REPORT NO. 29

W. N. Jibson

BRIEF REPORT ON ESTIMATED EFFECTS OF ADDITIONAL STORAGE DEVELOPMENT IN THE BEAR RIVER BASIN UPSTREAM FROM STEWART DAM

By

E. K. Thomas, Area Engineer
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CONTENTS

TABLES

GRAPHS

At the last Bear River Compact Commission meeting on September 28-29, 1954, the Commission requested the Bureau of Reclamation to study the effects of additional water storage upstream from Stewart Dam as based upon three hypothetical quantities of storage that might be allowed, as a maximum, in any one year. The three storage quantities specified were 20,000 acre-feet, 30,000 acre-feet and 40,000 acre-feet. The study has been made, and the results are given in this report.

This report gives the estimated effects of additional upstream storage (upstream from Bear Lake) upon water uses both above Bear Lake and below Bear Lake. The information is given in summary form in tables and graphs. The detailed calculations and reservoir operation studies upon which the summary tables and graphs are based are in the files of the Bureau of Reclamation. These may be examined by the Compact Commissioners or other interested persons.

Studies of Storage Above Stewart Dam

The potential storage sites upstream from Bear Lake, including those on tributaries, are rather numerous. Consequently, a large number of storage combinations would be possible, particularly within the larger storage allowances that were specified. It is doubtful that any of the various storage sites have been studied in sufficient detail to establish with accuracy the economic limit of development for each. Certainly, all of the sites have not been studied sufficiently to determine the best combination of sites that could be developed, including a selection of the reservoirs and their individual capacities that would comprise the best over-all development.

Within the short time that has elapsed since the last meeting no attempt has been made to study in detail any individual storage sites, or to arrive at any conclusions concerning the best combination of sites. It has been deemed practicable, instead, for the purposes specified by the Commission, to group the sites into two main categories, and thus to simplify the studies without introducing any substantial error in estimating the effects of additional storage above Stewart Dam. Sach grouping probably minimizes the over-all margin of error to the extent that errors on individual sites are offset or averaged out by errors on other sites within the group.

The first reservoir group, or Group 1, includes the Woodruff Narrows site on the Bear River main stem and also includes any combination of sites on tributary streams upstream from Woodruff Narrows. This grouping is appropriate because of the availability of the Woodruff Narrows stream flow record for determining the combined water supplies storable at Woodruff Narrows and the upstream tributary sites. Different combinations of Woodruff Narrows storage and the various upstream tributary developments probably would have no appreciable effect on the over-all storage supply for the group.

The other group, Group 2, includes storage sites on tributary streams downstream from Woodruff Narrows. These sites are on Woodruff Creek, Big Creek, Randolph Creek, and Twin Creek. Storage sites exist on some of the other tributaries below Woodruff Narrows, but these were excluded from the study because previous Compact studies by the Geological Survey indicate that there are no requirements for supplemental water in the areas under these sites. Stream flow records either are not available or are insufficient to permit accurate determinations of storable flows at most of the Group 2 sites. A fairly good stream flow record, however, is available for the largest site (Woodruff Creek) and since the other sites are small the storage operation studies of the Group 2 reservoirs probably are not greatly in error.

In making the storage studies for the three different storage allowances, the same rules of operation were applied to each group of reservoirs. In the three studies the maximum inflows to storage permitted in any one year were 20,000 acre-feet, 30,000 acre-feet, and 40,000 acre-feet for both groups of reservoirs. All studies were based on stream flows for the 1924-1954 period. In instances when findings for the 1924-1948 period appeared desirable, such findings were extracted from the 1924-1948 portions of the 1924-1954 studies.

In accordance with Article V of the July 8, 1954, draft of compact, storage operations were not permitted to interfere with direct flow rights or existing storage rights above Stewart Dam. Inasmuch as storage operations of existing reservoirs are reflected in the stream flow records used in the studies, interference with existing storage rights was automatically eliminated. It was assumed for the October 1-April 30 nonirrigation season that additional storage would not interfere with direct flow rights above Stewart Dam. During the May 1-

September 30 irrigation season, storage was permitted only to extent of flows in excess of 700 second-feet as measured in Bear River at the Border gaging station.

Technically, this 700 second-foot flow limitation at Border is not a direct indication of the upstream flows that could be stored without interfering with existing direct flow rights. According to previous studies of Mr. Iorns and Mr. Jibson, however, it can be used generally without inducing appreciable error. As in previous reports by Mr. Iorns, Mr. Jibson, and the Engineering Committee of the Compact Commission, the 700 second-foot limitation was used in the studies forming a basis for this report, in order to avoid a very large amount of detailed streamflow and diversion calculations on a daily basis.

Releases from storage were made in accordance with supplemental storage requirements of irrigated lands above Stewart Dam, as estimated by Mr. Jibson. Mr. Jibson's estimates of the supplemental storage requirements were for the May 1-July 15 period and were based on water regulation (direct flows) as provided by the July 8, 1954, draft of compact, rather than on past river operations. In the form furnished by Mr. Jibson, the estimated supplemental requirements represent the requirements as measured at the storage site, rather than the aggregate supplemental requirements as measured at the points of diversion of the various canals. The difference between the aggregate supplemental requirements and the supplemental requirement at the storage site would be that portion of return flow that could be recovered from a release from storage and be reused within the area participating in the storage development. The supplemental requirements on storage, as estimated by Mr. Jibson, are as follows:

SUPPLEMENTAL REQUIREMENTS ON STORAGE (Acre-feet)

Water year	Storage on main stem and tributaries above Woodruff Narrows	Storage on tributaries below Woodruff Narrows	Total
1924	32,400	9,300	41,700
25	10,800	3,700	14,500
26	26,500	8,000	34,500
27	10,400	3,400	13,800
28	21,200	6,600	27,800
1929	4,900	1,600	6,500
30	23,300	6,800	30,100
31	66,400	20,300	86,700
32	8,600	2,600	11,200
33	23,100	6,800	29,900
1934	94,600	27,700	122,300
35	16,300	5,000	21,300
36	21,600	6,600	28,200
37	22,700	7,400	30,100
38	15,100	5,300	20,400
1939	49,100	13,200	62,300
40	52,000	17,200	69,200
41	11,000	12,900	23,900
42	17,300	11,000	28,300
43	10,400	5,400	15,800
1944	3,600	8,100	11,700
45	5,700	6,600	12,300
46	27,700	8,600	36,300
47	4,900	2,500	7,400
48	30,400	8,900	39,300
Average, 1924-48	24,400	8,600	33,000
1949	5,300	2,000	7,300
50	1,100	100	1,200
51	5,800	500	6,300
52	4,300	600	4,900
53	10,800	5,400	16,200
54	52,700	11,500	64,200
Average, 1924-54	22,300	7,600	29,900

In addition to the provisions of the July 8, 1954, draft of compact, one other factor could influence the effects of additional storage above Stewart Dam. This is the reservoir capacities that might be developed for holdover storage. The compact draft includes no restrictions on reservoir capacities. The estimated supplemental requirements on storage vary considerably from year to year. In some years the estimated supplemental requirements are substantially less than the quantity of water available for storage, even under a storage allowance as low as 20,000 acre-feet. In years when the supplemental requirements would not be sufficient to require release of all water in storage, some storage could be held over for use during the following year or years when the supplemental requirements would be greater than the annual storage allowance, assuming of course that holdover capacity (capacity in excess of the annual storage allowance) would be provided. Since the average annual storage and use of water would be greater with holdover storage than without, and since the compact draft included no restrictions on holdover storage capacity, it was necessary to select capacities for the two groups of reservoirs before proceeding with the storage operation studies.

As a guide for selection of reservoir capacities for use in the storage studies, the reservoir yields (within the estimated supplemental requirements) for each reservoir group were compared with the reservoir capacities required to obtain such yields. Separate comparisons were made for the different conditions imposed by the three storage allowances (20,000 acre-feet, 30,000 acre-feet, and 40,000 acre-feet) specified for the study. To facilitate the comparisons, reservoir capacity-yield diagrams were prepared. These diagrams are reproduced on pages 24, 25, and 26 of this report. Estimated evaporation losses are reflected in the diagrams.

The reservoir capacity-yield diagram on page 24 is based on an annual storage allowance of a maximum of 20,000 acre-feet. If all of the Group 1 and Group 2 reservoirs were allowed to participate in a 20,000 acre-foot storage allowance, development of the best large storage site (Woodruff Narrows) probably would be precluded. In this event the entire storage allowance could not be used, at least to best advantage. Consequently, the reservoir capacity-yield diagram for a 20,000 acre-foot storage allowance is based on the assumption that the entire allowance would be used at the Group 1 reservoirs at Woodruff Narrows and on the upstream tributaries. The reservoir capacity-yield diagrams on pages 25 and 26 for annual storage allowances of 30,000 acre-feet and 40,000 acre-feet respectively, are based on the assumption that the storage allowances would be used in a combination of the Group 1 and Group 2 reservoirs.

From the capacity-yield diagram for the 20,000 acre-foot storage allowance (page 24) it can be seen that the first 5,000 acre-feet of capacity in the Group 1 reservoirs would yield about 4,700 acre-feet annually, or nearly 1 acre-foot for each acre-foot of capacity. The next 5,000 acre-feet of capacity (between 5,000 and 10,000 acre-feet) would yield 4,100 acre-feet annually, or 0.82 acre-foot for each acre-foot of capacity. The next 5,000 acre-feet of capacity (between 10,000 and 15,000 acre-feet) would yield 3,400 acre-feet annually, or 0.68 acre-foot for each acre-foot of capacity. The next 5,000 acre-feet of capacity (between 15,000 and 20,000 acre-feet) would yield 2,500 acre-feet annually, or 0.5 acre-feet for each acre-foot of capacity. Reservoir capacities in excess of 20,000 acre-feet would have even a smaller rate of yield.

The low rate of yield for capacities in excess of 20,000 acre-feet justifies the adoption of a 20,000 acre-foot storage capacity for a 20,000 acre-foot storage allowance for the studies of the storage effects. This does not suggest that a compact limitation be placed on storage capacity. It means only that a 20,000 acre-foot capacity is reasonable for the study. Even if a much larger capacity were used for the study, this would result in only a slight increase in reservoir yield and an even smaller increase in depletion of the water supply storable in Bear Lake. Consequently, a 20,000 acre-foot reservoir capacity was adopted for the study of the 20,000 acre-foot storage allowance.

Not because it would assist greatly in selecting reservoir capacities for use of the storage studies, but mainly out of curiosity, a study was made of the relationship between estimated reservoir development costs and reservoir yields for the Woodruff Narrows Reservoir. Because of the low-cost storage at this site and the fact that the reservoir capacity would increase very rapidly for each foot of dam height, and for each dollar invested in construction, it appeared conceivable that a large amount of holdover capacity might be justified.

The exceptionally good cost-capacity relationship is illustrated by the diagram on page 27. Using the cost-capacity diagram on page 27 and the capacity-yield diagram on page 24, a cost-yield diagram was prepared, as shown on page 28. As indicated by the cost-yield diagram and the capacity-yield diagram, the most favorable investment in a Woodruff Narrows Reservoir, on the basis of a 20,000 acre-foot storage allowance, would be one that would yield about 15,000 acre-feet annually and have a capacity of slightly more than 20,000 acre-feet. Although not intended to assist in a selection of the reservoir capacity for use in the storage study, the diagrams explained above tend to substantiate the selection of a 20,000 acre-foot capacity for the 20,000 acre-foot storage allowance study.

From the capacity-yield diagram for the 30,000 acre-foot storage allowance (page 25) it can be seen that the Group 2 reservoirs would yield 0.5 acre-foot or more for each acre-foot of capacity, up to a total capacity of about 7,000 acre-feet. Capacities in excess of 7,000 acre-feet would have a very low rate of yield. The Group 1 reservoirs would yield 0.5 acre-foot or more for each acre-foot of capacity, up to a total capacity of nearly 20,000 acre-feet. Capacities in excess of 20,000 acre-feet would have a low rate of yield. Despite the low rates of yield for capacities in excess of 7,000 and 20,000 acre-feet, a 7,500 acre-foot capacity for the Group 2 reservoirs and a 22,500 acre-foot capacity for the Group 1 reservoirs were selected for the 30,000 acre-foot storage allowance study in order to permit full use of the storage allowance.

The capacity-yield diagram for the 40,000 acre-foot storage allowance (page 26) includes the same curve for the Group 2 reservoirs as is shown on the diagram for the 30,000 acre-foot storage allowance. This is because the Group 2 curve in both instances is based on substantially complete development of the water resources of the tributary streams below Woodruff Narrows. The group 1 curve for the 40,000 acre-foot storage allowance rises to a somewhat higher level than the corresponding curve for the 30,000 acre-foot storage allowance because more water could be developed with the larger storage allowance.

Although the Group 1 reservoir capacity-yield curve on the 40,000 acre-foot storage allowance diagram rises somewhat higher than the corresponding curve on the 30,000 acre-foot diagram, both curves are substantially the same for capacities less than 25,000 acre-feet. Only for capacities over 25,000 acre-feet does the curve for the 40,000 acre-foot storage allowance rise above that for the 30,000 acre-foot storage allowance. This means that for both storage allowances the rates of yield are good to fair for total reservoir capacities up to 25,000 acre-feet. The 40,000 acre-foot storage allowance would permit somewhat larger yields than the 30,000 acre-foot storage allowance for total reservoir capacities over 25,000 acre-feet, but for such capacities the rates of yield for the 40,000 acre-foot storage allowance would not be much higher than those for the 30,000 acre-foot allowance.

For the 40,000 acre-foot storage allowance study, a total capacity of 7,500 acre-feet was selected for the Group 2 reservoirs, the same as that used for the 30,000 acre-foot storage allowance study. Despite the low rate of yield for capacities in excess of 25,000 acre-feet, a 32,500 acre-foot capacity for the Group 1 reservoirs was selected for the 40,000 acre-foot storage allowance study in order to permit full use of the storage allowance.

Using the selected reservoir capacities, annual operation studies were made for the three storage allowances (20,000, 30,000, and 40,000 acre-feet). To the extent possible under each storage allowance, reservoir releases were made in accordance with the estimated annual supplemental requirements on storage. As indicated by these operation studies, the extent to which storage in both the Group 1 and Group 2 reservoirs would improve the water supply and eliminate water shortages upstream from Stewart Dam is summarized in the tables on pages 12, 13, and 14. These tables show for each of the three storage allowances that were studied (1) the annual reservoir releases that could be made, (2) the estimated usable return flow that could be recovered from the storage releases, and (3) the estimated total water supply that would be made available in the area. The usable return flows listed in the tables were taken from the diagram shown on page 29. The diagram is based on judgment derived from such stream flow, diversion, and consumptive use data as have been collected in the area involved, and also in other similar Western areas. The estimated aggregate supplemental requirements of the area, including that portion of the requirements that would be met by return flow from storage releases, also are listed in the tables to show by comparison how effective the storage supplies would be in relieving water shortages. The same information is shown graphically by the diagram on page 30. The diagram on page 31 represents a final summary estimate of the improvement in water supplies for the area above Stewart Dam with the three different storage allowances.

ESTIMATED SUPPLEMENTAL WATER SUPPLY AVAILABLE FROM 20,000 ACRE-FEET STORAGE ALLOWANCE (Acre-feet)

		Estimated supplemental supply		
Water year	Total supplemental requirement	Direct storage releases	Usable return flow	Total
1924	45,700	19,200	2,800	22,000
25	16,600	10,800	1,500	12,300
26	38,500	19,200	2,800	22,000
27	15,700	10,400	1,400	11,800
28	31,500	19,200	2,800	22,000
1929	7,300	4,900	1,000	5,900
30	34,000	19,200	2,800	22,000
31	90,700	19,200	2,800	22,000
32	12,800	8,600	1,200	9,800
33	33,800	19,200	2,800	22,000
1934	126,300	19,200	2,800	22,000
35	24,300	16,300	2,300	18,600
36	31,900	19,200	2,800	22,000
37	34,000	19,200	2,800	22,000
38	23,300	15,100	2,100	17,200
1939	66,300	19,200	2,800	22,000
40	73,200	19,200	2,800	22,000
41	27,300	11,000	1,500	12,500
42	32,000	17,300	2,500	19,800
43	18,000	10,400	1,400	11,800
1944	13,300	3,600	400	4,000
45	14,000	5,700	700	6,400
46	40,300	19,200	2,800	22,000
47	8,400	4,900	600	5,500
48	43,300	19,200	2,800	22,000
Average, 1924-48	36,100	14,700	2,100	16,800
1949	8,300	5,300	600	5,900
50	1,300	1,100	100	1,200
51	7,000	5,800	700	6,500
52	5,500	4,300	500	4,800
53	18,500	10,800	1,500	12,300
1954	68,200	19,200	2,800	22,000
Average, 1924-54	32,600	13,400	1,900	15,300

ESTIMATED SUPPLEMENTAL WATER SUPPLY AVAILABLE FROM 30,0
STORAGE ALLOWANCE (Acre-feet)

Water year	Total supplemental requirement	Estimated supplement		
		Direct storage releases	Usable return flow	
1924	45,700	28,700	3,800	[illegible]
25	16,600	14,500	2,100	[illegible]
26	38,500	28,700	3,800	[illegible]
27	15,700	13,800	1,900	[illegible]5,700
28	31,500	27,800	3,700	31,[illegible]
1929	7,300	6,500	800	7,300
30	34,000	28,400	3,700	32,100
31	90,700	28,000	3,700	31,700
32	12,800	11,200	1,600	12,800
33	33,800	28,400	3,700	32,100
1934	126,300	28,300	3,700	32,000
35	24,300	21,300	3,000	24,300
36	31,900	28,200	3,700	31,900
37	34,000	28,700	3,800	32,500
38	23,300	20,400	2,900	23,300
1939	66,300	28,700	3,800	32,500
40	73,200	28,700	3,800	32,500
41	27,300	16,100	2,300	18,400
42	32,000	24,400	3,400	27,800
43	18,000	15,800	2,200	18,000
1944	13,300	10,700	1,500	12,200
45	14,000	12,300	1,700	14,000
46	40,300	28,700	3,800	32,500
47	8,400	7,400	1,000	8,400
48	43,300	28,700	3,800	32,500
Average, 1924-1948	36,100	21,800	2,900	24,700
1949	8,300	7,300	1,000	8,300
50	1,300	1,200	100	1,300
51	7,000	6,300	700	7,000
52	5,500	4,900	600	5,500
53	18,500	16,200	2,300	18,500
1954	68,200	24,600	3,500	28,100
Average, 1924-1954	32,600	19,500	2,600	22,100

ESTIMATED SUPPLEMENTAL WATER SUPPLY AVAILABLE FROM
STORAGE ALLOWANCE (Acre-feet)

Water year	Total supplemental requirement	Estimated suppl[illegible]: Direct storage releases	U[illegible] re[illegible] f[illegible]	[illegible]
1924	45,700	38,300	[illegible]	[illegible]
25	16,600	14,500	2[illegible]	[illegible]
26	38,500	33,600	3,[illegible]	[illegible]
27	15,700	13,800	1,[illegible]	[illegible]
28	31,500	27,800	3,[illegible]	[illegible]
1929	7,300	6,500		[illegible]
30	34,000	30,100	3,[illegible]	[illegible]
31	90,700	37,600	3,[illegible]	[illegible]
32	12,800	11,200	1,[illegible]	[illegible]
33	33,800	29,900	3,9[illegible]	[illegible]
1934	126,300	37,900	3,[illegible]	[illegible]
35	24,300	21,300	3,[illegible]	24,300
36	31,900	28,200	3,7[illegible]	3[illegible],900
37	34,000	29,800	3,8[illegible]	33,600
38	23,300	20,400	2,9[illegible]	23,300
1939	66,300	38,300	3,80[illegible]	[illegible]2,100
40	73,200	29,200	3,80[illegible]	33,000
41	27,300	16,100	2,300	18,400
42	32,000	24,400	3,400	27,800
43	18,000	15,800	2,200	18,000
1944	13,300	10,700	1,500	12,200
45	14,000	12,300	1,700	14,000
46	40,300	34,800	3,800	38,600
47	8,400	7,400	1,000	8,400
48	43,300	37,500	3,800	41,300
Average, 1924-48	36,100	24,300	2,900	27,200
1949	8,300	7,300	1,000	8,300
50	1,300	1,200	100	1,300
51	7,000	6,300	700	7,000
52	5,500	4,900	600	5,500
53	18,500	16,200	2,300	18,500
1954	68,200	38,300	4,000	42,300
Average, 1924-54	32,600	22,000	2,700	24,700

Depletion in Water Supply Storable in Bear Lake

Following the previously described studies of the supplement water supplies that could be provided by development under the thr storage allowances, estimates were made of the resultant depletion water supply storable in Bear Lake. The following table shows (1) supply storable in Bear Lake under present conditions and (2) the es mated depletions in the supply that would result from storage develop- ment above Stewart Dam under the three different storage allowances. The depletions listed in the table were derived from storage operation data and the return flow diagram on page 29.

WATER SUPPLIES STORABLE IN BEAR LAKE WITH AND WITHOUT ADDITIONAL STORAGE ABOVE STEWART DAM

Water year	Water supply storable in Bear Lake under present conditions (Acre-feet)	Estimated depletions resulting from storage development above Stewart Dam (Acre-feet) 20,000 acre-foot storage allowance	30,000 acre-foot storage allowance	40,000 acre-foot storage allowance
1924	407,200	18,100	25,000	29,400
25	276,000	19,500	29,100	39,100
26	157,100	9,700	10,800	8,400
27	289,100	19,600	29,200	34,500
28	383,800	9,300	10,300	10,700
1929	391,000	19,900	28,900	29,300
30	206,100	3,800	2,900	2,500
31	94,700	18,100	24,200	21,200
32	279,800	19,700	29,500	39,400
33	176,600	7,500	7,600	7,200
1934	27,800	18,100	24,500	20,900
35	89,800	18,900	27,700	31,800
36	394,400	15,200	17,800	24,100
37	333,300	18,100	24,500	24,200
38	338,600	19,000	28,000	29,500
1939	188,700	14,000	16,700	11,400
40	36,100	18,100	25,000	25,700
41	78,500	19,400	26,900	36,900
42	223,600	10,400	16,300	16,600
43	357,000	17,600	24,600	25,000
1944	284,200	11,100	16,600	17,000
45	202,900	4,300	11,400	11,800
46	441,600	4,600	8,600	5,700
47	384,400	19,900	29,800	36,300
48	318,500	3,800	3,700	-900
Average, 1924-48	254,400	14,300	20,000	21,500
1949	243,000	19,900	29,800	38,900
50	588,900	6,100	8,600	9,000
51	484,900	1,700	2,300	2,400
52	536,500	6,500	7,500	7,900
53	174,600	4,600	4,900	5,400
1954	97,600	9,700	12,400	7,200
Average, 1924-54	273,800	13,100	18,200	19,600

As shown in the preceding table the annual water supply storable in Bear Lake averaged 273,800 acre-feet for the 1924-54 period. As based on previous flow segregation studies of Mr. Iorns, Mr. Jibson, and the Engineering Committee, the 1924-1954 storable supply was used as follows. On the average, 92,700 acre-feet annually was used for irrigation below Bear Lake to supplement the available natural flow supplies. The same 92,700 acre-feet was used for power as the water flowed down Bear River enroute to the irrigation diversions. On the average, 145,500 acre-feet of Bear Lake water annually was used solely for power during the 1924-54 period, and passed the Cutler power plant into Great Salt Lake. About 18,800 acre-feet annually of the 145,500 acre-feet was obtained from Bear Lake drawdown. After allowance for this drawdown, the storable inflow to Bear Lake was sufficient to provide an average annual supply of 126,700 acre-feet solely for power. This was over and above the 92,700 acre-feet used for both irrigation and power. The remaining 54,400 acre-feet could not be accounted for in summing up the records of river flows, lake inflows, lake outflows, and diversions, and presumably was lost mainly by evaporation and transpiration in Bear Lake and Mud Lake. The above water supplies provided by the storable inflows to Bear Lake are illustrated by the diagram on page 32.

A depletion in water supply storable in Bear Lake definitely would result in a corresponding decrease in water supply available from Bear Lake storage. From the preceding explanation, however, including the diagram on page 32, it can be seen that none of the depletions listed in the table on page 16 would cause any decrease in the Bear Lake storage supply for irrigation and other consumptive uses below Bear Lake. This is true because the average storable inflow to Bear Lake, after storage is developed above Stewart Dam, will remain more than large enough to meet the irrigation and other consumptive requirements below Bear Lake, and because the storage facilities at Bear Lake can completely regulate the high river flows in wet years for use in dry periods that occur years later.

One single circumstance determines whether irrigation and other consumptive requirements below Bear Lake will be met by Bear Lake storage. This is not storage above Stewart Dam, or the resultant depletion in storable inflow to Bear Lake, but is the extent to which Bear Lake is operated solely for power. This would be true after development of additional storage above Stewart Dam, but no more so than is true for present conditions. Development of additional storage above Stewart Dam would not change this fundamental fact.

Bear Lake Irrigation Reserve

If additional storage were developed above Stewart Dam and the irrigation interests below Bear Lake were to be assured of no decrease in water supply as a result thereof, some adjustment in the operation of Bear Lake solely for power would have to be made to allow for the depletion in storable supply. The provision for the Bear Lake irrigation reserve, as included in the draft of compact, is intended as a means of insuring that such adjustment in storage operations would be made. The provision for the irrigation reserve means simply that water could be released from Bear Lake solely for power only when the lake level was in excess of a certain elevation, as yet unspecified in the compact draft. The volume of water in lake storage below that certain elevation would constitute the reserve and could be released only for irrigation and other consumptive uses, including incidental use for power as the water flowed down Bear River enroute to points of diversion.

The size of the reserve, and its controlling lake elevation, required to assure the irrigation interests of no decrease in past water supply can be established rather simply. It is necessary only to compute the maximum net draft on Bear Lake for irrigation and other consumptive uses that ever occurred, and to add a small safety factor to allow for such quantities of water that might be released from Bear Lake for irrigation use but which might actually be passed by points of diversion and be used for power as a result of rainstorms or other unpredictable occurrences. In the above explanation the term "net draft on Bear Lake for irrigation" means the amount by which the irrigation release exceeds the storable inflow minus lake losses, mainly evaporation and transpiration.

The maximum net draft on Bear Lake for irrigation occurred during the May 21, 1930-September 30, 1935, period. The net irrigation draft during this period amounted to 860,300 acre-feet. During the same period, the storable inflow was 668,700 acre-feet and lake losses were 485,000 acre-feet. After deducting the lake losses, the lake inflow available for storage and release from the lake amounted to 183,700 acre-feet. Since 860,300 acre-feet was required for irrigation and

See opposite page

668,700 - 485,000

only 183,700 acre-feet was available from net inflow to the lake, the remaining 676,600 acre-feet constituted an irrigation requirement on hold-over storage in the lake. For present conditions and without a safety factor, this figure would be equivalent to the lake reserve required to assure irrigation interests below the lake that their future Bear Lake supplies would not be less than those available in the past. A safety factor (as mentioned previously) of 5,000 acre-feet annually for the 6-year period is considered sufficient, and when added to the 676,600 acre-feet establishes the reserve at 706,600 acre-feet, as required for present conditions.

Additional storage above Stewart Dam would deplete the storable inflow to Bear Lake, and thus would increase somewhat the holdover storage, or the irrigation reserve, required for water supply assurance to the irrigation interests below Bear Lake. The necessary increase in the reserve to allow for additional storage development above Stewart Dam also can be determined readily. It is necessary only to add the 1931-1935 depletions resulting from any given storage development to the 706,600 acre-foot reserve required under present conditions. The 1930 depletion should not be added since it would occur prior to the May 21, 1930-September 30, 1935, period of maximum net irrigation draft on Bear Lake. The necessary increase in the reserve to allow for storage development above Stewart Dam under a 30,000 acre-foot storage allowance is determined as follows. In the table on page 16 in the column for the 30,000 acre-foot storage allowance, the estimated depletions are listed as 24,200, 29,500, 7,600, 24,500, and 27,700 acre-feet for the 5 years in the 1931-1935 period. The total estimated depletion for the period is 113,500 acre-feet. This is the necessary increase in the reserve for development under a 30,000 acre-foot storage allowance. The total reserve necessary for such development thus would be 820,100 acre-feet (706,600 plus 113,500). Using the 1931-1935 depletions listed in the 20,000 acre-foot and 40,000 acre-foot storage allowance columns, the necessary increases in the reserve for development under these storage allowances are determined as 82,300 acre-feet and 120,500 acre-feet, respectively. The total reserves necessary for development under the 20,000 acre-foot and 40,000 acre-foot storage allowances thus would be 788,900 acre-feet and 827,100 acre-feet, respectively (706,600 plus 82,300 and 706,600 plus 120,500). The Bear Lake Irrigation reserves required for development under different allowances for storage above Stewart Dam are summarized in the following tables and on the diagrams on pages 33 and 34. The corresponding lake surface elevations also are shown in the table and diagram.

BEAR LAKE IRRIGATION RESERVE REQUIRED TO ASSURE IRRIGATION INTERESTS BELOW BEAR LAKE OF NO DECREASE IN WATER SUPPLY

Annual allowance for additional storage above Stewart Dam (Acre-feet)	Bear Lake Irrigation Reserve: Capacity (Acre-feet)	Bear Lake Irrigation Reserve: Lake surface elevation (Feet)
0	706,600	5,913.29
20,000	788,900	5,914.52
30,000	820,100	5,914.99
40,000	827,100	5,915.09

Effect of Storage Development Above Stewart Dam on Power Production

If Bear Lake storage were operated in accordance with the irrigation reserve, which would insure the irrigation interests using Bear Lake water of no decrease in water supply, the depletion in Bear Lake storage supply resulting from additional storage development above Stewart Dam would constitute a decrease in Bear Lake water supply available for power production. The estimated decrease in water supply for power production that would occur following storage development above Stewart Dam under 20,000, 30,000, and 40,000 acre-foot storage allowances are equivalent to the corresponding depletions listed in the table on page 16. As based on the 1924-1954 period, the average annual decreases in water supply for power are estimated at 13,100, 18,200, and 19,600 acre-feet, respectively, for the three storage allowances. The Bear Lake water supplies available for power under present conditions (average for the 1924-1954 period) and the estimated decreases that would result from additional storage development under the three storage allowances are shown in the following table and on the diagram on page 36.

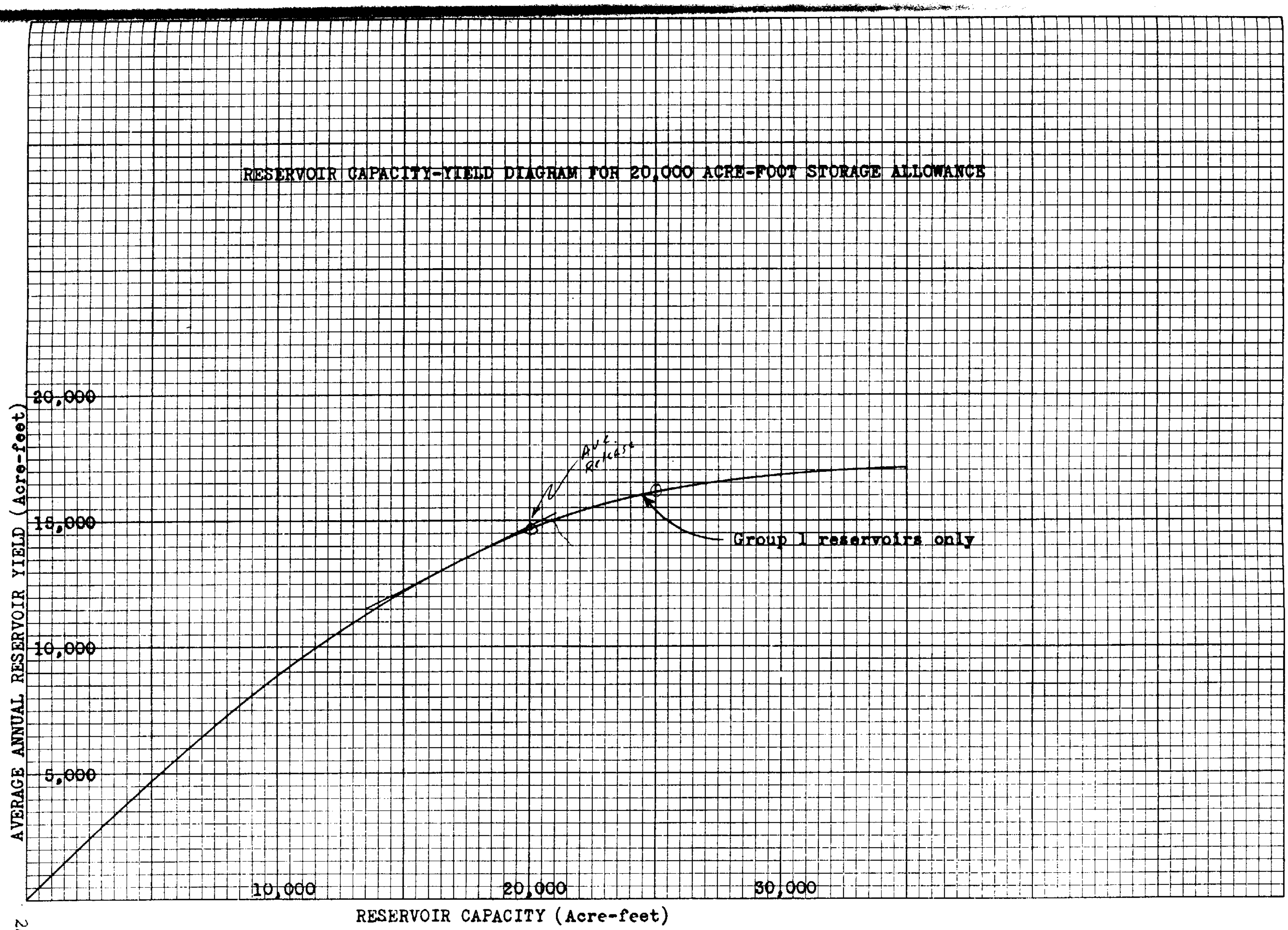
BEAR LAKE WATER SUPPLIES AVAILABLE FOR POWER
(Average annual, based on 1924-1954 period)

Bear Lake water supplies available for power, present conditions (Acre-feet)			Estimated depletions from storage development above Stewart Dam (Acre-feet)		
Irrigation releases usable for power	Releases solely for power	Total	20,000 acre-foot storage allowance	30,000 acre-foot storage allowance	40,000 acre-foot storage allowance
92,700	126,700	219,400	13,100	18,200	19,600

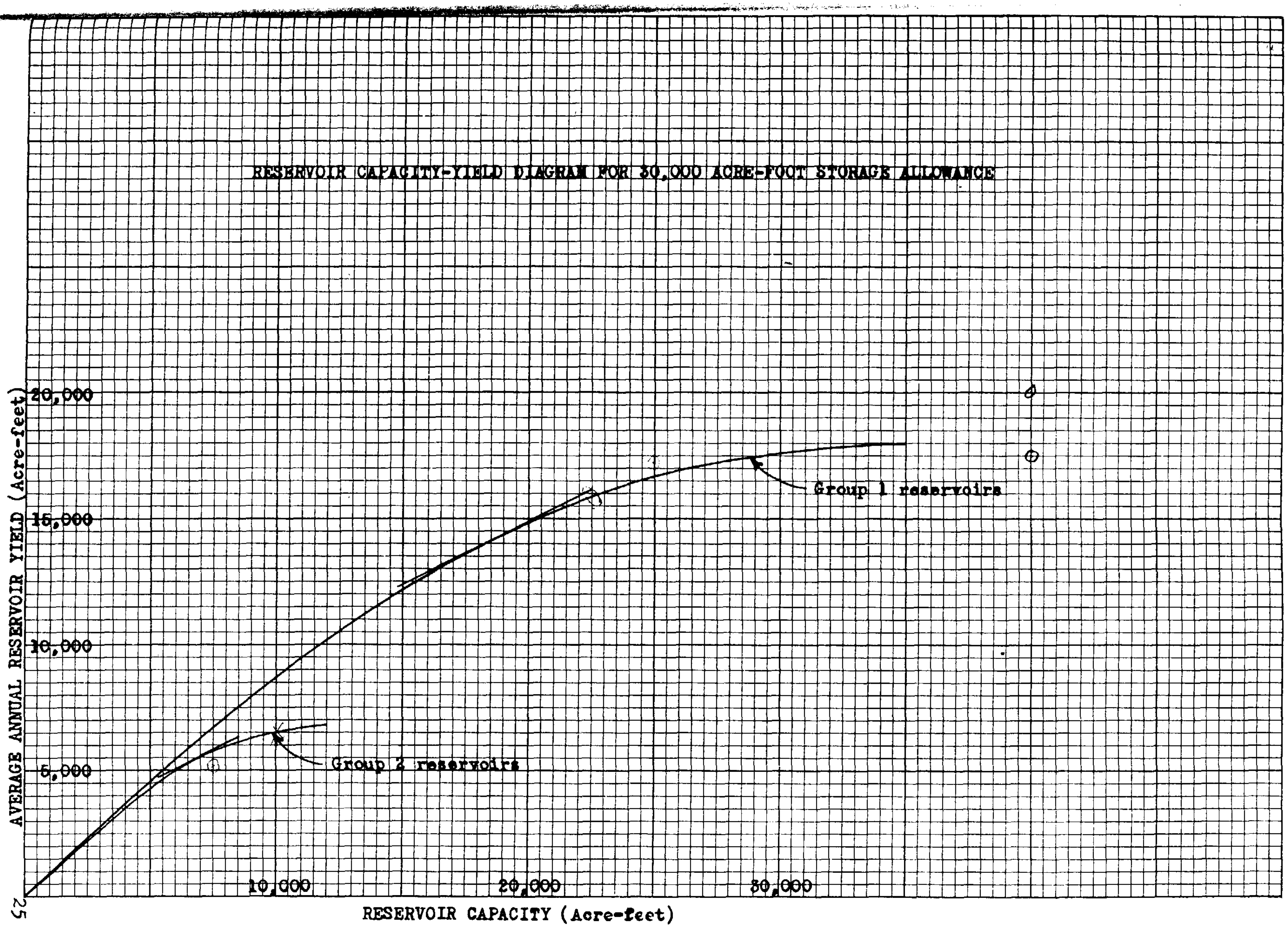
(Water supplies shown in table include only those obtainable from Bear Lake. Supplies originating below Bear Lake are not included.)

Summary

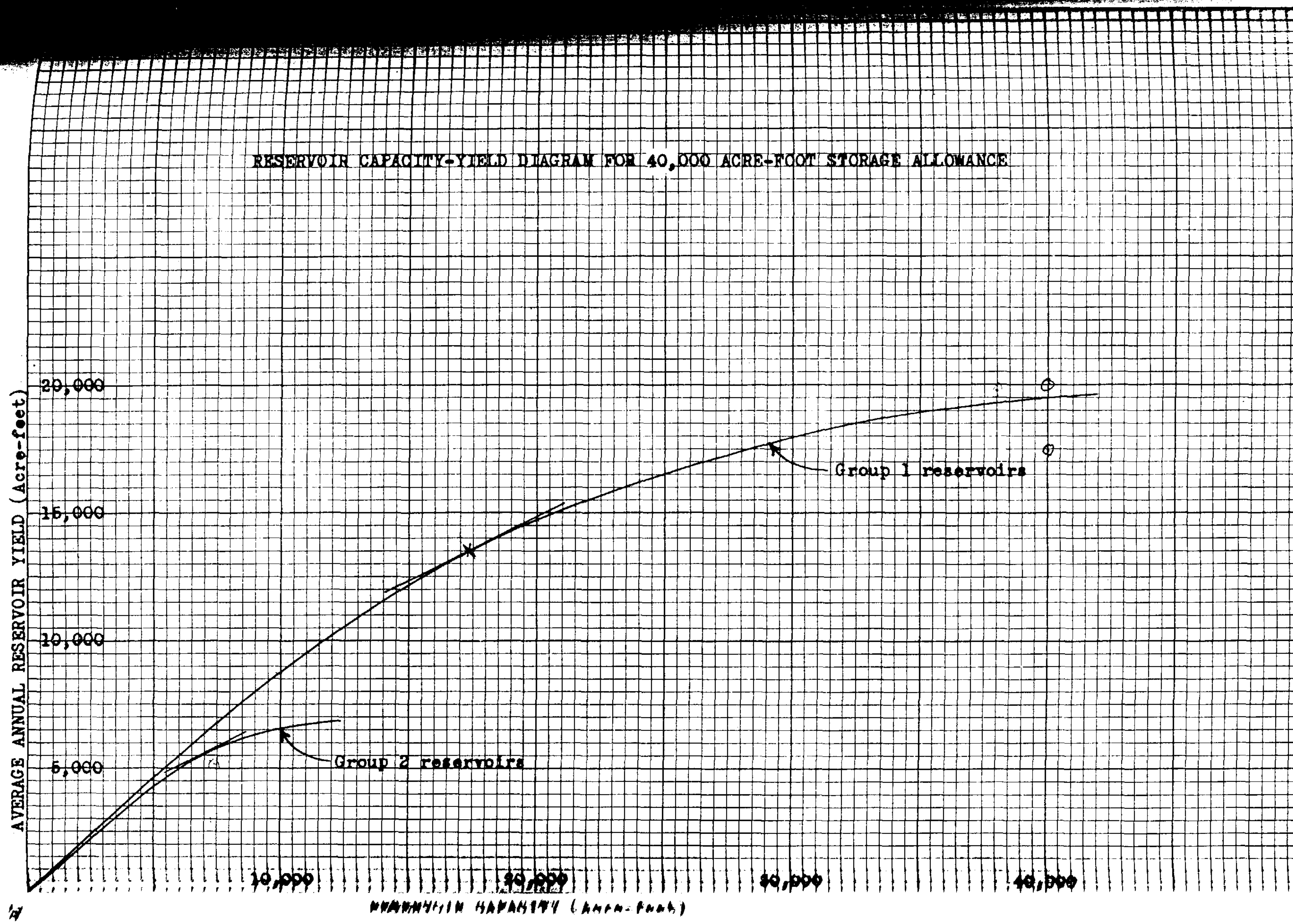
This report gives the probable effects of storage development above Stewart Dam under three storage allowances (20,000 acre-feet, 30,000 acre-feet, and 40,000 acre-feet) as based on supplemental water requirements within the May 1-July 15 period as estimated by Mr. Jibson. These effects include (1) the improvement in water supply for supplemental irrigation above Stewart Dam, (2) the depletion in water supply storable in Bear Lake and the corresponding decrease in water supply obtainable from Bear Lake, (3) the Bear Lake irrigation reserve that would be required to assure all irrigation interests using Bear Lake water of the same supply that they have had in the past, and (4) the decrease in Bear Lake Water supply available for power production that would occur if Bear Lake were operated in accordance with the Bear Lake irrigation reserve. This information, in the order mentioned above, is summarized in the diagram on page 31, the table on page 16, the diagrams on pages 33 and 34, and the diagram on page 35.

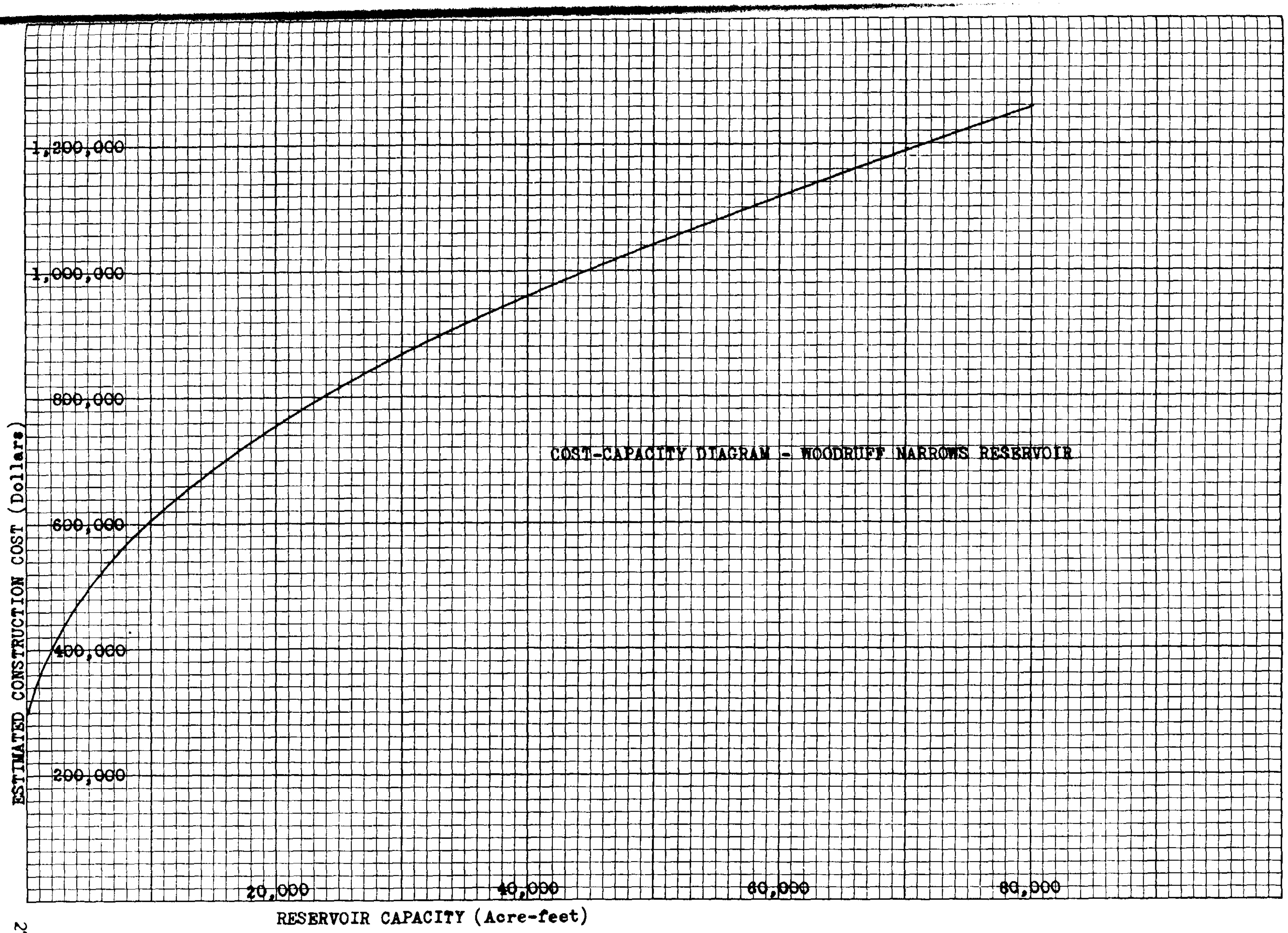


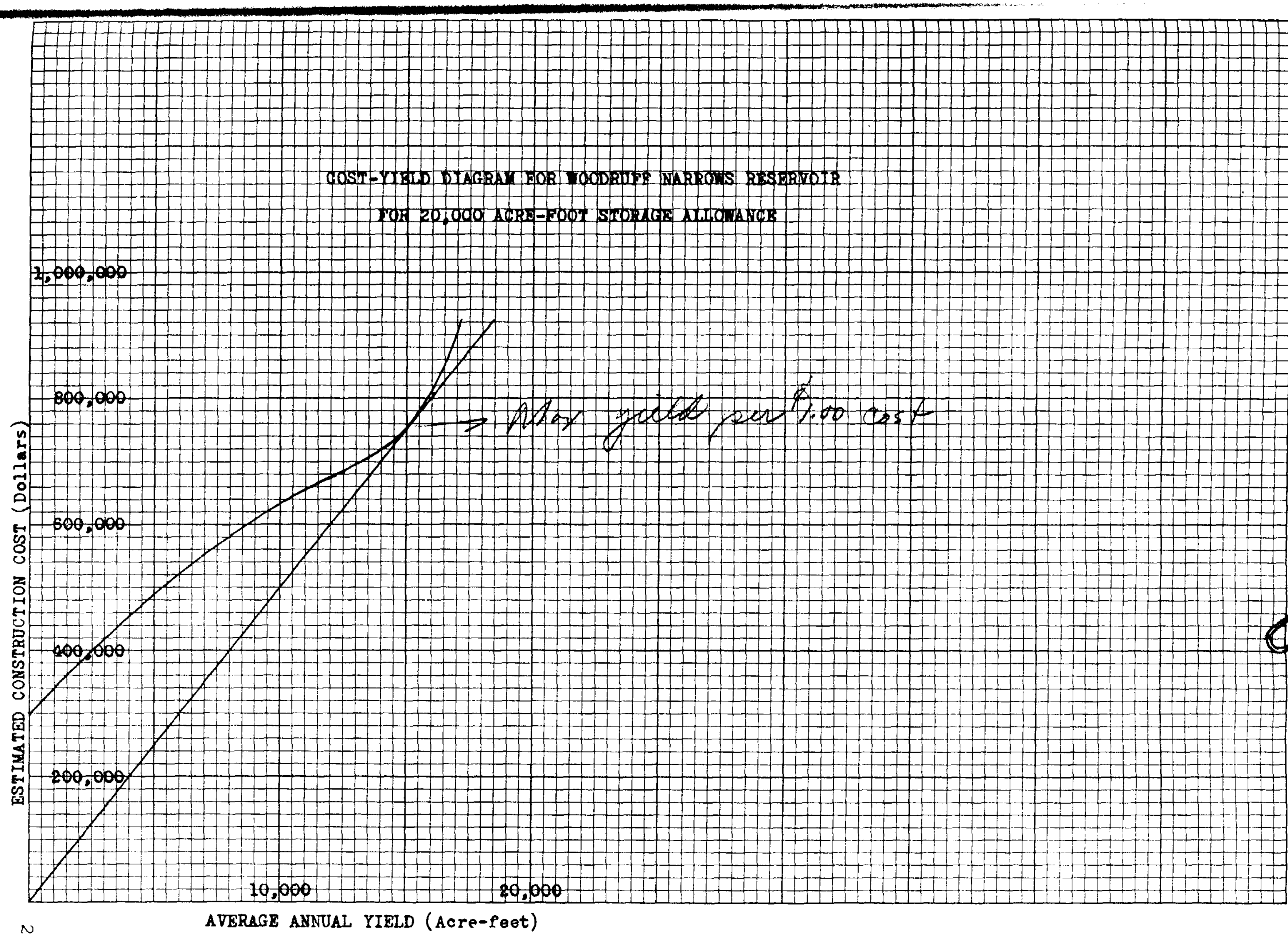
RESERVOIR CAPACITY-YIELD DIAGRAM FOR 20,000 ACRE-FOOT STORAGE ALLOWANCE
AVERAGE ANNUAL RESERVOIR YIELD (Acre-feet)
20,000
15,000
10,000
5,000
10,000
20,000
30,000
RESERVOIR CAPACITY (Acre-feet)
Group 1 reservoirs only


RESERVOIR CAPACITY-YIELD DIAGRAM FOR 30,000 ACRE-FOOT STORAGE ALLOWANCE
AVERAGE ANNUAL RESERVOIR YIELD (Acre-feet)
20,000
15,000
10,000
5,000
Group 1 reservoirs
Group 2 reservoirs
10,000
20,000
30,000
RESERVOIR CAPACITY (Acre-feet)

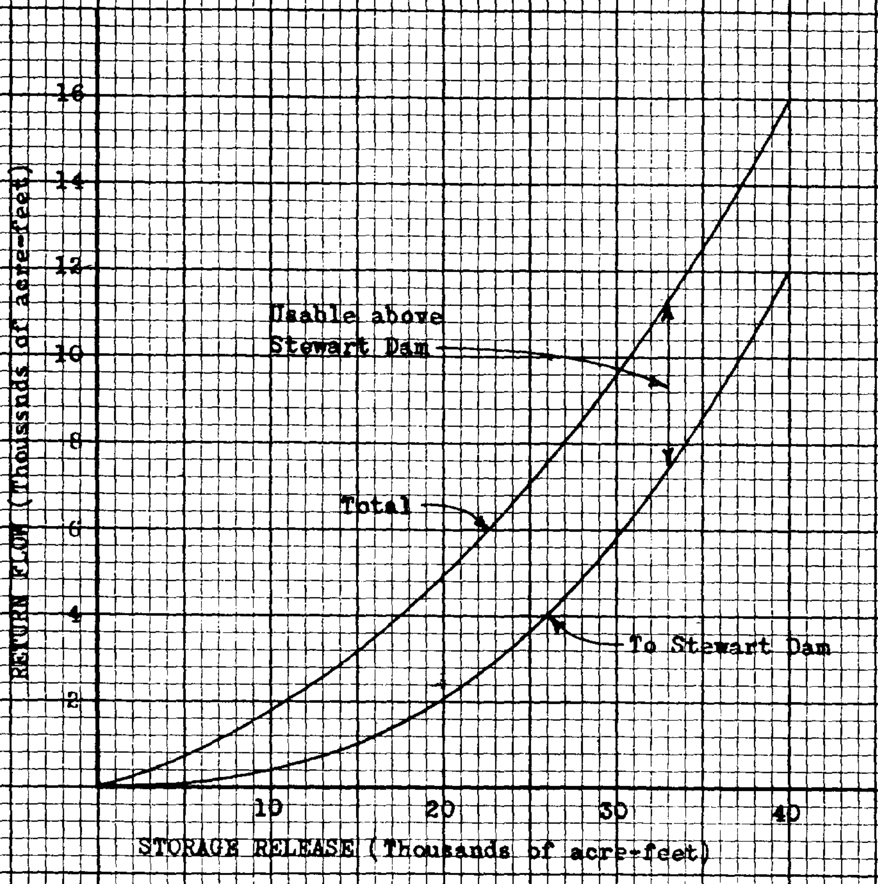
25

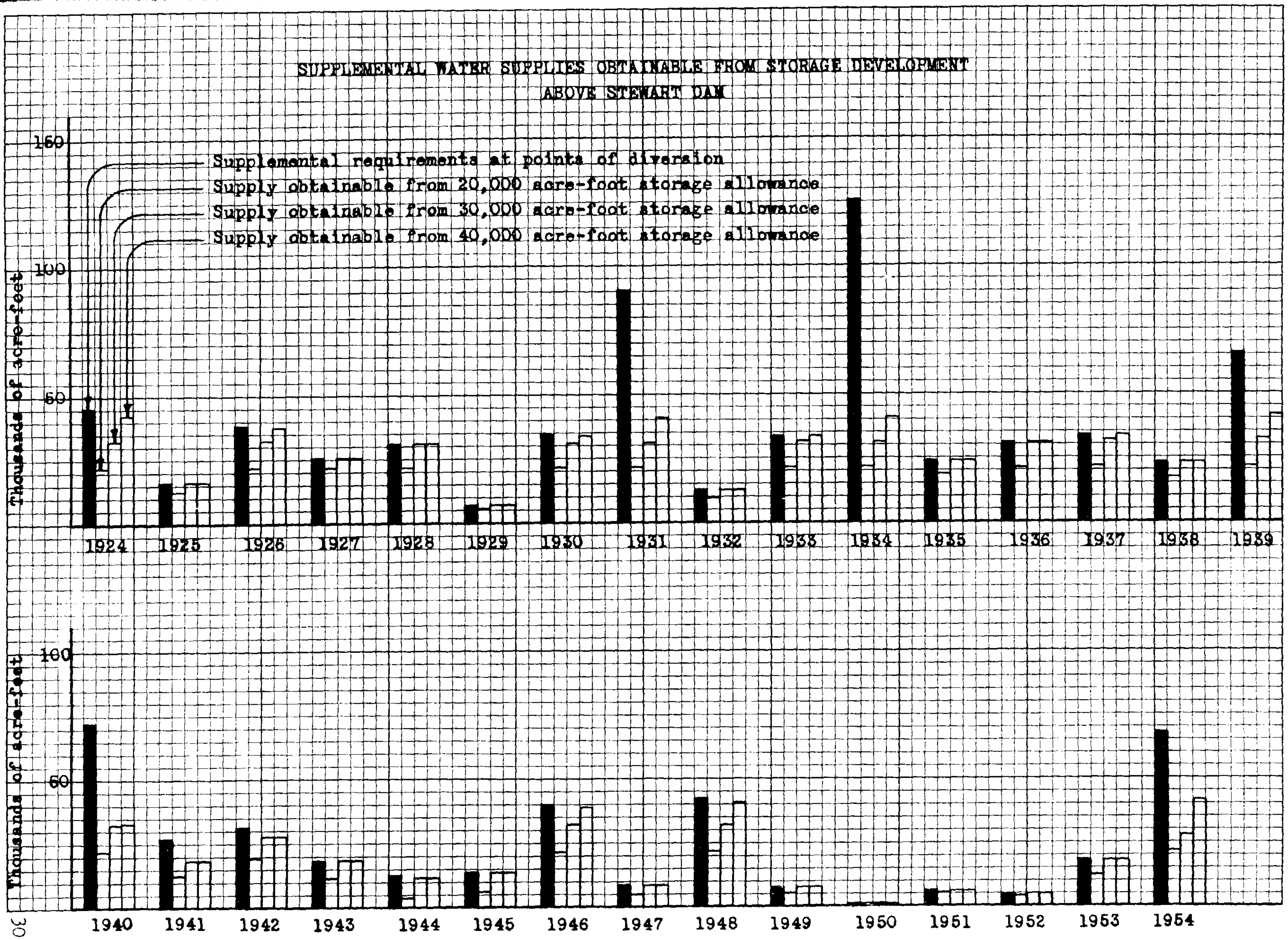

RESERVOIR CAPACITY-YIELD DIAGRAM FOR 40,000 ACRE-FOOT STORAGE ALLOWANCE
AVERAGE ANNUAL RESERVOIR YIELD (Acre-feet)
20,000
15,000
10,000
5,000
10,000
20,000
30,000
40,000
Group 1 reservoirs
Group 2 reservoirs

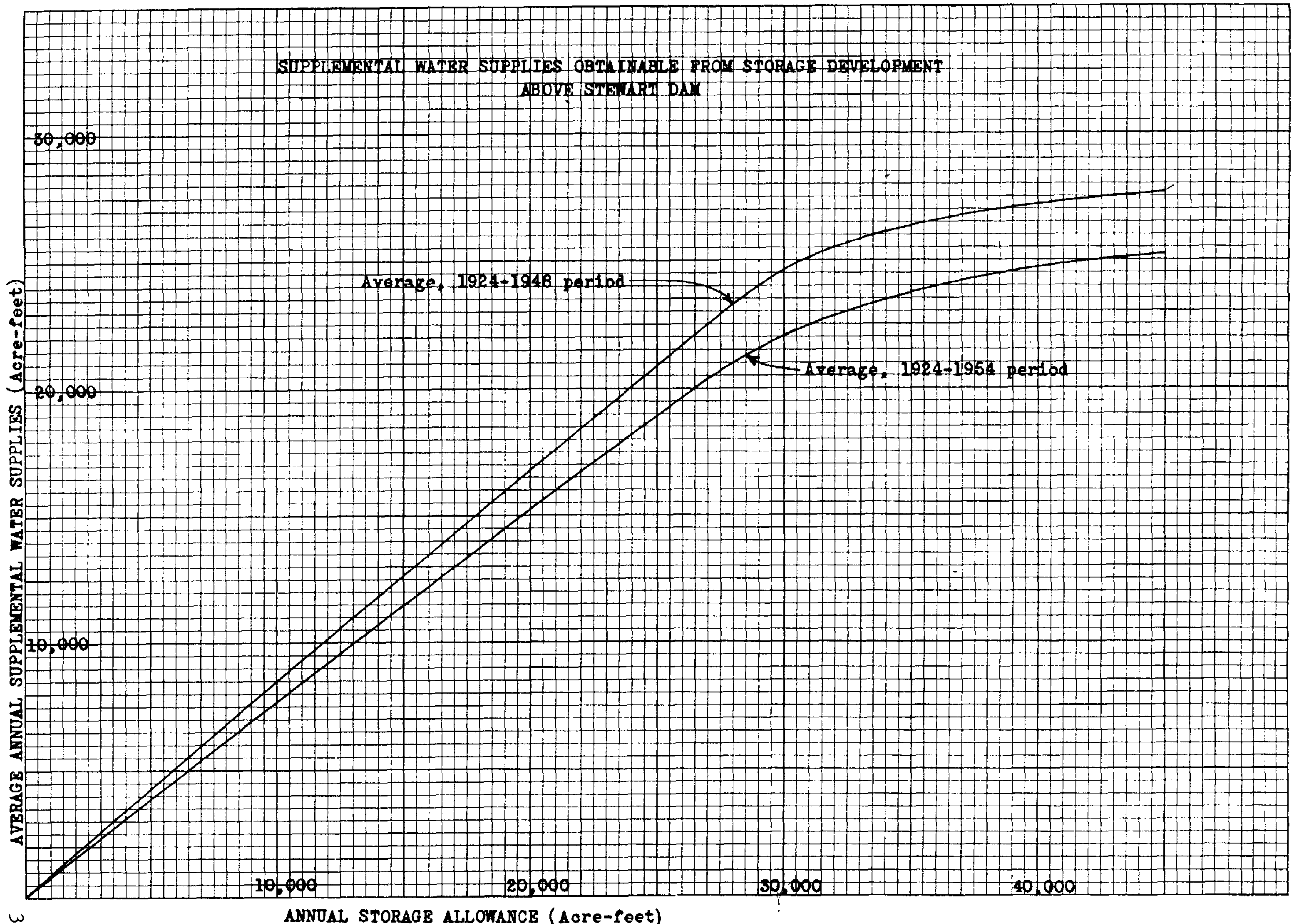

COST-CAPACITY DIAGRAM - WOODRUFF NARROWS RESERVOIR
ESTIMATED CONSTRUCTION COST (Dollars)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
20,000
40,000
60,000
80,000
RESERVOIR CAPACITY (Acre-feet)


COST-YIELD DIAGRAM FOR WOODRUFF NARROWS RESERVOIR
FOR 20,000 ACRE-FOOT STORAGE ALLOWANCE
1,000,000
800,000
600,000
400,000
200,000
10,000
20,000
ESTIMATED CONSTRUCTION COST (Dollars)
AVERAGE ANNUAL YIELD (Acre-feet)
→ Max yield per $1.00 cost

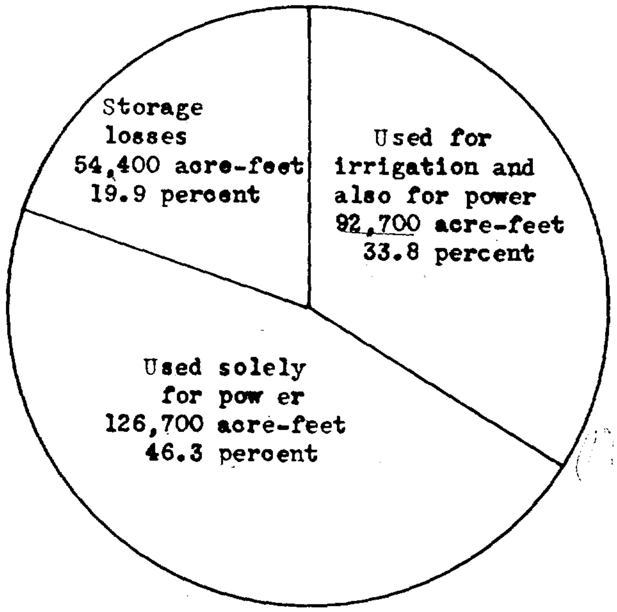
ESTIMATED RETURN FLOWS FROM STORAGE RELEASES
ABOVE STEWART DAM




SUPPLEMENTAL WATER SUPPLIES OBTAINABLE FROM STORAGE DEVELOPMENT
ABOVE STEWART DAM
Supplemental requirements at points of diversion
Supply obtainable from 20,000 acre-foot storage allowance
Supply obtainable from 30,000 acre-foot storage allowance
Supply obtainable from 40,000 acre-foot storage allowance
Thousands of acre-feet
150
100
50
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
Thousands of acre-feet
100
50
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954

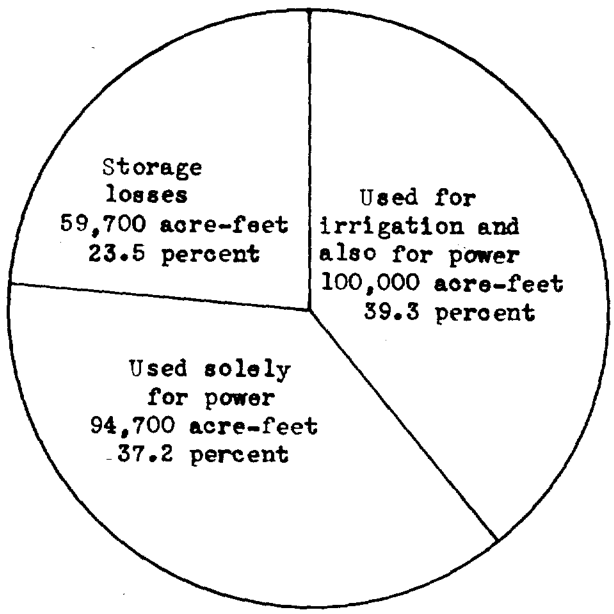

SUPPLEMENTAL WATER SUPPLIES OBTAINABLE FROM STORAGE DEVELOPMENT
ABOVE STEWART DAM
Average, 1924-1948 period
Average, 1924-1954 period
30,000
20,000
10,000
10,000
20,000
30,000
40,000
AVERAGE ANNUAL SUPPLEMENTAL WATER SUPPLIES (Acre-feet)
ANNUAL STORAGE ALLOWANCE (Acre-feet)

PAST USE OF WATER SUPPLIES STORABLE IN BEAR LAKE

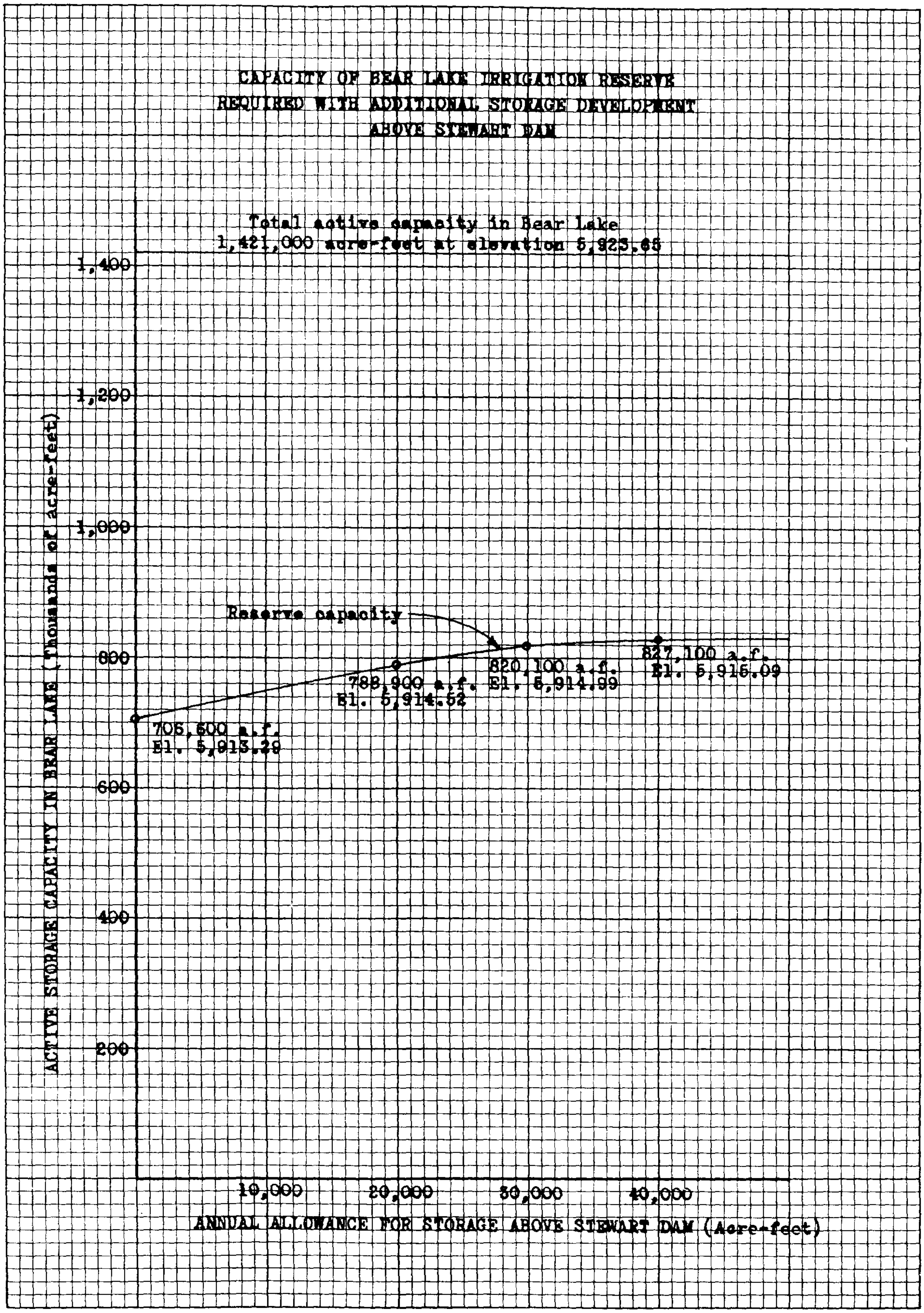


1924-1954 period
Average annual supply 273,800 acre-feet

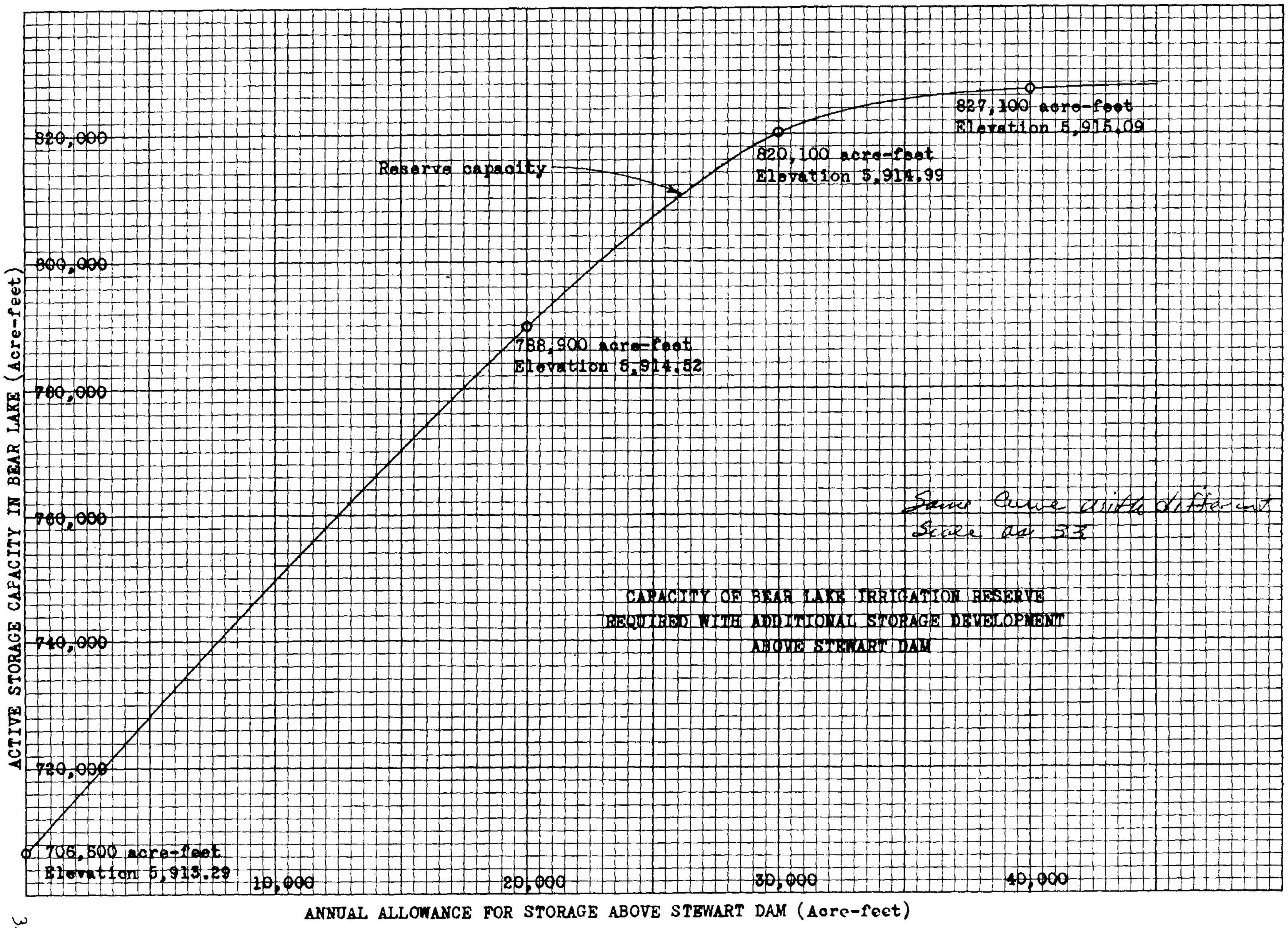
Gross Supply



1924-1948 period
Average annual supply 254,400 acre-feet

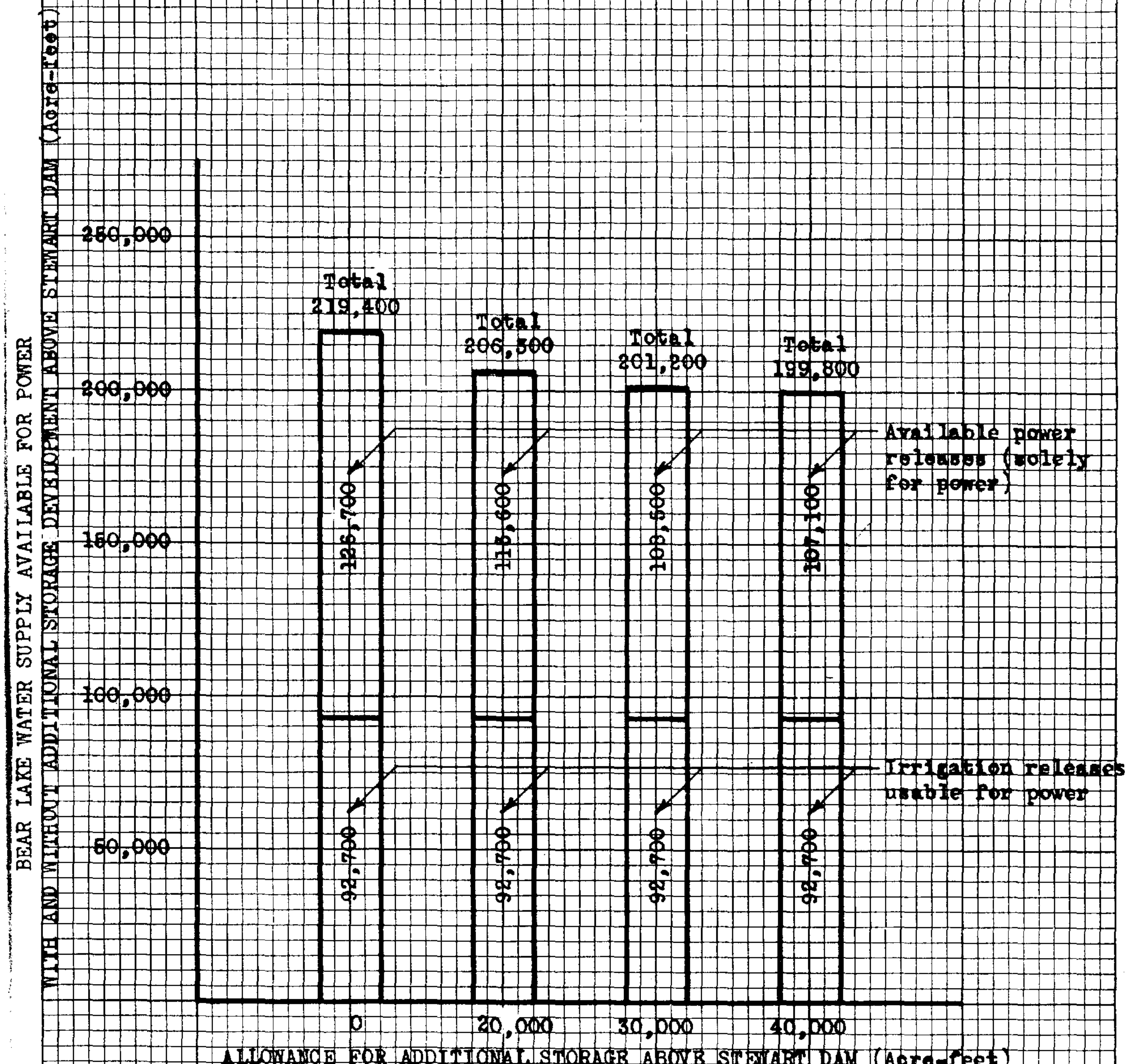


CAPACITY OF BEAR LAKE IRRIGATION RESERVE
REQUIRED WITH ADDITIONAL STORAGE DEVELOPMENT
ABOVE STEWART DAM
Total active capacity in Bear Lake
1,421,000 acre-feet at elevation 5,923.65
1,400
1,200
1,000
800
600
400
200
Reserve capacity
706,600 a.f.
El. 5,913.29
788,900 a.f.
El. 5,914.52
820,100 a.f.
El. 5,914.99
827,100 a.f.
El. 5,915.09
10,000
20,000
30,000
40,000
ACTIVE STORAGE CAPACITY IN BEAR LAKE (Thousands of acre-feet)
ANNUAL ALLOWANCE FOR STORAGE ABOVE STEWART DAM (Acre-feet)



CAPACITY OF BEAR LAKE IRRIGATION RESERVE
REQUIRED WITH ADDITIONAL STORAGE DEVELOPMENT
ABOVE STEWART DAM

BEAR LAKE WATER SUPPLIES AVAILABLE FOR POWER
(Average annual, based on 1924-1954 period)



(Diagram includes only the water supplies that are storable in Bear Lake. Does not include water supplies originating below Bear Lake.)