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AN INVESTIGATION OF METHODS OF DEVELOPING DUAL-PURPOSE DESALINATION PLANT SYSTEMS TO MEET AN EXPANDING MARKET

J. C. Moyers

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REACTOR DIVISION

NUCLEAR DESALINATION PROGRAM

AN INVESTIGATION OF METHODS OF DEVELOPING DUAL-PURPOSE DESALINATION PLANT SYSTEMS TO MEET AN EXPANDING MARKET

J. C. Moyers

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Abstract

An economic evaluation of the development of dual-purpose desalination plant systems to meet the demands of a linearly-expanding water market is presented. Systems considered included one where additional plants are constructed as needed, with overcapacity compensated by operation at less than the normal plant load factor; one where a low-pressure turbine is included to permit steam to be used for generation of additional electric power rather than water during periods when water demand is low; and three variations of a system which stores excess water production in a large reservoir.

The reservoir storage system is superior to the variable plant factor system for all distributions of product pricing. The low-pressure turbine system yields lower water cost than the variable plant factor system when power can be sold for more than 2 mills/kw-hr amd yields lower water cost than the reservoir storage system when power can be sold for more than 4 mills/kw-hr.

Introduction

An almost perpetual mismatch of installed capacity and market demand exists for any utility system supplying product to an expanding market. This is caused by the continuous nature of the market requirement change and the step changes in capacity introduced as new production facilities are brought on line. A system of dual-purpose desalination plants offers unique opportunities for minimizing the economic penalty caused by this mismatch. This study was performed to explore several schemes of system development and to determine the most economically attractive approach.

A market growth rate of 50 Mgd per year was assumed for the evaluation. A recent study by Burwell and Ebel[1] indicates that a plant size of about five times the annual market growth rate is a practical choice. Accordingly, the basic plants considered had design capacities of 250 Mgd of water and 500 Mw of electricity.

Present worth analyses of the system cost and electrical production for the various schemes were made for a 30-year period (the assumed lifetime of the first plant to go on-stream).

Description of Systems

Base System

The base system, which was evaluated for comparison with other schemes, was developed by adding 250-Mgd plants every five years to keep the system capacity equal to or larger than the market demand at all times. The system capacity exceeds the market requirement by 200 Mgd during the first year's operation for each new plant, with the excess capacity decreasing 50 Mgd per year to zero during the fifth year. This excess capacity is accommodated by operating each new plant at 20% plant factor the first year, 40% the second year, etc. Electrical production is balanced with water production at all times.

Low-Pressure Condensing Turbine System

The initial plant of this system is a basic 250-Mgd, 500-Mwe plant that includes an additional low-pressure turbine and condenser that accept exhaust steam from the normal back-pressure turbine, permitting full-load operation of the reactor and back-pressure turbine-generator at all times. The total net power output from the plant at a water output rate of 50 Mgd is 896 Mwe. The power output decreases each year to 500 Mwe during the fifth year when the water plant is at full load and the low-pressure turbine is idle.

[1] C. C. Burwell and R. A. Ebel, "A Speculative Analysis of the Cost Relationship Between Desalination System Size and the Market Growth Rate," ORNL-CF-65-7-49 (July 20, 1965).

All subsequent plants would be basic 250-Mgd, 500-Mwe plants that operate full-load at all times. The initial plant would be operated through its decreasing-power, increasing water production cycle as each new plant is added to the system to keep system water capacity and water market demands matched.

Reservoir Storage System

In an area where adequate storage capacity is available, all dual-purpose plants can produce water at full capacity for their entire lifetimes with any surplus water production being stored and subsequently withdrawn from storage during periods of deficit production to postpone the need for construction of new plants. For example, storage of surplus water in Lake Mead appears to be entirely practical for this purpose in areas now using water from the Colorado River. The distilled water product from dual-purpose plants would not be pumped to the lake, but would replace water that is normally transported from the Colorado River system to the market area, allowing a storage gain rate to the lake equivalent to the desalination system surplus capacity. Some evaporative loss occurs; however, using a large existing reservoir minimizes the incremental evaporative loss due to additional storage volume. This study is based specifically on the use of Lake Mead, but is generally illustrative of the benefit that can be realized through the use of storage in any large existing reservoir having surplus storage capacity. If it is necessary to construct a new reservoir for the purpose of storing surplus capacity from a system of desalination plants, the capital charges resulting from the construction would, of course, have to be included in the evaluation.

Three variations of the Lake Mead storage system were evaluated. The first scheme used 250-Mgd, 500-Mwe plants built during Years 0, 8, 12, 17, 22 and 27. The second scheme used a 250-Mgd, 500-Mwe plant built during Year 0, then 350-Mgd, 700-Mwe plants built during Years 9, 14, 23 and 28. The third scheme used a 250-Mgd, 500-Mwe plant built during Year 0, then 450-Mgd, 900-Mwe plants built during Years 9, 18, and 27. Figures 1, 2 and 3 show the fluctuations of storage for the three schemes. Evaporative losses are not indicated in the figures. These losses vary cyclically with the quantity of water in storage and range between 1 and 10 Mgd.

Method of Evaluation

The economic evaluations of the various systems included consideration of total annual costs, net electrical production, and in the Lake Mead storage schemes, the cost of evaporative loss makeup and the value of water stored at the end of 30 years. The quantity of water for sale just equals the market requirement and is the same from all of the systems. Therefore, the final method of evaluation of one system versus another is a comparison of the total cost of doing business and the net electrical generation during the 30-year period. The comparison is made on a present-worth basis.

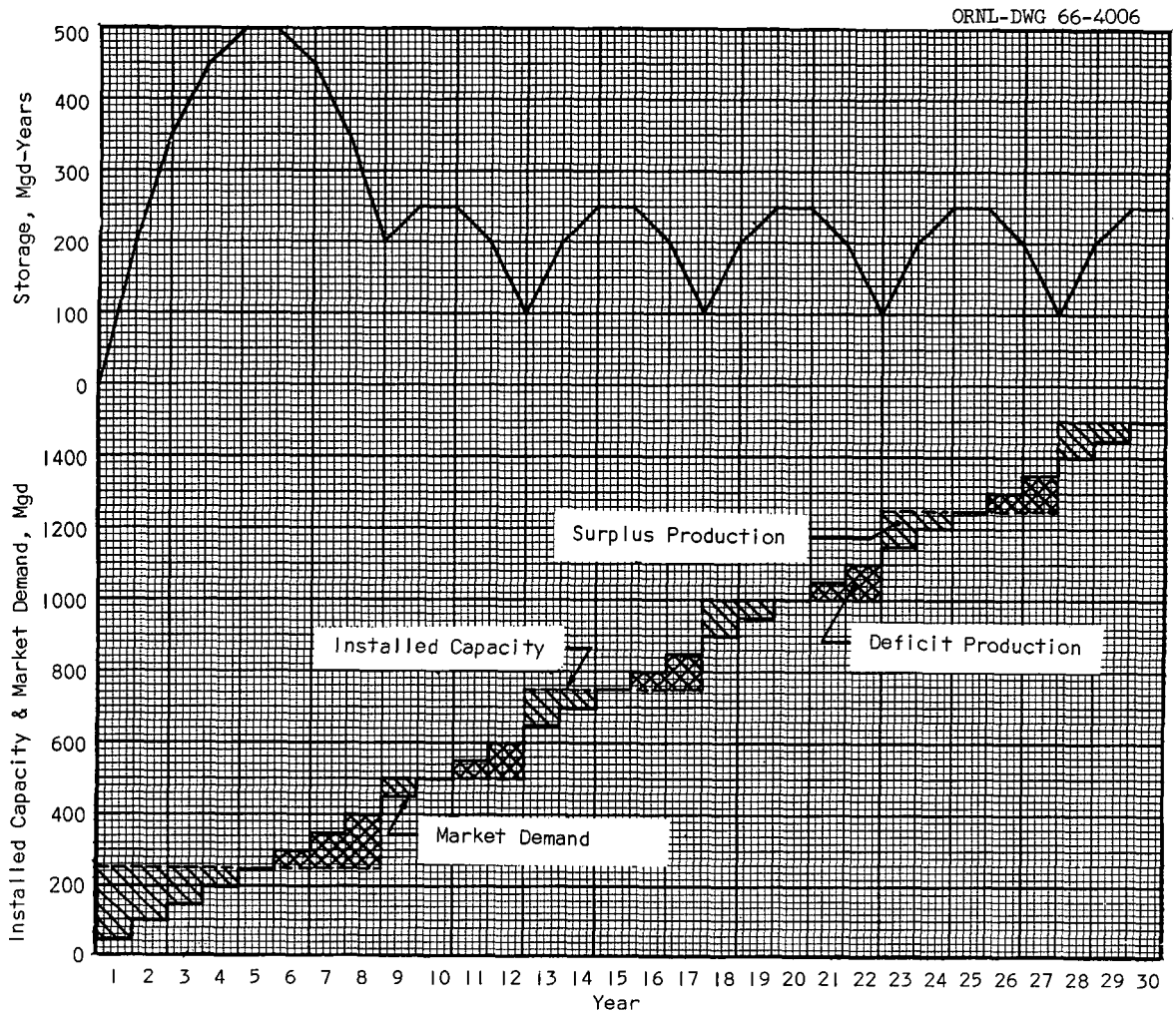

Fig. 1. Lake Mead Storage Scheme 1.

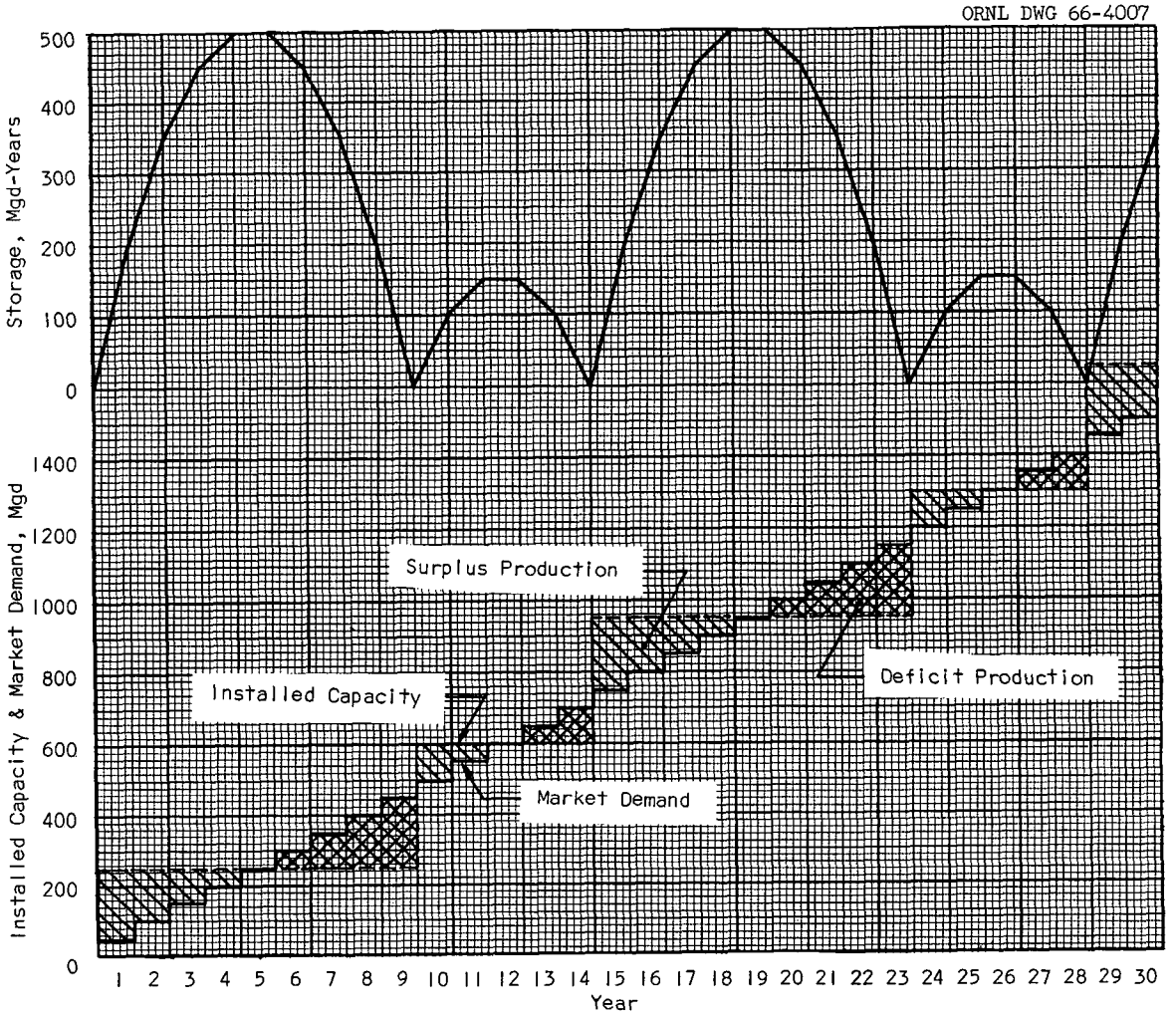

Fig. 2. Lake Mead Storage Scheme 2.

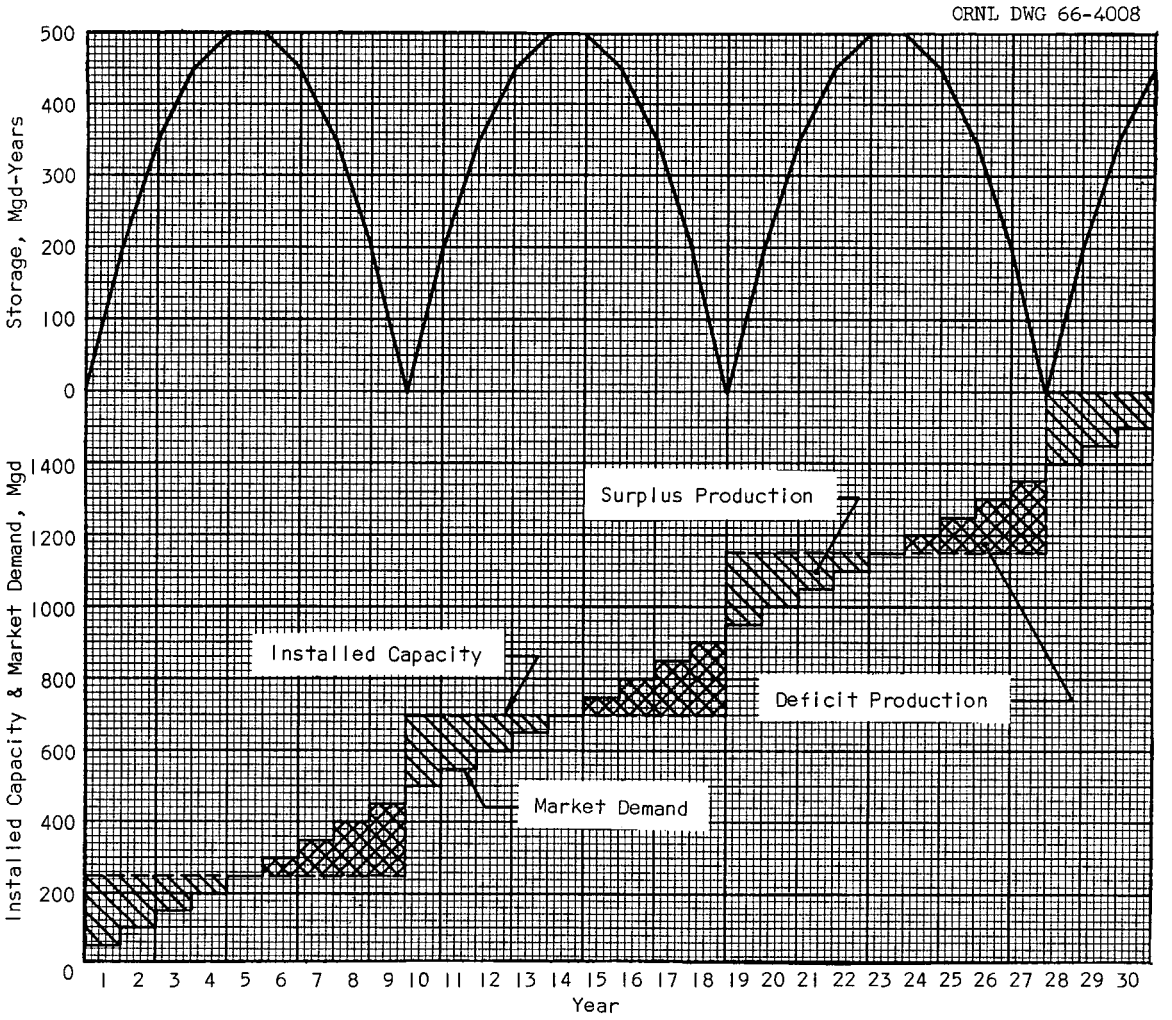

Fig. 3. Lake Mead Storage Scheme 3.

Annual costs for the dual-purpose plants used in the various systems were based on costs determined through use of the Integrated MSF Code with a PWR reactor and the following ground rules:

Interest rate	4%
Plant lifetime	30 years
Annual charge rate on depreciating items	7%
Plant factor	0.9
Turbine exhaust temperature	260°F

The capital and full-load annual costs for the plants used in various systems, as determined by the code, are summarized in Table 1.

In evaluating each system, estimates of the year-by-year system annual cost and electrical generation, based on the values shown in Table 1, were prepared. For the base system, in which the initial plant operates with a plant factor varying between 0.2 and 1.0 and all other plants operate at full load, the initial plant annual cost was assumed constant except for the costs of fuel and water plant chemicals, which varied proportionally with load. Appendix A details the annual cost and electrical generation for this system.

In evaluating annual costs for the low-pressure condensing turbine system, the annual cost of water plant chemicals for the initial plant was assumed proportional to water plant load. All other components of annual cost were assumed constant, with the annual cost due to investment adjusted upward from that of the basic plant to reflect the additional cost of the turbine plant. Appendix B presents the annual costs and electrical generation for this system.

Evaluation of the systems using storage in Lake Mead required determination of incremental evaporative losses from the reservoir due to increased storage volume. A planimeter survey of the contours adjacent to the reservoir yielded a relationship between additional surface area and additional storage volume. The incremental evaporative losses were then evaluated, assuming an evaporative loss rate of 6 feet per year. This evaporative loss was replaced as necessary by bringing new plants on line a fractional year earlier than would be necessary with no losses. The value of the water in storage at the end of the 30-year period was determined by calculating the cost of operating one of the plants for the period of time required to produce that quantity of water and deducting the value of the electricity that would have been generated during the same period. Appendix C presents the annual cost, electrical generation, evaporative loss, and the present worth of annual cost and generation for the Lake Mead storage schemes.

Since the basic 250-Mgd water plant consists of five 50-Mgd modules, it appeared that a saving of cost could result from a one-module-per-year buildup of the water plant to follow the market requirement. However, a present-worth analysis of this scheme showed a saving of only seven per cent and it is almost certain that the additional cost of extending the water plant construction period to five years would override this saving.

Table I

Capital and Annual Costs Summary for Dual-Purpose Plants

Plant Factor - 0.9

	Conventional Plants			L.P. Turbine Plant
Net Electrical Output, Mwe	500	700	900	896-500
Water Output, Mgd	250	350	450	50-250
Reactor Thermal Rating, Mwt	3228	4528	5831	3220
Capital Costs, 10^6 $				
Reactor Plant (PWR)	60.000	74.220	87.000	60.000
Turbine-Generator Plant	26.208	33.310	39.859	41.874
Water Plant	91.351	125.151	158.403	91.351
Interest on Construction	6.019	8.306	10.624	7.113
Non-Depreciating Items	3.752	4.570	5.308	3.752
Total	187.330	245.557	301.194	204.090
Annual Costs, 10^6 $/yr				
Reactor and T-G Plants Investment	6.644	8.338	9.900	7.741
Water Plant Investment	6.395	8.761	11.088	6.395
Tubing Replacement	0.818	1.134	1.443	0.818
Reactor O & M	1.725	1.876	2.005	1.725
Fuel	13.322	17.870	22.261	13.322
Water Plant O & M	0.723	0.808	0.893	0.723
Water Plant Chemicals	1.342	1.835	2.324	0.268-1.342
Total	30.968	40.622	49.914	30.992-32.066

Results and Discussion

The total electrical generation and cost of operation for each of the various systems over a 30-year period are presented in Table 2. All values shown are converted to present-worth at the beginning of Year 1. The low-pressure turbine system, while the most expensive of the systems studied, produces appreciably more power than the other systems. The incremental cost of the additional block of power generated, compared with the basic system, is only 2 mills/kw-hr. The storage schemes produce slightly more power at appreciably lower cost than the basic system, and as would be expected, the advantage increases with plant size.

Figure 4 presents the breakeven power versus water prices required for each of the systems. This figure demonstrates that no one system is best for all market situations of cost allocation between the two products. For a candid comparison of the methods of meeting the water market demands, only the systems incorporating 250-Mgd plants should be observed since the use of larger plants would change the cost structure of any of the systems. It is obvious that Storage Scheme 1 is superior to the basic system in that the water price is approximately 3 cents per 1000 gallons lower for all power prices. The low-pressure turbine system produces lower water prices than the basic system if the power is sold for at least 2 mills/kw-hr, and is superior to the Storage Scheme 1 if power is sold for at least 4 mills/kw-hr. If power were to be sold at less than 2 mills/kw-hr, the additional cost of the low-pressure turbine system would be unjustified.

The unusual power generation versus time relationship that results from using the low-pressure turbine system may create a problem in disposing of the power. Each new 250-Mgd, 500-Mwe plant that is added to the system causes an increase of 896 Mwe in the system electrical output for the first year of operation. This block of generating capacity then decreases each year to 500 Mwe during the fifth year of operation of the latest plant. However, as regional power pooling develops and with the predicted power market growth rate, it is believed that the unusual generation rate characteristic that results from this type of system can be integrated into the regional utilities' schedules of plant construction and retirement with only a slight economic penalty.

The computer-determined cost allocation between products for the basic 250-Mgd, 500-Mwe plant was such that power should be sold for approximately 3 mills/kw-hr and water for approximately 23.4 cents per 1000 gallons. It is noted from Figure 4 that, for the basic system, the price for water with power at 3 mills/kw-hr should be 26.5 cents per 1000 gallons. This higher water price is due to the part-load operation required when the basic plant is incorporated into a system which is geared to the assumed expanding market.

Table 2

Present Worth Valuation of Total Electrical Generation and Cost of Operation for 30-Yr Period

	Basic System	L.P. Turbine System	Scheme 1[a]	Scheme 2[b]	Scheme 3[c]
Total of 30 Yrs of Annual Costs, 10^6 $	1469.591	1584.336	1384.629	1342.245	1316.704
Value of Stored Water at End of 30-Yr Period, 10^6 $	0	0	(3.398)	(7.001)	(8.191)
Normalized Cost of 30-Yr Operation, 10^6 $[d]	1469.591	1584.336	1381.231	1335.253	1308.513
Total Electrical Generation, 10^9 kw-hrs	172.15	228.69	176.18	177.77	179.22

[a]250-Mgd, 500-Mwe plants built during Years 0, 8, 12, 17, 22 and 27.

[b]250-Mgd, 500-Mwe plant built during Year 0; 350-Mgd, 700-Mwe plants built during Years 9, 14, 23 and 28.

[c]250-Mgd, 500-Mwe plant built during Year 0; 450-Mgd, 900-Mwe plants built during Years 9, 18 and 27.

[d]The total amount of money on deposit at 4% per annum at the beginning of Year 1 that is necessary to cover the cost of 30 years of production.

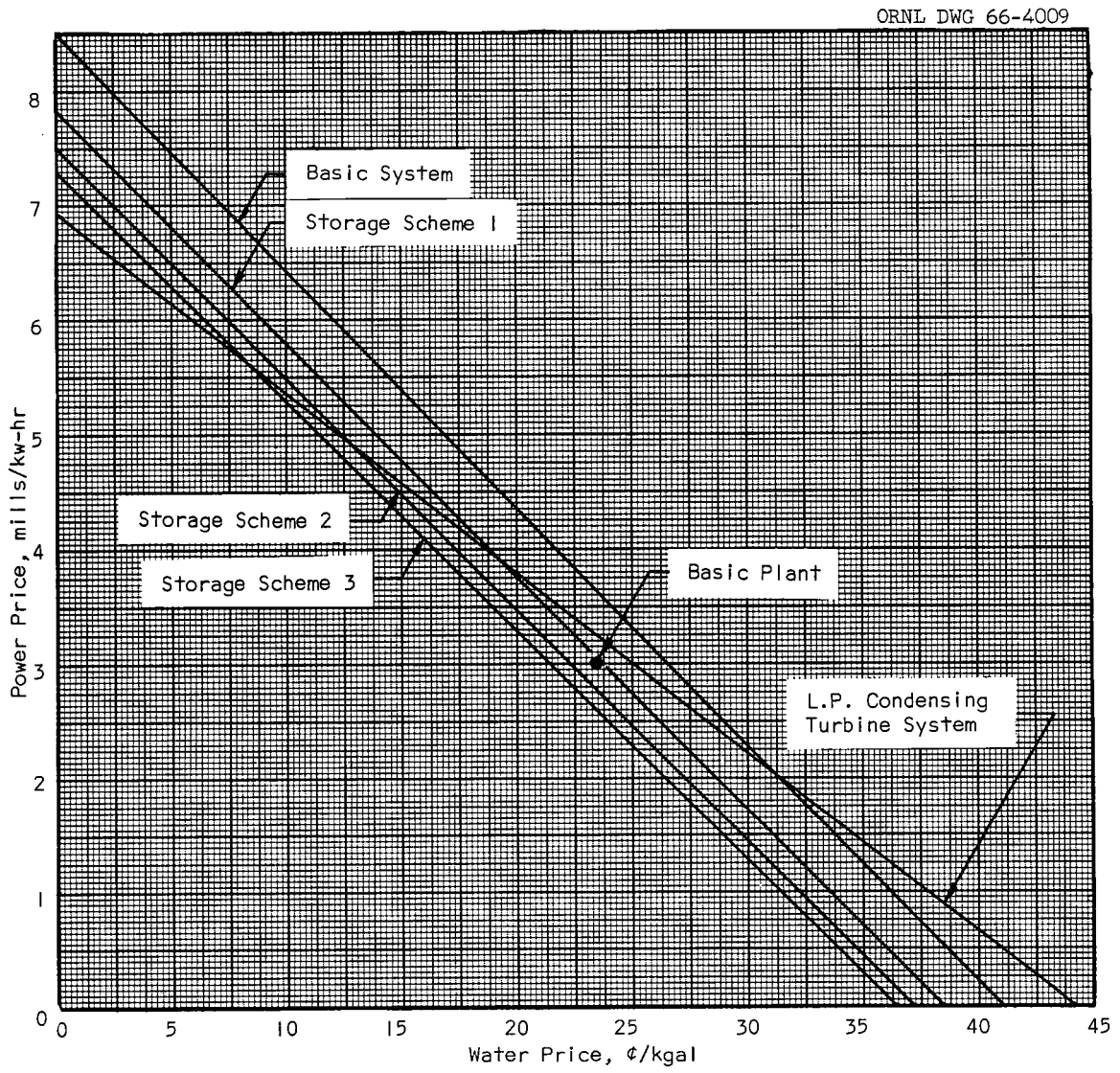

Fig. 4. Breakeven Power Versus Water Prices.

Appendix A

Base System Annual Costs and Generation

The annual costs for the initial basic dual-purpose 250-Mgd plant of the base system are estimated as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Water Production, Mgd	50	100	150	200	250
Net Electrical Production, Mwe	100	200	300	400	500
Annual Costs, 10^6 \$/yr					
Investment	13.038	13.038	13.038	13.038	13.038
Tube Replacement	0.818	0.818	0.818	0.818	0.818
O & M	2.448	2.448	2.448	2.448	2.448
Fuel	2.664	5.329	7.993	10.658	13.322
Chemicals	0.268	0.537	0.805	1.074	1.342
Total	19.236	22.170	25.102	28.036	30.968

The annual cost for each subsequent plant was assumed fixed at the full load value of \$30.968 x 10^6. The annual costs and generation and the present worth of these costs and generation for the entire system for the 30-year period are given in Table A-1.

Table A-1

Base System Annual Costs and Electrical Generation

Year	First Plant		Later Plants		Total System		Present Worth-Total System	
	Annual Cost 10^6\$	Generation 10^9 kw-hrs	Annual Cost 10^6\$	Generation 10^9 kw-hrs	Annual Cost 10^6\$	Generation 10^9 kw-hrs	Annual Cost 10^6\$	Generation 10^9 kw-hrs
1	19.236	0.788	0	0	19.236	0.788	18.496	0.758
2	22.170	1.577	0	0	22.170	1.577	20.497	1.458
3	25.102	2.365	0	0	25.102	2.365	22.316	2.102
4	28.036	3.154	0	0	28.036	3.154	23.965	2.696
5	30.968	3.942	0	0	30.968	3.942	25.454	3.240
6	19.236	0.788	30.968	3.942	50.204	4.730	39.677	3.738
7	22.170	1.577	"	"	53.138	5.519	40.381	4.194
8	25.102	2.365	"	"	56.070	6.307	40.970	4.608
9	28.036	3.154	"	"	59.004	7.096	41.456	4.985
10	30.968	3.942	"	"	61.936	7.884	41.841	5.326
11	19.236	0.788	61.936	7.884	81.172	8.672	52.728	5.633
12	22.170	1.577	"	"	84.106	9.461	52.533	5.909
13	25.102	2.365	"	"	87.038	10.249	52.272	6.155
14	28.036	3.154	"	"	89.972	11.038	51.957	6.374
15	30.968	3.942	"	"	92.904	11.826	51.586	6.567
16	19.236	0.788	92.904	11.826	112.140	12.614	59.873	6.735
17	22.170	1.577	"	"	115.074	13.403	59.076	6.881
18	25.102	2.365	"	"	118.006	14.191	58.251	7.005
19	28.036	3.154	"	"	120.940	14.980	57.403	7.110
20	30.968	3.942	"	"	123.872	15.768	56.534	7.196
21	19.236	0.788	123.872	15.768	143.108	16.556	62.800	7.265
22	22.170	1.577	"	"	146.042	17.345	61.624	7.319
23	25.102	2.365	"	"	148.974	18.133	60.443	7.357
24	28.036	3.154	"	"	151.908	18.922	59.262	7.382
25	30.968	3.942	"	"	154.840	19.710	58.084	7.394
26	19.236	0.788	154.840	19.710	174.076	20.498	62.787	7.393
27	22.170	1.577	"	"	177.010	21.287	61.391	7.383
28	25.102	2.365	"	"	179.942	22.075	60.007	7.362
29	28.036	3.154	"	"	182.876	22.864	58.639	7.331
30	30.968	3.942	"	"	185.808	23.652	57.288	7.292
							1469.591	172.148

Appendix B

Low-Pressure Condensing Turbine System

The additional cost of a basic dual purpose 250-Mgd plant due to the addition of a 342 Mw low-pressure condensing turbine-generator and condenser which would receive 80% of the backpressure turbine exhaust steam is estimated to be $15,665,700. The annual costs for a basic plant which includes this extra generating capacity would then be as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Water Production, Mgd	50	100	150	200	250
Gross Electrical Generation, Mwe	960	875	791	706	618
Auxiliary Power Requirement, Mwe	64	77	91	104	118
Net Electrical Production, Mwe	896	798	700	602	500
Annual Costs, $10^6$$/yr					
Investment	14.136	14.136	14.136	14.136	14.136
Tube Replacement	0.818	0.818	0.818	0.818	0.818
O & M	2.448	2.448	2.448	2.448	2.448
Fuel	13.322	13.322	13.322	13.322	13.322
Chemicals	0.268	0.537	0.805	1.074	1.342
TOTAL	30.992	31.261	31.529	31.798	32.066

The annual costs and generation and the present worth of these costs and generation for the entire system for the 30-year period are given in Table B-1.

Table B-1

Low-Pressure Condensing Turbine System Annual Costs and Electrical Generation

Year	L.P. Turbine Plant		Later Plants		Total System		Present Worth-Total System	
	Annual Cost 10^6\$	Generation 10^9 kw-hrs	Annual Cost 10^6\$	Generation 10^9 kw-hrs	Annual Cost 10^6\$	Generation 10^9 kw-hrs	Annual Cost 10^6\$	Generation 10^9 kw-hrs
1	30.992	7.0641	0	0	30.992	7.064	29.800	6.792
2	31.261	6.2914	0	0	31.261	6.291	28.903	5.816
3	31.529	5.5188	0	0	31.529	5.519	28.029	4.906
4	31.798	4.7462	0	0	31.798	4.746	27.181	4.057
5	32.066	3.9420	0	0	32.066	3.942	26.356	3.240
6	30.992	7.0641	30.968	3.942	61.960	11.006	48.968	8.698
7	31.261	6.2914	"	"	62.229	10.233	47.289	7.776
8	31.529	5.5188	"	"	62.497	9.461	45.666	6.913
9	31.798	4.7462	"	"	62.766	8.688	44.099	6.104
10	32.066	3.9420	"	"	63.034	7.884	42.583	5.326
11	30.992	7.0641	61.936	7.884	92.928	14.948	60.364	9.710
12	31.261	6.2914	"	"	93.197	14.175	58.211	8.854
13	31.529	5.5188	"	"	93.465	13.403	56.132	8.049
14	31.798	4.7462	"	"	93.734	12.630	54.130	7.293
15	32.066	3.9420	"	"	94.002	11.826	52.196	6.567
16	30.992	7.0641	92.904	11.826	123.896	18.890	66.149	10.085
17	31.261	6.2914	"	"	124.165	18.117	63.743	9.301
18	31.529	5.5188	"	"	124.433	17.345	61.424	8.562
19	31.798	4.7462	"	"	124.702	16.572	59.189	7.866
20	32.066	3.9420	"	"	124.970	15.768	57.035	7.196
21	30.992	7.0641	123.872	15.768	154.864	22.832	67.959	10.019
22	31.261	6.2914	"	"	155.133	22.059	65.460	9.308
23	31.529	5.5188	"	"	155.401	21.287	63.051	8.637
24	31.798	4.7462	"	"	155.670	20.514	60.730	8.003
25	32.066	3.9420	"	"	155.938	19.710	58.495	7.394
26	30.992	7.0641	154.840	19.710	185.832	26.774	67.028	9.657
27	31.261	6.2914	"	"	186.101	26.001	64.544	9.018
28	31.529	5.5188	"	"	186.369	25.229	62.150	8.413
29	31.798	4.7462	"	"	186.638	24.456	59.845	7.842
30	32.066	3.9420	"	"	186.906	23.652	57.627	7.292
							1584.336	228.694

Appendix C

Lake Mead Storage Systems

Evaporative Loss, Annual Costs and Electrical Generation

Each of the three Lake Mead storage schemes considered has a 250-Mgd, 500-Mwe dual-purpose plant initially. The three schemes differ in the sizes of plants installed subsequent to the first plant.

Scheme 1 utilizes 250-Mgd, 500-Mwe plants for all system additions. New plants go into operation nominally at the start of years 1, 9, 13, 18, 23 and 28. Table C-1 presents annual incremental evaporative loss, annual cost, annual power generation, and the present-worthed value of annual cost and power generation for the system over the 30-year period considered.

Scheme 2 utilizes 350-Mgd, 700-Mwe plants for all system additions after the first plant. These additions are made nominally at the start of years 10, 15, 24 and 29. Table C-2 presents annual incremental evaporative loss, annual cost, annual power generation, and the present-worthed value of annual cost and power generation for the system over the 30-year period.

Scheme 3 utilizes 450-Mgd, 900-Mwe plants for all additions after the first plant. These additions are made nominally at the start of years 10, 19 and 28. Table C-3 presents annual incremental evaporative loss, annual cost, annual power generation, and the present-worthed value of annual cost and power generation for the system over the 30-year period.

Evaporative losses are made up by bringing certain of the additional plants on line a fraction of a year earlier than would otherwise be necessary. These makeup additions are indicated in the tables and are scheduled to prevent the reservoir level from ever being lowered below the normal level it would have if the desalting system were not in existence.

Table C-1

Lake Mead Storage Scheme 1
Evaporative Loss, Annual Cost and Electrical Generation

Year	Total System Annual Cost 10^6\$	Total System Generation 10^9 kw-hrs	Present Worth Total System Annual Cost 10^6\$	Present Worth Total System Generation 10^9 kw-hrs	Annual Incremental Evaporative Loss A-ft	Year End Storage 10^3 A-ft
1	30.968	3.942	29.777	3.790	2130	199.57
2	"	"	28.632	3.645	5730	345.14
3	"	"	27.531	3.504	8220	437.77
4	"	"	26.471	3.370	9624	478.57
5	"	"	25.454	3.240	9948	468.62
6	"	"	24.474	3.115	9222	408.98
7	"	"	23.533	2.996	7458	300.67
8	"	"	22.628	2.880	4674	144.69
9	61.936	7.884	43.516	5.539	3540	191.58
10	"	"	41.841	5.326	3984	187.60
11	"	"	40.232	5.121	3378	133.79
12	"	"	38.685	4.924	1734	31.21
13	92.904	11.826	55.795	7.102	1698	130.36
14	"	"	53.650	6.829	3234	177.55
15	"	"	51.586	6.567	3690	173.86
16	"	"	49.602	6.314	3090	120.35
17	"	"	47.694	6.071	1452	18.04
18	123.872	15.768	61.147	7.783	1422	117.47
19	"	"	58.795	7.484	2970	164.93
20	"	"	56.534	7.196	3426	161.50
21	"	"	54.359	6.919	2838	108.24
22	"	"	52.269	6.653	1206	6.18
23	154.840	19.710	62.823	7.997	1176	105.86
24	"	"	60.406	7.689	2730	153.55
25	"	"	58.084	7.394	3192	150.36
26	"	"	55.849	7.109	2604	97.33
27	155.397[1]	19.781[1]	53.895	6.860	1014	0
28	186.365	23.652	62.149	7.887	1050	99.80
29	"	"	59.758	7.584	2604	147.62
30	"	"	57.460	7.292	3072	144.55
Total Present Worth			1384.629	176.180		

[1] Includes \$0.557 x 10^6 and 0.071 x 10^9 kw-hrs for makeup of 4534 A-ft.

Table C-2

Lake Mead Storage Scheme 2
Evaporative Loss, Annual Cost and Electrical Generation

Year	Total System Annual Cost 10^6\$	Total System Generation 10^9 kw-hrs	Present Worth Total System Annual Cost 10^6\$	Present Worth Total System Generation 10^9 kw-hrs	Annual Incremental Evaporative Loss A-ft	Year End Storage 10^3 A-ft
1	30.968	3.942	29.777	3.790	2130	199.57
2	"	"	28.632	3.645	5730	345.14
3	"	"	27.531	3.504	8220	437.77
4	"	"	26.471	3.370	9624	478.57
5	"	"	25.454	3.240	9948	468.62
6	"	"	24.474	3.115	9222	408.98
7	"	"	23.533	2.996	7458	300.67
8	"	"	22.628	2.880	4674	144.69
9	37.705[1]	4.857[1]	26.491	3.412	1506	0
10	71.590	9.461	48.363	6.391	1050	99.80
11	"	"	46.503	6.146	2604	147.62
12	"	"	44.715	5.909	3072	144.55
13	"	"	42.995	5.682	2484	91.64
14	72.760[2]	9.620[2]	42.017	5.555	954	0
15	112.212	14.980	62.307	8.318	2130	199.57
16	"	"	59.911	7.998	5730	345.14
17	"	"	57.606	7.690	8220	437.77
18	"	"	55.391	7.395	9624	478.57
19	"	"	53.260	7.110	9948	468.62
20	"	"	51.212	6.837	9222	408.98
21	"	"	49.242	6.574	7458	300.67
22	"	"	47.349	6.321	4674	144.69
23	118.949[1]	15.895[1]	48.261	6.449	1506	0
24	152.834	20.499	59.624	7.997	1050	99.80
25	"	"	57.331	7.690	2604	147.62
26	"	"	55.126	7.394	3072	144.55
27	"	"	53.006	7.109	2484	91.64
28	154.004[2]	20.658[2]	51.357	6.889	954	0
29	193.456	26.018	62.032	8.343	2130	199.57
30	"	"	59.646	8.022	5730	345.14
Total Present Worth			1342.245	177.771		

[1]Includes \$6.737 x 10^6 and 0.915 x 10^9 kw-hrs for makeup of 58,512 A-ft.
[2]Includes \$1.170 x 10^6 and 0.159 x 10^9 kw-hrs for makeup of 10,164 A-ft.

Table C-3

Lake Mead Storage Scheme 3
Evaporative Loss, Annual Cost and Electrical Generation

Year	Total System Annual Cost 10^6\$	Total System Generation 10^9 kw-hrs	Present Worth Total System Annual Cost 10^6\$	Present Worth Total System Generation 10^9 kw-hrs	Annual Incremental Evaporative Loss A-ft	Year End Storage 10^3 A-ft
1	30.968	3.942	29.777	3.790	2130	199.57
2	"	"	28.632	3.645	5730	345.14
3	"	"	27,531	3.504	8220	437.77
4	"	"	26.471	3.370	9624	478.57
5	"	"	25.454	3.240	9948	468.62
6	"	"	24.474	3.115	9222	408.98
7	"	"	23.533	2.996	7458	300.67
8	"	"	22.628	2.880	4674	144.69
9	37.407[1]	4.857[1]	26.282	3.412	1506	0
10	80.882	11.038	54.641	7.457	2130	199.57
11	"	"	52.539	7.170	5730	345.14
12	"	"	50.519	6.894	8220	437.77
13	"	"	48.575	6.629	9624	478.57
14	"	"	46.708	6.374	9948	468.62
15	"	"	44.911	6.129	9222	408.98
16	"	"	43.184	5.893	7458	300.67
17	"	"	41.522	5.667	4674	144.69
18	87.321[1]	11.953[1]	43.104	5.900	1506	0
19	130.796	18.134	62.081	8.607	2130	199.57
20	"	"	59.694	8.276	5730	345.14
21	"	"	57.397	7.958	8220	437.77
22	"	"	55.191	7.652	9624	478.57
23	"	"	53.068	7.358	9948	468.62
24	"	"	51.026	7.074	9222	408.98
25	"	"	49.064	6.802	7458	300.67
26	"	"	47.177	6.541	4674	144.69
27	137.235[1]	19.049[1]	47.596	6.607	1506	0
28	180.710	25.230	60.263	8.414	2130	199.57
29	"	"	57.945	8.090	5730	345.14
30	"	"	55.717	7.779	8220	437.77
Total Present Worth			1316.704	179.223		

[1]Includes \$6.439 x 10^6 and 0.915 x 10^9 kw-hrs for makeup of 58,512 A-ft.

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