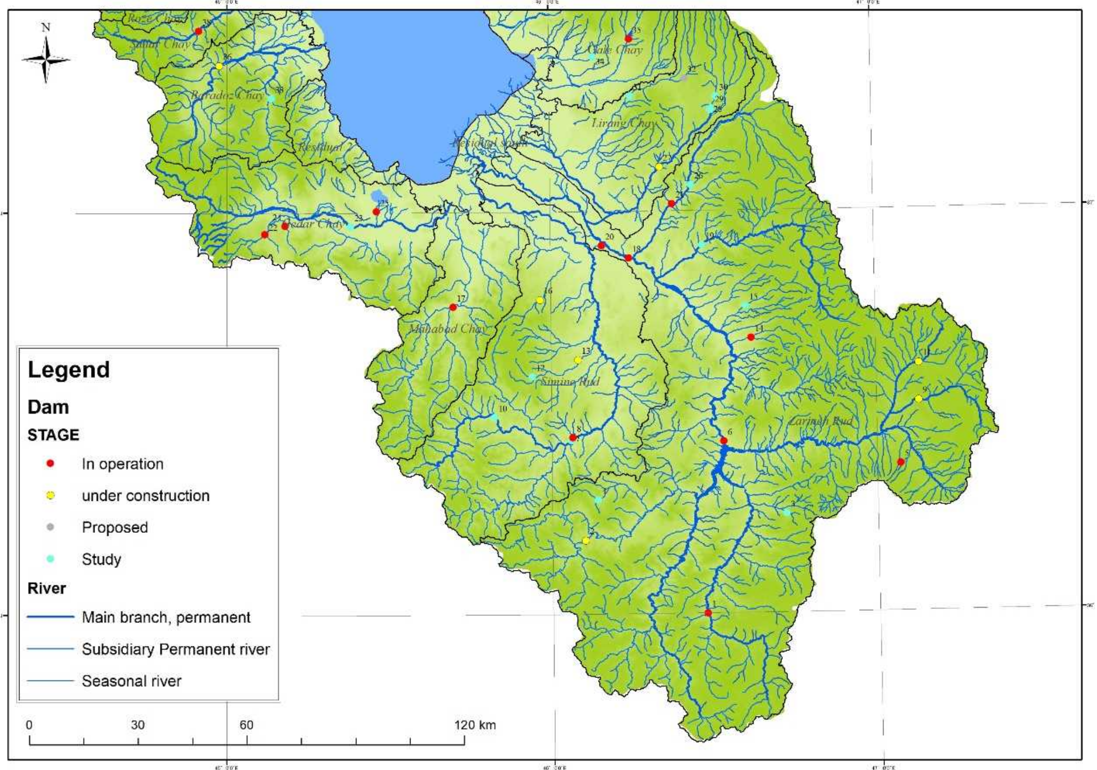


Figure 4.7.1 Distribution of Dams and Weirs in Southern Part of Urmia Lake Basin

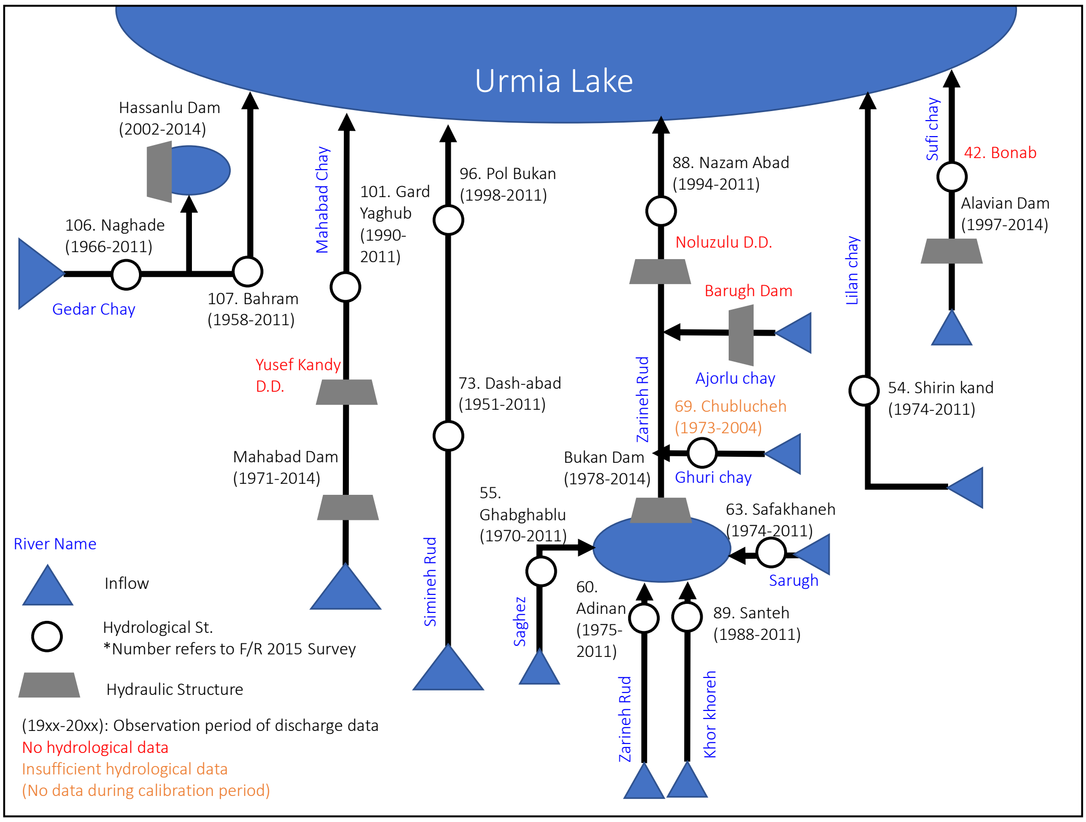
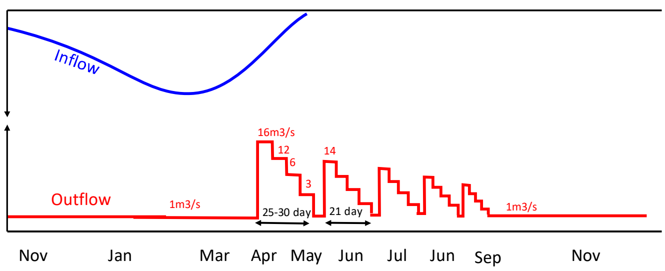
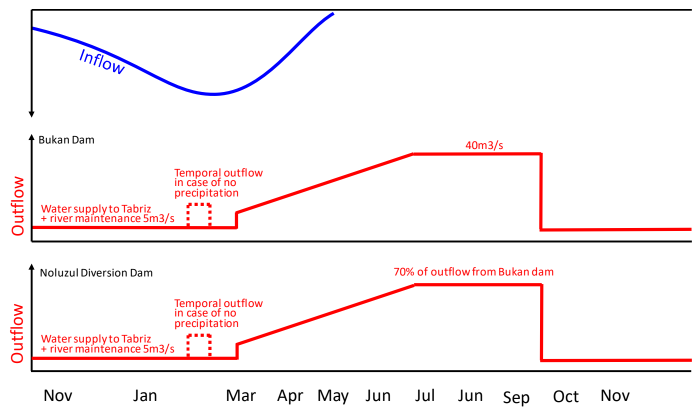


Figure 4.7.2 Diagram of Representative Dams and Weirs

Table 4.7.1 Water Allocation Plan of Dams in Southern Part of Urmia Lake Basin

Basin	Facility	Status	Description
Gadar	Chapar Abad Dam	Under construction	V=46MCM, CA=361km^2 Inflow=116MCM (28MCM from Khari Rush River and 88MCM from Lavine Chay via transboundary channel) **WAP:** 14.5MCM (12.5%) for drinking water 4MCM (3.5%) for agriculture 5MCM (4.5%) for environmental flow remained 87MCM (75%) for discharge to UL
	Hasanlu Dam	In operation	V=94MCM, CA=Approx. 0km^2 Inflow=94MCM via diversion channel on Gadar Chay **WAP:** 95% for agriculture (5,300ha) 2-3 % for industry remained for environmental flow *Agricultural water use in this year is 65MCM due to policy on reduction of agricultural water use 8%/year up to 40%
Mahabad	Mahabad Dam	In operation	V=197MCM, CA=806km^2 Inflow=140MCM **WAP:** 95MCM for agriculture (net 18,200ha) 36MCM for drinking water (18MCM for one year x2) remained for environmental flow *During Oct-Mar, 1m^3/s of discharge is secured for drinking, industry and evaporation *Annual operation pattern 
	Yusef Kandy Diversion Dam (Mahabad Irrigation Network)	In operation	Inflow=95MCM+α in 2017 **WAP:** 95MCM (100%) for agriculture (actual: 12,000ha, planned: 17,000ha), main crops are: apple (38%), wheat (11%), sugar beet (10%) and sapling (9%). 45MCM for left irrigation network (5,800ha), 50MCM for right (6,200ha) remained for discharge to UL (based on request from DOE) *Change in agricultural water use -before 2012: 146.5MCM 2013: 139MCM 2014: 113MCM 2015: 106MCM 2016: 95MCM

Basin	Facility	Status	Description
Zarine Rud	Bukan Dam	In operation	V=486MCM, CA=6,890km^2 Inflow=1.1BCM (plan:1.7BCM) 55% from Zarine, 10-15% from Sarugh, Saghes from 20-25% and 10% from Khor khoreh **WAP:** 200MCM for storage 700-900MCM for discharge -500MCM for Noruzlu D.D. (for agriculture) -157MCM for Drinking for Tabriz -186MCM for agriculture upstream of Noruzlu D.D. -Remained for UL *As of 21st Aug, 40m^3/s was discharged *85-90MCM is pumped up from dam lake (incl. drinking, agriculture and 60% for illegal uptake) *In 2016, 700MCM was discharged for UL
	Noruzlu Diversion Dam	In operation	Inflow (outflow from Bukan Dam) = 700-900MCM -500MCM for Noruzlu D.D. (for agriculture) 45% for left irrigated area, 55% for right 5m^3/s of constant flow for Urmia Lake restoration -157MCM for Drinking for Tabriz 
	Traditional channel b/w Bukan and Noruzlu D.D.	In operation	Command area: -Sedar (588ha) -Aghtappeh (337.5ha) -Dasheskan (108ha) -Hajiabad (600ha) -Gojali (400ha) -Aghchelu (107ha) *In Sedar, 8-10MCM with 3.5m^3/s of water intake Water is distributed 20 days in a month b/w Apr and Sept
Saghez (Sub-river of Zarine Rud)	Cheraghveys Dam	In operation (from March 2017)	V=85MCM (actual:91MCM), CA=365km^2 Inflow=134MCM **WAP:** 24MCM for drinking water 33MCM for agriculture (6,000ha) 29MCM for environmental flow 5MCM for industry 50MCM for discharge to Bukan Dam *Planned irrigated area is 6,000ha, 70% of progress

Basin	Facility	Status	Description
Saruq (Sub-river of Zarine Rud)	Saruq	In operation (from 2016)	V=51MCM, CA=332km^2 Inflow=31MCM (In study 70MCM of inflow was estimated but actual inflow is less because of less precipitation) **WAP:** 3.5MCM for drinking water (after 25yr will be 7MCM) 12MCM (in 2016) for inflow to Bukan Dam (27MCM in 2017) *Potential irrigated area: 1,250ha

*V: Storage Volume, CA: Catchment Area, WAP: Water Allocation Plan

4.7.2 Wells

As of November 2017, well information has not been updated.

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 4.7.3 show changes in annual permitted uptake water, Figure 4.7.4 show the present status of percentages of permitted uptake water amount from well for the purposes, and Figure 4.7.5 show the spatial distribution of wells in the present condition. Approximate 89,000 wells have already been constructed from which 1,600MCM of uptake water is permitted mainly for agricultural water use, ninety (90) percent. Wells are distributed with high density in plain areas.

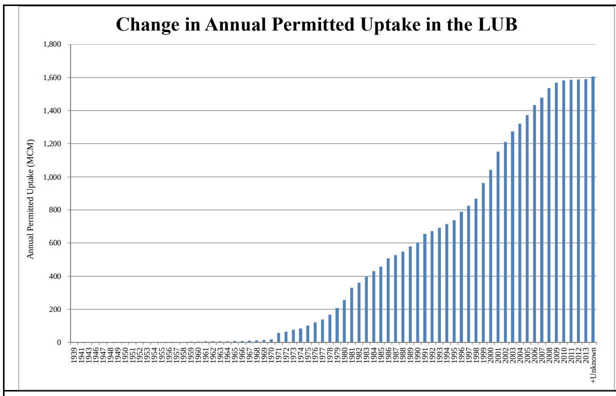


Figure 4.7.3 Changes in Annual Permitted Uptake Water in the Urmia Lake Basin

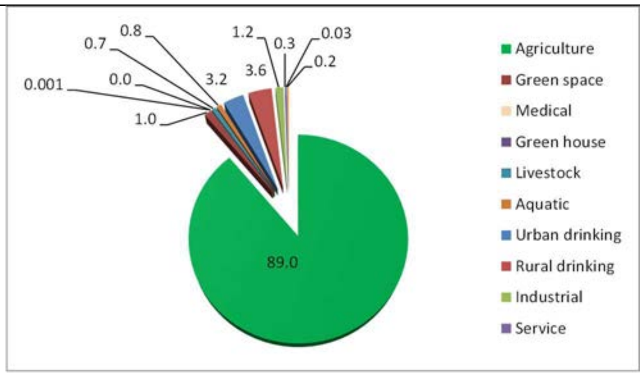


Figure 4.7.4 Percentages of Permitted Uptake Water Amount from Wells for Purposes in the Urmia Lake Basin

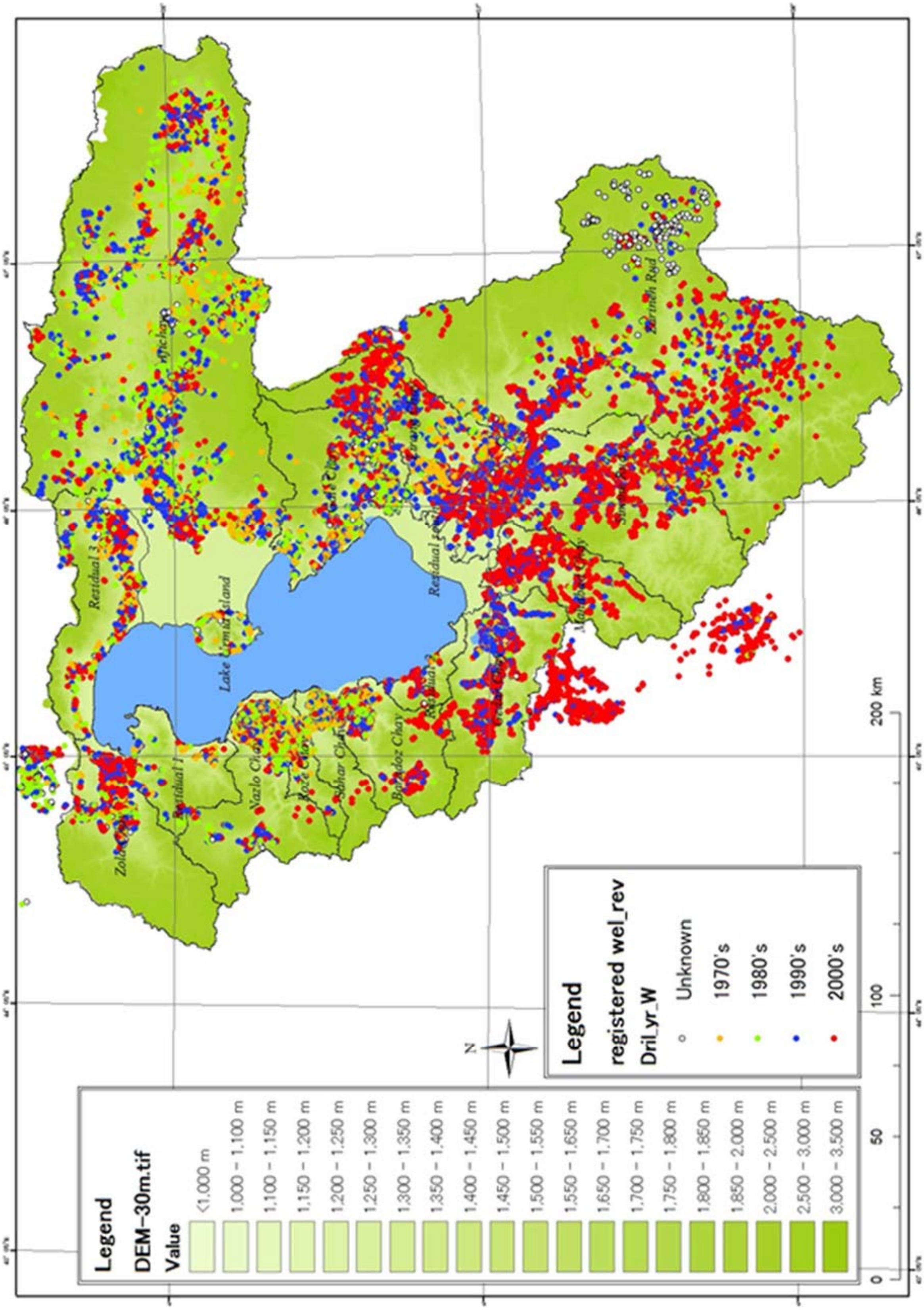
*Prepared by the Survey Team based on data from IWRM Co.

Table 4.7.2 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 the Survey Team based on data from WMC



*Prepared by JS based on data provided from WMC

Figure 4.7.5 Distribution of Well Permitted by WMC (Colored by Constructed Period)

4.7.3 Other Water Related Facilities

Information on water related facilities were provided from ULRP. These information/data are spatially and temporarily limited.

Table 4.7.3 Data Provided by ULRP

	File Name	Translated	Time Series	Available information
1	Abband	Waterway	2007-2010	Not to be applied (Detailed channel is not modeled)
2	Anhar1	Creek	2008-2010	Not to be applied (Creek is not modeled)
3	Motorpomp	Motor pump	2009	Orchard-Area/Irrigation method (TBC) To be referred but lack of amount
4	Qanat	Qanat	2008-2013 (gap time in 2011,2012)	Not to be applied (Qanat is not modeled)
5	Spring	Spring	2001, 2002, 2008, 2009, 2010, 2011	Not to be applied (Spring is not modeled)
6	Operation hours and discharge	Operation hours and discharge	-	Operation hour and discharge (TBC) These data seem to be that of pump.

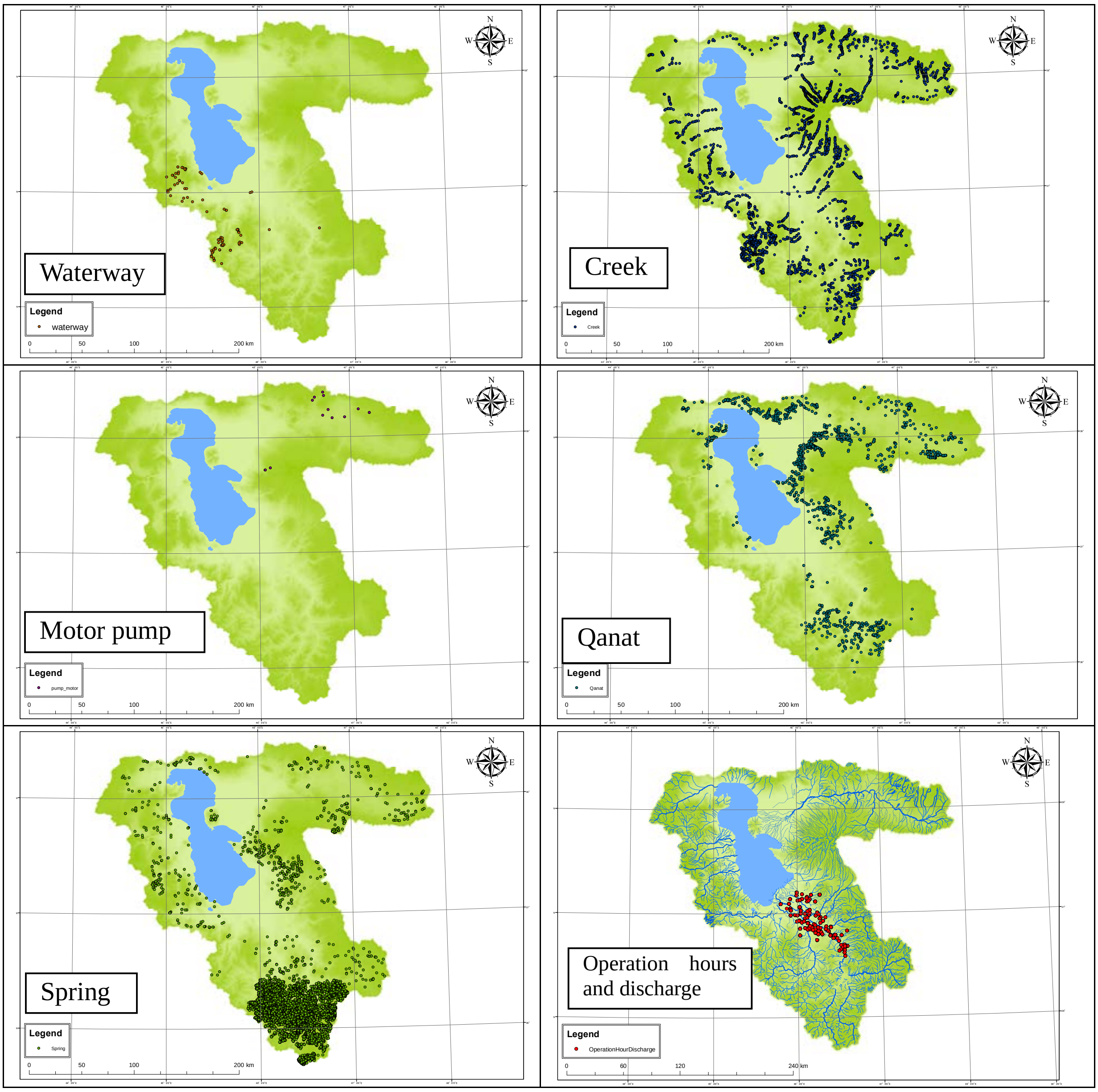


Figure 4.7.6 Collected Data of Water-Related Facilies