Alternative Strategies for **Desert Development** and **Management**

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WATER SALINITY AND CROP YIELDS IN A CALIFORNIA DESERT[1]

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ECONOMIC CRITERIA DEPEND UPON THE OBJECTIVES OF THE PROJECT

Economic criteria depend upon the actual objective of the desert irrigation project. Several possible objectives come to mind.

To Provide Food For A Starving People

The immediate economic evaluation of this objective would depend upon what the starving people were able to exchange for the food. If there were nothing they could exchange, then the cost of the project would have to be weighed economically against a saving of the food and medical supplies which were being donated to maintain life. The primary objective of this type of project as stated is not economic but humanitarian. The chief benefit sought was in good feeling developed in the donor of the project for his generosity and in the recipient for the relief of his starvation. Unless the starving people develop the project sufficiently to meet their own needs and produce a surplus for exchange, this type of project will not have economic encouragement and indeed should not be evaluated directly in economic terms since the objective was not an economic one.

Raising The Standard Of Nutrition Of The Inhabitants Of An Area

This objective as in the previous one is not stated in economic terms and, therefore, should not be dependent upon its economic merits. The food produced by the inhabitants over and above their own needs could be used to pay for the project. An indirect economic benefit might also accrue. People aware of their poor nutrition might resort to a violent display in order to express their desire for better food. Existing economic enterprises could be destroyed in such mob action. The value of the capital saved by a desert irrigation development could then be included in the economic equation of evaluating the project. Such a viewpoint could encourage a project that was questionable on purely economic criteria.

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To Attract People To Develop A Hostile Area

In this instance the economic costs of the desert irrigation project should be combined with all other commercial costs of development and weighed against the total productive capacity of the entire developed area. As is often the case, the desert area once developed for agriculture offers excellent rain-free climate and abundance of surface area ideal for industrial and commercial activity. While the irrigated desert project itself may be marginal economically, the added commercial and industrial activities which the project makes possible add economic benefits to the original investment. An indirect economic benefit may also be enjoyed in this objective. Those who come into the area may have been taken from a maintenance subsistence or welfare rolls, and the capital previously applied to these objectives could be credited to the project.

To Free A Nation From Extra-National Food Dependence

The economic value of a desert irrigation project with this in mind should be weighed against the capital saved in preventing extra national withdrawal of food. It should consider the value of the municipal, industrial, and commercial operations that would cease if the extra national food source dried up. An irrigation project with this objective would be an insurance policy that protects a nation from a food disaster and from this viewpoint under certain circumstances would assume the entire value of all that it protects. With this objective it would be economically justifiable to produce food at a higher cost than the present food costs available from an exterior market.

To Grow Food And Fiber At Less Cost Than Its Sale Value

This is the primary objective of the California irrigated desert projects. The economic evaluation of these projects depends upon (1) the cost to develop and operate the desert area and (2) the value of goods produced in the area. Unfortunately, the same goods and services assume different values in different areas and cannot be transposed from one nation to the other. Labor costs, energy, chemical emoluments, and high quality seed are a few examples. The cost of leveling a field in Southern California is the cost to hire a local contractor who provides his own equipment. In an area where no such service is available, the cost of leveling a field would include the cost to buy or lease the equipment and transport it to and from the area.

All Objectives Involve A Water Source And A Desert Area

In getting the water to the desert one must study the physical feasibility and the economic feasibility from the viewpoint of the stated objective.

The Water Source

The Sustained Flow Rate: must be determined to know if sufficient water will be available to mature the crop during each season. If sufficient water is not available, dams or reservoirs might be considered to preserve storm runoff for later periods. Such was the justification for the Hoover Dam along the Colorado River. The crop water requirement may be determined from lysimeter studies or from crop needs in areas similar to the one being developed. If climatologic data are available, an estimated crop water requirement may be calculated. However, in the Imperial Valley these crop needs were not developed. The crop needs were estimated from the appearance of the plants and past experience. Growers became adept at determining crop needs and supplying water before a yield reducing stress was produced. This could not have been done if the water were not in surplus or if it had been more costly to develop. Planning of desert irrigation projects at the present time should determine the sustained flow to get the volume available per unit time and then determine the crop acreage that could be supported.

Maximum Flow Rate: is a critical characteristic of the water source. Flood stage in rivers can overtop canal gates and wash them out as happened in Imperial Valley in 1905. During this year the entire flow of the Colorado River flowed along the path of the Alamo Canal washing out diversion structures, cutting deep gullies across farm land, and creating a vast lake in the low lying area of the valley. This lake covered railroad rights-of-way, farm land, and an industrial salt plant. This bankrupted the California Development Co. that had started the irrigation project. The great loss could have been prevented with adequate knowledge of the river maximum flow and structures adequate to withstand the force of the flood water.

Silt Load: is another important characteristic of a surface water source. It was the silt deposition in the Colorado which blocked the canal inlet structures and required the removal of the inlet structure. The inlet structures were designed to contain only the normal flows along the Colorado and the flood stage washed it out.

It was the silt load that necessitated the open ditch delivery system in Imperial Valley. Periodic cleaning was easier to accomplish from an open ditch. After the irrigation project had been in operation for 30 years, a desilting basin was constructed. By greatly increasing the cross sectional flow of the water, the rate was reduced allowing the silt to settle and be removed before water entered the main irrigation canal. The silt was returned to the river and periodically dredged out to low lying areas.

After construction of the desilting basins, the Coachella Valley received flows from the canal and could distribute water through an underground pipe system. The pipe system could be used at that time because removal of the silt at the river meant that the pipes would not become clogged with this material.

A knowledge of the silt load in the water source can determine the need for construction of desilting basins and prevent construction of reservoirs that would fill rapidly with silt and waste the capital invested.

Water Quality: in terms of total dissolved solids (T.D.S.) and in terms of lethal constituents should be determined. Elements such as arsenic or boron that could accumulate in soils to a lethal plant level should preclude a particular water supply. High sodium contents will require soil amendments to prevent sealing or impaired water intake. If no particularly harmful elements are present, then the combined total dissolved level should be evaluated. At present in the Imperial Valley water contains about 900 mg/l TDS. If nothing is done to prevent the steady increase in TDS, the value will reach 1,350 near the turn of the century. The effect of the higher TDS level on several of the major crops was determined by growing them with irrigation water raised to this level. The decrease in yield associated with the higher TDS level was then compared to the decrease predicted in Soils Bulletin 31 of the Food and Agricultural Organization of the United Nations. Good agreement was observed from the predicted and actual values as shown in Table 1 (Robinson, 1976). The data could be used to estimate the yield potential of a water source of a given TDS level.

Table 1. Prediction equations of yield declination from Ayers (1976) data and actual field yield T/ha of six crops grown at 877 ppm (1.35 mmho/cm) and 1,350 ppm (2.0 mmho/cm). (Robinson, 1976).

							Yield		
Crop	Data source	Year	Covariance equation*	r^2 %	Std err estimate	Fisher F level	1.35 mmho % or T/ha	2.0 mmho % or T/ha	Declination %
Onion	Predicted		Y = 114.3 - 17.3 X	98.4	2.3	0.005	90.8%	79.7%	12.3
	Granex 33	1974	Y = 88.8 - 16.4 X	49.0	5.96	0.010	66.7 T	56.0 T	16.0
	"	1976	Y = 57.5 - 8.4 X	35.9	3.99	0.050	46.2 T	40.7 T	11.8
	Early Premium	1974	Y = 51.6 - 5.7 X	30.8	3.03	0.061	44.0 T	40.3 T	8.4
	"	1976	Y = 39.3 - 3.6 X	13.9	3.18	0.230	34.4 T	32.1 T	6.8
Wheat	Predicted		Y = 126.9 - 8.1 X	99.1	3.51	0.005	100%	100%	0
	Cajeme 71	1975	Not significant				3.6 T	3.5 T	2.7
	"	1976	Y = 8.08 - 0.74 X	25.1	0.46	0.097	7.07 T	6.59 T	6.8
Beans	Predicted		Y = 119.8 - 31.0 X	98.1	3.71	0.005	77.9%	57.8%	25.8
	Green Crop	1974	Y = 5.24 - 1.61 X	38.9	0.72	0.038	3.07 T	2.02 T	34.1
Cabbage	Predicted		Y = 113.8 - 13.8 X	99.6	1.65	0.005	95.2%	86.3%	9.4
	Copenhagen Mkt	1974	Y = 78.6 - 6.87 X	19.0	5.05	0.157	69.3 T	64.9 T	6.4
Carrots	Predicted		Y = 116.0 - 24.5 X	99.7	1.41	0.005	83.0%	67.1%	19.2
	Imperator 58	1974	Y = 45.70 - 2.72 X	3.51	5.08	0.429	42.0 T	36.6 T	12.9
	"	1976	Y = 49.19 - 8.54 X	40.12	3.71	0.027	37.7 T	32.1 T	14.7
Alfalfa	Predicted		Y = 155.6 - 12.4 X	99.9	0.71	0.005	98.9%	90.8%	8.1
	UC 76	1974	Not significant				29.6 T	29.1 T	1.7
	UC 76	1975	Y = 27.4 - 2.77 X	10.1	2.95	0.31	23.6 T	21.8 T	7.6

* In the equations onion $0.9<x<2.7$, wheat $3.1<x<9.3$, beans $0.7<x<2.3$, cabbage $1.1<x<4.7$, carrots $0.7<x<2.7$, alfalfa $1.3<x<5.3$.
In Prediction equation Y = yield percentage of maximum, X + mmho/cm.
In Measurement equation. Y = yield in T/ha, X = mmho/cm.

The Desert Area

Having evaluated the yield potential of the water source, one must then look to the desert area for evaluation.

Soils: must be of sufficient depth to sustain growth between irrigations. The irrigation system must be designed to provide replacement of water before yield limiting stress develops. In shallow soils irrigation must be light, frequent, and carefully controlled to prevent surface runoff. Automated systems of sprinklers or tricklers may be needed. Deeper soils can store larger quantities of water and thus allow longer intervals between irrigations. Labor requirements for a surface system of this type would be lower than one serving a shallow soil. For example, alfalfa requires 0.91 cm per day during June in the Imperial Valley. The soils storing 15.24 cm should be irrigated every 16 days to avoid yield reducing water stress. A soil storing 7.12 cm would have to be irrigated twice as often which would require approximately twice the irrigator time. Because of salts in the soil, leaching water must be applied to remove these salts in addition to that needed for plant growth. In order for the leaching to take place, the soil must have sufficient porosity to allow water movement. Dense clays in Imperial Valley impede water movement and exhibit higher salt contents as a result. The saturation extracts of different textures on the Imperial

Valley Field Station after more than 50 years of irrigation are shown in Table 2. In the heavier textured soils salt tolerant crops such as cotton, bermuda grass, and sugar beets should be considered. Medium and light textured soils could support vegetables such as onions, carrots, and cabbage which are less tolerant of salt.

Where natural soil drainage is not available, it must be provided. Developers and growers in Imperial Valley noted the increase in water table elevation about 20 years after the initiation of irrigation. Drain ditches were constructed 3.5 m deep and on a 0.9 km grid across the valley. When this proved inadequate, drain tile installation began. The depths and distances between tile depend upon the soil drainage characteristics.

Table 2. 95% confidence intervals of conductivities of saturated soil extracts on four soil textural classes from two samples per year over 10 years on the Imperial Valley Field Station. mmho/cm. (Robinson, 1974).

Area No.	Top 30 cm	30-60 cm
	Imperial stratified clay and silt	
21	6.07 ± 0.67	8.13 ± 1.17
22	5.25 ± 0.53	7.60 ± 0.53
31	5.54 ± 0.77	6.77 ± 0.54
32	3.89 ± 0.53	5.51 ± 0.72
41	4.36 ± 0.77	5.21 ± 0.69
42	5.91 ± 1.51	6.64 ± 1.40
61	4.10 ± 0.46	6.27 ± 0.44
62	3.19 ± 0.32	5.37 ± 0.64
63	2.94 ± 0.46	4.82 ± 0.83
64	5.39 ± 0.76	6.64 ± 0.71
Average	4.66	6.30
	Meloland loam	
43	3.52 ± 0.45	4.85 ± 0.49
44	2.72 ± 0.56	3.47 ± 0.32
51	3.25 ± 0.36	4.79 ± 0.52
52	3.31 ± 0.54	5.15 ± 0.84
53	2.82 ± 0.35	3.30 ± 0.39
54	2.68 ± 0.36	3.09 ± 0.47
65	2.51 ± 0.26	4.26 ± 0.34
66	2.76 ± 0.39	4.35 ± 0.57
81	2.18 ± 0.22	2.86 ± 0.39
82	3.19 ± 0.57	5.27 ± 0.47
83	2.37 ± 0.27	3.45 ± 0.58
Average	2.84	4.07
	Imperial complex clays	
71	7.28 ± 0.73	8.72 ± 0.69
72	6.16 ± 0.75	7.99 ± 0.60
73	6.44 ± 0.59	8.03 ± 0.81
74	6.21 ± 1.11	7.09 ± 1.51
75	6.77 ± 0.60	9.18 ± 1.21
76	6.25 ± 0.68	8.17 ± 0.94
Average	6.51	8.19
	Indio sand	
91	2.69 ± 0.60	2.49 ± 0.63
92	2.46 ± 0.33	2.60 ± 0.54
94	2.50 ± 0.34	3.54 ± 0.67
96	3.71 ± 1.03	1.84 ± 0.46
97	2.16 ± 0.41	2.24 ± 0.28
Average	2.69	2.54

The Drainage System: in the Imperial Valley was dependent upon the existence of an evaporation sink (the Salton Sea) to receive the saline effluents. The drain tile empty into the drain ditch network which in turn empties into the two major rivers leading to the evaporation sink. Without a sink for the saline drain water, it would either remain in the soil gradually reducing the crop yields or be put back in the source stream degrading its quality. A sink for drainage of saline effluents should be located and identified before desert irrigation begins. A separate drainage canal to an ocean might be possible as is being constructed for the Wellton-Mohawk Irrigation District in Arizona.

When the drain ditch system proved inadequate to drain the salty ground water from soils in Imperial Valley, the installation of drain tile began. Many types have been used: clay, concrete, bituminous fiber, and the present corrugated plastic tubing. Presently pit run gravel is used for envelope and filter, but prefabricated materials are presently being tested to supplement the limited gravel supplies. The plastic tubing has many advantages: (1) light weight, one man can lift a 100 m roll. (2) The roll is in one piece and can be placed by machine that does not need hand placement as does the concrete or clay 30 cm segments. (3) Shifting or setting of the soil bed will not displace disconnected joints in the plastic.

Topography: is determanistic in the type of irrigation system utilized. The 60% slopes used for avocado growth in the San Diego area can be irrigated only by drip systems. Flow rates greater than a few liters per hour would run off the surface. The drippers are placed at each tree and deliver the required amount at frequent intervals. On rolling hills sprinklers or tricklers could apply moderate flow rates evenly over the surface or the surface could be smoothed for contour furrow irrigation. Surfaces with moderate slopes could be leveled for flood or furrow irrigation. Low intake rate soils (3 mm/hr) such as those in Imperial Valley are leveled to 0.1 or 0.2% grades to allow sufficient contact time to get adequate water penetration during irrigation. The courser sands are graded more steeply to get coverage. Where intake rates are too high to get efficient surface coverage, sprinklers or tricklers can be used. In the Wellton-Mohawk area of Arizona citrus is now requiring 11 to 12 feet of water for irrigation of the sandy soil there. It is believed that six feet would be adequate if applied by sprinkler or drip irrigation. Work by the University of Arizona is now being conducted to investigate this potential.

Surface furrow systems use siphons, spiles, or gated pipe to control water delivery. The furrows are typically 1/4 mile long. Salt that accumulates in the center of the plant beds is leached out prior to planting a new crop. Sprinkler irrigation is gaining in acreage for leaching purposes as well as for germination of seeds. The Imperial Irrigation District is encouraging pump back systems to return surface runoff to beneficial use and reduce the flow of water to the evaporation sink.

SUMMARY

The economic criteria used to evaluate a desert irrigation project depend upon the objectives of the project. Generally, the objectives will indicate whether the project is to be evaluated against the value of a healthy and peaceful population, the sum of the economic activities that would be supported and protected by the project, the sum of the economic activities that would be created by the project, or by the profitability of the food production by the project. The water source to the project must be characterized in its sustained flow and maximum flow to determine the need for dams, reservoirs, and specifications for structure construction. The water supply must be available for a long enough period to mature the crop. The silt load of the river must be determined to define the need for desilting structures and the estimated useful life of reservoirs. The quality of water should be determined to estimate the yield potential of the water.

Topography should be evaluated to decide upon the type of irrigation system to install and to estimate costs of land leveling or smoothing. Soils should be evaluated for depth, water holding capacity, and permeability to water flow. Texture will indicate the general salt retention to be expected and this in turn will indicate the type of crop that would be expected to flourish on the particular soil texture.

Costs of the project must be determined for each operation in the location of the project since costs for the same equipment and services will be different in each nation. The value of the project production should be determined with the objective in mind.

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