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THE ECONOMIC FEASIBILITY OF NUCLEAR DESALINATION OF GROUNDWATER IN NEW MEXICO

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By

Robert R. Lansford, Resource Economist, NMSU; Lynn Gelhar, Hydrologist, NMIMT; Raymond J. Supalla, Resource Economist, NMSU; Marshall Reiter, Geophysicist, NMIMT; William D. Gorman, Agricultural Economist, NMSU; D. B. Wilson, Chemical Engineer, NMSU; Stanley E. Logan, Nuclear Engineer, UNM; Richard Mead, Chemical Engineer, UNM; Allan R. Sanford, Geophysicist, NMIMT; William Schulze, Resource Economist, UNM; Shaul Ben-David, Resource Economist, UNM; Fred Roach, Resource Economist, UNM; Thomas H. Stevens, Resource Economist, NMSU; Bobby J. Creel, Resource Economist, NMSU.

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THE ECONOMIC FEASIBILITY OF NUCLEAR DESALINATION OF GROUNDWATER IN NEW MEXICO

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The Upper Rio Grande and Pecos River basins in New Mexico have smaller water supplies in relation to projected demand than any other region of the United States [5]. As a result, the concept of augmenting water supplies by desalting saline groundwater has attracted wide attention as a means of stimulating economic development in New Mexico. Previous studies have, however, resulted in contradictory evidence of the feasibility of such projects [1, 5].

This study utilizes benefit-cost analysis to examine the economic feasibility of the construction and operation of a proposed nuclear desalination project located in Southern New Mexico. The proposed project involves desalination of 500,000 acre-feet of saline groundwater annually, generation of 2,000 MW of electricity, and the establishment of an associated industrial, agricultural, and recreational complex [4].

Resource Economist, NMSU; Hydrologist, NMIMT; Resource Economist, NMSU; Geophysicist, NMIMT; Agricultural Economist, NMSU; Chemical Engineer, NMSU; Nuclear Engineer, UNM; Chemical Engineer, UNM; Geophysicist, NMIMT; Resource Economist, UNM; Resource Economist, UNM; Resource Economist, UNM; Resource Economist, NMSU; Resource Economist, NMSU, respectively.

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Project Description and Financial Analysis

The Tularosa basin in Southern New Mexico was selected as a site for the proposed project because of sparce population, availability of a large quantity of saline groundwater, existence of large areas of state and federally owned lands which would facilitate the development of an irrigation component, a favorable climate, desirable soil characteristics, and proximity to population and agri-industrial centers in the Rio Grande and Pecos River basins.

The principal project components include: (1) a well field consisting of 400 wells with a rated capacity of 1,000 gallons per minute each; (2) two nuclear reactors operated in conjunction with a multi-stage flash desalination plant; (3) a water storage-recreation reservoir; (4) a water conveyance and distribution system; and (5) a mineral recovery processing plant.

As proposed, product water from the desalination complex would be transferred to the reservoir for storage or directly to the final users. Since most product water would be initially obligated to agriculture, 80 percent or 400,000 acre-feet would be transported via a ten-mile length of 12-foot diameter concrete pipe to a storage reservoir during the non-agricultural season and directly to an irrigation distribution system during the irrigation season. This would involve delivering about 225,000 acre-feet a year to the reservoir and 175,000 acre-feet directly to agriculture. Because the proposed storage reservoir site is 1,000 feet above the desalination complex, ten relift pumping stations would be needed along the closed conveyance system.

Water from the storage reservoir would be released at specific intervals during the irrigation season to an irrigation distribution system, consisting of all necessary canals and laterals to ensure adequate deliveries to each farm gate. Brine from the desalination plant would be transported to a mineral recovery processing plant. The 21,000 acre-feet of reject brine would undergo electrolysis to recover magnesium metal, potash, and sodium sulfate for sale. All water requirements for mineral recovery would be met from the reject brine itself, with power requirements being supplied from the project reactors.

Engineering-economic cost estimates for the basic project components are presented in Table 1. Direct benefits would be derived from four sources: sale of electrical power, water, minerals, and recreation.

Determining a reasonable estimate of the marginal benefit of additional electrical energy generating capacity is difficult since price projections vary widely. However, for the purpose of this analysis, the alternative cost of a typical coal-fired generating station was utilized [2, 3].

A parametric programming model was developed to determine the maximum amount that the irrigated agriculture sector would be willing to pay for water. This amount was estimated to be $50 per acre-foot. The optimal cropping pattern was calculated to consist of alfalfa, barley, grain sorghum, and a variety of vegetables [2]. The value of water for municipal and industrial and for potential export out-

Table 1. Estimated capital, replacement, operating and maintenance costs in 1974 dollars

Component	Capital Cost	Replacement Cost	Annual Operating & Maintenance Costs
	- - - - - - - - -	-(million $)-	- - - - - - - - -
Well field	98.0	15.6	.44
Desalting plant	300.0		13.8
Nuclear reactors	974.0		119.0
Water storage-recreation reservoir	230.8		2.3
Water conveyance and desalination system	76.6	34.7	1.01
Mineral recovery	109.0		27.3
Total	1,788.4	50.3	163.7

Source: Lansford, Robert R., et al., A Preliminary Economic Feasibility Study for the Establishment of an Energy-Water Complex in the Tularosa Basin, New Mexico Water Resources Research Institute Report No. 68, Las Cruces, February 1976.

side the basin was estimated to be $100 and $90 per acre-foot, respectively.

The benefit from the sale of minerals was estimated to total $67 million annually, while a recreation demand analysis indicated that recreational benefits would be in excess of $3.7 million annually [2].

Economic Feasibility

Three alternative project designs were evaluated. The first alternative was formulated such that all water would be used within the Tularosa basin by a greatly-expanded agricultural sector and increased municipal and industrial development (mineral recovery). Electricity production, after fulfilling project power requirements, would be exported to surrounding areas in the Southwest and only enough to satisfy local needs would be designated for in-basin use.

The second alternative consisted of the production of power only. Water desalination was limited to an amount sufficient to satisfy cooling requirements. It was assumed that all power produced would be exported to surrounding regions in the Southwest.

The third alternative consisted of water production for export, power generation, and mineral recovery. All water produced over and above Tularosa basin needs (those that would have occurred without the project) would be exported to the Rio Grande. Only enough water to supply a "without project" local economy would be retained within the basin and all excess from the annual 500,000 acre-feet production would be transferred. All net power produced (excluding internal requirements) would be exported to other regions in the Southwest.

For the first alternative (nuclear reactor, desalting, mineral recovery, and agriculture), the total capital outlay is $1,788.7 million, and the total annual operating costs are $163.7 million (see Table 1). For alternative 2 (nuclear reactor only), the total capital outlay is $1,037.1 million, and the total annual operating costs are $119.13 million. Costs of the nuclear plant in this alternative are higher than in alternative 1 because the number of turbines for generating was increased to take advantage of available steam. The total capital outlay for alternative 3 (nuclear reactor, desalting, mineral recovery, and water export) is $1,551.3 million, and total annual operating costs are $161.34 million.

Sources of benefits for alternative 1 would be sales of power (local and export), water for in-basin use, minerals, and recreation. Benefits in alternative 2 would be from the sale of power only. Alternative 3 would derive benefits from sales of power (local and export), water (local and export to the Rio Grande), and minerals.

The present value of benefits (B_0) for each alternative is defined as:

$$1)\quad B_0 = \sum_{j=1}^{J} \sum_{t=1}^{T} (1 + r)^{-t} B_{jt}$$

where:

j = 1, 2... J sources of benefits

t = 1, 2... T project life

r = discount rate

B_{jt} = annual benefit from j source in year t

The value of capital outlays including interest (K_0) during construction is expressed as:

$$2) \quad K_0 = \sum_{i=1}^{I} \sum_{t=0}^{C_i-1} (1 + r)^t K_i/C_i$$

where:

i = 1, 2... I cost components

C_i = construction period in years for component i

K_i = total capital outlay for component i

Replacement costs are discounted to the initial period from the replacement year, l_i, giving as a present value:

$$3) \quad R_0 = \sum_{i=1}^{I} (1 + r)^{-l_i} R_i$$

Operating costs are expressed as:

$$4) \quad O_0 = \sum_{i=1}^{I} \sum_{t=1}^{T} (1 + r)^{-t} O_{it}$$

The benefit-cost ratio is then calculated as:

$$5) \quad B/C = (B_0 - O_0)/(K_0 + R_0).$$

Four discount rates--five, six, eight, and ten percent--were used. The two lower rates (five and six percent) represent rates commonly used for water project evaluations, and the two higher rates are representative of the lower range of publicly funded projects (municipal bonds).

Results of the analysis are reported in Table 2. The complete energy-water complex, alternative 1, appears to be infeasible for two primary reasons:

First, desalting technology at present is capital intensive and too costly in comparison to any reasonable projections of water values

Table 2. Results of the benefit-cost analysis for alternatives 1, 2, and 3, for the Tularosa basin project, New Mexico

Discount Rate (percent)	Net Benefits (million $)	Benefit-Cost Ratio
Alternative 1--Nuclear Reactor-Desalting-Agriculture		
5	-986.570	0.508
6	-1,012.340	0.505
8	-1,076.415	0.494
10	-1,137.528	0.486
Alternative 2--Nuclear Reactor Only		
5	57.723	1.050
6	84.421	1.072
8	110.042	1.090
10	132.817	1.105
Alternative 3--Nuclear Reactor-Desalting-Water Export		
5	-382.527	0.779
6	-424.824	0.758
8	-509.777	0.719
10	-578.612	0.693

to allow feasibility even when waste heat from power production is available. Feasibility would require an increase in the value of water to $221 per acre-foot for agricultural, municipal, and industrial uses at a six percent discount rate. Second, the capital costs and power drawdowns associated with storing water for agriculture are prohibitive in relation to the potential value.

In alternative 3, the value of water exported to the Rio Grande must be $187 per acre-foot to achieve feasibility. This value approaches minimum system cost of $149 per acre-foot for producing desalted water, excluding transportation costs. Projected local uses of water cannot justify production of desalted water at this cost. Desalting, even with a dual nuclear plant and mineral recovery facility, is not economically feasible with current technology on the scale proposed for the Tularosa basin.

The prospect of nuclear power production using brine water for cooling (alternative 2) may prove feasible and the possible construction of a nuclear energy park in the Tularosa basin may merit further investigation. This decision would, however, depend primarily on social, political, and environmental factors not evaluated in this study.

These conclusions do not, however, account for the possibility of technological change. Further, the value of project outputs may be enhanced by unforeseen market forces as well as changes in consumer tastes and preferences. For both reasons, the sensitivity of the results to technological change and price levels were examined.

First, nuclear capital costs may be reduced by as much as $100 million by introduction of a direct cycle HTGR process. Of greater importance is that desalting costs may be reduced by 25 to 30 percent if the vertical tube extraction desalination process becomes a reality [2]. With respect to benefits, recovery and sale of trace minerals and metals may result in increased revenues. Similarly, the recreational value of the project may be understated because recreational environments often represent assets of appreciating value. Finally, improved irrigation efficiencies, crop varieties and management practices may increase the value of water for agricultural uses [5].

In order to ascertain the sensitivity of the results to these factors, desalting capital costs were decreased by 25 percent with the associated operating and maintenance expenditures reduced by 15 percent. In addition, the value of irrigation water was increased to $70 per acre-foot, the value of export water to $125 per acre-foot, and recreation benefits were increased to $13.1 million.

Results of the sensitivity analysis are presented in Table 3. Even under the set of somewhat optimistic assumptions specified, the overall project is not economically feasible. Thus, economic feasibility of desalting for the applications examined has not been proven and efforts to reduce costs relative to alternative sources must be continued if desalination is to serve as a significant source of water supply.

Table 3. Sensitivity analysis results, alternatives 1 and 3, Tularosa basin energy-water complex, New Mexico

Discount Rate	Net Benefits	B/C Ratio	Total Benefits	Capital Cost	O&M Cost	Replacement Cost
	- - - - - - - - - - - - - - -(million $)- - - - - - - - - - - - - -					
Alternative 1--Nuclear Reactor-Desalting-Agriculture						
5%	-536.570	0.718	3848.652	1885.425	2482.288	17.509
6%	-594.391	0.694	3568.735	1925.249	2222.689	15.189
8%	-704.628	0.651	3132.447	2007.748	1817.852	11.1475
10%	-810.662	0.615	2814.455	2094.185	1522.218	8.714
Alternative 3--Nuclear Reactor-Desalting-Water Export						
5%	-230.382	0.858	3864.310	1604.534	2472.650	17.509
6%	-283.978	0.828	3579.965	1634.696	2214.058	15.189
8%	-382.439	0.776	3136.631	1696.802	1810.793	11.475
10%	-473.016	0.733	2813.343	1761.338	1516.308	8.714

Summary and Conclusions

Desalting groundwater in the Tularosa basin for the project scale proposed is not economically feasible. Yet as Chapman points out, "It is not correct to conclude that large-scale agricultural-energy complexes are inherently infeasible" [1]. For example, project designs which include highly profitable industries not examined here may be feasible. Further, the saline water resources of the Tularosa basin might be used to produce hydrogen through electrolysis. Alternatively, if hot dry rock geothermal experiments currently underway prove successful, the cost of desalination may be reduced substantially. Finally, the use of brine cooling water for nuclear power production may prove feasible and the concept of a nuclear energy park may warrant further examination.

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