# 1. SYRDARYA BASIN WATER AND ENERGY COMPLEX

## 1.1. Syrdarya Basin Water Resources

### 1.1.1. Hydrography of the Basin

The Syrdarya basin belongs to the basin of the Aral Sea and covers a territory of 44.9 thousand km$^2$ (32% of the whole territory of Central Asia). From the hydrographic point, the Syrdarya basin can be divided into four specific areas. The first is the upper mountain area, where the main streams originate; second is the flow transit area; third is the flow dispersion zone, where the basic irrigated lands are located, and where the water is withdrawn and partially returned to the river; and fourth is the delta of the Syrdarya River. The delta is the territory where the river flows into the Aral Sea, where the main river-bed splits into separate flowing arms with a specific natural complex. The delta of the Syrdarya River is delimited by the Kazalinsk hydro-junction upstream and by the Karateren hydro-post downstream where the river enters the sea.

Based on the hydrologic, physical-geographic, topographic and other conditions, the territory of the Syrdarya basin is generally divided into 3 water-using regions:

**Upstream** – the basins of the Naryn and Karadarya Rivers limited by the Atbashi and Alai mountain ranges, in the North and East – by Terskey-Alatau and Talas Alatau, in the West – by the spurs of the Kuraminsk and Chatkalsk mountain ranges, the basins of its left and right tributaries within the Fergana Valley. From an administrative point of view, the upstream lands are located within the territories of three countries – Uzbekistan, Kyrgyzstan, and Tajikistan.

**Midstream** – the basins of the Ahangaran, Chirchik, and Keles Rivers on the right side. The midstream contains the newly-irrigated lands located in the territories of Uzbekistan and Tajikistan – Golodnaya, Farish, Dzhizak, and Dalverzin steppes, and part of the lands of Kazakhstan and the Kyrgyz Republic.

**Downstream** – the basin of the Arys River. The downstream area is the water-using region, the territory of which lays on both shores of the Syrdarya, from Chardara reservoir down to the Aral Sea. This region also contains the right-side part of the Syrdarya Valley within the basin of the Arys River and non-outflow rivers of the slope of Karatau mountain range. Then the Kzylkm and Toguskent steppes follow. The whole downstream region is located within the territory of the Republic of Kazakhstan.

The Chu and Talas Rivers currently do not reach the Syrdarya, while in the past they were its tributaries on the right side. The biggest rivers of the Syrdarya basin (the Naryn, Karadarya, and Chirchik Rivers) and the majority of the small tributaries are rivers of snow-glacier supply, while rivers of glacier-snow supply are located only in the upstream of the Naryn

River, and on the Northern slopes of the Turkestan and Alai mountain ranges (the Aksu, Hodzhabakirgan, Isfara, Sokh, Shakhimardan, Isfairam, and Akbura Rivers). This distinguishes the Syrdarya basin from the basin of the Amudarya River, where the rivers of glacier-snow supply prevail. The second feature of the Syrdarya basin is its significantly smaller flow in comparison to the Amudarya basin (the average flow in the Syrdarya basin is 8 L/s/km$^2$, while in the Amudarya basin it is 11 L/s/km$^2$).

### 1.1.2. Main Tributaries and their Contribution to Formation of the Syrdarya Water Resources

The Syrdarya basin contains 29.78 thousand rivers, about 110 of which have been examined. The biggest ones are: the Syrdarya (together with Naryn), Karadarya (including Tar), Chirchik (together with Chatkal), and Arys Rivers. The outflow of the Naryn River (at Uchkurgan) equals about 36% of the total water resources of the basin, the outflow of Karadarya River (at Kampyrravat) is equal to 11%. Tributaries within the Fergana valley (at the exit from the mountains) are estimated as 21%, while tributaries within Golodnaya steppe are equal to 2%. The total flow of the Chirchik (at Hodzhikent), Keles (at Stepnoe), and Akhangaran (at Turk) Rivers is equal to 23%. The total flow of the Arys River, and of the rivers of the Karatau mountain range is estimated as 7%. For the main rivers, the average annual flows are as follows:

| River | Flow (km$^3$/year) |
|---|---|
| Naryn | 14.54 |
| Karadarya | 3.92 |
| Between Naryn and Karadarya | 2.07 |
| Right shore of Fergana valley | 1.19 |
| Left shore of Fergana valley | 4.55 |
| Midstream rivers | 0.30 |
| Chirchik | 7.90 |
| Akhangaran | 0.66 |
| Keles | 0.25 |
| Arys and Bugun | 1.18 |
| Downstream | 0.60 |
| Total | 32.20 |

The flow of the transboundary rivers is estimated as 27.64 km$^3$/year, or 74.3% of the total resources (transboundary and local), including the following:

| River | Flow (km$^3$/year) |
|---|---|
| Naryn | 12.83 |
| Karadarya | 2.06 |
| Fergana valley | 6.90 |
| Chirchik | 5.85 |
| Total | 27.64 |

### 1.1.3. Water Resources in Years of Different Water Supply

The annual water resources of the Syrdarya basin (the registered surface inflow) during the period 1910-93 is estimated to be 36 $km^3$/year on average, 31 $km^3$/year for the 75% year, and 27 $km^3$/year for the low water (90%) year. For the purpose of comparison: in the "Scheme of complex use and protection of water resources of the Syrdarya" the average annual surface inflow is 37.1 $km^3$/year, including the registered inflow of 36.2 $km^3$/year.

The general characteristics of the annual flows of the main rivers of the basin – Naryn, Karadarya, and Chirchik – in the region of flow formation, based on the inflows to the upstream water reservoirs – Toktogul, Andijan, and Charvak ($km^3$/year), are shown in Table 1.1.3.1.

**Table 1.1.3.1**
**Characteristics of Annual Flows ($km^3$/yr) of the Main Rivers of the Syrdaray Basin.**

| River<br>Reservoir | Naryn R.<br>Toktogul Res. | Karadarya R.<br>Andijan Res. | Chirchik R.<br>Charvak Res. | Total |
|---|---|---|---|---|
| 1910-1924 | 11.82 | 3.99 | 6.94 | 22.75 |
| 1925-1951 | 10.60 | 3.71 | 6.12 | 20.43 |
| 1952-1973 | 12.83 | 4.13 | 6.92 | 23.88 |
| 1974-1986 | 10.20 | 3.19 | 5.57 | 18.96 |
| 1987-1993 | 12.20 | 4.20 | 6.60 | 23.00 |

The arithmetic average amount of total flow during the whole existing period of record (1911-99) for the Syrdarya basin is 34 $km^3$/year, including: for the Naryn River (inflow to Toktogul reservoir) – 12.5 $km^3$/year, for the Karadarya River (inflow to Andijan reservoir) – 3.9 $km^3$/year, for the Chirchik River (inflow to Charvak reservoir) – 6.5 $km^3$/year, for the Ugam River – 0.7 $km^3$/year.

Analysis of hydrologic observations shows, during the current century, alternating periods of high and low flows in the rivers of the Syrdarya basin. The periods of 1900-24, 1952-73, 1987-88, 1992-93 were high flow years, while 1925-51, 1974-86, 1989-90 were low flow years. In the chronological set of flows of the basin, among the "century" cycles of 60 years, there can be distinguished "inner-century" cycles of 12 years, coinciding with the duration of solar activity, which also include small groups of years with high and low water flows. The period of 1951-74 is a typical period in this sense, which consists of two full cycles of 12 years. The standard flow for the Syrdarya basin calculated on the base of this typical period is estimated to be 37.2 $km^3$/year, including for the countries, for transboundary and local water ($km^3$/year) as shown in Tabel 1.1.3.2.

**Table 1.1.3.2**
**Syrdarya Basin Flow for Each Country: Transboundary and Local Waters ($km^3$/yr).**

| Country | Total | Transboundary | Local |
|---|---|---|---|
| Kazakhstan | 2.4 | 0.75 | 1.65 |
| Kyrgyz Republic | 27.6 | 23.39 | 4.21 |

| | | | |
|---|---|---|---|
| Tajikistan | 1.0 | 0.70 | 0.30 |
| Uzbekistan | 6.2 | 2.80 | 3.40 |
| Total | 37.2 | 27.64 | 9.56 |

For the purpose of comparison – the ordinates of the theoretical curves of provision of various annual amounts of flow for the rivers Naryn, Karadara, and Chirchik (km$^3$/year) for the zone of formation of water resources (three-parameters gamma-distribution) are given in Table 1.1.3.1.

The inflows to the Syrdarya basin for the years 1988 - 99 are shown in Tables 1.1.3.4-14 and Figures 1.1.3.1-6.

**Table 1.1.3.3**
**Curves of annual flows for Naryn, Karadara, and Chirchik Rivers (km$^3$/year).**

| Provision, % | Naryn river | Karadarya river | Chirchik river |
|---|---|---|---|
| 1 | 18.7 | 7.7 | 11.0 |
| 5 | 16.3 | 6.2 | 9.4 |
| 10 | 14.8 | 5.5 | 8.5 |
| 25 | 12.9 | 4.5 | 7.4 |
| 50 | 11.1 | 3.6 | 6.3 |
| 75 | 9.6 | 2.9 | 5.3 |
| 90 | 8.5 | 2.4 | 4.6 |
| 95 | 7.8 | 2.1 | 4.2 |
| 99 | 6.8 | 1.7 | 3.6 |

## Table 1.1.3.4. Inflows to Syrdarya Basin 1988-89

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to Upper Reservoirs: | | | | | | | | | |
| To Toktogul Reservoir | 2,705.6 | 3,051.2 | 113% | 9,356.4 | 7,276.0 | 78% | 12,062.0 | 10,327.2 | 86% |
| To Andijan Reservoir | 920.2 | 994.6 | 108% | 2,902.7 | 1,796.2 | 62% | 3,822.9 | 2,790.8 | 73% |
| To Charvak Reservoir (4 Rivers) | 1,337.1 | 1,277.5 | 96% | 5,667.9 | 4,531.0 | 80% | 7,005.0 | 5,808.5 | 83% |
| Total: | 4,962.8 | 5,323.3 | 107% | 17,927.0 | 13,603.0 | 76% | 22,889.8 | 18,926.3 | 83% |
| Lateral Inflows: | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 375.9 | 96% | 1,157.3 | 855.6 | 74% | 1,550.6 | 1,231.5 | 79% |
| Uchkurgan, Uchtepe-Kairakkum | 3,803.5 | 3,619.1 | 95% | 3,588.9 | 3,526.1 | 98% | 7,392.4 | 7,145.2 | 97% |
| Andijan-Uchtepe | 2,068.5 | 1,869.4 | 90% | 2,426.8 | 1,970.9 | 81% | 4,495.3 | 3,840.3 | 85% |
| Kairakkum-Chardara | 2,826.7 | 2,542.6 | 90% | 3,181.0 | 2,115.8 | 67% | 6,007.7 | 4,658.4 | 78% |
| Gazalkent-Chirchik Estuary | 885.6 | 631.8 | 71% | 977.1 | 471.8 | 48% | 1,862.7 | 1,103.6 | 59% |
| Total: | 9,977.5 | 9,038.8 | 91% | 11,331.0 | 8,940.2 | 79% | 21,308.5 | 17,979.0 | 84% |
| Grand Total: | | 14,362.0 | 96% | 29,258.0 | 22,543.0 | 77% | 29,258.0 | 36,905.0 | 126% |

## Table 1.1.3.5. Inflows to Syrdarya Basin 1989-90

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to Upper Reservoirs: | | | | | | | | | |
| To Toktogul Reservoir | 2,705.6 | 2,850.9 | 105% | 9,356.4 | 9,648.0 | 103% | 12,062.0 | 12,498.9 | 104% |
| To Andijan Reservoir | 920.2 | 888.2 | 97% | 2,902.7 | 2,340.5 | 81% | 3,822.9 | 3,228.7 | 84% |
| To Charvak Reservoir (4 Rivers) | 1,337.1 | 1,403.0 | 105% | 5,667.9 | 6,997.7 | 123% | 7,005.0 | 8,400.7 | 120% |
| Total: | 4,962.8 | 5,142.4 | 104% | 17,927.0 | 18,986.0 | 106% | 22,889.8 | 24,128.4 | 105% |
| Lateral Inflows: | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 417.2 | 106% | 1,157.3 | 1,309.6 | 113% | 1,550.6 | 1,726.8 | 111% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 3,636.1 | 96% | 3,588.9 | 3,589.2 | 100% | 7,392.4 | 7,225.3 | 98% |
| Andijan-Uchtepe | 2,068.5 | 1,992.6 | 96% | 2,426.8 | 2,537.1 | 105% | 4,495.3 | 4,529.7 | 101% |
| Kairakkum-Chardara | 2,826.7 | 2,758.0 | 98% | 3,181.0 | 2,924.6 | 92% | 6,007.7 | 5,682.6 | 95% |
| Gazalkent-Chirchik Estuary | 885.6 | 827.2 | 93% | 977.1 | 962.6 | 99% | 1,862.7 | 1,789.8 | 96% |
| Total: | 9,977.5 | 9,631.1 | 97% | 11,331.0 | 11,323.0 | 100% | 21,308.5 | 20,954.1 | 98% |
| Grand Total: | 14,940.4 | 14,774.0 | 99% | 29,258.0 | 30,309.0 | 104% | 44,198.4 | 45,083.0 | 102% |

**Table 1.1.3.6. Inflows to Syrdarya Basin 1990-91**

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to Upper Reservoirs: | | | | | | | | | |
| To Toktogul Reservoir | 2,705.6 | 2,787.6 | 103% | 9,356.4 | 7,928.2 | 85% | 12,062.0 | 10,715.8 | 89% |
| To Andijan Reservoir | 920.2 | 938.8 | 102% | 2,902.7 | 2,372.2 | 82% | 3,822.9 | 3,311.0 | 87% |
| To Charvak Reservoir (4 Rivers) | 1,337.1 | 1,347.9 | 101% | 5,667.9 | 4,425.1 | 78% | 7,005.0 | 5,773.0 | 82% |
| Total: | 4,962.8 | 5,074.3 | 102% | 17,927.0 | 14,726.0 | 82% | 22,889.8 | 19,800.3 | 87% |
| Lateral Inflows: | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 403.1 | 103% | 1,157.3 | 1,164.4 | 101% | 1,550.6 | 1,567.5 | 101% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 3,498.9 | 92% | 3,588.9 | 3,214.0 | 90% | 7,392.4 | 6,712.9 | 91% |
| Andijan-Uchtepe | 2,068.5 | 2,125.3 | 103% | 2,426.8 | 2,343.5 | 97% | 4,495.3 | 4,468.8 | 99% |
| Kairakkum-Chardara | 2,826.7 | 3,030.8 | 107% | 3,181.0 | 3,044.0 | 96% | 6,007.7 | 6,074.8 | 101% |
| Gazalkent-Chirchik Estuary | 885.6 | 773.9 | 87% | 977.1 | 829.5 | 85% | 1,862.7 | 1,603.4 | 86% |
| Total: | 9,977.5 | 9,832.0 | 99% | 11,331.0 | 10,595.0 | 94% | 21,308.5 | 20,427.0 | 96% |
| Grand Total: | 14,940.4 | 14,906.0 | 100% | 29,258.0 | 25,321.0 | 87% | 44,198.4 | 40,227.0 | 91% |

**Table 1.1.3.7. Inflows to Syrdarya Basin 1991-92**

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to Upper Reservoirs: | | | | | | | | | |
| To Toktogul Reservoir | 2,705.6 | 2,834.0 | 105% | 9,356.4 | 8,990.3 | 96% | 12,062.0 | 11,824.3 | 98% |
| To Andijan Reservoir | 920.2 | 877.1 | 95% | 2,902.7 | 2,976.5 | 103% | 3,822.9 | 3,853.6 | 101% |
| To Charvak Reservoir (4 Rivers) | 1,337.1 | 1,112.7 | 83% | 5,667.9 | 5,517.8 | 97% | 7,005.0 | 6,630.5 | 95% |
| Total: | 4,962.8 | 4,823.8 | 97% | 17,927.0 | 17,485.0 | 98% | 22,889.8 | 22,308.8 | 97% |
| Lateral Inflows: | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 396.0 | 101% | 1,157.3 | 1,473.8 | 127% | 1,550.6 | 1,869.8 | 121% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 3,709.8 | 98% | 3,588.9 | 4,277.9 | 119% | 7,392.4 | 7,987.7 | 108% |
| Andijan-Uchtepe | 2,068.5 | 2,038.3 | 99% | 2,426.8 | 2,473.3 | 102% | 4,495.3 | 4,511.6 | 100% |
| Kairakkum-Chardara | 2,826.7 | 2,528.7 | 89% | 3,181.0 | 3,762.7 | 118% | 6,007.7 | 6,291.4 | 105% |
| Gazalkent-Chirchik Estuary | 885.6 | 943.3 | 107% | 977.1 | 1,124.4 | 115% | 1,862.7 | 2,067.7 | 111% |
| Total: | 9,977.5 | 9,616.1 | 96% | 11,331.0 | 13,112.0 | 116% | 21,308.5 | 22,728.1 | 107% |
| Grand Total: | 14,940.4 | 14,440.0 | 97% | 29,258.0 | 30,597.0 | 105% | 44,198.4 | 45,037.0 | 102% |

**Table 1.1.3.8. Inflows to Syrdarya Basin 1992-93**

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 3,049.7 | 113% | 9,356.4 | 10,640.0 | 114% | 12,062.0 | 13,689.7 | 113% |
| To Andijan | 920.2 | 897.2 | 98% | 2,902.7 | 4,066.0 | 140% | 3,822.9 | 4,963.2 | 130% |
| To Charvak (4 rivers) | 1,337.1 | 1,284.9 | 96% | 5,667.9 | 6,943.8 | 123% | 7,005.0 | 8,228.7 | 117% |
| Total: | 4,962.8 | 5,231.8 | 105% | 17,927.0 | 21,650.0 | 121% | 22,889.8 | 26,881.8 | 117% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 486.3 | 124% | 1,157.3 | 1,582.1 | 137% | 1,550.6 | 2,068.4 | 133% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,414.3 | 116% | 3,588.9 | 3,974.8 | 111% | 7,392.4 | 8,389.1 | 113% |
| Andijan-Uchtepe | 2,068.5 | 2,291.9 | 111% | 2,426.8 | 3,046.4 | 126% | 4,495.3 | 5,338.3 | 119% |
| Kairakkum-Chardara | 2,826.7 | 2,996.2 | 106% | 3,181.0 | 4,358.8 | 137% | 6,007.7 | 7,355.0 | 122% |
| Gazalkent-Chirchik Estuary | 885.6 | 1,135.1 | 128% | 977.1 | 1,097.6 | 112% | 1,862.7 | 2,232.7 | 120% |
| Total: | 9,977.5 | 11,324.0 | 113% | 11,331.0 | 14,060.0 | 124% | 21,308.5 | 25,384.0 | 119% |
| Grand Total: | 14,940.4 | 16,556.0 | 111% | 29,258.0 | 35,710.0 | 122% | 44,198.4 | 52,266.0 | 118% |

**Table 1.1.3.9. Inflows to Syrdarya Basin 1993-94**

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 3,084.1 | 114% | 9,356.4 | 12,187.0 | 130% | 12,062.0 | 15,271.1 | 127% |
| To Andijan | 920.2 | 1,189.2 | 129% | 2,902.7 | 3,572.0 | 123% | 3,822.9 | 4,761.2 | 125% |
| To Charvak (4 rivers) | 1,337.1 | 1,564.6 | 117% | 5,667.9 | 7,053.9 | 124% | 7,005.0 | 8,618.5 | 123% |
| Total: | 4,962.8 | 5,837.9 | 118% | 17,927.0 | 22,813.0 | 127% | 22,889.8 | 28,650.9 | 125% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 462.3 | 118% | 1,157.3 | 1,601.9 | 138% | 1,550.6 | 2,064.2 | 133% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,415.0 | 116% | 3,588.9 | 3,765.0 | 105% | 7,392.4 | 8,180.0 | 111% |
| Andijan-Uchtepe | 2,068.5 | 2,837.0 | 137% | 2,426.8 | 2,833.3 | 117% | 4,495.3 | 5,670.3 | 126% |
| Kairakkum-Chardara | 2,826.7 | 3,694.9 | 131% | 3,181.0 | 4,611.7 | 145% | 6,007.7 | 8,306.6 | 138% |
| Gazalkent-Chirchik Estuary | 885.6 | 883.5 | 100% | 977.1 | 937.4 | 96% | 1,862.7 | 1,820.9 | 98% |
| Total: | 9,977.5 | 12,293.0 | 123% | 11,331.0 | 13,749.0 | 121% | 21,308.5 | 26,042.0 | 122% |
| Grand Total: | 14,940.4 | 18,131.0 | 121% | 29,258.0 | 36,563.0 | 125% | 44,198.4 | 54,694.0 | 124% |

## Table 1.1.3.10. Inflows to Syrdarya Basin 1994-95

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 3,013.3 | 111% | 9,356.4 | 8,005.9 | 86% | 12,062.0 | 11,019.2 | 91% |
| To Andijan | 920.2 | 1,004.3 | 109% | 2,902.7 | 1,965.5 | 68% | 3,822.9 | 2,969.8 | 78% |
| To Charvak (4 rivers) | 1,337.1 | 1,890.7 | 141% | 5,667.9 | 4,915.2 | 87% | 7,005.0 | 6,805.9 | 97% |
| Total: | 4,962.8 | 5,908.3 | 119% | 17,927.0 | 14,887.0 | 83% | 22,889.8 | 20,795.3 | 91% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 436.0 | 111% | 1,157.3 | 1,136.9 | 98% | 1,550.6 | 1,572.9 | 101% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,228.5 | 111% | 3,588.9 | 2,893.4 | 81% | 7,392.4 | 7,121.9 | 96% |
| Andijan-Uchtepe | 2,068.5 | 2,539.5 | 123% | 2,426.8 | 1,893.5 | 78% | 4,495.3 | 4,433.0 | 99% |
| Kairakkum-Chardara | 2,826.7 | 3,580.0 | 127% | 3,181.0 | 2,403.7 | 76% | 6,007.7 | 5,983.7 | 100% |
| Gazalkent-Chirchik Estuary | 885.6 | 904.0 | 102% | 977.1 | 863.6 | 88% | 1,862.7 | 1,767.6 | 95% |
| Total: | 9,977.5 | 11,688.0 | 117% | 11,331.0 | 9,191.1 | 81% | 21,308.5 | 20,879.1 | 98% |
| Grand Total: | 14,940.4 | 17,596.0 | 118% | 29,258.0 | 24,078.0 | 82% | 44,198.4 | 41,674.0 | 94% |

## Table 1.1.3.11. Inflows to Syrdarya Basin 1995-96

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 2,625.1 | 97% | 9,356.4 | 10,269.0 | 110% | 12,062.0 | 12,894.1 | 107% |
| To Andijan | 920.2 | 687.2 | 75% | 2,902.7 | 3,257.0 | 112% | 3,822.9 | 3,944.2 | 103% |
| To Charvak (4 rivers) | 1,337.1 | 1,290.3 | 97% | 5,667.9 | 5,659.0 | 100% | 7,005.0 | 6,949.3 | 99% |
| Total: | 4,962.8 | 4,602.6 | 93% | 17,927.0 | 19,185.0 | 107% | 22,889.8 | 23,787.6 | 104% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 372.0 | 95% | 1,157.3 | 1,249.2 | 108% | 1,550.6 | 1,621.2 | 105% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,224.9 | 111% | 3,588.9 | 2,990.6 | 83% | 7,392.4 | 7,215.5 | 98% |
| Andijan-Uchtepe | 2,068.5 | 2,128.6 | 103% | 2,426.8 | 2,877.8 | 119% | 4,495.3 | 5,006.4 | 111% |
| Kairakkum-Chardara | 2,826.7 | 2,177.8 | 77% | 3,181.0 | 3,463.7 | 109% | 6,007.7 | 5,641.5 | 94% |
| Gazalkent-Chirchik Estuary | 885.6 | 819.0 | 92% | 977.1 | 793.1 | 81% | 1,862.7 | 1,612.1 | 87% |
| Total: | 9,977.5 | 9,722.3 | 97% | 11,331.0 | 11,374.0 | 100% | 21,308.5 | 21,096.3 | 99% |
| Grand Total: | 14,940.4 | 14,325.0 | 96% | 29,258.0 | 30,559.0 | 104% | 44,198.4 | 44,884.0 | 102% |

## Table 1.1.3.12. Inflows to Syrdarya Basin 1996-97

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 3,106.3 | 115% | 9,356.4 | 7,908.8 | 85% | 12,062.0 | 11,015.1 | 91% |
| To Andijan | 920.2 | 760.4 | 83% | 2,902.7 | 1,435.6 | 49% | 3,822.9 | 2,196.0 | 57% |
| To Charvak (4 rivers) | 1,337.1 | 1,332.3 | 100% | 5,667.9 | 5,232.5 | 92% | 7,005.0 | 6,564.8 | 94% |
| Total: | 4,962.8 | 5,199.0 | 105% | 17,927.0 | 14,577.0 | 81% | 22,889.8 | 19,776.0 | 86% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 401.9 | 102% | 1,157.3 | 948.6 | 82% | 1,550.6 | 1,350.5 | 87% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,425.9 | 116% | 3,588.9 | 2,828.0 | 79% | 7,392.4 | 7,253.9 | 98% |
| Andijan-Uchtepe | 2,068.5 | 2,518.3 | 122% | 2,426.8 | 2,174.8 | 90% | 4,495.3 | 4,693.1 | 104% |
| Kairakkum-Chardara | 2,826.7 | 2,978.6 | 105% | 3,181.0 | 2,610.4 | 82% | 6,007.7 | 5,589.0 | 93% |
| Gazalkent-Chirchik Estuary | 885.6 | 816.0 | 92% | 977.1 | 663.4 | 68% | 1,862.7 | 1,479.4 | 79% |
| Total: | 9,977.5 | 11,141.0 | 112% | 11,331.0 | 9,225.2 | 81% | 21,308.5 | 20,366.2 | 96% |
| Grand Total: | 14,940.4 | 16,340.0 | 109% | 29,258.0 | 23,802.0 | 81% | 44,198.4 | 40,142.0 | 91% |

## Table 1.1.3.13. Inflows to Syrdarya Basin 1997-98

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 2,721.9 | 101% | 9,356.4 | 11,294.0 | 121% | 12,062.0 | 14,015.9 | 116% |
| To Andijan | 920.2 | 718.8 | 78% | 2,902.7 | 5,320.1 | 183% | 3,822.9 | 6,038.9 | 158% |
| To Charvak (4 rivers) | 1,337.1 | 1,268.0 | 95% | 5,667.9 | 8,109.4 | 143% | 7,005.0 | 9,377.4 | 134% |
| Total: | 4,962.8 | 4,708.7 | 95% | 17,927.0 | 24,724.0 | 138% | 22,889.8 | 29,432.7 | 129% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 411.2 | 105% | 1,157.3 | 1,260.3 | 109% | 1,550.6 | 1,671.5 | 108% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,260.2 | 112% | 3,588.9 | 3,427.8 | 96% | 7,392.4 | 7,688.0 | 104% |
| Andijan-Uchtepe | 2,068.5 | 2,144.0 | 104% | 2,426.8 | 3,103.8 | 128% | 4,495.3 | 5,247.8 | 117% |
| Kairakkum-Chardara | 2,826.7 | 3,956.8 | 140% | 3,181.0 | 4,898.8 | 154% | 6,007.7 | 8,855.6 | 147% |
| Gazalkent-Chirchik Estuary | 885.6 | 955.1 | 108% | 977.1 | 1,401.2 | 143% | 1,862.7 | 2,356.3 | 126% |
| Total: | 9,977.5 | 11,727.0 | 118% | 11,331.0 | 14,092.0 | 124% | 21,308.5 | 25,819.0 | 121% |
| Grand Total: | 14,940.4 | 16,436.0 | 110% | 29,258.0 | 38,815.0 | 133% | 44,198.4 | 55,251.0 | 125% |

**Table 1.1.3.14. Inflows to Syrdarya Basin 1998-99**

| Parameters | Non-Vegetation (mln.m3) | | | Vegetation (mln.m3) | | | Year (mln.m3) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Norm | Fact | % | Norm | Fact | % | Norm | Fact | % |
| Inflows to the Top Reservoirs: | | | | | | | | | |
| To Toktogul | 2,705.6 | 2,477.2 | 92% | 9,356.4 | 11,614.0 | 124% | 12,062.0 | 14,091.2 | 117% |
| To Andijan | 920.2 | 786.1 | 85% | 2,902.7 | 3,870.9 | 133% | 3,822.9 | 4,657.0 | 122% |
| To Charvak (4 rivers) | 1,337.1 | 1,559.7 | 117% | 5,667.9 | 5,909.7 | 104% | 7,005.0 | 7,469.4 | 107% |
| Total: | 4,962.8 | 4,823.0 | 97% | 17,927.0 | 21,394.0 | 119% | 22,889.8 | 26,217.0 | 115% |
| Lateral Inflows : | | | | | | | | | |
| Toktogul-Uchkurgan | 393.3 | 470.8 | 120% | 1,157.3 | 1,190.9 | 103% | 1,550.6 | 1,661.7 | 107% |
| Uchkurgan. Uchtepe-Kairakkum | 3,803.5 | 4,605.5 | 121% | 3,588.9 | 3,479.9 | 97% | 7,392.4 | 8,085.4 | 109% |
| Andijan-Uchtepe | 2,068.5 | 2,931.6 | 142% | 2,426.8 | 3,037.1 | 125% | 4,495.3 | 5,968.7 | 133% |
| Kairakkum-Chardara | 2,826.7 | 3,047.2 | 108% | 3,181.0 | 3,233.0 | 102% | 6,007.7 | 6,280.2 | 105% |
| Gazalkent-Chirchik Estuary | 885.6 | 1,074.3 | 121% | 977.1 | 596.0 | 61% | 1,862.7 | 1,670.3 | 90% |
| Total: | 9,977.5 | 12,129.0 | 122% | 11,331.0 | 11,537.0 | 102% | 21,308.5 | 23,666.0 | 111% |
| Grand Total: | 14,940.4 | 16,952.0 | 113% | 29,258.0 | 32,931.0 | 113% | 44,198.4 | 49,883.0 | 113% |

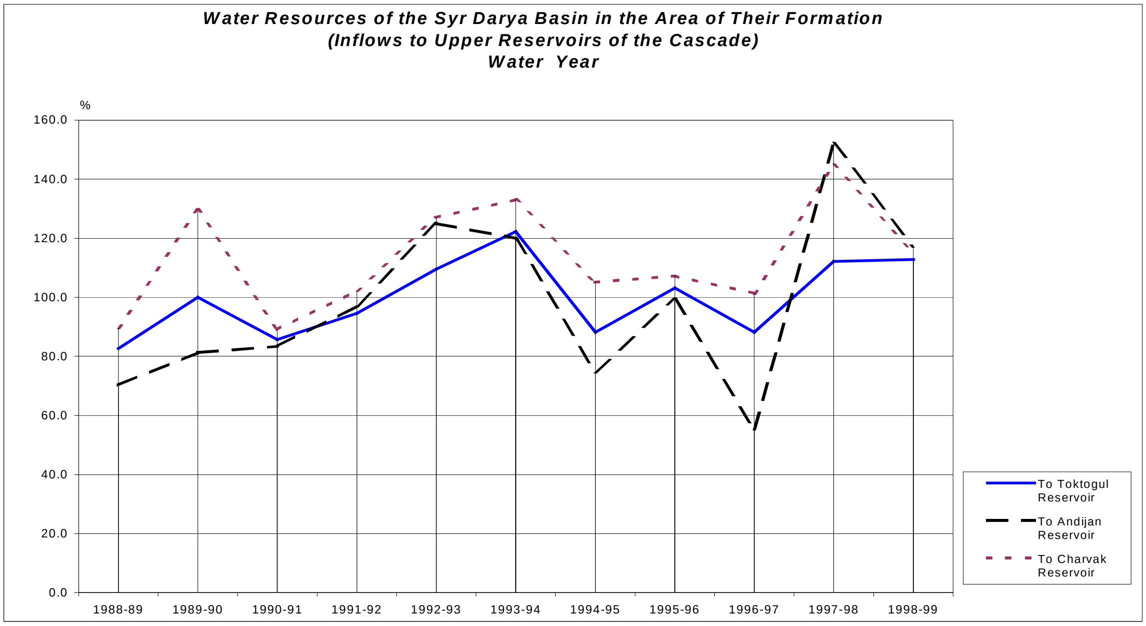



**Figure 1.1.3.1.**

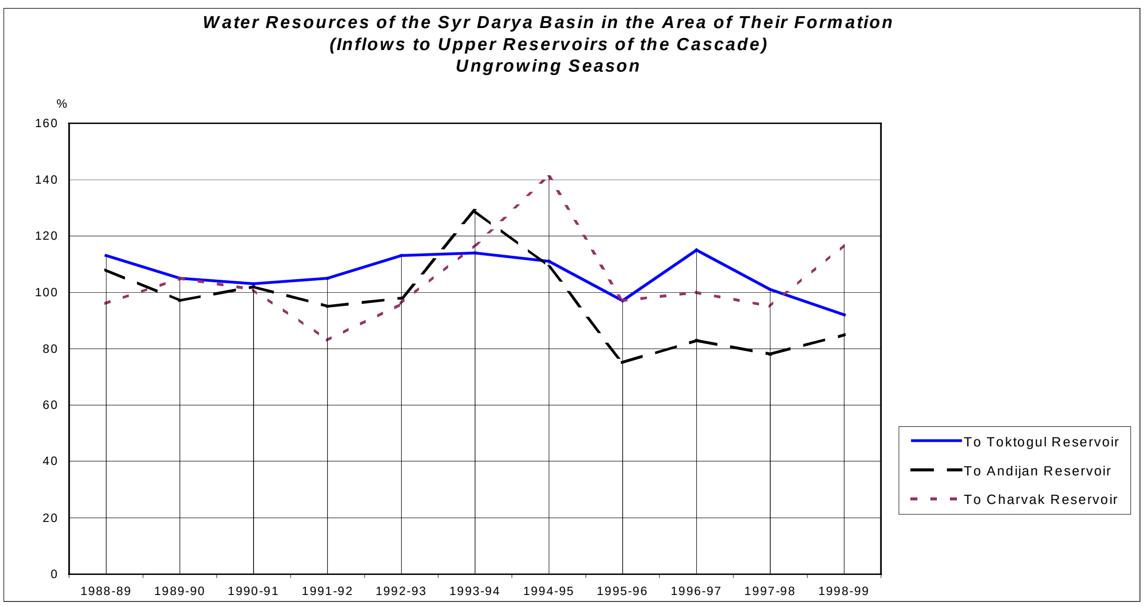



**Figure 1.1.3.2**

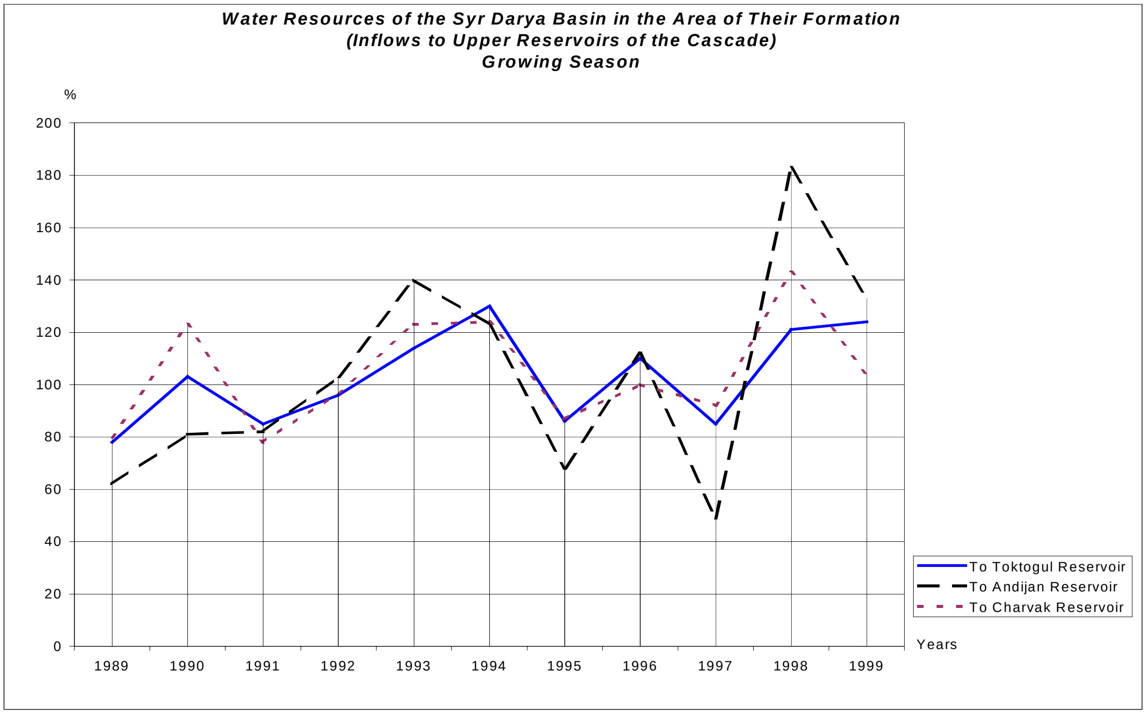



**Figure 1.1.3.3**

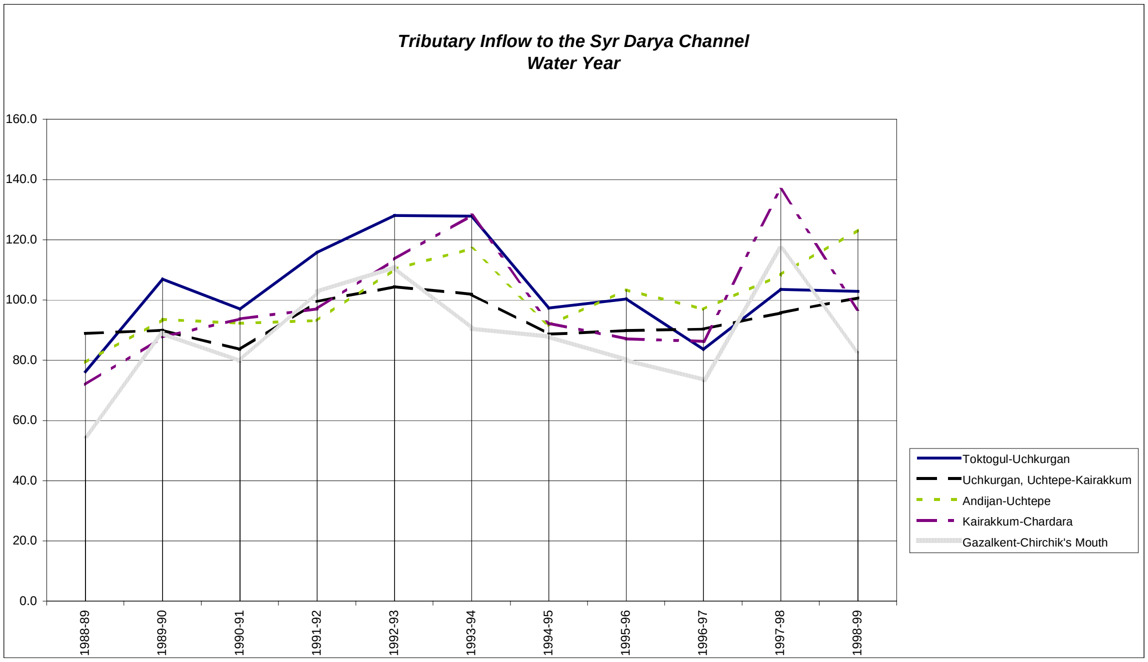



**Figure 1.1.3.4**

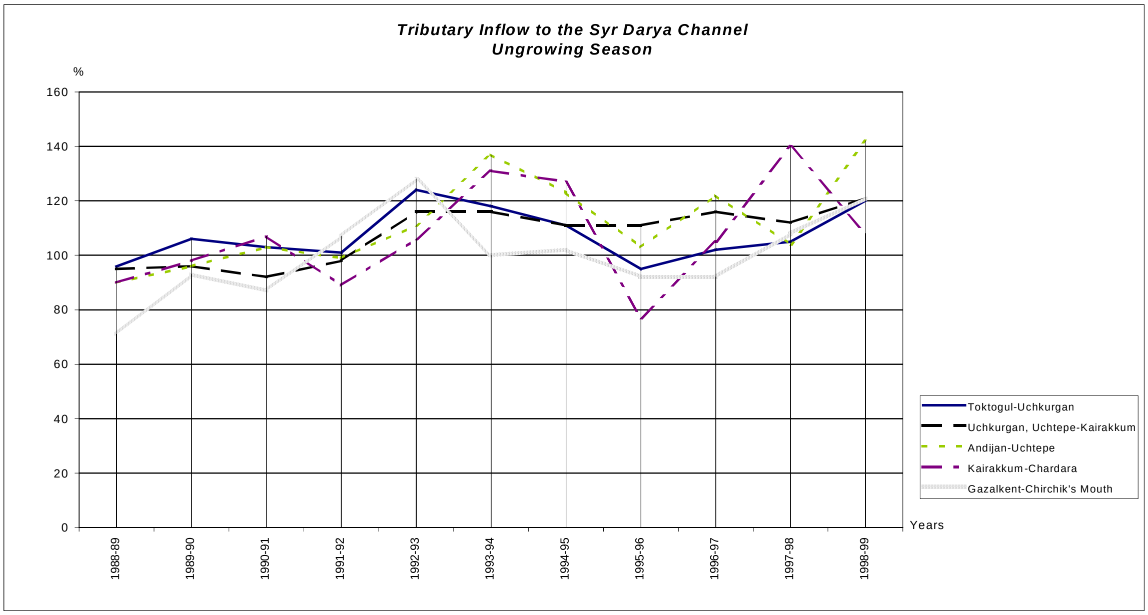



**Figure 1.1.3.5**

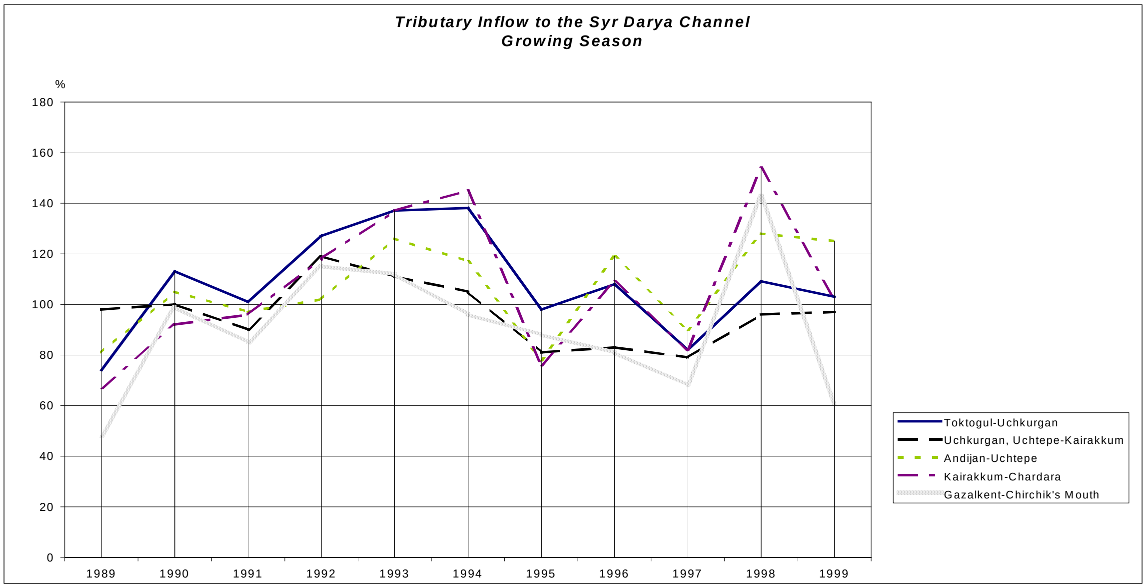



**Figure 1.1.3.6**

### 1.1.4. Water Balances at River Sites and Seasonal Flows Passing Through River Stations

The projected ("Scheme") option, the actual (1985, 1987-92), and the extended water balances for the Naryn and Syrdarya Rivers were calculated as shown in Table 1.1.4.1, before significant changes from these projected regimes in the scheme of the water reservoirs ($km^3$/year).

**Table 1.1.4.1**
**Water Balance for the Naryn-Syrdarya Basin ($km^3$/year).**

| Items of the Balance | Under the "Scheme" | 1985 | 1987-1992 |
|---|---|---|---|
| 1. Outflow below Toktogul | 11.03 | 9.19 | 12.42 |
| 2. Side tributaries | 15.98 | 21.43 | 19.78 |
| *Total inflow (1+2)* | *27.01* | *30.62* | *32.20* |
| 3. Withdrawal of water | 19.63 | 28.25 | 23.62 |
| 4. Losses net of non-registered inflow | 3.6 | 1.59 | 3.79 |
| 5. Inflow to reservoirs | 0.0 | 0.0 | 0.0 |
| 6. Inflow to the Aral Sea | 3.78 | 0.58 | 4.79 |
| *Total outflow (3+4+5+6)* | *27.01* | *30.62* | *32.20* |
| *Balance (outflow – inflow)* | *0.0* | *0.0* | *0.0* |

The current extended water balance of the transboundary rivers of the Syrdarya basin for the high-water year (10% of provision), middle-water year (50%), and low-water (90%) year, calculated with the assumption of no lack of irrigation ($km^3$/year) are shown in Table 1.1.4.2. The water balance for the Syrdarya basin below Chardara Reservoir is shown in Table 1.1.4.3.

**Table 1.1.4.2**
**Water Balance for the Syrdarya Basin for Different Water Supply Years ($km^3$/year).**

| Items of the balance | 10% | 50% | 90% |
|---|---|---|---|
| 1. Inflow to the upper water reservoirs (Toktogul, Andijan, Charvak) | 28.5 | 21.1 | 15.8 |
| 2. Side tributaries net of losses of inflow | 15.5 | 14.9 | 13.3 |
| 3. Regulation of the water flow by reservoirs: (+) inflow, (-) outflow | +4.0 | 0.0 | -3.5 |
| 4. Withdrawal of water from the rivers, total: | 32.0 | 32.0 | 29.3 |
| including from Naryn and Syrdarya Rivers | 21.5 | 21.5 | 18.8 |
| 5. Inflow to the Aral Sea | 8.0 | 4.0 | 3.0 |

**Table 1.1.4.3**
**Water Balance for the Syrdarya Basin below Chardara Reservoir ($km^3$/year).**

| Inflow items | Guaranteed | Min | Max |
|---|---|---|---|
| Inflow of the Syrdarya in Kokbulak alignment | 12.5 | 10.6 | 25.18 |
| Inflow to the Syrdarya from rivers Keles and Arys | 1.1 | 0.5 | 2.55 |
| Inflow of collected-drainage water to the river | 0.55 | 0.47 | 0.68 |
| Inflow of the local water to the river | 1.25 | 0.95 | 1.92 |
| Total inflow | 15.40 | 12.52 | 30.33 |
| Outflow items | | | |
| Supply of water users | 8.3 | 6.84 | 8.4 |
| Losses of flow in the river bed | 1.68 | 1.28 | 2.8 |
| Evaporation losses | 0.6 | 0.48 | 1.2 |
| Supply of natural complex | 2.14 | 0.9 | 3.3 |
| Inflow to Aral | 5.6 | 3.2 | 8.46 |
| Total outflow | 18.32 | 12.7 | 24.16 |
| Balance (outflow – inflow) | +2.92 | +0.18 | -6.17 |

An example of passing the flow through different river stations for the seasons of the year – vegetation in 1998, and non-vegetation in 1998-1999 (mln.$m^3$/year) is shown in Table 1.1.4.4.

**Table 1.1.4.4**
**Flow through River Stations for Vegetation and Non-vegetation Periods ($km^3$/year).**

| River Station | Vegetation (1998) | Non-vegetation (1998-99) | Water Year (1998-99) |
|---|---|---|---|
| Inflow to the water reservoirs: | | | |
| - Toktogul | 11,500 | 3,240 | 14,740 |
| - Andijan | 5,243 | 788 | 6,031 |
| - Charvak | 7,208 | 1,541 | 8,749 |
| Total | 23,951 | 5,569 | 29,520 |
| Outflow from the water reservoirs: | | | |
| - Toktogul | 3,680 | 7,940 | 11,620 |
| - Andijan | 4,582 | 588 | 5,170 |
| - Charvak | 6,007 | 2,426 | 8,433 |
| Total | 14,269 | 10,954 | 25,223 |
| Inflow to Kairakum | 8,594 | 11,897 | 20,491 |
| Outflow from Kairakum | 9,912 | 12,794 | 22,706 |
| Inflow to Chardara | 10,606 | 14,381 | 24,987 |
| Outflow from Chardara | 12,728 | 8,003 | 20,731 |
| Inflow to Aral | 3,535 | 4,706 | 8,241 |

### 1.1.5. River and the Aral Sea, their Role in Maintaining Basin Nature Complexes, Including Delta Territories

In 1920-30, water use in the Syrdarya basin didn't significantly affect the environment. During that period the hydrologic regime of the rivers was close to natural, the hydrographic net was not broken, the quantitative characteristics and the qualitative composition of the water flows in the zones of origination and dispersion of the flows didn't break the natural conditions of reproduction of the basin water-soil resources. The water flow, having an ability to renew and self-purify, supported the natural complexes of the basin. During those years, the whole Syrdarya River was a source of drinking water, mineralization of the river water in the midstream was not higher than 0.2-0.3 g/l, and in the downstream – 0.4-0.5 g/l. Before intensive development of irrigation began, the delta of the Syrdarya River received 4-5 $km^3$ of water per year. The natural-use complex, consisting of lakes, hayfields, tugai forests, and water-marshes, was developed normally and was a source of vegetable and wild animal life. Water supply to the lake systems and irrigated hayfields was carried out through natural drops, canals and channels.

The period since 1960 and up till now (2000) can be characterized as a period of active anthropogenic influence on the basin. The main reason of the loss of renewal abilities of the rivers during this period is the increase in consumptive water use, leading to a breakdown of the normal regimes of the natural complexes. During this period, filling of the delta with water decreased significantly, which has lead to its desertification and degradation. During the period of 1976-90, the average inflow of water to the delta was less than 850 mln.$m^3$, during specific years the delta received less than 500 mln.$m^3$. The flow below Kazalinsk has decreased, and the levels of water in the river did not allow filling of lakes and hayfields in the delta. With the lowering of the the Aral Sea, the erosion basis decreased, which used to make the river beds deeper.

To clearly see the role of the Syrdarya in the supply of river water to the the Aral Sea, consider the whole available set of inflow data (since 1912 to 1993 – hydropost Kazalinsk, since 1993 – hydropost Karateren) and evaluate which direction the dynamics of the flows to the sea changed during that period (Figures 1.1.5.1-4). The main hydro-technical constructions in the Syrdarya basin were carried out from the 1930's to the early 1960's, leading to an increase in regulation of the flow up to 93-94%, consequently the degree of use of the river flow increased, and the amount of water coming to the the Aral Sea decreased. This can be seen easily and clearly in the figures:

- since 1912 until approximately the middle 1930's, the inflow to the sea was significantly decreased only during low-water years (1917-18, 1923, 1927), being on average between 14–20 $km^3$, decreasing during low-water years to 9-11 $km^3$, and increasing during high-water years up to 22 $km^3$;
- after the middle 1930's, the inflow to the sea began to decrease slightly, but it became obvious only in the late 1950's, when the level of hydro-constructions were at their maximum and the river flow became almost totally regulated;
- the most clear evidence of the influence of the river flow regulation (used primarily for agricultural irrigation) on inflow to the sea is the significant decrease of inflow to the

Aral Sea in 1965 when Chardara reservoir was introduced and in 1974 after the introduction of Toktogul reservoir (Figure 1.1.5.2);

- that is why the decade average flow decreased, especially in the 1960's, and appeared below 10 $km^3$ for the first time, then in the 1970's it decreased down to 3 $km^3$, and in the 1980's it decreased down to the lowest level of 2.29 $km^3$; this was the beginning of operation of the BVO Syrdarya (Figure 1.1.5.4);
- for the analysis of data sets from the hydropost registering inflow to the the Aral Sea, ten years is not a significant or retrospective period, but the tendencies can be seen even in the last ten years; for the first time a decrease in the inflow to the sea was not registered (as it was during the whole of the 20-th century), but an increase by more than two times: 2.29 - 5.4 $km^3$ (Figure 1.1.5.4).

During the last high-water years (1991-2000) the flow at Kazalinsk increased, and the renewal processes of the delta improved. That is to say: during the last years, humanity has taken over the regulating functions in the downstream areas which were fulfilled by nature before, while water use for production and irrigation has somewhat decreased, water supply to the economic-ecological objects increased. At the same time, the chance of filling the economic-ecological objects (old river beds, lowlands, lakes, which are places where vegetation is growing, animals and birds live, cattle drink, hayfields and fisheries appear, and oases for the population are located) remains at a low level, because it largely depends on the amount of water in the river, and is related to significant losses.

Understanding the increase in environmental requirements during the last few years, especially after the beginning of operation of the ICWC in 1992, helped to increase the water supply to the natural complex and the Aral Sea. During the last few years, the water supply to these users was estimated as the following ($km^3$/year):

**Table 1.1.5.1**
**Environmental Flow Requirements ($km^3$/year).**

| | Average | Min | Max |
|---|---|---|---|
| Filling of the floodlands of the Syrdarya River | 1.80 | 0.10 | 2.56 |
| Filling of desert territories | 0.40 | 0.00 | 0.82 |
| Water supply to the Aral Sea | 5.60 | 2.58 | 8.46 |

The degree of deviation from these requirements demonstrates the necessity of a more careful regulation of water supply for environmental purposes. For this purpose, the project of developing a strategy for the Aral Sea proposes a minimum requirement of 5.2 $km^3$ of water flowing from the Syrdarya to the Northern Aral Sea.

With the aim of decreasing the dried areas on the bottom of the Northern Aral Sea, and creating more favorable conditions for the natural complexes of the pre-Aral zone, first of all it is necessary to stabilize the level of water in the Northern Sea. Calculations show that in order to stabilize the Nothern Aral Sea at a water level of 42 m about 3 $km^3$ of water are required per year from the Syrdarya River, and to maintain a level of 44 m, about 5-7 $km^3$/year are needed (at the same time the Northern Aral should be separated from the Large Aral by a dam across the Berg sound).

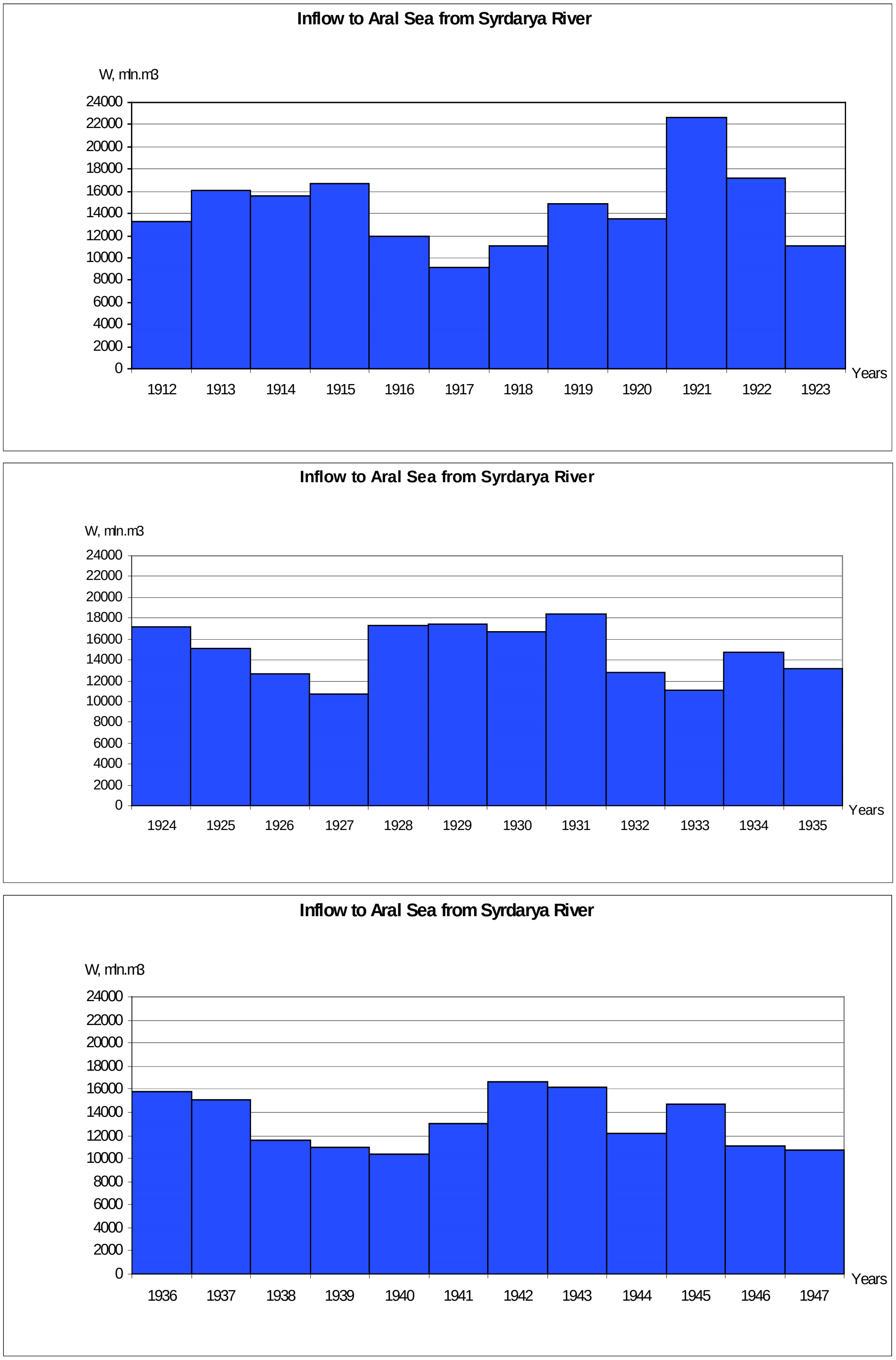



**Figure.1.1.5.1. Inflow to Aral Sea from Syrdarya River (1912 to 1947 –Kazalinsk).**

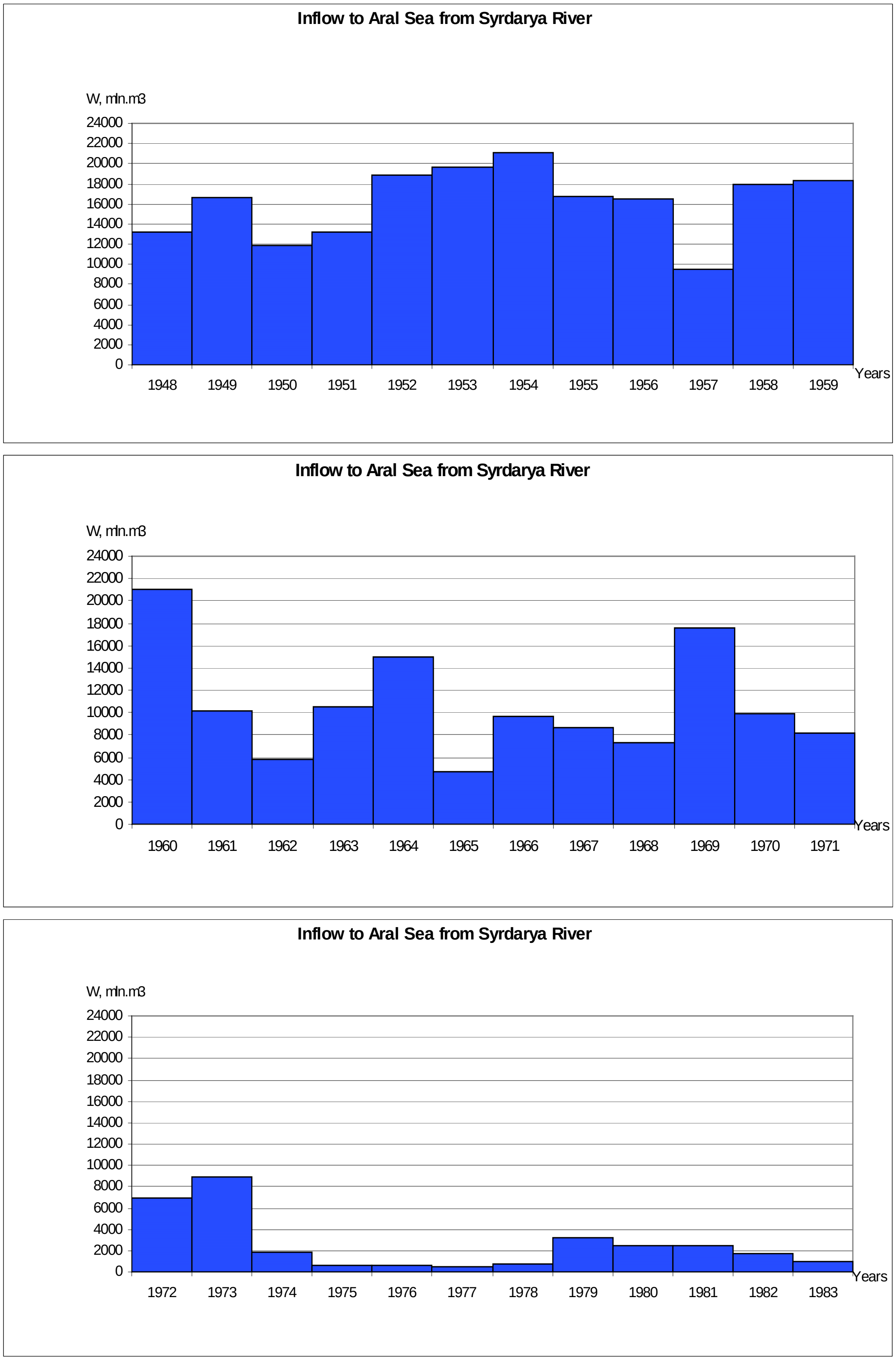
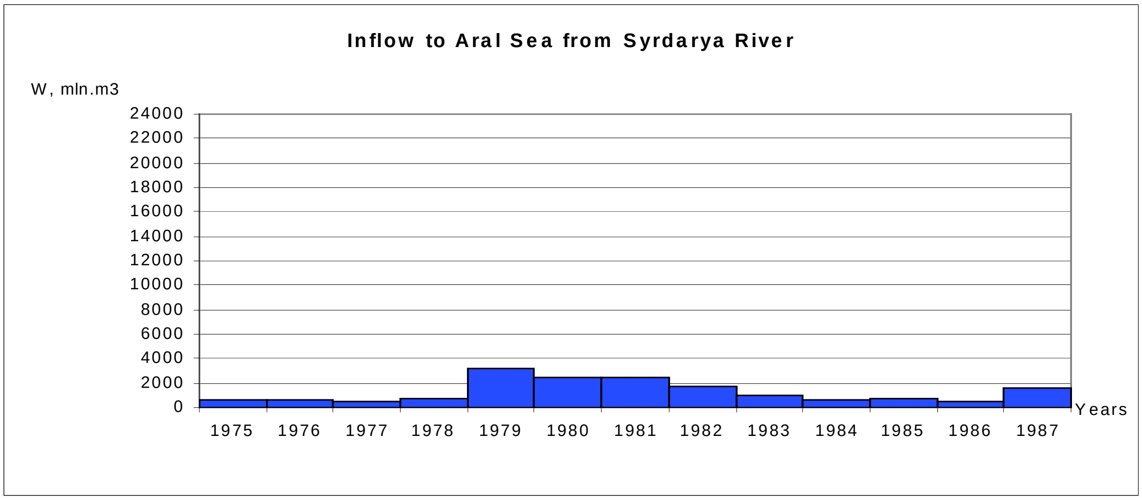



**Figure 1.1.5.2. Figure.1.1.5.1. Inflow to Aral Sea from Syrdarya River (1948 to 1983 – Kazalinsk).**



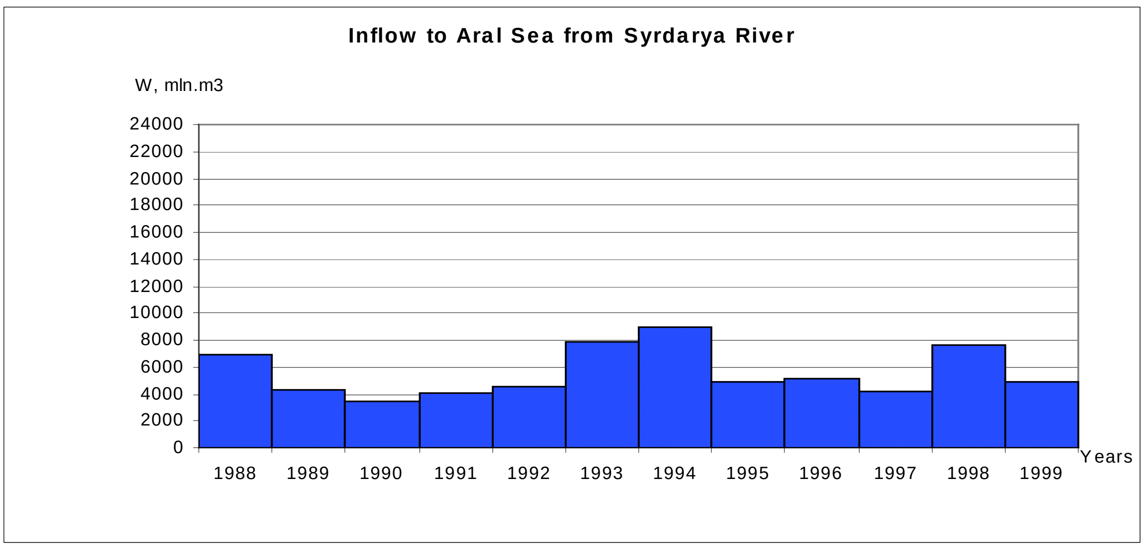




**Figure 1.1.5.3. Inflow to Aral Sea from Syrdarya River (1975 to 1992 –Kazalinsk; 1993 to 1999 – Karateren ).**

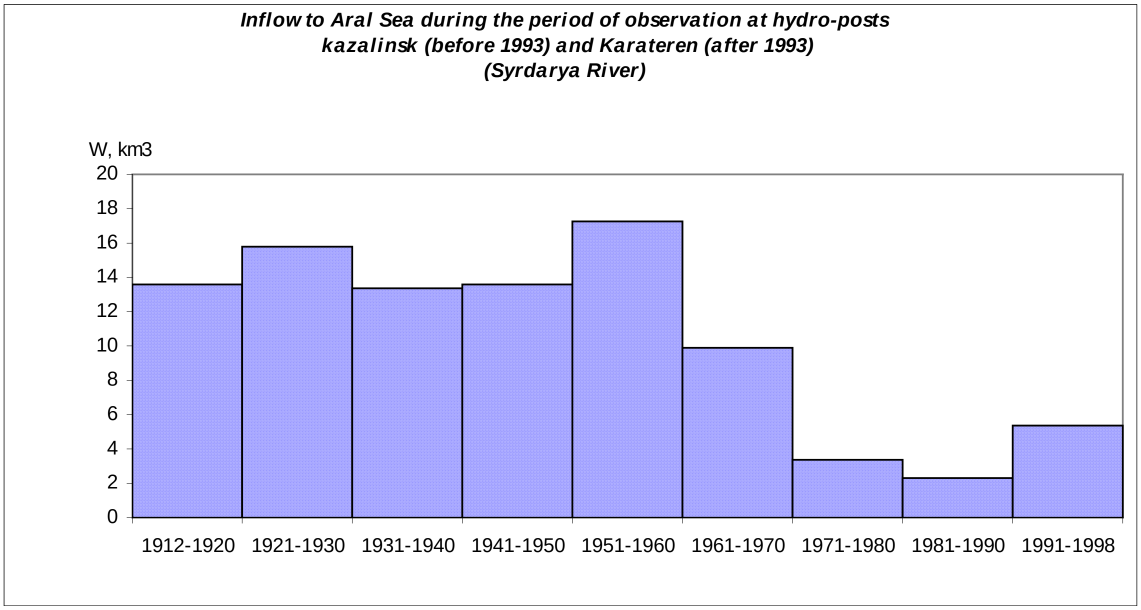



**Figure 1.1.5.4. Inflow to Aral Sea from Syrdarya River (1912 to 1999.**

## 1.2. Irrigation Development of the Basin

### 1.2.1. Irrigation in the Syrdarya Basin Republics During Soviet Times

During many centuries the Turkic and Persian nations living on the territory of the Syrdarya basin constructed and operated irrigation systems which were local, environmentally and economically stable, and effective. During the Soviet period the previous traditional systems in the basin were replaced by a system of centralized governmental planning, which set the priority on growing cotton and other irrigated crops with the resulting environmental and population related consequences.

During the Soviet period, lands of the Kyrgyz, Uzbek, Tajik and Kazakh Soviet Republics were located within the Syrdarya basin. The basin was a well-developed economic region of the Soviet Union, where more than half of the population of Central Asia were located, and half of the country's cotton was grown. The irrigable lands in the basin were estimated to be 6.15 mln.ha, which were distributed among the republics according to Table 1.2.1.1.

**Table 1.2.1.1**
**Irrigable Lands of the Syrdarya Basin (mln.ha).**

| Republic | Irrigable land |
|---|---|
| Kyrgyz SSR | 0.49 |
| Uzbek SSR | 1.96 |
| Tadzhik SSR | 0.17 |
| Kazakh SSR | 3.53 |

In the beginning of the 20-th Century, 1.25 mln.ha of lands were irrigated in the Syrdarya basin. During the civil war (1921-22) and during the years after the war, the irrigated areas significantly decreased; however, during 1930's the former level was reached again. In 1940, about 1.3 mln.ha of lands were irrigated in the basin, and about 1.8 mln.ha in 1950. The dynamics of irrigated land development in the basin since 1950 are shown in Table 1.2.1.2.

**Table 1.2.1.2**
**Irrigated Land Development in the Syrdarya Basin Since 1950.**

| Republic | Irragated Lands (mln.ha) | | | |
|---|---|---|---|---|
| | 1950 | 1970 | 1980 | 1990 |
| Kyrgyz SSR | 0.30 | 0.33 | 0.36 | 0.42 |
| Uzbek SSR | 1.06 | 1.47 | 1.66 | 1.90 |
| Tadzhik SSR | 0.08 | 0.17 | 0.21 | 0.26 |
| Kazakh SSR | 0.36 | 0.38 | 0.69 | 0.78 |
| Total | 1.80 | 2.35 | 2.92 | 3.36 |

An increase in irrigated area was experienced in all irrigation regions, however, it was most intensive in the midstream of the river. All measures for the construction of new and reconstruction of existing irrigation systems, and for the creation of water reservoirs were directed toward increasing water supply to the irrigated lands.

Up to 1990, development of irrigated lands in the basin reached 3.39 mln.ha, corresponding to full consumption of water resources, as determined by the "Scheme". The basin water-use system was created according to the projected regime of water-use.

The distribution of the total area of cultivation among the basin countries is shown in Table 1.2.1.3, the distribution of the land resources under its use within the borders of the three water-use regions mentioned above, and from the administrative point of view, is shown in Table 1.2.1.4, and the distribution of the irrigated lands among the water-use regions and countries of the basin – in Table 1.2.1.5.

**Table 1.2.1.3**
**Distribution of Cultivated and Irrigated Lands Among the Syrdarya Basin Countries**

| Republics | Cultivated Lands | | Irrigated Lands | |
|---|---|---|---|---|
| | Thous. ha | % | Thous. ha | % |
| Total | 48,445.1 | 100 | 3,309.9 | 100 |
| Republic of Uzbekistan | 7,338.9 | 14.5 | 1,905.2 | 57.6 |
| Republic of Tajikistan | 1,623.2 | 3.4 | 234.4 | 7.0 |
| Kyrgyz Republic | 11,429.5 | 23.8 | 416.6 | 12.6 |
| Republic of Kazakhstan | 28,053.5 | 58.3 | 753.7 | 22.8 |

The irrigated lands are the most productive and valuable of the agricultural lands in the basin, while their area, as can be seen from the presented data (Table 1.2.1.3) constitutes less than 10% of the total area of cultivated lands. More than half (57.6%) of the irrigated lands of the basin are concentrated in the Republic of Uzbekistan, 22.8% of the total area is located in the

Republic of Kazakhstan, 12.6% - in the Kyrgyz Republic, and 7.0% - in the Republic of Tajikistan.

**Table 1.2.1.4**
**Distribution of Syrdarya Basin Lands Among the Water-use Regions, the Countries, and the Basin in General (thous.ha).**

| Water Use Regions, basin, & countries | Total area of irrigated lands | Including | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Total Agricult. lands | Of which | | | | | | | |
| | | | Ploughed Fields | Perennial Plants | Deposits | Hayfields | Pastures | Personal plots | Other lands | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| Upstream | 14,298.6 | 7,656.0 | 1,364.8 | 121.6 | 13.5 | 160.1 | 5,996.0 | 119.2 | 6,523.4 | |
| Mid-stream | 7,544.1 | 5,103.3 | 1,815.4 | 114.3 | 22.6 | 76.0 | 3,075.0 | 78.6 | 2,362.2 | |
| Downstream | 26,602.4 | 21,120.9 | 998.5 | 17.4 | 35.0 | 226.7 | 19,843.3 | 24.5 | 5,457.0 | |
| Total basin | 48,445.1 | 33,880.2 | 4,178.7 | 253.3 | 71.1 | 462.8 | 28,914.3 | 222.3 | 14342.6 | |
| Including: | | | | | | | | | | |
| Uzbekistan | 7,338.9 | 4,355.9 | 1,897.5 | 163.3 | 9.8 | 35.8 | 2,249.5 | 125.9 | 2,857.1 | |
| Tajikistan | 1,623.2 | 848.0 | 257.3 | 38.3 | 14.2 | 0.6 | 537.6 | 17.5 | 757.7 | |
| Kyrgyzstan | 11,429.5 | 6,187.4 | 593.5 | 22.8 | 10.6 | 166.3 | 5,394.2 | 45.4 | 5,196.7 | |
| Kazakhstan | 28,053.5 | 22,488.9 | 1,430.5 | 28.9 | 36.5 | 260.0 | 20,733.0 | 33.5 | 5,531.1 | |

**Table 1.2.1.5**
**Distribution of Irrigated Lands in the Syrdarya Basin (thous.ha).**

| Republic | Upstream | Midstream | Downstream | Total |
|---|---|---|---|---|
| Uzbekistan | 921.9 | 983.3 | - | 1905.2 |
| Kyrgyzstan | 395.2 | 21.4 | - | 416.6 |
| Tajikistan | 67.9 | 166.5 | - | 234.4 |
| Kazakhstan | - | 188.5 | 565.2 | 753.7 |
| **Total** | 1381.0 | 1359.7 | 565.2 | 3309.9 |

### 1.2.2. Major Irrigated Lands, Irrigation Areas, and Crop Structures

Among the three water-use regions: (a) upstream; (b) midstream; and (c) downstream, the irrigated lands are distributed as follows.

- **Upstream:** (1) upstream of the Naryn basin, located in high mountains from the origins of the river down to the Kyrgyz portion of the Fergana valley; (2) Fergana valley, which includes part of the basin of the Naryn River and the basins of the Karadarya and the Syrdarya Rivers down to the Farkhad hydrostation (territory of the Kyrgyz Republic, Uzbekistan, and Tajikistan).

- **Midstream:** (3) midstream of the Syrdarya River from Farkhad hydro-junction down to Chardara reservoir (the territory of Uzbekistan, Tajikistan, and Kazakhstan), (4) Chirchik-Akhangaran-Keles region (CHAKIR), which includes lands in Uzbekistan, the Kyrgyz Republic, and Kazakhstan.
- **Downstream:** (5) Arys-Turkestan irrigation region (ARTUR) located in the territory of Kazakhstan, and (6) downstream of the Syrdarya River (Kazakhstan).

In 1990, the irrigated areas were distributed among the water-use regions according to Table 1.2.2.1.

**Table 1.2.2.1**
**Distribution of Irrigated Lands Among the Water-use Regions (mln.ha)**

| Water-use region | Total | River bed |
|---|---|---|
| Upstream of Naryn | 0.13 | 0.03 |
| Fergana valley | 1.32 | 0.53 |
| Middle Syrdarya | 0.89 | 0.84 |
| CHAKIR | 0.45 | - |
| ARTUR | 0.20 | - |
| Downstream of the Syrdarya | 0.37 | 0.37 |
| Total | 3.36 | 1.77 |

The water-use regions are divided into planning zones which are territories within an administrative oblast or its part, having specific features and water resource conditions, and common economic indexes of agricultural activities. The water resources formed within a planning zone are referred to as *local* water resources, and those received by the planning zone from the transboundary sources – *transboundary* water resources. The structure of a planning zone from the agricultural point of view consists of: (a) an irrigation system (arterial, inter-farm canals, etc.), (b) an outflow system (collection-drainage network), and (c) cultivated areas with corresponding agricultural crops.

During the years since independence (in 1991), there were no significant changes in the irrigated areas in the countries of the basin. Some changes occurred in the structure of the cultivated crops. The share of cotton, which is still the leading crop, has decreased, while cereals increased. The areas taken by fodder crops has somewhat decreased. During 1995-2000, the area of the irrigated lands in the Syrdarya basin was estimated as 3.6 mln.ha, of which 1.7 mln.ha was supplied by local sources, and 1.9 mln.ha was supplied by transboundary sources (see Table 1.2.2.2).

**Table 1.2.2.2**
**Distribution of Irrigated Lands by Local and Transboundary Water Source (mln.ha)**

| Country | Total | Local | Transboundary |
|---|---|---|---|
| Kazakhstan | 0.78 | 0.29 | 0.49 |
| Kyrgyzstan | 0.46 | 0.26 | 0.20 |
| Tajikistan | 0.27 | 0.09 | 0.18 |

| | | | |
|---|---|---|---|
| Uzbekistan | 2.17 | 1.10 | 1.07 |
| Total | 3.68 | 1.74 | 1.94 |

The areas irrigated from local sources are served by small irrigation systems with areas of 0.5-10 thous.ha, and those irrigated from transboundary sources are served by large irrigation systems with sizes up to 500 thous.ha (Golodnaya steppe, Kyzylkum area, Arys-Turkestan irrigation system, etc. See Table 1.2.2.3).

Availability and use of irrigated lands in the water-use regions, countries and the basin in general is characterized by the data in Table 1.2.4. The gross production of the main crops on the irrigated lands in the Syrdarya basin for the same items is presented in Table 1.2.5. The basin is a major producer of cotton, vegetables, and fruits in the region (Table 1.2.6).

**Table 1.2.2.3**
**Distribution of Irrigated Lands by Planning Zone (thous.ha)**

| Planning zone | Republic | Water-use region | Area |
|---|---|---|---|
| Kzyl Orda | Kazakhstan | Syrdarya Downstream | 286.0 |
| Golodnaya Steppe | Kazakhstan | Midstream | 125.0 |
| CHAKIR | Kazakhstan | CHAKIR | 67.5 |
| ARTUR | Kazakhstan | ARTUR | 213.6 |
| Kzylkum | Kazakhstan | Syrdarya Downstream | 81.3 |
| Naryn Midstream | Kyrgyzstan | Naryn Upstream | 21.1 |
| Chatkal | Kyrgyzstan | CHAKIR | 8.3 |
| Severno-Fergana | Kyrgyzstan | Naryn Upstream | 120.2 |
| Naryn Upstream | Kyrgyzstan | Naryn Upstream | 109.8 |
| Kampyr-Ravat | Kyrgyzstan | Fergana valley | 33.2 |
| Uzhno-Fergana | Kyrgyzstan | Fergana valley | 165.0 |
| Isfarin | Tajikistan | Fergana valley | 18.3 |
| Khodzhent | Tajikistan | Fergana valley | 200.9 |
| Shakhristan-Lakkat | Tajikistan | Fergana valley | 49.2 |
| Andijan | Uzbekistan | Fergana valley | 314.5 |
| Dzhizak | Uzbekistan | Midstream | 336.1 |
| Namangan-Naryn | Uzbekistan | Fergana valley | 269.1 |
| Namangan-Syrdarya | Uzbekistan | Fergana valley | 41.3 |
| Syrdarya | Uzbekistan | Midstream | 346.7 |
| Tashkent-Chirchik | Uzbekistan | Midstream | 404.6 |
| Tashkent-Syrdarya | Uzbekistan | Midstream | 54.1 |
| Fergana | Uzbekistan | Fergana valley | 414.2 |
| Total | | | 3680 |

**Table 1.2.2.4.**
**Availability and Use of Irrigated Lands in the Basin of Syrdarya River (thous.ha).**

| Water-use regions, basin, | Total area of | Of which used in | Including | | | | | | Not Used |
|---|---|---|---|---|---|---|---|---|---|

| & countries | irrigated lands | agriculture | Ploughed field | Perennial plants | Deposits | Hayfields | Pastures | Personal plots | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Upstream | 1385.0 | 1347.2 | 1095.1 | 120.5 | 0.3 | 3.6 | 41.2 | 86.5 | 37.8 |
| Midstream | 1359.7 | 1342.9 | 1156.4 | 108.5 | 4.0 | 3.2 | 6.0 | 64.8 | 16.8 |
| Downstream | 565.2 | 555.4 | 500.6 | 16.9 | 14.2 | 1.8 | 5.9 | 16.0 | 9.8 |
| Total basin | 3309.9 | 3245.5 | 2752.1 | 245.9 | 18.5 | 8.6 | 53.1 | 167.3 | 64.4 |
| Including: Uzbekistan | 1905.2 | 1872.5 | 1609.8 | 157.8 | 2.2 | 1.7 | 5.0 | 96.0 | 32.7 |
| Tajikistan | 234.4 | 231.1 | 176.0 | 38.3 | 1.1 | 0.1 | 1.6 | 14.0 | 3.3 |
| Kyrgyzstan | 416.6 | 398.3 | 298.8 | 21.7 | 0.3 | 5.0 | 39.0 | 34.1 | 17.7 |
| Kazakhstan | 753.7 | 743.0 | 667.5 | 28.1 | 14.9 | 1.8 | 7.5 | 23.2 | 10.7 |

## Table 1.2.2.5

**Gross Production of the Main Crops of the Irrigated Lands of the Syrdarya Basin (thous.ha)**

| Water use regions, basin, & countries | Cereals, excluding rice and corn | Corn for cereal | Rice | Cotton | Techn. Veget., water-melons | Pota-toes | Veget. | Water-melons | Grapes | Fodder, thous. Tons per unit |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Upstream | 436.9 | 257.5 | 9.9 | 1541.2 | 100.6 | 489.3 | 131.3 | 159.7 | 69.2 | 1931.8 |
| Midstream | 239.2 | 240.8 | 147.8 | 1455.8 | 106.6 | 717.9 | 224.5 | 113.1 | 177.7 | 1834.0 |
| Downstream | 66.8 | 62.5 | 590.3 | 191.8 | 23.4 | 91.0 | 99.6 | 32.1 | 45.5 | 529.7 |
| Total basin | 742.9 | 560.8 | 748.0 | 3188.8 | 230.6 | 1298.2 | 455.4 | 304.9 | 292.4 | 4295.5 |
| Including: Uzbekistan | 216.2 | 319.8 | 94.6 | 2542.0 | 150.9 | 926.7 | 278.7 | 178.9 | 139.3 | 2600.7 |
| Tajikistan | 34.2 | 23.9 | 11.6 | 255.4 | 17.9 | 135.5 | 22.7 | 47.8 | 47.6 | 221.4 |
| Kyrgyzstan | 335.8 | 119.4 | - | 78.7 | 30.3 | 93.5 | 20.2 | 13.3 | 13.4 | 740.2 |
| Kazakhstan | 156.7 | 97.7 | 641.8 | 312.7 | 31.5 | 142.5 | 133.8 | 64.0 | 92.1 | 733.2 |

**Table 1.2.2.6**
**Distribution of Planning Zone Irrigated Lands by Crop (thous.ha)**

| Planning zone | Total | Cotton | Cereals | Fodder | Other |
|---|---|---|---|---|---|
| Kzyl Orda | 286.0 | 0.0 | 118.9 | 73.1 | 94.0 |
| Golodnaya steppe | 125.0 | 67.2 | 11.2 | 30.8 | 15.8 |
| CHAKIR | 67.5 | 7.7 | 13.3 | 14.0 | 32.5 |
| ARTUR | 213.6 | 27.0 | 41.5 | 60.4 | 84.7 |
| Kzylkum | 81.3 | 6.5 | 26.7 | 20.8 | 27.3 |
| Naryn-midstream | 21.1 | 0.0 | 8.4 | 4.0 | 8.7 |
| Chatkal | 8.3 | 0.0 | 2.9 | 1.7 | 3.7 |
| Severno-Fergana | 120.2 | 19.7 | 27.4 | 15.2 | 57.9 |
| Naryn Upstream | 109.8 | 0.0 | 35.1 | 46.6 | 28.1 |
| Kampyr-Ravat | 33.2 | 0.0 | 9.0 | 9.2 | 15.0 |
| Uzhno-Fergana | 165.0 | 13.6 | 42.3 | 20.4 | 88.7 |
| Isfarin | 18.3 | 4.6 | 3.0 | 1.9 | 8.8 |
| Hodzhent | 200.9 | 55.0 | 33.4 | 22.8 | 89.7 |
| Shahristan-Lakkat | 49.2 | 10.1 | 6.1 | 4.2 | 28.8 |
| Andizhan | 314.5 | 109.3 | 51.5 | 19.2 | 134.5 |
| Dzhizak | 336.1 | 124.3 | 62.5 | 22.0 | 127.3 |
| Namangan-Naryn | 269.1 | 74.9 | 42.1 | 28.2 | 123.9 |
| Namangan-Syrdarya | 41.3 | 19.8 | 4.7 | 4.2 | 12.6 |
| Syrdarya | 346.7 | 138.7 | 75.2 | 20.7 | 112.1 |
| Tashkent-Chirchik | 404.6 | 91.1 | 68.4 | 48.4 | 196.7 |
| Tashkent-Syrdarya | 54.1 | 16.8 | 14.6 | 4.7 | 18.0 |
| Fergana | 414.2 | 128.6 | 53.0 | 51.1 | 181.5 |
| Total | 3680.0 | 914.9 | 751.2 | 523.6 | 1490.3 |

**Table 1.2.2.7**
**Production of the Main Agricultural Crops in the Syrdarya River Basin.**

| Type of the product | Units | Syrdarya Basin |
|---|---|---|
| Raw cotton | Mln.Tenge | 3,2 |
| Potatoes | Mln.Tenge | 0,2 |
| Vegetables | Mln.Tenge | 1,3 |
| Fruits and grapes | Mln.Tenge | 0,6 |
| Milk | Thous.Tenge | 1,6 |
| Meat | Thous.Tenge | 0,3 |
| Wool | Thous.Tenge | 18,4 |
| Eggs | Bln.Tenge | 1,8 |

### 1.2.3. Irrigation Technique and Technology

During the initial part of the Soviet period, opening up of new lands for irrigation was directed exclusively to increase the provision of water to agricultural production. As a result of overloading of lands with water, the natural melioration processes were broken, the environmental conditions worsened, and the productivity of the lands decreased.

During this period, traditional methods of surface irrigation were used everywhere – irrigation through furrows, lanes and pins. The measures taken in 1960-80's to improve the melioration condition of the soils (against flooding, secondary salinization, etc.) corrected the situation a little. Irrigation of the existing and opening up of new lands started to be carried out on a scientific basis, with the introduction of water-saving technologies, establishment of new methods of irrigation (basically sprinkling), and improvement of drainage techniques.

Currently, the main irrigation method in the basin is surface irrigation, which is used to irrigate 99-100% of the irrigated lands. Irrigation through furrows is the most frequent (70%).

Experience shows that through the use of rational design and optimal parameters furrow irrigation efficiency can reach 0.85. To compare: the sprinkling efficiency can reach 0.9, while drip irrigation systems – 0.95. Sprinkling and drip irrigation reduce water consumption by 10-40% in comparison to furrow irrigation, but require significant expense when being implemented. Currently, sprinkling units are working only in Kazakhstan (5-6% of irrigated area), while drip irrigation is more widely used in Uzbekistan (0.1-0.2% of irrigated area). Implementation of new technologies is economically efficient if copr productivity is increased by at least 30%, and is most effective in irrigation systems with low water provision, machine water elevating, where soils are characterized by high water permeability, and with high slopes and complex relief.

Today's economic and social conditions require development and improvement of irrigation in the basin. It is necessary to take into account not only local, but also regional conditions and tendencies - increasing lack of water resources, changes in environmental conditions, etc.

Water saving leads to implementation of scientifically well-grounded and complex melioration, including: (a) more effective use of traditional methods of surface irrigation, and implementation of "new" economic methods – sprinkling, inner-soil, and drip irrigation; (b) implementation of rational (for the specific environmental and economic conditions, and crops) elements of irrigation techniques (such as furrow length, distance between moisters, etc.) and methods of organizing work (laser planning of irrigated sites, etc.); (c) implementation of optimal irrigation schedules, inter-related with agro-technical measurements; (d) the use of modern technical means for irrigation (mechanisms and instruments) and materials; and (e) implementation of new methods of organizing work, taking into account the structure of farms under market economy conditions.

### 1.2.4. Dynamics of Irrigation Water Diversion

In 1920-30's, the total water consumption in the irrigated areas of the Syrdarya basin was estimated as 18 $km^3$/year, while non-returnable diversion of water was equal to 10 $km^3$/year, or 25% of the annually renewing water resources. About a half of the diverted water was returned back to the rivers, because the irrigated lands usually were located close to the natural canals. About 60% of the diverted water was used within the Fergana valley.

In the 1950's, 23.1 km$^3$/year of water were diverted from the rivers in the Syrdarya basin, while in late 1970's 42.5 km$^3$/year were taken, which is 1.8 times more. The increase in water diversion was not the same in all parts of the basin. Within the Fergana valley, the increase was related to taking water from the main river bed, while diversion of water from the side tributaries did not change much at all. In the midstream of the Syrdarya, some increase in water diversion from the Chirchik and Akhangaran Rivers took place, but basically this increase was related to opening up Golodnaya and Dzhizak steppes irrigated lands.

The current water needs in the basin are estimated as 50 km$^3$/year. The limits for diversion of water from the Syrdarya River plus inflow to the Aral Sea are 27 km$^3$/year, including diversion of 22 km$^3$/year. The dynamics of diverting water in the basin during 1986-1995 (km$^3$) are shown in Table 1.2.4.1. The average water diversion shares of the basin republics during 1986-95 are reported in Table 1.2.4.2. The water-use for various purposes are shown in Table 1.2.4.3. The avergage withdrawal of water from the Syrdarya River during recent years is showin Table 1.24.4. The current water consumption in the basin is estimated as 48 km$^3$/year, which is covered by diversion of water from the main river bed – 22 km$^3$/year, from the small rivers – 19 km$^3$/year, and by inner-contour use - 7 km$^3$/year.

**Table 1.2.4.1**
**Dynamics of Water Withdrawals in the Syrdarya Basin During 1986-1995 (km$^3$).**

| Year | Total | Surface water | Ground water | Return Flow | For Irrigation |
|---|---|---|---|---|---|
| 1986 | 42.3 | 33.3 | 6.2 | 2.8 | 37.5 |
| 1987 | 44.2 | 34.4 | 6.8 | 3.0 | 39.3 |
| 1988 | 47.9 | 38.0 | 6.7 | 3.2 | 42.0 |
| 1989 | 46.1 | 35.3 | 7.4 | 3.4 | 41.1 |
| 1990 | 46.1 | 35.8 | 6.5 | 3.8 | 40.3 |
| 1991 | 46.0 | 36.0 | 6.8 | 3.2 | 39.9 |
| 1992 | 47.2 | 37.2 | 6.8 | 3.2 | 41.9 |
| 1993 | 46.7 | 37.2 | 6.3 | 3.2 | 41.1 |
| 1994 | 43.2 | 33.8 | 6.1 | 3.3 | 37.9 |
| 1995 | 41.4 | 32.7 | 5.9 | 2.8 | 36.0 |

**Table 1.2.4.2**
**Average Water Diversion Shares of the Syrdarya Basin Republics During 1986-95 (%).**

| Republic | Share (%) |
|---|---|
| Uzbekistan | 58 |
| Kazakhstan | 25 |
| Kyrgyzstan | 11 |
| Tajikistan | 6 |

**Table 1.2.4.3**
**Water Use for Various Purposes During 1986-1995 (%).**

| Use | % |
|---|---|
| Housekeeping and drinking | 4.1 |
| Agriculture | 1.9 |
| Industrial and technical | 3.2 |
| Fishery | 1.6 |
| Irrigation | 88.0 |
| Other | 1.2 |

**Table 1.2.4.4**
**Withdrawal of Water from the Syrdarya River During Recent Years (km$^3$/year).**

| Year | Withdrawal |
|---|---|
| 1994-95 | 19.2 |
| 1995-96 | 22.2 |
| 1996-97 | 20.7 |
| 1997-98 | 21.5 |

A significant part of the lack of water since the early 1970's is covered by secondary use of return flows, part of which goes back to the rivers. The return flows generally consists of collected drainage flows from irrigation, and sewage water from municipal and industrial (M&I) use. The collected drainage water makes up the biggest share of the returning water (92% in 1990, 90% in 1998).

The return flow in the basin has increased over time. Since the 1950's till the late 1970's, it increased 2.3 times and reached 12 km$^3$/year. The dynamics of formation of return water in the Syrdarya basin during 1970-97 (for the extreme years) in the water-use regions is shown in Table 1.2.4.5. The distribution of return water formation among the Syrdarya basin countries during 1990-97 is shown in Table 1.2.4.6. Currently, about 12-13 km$^3$/year of collected water are formed in the basin, 8-9 km$^3$/year of which go back to the rivers.

**Table 1.2.4.5**
**Return Water Formation in the Syrdarya Basin During 1970-97 (km$^3$/year).**

| Water-use region | 1970 | 1974 | 1979 | 1990 | 1997 |
|---|---|---|---|---|---|
| Fergana valley | 8.2 | 5.5 | 8.7 | 7.1 | 7.7 |
| CHAKIR | 0.8 | 0.7 | 1.8 | 1.2 | 1.1 |
| Midstream | 2.6 | 2.4 | 3.9 | 2.5 | 2.5 |
| ARTUR | 0.4 | 0.3 | 1.2 | 0.9 | 0.8 |
| Downstream | 0.2 | 0.3 | 3.5 | 2.3 | 2.3 |
| Total | 12.2 | 9.2 | 19.1 | 14.0 | 14.4 |

**Table 1.2.4.6**
**Distribution of Return Water Formation Among the Syrdarya Basin Countries During 1990-97 (%).**

| Republic | % |
|---|---|
| Uzbekistan | 63 |
| Kyrgyz Republic | 16 |
| Kazakhstan | 14 |
| Tajikistan | 7 |

The drainage collector network in the Fergana valley is basically natural. Here, especially in the zone of influence of the Great Fergana Canal, a network of large collectors was developed. In the Golodnaya steppe area, a zone of old irrigation systems, large collectors are functioning, which bring drainage water to the Syrdarya River, and from the zone of new irrigation systems – to the Arnasai depression. In the downstream of the Syrdarya, the drainage water dos not return to the river bed. The total drainage area in the basin is estimated as 2 mln.ha, and the distribution of this to the planning zones is shown in Table 1.2.4.7.

**Table 1.2.4.7.**
**Distribution of Drainage area in the Syrdarya Basin Planning Zones (mln.ha)**

| Planning Zone | Drainage Area |
|---|---|
| Andizhan | 0.17 |
| Dzhizak | 0.25 |
| Namangan-Naryn | 0.10 |
| Namangan-Syrdarya | 0.04 |
| Syrdarya | 0.28 |
| Tashkent-Chirchik | 0.18 |
| Tashkent-Syrdarya | 0.04 |
| Fergana | 0.26 |
| Kzylorda | 0.21 |
| Golodnaya steppe | 0.16 |
| ARTUR | 0.21 |
| Kzylkum | 0.03 |
| Khodzhent | 0.07 |

### 1.2.5. Flow Regulation to Increase Water Supply to Irrigated Lands

Construction of large hydro-technical structures in the region began in the second five-year period of the Soviet era (1933-38). During that period, Kampyrravat dam was constructed on Karadarya river, and Gazalkent dam was constructed on the Chirchik river. This allowed the planned use of water in the basins of these two large rivers. In 1948, Farkhad water junction was put into operation for the purposes of irrigation and power generation on the Syrdarya river.

In 1950-70's, construction of Kairakum, Chardara, and Charvak reservoirs allowed an increase in the irrigated areas of the basin, improved their water provision, and helped to solve the problem of seasonal regulation, as well as the problem of distribution of the return flows coming to the Syrdarya River. The flow regulation measures taken during that period guaranteed full satisfaction of water users during an average- or low-water year, while the water needs of Fergana, Tashkent and Golodnaya steppe irrigated areas could be met with no shortage. Limitations of water occurred only during especially low-water years. To cover such shortages, it was necessary to construct additional reservoirs in the basin for multiyear regulation.

Different opinions existed about allocation of reservoirs for multiyear regulation in the basin. One of the ideas was to use the Arnasai depression located close to Chardara reservoir. A project was developed which included a dam, pump-station, and canal for the purpose of bringing up to 2.5 $km^3$/year of water to Chardara reservoir from Arnasai during low-water years. The project was not realized and currently Arnasai is used only as a reservoir for catastrophic outflow of "surplus" water from Chardara reservoir. Currently, the possibility of using this depression as a contra-regulation reservoir is being considered, with the aim of using part of the winter flow of the Syrdarya for Uzbekistan's interests.

In 1975, Toktogul reservoir was put into operation, and in 1980 – Andijan reservoir. Toktogul reservoir serves to compensate for the lack of flow for irrigation of lands in the Fergana valley and midstream of the basin, and also for power generation and environmental releases. Putting Toktogul reservoir into operation allowed an increase in the irrigated areas by 400 thous.ha, and an improvement of water provision to the existing irrigation systems on 900 thous.ha in the Republics of Uzbekistan and Kazakhstan.

Construction of Andijan reservoir allowed the guaranteed provision of water for the Karadarya system, mainly in the zone of influence of the Great Fergana Canal, as well as to cover the lack of flow during critical periods in the midstream of the Syrdarya through transferring of flow from the Karadarya River.

Thus, in 1980 the Syrdarya basin was transferred to multiyear regulation, and was almost totally regulated. The reservoirs currently existing in the basin are characterized by a regulation coefficient of 0.93, and provide control of 35.2 $km^3$/year of water resources above Chardarya reservoir, while the average annual water resources are 37.8 $km^3$. The regulated flow, together with the return flow, constitutes the water resources available for use – 46 $km^3$, which are used for limited provision of Chardara reservoir, water consumption, and losses. Resources available for use allow irrigation of 3.39 mln.ha in the basin.

The Syrdarya water-use complex is currently a composition of interrelated water system elements (rivers and water reservoirs) and components, which use the water resources of the system; the latter, through changing the natural regime of water sources, provide satisfaction of the water-users' needs.

It is necessary to take into account the natural character of the tributaries to the upper, multiyear water regulation reservoirs, based on the historical record of flow. Unlike Toktogul, Andizhan, and Charvak, the river-bed reservoirs of the cascade – Kairakum and Chardara – use the flow released from the upper water reservoirs of the cascade plus the side flow which comes below those reservoirs. To evaluate the resources which come to these reservoirs, detailed water-use balances were developed for the whole system of the Syrdarya region, including the sources of water and water-use regions.

The Syrdarya system was designed to provide 100% of the municipal and industrial water demands, however, there is only a 90% probability of providing the irrigation and hydroelectric demands of the basin. The agricultural sector in the basin can not withstand more than a 25% deficit of water without collapse. The estimated water resources of the rivers of the Syrdarya region, which serve as the basis for the development of the operating regime of the main reservoirs of Naryn-Syrdarya cascade, are shown in Table 1.2.5.1; while the estimated flow to the reservoirs, necessary for the provision of water-users' requirements during a year with 90% provision, is presented in Table 1.2.5.2.

**Table 1.2.5.1**
**Estimated Water Resources of the Syrdarya River (mln.m$^3$/year).**

| Name | Average Year | 90% Year |
|---|---|---|
| Naryn-Toktogul HPP | 11,320 | 8,140 |
| Side inflow above Uchkurgan | 2,450 | 1,980 |
| Outflow from Fergana valley | 6,987 | 3,483 |
| Outflow from CHAKIR | 4,942 | 2,305 |
| Returns above the midstream | 730 | 730 |
| Outflow from Syrdarya HPP | 1,170 | 1,170 |
| *Subtotal* | 27,599 | 17,808 |
| Release of storage from multiyear regulation reservoirs | 0 | 6,675 |
| *Total* | 27,599 | 24,483 |

Therefore, the inflow to Kairakum reservoir, which increases water provision in the midstream during a 90% water year consists of the following:

- outflows from Toktogul reservoir;
- outflows from the rivers and water reservoirs in the Fergana valley;
- return water from the irrigation lands in the Fergana valley.

**Table 1.2.5.2**
**Estimated Release of Reservoirs During a 90% Water Year (mln.m$^3$/year).**

| Reservoir | Release | |
|---|---|---|
| Toktogul reservoir | 8,140 | |
| Kairakum reservoir | 7,237 | |
| including compensating outflow (Toktogul) | | 3,754 |
| Chardara reservoir | 9,106 | |
| including – sanitary outflow | | 3,154 |
| - compensating outflow | | 609 |
| - outflow from CHAKIR | | 2,305 |
| - returns above the midstream | | 730 |
| - outflow from Syrdarya HPP | | 1,170 |
| - release from multiyear regulation reservoirs | | 1,138 |
| *Total* | 24,483 | |

During high-water years, when Toktogul reservoir is full, the outflows from this reservoir go to Kairakum reservoir as extra flows contributing to the water consumption schedule; while during low-water years, the compensating flows are deivered to the downstream water-users.

The inflow to Chardara reservoir during years with the estimated water provision and below consists of:

- sanitary outflow from the water reservoirs located above;
- compensating outflow from Toktogul reservoir;
- outflows above the water consumption schedule and return water from CHAKIR;
- return water from the midstream region; and
- outflow from the Syrdarya HPP.

As with Kairakum reservoir, during high-water years, the outflow from Toktogul and Kairakum reservoirs comes to Chardara in excess of the water consumption schedule.

The water-users, whose requirements constitute the outflow part of the balance equation, include:

- agricultural irrigation;
- municipal and industrial (M&I) water supply (supplied from surface sources);
- fisheries;
- hydro-power generation;
- sanitary outflows;
- river bed losses (environmental measures); and
- losses at reservoirs.

Agricultural irrigation is the largest water user, consuming 85-90% of the flow in the rivers. The M&I requirements, as well fisheries, are estimated in the balances as non-returnable losses of flow.

An important component of the water-use complex of the basin is hydro-power generation. The problem of rational use of water in the basin is solved by balancing the interests of irrigation and hydro-power generation, based on different time requirements for the release regime.

Another outflow item in the water-use balance are the sanitary outflows from Toktogul and Kairakum reservoirs (about 100 $m^3/s$), and Chardara reservoir (about 50 $m^3/s$), as well as the hydro-energy generation outflows from Toktogul reservoir (80 $m^3/s$ – above the sanitary minimum).

The requirements of the water-use system of the basin are presented in Table 1.2.5.3.

**Table 1.2.5.3**
**Requirements of the Syrdarya's flow**

| Item | mln.$m^3$/year |
|---|---|
| Non-returnable consumption in the upstream | 170 |
| Diversion to water-users | 22,797 |
| Including - Fergana valley | 5,437 |
| Midstream | 9,210 |

| | |
|---|---|
| Downstream | 8,150 |
| Losses in lakes, rivers, and reservoirs | 860 |
| Sanitary outflows | 656 |
| *Total* | 24,483 |

The water-use balances developed on the basis of the operating regime of the main reservoirs of the Naryn-Syrdarya cascade allow the provision of water to users in the basin during a 90% flow year. Calculations show that water provision to the irrigated areas in the Fergana valley at the level of total consumption of water resources reaches 90%, while the guaranteed outflow from the water reservoirs in Fergana valley, and the regime of their operation are marginal. The CHAKIR region is different in terms of strong controversies between the interests of irrigation, and heat and power generation, while it is the main industrial junction of Central Asia, and has significant requirements for provision of its M&I water needs. Requirements of the midstream region are fully satisfied by the water from the Syrdarya, and by the use of return water. Requirements of all water-users are taken into account in water-use balances of the downstream region, which must be covered by the water from Chardara reservoir, by the use of return water of this region, as well as of return water from the ARTUR region. The downstream region's balances also take into account the requirements of environmental protection, which are the river bed losses in tugai forests, reeds, etc., in the amount of 2 $km^3$. The general idea about the conditions of water provision in the Syrdarya basin can be seen from the combined water-use balance presented in Table 1.2.5.4.

**Table 1.2.5.4**
**Combined Water Use Balance of the Syrdarya Basin.**

| Items of the Balance | | mln.m$^3$/year |
|---|---|---|
| *Inflow items* | | |
| Average annual water resources above Chardara | | 37,880 |
| Coefficient of regulation of the flow | | 0.93 |
| Regulated water resources | | 35,234 |
| Return water to the Syrdarya | | 6,669 |
| including | - from Fergana valley | 2,480 |
| | - from CHAKIR | 1,720 |
| | - from the midstream | 2,469 |
| Use of return water | | 7,878 |
| Including | - in Fergana valley | 3,355 |
| | - in CHAKIR | 803 |
| | - in the midstream | 1,720 |
| | - in the downstream | 2,000 |
| *Total inflow* | | 49,781 |
| *Outflow items* | | |
| Water use by the branches of national economies | | 43,347 |
| Including | - upstream | 170 |
| | - Fergana valley | 17,759 |
| | - CHAKIR | 6,698 |
| | - midstream | 10,660 |
| | - downstream | 8,060 |
| Non-returnable losses | | 6,434 |
| Including | - losses from water reservoirs | 1,150 |
| | - losses from lakes and rivers | 580 |
| | - accumulation of ground water | 200 |
| | - consumption of return water | 1,189 |
| | - environmental protection | 2,090 |
| | - sanitary outflow | 1,225 |
| *Total outflow* | | 49,781 |

After the collapse of the USSR and breakage of economic relations between the republics, the Kyrgyz Republic had to reconsider the operation regime of Toktogul reservoir under its new power generation interests. The change in hydrologic regime of the Naryn river below Toktogul reservoir (decreased in the vegetation period, and increased in the non-vegetation (or winter) period) lead to a decrease in the guaranteed water provision to irrigated lands downstream, and to losses in river flow during winter (e.g., large inflows to Arnasai depression). It is possible to increase the guarantee of water provision in the basin only through operation of the Naryn-Syrdarya cascade. However, it is possible to carry out such measures only on the basis of agreements between sovereign countries which take into account compensation for expenses and damages.

### 1.2.6. Flow Withdrawal Impact on the Aral Sea and Basin Natural Complexes

Water resources of the Syrdarya basin are mainly spent on:

- consumption by branches of the national economies;
- losses in the river beds and reservoirs;
- inflow to Arnasai depression;
- use of water in the Aral region; and
- inflow to the Aral Sea.

During 1911-60, the Aral Sea received 56 km$^3$/year on average (including 15 km$^3$ from the Syrdarya), the level of water in the sea was 53 m, while the surface area was 66 thous.km$^2$, and the volume was more than 1 thous.km$^3$. Since the early 1960's, the amount of water diverted from the rivers feeding the sea began to increase, and the inflow to the sea decreased; by 1970 the level of water in the sea decreased to 51.5 m, and by 1980 it decreased to 45.9 m. In the 1980s, for several years the inflow to the Aral Sea almost stopped. In 1987, the Large Aral Sea separated from the Small (Northern) one (a natural dam appeared); the volume of the Large Sea was 342 km$^3$, and of the Small Sea – 21 km$^3$. During the high-water year of 1988, the dam disappeared, and in 1989 the Large Sea again separated from the Small one. Due to a more rapid decrease in the level of water in the Large Sea than in the Small one, a difference in their levels appeared. As early as 1992, the difference was more than 3 m, and the influence of the Large Sea over the Small one almost disappeared. From 1988 until 1995, on average, about 4 km$^3$/year flowed into the Small Sea from the Syrdarya, while the level of water in the sea decreased from 40.7 to 40.1 m. After 1995, the level of water in the Small Sea stabilized at 40.5 m.

The amounts of water were coming from the Syrdarya to the Small (Northern) Aral Sea during the years of 1995-98 (km$^3$) are reported in Table 1.2.6.1.

**Table 1.2.6.1**
**Syrdarya Flow to the Northern Aral Sea During 1995-98 (km$^3$).**

| Year | Kazalinsk | Karateren |
|---|---|---|
| 1995 | 5.5 | 4.5 |
| 1996 | 6.7 | 4.9 |
| 1997 | 5.7 | 3.8 |
| 1998 | 9.2 | 7.4 |

The largest inflow to the Northern Aral Sea comes in winter, because in summer irrigation consumes most of the water released from Chardara reservoir, while in spring and autumn, hayfields and lakes are filled in. In the downstream region, the area of flooded hayfields during recent years has been 26 thous.ha, and their water consumption has been 138 mln.m$^3$. On average, about 100-120 mln.m$^3$ per year are diverted from the Syrdarya River to fill in artificial ponds and fisheries. Losses in the whole river bed, in floodlands, and water reservoirs can reach 4-7 km$^3$ per year depending on the water level during the year. On average, during 1995-98 the available water resources of the Syrdarya River were estimated as 36 km$^3$/year. The diversion of water from the river is shown in Table 1.2.6.2.

**Table 1.2.6.2**
**Available Water Resources of the Syrdarya During 1995-98 ($km^3$/year).**

| Item | Amount ($km^3$/year) |
|---|---|
| Withdrawal of water | 21.0 |
| River bed, floodlands, and reservoir losses | 5.8 |
| Inflow to Arnasai | 2.3 |
| Water consumption by environmental systems | 1.7 |
| Inflow to the Aral Sea | 5.2 |
| Total | 36.0 |

When considering the problems of the Aral Sea crisis under current conditions, we cannot limit ourselves by solving the problems related only to the desiccation of the Aral Sea and to degradation of the Aral region. New environmental systems that have been created as a result of economic activities, such as Arnasai, require specific approaches.

The Aranasai system includes three lakes related to each other: Aidarkul, Tuzkan, and Vostochnoe. The outflows from Chardara reservoir to Arnasai began in 1967, before that, Tuzkan lake was supplied by water only from springs and the Kly river, and since the middle 1950's Arnasai was supplied also by collected drainage water from the irrigated areas of Golodnaya and Dzhizak steppes.

After the high-water year of 1969, as a result of a catastrophic outflow of water from Chardara, the level of water in the Aranasai lakes increased to 239 m, the area of the system reached 2.2 thous.$km^2$, and the volume – 18 $km^3$; during the following 8 years, the level of water decreased, and reached 235 m in 1997 (the area was equal to 1.9 thous.$km^2$, the volume – 16 $km^3$). During that period, reconstruction of the lakes system began – dams and canals between lakes Tuzkan and Aidarkul were constructed. The water exchange between the lakes improved.

Due to periodic outflows of water from Chardara reservoir since 1993 and due to the increase in the level of water in the lake system, again extra attention has been paid to Arnasai. Currently, measures are being developed to stabilize the hydrologic regime of Arnasai lakes, and proposals have been made to establish the status of Arnasai system as a large environmental system and recreational area. The characteristics of Arnas Lake for 1993-99 are shown in Table 1.2.6.3.

**Table 1.2.6.3**
**Characteristics of Arnasia Lake During 1993-99.**

| Year | Level of water, m | Area of surface, thous.$km^2$ | Volume of water in the lake, $km^3$ |
|---|---|---|---|
| 1993 | 237.6 | 2.05 | 16.7 |
| 1994 | 238.7 | 2.22 | 18.6 |
| 1995 | 241.6 | 2.68 | 25.7 |
| 1996 | 242.5 | 2.82 | 28.0 |
| 1997 | 242.5 | 2.82 | 28.0 |
| 1998 | 242.6 | 2.85 | 28.5 |
| 1999 | 243.9 | 3.07 | 32.3 |

An increase in the level of water in Arnasai leads to flooding of lands, destruction of dams, and roads. Electricity poles are under the threat of flooding. Calculations show, that further annual inflows to Arnasai in the amount of more than 1-1.5 $km^3$/year will lead to further increases in the level of water, flooding of new territories, creation of head in collectors, with the consequent worsening of melioration conditions of irrigated lands. Cessation of inflows to Arnasai will lead to a decrease of the level of water, and its stabilization at about 237 m, while the area of dried up bottom should reach 800 $km^2$.

## 1.3. Formation of the Naryn-Syrdarya Cascade of Reservoirs, and its Impact on Irrigation and Hydro Power Development

### 1.3.1. Reservoirs of the Naryn-Syrdarya Cascade and their Main Parameters

The most comprehensive and rational method of use of river flow for the satisfaction of economic needs is its regulation, for which reservoirs are constructed on the rivers. Flow regulation by reservoirs is carried out through redistribution of the volume and flow of water in time in accordance with the requirements of consumers and users, which allows the elimination, to the maximum extent possible, of inconsistencies between the natural fluctuations of the level of water in the rivers, and the needs of economic activities. Creation of the ability to fully and effectively use the natural water resources through river flow regulation allows fulfillment of two main tasks – increasing the flow in the rivers during the periods of low-water, and reducing the level of floods and high water. Therefore, users are guaranteed to receive a determined, larger minimum amount of water. River flow regulation is a very significant measure, that allows a fuller and more rational use the resources of the river to satisfy the needs and necessities of consumers and users, agricultural irrigation, hydro-power generation, water supply, fisheries, recreation, flood prevention, and for the increase of environmental stability of water and other natural systems of the river basin.

The flows of the rivers Naryn, Karadarya, Chirchik, and Syrdarya from Toktogul reservoir to Chardara reservoir, a distance of about 1000 km, are regulated by the Naryn-Syrdarya cascade of reservoirs. There are five important reservoirs in the cascade: three upper reservoirs for multiyear regulation – Toktogul (with a full capacity of 19.5 $km^3$), Charvak (2.0 $km^3$), and Andijan (1.9 $km^3$), as well as two river bed reservoirs for seasonal regulation – Kairakum (4.03 $km^3$), and Chardara (5.7 $km^3$). The total useful capacity of the water reservoirs of the cascade is currently 24.1 $km^3$. Also, there are many reservoirs on small rivers for seasonal regulation of river flow. The degree of regulation of the Syrdarya flow has reached 0.93. The list and the main projected characteristics of the reservoirs of the basin are presented in Table 1.3.1.1. The most significant parameters of the reservoirs are shown in Table 1.3.1.2. Let us shortly describe the main reservoirs of the cascade located on the main river bed of Naryn-Syrdarya.

**Toktogul reservoir,** located on the Naryn river in the Kyrgyz Republic has an active capacity of 14.0 $km^3$ and was put into operation in 1974. The complex irrigation and hydropower reservoir with multiyear flow regulation capability is located there. The main elements of the facility are:

- a large concrete gravitation dam with a maximum height of 210 m;
- two deep emergency canals;
- one surface emergency canal with a capacity of 3300 $m^3/s$;
- HPP building with water-receivers and turbine canals.

The canals of the facility are located in the body of the dam; the plant building is located in the river bed. The main parameters of Toktogul reservoir are presented in Table 1.3.1.1.

**Kairakum reservoir**, which was put into operation in 1957, is located in the midstream of the Syrdarya River in Tajikistan, 18 km from the city of Khojent. The full designed capacity is 4.03 $km^3$, and the useful capacity is 2.6 $km^3$; in 1975 the reservoir had the full capacity of 3.4 $km^3$, and an active capacity of 2.55 $km^3$. The reservoir serves for seasonal and partially for multiyear regulation of the Syrdarya flow. The facility consists of a blind alluvial dam, and a HPP. The dam with the total length of 1202 m covers the old river bed of the Syrdarya, and the right side water-meadow; the length of the river bed part of the dam is 503 m, and of the water-meadow part is 699 m. The height of the dam in the river bed part reaches 32 m; the HPP was designed to be built-in with canals above the generation rooms. The plant building is located near the left shore of the river; on its right side the buildings are attached to the ground dam by a large contra-force shore base. The HPP is equipped with 6 aggregates, each of which consists of a turbine with maximum flow of 185 $m^3/s$, maximum head of 24 m, and minimum head of 14 m. The facility is designed for a flow of 4400 $m^3/s$.

**Chardara reservoir** was put into operation in 1965, and is constructed in Kazakhstan at the end of the midstream of the Syrdarya. This river bed reservoir was created for irrigation and power generation purposes; the designed full capacity is 5.7 $km^3$, the useful capacity is 4.7 $km^3$; currently these indexes are 5.4 $km^3$, and 4.4 $km^3$ correspondingly. The reservoir consists of two hydro-stations: Chardara on the Syrdarya River, and Arnasai on the exit to Arnasai depression.

Chardara hysro-station includes a ground alluvial dam, the total length of which, together with the left-side dam, is 5.3 km, with a maximum height of 26.5 m; Kzylkum regulator in the body of the dam with a capacity of 200 $m^3/s$; and the HPP building, which is attached to the canal, and is equipped with four aggregates with a total capacity of 100 MW, with an operational water head of 15.8 m, and a designed flow of 768 $m^3/s$. Arnasai canal construction has designed flow of 2100 $m^3/s$, and the outflow is carried out through a hole, consisting of five parts each 10 m wide.

**Table 1.3.1.1.**
**General Information about the Reservoirs of the Syrdarya Basin.**

| Name of reservoir | Type and Regulation | Basin | Year put into operation | Designed capacity ($km^3$) full | Active | Purpose |
|---|---|---|---|---|---|---|
| Kairakum | River bed, seasonal | Syrdarya | 1956 | 4.03 | 2.55 | Irrigation, power generation |
| Chardara | -”- | -”- | 1965 | 5.7 | 4.7 | -”- |
| Toktogul | River bed, perennial | Naryn | 1974 | 19.5 | 14.0 | -”- |
| Andijan | -”- | Karadarya | 1980 | 1.9 | 1.75 | -”- |
| Urtatokoi | River bed, seasonal | Kassansai | 1954 | 0.17 | 0.16 | Irrigation |
| Bazarkurgan | Worked by water | Kugart | 1962 | 0.02 | 0.02 | -”- |
| Naiman | -”- | Kyrgyzata | 1966 | 0.04 | 0.04 | -”- |
| Karkidon | -”- | Isfairam Karadarya | 1963 | 0.02 | 0.22 | -”- |
| Tortgul | Worked by water | Isfara | 1970 | 0.09 | 0.08 | -”- |
| Bugun | -”- | Bugun | 1970 | 0.37 | 0.36 | -”- |
| Kattasai | River bed, seasonal | Kattasai | 1965 | 0.06 | - | -”- |
| Dzhizak | Worked by water | Sanzar | 1967 | 0.09 | 0.09 | -”- |
| Akhangaran | River bed, seasonal | Akhangaran | 1974 | 0.18 | 0.17 | -”- |
| Tuyabuguz | -”- | -”- | 1960 | 0.26 | 0.22 | -”- |
| Charvak | River bed | Chirchik | 1970 | 2.00 | 1.6 | Irrigation, power generation |
| Bagam | Worked by water, seasonal | Badam | 1974 | 0.06 | 0.06 | Irrigation |
| Small reservoirs | Seasonal | Tributaries to Arys | | 0.002-0.012 | 0.001-0.011 | -”- |

### 1.3.2. Hydropower Plants (HPPs) as Parts of the Reservoirs and Basin

The Syrdarya River begins in the Kyrgyz Republic, crosses Uzbekistan and Tajikistan, a part of Kazakhstan, and flows into the Aral Sea. In the Syrdarya basin, a water-use system developed historically, based on shared use of water resources and the mutual interests of Kyrgyzstan, Uzbekistan, Tajikistan, and Kazakhstan. A complicated system of hydro-technical constructions, created through dozens of years, provides a high degree of regulation of the river flow, and provides necessary conditions for activities of the population in the region.

The HPPs of the Naryn-Syrdarya cascade are located on the rivers of Naryn, Karadarya, Chirchik, and the Syrdarya. There are five main water reservoirs of the cascade: three upper water reservoirs for multiyear regulation (Toktogul, Charvak, and Andijan) as well as two river bed water reservoirs for seasonal regulation (Kairakum and Chardara).

**Toktogul HPP** – a complex irrigation and power generation hydro-junction on the Naryn river in Osh Oblast of Kyrgyzstan, constructed in 1962-82. The Naryn river is a river with snow-glacier supply. The reservoir has a full volume level of 900 m, a full capacity of 19.5 $km^3$, an active capacity of 14.0 $km^3$, and a dead volume level of 837 m, and provides multiyear regulation of the river flow, the influence of which covers the whole Syrdarya basin. The flow regulation in Toktogul reservoir is carried out together with the operation of Kairakum and Chardara seasonal water reservoirs, for the guaranteed water supply of the irrigated areas.

Toktogul HPP has a capacity of 1200 MW and generates power for the energy system of Central Asia (ES CA). The HPP has provided irrigation releases during the vegetation periods of the last years (up to 800 $m^3/s$), and power generation releases during the non-vegetation periods (up to 650 $m^3/s$).

| | | |
|---|---|---|
| Estimated power generation capacity of turbines | - | 1200 MW |
| Quantity of aggregates | - | 4 |
| Maximum capacity of turbines | - | 924 $m^3/s$ |
| Maximum consumption of hydro-junction | - | 4290 $m^3/s$ |
| Standard horizon of water reservoir | - | 900 m |
| Horizon of dead volume | - | 837 m |
| Full capacity of water reservoir (at *SH*) | - | 19,5 $km^3$ |
| Useful capacity of water reservoir | - | 14,0 $km^3$ |
| Water Heads of HPP: maximum | - | 180 m |
| Projected | - | 140 m |

**Kurpsai HPP** – the second stage of the Naryn Cascade – is located 40 km downstream from Toktogul HPP and it has been under construction since 1975. The reservoir, with a full capacity of 370 mln.$m^3$ and active capacity of 35 mln.$m^3$, provides daily and weekly regulation of Toktogul HPP releases. The estimated capacity of the HPP is 800 MW. The HPP regulates the irrigation and power generation releases from Toktogul reservoir, plus the side inflows from tributaries above the Kurpsai alignment. This hydro-junction serves only for power generation. The HPP reservoir provides daily regulation of Toktogul HPP releases in winter. Water reservoirs of the HPP of the cascade located below Kurpsai provide daily regulation of Kurpsai HPP releases in winter.

| | | |
|---|---|---|
| Estimated power generation capacity of turbines | - | 800 MW |
| Quantity of aggregates | - | 4 |
| Full capacity of water reservoir | - | 370 mln.$m^3$ |
| Useful capacity of water reservoir | - | 35 mln.$m^3$ |
| Standard horizon of water | - | 724 m |
| Horizon of dead volume | - | 721,6 m |
| Capacity of canal (with deep diversion of water) | - | 1074 $m^3/s$ |
| Maximum capacity of turbines | - | 972 $m^3/s$ |
| Capacity of canal (with surface diversion of water) | - | 1680 $m^3/s$ |

**Tashkumyr HPP** – the third stage of the cascade of HPPs on the Naryn river. This hydro-junction is located 400 m below the right-side Karasu river tributary, and 18 km below Kurpsai

HPP. The construction of Tashkumyr HPP was started in 1981. The reservoir, with a full capacity of 140 mln.$m^3$ and an active capacity of 16 mln.$m^3$, provides daily regulation of flows. The estimated capacity of the HPP is 450 MW. Tashkumyr HPP is solely a power generation object and it operates on the releases from Toktogul reservoir.

| | | |
|---|---|---|
| Estimated capacity | - | 450 MW |
| Quantity of aggregates | - | 3 |
| Full capacity of water reservoir | - | 144 mln.$m^3$ |
| Useful capacity of water reservoir | - | 11 mln.$m^3$ |
| Standard horizon of water | - | 628 m |
| Horizon of dead volume | - | 626,5 m |
| Maximum capacity of: turbines | - | 950 $m^3$/s |
| Surface canal | - | 1200 $m^3$/s |
| Projected water head | - | 53 m |
| Deep diversion of water | - | 1500 $m^3$/s |

**Shamaldysai HPP** – (partially under construction) the fourth stage of the Naryn cascade of HPPs – is located in the territory of Osh Oblast of Kyrgyzstan. The hydro-junction serves solely for power generation purposes, and also receives the flow of the Naryn river between Tashkumyr HPP, and Uchkurgan HPP. Shamaldysai HPP provides daily regulation of the releases from Toktogul reservoir and the side tributaries above the HPP. The full capacity of the water reservoir is 40.9 mln.$m^3$, and the active capacity is 5.4 mln.$m^3$. The estimated capacity of the HPP is 240 MW. Currently, three aggregates operate. The maximum capacity of one aggregate at the water head of 19.7 m is 50 MW.

| | | |
|---|---|---|
| Estimated capacity | - | 240 MW |
| Quantity of aggregates | - | 3 |
| Full capacity of water reservoir | - | 40,9 mln.$m^3$ |
| Useful capacity of water reservoir | - | 5,4 mln.$m^3$ |
| Standard horizon of water | - | 572 m |
| Horizon of dead volume | - | 569,5 m |
| Projected consumption through turbines | - | 1035 $m^3$/s |
| Water heads of PP: maximum | - | 30 m |
| Projected | - | 26 m |

**Uchkurgan HPP** – the fifth and last stage of the Naryn cascade of HPPs, was constructed in 1956-64 in the downstream of the Naryn river, above the exit of the river into the Fergana valley. The full capacity of the water reservoir is 1.5 mln.$m^3$, and the active capacity is 4.0 mln.$m^3$. Uchkurgan HPP has an estimated capacity of 180 MW, and diverts water into the irrigation canals (Sredne-Fergana canal, Great Fergana canal, and the Supply Canal) based on the level of water flow without the ability of daily regulation. Regulation of the diversions is carried out with the approval of the BVO Syrdarya.

| | | |
|---|---|---|
| Estimated capacity | - | 180 MW |
| Quantity of aggregates | - | 4 |
| Maximum capacity of canals and the bottom outflows | - | 2580 $m^3$/s |

| | | |
|---|---|---|
| Maximum capacity of turbines of HPP (at the design water head) | - | 720 $m^3/s$ |
| Standard water horizon | - | 539,5 m |
| Water heads of HPP: maximum | - | 36 m |
| projected | - | 29 m |
| minimum operating | - | 18,5 m |
| Full capacity of the water reservoir (at the level of 539,5 m) | - | 17,5 mln.$m^3$ |
| Useful capacity of the water reservoir | - | 4 mln.$m^3$ |
| Minimum level of the head water | - | 538,5 m |

**Kairakum HPP** – was constructed in 1951-57 on the Syrdarya River near the western border of the Fergana valley. The full capacity of the reservoir is 3.413 $km^3$. The estimated capacity of the HPP is 126 MW. Kairakum HPP operates in the regime of daily and seasonal regulation, using the reservoir for seasonal regulation, the main purpose of which is water supply for irrigation.

| | | |
|---|---|---|
| Estimated capacity | - | 126 MW |
| Quantity of aggregates | - | 6 |
| Standard horizon of the water reservoir | - | 347,5 m |
| Horizon of dead volume | - | 340,6 m |
| Full capacity of the water reservoir (at SH) | - | 3,413 $km^3$ |
| Maximum consumption through turbines of HPP | - | 900 $m^3/s$ |
| Water heads of HPP: maximum | - | 24,5 m |
| minimum (technically allowed for the turbines) | - | 13 m |
| Amount of parts of the outflow dam | - | 6 m |
| Outflow capacity through canals at SH | - | 3410 $m^3/s$ |

**Farkhad HPP** – was constructed in 1943-49 on the Syrdarya River, near Farkhad rocks, which border the river at the eastern end of Golodnaya steppe. Farkhad HPP is of the derivation type, with an estimated capacity of 126 MW and a reservoir for daily regulation, and uses releases from Kairakum reservoir. The full capacity of the reservoir is 29.7 mln.$m^3$ at a level of 319.5 m.

| | | |
|---|---|---|
| Estimated capacity | - | 126 MW |
| Quantity of aggregates (including 2 x 30 и 2 x 33) | - | 4 |
| Maximum capacity of the turbines of HPP | - | 490 $m^3/s$ |
| Standard horizon of the water reservoir | - | 319,0 m |
| Maximum horizon of water reservoir | - | 319,5 m |
| Maximum horizon of water head basin | - | 319,0 m |
| Full capacity of the water reservoir at the horizon of 319,5 m with the consumption of 500 $m^3/s$ | - | 29,7 mln.$m^3$ |
| Regulated volume at the horizon from 318,5 m to 319,5 m | - | 8 mln.$m^3$ |
| Maximum derivation consumption | - | 500 $m^3/s$ |
| Maximum capacity of idle outflow | - | 200 $m^3/s$ |
| Maximum capacity of the outflow canal | - | 30 $m^3/s$ |
| Same for the canal at the main junction at standard horizon at the dam of 319.0 m | - | 3500 $m^3/s$ |
| Same for the canal at the main junction at maximum horizon of | - | 4000 $m^3/s$ |

| | | |
|---|---|---|
| 319.5 m | | |
| Same for the flow galleries of the main junction | - | 140 $m^3/s$ |

**Andijan HPP** – located at Andijan reservoir, with a designed capacity of 140 MW, operates on the irrigation releases.

**Chardara HPP** – was constructed in 1958-66 in Kzyl-Orda Oblast of Kazakhstan at the border between the midstream and downstream of the Syrdarya River. The estimated capacity is 100 MW. The reservoir has a full capacity of 5.2 $km^3$, an avtive capacity of 4.22 $km^3$, and serves to accumulate winter flows, to re-regulate flows for summer irrigation needs, and to prevent floods and freshets of the lands located below. The reservoir was created with the help of two hydro-junctions: Chardara river hydro-junction, and Arnasai outflow hydro-junction (with a flow capacity of 1700 $m^3/s$), located to the left from the river-bed water reservoir. The operation of the reservoir and the HPP depends on the requirements of irrigation and fisheries located downstream.

| | | |
|---|---|---|
| Estimated capacity | - | 100 MW |
| Quantity of aggregates | - | 4 |
| Maximum capacity of the turbines of HPP | - | 780 $m^3/s$ |
| Maximum water consumption through the bottom outflows | - | 1000 $m^3/s$ |
| Maximum outflows through HPP under the condition of no floods should not be higher exceed | - | 1500 $m^3/s$ |
| Maximum capacity of the outflow construction of Arnasaiskiy junction | - | 1700 $m^3/s$ |
| Maximum capacity of Kyzylkum regulator | - | 200 $m^3/s$ |
| Standard horizon of water (SH) | - | 252 m |
| Horizon of dead volume | - | 244 m |
| Water heads: maximum | - | 23 m |
| Minimum | - | 9 m |
| projected, at which normal operation of HPP at maximum capacity is possible | - | 15,8 m |
| Full capacity of the water reservoir | - | 5,2 $km^3$ |
| Useful capacity of the water reservoir | - | 4,22 $km^3$ |

**Charvak HPP** – was constructed on the Chirchik river in 1963-76 in Tashkent Oblast in Uzbekistan – 60 km from the city of Tashkent. The facility, serving complex irrigation and power generation purposes, is the upper stage of the cascade of HPPs on Chirchik river. The reservoir, with a useful capacity of 1.6 $km^3$, allows seasonal regulation of the river flow for irrigation, water supply, power generation purposes, and improves winter exploitation of 18 HPPs located downstream. The estimated capacity of Charvak HPP is 620.5 MW. The contra-regulator of the flow located in the tail water of the HPP allows daily regulation at the HPP.

| | | |
|---|---|---|
| Estimated capacity | - | 620.5 MW |
| Quantity of aggregates | - | 4 |
| Full capacity of water reservoir | - | 2,01 $km^3$ |
| Useful capacity of water reservoir | - | 1,58 $km^3$ |

| | | |
|---|---|---|
| Standard horizon of water | - | 890 m |
| Horizon of dead volume | - | 835 m |
| Forced horizon of water | - | 891,25 m |
| Projected consumption of turbines | - | 600 $m^3/s$ |
| Water heads: maximum | - | 148 m |
| projected | - | 118 m |
| Capacity of mine canal (4 parts) | - | 1200 $m^3/s$ |
| Capacity of canal on the II level | - | 450 $m^3/s$ |
| Horizon of mine canal | - | 885 m |
| Horizon of canal on the II level | - | 815 м |
| Area of the surface of water in the water reservoir | - | 40,1 $km^2$ |

**Khojikent HPP** – the second stage of the Middle-Chirchik cascade, was constructed in 1971-76, 10 km downstream from Charvak HPP. The estimated capacity of the HPP is 165 MW. The reservoir, with a useful capacity of 9 $mln.m^3$, operates in the same regime as Charvak HPP.

| | | |
|---|---|---|
| Estimated capacity | - | 165 MW |
| Quantity of aggregates | - | 3 |
| Area of surface of water (at SH) | - | 3,8 $km^2$ |
| Capacity (at SH) | - | 31 $mln.m^3$ |
| Standard horizon of water | - | 742,8 m |
| Minimum horizon of worn | - | 738,5 m |

**Gazalkent HPP** – the third stage of the Middle-Chirchik cascade, was constructed in 1977-81, 8 km downstream from Khojikent HPP. The reservoir, with a useful capacity of 7 $mln.m^3$, re-regulates the daily releases of Charvak and Khojikent HPPs, operating simultaneously, and helps cover the peak loads of the power system. The estimated capacity of the HPP is 120 MW.

The remaining 16 HPPs of the Middle-Chirchik cascade, with capacities of 4 MW to 84 MW, were built during 1926-55 and have different parameters, schemes, buildings, and equipment made by different enterprises and foreign companies 30-60 years ago. All HPPs operate during the year based on the daily load schedule.

## Table 1.3.2.1
## Characteristics of the Reservoirs of Naryn-Syrdarya Cascade

| Name | Year | Design | | | Actual | | | Idle. | Indexes | Area of | Length | Width, km | | Depth, m | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | put into operation | Max. capacity, mln.$m^3$ | Dead capacity, mln.$m^3$ | Max. water head, m | Max. capacity, mln.$m^3$ | Dead capacity, mln.$m^3$ | Max. Water head, m | consumpt., $m^3/s$ | of NPU, m | surface, $km^2$ | km | Ave. | Max. | Ave. | Max. |
| Toktogul | 1974 | 19,500 | 5,500 | 183 | 19,500 | 5,500 | 183 | 3640 | 905 | 284 | 65 | 4.4 | 12 | 68.7 | 230 |
| Kairakkum | 1959 | 4,160 | 1,560 | 24 | 3,400 | 850 | 24 | 3890 | 346.6 | 544 | 60 | 9.1 | 12 | 6.3 | 23 |
| | | | | | | | | 1500-Syr | | | | | | | |
| Chardara | 1967 | 5,700 | 1,000 | 23 | 5,200 | 500 | 23 | 2100-Arn | 252 | 783 | 80 | 9.8 | 25 | 6.6 | 22 |
| Andijan | 1980 | 1,900 | 150 | 95 | 1,900 | 150 | 95 | 1700 | 905 | 55.2 | | | | | 95 |
| Charvak | 1970 | 2,010 | 426 | 148 | 2,010 | 426 | 148 | 1650 | 890 | 40.1 | 22 | | 10 | | 148 |

### 1.3.3. Reservoir Role in Irrigation and Power Development, and Operating Rules as Parts of the Water and Energy Complex

The problems of rational use of river flow are solved by requiring that water reservoirs operate under specific rules of regulation, which determine the schedule of accumulation and release of water resources, depending on the hydraulic situation, and requirements of the water-users. The basic means of this regulation is the dispatcher schedule, whose tasks include the following:

- to provide releases according to the requirements of the water-users;
- to minimize the deviations from the limits of the projected water deliveries, which may occur due to nonsystematic use of the resources;
- to find water surpluses, and to use them to increase deliveries and flows; and
- to prevent accidental floods.

Reservoir operating rules should take into account the following factors: the flow, the planned water consumption, and the available stock of water in the water reservoir. The combination of the above factors determines the proper releases of water at the current moment of operation of the reservoir. The rules determine the release of water under the following possible water levels:

- **Normal** - when the water-users are guaranteed to be provided with the necessary water resources;
- **Low** - when the guaranteed regime is broken, and it is necessary to determine the distribution of water deficits in order to prevent catastrophic interruptions in the guaranteed flows;
- **High** - when the flows must increase, and during extra high water years non-accidental releases are provided.

Therefore, there are the following zones in the dispatcher schedule, each of which corresponds to a regime of operation of the reservoir with specific releases:

1. Guaranteed;
2. Low (zone of limited releases and possible deficits); and
3. High (zone of surplus dstribution).

These zones are distinguished by specific lines, which are the basic elements of the dispatcher schedule. When creating these lines, it is necessary to fulfill the following important principles. In case of multiyear regulation of the flow, different combinations of releases are made from the multiyear regulation reservoirs. That is why, to provide guaranteed releases under unpredictable combinations of years with different volumes and distribution of flow, operations must be carried out based on the speific year and water resources.

Operation of water reservoirs is usually cyclic – long periods of normal flows are may be followed by groups of unfavorable years. When a low water period occurs, full consumption of water resources stored in reservoirs is scheduled, and a lack of water will exist in reservoirs during the following years (usually two or more low water years occur one after another) which puts the system into a long period of difficult conditions. That is why, in order to soften such interruptions, it is reasonable to decrease releases under these conditions. Under conditions of developing water shortage, water distribution is carried out on the basis of priority of specific groups of water-users, together with deficits of water supply to the other water-users. The first priority is municipal and industrial (M&I) needs, then the shortage is distributed among agricultural irrigation and power generation. Deficits are distributed on the basis of equality of damages for users served by the irrigation system. The schedule of shortages is developed on the basis of depth of interruptions, and on the stage of vegetation process, while decreasing the yield to its minimum.

High water outflows are scheduled only in case extra water resources are available in the reservoir, or on the basis of a prognosis of high levels of water during the upcoming period.

When analyzing the operation regimes of the three water reservoirs of the Naryn-Syrdarya cascade, it is necessary to mention that the mutual operating regimes of Toktogul and Kairakum reservoirs are considered due to a lack of guaranteed filling of Kairakum year after year. Each reservoir fulfills specific regulatory functions, depending on the operating regime of the other one. The purpose of distribution of the regulatory functions among the reservoirs is to reach the maximum possible effect of their exploitation.

Toktogul reservoir with a useful capacity of 14 km$^3$ carries out compensating regulation of flow Fergana valley, the midstream and downstream regions. On the contrary, Kairakum reservoir with a useful capacity of only 2.5 km$^3$ is limited in its regulation capabilities; therefore, this water reservoir, when at the beginning of the vegetation period, must be emptied during the vegetation period, partially satisfying the needs and requirements of water-users in the midstream region. Thus, the amount of compensating outflow from Toktogul depends on the water resources available in Kairakum reservoir during each year, which releases water to according to the requirements of the water-users located in the midstream region, and sanitary outflows.

For Toktogul reservoir, the operating rules determine the minimum volume (900 mln.m$^3$) which guarantees a power generating outflow of 80 m$^3$/s during the non-vegetation period (October – March). Under multiyear regulation of flow, accumulating storage in Toktogul reservoir requires a significant period of time, that is why release of multiyear reserves puts the reservoir into a long period of operation with the indexes much lower than the design.

Chardara reservoir provides irrigation water for lands in the downstream region of the river, and its regime of operation corresponds to the main rule that the requirements of water-users must be fulfilled first of all by local sources, and only their lack can be compensated by releases from the upstream reservoirs. The most important operation rules for Chardara reservoir are the following: during September to April the reservoir is filled and, beginning in April, necessary releases for irrigation are made. When a critical low water period comes, and if the storage in the reservoir is consumed by the middle of the vegetation period, then compensating releases can be scheduled in July-August from Toktogul reservoir. In order to provide the guaranteed flow when a low water period is predicted, it is necessary to have the reservoir filled with 2.7 km$^3$ before the beginning of the critical period.

Thus, in order to satisfy the requirements of agricultural irrigation, which was designed to be the main water-user of the region together with power generation, the main operating rules of the Naryn-Syrdarya cascade are the following:

- to carry out compensating releases from Toktogul reservoir for the users located in Fergana valley, midstream, and downstream regions during June - September;
- to carry out guaranteed power generation and sanitary releases from Tokogul reservoir during autumn, winter, and spring (October to May);
- to carry out releases from Kairakum reservoir according to the requirements of water-users located in the midstream region, as well sanitary releases to Chardara reservoir; and
- to satisfy the requirements of the downstream region through releases from Chardara reservoir.

Consider the issue of floods in the Syrdarya, characterized by high levels of maximum releases coming through the river in two or three waves, related with high levels of water accumulation in the reservoirs. Recall, that the struggle against floods in the region takes place over many years, and in the past it was carried out through construction of dams to protect cities, villages, and irrigated lands. Under the complex use of water resources, the struggle against floods should be carried out with the help of the same reservoirs, which were created to regulate low water flows with the aim to use then for the needs of different branches of the national economies. This contradictory character of use of the reservoirs makes it more difficult to solve these tasks, because the reservoirs should be filled for irrigation purposes, but, on the other hand, they must be empty enough to catch the flood flows. It is possible to solve such tasks only with the availability of exact information, well in advance, about the time of flood flows, their volumes, and the character of their hydrographs, which is almost impossible at the present time (2000). However, regulation of the flood flows in the Syrdarya basin has the following two objectives:

- to reduce the maximum flows released from reservoirs; and
- to rationally use the reservoirs to reduce the peak of the flood flow hydrographs.

However, with a high coefficient of flow regulation in the Syrdarya basin (0.93), the possibility of reducing flood flows during high water years is limited by the use of flood surcharge volumes in the reservoirs, which are available in addition to the normal horizons. Such volumes are located at Toktogul, Kairakum, and Chardara reservoirs – 0.8 $km^3$ in each; which means that such abilities are limited. The optimal regulation of flood flows of the river should take into account the size of water-regulating constructions located at the hydro-junctions of the cascade, as well as the capacity of different parts of the river bed. The scheme of regulation of Syrdarya River floods takes into account that non-regulated flows from Karadarya and the rivers of the Fergana valley must be passed downstream, while adding the necessary releases from Toktogul reservoir; that is, Toktogul reservoir should provide regulation of flood flows to Kairakum reservoir, which transforms the flood flow to achieve maximum levelling of the flood hydrograph, taking into account the capacity of the river bed between Kairakum and Chardara reservoirs; the latter fulfills analogous tasks within the downstream region of the river.