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Storage and Conveyance Alternative Component Refinement Process

Prepared by the CALFED Storage and Conveyance Refinement Team
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I. Introduction

The purpose of the storage and conveyance component refinement process is to develop a range in which the storage and conveyance components are reasonably well balanced in capacities. By this we mean that the selected combination of components would operate efficiently over a normal range of hydrologic conditions, thus incurring the least cost and environmental impact associated with providing water supply opportunities. The results reported here are intended to provide CALFED agencies and stakeholders with an introduction to the use of DWRSIM system simulation modeling, coupled with spreadsheet post-processing, as tools in the component refinement process. It is important to emphasize that the information provided here is very preliminary and subject to revision. Initial component choices in no way reflect an endorsement of or rejection of specific facilities. Increasingly detailed site and facility evaluations will take place as more complete information becomes available and as analytical tools are improved. In addition, a more complete range of operating assumptions and impact analyses will be evaluated in later phases as well.

The Benchmark DWRSIM run (472) was the foundation for the preliminary analysis described in this report. It was based on the assumption that existing facilities and operating constraints would apply, with the exception that export water demands were for the year 2020. Due to the large number of model changes recently incorporated into DWRSIM and the tight scheduling constraints imposed by the CALFED Bay-Delta solution finding process, this run was released before it could be fully evaluated. It will be reviewed and updated as the model changes are fully debugged and verified.

Based on the preliminary Benchmark Run, water supply opportunities and the effects of various storage and conveyance facilities were evaluated using post processing spreadsheets. The spreadsheets were used in place of additional DWRSIM runs due to delays in implementing extensive modifications to DWRSIM (described in the attached assumptions packages) and due to the large number of runs required to define the relationships between the various facilities and water supply opportunities.

This preliminary refinement process evaluated various storage and conveyance components, including north of Delta surface and groundwater storage, through-Delta and dual transfer conveyance, in-Delta storage, and south of Delta surface and groundwater storage. The effect of various combinations of these components, added to the existing water management infrastructure, was also evaluated.

In the spreadsheet post-processing existing facilities could not re-operated to take advantage of new facilities due to the complex nature of the coordinated operations of the CVP and SWP. The process simply identifies available water supply opportunities and allocated that water based on existing operating rules and assumed conveyance and storage constraints. Implemented carefully, this approach can provide reasonable comparative results. Spreadsheet results will be verified by conducting detailed DWRSIM runs, which integrates the operation of the entire system, once DWRSIM modifications are completed. Based on the results of the initial refinement process documented herein, further changes and refinements will be made to achieve balanced combinations of components.

During this refinement process it is impossible to anticipate what changes in operational rules may eventually be selected for operating the system to achieve environmental and water supply objectives. For the most part, it was assumed that the system would be operated according to existing rules, including the May 1995 Water Quality Control Plan. These assumptions are set forth in the attached **"DWR Planning Simulation Model (DWRSIM) Assumptions for CALFED Benchmark Study 1995C6D-CALFED-472"**. Additional assumptions were required to operate the proposed additional storage and conveyance components using spreadsheet post-processing. Those assumptions are documented under separate cover. There is substantial uncertainty over future no-project conditions, including implementation of the Central Valley Project Improvement Act, Trinity River flow allocations, allocation of American River flows, coordinated operations of the SWP and the CVP, and third-party participation in the State Water Resources Control Board Water Quality Control Plan implementation. Pending resolution of these and other uncertainties, the Team felt that the most reasonable approach was to proceed by assuming current operating rules. The following paragraphs provide some background regarding the Modeling Team's reasoning in arriving at these assumptions, as well as caveats regarding their intended use.

II. Water Supply Opportunities

The proposed surface and groundwater storage components north of the Delta would be filled only after existing needs for water are met, including in-basin consumptive use, in-stream flow requirements, and Delta protective standards. In addition, this analysis also assumes that further diversions from the Sacramento River system would not occur until adequate seasonal flushing flows had occurred. Such flows are assumed to help restore river gravels, to maintain the river meander zone above Chico Landing, and to move salmon smolts downstream. A preliminary evaluation of the historical record suggests that when Sacramento River flow at the latitude of Hamilton City (River mile 200) equal or exceed 550 thousand acre feet in a given month, the river will experience peak flow in excess 60,000 cfs some time during the month. For the sake of this preliminary analysis, these flows are deemed to be sufficient to meet the need for seasonal flushing.

The post-processing spreadsheet models included the assumption that diversions of water to off stream storage were allowed only after this flushing flow requirement had been met. Flows available for storage are defined as the minimum of:

1) Flows in excess of navigation flows at Wilkins Slough,

2) Flows in excess of minimum salinity repulsion flows at Freeport,

3) Flows in excess of minimum Delta outflow requirements, and

4) Flows that would not cause the Delta Export/Inflow ratio to exceed the acceptable limit.

The same rule was applied to determine when flows could be diverted to north of Delta groundwater storage. When flows were limiting, the spreadsheets gave a higher priority to filling ground water storage reservoirs and second priority to filling surface water storage. The reason for this is that diversion rates to groundwater are often limited by the rates at which water can be injected or infiltrated to storage.

III. Accounting for Water Supply Benefits and Impacts

During the development and review of the storage and conveyance refinement assumptions there was considerable discussion and concern regarding how water supply opportunities could be accounted for. The initial proposal by the Modeling Team was to use changes in SWP supplies as a surrogate for water supply opportunities for all beneficial uses. Several agency representatives expressed concern that this would be too narrow an approach, which could skew the results of the analysis. Accordingly, the spreadsheet analytical approach was modified to include environmental demands and unmet CVP demand as well as unmet SWP demands. It is likely that future storage and conveyance components would be integrated into both the State Water Project and Central Valley Project, with an effect on the water supply from both systems.

To estimate environmental demands, above those defined by existing Delta operating rules and in stream flow requirements, a surrogate was applied which assumed that Delta outflow would not be allowed to fall below 7,000 cfs until reservoir storages were exhausted. This resulted in reservoir filling during times of high flow and releasing it during periods of low flow. This approach does not imply a recommendation that new Delta outflow criteria be set; rather it serves as an example of how such rules can affect reservoir analysis results.

The spreadsheets allowed for varying allocation of available storage to environmental and project purposes, on a pro rata basis.

It was recognized that criteria for sharing resources between the SWP and CVP are uncertain under the May 1995 WQCP, and therefore this issue will need to be carefully reviewed and modified for Phase II of the analysis.

Similarly, there are many ways to allocate new supplies between environmental, agricultural, and urban needs. Various allocation themes can be developed through open CALFED technical discussions and negotiations and bundled as alternative operating constraints. Water supply benefits and impacts can then be compared to specific targets. The relatively crude criteria for protection of in stream values and criteria for release of water for environmental benefits are expected to be refined by the Ecosystem Restoration Workgroup and other CALFED workgroups.

IV. Conveyance Assumptions

The 1994 Bay-Delta Accord is based on the need to protect a wide range of beneficial uses, based on the existing configuration of the Bay-Delta system. A significant alteration of the existing through-Delta water supply system would likely require a re-evaluation both to assure that beneficial uses are protected and to assure that operating rules are not unnecessarily restrictive.

Among the most likely candidates for re-evaluation would be the Delta export-inflow ratios, designed to limit entrainment of eggs, larvae, and fish at in-Delta export facilities. If part of the inflow to the Delta is diverted through one or more screened intakes at the northern end of the Delta into an isolated conveyance channel, that portion of the inflow could be either counted as part of the Delta inflow or subtracted from the Delta inflow. Similarly, export flows taken through an isolated conveyance could be counted either way. Thus without making any changes to the existing Bay-Delta standards there are various ways to compute the export-inflow ratio. The two most likely approaches would be to:

- Include the isolated component in both inflow and export when computing the ratio.

- Delete the isolated flow from both inflow and export when computing the ratio.

The Team felt that the issue of how to account for the isolated export component required discussion among a broad group of stakeholders. To facilitate that discussion and to gain some insight into the sensitivity of the system to changes in this criterion the spreadsheet post-processing was run both ways.

V. Surface Storage Facility Assumptions

In order to evaluate the performance of the various storage components we needed to assume general geographic locations, capacities, and operating rules for filling and emptying. For

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example, as a surrogate for north of Delta surface storage we assumed a reservoir in the foothills west of Colusa. For south of Delta surface storage, we assumed a reservoir in the vicinity of the existing San Luis Reservoir. In the future, additional analysis will be performed to test the sensitivity of these assumptions for geographic locations.

For in-Delta storage, specific islands were not selected. However, the assumption was made that the islands would be close enough to the SWP and CVP export facilities to provide direct connections through a series of siphons, thus eliminating the need to screen export water from this source twice.

It is important to emphasize that these choices in no way reflect an endorsement of or rejection of specific facilities. Detailed site and facility evaluations will take place in Phase II or Phase III of the process.

VI. Groundwater Storage Facility Assumptions

Groundwater resources can be used to provide increased groundwater storage in several ways. One approach, referred to here as direct groundwater storage, involves treating the groundwater basin like a surface water reservoir, except that it is filled by seepage from percolation basins or injection wells, and emptied by pumping from wells. This approach may involve high capital and operating costs, and is limited by the capacities of project facilities.

A second approach, referred to here as in-lieu groundwater storage, involves varying regional uses of groundwater and surface water resources such that surface water deliveries are supplemented in wet years and cut back in dry and critical years. This results in greater annual variations in groundwater use and storage. The net effect is to make greater stream flows in wet years available for other uses during dry and critical years. The in-lieu approach tends to be more practical and economical, because it takes advantage of water use patterns over large areas and existing water distribution and extraction facilities.

Both of these approaches will be evaluated for the areas upstream of the Delta during the extended component refinement process. However, the extensive DWRSIM programming and input data development required to simulate in-lieu conjunctive use has not been completed at this time. Accordingly, only the groundwater storage option was analyzed.

Direct Groundwater Storage

The evaluation of north of Delta groundwater resources was simplistic due to the lack of detailed hydro-geologic information and lack of operational experience.

The overall approach for modeling direct groundwater storage in the Sacramento Valley was to identify areas in which natural recharge through seepage from nearby streams was relatively slow. During this refinement process it is premature to model specific storage areas; rather it was assumed that the groundwater basins could be simulated as a single basin, with composite recharge, storage, and discharge characteristics. This basin would be incorporated into DWRSIM through a single node, through which flow project recharge, non-project recharge, and pumped withdrawals from storage.

A maximum of 500,000 acre-feet of operable groundwater storage capacity was assumed. A maximum project recharge rate of 500 cfs and discharge rate of 1000 cfs were assumed. In addition, the total non-project recharge capacity was set as a function of the percent of dewatered to reflect hydro geologic constraints.

Non-project recharge was accounted for in project operations whenever the groundwater basins are only partly filled. The rate of recharge is greatest when the groundwater basin is depleted, diminishes as it fills, and ceases at 60 percent of capacity. Whenever artificial recharge occurs, the simulated volume of water in storage is updated, and the natural recharge rate adjusted downward accordingly. These rules simplistically simulated the assumed natural recharge pattern.

Implementation of groundwater storage components which rely on direct withdrawal of groundwater for export from the Sacramento Valley would need to be coordinated with institutional constraints such as Sect 1220 of the Water Code. This Section prohibits groundwater extraction from the Sacramento Valley for export, unless certain conditions are met.

For south of Delta groundwater storage it was assumed that simulating a groundwater storage basin with characteristics like those underlying the Kern River fan would provide insight into the potential effects on water supply opportunities of groundwater facilities developed elsewhere in the San Joaquin Valley. Such facilities have been described in detail elsewhere.

In-Lieu Groundwater Storage

This option involves altering delivery patterns to areas where surface water and ground water resources are both used for irrigated agriculture. In wet years additional surface water would be delivered, allowing groundwater resources to accumulate; in dry and critical years surface water deliveries would be reduced, resulting in a greater use of groundwater storage in meeting total demands.

Various approaches to modeling conjunctive use within DWRSIM have been considered. The most promising approach would involve modifying the input hydrology files for one or more of the Depletion Areas. The demand pattern would have the same shape as the existing pattern within a given Depletion Area; only the annual volume would be adjusted.

The demand during wet years (based on the Sacramento River Index) would be increased to reflect increased surface deliveries, while the demand during dry and critical years would be reduced to reflect increased groundwater use. The current hydrologic record has about 20% wet and 20% dry and critical years.

As a starting point for evaluation, 100 TAF would be exercised in any given year. Subsequent evaluations could look at 200, 300, and greater annual volumes. Due to non-project seepage, additional reservoir releases would be required to transport a given water volume. For example, to deliver 100 TAF, a release of 125 TAF might be required. The 25 TAF would offset non-project recharge.

The net effect of any program which exercises groundwater storage would be a reduction in the long-term average groundwater level (except in areas where groundwater levels are already depressed due to overdraft). Therefore a key criterion for implementation would be that there be no long-term unmitigated effects.

The simulation approach would be similar for both the Sacramento Valley and the San Joaquin Valley.

VIII. Refinement Process Results

The following categories of facilities were considered:

North of Delta (Tributary) Conjunctive Use
North of Delta (Tributary) Surface Storage
In-Delta Surface Storage
Delta Conveyance
South of Delta (Off-Aqueduct) Storage
South of Delta (Off-Aqueduct) Conjunctive Use

Each of the various types of storage facilities noted in this list could be provided with a range of conveyance facilities for moving water to and from storage. In addition, there is a limitless range of possible operating rules for meeting water supply needs and meeting environmental protective goals. As a result, there is a very large number of possible combinations of facilities and operating rules which could be explored to determine which were most effective and economical. For example, if the analysis is restricted to four incremental capacities for each of the above types of facilities, the potential operating rules are bundled into 5 sets, and 5 Delta conveyance configurations are evaluated, there would be over 100,000 possible combinations.

It is not practical to investigate these alternative combinations exhaustively. Instead, the components were first evaluated individually, then evaluated in a few combinations to evaluate their interactions, as follows:

- North of Delta Surface Storage and Conveyance: Determine a reasonable pairing of north of Delta off stream reservoir storage capacity and the conveyance capacity between the reservoir and source stream.

- Individual Storage Components: Evaluate each storage component individually over a range of capacities, assuming existing Delta conveyance capacity.

- Combined Storage Components: Evaluate the effect of one or more storage components working together, assuming existing Delta conveyance capacity.

- Improved Delta Conveyance: Determine the impact of improved Delta conveyance capacity on individual and combinations of north of Delta and off-aqueduct reservoir storage capacity.

North of Delta Surface Storage and Conveyance

A series of spreadsheet analyses were run, varying both reservoir capacity and conveyance capacity to the reservoir. The result was a series of curves as shown on page 42. In general, incremental reservoir water supply contributions decreased with increasing capacity because the odds of filling a reservoir each season decreases. For a given reservoir capacity, incremental benefits of additional pumping capacity also decreased with increasing capacity. Thus there are decreasing marginal rates of return for both storage and conveyance. The upper limits are defined by the available water supply opportunities in the Sacramento River system, by assumed demands for water releases from storage, and by the incremental costs associated with each incremental improvement in water supply.

The relationship between the capacities of the storage and conveyance capacities is a function of relative cost and hydrology. For example, if conveyance capacity is costly relative to storage capacity, the best combination would be a reservoir with relatively small conveyance capacity to and from the river system.

For the preliminary analysis the cost of storage was assumed to follow the cost curve for "West-Side Sacramento Valley Storage (Sites)" and the cost of conveyance was assumed to follow "Conveyance from Chico Landing to the T-C Canal". Costs included both capital and O&M costs, but were based upon simple escalation of previous studies, and are therefore assumed to be low by current standards. Simple cost escalation involves applying a multiplier to the original cost figures to reflect inflation and, to some extent, changes in construction practice. However, such cost escalation may not accurately reflect changing environmental mitigation requirements, new seismic standards, and other cost escalation factors unique to a particular area. The cost curves will be refined as better information becomes available. The selection of these curves does not imply that these facilities have been selected; rather they are used to evaluate and refine the analytical approach, as well as to provide an order of magnitude basis for facilities evaluation.

It was assumed that all water would be provided to the reservoir through the new conveyance from the Sacramento River near Chico Landing, in order to minimize impacts upon the unleveed portion of the Sacramento River most important for salmon spawning and rearing habitat.

The analysis is shown in calculations labeled "(1)North of Delta Storage, Surface, 9/21/96" and "(2)...". Based on these, the following relationships were selected:

Reservoir Capacity	Stream to Reservoir Conveyance Capacity
500 taf	2000 cfs
1000 taf	3000 cfs
2000 taf	4000 cfs
3000 taf	5000 cfs

For any portion of reservoir storage and stream to reservoir conveyance capacity devoted to Delta outflow and north of Delta environmental purposes there is no dependence upon Delta conveyance capacity.

Individual Storage Components

In the spreadsheet post-processing, all new storage reservoirs were assumed to be operated to meet demands without regard to carryover for future years. This had the effect of overestimating reservoir yields since storage is thereby assumed to be more fully exercised each season than would be likely with real facilities. In practice, releases are usually cut back when reservoir storage is depleted as a hedge against drought in following years. In addition, reservoir evaporation was not included as an annual loss in the spreadsheet analyses, again resulting in an overestimate of yield. These factors, coupled with the assumptions that the storages would be used to meet both unmet SWC and CVP demands, result in higher water supply benefit estimates than previously estimated. The results are very preliminary, and are presented in order to familiarize CALFED participants with the analytical tools and general patterns of system response to new facilities.

A range of north of Delta surface storage capacities from zero to 8,000 thousand acre-feet was evaluated. The average annual incremental gains in water supply opportunities were plotted as a function of storage capacity. The average annual water supply opportunities were evaluated for the entire 71 years of record as well as for the critical 7 year period from March, 1928 to February, 1935.The evaluation was performed three different ways: Assuming that all the water would be devoted to project water supply, that all the water would be devoted to environmental enhancement, and assuming that the water would be devoted to both, in a 50/50 split. Figures 1, 2, and 3 show the results.

When the reservoir is devoted exclusively to either environmental or project purposes, the annual water supply benefit curves are similar. For benefits averaged over the entire period of record, there is a clear decrease in slope at about 600 TAF-800 TAF capacity, with smoothly decreasing benefits thereafter. Although the maximum size would ultimately be affected by cost, it is clear that beyond 2,500 TAF the incremental gains in benefits are slight. For benefits averaged over the critical period, the two break points are at 400 TAF and 2500 TAF respectively.

When the reservoir capacity is allocated 50/50 between environmental and project uses, the benefits curve for benefits averaged over the entire 71 year period of record rises correspondingly, indicating that demand, rather than available water supply opportunities, limited the benefits of the reservoir when devoted to a single purpose. As Figure 3 shows, for benefits averaged over the entire 71 year period of record, there is a break point at 1000 TAF, with gradually decreasing slope thereafter. For benefits averaged over the critical period, the two break points are at 400 TAF and 2000 TAF respectively and the net benefits curve is lower than for the single purpose options, because the heavy demands on the reservoir during periods of inadequate supply drain the reservoir sooner.

North of Delta groundwater storage was limited to a maximum of 500 TAF maximum depletion, as described earlier, but evaluated over a range of 0-700 TAF. With flow to storage limited to 500 cfs and pumping from storage limited to 1000 cfs, there is one break point in the curve at 100 TAF and none thereafter (Figure 4). This reflects the fact that the assumed groundwater storage configuration is not nearly large enough nor with sufficient in/out capacity to take advantage of available water supply opportunities.

In-Delta Storage was evaluated over a range of 0-700 TAF (Figure 5). In-Delta storage was operated for both environmental and project benefits. There is no distinct break point in the supply benefits curve, which decreases in slope monotonically throughout. The maximum storage capacity as a stand-alone project would be dictated by economics and physical constraints.

South of Delta surface storage was evaluated over a range of capacities between 0 and 3,000 TAF (Figure 6). For both the 71 year period of record and the 7 year critical period, there is a distinct break point in the vicinity of 400 TAF to 500 TAF with existing conveyance capacity.

South of Delta groundwater storage was evaluated over a range of capacities between 0 and 500 TAF (Figure 7). For both the 71 year period of record and the 7 year critical period, there is a distinct break point in the vicinity of 100 TAF with existing conveyance capacity.

Combined Storage Components

North of Delta surface storage and north of Delta ground water storage were analyzed in combination (Figures 1 and 8). For supply benefits averaged over the 71 year period of record, the addition of groundwater storage causes the surface reservoir benefits curve to flatten out at a lower storage threshold, 400 TAF - 600 TAF, rather than 600 TAF - 800 TAF for the surface storage reservoir alone. For the critical 7 year period, the supply benefits curve levels off at a somewhat greater storage, closer to 3,000 TAF rather than 2,500 TAF, and the average annual supply is greater. This reflects the fact that the groundwater storage provides a portion of the critical period supply, delaying the time at which the surface reservoir is drained.

It is most likely that new surface storage north of the Delta would be developed together with implementation of conjunctive use of groundwater. At this early stage of evaluation, with the given operational assumptions, it is reasonable to set the upper limit on north of Delta surface storage at 3,000 TAF.

In-Delta storage was analyzed in combination with north of Delta surface storage and groundwater storage on the assumption that the facilities would be competing for the same supply. Figure 5 shows in-Delta storage alone, whereas Figure 9 shows it in combination with full development of north of Delta surface and groundwater storage (3,000 TAF and 500 TAF respectively). There was virtually no change in the net storage benefits of the in-Delta storage facility, indicating that it can take advantage of additional water supply opportunities further downstream in the river system. Therefore the in-Delta storage facility should not be initially limited to less than 400 TAF. Further economic evaluation of this option would set the upper limit on viable storage capacity, given the gradual decline in incremental benefits with increasing capacity.

South of Delta surface storage and south of Delta ground water storage were analyzed in combination (Figures 10 and 11). For supply benefits averaged over the 71 year period of record, the addition of groundwater storage causes the groundwater reservoir benefits curve to decline with increasing surface. For the critical 7 year period, the groundwater benefits curve declines more rapidly, indicating that water supply is insufficient to charge both surface and groundwater storages prior to the critical period. The results are to some extent an artifact of the analytical process. All storage components are assumed to be empty at the beginning of the spreadsheet analysis in order to eliminate the effect of various combinations of components on starting system storage. It is probably unrealistic to begin by assuming that groundwater storage is fully depleted at the beginning of the simulation. Second, the distribution of water between the south of Delta groundwater and surface water storage components is arbitrary in the spreadsheet post-processing: It assumes that groundwater storage is filled after surface storage. Nevertheless, it is reasonable to conclude that the as the combined groundwater and surface storage volume is increased substantially beyond 1,000 TAF, there are sharply reduced benefits, due to the inability of the system to supply enough water for storage.

It is most likely that new surface storage south of the Delta would be developed together with implementation of conjunctive use of groundwater. At this early stage of evaluation, with the given operational assumptions, it is reasonable to set the upper limit on south of Delta (off aqueduct) combined storage capacity at 1,000 TAF or less, assuming current Delta conveyance constraints.

Improved Delta Conveyance

The storage and conveyance refinement process will ultimately examine the relative benefits and impacts of various Delta conveyance options on water supplies, water quality, aquatic resources, and numerous other resource categories. In this preliminary analysis it was assumed that the existing Delta operating rules would be in effect. These offer no significant advantage to isolated conveyance alternatives as compared to through-Delta alternatives in terms of water supply opportunities. As described under IV. Conveyance Assumptions, the effect of exempting the isolated component of Delta export flows from the inflow-export ratio was evaluated and found to be relatively insignificant. Accordingly, in this analysis we cannot distinguish between various Delta conveyance improvement options, but merely simulate their common assumed effect: Export capacity would be limited only by the physical capacity of the SWP and CVP pumping plants and available water supplies above those required to meet existing and proposed Delta operating rules.

The storage components most likely to be affected by improved Delta conveyance would be south of Delta storage. Figure 10, in comparison with Figure 6, shows the significantly improved benefits of south of Delta storage in conjunction with improved Delta conveyance. The supply benefits curves for both the 71-year average and the 7-year critical period average reach about twice the benefits and break points in slope are at greater storage thresholds. Inspection of Figure 10 suggests that a storage volume of up to 1,500 TAF provides benefits during the critical period. Even larger storage volumes provide benefits when averaged over the 71-year period. !,500 TAF or more storage capacity
should be considered in further analyses for which Delta conveyance improvements are assumed to be completed.

When south of Delta groundwater storage is added (Figure 11), the supply benefits of south of Delta groundwater storage are somewhat diminished as surface storage capacity is increased, indicating that these facilities would to some extent compete for available storable water and in meeting south of Delta demands. That there is no discernible effect on the south of Delta surface storage benefits curves is an artifact of the spreadsheet post-processing; the surface reservoir is given priority in competing for available supplies.

When north of Delta surface and groundwater storage are added to the system, this has the effect of depressing the supply benefits curve for south of Delta surface storage. Thus the effect of a system wide diminishing rate of return was noted (Figures 12, 13, and 14). Figure 14 compares the incremental gain in supply benefits for incremental gain in storage capacity (slope of the supply benefits curves). It shows that a given incremental gain is reached at a significantly lower south of delta surface storage capacity when the other storages are available. For example, the gradient of 0.4 TAF per year of supply per TAF of added storage capacity is reached at 670 TAF for the south of Delta storage facility acting alone, but is reached at 360 TAF when combined with the other storages. Adding in-Delta storage would further accentuate this effect.

This result would suggest that optimal south of Delta surface storage would be significantly less when combined with other storages, and would probably be in the range of 1,000 to 1,500 TAF, depending upon operational rules and economic analyses.

A more detailed analysis would also include the marginal value of water during times of scarcity. During a drought, as water use is increasingly directed to high value uses such as keeping orchards alive, maintaining key industries, direct human use, emergency services, and so on, the marginal value of water may rise to $2000 per acre-foot. Therefore, even though the marginal improvement in annual water supply improvement might be relatively small as reservoir storage becomes large, the value of that additional supply during drought might make it worthwhile. It will therefore be necessary to conduct such a detailed economic evaluation to accurately identify the appropriate reservoir volume.

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Figure 1. Single Component Sensitivity, WP=1, North of Delta Storage

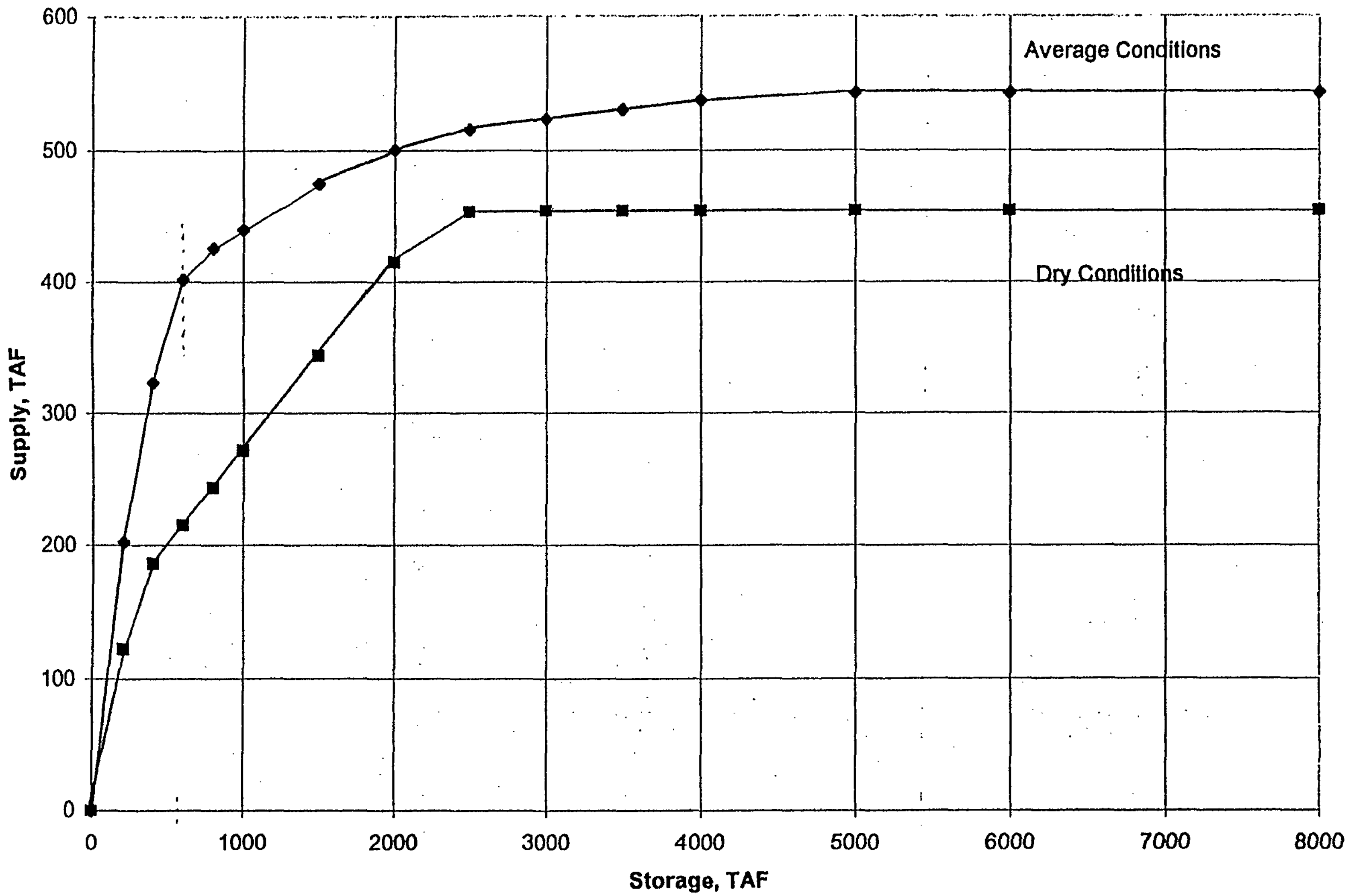

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Figure 2. Single Component Sensitivity, ENV=1, North of Delta Storage

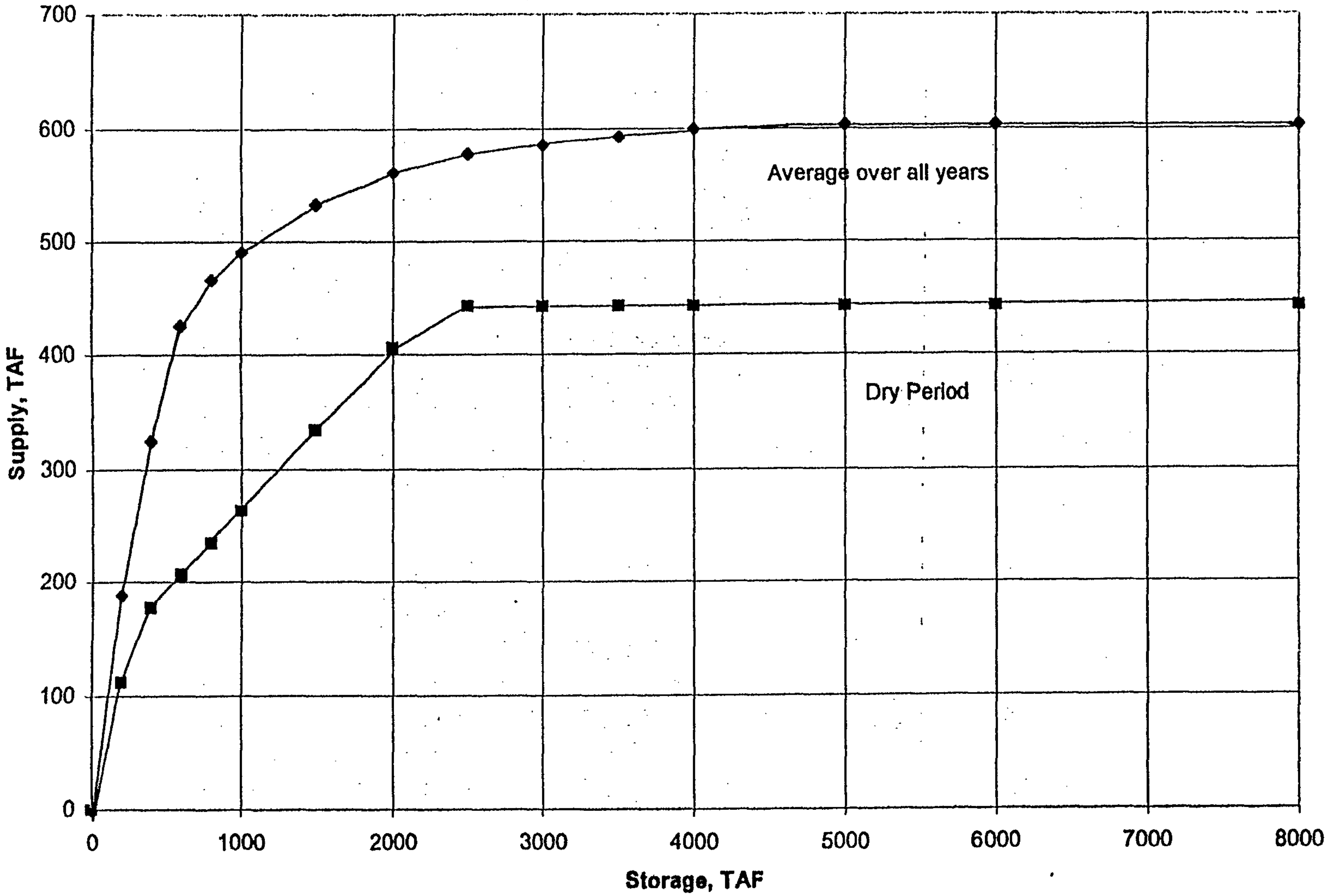

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Figure 3. Single Component Sensitivity, WP=0.5,ENV=0.5, North of Delta Surface Storage

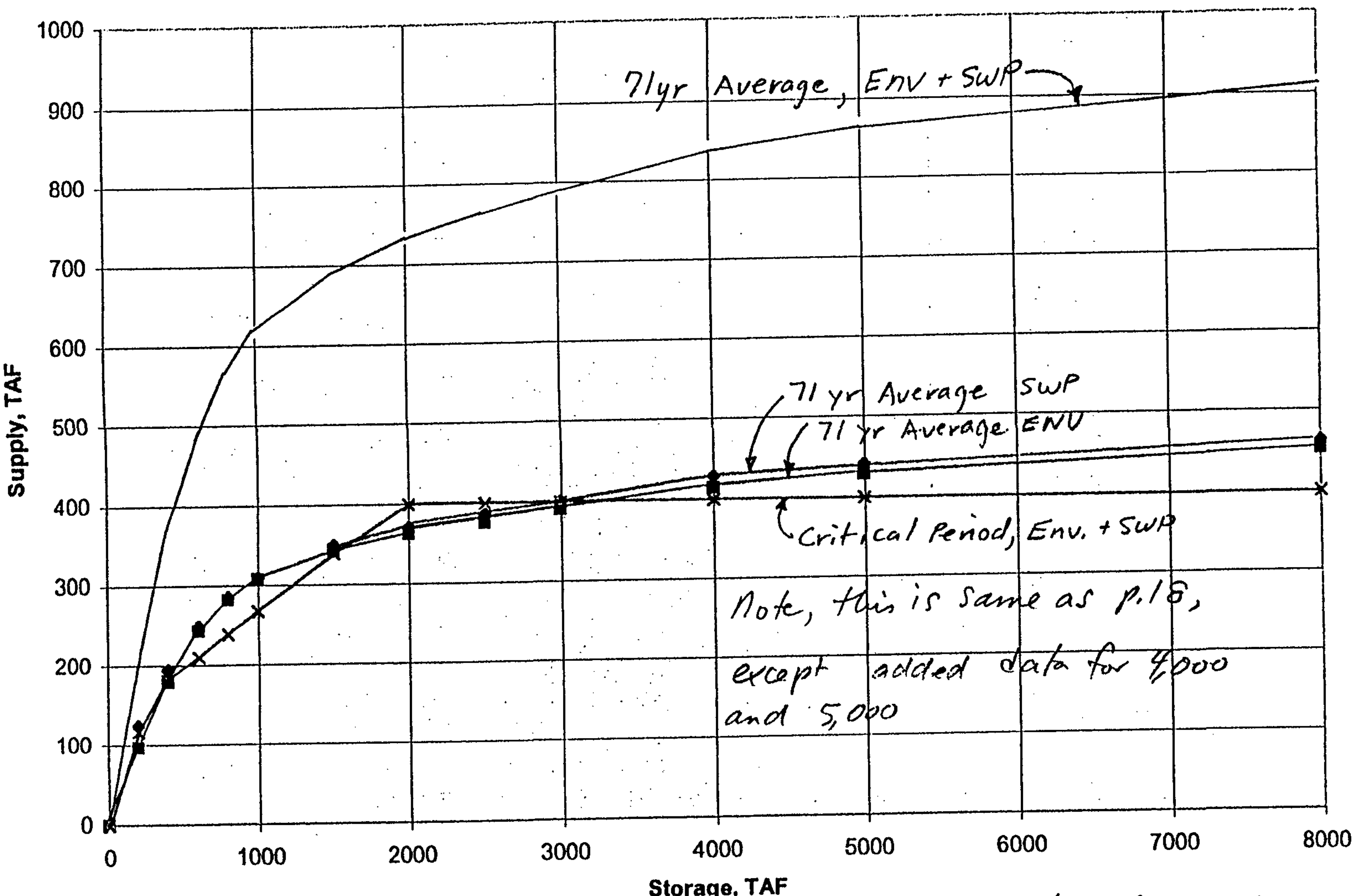

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Figure 4. Single Component Sensitivity, WP=1, North of Delta Groundwater Storage

ENV=1 same

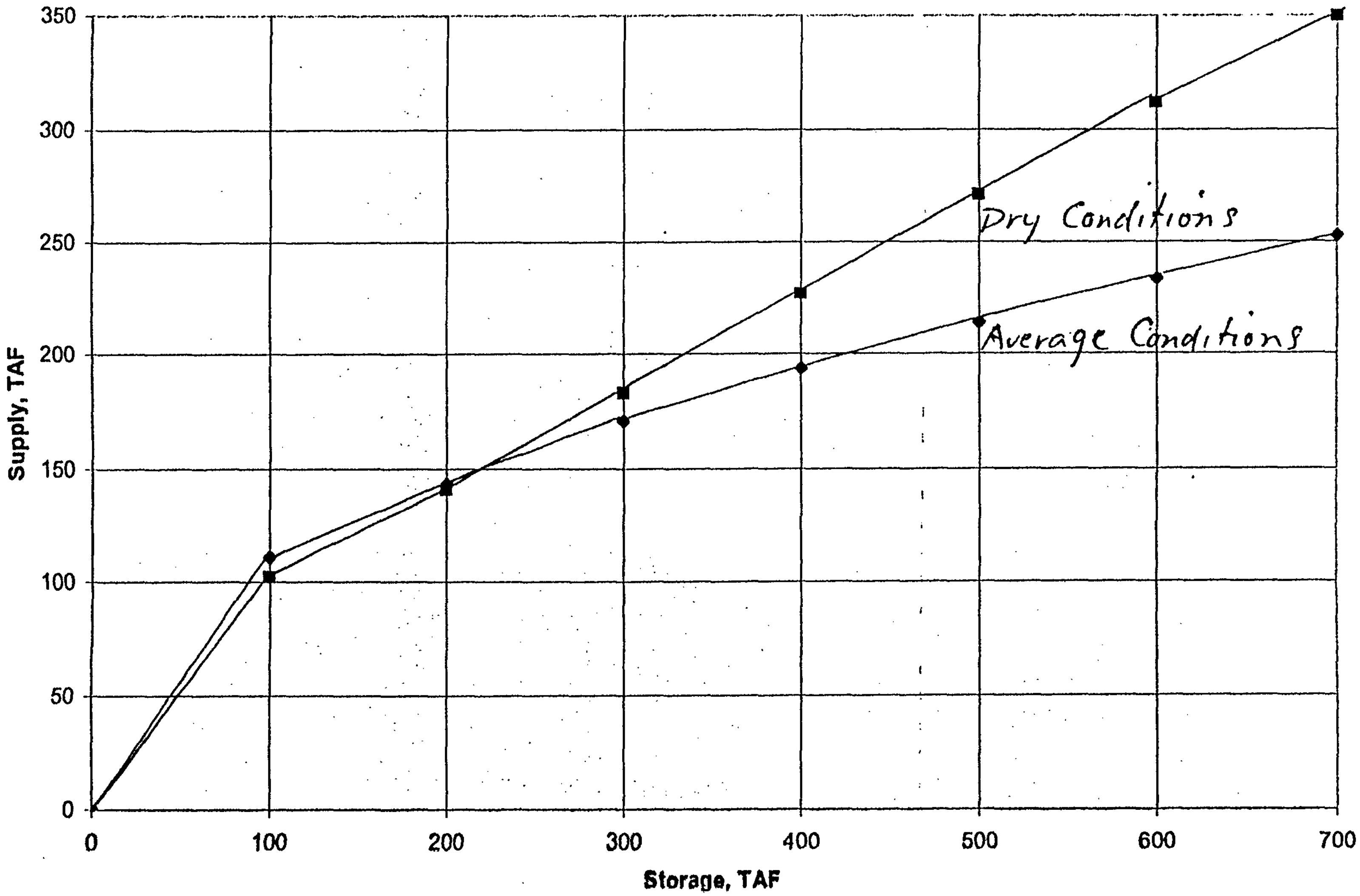

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Figure 5. Single Component Sensitivity, Variable Split, In-Delta Storage

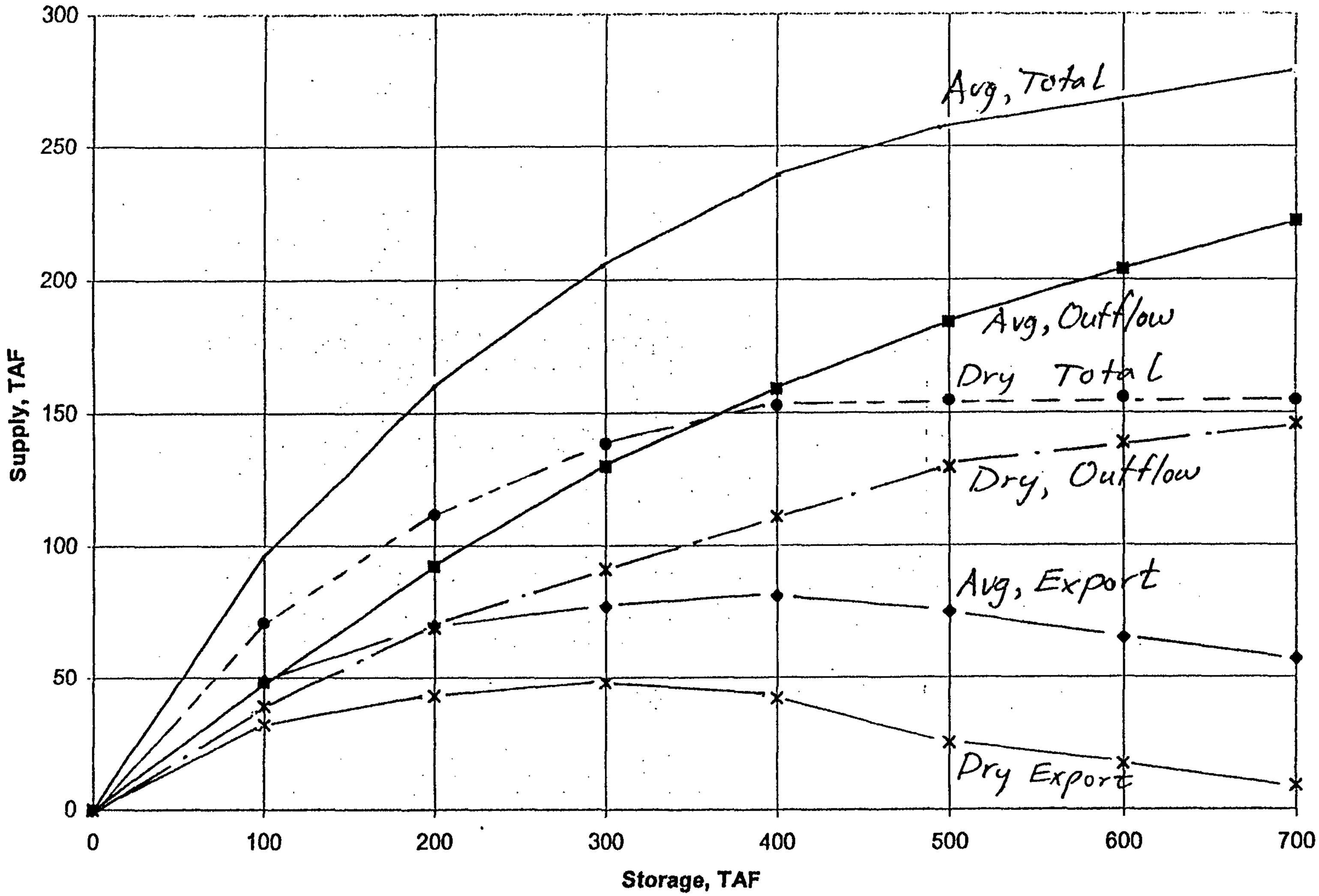

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Figure 6. Single Component Sensitivity, WP=1, South of Delta Storage

ENV=1 Same

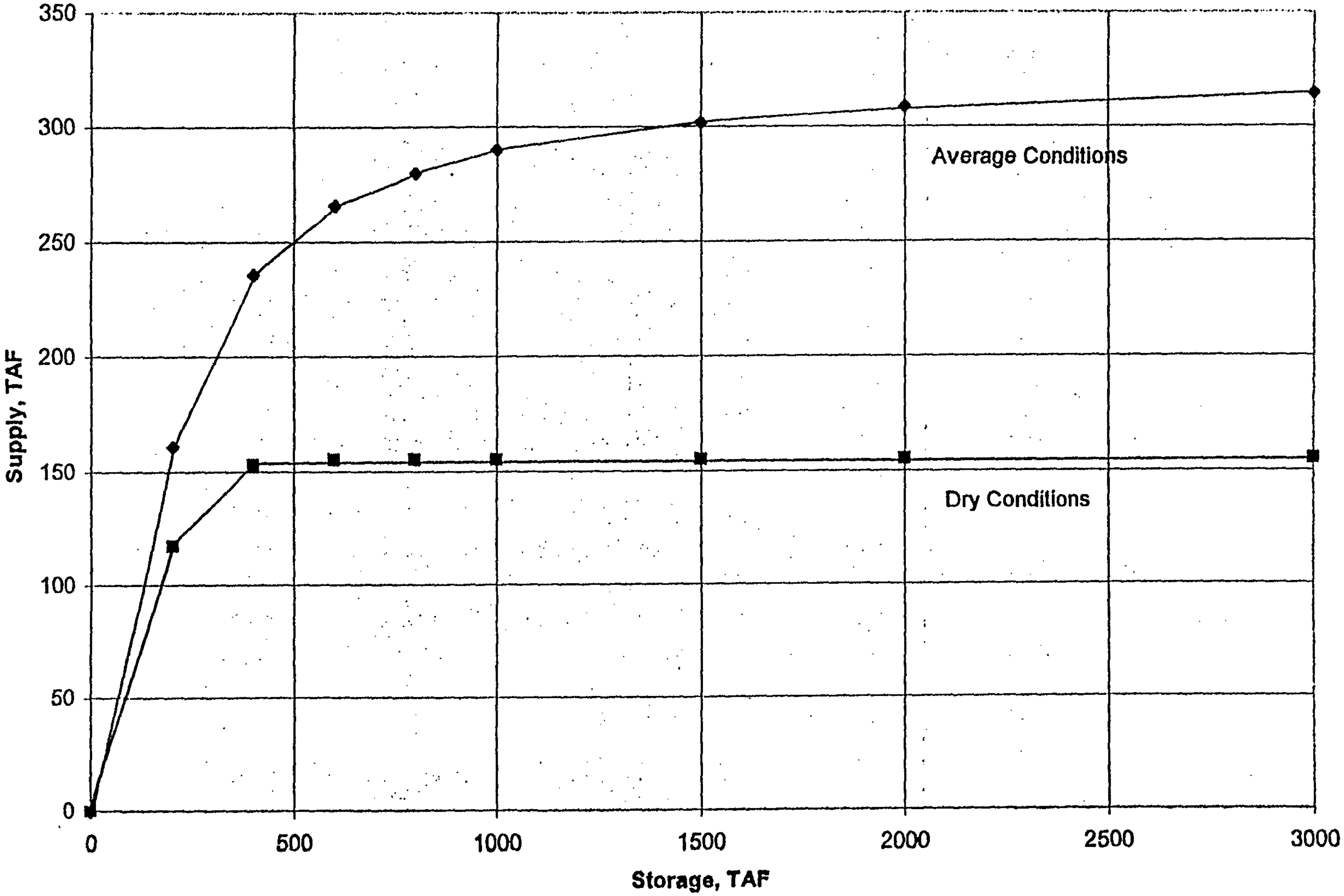

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Figure 7. Single component sensitivity, WP=1, South of Delta Groundwater Storage

ENV=1, same

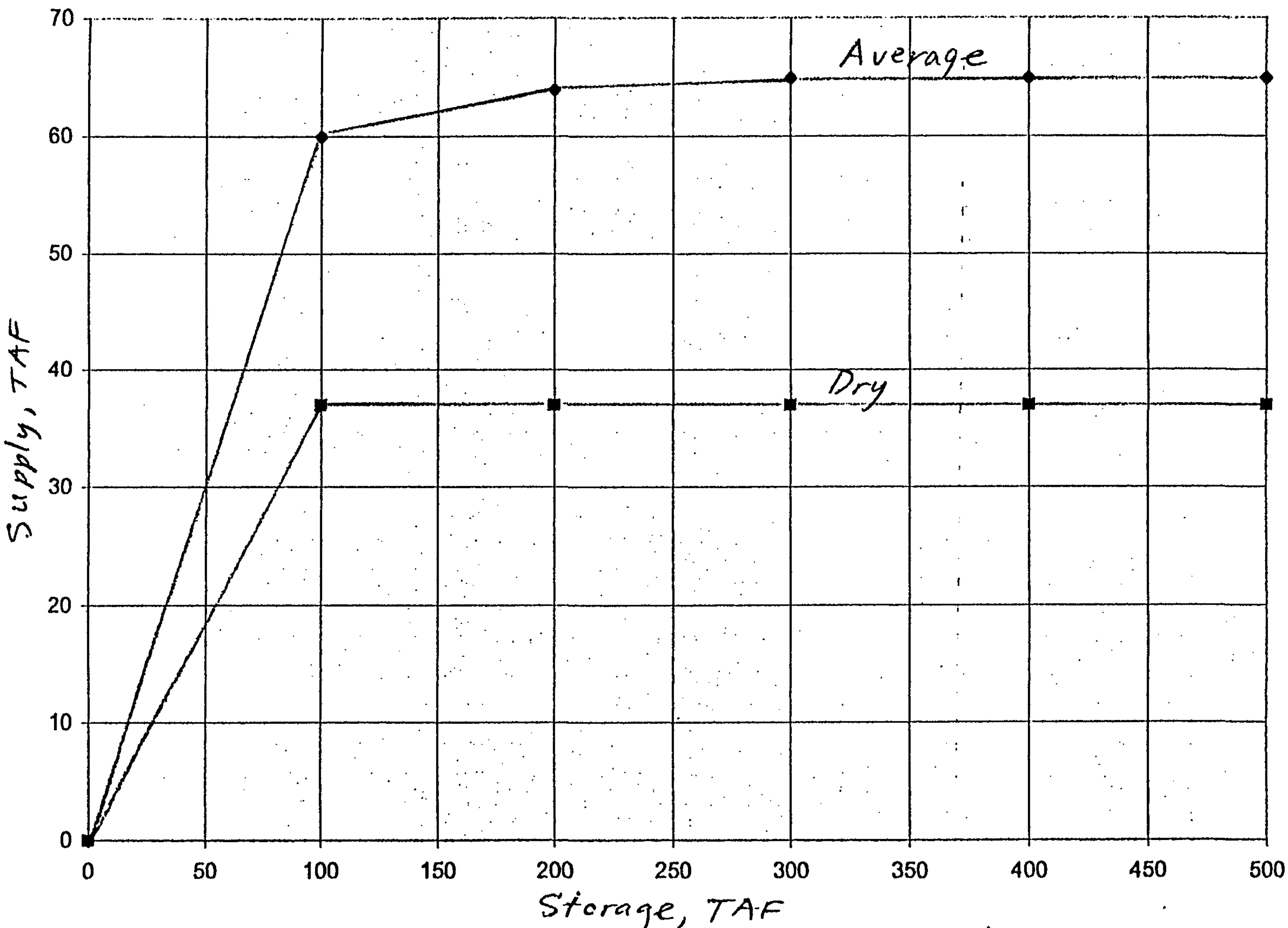

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Figure 8. Dual Component Sensitivity, WP=1, North of Delta Surface Storage + 500 taf gw

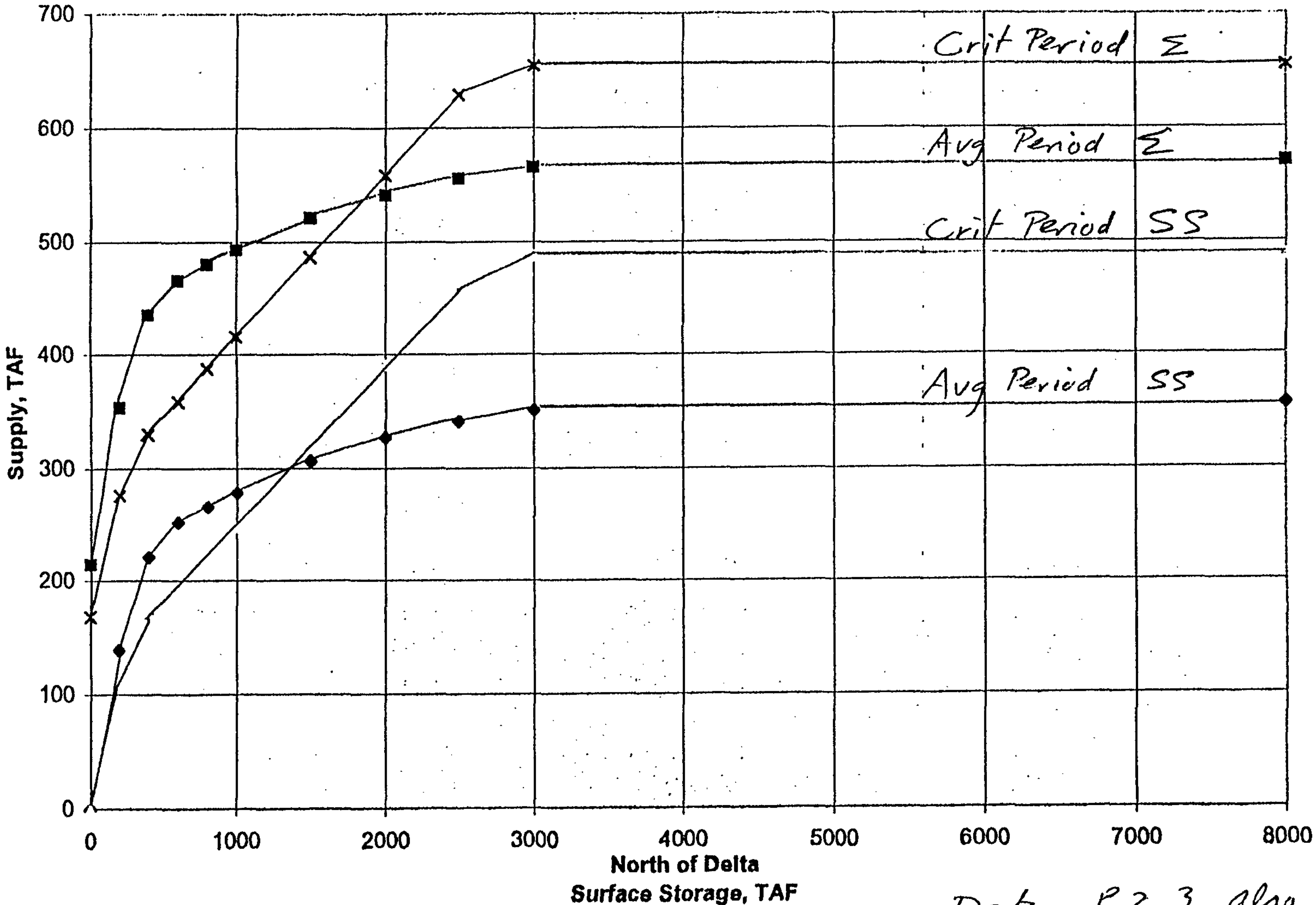

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Figure 9. Dual Component Sensitivity, In-Delta with Max North of Delta Surface and GW Storage

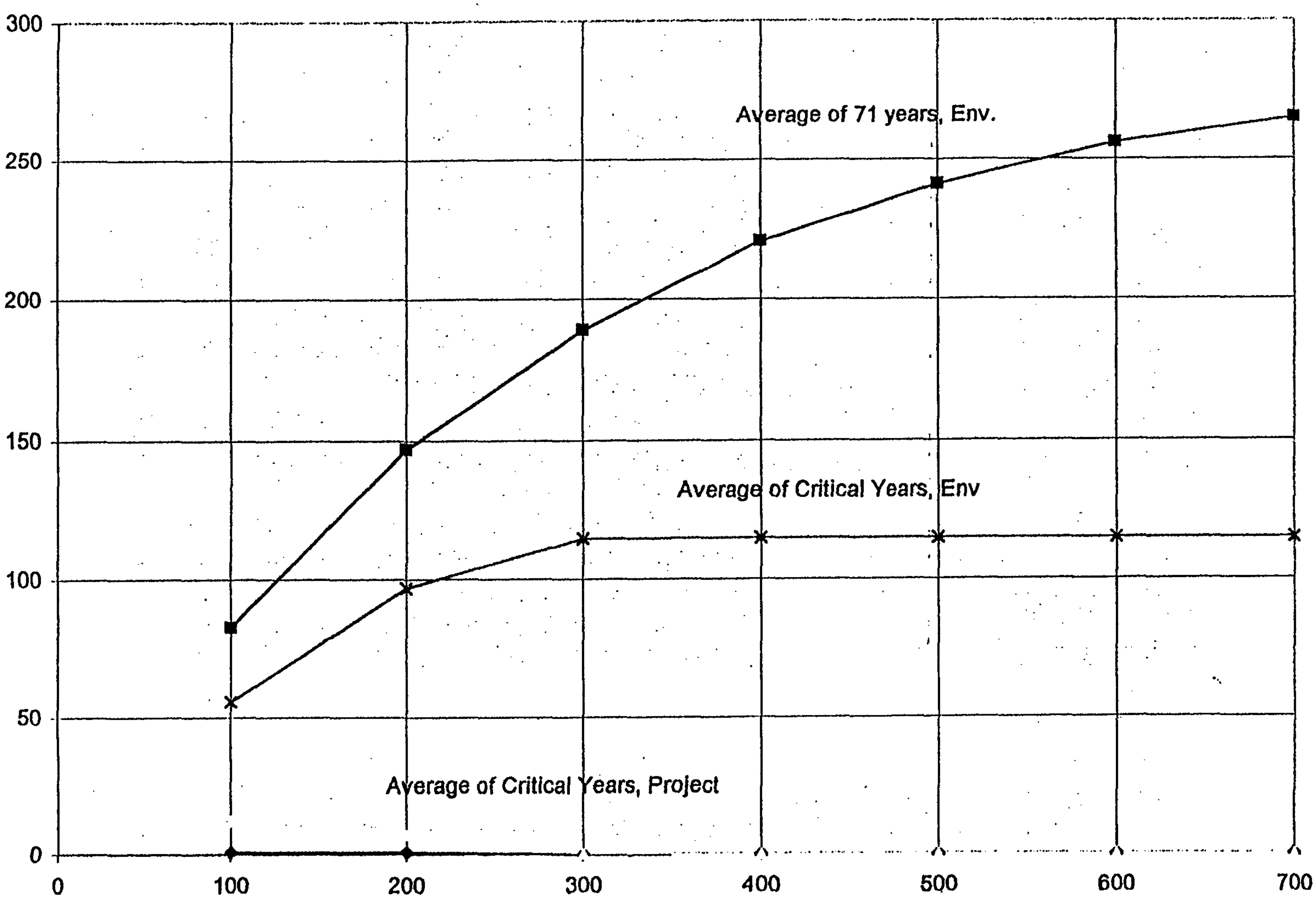

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Figure 10. Single Component Sensitivity, WP=1, South of Delta Storage

with Delta Improvements

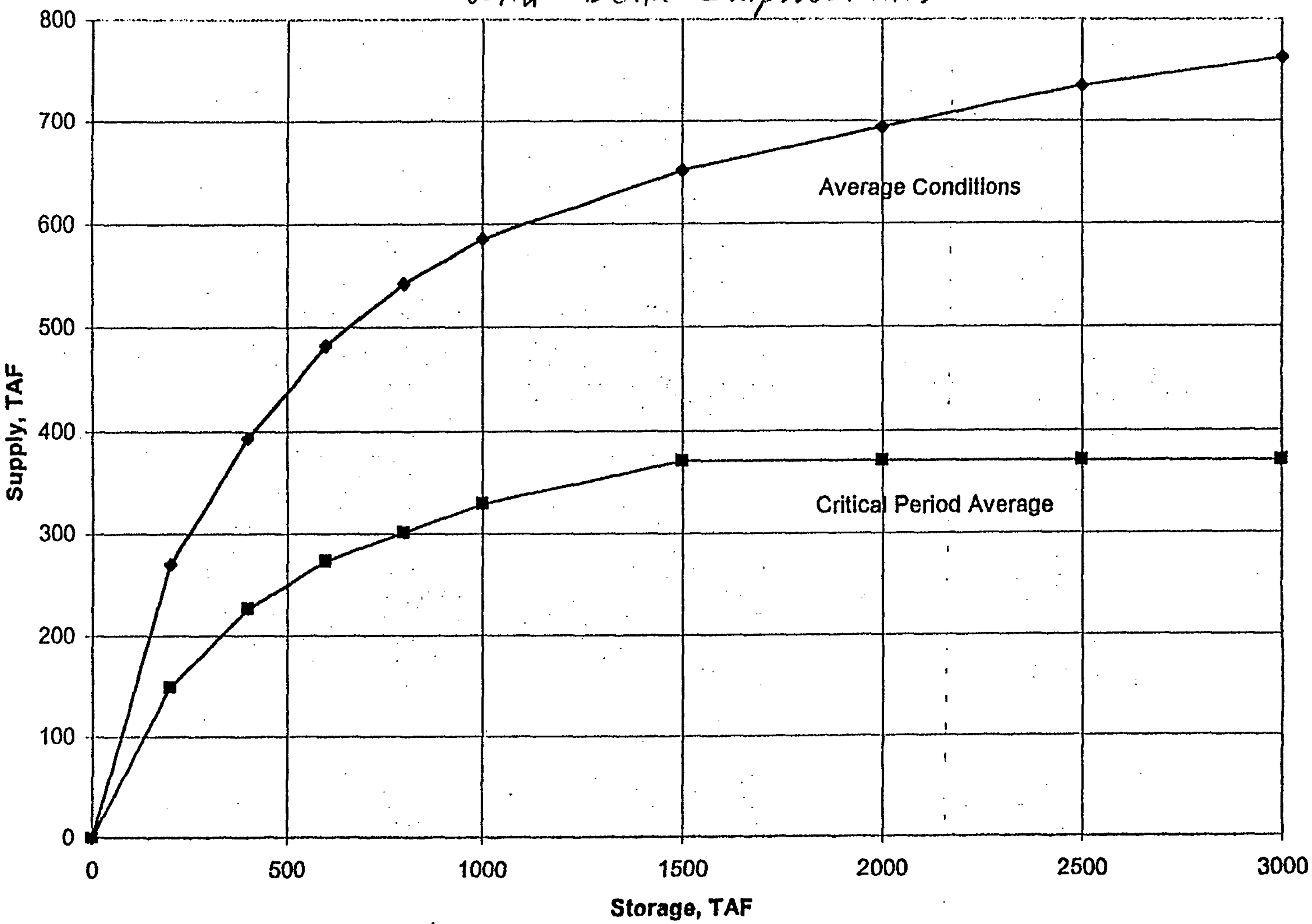

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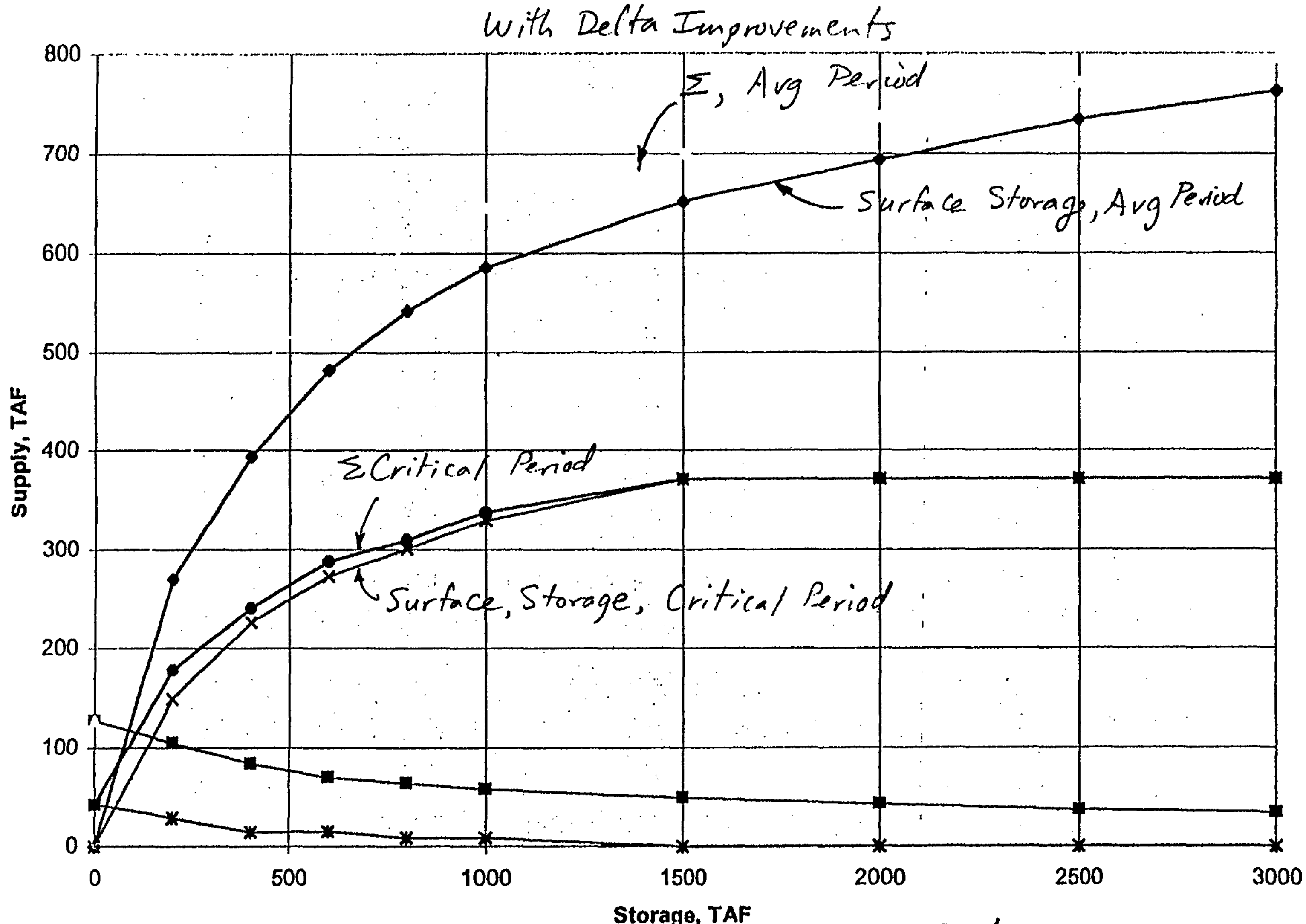
Figure 11. Dual Component Sensitivity, South of Delta Storage +GW



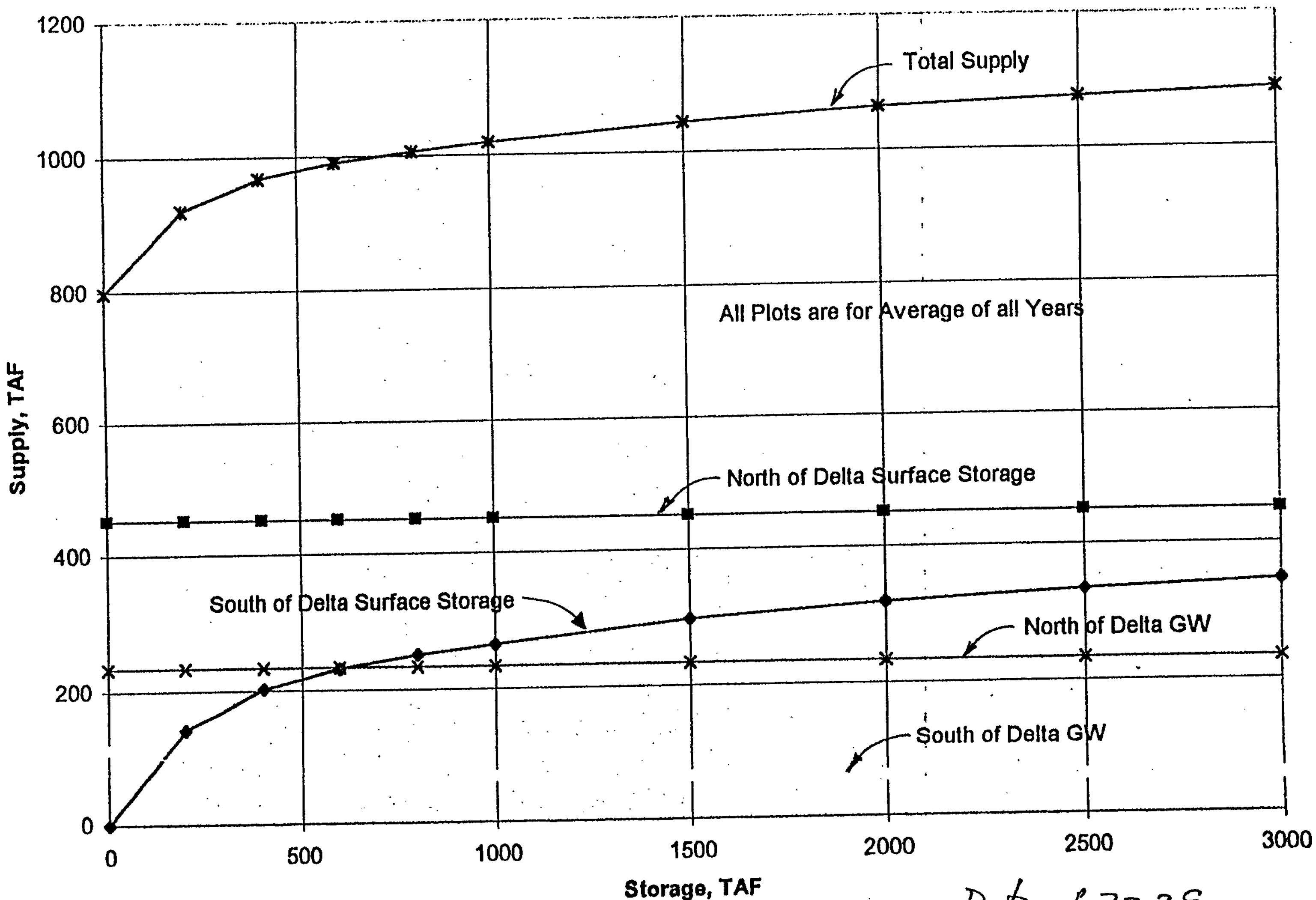
Data P. 27, 28

23

12

SmB 9/29/96

Figure 12. Effect of North of Delta Storages on South of Delta Storage



Data P. 27, 28

D—003803

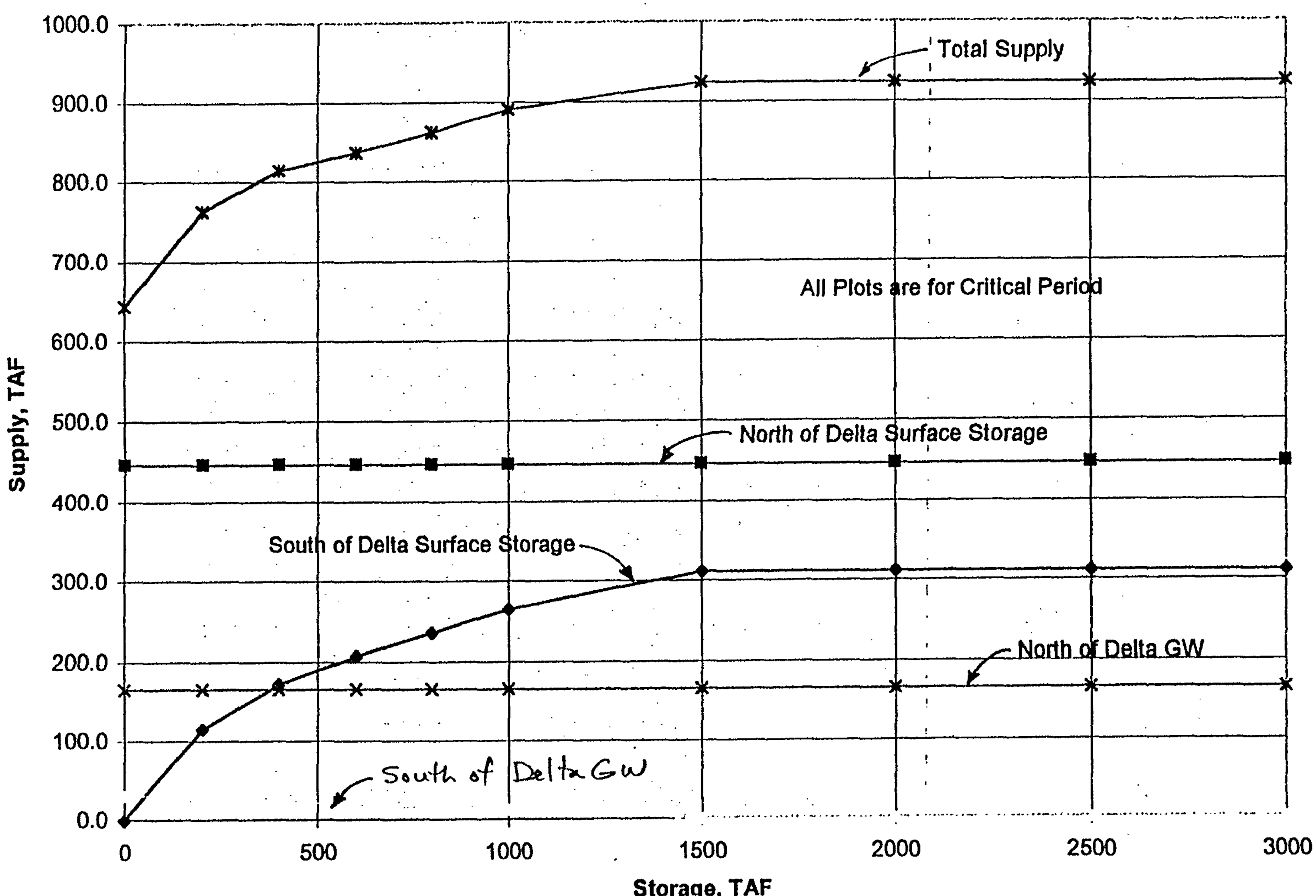
24

22

D-003804

Smm 9/29/96

Figure 13. Effect of North of Delta Storages on South of Delta Storage



Data p. 27, 28

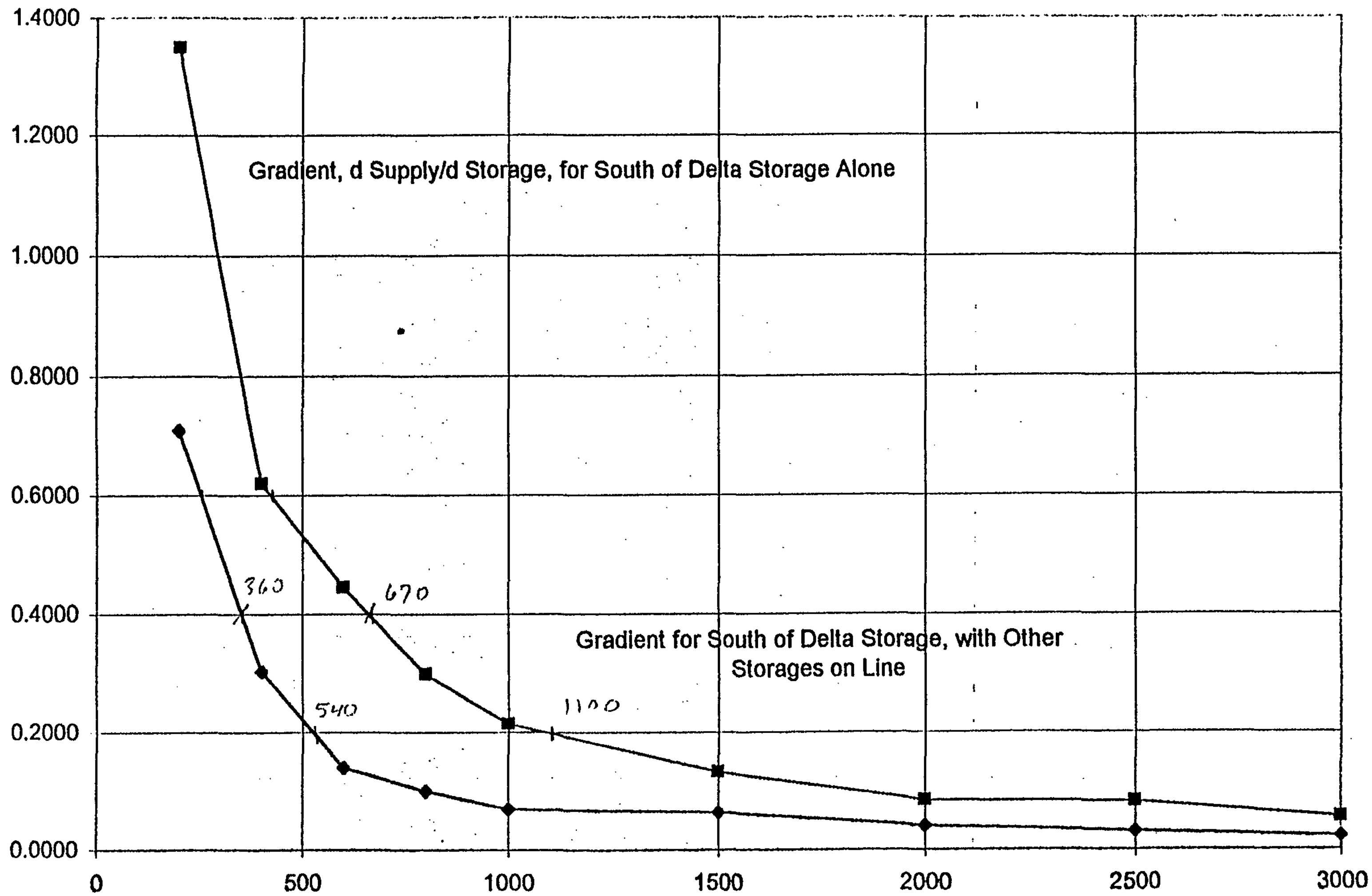
D-003804

25

23

Figure 14.

Comparison of Supply/Storage Gradient for South of Delta Surface Storage, with and without Other Storages



Data P. 26, 28, right margin

26

24

Appendix 1.

Spreadsheet Post_Processing Output

Used for Graphs

	B	C	D	E	F	G	H	I	J	K	L	M	N	O
3														
4	Groundwater Storage Data													
5														
6	North of Delta Facilities			South of Delta Facilities				Non-Project Recharge Rate						
7														
8	Recharge Rate (CFS)	[redacted]		Recharge Rate (CFS)	[redacted]			Deficit	Storage	Rate				
9	Extraction Rate (CFS)	[redacted]		Extraction Rate (CFS)	[redacted]			1	0	0.0215				
10	Maximum Storage (TAF)	[redacted]		Maximum Storage (TAF)	[redacted]			0.77	0	0.0166				
11	Starting Storage (TAF)	[redacted]		Starting Storage (TAF)	[redacted]			0.63	0	0.0143				
12	Extraction Ratio [1]	[redacted]		Extraction Ratio [2]	[redacted]			0.53	0	0.0117				
13	Water Supply Factor	[redacted]												
14	Environmental Factor	[redacted]						0.46	0	0.0095				
15	[1] Percent of Offstream Storage to Begin Extraction			[2] Percent of Offstream Storage to Begin Extraction				0.41	0	0				
16														
17	Offstream Storage Data							SWP Distribution Pattern			CVP Distribution Pattern			
18														
19	North of Delta Storage			South of Delta Storage				OCT	[redacted]	0.070	OCT	[redacted]	0.056	
20								NOV	[redacted]	0.065	NOV	[redacted]	0.045	
21	Conveyance to (CFS)	[redacted]		Conveyance to (CFS)	Limited [3]			DEC	[redacted]	0.066	DEC	[redacted]	0.059	
22	Conveyance from (CFS)	[redacted]		Conveyance from (CFS)	Limited [3]			JAN	[redacted]	0.061	JAN	[redacted]	0.027	
23	Maximum Storage (TAF)	[redacted]		Maximum Storage (TAF)	[redacted]			FEB	[redacted]	0.062	FEB	[redacted]	0.028	
24	Starting Storage (TAF)	[redacted]		Starting Storage (TAF)	[redacted]			MAR	[redacted]	0.070	MAR	[redacted]	0.060	
25	Water Supply Factor	[redacted]						APR	[redacted]	0.081	APR	[redacted]	0.090	
26	Environmental Factor	0		[3] Limited only by Aqueduct Capacity.				MAY	[redacted]	0.092	MAY	[redacted]	0.111	
27								JUN	[redacted]	0.113	JUN	[redacted]	0.150	
28								JUL	[redacted]	0.117	JUL	[redacted]	0.160	
29	In-Delta Storage				Ecosytem Demand			AUG	[redacted]	0.115	AUG	[redacted]	0.144	
30					Target Delta Outflow (CFS)			SEP	[redacted]	0.088	SEP	[redacted]	0.070	
31	Conveyance to (CFS)	[redacted]												
32	Conveyance from (CFS)	[redacted]			OCT	[redacted]		Total	3104.4	1.000	Total	2588.9	1.000	
33	Maximum Storage (TAF)	[redacted]			NOV	[redacted]								
34	Starting Storage (TAF)	[redacted]			DEC	[redacted]								
35					JAN	[redacted]								
36					FEB	[redacted]								
37					MAR	[redacted]								
38	In-Delta Storage				APR	[redacted]								
39	Minimum Storage to Extract for Exp. (TAF)				MAY	[redacted]								
40	Factor				JUN	[redacted]								
41	OCT	0	[redacted]		JUL	[redacted]								
42	NOV	0	[redacted]		AUG	[redacted]								
43	DEC	0	[redacted]		SEP	[redacted]								
44	JAN	0	[redacted]											
45	FEB	0	[redacted]											
46	MAR	0	[redacted]											
47	APR	0	[redacted]											
48	MAY	0	[redacted]											
49	JUN	0	[redacted]											
50	JUL	0	[redacted]											
51	AUG	0	[redacted]											
52	SEP	0	[redacted]											
53														
54														
55	Delta Conveyance (CFS)	[redacted]												
56														

Existing Delta Conveyance

28

12

Marco A. Bell, P.E.
Component Refinement

September 27, 1996
CALFED Bay-Delta Program

SINGLE COMPONET SENSITIVITY RUNS - AVERAGES - SWP=1 EXISTING CONDITIONS

INPUT (STO in TAF and CONV in CFS)						AVERAGE EXPORTS						AVERAGE OUT Q's				AVG
DELTA CONV	N DELTA STO	IN-DELTA STO	S DELTA STO	N GW STO	S GW STO	S Delta Export	In-Delta Export	N Delta Export	S CU Export	N gw Export	TOTAL EXPORT	N DELTA OUT Q's	N CU OUT Q'S	IN-DELTA OUT Q'S	TOTAL	GRAND TOTAL
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	500	0	0	0	65	0	65	0	0	0	0	65
7500	0	0	0	0	400	0	0	0	65	0	65	0	0	0	0	65
7500	0	0	0	0	300	0	0	0	65	0	65	0	0	0	0	65
7500	0	0	0	0	200	0	0	0	64	0	64	0	0	0	0	64
7500	0	0	0	0	100	0	0	0	60	0	60	0	0	0	0	60
7500	0	0	0	0	0	0	0	0	0	253	253	0	0	0	0	253
7500	0	0	0	700	0	0	0	0	0	253	253	0	0	0	0	253
7500	0	0	0	600	0	0	0	0	0	234	234	0	0	0	0	234
7500	0	0	0	500	0	0	0	0	0	214	214	0	0	0	0	214
7500	0	0	0	400	0	0	0	0	0	194	194	0	0	0	0	194
7500	0	0	0	300	0	0	0	0	0	171	171	0	0	0	0	171
7500	0	0	0	200	0	0	0	0	0	144	144	0	0	0	0	144
7500	0	0	0	100	0	0	0	0	0	111	111	0	0	0	0	111
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	3000	0	0	315	0	0	0	0	315	0	0	0	0	315
7500	0	0	2000	0	0	309	0	0	0	0	309	0	0	0	0	309
7500	0	0	1500	0	0	302	0	0	0	0	302	0	0	0	0	302
7500	0	0	1000	0	0	290	0	0	0	0	290	0	0	0	0	290
7500	0	0	800	0	0	280	0	0	0	0	280	0	0	0	0	280
7500	0	0	600	0	0	266	0	0	0	0	266	0	0	0	0	266
7500	0	0	400	0	0	236	0	0	0	0	236	0	0	0	0	236
7500	0	0	200	0	0	161	0	0	0	0	161	0	0	0	0	161
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	700	0	0	0	0	57	0	0	0	57	0	0	222	222	279
7500	0	600	0	0	0	0	65	0	0	0	65	0	0	204	204	269
7500	0	500	0	0	0	0	75	0	0	0	75	0	0	184	184	259
7500	0	400	0	0	0	0	81	0	0	0	81	0	0	159	159	240
7500	0	300	0	0	0	0	77	0	0	0	77	0	0	130	130	207
7500	0	200	0	0	0	0	70	0	0	0	70	0	0	92	92	162
7500	0	100	0	0	0	0	49	0	0	0	49	0	0	48	48	97
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	8000	0	0	0	0	0	0	543	0	0	543	0	0	0	0	543
7500	6000	0	0	0	0	0	0	543	0	0	543	0	0	0	0	543
7500	5000	0	0	0	0	0	0	543	0	0	543	0	0	0	0	543
7500	4000	0	0	0	0	0	0	538	0	0	538	0	0	0	0	538
7500	3500	0	0	0	0	0	0	531	0	0	531	0	0	0	0	531
7500	3000	0	0	0	0	0	0	524	0	0	524	0	0	0	0	524
7500	2500	0	0	0	0	0	0	516	0	0	516	0	0	0	0	516
7500	2000	0	0	0	0	0	0	501	0	0	501	0	0	0	0	501
7500	1500	0	0	0	0	0	0	475	0	0	475	0	0	0	0	475
7500	1000	0	0	0	0	0	0	440	0	0	440	0	0	0	0	440
7500	800	0	0	0	0	0	0	426	0	0	426	0	0	0	0	426
7500	600	0	0	0	0	0	0	402	0	0	402	0	0	0	0	402
7500	400	0	0	0	0	0	0	323	0	0	323	0	0	0	0	323
7500	200	0	0	0	0	0	0	203	0	0	203	0	0	0	0	203
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Marco A. Bell, P.E. — **September 27, 1996**
Component Refinement — **CALFED Bay-Delta Program**

SINGLE COMPONET SENSITIVITY RUNS - DRY YEAR AVERAGES - SWP=1 EXISTING CONDITIONS

INPUT (STO in TAF and CONV in CFS)						DRY YEAR AVERAGE EXPORTS						DRY YEARAVERAGE OUT Q's				DRY
DELTA CONV	N DELTA STO	IN-DELTA STO	S DELTA STO	N GW STO	S GW STO	S Delta Export	In-Delta Export	N Delta Export	S CU Export	N gw Export	TOTAL EXPORT	N DELTA OUT Q's	N CU OUT Q'S	IN-DELTA OUT Q'S	TOTAL	GRAND TOTAL
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	500	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	400	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	300	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	200	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	100	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	0	0	0	0	0	350	350	0	0	0	0	350
7500	0	0	0	700	0	0	0	0	0	350	350	0	0	0	0	350
7500	0	0	0	600	0	0	0	0	0	312	312	0	0	0	0	312
7500	0	0	0	500	0	0	0	0	0	271	271	0	0	0	0	271
7500	0	0	0	400	0	0	0	0	0	227	227	0	0	0	0	227
7500	0	0	0	300	0	0	0	0	0	183	183	0	0	0	0	183
7500	0	0	0	200	0	0	0	0	0	141	141	0	0	0	0	141
7500	0	0	0	100	0	0	0	0	0	102	102	0	0	0	0	102
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	3000	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	2000	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	1500	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	1000	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	800	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	600	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	400	0	0	153	0	0	0	0	153	0	0	0	0	153
7500	0	0	200	0	0	117	0	0	0	0	117	0	0	0	0	117
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	700	0	0	0	0	9	0	0	0	9	0	0	146	146	155
7500	0	600	0	0	0	0	17	0	0	0	17	0	0	139	139	156
7500	0	500	0	0	0	0	25	0	0	0	25	0	0	130	130	155
7500	0	400	0	0	0	0	42	0	0	0	42	0	0	111	111	153
7500	0	300	0	0	0	0	48	0	0	0	48	0	0	91	91	139
7500	0	200	0	0	0	0	43	0	0	0	43	0	0	69	69	112
7500	0	100	0	0	0	0	32	0	0	0	32	0	0	39	39	71
7500	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
7500	8000	0	0	0	0	0	0	494		0	494	0	0	0	0	494
7500	6000	0	0	0	0	0	0	494		0	494	0	0	0	0	494
7500	5000	0	0	0	0	0	0	494		0	494	0	0	0	0	494
7500	4000	0	0	0	0	0	0	494 454		0	494	0	0	0	0	494
7500	3500	0	0	0	0	0	0	494 453		0	494	0	0	0	0	494
7500	3000	0	0	0	0	0	0	494 454		0	494	0	0	0	0	494
7500	2500	0	0	0	0	0	0	494 347		0	494	0	0	0	0	494
7500	2000	0	0	0	0	0	0	455 415		0	455	0	0	0	0	455
7500	1500	0	0	0	0	0	0	384 343		0	384	0	0	0	0	384
7500	1000	0	0	0	0	0	0	312 272		0	312	0	0	0	0	312
7500	800	0	0	0	0	0	0	284 244		0	284	0	0	0	0	284
7500	600	0	0	0	0	0	0	255 215		0	255	0	0	0	0	255
7500	400	0	0	0	0	0	0	227 186		0	227	0	0	0	0	227
7500	200	0	0	0	0	0	0	153 122		0	153	0	0	0	0	153
7500	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0

	B	C	D	E	F	G	H	I	J	K	L	M	N	O
3														
4				Groundwater Storage Data										
5														
6	North of Delta Facilities			South of Delta Facilities					Non-Project Recharge Rate					
7														
8	Recharge Rate (CFS)	[redacted]		Recharge Rate (CFS)	[redacted]			Deficit	Storage	Rate				
9	Extraction Rate (CFS)	[redacted]		Extraction Rate (CFS)	[redacted]			1	0	0.0215				
10	Maximum Storage (TAF)	[redacted]		Maximum Storage (TAF)	[redacted]			0.77	0	0.0166				
11	Starting Storage (TAF)	[redacted]		Starting Storage (TAF)	[redacted]			0.63	0	0.0143				
12	Extraction Ratio [1]	Not Used		Extraction Ratio [2]	[redacted]			0.53	0	0.0117				
13	Water Supply Factor	[redacted]												
14	Environmental Factor	[redacted]						0.46	0	0.0095				
15	[1] Percent of Offstream Storage to Begin Extraction			[2] Percent of Offstream Storage to Begin Extraction				0.41	0	0				
16														
17			Offstream Storage Data						SWP Distribution Pattern			CVP Distribution Pattern		
18														
19	North of Delta Storage			South of Delta Storage				OCT	[redacted]	0.070	OCT	[redacted]	0.056	
20								NOV	[redacted]	0.065	NOV	[redacted]	0.045	
21	Conveyance to (CFS)	[redacted]		Conveyance to (CFS)	Limited [3]			DEC	[redacted]	0.066	DEC	[redacted]	0.059	
22	Conveyance from (CFS)	[redacted]		Conveyance from (CFS)	Limited [3]			JAN	[redacted]	0.061	JAN	[redacted]	0.027	
23	Maximum Storage (TAF)	[redacted]		Maximum Storage (TAF)	[redacted]			FEB	[redacted]	0.062	FEB	[redacted]	0.028	
24	Starting Storage (TAF)	[redacted]		Starting Storage (TAF)	[redacted]			MAR	[redacted]	0.070	MAR	[redacted]	0.060	
25	Water Supply Factor	[redacted]						APR	[redacted]	0.081	APR	[redacted]	0.090	
26	Environmental Factor	1		[3] Limited only by Aqueduct Capacity.				MAY	[redacted]	0.092	MAY	[redacted]	0.111	
27								JUN	[redacted]	0.113	JUN	[redacted]	0.150	
28								JUL	[redacted]	0.117	JUL	[redacted]	0.160	
29	In-Delta Storage				Ecosytem Demand			AUG	[redacted]	0.115	AUG	[redacted]	0.144	
30					Target Delta Outflow			SEP	[redacted]	0.088	SEP	[redacted]	0.070	
31	Conveyance to (CFS)	[redacted]			(CFS)									
32	Conveyance from (CFS)	[redacted]			OCT	[redacted]		Total	3104.4	1.000	Total	2588.9	1.000	
33	Maximum Storage (TAF)	[redacted]			NOV	[redacted]								
34	Starting Storage (TAF)	[redacted]			DEC	[redacted]								
35					JAN	[redacted]								
36					FEB	[redacted]								
37					MAR	[redacted]								
38	In-Delta Storage				APR	[redacted]								
39	Minimum Storage to Extract for Exp. (TAF)				MAY	[redacted]								
40	Factor				JUN	[redacted]								
41	OCT	0	[redacted]		JUL	[redacted]								
42	NOV	0	[redacted]		AUG	[redacted]								
43	DEC	0	[redacted]		SEP	[redacted]								
44	JAN	0	[redacted]											
45	FEB	0	[redacted]											
46	MAR	0	[redacted]											
47	APR	0	[redacted]											
48	MAY	0	[redacted]											
49	JUN	0	[redacted]											
50	JUL	0	[redacted]											
51	AUG	0	[redacted]											
52	SEP	0	[redacted]											
53														
54														
55	Delta Conveyance (CFS)	[redacted]												
56														

Existing Delta Conveyance

Component Refinement **CALFED Bay-Delta Program**

SINGLE COMPONET SENSITIVITY RUNS - AVERAGES - ENV=1 EXISTING CONDITIONS

INPUT (STO in TAF and CONV in CFS)						AVERAGE EXPORTS						AVERAGE OUT Q's				AVG
DELTA CONV	N DELTA STO	IN-DELTA STO	S DELTA STO	N GW STO	S GW STO	S Delta Export	In-Delta Export	N Delta Export	S CU Export	N gw Export	TOTAL EXPORT	N DELTA OUT Q's	N CU OUT Q'S	IN-DELTA OUT Q'S	TOTAL	GRAND TOTAL
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	500	0	0	0	65	0	65	0	0	0	0	65
7500	0	0	0	0	400	0	0	0	65	0	65	0	0	0	0	65
7500	0	0	0	0	300	0	0	0	65	0	65	0	0	0	0	65
7500	0	0	0	0	200	0	0	0	64	0	64	0	0	0	0	64
7500	0	0	0	0	100	0	0	0	60	0	60	0	0	0	0	60
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	700	0	0	0	0	0	253	253	0	0	0	0	253
7500	0	0	0	600	0	0	0	0	0	234	234	0	0	0	0	234
7500	0	0	0	500	0	0	0	0	0	214	214	0	0	0	0	214
7500	0	0	0	400	0	0	0	0	0	194	194	0	0	0	0	194
7500	0	0	0	300	0	0	0	0	0	171	171	0	0	0	0	171
7500	0	0	0	200	0	0	0	0	0	144	144	0	0	0	0	144
7500	0	0	0	100	0	0	0	0	0	111	111	0	0	0	0	111
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	3000	0	0	315	0	0	0	0	315	0	0	0	0	315
7500	0	0	2000	0	0	309	0	0	0	0	309	0	0	0	0	309
7500	0	0	1500	0	0	302	0	0	0	0	302	0	0	0	0	302
7500	0	0	1000	0	0	290	0	0	0	0	290	0	0	0	0	290
7500	0	0	800	0	0	280	0	0	0	0	280	0	0	0	0	280
7500	0	0	600	0	0	266	0	0	0	0	266	0	0	0	0	266
7500	0	0	400	0	0	236	0	0	0	0	236	0	0	0	0	236
7500	0	0	200	0	0	161	0	0	0	0	161	0	0	0	0	161
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	700	0	0	0	0	57	0	0	0	57	0	0	222	222	279
7500	0	600	0	0	0	0	65	0	0	0	65	0	0	204	204	269
7500	0	500	0	0	0	0	75	0	0	0	75	0	0	184	184	259
7500	0	400	0	0	0	0	81	0	0	0	81	0	0	159	159	240
7500	0	300	0	0	0	0	77	0	0	0	77	0	0	130	130	207
7500	0	200	0	0	0	0	70	0	0	0	70	0	0	92	92	162
7500	0	100	0	0	0	0	49	0	0	0	49	0	0	48	48	97
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	8000	0	0	0	0	0	0	0	0	0	0	604	0	0	604	604
7500	6000	0	0	0	0	0	0	0	0	0	0	604	0	0	604	604
7500	5000	0	0	0	0	0	0	0	0	0	0	604	0	0	604	604
7500	4000	0	0	0	0	0	0	0	0	0	0	600	0	0	600	600
7500	3500	0	0	0	0	0	0	0	0	0	0	593	0	0	593	593
7500	3000	0	0	0	0	0	0	0	0	0	0	586	0	0	586	586
7500	2500	0	0	0	0	0	0	0	0	0	0	578	0	0	578	578
7500	2000	0	0	0	0	0	0	0	0	0	0	561	0	0	561	561
7500	1500	0	0	0	0	0	0	0	0	0	0	533	0	0	533	533
7500	1000	0	0	0	0	0	0	0	0	0	0	491	0	0	491	491
7500	800	0	0	0	0	0	0	0	0	0	0	467	0	0	467	467
7500	600	0	0	0	0	0	0	0	0	0	0	426	0	0	426	426
7500	400	0	0	0	0	0	0	0	0	0	0	325	0	0	325	325
7500	200	0	0	0	0	0	0	0	0	0	0	188	0	0	188	188
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Component Refinement CALFED Bay-Delta Program

SINGLE COMPONET SENSITIVITY RUNS - DRY YEAR AVERAGES - ENV=1 EXISTING CONDITIONS

INPUT (STO in TAF and CONV in CFS)						DRY YEAR AVERAGE EXPORTS						DRY YEARAVERAGE OUT Q's				DRY
DELTA CONV	N DELTA STO	IN-DELTA STO	S DELTA STO	N GW STO	S GW STO	S Delta Export	In-Delta Export	N Delta Export	S CU Export	N gw Export	TOTAL EXPORT	N DELTA OUT Q's	N CU OUT Q'S	IN-DELTA OUT Q'S	TOTAL	GRAND TOTAL
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	0	500	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	400	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	300	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	200	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	100	0	0	0	37	0	37	0	0	0	0	37
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	0	700	0	0	0	0	0	350	350	0	0	0	0	350
7500	0	0	0	600	0	0	0	0	0	312	312	0	0	0	0	312
7500	0	0	0	500	0	0	0	0	0	271	271	0	0	0	0	271
7500	0	0	0	400	0	0	0	0	0	227	227	0	0	0	0	227
7500	0	0	0	300	0	0	0	0	0	183	183	0	0	0	0	183
7500	0	0	0	200	0	0	0	0	0	141	141	0	0	0	0	141
7500	0	0	0	100	0	0	0	0	0	102	102	0	0	0	0	102
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	0	3000	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	2000	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	1500	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	1000	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	800	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	600	0	0	155	0	0	0	0	155	0	0	0	0	155
7500	0	0	400	0	0	153	0	0	0	0	153	0	0	0	0	153
7500	0	0	200	0	0	117	0	0	0	0	117	0	0	0	0	117
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	0	700	0	0	0	0	9	0	0	0	9	0	0	146	146	155
7500	0	600	0	0	0	0	17	0	0	0	17	0	0	139	139	156
7500	0	500	0	0	0	0	25	0	0	0	25	0	0	130	130	155
7500	0	400	0	0	0	0	42	0	0	0	42	0	0	111	111	153
7500	0	300	0	0	0	0	48	0	0	0	48	0	0	91	91	139
7500	0	200	0	0	0	0	43	0	0	0	43	0	0	69	69	112
7500	0	100	0	0	0	0	32	0	0	0	32	0	0	39	39	71
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7500	8000	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	6000	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	5000	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	4000	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	3500	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	3000	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	2500	0	0	0	0	0	0	0	0	0	0	443	0	0	443	443
7500	2000	0	0	0	0	0	0	0	0	0	0	406	0	0	406	406
7500	1500	0	0	0	0	0	0	0	0	0	0	334	0	0	334	334
7500	1000	0	0	0	0	0	0	0	0	0	0	263	0	0	263	263
7500	800	0	0	0	0	0	0	0	0	0	0	234	0	0	234	234
7500	600	0	0	0	0	0	0	0	0	0	0	206	0	0	206	206
7500	400	0	0	0	0	0	0	0	0	0	0	177	0	0	177	177
7500	200	0	0	0	0	0	0	0	0	0	0	112	0	0	112	112
7500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Stein Buer Component Refinement										Average of All Water Years					
Input	Variables								Output	Averaged over Period of Record					
								Exports						Outflows	
Delta Conv	N Delta St	In Delta St	S Delta St	N GW St	S GW St	South Stor	In-Delta	North Stor	South CU	North GW	Total	North	North CU	In-Delta	Total
SWP=1,ENV=0	Dual Component Sensitivity, North of Delta Surface Storage + 500 TAF gw														
7500	0	0	0	500	0	0	0	0	0	214	214	0	0	0	0
	200			500		0	0	139	0	214	353	0	0	0	0
	400			500		0	0	221	0	214	435	0	0	0	0
	600			500		0	0	252	0	214	466	0	0	0	0
	800			500		0	0	266	0	214	480	0	0	0	0
	1000			500		0	0	279	0	214	493	0	0	0	0
	1500			500		0	0	307	0	214	521	0	0	0	0
	2000			500		0	0	327	0	214	541	0	0	0	0
	13000			500		0	0	361	0	214	575	0	0	0	0
	8000			500		0	0	356	0	214	570	0	0	0	0
	3000			500		0	0	351	0	214	565	0	0	0	0
SWP=1,ENV=0	Dual Component Sensitivity, In Delta + 500 TAF GW + 3,000 TAF surface														
7500															
	3000	700		500		0	0	351	0	214	565	0	0	265	265
	3000	600		500		0	0	351	0	214	565	0	0	256	256
	3000	500		500		0	0	351	0	214	565	0	0	241	241
	3000	400		500		0	0	351	0	214	565	0	0	221	221
	3000	300		500		0	0	351	0	214	565	0	0	189	189
	3000	200		500		0	1	351	0	214	566	0	0	147	147
	3000	100		500		0	1	351	0	214	566	0	0	83	83
SWP=.5,ENV=.5	Single														
7500															
	0	0		0		0	0	0	0	0	0	0	0	0	0
	200	0		0		0	0	125	0	0	125	97	0	0	97
	400	0		0		0	0	195	0	0	195	179	0	0	179
	600	0		0		0	0	249	0	0	249	243	0	0	243
	800	0		0		0	0	286	0	0	286	282	0	0	282
	1000	0		0		0	0	310	0	0	310	308	0	0	308
	1500	0		0		0	0	349	0	0	349	341	0	0	341
	2000	0		0		0	0	372	0	0	372	362	0	0	362
	2500	0		0		0	0	386	0	0	386	375	0	0	375
	3000	0		0		0	0	401	0	0	401	390	0	0	390
	4000	0		0		0	0	429	0	0	429	414	0	0	414
	5000	0		0		0	0	441	0	0	441	428	0	0	428
	8000	0		0		0	0	462	0	0	462	451	0	0	451
Single Component Sensitivity, SWP=1, South of Delta Storage, with Through Delta Conveyance															
10300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10300	0	0	200	0	0	270	0	0	0	0	270	0	0	0	0
10300	0	0	400	0	0	394	0	0	0	0	394	0	0	0	0
10300	0	0	600	0	0	483	0	0	0	0	483	0	0	0	0
10300	0	0	800	0	0	543	0	0	0	0	543	0	0	0	0
10300	0	0	1000	0	0	586	0	0	0	0	586	0	0	0	0
10300	0	0	1500	0	0	652	0	0	0	0	652	0	0	0	0

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not plotted
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			Output	Average of 3/28-2/35								
				Averaged over March 1928-February 1935								
				Exports						Outflows		
Grand Total		South Stor	In-Delta	North Stor	South CU	North GW	Total	North	North CU	In-Delta	Total	Grand Total
		0	0	0	0	168	168	0	0	0	0	168
353		0	0	109	0	168	276	0	0	0	0	276
435		0	0	162	0	168	330	0	0	0	0	330
466		0	0	190	0	168	358	0	0	0	0	358
480		0	0	219	0	168	387	0	0	0	0	387
493		0	0	248	0	168	415	0	0	0	0	415
521		0	0	319	0	168	487	0	0	0	0	487
541		0	0	390	0	168	558	0	0	0	0	558
575		0	0	488	0	168	656	0	0	0	0	656
570		0	0	488	0	168	656	0	0	0	0	656
585		0	0	488	0	168	656	0	0	0	0	656
0												
0												
830		0	0	488	0	168	656	0	0	115	115	770
821		0	0	488	0	168	656	0	0	115	115	770
806		0	0	488	0	168	656	0	0	115	115	770
786		0	0	488	0	168	656	0	0	115	115	770
754		0	0	488	0	168	656	0	0	115	115	770
713		0	7	488	0	168	663	0	0	97	97	760
649		0	12	488	0	168	668	0	0	56	56	724
0		0	0	0	0	0	0	0	0	0	0	0
222		0	0	61	0	0	61	56	0	0	56	117
374		0	0	93	0	0	93	89	0	0	89	182
492		0	0	108	0	0	108	103	0	0	103	210
568		0	0	122	0	0	122	117	0	0	117	239
618		0	0	136	0	0	136	131	0	0	131	268
690		0	0	172	0	0	172	167	0	0	167	339
734		0	0	197	0	0	197	203	0	0	203	400
761		0	0	197	0	0	197	203	0	0	203	400
791		0	0	197	0	0	197	203	0	0	203	400
843		0	0	197	0	0	197	203	0	0	203	400
869		0	0	197	0	0	197	203	0	0	203	400
913		0	0	197	0	0	197	203	0	0	203	400
0		0	0	0	0	0	0	0	0	0	0	0
270		149	0	0	0	0	149	0	0	0	0	149
394		226	0	0	0	0	226	0	0	0	0	226
483		273	0	0	0	0	273	0	0	0	0	273
543		301	0	0	0	0	301	0	0	0	0	301
586		330	0	0	0	0	330	0	0	0	0	330
652		371	0	0	0	0	371	0	0	0	0	371

Gradient, South of Delta Storage, with no other storages on line

So'D stor	Supply	dy/dx
0	0	
200	270	1.3500
400	394	0.6200
600	483	0.4450
800	543	0.3000
1000	586	0.2150
1500	652	0.1320

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10300	0	0	2000	0	0	694	0	0	0	0	694	0	0	0	0
10300	0	0	2500	0	0	735	0	0	0	0	735	0	0	0	0
10300	0	0	3000	0	0	763	0	0	0	0	763	0	0	0	0
Dual Component Sensitivity, SWP=1, South of Delta Storage, with through Delta Conveyance															
10300	0	0	0	0	500	0	0	0	128	0	128	0	0	0	0
10300	0	0	200	0	500	270	0	0	105	0	375	0	0	0	0
10300	0	0	400	0	500	394	0	0	84	0	479	0	0	0	0
10300	0	0	600	0	500	483	0	0	70	0	553	0	0	0	0
10300	0	0	800	0	500	543	0	0	64	0	607	0	0	0	0
10300	0	0	1000	0	500	586	0	0	58	0	645	0	0	0	0
10300	0	0	1500	0	500	652	0	0	49	0	700	0	0	0	0
10300	0	0	2000	0	500	694	0	0	43	0	737	0	0	0	0
10300	0	0	2500	0	500	735	0	0	37	0	772	0	0	0	0
10300	0	0	3000	0	500	763	0	0	34	0	797	0	0	0	0
Effect of North of Delta Storage on South of Delta Storage					SWP=1, Vary South of Delta Storage, with GW, through Delta, and North of Delta										
10300	3000	0	0	500	500	0	0	453	113	233	798	0	0	0	0
10300	3000	0	200	500	500	142	0	453	93	233	921	0	0	0	0
10300	3000	0	400	500	500	203	0	453	79	233	968	0	0	0	0
10300	3000	0	600	500	500	231	0	453	74	233	991	0	0	0	0
10300	3000	0	800	500	500	251	0	453	70	233	1007	0	0	0	0
10300	3000	0	1000	500	500	265	0	453	69	233	1020	0	0	0	0
10300	3000	0	1500	500	500	297	0	453	64	233	1046	0	0	0	0
10300	3000	0	2000	500	500	318	0	453	61	233	1065	0	0	0	0
10300	3000	0	2500	500	500	334	0	453	59	233	1078	0	0	0	0
10300	3000	0	3000	500	500	346	0	453	57	233	1089	0	0	0	0

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694		371	0	0	0	0	371	0	0	0	0	371			2000	694	0.0840
735		371	0	0	0	0	371	0	0	0	0	371			2500	735	0.0820
763		371	0	0	0	0	371	0	0	0	0	371			3000	763	0.0560
128		0.0	0.0	0.0	42.9	0.0	42.9	0.0	0.0	0.0	0.0	42.9					
375		149.2	0.0	0.0	28.8	0.0	177.9	0.0	0.0	0.0	0.0	177.9					
479		226.2	0.0	0.0	14.7	0.0	240.9	0.0	0.0	0.0	0.0	240.9					
553		272.6	0.0	0.0	15.3	0.0	287.9	0.0	0.0	0.0	0.0	287.9					
607		301.1	0.0	0.0	8.8	0.0	309.9	0.0	0.0	0.0	0.0	309.9					
645		329.7	0.0	0.0	8.8	0.0	338.5	0.0	0.0	0.0	0.0	338.5					
700		371.3	0.0	0.0	0.0	0.0	371.3	0.0	0.0	0.0	0.0	371.3					
737		371.3	0.0	0.0	0.0	0.0	371.3	0.0	0.0	0.0	0.0	371.3					
772		371.3	0.0	0.0	0.0	0.0	371.3	0.0	0.0	0.0	0.0	371.3					
797		371.3	0.0	0.0	0.0	0.0	371.3	0.0	0.0	0.0	0.0	371.3					
															Gradient, South of Delta Storage,		
															with all others except in-Delta		
															So'D stor	Supply	dy/dx
798		0.0	0.0	447.4	30.8	166.6	644.8	0.0	0.0	0.0	0.0	644.8			0	0	
921		115.6	0.0	447.4	33.3	166.6	762.9	0.0	0.0	0.0	0.0	762.9			200	142	0.7100
968		172.7	0.0	447.4	27.7	166.6	814.5	0.0	0.0	0.0	0.0	814.5			400	203	0.3050
991		208.0	0.0	447.4	15.0	166.6	837.0	0.0	0.0	0.0	0.0	837.0			600	231	0.1400
1007		236.6	0.0	447.4	12.1	166.6	862.7	0.0	0.0	0.0	0.0	862.7			800	251	0.1000
1020		265.1	0.0	447.4	12.1	166.6	891.3	0.0	0.0	0.0	0.0	891.3			1000	265	0.0700
1046		311.2	0.0	447.4	0.0	166.6	925.2	0.0	0.0	0.0	0.0	925.2			1500	297	0.0640
1065		311.2	0.0	447.4	0.0	166.6	925.2	0.0	0.0	0.0	0.0	925.2			2000	318	0.0420
1078		311.2	0.0	447.4	0.0	166.6	925.2	0.0	0.0	0.0	0.0	925.2			2500	334	0.0320
1089		311.2	0.0	447.4	0.0	166.6	925.2	0.0	0.0	0.0	0.0	925.2			3000	346	0.0240

Appendix 2.

Evaluation Notes and Calculations

D-003817

(1) North of Δ Storage, Surface
Preliminary Evaluation of Smrs 9/21/96
Res storage vs Pumping Capacity

Zero N of Δ GW
Zero Δ Storage
Delta Conv 7500
Water Supply factor 0
Env. Factor 1.0

Table = Env Outflow TAF

North of Δ	Conveyance				
Storage	1000	2000	3000	4000	5000
500	167				
1000	194				
1500	205		457		537
2000	212				
3000	212				593

This table serves as a check on spreadsheet Benchmark post process spreadsheet was revised slightly.

This run fully exercises north of Delta storage for environmental purposes. Conclusion:

Yield	Storage	Pump Capacity	index $/AF
300 TAF	750	2,000 cfs	$.18
400 TAF	800	3,000 cfs	.19
500 TAF	1200	4,000 cfs	.21

	B	C	D	E	F	G	H	I	J	K
4	Groundwater Storage Data									
5										
6	**North of Delta Facilities**			**South of Delta Facilities**				**Non-Project Recharge Rate**		
7										
8	Recharge Rate (CFS)	500		Recharge Rate (CFS)	500			Deficit	Storage	Rate
9	Extraction Rate (CFS)	1000		Extraction Rate (CFS)	1000			1	0	0.0215
10	Maximum Storage (TAF)	~~500~~	0	Maximum Storage (TAF)	350			0.77	115	0.0166
11	Starting Storage (TAF)	~~300~~	0	Starting Storage (TAF)	200			0.63	185	0.0143
12	Extraction Ratio [1]	Not Used		Extraction Ratio [2]	0.8			0.53	235	0.0117
13	Water Supply Factor	0.5								
14	Environmental Factor	0.5						0.46	270	0.0095
15	[1] Percent of Offstream Storage to Begin Extraction			[2] Percent of Offstream Storage to Begin Extraction				0.41	295	0
16										
17	Offstream Storage Data							SWP Distribution Pattern		
18										
19	**North of Delta Storage**			**South of Delta Storage**				OCT	217.5	0.070
20								NOV	203.3	0.065
21	Conveyance to (CFS)	~~3000~~	vary	Conveyance to (CFS)	Limited [3]			DEC	206.4	0.066
22	Conveyance from (CFS)	~~5000~~		Conveyance from (CFS)	Limited [3]			JAN	189.5	0.061
23	Maximum Storage (TAF)	~~1500~~		Maximum Storage (TAF)	850			FEB	193.6	0.062
24	Starting Storage (TAF)	500		Starting Storage (TAF)	250			MAR	218.2	0.070
25	Water Supply Factor	~~0.5~~	0					APR	249.9	0.081
26	Environmental Factor	~~0.5~~	1	[3] Limited only by Aqueduct Capacity.				MAY	285.4	0.092
27								JUN	349.6	0.113
28								JUL	361.7	0.117
29	In-Delta Storage				Ecosytem Demand			AUG	357.0	0.115
30					Target Delta Outflow			SEP	272.4	0.088
31	Conveyance to (CFS)	5000			(CFS)					
32	Conveyance from (CFS)	5000			OCT	7000		Total	3104.4	1.000
33	Maximum Storage (TAF)	~~200~~	0		NOV	7000				
34	Starting Storage (TAF)	~~100~~	0		DEC	7000				
35					JAN	7000				
36					FEB	7000				
37					MAR	7000				
38	In-Delta Storage				APR	7000				

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Criteria

	B	C	D	E	F	G	H	I	J	K
39	Minimum Storage to Extract for Exp. (TAF)				MAY	7000				
40	Factor				JUN	7000				
41	OCT	200	1		JUL	7000				
42	NOV	200	1		AUG	7000				
43	DEC	200	1		SEP	7000				
44	JAN	200	1							
45	FEB	200	1							
46	MAR	200	1							
47	APR	200	1							
48	MAY	180	0.9							
49	JUN	160	0.8							
50	JUL	140	0.7							
51	AUG	120	0.6							
52	SEP	100	0.5							
53										
54										
55	Delta Conveyance (CFS)	7500								

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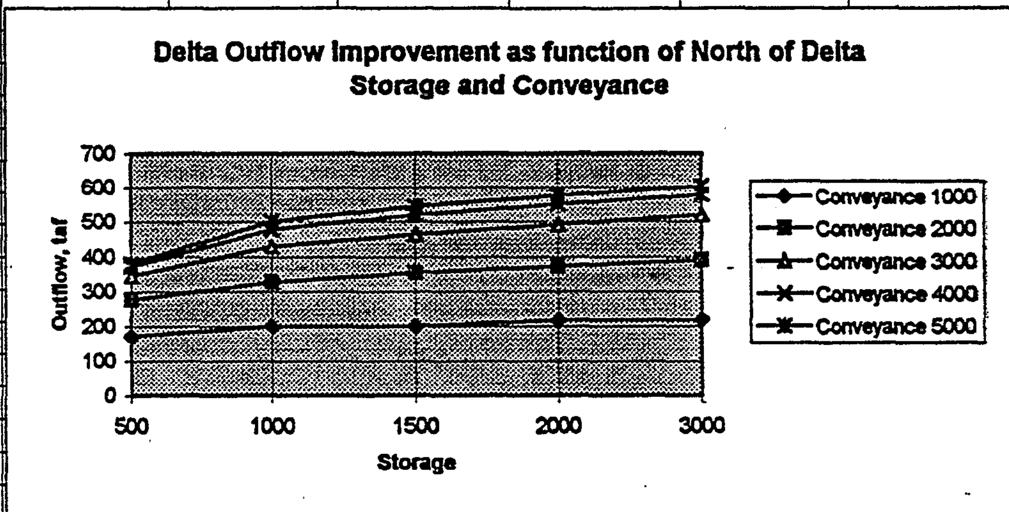
SmB 9/19/96

North of Delta Storage	Conveyance 1000	Conveyance 2000	Conveyance 3000	Conveyance 4000	Conveyance 5000
500	172	278	345	373	381
1000	200	328	430	478	501
1500	200	355	464	519	545
2000	218	372	491	550	577
3000	221	390	519	578	603



Outflow Increment	Required Storage,taf	Required conveyance, cfs	Storage Cost, $million/yr	Conveyance Cost	Net Cost/Outf
200	1500	1000	$30	$21	$0.25
300	750	2000	$12	$41	$0.18
400	600	5000	$10	$104	$0.28
400	650	4000	$11	$83	$0.23
400	800	3000	$13	$62	$0.19
400	3000	2000	$98	$41	$0.35
500	1000	5000	$17	$104	$0.24
500	1200	4000	$20	$83	$0.21
500	2100	3000	$45	$62	$0.21
600	3000	5000	98.1	103.7	$0.34
Minimum cost combos:		storage	conveyance		
		750	2000		
		800	3000		
		1200	4000		
		~~2100~~	~~3000~~		

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(2) North of Δ Storage, Surface Reservoir Storage vs Pumping Cap. SMB 9/21/96

~~Zero~~ N of Δ GW
~~Zero~~ Δ Storage
Delta Conveyance 7500
Water Supply factor 0.5
Env Factor 0.5

Table: Env. Outflow + Σ Exports

North of Δ Storage	Conveyance 1000	2000	3000	4000	5000
500	453	545	603	636	650
1000	479	599	698	774	832
1500	488	630	740	834	904
2000	491	652	769	867	947
3000	493	674	813	917	1001

Flow Inc	Req'd Stor	Req'd Conv.	Stor Cost	Conv Cost	$M/TAF
500	3000	1000	98.1	20.8	.238
600	1000	2000	16.50	41.6	(.097)
600	500	3000	8.25	62.4	.118
700	640	5000	10.56	104	.164
	740	4000	12.21	83.2	.136
	1000	3000	16.50	62.4	(.113)
800	900	5000	14.85	104	.149
	1200	4000	19.80	83.2	(.129)
	2500	3000	73.35	62.4	.170
900	1500	5000	29.25	104	(.148)
	2700	4000	83.25	83.2	.185

Reservoir storage vs 8mvs 9/21/9

Pumping capacity

For a Given storage facility, compute minimal water cost as function of conveyance:

Stor	Conv	Yield	$S	$C	Σ$	$/AF	Conv	$C	Σ$	$/AF
							if conveyance to 1/3			
500	1000	453	8.25	20.8	29.0	.064	*	6.93	15.18	0.0335
	2000	479	8.25	41.6	49.8	.104		13.87	22.12	0.0462
	3000	488	8.25	62.4	70.6	.145		20.8		0.0595
	4000	491	8.25	83.2	91.4	.187		27.73	35.98	0.0733
	5000	493	8.25	104	112.2	.228		34.7		
3000	1000	493	98.1	20.8	118.9	0.24	1000	6.93	105.03	0.213
	2000	674		41.6	139.7	0.21	2000	13.87		0.166
	3000	813		62.4	160.5	0.197	3000	20.8		0.146
	4000	917		83.2	181.3	0.197	*4000	27.73		0.137
	5000	1001		104	202.1	0.202	5000	34.7		0.133
	6000	1070		125			6000	41.6		0.131
2000	1000	491	48.6	20.8	69.40	.141	7000	48.5		0.1309*
	2000	652		41.6	90.20	.138 *	8000		153.6	0.1335
	3000	769		62.4		.144	9000	62.4	160.5	0.138
	4000	867		83.2		.152				
	5000	947		104.		.161				

Conclusion:

	Conveyance Range	Use:
500 TAF	1000 cfs - 2,000 ✓	2,000 cfs
1000 TAF	3,000	3,000 cfs
2000 TAF	2000 cfs - 4,000	4,000 cfs
3000 TAF	4,000 cfs - 7,000 cfs	5,000 cfs

Criteria

	B	C	D	E	F	G	H	I	J	K
4	Groundwater Storage Data									
5										
6	**North of Delta Facilities**			**South of Delta Facilities**				**Non-Project Recharge Rate**		
7										
8	Recharge Rate (CFS)	500		Recharge Rate (CFS)	500			**Deficit**	**Storage**	**Rate**
9	Extraction Rate (CFS)	1000		Extraction Rate (CFS)	1000			1	0	0.0215
10	Maximum Storage (TAF)	500	0	Maximum Storage (TAF)	350			0.77	115	0.0166
11	Starting Storage (TAF)	300	0	Starting Storage (TAF)	200			0.63	185	0.0143
12	Extraction Ratio [1]	Not Used		Extraction Ratio [2]	0.9			0.53	235	0.0117
13	Water Supply Factor	0.5								
14	Environmental Factor	0.5						0.46	270	0.0095
15	[1] Percent of Offstream Storage to Begin Extraction			[2] Percent of Offstream Storage to Begin Extraction				0.41	295	0
16										
17	Offstream Storage Data							**SWP Distribution Pattern**		
18										
19	**North of Delta Storage**			**South of Delta Storage**				OCT	217.5	0.070
20								NOV	203.9	0.065
21	Conveyance to (CFS)	5000	vary	Conveyance to (CFS)	Limited [3]			DEC	206.4	0.066
22	Conveyance from (CFS)	6000		Conveyance from (CFS)	Limited [3]			JAN	188.5	0.061
23	Maximum Storage (TAF)	1600		Maximum Storage (TAF)	850			FEB	193.6	0.062
24	Starting Storage (TAF)	500	0?	Starting Storage (TAF)	250			MAR	218.2	0.070
25	Water Supply Factor	0.5	0					APR	249.9	0.081
26	Environmental Factor	0.5	1.	[3] Limited only by Aqueduct Capacity.				MAY	285.4	0.092
27								JUN	349.6	0.113
28								JUL	361.7	0.117
29	In-Delta Storage				Ecosytem Demand			AUG	357.0	0.115
30					Target Delta Outflow			SEP	272.4	0.088
31	Conveyance to (CFS)	5000			(CFS)					
32	Conveyance from (CFS)	5000			OCT	7000		Total	3104.4	1.000
33	Maximum Storage (TAF)	200	0		NOV	7000				
34	Starting Storage (TAF)	100	0		DEC	7000				
35					JAN	7000				
36					FEB	7000				
37					MAR	7000				
38	In-Delta Storage				APR	7000				

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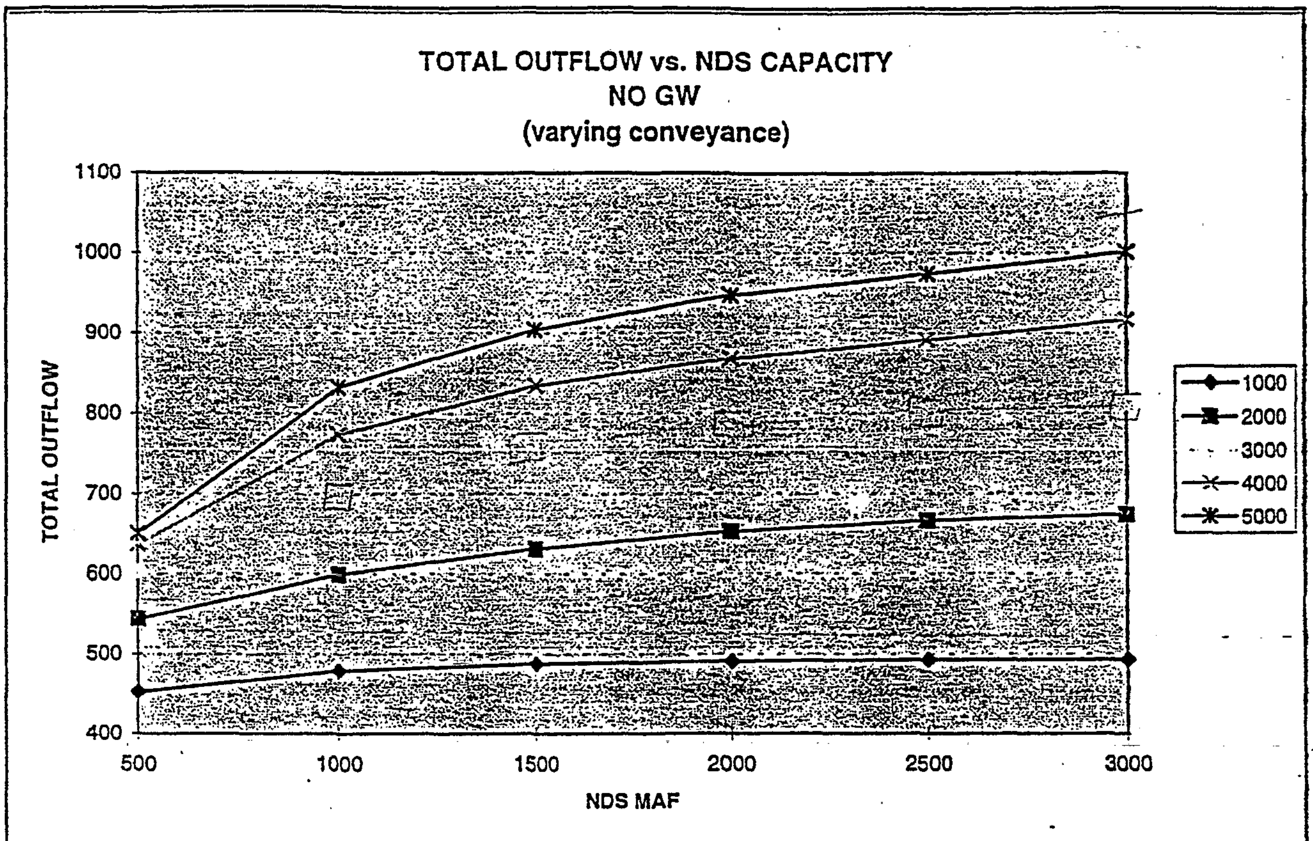
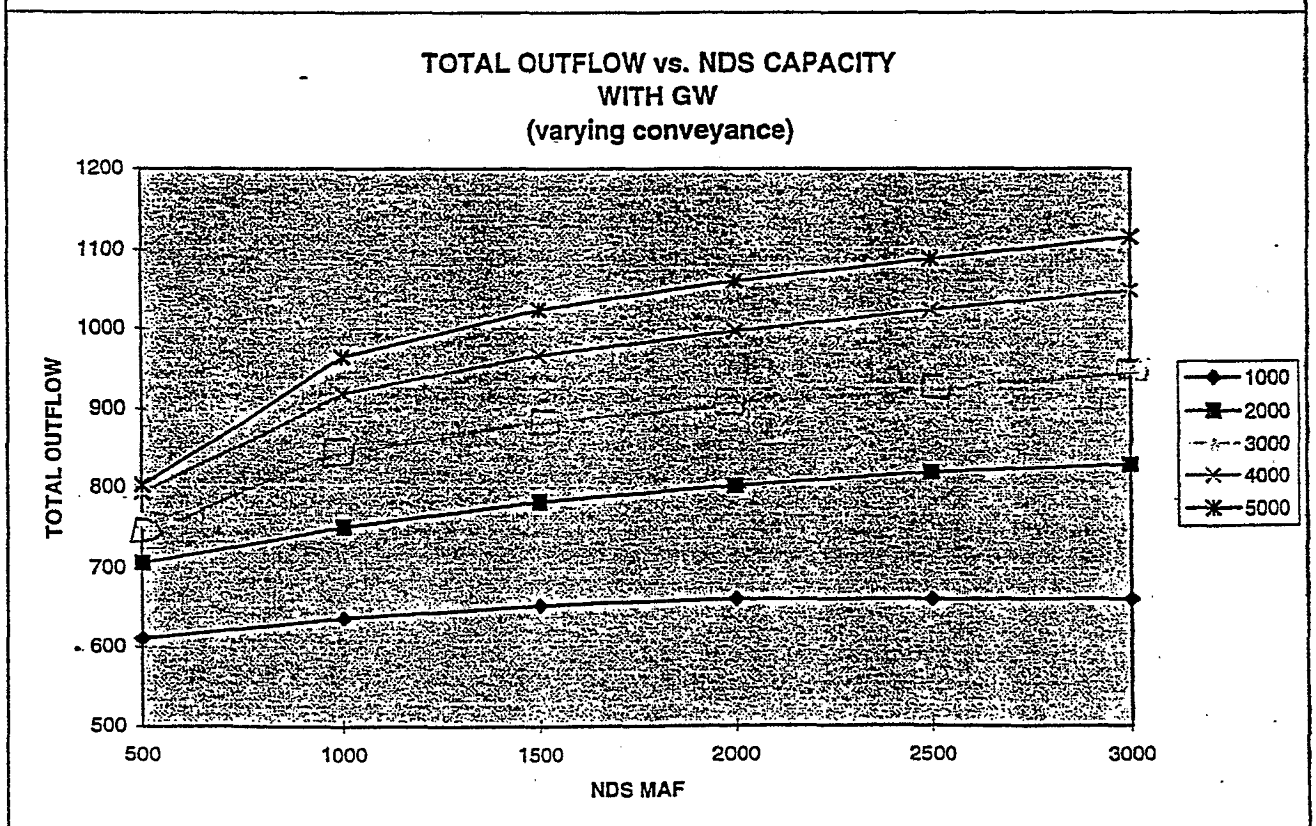

TOTAL OUTFLOW vs. NDS CAPACITY
NO GW
(varying conveyance)
1100
1000
900
800
700
600
500
400
TOTAL OUTFLOW
500
1000
1500
2000
2500
3000
NDS MAF
1000
2000
3000
4000
5000


TOTAL OUTFLOW vs. NDS CAPACITY
WITH GW
(varying conveyance)
1200
1100
1000
900
800
700
600
500
TOTAL OUTFLOW
500
1000
1500
2000
2500
3000
NDS MAF
1000
2000
3000
4000
5000

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Environmental Factor .5 Water Supply .5
Ground water storage and In Delta Storage OFF

Outflow+Exports (no gw)

	NDS===>>>					
Conv.	500	1000	1500	2000	2500	3000
1000	453	479	488	491	493	493
2000	545	599	630	652	666	674
3000	603	698	740	769	792	813
4000	636	774	834	867	891	917
5000	650	832	904	947	974	1001

Environmental Factor .5 Water Supply .5
Ground water storage ON and In Delta Storage OFF

Outflow+Exports (+ gw)

	NDS===>>>					
Conv.	500	1000	1500	2000	2500	3000
1000	611	637	653	661	661	661
2000	707	753	783	803	820	830
3000	760	850	883	909	932	951
4000	794	919	967	997	1024	1048
5000	803	965	1024	1060	1089	1116

NDS	$M/yr.
1200	19.8
1800	38.7
3000	98.1

Combine Facily Cost ($M/yr.)

	NDS===>>>								
Conv.	500	1000	1500	2000	2500	3000		Forecasted Cost	
1000	$33	$36	$51	$71	$96	$121	$21	500	($14)
2000	$53	$56	$71	$91	$116	$141	$41	1000	$8
3000	$74	$77	$92	$112	$137	$162	$62	1500	$30
4000	$95	$98	$113	$133	$158	$183	$83	2000	$52
5000	$116	$119	$134	$154	$179	$204	$104	2500	$74
	$12	$15	$30	$50	$75	$100		3000	$97

NET COST / WATER - Outflow+Exports (no gw)

	NDS===>>>					
Conv.	500	1000	1500	2000	2500	3000
1000	0.07	0.08	0.10	0.14	0.19	0.25
2000	0.10	0.09	0.11	0.14	0.17	0.21
3000	0.12	0.11	0.12	0.15	0.17	0.20
4000	0.15	0.13	0.14	0.15	0.18	0.20
5000	0.18	0.14	0.15	0.16	0.18	0.20

			NET COST / WATER - Outflow+Exports (+ gw)					
	NDS===>>>							
Conv.	500	1000	1500	2000	2500	3000		
1000	0.05	0.06	0.08	0.11	0.15	0.18		
2000	0.07	0.07	0.09	0.11	0.14	0.17		
3000	0.10	0.09	0.10	0.12	0.15	0.17		
4000	0.12	0.11	0.12	0.13	0.15	0.17		
5000	0.14	0.12	0.13	0.15	0.16	0.18		

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Project Conveyance/Storage　　Sheet a

Feature North of Delta Surface　　Designed SMB　　Date 9/28/96

Item　　Checked　　Date

▶ How does N o Δ gw storage affect break pt. in surface storage curve? Compute gradient in N o Δ surface curve, @ 500 TAF and 1,000 TAF

No Δ SS (P. 1,2,3) w/ GW			No Δ SS alone (P. 8,10,11)			
St	Su	d Supply / d Storage	St	Supply	d Supply / d Stor	
1000 800 600 400	279 266 252 221	.065 .070 .155	1000 800 600 400	440 426 402 323	.070 .120 .395	Avg of whole record
1500 1000 800 600 400 200	319 248 219 190 162 108	.142 .145 .145 .140 .270	1500 1000 800 600 400 200	343 272 244 215 186 122	.140 .140 .145 .145 .320	Dry period Avg

Conclusions:

- For average of whole record adding groundwater storage causes supply curve for reservoir to level off sooner: at 400 TAF rather than 800 TAF storage
- For Dry period average, adding groundwater storage causes supply curve for reservoir to level off later – at 3,000 TAF rather than 2500 TAF.

This indicates that surface and gw storage compete to some extent with each other for

DWR 128-R (REV. 5-79) 87 46605

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Project________ Sheet 6

Feature________ Designed________ Date________

Item________ Checked________ Date________

annual yield. However, gw storage allows for retention of larger critical period supplies in SS.

- Conclusion upper limit for north of Δ storage, with existing conveyance, is 3,000 TAF.

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Project Conveyance / Storage — Sheet C
Feature Delta Storage — Designed SMB — Date 9/28/96
Item — Checked — Date

► How does north of Δ surface and gw storage affect in Delta storage?

Compare in Δ storage alone with in Δ storage plus nΔ SS and NΔ gw.

With in-Delta storage alone, (P. 7), Yield levels of smoothly, but continues to gain at 700 TAF. With 3,000 TAF SS + 500 TAF GW, the yield from in Δ storage is 0 TAF for SWP. However yield from in Δ storage for outflow is 265 TAF, (vs 279 on P7)

This indicates that in Δ storage provides additional opportunities to capture surplus flows (almost undiminished yield) but export capabilities or demand limit exports from delta.

(Figures from Sb-Exist.xls → cr_buer.xls

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Project: Conveyance / Storage | Sheet: 2
Feature: North of Delta Surface | Designed: SMB | Date: 9/28/96
Item: | Checked: | Date:

▶ How does dual use of N of Δ Surface water storage affect break point in surface storage curve?

We have explored single component curve for SWP = 1 (P. 8), ENV = 1 (P. 13). Inspection of these two graphs suggests that break point in curves shift very little, although absolute value for env=1 curve is higher. Thus I would expect that 50/50 split would look similar but demand would be higher. Inspection of p 17 confirms that major break point is still in 800 - 1,000 TAF range, with secondary break point ~ 3,000 TAF. See p. 18, p 19 (19 is same as 18, but with data points for 4,000 TAF and 5,000 TAF added.

DWR 132 B (REV. 5-70)

Project Conveyance / Storage | Sheet e
Feature South of Δ Surface | Designed SMRS | Date 9/29/96
Item | Checked | Date

► How does improved Delta conveyance affect break point in S of Δ surface storage curve. Zero out other storages. Water supply factor = 1.0, Conveyance set to 10,300

☐ Why doesn't spreadsheet show gain in yield from add'l conveyance alone? - - - - - - - - - - -
Compare P. 6 to P. 19. With existing Conveyance break point is in the vicinity of 400-500 TA storage. With improved conveyance, break point shifts to about 1500 TAF.

Project Conveyance / Storage Sheet f

Feature South of Δ Surface Designed SMB Date 9/29/96

Item Effect of Adding GW Checked Date

➤ How does adding GW south of Δ affect surface storage? To find out, add maximum GW and examine impact on Surface storage curve.

Compare P. 20 and P. 21. The results show that there is significant change in the breakpoint for the surface storage vs supply curve. ~~It also~~ It shows that south of Delta surface and gw storage compete for available supplies, as gw storage declines with increasing surface storage.

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Project: Conveyance / Storage — Sheet: 8
Feature: South of Δ Surface + GW — Designed: SMRS — Date: 9/29/96
Item: Effect of North of Δ Storage — Checked: — Date:

▶ How does adding North of Delta, Surface and GW, affect South of Delta Surface Storage curve?

Compare South of Delta Surface Storage alone (P.20) to adding all other storages, except in-Delta, (p 22).

The result: The other available storages in system reduce gradient of $\frac{d\ Supply}{d\ Storage}$. Data tabulated below, and plotted on p 24. Example: for a storage of 670 TAF, gradient is $\frac{0.4\ TAF\ Supply}{1.0\ TAF\ Storage}$ for

Gradient, South of Delta Storage, with all others except in-Delta		
So'D stor	Supply	dy/dx
0	0	
200	142	0.7100
400	203	0.3050
600	231	0.1400
800	251	0.1000
1000	265	0.0700
1500	297	0.0640
2000	318	0.0420
2500	334	0.0320
3000	346	0.0240

Gradient, South of Delta Storage, with no other storages on line		
So'D stor	Supply	dy/dx
0	0	
200	270	1.3500
400	394	0.6200
600	483	0.4450
800	543	0.3000
1000	586	0.2150
1500	652	0.1320
2000	694	0.0840
2500	735	0.0820
3000	763	0.0560

South of Delta Storage alone. With other storages on line, that gradient is reached at 360 TAF. Thus a smaller reservoir is economically justified.