4.7. Basin level water resources development, 1945-2010

H. Murray-Rust, H. R. Salemi and P. Droogers

4.7.1. History of Water Resources Development, 1945-2010

Over the past 50 years, the Zayandeh Rud basin has experienced a series of water resource development projects aimed at overcoming water scarcity in a naturally water short basin. Five phases of development can be identified:

Phase 1: Before 1953, water resources development consisted of simple community built diversion structures for irrigation along the plain of the Zayandeh Rud, with little overall control over discharges in the river or into systems. Average annual flows are estimated to have been 900 MCM during this period.

Phase II: In 1953, the first transbasin diversion was completed from the Kuhrang River to the Zayandeh Rud, providing an additional 338 MCM per year. Most of this flow was available only during the spring snow-melt period when the Zayandeh Rud was also at maximum levels.

Phase III: In 1972, the Chadegan Dam was completed, providing storage of some 1,500 MCM, slightly more than the annual flow of the Zayandeh Rud and Kuhrang tunnel No. 1. This allows a small increase in total water supply for the basin but more importantly allows some winter floods to be stored for release during the summer growing season. At the same time, community diversion structures were replaced with modern cross-regulators and traditional irrigation systems in the valley were incorporated into large modern irrigation systems.

Phase IV: In 1986, the second Kuhrang tunnel with an annual capacity of 250 MCM was opened. This is the current level of development in the basin.

Phase V: Planned for completion by 2010 is the development of a third tunnel at Kuhrang with a capacity of 280 MCM per year, and development of local springs and other water sources totaling 150 MCM. Once this is developed, the total planned basin supply will be 1,917 MCM. It is not expected that any other significant water resources will be available once this phase of development is completed.

The progress of water resources development from 1953 to 2020 is shown diagrammatically in figure 4.21. Discharges at the head and tail of the basin and water utilization patterns over the same period are shown in figure 4.22. This figure shows several important aspects of the balance between water supplies and demand in the basin.

Firstly, water supplies vary considerably from year to year. The flow of both the Zayandeh Rud and the Kuhrang rivers are dependent on the winter precipitation in the Zagros Mountains. When precipitation is below normal, discharges in the Zayandeh Rud and the transbasin diversion tunnels are also below normal. In this regard, the tunnels do not provide any significant insurance against a drier than normal winter, and neither does the Chadegan Reservoir, because its capacity is only equal to the annual average flow of the Zayandeh Rud.

Figure 4.21. Development of water resources in the Zayandeh Rud basin, 1945-2020.

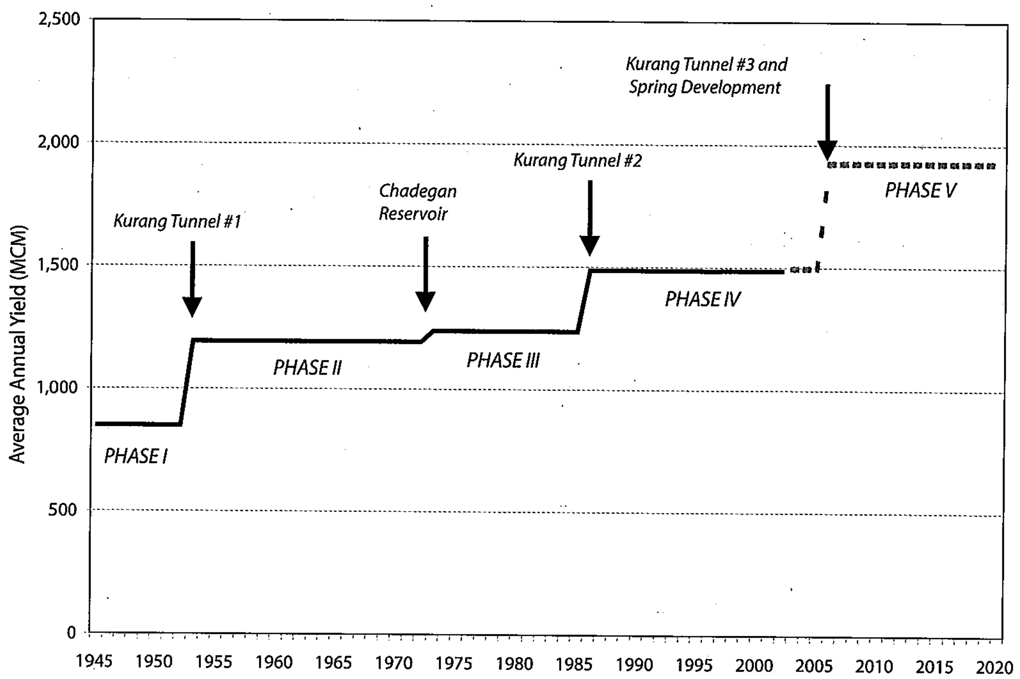
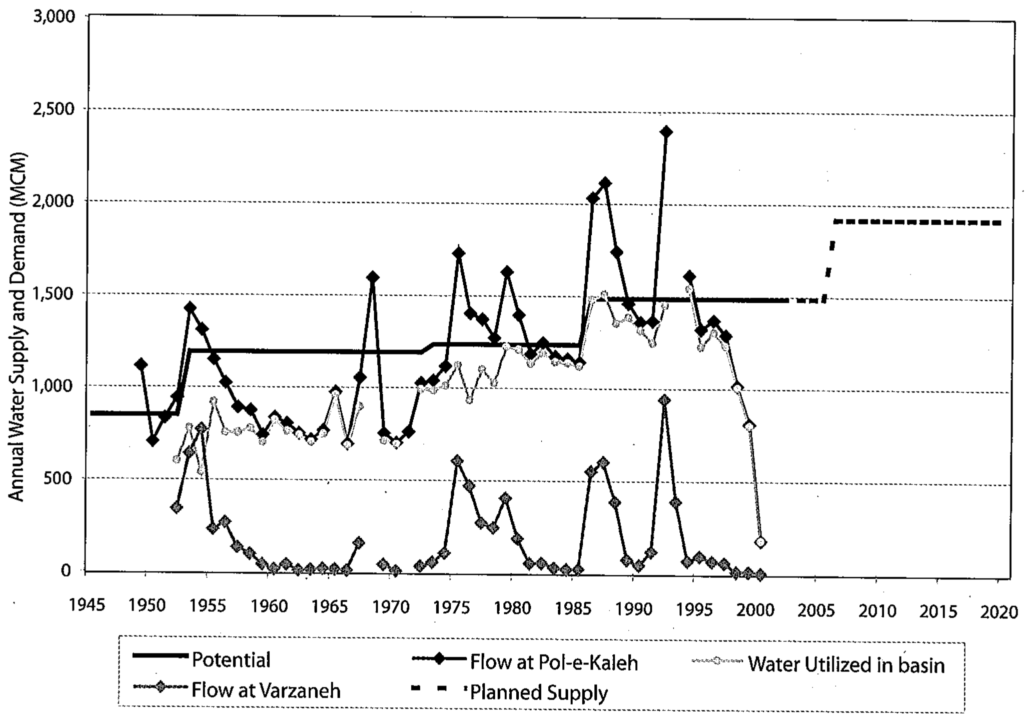


Figure 4.22. Flows and water utilization in the Zayandeh Rud, 1945-2000.



There is a clear sequence of wet years, particularly after 1967, but these are offset by drier periods. Using average data under such circumstances underestimates the impact of dry periods. Secondly, it is clear that the potential demand for water increases almost immediately after a new water resource has been developed. This effect was less marked in Phase II because water supply conditions were poor for much of this phase, but in Phase III and Phase IV, extractive potential quickly reached the planned supply. This means that each new development had no influence on the overall vulnerability of the basin to drought because all new water resources were allocated immediately.

Thirdly, it is clear that water users take as much as they can up to the planned limit. If supplies are less than the plan, then the impact is clearly seen by looking at flows at Varzaneh, the gauging station immediately upstream of Gavkhouni swamp. When actual supplies at Pol-e-Kalleh fall below the planned level, then all water is used up between Pol-e-Kalleh and Varzaneh, and little or no water reaches the swamp.

Available data indicate the basin closed in 1960 (closed in this context meaning no flow below Varzaneh because geologically this is an inland basin), and has only had four periods, totalling 15 years, with the last event occuring in 1993.

4.7.2. Analysis of basin vulnerability to drought

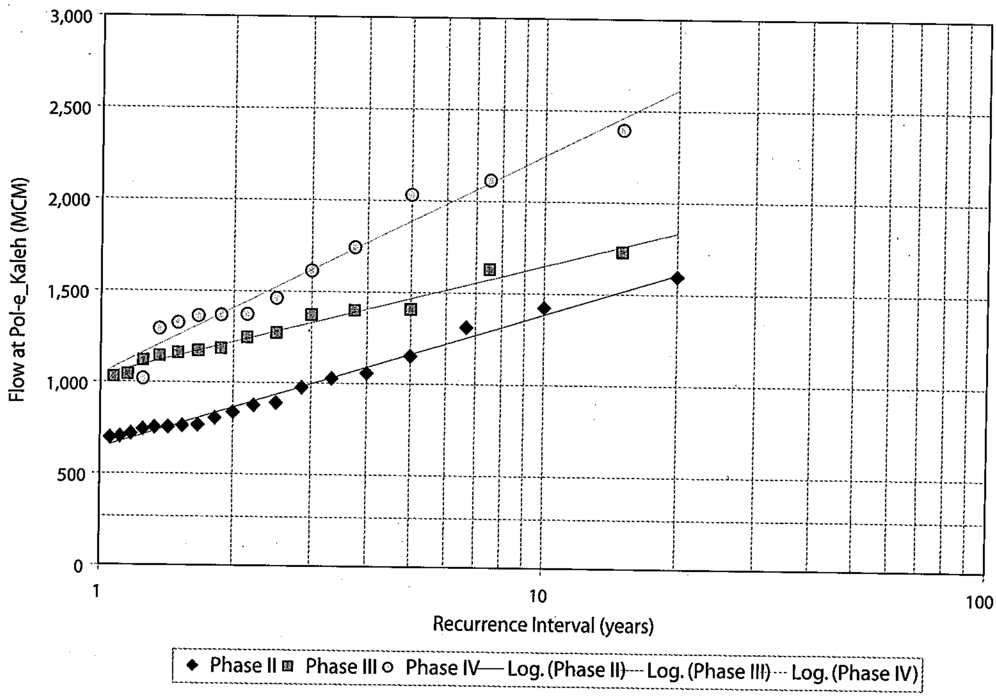
The Zayandeh Rud remains vulnerable to drought despite the series of water resources development over the past 50 years (Yekom Consulting 1998). This is because the extractive capacity of all users is at or even above average. If the flows at Pol-e-Kalleh are plotted in terms of their recurrence interval for each of Phases II, III and IV then, it is clear that the basin remains vulnerable (figure 4.23).

In phase II, the planned flow at Pol-e-Kalleh was met only half of the time, and was less than 90 percent of plan one year in three. In phase III, following the construction of the reservoir, the planned supply again exceeded half the time and was less than 90 percent of plan one year in seven. During this phase, the vulnerability against drought appears to have diminished and overall water conditions appear to have been quite favorable.

In the current phase, however, things have deteriorated again. Even before the catastrophic drought of 1999-2001, which could not have been mitigated under any level of water resources development, planned flows were exceeded in only 5 of 11 years, and were less than 90 percent once every 3 years.

The cause of this continued vulnerability is the result of two interlinked factors. Firstly, planners apppear to have used average conditions for planning purposes, meaning that there will be a shortfall once every 2 years (on average, and with a high probability of 2 or more consecutive years below average), and the fact that both the natural flows in the basin and the transbasin flows into the basin are highly correlated to winter precipitation.The steeper slope of the graph for 1984 onwards suggests more vulnerability to water scarcity than in earlier years, with little or no margin for coping with water shortages. The construction of new water resource developments that include the third tunnel at Kuhrang and various local springs and water resources, will not overcome this overall vulnerability to drought under current management practices.

Figure 4.23. Recurrence interval of flows at Pol-e-Kaleh, 1948-1999.



Experience to date indicates that in a water-short basin, all available water is used up as soon as it is made available (Molden 2001). This means that the basin has maintained the same relative level of water scarcity throughout each phase of development. It is almost inevitable this will again occur once the final phase of water resources development is complete. The construction of new irrigation infrastructure at Rudasht, in the tail-end of the basin, increases extractive capacity (assuming water reaches there in sufficient quantity). Much more worrying, however, is that irrigation has been extended to Borkhar and Mahyar—areas traditionally relying only on groundwater for irrigation. The logic appears to be that the surface systems can supplement groundwater in periods of water-stress. However, supplying surface water to these areas will likely encourage farmers to increase their irrigated area and in water-short periods when surface water supplies are in deficit, they will merely increase groundwater pumping. Borkhar has already experienced a 15-meter drop in groundwater levels in the past 10 years, and with low rainfall and deficit surface supplies, groundwater levels are unlikely to stabilize in the future.

Groundwater development has always been important, initially as "kariz" or "kanat" systems. Nowadays these traditional systems have been made obsolete by the sinking of large numbers of deep boreholes. Dropping groundwater levels throughout the basin may alleviate short-term water scarcity, but the ratio of extractive potential to actual flows means than there is little prospect of recharge to earlier levels.

4.7.3. Changes in water use for agriculture and other sectors

Figure 4.24 shows that each of the four major developments (Kuhrang Tunnels 1,2 and 3) and the Chadegan Reservoir (A) have all led to increased shares of water for agriculture. While Chadegan did not increase total basin yield, it allowed more flood water to be stored and released for irrigation later in the year. From 1945 to 2000, the share of water for agriculture remained between 80-90 percent of all water in the basin, but is projected to drop to 60 percent over the next 40 years as demands for other sectors and other basins increase (B is diversion to Yazd). This requires rethinking current management practices, an issue discussed in chapter 6.

Figure 4.24. Changing water allocations to agriculture.