Chapter 2

ENGINEERING AND DEVELOPMENT PROJECTS IN THE JORDAN RIVER BASIN

Water has played a clear and important part in plans for development and stability in the Jordan River basin. A number of such plans were developed during the 1940s and 1950s. The most important of these was one which came to be known as the Johnston Plan. It was developed, and in fact agreed to by the technical representatives of both Israel and the Arab states in the 1950s, but never formally ratified by the governments. In a number of respects, this plan represents a compromise and can be seen as an outgrowth of several earlier plans which are summarized below.

2.1 Riparians

The primary users of the waters of the Jordan River and its tributaries are Israel and Jordan. Between them, the Jordan River System has been extensively exploited and its waters account for about one-half of the water use of these two riparians. For practical purposes, the entire available quantity of high quality water is presently extracted, leaving only highly saline waters in the main stem of the lower Jordan River. Of watercourses appropriate for development, only the winter flood of the Yarmuk is at present uncontrolled and unused because political conflicts have prevented construction of storage facilities. Thus, the potential for conflict is great because both societies are expanding with an ever increasing thirst which they can slake only at the expense of their neighbors.

The other riparian states of the Jordan River System are Lebanon and Syria. Lebanese use of the Jordan River at present is minor in comparison to that of the other riparians. Syria uses the waters of the Jordan, i.e., the Yarmuk, but does not publish direct measurements; estimates will be given based on the croppages, which <u>are</u> reported.

2.2 Planning History

The Lowdermilk Plan of 1944 envisioned the diversions of fresh (i.e., low salinity) waters from the Upper Jordan and the Yarmuk River into canals running around the slopes of the Jordan Valley. This concept eventually became the basis of the Johnston Plan. Such canals would allow the irrigation by gravity flow of the lands adjacent to but upslope from the Jordan. This approach also allows the use of the high-quality upstream water before it mixes with the saline influents and becomes unsuitable for most purposes[0584]. (The Lowdermilk Plan also called for a canal to link the Mediterranean and Dead Seas.)

The Lowdermilk Plan and the Hays-Savage Plan of 1948 were forerunners to others including the TVA Plan, also known as the Main Plan[0099]. This plan took its name from its drafter, Charles T. Main, Inc., and from the role of the Tennessee Valley Authority in developing the plan. The Main Plan became the basis of the Johnston Plan, named after the U.S. special ambassador to the Middle East. He developed a compromise which grew out of the Main Plan and the separate plans drawn up by Israel and Jordan. The result, also known as the Unified Water Plan, called for about 60 percent of the water to be available to the three Arab states and 40 percent to Israel. The plan tacitly conceded Israel's out-of-basin usage, the Litani was not included, and Lake Tiberias was excluded by lack of consent as a storage facility. The Johnston Plan was rejected by the Arab states on political considerations, and was never formally ratified by Israel.

In spite of this, both Israel and Jordan continued separately to develop the Jordan in a manner which each claims to be largely consistent with the spirit of the Johnston Plan. For Israel, the implementation of water works took the form of the construction of the National Water Carrier, and for Jordan, the Greater Yarmuk Project or East Ghor Canal. In practice (see water balance in Chapter 5), Jordan receives no usable water in the Lower Jordan and less than a third of its designated allocation of 377 Mcm/yr from the Yarmuk under the Johnston Plan.

2.3 Jordanian Development

The development plan undertaken by the Jordanians originally involved cooperative efforts with the Syrians. The Jordanian Greater Yarmuk Project was undertaken at the same time as Israel's National Water Carrier in the early sixties[0422]. At the time of the last complete study of the system[1741] in 1977, the total irrigated land in Jordan was 336,000 dunums of which 253,700 dunums were within the watershed of the Jordan River and its East Bank tributaries. Some 104 Mcm/yr of water from the East Ghor Canal, Jordan's portion of the Greater Yarmuk Project, was directly used to irrigate 136,000 dunums, with the remainder of the watershed's irrigated land using water drawn from tributaries and local surface and groundwater sources before it reached the main canal. By 1982, the total amount of irrigated land in Jordan had risen to 380,000 dunums[3292]. In 1985, irrigation water use from the East Ghor Canal was 120 Mcm/yr.

2.3.1 East Ghor Canal

Initially, the East Ghor Canal plan called for two canals to run parallel to the Jordan and carry low salinity waters through the East and West Banks for irrigation and other uses. These efforts were called the East Ghor Canal and the West Ghor Canal. The West Ghor Canal was never started because of the 1967 war and the subsequent occupation of the West Bank. The Upper East Ghor Canal phase was completed in 1964, and, by 1986, it had reached a length of 120 km; a further expansion is being implemented to bring it adjacent to the Dead Sea (see Figure 2.1).

Details of the East Ghor Main Canal are taken from the engineering plans of 1959[3104]. The intake is located on the Yarmuk River at Adassiya. The water is conveyed via a 120 m diversion channel with control gates, transition and tunnel intake structure. The design water level at the intake is -203.6 m, and the invert elevation of the diversion channel at the intake is approximately -206 m. From the diversion channel, the water passes to a 977 m tunnel (horseshoe in cross section) designed for a flow of 20 cu m/s. The cross-sectional area is 6.69 sq m, and, under design flow conditions, the velocity is 2.99 m/s. The elevation drops from -208.77 m to -210.44 m (slope is 0.0020 m/m).

The tunnel discharge is to a concrete lined canal built on a slope of 0.0018 m/m. The canal is trapezoidal in cross-section, with sides 1.5:1, bottom width of 2.97 m, depth of 1.77 m, cross-sectional area of 9.96 sq m, and a velocity of 1.00 m/s at the design flow of 10 cu m/s. The canal is also designed with 0.30 m freeboard. The canal begins 1096.8 m from the intake and, as the East Ghor Main Canal, extends to the Zerqa River at a distance of 65.2 km from the intake. The ~~East~~ Ghor South Canal begins at the Zerqa. The south section is similar to the north, except the slope is increased to 0.0028 m/m, thus increasing the velocity to 1.21 m/s and the design flow to 12 cu m/s.

Along the length of the canal, there are a variety of crossings and other appurtenances. These include a number of culverts, primary and secondary bridges, etc. A siphon, of capacity 20 cu m/s, is located 7706 m below the intake. Flumes are used for crossing most of the wadis:

Wadi Name	Below Intake in km	Design Flow in cu m/s
el-Arab	11.52	20
el-Hisa	19.02	19
Taibe	20.51	19
Ziqlab	22.77	18
Yabis	37.35	17
Abu Kharrub	46.99	17
Kufrinja	53.99	15
Rajib	58.09	13
el-Khor	62.85	13

The Wadi Abu Mheir, which is 3.20 km below the start of the East Ghor South Canal, is crossed by a flume of capacity 12 cu m/s.

Monolithic concrete siphons are used to cross the the Wadi el-Qarn (43.45 km, 16 cu m/s), the River Zerqa (0.09 km below start of East Ghor Canal South, 12 cu m/s), Wadi Sha'ban (2.45 km EGC-S, 12 cu m/s), and Wadi Bliwa (4.62 km EGC-S, 12 cu m/s). The Wadi Dabar (26.0 km) is crossed without special structures.

Watering facilities are located at a variety of points. These are locations where water may be withdrawn for irrigation purposes. In terms of the distances below the Adassiya intake, they are located at 7.75, 10.24, 14.03, 24.31, 29.95, 33.05, 35.45, 37.99, 41.42, 48.28, 54.27, 57.40, 59.59, 61.33, and 63.26 km on the Main Canal, and at 1.94 km on the South Canal.

Wasteways are provided in conjunction with some of the wadis as a means of discharging the flow of the canal. The wasteways are positioned at 11.50, 19.00, 46.97, and 58.05 km below the intake, and at 0.06 and 4.58 km below the start of the South Canal. Checks and valves are located at numerous points along the length of the canal.

A number of irrigation lateral inlets are provided. These allow the water from the side wadis to be used to irrigate fields above the canal with the return flow discharging to the canal. The irrigation laterals are the Wadi el-Arab (10.24 km), the Sasiya Canal (12.04 km), Wadi Ziqlab Bseile Canal (23.70 km), Wadi Jurum north (30.57 km) and south (32.53 km) branches, Wadi Yabis north (37.31 km) and south (37.67 km) branches, Wadi Kufrinja north (52.70 km) and south (54.14 km) branches, Wadi Rajib north (56.62 km) and south (58.38 km) branches, an unnamed canal at 58.98 km, the Zerqa River Izrar (60.95 km), Deir Alla (63.21 km), and Dbab (0.5 km on EGC-S).

This system is currently used to irrigate more than 157,000 dunums (15,700 ha), and expends 120 Mcm/yr of water. In 1975, the total irrigated by the EGC was 136,000 dunums[2820].

2.3.2 Dams and Reservoirs: Yarmuk Basin

The Maqarin Dam phase of the Greater Yarmuk Project involved the planned construction of a dam at Maqarin on the Jordan-Syria border. Two dams were eventually proposed for the Yarmuk River (see Figure 2.1). The Maqarin Dam was to be located approximately 35 km east of the confluence of the Yarmuk River and the Jordan. The Mukheiba (Khalid Ibn al-Walid) Dam was to be located about 10 km east of the Yarmuk-Jordan confluence. Work on these two dams was blocked by the 1967 war. The Mukheiba Dam site now lies below the Israeli-occupied Golan Heights. Israel and Jordan were thought to have reached an agreement mediated by Philip Habib regarding the Maqarin Dam, but work has not begun. Conflicts between Jordan and Syria have also impeded the construction of the Maqarin[0359].

The Maqarin Dam was planned for a height of 150 m, storage of 350 Mcm and phase I irrigation for 20,000 ha[0961]. A 22 MW hydropower generating station was included in the plans. The average annual flow of the Yarmuk at Maqarin is 240.3 Mcm which is derived from a drainage area of 5950 sq km. The Khalid Dam was planned as an adjunct to the Maqarin Dam. It was to have live and total storage volumes of 220 and 235 Mcm, respectively[2823], and would be used for power production. The average annual intervening flow between Maqarin and Khalid is 127.5 Mcm.

Higher in the Yarmuk basin are two reservoirs in the Mafraq region, designed for irrigation purposes. The reservoirs at Ghadeer Abyad and Bowayda each have a capacity of 0.7 Mcm and derive their water from the flow of local wadis[3055]. Also in the Mafraq area are two reservoirs designed for storage for domestic purposes. The Umm al-Jemal reservoir has a storage capacity of 1.8 Mcm, that at Sama Sudud stores 1.7 Mcm[3055].

2.3.3 Dams and Reservoirs: Zerqa Basin

The King Talal Dam, completed in 1977, lies across the Zerqa River just below the confluence of the Zerqa and the Wadi Rumeimin. This is an earth and rockfill dam. It has a storage volume of 56 Mcm, a live capacity of 48 Mcm, and a generating capacity of 5 MW. Its estimated annual yield is 48 Mcm. The height of the dam is 92 m (169 m above msl). The flooded area at the crest elevation is 2.5 sq km. The catchment area of 3300 sq km yields an average of 94.4 Mcm/yr, with a yield at the dam site of about 75 Mcm/yr[1741]. (Other studies give different estimates.) The evaporation loss averages 2000 mm/yr. The dam was originally proposed for irrigation purposes and it is used to supply water for 60,000 dunums. In its early days, in response to severe demands for water in the Amman region, proposals were made to recover some of the water and, following treatment, pipe it to Amman as a domestic supply.

Pollution of the King Talal Dam Reservoir has made it impossible to use the water for domestic purposes. For this reason, the plan to supply Amman with water from the King Talal Reservoir was scrapped[0145]. Since the diversion of new drinking water sources to the Amman area (e.g., 16 Mcm/yr from Azraq), the capital city has been draining its treated wastewaters into the Zerqa River. Thus, the flow at the King Talal Dam is now thought to exceed 100 Mcm/yr.

Plans to raise the height of the King Talal Dam have led to the initiation of construction in mid-1983 by the South Korean-based Hanbo General Construction Company[0359]. The plan calls for a completed height of 108 m. This will raise the storage capacity from 56 Mcm to 80 Mcm and will provide for an additional 4 MW hydropower unit. It is estimated that the maximum life of the reservoir after raising will be 60-90 years due to the siltation.

The flow in the Zerqa River at Deir Alla, close to its confluence with the Jordan, is 67.3 Mcm/yr on an annual average basis. A sprinkler irrigation project there is used to cultivate 5077 ha, utilizing in excess of 30 Mcm/yr. Also at Deir Alla but not in the Zerqa River basin, a pipeline was built in 1984 to convey up to 45 Mcm/yr from the East Ghor Canal (EGC) at Deir Alla to a terminal reservoir on the outskirts of Amman at Suweileh. The diversion system was designed to pump water in a 35 km-long buried pipe up the 1350 m elevation Jordan Valley to the plateau[0145]. The capacity of the Suweileh reservoir is 0.25 Mcm[0359]. Doubts were immediately raised, however, about the suitability of using water from the EGC as drinking water, and the feasibility of treatment to bring it up to potable standards. Since 1984, studies have been under way to investigate the treatability of the water and the health effects of using it as a drinking water source.

Upstream on the Zerqa in the Dhuleil area, the al-Lakafi reservoir with a capacity of 0.7 Mcm is supplied by local wadis[3055]. This is a pilot project for artificial groundwater recharge.

In all, within the Zerqa basin nearly 51,000 dunums was irrigated in 1975, one fifth from surface water and the rest from groundwater. The current figure is probably in excess of 58,000 dunums.

2.3.4 Other Dams and Reservoirs

Other than the rivers Yarmuk and Zerqa, the average annual flows of the East Bank wadis is some 100 Mcm/yr. Of these, five wadis have seen major water storage or diversion projects for use in the irrigation of 41,780 dunums (4,178 ha) in 1975. Water from wadis without engineering projects is used for local irrigation of an additional 12,600 dunums. The source of this water is about evenly split between surface catchment and underground spring/well sources. The summary of the basic information regarding the five wadis with major engineering works is as follows:

Water Storage or Diversion Projects On East Bank Wadis

	Drainage Area-km^2	Streamflows in Mcm/yr	Capacity Live-Mcm	Irrigated Area-dunum
el-Arab	267	28.8	20.0	3,325
Ziqlab	106	9.5	4.4	5,810
Shueib	178	9.8	2.3	11,190
Hisban	58	5.0	--	6,745
Kufrein	163	14.3	4.8	14,710
Totals	*772*	*67.4*	*31.5*	*41,780*

Sources: GTZ, *National Water Master Plan of Jordan*, vols. I[1741], V[2820]; Government of Jordan statistics, see Appendix A; note that the irrigation areas given are for 1975.

The Wadi Arab Dam was first proposed in the late 1970's. It has a live capacity of 20 Mcm and a height of 65 m, although plans are already prepared to raise the height to 83 m[0359]. The first phase, i.e., to a height of 65 m, was completed in 1985. The main function was to supply water for irrigation purposes (12,000 dunums using sprinkler irrigation) in the Jordan Valley. The Wadi Arab has a mean annual stream flow of 28.8 Mcm, derived from a drainage basin of 267 sq km[2827][2828][2829].

The Ziqlab reservoir, located on the Wadi Ziqlab, has a live capacity of 4.4 Mcm, a mean annual flow of 9.5-10.5 Mcm, and an estimated yield of 10 Mcm/yr[2823]. The upstream drainage area is 106 sq km. The intake invert is located at 89.0 m and the spillway crest is at 124.0 m. It was completed in 1963 and its primary function is to supply water for irrigation. Water is supplied to the Ziqlab irrigation project and to the East Ghor Main Canal.

The Shueib reservoir is located on the Wadi Shueib at 31°55'N, 35°39'E. It is used for irrigation, and to store flood waters and then to recharge them to groundwater. It has a live capacity of 2.3 Mcm[3055]. The mean annual flow is 9.8 Mcm[2823].

The Hisban conduit, completed in the late 1970s, is located on the Wadi Hisban, a tributary of the Wadi Kufrein. It functions to divert water in excess of local demand to the Kufrein Reservoir from which releases are made for irrigation. The mean annual flow at the Hisban is 6.6 Mcm[2823]. The average annual flow of the Wadi Hisban, which drains an area of 58 sq km, is 5 Mcm near el-Rama[2827][2828][2829]. The reservoir is located at 31°49'N, 35°40'E.0

The Kufrein dam, completed in 1968, has a live capacity of 4.8 Mcm[2823]. The area drained is 163 sq km. The mean annual flow at the dam is 14.3 Mcm[2827][2828][2829]. The dam, which is used for irrigation purposes, is located on the Wadi Kufrein at 31°51'N, 35°40'E.

Two reservoirs built in the early 1960's are currently little used because of the excessive losses due to evaporation and seepage. These are on the Wadi Qatrana, capacity 4.2 Mcm, and the Wadi Sultani, capacity 1.3 Mcm. Both were designed to control flood flows, and are on tributaries of the Wadi Mujib, the "Grand Canyon" of Jordan which flows directly into the Dead Sea from the east.

2.4 Syrian Development

Within the Yarmuk basin in Syria, only the Deraa surface dam is included in the 1979 summary of Syrian dams from the Statistical Abstract of Syria. Except for the three Muzeirib projects, the reported irrigation projects are all small in scope. The Muzeirib projects were part of the joint Syrian-Jordanian planning for the Greater Yarmuk Project, and were intended to provide controlled winter irrigation and expanded summer irrigation for Syrian farmers.

In the Deraa region, there are a number of canal networks as reported in the *Syrian Agricultural Sector Assessment* (SASA) of 1980[3046]. These are the Upper Muzeirib, which derives water from springs and is associated with the irrigation of 1946 ha; the Middle Muzeirib, which is spring fed and is used to irrigate 2802 ha; and the Lower Muzeirib, which uses water from the Yarmuk to irrigate 2204 ha. The al-Ajamy network is fed from the Ajamy spring and irrigates 215 ha.

SASA[3046] reports that the Shaykh Meskin network, fed from the spring at Umm Dananir, conveys water to 353 ha. A 1984 journalistic source[2204] reports that a Shaykh Meskin Dam on the Yarmuk was planned for completion in 1984; its purpose was to provide water for a 40 km irrigation network supplying a 1300 ha project[2204]. Another storage dam for the same area is also planned for later in this decade. It will be used to irrigate 650 ha.

SASA[3046] indicates that the early Deraa Dam, located east of the town of Deraa is "not well exploited", and is used to irrigate 280 ha. The later article from Tishrin[2204] reports the construction of a storage reservoir behind the Deraa dam which will have a capacity of 7 Mcm. The second stage of the Deraa Dam irrigation network was scheduled for completion in 1984. It is intended for use in supplying irrigation water through a 15 km network for 450 ha[2204].

Two other irrigation network dams on the Yarmuk are the Abta and the al-Sariya[2204]. In the late 1970s, the water from the Abta Dam was used to irrigate 500 ha[3046]. The Eastern al-Fariyah project is planned to supply irrigation water for a 250 ha project via a 10 km network. The Tafas Dam is a storage dam on the Yarmuk. Its construction schedule indicates a contemporary start-up date. It will be used to irrigate 500 ha in Tafas and Jallin. Completion is expected in 1988[2204].

In Quneitra province, three canal networks are used to convey irrigation water from springs to fields. The Kom al-Wesieh and Ain Nowieh systems are used to irrigate 260 ha. The Fawar spring project provides water for 170 ha, and Ain al-Beida project for 40 ha.

The above projects total 11,270 ha, which represent 83 percent of the total 13,595 ha reported as irrigated in 1981 in Deraa and Quneitra provinces. All of the land irrigated from surface sources -- 88 percent of the total irrigated land in 1981 -- was in Deraa province. A little over half of the land irrigated from groundwater in the two provinces is encompassed in the above projects, a total of 1,028 ha out of the 1,915 ha reported in 1981.

2.5 Israeli Development

For Israel, the implementation of water works following the failure of the Johnston negotiations took the form of the construction of the National Water Carrier, an extensive conduit system designed to transport water from the water-rich (at least 1000 mm precipitation/yr) north to the potentially fertile but arid (30-200 mm/yr) out-of-basin regions of the Negev Desert. The Carrier, completed in 1964, lies entirely within Israel's pre-1967 boundaries and diverts water from the Jordan from the northern edge of Lake Tiberias primarily to areas along the coast and south to the Negev. It is also used to connect water users with the principal Israeli aquifers, the Coastal Plain Sandstone and the Yarkon-Tanninim Limestone aquifers.

The Yarkon-Negev part of the National Water Carrier system, completed in 1955, is fed by wells east of Tel Aviv and provides 270 Mcm for that city and for irrigating the Lachish area. Another portion of the system is used to collect water from northern Galilean creeks which was formerly discharged to the Mediterranean and to irrigate portions of the Esdraelon Valley. A third part of the system drained marshy areas (Huleh Valley) in an effort to improve the flow of the Upper Jordan. These three parts of the overall system were completed early and are often not considered to be part of the National Water Carrier proper.

Lake Tiberias serves as a storage reservoir for the National Water Carrier (NWC). Its total capacity is 4000 Mcm. The lake is fed by the three tributaries, the Dan, Hasbani, and Banias. Together they currently discharge a measured average of 521 Mcm/yr to the lake. Minor tributaries and direct precipitation bring the total inflow to 600-650 Mcm/yr. The annual design withdrawal for the National Water Carrier was 320 Mcm, although current extraction seems to exceed that figure by nearly 40 percent. Evaporation rates are reported as 1619-1786 mm/yr for the period 1969-1977[2591]; estimates for longer periods give evaporation estimates as high as 1870 mm/yr.

2.5.1 The National Water Carrier

The Carrier consists of a series of pumps, canals, and tunnels used to convey water taken from Eshed Kinrot on Lake Tiberias (210 m below sea level) to as far as 200 km to the south[1584]. A schematic cross-section is shown in Figure 2.2, and a location map in Figure 2.3. The average design water flow is 320 Mcm per year and the maximum elevation difference is 360 m. A 3 m diameter steel jacketed reinforced concrete pipeline laid in a trench on the floor of Lake Tiberias conveys water through several hundred meters to the Eshed Kinrot pumping station.

On its way to the pumping station, the water passes into an inlet canal and from there to the bottom of three pump chambers each rated at 22,000 kW with a capacity of 6.75 cu m/s or 213 Mcm/yr each if operated continuously. Each pump consists of a vectorial centrifugal feed pump and a horizontal pump. The main pumps are horizontal centrifugal single pumps with a double inlet. The pumps are situated 7.5 m above the maximum water level of the lake and are fed via two feed pumps, and may operate with the level as low as 216 m below msl. The spilling levels for the lake are maintained at different levels at different seasons of the year in order to accommodate storage of winter runoff; in January-February of 1981, the water was spilled if it rose above -209.4 m below msl, by May the spill level was raised to -208.9 m[1698].

The water is pumped through a penstock (2300 m) and lifted through 250 m into the Jordan Canal[2243]. The water flows by gravity along a slope of 0.00016 (16 cm/km) for 16 km along an open 2.70 m deep concrete lined canal, trapezoidal in cross-section (12 m wide on top and 2.50 m wide at the bottom). The canal bottom and floor are covered by an asphaltic membrane 1 cm thick over which a 10 cm concrete lining has been cast. The course of the Jordan Canal is interrupted by two wadi-gorges which are crossed by the use of siphons. These are located at Nahal Amud and Nahal Tsalmon.

The water then flows into the Tsalmon Reservoir which is concrete lined with a total volume of 880,000 cu m, and a minimum operational capacity of 217,000 cu m. The reservoir surface area is 20 ha and the maximum depth is 4.5 m[1568]. The purpose of the Tsalmon Reservoir is to provide a reserve for the Tsalmon Pumping station and to cushion any excessive inflow entering from the Jordan Canal. The floor and banks of the Tsalmon Reservoir are bedded with a layer of compacted clay 1 m thick. A perimeter drainage system conveys runoff water into a downstream reach of the Nahal Tsalmon.

The water is pumped out of the Tsalmon Reservoir by means of a vertical pump, and then passes through a 800 m long penstock and reaches the Eshkol Canal (Beit Netofa Canal) at an elevation of 149.49 m. The Tsalmon pumping station is the second lifting stage of the NWC. It consists of three pumping units of capacity 6.75 cu m/s or 213 Mcm/yr each, powered by 11,000 kW motors each. The Beit Netofa Canal is an 18 km long concrete waterway leading to the inlet of the Beit Netofa (Eshkol) Reservoir at an elevation of 145.40 m. The canal has a curved bottom. It is 2.60 m deep (2.15 m water depth), 20 m wide at the top, and 12 m wide at the bottom. The reservoir actually consists of two reservoirs, the first acting as a settling basin of volume 1.5 Mcm[1568]. The reservoir has a maximum capacity of 3,810,000 cu m and a minimum of 1,540,000 cu m, corresponding to elevations of 147.0 and 144.0 above msl, respectively. The operating volume of the reservoir is 1,270,000 cu m, disregarding the settling basin. The area of both sections is 140 ha, and the maximum depths are 4.5 m and 7.5 m, respectively[1568].

From the Eshkol Reservoir, the water flows to Menashe station via a 108" (= 2.74 m) pipe. This pressurized system conveys water to the Zohar Reservoir. The connection between the two reservoirs consists of 85 km of a 108"-diameter prestressed concrete pipe which splits at Rosh-Haayim to form two 60 km lines, the Western Yarkon Line (70" = 1.78 m) and the Eastern Yarqon line (66" = 1.68 m). On the southward run from Beit Netofa to Rosh-Haayim, the 108" pipeline passes through the three tunnels called the Shimron, Menashe "A" and Menashe "B" tunnels. The Zohar Reservoir has an area of 120 ha, maximum volume of 8.5 Mcm, and a maximum depth of 17 m[1568]. From the Zohar Reservoir, a 66" line carries water farther south to the Negev via the Simha, Tal Or, and Mivtahim pumping stations.

The Tsalmon and Netofa Reservoirs receive water solely from Tiberias. The Zohar Reservoir also receives some ground water[1568]. The completion in 1969 of a series of booster pumping stations at Tsalmon, Menashe, and points downstream has raised the effective capacity of the system from 11 cu m/s to 16 cu m/s (from 347 to 505 Mcm/yr)[1568].

As an adjunct to the Carrier, work has been undertaken to reduce the saline inputs to Lake Tiberias in an effort to reduce the salinity in that lake which serves as a reservoir for the National Water Carrier[0584]. The saline inputs are developed from a number of springs, some of which are in the bottom of the lake and some on the shore. There are three principal on-shore sources: at Nur north of Tabigha, at Fulia north of the town of Tiberias, and at the hot springs south of the town[0787]. Part of the success in lowering the salinity of Lake Tiberias is due to diversion of salty spring water around the lake to the Jordan River downstream from Lake Tiberias [2849]. The discharges of the peripheral saline springs are intercepted and conveyed via an open canal. At the town of Tiberias, the open canal is replaced with two buried 36" (= 91 cm) diameter asbestos-cement pipes. The canal begins on the west shore of the lake at Tabcha and enters the Jordan River about 1 km below the lake at a point below the Deganiah and Alumot Dams. The chloride concentration of the diverted water is 2500-6000 mg/L[0597].

Other Israeli development has included drainage and canalization work in the Huleh Valley to control runoff and flooding in the area.

2.5.2 Mediterranean-Dead Sea Canal

In recent years, the possibility of the much-discussed Mediterranean-Dead Sea Canal was again suggested[1248], although it was officially shelved by Israel in June, 1985. The fundamental premise behind this project is that a means must be found to keep the level of the Dead Sea stable. With the continued exploitation of the Jordan River, the level of the Dead Sea has been dropping over the past twenty years and the sea will continue to show a significant negative water balance into the foreseeable future.

As proposed by the Israelis in 1980, the plan to link the two seas would exploit the 400 m elevation difference between them by including hydroelectric stations rated at 600 MW. In addition, proposals were made to use the water for cooling nuclear power stations of total capacity 1800 MW, and to investigate the feasibility of generating 1500 MW from solar ponds. The Canal would be 72 km long, including a 32 km section which would be open and a 40 km tunnel. The first 12.5 km would traverse occupied territory in the southern Gaza Strip. The quantity of water involved is estimated to be 1550-1770 Mcm/yr, depending on the level to which the Dead Sea will be raised (-395 or -390 m).

An annual flow such as 1500 or 1700 Mcm would increase the level of the Dead Sea and this might be expected to have an adverse effect on Jordanian and Israeli industry and tourism along the shore of the Dead Sea. In fact, it should be pointed out that the elevation of the Dead Sea has fluctuated since 1800. During the 19th century, the elevation ranged between -399.3 and -393 m. In the last decade of the previous century, the water level rose to -389 m and remained above -392 m until the mid-1950s. Since then the level has dropped to -399 m in 1980[3087] and to -403 m in 1986.

Salameh and Khawaj[0497] concluded that maintenance of the sea's level at -395 m would be best for all parties. At that elevation, the evaporation would be 1880 Mcm/yr; at the slightly higher elevation of -390 m (at which level adverse effects would be felt), the evaporation would be 2032 Mcm/yr. Since we calculate below (see Chapter 5) that the Jordan River system currently contributes only 291 Mcm/yr to the Dead Sea, added to local contributions of 264 Mcm/yr, it would require 1325 Mcm/yr in incremental flows to stabilize the level at -395 m and an increment of 1477 Mcm/yr to stabilize the level at -390 m. It is suggested that the former level is optimum, and that raising the sea to -390 m would cause saline infiltration of adjacent fresh water sources as well as damage to touristic and industrial potash mining installations on both shores.

2.6 Use of Reclaimed Wastewater

The principal use of reclaimed wastewater in the study area is associated with Israeli efforts. In this case, the major uses are in the agricultural and industrial sectors. Other options for reuse include aquaculture, recreational impoundments, some restricted municipal use, and groundwater recharge[2872]. Restricted municipal use refers to street cleaning, watering golf courses, and other non-contact purposes. There are too many lingering public health questions regarding the survivability of viruses and the presence of trace contaminants to recommend the use of reclaimed wastewater for unrestricted municipal uses.

In the mid 1980s the use of treated effluents in Israel amounted to 57 Mcm/yr, all for agriculture. This is approximately 24 percent of the total available national effluent[1675].

2.6.1 Small Israeli Projects

It is estimated that by 1980 approximately 250 effluent irrigation projects were in operation. In most of these, a relatively small amount of wastewater is used, and this comes from the agricultural communities themselves. In a small number of projects, municipal wastewater effluent is used.

The pattern of effluent use in these projects has generally been to apply the wastewater only during the drier summer season. Depending on the locale and the crop under irrigation, this means that effluent is not used during a six to eight month period each year. At these times, the effluent is typically diverted to a near-by stream. Since most of the streams in Israel are intermittent, the consequence of this policy is that the entire flow in some streams is occasionally made up solely of effluent. This is not only objectionable from an environmental viewpoint, but it also represents a wasted asset from the water resources viewpoint. Consequently, a number of storage projects have been planned to store the effluent for later irrigation use.

There are a number of major seasonal impoundment projects. These include the Kishon Project in which treated effluent from Haifa will be pumped 20 km to a storage facility in the Ezraelon Valley. This will be augmented with stormwater runoff and will add 18 Mcm of irrigation water/yr to the region. Another project calls for the diversion of about 10 Mcm/yr of activated sludge effluent to from Jerusalem to the Gazaza coastal plain area. It is anticipated that the water will be used to irrigate about 1800 ha of cotton and 600 ha of cereals by the mid-1980s. The seasonal reservoir will have a storage capacity of about 3 Mcm, depth of 10 m, and area of about 38 ha[0224].

In the upper Galilee, a major effort is to reduce the pollution of Lake Tiberias. The Einan reservoir, completed in 1984, receives the water of the western canal which includes sewage and effluents. This has diverted a large amount of effluent away from the Jordan River. The treatment of Zefat sewage has resulted in an improvement in the quality of the receiving water.

In Western Galilee, a relatively small fraction of the effluent is used for irrigation. Effluent is stored in reservoirs for later use[1675]. The San Jean reservoir has been planned by Tahal to store effluent from Acre and from some Arab villages.

In Haifa and its suburbs, sewage is conveyed to the Haifa reclamation facility. Some of this effluent is used for irrigation; most is pumped to the recently completed storage reservoir of the Kishon corporation.

In the Esdraelon Valley, reservoirs hold the effluents from Affula, Nazareth, Migdal-Haemek and the agricultural settlements. The water is used for irrigation. Reuse of the effluents from settlements in the Tabor river area has solved the pollution problems of that river. Effluents from the Beit Shean region are utilized for irrigation.

Kefor Sabla, Baanana and Ramat-Hasbaron's effluents are utilized only in the summer. At other times, the effluents flow to the Yarkon and Poleg rivers. This practice will stop when the plan is complete. Treated effluent from Netaniah is partially used in neighboring settlements. Surpluses flow to the Alexander River[1675].

Effluent from Lod, Yahud, and Zerifim are pumped throughout the year to the Noan reservoir from which irrigation water is pumped in the summer. Surplus effluent flows to the Ayalon River[1675].

Sewage effluent from Jerusalem is split with flows occurring west to the Sorek, south to the Refaim and east to the Kidron River. The effluents drained to the Sorek River (about 5 mcm/yr) are reclaimed at Ein-Karem for irrigation of the groves of the Haarazim Valley.

In the south and in the Negev, effluents from Kiriat-gat Ashdod, Beer-Sheba, and Eilat are being utilized. Ashkelon's effluent will be used for irrigation via the Nitzanim reservoir, currently (November, 1985) under construction[1675].

Israel used 57 Mcm/yr of municipal effluents for agriculture according to a 1985 source[1675]. The above projects account for 33 Mcm of that total, with the remaining 25 Mcm coming from the Dan Project (see below). There are plans to use at least 100-150 Mcm/yr and perhaps as much as 200-300 Mcm/yr for agricultural purposes.

2.6.2 Dan Region Project

Clearly, the most important, advanced, and controversial wastewater reclamation scheme in the study area is the Dan Region Project, situated in the Tel Aviv area (see Figure 2.4). The Dan Region Wastewater Reclamation Project is the largest part of an overall plan to reclaim wastewater in Israel. The purpose of the reclamation plan is to provide the 200-300 Mcm/yr estimated shortfall needed by Israel in the most cost-effective manner. Although the Dan Project had its beginnings in the 1950s, it was not until after the initiation of the National Sewerage Plan following the cholera outbreak of 1970 that it moved ahead quickly.

The Dan Region Project is the second largest wastewater reuse system in the world. It serves the Tel Aviv metropolitan area, the largest in Israel, including Tel Aviv-Yafo, Ramat Gan, Bnei Beraq, Givatayim, Petah Tiqwa, Rishon-Le-Zion, Holon, and Bat Yam. The purposes of the project are to stop pollution of the Tel Aviv shore line due to wastewater discharge into the Mediterranean Sea, and to recycle water to supplement Israel's limited natural water resources, primarily for agricultural and industrial uses[0225][0237].

Stage I of the Dan Project went on-line in January, 1977. The system currently treats an influent flow of 25-30 Mcm/yr of wastewater using three major treatment techniques (Figure 2.5). Recirculated oxidation ponds serve as biological treatment units for the stabilization of organics. This is followed by high lime-magnesium treatment in a sludge-blanket reactor-clarifier. The process is so-named because additional lime is added to elevate the pH to approximately 11 which is sufficient for the precipitation of magnesium, as the hydroxide. Under these conditions, treatment efficiency is enhanced. This unit provides additional BOD removal, nutrient removal, pH adjustment and suspended solids removal. The final treatment step consists of polishing ponds for ammonia stripping, natural recarbonation, and final suspended solids removal.

The oxidation ponds remove 65 percent of the Kjeldahl nitrogen and 70 percent of the total nitrogen in the winter. Summertime removals are, of course, higher. The influent total nitrogen value is unusually high by U.S. standards, averaging 90 mg/L. The high lime-magnesium process removes phosphorus, suspended solids, many heavy metals (as insoluble hydroxides), algae, color, boron, silica, and fluorides. The elevated pH developed during the process also provides disinfection and prepares the ammonia for stripping in the subsequent step. The polishing ponds reduce the pH by recarbonation and provide ammonia stripping[0234].

Following the three major processing techniques, the reclaimed wastewater is recharged to the groundwater. The effluent is intermittently spread over fine dune sand recharge basins. As the effluent flows through the soil, more purification and recarbonation occur. Groundwater recharge also provides seasonal and year-to-year storage, dilution with high quality groundwater, and an additional factor of safety[0234]. The water is reclaimed with recovery wells, chlorinated, and distributed in the national distribution network.

Stage II of the Dan Region project is under development with start-up scheduled for the last half of the present decade. The plan calls for the collection of raw sewage from an urban service area of 20 sq km and a tributary[1985] population of 1.3 million, and its conveyance to a regional wastewater treatment plant (Figure 2.6).

The design flow is approximately 50 Mcm/yr, with provisions for expansion to 160 Mcm/yr after the year 2000. Raw wastewater from an anticipated population of 1.3 million will be collected and treated. This second stage will connect with a dual supply system operating in the south of the country.

High quality reclaimed wastewater for non-potable uses, mainly irrigation, will come from one system. The other will provide municipal drinking water from groundwater wells and a different distribution main(0225).

The processes used in the Stage II treatment will include secondary treatment, using a modified, low-rate activated sludge process, without primary clarification. The process will be operated as a single sludge system achieving nitrification, denitrification, and high removals of carbonaceous BOD and phosphorus(0237). Provision has been made for additional polishing and/or physical/chemical treatment should they be needed in the future.

The controversial aspect of the Dan Project centers on the potential use of the recovered water. The original concept was that the effluent would be available for any purpose, i.e., drinking or agriculture. Consequently, the original plan called for the injection of the effluent directly into the National Water Carrier via the 70 in. (= 1.78 m) National Water Supply Western Pipeline which is adjacent to the project area(2633). However, as data became available during the 1970s with respect to the complex toxicological and microbiological issues surrounding wastewater reuse, it was decided in 1976 that reuse of the Dan effluent would be limited to agricultural uses. This will be accomplished by using the 70 in. supply line for the effluent; separate drinking water supply systems will be developed for the communities presently receiving their drinking water from that supply line(2633).

2.6.3 Aquaculture

Another important use of wastewater in Israel is to support food production in fish ponds. These facilities combine efficient wastewater treatment along with the conversion of wastewater carbon and nitrogen to fish protein.

Some pretreatment of the sewage is necessary in order to maintain aerobic conditions within the pond, especially during nighttime periods. This is accomplished by either dilution or by the use of ponds with very long detention times. In Israel, the dilution method is most often utilized. In these applications, most often associated with the rural kibbutzim (population typically 500 to 1500), the pond is initially filled with freshwater, and sewage is used to replace evaporation losses. These ponds are generally of area ~~50~~ to 100 ha, depth 150 cm, and they receive 100 to 600 cu m of (perhaps pre-settled) wastewater per day.

Data collected from these ponds indicate that fish yields are about 70 percent greater in ponds receiving organic wastes, and that 40 percent less supplemental food is required to produce a kilogram of fish[(0870)]. Health problems have not been experienced with high quality fish grown with wastewater. However, very little work has been carried out on the contamination of fish by human pathogenic viruses, and there is controversy concerning the survival of human enterobacteria within the fish[(0870)].

2.6.4 Industrial Reuse in Israel

Industrial reuse of water is legally enforced in Israel. Water use standards have been set for each industrial category. These standards have become progressively more stringent as the state-of-the-art has improved. The Office of the Water Commissioner has used its legal authority to regulate the magnitude of industrial water allocations. In this way the Office has actively encouraged industries to reuse and conserve water. This program has been quite successful, with the inflation-adjusted value of industrial output per unit of water use increasing by a factor of 2.6.

One example of the potential for industrial re-use is in the paper industry. Paper mills are historically well-known as large consumers of water. Water use can be as high as 120 cu m water per ton paper. There is a paper mill in Hadera, Israel, which uses only 12 cu m/ton.

Another option is the industrial use of treated municipal effluent. An early project of this nature involves the use of 4 Mcm/yr of biological treatment effluent from Haifa as cooling water in nearby oil refineries.

2.6.5 Jordanian Waste Treatment

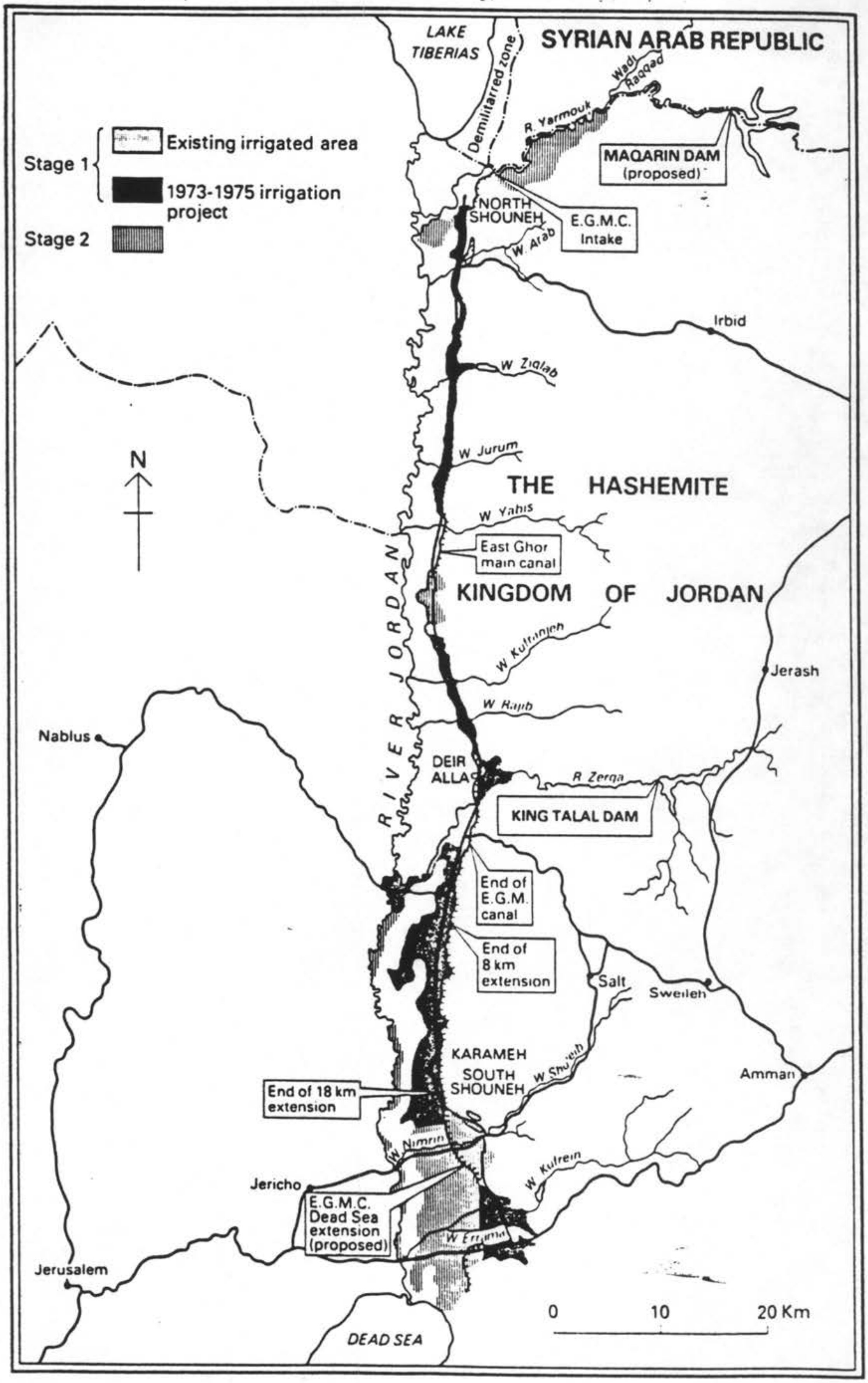
Water treatment for potable purposes in Jordan has traditionally involved the chlorination of groundwaters. With the advent of surface storage schemes, more rigorous treatment has become necessary. The proposed treatment for the water stored by the King Talal dam included coagulation with aluminum sulfate, sedimentation, and rapid sand filtration in addition to disinfection by chlorination[(2694)]. Soon after completion of the King Talal Dam, it became apparent that, even with treatment, the quality of the water would be unsuitable for domestic use[(2837)(2848)]. The continued pollution of the river has brought about a condition in which it is neither technically nor economically feasible to treat Zerqa River water for human consumption[(0548)(0908)]. Suggestions have been made to use the water of the reservoir for artificial recharge in the Baq'a Valley[(1854)].

Three cities in Jordan have central sewage collection systems. In Amman, approximately 12,000 cu m/day were treated in 1978 with an activated sludge system[(0423)]. The Ain Ghazzal sewage works has been expanded to 30,000 cu m/d and a further expansion to 68,000 cu m is planned[(0908)]. In 1986, a new wastewater treatment plant for the greater Amman-Zerqa area became operational at Khirbet Samra, located 40 km northeast of Amman. The treatment plant consists of stabilization ponds with anaerobic and aerobic lagoons. Wastewater from Amman flows by gravity to the treatment site. The mean rersidence time of wastewater is 28 days. The depth of the ponds is 1-1.5 m. Each line of treatment consists of five lagoons: two anaerobic, two aerobic, and one facultative. The effluent of the treatment is chlorinated and discharged into the Wadi Dhuleil, a tributary of the Zerqa River, joining the Zerqa River at Sukhneh and flowing thence to the King Talal Dam. Some concern has been raised about the efficacy of this treatment system. The wastewater casts an odor over the region, and there are local press reports about the death of aquatic organisms for some tens of kilometers along the Zerqa River below the inflow point of the chlorinated effluent.

In other locales, contracts have recently been let for the supply and installation of the main sewerage pipes for Zerqa and Russaifa[(1947)]. The city of Salt is at least 40 percent sewered with an aerated lagoon biological waste treatment system. In Aqaba, primary effluent is discharged to the Gulf of Aqaba. Stabilization ponds are under planning for the treatment works at Aqaba[(0454)]. In the balance of Jordan, domestic aqueous waste disposal is by means of on-site systems, especially cesspools. The overflow of cesspools in recent years have been related to outbreaks of cholera[(0454)]. Such problems are prompting the construction of sewer systems. The anticipated production of sewage in Zerqa and Ruseifa for the year 2000 is 86 and 67 L/cap-day, respectively[(0454)]. This area will become sewered in the last two decades of the present century. The projection is that the sewered population will increase from 288,000 in 1982 to 324,300 in 1990 and 442,100 in 2000[(0454)]. The plan calls for the construction of trunk sewers and primary sewage treatment followed by anaerobic sludge digestion of the waste solids.

Industrial pollution is a growing problem in Jordan. In the Amman-Zerqa area, a number of industries discharge wastes to the Seil Zerqa. These wastes ultimately reach King Talal Dam and contribute to water pollution there. The rising concern with industrial pollution prompted the Jordanian government to issue strict pre-treatment regulations[(0454)].

Fig 2.1: Jordan Valley Commission - Irrigation Development Plan 1975-82



Source: Khoury(0145), p. 100.

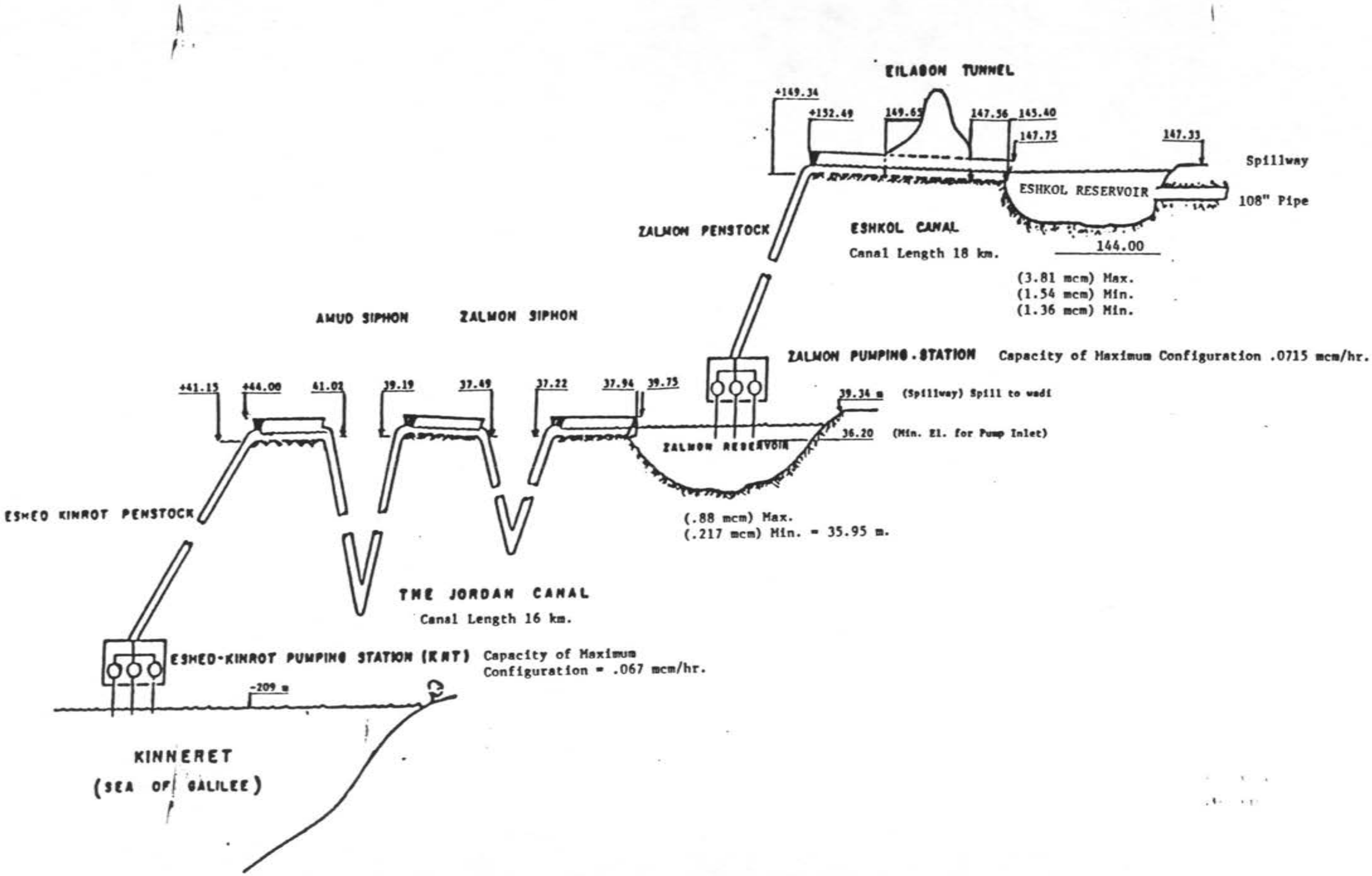


Fig. 2.2: NATIONAL WATER CARRIER, SECTION KINNERET TO ESHKOL: SCHEMATIC LAYOUT.

Source: Damelin and Shamir(2243), p. 272.

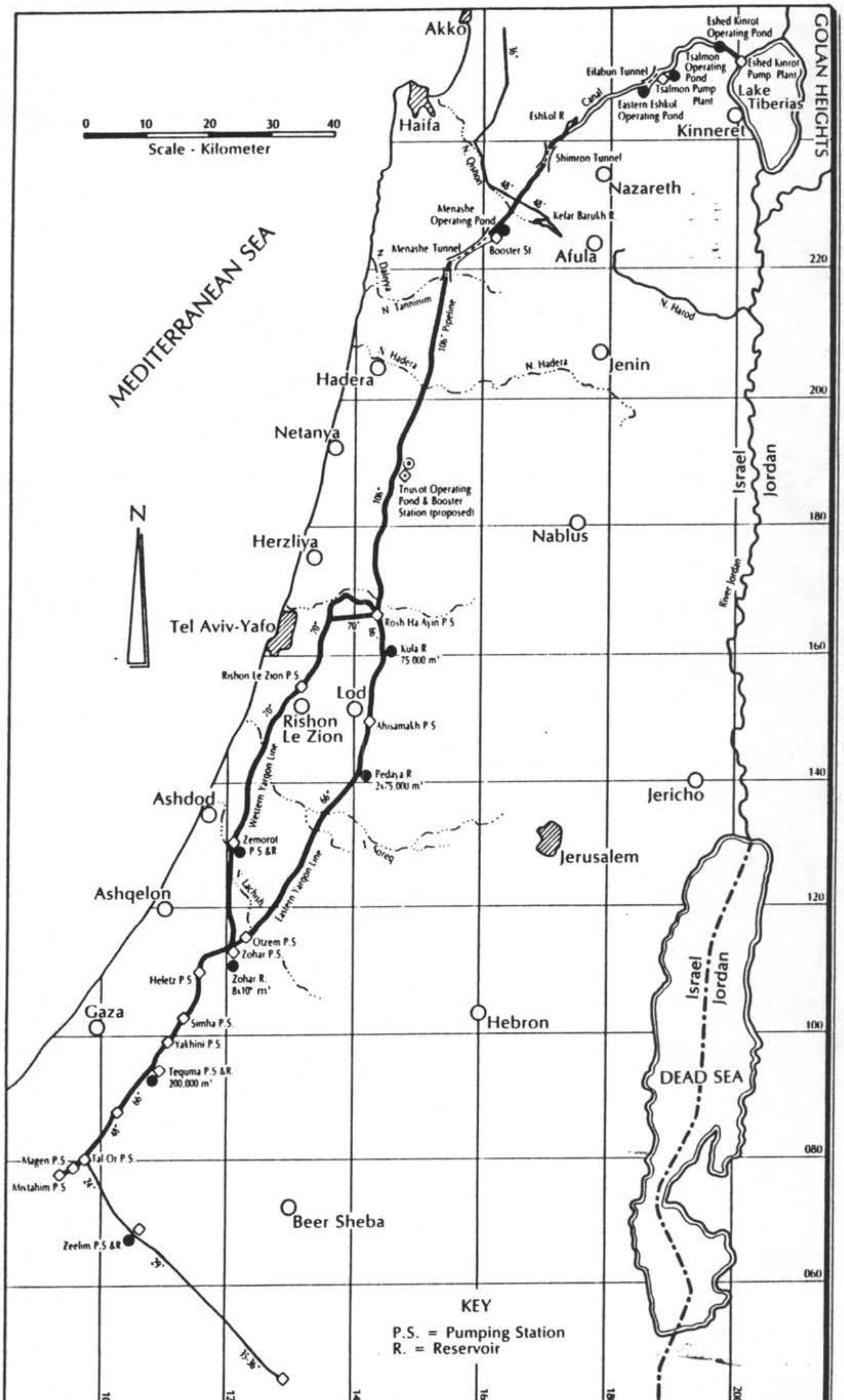
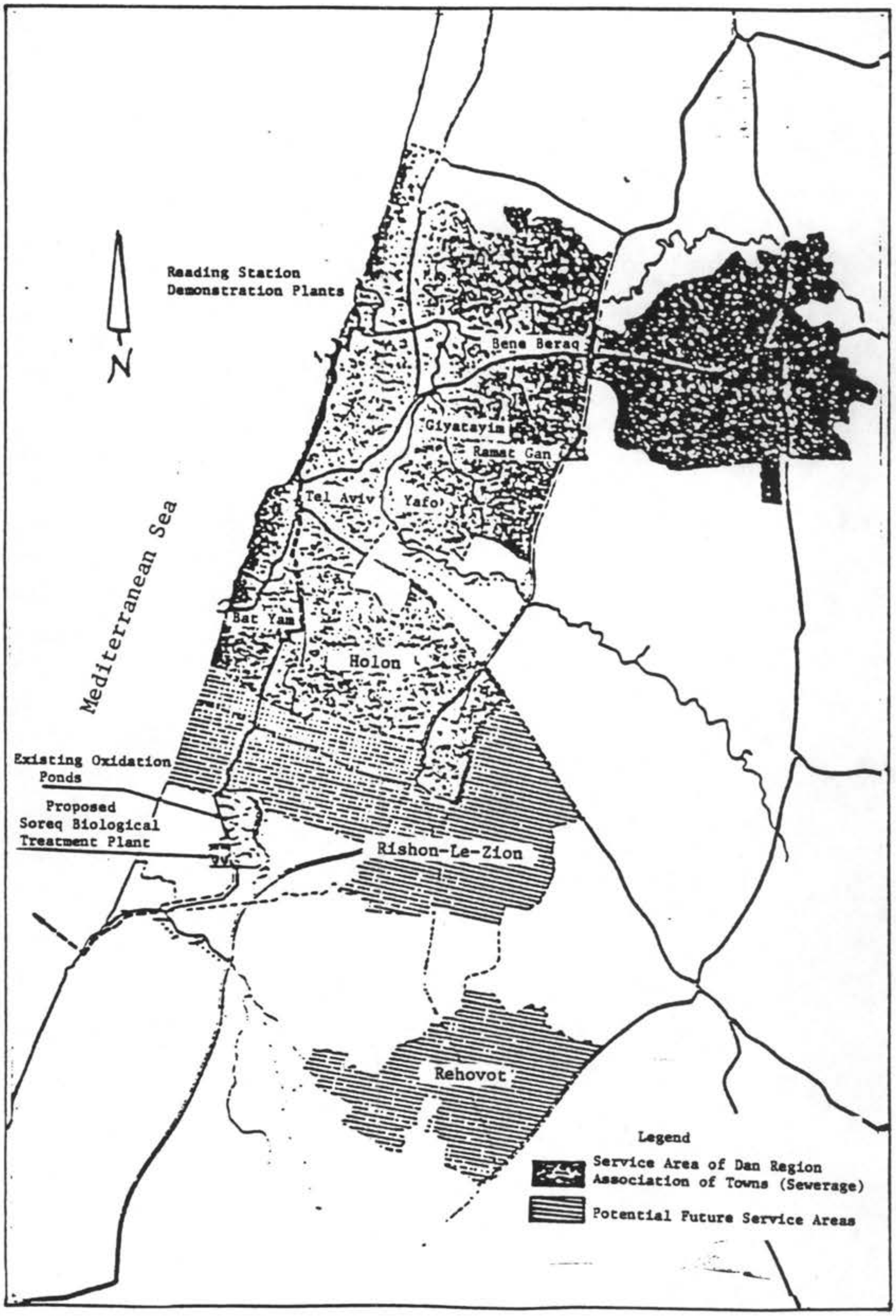


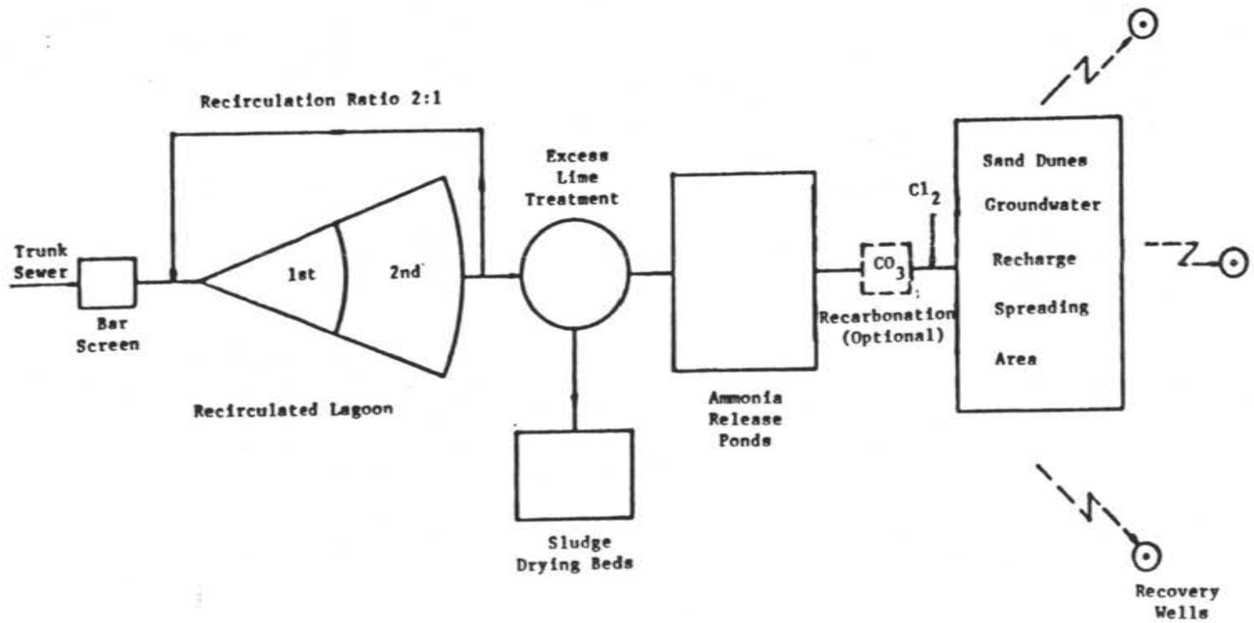
Fig. 2.3: Israel's National Water Carrier.

Fig 2.4: Dan Region Vicinity Map



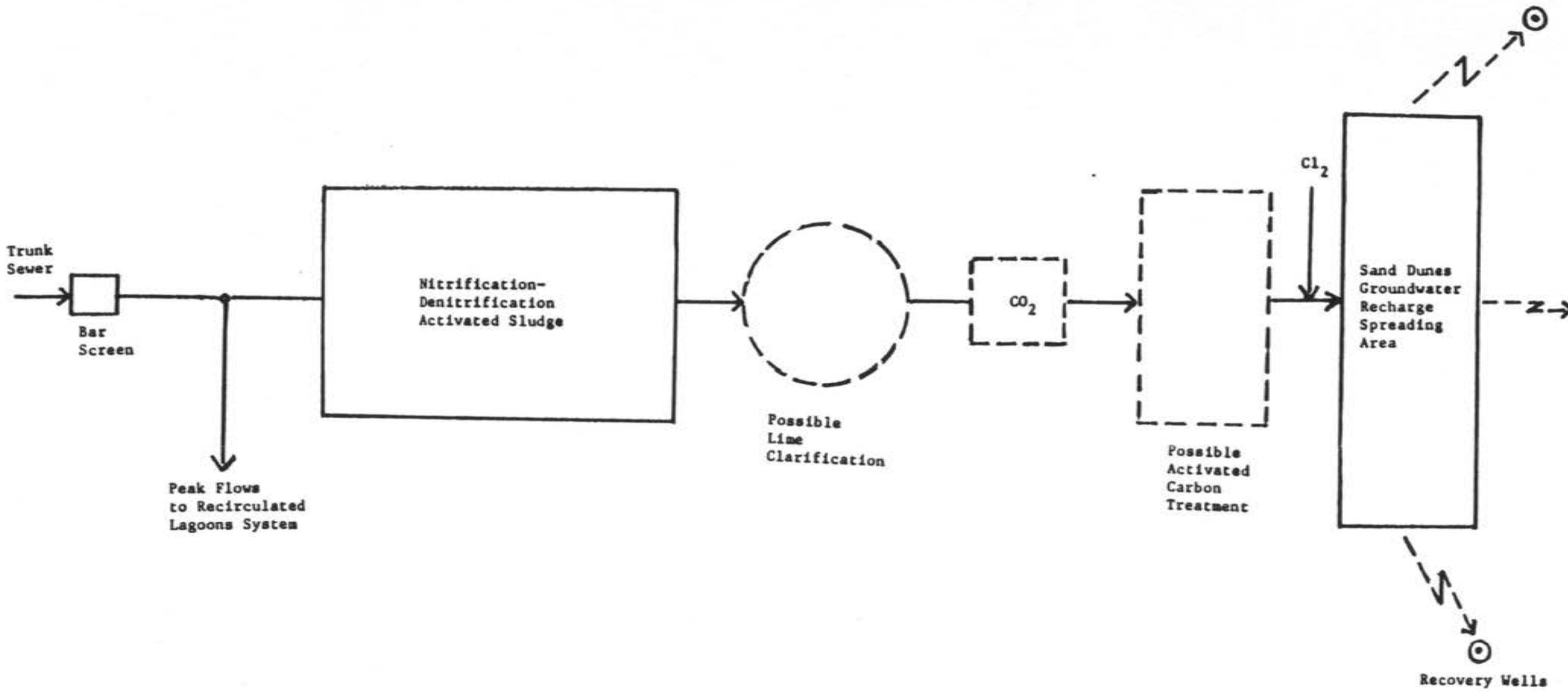
Source: Arueste[2583]

Figure 2.5. Schematic Plan of the Dan Region Wastewater Treatment and Reclamation Plant (Stage I)



Source: Shelef (2691).

Figure 2.6. Schematic Plan of the Dan Region Wastewater Treatment and Reclamation Plant (Stage II)



Source: Shelef (2691).