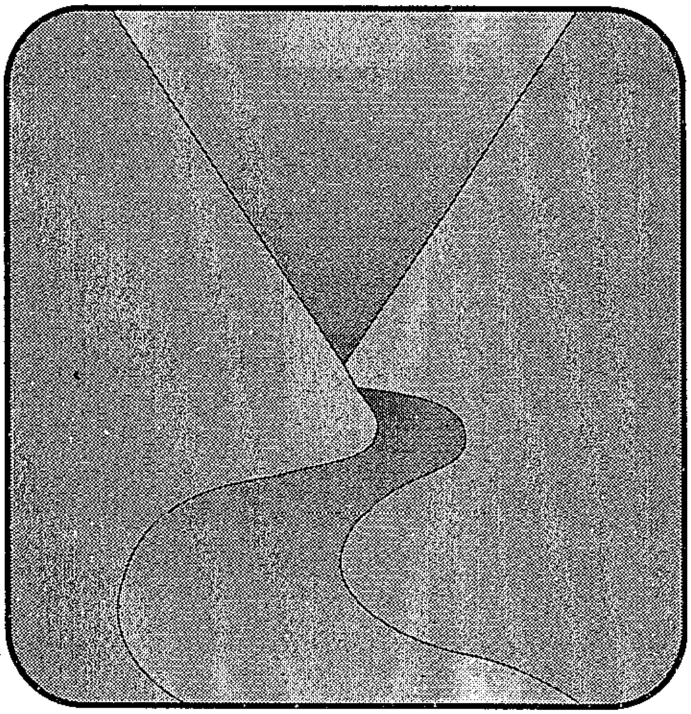
Water Reliability Analysis and Planning (WRAP)

Model Description, Documentation, and Operating Instructions



California Urban Water Agencies

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NOTICE

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I. INTRODUCTION

Since the summer of 1991, California Urban Water Agencies (CUWA) has been engaged in a major effort to provide guidance to the state's urban water suppliers in the definition, measurement, and optimization of water supply reliability. The first phase of the project was largely conceptual in nature and enabled participants to reach a common understanding of terms and underlying principles.[1] Figure I-1, reproduced from the Phase 1 report, illustrates the reliability planning framework that emerged.

The second phase of the work, has focused on two major products:

- A field-ready contingent valuation survey instrument to assess the economic value to residents of water supply reliability; and

- A PC-based reliability model that can serve as a prototype for a tool to be used by water agency planners.

The purpose of this report is to describe the prototype reliability model, its various potential uses, and the information that agencies must develop to make use of the model (or a more complete and "user-friendly" successor). The model is called the **WRAP** (Water Reliability Analysis and Planning) model.

One of the major purposes of the CUWA project is a standardization of definitions and measures of water supply reliability. The WRAP model was developed to enable utilities to forecast and analyze their reliability using the definitions and measures that were agreed to in Phase 1. In Phase 1, water supply reliability was defined as:

> *The degree to which water customers receive their full-service demand within acceptable quality and service standards.*

Phase 1 concluded that the analysis of water supply reliability requires the application of probabilistic concepts, since reliability depends on the relationship between customer demand and available supply, both of which are probabilistic variables. A complete specification of the reliability of water supply in any year requires the use of cumulative frequency distributions (CFDs), which depict the likelihood of occurrence of particular shortage magnitudes. More precisely, a CFD plots the probabilities of

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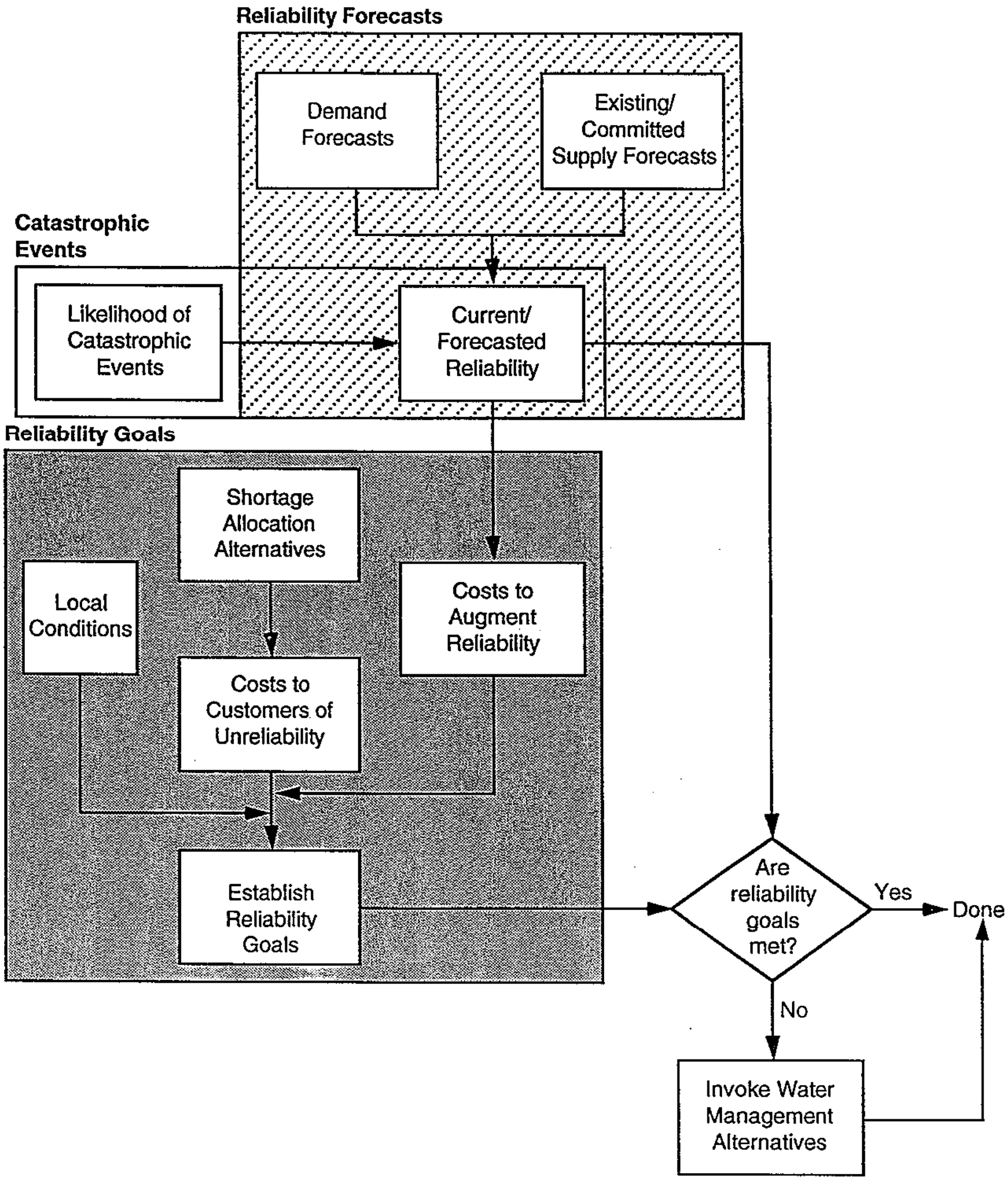
[1]For a summary of the results of this first phase, see *Water Supply Reliability in California: How Much Do We Have? How Much Do We Need?* California Urban Water Agencies. January 1992.

Figure I-1

A Generic Reliability Planning Framework



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shortages larger than particular percentages of full-service demand. A sample CFD is shown in Figure I-2.

Phase 1 also defined three reliability indices that summarize particular aspects of system reliability in a more tractable form than the complete CFD. These indices are:

- **Probability of Shortage (POS)**. The probability that available supply will fall short of the full-service demand (i.e., the probability of a shortage of *any* magnitude).

- **Probability of Designated Shortage (PODS)**. The probability that available supply will fall short of full-service demand by more than a particular percentage of full-service demand. For example, PODS (10%) is the probability of a shortage exceeding 10% of full-service demand. POS is a special case of PODS (i.e., PODS (0%).

- **Expected Unserved Demand (EUD)**. The expected percentage of full-service demand not served.

Each of these indices, as well as the entire CFD, can be forecast for any future year.[2]

OBJECTIVES OF THE WRAP MODEL

The major objective of the WRAP model is to forecast current and future reliability to assist planners in estimating how system reliability will be affected by supply/demand relationships. The model allows planners to easily see the reliability implications of varying:

- Available supply resources, e.g., by addition of new supplies, water marketing, etc;
- Demand-side management (conservation);
- System operating rules; and
- Externally-imposed supply constraints.

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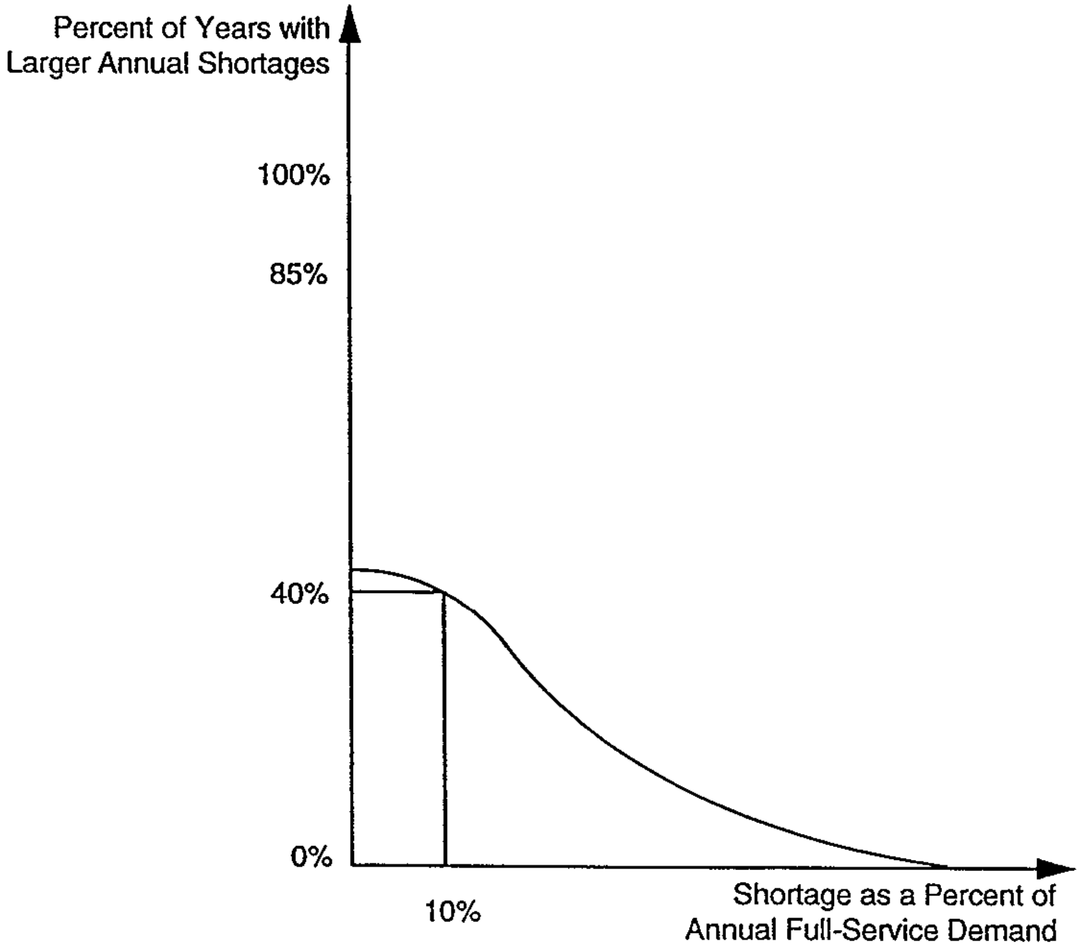
[2]System reliability could be analyzed for a period other than a full year. For example, for systems that have insufficient local storage or transmission limitations, the reliability of the system to meet seasonal or peak-period demands may be of particular interest. All of the same definitions and principles could be applied equally well to these periods. To do so would require development of appropriate demand and available supply data series. These alternative uses of the reliability indices are not discussed in this report.

Figure I-2

Example of System Reliability Cumulative Frequency Distribution for a Specific Future Year



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It also allows planners to track changes in reliability over time as available supplies and demands change.

WRAP allows agencies to compare the system reliability implications of alternative resource futures. In addition, the path of future system reliability under various resource scenarios can be easily and consistently communicated to policymakers and various stakeholder groups.

Referring to Figure I-1, the current version of WRAP addresses the top shaded area of the diagram, labeled "Reliability Forecasts."

THE MODEL AS POST-PROCESSOR

The current version of WRAP is purely a *post-processor*. It does not attempt to describe or derive agency-specific supply or demand characteristics. It assumes that water agencies will have developed their own probabilistic forecasts of customer demands and available supplies, which will be treated as inputs to the model. The manner in which agencies develop these forecasts is not a direct concern of WRAP, although the format in which the information is provided is critical.

Developing supply and demand forecasts can be a difficult undertaking. The complexity and the specific form of the forecasts vary according to the size and type of system and the precision desired by system planners. The alternative types of supply and demand forecasting models are discussed in Section IV.

ORGANIZATION OF THE REMAINDER OF REPORT

The remainder of the report is organized as follows:

- Section II discusses the characteristics of the WRAP model, including required inputs and types of model outputs.

- Section III describes how the model can be used to enhance system planning, and includes a multi-layered illustrative example.

- Section IV addresses the requirements for supply and demand forecasts that are usable by the WRAP model.

- Section V addresses the issue of reliability optimization and how the model could be extended to assist planners to develop appropriate reliability goals for their systems.

- Finally, Section VI presents complete and detailed instructions for operating the WRAP model.

A copy of version 1.0 of the WRAP model, on 3½" diskette, is enclosed with this report. The contents of this diskette are described in Section VI.

II. WRAP MODEL CHARACTERISTICS

The current version of WRAP is designed as a spreadsheet using version 3.1 of the Lotus 1-2-3® software. It converts externally-generated data on water supply and demand characteristics into cumulative frequency distributions (CFDs) and reliability indices for user-specified future years. Users have several choices regarding the form of the supply and demand data inputs. The model allows direct comparisons to be made among different future years or among different supply and demand scenarios. WRAP produces both graphical and numerical results.

As indicated in the introduction, this prototype model is designed to act as a "post-processor." As such, its role is to analyze system-specific supply and demand forecasts to produce forecasts of system reliability. As currently constituted, the model is completely dependent on system-specific data generated by the user utility. It is assumed that the user utility has its own capability of generating such information. (The agency analytical requirements are discussed in Section IV below.) The most effective use of the model is as an integral component of an agency's own planning and modelling processes.

MODEL INPUTS

The model's data requirements for demand and supply forecasts are as simple and straightforward as possible. A detailed description of the necessary data format is included in Appendix A. Following are brief discussions of the demand and supply data required by the model.

Demand Inputs

Most agencies have developed demand forecasts, at various levels of disaggregation, that predict customer water needs for some future planning period. For each future year for which the user wishes to generate reliability forecasts, water demand may be provided to the model in one of two formats:

- A single point best estimate.

- Three figures, which represent (1) a best estimate, (2) a high-side estimate, and (3) a low-side estimate, along with an appropriate weighting for each of those estimates.[3]

Supply Inputs

In the context of this model, water supply means the *water available to customers.* For the majority of agencies, supply is not the same as hydrologic input to the supply system because, depending on their water contracts and rights and operating rules for storage reservoir filling and release over the year, more or less than the hydrological supply may be made available to customers. Many agencies can predict available supplies based on an historical or hypothetical hydrological record using a system planning model. The planning model reflects relevant operating rules and considers different levels of customer demand. These issues are addressed in more detail in Section IV.

For most large urban systems in California, *available supply is in part a function of demand.* This is because these systems depend to some extent on carryover storage, the operating rules for which depend partly on demand. This interdependence of supply and demand is critical to the manner in which supply inputs are provided to the WRAP model. *Each supply forecast must be explicitly associated with a demand forecast.*

WRAP permits users to characterize expected available supply for selected future years as a discrete series. This could be a series of available supplies that is based on a number of years of historical hydrologic record, coupled with expected system operating conditions for the future year being examined. Alternatively, the series could be based on historical records of deliveries from a wholesale supplier. A third possibility is a history of groundwater yields.

For suppliers with multiple sources, the series would be a composite of several data sets aggregated into a single data set that represents the total available supply. The statistical analysis performed by the WRAP model does not depend on the number or type of supply sources.

[3]The data templates provided with the model contain the default weighting values of 50% for the "best estimate," and 25% for the high-end and low-end demand estimates. These can be changed where required.

In some instances, this series could be based on a "synthetic," rather than an historical hydrological record. Synthetic data series are created when planners generate longer periods of runoff data that match the statistical properties of shorter available historical records. In some cases, synthetic series may be modified historical records into which planners have inserted artificially intensified drought sequences as a test of their supply system under assumed worst-case scenario conditions. The use of this latter type of synthetic data set may result in an unrealistic set of system reliability indices.

The specification of available supply must be coupled with a particular demand forecast, and must be appropriate to the system configuration and external conditions expected in each selected future year. Thus, for example, if new facilities are expected to become operational or if increases in future in-stream flow requirements are expected to reduce available supplies, the available supply forecasts must reflect these new conditions.

The model will permit the user to define up to five *resource scenarios*. A resource scenario is defined as a particular combination of supply-side and demand-side resources, operating conditions, and external constraints that uniquely define available supply and customer demand for each of up to six future years. For each scenario, the model can produce outputs for each of a maximum of six future years (e.g., 1993, 2000, 2010, 2020, 2030 and 2040).

MODEL OUTPUTS

The modelling results are designed to describe future-year system reliability associated with various demand/supply forecasts. WRAP can produce a wide variety of outputs which combine graphical and tabular presentations of cumulative frequency distributions and specified reliability indices. In general, the outputs can be cross sectional comparisons of different resource scenarios for a single future year or time-series comparisons which track, over time, the reliability implications of a single resource scenario.

Major types of output include:

- Graphical plots of cumulative frequency distributions for specified future years;
- Tables of reliability indices for particular future years and resource scenarios;

- Graphical plots of changes in cumulative frequency distributions or specific indices over time; and

- Graphical comparisons of CFDs or specific indices in a particular year across alternative resource scenarios.

By strategically combining these outputs, system planners will be able to improve their understanding of the planning implications of different resource futures. The significance of the various types of model outputs are explored in detail in Section III below.

The WRAP model estimates the probability of annual shortages but does not attempt to predict when and in what pattern they are likely to occur. It does not consider the probability or sequencing of multi-year future shortages.

Interpretation of Model Outputs

The usefulness of the WRAP model lies in its ability to allow system planners to improve their understanding of the system reliability implications of alternative resource futures. It is therefore important to understand in general terms how and why the reliability measures may vary and what these variations mean.

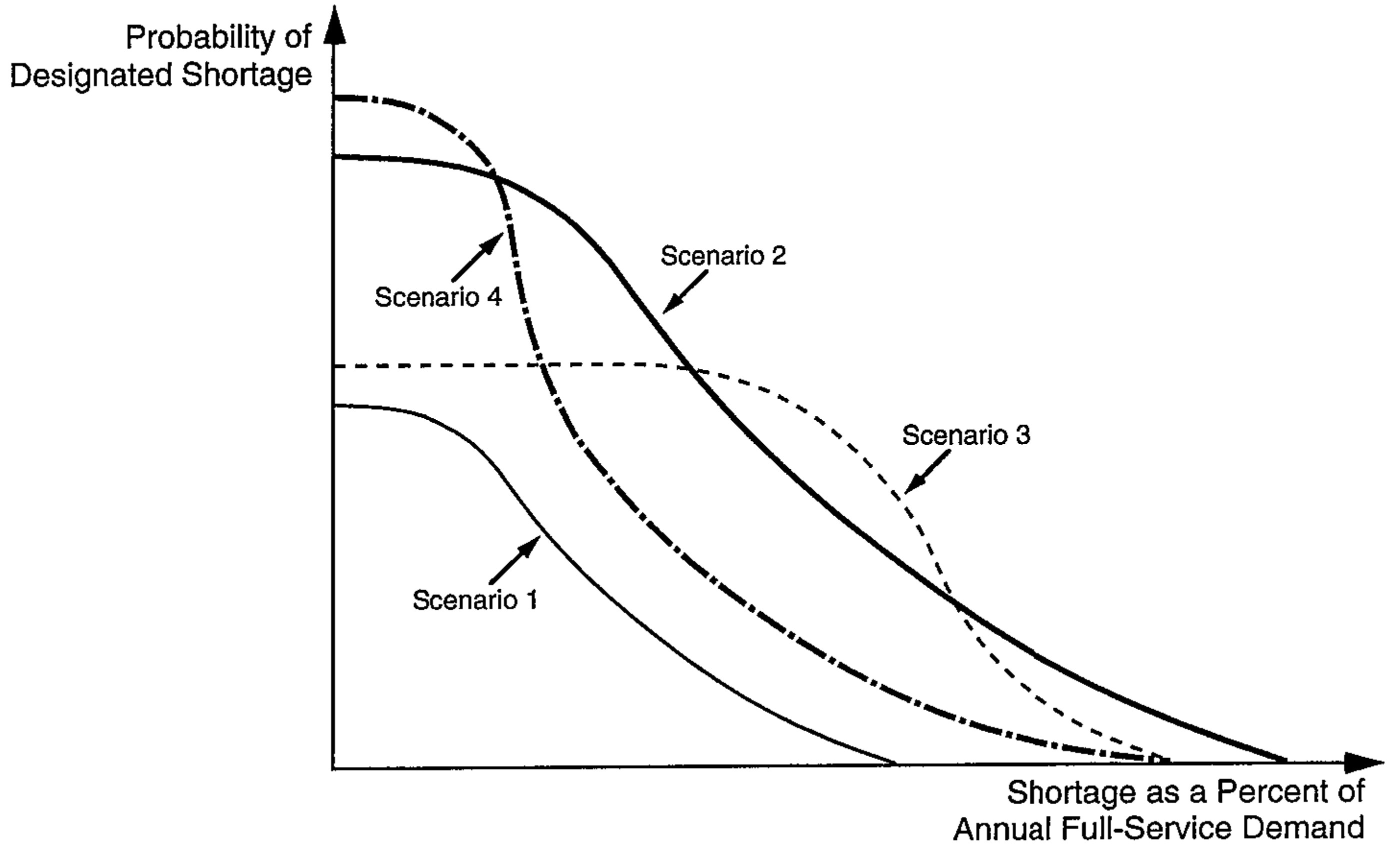
Cumulative Frequency Distributions

As discussed in Section I, the basic and most complete characterization of system reliability is embodied in the cumulative frequency distribution (CFD). The CFD is a plot of the probabilities of shortages larger than particular magnitudes. Figure II-1 presents several hypothetical CFDs for different supply/demand scenarios. The lower CFDs generally connote more reliable systems (i.e., Scenario 1 is more reliable than Scenario 2). The shape of the CFD is also revealing. A CFD that decreases very gradually (e.g., Scenario 3) indicates that larger shortages are almost as likely as smaller ones, whereas CFDs that fall off more rapidly (such as Scenario 4) indicate that large shortages are very unlikely. Clearly, where planners are faced with CFDs that are markedly different for two or more alternative future resource scenarios, the CFDs provide a basis for assessing the comparative advantages and tradeoffs associated with a particular resource selection.

Note that any such curve describes the forecasted system reliability for a *particular future year*. As demand grows and the resource mix changes, the level and shape of

Figure II-1

Hypothetical Cumulative Frequency Distributions For Alternative Resource Scenarios



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the CFD will also change. WRAP will allow planners to track these changes over time.

Changes in the CFD are not only a function of resource scenarios and the passage of time, but also of changes in system operation. Thus, for systems with significant carryover storage, changes in operating rules will alter the character of future shortages. Comparing the CFDs for such contemplated changes will assist planners and policymakers reach more informed decisions.

To conveniently and usefully summarize some of the key characteristics of the CFD, WRAP also produces outputs of the three reliability indices, as follows.

The Probability of Shortage (POS) Index

POS is the probability of *any* shortage occurring. It therefore indicates the probability that an agency must implement some form of shortage contingency measures to reconcile demand and supply. For a particular future year, a POS of 20% means that there is a one in five likelihood of a shortage in that year. Like the other reliability indices, the POS will differ for different future years, depending on demand growth, supply-side or demand-side resource additions, operational changes, or externally-imposed changes in available supply.

While the POS indicates the likelihood of *some* shortage, it does not provide information on the likelihood of differing levels of shortages. Put another way, the POS tells us where the vertical intercept of the CFD is; but it tells us nothing about the shape of that curve. Thus, two scenarios with equal POS values may have markedly different reliability characteristics, as indicated in Figure II-2. Although both scenarios depicted in Figure II-2 yield the same POS, Scenario 1 is obviously a more reliable system. On the other hand, as indicated in Figure II-3, the POS values by themselves may be misleading in terms of which of two scenarios is "more reliable." While Scenario 1 results in a higher POS, it has a much smaller likelihood of large shortages than does Scenario 2. In order for policymakers to make informed choices between the two resource futures, more information than the POS is required.

The Expected Unserved Demand (EUD) Index

Whereas POS captures one aspect of a system's reliability characteristics (namely the likelihood of very small shortages), EUD summarizes all of the information contained

Figure II-2

Two Resource Scenarios with Equal POS Values

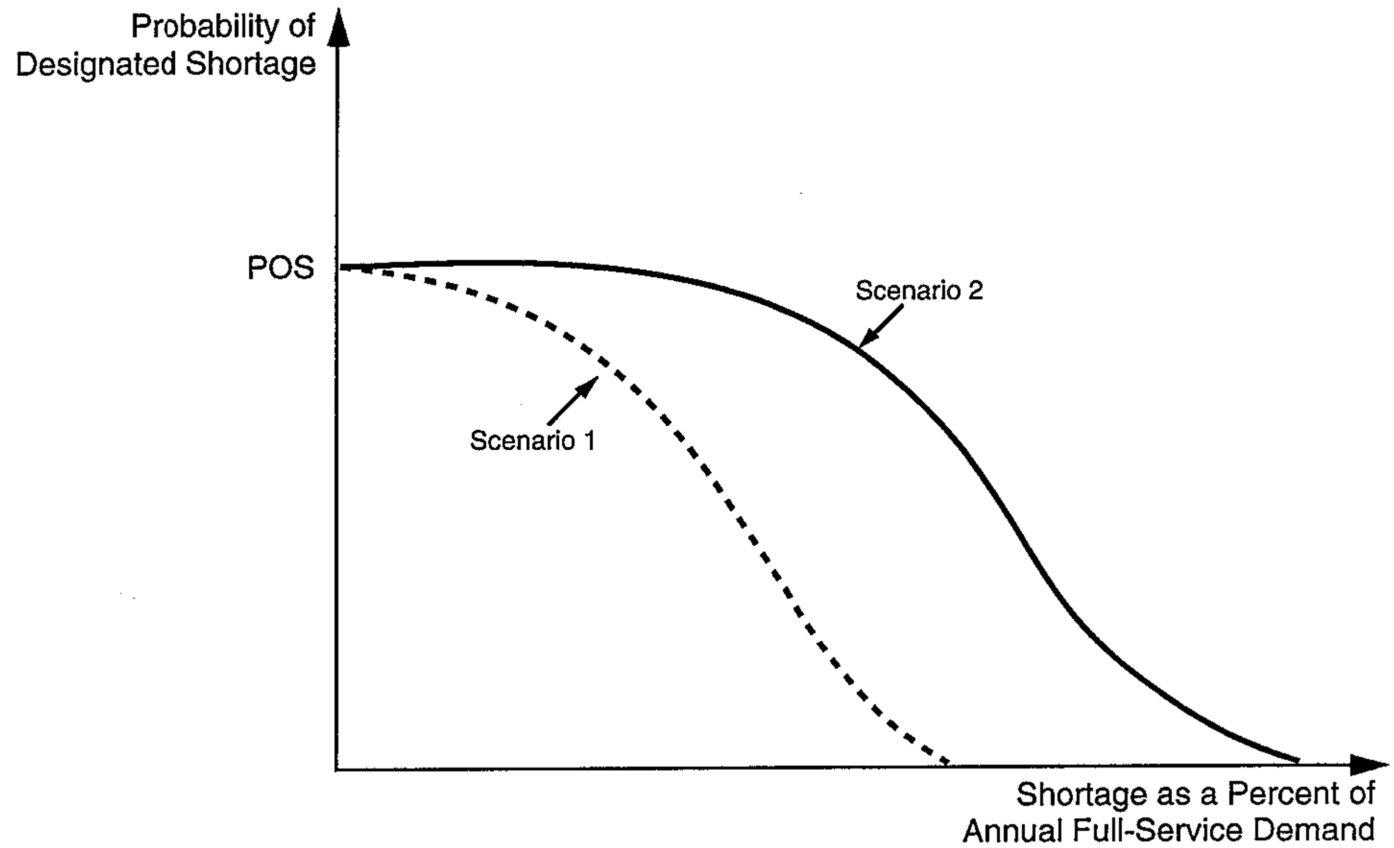

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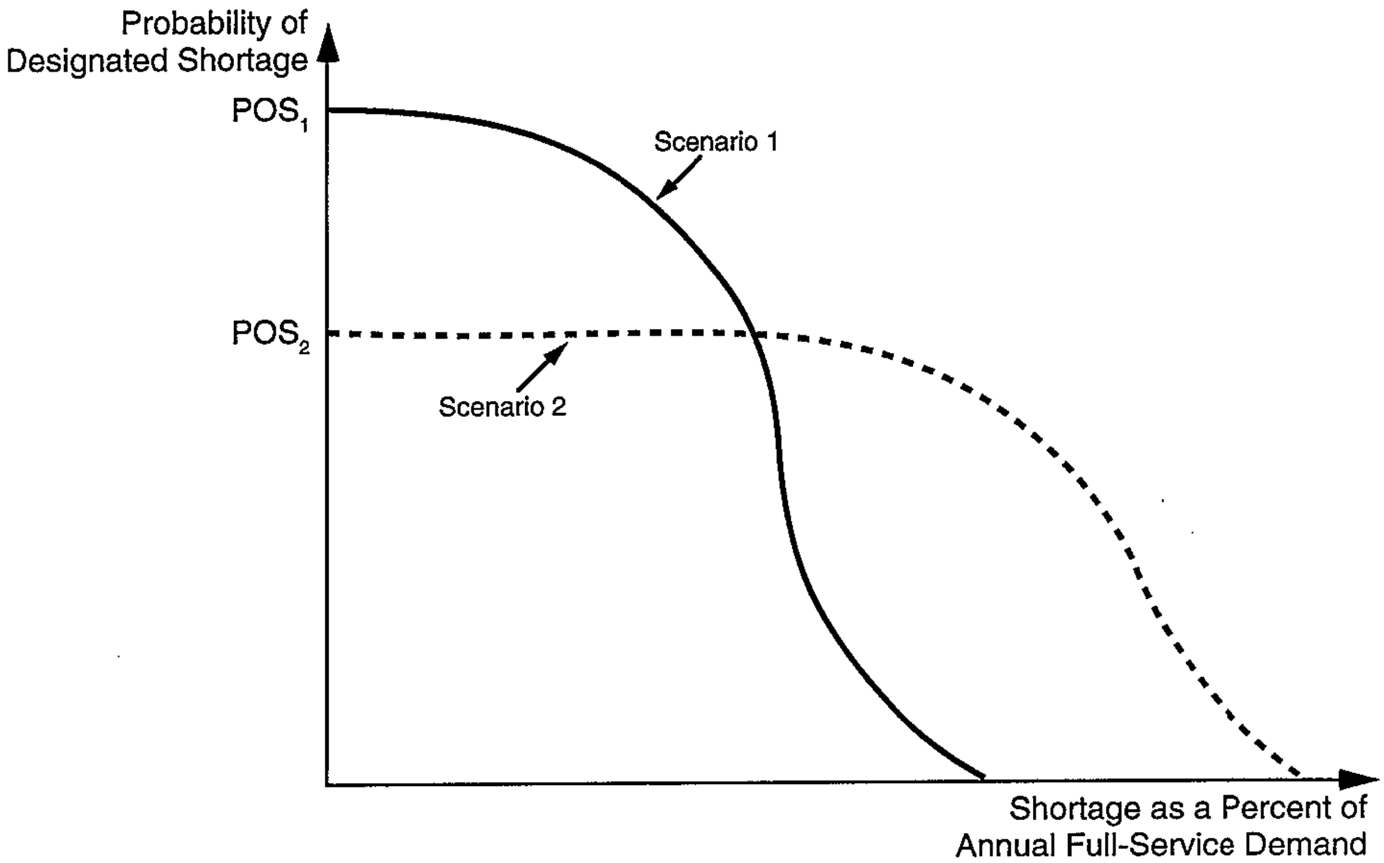
Figure II-3

Two Resource Scenarios with Different POS Values and Different Reliability Characteristics



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in the CFD.[4] Of course, by so doing, it sacrifices much of the detail that can be gleaned from the CFD itself. Thus, the EUD of the two scenarios depicted in Figure II-3 may be identical, although the reliability characteristics of the two systems are very different.

The EUD indicates the expected percentage of full-service demand that will remain unserved in a particular future year. In effect, the EUD summarizes the universe of predicted shortages as a single average value of unmet demand.

The Probability of Designated Shortage (PODS) Indices

Each PODS value indicates the chance of experiencing a shortfall in supply greater than a particular percentage of full-service demand. Thus, as indicated in Figure II-4, the set of PODS indices completely specifies the CFD. The PODS of a larger shortage will always be less than or equal to the PODS of a smaller shortage. The difference between two designated shortage PODS values gives the probability of a shortage within that shortage range.

While the universe of PODS values completely specifies the reliability characteristics of the system, individual PODS values are useful to planners by indicating the probability that a particular shortage contingency planning level must be implemented.

Time Series of CFDs and Reliability Indices

As indicated above, the CFD will change over time. In the simplest case, as demand grows and no new resources are added, the curve will shift upward and to the right, indicated deteriorating reliability (see Figure II-5). For example, this type of shift characterizes what is currently happening in California to the State Water Project due to rising demand and essentially fixed resource capabilities. Of course, if patterns of demand change and/or new resources are added, the shape of the curve can change.

Along with changes in the CFD come changes in the indices that summarize the CFD. The WRAP model has the capability of producing tables or graphs that chart the changes over time of particular reliability indices in response to specified changes in supplies or demands. Figure II-6 illustrates the changes over time in EUD for a

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[4]EUD conveys the CFD information concerning expected shortages in an important format, namely the average percent of demand unmet, which is the sum of the product of each percentage shortage and its probability of occurrence.

Figure II-4

The Relationship Between PODS Values and the Cumulative Frequency Distribution

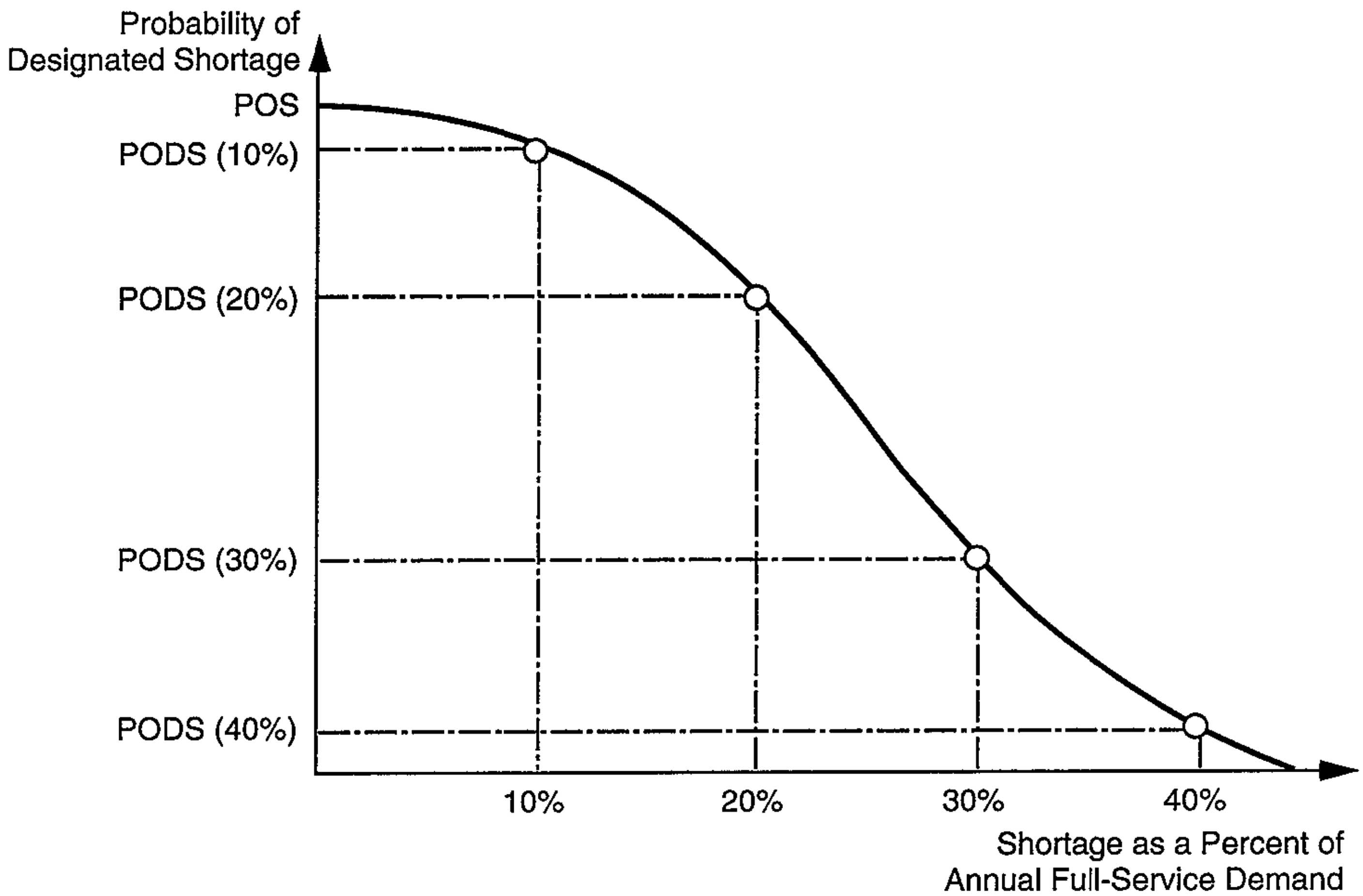

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Figure II-5

Impact on Cumulative Frequency Distribution of Demand Growth over Time

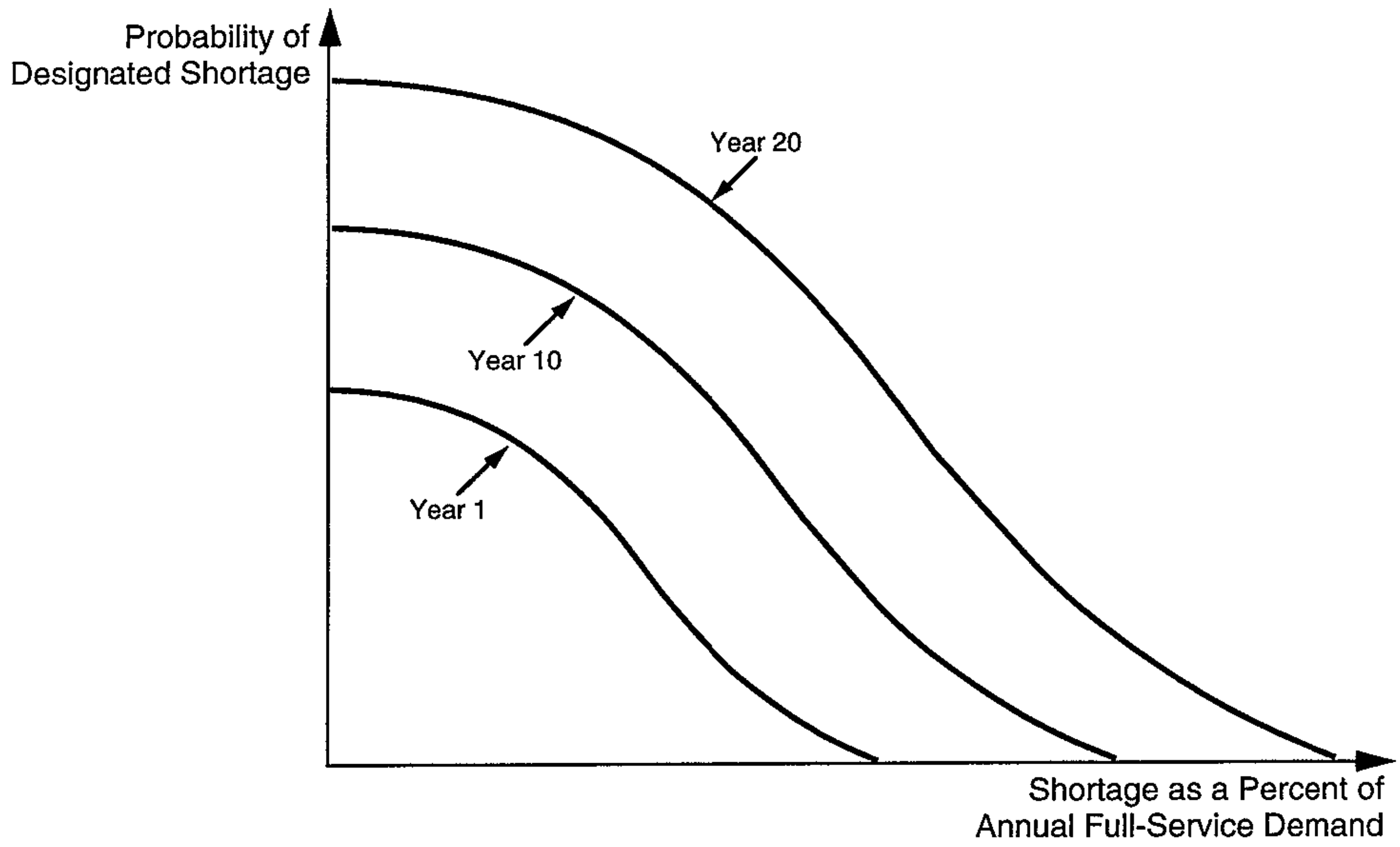

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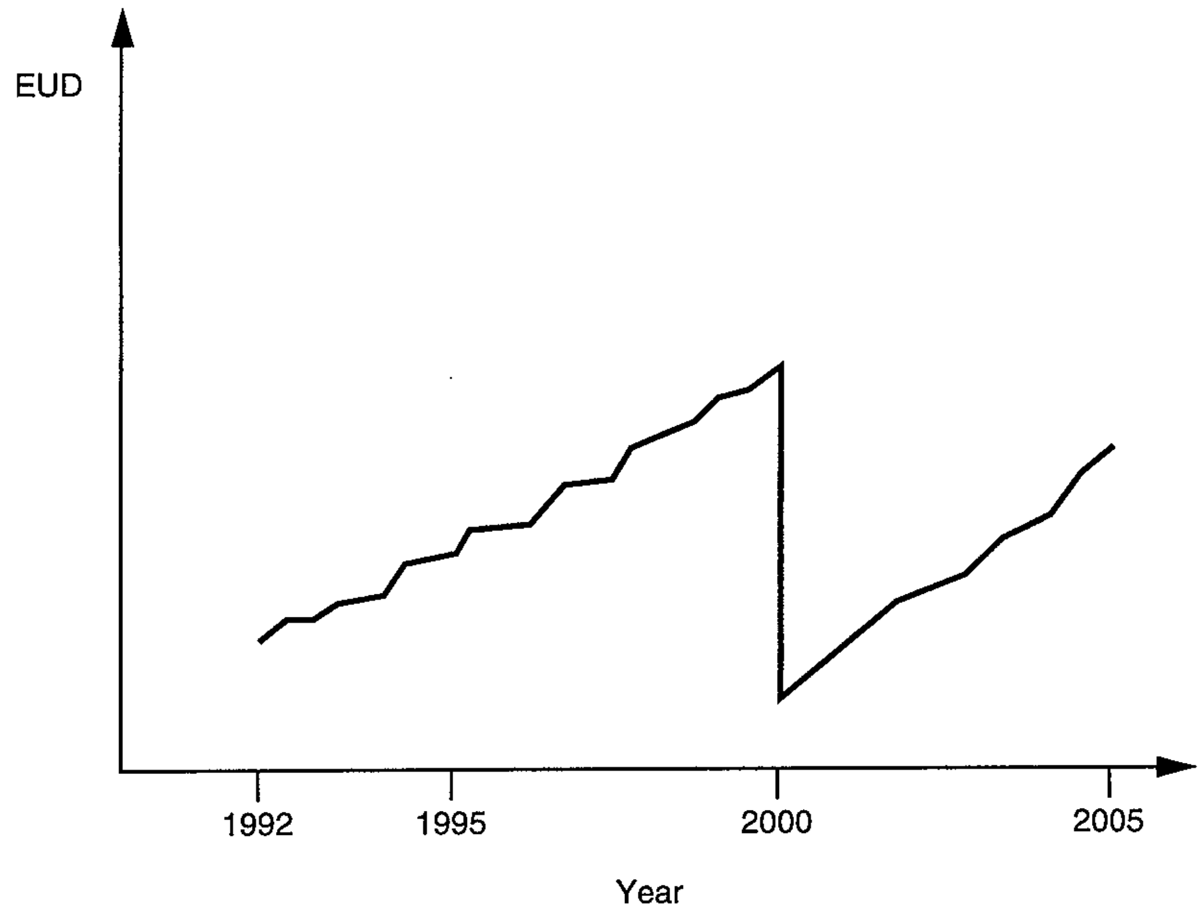
Figure II-6

Change in EUD over Time for a Hypothetical System



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system that is experiencing steady growth in demand, and is expected to add a new major source of supply in the year 2000.

Finally, WRAP will also allow direct comparisons of changes over time in reliability indices for different future resource scenarios. This is illustrated in Figure II-7, which shows the changes in the PODS of 10% (i.e., the probability of a shortage greater than 10%) for three alternative resource futures.

While the model outputs can be of great use to system planners, they must, like any analytical results, be interpreted with caution and combined with other pertinent information. For example:

- A particular resource future will often not be clearly "more reliable" than another. Certain resource scenarios will have specific reliability attributes (e.g., fewer large shortages or more stability over time or a particular PODS less than a specified threshold) that meet certain policy objectives. Thus, model results must be measured against these objectives;

- Reliability indices that are expressed as percentages of full-service demand will, as future system demand grows, denote growing volumes of water;

- For less frequent events or for long planning horizons, reliability indices may be imprecise due to inadequacies in the hydrological record (duration, representation of extreme drought cycles, etc.) or in demand forecasts (population growth, water use characteristics, etc.);

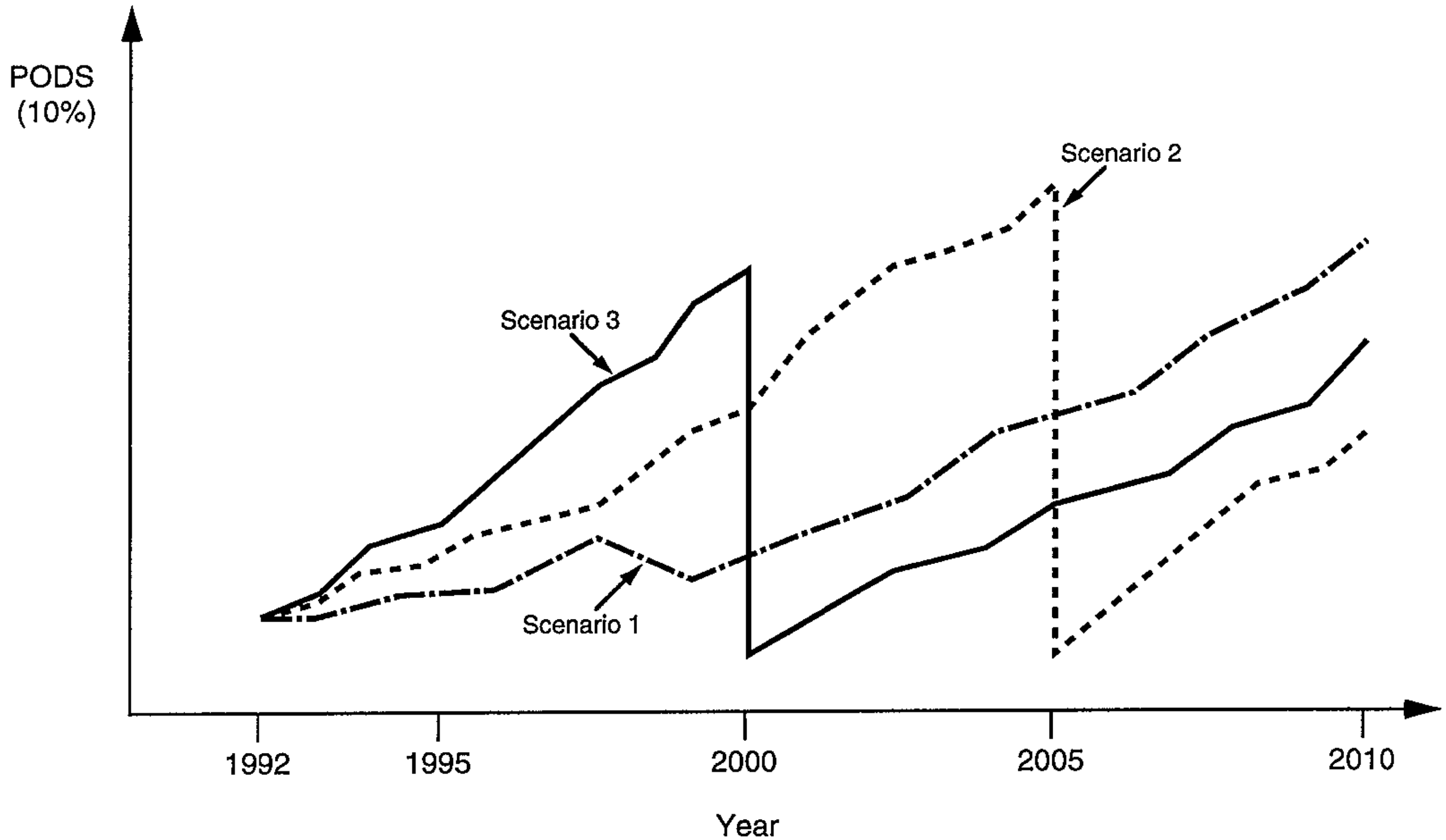
- Depending on the resource mix with which it is associated, a particular percentage shortage may have differing implications to customers. Thus, to the extent that long-term conservation programs harden demand, shortages associated with resource scenarios that include large amounts of conservation, may be more difficult to manage, and potentially more costly to customers;

- "More reliable" systems are generally more expensive; and

- The issue of the "right" level of reliability is not addressed by the current model. (See Section V for a more complete discussion of this issue.)

Figure II-7

Change in PODS (10%) over Time for Different Resource Scenarios



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III. USES OF THE WRAP MODEL

As described above, the WRAP model can be useful to water resource planners. This section describes the major potential uses of the model, including:

- Developing forecasts of future system reliability;
- Assessing the impact on reliability of planning and operational changes including:
  - adding, subtracting or altering supply-side and demand-side resources;
  - changing the manner in which the system is operated; and
- Evaluating the reliability impact of various "external" variables that effect demand or available supply.

These model applications can enhance the quality of an agency's resource planning decisions. They can also assist the agency in communicating information regarding future system reliability to the public, specific stakeholder groups, and political bodies. As the model description in Section II has indicated, these model applications can effectively be combined. For example, forecasts of system reliability under a "no-action" scenario can be compared to reliability forecasts which assume various combinations of future resource additions.

This section will begin with descriptions of the major uses of the WRAP model. These descriptions will be followed by a multi-layered example to illustrate these model applications.

Common to all of these model applications are several steps the user must undertake:

- Decide upon the demand and supply configurations and future years to be analyzed;
- Develop the appropriate supply and demand inputs, recognizing their interdependence; and
- Choose the appropriate form and content of the desired model outputs.

FUTURE YEAR RELIABILITY FORECASTS

As a starting point, WRAP enables planners, decision makers, and the public at large to better understand the path that system reliability will follow under the so-called "do-nothing" alternative (i.e., assuming no future resource additions beyond those for which commitments have already been made, and no changes in system operations). Agencies can then determine whether or not these results are acceptable. If not, then they can proceed to assess the impact of differing combinations of supply-side and demand-side resource additions and/or operational changes.

Developing these forecasts will generally require the following steps:

- Establish a baseline reliability by running the model with current demand and under current supply and operating conditions;
- Specify a set of future years for which system reliability should be characterized. This set should cover the planning horizon;
- Forecast the demand or range of demands in each year;
- Develop supply forecasts for each year associated with each potential demand level. If appropriate, develop alternative supply forecasts for differing assumptions regarding future "external" events;
- Run the model to develop reliability forecast(s) for each year under this "no-action" scenario; and
- Chart reliability changes under this no-action scenario over time.

ASSESSING THE IMPACT OF RESOURCE ADDITIONS

Once the user has developed and understood the "no-action" reliability forecast, the model can then be used to evaluate the impact of supply-side or demand-side resource additions. The analytical steps are similar to those described in subsection A above. However, instead of running the model with forecasts of demand and available supply based on the current resource mix, the inputs are modified to reflect the desired new resources. The user must keep in mind that, in general, available supplies in systems with significant carryover storage depend on demand. It is important that this relationship be well-understood not only for the current resource mix, but also for the new resource mix that is being assessed. Thus, the addition of storage capacity will likely change the form of the dependence of available supply on demand.

The magnitude of the demand-side or supply-side resource additions may themselves be uncertain. Thus, the demand-reduction impacts of a conservation program may not be easily forecast. Similarly, the available supply associated with, say, a storage facility will depend on hydrology.[5] In either case, the uncertainty associated with the new resource(s) must be reflected in the new supply and demand forecasts in a manner that reflects potential operational interactions with existing resources. Whether or not the specification of the new resources reflect uncertainty, the end result of adding new resources will be a new set of supply and demand forecasts, which define a new resource scenario.

Once the supply and demand inputs are appropriately modified, graphical or tabular comparisons can be made across resource scenarios and over time, as illustrated in subsection E below.

ASSESSING THE IMPACTS OF CHANGES IN SYSTEM OPERATIONS

Available supply, and the dependence of available supply on demand, especially for a system with carryover storage, can be affected not only by the addition of new resources, but also by changes in the way the system is operated. For example, many agencies have operational thresholds at which they invoke shortage management techniques such as rationing. Even though there may be sufficient stored water to supply demand within a particular water year, some is withheld as an "insurance policy" against subsequent dry years. Changes in these rules will modify a multi-year series of available supplies corresponding to a particular hydrological history.

Operational changes can result from regulatory or policy decisions including those related to water quality, downstream water rights, environmental management, groundwater protection or hydroelectric generation. Section IV discusses approaches that agencies can use to model these kinds of system operations changes.

EVALUATING THE IMPACTS OF CHANGES IN EXTERNAL CONDITIONS

While available supplies depend on hydrology, demands, resource additions, and system operations, they are also affected by external changes over which the water

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[5]It will, of course, also depend on system operating rules.

agency may have little or no control. For example, the courts or regulatory agencies may mandate enhanced in-stream flows that reduce the volumes available to the agency. Holders of senior water rights that may not have been fully exercised in the past may withdraw larger volumes in the future. New federal water quality requirements may render certain sources unavailable—or significantly increase their costs.

In addition to being largely beyond the control of urban suppliers, these potential changes are extremely uncertain. Water suppliers cannot predict with certainty which changes will occur or the timing of those changes. The WRAP model could be programmed to allow the user to assign probabilities to several "external futures." Model outputs can then be generated for each such future individually and for the composite "expected future," based on the assigned probabilities (see Step 4 below).

ILLUSTRATIVE EXAMPLE

The following hypothetical example will illustrate how a water agency might make use of many of the features of the WRAP model.

The Acme Water District is a large metropolitan water agency which has its own large surface reservoir filled by local runoff. It has amassed 72 years of runoff data which it assumes is representative of the range of future supply conditions.[6] The reservoir storage capacity (net of dead storage and minimum spring flood pool reservation) is 450,000 AF. The best estimates of Acme's demand forecasts are as follows:

Year	Demand (AF)
1993	400,000
2000	460,000
2020	575,000

In each of these years, the low-end demand forecasts are estimated to be 5% below these levels; the high-end forecasts are 10% above these levels. A weighting is assigned to each of these three demand levels. These weightings represent the

[6]This example is intended to be representative of situations faced by California water agencies. The runoff data are real. The storage capacity and demand forecasts are hypothetical, but realistic.

probable likelihood of occurrence. The "best estimate" has a weighting of 50% and the low-end and the high-end forecasts each have a weighting of 25%.

Historically, annual runoff into the reservoir net of downstream release requirements for other water rights holders and in-stream obligations has varied from 1 million AF down to a minimum of 150,000 AF. Annual runoff that exceeds the sum of annual demand and available storage capacity in the reservoir is spilled.

If runoff is less than annual demand, carryover storage in the reservoir is drawn down to make up the shortfall. The reservoir is drawn down as far as necessary to meet the demand in the current year; no carryover requirements for subsequent water years are imposed.

There are many ways that Acme could use the WRAP model to assess future system reliability. The following example illustrates one possible analytical sequence that the agency might pursue.

Step 1

Acme first produces a reliability forecast from the foregoing base forecasts of demand and supply. Table III-1 presents the key reliability indices for the forecast years 1993, 2000, and 2020, while Figure III-1 illustrates the cumulative frequency distributions (CFDs) for those years, both based on the "best guess" demand estimate.[7] Based on current demands and the historical record of available supply for this system, current (1993) reliability is clearly extremely high. Reliability begins to deteriorate by 2000 and is seriously deficient in the year 2020.

Figure III-2 tracks reliability over the same period by focusing on a single reliability index, in this case EUD. This graphic readily illustrates the deterioration in system reliability over the planning period, with the expected unserved demand rising to 9.5% by 2020. The model can produce similar graphs for any user-specified index.

Figure III-3 compares the CFDs for the year 2020 for each of the three possible levels of demand. These curves reflect not only the actual differences in the demand forecasts, but also the associated changes in available supply due to the operation of the storage reservoir. Note that the +10%/-5% range of potential demands significantly affect the position of the curves.

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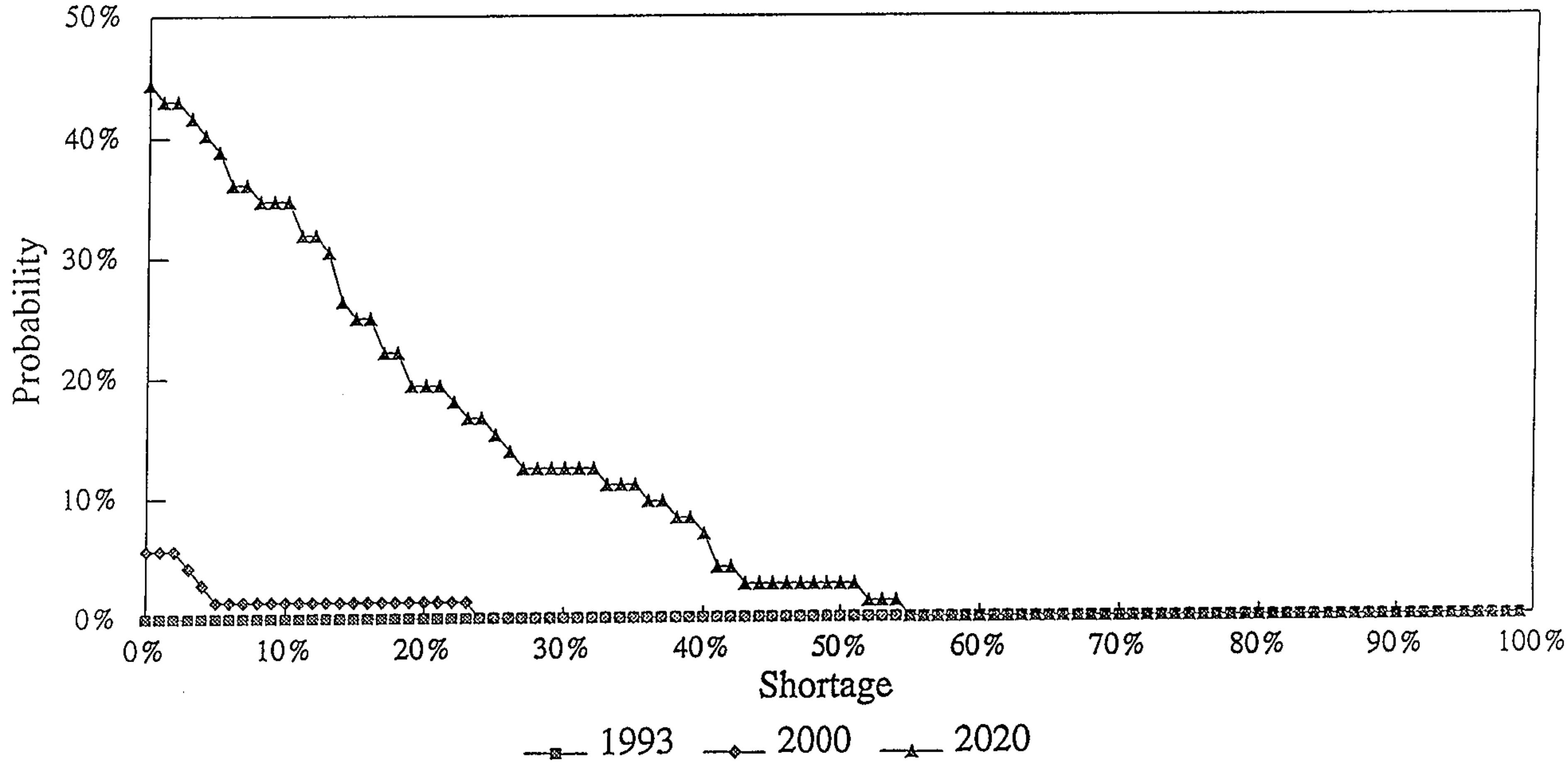
[7]This table and all subsequent figures and tables are direct model outputs produced for this hypothetical example.

TABLE III-1
RELIABILITY INDICES FOR BASE RESOURCE SCENARIOS

	YEAR		
Designated Shortage	1993	2000	2020
PODS (0%)	0.0%	5.6%	44.4%
PODS (5%)	0.0%	1.4%	38.9%
PODS (10%)	0.0%	1.4%	34.7%
PODS (15%)	0.0%	1.4%	25.0%
PODS (20%)	0.0%	1.4%	19.4%
PODS (25%)	0.0%	0.0%	15.3%
PODS (30%)	0.0%	0.0%	12.5%
PODS (35%)	0.0%	0.0%	11.1%
PODS (40%)	0.0%	0.0%	6.9%
PODS (45%)	0.0%	0.0%	2.8%
PODS (50%)	0.0%	0.0%	2.8%
PODS (55%)	0.0%	0.0%	0.0%
PODS (60%)	0.0%	0.0%	0.0%
PODS (65%)	0.0%	0.0%	0.0%
PODS (70%)	0.0%	0.0%	0.0%
PODS (75%)	0.0%	0.0%	0.0%
PODS (80%)	0.0%	0.0%	0.0%
PODS (85%)	0.0%	0.0%	0.0%
PODS (90%)	0.0%	0.0%	0.0%
PODS (95%)	0.0%	0.0%	0.0%
POS	0.0%	5.6%	44.4%
EUD	0.0%	0.5%	9.5%

FIGURE III-1

CFDs FOR BASE RESOURCE SCENARIO



Note: The probability of any shortage in 1993 is zero.

FIGURE III-2

FORECAST OF EUD FOR BASE RESOURCE SCENARIO

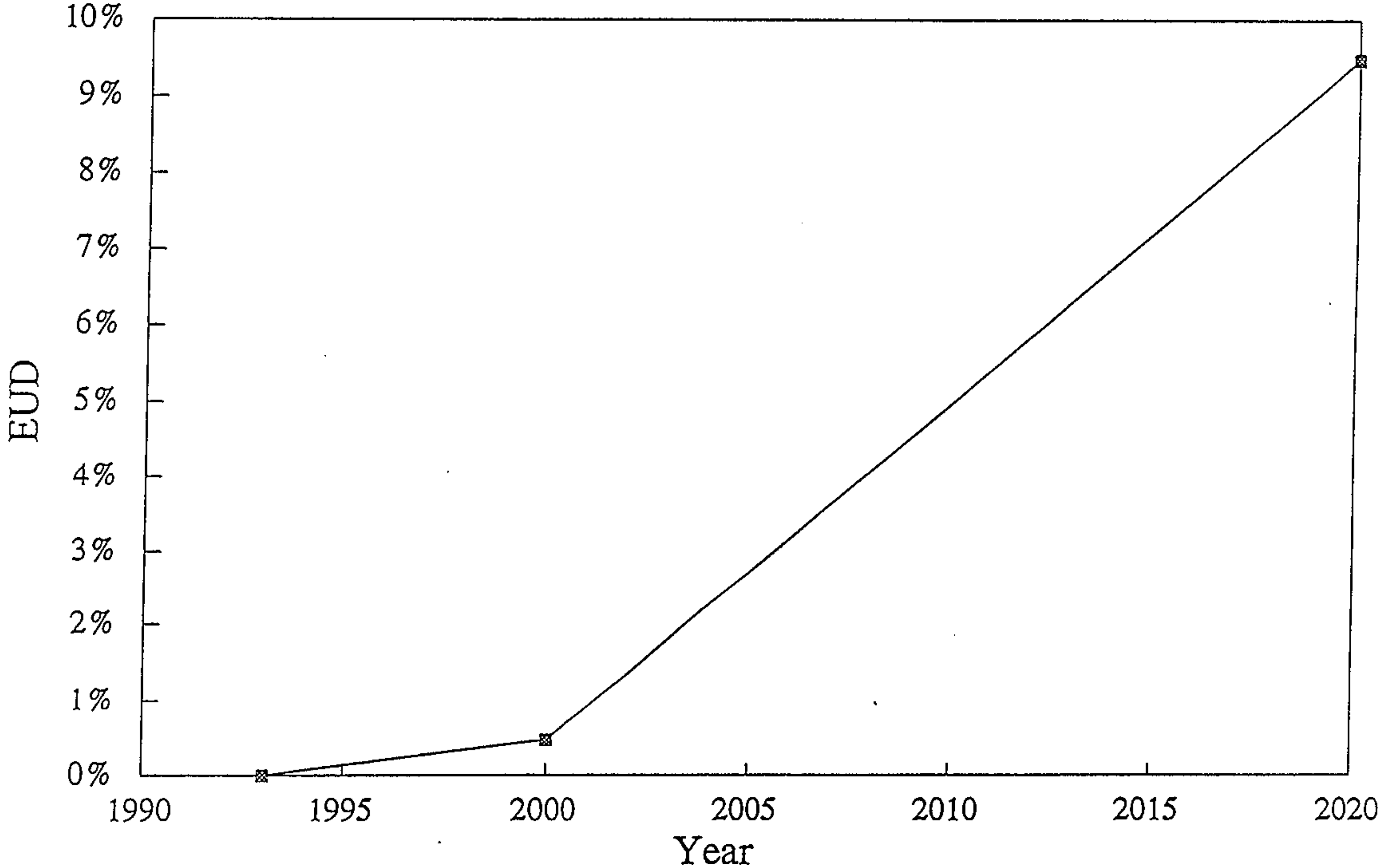


FIGURE III-3

CFDs FOR DIFFERENT DEMANDS FOR BASE RESOURCE SCENARIO

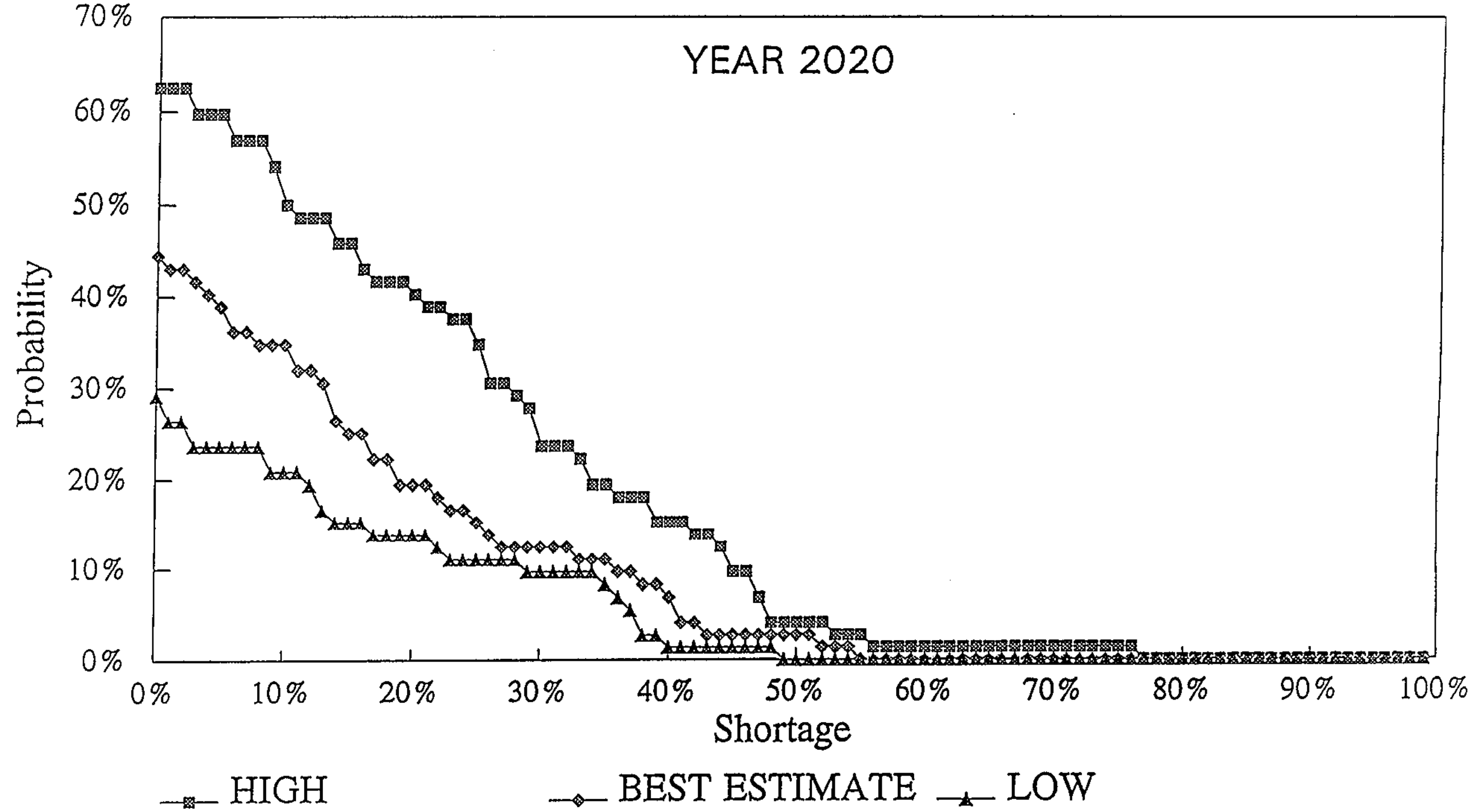


Figure III-4 focuses on the time pattern of EUD for each of the three possible demand values, as well as the expected value of demand. If the high-demand forecast is realized, the EUD in 2020 rises to about 17%.[8]

Step 2

Acme determines that these reliability forecasts are unacceptable and commences to examine the reliability impacts of two possible resource additions. The first is a plan to raise the height of the dam to increase usable carryover storage volume (i.e., net of dead storage and flood control requirements) from 450,000 to 550,000 acre-feet. This work would be completed after the year 2000, but before 2020.

The second possible resource addition is a program of conservation to realize annual savings of 50,000 AF by the year 2000 and 100,000 AF by the year 2020.

Acme modifies its demand and/or supply forecasts to correspond to these resource scenarios. (Note that the demand management program requires re-estimation of the 72-year supply series.) Based on these modified forecasts, the model is re-run.

Table III-2 presents the reliability indices over the planning period for the dam option, while Figure III-5 shows the corresponding CFDs. Table III-3 and Figure III-6 shows similar information for the conservation option. Figure III-7 compares the CFDs for the year 2020 for both resource options and the base resource scenario, while Figure III-8 tracks the PODS (10%) index over time for the three scenarios.

What is especially interesting about these examples is that, for this system, for this particular future year, with this particular reservoir operating rule, the addition of storage capacity does not significantly improve reliability, while investment in demand management does. The reliability benefits of increased storage capacity depend critically on the relationship between demand and hydrology and on the manner in which the storage capacity is operated. The WRAP model can be an important tool to assist planners to better understand the changing impacts on system reliability of different combinations of reservoir sizes and operating rules.

The following discussion of Step 3 of Acme's analysis illustrates a simple example of how the model can be used to assess alternative operating rules.

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[8] Note that this percentage is applied to a higher level of full-service demand, resulting in a larger volume of shortfall.

FIGURE III-4

EUD FORECASTS FOR DIFFERENT DEMANDS FOR BASE RESOURCE SCENARIO

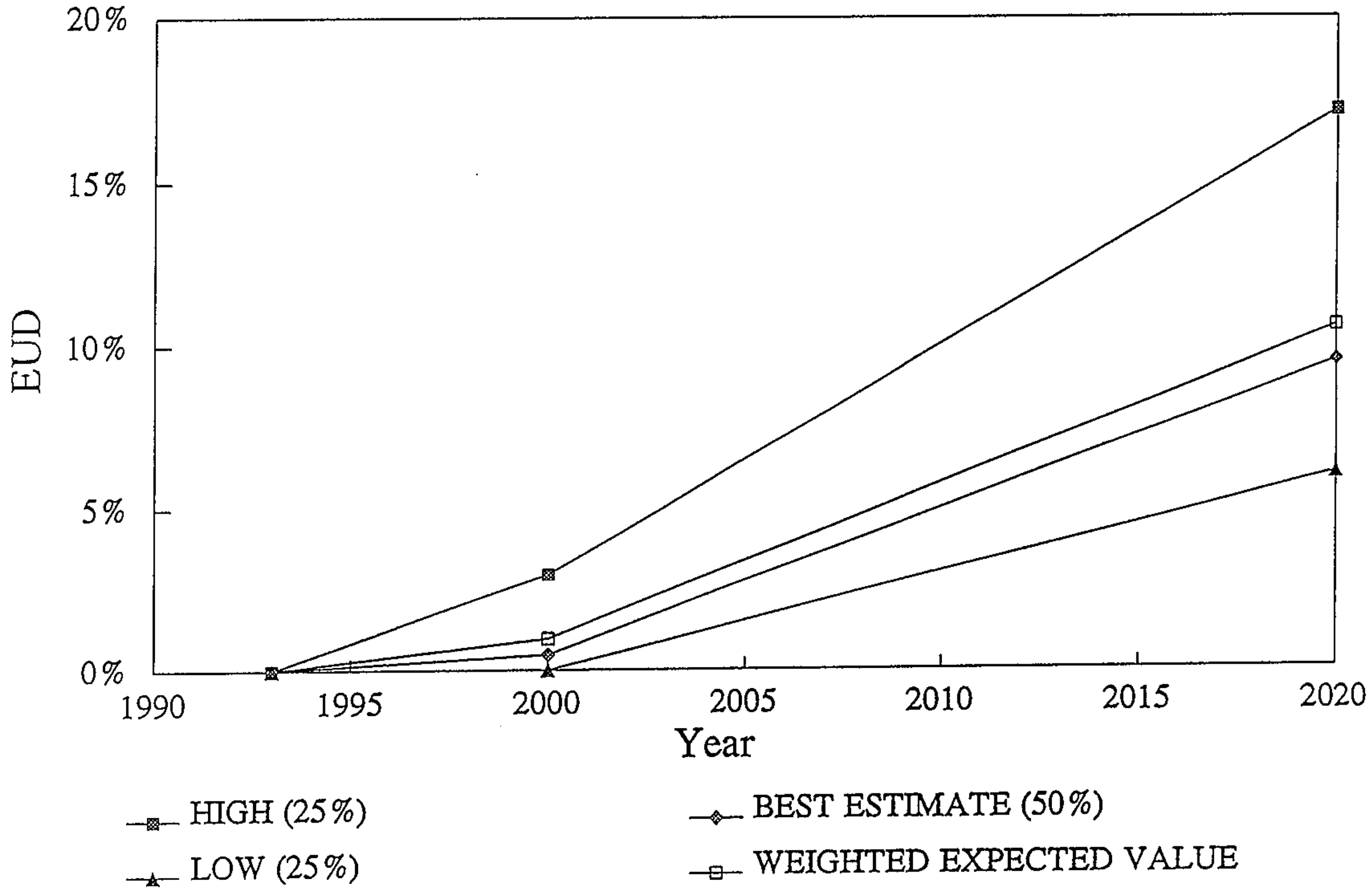


TABLE III-2
RELIABILITY INDICES FOR RAISED DAM OPTION

	YEAR		
Designated Shortage	1992	2000	2020 (100,000 AF)
PODS (0%)	0.0%	5.6%	43.1%
PODS (5%)	0.0%	1.4%	37.5%
PODS (10%)	0.0%	1.4%	33.3%
PODS (15%)	0.0%	1.4%	25.0%
PODS (20%)	0.0%	1.4%	18.1%
PODS (25%)	0.0%	0.0%	15.3%
PODS (30%)	0.0%	0.0%	12.5%
PODS (35%)	0.0%	0.0%	11.1%
PODS (40%)	0.0%	0.0%	6.9%
PODS (45%)	0.0%	0.0%	2.8%
PODS (50%)	0.0%	0.0%	1.4%
PODS (55%)	0.0%	0.0%	0.0%
PODS (60%)	0.0%	0.0%	0.0%
PODS (65%)	0.0%	0.0%	0.0%
PODS (70%)	0.0%	0.0%	0.0%
PODS (75%)	0.0%	0.0%	0.0%
PODS (80%)	0.0%	0.0%	0.0%
PODS (85%)	0.0%	0.0%	0.0%
PODS (90%)	0.0%	0.0%	0.0%
PODS (95%)	0.0%	0.0%	0.0%
POS	0.0%	5.6%	43.1%
EUD	0.0%	0.5%	9.2%

FIGURE III-5
CFDs FOR RAISED DAM OPTION

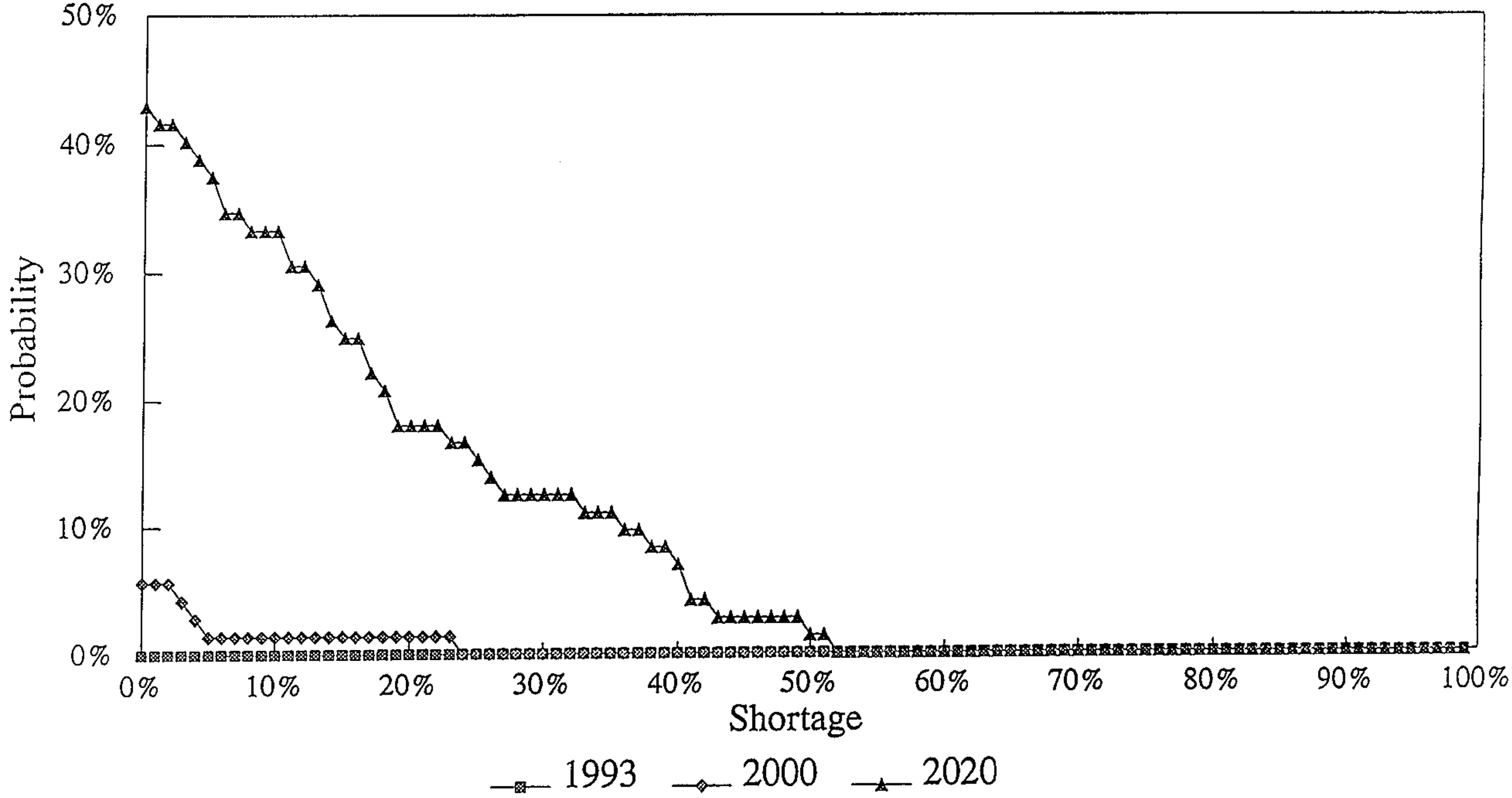


TABLE III-3
RELIABILITY INDICES FOR CONSERVATION OPTION

	YEAR		
Designated Shortage	1992	2000 (50,000 AF)	2020 (100,000 AF)
PODS (0%)	0.0%	0.0%	5.6%
PODS (5%)	0.0%	0.0%	5.6%
PODS (10%)	0.0%	0.0%	5.6%
PODS (15%)	0.0%	0.0%	4.2%
PODS (20%)	0.0%	0.0%	2.8%
PODS (25%)	0.0%	0.0%	2.8%
PODS (30%)	0.0%	0.0%	0.0%
PODS (35%)	0.0%	0.0%	0.0%
PODS (40%)	0.0%	0.0%	0.0%
PODS (45%)	0.0%	0.0%	0.0%
PODS (50%)	0.0%	0.0%	0.0%
PODS (55%)	0.0%	0.0%	0.0%
PODS (60%)	0.0%	0.0%	0.0%
PODS (65%)	0.0%	0.0%	0.0%
PODS (70%)	0.0%	0.0%	0.0%
PODS (75%)	0.0%	0.0%	0.0%
PODS (80%)	0.0%	0.0%	0.0%
PODS (85%)	0.0%	0.0%	0.0%
PODS (90%)	0.0%	0.0%	0.0%
PODS (95%)	0.0%	0.0%	0.0%
POS	0.0%	0.0%	5.6%
EUD	0.0%	0.0%	1.1%

FIGURE III-6

CFDs FOR CONSERVATION OPTION

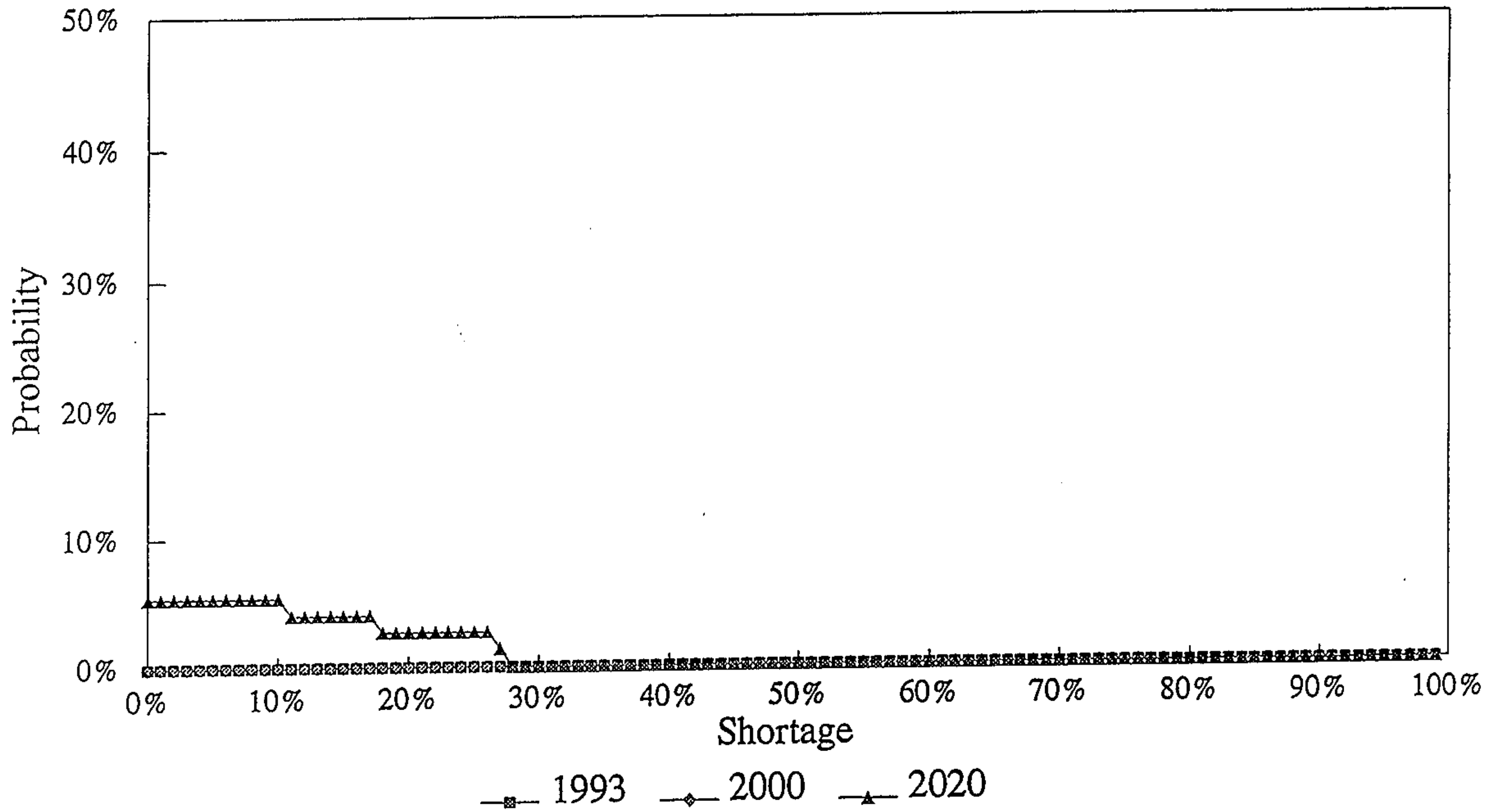


FIGURE III-7

CFDs FOR DIFFERENT RESOURCE SCENARIOS

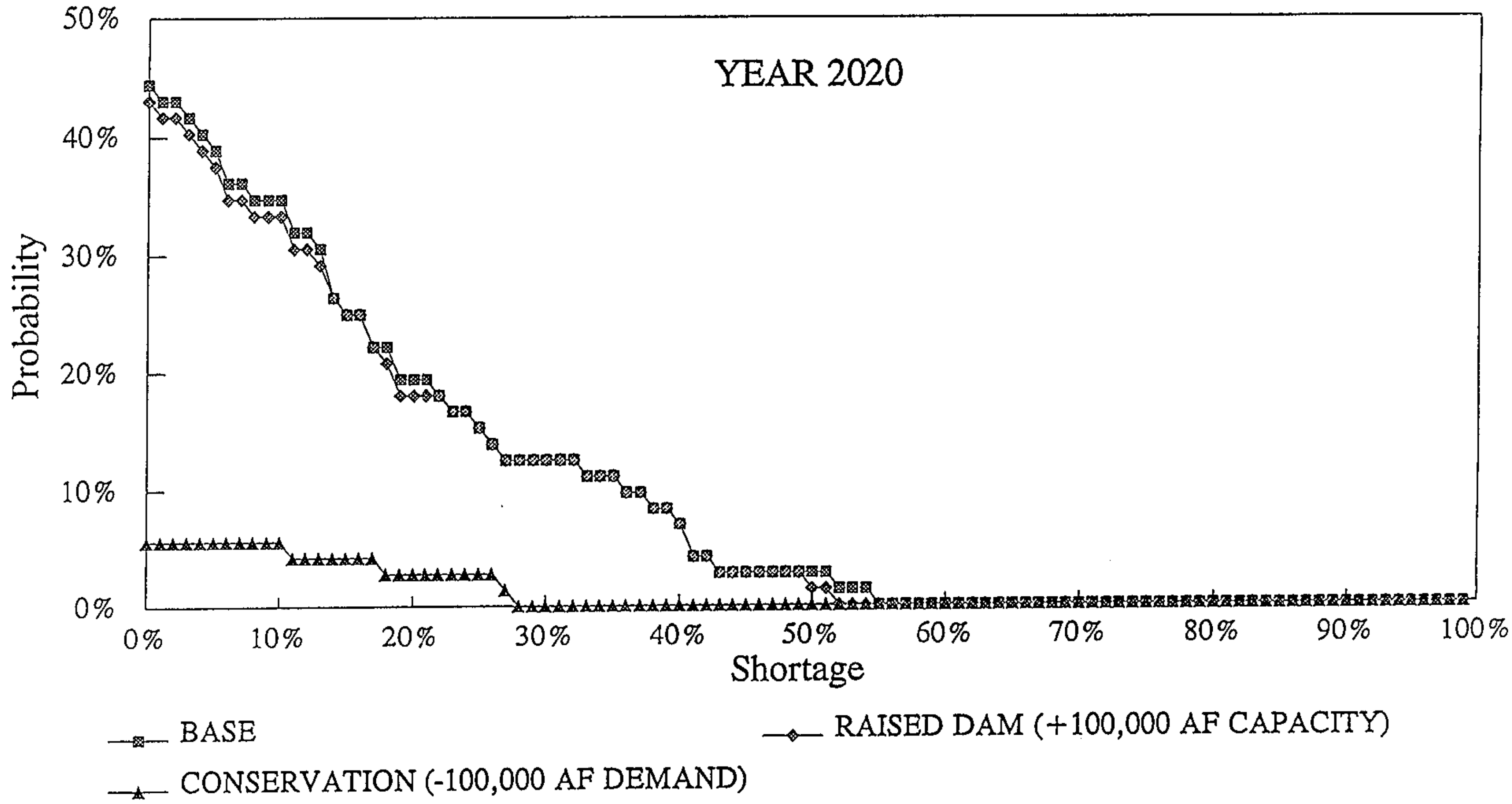
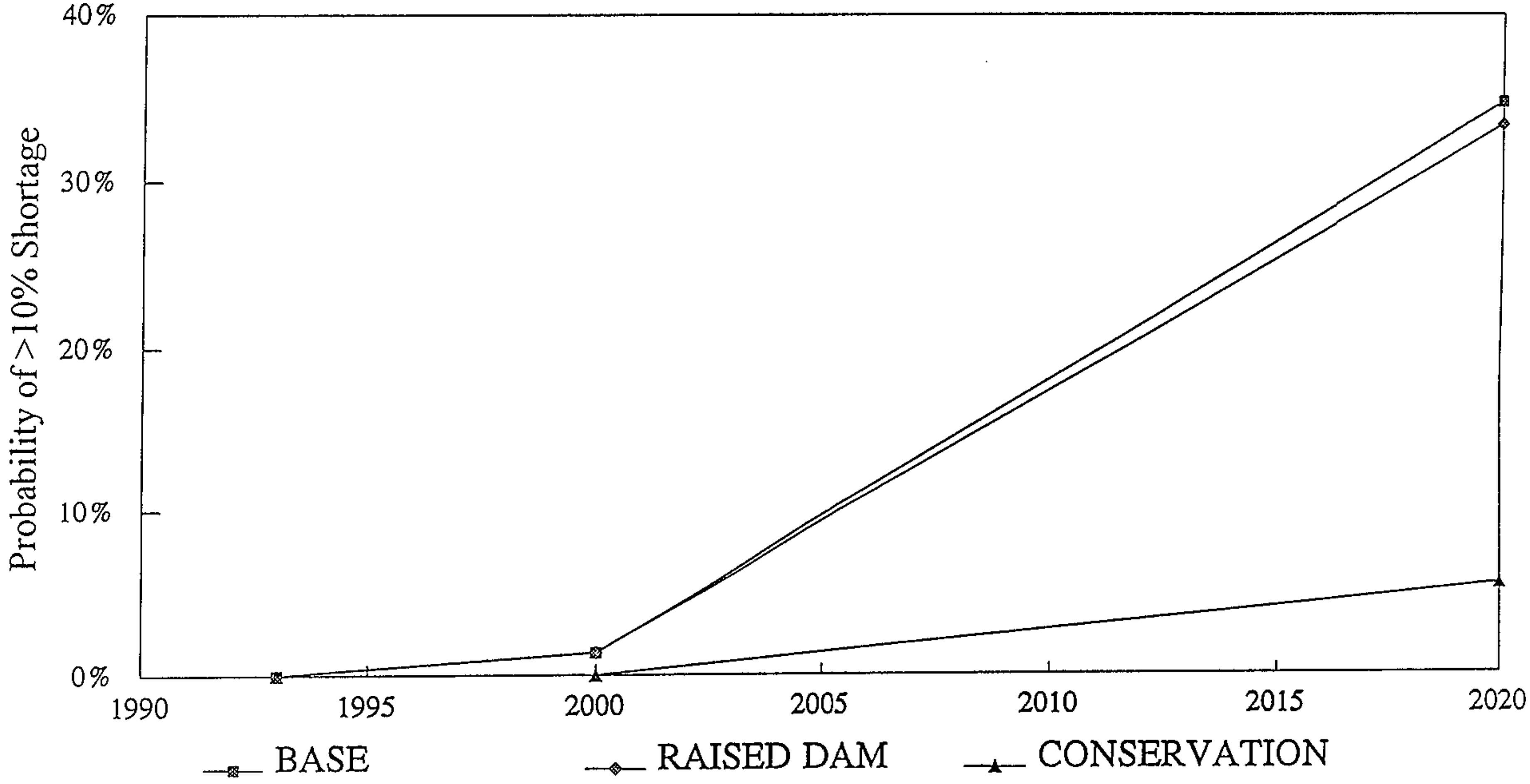


FIGURE III-8

FORECAST OF PODS OF 10% FOR DIFFERENT RESOURCE SCENARIOS



Step 3

Instead of resource additions, Acme planners wish to assess the reliability impacts of modifying the operating rules for the reservoir. Specifically, Acme is considering imposing a "peak shaving" rule which would allow reservoir withdrawals to take place down only to a minimum level of retained storage unless the forecasted shortage for the year exceeds a specified threshold. Acme planners project the shortage for each year and determine whether to retain or release the designated minimum storage. This is dependent on the designated threshold level. If the projected shortage is less than the specified threshold, the minimum storage will be retained. If, on the other hand, the projected shortage exceeds the threshold, a portion of the storage will be released to reduce the shortage down to below this threshold level.

Figures III-9 and III-10 illustrate the results of imposing such a rule in the years 2000 and 2020. In both years, the new operating rule insures to some extent against particularly severe shortages by increasing the likelihood of smaller shortages.

Step 4

Acme planners also realize that there is a possibility of state regulatory action that would increase annual in-stream flow requirements by 80,000 acre-feet by the year 2000, thereby substantially reducing available supplies. To test the sensitivity of the reliability results to this possible change, they re-estimate the base case available supply series assuming that this event occurs. Figures III-11 and III-12 illustrate the reliability impacts of this external change, compared to the base case. Figure III-11 compares the CFDs for the two cases. Figure III-12 shows the forecasted POS index in the three cases.

The potential of added in-stream flow requirements could have a significant adverse impact on system reliability, increasing the probability of a shortage by the year 2020 to 70%, and the probability of a shortage as large as 50% to nearly one in five. Depending on the subjective probability that system planners assign to this event, they may wish to develop resource plans to deal with this eventuality. (Of course, this runs the risk of a substantially "overbuilt" system.)

FIGURE III-9

CFDs SHOWING IMPACTS OF OPERATING CHANGES

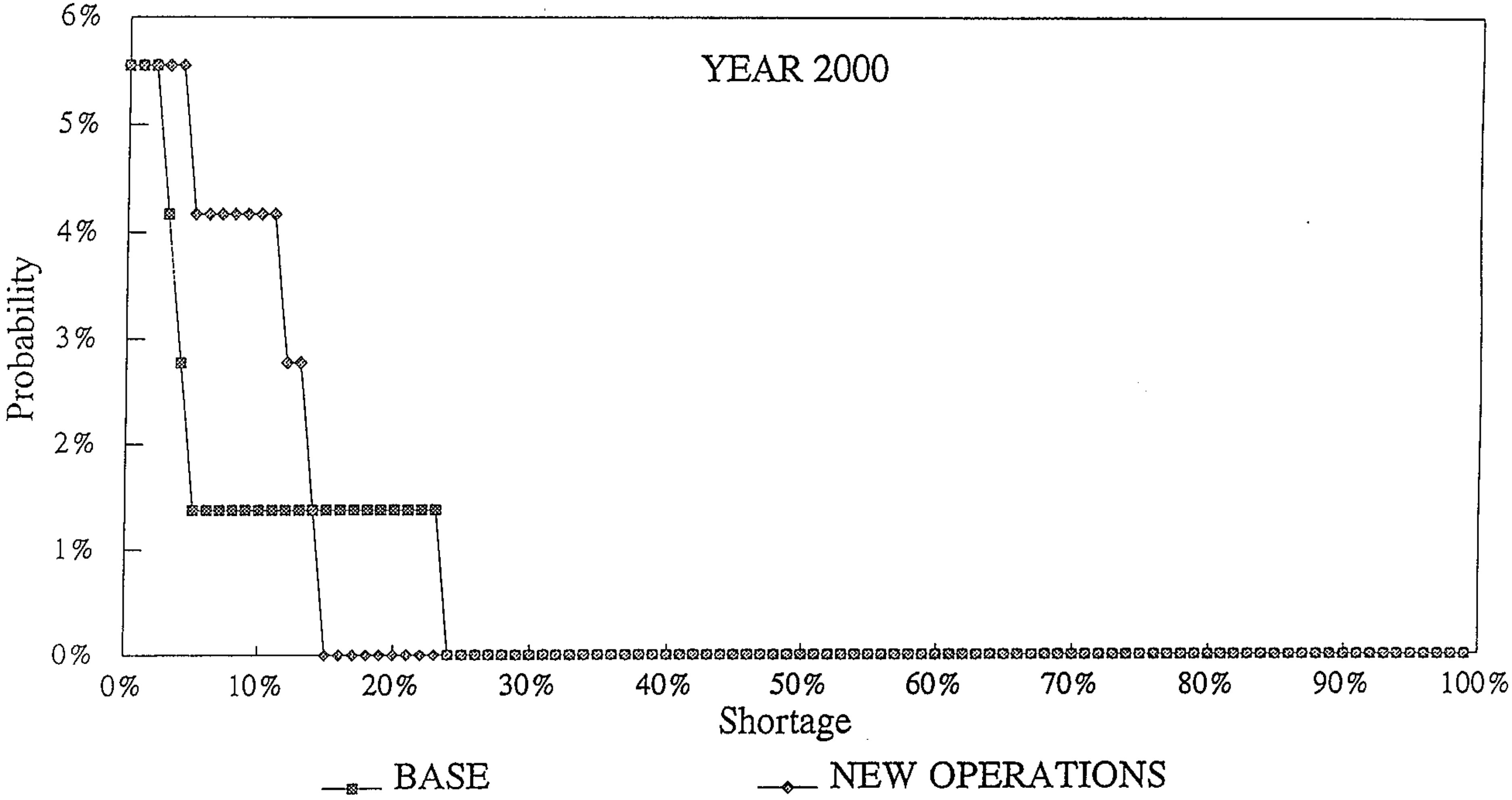


FIGURE III-10

CFDs SHOWING IMPACTS OF OPERATING CHANGES

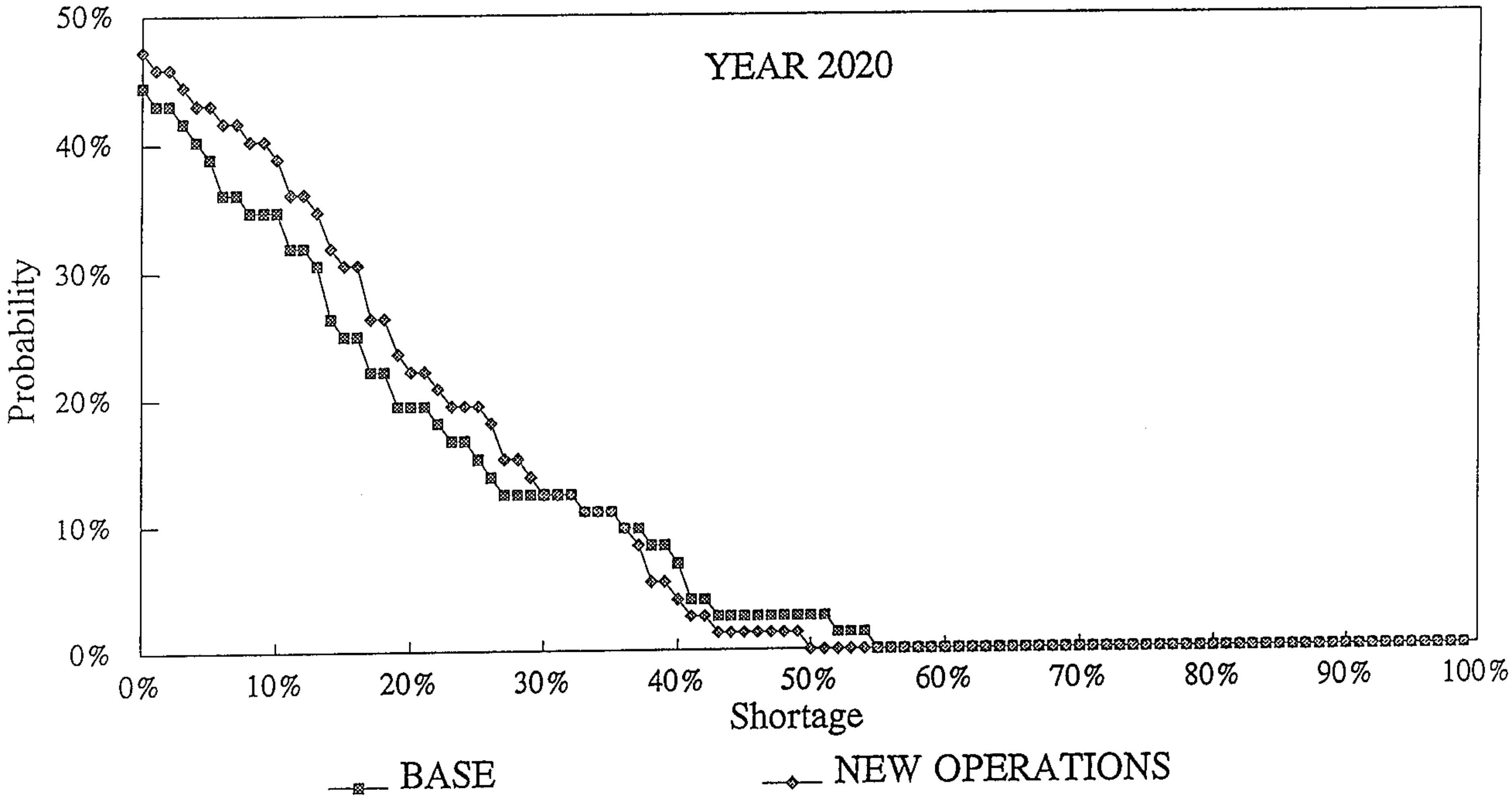


FIGURE III-11

CFDs SHOWING IMPACT OF RELEASES

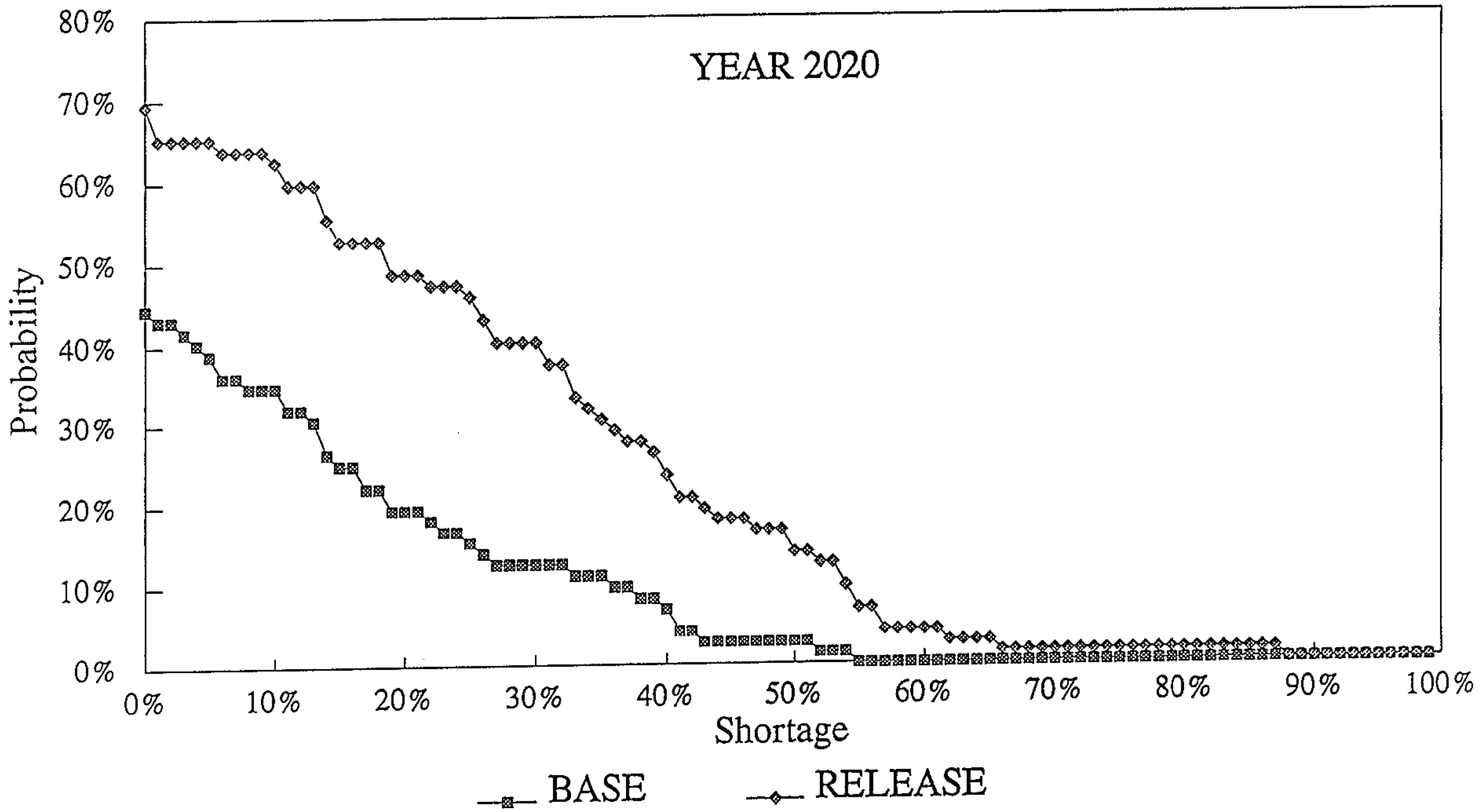
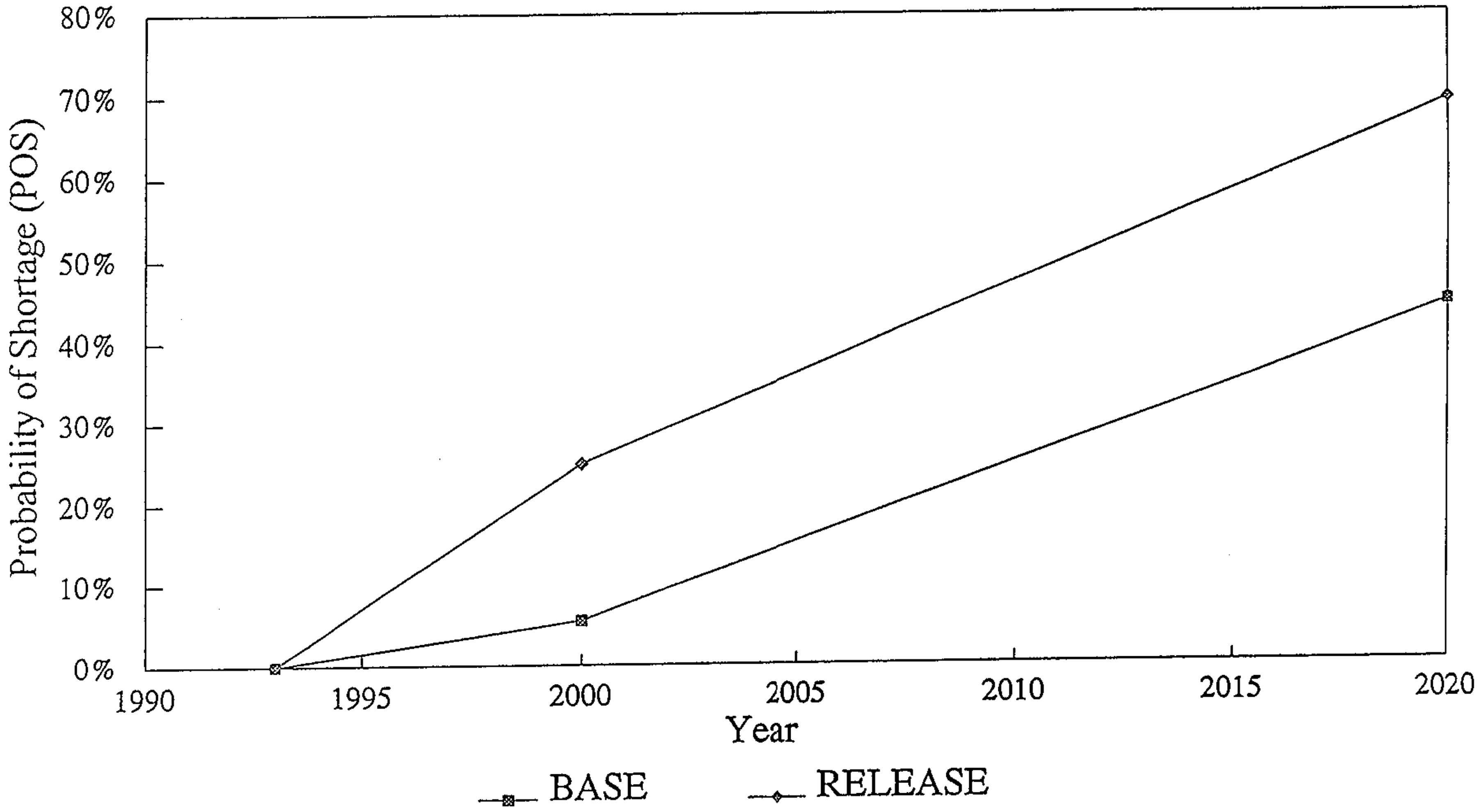


FIGURE III-12
FORECAST OF POS SHOWING IMPACT OF RELEASES



Step 5

Many of the foregoing analyses could be combined. For example, Acme might wish to jointly examine the reliability impacts of the two resource options and the three possible demand forecasts. This joint analysis is illustrated in Figures III-13 and III-14.[9] Figure III-13 compares the CFDs for the six demand/resource scenarios for the year 2020. Thus, if the high-demand forecast is realized, the probability of a shortage will exceed 60% if the dam height is increased; it will be about 22% if the conservation program is implemented. It is also interesting to note that the reliability characteristics are similar for the conservation/high demand and the dam raising/low demand cases.

Figure III-14 compares the EUD forecasts over the planning period for the six demand/resource combinations.

Comparisons such as these can be very useful to agencies that wish to understand the range of reliability impacts of particular resource combinations. By viewing the entire range of impacts, agencies can reach resource decisions that account explicitly or implicitly for their risk preferences.

The foregoing analytical steps illustrate how one agency might use the WRAP model to analyze future system reliability. Other agencies facing different types of resource planning decisions would undoubtedly use the model differently. The flexibility of the WRAP model permits a wide variety of analytical configurations. However, as Figures III-13 and III-14 illustrate, the complexity of the outputs increases rapidly as more dimensions of uncertainty are considered simultaneously. Model users must therefore give careful thought to the appropriate analytical strategy.

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[9]Note that these particular figures cannot be generated by the current WRAP Model, version B1.01. The ability to graphically pair different demands with different scenarios will be a feature of the final version of the model discussed in Section VI.

FIGURE III-13

CFDs FOR DIFFERENT DEMAND LEVELS AND RESOURCE OPTIONS

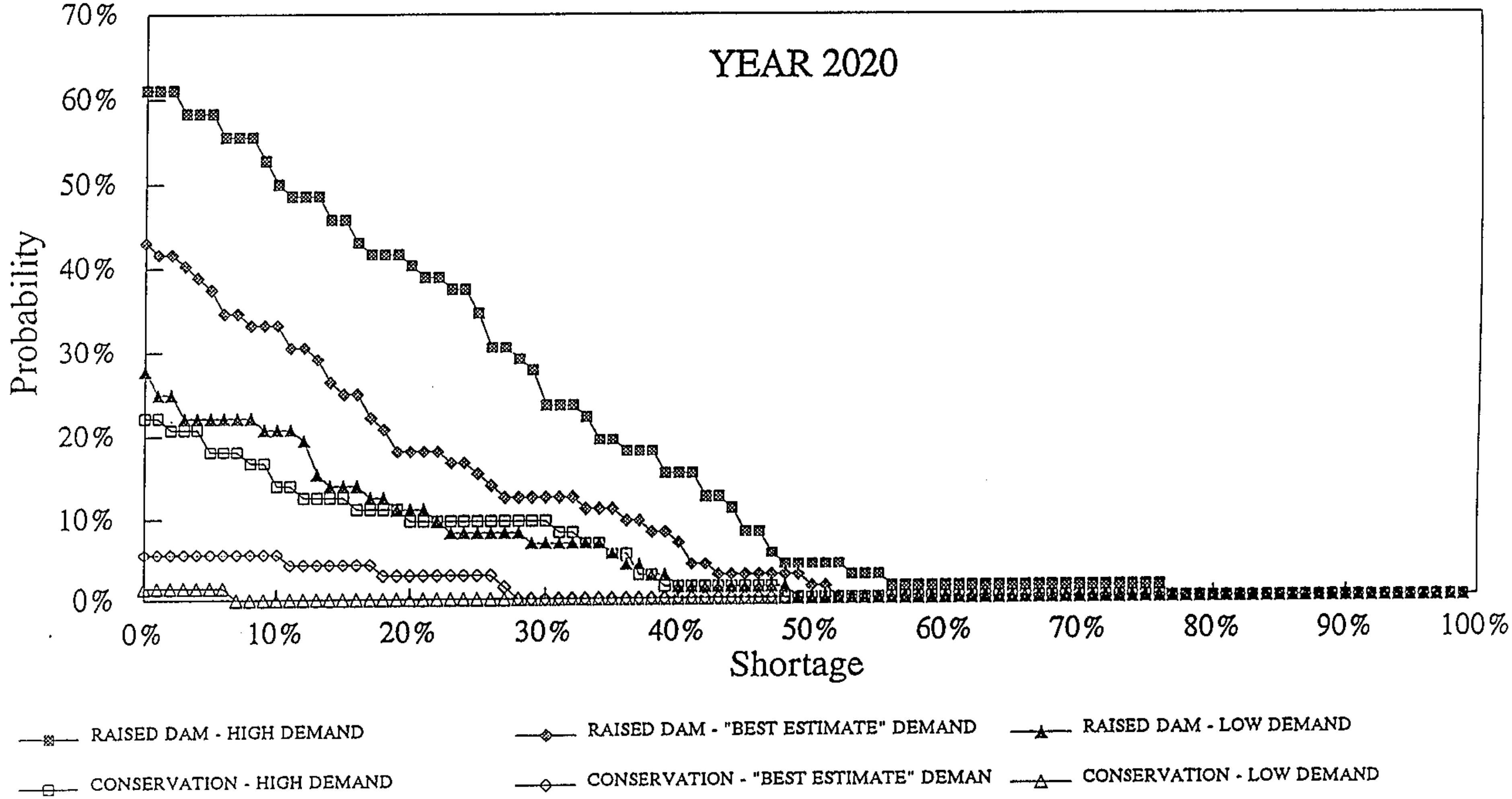
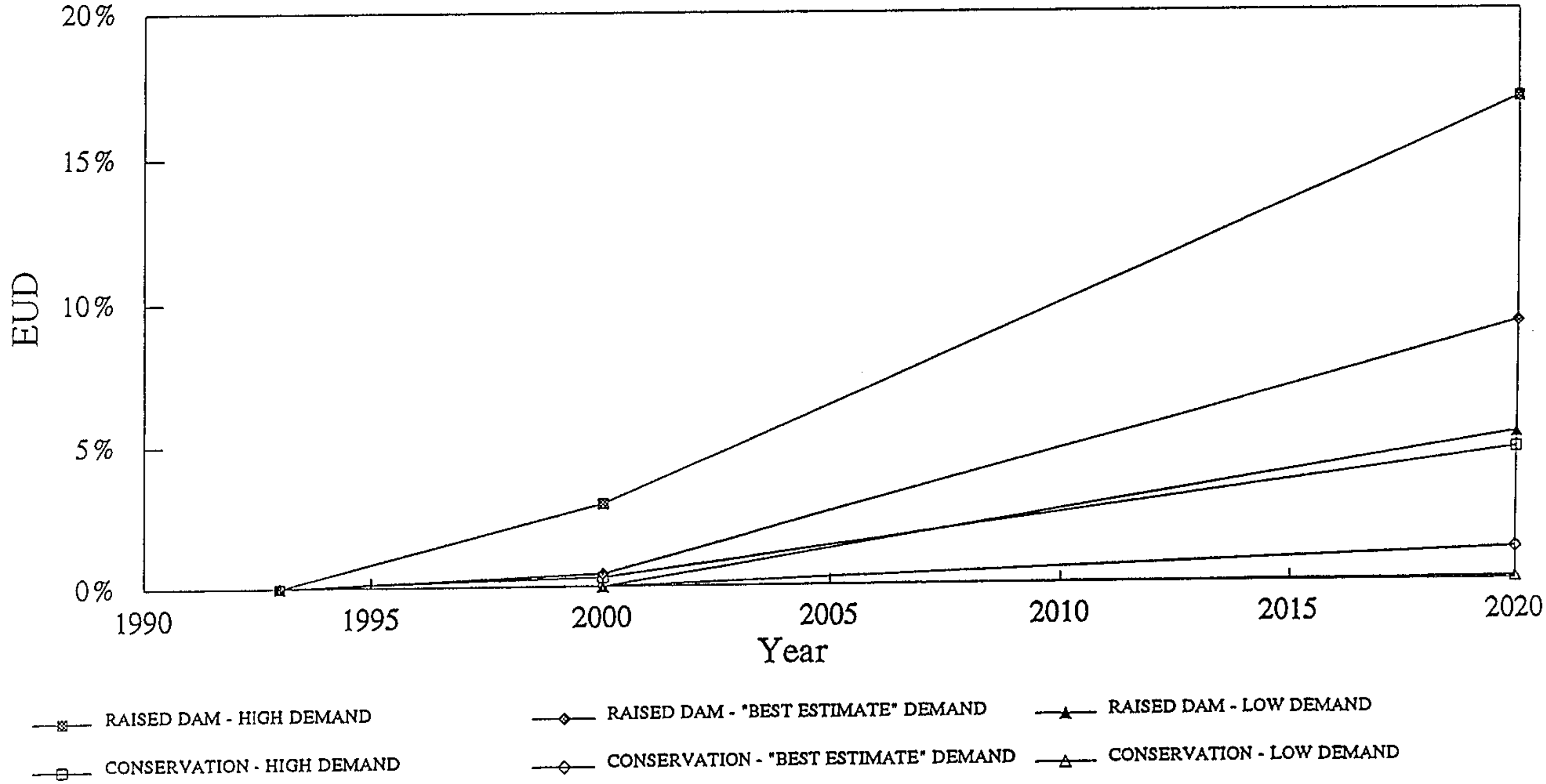


FIGURE III-14

FORECAST OF EUD FOR DIFFERENT DEMAND LEVELS AND RESOURCE OPTIONS



IV. AGENCY PROCESSING REQUIREMENTS

The WRAP model is designed to analyze the reliability implications of different resource mixes. The model requires input forecasts of demands and supplies associated with these resource scenarios. These forecasts may be probabilistic and may differ in different future years. As already discussed, the supply and demand forecasts are not independent.

It is the job of the agency to develop these inputs. Depending on system characteristics and each agency's level of modeling sophistication, there will be as many ways to develop these forecasts as there are agencies. Some agencies already have in place sophisticated modeling tools to generate demand and supply forecasts; others use less complex tools. The purpose of this section is to discuss in general terms the types of modeling approaches that are available at various levels of sophistication.

DEMAND FORECASTING MODELS

There are three general types of demand forecasting approaches, which are described below in increasing order of complexity. Note that they are not mutually exclusive; often, combinations of two or more approaches are used.

Extrapolation

Extrapolation is based on the assumption that future growth patterns will be a continuation of past patterns. Specific methods include use of compound growth rates, fitting of mathematical growth curves, and the use of graphs of historical data. As long as the factors contributing to growth are stable over long periods of time, extrapolation produces fairly accurate results. Note that the factors influencing growth are not explicitly identified. Neither are their effects on the forecast isolated.

Econometric Forecasts

Econometric techniques develop sets of equations that attempt to describe causal relationships between water usage and various factors that influence usage. The water usage is known as the *dependent variable*, while the factors are called *independent variables*. The form of the equation(s) must be postulated by system planners based on their understanding of the underlying relationships. The equation coefficients are estimated based on historical data, using one of a variety of statistical techniques. Then, future usage is forecast based on forecasts of the independent variables.

Econometric techniques are clearly more sophisticated than simple extrapolations. They explicitly allow the impacts of particular factors on water consumption to be modeled. This approach is commonly used by many water and energy utilities to develop demand forecasts.

Econometric forecasts do, however, share a shortcoming with extrapolation, namely the assumption that historical relationships will continue into the future.

End-Use Forecasts

This most-sophisticated form of demand forecasting disaggregates demands into end uses for particular customer classes. For example, residential end uses include lawn watering, toilet flushing, and dishwashing. Based on estimates of unit water consumptions for each end use, saturations of each end use per customer (e.g., number of dishwashers per household, square feet of lawn area per customer, etc.), and usage patterns (e.g., number of flushes per household per day), a "bottom up" estimate of total demand is developed.

The detail of end-use models allows for more precise forecasts and permits planners to readily incorporate changes in technology (e.g., new residential plumbing standards) and the impact of conservation programs. This very detail makes the data requirements for end-use forecasting models quite formidable. While such models have become more common for energy utilities, the general lack of good unit water use, saturation, and usage pattern data has made their use less prevalent at this point for water suppliers. As the quality of data improves, the use of this type of model by water agencies will undoubtedly become more widespread.

Examples of current demand forecasting models being used in the water industry include the U.S. Army Corps. of Engineer's IWR-MAIN and Metropolitan Water District of Southern California's MWD-MAIN.

SUPPLY FORECASTING MODELS

Many water supply systems include significant carryover storage capacity. As previously described, available supply for such systems is partly dependent on annual demand and reservoir system operations as well as on hydrology. Annual and seasonal hydrological variations are considerable. Reservoir storage and release requirements are complex, having to respond to such priorities as flood control, hydropower generation, irrigation, recreation, and fisheries management, as well as water supply. In order to accurately predict available supply to customers in any one year, some form of computer model is required in all but the simplest systems.

To avoid confusion, a distinction can be made between *system operating models* and *system planning models*. System operating models are developed by water agencies to manage their day-to-day water supply system operations and control terminal storage releases, pumping station operations, delivery-line pressures and so forth. They can use these models to develop and test appropriate system operating rules. Through a process of telemetry, sensors on key facilities are often linked to a central control system from which operations staff can monitor and control at any time the release of water into aqueducts, rates of flow through a treatment plant, main-line booster station operations, etc.

Here, the concern is with system planning models, which are analytical tools that reproduce the major physical and operational characteristics of the system but do not actually regulate or control any physical processes. The model attempts to predict what would happen to daily, monthly or annual supplies under a given set of hydrological and operational conditions and assuming a particular level of customer demand. The results are used to make planning decisions and analyze the supply impacts of operational or structural changes to the system.

Model parameters generally represent operating rules, physical characteristics of system components, rates of processes, etc. that are necessary to create a *water balance*. In simplest terms, a water balance ensures consistency among the quantity of water at the beginning of a period (typically a month or a year), water inflows during the period, water outflows to various parties, and water volumes at the end of the period. Mathematically, the water balance for any period can be expressed as follows:

$$\textit{Change in storage in time increment } \Delta t = \textit{Rate of inflow} * \Delta t - \textit{Rate of outflow} * \Delta t$$

Types of System Planning Models

System planning models generally fall into one of two broad categories: *simulation models* and *optimization models*.

Simulation Models

This is by far the more common of the two modeling types. As the name implies, a simulation model attempts to mimic the essential characteristics of water supply system operation by mathematically summarizing these characteristics. For virtually any system, this will require some degree of simplification, because it is impossible (or, at the very least prohibitively expensive) to faithfully model every nuance of the system. As will be described below, planners must decide on the appropriate level of modeling sophistication to meet their needs.

A non-exhaustive list of the types of variables that may be included in water system simulation models includes:

- Precipitation
- Catchment/river runoff
- Reservoir storage volumes, depths, surface area evaporation rates, seepage, dead storage levels
- Intake rates
- Groundwater pumping and recharge rates
- Releases for fishery flows
- Flood control requirements
- Hydroelectric generation constraints
- Channel losses and in-stream uses
- Transfers to terminal storage reservoirs
- Releases to end-users and unaccounted for water losses (fire fighting, leaks and breaks, theft)
- Customer demand
- Pumping capacities
- Minimum carryover criteria
- Downstream release criteria
- Climate

Simulation models have a number of equations that relate these variables. For example, reservoir evaporation will depend on climate and reservoir surface area, which in turn will depend on reservoir storage depth.

Most major water systems have at least one simulation model for use in system planning and operational analysis. This can vary from a simple spreadsheet model operating at an annual time-step, to a complex mainframe program simulating hydrological and supply system conditions at a daily, weekly or monthly time-step.

Simulation models can be generic or system-specific. Generic models are designed to be adapted to particular systems. They include such models as HEC-3, HEC-5, IRIS, Res-Q and Stella.

System-specific models, such as DWRSIM, PROSIM, or EBMUDSIM are designed to model the characteristics of an individual system. Depending on the complexity of the system and the degree of sophistication desired by system planners, such a model can be quite expensive and time-consuming to develop and maintain.

Optimization Models

Whereas simulation models are designed to describe what a water supply system will do under various defined conditions, optimization models prescribe the most appropriate way to develop or operate a system in terms of cost-effectiveness, productivity, reliability, etc. Optimization models have been used for a number of supply systems, but typically only for fairly narrowly-focused studies. The U.S. Army Corps. of Engineers is currently developing a more generic reservoir optimization model (HEC-PRM).

MAJOR SUPPLY MODEL COMPONENTS

No two supply models are the same, just as no two systems are alike. However, there are three categories of issues that any model might address:

- Hydrology
- Storage and distribution
- Operations

Following are discussions of each of these potential model components.

Hydrology

There are many ways of modeling hydrology. The approach chosen depends in part on whether the system being modeled relies on surface water or groundwater or both. As always, agencies must determine the appropriate level of complexity (see subsection D below). In some cases, an agency may wish to model runoff based on knowledge of the processes and the physical characteristics of the catchment area. Other agencies may feel that it is sufficient to rely on statistically-developed hydrological data without considering the processes responsible. Agencies must decide which of these is appropriate.

Model simulation would require reproduction of the important characteristics of and relationships among precipitation, temperature, snow-melt, detention, infiltration, overland flow, channel flow, groundwater percolation, etc. as appropriate. It might also require the inclusion of other factors including upstream water rights and actual appropriations, as well as the operating characteristics of other agencies' facilities upstream. Where appropriate, additional sources of supply must be included in the simulation, such as water transfer arrangements with other agencies, or the circumstances under which an agency could purchase additional water from a special state water bank under drought conditions.

There are two broad approaches to forecasting hydrology. One is to base the forecast on an historical hydrologic sequence. The other is to take a stochastic approach and use statistical procedures to produce a synthetic hydrology that reflects one or more mathematical characteristics of the historical record. Great care must be taken with this approach to ensure that the generation of synthetic supplies accounts for the physical factors that control the multiple-year relationships between wet and dry years. Additionally, planners may create synthetic sequences by developing a "design" drought in which an historical series is modified to include a more intense dry year, or longer dry period. While this may be useful in determining the "worst-case" operating limits and the robustness of the supply system, it does not provide a probabilistic base for assessing supply reliability.

Storage and Distribution

Specification of surface storage components for any supply system model is a fairly straightforward process that involves establishing the physical relationship between key variables and parameters. For surface reservoirs it is necessary to know the maximum usable storage volume and the dead storage volume. If the model is to calculate the evaporative and seepage losses from the reservoir, the relationship between intermediate volumes, water surface area, and the submerged bed area must be established from bathemetric information. The relationship between the rate of seepage and the depth of storage must also be established and may require linkage to a groundwater model. For any simulation, it is necessary to make some assumption concerning storage volume at the start.

Groundwater simulation is a more complex process. Information on physical size, relationships between volume stored and depth of water, and boundary conditions must be developed. Among other factors, it is necessary to know the rates and origins of recharge over time, the gradient, directions and rates of groundwater flow, and the rates and location of withdrawals. In some cases, surface water models may provide input into groundwater models in the form of catchment infiltration (if included), reservoir seepage and river channel losses.

Whether distribution system information is included in supply system modelling depends on the time and space resolution of the model. Clearly, the physical size of aqueducts, pumping stations and smaller terminal reservoirs affects how water is withdrawn from the main storage reservoir and may be important prior to and during periods of runoff.

Operating Rules

System models must include all relevant operating rules that determine how and when water is released from storage reservoirs. Some rules are imposed on an agency by regulatory and legal requirements, while others are designed by agency staff to meet planning objectives. Examples of typical externally-imposed operating rules include:

- **Flood control storage and release.** Surface reservoirs may need to be drawn down prior to winter or spring runoff to permit them to absorb high peak flows and prevent flooding.

- **Fishery releases.** Regulators may mandate minimum releases of water to maintain run-of-the-river flows and water temperatures at key periods of the year to preserve fishery productivity.

- **Water rights.** Sufficient water must be released to satisfy all prior downstream rights and maintain regulated minimum in-stream flow levels.

- **Recreation.** Many water supply reservoirs have dual uses as recreation facilities for boating, fishing and other water sports. Agencies may be required to maintain surface levels within a certain minimum and maximum range to avoid adverse effects on recreation.

Typical agency-imposed rules include:

- **Hydroelectric releases.** Agencies often have agreements with energy utilities to maintain stored depth and periodically release water to produce electricity.

- **Subsequent-year carryover.** As discussed above, agency planners must decide whether and how they wish to utilize storage as an "insurance policy" against subsequent dry years. This forced carryover is triggered by predetermined criteria usually based on remaining volume in storage, time during water year and prior year(s) conditions (as an indicator of the probability of drought conditions prevailing).

LEVEL OF SOPHISTICATION

As discussed above, agencies must decide the appropriate level of sophistication for their modeling efforts. Models can be more or less sophisticated in many ways, including the number of variables considered, the equations that relate them, the time period being analyzed (days, weeks, months, seasons, years), the level of disaggregation (regional, sub-regional, end-use), and the analytical approach. In deciding on the appropriate level of sophistication, planners should consider the following issues:

- **Planning needs.** What questions will the model results be used to answer?

- **Data limitations.** The level of model sophistication cannot outstrip the validity of the available data.

- **System complexity.** All else being equal, a more complex system will require a more complex model.

- **Available technical skills.** The sophistication of the model will be limited by the available in-house or consulting expertise.

- **Financial resources.** More sophisticated models are more expensive to develop and maintain.

Conceptually, the decision regarding the appropriate level of model sophistication should balance the costs of additional levels of complexity and the benefits of the additional precision that will be achieved.

DATA NEEDS AND SOURCES

Demand Forecasting Data

The data necessary to forecast demand depends on the type of forecasting approach that is used. Simple extrapolations require little data beyond the past patterns of demand. Econometric forecasts vary in complexity. But even the simplest econometric models require historical data and forecasts of independent variables that typically reflect demographic, geographic, economic, and climatic variations, as well as various externally-imposed influences on demand patterns, such as drought-induced rationing, utility conservation programs, or changes in plumbing codes and/or local ordinances. More complex models may require water use to be broken down into finer periods, smaller geographical areas, or customer classes.

Much of this information, particularly for the simpler models, is readily available from sources such as the Census Bureau, local, regional, or state planning agencies, or from the utility's own records. The richness of an econometric model will often be limited by the unavailability of particular types of data.

As discussed in subsection A above, data limitations become particularly severe for end-use forecasting models. Generally speaking, the necessary data for end-use water demand forecasting has not been developed. As an alternative, planners can attempt to disaggregate estimated total demand first to customer class and then to end-uses based on a more general understanding of the relative consumption of customer classes and end-uses within each class. Care must be taken when using such approximations.

Supply Forecasting Data

The type, complexity, accuracy and ease of collection of supply data needed for model development depends very much on the type of supply system. Groundwater systems generally have greater data limitations than surface water systems due to the relative lack of empirical data and monitoring programs on the physical characteristics and conditions of aquifers, and the unregulated and unrecorded use of regional aquifers by multiple parties. In many cases, deterministic groundwater models use a number of theoretical parameters which are calibrated against empirical records such as recorded water levels or drawdown over time.

Most major streams and rivers are equipped with automatic gauges that measure the flow at calibrated control stations. Agencies such as the United States Geological Survey and the State of California Department of Water Resources Division of Flood

Management collect, process and disseminate this information. Generally, records of seventy years or longer are now available for most surface water systems. Many water agencies maintain their own gauges in their catchment system and at the point of inflow to reservoirs, have meteorological stations in the catchment area and adjacent to the reservoir, and record the timing and amount of releases. The National Weather Service also provides precipitation and pan-evaporation data from relevant weather stations that may be used in a supply system model.

The physical characteristics of most hydrological and supply systems are also available, for aquifers from geological and hydrogeological surveys, and for surface water systems from topographic and bathemetric maps of catchment and reservoir locations. The combination of this historical and physical data means that most agencies have at their disposal the minimum amount of data necessary to develop, parameterize and calibrate a supply system model that can produce meaningful planning data.

While historical conditions are well known and models can be developed and tested to take advantage of the historical data, the major limitation facing planners is the uncertainty associated with future conditions. The model's predictive ability depends on the degree to which the data input to the model reflects the future conditions. There are many reasons why this may not be the case, one of the most prominent being the relatively short periods over which historical data is typically available. Even if the future will be like the past, the past seventy to eighty years may be atypical of that past.

Alternatively, the frequency and magnitude of future events may differ due to long-term fluctuations or changes in climatic and physical conditions within the catchment of the water source. Conditions such as global warming, deforestation, and urbanization could effect surface runoff and groundwater recharge and provide an added level of uncertainty to model predictions.

In cases where planners have reason to believe that use of historical records will provide insufficient accuracy, they may resort to creation of synthetic hydrology to better model future conditions.

V. RELIABILITY OPTIMIZATION

One of the issues addressed by Phase 1 of this project was that of the "right" level of water supply reliability, the determination of which is based on a minimization of total costs, including external costs. Total costs include both the costs of resource development to achieve particular reliability levels and the costs to customers that result from shortages associated with each level of reliability. Figure V-1 is reproduced from the Phase 1 report to illustrate this cost-minimization concept.

The WRAP model in its current form does not attempt to estimate the optimal level of reliability. However, the descriptive information that WRAP develops could provide a basis for an optimization module. To understand the additional requirements of such a module, it is useful to refer once again to Figure I-1 (reproduced on the following page), which illustrates the reliability planning framework developed in Phase 1.

WRAP currently addresses solely the top shaded area of the diagram, labeled "Reliability Forecasts." An optimization module would use as one input the products of this forecasting model, specifically the results of the base or "do-nothing" scenario, to describe the starting point of the optimization analysis. As the lower shaded area indicates, the optimization model would then require several other inputs, most notably:

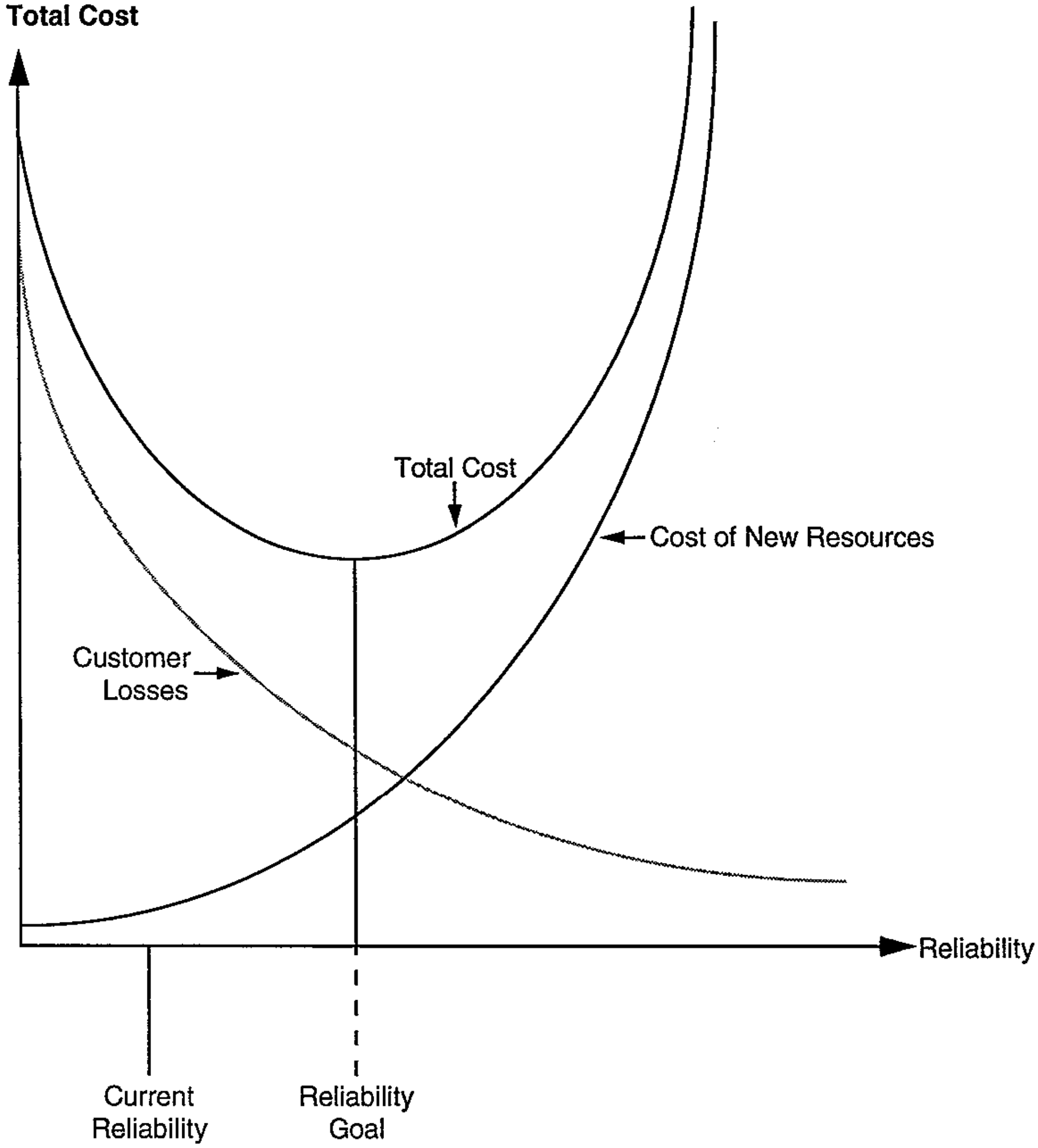
- The costs of resources that would be developed to improve reliability from that level indicated in the base case; and

- The costs to customers of shortages associated with various levels of "unreliability."

As Figure V-1 indicates, each of these inputs can be viewed as cost functions. The inputs to an optimization model would likely be in the form of tabular representations of these functions. The model would then add the two cost components and produce graphical and tabular outputs that identify the least-cost level of reliability. The model could also perform analyses of the sensitivity of these results to uncertainties in the resource cost and customer shortage cost data.

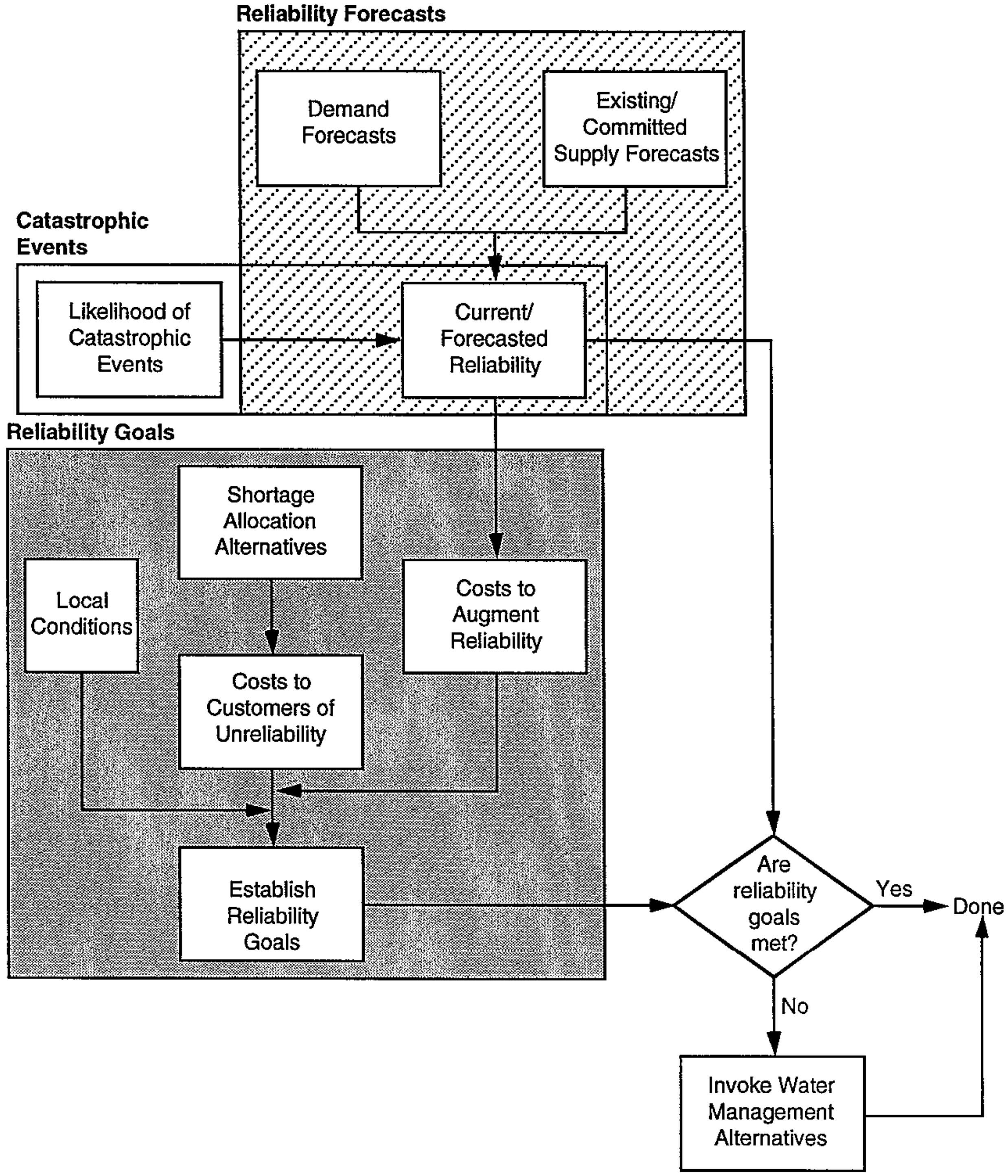
The resource cost function merits some additional discussion. When referring to the costs of resources, any external costs that are relevant to the optimization decision must be included. In particular, the environmental costs that are associated with particular resource options must be reflected. Such costs are inherently difficult to estimate; however, that difficulty does not minimize their importance.

Figure VI-1
Determining the Water Supply Reliability Goal



1411.CUWA.ap

Figure I-1
A Generic Reliability Planning Framework



1411.CUWA.ap

There are many techniques that could be used to estimate environmental costs. One that has been applied by many researchers is contingent valuation (CV). The CV survey that CUWA is using to assess customer shortage costs does not separately quantify customers' valuation of environmental damages. A separate CV survey could be developed to estimate the magnitude of various types of environmental costs. However these costs are estimated, Figure V-1 presumes that they are included in the resource cost function that is used in the optimization analysis.

As Figure I-1 demonstrates, the model could be enhanced to consider other variables, such as the manner in which agencies have chosen to allocate future shortages among customer classes or other specific local conditions.[10] Of course, many such local conditions cannot and should not be incorporated into a model of this type. They can only properly be reflected in the decision making process of the water supply agency itself. The results of this type of optimization modelling process will be but one of many useful types of information to be considered in that process.

The additional programming requirements to extend the WRAP model to include an optimization module are not large.

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[10]Since each customer class experiences different types and magnitudes of shortage costs, the way that the shortage is allocated will affect the overall shortage cost which may, in turn, influence the least-cost level of reliability.

VI. WRAP MODEL OPERATING INSTRUCTIONS

(for use with WRAP Version 1.0)[11]

The WRAP model runs best on a 386 or 486 PC because of the large number of calculations and data manipulations that the model makes when the full six year, five scenario data option is selected. Users should read these instructions before proceeding with the model.

The disk supplied with this documentation contains:

- WRAP version 1.0;
- The files needed to test the model; and
- Blank data templates to guide correct formatting of new input data sets.[12]

Description	Worksheet Files	Format Files
Model	WRAP.WK3	WRAP.FM3
Test supply and demand data	WRAP_SDD.WK3 WRAP_1SD.WK3	WRAP_SDD.FM3 WRAP_1SD.FM3
Test reliability indices data	WRAP_RID.WK3 WRAP_1RI.WK3	WRAP_RID.FM3 WRAP_1RI.FM3
Blank data templates	WRAP_TP3.WK3 WRAP_TP1.WK3	WRAP_TP3.FM3 WRAP_TP1.FM3

The user can store data files in any directory or sub-directory location, on a floppy drive, a hard drive or on a network, as long as they are all stored in the same location (for example C:\WRAPFILE\). It is *not* necessary to store the WRAP model program file WRAP.WK3 in the same directory as the data files.

[11] A schematic flow diagram of the WRAP model is included as Appendix B of this document.

[12] See Appendix A for complete data formatting instructions.

STARTING THE MODEL

To run WRAP, the user must first boot up Lotus 1-2-3, version 3.1 and use the "/FR" command to locate and retrieve the file WRAP.WK3.[13] Lotus 1-2-3 should be running in WYSIWYG mode (see the troubleshooting suggestions for instructions on how to invoke WYSIWYG). The user is presented with a Welcome Screen (Figure VI-1). The user starts the model by pressing the Alt and A keys simultaneously.

The user is presented with a series of menus that ask for specific actions to be performed. The user should carefully read and follow the instructions in the menu screens.

The File Location menu (Figure VI-2) then asks for the full directory path where the data files are located. Note that the path should include the correct syntax of all the directory and sub-directory names and must end with a final \ (e.g. C:\WRAPFILE\).

After typing the path and pressing the Enter key twice, the user is asked by the File Location Confirmation menu (Figure VI-3) to confirm that the path has been correctly typed by pressing the Y or N key, and then pressing the Enter key twice. If the path is incorrectly typed or the directory does not exist, the user receives an error message and is given the option to return to the File Location menu by pressing the Y key and then the Enter key. Pressing the N key and the Enter key will exit WRAP and return the user to a blank Lotus spreadsheet where directories can be examined for the correct location of files.

IMPORTING DATA

Once the correct data file path is entered, the user is presented with Data Input Choices (Figure VI-4). The user can choose to Import Supply and Demand Data by pressing the A key, or to Retrieve Saved Reliability Indices by pressing the B key. The user may also press the C key to Exit the WRAP model without importing a data file. The B option is for a user who has previously run the WRAP model with a supply and demand data set and who saved the indices into a Lotus file (see below).

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[13]Prior to retrieving the WRAP model, network users of Lotus 1-2-3 should ensure that Lotus is set to store temporary print and graphing files to the user's hard drive, rather than the network drive. This can be accomplished through the following Lotus commands:

/ Worksheet Global Default Temp Escape
C:\ <Enter>
Update Quit

Figure VI–1 – WRAP Welcome Screen

WELCOME TO THE WRAP MODEL

Model for
Water Reliability Analysis and Planning

Version 1.0

Developed by
Barakat & Chamberlin, Inc.
for California Urban Water Agencies

Press 'ALT–A' to Run the Model

Notice: Copies of WRAP Model are available from California Urban Water Agencies (CUWA). Use and dissemination of WRAP should be accompanied by appropriate attribution to CUWA and Barakat & Chamberlin, Inc.

Figure VI–2 – File Location menu

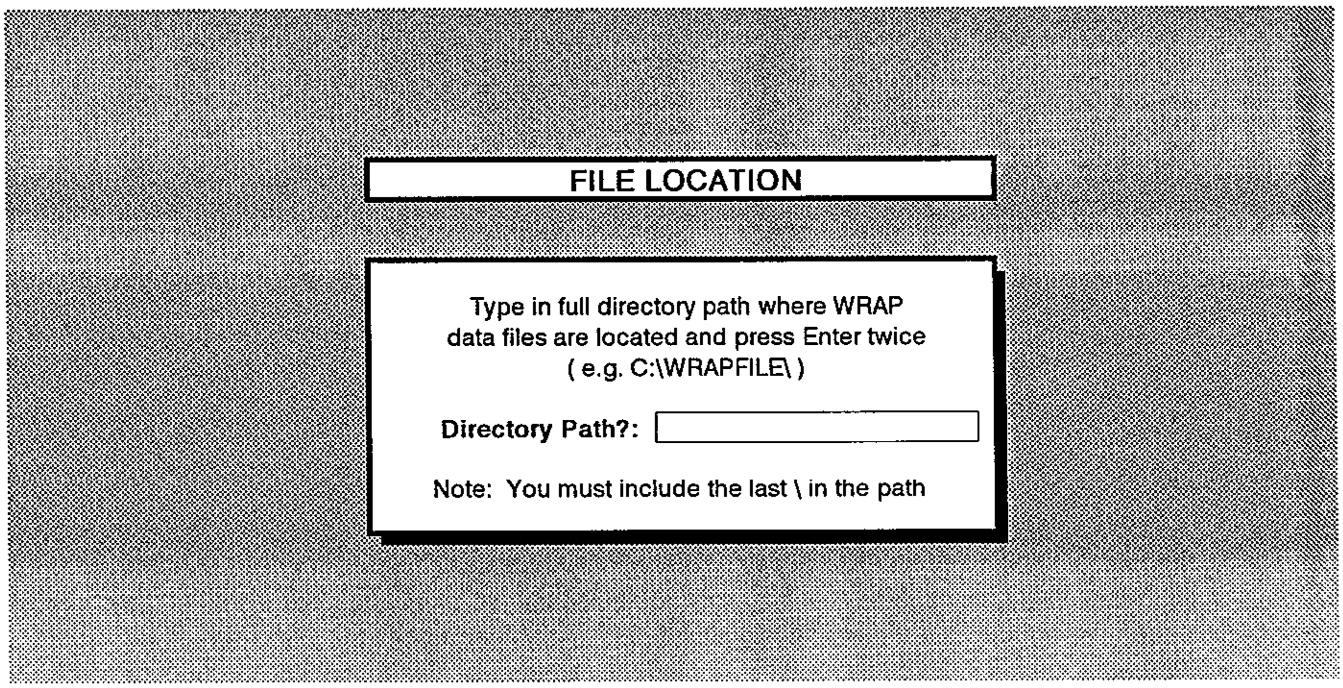


Figure VI-3 – File Location Confirmation menu

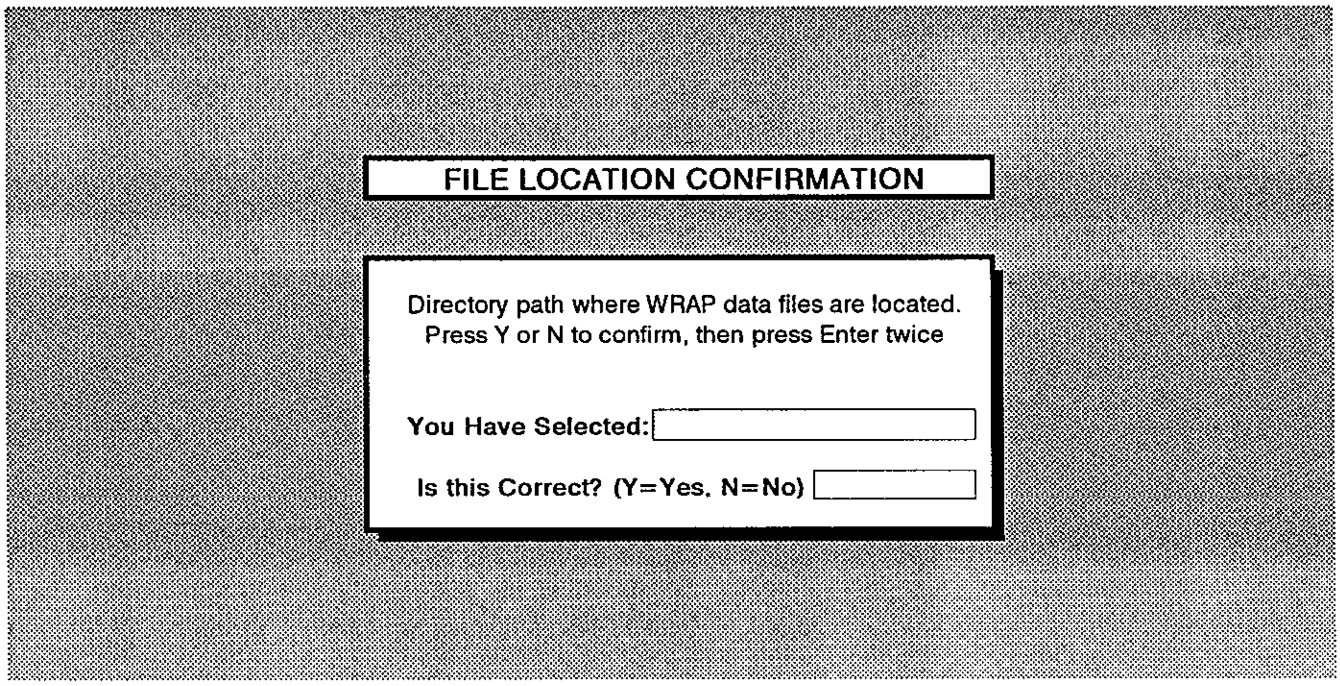
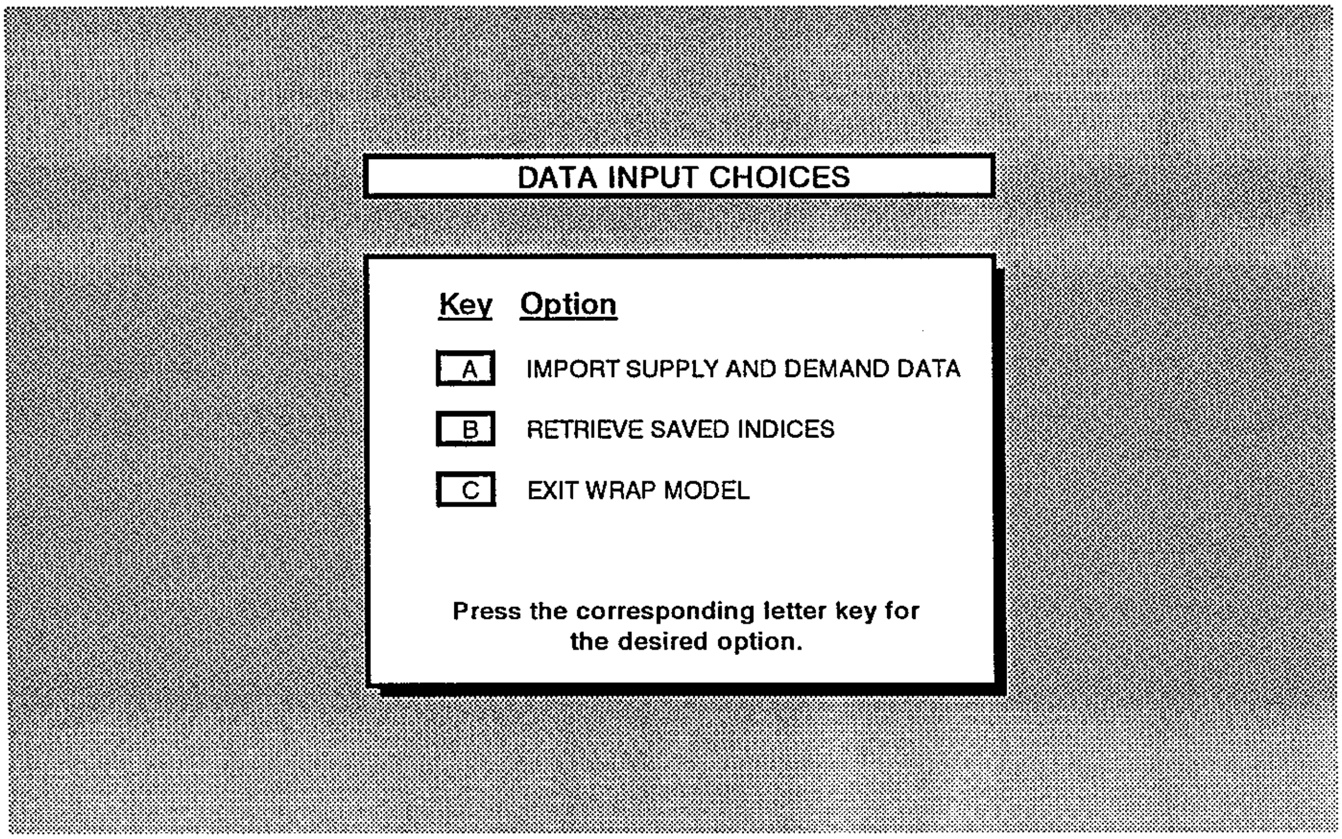


Figure VI–4 – Data Input Choices menu



This allows the user to skip the calculation stage in which the supply and demand data is used to create reliability indices for different scenarios, different years, and different levels of demand. Thus, for any one demand and supply data set, this calculation stage need only be completed once.[14]

Pressing key A or B will present the contents of the directory path that was specified previously in the File Location menu. The user should toggle to the appropriate Lotus worksheet file and press the Enter key. The user then sees the contents of the file imported into the appropriate location in the WRAP model and is presented with the next menu of options. If the user makes a mistake in specifying the file name, an error message will result and return the user to the Data Input Choices menu.

CALCULATING RELIABILITY INDICES[15]

If the user pressed the A key to retrieve a supply and demand data set, the next menu asks for the number of years in the data set (Figure VI-5). The user should press the appropriate key from 1 to a maximum of 6. The following menu requires the user to specify the number of scenarios in the data set (Figure VI-6). The user should press the appropriate key from 1 to a maximum of 5. The following menu asks how the is demand is specified (Figure VI-7). If the data set contains only one demand for each year (a single best estimate), the user should press the A key; if it contains three levels of demand for each year (high, best and low), the user should press the B key. These are the only two choices.

(Note that it is absolutely *critical* that the supply/demand date file be in the correct format. That format is described in Appendix A and is reflected in the templates provided on the WRAP diskette.)

WRAP then calculates the reliability indices for the various combinations of supply and demand for each scenario in each year. While it is doing so, a screen appears asking users to await further instructions (Figure VI-8). The keyboard is locked during this process and will not respond to keys being pressed. The time consumed by

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[14]Any of the supply and demand data files created for testing WRAP, or the reliability indices files created by WRAP can be loaded as independent documents into Lotus 1-2-3 by any user. This is particularly useful in the case of the saved reliability indices. If a skilled Lotus user requires specific customized graphing, for instance, with a specific format and titles, the user could go straight to the saved reliability files and develop graphs using the Lotus graphing commands.

[15]Users that have selected Option B—Retrieve Previously Saved Indices—from the Data Input Choices menu should proceed to the next section, "Selecting Resources Cases."

Figure VI–5 – Number of Years in Data Set menu

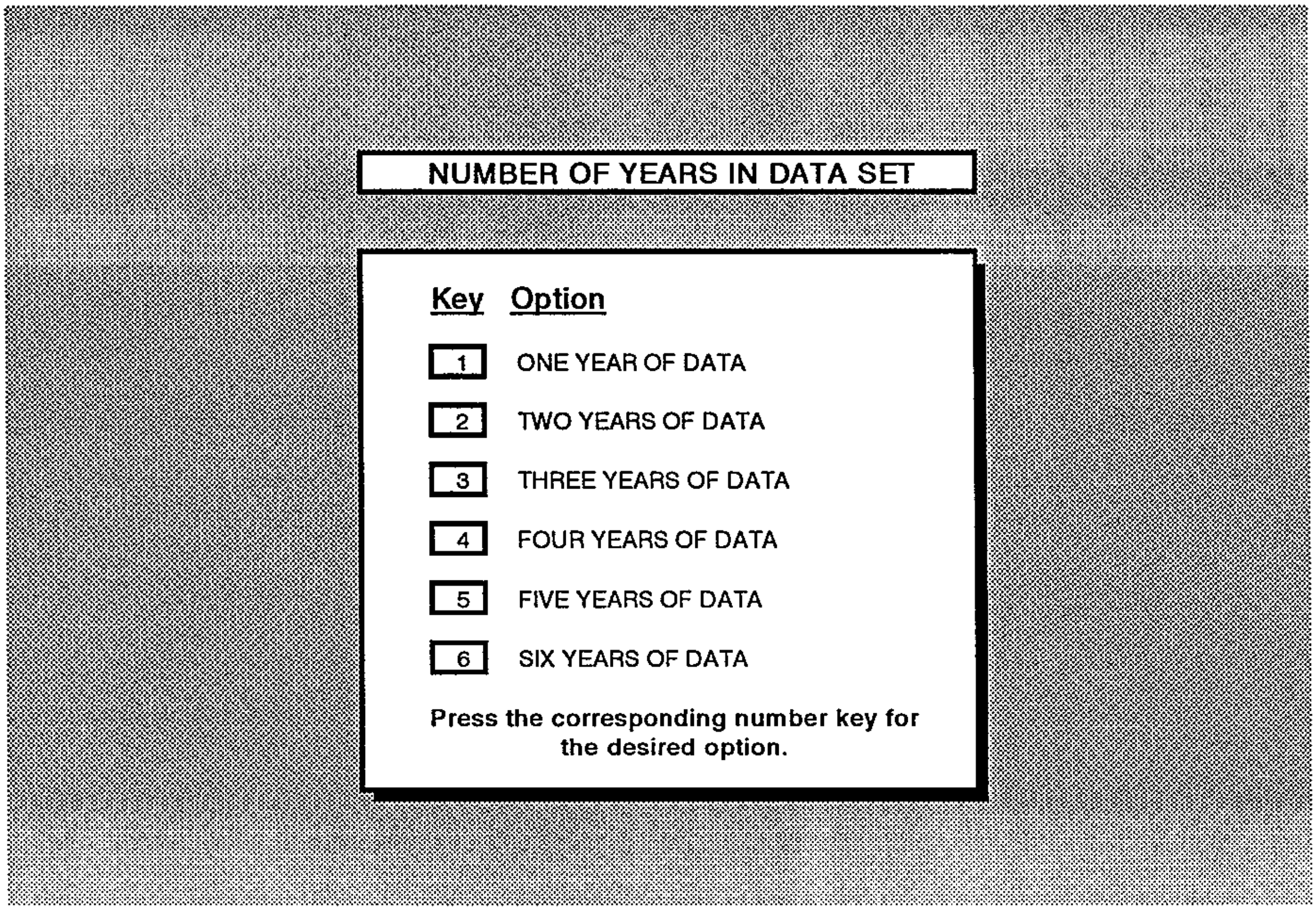


Figure VI–6 – Number of Scenarios in Data Set menu

NUMBER OF SCENARIOS IN DATA SET

Key	Option
1	ONE SCENARIO
2	TWO SCENARIOS
3	THREE SCENARIOS
4	FOUR SCENARIOS
5	FIVE SCENARIOS

Press the corresponding number key for the desired option.

Figure VI-7 – How is Demand Specified? menu

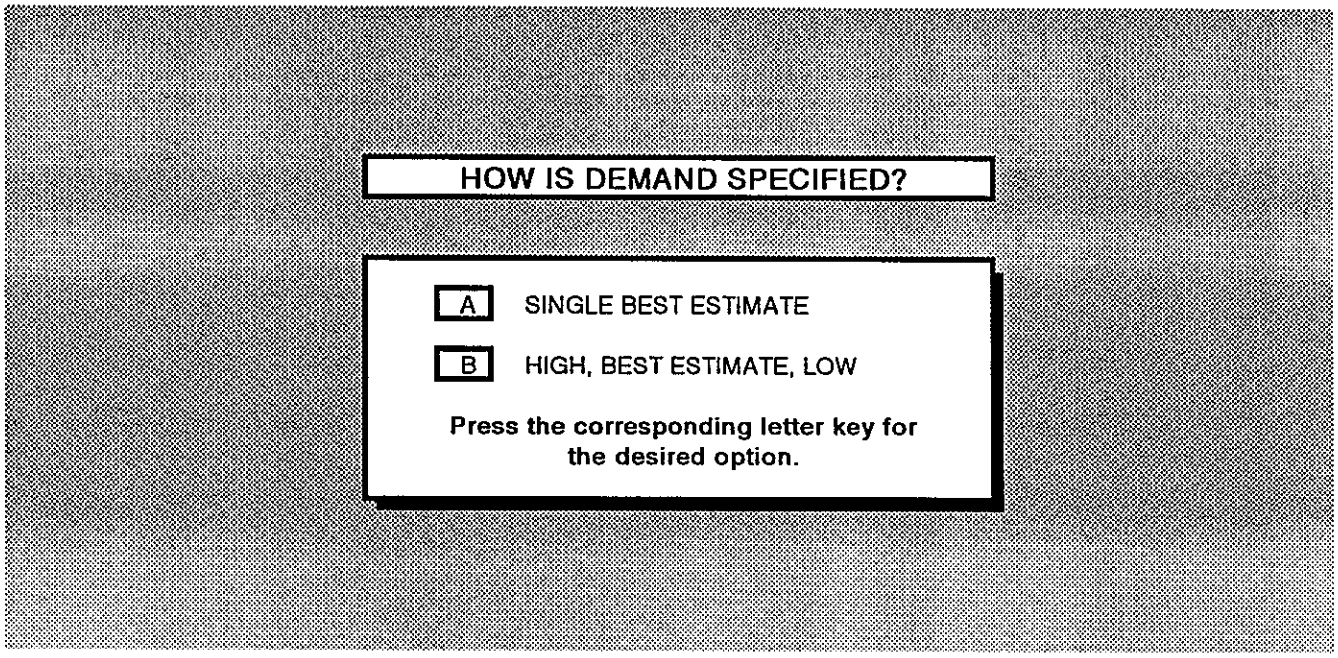
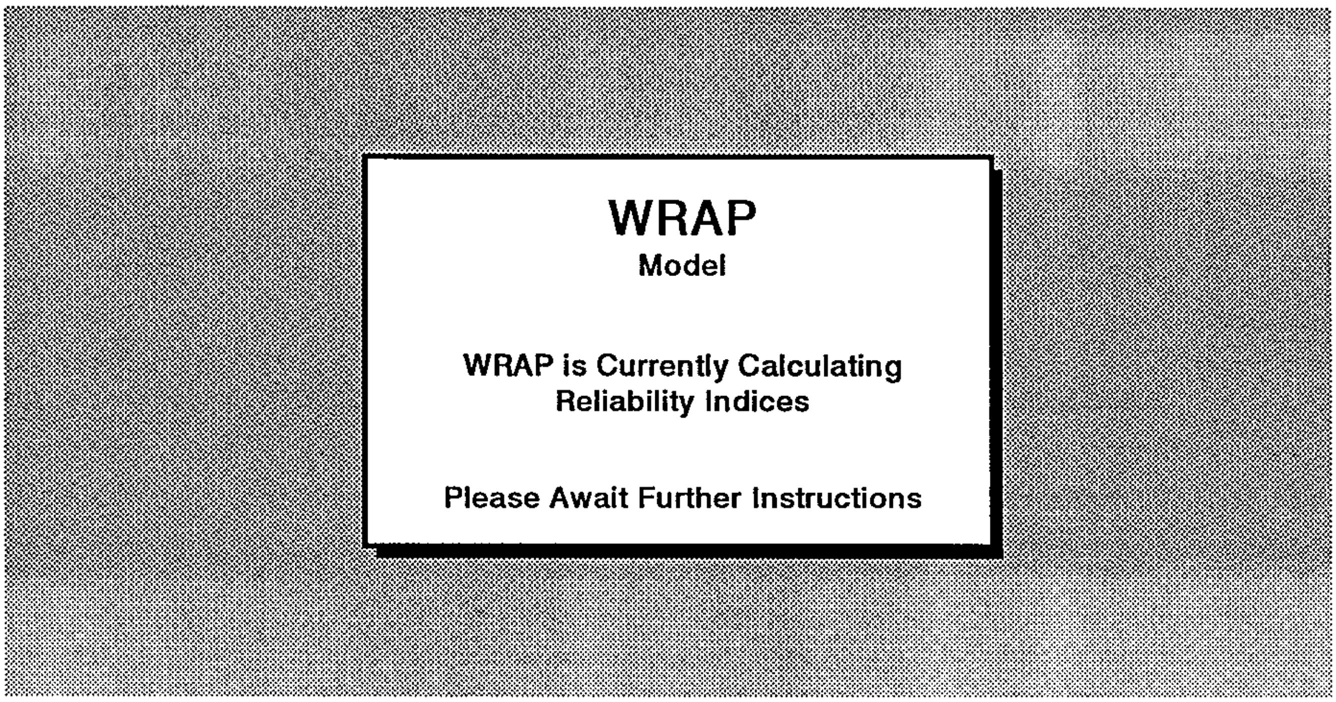


Figure VI-8 – Wait for Calculations Screen



these calculations will vary considerably depending on the number of years, scenarios, and demand levels, as well as the type of computer and the network configuration.

Each user should remember that WRAP is a post-processor and that the reliability results it produces are only as meaningful as the supply and demand data developed by the water utility. It is important that each user follow the guidelines and rationale for developing supply and demand data as described in the preceding chapters.

SELECTING RESOURCE CASES

Once the calculations are completed, the user is presented with the Selection of Cases menu (shown blank in Figure VI-9). (This menu is the starting point for those users who chose to retrieve a previously saved set of reliability indices.) The WRAP model allows the user to specify up to six combinations of years, scenarios, and demand levels to present in tabular or graphical format. Each such specified combination is called a "case." For example, if a user wants to compare the water supply reliability in a base year against the high demand estimate for two different resource scenarios in two future years (five cases in all), tables and graphs illustrating this particular comparison can be produced.

The user selects cases by pressing option keys as listed in the Selection of Cases menu. When this menu screen appears, the user is first asked to indicate the number of case selections to tabulate and/or graph. This must be a number between 1 and 6. If the user presses any other key, an error message results and the question is asked again until a number key between 1 and 6 is pressed.

Once the number of case selections has been pressed, the user is prompted to press the key that corresponds to the year, scenario and demand of each case, except where the original data file has only one demand level per year, in which case the single best estimate demand will automatically be selected. All prompts appear at the top of the screen. The key options are clearly shown in the upper part of the menu and the selections appear immediately in the table of cases. If the user presses a key that is not shown as a Year, Scenario or Demand option in the menu boxes, an error message results and the user is prompted to press a correct key.

Once all of the cases have been completed (shown with data from WRAP_SDD.WK3 in Figure VI-10), the user is asked to type in a number from 1 to 99 that represents a probability of designated shortage (PODS) of particular interest. This is later highlighted in tables or graphs. For example, if a user is interested in looking at the probability of exceeding a shortage of 25%, the user can type 25 and press the Enter

Figure VI–9 – Selection of Cases menu

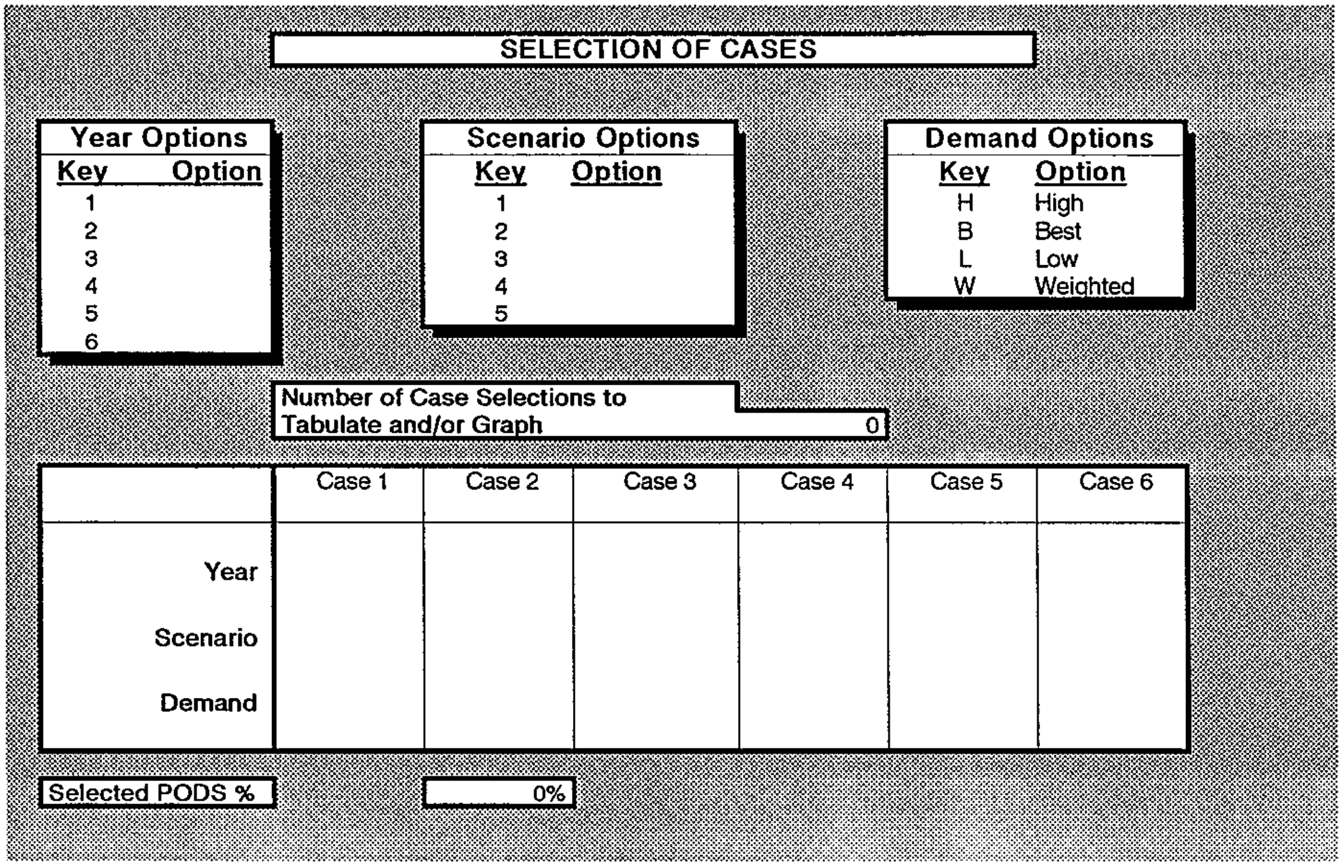


Figure VI–10 – Example of completed Selection of Cases menu

SELECTION OF CASES

Year Options

Key	Option
1	1993
2	2000
3	2020
4	
5	
6	

Scenario Options

Key	Option
1	Baseline
2	Releases
3	Raised Dam
4	Conservation
5	New Operation

Demand Options

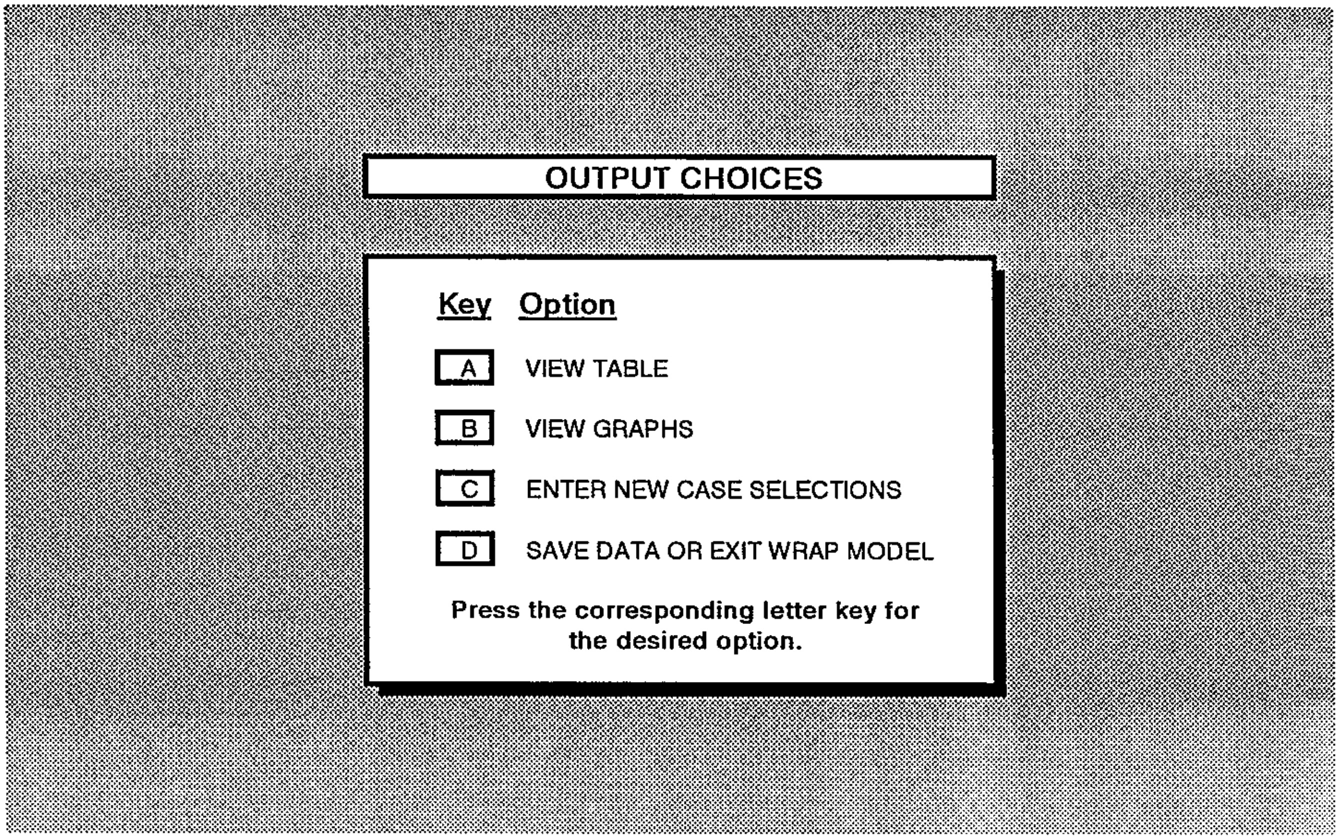
Key	Option
H	High
B	Best
L	Low
W	Weighted

Number of Case Selections to Tabulate and/or Graph 5

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Year	2020	2020	2020	2020	2020	
Scenario	Baseline	Releases	Releases	Releases	Releases	
Demand	Best	High	Best	Low	Weighted	

Selected PODS % 25%

Figure VI–11 – Output Choices menu



key. Users must enter an integer between 1 and 99, i.e., they cannot skip this step or enter zero. If anything other than an integer from 1 to 99 is entered, an error message results and the user will be prompted for a correct entry.

Once this data entry process is complete, the user is prompted to confirm that the selections made are correct. If the user presses Y and then Enter, the Output Choices menu appears (Figure VI-11). If the user presses N and then Enter, the case selections are erased and the user is prompted for a new set of combinations.

VIEWING AND PRINTING TABLES

The Output Choices menu allows the user to choose to view the selected cases in tabular or graphical format. To view a table, the user presses A, and to view graphs, the user presses B. The user can also elect to go back and enter new case selections (press C) or to save data or exit the WRAP model (press D).

If the user presses A, the Reliability Indices Table appears (Figure VI-12). This table presents the PODS at 5% intervals as well as the POS, the EUD and the selected PODS (from 1 to 99%) for each of the selected cases in the order they were selected. The column headings indicate the scenario name, year and demand type. Also included below the table is the date and time that the table was created, and the name of the original supply and demand data file from which the reliability indices were calculated.

The table remains on the screen until the user presses either the Y key or the N key, followed by the Enter key in response to the prompt "Do You Want To Print This Table?" which appears at the top of the screen. Pressing the Y and then the Enter key will print the table. Version 1.0 of WRAP assumes default printing to a Laser Printer and will print the table portrait-style on a single 8½" x 11" page (Figure VI-13). The appearance of the table may vary from user to user due to the settings of local installation of Lotus 1-2-3 and local printer hardware and software (see Troubleshooting suggestions below). Printing removes any blank columns shown on the screen.

Figure VI-12 - Reliability Indices Table Screen

RELIABILITY INDICES TABLE

SCENARIO		Baseline	Releases	Releases	Releases	Releases	
YEAR		2020	2020	2020	2020	2020	
DEMAND TYPE		Best Estimate	High	Best Estimate	Low	Weighted	
PODS	0%	44.4%	86.1%	69.4%	62.5%	71.9%	
PODS	5%	38.9%	81.9%	65.3%	56.9%	67.4%	
PODS	10%	34.7%	70.8%	62.5%	51.4%	61.8%	
PODS	15%	25.0%	69.4%	52.8%	44.4%	54.9%	
PODS	20%	19.4%	63.9%	48.6%	41.7%	50.7%	
PODS	25%	15.3%	58.3%	45.8%	37.5%	46.9%	
PODS	30%	12.5%	48.6%	40.3%	29.2%	39.6%	
PODS	35%	11.1%	44.4%	30.6%	23.6%	32.3%	
PODS	40%	6.9%	34.7%	23.6%	18.1%	25.0%	
PODS	45%	2.8%	26.4%	18.1%	15.3%	19.4%	
PODS	50%	2.8%	20.8%	13.9%	12.5%	15.3%	
PODS	55%	0.0%	13.9%	6.9%	4.2%	8.0%	
PODS	60%	0.0%	6.9%	4.2%	2.8%	4.5%	
PODS	65%	0.0%	4.2%	2.8%	1.4%	2.8%	
PODS	70%	0.0%	1.4%	1.4%	1.4%	1.4%	
PODS	75%	0.0%	1.4%	1.4%	1.4%	1.4%	
PODS	80%	0.0%	1.4%	1.4%	1.4%	1.4%	
PODS	85%	0.0%	1.4%	1.4%	1.4%	1.4%	
PODS	90%	0.0%	0.0%	0.0%	0.0%	0.0%	
PODS	95%	0.0%	0.0%	0.0%	0.0%	0.0%	
POS		44.4%	86.1%	69.4%	62.5%	71.9%	
EUD		9.5%	29.5%	22.7%	18.8%	23.4%	
PODS	25%	15.3%	58.3%	45.8%	37.5%	46.9%	
DEMAND		575,000	632,500	575,000	546,250	582,188	

Figure VI-13 - Printed Reliability Indices Table

RELIABILITY INDICES TABLE

SCENARIO		Baseline	Releases	Releases	Releases	Releases
YEAR		2020	2020	2020	2020	2020
DEMAND TYPE		Best Estimate	High	Best Estimate	Low	Weighted
PODS	0%	44.4%	86.1%	69.4%	62.5%	71.9%
PODS	5%	38.9%	81.9%	65.3%	56.9%	67.4%
PODS	10%	34.7%	70.8%	62.5%	51.4%	61.8%
PODS	15%	25.0%	69.4%	52.8%	44.4%	54.9%
PODS	20%	19.4%	63.9%	48.6%	41.7%	50.7%
PODS	25%	15.3%	58.3%	45.8%	37.5%	46.9%
PODS	30%	12.5%	48.6%	40.3%	29.2%	39.6%
PODS	35%	11.1%	44.4%	30.6%	23.6%	32.3%
PODS	40%	6.9%	34.7%	23.6%	18.1%	25.0%
PODS	45%	2.8%	26.4%	18.1%	15.3%	19.4%
PODS	50%	2.8%	20.8%	13.9%	12.5%	15.3%
PODS	55%	0.0%	13.9%	6.9%	4.2%	8.0%
PODS	60%	0.0%	6.9%	4.2%	2.8%	4.5%
PODS	65%	0.0%	4.2%	2.8%	1.4%	2.8%
PODS	70%	0.0%	1.4%	1.4%	1.4%	1.4%
PODS	75%	0.0%	1.4%	1.4%	1.4%	1.4%
PODS	80%	0.0%	1.4%	1.4%	1.4%	1.4%
PODS	85%	0.0%	1.4%	1.4%	1.4%	1.4%
PODS	90%	0.0%	0.0%	0.0%	0.0%	0.0%
PODS	95%	0.0%	0.0%	0.0%	0.0%	0.0%
POS		44.4%	86.1%	69.4%	62.5%	71.9%
EUD		9.5%	29.5%	22.7%	18.8%	23.4%
PODS	25%	15.3%	58.3%	45.8%	37.5%	46.9%
DEMAND		575,000	632,500	575,000	546,250	582,188

4/29/93 - 6:11 PM - WRAPTEST.WK3

VIEWING AND PRINTING GRAPHS

Once the table has been printed, or when the user presses the N and then the Enter key, WRAP returns to the Output Choices menu.[16] Pressing the B key will then enable the user to view graphs of the reliability indices. Pressing B is followed by a delay during which a screen appears indicating that WRAP is preparing the graph data in the spreadsheet and asking the user to await further instructions (Figure VI-14). The user will then see the Graph Choices menu (Figure VI-15). Pressing keys A, B, C, or D (or using the arrow keys to move to the appropriate letter and then pressing Enter) allows the user to see one of four graphs of reliability indices for the selected cases. After pressing the A, B, C or D keys, the user must then press Enter. (If the initial letter choice was selected using the arrow keys, the Enger key must be pressed twice.) Pressing key E returns the user to the Output Choices menu. Pressing key F allows the user to save the reliability indices data or exit the WRAP model.

Pressing key A and then Enter brings up a graph of the Cumulative Frequency Distributions of the shortages for the cases selected by the user (Figure VI-16).

Pressing key B and then Enter brings up a graph of the Expected Unserved Demand (EUD) for the scenarios and demands selected by the user for the years defined by the user (Figure VI-17).

Pressing key C and then Enter brings up a graph of the Probability of any Shortage (POS) for the scenarios and demands selected by the user for the years defined by the user (Figure VI-18).

Pressing key D and then Enter will bring up a graph of the selected Probability of Designated Shortage (PODS), for the scenarios and demands selected by the user for the years defined by the user (Figure VI-19). Thus, if a user entered 25% after making the case selections, the time-variation of the probability of exceeding a 25% shortage would be shown in this graph.

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[16]If a user should want to save the reliability indices tables as a separate file for direct importation into a word processing document, this is possible by temporarily escaping from the model macros. The user should press the Escape key when presented with the Output Choices Menu after looking at a table of the selected reliability indices. The user should type in the following sequence: / File Xtract Values [the name of file (maximum of 8 characters)]. Return E:B1..E:I35 Return. The table of indices located in range E:B1..E:I35 will be saved in a separate file. To get back to the Output Choices Menu, the user simply presses the Alt-Z key combination.

Figure VI–14 – Wait for Graph Preparation Screen

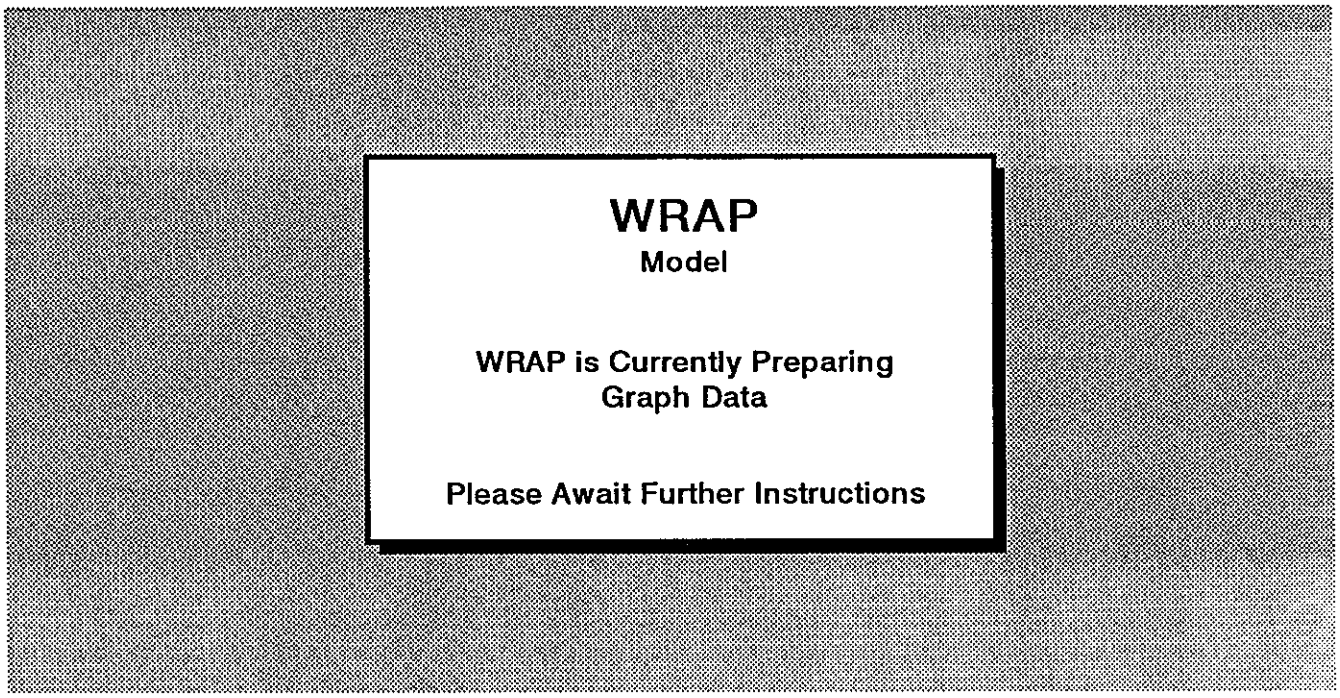


Figure VI–15 – Graph Choices menu

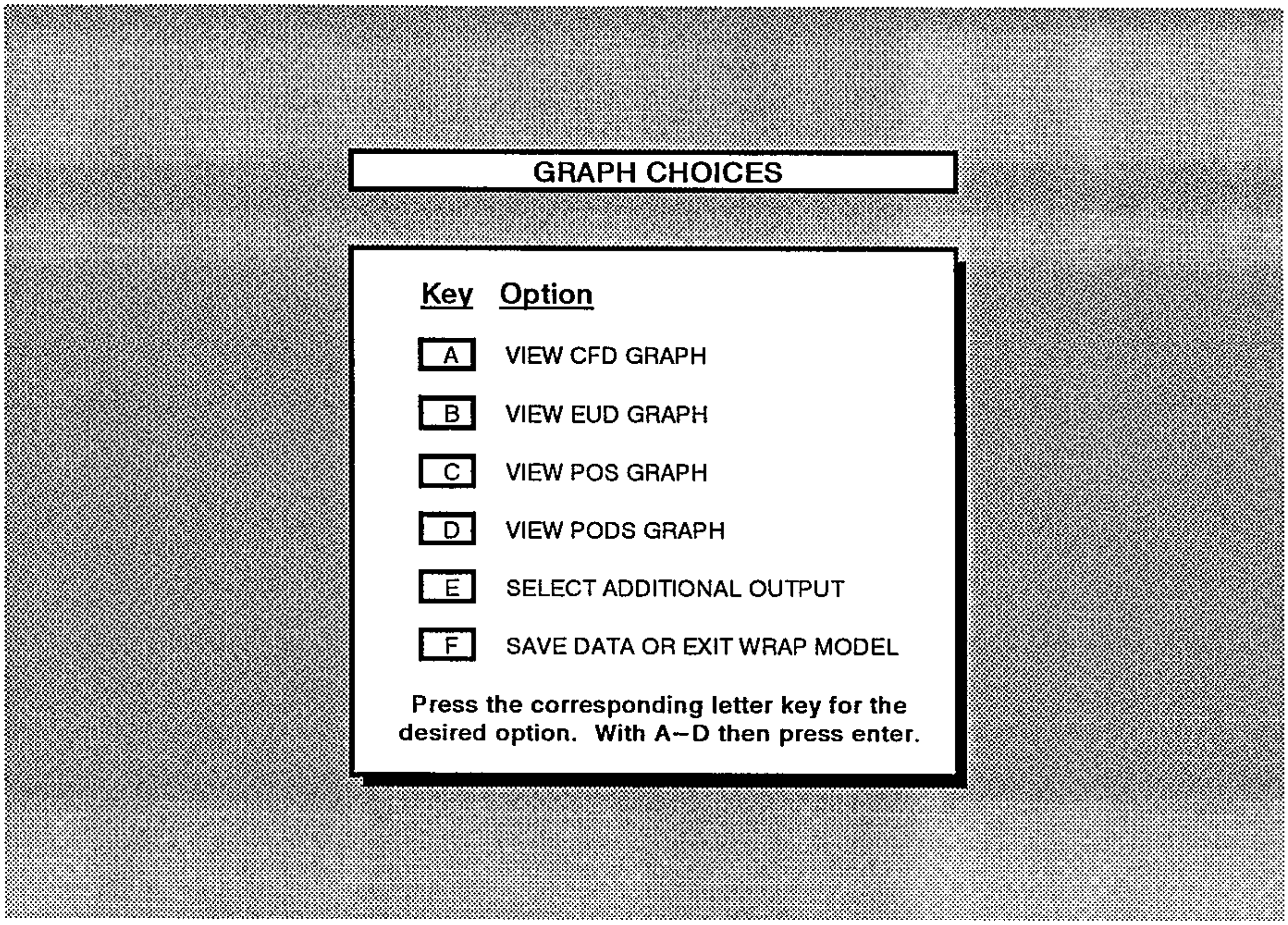


Figure VI-16 - Graph of Cumulative Frequency Distribution

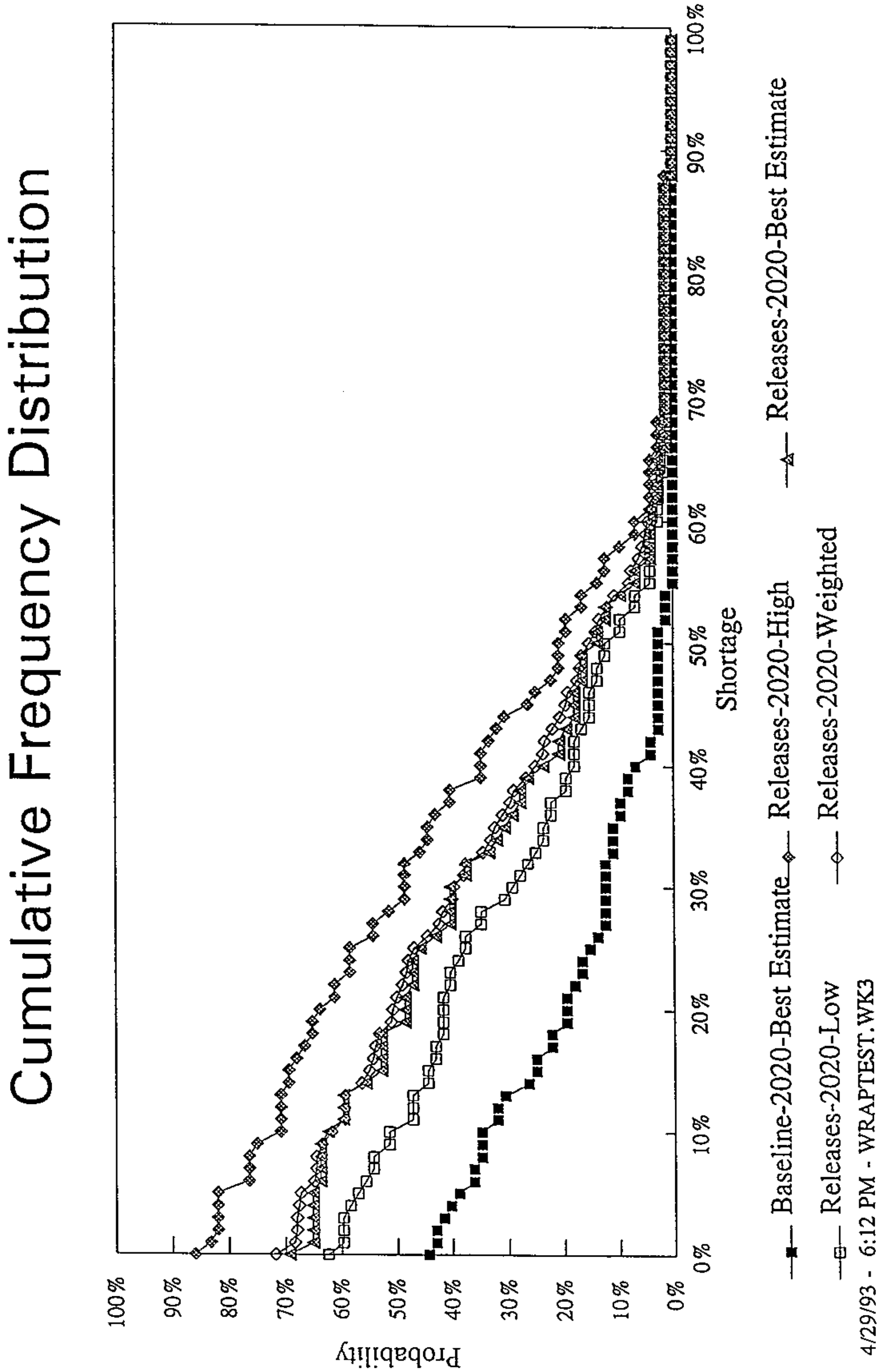


Figure VI-17 - Graph of Expected Unserved Demand

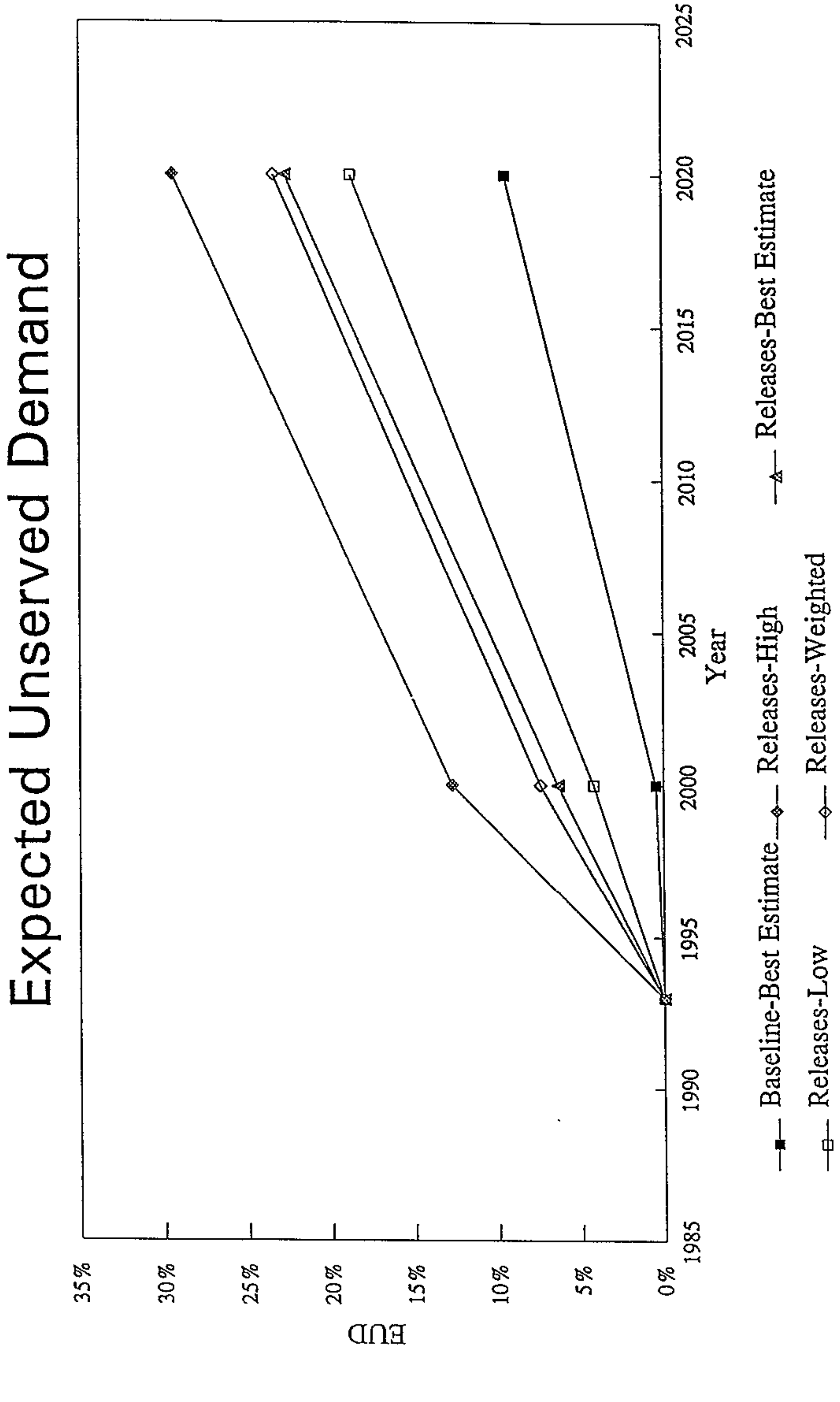


Figure VI-18 - Graph of Probability of a Shortage

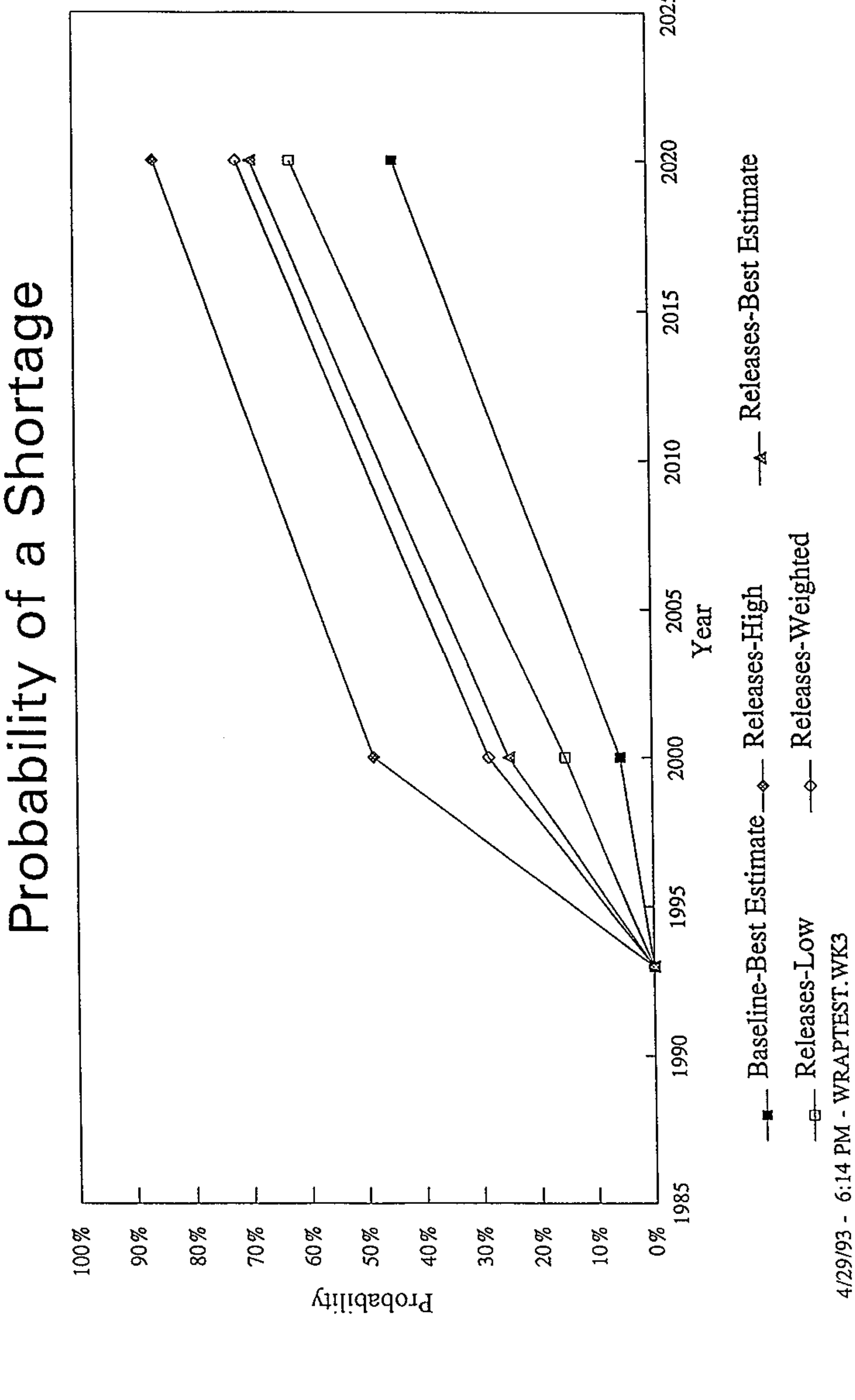
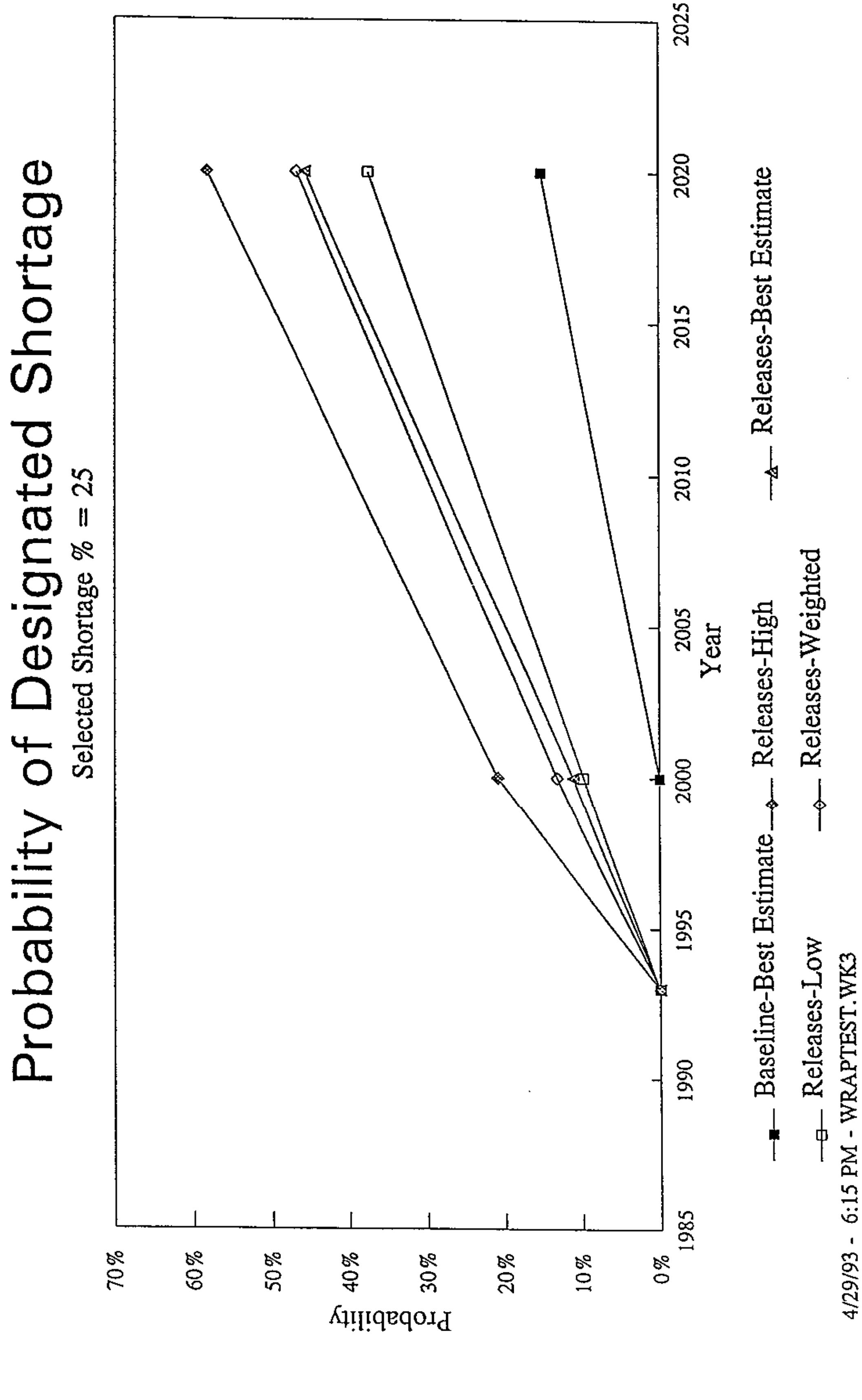


Figure VI-19 - Graph of Probability of Designated Shortage



In each of the graphs, the legend indicates the case that each line represents. Additionally, each graph contains a footnote which contains the date and time of creation and the name of the original supply and demand data file from which the reliability indices were created.

Once the selected graph is displayed, pressing the Enter key will bring up the Graph Print Choices menu (Figure VI-20). Selecting A will print the graph just viewed and returns the user to the Graph Choices menu; B will allow the user to save the last graph viewed as a graphical image file for direct importation into a word processing file: and C will return the user to the Graph Choices Menu. Option B will require the user to type in a file name of up to 8 characters and then press the return key. The user should select a unique name for each graphic file since WRAP will not replace the contents of existing files. The filename has the syntax FILENAME.CGM and will be placed in the path location entered in the File Location menu.

Version 1.0 of WRAP assumes default printing to a Laser Printer and will print the graph landscape-style on a single 8½" x 11" page. The appearance of the graph may vary from user to user due to the local installation settings of Lotus 1-2-3 and local printer hardware and software (see Troubleshooting suggestions).

On returning to the Graph Choices menu, if the user has finished viewing graphs, the user can select additional output by pressing the E key. The user returns to the Output Choices menu and can choose to go back to viewing the table or to enter new case selections.

SAVING DATA SETS

In the Output Choices menu (the D key), and the Graph Choices menu (the F key), users are given the option of saving the data or exiting the WRAP model. Pressing either key brings up the Save Choices menu (Figure VI-21). The user has five choices.

The A or B keys will save the reliability indices in a Lotus file to prevent the need to recalculate the indices (B allows the user to overwrite data stored in an existing file). If the user makes a mistake when typing in the name of the new file or selecting the existing file, an error message will appear on the screen and WRAP will return to the Save Choices menu. With option A, the user should not give the new reliability indices file the same name as a supply and demand data file, otherwise the original data will be replaced and lost.

Figure VI-20 – Graph Print Choices menu

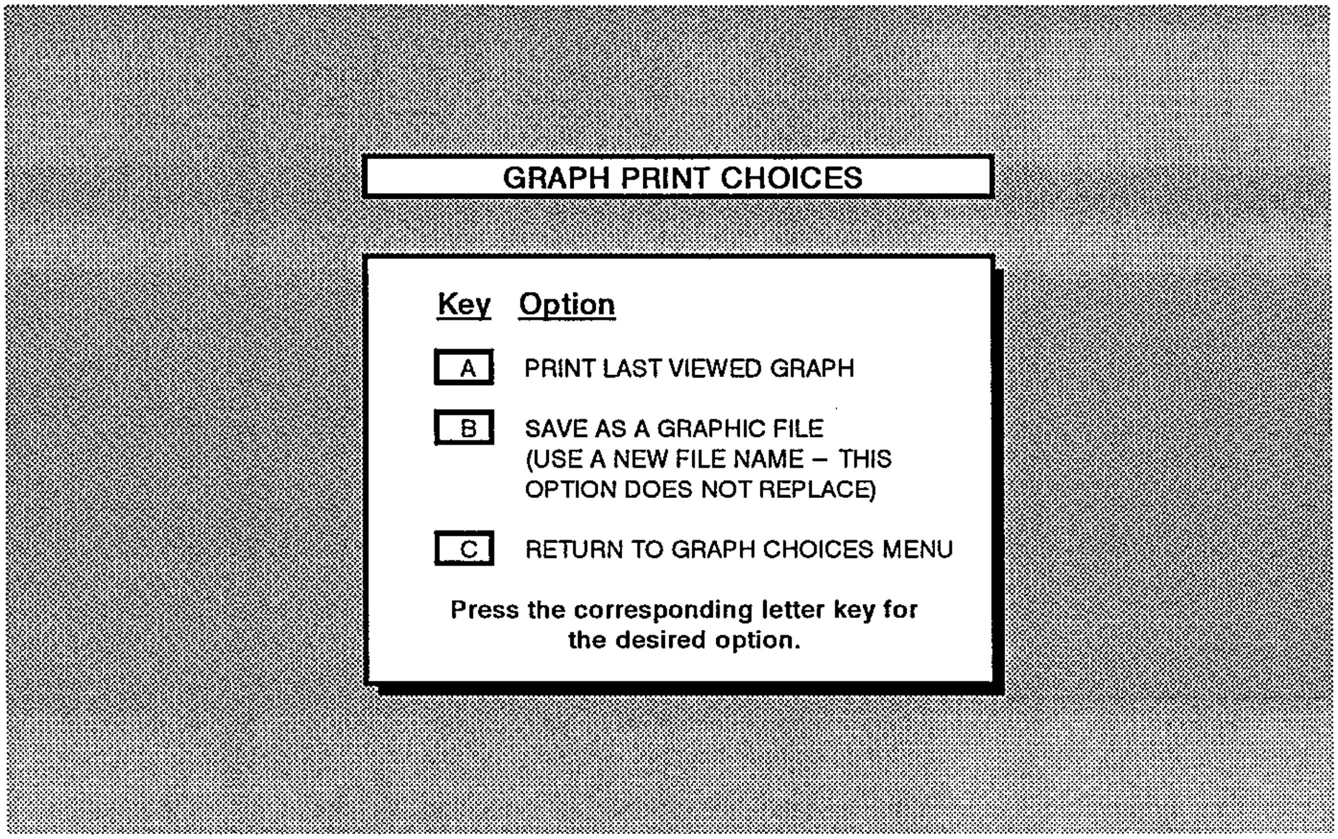


Figure VI–21 – Save Choices menu

SAVE CHOICES

Key	Option
A	SAVE INDICES TO A NEW FILE (DO NOT USE SAME FILE NAME AS SUPPLY AND DEMAND DATA)
B	SAVE INDICES TO AN EXISTING FILE
C	RETURN TO BEGINNING OF WRAP
D	RETURN TO OUTPUT CHOICES MENU
E	EXIT WRAP

Press the corresponding letter key for the desired option.

If the user has elected to save reliability indices data prior to viewing tables and graphs by selecting D in the Output Choices menu, he or she can return immediately to this menu by selecting Option D in the Save Choices menu.

IMPORTING ADDITIONAL DATA

Pressing C from the Save Choices menu will return the user to the Data Input Choices menu (Figure VI-4). WRAP assumes that all the relevant data files are stored in the directory location originally specified in the File Location menu (Figure VI-2).

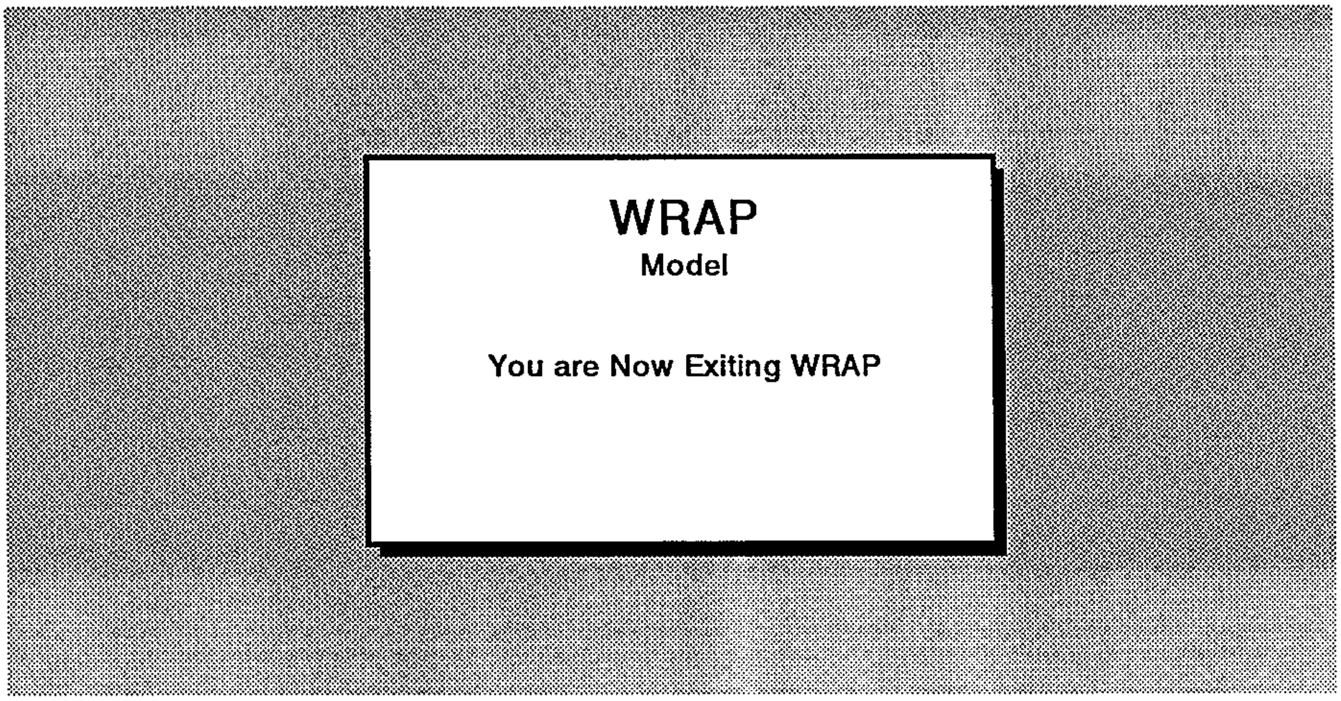
EXITING THE WRAP MODEL

Pressing E from the Save Choices menu will exit WRAP (Figure VI-22) and return the user to a blank Lotus 1-2-3 spreadsheet. Note that, if the user has not already saved the indices, this choice will not save them.

TROUBLESHOOTING

Appendix C addresses several potential difficulties that WRAP users might encounter.

Figure VI-22 – WRAP Exit Screen



Appendix A
WRAP MODEL INPUT DATA FORMAT

APPENDIX A: WRAP MODEL INPUT DATA FORMAT

Prior to running the model, the user must make sure that the data set or sets generated for use in the analysis have been correctly developed and configured.

Consider the following rules for data:

- The model can only use one data set at a time.

- Each level of demand, for each year, for each scenario must have its own individual supply associated with it. This must be generated externally by some form of supply system simulation model that accounts for water supply system runoff, storage, releases and so forth as appropriate to each local situation.

- The data set must be configured in exactly the right manner as a Lotus 1-2-3 spreadsheet. Information must be placed in the correct rows and columns. Failure to do so will result in the wrong data being imported into the calculation spreadsheet and could cause erroneous reliability indices.

- Each data set should contain all the years for all the scenarios to be examined and compared. Note that because of the automatic table and graph options (main menu F and G), the model does not allow the user to skip intervening years or scenarios. Thus, for example, if the user has a data set with four years—1993, 2000, 2010 and 2020, the model cannot automatically produce a graph or table showing only years 1993 and 2020. To do this, another data set must be created with only these two years for each scenario and run through the WRAP model to get the desired tables and graphs.

Users of the model are provided with two Lotus 1-2-3 files in which the full six year, five scenario data set formats are provided with generic titles, zeros and default values (files WRAPTEM1.WK3 for one demand and WRAPTEM3.WK3 for three demands). The user then has the opportunity to edit these to reflect their own particular scenario titles, years, demands, weighting and available supplies. The templates give the correct format for input data for the two alternative options by which the user can either specify three levels of demand (high-end, best estimate, low-end) or else a single demand (best estimate).

For reference purposes, truncated versions of the two full templates are illustrated in this appendix; Template D3 and D1. These templates show only the format of data for the first scenario for the possible six selected years. Each subsequent scenario repeats the same format from column B to the right. In both templates, the information in column A is a guide. Rows 6 to 105 contain the number of each of the available supplies from 1 to a maximum of 100. They have been termed Year 1 to Year 100, because most users of the model will be entering a data set generated from a sequential hydrological record up to a maximum of one hundred years in length.

For WRAP, only the information in columns B and to the right are important. It is imperative that the user's data adopts exactly the positional format illustrated in the two templates.

Template D3 is the format for situations where three demand levels are projected, each given a weighting as to their likelihood of occurrence. Shown in Template D3 are the 18 columns B through S that are associated with the first of the five possible scenarios that the user may input to the model. Each of the six years have three columns of data. Even if the user has only two years of demand and available supplies (6 columns), the user must allow for four more years (the additional 12 columns) before the next scenario data is input beginning in column T. The WRAP model will not read from these blank columns, but the macros that locate each year of data for each scenario require them.

The following Table A.1 shows which columns comprise which of the scenarios and years in the full five scenario, six year data set.

Table A.1
DATA COLUMNS BY SCENARIO AND YEAR (3 DEMANDS)

COLUMNS	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
Scenario 1	B–D	E–G	H–J	K–M	N–P	Q–S
Scenario 2	T–V	W–Y	Z–AB	AC–AE	AF–AH	AI–AK
Scenario 3	AL–AN	AO–AQ	AR–AT	AU–AW	AX–AZ	BA–BC
Scenario 4	BD–BF	BG–BI	BJ–BL	BM–BO	BP–BR	BS–BU
Scenario 5	BV–BX	BY–CA	CB–CD	CE–CG	CH–CJ	CK–CM

TEMPLATE D3 TRUNCATED TEMPLATE SHOWING SCENARIO 1 WITH THREE DEMANDS

ROW	COLUMN A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1		Scenario 1	1st Year		Scenario 1	2nd Year		Scenario 1	3rd Year		Scenario 1	4th Year		Scenario 1	5th Year		Scenario 1	6th Year	
2		High	Best Estimate	Low	High	Best Estimate	Low	High	Best Estimate	Low	High	Best Estimate	Low	High	Best Estimate	Low	High	Best Estimate	Low
3	Demand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Weighting	0.25	0.5	0.25	0.25	0.5	0.25	0.25	0.5	0.25	0.25	0.5	0.25	0.25	0.5	0.25	0.25	0.5	0.25
5		Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply	Supply
6	Year 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Year 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Year 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Year 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Year 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued	...continued
103	Year 98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
104	Year 99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
105	Year 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

When the user develops a data set, rows 2 and 5 should stay the way they are shown in the template across all the scenarios (up the maximum of five). The High, Best Estimate, and Low demands should always be sequenced in this manner.

Where Template D3 lists "Scenario 1" (B1, E1, H1, K1, N1, Q1 and so forth across the next scenario), the user should enter a name for the scenario. This should not exceed 13 characters.

Where Template D3 lists "1st Year" (C1), the user should enter the date of the year that the three columns of data relate to (e.g., 1993) and so forth (F1, I1, L1, O1) out to "6th Year" (e.g., 2040) listed in cell R1. This should be repeated for each scenario.

In each column, the user should enter the available supplies in rows 6 through 105 (where the user has less than 100 annual supplies, the bottom rows will contain zeros). Data can be transferred from the appropriate column of available supply data generated as a Lotus 1-2-3 worksheet by a system planning model. The demand associated with that column of supplies (High, Best Estimate, or Low) should be entered on row 3. The weighting of that demand (i.e., the likelihood that this will be the actual demand) should be entered on row 4 below. Note that the combined weighting of the three demands should equal exactly 1.0. Note also that Template D3 has 0.25 for High, 0.5 for Best Estimate, and 0.25 for Low entered on row 4. These should be the default values unless the user decides to change them.

Consider Template D1. This is the format for situations where only one possible demand level for each year is assumed. Shown in Template D1 are the 6 columns B through G that are associated with the first of the five possible scenarios that the user may input to the model. Each year has one column of data. Even if the user has only two years of demand and available supplies (2 columns), the user must allow for four more years (the additional 4 columns) before the next scenario data is begun in column H. The WRAP model will not read from these blank columns, but the macros that locate each year of data for each scenario require them.

TEMPLATE D1 TRUNCATED TEMPLATE SHOWING SCENARIO 1 WITH ONE DEMAND

COLUMN

ROW	A	B	C	D	E	F	G
1		Scenario 1	Scenario 1	Scenario 1	Scenario 1	Scenario 1	Scenario 1
2		1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
3	Demand	0	0	0	0	0	0
4	Weighting	1.00	1.00	1.00	1.00	1.00	1.00
5		Supply	Supply	Supply	Supply	Supply	Supply
6	Year 1	0	0	0	0	0	0
7	Year 2	0	0	0	0	0	0
8	Year 3	0	0	0	0	0	0
9	Year 4	0	0	0	0	0	0
10	Year 5	0	0	0	0	0	0
	..continued	..continued	..continued	..continued	..continued	..continued	..continued
103	Year 98	0	0	0	0	0	0
104	Year 99	0	0	0	0	0	0
105	Year 100	0	0	0	0	0	0

The following Table A.2 shows which columns comprise which of the scenarios and years in the full five scenario, six year data set.

Table A.2
DATA COLUMNS BY SCENARIO AND YEAR (1 DEMAND)

COLUMNS	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year
Scenario 1	B	C	D	E	F	G
Scenario 2	H	I	J	K	L	M
Scenario 3	N	O	P	Q	R	S
Scenario 4	T	U	V	W	X	Y
Scenario 5	Z	AA	AB	AC	AD	AE

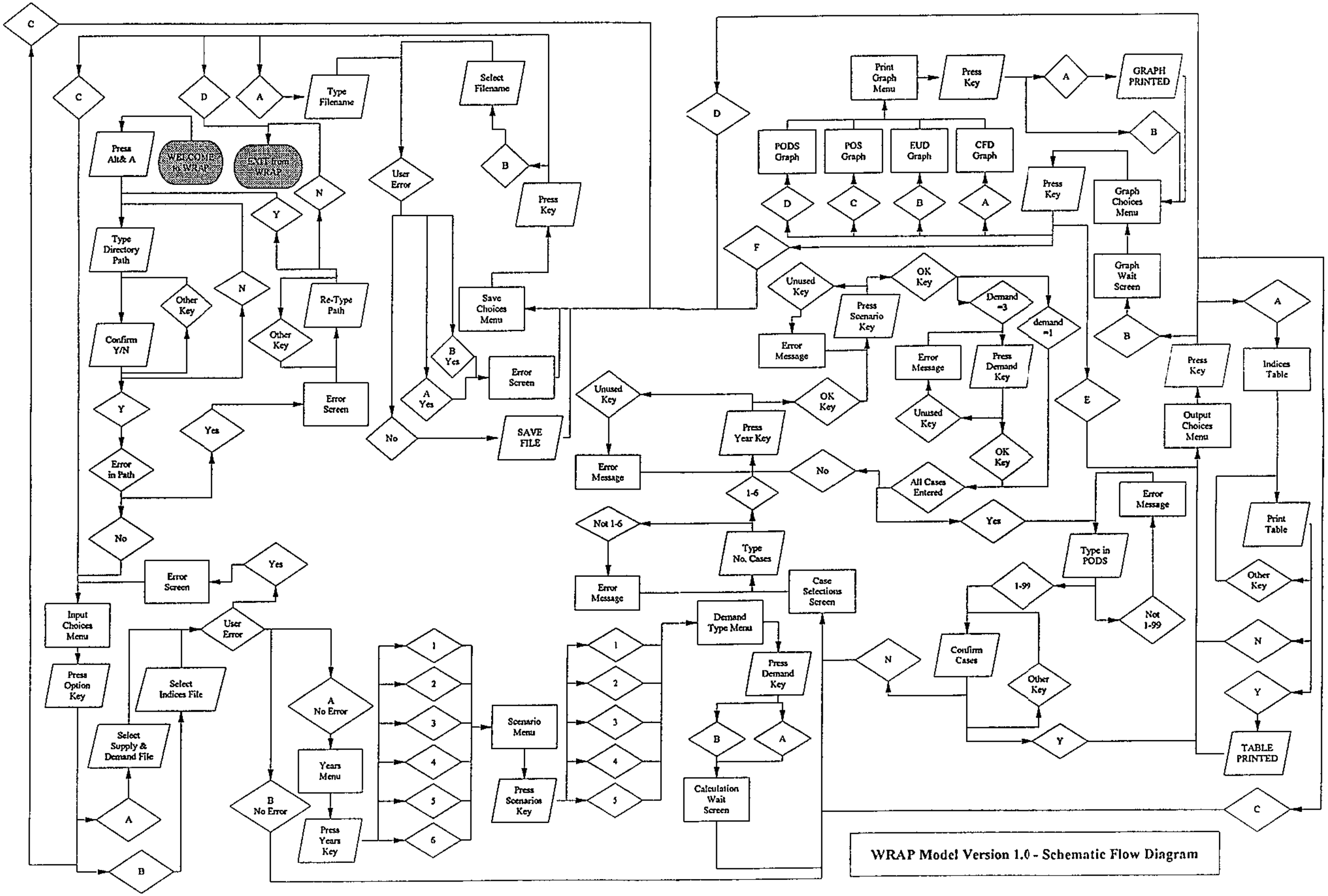
When the user develops a data set, row 4 and 5 should not be changed (i.e., each cell on row 5 from column B across to the rights should contain the word "Supply" and each cell on row 4 the value "1.0").

Where Template D1 lists "Scenario 1" (B1, C1, D1, E1, F1, G1 and so forth across the next scenario) the user should enter the name of the scenario. This should not exceed 13 characters.

Where Template D1 lists "1st Year" (B2), the user should enter in the date of the year that the column of data relates to (e.g., 1993) and so forth (C2, D2, E2, F2) out to "6th Year" (G2) for the scenario (e.g., 2040). This should be repeated for each scenario.

In each column, the user should enter the available supplies in rows 6 through 105 (where there are less than 100 annual supplies, the bottom rows will contain zeros). Data can be transferred from the appropriate column of available supply data generated as a Lotus 1-2-3 worksheet by a supply planning model. The demand associated with the column of supplies (one Best Estimate) should be entered on row 3. The weighting of that demand is "1.0" for all columns and is entered on row 4 below. This value should not be changed.

Appendix B
WRAP MODEL SCHEMATIC FLOW DIAGRAM



WRAP Model Version 1.0 - Schematic Flow Diagram

Appendix C
TROUBLESHOOTING

APPENDIX C: TROUBLESHOOTING

1. Accidental Escape From WRAP Macros

The user mistakenly hits the Escape key, which suspends the WRAP macros and returns the user tot he Lotus spreadsheet.

Regular Lotus users learn to use the escape key to deselect command options or undo changes made to cells. Therefore, some users may hit the escape key if they decide they want to choose another option from a previous menu or if they entered a number they didn't want in response to a WRAP question. Because the WRAP model functions using a collection of Lotus macros, pressing the escape key under certain circumstances may lead to the user halting the macro execution and ending up somewhere in one of the WRAP worksheets. To re-enter the model, the user should press either the Alt-A or the Alt-Z keys. The Alt-A key will place the user at the very beginning of WRAP, whereas the Alt-Z key will place the user back at the output choices menu, retaining any selections and reliability indices calculations.

2. Lotus is not in WYSIWYG Format

The user loads the WRAP program but does not get the Lotus WYSIWYG option which formats the spreadsheet so that the menus appear like those shown in the figures in this user documentation.

Depending on the local installation and default settings of Lotus, WYSIWYG may or may not automatically be invoked on booting up the program. The user can set the Lotus 1-2-3 software to invoke WYSIWYG automatically by completing the following sequence of commands. Every time a user logs into Lotus thereafter, the screen will be in WYSIWYG mode.

1. Press the ALT and F10 keys together
2. Select the SETTINGS option
3. Select the SYSTEMS option
4. Select the DIRECTORY option—the user is asked to specify the add-in directory path for 123 to search e.g. C:\123R31\ADDINS\ for WYSIWYG and press Enter

5. Select the SET option—the user will be asked to enter the add-in to read into memory automatically and should toggle to WYSIWYG.PLC and press Enter

6. Indicate YES when asked if the user wants to automatically start this application when it is read into memory—the user will be asked if he or she wants to assign a function key to load or unload WYSIWYG manually—toggle to None, Alt-F7, Alt-F8 or Alt-F9 and press Enter

7. Select the UPDATE option

8. Select the Quit option.

3. The Computer Has Insufficient Memory

The computer seems to have insufficient memory and freezes up during the operation of WRAP.

WRAP was developed on a 386 machine with 4 MB of RAM, but has also been run successfully on a machine with 1 MB of RAM. When full with data, the WRAP model takes up approximately 400 KB. Users should therefore not experience memory problems that cause the WRAP model to fail. However, in Lotus 1-2-3, there are several factors that affect the actual amount of memory available for files at any time. These include the size of the operating system (RAM) and other programs in operation, the size of drivers selected during the installation of Lotus, and whether the Undo function is activated. If the computer is having a memory problem, the user will have seen the letters MEM appear at the bottom of the screen. The user can try turning off the Undo function (which is not needed for WRAP) or exiting from the model and reloading it. The Undo function is turned off by the sequence / Worksheet Global Default Other Undo Disable Quit. The user should do this before entering WRAP, or exit WRAP and reload and start WRAP again. If this does not work and the user continues to experience freezing, he or she should consult the Lotus vendor or hardware supplier for assistance.

Other possible reasons for freezing include difficulties with using Lotus 1-2-3 on a network from its location on the hard drive of a file server. Multiple accessing of Lotus 1-2-3 files may cause the local program to crash due to data sharing problems.

4. Printing Graphs

The user tries to print graphs but they don't come out like the ones illustrated in the model documentation. They have different size fonts or symbols, and/or there are pagination difficulties.

The WRAP model was developed in an environment in which printing was carried out on an HP LaserJet Series III with additional memory and no cartridge. Graphs were developed with default settings for position, size, fonts and so forth. While there may be some slight stylistic variation from printer to printer (or on plotters) due to the types of default resident fonts, users should experience no fundamental problems when printing.

Lotus 1-2-3 requires that in installing the software, the user specifies the kinds of printers he or she plans to use for printing text and graphics. These are then included in the 123 driver set. In order to achieve satisfactory printing, the user must both select the printer for inclusion in the 123.DCF during the install process and make sure that the correct printer device is selected prior to loading WRAP. This is done by the sequence: / Print Printer Options Advanced Device Name "select number option listed for correct printer" Quit.

If users have copied Lotus 1-2-3 from one work environment to another without reinstalling the software, or have changed or switched printers for the same PC, it may be that printing problems will occur until the software is reinstalled or the correct printer driver is selected. Similarly, if the user specified a multiple printer environment, for example, if the PC can print to a laser printer, dot-matrix and plotter, the user should check to see if the correct driver is selected prior to printing.

If users are printing Lotus 1-2-3 tables or graphs on a networked printer, problems in printing may arise if other users are submitting other print jobs simultaneously, particularly other Lotus 1-2-3 jobs which may be issuing printer control commands that interrupt or affect the next print job. The user should try using WRAP on a PC connected to a dedicated printer, making sure that the printer is one that has been selected in the install program.

Additionally, problems with printing may arise if users are accessing the software from a PC linked to a network where the software is stored. Lotus 1-2-3 version 3.1+ was not written to be shared by multiple users on a network and it may be that attempts to access shared printer drivers, font caches or other files may cause errors during the printing process. Users should consult their network manager or software supplier for more details. During beta-testing of the model, some networked users experienced problems in producing printer output. Such problems can be avoided by using WRAP on PCs with their own resident copy of Lotus 1-2-3 version 3.1+ on the local hard drive, and preferably a dedicated laser printer connected directly to the PC parallel port.

What can a user do if printing problems persist?

The WRAP model Graph Printing Choices menu has the option of saving graphs as graphic files (FILENAME.CGM) which can then be incorporated directly as a picture into a word processing file. Users can thus obtain graphical print out in this manner.

Appendix D
USING WRAP WITH OTHER HARDWARE-SOFTWARE COMBINATIONS

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BARAKAT & CHAMBERLIN, INC.

Oakland
Washington, D.C.
Toronto
Portland, OR
Boulder
San Diego

MEMORANDUM

TO: CUWA Water Supply Reliability Project Advisory Committee

FROM: Gary Fiske, Michael D. Lee

RE: Using WRAP on other software-hardware combinations

DATE: May 5, 1993

We have attempted to run the WRAP model Version B1.02 in different computer hardware-software environments including:

A. MS-DOS PC + Excel Version 4.0a for Windows
B. Macintosh PC + Excel for Macintosh
C. MS-DOS PC + Quattro-Pro
D. Macintosh PC + Lotus 1-2-3 for Macintosh

The general conclusion arising from these tests and from a review of each software documentation is that the basic formulaic components and most of the data manipulation macros written in Lotus 1-2-3 are executable in each of the different software. However, because the manner in which spreadsheet and graph screens appear and ranges and graphs are printed differ in the Macintosh environment and in each different software environment, macros that control these activities in the current WRAP model do not function the same way. Macros that contain "WYSIWYG" commands for display or printing fail to be read and executed. This includes macros designed to freeze the display and keyboard during calculations. Similarly, the formatting of screens and menus are altered to varying degrees when loaded into the other hardware and software environments.

Because the user-friendliness of the WRAP model is in large part predicated on the use of range formatting and screen selections and macros that are in large measure software and hardware specific, we conclude that to create versions of WRAP that are identical in each environment would require significant reprogramming. For each hardware and software combination, this programming would be at least equal to the work undertaken to modify WRAP version B1.01 to create the user-friendly version B1.02. From our review, it is also clear this would be the case regardless of the original environment in which the

WRAP model was created. If the model had been developed in Excel on an MS-DOS PC, for example, an equivalent level of reprogramming would be required to create an identical product in Lotus 1-2-3. Compatibility between competing software only goes so far.

Our experiences with WRAP for each software and hardware combination are summarized in the following sections.

MS-DOS PC + Excel

We first attempted to load the WRAP model into Microsoft Excel Version 4.0a for Windows. The model converted the Lotus 1-2-3 WK3 and FM3 files quickly into an Excel file that largely maintained the appearance of the original. The colors, outlining and text alignment remained in each of the screens and menus but the font sizes changed so that text was clipped or overlapped.

Excel converted the various Lotus 1-2-3 formulae that use @ functions into their equivalent Excel functions and the formulae were re-written in their correct syntax. We did not check all of the formulae for absolute compatibility. The macros written for Lotus 1-2-3 using the / command to manipulate data within the spreadsheet did not function as Excel macros (Excel calls up menu commands using Alt and a letter). Because of the differing menu structure, each of the menu commands would have to be checked and where necessary rewritten to make the macros work in the same way as the current WRAP model. Range names and locations appear to have been fully preserved in the Excel worksheet structure. Excel provides a help function in which the user can interactively identify the equivalent key strokes to reproduce Lotus 1-2-3 menu commands. This would be very useful for recording new macros to reproduce those in the current WRAP model.

Excel contains the worksheet and the format information in the same workbook file (main file plus bound sub-files) which is four times as large as the Lotus 1-2-3 file. Users would need to have much greater active memory (700-1000 k) to run an equivalent to the current WRAP in Excel.

Macintosh PC + Excel for Macintosh

The results for this environment were fairly similar to the Excel for MS-DOS Windows situation. Our first attempt to load WRAP into Excel on a Macintosh LC failed due to lack of memory. When we switched to a more powerful Macintosh II with more memory, the WRAP model loaded easily and smoothly. The failure to load on the less powerful machine could be explained by the fact that as Excel converts the Lotus 1-2-3 file, it creates a series of bound worksheets that together take up several times the RAM and disk-space of the original WRAP model.

Although the model loaded, a portion of the "WYSIWYG" appearance was lost, particularly text alignment. Lotus 1-2-3 @ functions appeared to have been translated into their Excel equivalent, but we did not evaluate whether there was full compatibility. Because of the differences in Macro structure, macros did not run and would need to be reprogrammed to reproduce the WRAP calculations and data manipulation that generate the reliability indices, tables and graphs.

MS-DOS PC + Quattro-Pro

When loading WRAP into Quattro-Pro version 4.0, we attempted several options. We tried loading WRAP first into the "WYSIWYG" environment of Quattro-Pro. Although the multiple worksheets loaded, Quattro-Pro could not handle the formatting and the load was aborted, returning us to DOS. We then tried loading WRAP without the "WYSIWYG" environment and were successful.

As with Excel, Quattro-Pro has different function commands, some of which work the same way as Lotus 1-2-3. Although we did not check each of the formulae that use @ commands, we did see that several of the @ functions in WRAP were not working the same way including, for example, the macro that keeps track of the date and time that tables and graphs are created. An apparent major drawback is that Quattro-Pro creates one new worksheet for each of the multiple spreadsheets in WRAP, but does not preserve range name cell references across sheets, so that if a formula in spreadsheet A refers to a range name in B, it will not work.

Since Quattro-Pro required us to ignore the "WYSIWYG" format when loading the WRAP file, all of the screen and menu formatting was lost. Centered text became misaligned and borders, colors and shading were lost.

The Lotus 1-2-3 commands in macros that are activated by a / key cannot be executed because the menu structure is different in Quattro-Pro. For example, although / will activate the menu selection, /c will not copy a range because copy in Quattro-Pro is /ec due to the copy command being part of the edit menu. Clearly the format of each of the screens and menus would need to be reset and most of the macros would need to be completely re-written. All of the formulae using range names and @ functions would need to be checked.

Quattro-Pro seems to present the most inhospitable environment for conversion and use of the WRAP model out of the four hardware and software combinations that we tested.

Macintosh PC + Lotus 1-2-3 for Macintosh

WRAP loaded easily into Lotus 1-2-3 for Macintosh, although the "WYSIWYG" format of the original was not fully preserved. While the colors, borders and shading of the WRAP screens and menus were retained, the text size and alignment were altered.

All of the formulae were preserved along with @ functions and range names. Most of the macros that use / and menu commands still functioned when invoked from the Tools menu since Lotus 1-2-3 for Macintosh has a "Lotus Classic" feature which calls up the original menu structure and commands in response to / and letter combinations. However, the Macros written to invoke "WYSIWYG" functions did not execute including, for example the print table and print graph macros. However, the macros that manipulate the data to generate the graphs did work, and by escaping from the appropriate macro, both tables and graphs could be printed. Because of the different default formatting in the Lotus 1-2-3 for Macintosh, both would need to be reformatted.

Creating a Lotus 1-2-3 version of WRAP for the Macintosh would be the simplest of the four environments. However, a significant amount of reformatting and macro reprogramming would still be required.

Running WRAP in Lotus 1-2-3 for Windows

In the process of developing WRAP Version B1.02, we also had occasion to run the model using Lotus 1-2-3 for Windows on an MS-DOS PC. All of the macro commands in Lotus 1-2-3 Version 3.1 work in the Windows environment except the starting macro /A. This macro must be activated using the Run option, in the Macro command, in the Tools pull-down menu. Lotus 3.1 / commands are implemented by the Lotus classic feature of Lotus for Windows. However, because Lotus 1-2-3 for Windows ignores certain version 3.1 "WYSIWYG" commands, various screens are not sized correctly; hence some of the menus and the table are clipped. Because of the similarities between the two Lotus versions, this could be corrected relatively simply by reprogramming selected macros to substitute Windows formatting commands. However, even though menus are clipped in the computer screen, all of the options can be selected and the existing macros function correctly, printing tables and graphs similar to those created with Lotus 1-2-3 version 3.1.

Note that Lotus 1-2-3 for Windows runs WRAP more slowly than Lotus 1-2-3 Version 3.1.