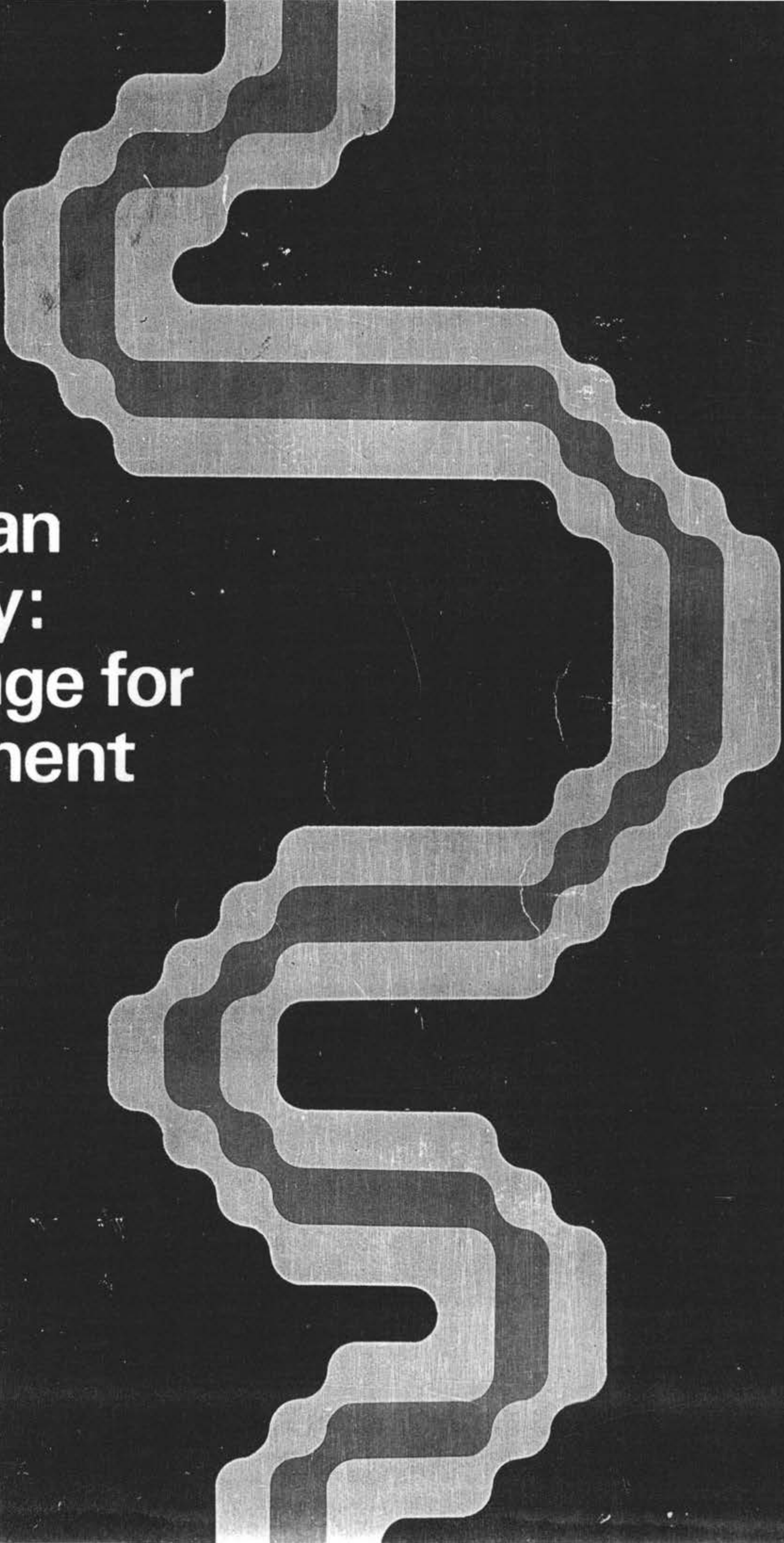
The Jordan Rift Valley: A Challenge for Development



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Landsat – 1,910 km., Imagery has been obtained from Nasa under a Nasa approved program of apolications of Landsat imagery for Israeli multi-disciplinary studies. Courtesy of Prof. Joseph Otterman, Department of Environmental Science, Tel-Aviv University.

Introduction

The Jordan Valley is once again the scene of hostile turmoil from the Lebanese border in the north down to the Gulf of Aqaba in the south. Four nations, all bordering on the Valley, take part in the current martial games – Lebanon, Syria, the Hashemite Kingdom and Israel.

This tragic saga of ruin and destruction seems so infinitely purposeless in the Jordan Valley, a valley which contains within it the seeds of development; a valley where a society and an economy could flourish. If the nations engaged in battle in this valley were to cooperate in a program of regional development, many accomplishments could be realized. Each of which would be to the advantage of each nation's own economic growth and development. In this process, the problem of the refugees, an extremely severe problem facing the Middle East, would be solved. Such a positive program of regional development would, no doubt, attract the active aid and interest of the predominant world powers along with other nations. These nations would provide technical and financial aid for the creation and encouragement of new economic enterprises. It will probably prove more applicable to establish a partnership between the various governments concerned and the great industrial enterprises possesing stores of technical knowledge, flexible marketing tools, and sophisticated management.

The specific geographic location of this region bridging three continents – industrial Europe, developing Asia, and Africa – leads to important potential advantages which may be realized without insuperable difficulties.

To begin with, if the billions of gallons of fresh water available along the Jordan Rift were used for irrigation rather than squandered each year, thousands of families could be settled in the Valley. Moreover, there is sufficient fertile soil. Thus, the existing fresh water need only be stored in artificial reservoirs and canals constructed to conserve or carry it to the fields on demand. Modern scientific agricultural methods combined with the mild climate found in the Valley would result in growing several crops a year. Such a year-round growing season provides the basis for a continuous stream of fruit and vegetables to be shipped to distant world markets in refrigerated planes and boats. The attainments of the farmers in the northern Jordan Valley near the Sea of Galilee are ample evidence to the claim that the Jordan Valley can be converted into highly a productive agricultural zone.

Beside the obvious agricultural possibilities, the industrial potential of the entire Valley is remarkable. As agricultural development needs water so industrial development demands abundant and cheap electricity. The unlimited use of atomic energy for peaceful purposes presents the advent of a new era in men's enlightment by means of releasing vast quantities of cheap energy to handle difficult and time-consuming tasks. Mineral production from the sea or the desalination of vast quantities of water are sure to attract everyone's attention.

Realizing this, the atomic scientists and engineers of Oakridge, Tennessee, proposed the eventual application of atomic energy for the operation of agro-industrial centers where atomic power could be harnessed for the needs of huge food factories.

Atomic power would assist to desalinate sea water and provide it to food factories. It would also supply power required to convert seawater brine into fertilizers and light metals. But the production of high quantities of cheap energy depends on the successful development of the "fast-breeder" atomic reactor.

Regional development ideas behind the Oakridge proposal can be implemented immediately in the Jordan Valley without the usage of atomic reactors. One need only consider the possible exploitation of the physiography of the Jordan Rift Valley, particularly the Dead Sea depression. Consider first that the same operation which will utilize the flow of fresh water for irrigation and industrial purposes will also cut off the Dead Sea from its fresh water source. This operation though desirable for agriculture, will be most undesirable for the Dead Sea. The Dead Sea will gradually recede and the area will, then, become a continuous accretion of large white salt marshes.

To prevent such a situation, a flow of water from other sources into the Dead Sea must be ensured. Accordingly, a solution is proposed herewith. The water should be brought from the Mediterranean to the Dead Sea through a canal along the Jezreel Valley. The flow of water from the sea level of the Haifa Gulf to the Dead Sea, the world's lowest lying lake, will create a natural waterfall. Consequently, a hydroelectric power station could be constructed. This plant would produce great quantities of very cheap electric power meeting the requirements of very large chemical, petrochemical and light metal industry. These industries could be constructed in the Arava, in the area from the Bay of Eilat–Aqaba to the Dead Sea. The proximity of the area to oil resources only serves to heighten the attraction of the region as the locus of a petrochemical complex which would produce fertilizers, plastics and chemicals, all of which are in an ever increasing demand in the world today. Dead Sea electric energy will facilitate the production of numerous fertilizers to be derived from the potash found in the Dead Sea, along with light metals such as magnesium and aluminium, and also numerous compositions of new materials ranging between light metals and plastics. Together with this industrial complex, it will be possible to develop a sizeable industry composed of small and medium-sized enterprises producing allied products.

To support the industrial complex, the construction of an inland navigational canal becomes a matter of the utmost importance. The canal can be large enough to carry ocean-going vessels, bulk-carriers, mammoth tankers, and container ships. These vessels will bring raw materials to factories in the Arava Valley and carry fertilizers and other finished products to all parts of the globe.

As a result of the flow of water in the Jezreel canal, the level of the Dead Sea will be raised to create a lake twice its present size. Consequently, expanding the surface lake area will increase the evaporation and allow more water to be discharged into the Jordan Valley, ultimately producing more electricity. An equilibrium will thus be maintained between the amount of water entering the Dead Sea and the amount of water evaporating from its surface.

While the Oakridge plan of constructing agro-industrial complexes is based on atomic energy power centers, the agro-industrial complex at the Dead Sea can be erected immediately on the basis of the artificial waterfall coursing from the Mediterranean to the depression of the Dead Sea. Here, in a region characterized by a maximum rate of evaporation (since it has the greatest number of sunny days) and owing to an impressive concentration of minerals in the Dead Sea, a flourishing chemical industry, based upon Dead Sea brine, promises to be highly successful. The Oakridge concept is thus implemented but with hydroelectric power for industry, natural water for agriculture, and Dead Sea brine for fertilizers and light metals.

In a generation or two, as industry develops the need for cheaper energy, and additional fresh water will be imperative. By that time, fast breeder reactors will have reached their ultimate stage of development, and the technology of desalination will be economically practical, enabling single and dual purpose power centers.

The proposed plan will not bring peace even in its most persuasive element. In war logic fails. This plan can only be realized in time of peace. However, even at this stage, at this time in the history of the Middle East, such a plan must be examined, studied and weighed, bearing in mind the development which can and should accrue to each nation. People in the Middle East and those outside with positive aspirations for the development of the Middle East should seize the initiative to put such a plan into effect.

The Jordan Rift Valley

The Valley in which the Dead Sea is located is a geological saga in itself, a limnological wonder, and the introduction of an ancient and abundant chapter in human history.

The Jordan Rift begins in Northern Syria, between the Lebanon and Anti-Lebanon, and continues through the Jordan Valley south through the Gulf of Aqaba to the Red Sea. From there it proceeds through the Strait of Aden to the Indian and Atlantic Oceans. The Rift is deep and narrow, running between mountains rising to a height of 1,500 to 1,700 meters above sea level and wending its way 105 kilometers southward from the Sea of Galilee (210 meters below sea level) to the Dead Sea (397 meters below sea level). From the Dead Sea, the Rift continues through the Arava to the Gulf of Aqaba-Eilat, covering a total distance of 375 kilometers from the Sea of Galilee.

Summer temperatures along the Rift are among the highest in the world, ranging up to 50C. The maximum number of sunny days in the year average 90 percent. The Rift is distinguished by strong, dry winds, relatively low humidity (55 percent) with recorded data revealing even lower records and a comparatively high level of aridity. Since the conditions are ideal for a high evaporation rate, it is not surprising to find that the yearly evaporation rate in this area is among the highest in the world.

The Dead Sea is located in an area where a large lake had once existed, known as the Lisan Lake. It had once covered an area of 3,000 square kilometers and began for rise approximately 100,000 years ago, reaching a maximum level of 180 meters b.s.l. about 25,000 years ago. Lisan Lake extended from the Sea of Galilee in the North, to Hatseva, south of the Dead Sea. Lisan Lake receded and dried up between 15 – 17,000 years ago, leaving behind two separate lakes – the Sea of Galilee in the North and the Dead Sea in the South.

The Dead Sea, bound by the vast Arabian desert, is the lowest lake in the world, its surface lying 397 meters below that of the Mediterranean. The yearly rainfall is scanty: 101 millimeters in the northern basin and 55 millimeters in the southern basin of the Sea. The Dead Sea area is approximately 1,000 square kilometers; its length about 80 kilometers and the maximum depth 400 meters. The Dead Sea contains approximately 136 billion cubic meters of water and 44 billion tons of dissolved salts. The salt concentration increases with the water depth; 300 grams to a liter of water at a depth of 40 meters; 320 grams at 100 meters; and 332 grams at 400 meters. In comparison, Mediterranean Sea water contains 38 grams of salt per liter of water.

Total Quantity of Salt in the Dead Sea

	Average Salinity	Depth Range	Volume	Weight of Salt
	gm/1	m	km^2	10^9 tons
Upper Water Mass	299.9	0.40	28	8.4
Lower Water Mass				
Transitional Member	319.3	40-100	32	10.2
Deep Member	332.1	100-400	76	25.2
Total Water Volume	322.1	0-400	136	43.8

Source: David Neev and K.O. Emery, The Dead Sea Jerusalem, 1967

The Dead Sea is cut off from the Mediterranean and Red Sea by two major topographical barriers: the Jezreel Valley, which is 59 meters above sea level, separating the Jordan Valley from the Mediterranean; and the Arava, which is 220 meters above sea level, separating the Dead Sea from the Red Sea.

At present, there is a smaller inflow of water into the Dead Sea than 30 years ago. There are several reasons for this decline. Water from the Jordan River now flows into a national water carrier for irrigation purposes. The water from the Yarmuk River is being partly drawn off by the irrigation system in the Kingdom of Jordan. Plans are in process for the use of the remainder of the water for the irrigation of the eastern slope of the Jordan Valley. All sources of fresh water from the Jordan Valley will in the future be utilized for irrigation. Thus there will be no obstacles in desalinating brackish springs for agricultural purposes. With the development of agriculture in the region, even precipitation run-off will be collected. Except for rainwater which falls directly on the lake surface, expropriated run-off and the limited flow of groundwater (a total quantity of approximately 500 million m^3/year), it is expected that all sources of water flowing into the Dead Sea will eventually be exhausted.

The Dead Sea presently contains massive reserves of chlorine, magnesium, sodium, calcium, potash and bromine. In addition to these, sizable quantities of sulphates, secium, cobalt, lithium, rubidium, and manganese are to be found, along with traces of a large number of metallic and non-metallic minerals. These minerals furnish the raw materials for innumerable products.

Although the same minerals can be found and extracted from the ocean, their concentration in the Dead Sea is several times greater. It can be surmised, therefore, that the exploitation of these resources would be of even greater value.

If alternative water resources are not found, the Dead Sea will evaporate and be converted into a salt deposit and dry mine (which is the history of the world's potash deposits). For the Dead Sea, this process will take several hundred years and will leave an area rich in minerals.

However, two sources of water for the Dead Sea exist not far away: the Mediterranean and the Red Sea. If the topographical barriers in the Jezreel or the Arava Valleys could be eliminated, any quantity of water would be available for flowing from the Mediterranean or Red Sea to the Dead Sea, allowing the Dead Sea to keep its balance and expand its area.

Distribution of Minerals Found in the Dead Sea
Depth in meters

Ion (gm/1)	0	35	45	100	310
Magnesium	37.00	37.68	41.08	44.35	44.54
Calcium	13.78	13.57	14.55	15.81	16.08
Sodium	36.51	37.32	37.05	38.18	38.60
Potassium	7.26	7.27	8.19	8.52	8.54
Sulphate	0.60	0.48	0.49	0.37	0.71
Bromine	4.56	4.64	5.01	5.39	5.45
Chlorine	194.44	195.20	207.74	219.55	221.95
Strontium	0.24	0.24	0.24	0.25	0.25
Lithium	0.012	0.012	0.012	0.012	0.012

(These analyses were made by the Dow Chemical Company, U.S.A.)
Source: Neev-Emery

On the basis of the minerals available in the Dead Sea, a huge chemical complex could be developed on an international scale.

Chemical industries of this size and complexity, however, require cheap and ample electricity as well as large quantities of water for production and condensation. Markets to the East and West, to which the processed materials would be exported, must be reached by efficient and economical means of transportation. Thus industry based on the Dead Sea resources, must have access to water transportation. Therefore, the solution to these problems is water – for electricity, chemical production, and transportation.

The Jordan Rift Regional Development Scheme is brought forward as a plan utilizing the natural resources of the area by recreating and improving upon earlier natural phenomena.

Hydroelectricity

The physiography of the Jordan Rift is conductive to the production of sizable quantities of electrical energy. To produce electrical energy cheaply and in large quantities, it is essential to take advantag of the difference in height of the water level between the Mediterranean and the lowest place in the world, the Dead Sea. An artificial waterfall could be created to operate hydroelectric power generators with a potential capacity of 3,000 mw. In addition to the tremendous force of gravity of the waterfall, the evaporation rate is exploited. By transporting water from the Mediterranean to the Dead Sea depression, the level of the Dead Sea is raised to a height of 300 meters below the level of the Mediterranean. The lake area will expand to 1,900 square kilometers thus enlarging the potential evaporation area. Due to the high temperatures that prevail most of the year, the numerous sunny days, the relatively low humidity, and the intense, dry, desert winds, ideal conditions for rapid evaporation rates are realized. Therefore the enlarged expanded lake will result in correspondingly larger quantities of water evaporated by the sun during the year, which will be discharged into the Jordan Valley. Thus, waters from the Mediterranean will, if brought to the Dead Sea depression, generate electricity and add water to the atmosphere.

Approximately 140 billion cubic meters of water will be required to flow from the Mediterranean to the Jordan Valley to raise the water level to 300 m. b.s.l. Approximately 44 billion tons of salt are found now in the basin of the Dead Sea. This quantity of water (140,000 million m^3) will bring with it approximately five billion tons of minerals to the Dead Sea. After raising the level of the New Lisan Lake to 300 b.s.l., the constant annual flow of five billion cubic meters from the Mediterranean will bring with it 120 million tons of salt per year in comparison with two million tons per year that the Jordan pours into the Dead Sea.

Elements Present in Sea Water
Milligrams per liter

Chlorine	19,441.0
Sodium	10,812.0
Magnesium	1,302.0
Sulphur	905.0
Calcium	410.0
Potassium	389.0
Bromine	66.0
Carbon	28.0
Strontium	13.1
Boron	4.6

Source: H.U. Sverdrup, et al., The Oceans, 1942

The level of the New Lisan Lake (300 m. b.s.l.) will result in a further increase in the boundary of the saline areas which in earlier generations, constituted, the contours of the Old Lisan Lake. In comparison with its present boundary, the width of the lake will not alter considerably (approximately 20 kilometers), and its length from north to south will be approximately 185 kilometers.

According to Dr. R.M. Bloch and Messrs. David Neev and K.O. Emery, the Dead Sea waters will not combine or mix with the water of the Mediterranean. This will thus result in the gradual upper layer of water on the surface of the Dead Sea water. The two water masses will be separated by a stable interface due to which the specific mineral composition and concentration of the Dead Sea brines will be preserved in the lower water mass. With the change in the Dead Sea level, it will be possible to pump the brine, from the lower water mass to the evaporating ponds above.

In time, it will be necessary to trap the healing springs on the shores of the Dead Sea (Zohar, Ein Gedi, Ein Bokek, and others) for the purpose of conserving them as spas under the new topographical conditions. There is no doubt that by that time, all other springs, even brackish springs such as Ein Fashkha, will be conserved for irrigation and desalination.

It will be advisable to relocate the present potash plant (and its evaporating ponds) at Sdom, to the southern Arava Valley, where a large area is to be found, suitable for the creation of new evaporating ponds. A plentiful supply of sea water will be available to wash the salt sediment that settles underneath in the ponds. The evaporation rate in this area is as high as the rate of evaporation on the surface of the southern basin of the Dead Sea. By that time, the present plant may be obsolete, and it is reasonable to assume that the technological development of the industry will then require a new plant with a greater production capacity.

The same quantity of water, 140 billion cubic meters, that will flow from the Mediterranean Sea to the Jordan Valley to raise the level of the water to 300 m., will generate energy amounting to 120 billion kwh. The hydro-electric power plant will be integrated into the regional grid of the electrical system.

It will be possible to regulate the water flow in the canal from a minimum to its maximum flow capacity of 1400 cubic meters per second which corresponds with an installed capacity of 3,000 mw. There must be a possibility of regulating water flow to provide flexibility according to daily or seasonal variations. Such a system will be much more efficiently realized in an integrated regional electrical system.

It is evident that raising the annual electrical potential will be gradual, corresponding to a ris in consumption. This amount of electrical energ will enable the production of approximately 50,000 tons of magnesium, for example, and th desalination of 100–200 million cubic meters o water annually for agricultural and industrial purposes. Great quantities of electricity will be left for the development of the chemical industr in the region. The hydro-electric power plant is not dependent on the rate of evaporation of the lake surface but rather on the rate of the annual electrical demand corresponding to the rate of the yearly flow. Therefore the number of years required must be extended to allow 140 billion cubic meters of water to flow to the Jordan Rif to create the New Lisan Lake. This power will provide the impetus for regional development. For the basic development period, an installed capacity with a potential of 3,000 mw is selecte since it is assumed that such a power station would provide a flexible supply to meet the bas and peak load required. (12 billion kWH annua and 24 billion kWH in emergency times).

Hydro-Electrical Power Plants Of 3000 MGW
Installed Capacity

Mediterranean Sea Level	
Dead Sea – Lisan Lake Level	–300 m.
Dead Sea – Lisan Lake Area	1840 sq.
Beisan Lake Level	–260 m.
Beisan Lake Area	52 sq.
Waterfall	H=290
Length of Canal	58 k
Capacity of Canal	1400 m^3/s
Evaporation Rate at –300 m.bsl	185 cm. annu

Base Load

Flow of Mediterranean Water	340 m^3/s
Installed Capacity	740 MG
Annual Production in Million KWH	56

Peak Hour Production

Utilizing the flow of Mediterranean water and pumped storage

Installed Capacity	3000 MG
Annual Production in Million KWH	120

The Capacity of Emergency Production

Flow of Mediterranean Water	1400 m^3/s
Production Potential in Million KWH	240

In the future, i.e. in another 20–25 years, wher the level of the water of New Lisan Lake will reach 300 m. b.s.l. the flow of the water from the Mediterranean will have to be regulated to correspond with the annual evaporation rate, an act in correspondence with the water balance o the great reservoir. Under the climatic conditio of the Jordan Rift, what will the yearly evaporation rate over New Lisan Lake – which is composed of water from the ocean and the ultrasaline Dead Sea – be? The present calculation of evaporation over the surface of the Dead Sea is estimated at 1.60 meters per year. In his article, "Tentative Energy and Water Balances for the Dead Sea", Dr. J. Newman suggests the number 1.5 m. per year for the annual rate of evaporation of the northern basin, 1.8 m. per year for the southern basin and an average at the Dead Sea of 1.55 meters per year. Dr. C.E. Jacob, Brigham Young University, Provo, Utah, U.S.A., also reported an evaporation rate of 1.70 m. per year. Dr. R.M. Bloch, Research Laboratory, Dead Sea Works, Ltd., however, estimated 1.80 meters per year, while Prof. A. deLeeuw suggested 1.70 m. per year. James B. Hays estimated 2 m. per year as did Mr. S. Blass and John S. Cotton.

An average yearly flow of 1,600–1,700 million cubic meters into the Dead Sea was recorded before the Jordan resources were utilized for irrigation. This constituted a flow of 52–53 cubic meters per second. This quantity of water is relatively small and would produce a small quantity of potential electricity, a fact which places in doubt the profitability that would eventuate from construction of a canal or tunnel from the Mediterranean or Red Sea to the Jordan Rift.

The evaporation rate of fresh water is higher than that of water with a high salt content. Measurements made by the Dead Sea Works between 1926 and 1944, under the supervision of Dr. D. Ashbel, indicate that the average annual rate of evaporation of fresh water is 3,642 m. in the northern basin, at the Sea of Galilee 2.15 m. and in Tiberias 2.56 m. and according to Tahal 1.78 m. per year. Compare with the annual evaporation of fresh water at the Gulf of Aqaba – Eilat, which is 3.445 m.

The evaporation rate of the Mediterranean water with climatic conditions corresponding to the Dead Sea, will be higher than the present rate of evaporation over the surface of the Dead Sea (1.60 m./yr.) The water of the Mediterranean may be considered nonsaline because of the relatively low concentration of salt (38 grams per liter). The evaporation rate is increased by means of an upper mass of Mediterranean water to a depth of 100 meters, that is, between the level of the concentrated Dead Sea mass (approximately 400 meters below sea level) and the surface level of the new lake (300 meters below sea level). Since the New Lisan Lake will extend 185 kilometers, it will be affected by the various climatic fluctuations with differing rates of evaporation along its entire length.

A reasonable suggestion adopts the figure of 1.85 m. per year as the average rate of evaporation of New Lisan Lake. The figure of 1.85 may seem on the low side as it is known that the evaporation on the northern end of the proposed Lisan Lake (Sea of Galilee) is 1.78 m. per year, and on the southern end of the proposed Lisan Lake (over the surface of the Dead Sea) is much greater. The upper mass of water to a depth of 100 m. consist of water from the Sea. Therefore, the average evaporation of the whole lake could be greater than the above mentioned 1.85 m. per year.

But what is the constant quantity of water that will, however, continue to flow to the great lake after all the fresh water is utilized for agriculture An estimated total of 500 million cubic meters of water per year will continue to flow, including wild run-off, ground water, and rain that will fall on the surface. Since the evaporation rate of the lake is estimated at approximately 3,500 million m^3., the balance of 3,000 million m^3. yearly flo from the Mediterranean in to the Lisan Lake.

The rate of evaporation permits a flow corresponding to 100 m.^{3} of water per second all year round. But, if the hydro-electric power plant is operated only at peak hours to meet the heavy operational daytime load, a flow of 460 m.^{3}/second can be achieved. It will be capable of operating at full capacity, that is the power potential of the turbogenerators (1,000 mw) with which the plant is equipped. The flexibility of the power plant is of a high order. The price of producing a unit of kwh of electricity at this plant is lower than at plants requiring fossil combustible or nuclear fuel. Furthermore, foss fuel or uranium is not-required. The source of energy is unlimited owing to the unlimited quantities of water derived from the Mediterranean and the solar energy cycle.

If the above proposal is rejected, it is expected that, in the future in the process involved in the production of electricity, both conventional power facilities and thermo-nuclear power stations must be employed. Both fossil fuel and the uranium required for these operations will have to be obtained from foreign sources. Acquisition of uranium will not be a routine matter not only because of price fluctuations and sources of supply but also because of disturbances which may be expected during local or global emergencies.

However, by utilizing sea water and the energy of the sun's rays, a basic electrical supply independent of external energy sources will be available.

Another 2,000 mw can be generated by operatin as a pumped-storage hydro-electric power plant. Fundamentally, a pumped-storage hydro-electric power installation collects the unused energy o all the conventional power plants available in t system by means of night pumping. The next day the collected water flows to the turbogenerators at the peak hours. Pumped-storage plants possess operation and design flexibility. These are reliabl particularly in case of blackout. They are hydrologically independent, being immune to seasonal variations since they operate at closed-circuit installations.

The United States Federal Power Commission has predicted 20 million kwh of pumped-storage capacity by 1980. The public utility industry bases construction estimates upon a formula of 80 percent nuclear and 20 percent pumped-storage in predicting construction. Topography, costs, and power loads will determine the geographical pumped-storage pattern. It is possible that "reverse" pumped-storage will make pumped-storage practical in areas of unsatisfactory terrain. Here, water is dropped through a turbine into an underground storage cavern in times of peak electrical demand and pumped out during slack hours in preparation for another generation cycle. Pumped-storage plants, in conjunction with conventional hydro-electrical plants, will make sites practical that cannot be economically developed for conventional hydro-electric power alone.

The development of thermo-nuclear reactor plants in conjunction with pumped-storage plants results in the thermo-nuclear plants taking care of the base loads and pumped-storage plants meeting the requirements for peaking power. Thus, both fuel costs and the need to keep thermal plants operating as continuously as possible are considered. Nuclear reactor power plants are able to lift water into a pumped-storage plant reservoir at an incremental fuel cost which allows the pumped-storage plant to produce power more cheaply than by alternate means, even though it takes 3 kwh of pumping to produce 2 kwh of power.

Pumped storage plants also assist modern thermal plants in operating more efficiently. While modern thermal plants are expensive to install, they are cheap to run on an incremental fuel basis, and are best operated around the clock and calendar at full capacity. Every night during low consumption hours it will be possible to pump water from New Lisan Lake to the upper Jezreel canal. The following day, this water returns through the turbo-generators, and thus the power plant of 2,000 mw operates. The flexibility of the flow is then high. It is possible to cause larger quantities of water to flow into the lower lake in the summer, and return the water to the upper canal and the canal by means of graduated night or seasonal pumping to meet seasonal and daily electrical demands efficiently. Thus quantities of up to seven billion kwh can be collected in the low hours for peak demand of unutilized energy of the conventional stations by means of a hydro-electric plant, without disturbing the water balance of the New Lisan Lake.

The total annual production of the 3,000 mw installed capacity is 9 billion kwh annually — an 24 billion kwh — in emergency times.

Water Sources

The Jordan Rift basin usually attracts 1.7 billion m.^{3} of water. From this amount, Israel takes 60 million m.^{3} of water from the northern sources of the Jordan. The remaining 1.1 billion m.^{3} are unused, running off either into the Dead Sea or the Mediterranean. There has been no exploitation of the benefits derivable from this run-off. The efficient exploitation of these water resources would permit the tilling of the fertile soil of the Jordan Valley. Because of the perfect climatic conditions which allow for the growing and marketing of those agricultural products preferred by Europe in the seasons when Europe lacks fruit and vegetables, extensive use of the run-off waters would convert this valley into an ideal area for intensive agriculture. Although a market for these agricultural products from the Jordan Valley exists, all that is required here is t collect and store the water by means of the proper engineering installations and convey it to the fields to be irrigated; construct a system of dams and canals to supply water; and plan a flourishing agricultural region of towns and villages, bringing back previous residents of the valley and encouraging new settlers. With the influx of new farmers to the valley, use can be made of the agricultural knowledge exhibited by the Israeli farmers who have already overcome the unique climatic and soil conditions of the area.

It will be necessary, therefore, to exploit the water resources discharged into the Jordan Valle and on its borders. These include the waters of the Yarmuk River with 480 million cubic meters of water per year; approximately 180 million cubic meters of water flowing from springs some of which contain fresh water and some are brackish and enable desalination. Run-off from the Litani River which discharges into the Mediterranean, squandering approximately 440 million cubic meters of water per year, can also be utilized.

These water sources need to be examined at lengthier detail. The annual flow of the Yarmuk River is approximately 480 million m.^{3} of water per year. As far as planning is concerned, the Yarmuk Irrigation Project has been almost completed, and excavation work on the site of the first dam in a proposed system of dams. A concrete canal is being constructed to transport the water for the irrigation of the fields east of the Jordan. The Six Day War, however, has brought the development work to a halt and has even damaged sections of the Gore Canal. The Litani River rises in the Lebanon Valley, flows south where it is confronted by the configuration of the Jordan Rift in the north. It continues flowing westwards through a narrow opening in a very deep ravine to the Mediterranean. Approximately 440 million m.^{3} of the Litani water surplus can be diverted to the Jordan Valley.

There are several engineering alternatives for the diversion of the Litani water surplus. It is possible to store the overflow of the Litani at a topographical level of 600–650 meters above sea level, and let it fall to the original bed (200 meters above sea level). This water fall could then operate a hydro-electric power station (1,000 mw) which would supply Lebanon with three billion kwh annually, to meet the base and peak load required, an inexpensive source of electricity. The tail waters can be diverted through a tunnel to the Jordan Valley.

Approximately 180 million m.^{3} of water is discharged from Jordan Valley springs, of which approximately 70–80 million m.^{3} consist of brackish water. If it is necessary to desalt this water, a system of electrodialysis or reverse osmosis can be made available. Brackish water may be used for industrial purposes if mixed with fresh water. If the above three water sources are carefully exploited as suggested, there will be enough fresh water in the area and a sufficient quantity of cheap energy generated by the hydro-electric plant. Until the twenty-first century there is no need for integrated thermonuclear power centers to produce electricity and to desalinate water.

At the same time, the area itself will reach a more advanced stage and require more electricity and water for a larger population. The chemical and metallurgical industries will need additional quantities of cheap energy and agriculture will need more water. It is expected that within 20–30 years, the fast breeder atomic reactors will produce cheap electricity, and the technology of water desalination will advance to the point that the low price of desalinated water will make it attractive for agricultural use. Only at this stage will it be appropriate to erect a nuclear energy power center to produce electricity and fresh water.

Jezreel Valley Canal

The dimensions and water depth of the Jezreel Valley Canal make it suitable for ocean-going vessels, especially for container ships. It would be advisable to earmark land for container ports along the canal, as well as a container terminal in the Beisan Lake. The distance from Beisan to the Mediterranean (58 km.) is shorter than that of many busy port towns such as Manchester from the Irish Sea or Hamburg from the North Sea.

The Port of Haifa does not possess the capacity for container ships whose cargoes require large storage areas. The natural location for the conta or ports will therefore be along the canal in the Haifa Bay, where adequate storage area is available.

A container-ship port in Lake Beisan is of prime significance and of utmost importance to the Kingdom of Jordan as an outlet to the Mediterranean. It is located on the Jordanean border, a by constructing an elevated highway of 8 km. th port can be linked to Jordan. Jordanian merchants will be able to use this port most advantageously by converting it into a container port for Saudi Arabia and the Sheikhdoms of the Persian Gulf and even Baghdad, while presently ten days are required to navigate round the Sue Canal and the Red Sea.

The Port will place Jordan on the international navigational commercial map. Thus, from Jorda point of view, the importance of the port must considered together with the other advantages which it will derive from the Regional Development Plan.

Reclamation of the Sea from Cape Carmel to th Bay of Athlit

A canal of such dimensions involves a vast excav tion, which presents a problem of the disposal of the enormous amount of dig material. The usual practice is to heap up the earth on both sides of the canal. In this case, disposal on the banks of the canal would mean covering up and spoiling fertile land. An alternative method is suggested. Namely, that of transporting the exce dig on barges or conveyor belts, and reclaiming a shallow off-shore strip between Cape Carmel and the ancient bay of Athlit. The archeological sites of the Bay would not be touched. An area of some 10,000 acres would be added to Haifa's municipal borders, and the city would extend ar develop southwards along the seashore. Mount Carmel could then be preserved in its natural beauty.

The Sea of Galilee

The Sea of Galilee is located on the northern extremity of the Jordan Depression. It is the deepest fresh water lake on the surface of the globe, 210 meters below sea level. It has an area of approximately 168 square kilometers, a volume of approximately 4,300 million m.^{3}, and a maximum depth of approximately 44 m. It is used as a central storage reservoir for supplying the Israeli national water system.

Approximately 500 million m.^{3} of water flow into the Sea of Galilee from the sources of the northern basin of the Jordan (excepting flood and rain water which fall on its surface), but th

Israeli national water system pumps only 320 million m.^{3} of water per year, and a similar quantity evaporates over the surface of the lake. Average evaporation here is 178 cm./year. The average evaporation rate calculated over fifty years is approximately 300 million m.^{3}/year.

The salinity of the Sea of Galilee is high, reaching approximately 327 – 380 mgs. of chloride/liter of water. The salinity of the Sea of Galilee is caused by a group of mineralized thermal springs with a varying level of salinity between 1,000 – 22,000 ppm. There is, however, an irrelevant quantity of chloride (14 – 24 mg./liter) in the waters of the northern basin of the Jordan (at the Daughters of Jacob Bridge) before the Jordan flows into the Sea of Galilee.

The Sea of Galilee, as a principal storage reservoir, is beset by problems. First, owing to its high salinity content, and secondly, owing to the large loss of water due to the high rate of evaporation. The level of the lake is also too low in relationship to its major sources of the Jordan which rise 170 meters above sea level. Water must be raised to the irrigated land where it must flow 150 meters above sea level. Because of the natural depression of the lake, water must be pumped to a height of 368 meters to the national water carrier.

A strange picture is presented – approximately 500 million cubic meters of water from the sources in the northern basin of the Jordan flow into the Sea of Galilee creating in their path a waterfall of 270 meters. This water is fresh with almost no salinity. Only 320 million m.^{3} of water are pumped from the lake – its salinity is critical (330–380 milligrams of chloride). This salinity must be reduced by mixing the pumped water with fresh water in the national water carrier thus reducing the salinity to 170–250 milligrams of chloride to render the water suitable for irrigation. Of the remaining 180 million m.^{3} of water from the sources of the northern basin of the Jordan that flow into the lake, only part is used for irrigating the land bordering the lake and the Jordan valley south of it; while another part is dedicated to preserving the balance of the water level and simply evaporates. While success is achieved in preventing saline springs from flowing into the Sea of Galilee, more fresh water is wasted by evaporation. In addition, the surface level of the Sea of Galilee is balanced by ground water, the flow of subsurface springs, run-off shore springs, as well as surface rainfall.

If, however, the entire 500 million m.^{3} of water from the sources of the northern basin of the Jordan would flow directly through the national and regional irrigation structure and not into the Sea of Galilee, several advantages would ensue. As the Jordan water is not saline, there will be no need to mix this water to reduce its salinity, nor would it be necessary to pump it to a height of 368 meters to the national water carrier.

Even if this plan was to be effected, the Sea of Galilee could continue to be used as a storage reservoir for many years. It will receive its water from rain water, flood-water of the northern Jordan basin, floods around the Sea of Galilee, and from underground saline springs that gush into the lake. It would also be possible, to divert the flood surplus of the Yarmuk waters, which during rainy years are above the volume capacity of the Yarmuk reservoirs and dams. These flood waters would pour directly into the Sea of Galilee It would be possible to pump water from the lake to the national water carrier and mix this water with the fresh water flowing in the water carrier. But this could only be done in time of need. The same is true of the surplus water of the Yarmuk which could be stored in the Sea of Galilee and flow into the carriers to the Jordan Valley.

The Industrial Complex

While the Jordan Valley north of the Dead Sea is suitable for agricultural settlement and tourist industries, the Arava Valley, south of the Dead Sea to the Bay of Aqaba, is suited to the establishment of a chemical industrial complex. Such a complex could include fertilizer and light metal industries, utilizing the minerals found in the Dead Sea as raw materials, and a petrochemical industry, based on crude oil obtainable in abundance just around the corner. To supply the large amount of electrical energy to operate such variegated industries, an ample supply of cheap electricity is needed.

Since the entire chemical complex is dedicated to export production, it should be given the advantage of sea shipping by means of the construction of an inland canal from the Bay of Aqaba along the Arava Valley. This would enable transportation of the minerals from their source by means of the most modern shipping facilities, bulk-carrier container ships (carrying the finished chemicals directly from the factory to the ship) or by tankers transporting liquified chemicals. By employment of bulk carriers, it would also be possible to bring raw materials such as alumina or bauxite as well as heavy industrial equipment directly to the factory, while the mammoth tankers could carry crude oil.

The Bay of Aqaba is extremely beautiful and abundant in its variegated marine life. The latter must be protected from pollution. Aquatic sports and a broadly based tourist program must be encouraged. In fact, this characteristic of the Bay is to be preferred over its assets as a deep water port. Therefore, the terminals and crude oil storage depots for the minerals and chemicals should be sited along the canal as far as possible from the Bay. The Bay of Aqaba must be preserved. Eilat and Aqaba will become port cities, centers of management, education research and trade for a rich, varied internal industry.

The production of cheap electricity will permit the exploitation of magnesium salts found in abundance in the Dead Sea to establish a magnesium metals industry. In each liter of Dead Sea Water, 36–42 grams of magnesium salts are to be found as compared with 1.3 grams of magnesium salts in each liter of ocean water. Moreover, the existence of cheap electricity will justify the establishment of an aluminum industry in proximity to the magnesium industry. It will be possible to bring the alumina or bauxite via the sea in bulk carriers from every place where they are found: the shores of the Red Sea, Africa, Greece, Yugoslavia, and even Australia which supplies alumina and bauxite to Scotland and Norway.

The presence of this industry will allow the establishment of a light metal alloy industry to produce a wide selection of light metals possessing very unusual properties. The proximity of the polymers producing petrochemical industry(which we usually refer to as synthetic plastic materials) combined with the above mentioned light metals, would enable the production of materials distinguished by properties withstanding high temperatures, rust and corrosion, and stronger and lighter than the toughest steel.

All the conditions exist at the Dead Sea to produce a broad range of fertilizers, both basic and compound. Fertilizers in the form of potash abound in great quantities in the Dead Sea. Nitrogen fertilizer is derived from the source materials of the petrochemical industry, and phosphate fertilizer is obtained from the relatively rich mines located east and west of the Arava Vally. Moreover, it appears that the demand for fertilizer will grow at the same rate as the population growth in Africa and Asia which are the natural markets for these products.

A varied and integrated organizational structure for the production of fertilizers would allow application and adaptation to the needs of developing countries. It will be possible to supply fertilizers of all kind, from organic to the most sophisticated compounds. These fertilizers coul be shipped by sea directly from the plants to th bulk carriers or tankers, which would transport the fertilizer to the consumer nation. It is extremely important to possess the know-how required to produce these fertilizers in an economic manner and market them successfully.

The range of products in the chemical industry is enormous – from plastics to synthetic fibers, fertilizers to pharmaceuticals, from detergents and dyestuffs to explosives. Raw materials include oil, natural gas, coal, salt, potash, and sulphur. The chemical industry is international in scope, and as we have noted, large companies have extensive interests and operations in countries other than their own. Moreover, chemical companies are distinguished by varied operations. Thus, the largest indigenous French chemical company, Rhone-Poulen, is also a huge fibers group. The second largest French chemical company, Ugine-Khulmann, too, has extensive interests in aluminum and steel. The Japanese chemical industry is dominated by the powerful and traditional trading companies. In fact, Mitsubishi even possesses two separate, distinct, and competitive outfits: Mitsubishi Chemical an Mitsubishi Petrochemical.

Another part of the industrial complex is the petrochemical group which is capable of supplying basic materials to the broad, diversified chemical complex, and of producing a wide range of industrial products including nitrogen fertilizers, the varied assortments from the polymer industry with its products so evident in the world of plastics, and even proteins for animal and human consumption.

The rest of this chapter examines the current status of the industries involved, keeping in mind how they bear on the development of an industrial complex centered around the proposed canal. The issue was divided into three sections: (1) Chemicals and Petrochemicals, (2) Light Metals, and (3) Fertilizers.

Chemicals and Petrochemicals

The petrochemical industry is witnessing a phenomenal growth rate both in North America and Western Europe. Petroleum is basically a mixture of hydrocarbons, and the organic chemical emphasis has thus been on carbon and hydrogen with such end products as plastics and resins, synthetic detergents, rubber and fibers, fertilizers and solvents. In the inorganic chemical areas, hydrogen is extracted for ammonia products from petroleum; sulphur can be recovered as an impurity in some crude oils, and carbon black and hydrogen cyanide may be petroleum-based. It is estimated that by 1985, the production of petroleum-based organic chemicals in the non-Communist world will reach 200 million tons, with oil and natural gas becoming by then the source of virtually all organic chemicals. By the year 2000, production is estimated at 600 million tons. Of this total, approximately two-thirds will be plastics, and the remainder synthetic fibers, rubber, agricultural chemicals, industrial chemicals, and new chemical products as yet unknown. Petroleum-based products such as proteins are still being investigated. These and others will certainly emerge to take their place as major products of the petrochemical industry.

Petrochemical production began in the United States and spread to Western Europe after World War II. Japan and Australia are now developing their own complexes. Furthermore, the oil producing countries of the Middle East and the Caribbean area are interested in similar development.

The main part of the petrochemical industry is the ethylene plant which produces ethylene and propylene by means of thermal cracking of hydrocarbon feedstocks (usually naphtha in Europe, and ethan, propane, and butane in the United States). Olefin plants specialize in production recovery of such byproducts as butadiene and aromatics fractions. In the past 10 or 15 years, the size of the plants has grown from 30,000 tons of ethylene per year to 300,000–500,000 tons, which greatly enhances the recovery of by-products. The petrochemical producer must think in terms of a petrochemical complex constituting perhaps a dozen plants, thus involving investment in by-products.

Aromatics. The by-product known as aromatics refers to the base hydrocarbons: benzene, toulene, and the three xylenes. Since World War II, the demand for aromatics for chemical purposes has increased tremenduously. While aromatics were previously a product of the carbonization of coal, today they are a by-product of the steam cracking of petroleum fractions. Benzene is used in the production of detergents, plastics, pharmaceutical products, synthetic rubber, synthetic fibers, explosives, agricultural chemicals, and dyestuffs. Toluene is primarily employed as a solvent, and especially in certain types of surface-coating material; as a basic material in the production of polyurethane foams; and in dyestuffs, pharmaceuticals and explosives. The demand for aromatics has become so great that its production has risen from that of its former state as a by-product to plants specially designed for its production alone. Such plants are being constructed in every important industrial country.

To supply the growing demand for polymers used in the production of synthetic rubber and fibers as well as plastics, activity has expanded in the heavy organic chemical industry. Ethylene, propylene, and butadiene, are derived from naphtha cracking and styrene, an intermediate material, which is produced at a further stage of manufacture from ethylene and benzene. Approximately 10 percent of propylene in Europe is used for the manufacture of polypropylene, and 12 percent for the production of acrylonitrile which is developed into acrylic fiber. Approximately 65 percent of styrene-based butadiene rubber is used to manufacture tires.

To meet the demand for these materials, American chemical and petrochemical companies have increasingly participated in the European industrial scene throughout the past decade. There has been a massive concentration of capital in a few selected sites containing highly integrated plants, located in proximity to petroleum refining centers and such deep water ports as Antwerp, Rotterdam, and Teesside. The huge American chemical companies, Dow, Monsanto, Union Carbide, and DuPont, have expanded their bases in Europe at the same time as the Gulf, Esso, Philips, Texaco, Conoco, Mobil, Standard Oil of Indiana, and Occidental oil companies, have been diversifying into petrochemicals. Production of petroleum-based chemicals is expected to reach 88 million tons in 1985 and 240 million tons in the year 2000. In 1965, the world wide proportion of organic chemicals from petroleum was 80 percent, and it is expected to rise to 98 percent in 1985 and 99 percent in 2000. During the last 25 years, the ability to synthesize organic polymers has had a tremendous impact on everyday life and on technology. The synthetic polymer industry.is now one of the fastest growing areas of the world economy, production has added a wide range of plastics and fibers to the range of traditional materials.

Plastics. The petrochemical industry utilizing organic chemical produced from oil and natural gas and based upon carbon and hydrogen is responsible for the production of such daily mainstays as detergents, synthetic rubber, all the myriad members of the plastics family, and synthetic fibers such as terylene, dacron, acrilan, and nylon. Today, plastics are usurping the traditional position of glass and metals in many areas of the building industry. There is adequate reason to believe that there is considerable scope for further innovation. Indeed, John Loudon, the former chief of Royal Dutch Shell, has been cited as espousing the prefabrication of houses by sections in the factory, to be assembled on the site with plastic washing machines, refrigerators, dishwashers, and vacuum cleaners.

One of the most significant characteristics of organic molecules is their ability to link up to form large structures. These structures are polymers. The nature of the polymer produced depends primarily upon the components from which it is made, the appropriate choice of these components, and the reaction conditions. These factors control the properties of the polymer. Polymers may be softened by heating to create thermoplastics; they may be decomposed without softening to emerge as thermosetting resins; they can be glassy, amorphous, and brittle as in the case of polystyrene or polymethyl methacrylate; or they may be opaque, crystalline and tough as nylon or polyacetal. Their properties can be influenced by the incorporation of other materials, and while normally white or colorless, they can be pigmented at will. While plastics are basically organic chemical compounds, their value as materials depends almost entirely upon their physical properties. They can exhibit the low melting or softening points characteristic of organic materials and thus be readily molded under moderate temperature or pressure conditions. The molding techniques of injection and extrusion furnish a convenient and efficient method of large scale production of complex products. These processes are relatively economical since the method of conversion requires modest amounts of power. While further economies arise from the reduction in finishing operations, the molded component is frequently available for service without further treatment.

Plastics are distinguished by their resistance to many environments that are deleterious to metals. This characteristic accounts for their extensive use in such areas as surgical implants and chemical plants. Since the density of plastics is much less than that of metals and glass, fiber reinforced resins possess high strength to weight ratios. They are thus much in demand in the transportation and contruction fields. In addition, plastics, are efficient thermal and electrical insulators, have considerable friction and wear characteristics, and transmit light. An

More-over, polypropylene, polyformaldehyde, glass-filled nylon, and polycarbonate, all possess properties which encourage their use in place of metal. Metal coated with plastic, or plastic coated with metal, is expected to have an increasing demand; the former used as reinforced plastic for aircraft parts, automobile accessories, or common water faucets. To prevent and/or resist corrosion, steel pipes lines with plastic are being produced in great quantities, and plastic-coated steel is being developed for construction purposes.

While no polymers of new chemical structure have appeared at the moment, polyphenylenes are now marketed in England and evaluated for use with carbon fiber reinforcement in the hotter parts of Rolls Royce engines. Some very complex polymers, containing such elements as phosphorus, titanium, silicon, and boron in combination with other elements, are beginning to be synthesized in the laboratory; they may bear fruit in the future.

The plastics industry is now regarded as big business, more than 40 percent greater than the production of aluminum. The figure is rising rapidly so that almost every great chemical company in the world is now engaged in manufacturing plastics. Polyolefins, PVC, and polystyrene with its copolymers account for 63 percent of total U.S. production and 57 percent of total United Kingdom production.

These three plastics are extremely versatile: they are tough; they have a high temperature resistance; and they are easy to manipulate. They are cheap because they are made from relatively simple molecules – ethylene gas playing a vital part in their production. The largest producers are the United States, Japan, West Germany, and the United Kingdom.
Indeed, with the ease of production, it has been predicted that in the year 2000, 1,700 metric tons of plastic will be produced versus 2,250 metric tons of iron, 250 metric tons of aluminum, 2,535 metric tons of all metals including copper and zinc, and 44 metric tons of rubber. This output must be contrasted with the 1966 production of 16 metric tons of plastics versus 464 metric tons of iron, 7.7 metric tons of aluminum, 486 metric tons of all metals

including copper and zinc, and 3.9 metric tons of rubber.

Plastics are now accepted in their own right and not just as substitutes for other products.

Man-made fibers. Man-made fibers which are produced from such diverse elements as polymers and ceramics have unusual qualities of strength, high energy absorption, and temperature resistance. Until World War II, the field of fibers was limited to natural fibers such as cotton, jute, wool, flax, asbestos and silk, or rayons, which were the first synthetic fibers developed in the late 19th century. Viscose rayon, the first chemically produced commercial fiber is composed mainly of regenerated cellulose obtained from wood pulp or the waste product, cotton linters. As a result, the chemical composition of rayon is still somewhat similar to the natural fiber, cotton.

Today, there are many varieties of polyamide and polymeric fibers based on polyesters, acrylics, modified acrylics (modacrylics) and olefins such as polypropylene. Fibers can be made from most materials and have been successfully produced from glass, quartz, metals, graphite, and ceramics.

As a result of its interests in polymers, the fiber-producing industry is now an extension of the chemical industry. Previously, the textile industry was largely a fabricating industry which purchased natural fibers and acetates to be processed on looms and knitting machines. However, man-made fibers are utilized in ways other than in the textile industry. The composition of cordage-rope has now been extensively replaced by nylon and polypropylene, since polymeric fibers do not mildew, rot, or absorb moisture. Nylon is especially adaptable for tow rope, mountain-climbing rope, and parachute harnesses. Polypropylene, less dense than water, floats, which is extremely useful in marine applications. Polyester has been used for sailcloth since it resists growth under tension and thus may be buffeted by wind without becoming floppy or saggy. Acrylics resist the elements, and thus, in highly humid regions, have replaced cotton for sandbags, and have been attractive as awnings and tents. Coated nylon and polyester fabrics have been used for constructing storage buildings.

Strong, stiff fibers which may be used as reinforcing agents are produced either from light elements or compounds of two light elements including beryllium, beryllium oxide, boron, boron carbide, silicon carbide, silicon nitride, and carbon and aluminum oxide. All these materials possess high melting points, indicating strong interatomic bonding and high stiffness. Carbon and boron fibers are the best known because of their attractive properties and availability. However, aluminum oxide is gaining in popularity. Carbon fibers are jet black, silky and finer than most human hairs. Their importance lies in the fact that they can be made stronger and stiffer than any other synthetic or natural material of the same weight except for single crystal "whiskers" which can be produced only on a microscopic scale. These fibers promise a new order of stiffer yet lighter construction for a vast range of man-made objects. In the ten years they have been available, much has been done to put them to practical and economic use. Most new technical accomplishments ultimately prove useful in fields outside that for which they were developed, and a new material will probably affect every field of man's endeavor. Like so many accomplishments, carbon fibers were created for the world of aerospace. Already the first production hardware designed to incorporate them, the Rolls-Royce RB. 211 turbofan engine, is running on the test bed and coming into production. Some of its most important components are made of a composite material, having a density half that of aluminum and consisting of a resin matrix reinforced with about 600,000 carbon fibers per square centimeter of cross section. Later, hotter parts of engines may be made of other composites in which the fibers are used to reinforce a matrix of ceramic or metal. The fibers themselves retain strength at very high temperatures for they are born in a furnace at a temperature far above that of molten steel.

Today's carbon fibers are sold at the high prices characteristic of anything just emerging from the laboratory. After a decade of mass production, starting in the United States, resin composites will be cheaper than a number of metals and other special materials.

The future of carbon fibers, nevertheless, seems very large indeed. The world market should reach the level of thousands of tons a year within the next decade, although the inevitable considerable price advantage of glass fiber will restrict carbon to true engineering structures and other hard-worked parts. A conservative estimate for 1978 is that carbon fibers will have a market 15 percent as large as that of glass fiber.

Synthetic Food. Synthetic food must contain all the indispensable salts and vitamins. These must be produced on a large scale through chemical and microbiological processes. The production of proteins on an industrial scale is being undertaken in several countries including France, England, and the Soviet Union. These countries are engaged in the production of fodder yeasts, whose raw material is paraffin. Hydrocarbon yeast has a 40 percent protein content as compared with the 30 percent of soya beans, the most nourishing agricultural product.

Alfred Champagnat, director of a Marseilles laboratory, has noted that the annual world shortage of animal protein amounts to 3 million tons or 15 million tons of beef cattle. In an annual production of a billion tons of petroleum, approximately 700 million tons will be paraffin-based. It is estimated that to produce 7 million tons of protein-vitamin concentrate, equivalent to 3 million tons of protein, only one percent of the above mentioned 700 million tons of petroleum would be consumed. Moreover, 6 million tons of synthetic protein are required annually to meet the needs of 250 million persons, whereas to nourish the same number with protein produced by stock farming, would require the production of from 50–100 million tons of dehydrated protein to feed the animals themselves.

A British petroleum plant has developed a process at its French refinery (Lavera) which will produce protein from crude oil. The final produce, a yellowish, odorless powder comparable to fish-meal in composition and not yet suitable for direct human consumption, is available as feed for animals and poultry which ultimately is converted to meat, milk and eggs.

Although it may be ten years before food for human consumption is derived directly from protein produced from petroleum or natural gas, several oil and chemical companies have already begun development programs. For example, India is producing protein from petroleum hydrocarbons.

From this brief overview of the diversity of products available from petrochemicals, it is evident that the development of petro-chemical industrial complexes along the Arava canal will be nothing but beneficial for the area.

Light Metals

Magnesium. Magnesium is the lightweight champion among metals. Even aluminum is more than one and one-half times heavier. Its low density, combined with a relatively high strength for its weight, has made magnesium important in industry. While the raw materials containing magnesium are widely distributed throughout the earth, the metal itself, is so difficult to extract that it may be exploited only by highly industrialized communities. While pure magnesium is not particularly strong, suitably blended (alloyed with one or more elements) and worked, its strength can be doubled and even trebled. The most widely used alloying elements are aluminum, zinc, manganese, and zircqnium. Aluminum and zinc are added as hardeners to raise the mechanical properties of magnesium, manganese is added to improve corrosion resistance, and zirconium is added to reduce the size of the individual grains out of which the alloy is composed, making the metal stronger and giving it ductility, creep-resistance, and strength at elevated temperatures. Magnesium-zirconium alloys are important in the transportation industry, especially in aeronautical production.

Magnesium is found as a chloride in sea water and in certain deepwell brines, including those of Michigan. Magnesite ($MgCO_3$ which is the most important solid source of magnesium, is widely distributed throughout the world, the largest deposits occuring in Australia, the U.S.S.R., Greece, Czechoslovakia, Manchuria, and the Pacific Coast of North America. Leading producers of primary magnesium in the second half of the 20th century include the U.S., the U.S.S.R., Norway, Canada, Italy, the United Kingdom, France and Japan; while magnesite is produced in quantities by the U.S.S.R., Austria, China, Czechoslovakia, the U.S., and Yugoslavia.

In the second half of the twentieth century, two principal methods for the commercial production of magensium are in use. One is electrolytic, accounting for the bulk of industrial production, and the other, thermal. In Germany, where the magnesium industry was first developed on a large scale, the process is based on the electrolysis of molten magnesium chloride, a by-product from the potash and carnallite operations at Stassfurt. Magnesium chloride may also be produced from brines, sea water, processed dolomite or by chlorinating magnesite. During World War II, the sea water electrolytic process, which in 1941 was the newest method of producing magnesium, accounted for the bulk of production in the U.S. In this process, sea water, which contains about 0.13 percent magnesium, is pumped into huge settling tanks where it is mixed with lime. The calcium from the lime is exchanged with the magnesium in the sea water which precipitates as insoluble magnesium hydroxide. This settles to the bottom of the tank and is filtered off. The magnesium hydroxide is then converted to magnesium chloride by reaction with hydrochloric acid prepared from natural gas and chlorine. After thorough drying, which may be accomplished by means of spray or shelf driers or a combination of the two, the magnesium chloride or cell feed is fed to the electrolytic cells where electricity breaks it down into magnesium metal and chlorine gas.

After World War II, intensive research and development work produced strong light alloys which aided in world-wide and rapid development of the aircraft industry. These magnesium alloys were used especially for structural purposes. Perfection of alloys fabricated successfully by casting, extrusion, rolling and forging, opened up many new fields of use. Magnesium possesses special properties which make it particularly desirable for certain types of applications, including exceptional machining qualities, good fatigue resistance and damping capacity under impact stress. The attainment of high standards in the pressure die-casting technique has opened up new spheres of application in the instrument, tool, optical, and other industries where designers are often able to substitute a single casting for parts formerly built up from sheets and sections; die casting is stronger and more rigid but not heavier.

Because of their low specific gravity, magnesium alloys are widely used in the aircraft industry, as was illustrated during and after World War II. Some typical applications include housings for camshafts, timing gears, superchargers, oil filters and pumps, landing wheels, forged radial engine crankcases and propeller blades for small planes, floor beams, frames for seats, and many small parts such as die-cast instrument housings. Increased use has been made of magnesium sheet in the monocoque or stressed skin type of wing construction and it has been used on a considerable scale for fairings, cowlings and tanks. Magnesium missile sheet has been produced in volume, and various alloys have been applied in spacecrafts and in guidance systems. Magnesium tooling plate has also been used for making memory disks in electronic computer systems.

Although in the transportation area magnesium has found its greatest use in aircraft, there is a growing interest in applying its advantages to other types of equipment, especially in automotive equipment. In Europe, particularly Germany, magnesium alloys are used in bodies and frames for motor buses and trucks, cast wheels for tramways and buses, for motor buses and trucks, cast wheels for tramways and buses, and in a variety of small parts. In the U.S., magnesium has also been used in the construction of truck bodies and auto-transport trailers. Its use in railroad equipment includes frames for seating, partitions in Pullman cars, and instrument panels and housings.

Magnesium is increasingly being used for various types of portable goods such as the housings and handles of tools. Portable platforms and conveyor systems, dockboards, hand trucks, milk crates, office equipment, such as typewriter and adding machine frames, and various types of instrument housings are also made from magnesium.

Due to their light weight and their ability to absorb dynamic energy, magnesium alloys are being used in parts of high-speed and reciprocating machinery such as warp beams, bobbins, spools and knitting bars, so necessary to textile plants. Cast magnesium foundry flasks and molding and core boxes are used in foundries, and it is also utilized for industrial gratings and pedestrian bridges.

The use of magnesium in consumer goods of various types is constantly expanding, now including such items as domestic vacuum cleaners, griddles, wheel toys, luggage, lawn mowers, step ladders, and photographic and motion-picture cameras.

Magnesium functions as an important element in aluminum alloys. Its chief function involves increasing the mechanical and corrosion-resisting properties. It also facilitates heat treatment. A growing use of magnesium is as an expendable galvanic anode for the cathodic protection of buried metal structures such as pipelines, as well as for ship hulls and tanker compartments.

With its high affinity for oxygen, magnesium is used as a deoxidizer in the manufacture of metals. The increasing production and use of zirconium hafnium, uranium and beryllium has resulted in an increased demand for magnesium as a reducing agent.

Markets exist because of the increase in the use of magnesium. Exploitation of larger amounts of magnesium found in the Dead Sea should be considered. Cheaper outlets to markets for Dead Sea magnesium along with cheaper sources of electricity for the extraction of magnesium from magnesium chloride can be considered.

Aluminum. Aluminum is replacing many metals, such as steel and copper, since it is light, weather-resistant and a good conductor of heat and electricity. It is a good reflector of light and radiant heat too. Six big producers (Aluminum Company of America, Alcan Aluminum Ltd., Reynolds, Kaiser, Pechiney, and Alusuisse) account for approximately three-quarters of western smelting capacity, and the top four possess more than one-third of the western world's semi-manufacturing capacity.

The production of aluminum in the United States is a major industry, second only to iron and steel in the metallic sector. The industry received its primary impetus during World War II when there was an insatiable demand for the product for its light, strong qualities. Since then new uses have increased the demand, as its qualities were revealed as an ideal building material. Furthermore, its use in automobile production has increased ten-fold since 1946; railroad and marine enterprises have increased their conumption annually. It is a popular material in the manufacture of consumer durables, machine parts, tools, and equipment. The net result has been that the local supply in the United States, is now inadequate to meet the demand, and over 85 percent of the bauxite (the raw material for aluminum) currently in use is imported.

Smelters have been concentrated in countries with abundant hydroelectric or thermal power resources, such as the United States, Canada, and Norway, since power utilized in the smelting process accounts for approximately 15 percent of costs and a power price difference of 0.1 U.S. cent per unit adds 3 percent in costs. In high-cost energy countries, such as France, Germany, and Italy, smelting is undertaken by means of special pricing. Since 1954, North America has been the major producer of aluminum and the main supplier to European semi-manufacturers. However, North American capacity now provides only 48 percent of the total as compared with 85 percent in 1945. Location of smelters is now determined more by transportation costs and semi-manufacturing is carried on in proximity to the ultimate consumer.

Many factors have combined to promote the desirability of locating smelters in metal-consuming countries. Power costs, of course, have a significant influence since, in the smelting process, the aluminium is separated from the oxygen by massive doses of electricity. It takes approximately 18,000 kwh to make a ton of aluminium which is roughly the equivalent of a two-bar electric fire which has been switched on for more than a year. The most influential considerations include: the prospect of nuclear power costs falling to 4 or 5 U.S. mills a unit within the next 10 years; shorter haulage and lower handling costs if the aluminium is shipped directly to Europe (and not to a North American smelter first); and high tariffs, particularly the 9 percent external tariff of the Common Market. In addition, some governments are providing financial incentives to encourage the erection of smelters within their borders. Eventually, when nuclear power is universally available, and the demand for aluminium in the raw material producing countries represents a more notable share of the market, it is probable that new smelters will be located near the bauxite and aluminium plants. Such a process would certainly cut transportation costs, but, in the foreseeable future, it appears that semi-manufacturing will continue to be carried on in proximity to the ultimate consumer. Transportation is a decisive factor in this area, too. The processes of rolling and extruding add value but also result in much more awkward shapes, which in turn, result in approximately doubling the transportation charges. Tariffs, too, are higher on semi-manufactured goods.

An investment of approximately 3,000 dollars is required to produce one ton per year of semi-manufactured aluminium. The economies of scale which can be gained by combining all operations in one plant from mining the bauxite to rolling have tended to greatly increase the size of new plants.

In dealing with this situation, producers have moved into the semi-manufacturing stage, thus increasing integration. Approximately 80 percent of the entire semi-manufacturing capacity in the United States and Canada is owned by aluminum producers. The Aluminum Corporation of America processes virtually all of its own aluminum. While, at one time, Alcan Aluminium Limited processed only approximately one-quarter of its aluminum, it now processes 50 percent, and is moving towards 60 percent.

In Norway, Alnor (51 percent Norwegian and 49 percent American) has opened a new smelter with an initial capacity of 80,000 tons and an envisaged expansion to 240,000 tons. It is located on the island of Karmoy, approximately 50 kilometers north of Stavanger. The plant is integrated to produce not only raw aluminum but also semi-manufactured goods. This plant has the advantage of cheap hydroelectric power (3 US mills/kwh. plus delivery) and a modern production process. The oxide is reduced to metal which is semi-manufactured in the same building without being cast into ingots. Beside the raw aluminum, semi-manufactured goods such as "sheet", "strip," "tubes," and "wire rod" will be produced. When the extrusion plant is in operaton, the company expects that approximately one-third of the total output will be in the form of semi-manufactured goods, while the remainder will be in the form of straightforward ingots, billets, and slabs. However, the ultimate goal is a fifty-fifty division of the two types of product. Elimination of the intermediate stage of production is expected to reduce costs by 50 percent. The Norwegian partner in the enterprise, Norsk Hydro, is the world's second largest producer of magnesium. They believe that it is beneficial to have an interest in all industries connected with water power. The electricity which powers this smelter is hydro-generated. The American partner, Harvey Aluminum, will supply the Alnor smelter with alumina produced by bauxite deposits in the Virgin Islands. The Harvey Company will receive 25 percent of the smelter's output free of charge for sale in the United States.

In England, British Aluminum (partly owned by Reynolds Metals of the United States) and the British Mining concern, Rio Tinto Zinc Corporation, are building two smelting plants to produce 224,000 tons of ingots by 1971. Rio Tinto will build its 112,000 ton smelter on the island of Anglesey at Holyhead in Wales and obtain cheap power from the Dungeness "B" nuclear power station in Kent. British Aluminum is building its 112,000 ton smelter at Intergordon in Scotland, the last undeveloped deepwater port in the United Kingdom. Electricity for these two smelters will cost 0.6d per unit because of government subsidy. The Invergordon plant will receive its power from the Hunterston "B" station of the South of Scotland Electricity Board.

If New Zealand agrees to grant tax concessions, a consortium of British, Australian, and Japanese companies will build a major aluminum smelter in that country. The basic attraction is New Zealand's cheap water power. The proposed British investors of this vertically integrated plant have already begun working the world's largest bauxite deposits at Weipa in northeastern Australia. Processing of this ore takes place at the world's largest single-stream alumina plant at Port Gladston, in Queensland, Australia, and this alumina is now being smelted in North America. The proposed smelter would be built at the deep-sea port of Bluff, near Invercargill in the southern part of New Zealand's South Island. The power would be obtained from Lake Manapouri in South Island. (with an eventual output of 620 mw on a continuous basis and 700 mw at peak load). The smelter would be built with an initial capacity of 105,000 tons to be increased to 290,000 tons by the early 1980's. Manapouri power will cost less than 2 mills/kwh., (0.2 United States cents), as compared with hydro-electric kwh., (0.2 United States cents), as compared with hydro-electric power costs of nearly 4 mills in Australia, and approximately 3 mills in the United States, where much of Australia's alumina is now being smelted. (The cheapest power until now has been at Bonneville in the United States – 2½ mills/kwh.) The Japanese users of this aluminum would gain an even greater advantage since Japanese power costs 7 – 7½ mills/kwh.

At the present, West Germany is on the verge of increasing its aluminum production capacity which, until now, has averaged 60 percent of the amount used by German industry. The price of electric power has, until recently, hampered German development since this cost is an important factor in aluminum production. In the production of aluminum, 18,000 kwh are required to make one ton. The interest in increased production of aluminum all over the world is apparent when one realizes that none of the three proposed entrepreneurs represent German companies but rather the American Kaiser Company; the Swiss Alusuisse (in association with Metallgesellschaft of Frankfurt); and Pechiney of France. The three sites are all in the Ruhr.

With the proposed hydroelectric power plant on the shore of the Dead Sea, sources of cheap electrical power will be available. Aluminum extraction from bauxite can thus be integrated into the industrial complex, the canal being the means of transporting raw and refined materials.

Titanium. In recent years, titanium has become important in alloy forms. Principal employment of titanium metal is in structural parts in high-speed military aircraft where high strength and low density are important. Titanium and titanium alloys can be used at temperatures up to 800 F., several hundred degrees higher than the useful temperature range for aluminum. It is used in the compressor section of jet engines, in airframe construction, aircraft skins, fire walls, and as fasteners. In other military applications, it may prove useful for armor plate because of its toughness, and for structural components of atmosphere makes it suitable for special applications, such as heat exchanger tubes, superstructure parts, valves, and propellor blades.

In corrosion-resistant applications, titanium is used in valves and pumps for corrosive chemicals, in wire cloth for filtering equipment, and screens. It is employed to line pulp bleaching equipment in chlorine dioxide environments. It has been used in centrifuges, condensers, filter presses and heat exchangers where corrosion is a problem. In the electroplating industry, titanium has been found to be excellent for anodizing racks. It is used in prosthetic devices because there is no reaction between titanium and fleshy tissues or bones.

A list of the potential applications for titanium is lengthy because the combination of its high strength, low density and excellent corrosion resistance creates a multitude of uses. However, the high cost of titanium ($20/pound for mill products), has precluded its use in many applications. Continued decrease in price to a competitive level with other metals would ensure that large quantities of titanium be used in transportation equipment other than aircraft, such as automobiles, trucks, buses, railroads and ships.

Titanium is the ninth most abundant mineral, exceeded only by oxygen, silicon, aluminum, iron, calcium, magnesium, sodium and potassium. It is known to exist in approximately 98% of all rocks and found in practically all sand, clay, and other soils. It has also been found in oil, coal, natural waters, vegetation, animal flesh and bones, volcanic ash, deep-sea dredgings and meteorites However, despite this widespread distribution there are numerous deposits of highly concentrated titanium minerals readily accesible and easily minded. Of the many minerals which contain titanium, only two are of prime commercial importance: ilmenite and rutile. Ilmenite, the more abundant of the two minerals, is a combined iron-titanium oxide usually expressed as iron titanate ($FeO-TiO_2$) although its composition varies considerably. Ilmenite contains about 32 percent titanium and 37 percent iron. Ilmenite occurs frequently with hematite and magnetite (iron bearing ores) in rock formations and in sand in beaches and rivers. Rutile, which in pure form is titanium dioxide (TiO_2), is richer in titanium content than ilmenite but is generally diluted with other minerals either in rock formations or beach and river sand. Known deposits of rutile are not so extensive as ilmenite.

Titanium ores are abundant in North America, Australia, Brazil, India, the Malay States, Norway, Russia, Sweden, Finland, Portugal as well as in various places in Africa. Travancore, India, is one of the major sources of titanium ores because of its high TiO^2 content, and much of the titanium ores imported by the United States for production of titanium dioxide pigments comes from India.

The most important compound of titanium from the point of view of consumption is TiO^2, which is used extensively in the pigments industry because of its excellent hiding power or opacity. Titanium dioxide, a pure white compound having high reflectivity, is ideal for use in white paints, enamels and lacquers and can be used in conjunction with other pigment compounds in colored paints. It is also used in pigments for rubber, paper, oilcloth, leather, textiles, inks, and cosmetics. Titanium dioxide is produced from rutile or ilmenite by dissolving the ore in a sulfuric acid solution and precipitating the iron compounds. The solution is then hydrolyzed, producing a hydrous titanium oxide, which is washed and calcined.

Titanium tetrachloride, the raw material for producing titanium metal, is the next important compound. It is produced by chlorinating TiO^2 or titanium ores in the presence of carbon. The minor amounts of iron, silicon oxygen and other impurities present after chlorination are removed by fractional distillation. Other important uses for titanium tetrachloride are as a catalyst in many chemical reactions and as a smoke-producing compound for sky-writing or smoke screens. Titanium carbide, a compound produced by reacting carbon with a titanium compound, is used in conjunction with tungsten carbide in cutting tools and dies.

Fertilizers

The manner for accelerating the economic growth of the developing countries is one of today's most urgent problems. One of the obstacles is the failure of food production to keep pace with the population explosion. Indeed, preliminary estimates indicated that the per capita food production in the developing regions had declined to the 1957/1958 level which was equivalent to the inadequate pre-World War II level. Food output can be increased by at least 50 percent (under the conditions prevailing in many developing countries) by the application of fertilizers even without the use of other inputs. Thus greater and more and more careful use of fertilizers comprises the best prospect for a country with a rapidly growing population which cannot increase the amount of land available fc agriculture.

The population increase in the period 1960–2000 will be as great as the total growth throughout previous recorded history. This is true because of the success of current measures to improve man's health and well-being, and also the failure of present population control measures to retard the birth rate sufficiently to reduce the growth rate of world population. Population growth rates are, on the whole, higher in the world's developing areas.

Future world food needs will be affected by two salient factors: population growth and rate of economic development. Among the various estimates which have been developed pertaining to future food requirements F.A.O. has concluded that the world's food supply would have to be doubled between 1960 and 1980 to meet reasonably adequate levels of nutrition. This will require an annual rate of increase in food production of 3.5 percent throughout the period. But if the population of the world's developing areas expands to the predicted three billion persons by the year 2000, these areas would, of necessity, have to develop an additional food production capacity equal to current production throughout the world.

The main hope in achieving rapid growth in food production lies in increasing crop yields on land already under cultivation. Existing levels of crop production are generally low in the developing countries where there is the greatest urgency to increase the food supply. Wheat yields reported in Algeria, Pakistan, and Argentina averaged 6.0, 8.1, and 11.2 hundred kilograms per hectare compared with 16.1, 35.6, and 43.0 in the United States, the United Kingdom, and the Netherlands respectively. At the same time rice yields in the Philippines and India averaged 11.8 and 15.2 hundred kilograms per hectare, while those in the United States and Japan were 38.3 and 47.8, respectively.

The increase in crop yields in the technologically advanced countries has been accomplished by the increased use of fertilizers. Almost one-half of the yield increase in the United States has been attributed to the increased use of fertilizers.

The decision to produce or import fertilizers will be affected by the availability of local and external sources of low cost raw materials and other inputs required by the fertilizer industry. While the potash and phosphorus manufacturing processes entail raw materials, nitrogen fertilizers are generally based upon the complex and costly production of ammonia. Modern methods encompass fixing nitrogen from the air and combining it with hydrogen to form ammonia, which required a sizable electric power supply or other engergy sources.

It has been suggested that regional cooperation among countries be projected as an efficient means of promoting economic development in those regions of the world whose national markets are so small that the cost of domestic manufacture of fertilizers becomes burdensome. Countries adopting a plan of joint development of fertilizer projects would experience the economic problems typical of the construction and operation of a large-scale venture. There would, however, be a reduction not only in unit cost but also in total capital investment.

Importance of Fertilizers. In considering the importance of fertilizers in production and consumption in the developing countries, emphasis is placed upon three plant nutrients: nitrogen, phosphorous, and potassium.

The present outlook for the world food situation implies that food demand will rise faster than food supply in the developing countries for a substantial period into the future. If the F.A.O. nutritional targets are considered (based upon present medical knowledge of physiological needs), meeting its minimum would require an increase of 26 percent in total food supply per capita over the average 1962–64 level in the developing countries as a whole, which, disregarding future possible changes in population growth, would not be possible until 1996.

Since developing countries have, in the period of the last twenty years or so, considerably reduced the margin between the cultivated area and the total area of suitable land that could be brought under cultivation without injections of heavy capital investment, future progress in production can occur only by more frequent crops and by increasing yield per acre or hectare. Whichever method is employed, fertilizers will have to perform a leading role in increasing agricultural production. Except where very high quality soils and limited time periods prevail, more frequent cropping, reducing the time that land is permitted to lie fallow, and sustained increases in yield per hectare of crop, demand increasing applications of fertilizer. Water as well as fertilizers is important during the growing period. Experiments have shown that where water and fertilizers are combined, the yield response of the crops may be much higher than in cases where additives are applied alone.

Consumption of fertilizers by developing countries has grown at a rate of 12–13 percent per year and reached almost 15 percent in 1965–66. Estimates indicate that by 1980 the developing countries' share will reach one-third. However, even this demand will be insufficient when compared with need. Moreover, farmers will have to be allowed to purchase fertilizers on credit, if necessary, and they will have to find a market with the assurance of a fair price for their increased population.

Developing countries will continue to be sizable fertilizer users in the future. While net imports of nitrogenous fertilizers will increase less than the average, potash imports will rise rapidly. More than half of the 40 million tons of fertilizer nutrients consumed in 1980 by the developing world will be covered by imports. At the same time, the high proportion of imports to satisfy fertilizer consumption in developing coutries and also the considerable proportion of imported raw materials in local fertilizer production by 1980 could require foreign exchange expenditures of 7 billion dollars per year. While fertilizer production in developing countries is generally more expensive than the import of fertilizers, local production makes less demand upon international finance. However, in terms of foreign exchange, fertilizer imports are much more desirable than grain imports.

By 1972–73, world production of fertilizer had more than doubled over its 1956–57 level, up to 81 million tons. However, consumption was somewhat below this figure because of losses in fertilizer transport. In 1955–56, developing countries produced 6.0 percent of the world fertilizer total and consumed 10.6 percent. By 1972–73, production had risen to 10 percent and consumption to 14.6 percent respectively. The output of nitrogen was estimated at 36 million tons: Production of phosphoric acid, estimated at 25 million tons, while potash production rose to an estimated 20 million tons. Europe continued to be the heaviest user of fertilizelizers, with a consumption of some 157 kilograms of all fertilizer nutrients per hectare of arable land.

Asia's fertilizer production in the developing world has risen sharply in the last ten years. Eight countries in Asia produce nitrogen, two of which, India and Taiwan, produce more than 60 percent of the total. (Threee of the seven countries in Latin America which produce nitrogen, produce the bulk, and similarly one of the four European producers, produces more than half.) The same concentration may be observed in phosphate and potash production. The total of Asian potash production comes from Israel. Today, there is no production of potash in Africa.

Developing countries which produce an excess of fertilizers, export their surpluses almost completely to developed countries; there is thus little trade between developing countries. Net imports of phosphate and potash fertilizers are three and four times greater than in 1955–56. While the share of nitrogenous fertilizer imports in total consumption declined, the share of trade in covering total consumption of phosphates and potash fertilizers has increased. Moreover, the development of bulk shipping appears to have affected the consumption increase. While in Asia, the growth rate for phosphates was higher than that for potash, in the world as a whole, there has been a faster rate of growth in potash demand. However, nitrogen predominates in fertilizer consumption in many developing countries.

It is estimated that by 1970 total world consumption of fertilizer will range between 53.3–65.5 million tons, and in 1980 between 89.7–108 million tons. These estimates are, of course, heavily influenced by population projections, political stability, availability of foreign exchange, and government policies. Naturally, an overall yield relationship is assumed between fertilizer use an additional food production. Estimates of future fertilizer consumption by developing countries excluding less developed Europe, include a figure of between 9.2–11.2 million tons in 1970 and 27–38 million tons in 1980.

Rated capacity in developing countries for the production of fertilizers amounted to 5.5 million tons of nutrient in 1965 or approximately 9.8 percent of the world total. The world production capacity by 1970 may reach approximately 90 million tons of nutrients of which 14.3 million tons would be located in developing countries (15.9 percent). In respect to the components of this figure, nitrogen capacity would roughly treble, phosphate capacity would increase two and a half times, and potash capacity nearly three and a half times.

Rated capacity possesses two defects as an indication of practical production possibilities. Plants which are located in the developing world cannot expect to have a sustained rate of operation compared with plants in the developed world, owing to the fact that it is more difficult to manage these plants efficiently, the sources of spare parts are remote, engineering ability may vary in quality, and greater organizational and transportation problems are present. Moreover, approximately three years are required to bring a new plant up to its sustained level of operation.

Nitrogen Fertilizer. Ammonia is the basic intermediate product required in the production of nitrogenous fertilizers. It is synthetically produced from a hydrogen source and the nitrogen in the air. Hydrogen sources are easily accessible all over the world since they are found locally either as natural gas or produced as a by-product from such processing fuels as naphtha or refinery gases at refinery sites. Production of ammonia is very capital-intensive and subject to important economies of scale, even at such large unit sizes as 1.000 or more tons per day. Seaborne transportation of ammonia is on the rise and expected to increase rapidly in the coming years as trade and size of ammonia tankers increase. Thus new ammonia plants will tend to be very large in size, located at close proximity to cheap sources of natural gas, the cheapest hydrogen source of ammonia.

Considerable sources of natural gas are to be found in the developing counrtries, particularly in the Caribbean, the Middle East, southern Latin America, Nigeria, and the Far East. Refined techniques of transporting liquefied natural gas are tending to challenge the present advantage of producing ammonia at the source of natural gas. Naphta supplies are more limited since other consumers compete for its use. Its availability is affected by the breakdown of consumption between heavy and light products, the nature of the crude oil input, and the existence of a petrochemical industry. Furthermore, refineries in developing countries seldom produce enough naphtha to feed very large ammonia plants. The fact that the ammonia plants are subject to very significant economies of scale, has led to the establishment of a number of plants of very large size. However, technical problems in running these very large ammonia plants have still not been fully overcome. Their operation is extremely complex, and these large plants have experienced serious difficulties in working up to capacity.

Phosphate Fertilzer. While basic slag, a by-product of steel production, is used as a phosphate fertilizer, the only source of phosphorus for fertilizer production is phosphate rock. While deposits of phosphate rock are found in many parts of the world, economical mining requires an output of approximately 500.000 tons per year. Thus mineable phosphate deposits in developing countries are operated only in North Africa. West Africa (Senegal and Togo), in the Pacific Islands, and the Middle East – producing one-thirds of the total world output.

Phosphate Rock Mining Capacity in 1970
in millions of tons

U.S.A.	38.0
U.S.S.R.	25.0
North Africa	24.5
Others (mainly Oceania and West Africa)	[illegible]
Total	97.0

Source: Supply and Demand: Prospects for Fertilizers in Developing Countries, OECD, 1968.

While single-super-phosphate contains approximately 18–21 percent of the active ingredient, making it more economical to ship enriched rock, triple-super-phosphate which contains 46 percent of the active ingredient is coming more into use, creating an advantage for producing the fertilizer at or near the mine. World reserves of phosphate rock deposits are reported to be close to 72 billion tons, of which one to two-thirds is considered to be economically mineable. In 1973, production reached 94 million tons. On the export side, Morocco is the world's biggest single exporter of phosphate rock. An outstanding new development is the report of large reserves of phosphate rock in the Spanish Sahara (the second largest in the world). Plans are already underway to produce 3 million tons a year, rising to 10 million tons in seven years.
The other principal raw material essential in the treatment of phosphate rock is sulphur, in the form of sulphuric acid. Nearly half of the world's total sulphur production is used by the fertilizer industry. Restricted sources of cheap sulphur would tend to keep prices up which, in turn, would hasten the trend towards elemental phosphorus production by means of the electric furnace process (relying upon cheap electric power) and also the treatment of phosphate rock by means of nitric acid. The latter process may be more economical in the production of complex fertilizers as it requires much less sulphur. When a cheaper process is perfected for purifying heating oils, an enormous source of sulphur will become available.

Potash Fertilizer. Potash fertilizer is an adjunct of potash salt deposits which are even more narrowly restricted in locale than phosphate rock mines. Spain and Israel, alone of the developing countries, produce this element with small quantities coming from Chile and Peru. While by 1970 Jordan, Congo (Brazzaville), Ethiopia, Morocco, and West Pakistan are likely to have some potash capacity, the total for all of these countries will not amount to much over 10 percent of total world capacity. As potash fertilizers require only a relatively minor amount of processing at the mine, they will continue to occupy a prominent place in international trade. The main suppliers, at the moment, are France, Germany, the U.S.S.R. and the U.S.A. Low-cost mines in Canada, now in production, affect trade patterns.

Estimated World Reserves of Soluble Potash Materials
in millions of tons of K_2O

U.S.S.R.	15,800 – 18,300
Canada	15,800
East Germany	12,700
German Fed. Rep.	18,000
France	280 – 360
Israel and Jordan (Dead Sea)	1,800
Spain	250 – 460
United States	380
United Kingdom	130

Apart from the Dead Sea area, potash deposits exist in developing countries including the Congo (Brazzaville), which ought to be going into production at the end of 1968. Ethiopia is likely to develope a potash industry in the very near future, and West Pakistan, where a mineable deposit has just been discovered. The size of the reserves in Pakistan and Ethiopia has not yet been assessed but is reported to be higher than 30 million tons of ore in each case. In the Congo, production is based on a mining concession which contains 50 million tons of mineable sylvinite ore. Further research is being done at the moment, and the Congo reserves are supposed to be considerably larger. Production will start at 500,000 tons of potash per year.

While the production of salt from sea water and inland salt lakes by means of solar evaporation in shallow pans made of consolidated clay is an ancient practice in the arid and semi-arid regions of the world, it is only since 1932 that potash has been manufactured from the brine of the Dead Sea. In 1974 its production reached one million tons.

In Jordan, the Arab Potash Company has a concession covering one half of the southern end of the Dead Sea – 100 km^2 in area, capable of producing 420,000 to 600,000 tons of potash annually. The process is similar to that ulilized by the Dead Sea Works in Israel, and the cost of production will, according to estimates, be the same.

Chile and the United States also employ the solar evaporation method of producing potash. However, where potash occurs as a solid deposit below the surface of the earth, the process utilized is that of mining these underground deposits. This system is used in Canada, Germany, France, and New Mexico (U.S.A.). There, coal mining methods are employed. While it is usual to recover approximately 60 percent of the deposit, ultimate recovery can be increased to 90 percent by removing the pillars at the final stage of mine operation. The cost of these mining operations mainly depends upon the following: the depth of the deposit beneath the surface; the nature of underground formations to be traversed; the thickness of the potash deposits; the location and remoteness of the site.

Since mining development costs can be written off as a percentage of the ore mined over a period of years, large development costs reflect only a small portion of the cost of the ore. Use of modern machinery also serves to minimize labor costs.

Solution mining is also utilized in Canada for the recovery of potash at depths which are impractical for mining by conventional shaft methods. Here water is pumped into the solid potash deposit by means of drilled holes. This water dissolves the potash, and the solution is forced to the surface from which the potash may be recovered by means of concentration and crystallization. Recently, it has been deemed fortuitous to inject a blanket of natural gas over the potassium chloride deposit to prevent excessive disolution of the covering sodium chloride layer to maintain the relative purity of the potash solution.

The investment for the crystallization process is approximately 30 percent larger than for the flotation process. The significant difference in the cost of production ($17.37 per ton as compared with $15.61 per ton) is caused by high utilities requirements for the crystallization process and great fixed costs. In Canada, the cost of production by the flotation process is lower ($14.26 per ton) because the potash content of the ore is greater, although the Canadian investment is larger. The cost of production of muriate of potash by solar evaporation assuming no cost for raw materials, is $10.50, and adding fixed costs, the total cost amounts to $20.04 per ton which is $4 to $6 per ton higher than potash produced in Saskatchewan, Canada, or Carlsbad, New Mexico.

To fully exploit potash production in developing countries, costs must be kept low and competitive particularly in those areas such as Israel and Jordan where potential internal consumption is not very large. In exporting to the Middle and Far East, these nations must base their cost computations upon the necessity to compete with the vast resources and low prices of the Canadian product. Thus, competitors in developing countries would be well advised to hold their cost of production to the lowest possible level and to immediately initiate steps leading to the progressive reduction of costs. Such measure should include:

a. reducing capital requirements for potash products as much as possible by reducing infrastructure and other costs or allocating them to some other account;
b, increasing the capacity for production to the maximum extent possible;
c. utilizing by-products and co-products;
d. developing bulk handling facilities for moving raw materials as well as finished products;
e. designing processing plants in an integrated manner and providing facilities for future expansion with minimum costs;
f. taking all essential steps to attain full capacity rapidly; keeping production at full capacity by employing competent personnel, providing adequate exchange funds, and assuring sufficient raw materials, adequate utilities, and product sales.

Location of Fertilizer Plants. The fertilizer is worldwide in scope and is becoming increasingly complex. The increase in world fertilizer needs by 1980 (70 million tons) will entail an estimated future outlay of approximately $7 billion for new fertilizer plants. The location of these plants is, of course, extremely important for the developing ing countries both as producers and consumers.

The transportation factor is usually dominant in the location of primary fertilizer plants, particularly in respect to raw material supplies, and to a lesser extent delivered costs of products to secondary producers, lenders, and/or distributors. The effect of transportation costs plus loading, unloading, and port charges can be seen from the fact that the ex-mine costs of phosphate rock can be less than one-half the delivered cost to producers located overseas. Therefore, it must be stressed that it is no less important to secure the lowest cost transportation and improvements in bulk shipping and cargo handling them to press for greater skill in production and new developments in process technology.

Transportation factors, with respect to finished goods, are also of considerable significance in determining the optimum location of a primary fertilizer producer. The impact of lower delivery costs to consumers, on the part of competitors, renders it imperative that the selection of a location be made which allows minimum cost deliveries, emphasizing also reliability and efficiency. Bulk shipments and deliveries are thus assuming increasing importance.

Power costs are also a factor in location. In those areas of the world where ample hydroelectric energy is available, power costs may be reckoned as low as three mills per kwh; whereas in countries dependent upon imported fossil fuels, the local power rate may be between 10–20 mills/kwh. For example, an ammonia plant might require about 700 kwh/ton of product. Thus, the availability of low cost power is definitely a positive factor in plant location of processes with appreciable net energy requirements.

Water availability is also a salient factor in plant location. Adequate supplies are required for process needs, cooling, power and other purposes. Where fresh water supplies are insufficient, sea water is frequently utilized for cooling purposes. Water for process requirements, boiler feed, and human consumption necessitates relatively high purity standards which, if fresh water supplies are inadequate, can be obtained through ion exchange, condensate recover, or steam distillation. Skilled process design frequently permits considerable economies to be achieved in process water requirements which often amount to a fraction of cooling water needs. In ammonia manufacture, approximately 50,000 gallons of water per ton of ammonia could be specified for cooling purposes as compared with 10,000 gallons of condensation for re-use in the boiler or other parts of the plant.

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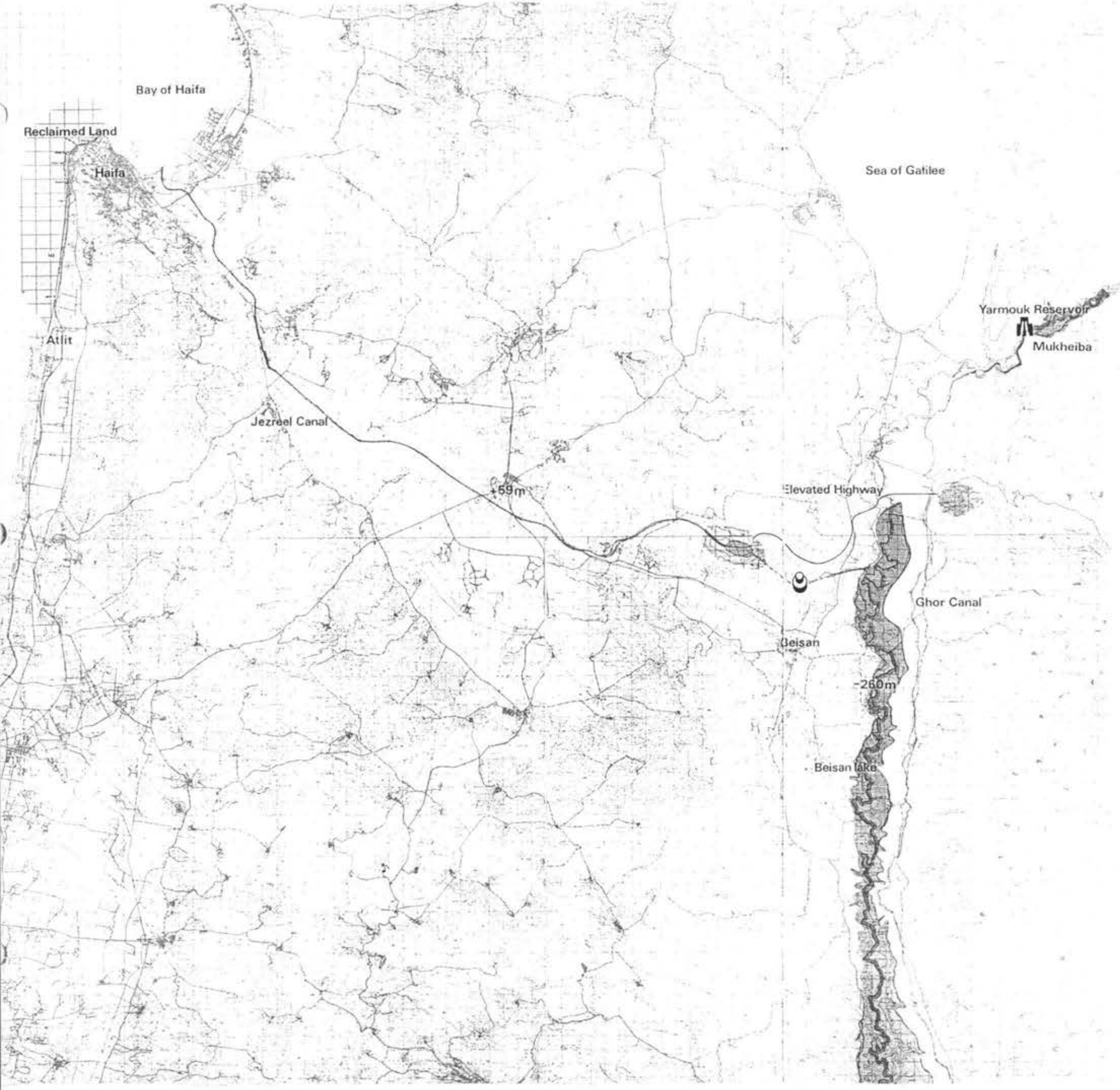
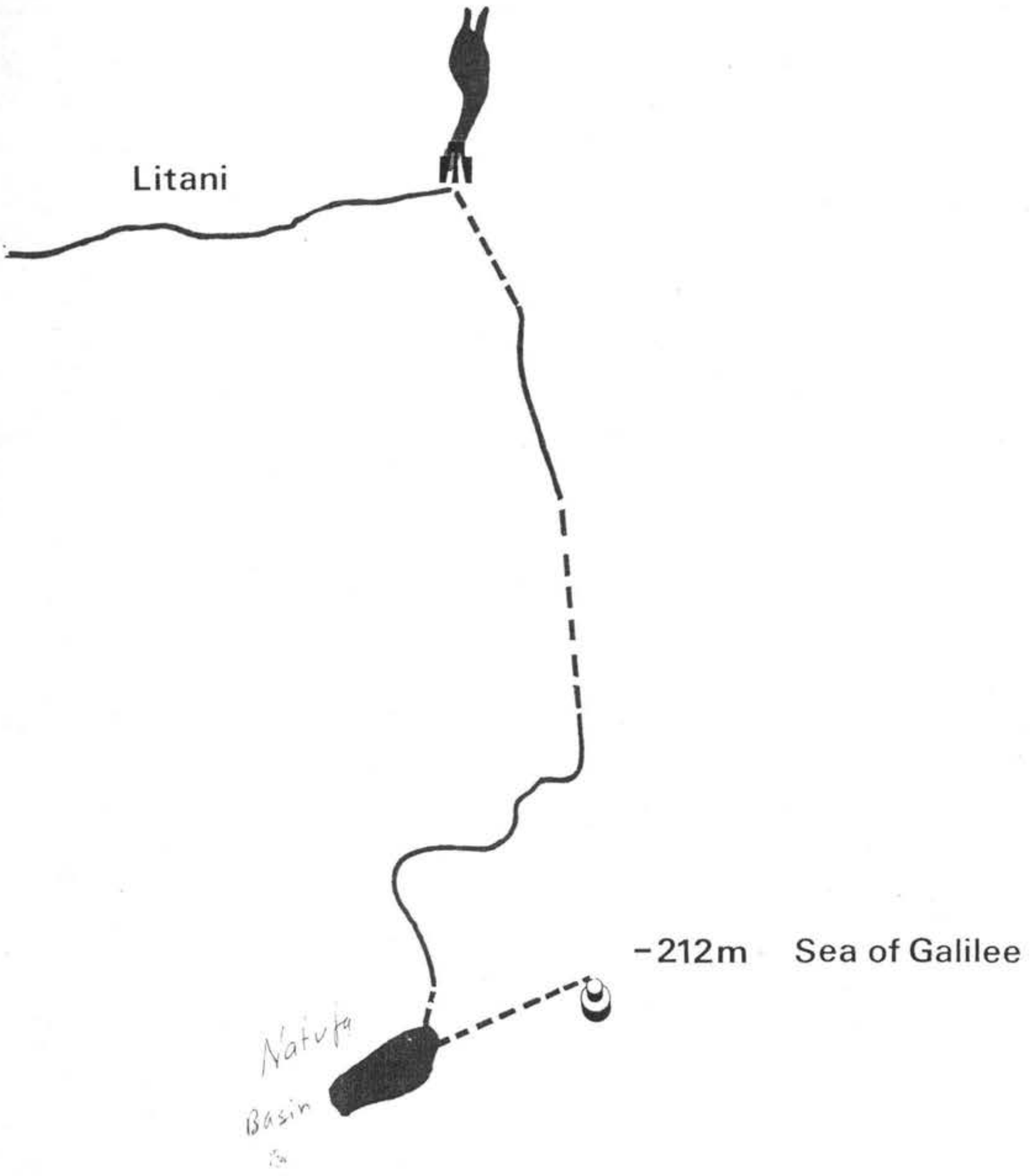
Jezreel Valley Canal

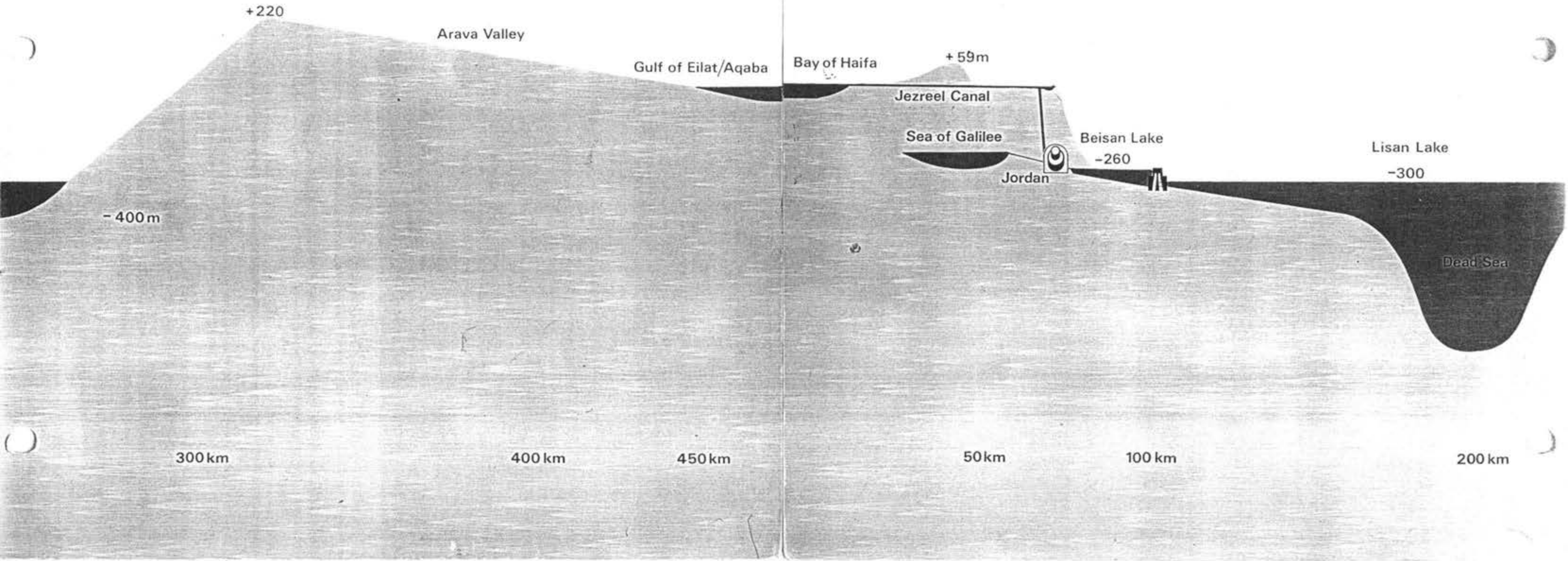


Hydro electric Power Plant

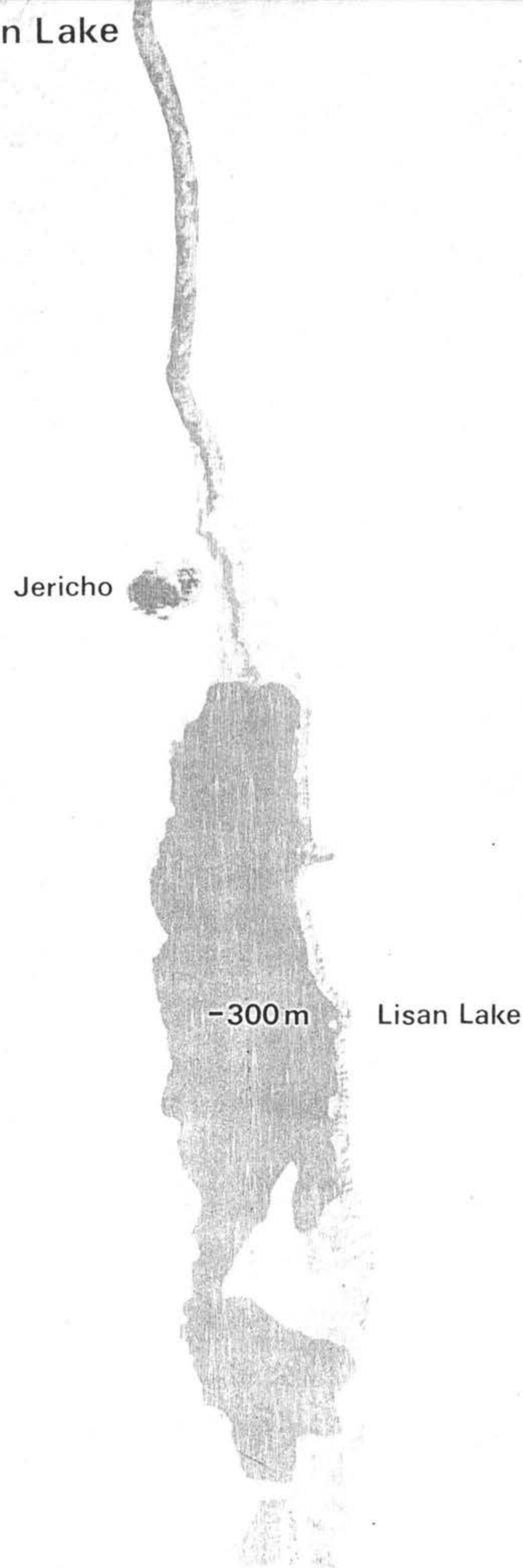
Tunnel

The Litani Diversion




+220
Arava Valley
Gulf of Eilat/Aqaba
Bay of Haifa
+59m
Jezreel Canal
Sea of Galilee
Beisan Lake
-260
Jordan
Lisan Lake
-300
-400m
Dead Sea
300km
400km
450km
50km
100km
200km

The Lisan Lake



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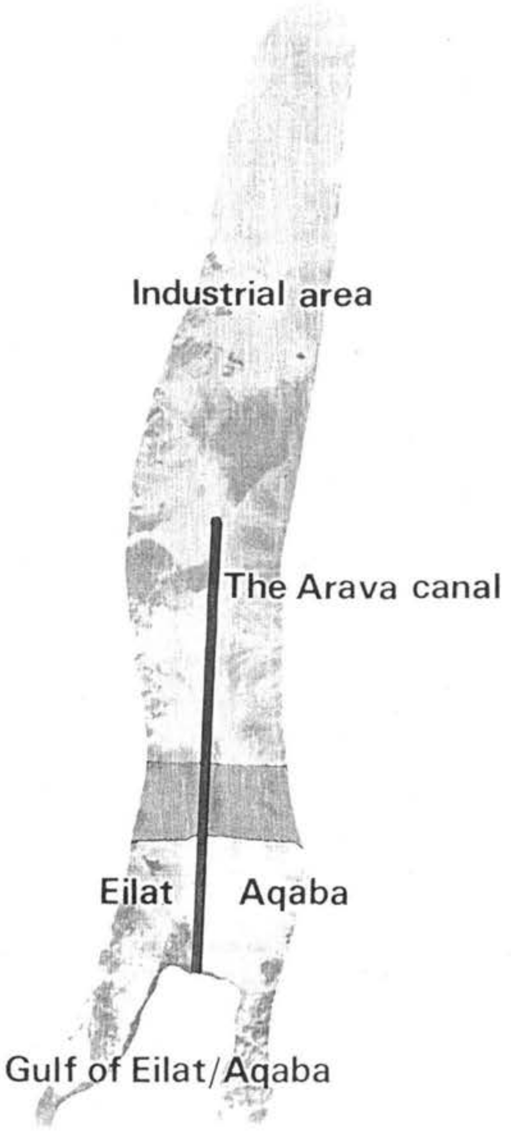

The Jordan Rift Valley Regional Development plan